



Sunshot: Australia's opportunity to create 395,000 clean export jobs

DETAILED REPORT

October 2021

Commissioned by



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Acknowledgement of country

Accenture and the commissioning organisations respectfully acknowledge Australia's Aboriginal and Torres Strait Islander people as the Traditional Owners of Australia and pay respect to their Elders past, present and emerging.

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The Australian Conservation Foundation is Australia's national environment organisation. We are 700,000 people who speak out for the air we breathe, the water we drink, and the places and wildlife we love. We are proudly independent, non-partisan and funded by donations from our community.

About ACTU

The Australian Council of Trade Unions is the peak body for Australian unions, made up of 38 affiliated unions who together represent about 1.8 million workers and their families.

About BCA

The Business Council of Australia represents Australia's largest employers, advocating for good policy on behalf of the business community and the Australians they employ.

About WWF

WWF-Australia is part of the world's leading conservation network and has been working to create a world where people live in harmony with nature since 1978. WWF's mission is to stop the degradation of the earth's natural environment and to build a future in which humans live in harmony with nature. At every level, we collaborate with people around the world to develop and deliver innovative solutions that protect communities, wildlife, and the places in which they live. Since 2019, WWF has been advocating for Australia to become a world leading renewable energy export nation through its Renewables Nation program.

Australia's opportunity to create 395,000 clean export jobs

Australia's exports are dominated by fossil fuels and high embodied carbon products. Among Australia's top 10 exported goods, which together represent 60% of total export value, 97% are either fossil fuels, products with high embodied emissions, or inputs into high-emissions processes. Australia's exports are also significantly more emissions intensive than those of other countries: Australia ranks in the top 3 for exported fossil fuel emissions behind Russia and Saudi Arabia.

These exports are now at risk due to the increased global focus on combating climate change. Demand for thermal coal—which represents 6% of Australia's current exports—is expected to decline 80% globally by 2050 in the IEA's net zero by 2050 scenario. Many countries including our major export destinations (e.g. China, Japan, Korea) have adopted net zero carbon targets. Demand for Australia's high carbon embodied products is also at risk due to regulations that tax carbon-intensive imports such as the European Union's planned carbon border adjustment mechanism.

While the energy transition puts some of our exports at risk, it also opens a path to new clean export opportunities. Australia has a natural clean energy advantage: an abundance of solar and wind energy and the metals and minerals required for the energy transition. Australia has the highest average solar radiation per square metre of any continent in the world and is already the world's largest miner of lithium, a key input into batteries. Australia is the largest producer of some of the most important

materials for industrial development and decarbonisation (including iron ore, copper and bauxite) which we are well placed to process with renewable energy. Our combination of high-quality renewable energy resources and abundant metals and minerals means that Australia could be positioned to prosper in the global energy transition.

This report explores six clean export opportunities in clean energy, technologies and services that can fuel Australia's growth in the low emissions economy.¹

There are two sets of opportunities: energy and minerals; and technology and services.

In energy and minerals, three opportunities stand out:

1. Exporting hydrogen or ammonia produced with renewable energy
2. Processing and exporting higher value metals (e.g. steel and aluminium) using renewable energy
3. Exporting minerals critical for production of clean energy technology

In technology and services, there are three leading opportunities:

4. Exporting batteries manufactured in Australia
5. Exporting education and training services built on our strong clean energy economy
6. Providing clean energy services

Note: 1. The report does not explore all clean energy export opportunities and focuses only on those where Australia has a distinct advantage



Australia's opportunity to create 395,000 clean export jobs

In total, Australia's six clean export opportunities are enormous. By conservative estimates, they have the potential to generate \$89 billion of gross value added (GVA) and 395,000 jobs for Australia in 2040. To give some sense of the size of the opportunity, this is larger than the GVA of our fossil fuel industry today and with many more jobs. Each of these opportunities represent a substantial new industry and together they would form a formidable new set of exports for Australia.

These industries would not just bring export revenue – they could also produce a range of jobs, many in regional areas. A range of jobs accessible by workers across qualification levels would be created; more than half of jobs would be in mining, manufacturing, and professional services. A high proportion of new jobs could be in regions with existing high-carbon activities.

But fully exploiting these new opportunities will not be easy and will require concerted effort across a range of actors. While governments are taking steps to support new clean sectors especially through renewable energy zones and support for new technology, greater scale of effort will be required to fully develop these opportunities. Unlocking clean exports at this scale would require 6 times the current national electricity output and a commitment to commercialise new industries such as renewable hydrogen and green steel.

For this reason, the four partners of this report believe significant new policies and actions are required to realise this opportunity.

Australia will need to act quickly as we face significant competition from other countries.

Five policies and actions are required:

1. Coordinated investment in clean export industrial precincts
2. Co-investment in new industries
3. Support for workers and regions to diversify
4. Low-carbon material procurement
5. Interim target for renewable hydrogen and green metals production

Investment will be required to underwrite new renewable energy supply as technology costs decline and global demand strengthens. There will also need to be significant investment in new renewable energy industrial clusters to co-locate renewable energy generation and energy storage with manufacturing and clean exports production. Targets will be important to galvanise industry and signal our ambition to investors. Critically, there is a role for government to help local economies diversify by providing leadership, coordination and support to workers moving from the carbon economy to the clean economy. These policies could have a catalytic effect on Australia's clean export industries, supporting new investment, growth and jobs.

With these commitments, Australia can become a clean exports powerhouse, realise a \$89 billion opportunity and create 395,000 new jobs.



**Australia's exports are
exposed to the global energy
transition**



Australia's exports are dominated by fossil fuels, high-embodied emissions goods and inputs into such goods

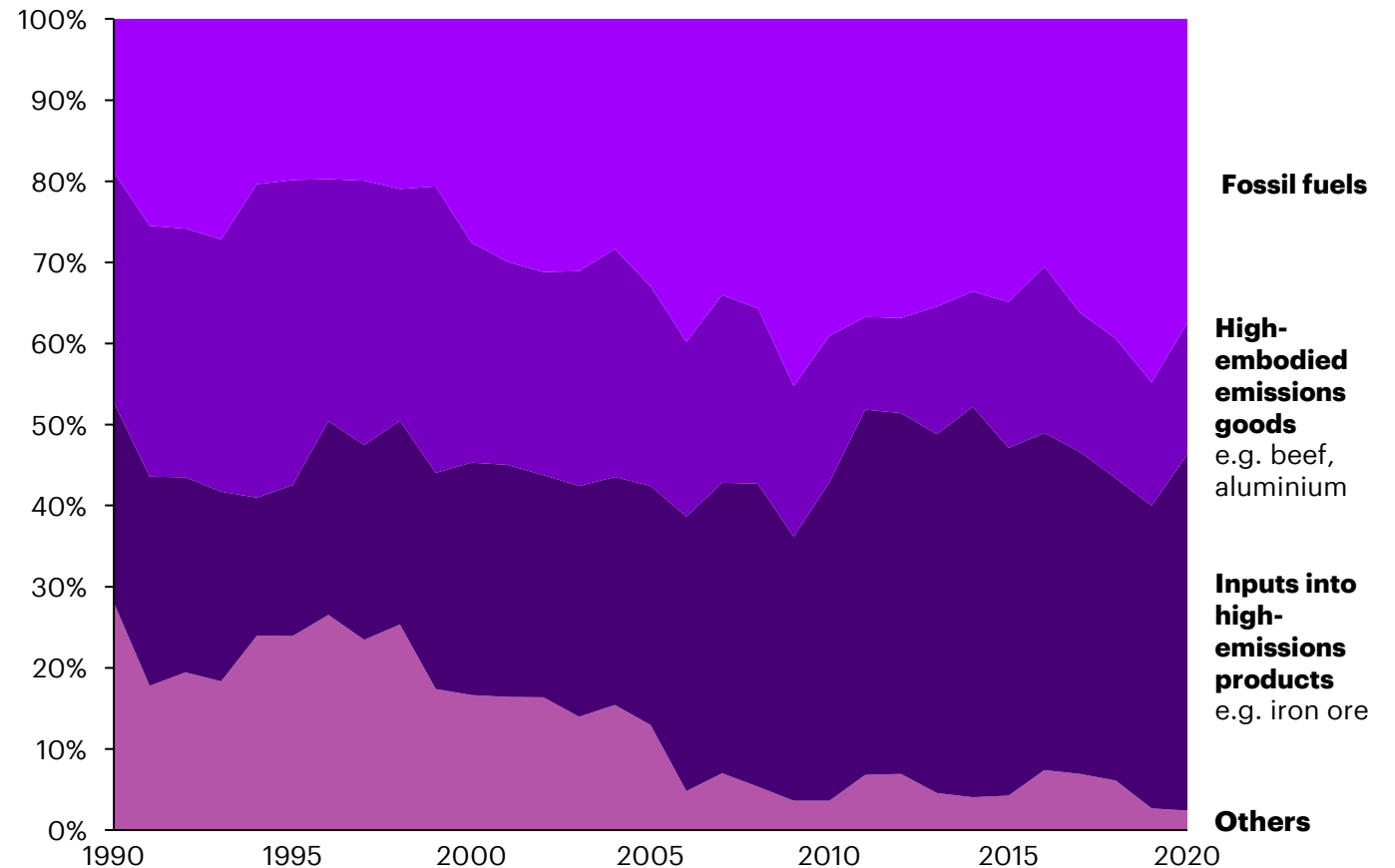
Australia's exports have become increasingly dominated by fossil fuels, high embodied emission goods and inputs into high embodied emission goods. **The top 10 goods represent 60% of total export value and 16% of GDP, of which 97% are fossil fuels or have high embodied emissions.** Hence, 16% of Australia's GDP is at risk as the world transitions to carbon neutral based on our current composition. Australia will need to restructure the composition of its exports to respond both to the decrease in global fossil fuel demand and the increase in emissions reduction ambition. This will require an unprecedented scale of change for Australia.

Australia has consistently been a commodities and resources based export economy, with resources representing as much as 60% of exports since 2017. Further, fossil fuels have represented over 25% of exports on average over the last 10 years. As countries phase out fossil fuel use, there will be increasing volatility in fossil fuel markets as the number of markets reduce.

The graph highlights the high proportion of exports that are at risk through either direct fossil fuel import reduction or an increase in emission reduction ambition. This risk is most prominent for goods exports, which represent 80% of total export value.

Figure 1: Share of energy intensive and fossil fuel exports in Australia's top ten goods exports¹

%, share of total top ten goods exports value



Source: 1. DFAT TRIEC pivot tables Notes: Fossil fuels include coal anthracite and bituminous, crude petroleum, and petroleum gases and other gaseous hydrocarbons processed. High-embodied emissions goods include non-monetary gold, meat and meat preparations, metallic minerals processed, road motor vehicles and parts, and machinery for specialised industries. Inputs into high-emissions processes include iron ore and concentrates, other metalliferous ores and concentrates and non-ferrous metals simply transformed.

There are three distinct types of at-risk goods in Australia's export portfolio

Fossil fuels are directly at risk as demand switches to zero-carbon energy sources.

Goods with high embodied emissions like beef and aluminium produced using high-carbon electricity are at risk as customers switch to lower-carbon alternatives.

Inputs like iron ore and metallurgical coal which go **into high-emissions or energy-intensive products** are at risk as decarbonisation drives substitution into low-carbon alternatives. Low-carbon production using some of these inputs, such as iron ore, is likely to become commercial over time resulting in the reduction of embodied emissions.

Countries are beginning to impose tariffs on embodied emissions in imported goods, such as the EU's CBAM. This is an example of a mechanism that will drive customers towards lower-carbon alternatives, and as such will have an impact on type 2 and 3 emissions intensive exports. EU is only the first of several countries such as the US considering a similar CBAM.

Type of emissions intensive exports

1

Fossil fuels

Fossil fuels that produce emissions when used are considered high emission fuels. **Examples of these exports include thermal coal and natural gas.**

2

Goods with high embodied emissions

Emissions produced during the mining, processing or manufactured stages in the goods value chain are considered as embodied emissions. **Examples of these exports with high-embodied emissions include beef, and high energy intensity manufactured goods such as aluminium.**

3

Inputs into high-emissions or energy-intensive products

Inputs into high-embodied emissions goods refer to the raw materials used in the production of goods that are responsible for a high level of emissions. **For example, iron ore and metallurgical coal are inputs into steel, which is responsible for a high level of emissions in the manufacturing process. Additionally, metal ores that require energy-intensive processing or smelting are also captured.**

Case study: European Union's Carbon Border Adjustment Mechanism (CBAM)

In 2021, the EU adopted a proposal to implement a CBAM which will require importers to report the embodied emissions in carbon-intensive products such as aluminium, steel, and fertiliser. Importers will then have to buy certificates for the embodied emissions, just as domestic producers do under the EU emissions trading scheme.

The EU's adoption of a CBAM indicates an increased focus on reducing consumption-related emissions and addressing competitiveness concerns from European producers competing against imports from countries with weaker carbon regulation.

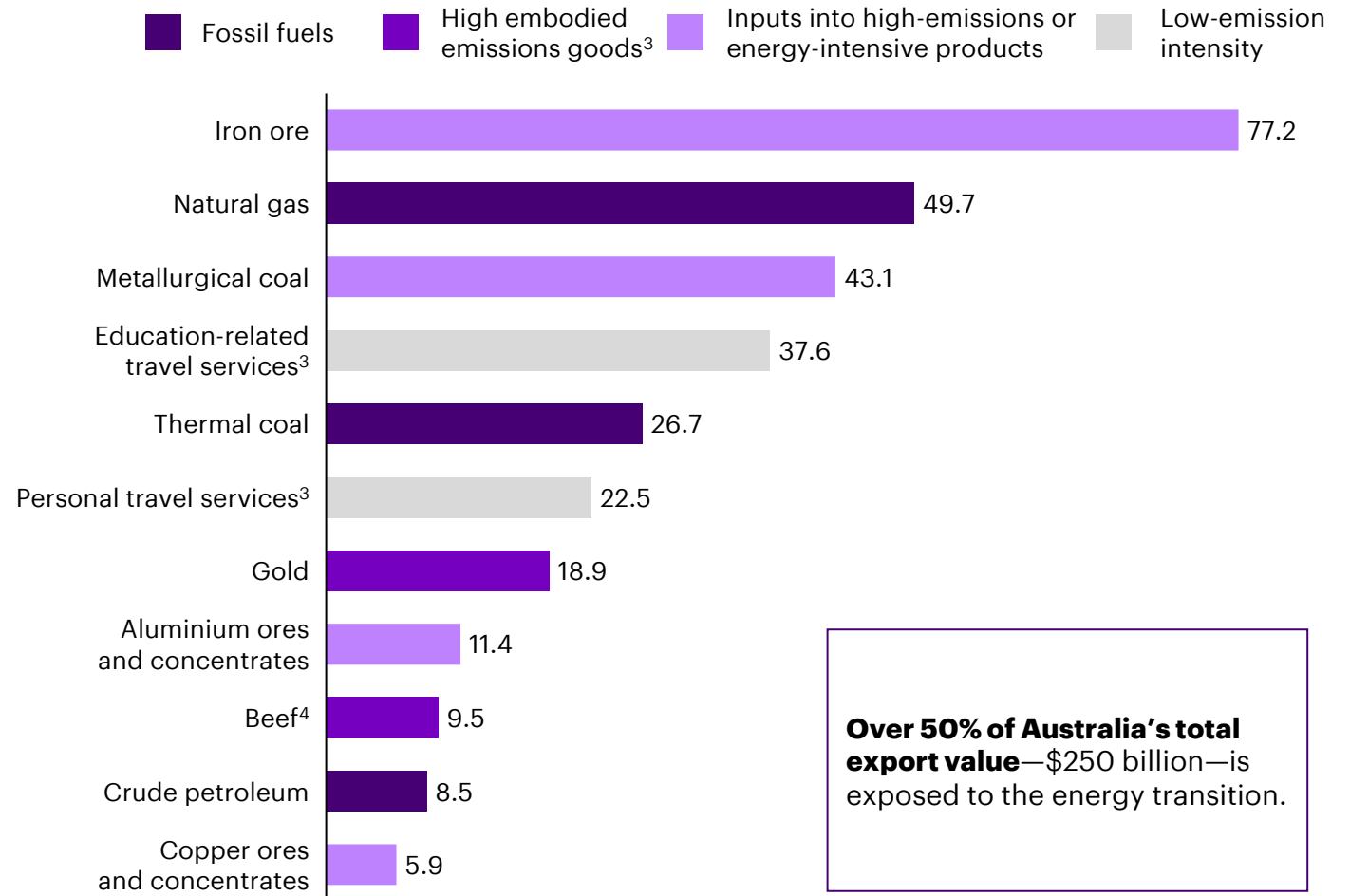
Currently, 8 out of 10 of Australia's largest exports are exposed to risks from the energy transition

Over 50% of Australia's existing export value is generated from fossil fuels or other exports at risk from the global energy transition. Fossil fuels alone represent almost 20%, or \$76 billion, of Australia's exports by value.

Exports are a significant contributor to Australia's GDP. Trade is equivalent to 45% of GDP and directly responsible for 1 in 5 Australian jobs. Australia's exports are at risk from the global energy transition represent a considerable portion of Australia's economy. **This risk must be managed through rapid action to coordinate the transition as international demand moves away from emissions intensive exports.**

Figure 2: Australia's top ten exports by balance of payment basis^{1,2}

Billion dollars, 2018-19



Source: 1. DFAT (2020), [Trade and Investment at a Glance](#) 2. DIIS-OCE (2019), [Resources and Energy Quarterly](#)

Notes: Coal is considered a singular export by DFAT however the Department of Industry reports on thermal and metallurgical coal separately and given their distinct uses they have been presented separately here. 3. Education-related and personal travel services have experienced a significant decline in 2019-20 data. 4. Beef and other high embodied emission goods were not within the scope of this report.

The carbon intensity of Australia's electricity generation is among the highest in the world

Beyond direct fossil fuel exports, Australia's carbon intensive electricity generation places Australia at a further disadvantage as customers move to lower carbon products.

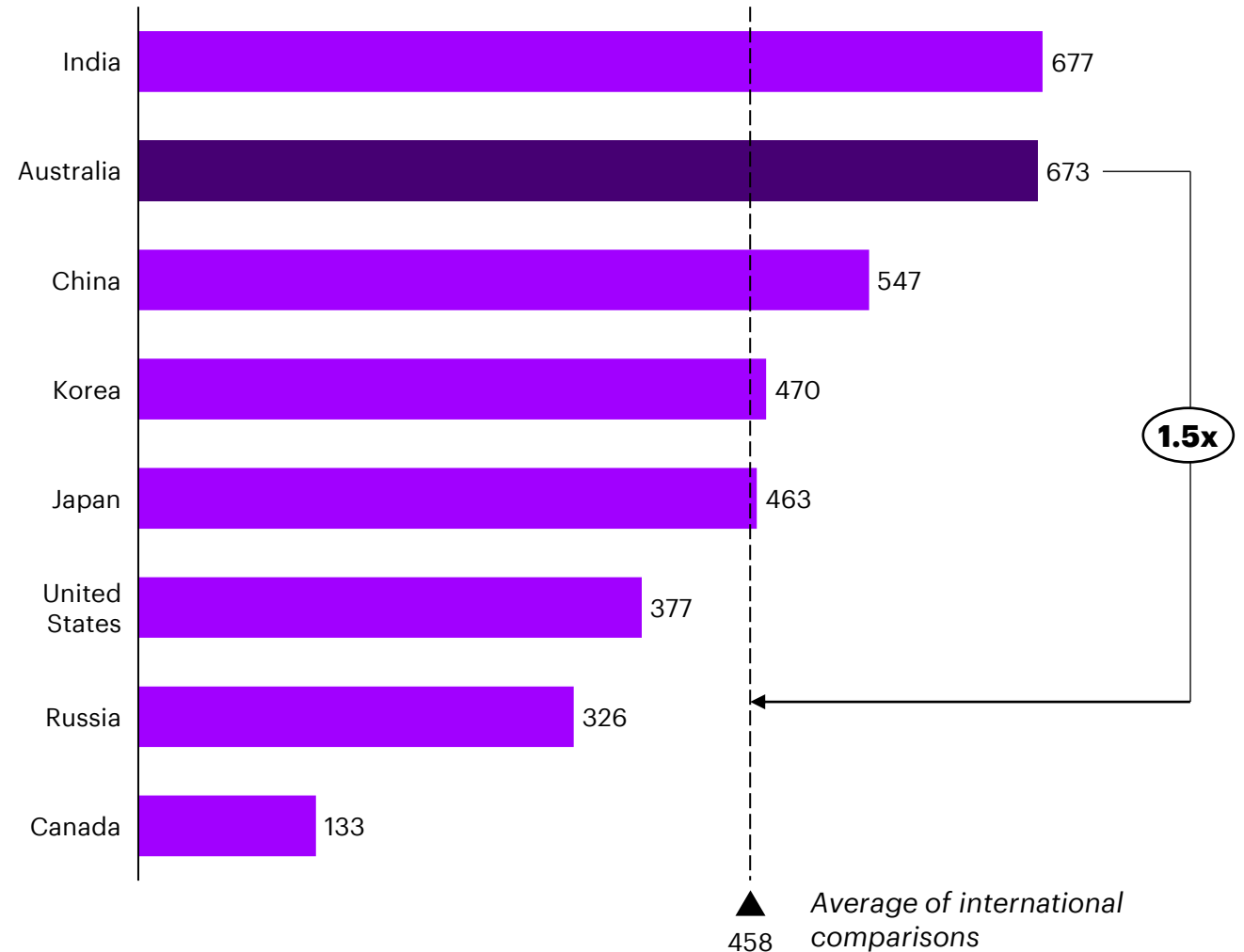
Countries and companies are prioritising products with low embodied emissions. This prioritisation reflects a shift towards lowering consumption emissions. For Australia to align with the emissions reduction ambitions of our customers and be competitive with other exporters, Australia requires low-carbon electricity generation.

Australia's average CO₂ emission factor—which measures the CO₂ emissions for every unit of electricity produced—is at least 50% higher than the US, Japan, China, UAE, Korea and Russia, and three times higher than Canada, Sweden, UK and New Zealand.

With embodied emissions increasingly driving customer decisions, Australia is at a significant disadvantage unless action is taken to reduce the emissions factor.

Figure 3: Emissions factor across existing steel and aluminium manufacturing countries¹

gCO₂/kWh, 2019

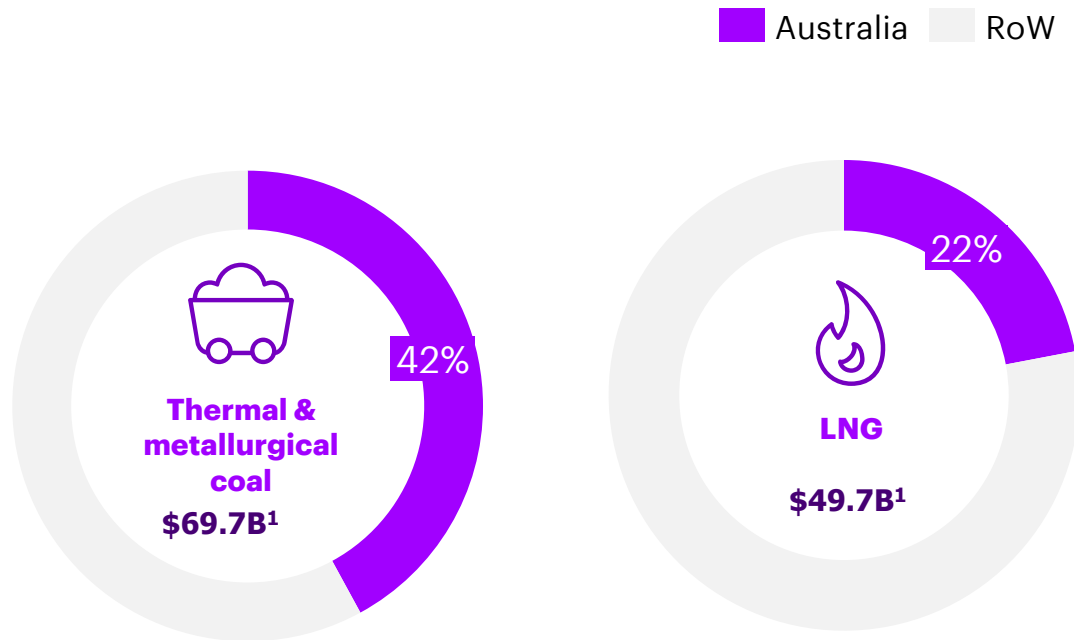


Source: 1. Carbon Transparency (2020), [Climate Transparency Report 2020](#)

Australia is a major global supplier of fossil fuels and ranks among the highest countries for CO₂ emissions from fossil fuel exports

Figure 4: Share of global coal and natural gas exports^{2,3}

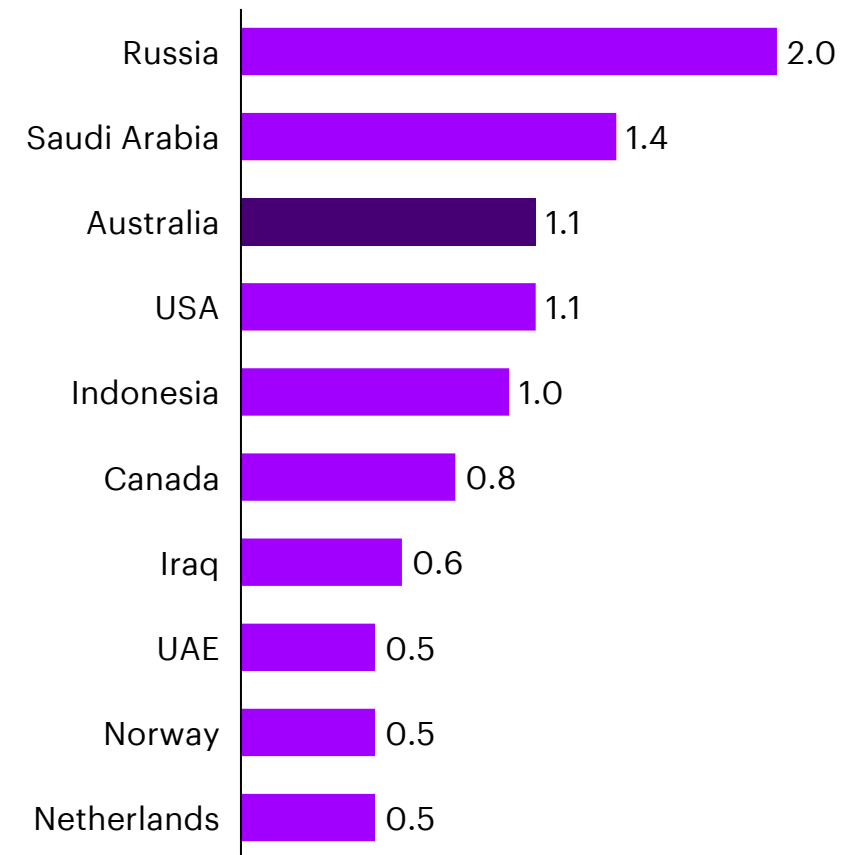
% of global exports, 2019-20



Australia is the world's top exporter of thermal and metallurgical coal², and the world's largest liquefied natural gas (LNG) exporter³

Figure 5: Global ranking of CO₂ emissions due to fossil fuel exports⁴

billion tonnes



Note: 1. Current value of Australian exports

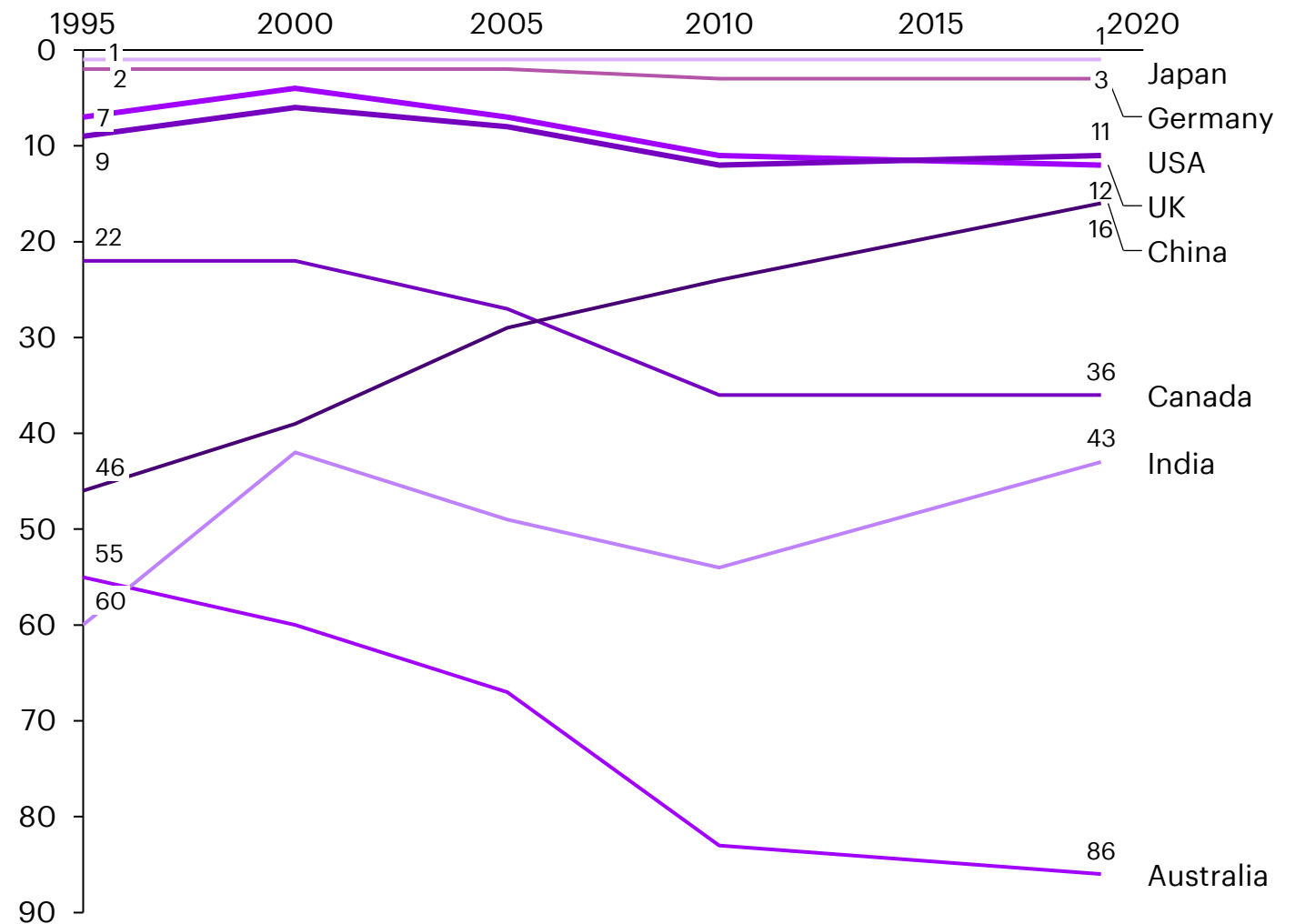
Sources: 2. Office of the Chief Economist (2021), *Resources and Energy Quarterly June 2021* 3. Government of Western Australia (2021), *Western Australia LNG profile – April 2021* 4. Australia Institute (2020), *High Carbon from a Land Down Under*

When ranked against international examples, Australia's exports, and broader economy, lack complexity

Australia's exports are notably less complex than many OECD and large developing countries. Harvard University's *Atlas of Economic Complexity* ranks Australia 86th for economic complexity. This reflects the minimal diversity – how many products exported – and higher ubiquity – how many other countries export the same product – of our exports.¹

Australia's complexity ranking indicates Australia's exports are more concentrated in a small number of sectors compared to other countries. While these exports remain in demand, Australia is well positioned to capture this market. However, as demand shifts, Australia risks being stranded being over-indexed in a small number of exports.

Figure 6: Economic complexity of Australia ranked against international examples²



Sources: 1. DIIS, OCE 2. Harvard, [Atlas of Economic Complexity](#)

Australia's largest export markets have set ambitious renewable energy and net-zero targets

The majority of Australia's export markets have committed to increasing their share of renewables by 2030 and a net-zero target by 2050. These commitments and targets from Australia's largest export markets indicate a shifting demand for fossil fuel and energy intensive exports. An increase in global emission reduction ambition will create risk to exports as countries shift away from fossil fuel based energy production and as countries, businesses and customers demand lower consumption emissions.

Given the countries with net-zero targets represent a 66% share of Australia's export market share, it is imperative that Australia adjusts its future exports to align with these shifting markets. **If Australia does not adjust accordingly, it risks losing export revenue without supplementing historic exports with new opportunities.**

Figure 7: Australia's top 10 export markets and their renewable energy and net-zero targets

Export markets	% share of Aus exports	Renewable energy target	Net-zero target	
China	32.6	40% by 2030	✓	2060
Japan	13.1	36-38% by 2030	✓	2050
Republic of Korea	5.9	42% by 2034	✓	2050
United States	5.3	100% by 2035	✓	2050
India	4.9	60% by 2030		
New Zealand	3.4	97% by 2030	✓	2050
Singapore	3.4	2GW solar energy by 2030		
Taiwan	2.9	20% by 2030	✓	2050
United Kingdom	2.9	38-40% by 2030	✓	2050
Malaysia	2.5	20% by 2025		

Over 65% of Australia's export market share have an 100% net-zero target emission by 2060

Sources: Energy and Climate Intelligence Unit (2021), *Net Zero Tracker*.

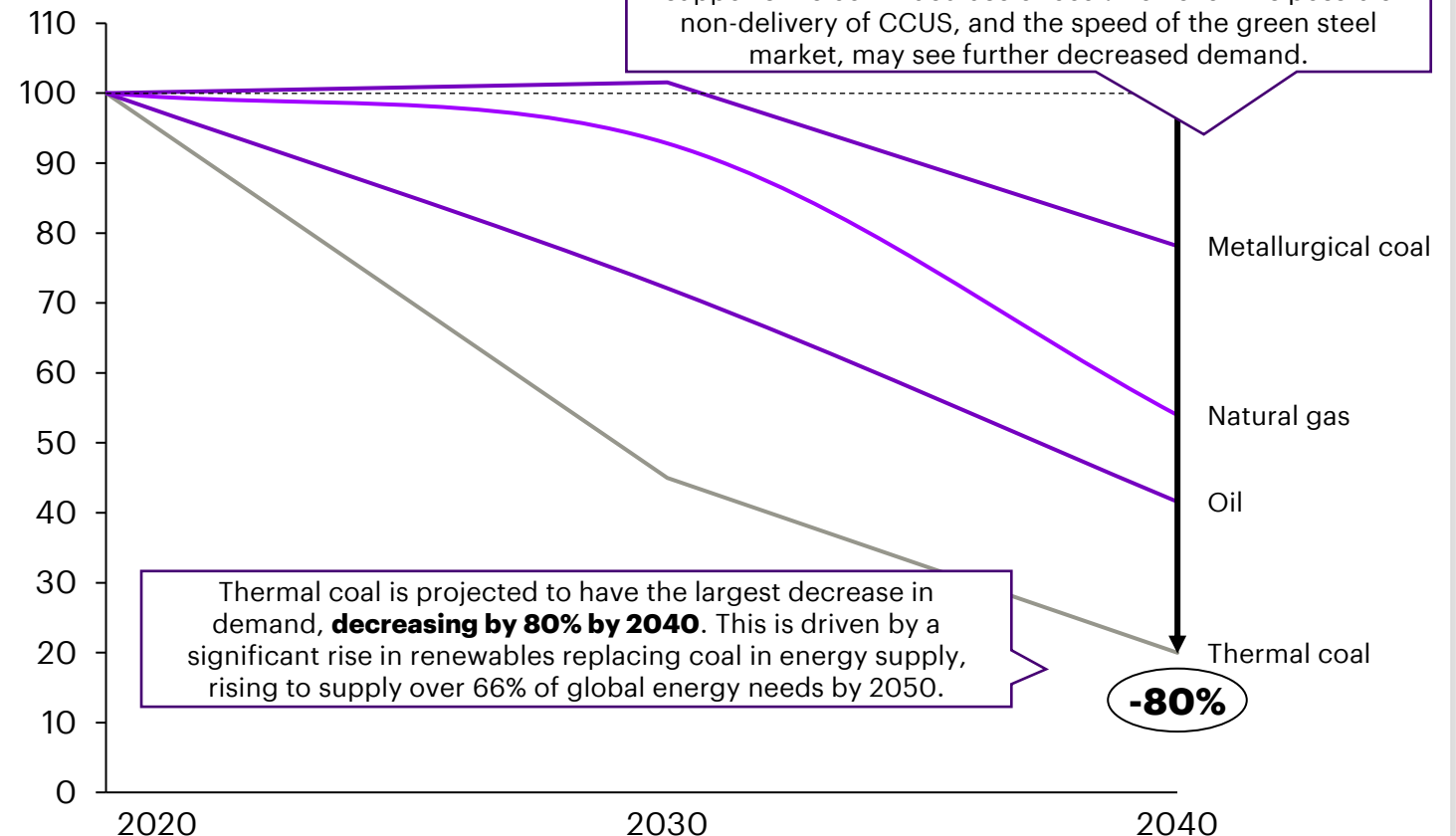
These exports are now at great risk due to the increased focus on mitigating climate change

The IEA's Net Zero by 2050 scenario lays out the necessary steps to achieve net zero energy-related and industrial process greenhouse gas emissions globally by 2050. **This target is consistent with limiting the global average temperature rise to 1.5°C** without overshoot (with 50% probability).

The IEA projects significant declines in demand for thermal coal, oil and natural gas by 2040, with further reductions expected to achieve net zero emissions by 2050. Given Australia's high exposure to fossil fuels, this reduction will have a significant impact on the market for Australian exports.

Figure 8: Change in global fossil fuel demand, 2020-2040, according to IEA Net Zero by 2050 scenario¹

Index; 100 = fossil fuel supply in 2019



There may be greater decreases in demand of fossil fuels if CCUS technology does not perform as expected. For example, metallurgical coal has the smallest decrease, given the modelled adoption of CCUS in steelmaking that supports the continued use of coal. However it is possible non-delivery of CCUS, and the speed of the green steel market, may see further decreased demand.

Thermal coal is projected to have the largest decrease in demand, **decreasing by 80% by 2040**. This is driven by a significant rise in renewables replacing coal in energy supply, rising to supply over 66% of global energy needs by 2050.

-80%

Notes: 1. The index shown here for thermal coal, natural gas and oil are taken directly from the IEA NZE projections for 2040. The reduction in metallurgical coal was inferred from the reduction in steel production since metallurgical coal is used almost exclusively for steel production. The share of primary steel production by method is provided for 2019, 2030 and 2050. Further the total production of steel for 2019, 2030, 2040 and 2050 are provided. By summing the proportion of steel made via methods using metallurgical steel, the percentage decrease in steel manufactured using metallurgical steel can be calculated.

Australia's economic opportunities in clean energy exports



Australia has a natural advantage with an abundance of solar and wind energy, and the metals and minerals required for the energy transition

Figure 9: High solar and wind power potential across Australia^{1,2}

kWh/kWp, W/m²

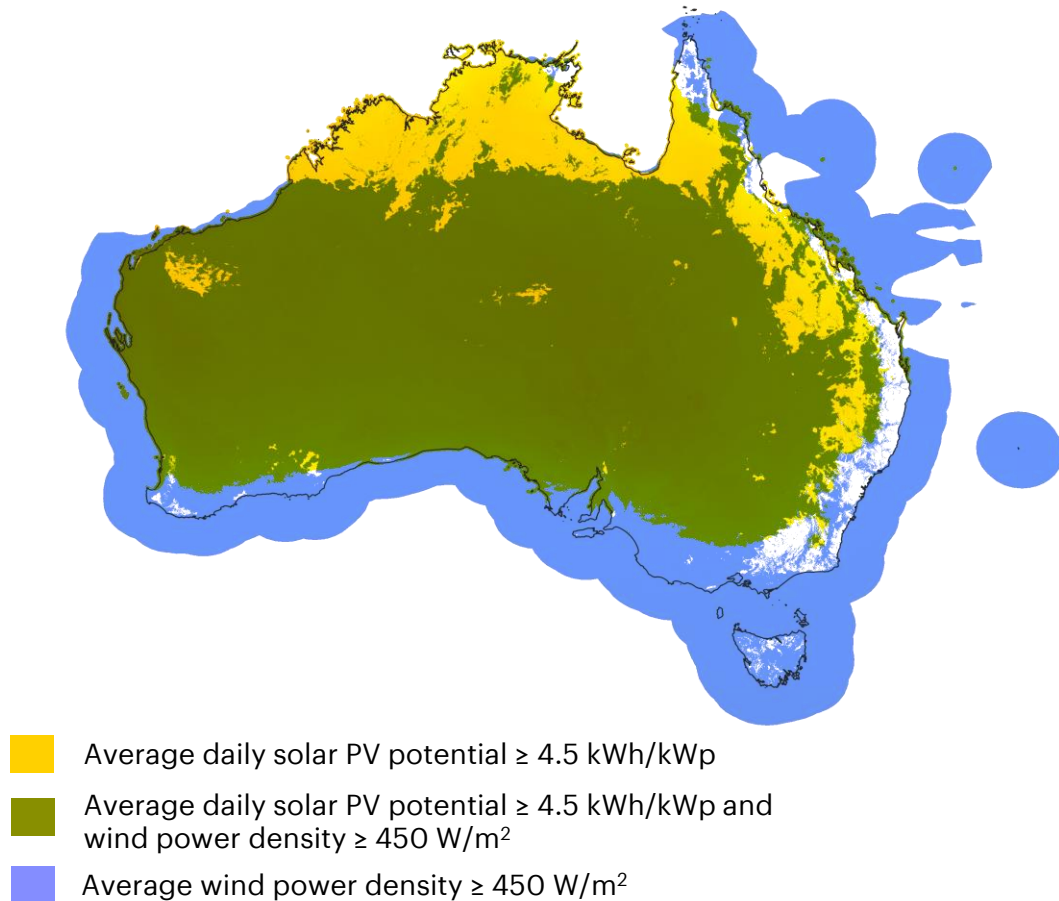
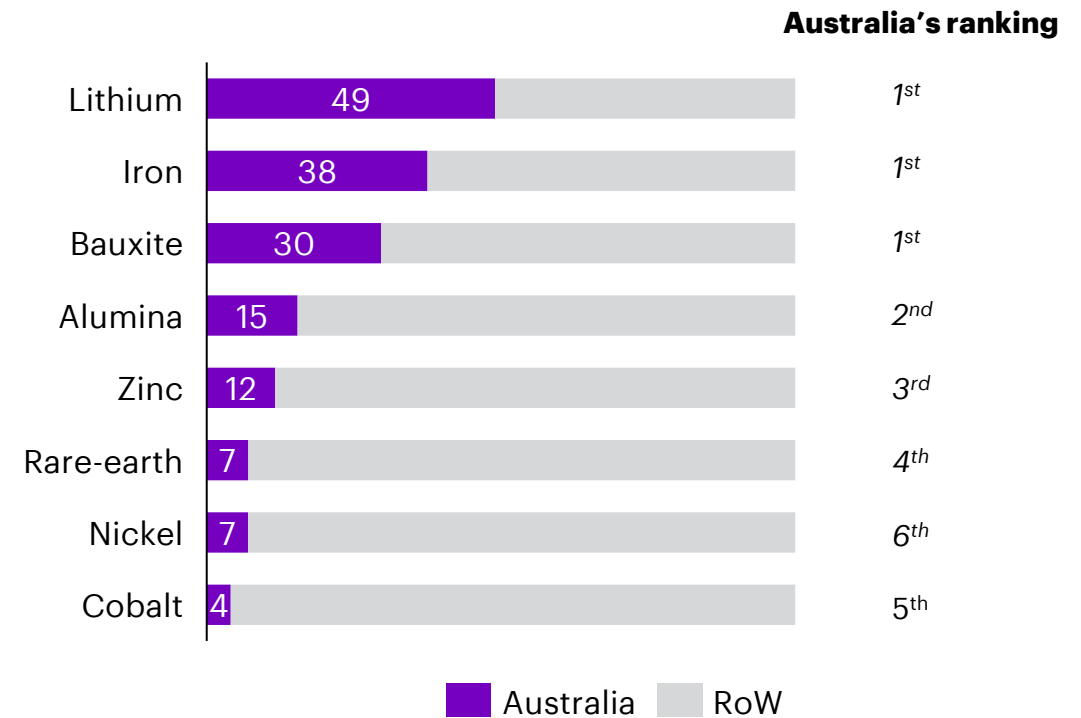


Figure 10: Australia's production of select metals and minerals essential for the energy transition³

% of global production



Australia can also benefit from the desire to diversify global supply chains

Production and export of clean energy materials and technologies is concentrated to a few countries. For example, in the batteries manufacturing value chain, Australia is responsible for 50% of raw materials mining, China is responsible for ~89% of the world's raw material refining and 50% of the world's cell manufacturing, and Japan is responsible for 53% of the world's component assembly.¹ High level of concentration and complex supply chains increases the risk arising from physical disruption or trade restrictions.²

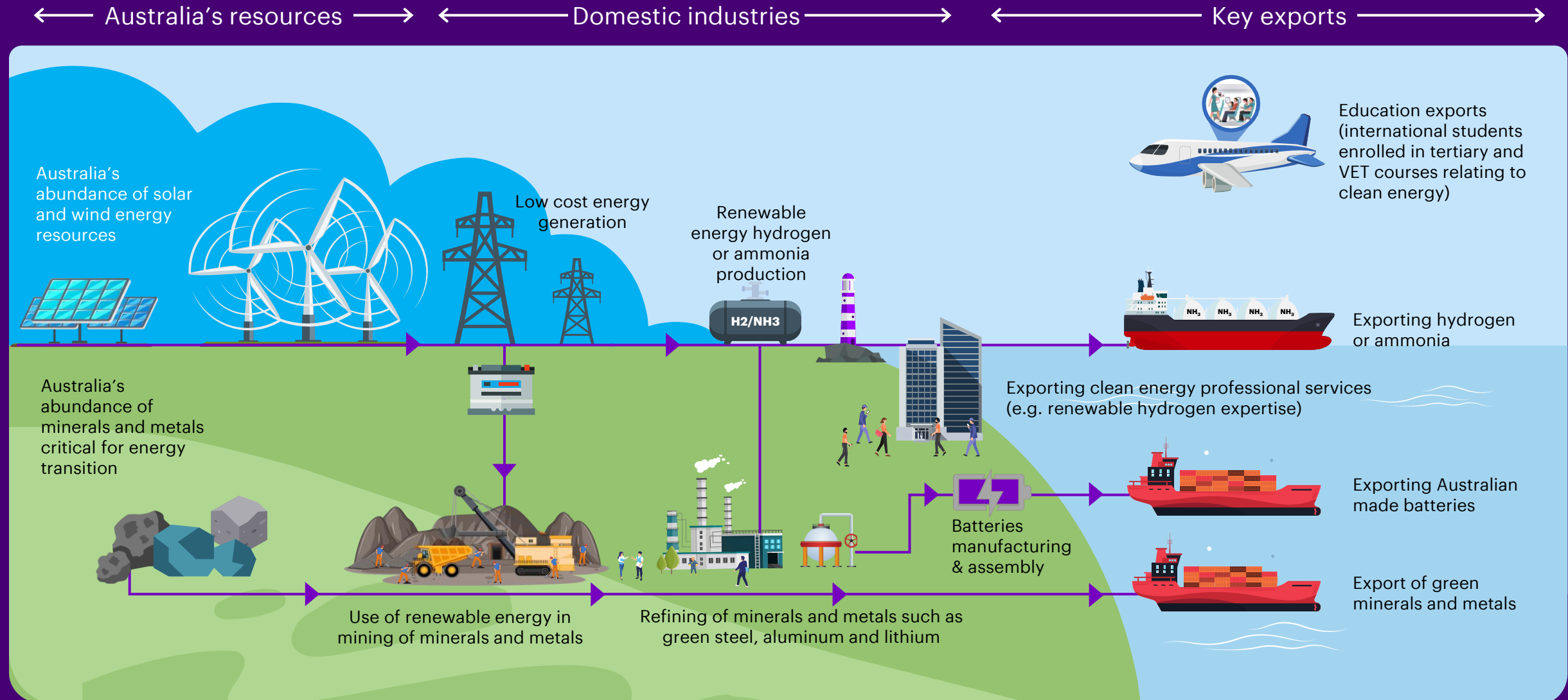
Shutdown of major industries during COVID-19 has demonstrated the impact of relying on single suppliers. Global businesses, as part of their resilience strategies, are seeking to diversify their supply chain operations. With global businesses and countries seeking new partnerships, **Australian exporters have an opportunity to tap into new markets and expand their customer base.**

Figure 11: Battery manufacturing value chain segments and market share²
Global market share by segments

	Value chain component	Key Region	Global Market Share (%)
1	Mining and raw materials	Australia	50%
2	Refining to chemicals	China	89%
3	Active materials	China	64%
4	Cell manufacturing	China	50%
5	Battery pack assembly	Japan	53%
6	Integration service & maintenance	N/A	Highly localised
7	Re-use & recycling	China	45%

Source: 1. Accenture (2021), Future Charge Report 2: International Energy Agency

As the world transitions to a low emissions economy, Australia is well placed to pivot to lead the global energy transition



This report explores six export opportunities in clean energy and technologies that can fuel Australia's growth in the low emissions economy

Energy & materials



Renewable hydrogen and ammonia

Export of hydrogen, likely in the form of ammonia as a carrier, produced with renewable energy. This may take the form of electrolyzers connected to a grid serviced by renewable energy or an off-grid renewable energy development.



Green metals

Processing & export of high-value metals such as aluminium and steel produced using renewable energy

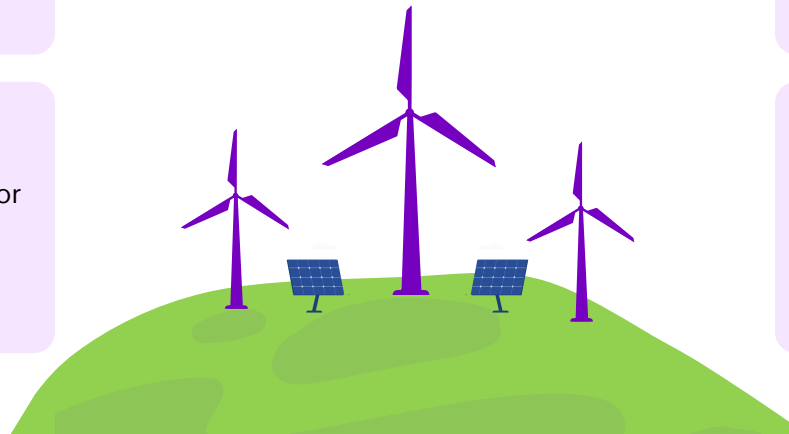


Critical minerals

Export of critical minerals that are required for clean energy technologies. This includes the export of raw minerals and the refinement in Australia and export of the metals.¹

2040

Australia's clean energy export opportunities¹



Technology & services



Batteries

Export of batteries manufactured in Australia



Education & training

International student enrolments in clean energy and environment related fields of study at Australian Universities and VET institutions, driven by growing demand for skills in clean energy sector



Engineering, ICT & consulting services

Export of services required to scale clean energy projects globally, including engineering and project management, construction, research and technology, systems integration, and much more.

Notes: A long list of potential export opportunities including others such as direct electricity transfer, heating & cooling technologies, electric vehicles, solar and wind turbine components and many more were identified. The following six were selected for further exploration based on market attractiveness and Australia's comparative advantage. 1. This opportunity includes only the expected demand for clean energy technologies and not total critical mineral demand.

Our methodology considers supply and demand conditions in 'business as usual' and policy scenarios to estimate size of each opportunity; the policy scenario has been sized based on conservative estimates of demand- and supply-side drivers

Methodology to estimate economic value creation for each opportunity

Opportunity drivers

Demand-side drivers	1	Global market demand by 2040	What is the global market demand for this opportunity?
	2	Demand for Australian exports	Is there an export market for Australian goods? Which markets are key?
Supply-side drivers	3	Australia's current production	What is our current production?
	4	Technology	Is it technologically feasible? Or when do we predict technology would be feasible and commercially scalable?
	5	Supply capabilities	Do we have the raw materials and the expertise?
	6	Investment/infrastructure	Does this require significant infrastructure investment?

Scenario

PATH 1:
Australia's projected 2040 export revenue in a 'Business as usual' (BAU) scenario

PATH 2:
Australia's projected 2040 export revenue in a policy scenario

Outputs

Gross value added

Measures the marginal economic value that is added by an industry (or business) to the costs of inputs. E.g. if a business spent \$55 on inputs for its \$100 revenue, then it has created \$45 of value-added. This is defined as direct gross GVA.

From this direct expansion in the economy, flow-on supply-chain effects in terms of local purchases of goods and services are anticipated, and it is estimated that these indirect impacts would result in a further increase to value-added. This is defined as indirect GVA.

Job creation

Measures the total number of new jobs created (full time, part-time and casual) due to additional industry output (revenue). Direct jobs refers to jobs created in the specific industry due to additional revenue. Indirect jobs refer to jobs created due to flow-on supply-chain effects.

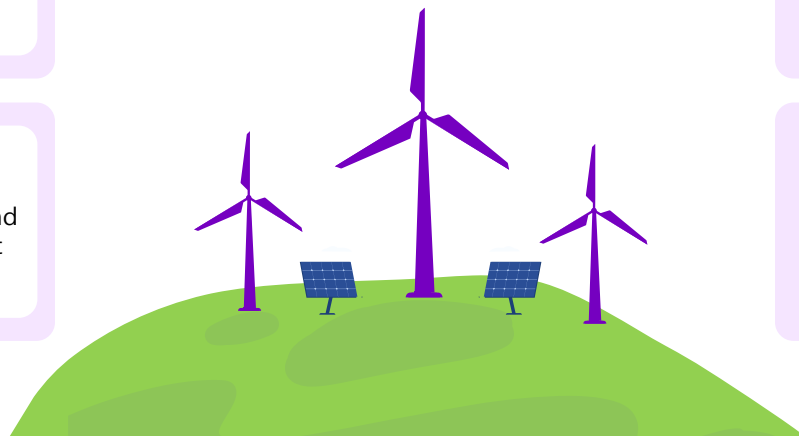

Based on conservative estimates, clean energy opportunities have the potential to generate \$89B in gross value added for Australia and create 395,000 jobs in 2040

← Energy & materials →

← Technology & services →


2040

Australia's clean energy export opportunities ¹


Renewable hydrogen/ammonia

\$28.9 B	\$22.3 B	33k
Revenue	Direct and Indirect GVA	Direct and Indirect Jobs




Green metals*

\$35.3 B	\$20.1 B	111k
Revenue	Direct and Indirect GVA	Direct and Indirect Jobs




Critical minerals mining & refining**

\$38.4 B	\$24.1 B	110k
Revenue	Direct and Indirect GVA	Direct and Indirect Jobs




Batteries

\$27.6 B	\$6.9 B	45k
Revenue	Direct and Indirect GVA	Direct and Indirect Jobs



Education & training

\$11.9B	\$10.5 B	66k
Revenue	Direct and Indirect GVA	Direct and Indirect Jobs



Engineering, ICT & consulting services

\$5.9 B	\$5.0 B	30k
Revenue	Direct and Indirect GVA	Direct and Indirect Jobs

Source: Accenture analysis

*Only estimated for green alumina, green aluminium, green steel and direct reduced iron (DRI)

**Only estimated for copper, nickel, lithium, cobalt, and rare-earth minerals required for the clean energy transition

Note: 1. The numbers represent the policy scenario for all opportunities. Gross value add and jobs are based on estimated export revenue for opportunities in 2040. Conservative estimates have been taken for each of the opportunities. These values should be considered only a baseline value and not the maximum possible value available to be captured.



While the largest opportunities are in new energy and metals, services will be a significant beneficiary of these developments

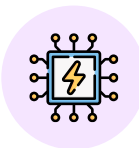
Seizing these export opportunities will unlock a range of new capabilities such as:



Renewable energy building and operations



Grid build, management and maintenance



Energy systems design and operations



Smart technologies and ICT services



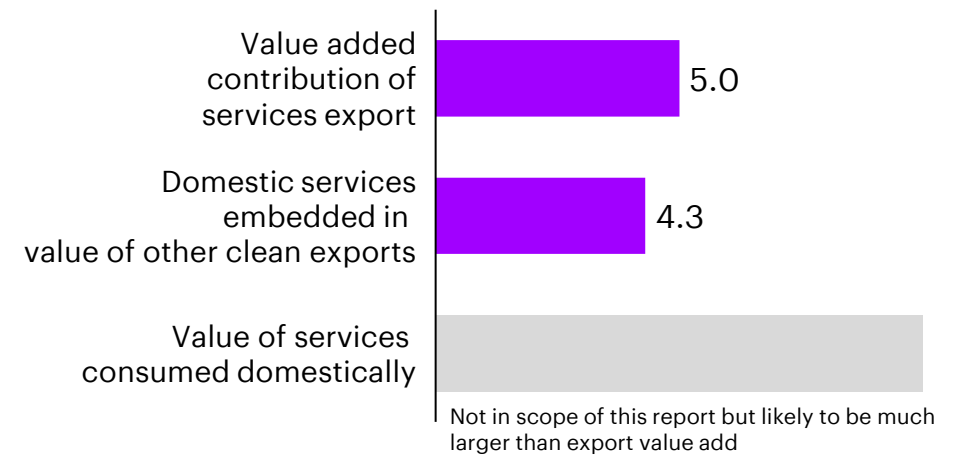
Clean energy legal, advisory and financial services for large infrastructure projects

The services sector is an important enabler of global value chains.

The sector plays a role not only directly through the services export but additionally through indirect contribution within each of the export opportunities. While some services are exported directly, others are used as inputs to the production of goods exports – for example, engineering services embodied in manufacturing exports. Services embedded in other clean energy export opportunities could add a further \$4.3B to the economy. In addition to this contribution, there will be further consumption of services domestic that have not included in the calculations below.

Figure 12: Many of which will provide the backbone for domestic and export services

2040 Gross Value Add (\$B)



Australia will need to act quickly as it faces significant competition from other countries

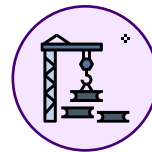
We must act fast in order to capture the full potential of these opportunities.

There is substantial international competition for many of the clean energy exports evaluated in this report. Many countries also have high potential renewables resources and have outlined strategies and funding for export opportunities so Australia's place as a leader is not assured. Hence, it is imperative that Australia acts fast if it is to capture a substantial share of the global market over countries with similar aspirations and renewable resources. Australia's competitors have existing targets that are ambitious and fast-moving, some as early as 2025. Further, countries such as China have an existing advantage in the refining of critical minerals, which further emphasizes the need for Australia to act quickly and at scale to capture these markets.

Opportunity



Renewable hydrogen / ammonia



Green metals



Critical minerals mining & refining

Example countries that are making significant investments in clean energy exports



Chile has announced an ambitious National Green Hydrogen Strategy that outlines plans to produce green hydrogen at scale. The Government of Chile has committed \$50 million in financing for pilot projects to reach three main goals: 1) to reach 5 GW of electrolysis capacity under development by 2025, 2) produce the most cost-efficient green hydrogen by 2030, and 3) be within the top 3 exporters by 2040.^{1,2} Chile has similar renewable energy resources to Australia and hence a similar competitive advantage to producing hydrogen.



Germany has committed to the ambitious national target of carbon neutral by 2045. To decarbonize their industries, Germany has committed €8, or \$12.9, billion to fund large-scale hydrogen projects to support chemical, steel and transport industries. The government has committed over \$8 billion to clean up steel production specifically. In 2020, Germany was the 8th largest producer of steel globally³ and could capture a similarly significant share of green steel through significant funding for decarbonization.



China currently has the majority global share of processing all of the critical minerals of interest; copper, nickel, cobalt, lithium and rare earth elements. In 2019, China was responsible for processing a 65% share of Cobalt, 58% share of Lithium and 87% share of rare earths.⁴ China's has developed an expertise and infrastructure of processing that has led to the cornering of the market.

Sources: 1. International Climate Initiative (IKI) (2021), *Chiles National Green Hydrogen Strategy* 2. Government of Chile-Department of Energy (2020), *National Green Hydrogen Strategy* 3. World Steel Association (2021), *World Steel in Figures* 4. IEA (2021), *The Role of Critical Minerals in Clean Energy Transitions*

These new export opportunities are greater in scale than current fossil fuels exports and could be an important avenue of diversification for regional economies

These six clean energy export opportunities¹ could create 19% greater revenue, 11% greater value add and over 83k more direct jobs in 2040 than the current fossil fuel² industry generated in 2020. In addition to the greater economic contribution, the six opportunities identified in this report will improve Australia's economic complexity and encourage a diversity of industries. This comparison highlights the scale of the new opportunities which could exist in conjunction to existing traditional industries.

Figure 13: Revenue of clean energy exports (2040) and fossil fuel exports (2020)³

2020 \$ billion

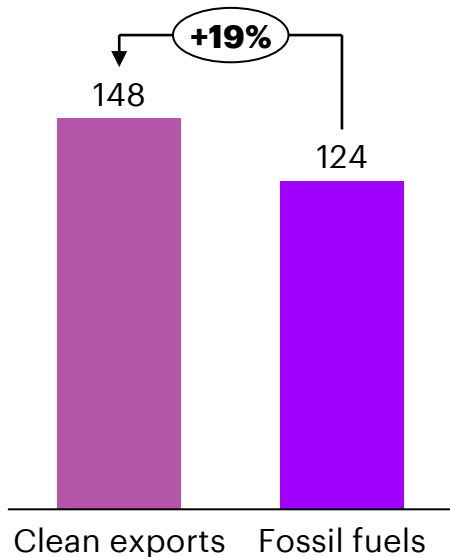


Figure 14: GVA of clean energy exports (2040) and fossil fuel exports (2020)⁴

2020 \$ billion

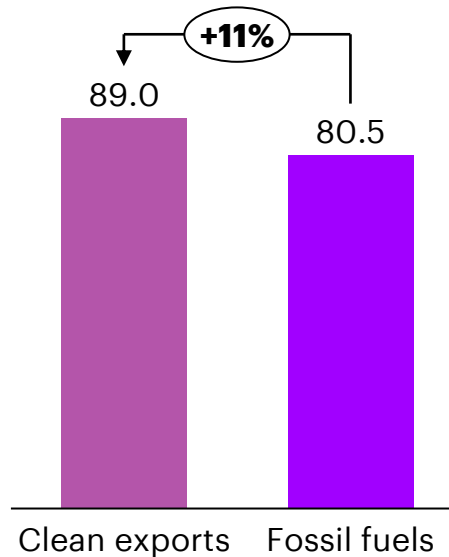
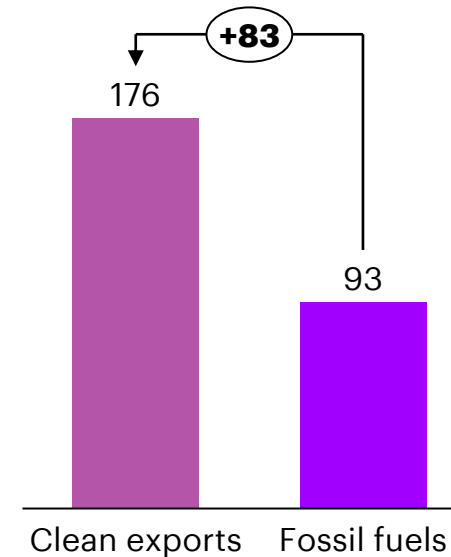


Figure 15: Direct jobs from clean energy exports (2040) and fossil fuel industry (2020)⁵

Direct jobs, '000



Clean exports include industries that employ more people per dollar of revenue than the current fossil fuel industry.

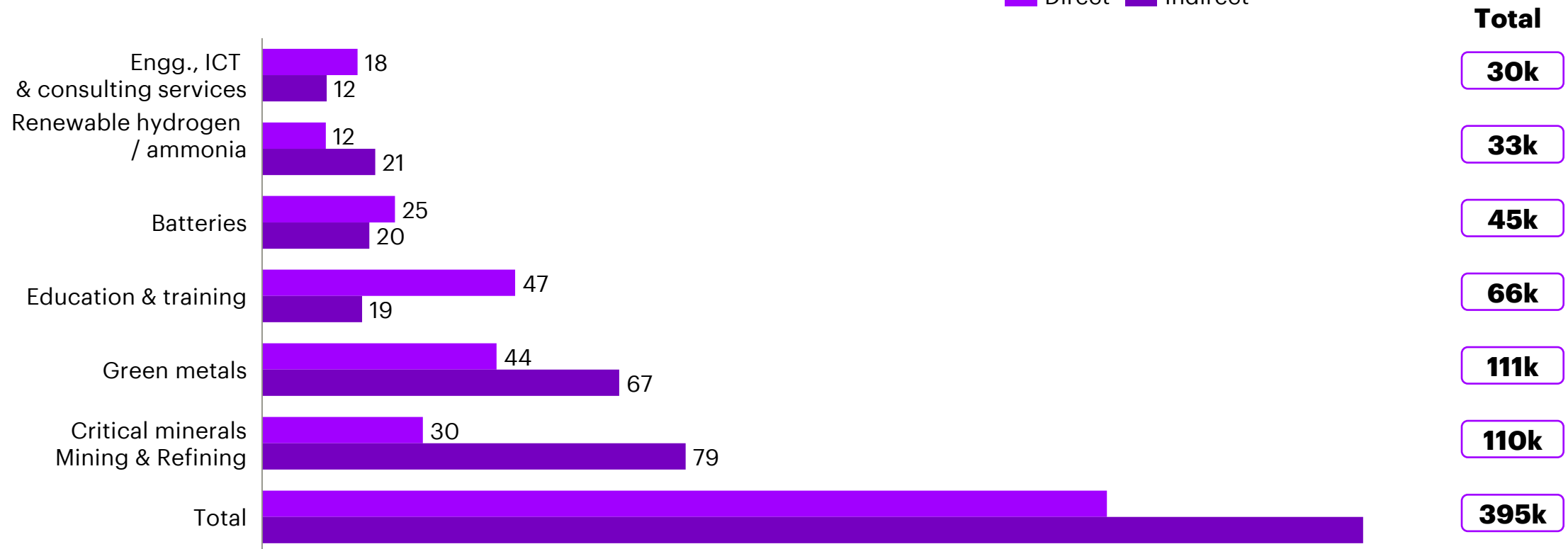


The clean energy opportunities will create 176K direct jobs and 219k indirect jobs due to the flow-on supply chain

Figure 16: Jobs enabled by Australia's clean energy export opportunities

Direct and indirect jobs in policy scenario, '000

Direct Indirect



Note: Represents the total number of new jobs created (permanent and casual) due to additional industry output (revenue) Direct jobs refers to jobs created in the specific industry due to additional output. Indirect jobs refer to jobs created due to flow-on supply-chain effects. Indirect jobs will include some but not all potential new renewable energy jobs created in the economy.

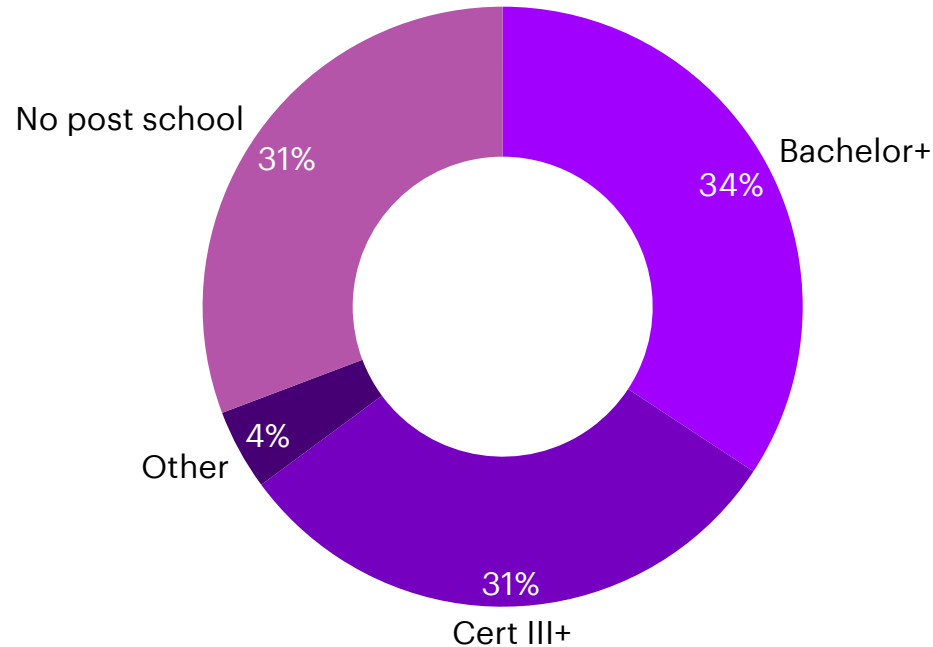
Source: Accenture analysis



Clean exports will create opportunities for workers across qualification levels; more than half of jobs would be in mining, manufacturing, and professional services

Figure 17: Breakdown of jobs by qualification required

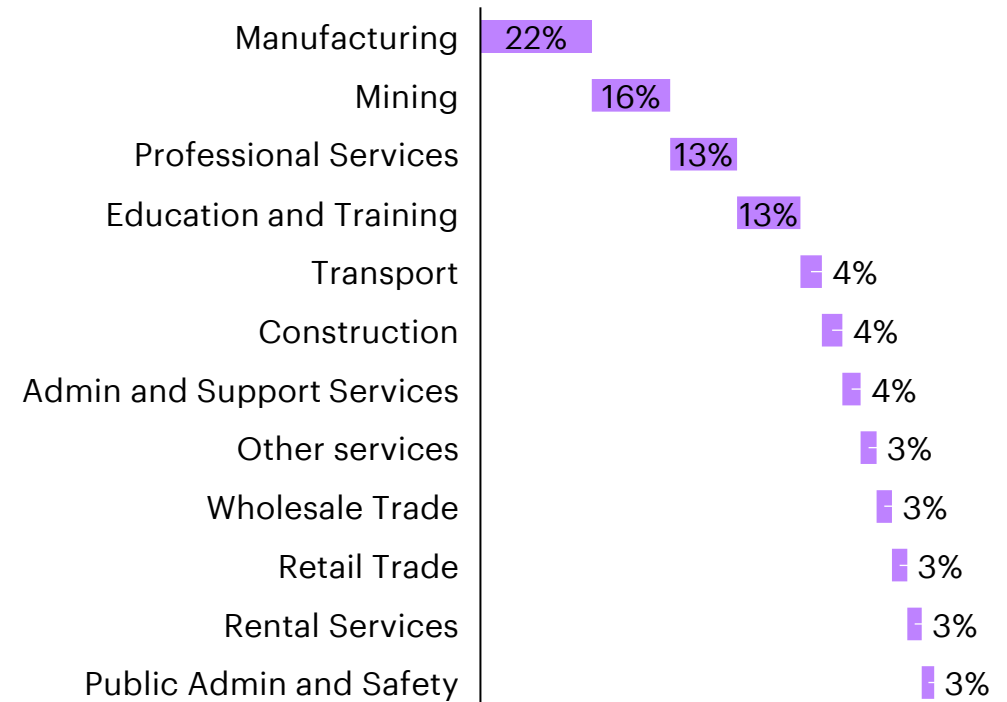
% of total direct and indirect jobs



Clean exports will create equal opportunities for workers across qualification levels, with approximately an equal division of jobs requiring bachelor and above, certification III and above, and no post school qualifications

Figure 18: Breakdown of jobs by industries

% of total direct and indirect jobs



More than half of new jobs would be in mining, manufacturing, and professional services industries. ~80% of jobs will offer permanent full-time or part-time employment, with remaining ~20% offering casual employment¹

Note: Remaining 9% of jobs are in other sectors with <2.5% of total

Source: Accenture analysis

Note: 1. According to ABS, casual workers are defined as employees without access to paid leave entitlements. Estimated based on ABS's estimates of casual workers and applying a similar ratio to the new jobs created in each industry. ABS estimates of casual workers in some industries is conservative as some casual workers who found their job through a labour hire firm/employment agency can be categorised as permanent employees within 'Admin and support services' industry

69k of new jobs could be located in WA, 78k in QLD, 31k in SA and 6k in NT

NT

Clean export jobs¹

6.3k

Top 3 opportunities driving the jobs

- 4k critical minerals mining & refining
- 1k green metals
- 1.3k other opportunities

WA

Clean export jobs

68.5k

Top 3 opportunities driving the jobs

- 23k critical minerals mining & refining
- 28k green metals
- 8k hydrogen

QLD

Clean export jobs

77.8k

Top 3 opportunities driving the jobs

- 38k critical minerals mining & refining
- 15k green metals
- 9k education and training

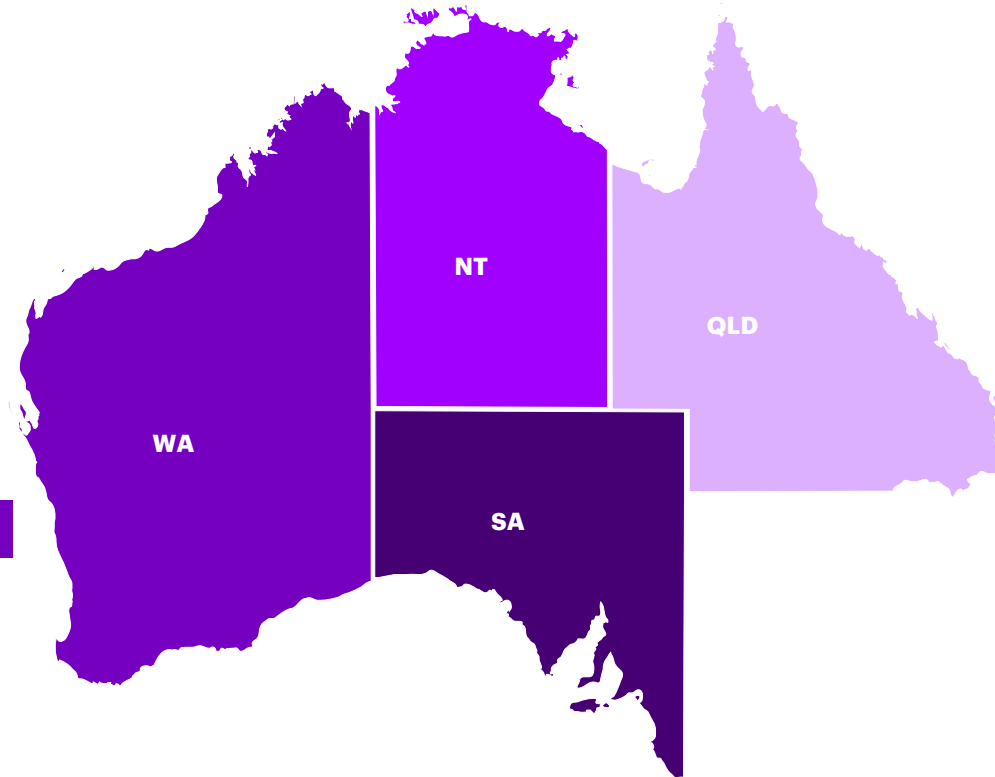
SA

Clean export jobs

30.7k

Top 3 opportunities driving the jobs

- 14k green metals
- 4k education and training
- 5k critical minerals mining & refining



99k of new jobs could be located in NSW, 68k in VIC, 4k in ACT and 11k in TAS

NSW

Clean export jobs

98.7k

Top 3 opportunities driving the jobs

- 23k critical minerals mining & refining
- 34k green metals
- 19k education and training

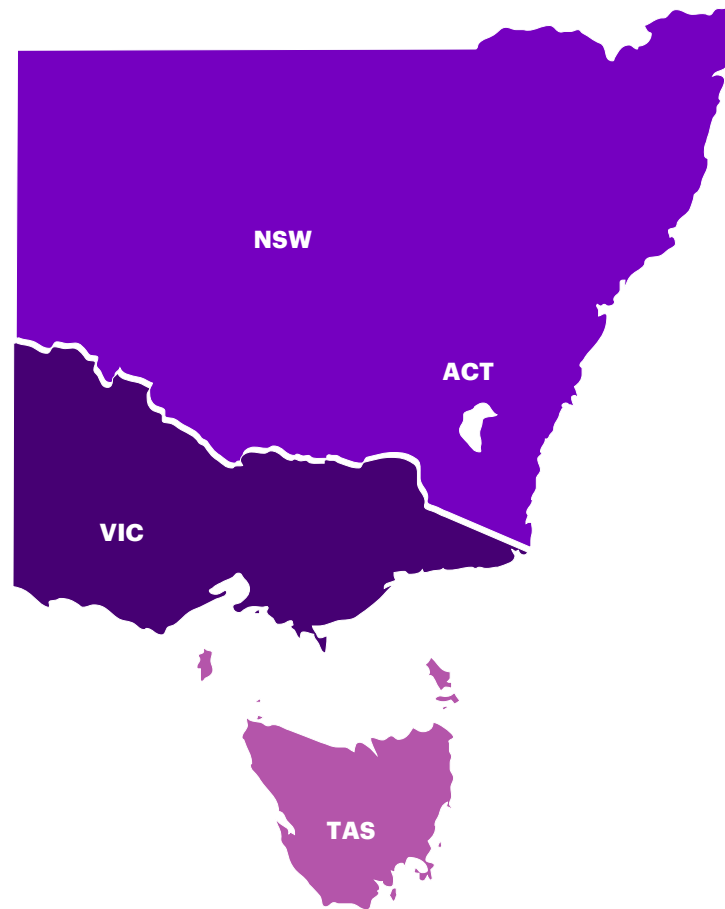
VIC

Clean export jobs

67.5k

Top 3 opportunities driving the jobs

- 24k critical minerals mining & refining
- 14k batteries
- 13k green metals



ACT

Clean export jobs

4.1k

Top 3 opportunities driving the jobs

- 1.7k education and training
- 1k critical minerals mining & refining
- 0.7k green metals¹

TAS

Clean export jobs

11.2k

Top 3 opportunities driving the jobs

- 5k green metals
- 3k critical minerals mining & refining
- 1k education and training



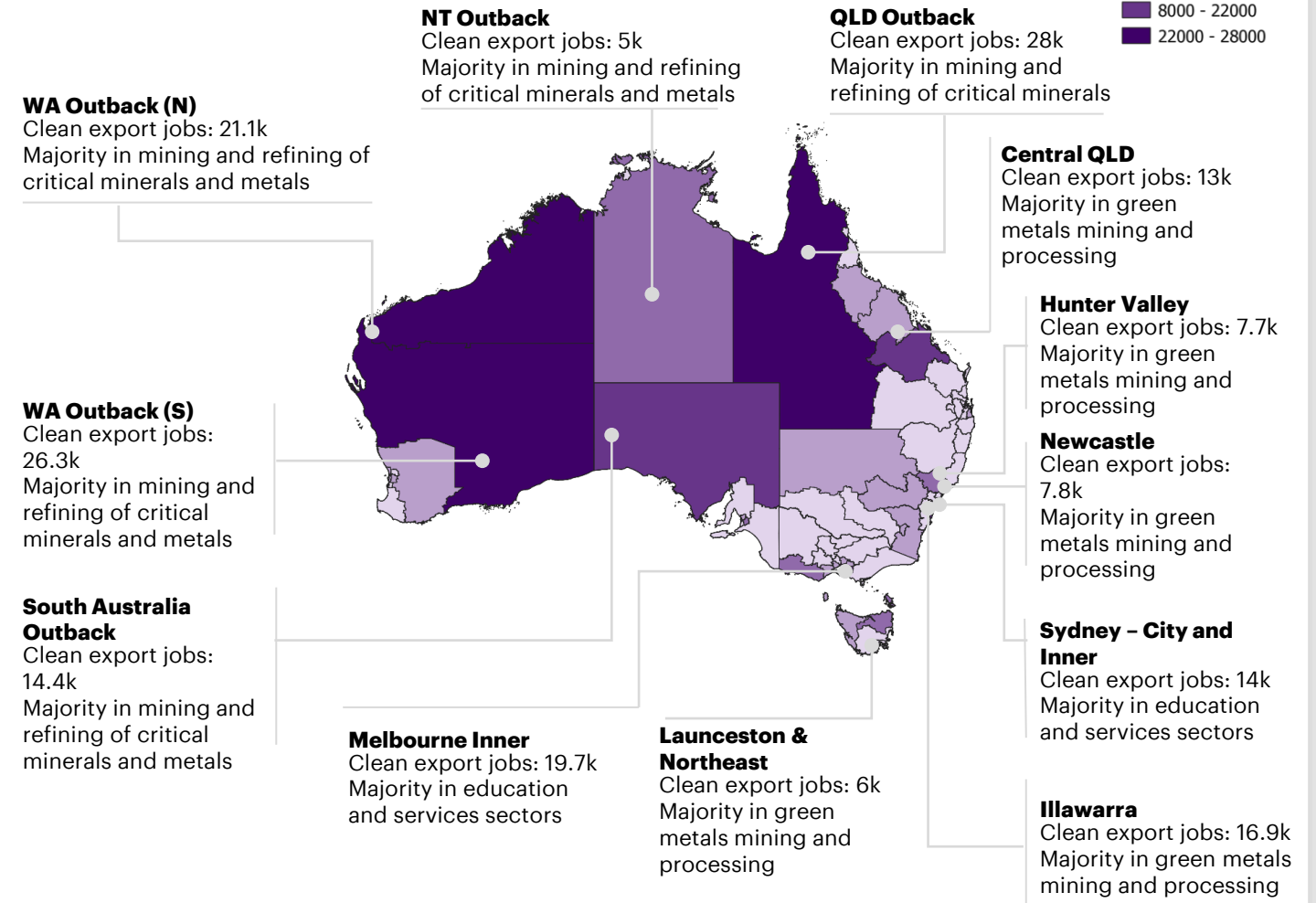
New jobs could be supported in several regions across Australia

Regional Western Australia, Central and Outback Queensland, Outback South Australia and Illawarra region in New South Wales are the major regions that could see a significant growth in employment, primarily driven by mining, value added refining and processing of critical minerals and metals. Both Central QLD and WA Outback have a rich endowment of several critical minerals such as lithium, bauxite, and rare-earths. The Illawarra region is currently a steel producing hub and may well transition to producing green steel. However, if Australia moves to green steel, steel plants could also be located closer to the ore and source of renewable energy in WA and SA Outback.

Clean export opportunities will also create employment in major cities and surrounding regions such as Melbourne Inner (19.7K) and South East, Sydney City and Inner South (14K), and Brisbane Inner City (5.3K). The majority of these jobs will be enabled due to growth in education services sector as well as growth in domestic ICT and other professional services supporting clean energy opportunities.

Figure 19: Distribution of clean export jobs (direct and indirect)

direct and indirect jobs by SA4¹, 2040



Note: 1. Statistical Area Level 4 (SA4s) are the largest sub-state regions in the main structure of the Australian Statistical Geography Standard.

Source: Accenture analysis

Many jobs could be in regions that currently employ high numbers of coal mining and LNG workers

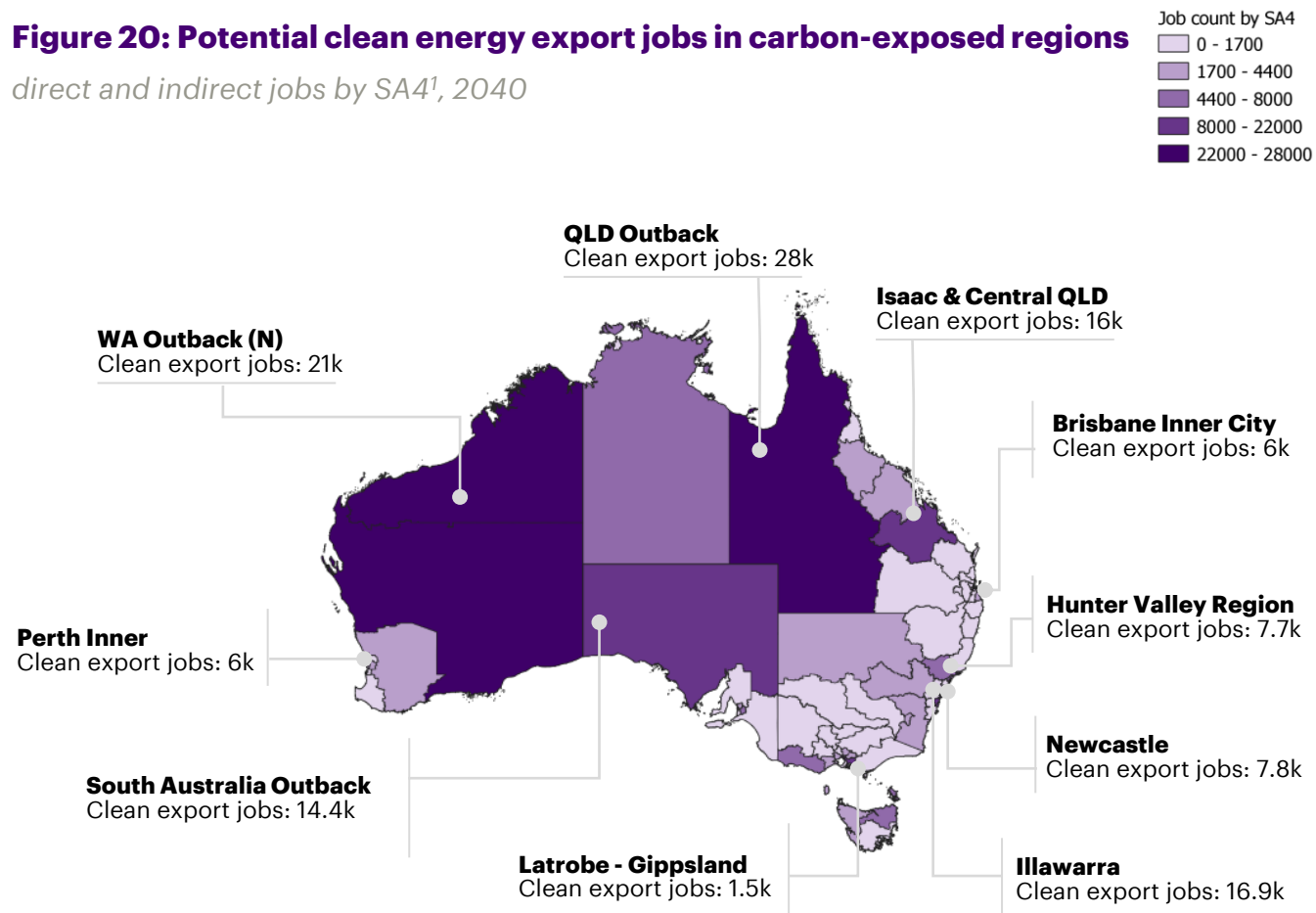
There are ~120,000 workers currently employed directly in carbon-intensive industries.¹ These industries include coal mining, oil and gas extraction, iron and steel forging, electricity generation, and metals and metals products manufacturing. There are 36,000 carbon workers in coal mining regions such as Central QLD and Hunter Valley region in NSW. An additional 7,700 are in Newcastle and Illawarra regions in NSW. Areas surrounding Brisbane and Perth are home to ~5,000 and ~4,000 workers. The remaining are scattered across the country.

The top seven regions in Australia with highest number of direct carbon workers account for 60,000 jobs (50%). Clean energy export opportunities could create as many as 38,400 direct jobs and 43,700 indirect jobs in those regions.

Delivering these jobs will not be easy. Strong policy action, as outlined in this report, will be required to drive clean energy opportunities and create new employment. In addition, a transition authority with an appropriate budget would be required to support a just transition for regions, workers and families currently supported by employment in carbon-intensive industries (refer to Section 5 for further discussion).

Figure 20: Potential clean energy export jobs in carbon-exposed regions

direct and indirect jobs by SA4¹, 2040



Note: 1. Statistical Area Level 4 (SA4s) are the largest sub-state regions in the main structure of the Australian Statistical Geography Standard
Source: ABS Census (2016), Accenture analysis

**Deep dive into the
six clean export
opportunities**



Critical minerals mining & refining



Critical minerals mining & refining

Critical minerals play a central role in many low-emissions energy generation and storage technologies. The IEA identifies nine critical minerals needed for clean energy technologies, of which, Australia has significant reserves of five: copper, nickel, lithium, cobalt and rare earth elements (REE). Copper is a key input of high importance into solar PV, wind, electricity networks and EVs. Nickel is an important input into batteries and hydrogen. Lithium and cobalt are key inputs into lithium-ion batteries used for electric vehicles (EV) among other applications. IEA predicts an rapid increase in EV sales, increasing more than 7 fold from 2020 to 2040.

Australia is well placed to play a significant role in the mining and refining of lithium, copper, nickel, cobalt and rare earth elements for clean technologies. Australia is currently one of the largest producers of lithium and cobalt, and has a significant proportion of global economic reserves. Further, given Australia's existing expertise in mining, critical minerals is an attractive opportunity for Australia given the dramatic increase in demand through to 2040 and Australia's high share of resources.

Scale of barriers: High Low

Opportunity drivers

Summary of findings

Opportunity drivers		Summary of findings	
Demand-side drivers	1 Global market size by 2040		To meet the IEA's projected demand for copper, nickel, lithium, cobalt and REE by 2040, the global market size is \$500 billion by 2040¹ .
	2 Demand for Australian exports		The demand for critical minerals is driven by the strong projected uptake in renewable energy generation as well as EVs and associated batteries required. Australia is well placed to capture markets looking for reliable and ethical sources of critical minerals for clean energy technology.
Supply-side drivers	3 Australia's current production		Australia is currently one of the largest producers of lithium and REE and has the potential to supply a significant share of cobalt, copper and nickel. Australia produces 49% of annual lithium produced, 7.1% of renewableE, 6,8% of nickel, 4.4% of copper and 4.1% of cobalt. ^{2,3}
	4 Technology		There are no new technologies required to green critical mineral mining, rather existing processes must be electrified, and the source of energy must be swapped to renewables. However, refining technologies will need to be developed for Australia to capture the additional value add. Australia has existing mining expertise that has the capacity to be expanded. ²
	5 Supply capabilities		Australia has significant economic resources of these select critical minerals. Australia has 22% of the known economic reserves of lithium, 20% of cobalt reserves, 21% of nickel reserves, 20% of copper reserves and 2% of REE reserves. ² Further, Australia is a desirable supplier due to the political stability and ability to scale up quickly to demand. Australia does not have significant existing facilities or expertise to scale up refining to capture total value add and would require significant investment and policy to develop this industry.
	6 Investment/infrastructure		Australia has well established infrastructure and transport for mining however this would require expansion to meet the increase in demand.

Source: 1. IEA (2021), *Net zero by 2050* 2. Austrade (2020), *Australian Critical Minerals Prospectus* 3. United States Geological Survey (2021)



Clean energy technologies are set to emerge as a major force in driving global demand for critical minerals

The IEA Net Zero by 2050 scenario predicts significant increase in global demand of critical minerals in 2040 by as much as 6x 2020 levels. These demands are driven by the dramatic expansion of clean energy technologies such as solar PV, wind turbines, and battery storage as well as the rapid uptake of electric vehicles.

All low-emissions energy technologies require critical minerals as inputs. The minerals most commonly in demand across all technologies are copper, aluminium, nickel, and chromium. Other critical minerals such as lithium, cobalt and rare earths are not inputs across all technologies however are central inputs for specific technologies such as battery storage.

A share of the global demand will be provided through recycling of existing metals. This recycling is likely to be most economically performed domestically where the metals have been used.

Figure 21: Total mineral demand for clean energy technologies^{1,2}

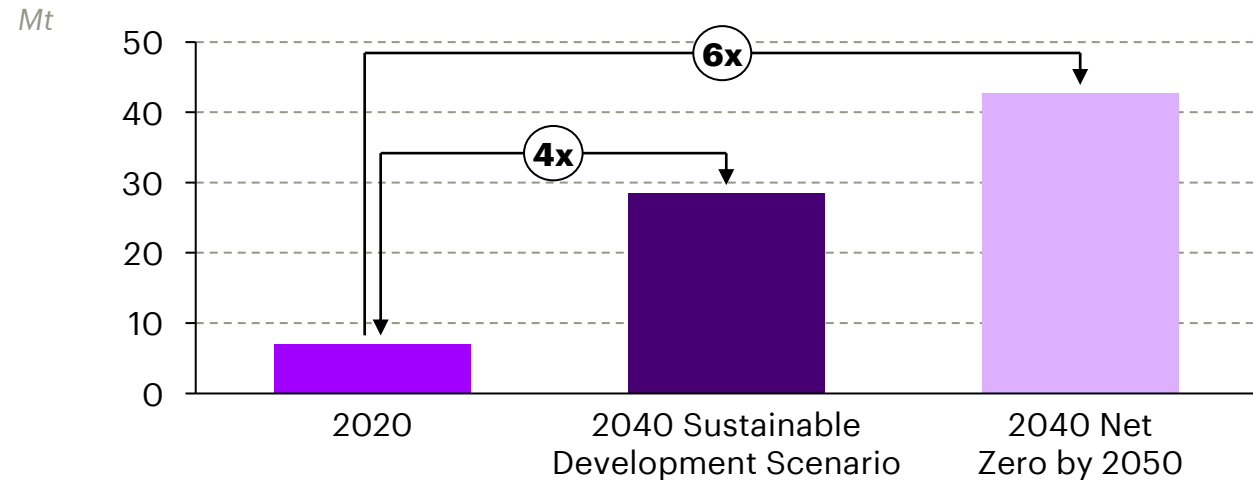
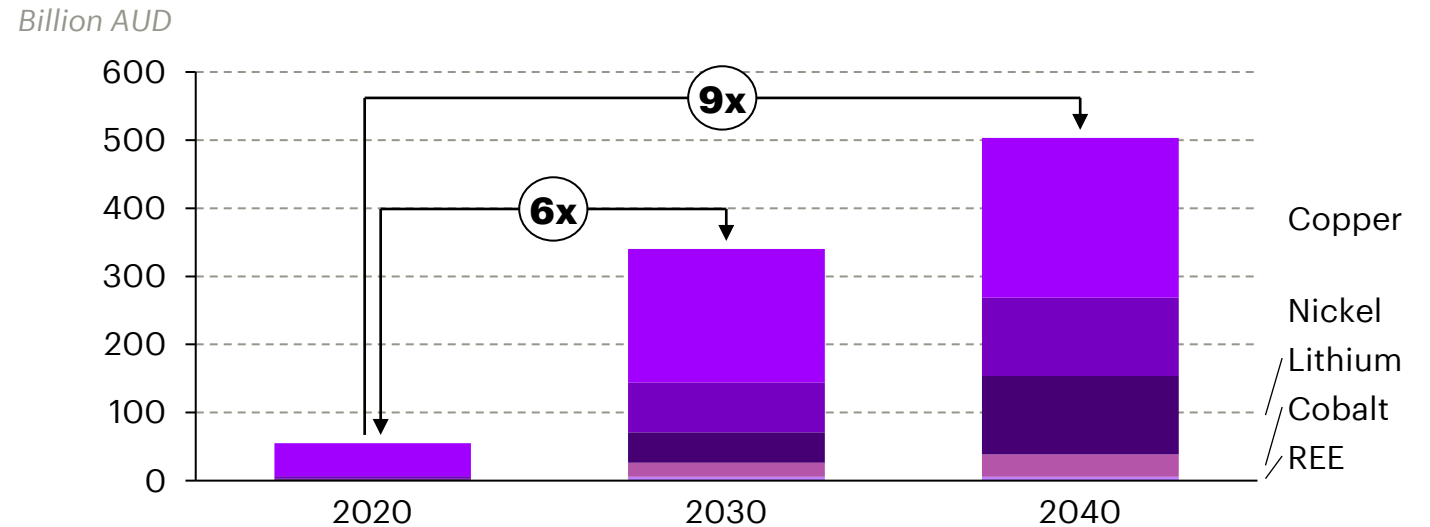


Figure 22: Global value of select critical minerals in IEA Net Zero Emissions scenario³



Source: 1. Clean energy technologies include solar PV, wind, other low-carbon power generation, EV and battery storage, electricity networks, hydrogen 2. International Energy Agency (2021) [The Role of Critical Minerals in Clean Energy Transitions](#); 3. International Energy Agency (2021), [Net Zero by 2050](#). 4. Austrade (2020), [Critical Minerals Prospectus](#)

Australia is one of the largest producers of critical minerals essential to scaling clean energy technologies

Australia can play a key role in the production of certain critical minerals for clean technologies. Australia is currently one of the largest producers of lithium and REE and has the potential to supply a significant share of cobalt, copper and nickel. Australia produces 49% of annual lithium produced, 7.1% of REE, 7% of nickel, 4.4% of copper and 4.1% of cobalt. Currently, Australia is overrepresented in production relative to reserves for lithium and REE and underrepresented in production compared to reserves of cobalt, copper and nickel.

Australia is well positioned to meet the expanding demand of critical minerals given the country's existing mining expertise and extensive infrastructure. Further, Australia is a desirable supplier due to the political stability and ability to scale up quickly to demand. Further investment will be required to extend the existing infrastructure to facilitate the expansion required to maintain, or grow, Australia's existing market share and the total size of the market increases. Australia has additional competitive advantages to refining through vertical integration from mining to refining.

Figure 23: Global share of critical minerals production¹

2020, by country

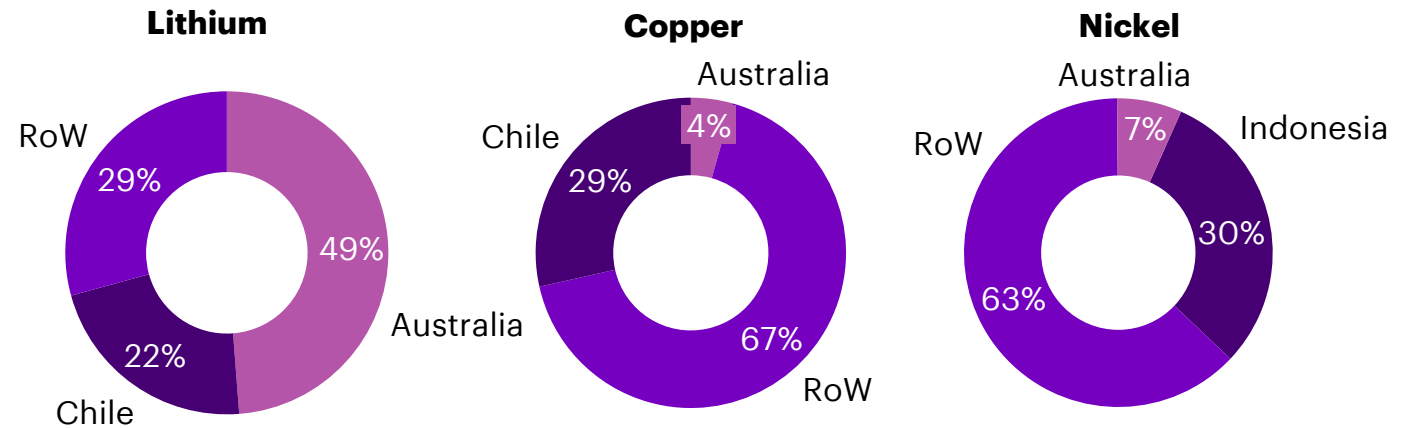
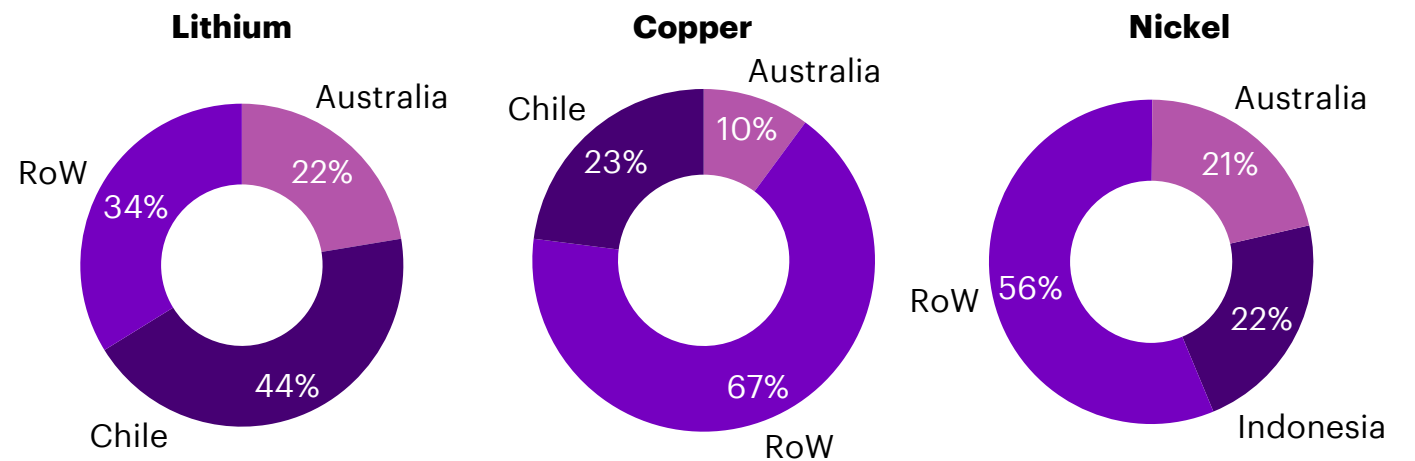


Figure 24: Global share of known mineral resources¹

2020, by country



Note: RoW = Rest of World.

Sources: 1. United States Geological Survey (2021)

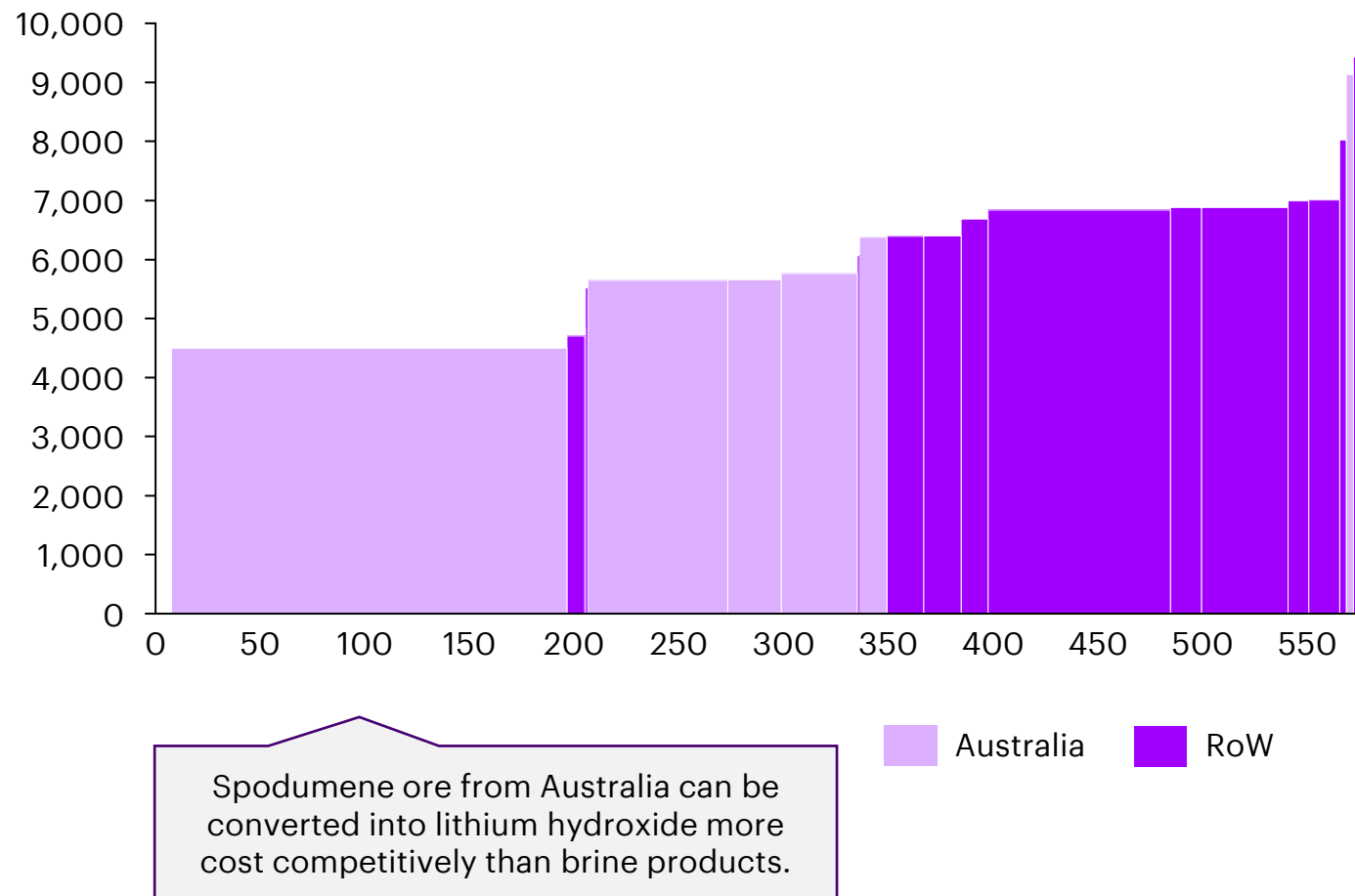
Cost curves indicate Australia can maintain a competitive position in lithium hydroxide production through to 2040

Among Australia's critical minerals opportunities, lithium is expected to form the largest share of revenue given Australia's significant market share. Within the lithium market, there are two main chemicals that are traded globally: lithium carbonate and lithium hydroxide. Lithium hydroxide is expected to increase in market share as battery chemistry shifts towards nickel-rich NCM-811 batteries. Currently Australia primarily mines minerals and does not have a developed refining industry, and hence is not capturing the additional value add and jobs. Yet Australian spodumene concentrate is currently more cost competitive to produce into lithium hydroxide than counterpart brine producers. Australia is well placed to capture these additional benefits through expanding into processing.³

In addition to Australia's economic advantage, Australia is a desirable market due to its political stability and established infrastructure and ports. Further, for the lithium opportunity specifically, spodumene miners can scale up operations far more rapidly than brine producer counterparts.

Figure 25: Projected lithium hydroxide total cash cost curve¹

\$/t LiOH of production, share of production, 2021



Sources: 1. Accenture analysis using S&P Global Market Intelligence (2021), *Lithium and Cobalt Cost Curves 2021, 2040*. 2. Metal Bulletin (2021), [Global lithium warp](#)

Notes: 3. It is possible that there will be improved methods of refining from both spodumene and brine in the coming decades. Conversion costs from concentrate and carbonate assumed constant from 2020.

Australia has several competitive advantages across the cost base of minerals refining

Australia's strength and significant share in the mining industry provides noteworthy advantages to Australian companies seeking to refining minerals. In particular, through vertical integration, Australian refiners can reduce logistics and material input costs significantly. Mining companies that expand down the value chain into refining have competitive advantages from secure supply of raw materials, reduced input costs for the raw material over companies that are not integrated, and lower logistics costs from on-site refining. Transportation of raw materials is often highly inefficient, since often the ore contains a very small percentage of the final metal.

Australia does however face several barriers to a competitive refining industry such as high capital costs associated with establishing plants and facilities. These relatively high capital costs are driven by Australia's high wages for construction workers, almost 2x Japan and 8x China.¹ These projects are beneficial to Australia through providing high paid work for employees.

Source: 1. International Labour Organisation (2021), *Mean nominal monthly earnings of employees*. National Institute of China (2020), *Average Annual Wage of employed persons in different positions*

Figure 26: Cost base for metals refining and Australia's competitive position

Input	% of unit cost (benchmark) ¹	Australia's competitive position
Materials	55	Australia is well placed to reduce material input costs for ores mined in Australia. However, Australia will need to import processing chemicals.
Energy	17	Australia is expected to produce renewable energy at extremely low cost. This will be discussed in greater detail in the Hydrogen opportunity.
Tax	16	Australia has a higher corporate tax rate than the benchmarked countries. However, Australia does have dividend imputation that gives investors a tax credit equal to tax paid by the company.
Labour	6	Australia has a well developed education industry and can train the required skill profiles however labour costs are higher than other comparative countries, leading to greater capital expenditure costs to build refining plants.
Logistics	6	Australia can save costs by co-locating refining with the extraction of raw materials.

Note: 1. Given Australia does not yet have a refining industry, a model cost base for refining has been captured from countries with an existing refining industry, such as Taiwan and South Korea.

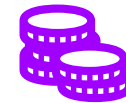
In the policy scenario, the share of refining is increased, and revenue reaches over \$38B in 2040

BAU

Australia has a strong mining industry with significant expertise in the sector and an export focused outlook.

In the BAU scenario, there are no incentives for refining or funding for R&D of the refinement processing. Given the existing industry's strengths, Australia maintains significant shares across the minerals. The opportunity is left to companies to develop, leading to lithium as the only mineral refining completed in Australia, a 20% share of mined lithium. Revenue increases from \$17 billion^{4,5} in 2020 for critical mineral mining to \$27.5 billion for clean critical mineral mining for clean technology only.

Market shares: 31% lithium, 7.6% nickel, 4.2% copper, 3.5% cobalt, 11.3% REE
Refining share: 20% lithium, 0% other
Increase in employment from 2020: 12k



\$27.5B
Revenue



\$17.3B
GVA¹



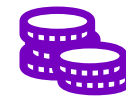
21.6k
Jobs²

POLICY SCENARIO

Additional revenue and value add is realised through the expansion of value chains to include refining the minerals in Australia.

Through additional policy measures to encourage the development of a refinement industry in Australia, 60% of mined minerals are refined in Australia, a significant increase from very few refineries in 2021. This grows the total revenue captured by the opportunity by over \$10 billion. Most notably, this is driven by the refinement of up to 230 kt of lithium from spodumene to produce lithium carbonate or hydroxide. Revenue increases from \$17 billion^{4,5} in 2020 for critical mineral mining to \$38.4 billion for clean critical mineral mining and refining for clean technology only.

Market shares: 31% lithium, 7.6% nickel, 4.2% copper, 3.5% cobalt, 11.3% REE
Refining share: 60% for all minerals
Increase in employment from 2020: 21k



\$38.4B
Revenue



\$24.1B
GVA¹



30.1k
Jobs²



Critical minerals could contribute \$24.1 billion annually to Australia's economy and support 30.1k jobs by 2040

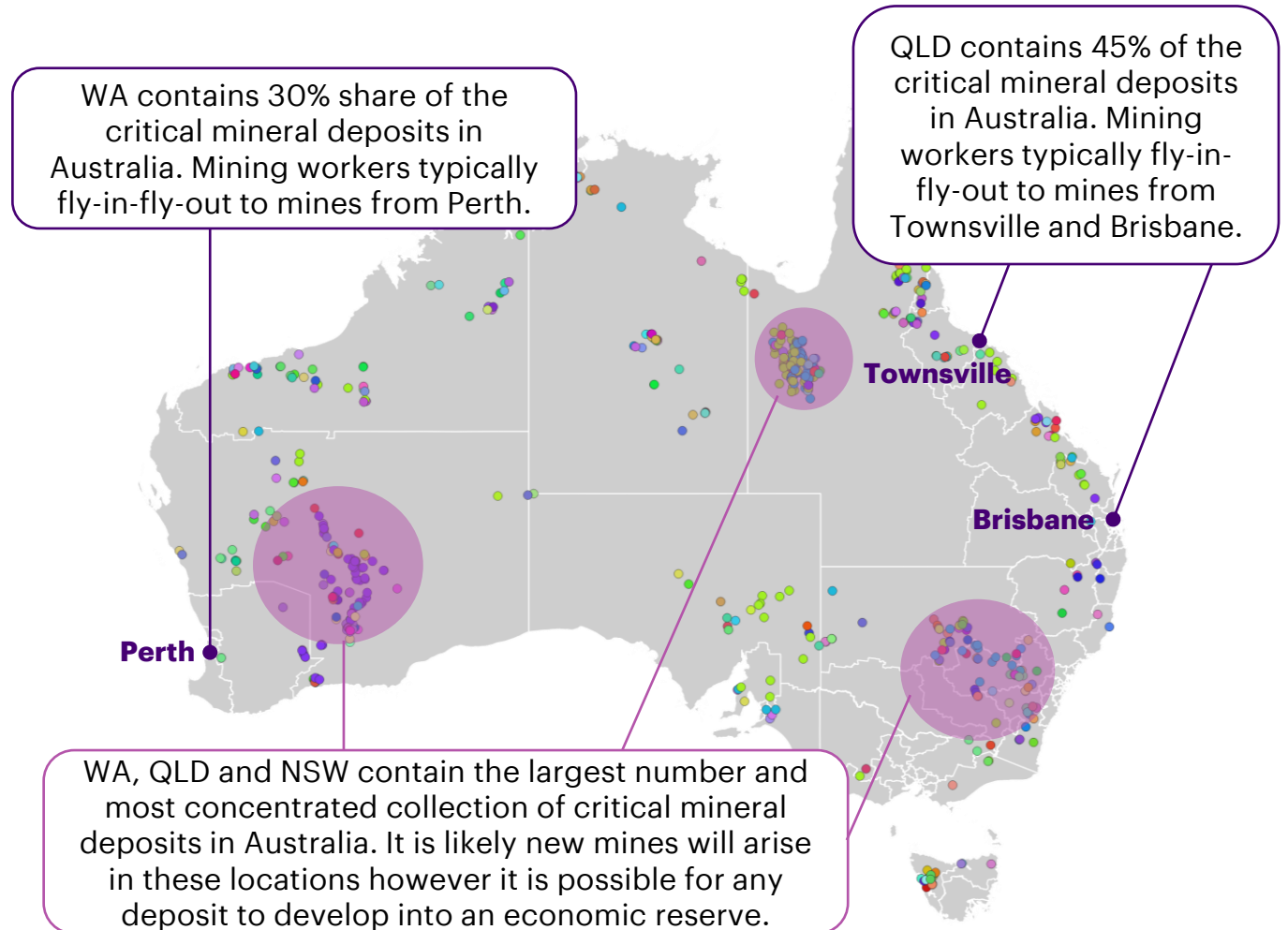
For the critical minerals opportunity, the place of work is heavily dependent on the quality and economic viability of deposits that are yet to be explored. Hence, it is not possible to determine the specific locations of jobs for the critical minerals of interest in 2040. Preference should be made towards using existing mines before creating new mines to reduce environmental impact.

Mining jobs are typically fly-in-fly-out (FIFO) and therefore the place of work and place of residence differ. Hence, it is possible to infer the hubs for mining workers given the existing hubs for workers across large mining states such as Western Australia and Queensland.

The critical mineral opportunity creates equal opportunities for workers across qualification levels, with approximately an equal division of jobs requiring bachelor and above, certification III and above, and no post school qualifications. The opportunity is expected to support employment indirectly in professional services, construction, manufacturing, and wholesale and retail trade.

The identified mineral deposits sit on Aboriginal Land and as such free, prior and informed consent (FPIC) from First Nations Peoples must be obtained, along with their continued effective and meaningful participation.

Figure 27: Locations of known critical minerals deposits and prospectus locations of bases for workers in the critical minerals opportunity¹



Source: 1. Geoscience Australia (2021), *Australian Mines Atlas*, Accenture analysis

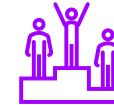
Australia's critical minerals opportunity rests on two assumptions



Global demand will grow strongly

The modelled revenue is dependent on strong projected growth in demand for critical minerals as clean energy technology expands. The demand is not country-specific but does rely on the growth of global demand for the select critical minerals and assumes no substitution of existing input materials.

Expected of each of the minerals for clean energy technologies in 2040 is: 1,356 kt of lithium, 683 kt of cobalt, 70 kt of REE, 22.7 Mt of copper and 5.7 Mt of nickel.



Australia is cost-competitive

The policy scenario assumes given sufficient government policy support, Australia can mine and refine critical minerals at a cost-competitive rate compared to international competitors. Australia has over 20% of known reserves for lithium, cobalt, nickel and copper and is well placed to competitively mine these minerals at scale. Further, Australia has an advantage of vertical integration to reduce costs between mining to refining. For this opportunity, Australia will require significant low-cost renewable energy for mining and refining.

Three policies would support the expansion of the critical minerals opportunity



Incentivising new mines to develop refineries

Policy is required to incentivise the development of refineries alongside new mines given the nascent scale of the refinery industry in Australia. Barriers to developing new industries such as high capital expenditure costs and low existing industry experience can be overcome by providing incentives to companies that wish to develop new mines. For example, an incentive could take the form of a royalty discount to promote refining, similar to processing discounts implemented by Western Australia and Queensland.¹



Targeted workplace and skills strategy

Policies targeted towards ensuring there is a sufficient pipeline of workers and students trained in critical minerals sector will ensure there is the workforce in place to meet the increased demand. This demand could be met through retraining of coal miners given their existing relevant skills. Enrollment and completion of resources related training and education have significantly decreased and policy is required to ensure there is an adequately trained workforce.²



Incentives for R&D in extraction and refining

Policies that encourage the research and development of new methods of extracting and refining minerals using renewables will improve Australia's competitiveness and energy efficiency in the extraction and refining process. Australian specific R&D could develop processes for Australian-specific minerals that differ in composition to other countries. This expertise would enhance Australia's local extraction industry.



Renewable hydrogen and ammonia



Renewable hydrogen and ammonia

Renewable hydrogen represents a significant opportunity for decarbonising large areas of the economy such as in industry, heavy transport, refineries or power plants. However, there is a degree to which the uptake, and hence opportunity, is unknown. The degree of uptake is uncertain and dependent on hydrogen production and transport costs and the costs of competing technologies such as electrification.

To produce renewable hydrogen, significant supplies of renewable electricity are required for the electrolysis process. Australia has the natural resources – specifically the cross of wind and solar – to produce the necessary quantities of zero-carbon energy. An extensive expansion of renewable energy capacity paired with storage is required to utilise renewable energy for industrial purposes, such as producing hydrogen. Ammonia is the most likely vessel through which hydrogen will be exported for long-distance travel. For the remainder of the report, the opportunity will be referred to as renewable hydrogen, to encapsulate the renewable hydrogen and the export carrier, likely to be ammonia. Ammonia can also be used as a fuel in its own right.

Scale of barriers: High Low

Opportunity drivers

Summary of findings

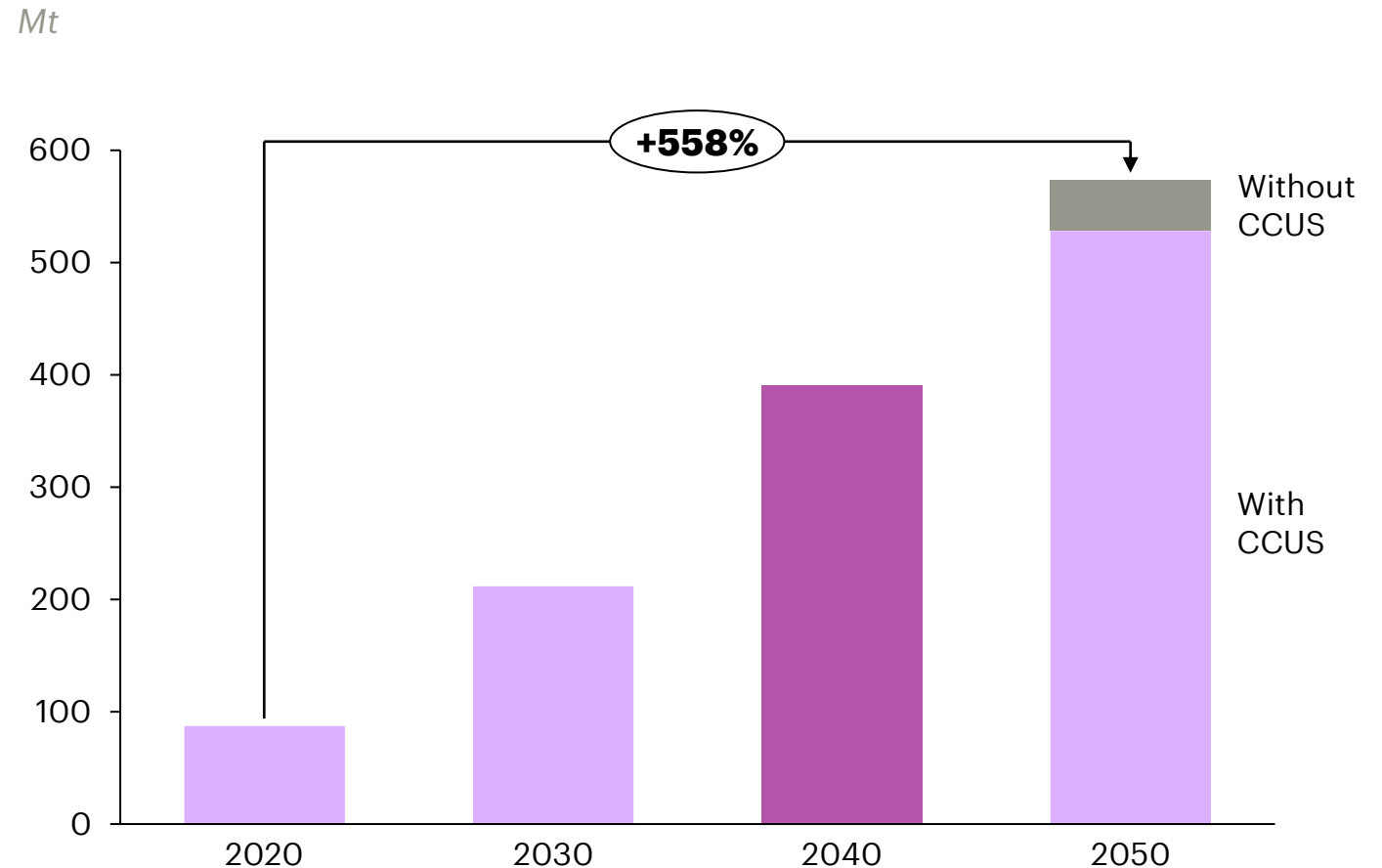
Opportunity drivers	Summary of findings
Demand-side drivers	1 Global market size by 2040 ■ To meet the IEA projected production of renewable hydrogen by 2040, the global market size is projected to be \$750B by 2040 ¹
	2 Demand for Australian exports ■ Australia is well placed to produce hydrogen or ammonia for nearby Asian markets, in particular Japan, Singapore, Korea and China. ²
Supply-side drivers	3 Australia's current production ■ Australia currently produces very little renewable hydrogen. However, there are several projects underway to build local capability and understand the use of renewable hydrogen. ³ Australia does currently produce ammonia to be used in fertilizer and explosives, however this is produced from fossil fuels and not renewable hydrogen. There are renewable pilot programmes under way, such as the Yara Pilbara plant, however these are yet to be completed or reach the scale of this opportunity.
	4 Technology ■ The technology for electrolysis exists however the scale must increase to bring the price of production down. Technology for storage and transport of ammonia exists however is still under development for hydrogen. Further, processes to extract hydrogen back out from ammonia are still being developed.
	5 Supply capabilities ■ Australia has the natural resources to produce high quantities of renewable energy given the wind and solar resources. ⁴ Australia also has significant infrastructure and skills from the LNG industry that may be repurposed for the hydrogen industry.
	6 Investment/infrastructure ■ Given the current state of hydrogen as a nascent industry, significant capital costs would be required to scale up hydrogen production.

Source: 1. IEA (2021), *Net Zero by 2050* and CSIRO 2019 *National Hydrogen Roadmap*. 2. ACIL Allen (2018), *Opportunities for Australia from hydrogen exports*. 3. CSIRO (2019), *National Hydrogen Roadmap*. 4. Grattan Institute (2020), *Start with Steel*.

There will be significant uptake of hydrogen and hydrogen-based fuels as sectors decarbonise

It is expected that hydrogen will become imperative in the decarbonisation of hard to abate sectors such as heavy transport, industrial processes and chemical feedstocks. A strong global demand in the magnitude of 390 Mt (49 EJ) by 2040 is expected to drive technology improvements and will likely see the decline in electrolyser capital costs. For global demand to reach the scale and magnitude projected, hydrogen is envisaged as a use case for at least, but not exhaustively, industry, fertiliser, chemical feedstock, and electricity generation. Hydrogen is expected to be used to produce hydrogen-based fuels to be used for shipping, aviation and heavy transport. A notable use case for hydrogen in industry is to produce green steel and replace metallurgical coal in the reduction process of iron ore. A steel industry in Australia would support hydrogen for domestic consumption in addition to global demand.

Figure 28: Growth in hydrogen demand in the IEA Net Zero by 2050 Scenario



The demand for hydrogen could increase by 45 Mt by 2050 in the IEA's Low Carbon Capture Utilisation and Storage (CCUS) case to replace energy otherwise produced through fossil fuel CCUS projects.

Source: IEA (2021), *Net Zero by 2050*

Australia is well placed to produce internationally competitive hydrogen given a low LCOE from renewables

Australia has a number of competitive advantages to producing cost-competitive hydrogen for export. These include Australia's physical wind and solar resources for renewable energy production resulting in a low levelized cost of electricity (LCOE), the existing ports and gas pipelines, as well as the existing expertise from the LNG industry.

The primary driver of production costs for hydrogen is the electricity cost, accounting for approximately 75% of production costs. Accordingly, for a country to be a globally competitive hydrogen producer, a significant supply of cheap renewable energy is necessary. Given Australia's high capacity factor for renewables and opportunities for solar and wind co-located, Australia is in the position to produce hydrogen competitively, as shown by Figure 30 comparing Australia with international comparators. These figures are for the production cost using variable renewable energy and are not inclusive of storage and transmission. Further, electrolysis capital costs are expected to reduce dramatically, further enabling the reduction in total hydrogen production costs.

Figure 29: LCOE of variable renewable technologies¹

c/kWh, 2040, select countries

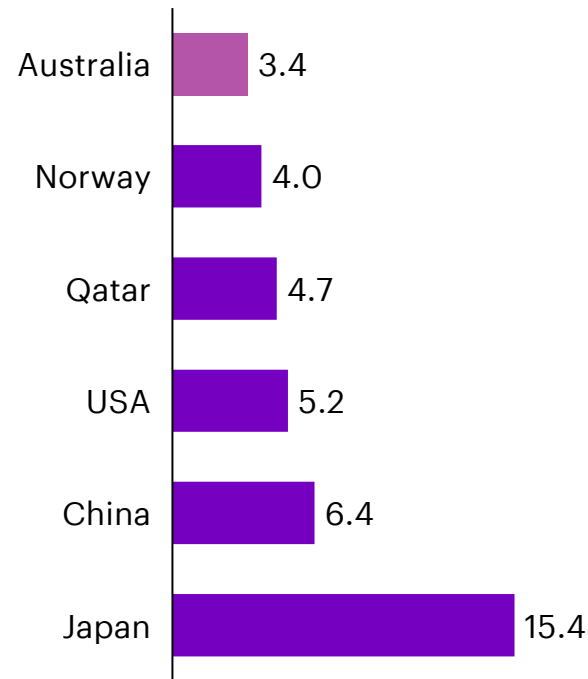
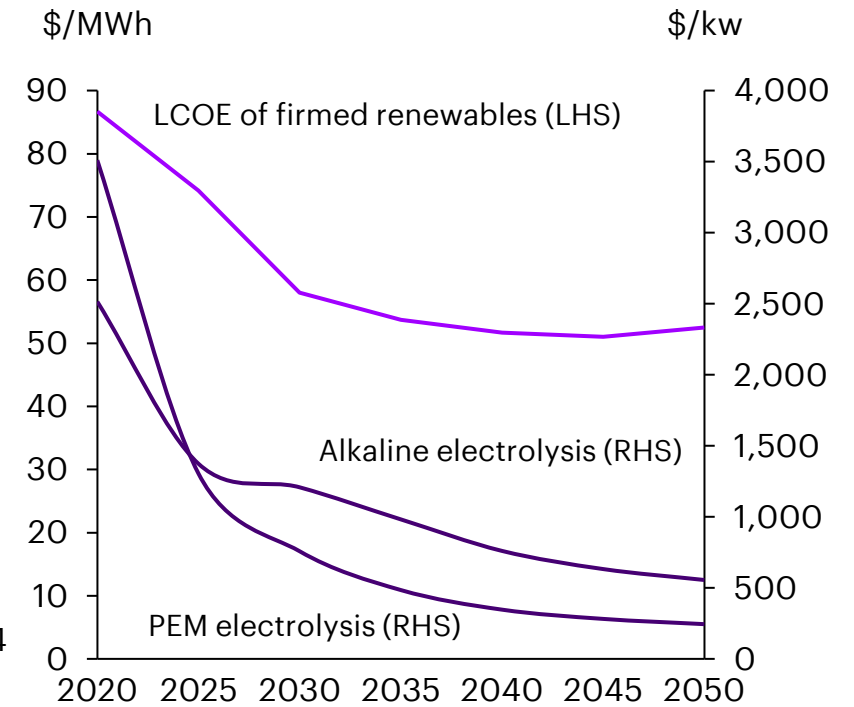


Figure 30: Decline in LCOE of firmed renewables in Australia and capital costs of electrolysis²

2020-2050



Energy is 75% of production cost for hydrogen.¹ LCOE below \$60/MWh from 2030 is highly competitive for production of renewable hydrogen in Australia. Further, capital costs for electrolyzers contribute a further 17% to production costs.¹ These are expected to dip below \$1000/kw by 2030.

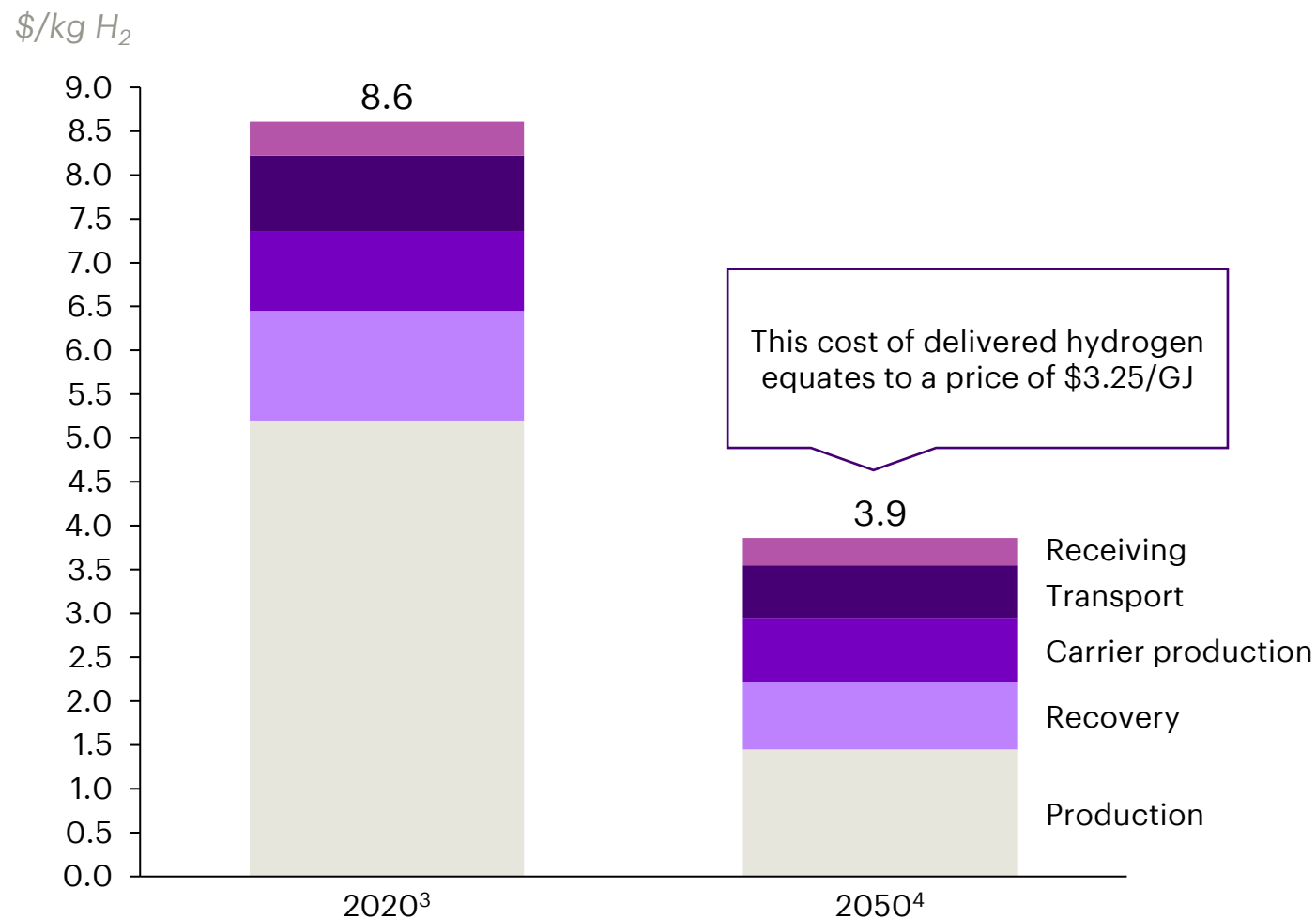
Source: 1. ARENA (2018), Opportunities for Australia from hydrogen exports 2. Energy Transition (2021), Phase 1 – Technical Report Notes: There are two types of electrolyzers that can produce hydrogen from renewable energy: alkaline and proton-exchange membrane (PEM) electrolyzers. CSIRO GenCost 2020-21 report assumes PEM electrolyzers will have the greatest market share in a net zero by 2050 scenario. LCOE in Figure 30 represents the lowest cost across all renewables for each country.

Australia can deliver competitively priced ammonia to export markets in Asia

The cost base for the delivery of hydrogen using ammonia as a carrier includes carrier production, recovery, transport and receiving costs.¹ Other forms of exporting hydrogen, such as liquefied hydrogen or methanol, are possible alternatives however each less desirable than ammonia. Liquefied hydrogen poses significant logistical and technical issues and costs while methanol does not offer the same use cases and opportunity to recover hydrogen as ammonia does.

Given Australia's extremely low LCOE as the primary cost in the production of hydrogen, Australia is able to offset the challenge of great physical distances from export markets and produce hydrogen at a relatively low cost of delivery. By 2050, a delivered cost of hydrogen of \$3.90/kg equates to approximately \$3.25/GJ.

Figure 31: Forecast cost of delivered renewable hydrogen to Japan using ammonia as a carrier^{1,2}



Source: 1. Australian Industry Energy Transition Initiative (2021), *Phase 1 Technical Report* 2. Advisian-CEFC (2021), *Australian hydrogen market study*

Note: Receiving refers to the infrastructure required to receive the export. Carrier production refer to producing the carrier, i.e. ammonia, from hydrogen. Recovery refers to extracting hydrogen from the carrier. 3. Assumes alkaline electrolysis with PPA. 4. Assumes PEM electrolysis using variable renewables

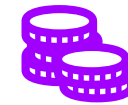
In the policy scenario, the global share of hydrogen is increased, and revenue reaches almost \$29B in 2040

BAU

The CEFC and ARENA finance projects through investment or grants leading to limited additional support beyond grants for pilot stage development.

Without government support for significant expansion of renewable energy capacity, Australia will not have the renewable capacity required to capture a large share of the global market. Through individual projects, such as FMG's renewable hydrogen plant commitment, companies could maintain Australia's existing share of global ammonia production in a BAU scenario. Australia produces hydrogen to export and to maintain Australia's current domestic steel industry. Revenue increases from \$97.5 million in 2019 to \$9.1 billion in 2040.

Volume of H₂ output: 4.7 Mt for export, 0.7 Mt for domestic steel opportunity
Energy input required: 275 TWh
Share of global market: 1.2%



\$9.1B
Revenue



\$7.1B
GVA¹



3.7k
Jobs²

POLICY SCENARIO

The government institutes significant policy support to bridge the cost gap between fossil-fuel and renewable hydrogen and create scale early to capture the market.

Through additional policy support, Australia becomes a leading renewable hydrogen exporter, capturing almost 4% of the global market. Large hubs across Australia exist both on-grid, through the expansion of renewable grid capacity, and off-grid in coordinated export hubs, totaling 940 TWh of renewable capacity. Australia produces hydrogen both for export and for the domestic steel industry. Revenue increases from \$97.5 million in 2019 to \$28.9 billion in 2040.

Volume of H₂ output: 15 Mt for export, 3.6 Mt for domestic steel opportunity
Energy input required: 940 TWh
Share of global market: 3.8%



\$28.9B
Revenue



\$22.3B
GVA¹



11.9k
Jobs²



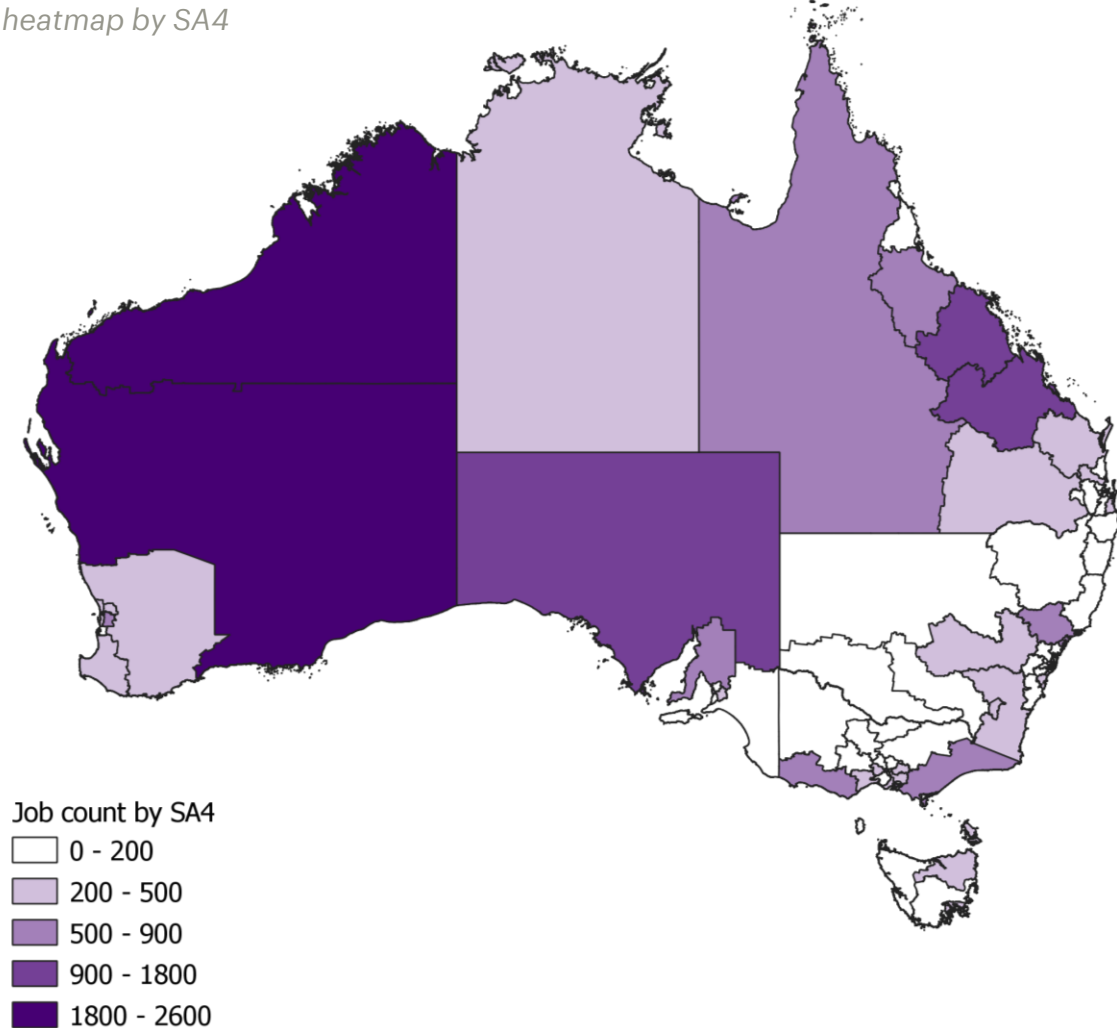
Hydrogen jobs will develop largely in Western Australia, South Australia and Central Queensland

The jobs in renewable hydrogen are expected to be in regions with significant renewable energy potential, industrial ports and required workers. The key areas of development for the renewable hydrogen opportunity are across the north and south Western Australia Outback, Central Queensland, Perth, and the Mackay Isaac Whitsunday region. As Figure 33 demonstrates, there are several other hubs across Australia that will see a smaller scale of growth through this opportunity such as Bell Bay, South Australia outback, Hunter Valley, Latrobe Gippsland, and Portland.

The renewable hydrogen opportunity creates equal opportunities for workers across qualification levels, with approximately an equal division of jobs requiring bachelor and above, certification III and above, and no post school qualifications. The hydrogen industry is extremely nascent and therefore the specific breakdown of supply chain industries are still to be determined.

Figure 32: Clean export jobs created by the hydrogen opportunity¹

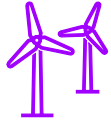
2040, heatmap by SA4



Source: Accenture analysis using Geoscience Australia 2021, [Australian Hydrogen Projects and Research Centres Dataset](#), Arup 2019, [Australian Hydrogen Hubs Study](#)

Note: This analysis is informed by identified prospectus hydrogen hubs and existing or planned projects. This does not limit additional jobs being created beyond the conservative estimate in Figure 33.

Four preconditions will be necessary for the success of the renewable energy hydrogen or ammonia opportunity in Australia



Australia's competitive advantage driven by low cost renewable energy

Firm renewable energy at or below \$65/MWh is a precondition to Australia producing cost-competitive hydrogen for export. This drives the precondition that Australia is internationally competitive and therefore can capture 3.8% of global supply.



Adoption of hydrogen across industries for decarbonisation

For there to be a significant global market for hydrogen, it must be the chosen instrument to decarbonize sectors such as, but not limited to, industry, fertilizer, chemical feedstock, electricity generation and heavy transport such as shipping.



Export market demand assumptions

This opportunity relies on a dramatic increase in the demand for hydrogen from key trade partners in Asia such as China, Japan, South Korea, and Singapore. This is expected as countries move to decarbonize using hydrogen as a clean alternative.



Reduction in costs across the value chain

As production increases in scale, costs are expected to reduce across the value chain; including electrolyser costs, firm renewable energy, storage, transport and conversion between ammonia and hydrogen. CSIRO forecasts PEM electrolysers capital costs will decrease by 93% between 2020 and 2050.

Three policies would build upon existing roadmaps and strategies to set Australia on course to capture the maximum opportunity for renewable hydrogen and ammonia



Co-investment for renewable hydrogen production facilities

Through co-investment, governments can directly support flagship projects to drive the scale-up of Australia's clean export industries, attract global investment and accelerate the diversification of Australia's exports.

Co-investment would ensure that renewable hydrogen production facilities can scale and reach the cost competitive stage despite the existing cost gap.



Carbon contracts for difference

Carbon contracts for difference (CCfDs) bridge the cost gap between hydrogen produced with renewable energy and hydrogen from fossil fuels, helping support demand for the zero-carbon fuel. By providing reliable price support, CCfDs provide an attractive risk profile for investment.

CCfDs are highly effective but can be expensive in the early stages of market development when the cost gap is wide. The cost of CCfDs declines over time as the cost gap narrows.



Targets for electrolyser capacity

Specific, measurable and time-bound targets for electrolyser capacity underpinned by credible policies would encourage the expansion of hydrogen production capacity.

Green metals



Green iron and steel

Steel is an important input into construction, transport and industrial uses and accounts for between 7 and 9% of emissions globally.¹ Australia has several key advantages to producing green steel domestically: we are the largest producer of iron ore in the world and have renewable energy potential in wind and solar to be used for direct reduction and electric arc furnaces.

World steel demand is expected to follow economic growth driven by the construction, transport and industrial sectors, reaching a market value of \$1.2 trillion in 2040. By 2040, however, much needs to change for a new green steel industry to become a reality. Large scale capital investment will be required for renewable energy hydrogen plants to make green steel, as well as multiple new smelting facilities. With the commercial viability of hydrogen based green steel likely to be 2030 and beyond, this would leave 10 years for these plants to be operational and scaled by 2040.

Key steel markets in Asia (Korea, Japan, China, Indonesia) consider steel to be a strategic industry where production is a larger share of consumption than imports. This opportunity therefore considers exports not only of finished steel but also hot briquetted iron (HBI), a form of reduced iron ore and a raw input into steel.

Scale of barriers: High Low

Opportunity drivers

Summary of findings

Opportunity drivers		Summary of findings
Demand-side drivers	1 Global market size by 2040	The global market for steel is projected to be \$1.2 trillion by 2040. ² This is based on a forecast of 1,958 Mt of steel production by 2040. ³
	2 Demand for Australian exports	Export markets like Japan, Korea & China highly value their own domestically produced steel and may be hesitant to substitute their supply for imported Australian green steel. Given the importance of domestic steel industries for key export markets, HBI exports may be suitable to allow the continuation of domestic production of steel.
Supply-side drivers	3 Australia's current production	Australia currently produces 5.5 Mt of steel annually. Hydrogen based green steel is not currently produced in Australia. ³
	4 Technology	Technology for hydrogen based green steel is likely not available commercially before 2030. The first green steel has been produced by SSAB in 2021 and technology costs should reduce significantly by 2030.
	5 Supply capabilities	Australia is the largest producer of iron ore. Our refining expertise is small scale with 2 major steel plants nationally. These plants produce for domestic use only.
	6 Investment/infrastructure	There are high costs to establish and scale hydrogen based direct reduction, and renewable energy based electric arc furnaces. Investment in up to ten new green steel plants is needed to scale production.

Source: 1. World Steel Association 2. IEA (2021), Net Zero by 2050: A roadmap for the global energy sector. 3. World Steel Association (2020), World Steel in Figures.

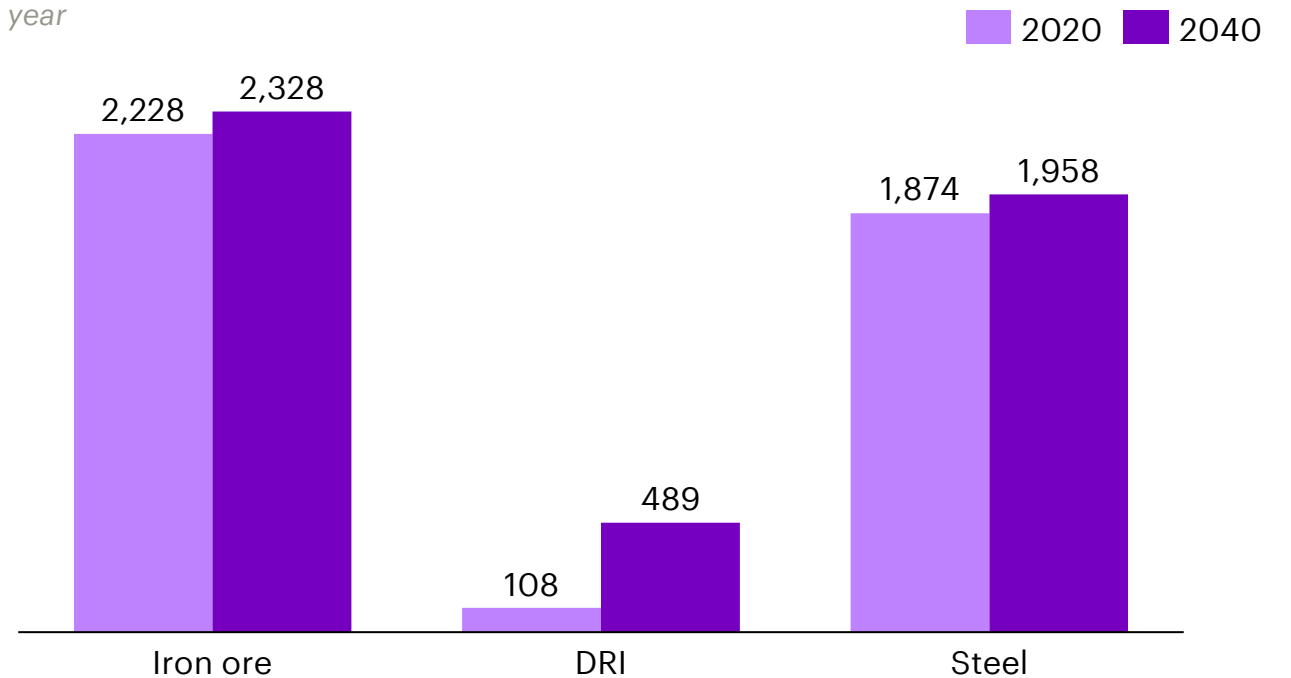
Steel will continue to be an important commodity with production forecasted at 1,958 Mt in 2040

Steel production is tied to global economic growth, being one of the most commonly used metals in the world by the construction, automotive and manufacturing industries. Steel is also important for energy transition, given its use in solar panels, wind turbines, transmission and electric vehicles. The IEA has predicted that world steel production will reach 1,958 Mt by 2040. Steel is a vital domestic industry for many large countries, with global trade represents only 25% global steel production in 2019.¹ Almost all of Australia's key trading partners have scaled steel producing industries, namely China, Japan, South Korea and the US.

Green iron, specifically direct reduced iron (DRI) is a key input into green steel with the global market expected to increase from 108 Mt in 2020 to 489 Mt in 2040. DRI is traditionally produced with gas but will grow increasingly important as low emissions methods become commercially viable. Australia can tap into the markets for both green iron and steel if it is cost competitive and trading partners have an appetite to import low carbon embodied steel instead of making it domestically.

Figure 33: Steel commodities will continue to grow, with the highest growth expected for DRI¹

Mt per year



Australia is the largest producer of iron ore but is a small producer of finished steel by global standards, indicating our limited presence in downstream refining. Australia's current share of world steel output is ~0.3%, compared to the world's largest producers; China (57.2%), India (6.4%), Japan (5.7%) and the US (5.0%). There are different methods to producing DRI that include natural gas², hydrogen or other inputs, but Australia currently neither produces nor exports DRI/HBI.

Source: 1. World Steel Association (2020), World Steel in Figures. 2. International Iron Metallurgy Association, Production Technologies.

Australia currently produces ~40% of world iron ore, but less than 1% of world steel

Australia is the world's largest producer of iron ore, and the world's largest estimated reserves of iron ore with 52 billion tonnes, or 30%, of the world's reserves.¹ By contrast, Australia is responsible for 0.32%, or 5.5Mt, of global steel production, most of which is consumed domestically.

Crude steel is produced from iron ore at Port Kembla in NSW and Whyalla in SA. Both of these production locations produce steel in a blast furnace using coking coal, currently an emissions intensive process.

Traditionally, direct reduced iron (DRI) production requires cheap and readily available natural gas however green iron can be produced with renewable hydrogen. Steel can be produced via two main processes: either using a basic oxygen furnace (BOF) or an electric arc furnace (EAF). Australia's renewable energy resources represent an opportunity to green metals through renewable energy and hydrogen.

Figure 34: World iron and steel output forecast²

Mt, 2020

	Iron ore	DRI / HBI	Steel
Global demand	2,228 Mt	108 Mt	1,875 Mt
Price (AUD)/t	\$91	\$265*	\$618
Australia's current share of global production	40.4%	0%	0.3%
% of Australian production exported	98.8%	n/a	22%
Key competitor	Brazil	India	China

* HBI does not have an established benchmark price. There is only one marker, the Venezuelan export price at \$265/t, but it is unreliable because the quality and availability of Venezuelan HBI has been highly variable for the past several years.

Source: 1. Government of Western Australia (2021), [Iron Ore](#) 2. World Steel Association (2019), [Steel in statistics forecasts](#)

With low-cost renewable hydrogen, it will be cheaper to export green steel than to export both hydrogen and iron ore to our key trading partners

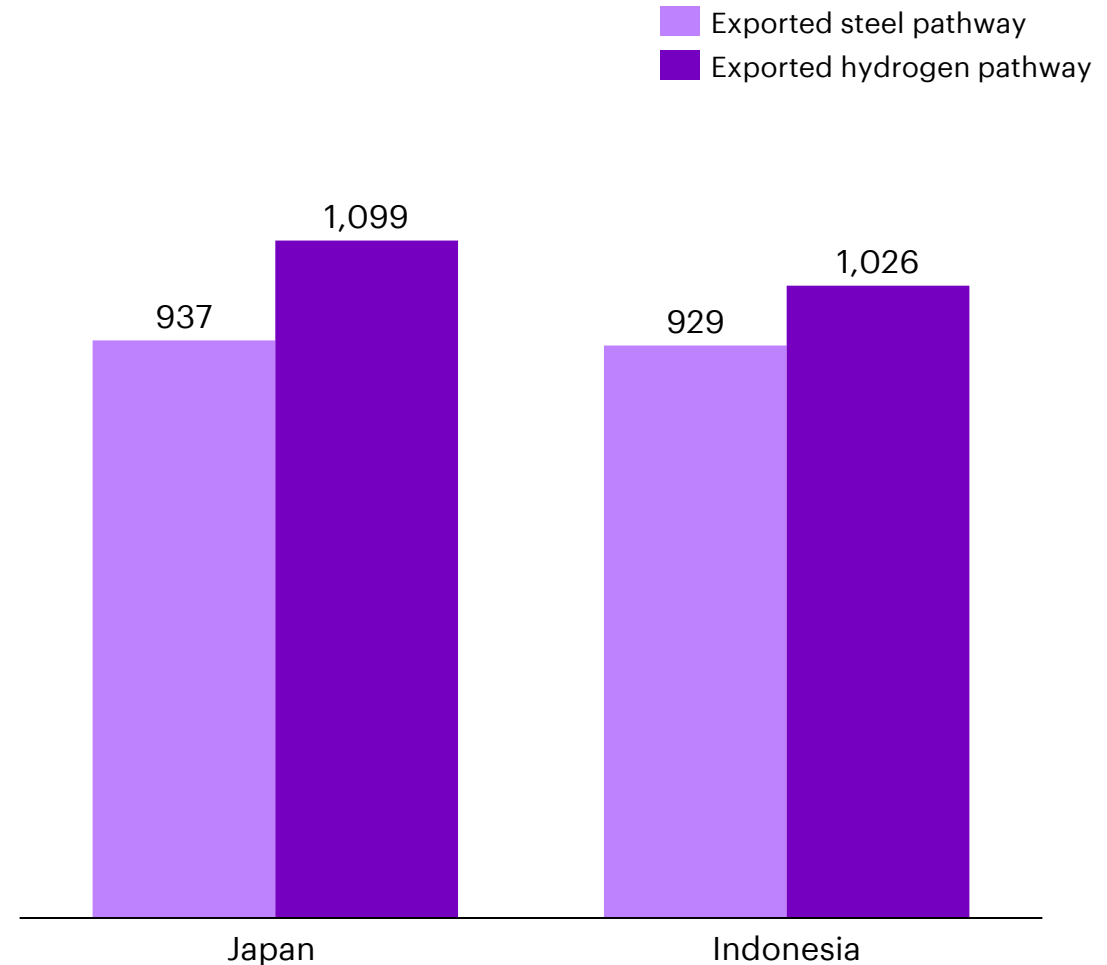
The key cost drivers for renewable hydrogen-based DRI are raw materials, electricity, processing and labour costs. The source of Australia's competitive advantage is likely to be the lower cost of hydrogen generation and running electric arc furnaces (EAF) on renewable energy.

Analysis indicates that it will be cheaper for key markets such as Japan and Indonesia to import semi-finished steel rather than importing iron ore and hydrogen for local green steel production.⁴ This cost gap is driven by the superior renewable resources in Australia compared to Japan and Indonesia.

As established in the hydrogen opportunity analysis, the cost of producing hydrogen is expected to decline significantly in Australia and hence Australia is well placed to produce cost-competitive low-emissions steel.

Figure 35: Cost of semi finished steel landed in key Australian export markets⁴

AUD \$ / t



Sources: 1. S&P Global (2020), *Market Insights: Green Hydrogen Costs*. 2. CSIRO (2012), *Energy use in metal production*. 3. Australian Industry Energy Transitions Initiative (2021), *Phase 1 Technical Report*. 4. Grattan Institute (2021), *Start with Steel*.

In a policy scenario, where green iron and green steel production is ramped up, we estimate that Australia could generate up to \$18.7B in export revenue by 2040

BAU

Technology and private investment maintain Australia's current market share of iron and steel production

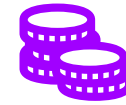
This scenario assumes Australia could export 2.9 Mt of green steel and 6.4 Mt of green Hot Briquetted Iron (HBI). Australia will be able to take advantage of its large iron ore reserves to do some refining and smelting. Barriers will remain, however, namely in Australia's cost competitiveness compared to other countries who are large producers. 6.1k in employment from new steel exports will be added in 2040 compared to the existing 4.2k employed in the existing steel industry in 2021 and revenue increases from a negligible steel export industry³ in 2019 to a revenue of \$3.5 billion.⁴

Volume of output 2020: 5.5 Mt steel³, 0 DRI

Volume of green output 2040: 5.5 Mt steel; 12.9 Mt DRI

Energy input required: 46 TWh

Share of global market: 0.3% steel market



\$3.5B

Revenue



\$1.9B

GVA¹



6.1k

Jobs²

POLICY SCENARIO

Policy action and funding supports flagship projects for new smelters to ramp up green iron and steel production capacity

With significant policy support and funding for flagship smelting plants, Australia will be able to shift downstream and engage in more value added processing of its large iron ore reserves. This scenario assumes green steel exports of 17.4 Mt and HBI exports of 30 Mt and investment in up to six new smelters to increase production. 33.1k in employment from new steel exports will be added in 2040 compared to the existing 4.2k employed in the existing steel industry in 2021 and revenue increases from a negligible steel export industry³ in 2020 to a revenue of \$18.7 billion.⁴

Volume of output 2020: 5.5 Mt steel³, 0 DRI

Volume of green output 2040: 20 Mt steel; 53.4 Mt DRI

Energy input required: 189 TWh

Share of global market: 1.15% steel market



\$18.7B

Revenue



\$10.0B

GVA¹



33.1k

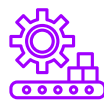
Jobs²

The following preconditions will be critical to enabling Australia's green steel opportunity



Technology adoption and costs

While the potential opportunity for a future green metals industry is large, substantial investment and technological uptake is needed by 2040 to realise economic benefits. Recent analysis¹ assumes a market uptake of renewable energy hydrogen, an important input for green metals, to be from 2030. However, initiative must be taken before this point to drive costs down and develop a domestic industry ready for the ramp up required beyond 2030. Australia will need to be cost competitive with access to cheaper renewable energy and hydrogen production to support the green steel industry.



Production ramp up

Significant investment is required for green metals to be commercially viable in Australia. To reach 20 Mt this would require ~6 new plants to be built. Large investments in new refining and smelting plants to increase production from 5.5 Mt of steel to 20 Mt, and from zero DRI today to 53.4 Mt in the policy scenario. Production of renewable energy hydrogen-enabled DRI and steel will require substantial energy input. Majority of this energy will be for hydrogen, which is covered in the hydrogen opportunity. The remaining energy inputs are:

Scenario	Production (Mt)	Electricity required	New smelters ¹
No policy	5.5	6 TWh	-
Policy	20.0	23 TWh	6



Export markets

This opportunity will depend on demand or co-investment for HBI and green steel from export markets. Japan, South Korea and China have large domestic steel industries and do not rely on imports. This can be seen by the low percentage of imports out of total steel production for each country. This may shift due to changing cost drivers of green metals and demand for low-carbon embodied steel. For Australia to capture a portion of the global steel market, it is assumed that the percentage of imports of total production will shift towards higher share of imports.

Country	Imports (Mt) ²	Production (Mt) ²	%
Japan	5.0	83.2	6
S Korea	11.5	67.1	17
China	37.9	1065	4



Green alumina and aluminium

Australia is the largest producer of bauxite in the world, and the second largest producer of alumina, both of which are key inputs into aluminium.

While Australia is currently a small producer of primary aluminium at 1.59 Mt out of 64.8 Mt globally (a 2.45% share). Global demand is expected to grow in line with economic growth to 2040, driven by end use in the transport, electronics and consumer product sectors. Australia's key markets for aluminium are Japan, South Korea, Taiwan and Thailand, none of which are large producers themselves and therefore not as likely to compete as in the case of steel.







While renewable electricity technology is available to green the refining and smelting process, aluminium product has high levels of energy input. For Australia to compete globally, firming renewable electricity will need to be available and affordable for smelters to operate and maintain their market share.

Aluminium smelters in Australia, like Alcoa's Portland plant, are at risk of being priced out of the market due to high production costs.¹ Green aluminium is a pathway to making the industry more viable if it can take advantage of cheap firming renewable electricity and supply global demand for lower carbon emitting commodities.

Scale of barriers:  High Low

Opportunity drivers

Summary of findings

Opportunity drivers	Summary of findings
Demand-side drivers	1 Global market size by 2040  The world aluminium market is projected to reach \$164 billion by 2040. This assumes 82.8 Mt of primary aluminium to be produced by 2040 ²
	2 Demand for Australian exports  Key export markets are Japan, Taiwan, South Korea & Thailand, which are not large producers themselves. ³ Australia is the world's sixth largest producer of aluminium and second largest producer of alumina.
Supply-side drivers	3 Australia's current production  Australia produces 1.6 Mt of primary aluminium and 21 Mt of refined alumina. There are four aluminium smelters nationally and six alumina refineries ⁴
	4 Technology  The capability exists to power the smelting process (including electrolysis) with renewable electricity like wind and solar PV however firming still poses a challenge for renewable energy.
	5 Supply capabilities  Australia is the largest world producer of bauxite and the second largest producer of alumina. Additionally, Australia has good renewable energy potential to power green smelters but would need to scale low-cost firming renewables significantly.
	6 Investment/infrastructure  Investment in to six new smelting plants are needed to scale production. Investment can start before 2030 with available technology

Source: 1. AFR (2020), *Alcoa says Australia's power prices highest on the plant*. 2. International Aluminium Organisation, *Alucycle 2040*; Accenture analysis. 3. Australian Anti-Dumping Commission (2016), *Analysis of steel and aluminium markets*; Accenture analysis. 4. Australian Aluminium Council (2021), *Australian Aluminium*

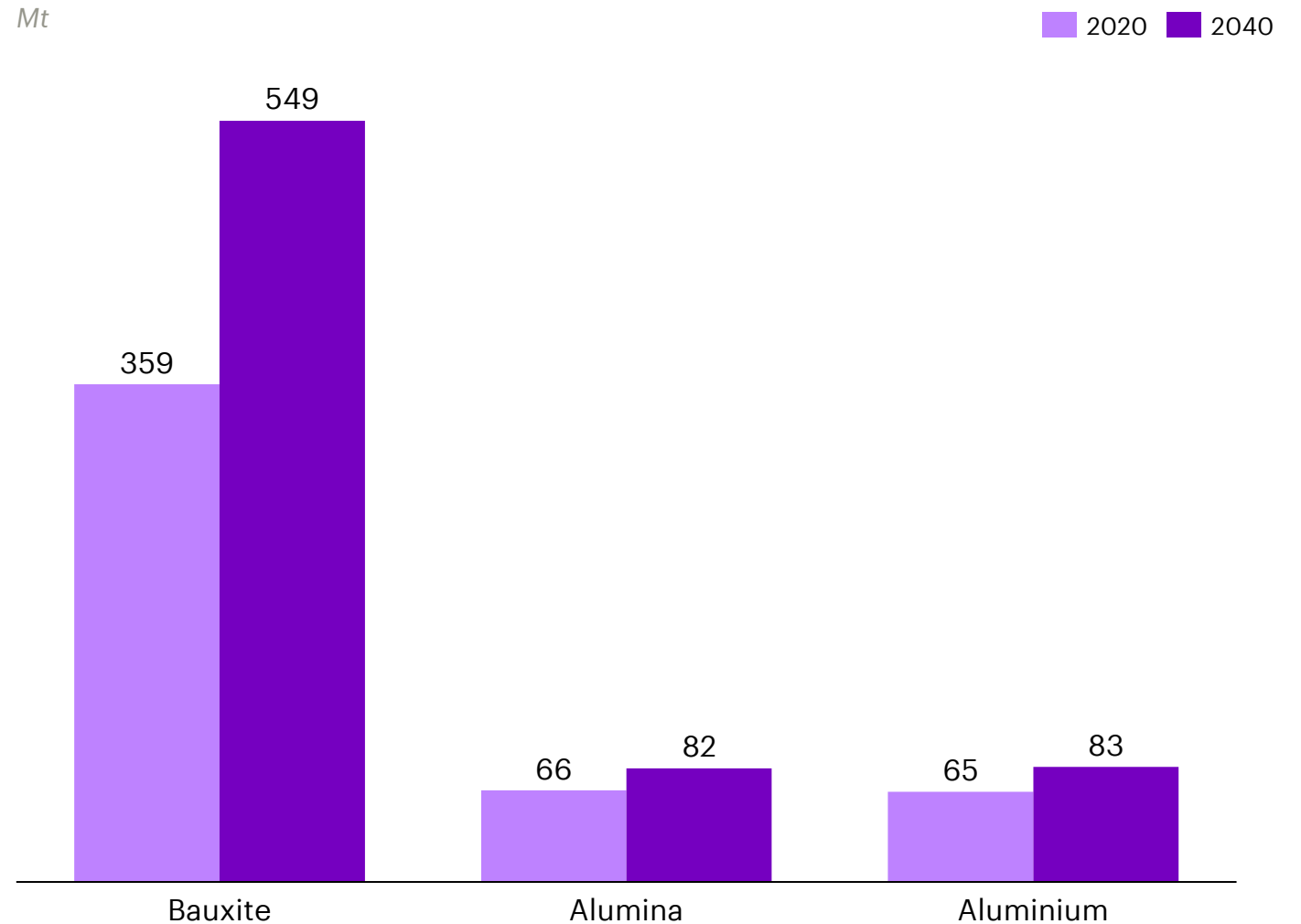
Aluminium will continue to be a significant global industry, with demand estimated to increase by 1.2% per annum to 82.8 Mt by 2040

Aluminium is produced by applying electricity to alumina derived from bauxite. Production of aluminium is tied to economic growth, with production forecasted to continue increasing to 2040. Global output of primary aluminium ingots is projected to increase from 64.8 Mt in 2019 to 82.8 Mt in 2040, and as the industry reduces emissions intensity, recycled aluminium is projected to have faster growth, from 33.7 Mt to 71.6 Mt over the same period.

Alumina and aluminium production is a highly energy intensive process. In Australia, Alumina refining accounts for approximately 24%, or 14 Mt. of Australia's direct, non-electricity (scope 1) emissions annually. Aluminium smelting uses ~10% of the country's electricity and creates 6.5% of total carbon emissions (largely scope 2 emissions) from the generation of electricity.¹

Green alumina and aluminium is defined as alumina and aluminium produced using renewable energy. Demand for green alumina and aluminium is going to be driven by economic growth as it continues to be widely used in construction, transport, electrical, machinery and consumer product sectors.²

Figure 36: World aluminium output²



Sources: 1. IEEFA (2020), [Aluminium Smelters](#). 2. World Aluminium Institute (2019), [Alucycle](#).

Australia is the world's largest exporter of bauxite and alumina and supplies ~3% of global aluminium

Alumina

There are six alumina refineries operating in Australia producing alumina for both the domestic and export markets. Australia is the second largest producer of Alumina (21.2 MT) globally. 87% of alumina is exported.

Aluminium

Australia currently has four smelters that together produced 1.59 Mt of primary aluminium ingots in 2019, or 2.52% of global aluminium production. Almost all Australian aluminium is exported. Key export markets for Australian aluminium include the US, Thailand, Taiwan, Japan, South Korea. China is both the largest producer and consumer of aluminium.

Australia's aluminium industry has been in decline since 2010 due to declining aluminium prices and high cost of operations. High electricity prices push even the best-performing of Australia's smelters out of the top 25% of global competitiveness.⁴ With increasing demand for low-carbon aluminium globally and potential introduction of carbon tax by major importers such as the European Union, the Australian aluminium industry is most at risk if Australia fails to transition to green alumina and aluminium production.

Figure 37: World aluminium output forecast ^{1,2,3,4,5}

Mt, 2020

	Bauxite ore	Refined alumina	Primary aluminium
Global demand	360 Mt	66 Mt	67 Mt
Price (AUD)/t	\$36	\$350	\$2.541
Australia's current share of global production	32%	17%	2.5%
% of Australian production exported	36%	85%	90%
Key competitor	China	China	China

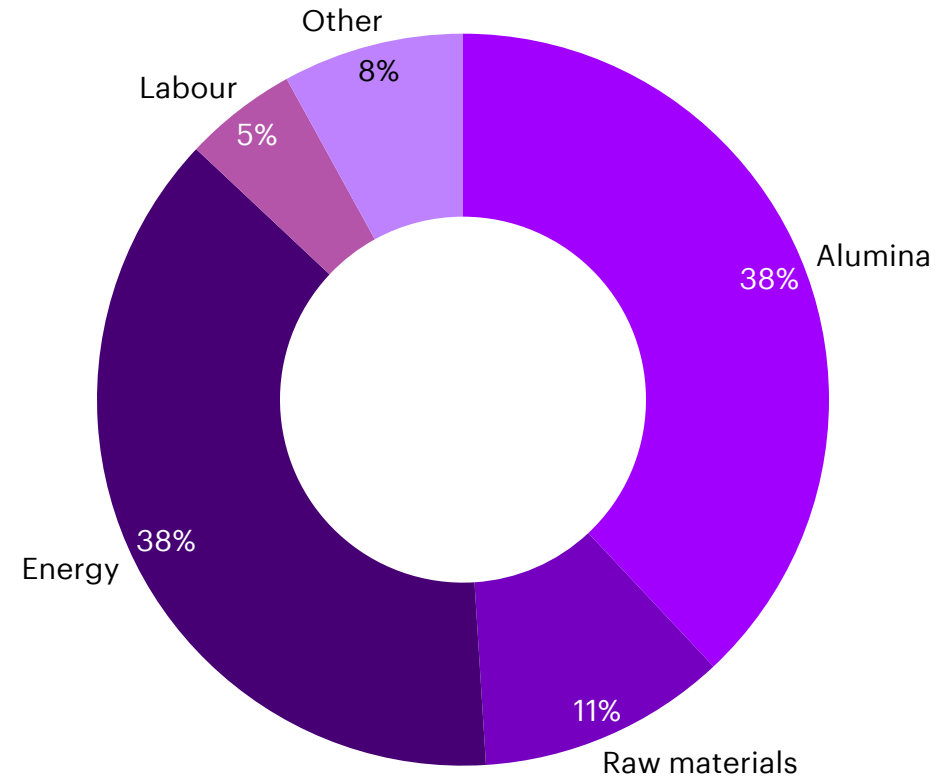
Sources: 1. World Aluminium Institute (2019) *Alucycle* 2. Australian Aluminium Council (2020), *Australian Alumina* 3. Grattan Institute (2014) *Less cost, less coal* 4. Geoscience Australia (2016), *Bauxite* 5. DISER (2020) *Office of the Chief Economist: Historical Forecast*

Australia's competitiveness in aluminium depends on the cost of production

Australia's current smelters are some of the most expensive in the world. Alumina (38%) and electricity (38%) represent the two major cost drivers of every smelter. Australia is expected to have a cost advantage to procuring alumina through possible vertical integration or onsite refining. Smelting is the most energy-intensive stage of aluminium production, accounting for 95% of electricity usage.

Switching to low-cost renewable power, Australia has an opportunity to establish itself as a major player in green aluminium. The LCOE of firmed renewables is projected to be below \$60/MWh in some Australian zones by 2030.¹ The CEO of Australia's largest smelter recently indicated price of A\$45/MWh for firmed renewables would be cost competitive enough to make green aluminium possible.² Policy intervention would be required to bridge the cost gap until firmed renewables can reach that price. Firmed renewables is important for this opportunity as aluminium smelters cannot go without power for more than four hours at a time.

Figure 38: Aluminium smelting operation costs²
% of total cost



Source: 1. CSIRO (2021), CSIRO GenCost 2020-21 2. IIEEFA (2020), Why aluminium smelters are a critical component in Australian decarbonisation..

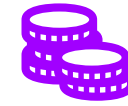
With additional policy support, where green alumina and green aluminium production is ramped up, Australia could generate up to \$16.6B in export revenue by 2040

BAU

Australia will slightly increase output levels assuming aluminium producers will access cheap renewable electricity

The BAU scenario assumes Australia can at least maintain its market share in aluminium and alumina. In this scenario, it is assumed ~30% of alumina refining capacity will be 'greened' by 2040. Even if Australia's natural advantages in renewable electricity and bauxite reserves are realised, production will be limited without policy support and funding for flagship projects to ramp up green production by 2040. Employment increases from 3.2k in the aluminium industry in 2021 to 3.8k from exports in 2040 while revenue decreases from \$10.7 billion³ in 2021 to \$5.9 billion in 2040.⁴

Volume of output 2019: 1.59 Mt aluminium, 21.2 Mt alumina
Volume of green output 2040: 2.0 Mt aluminium; 7.9 Mt alumina
Energy input required: 44 TWh
Share of global market: 2.5% aluminium market



\$5.9B
Revenue



\$3.6B
GVA¹



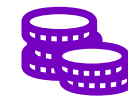
3.8k
Jobs²

POLICY SCENARIO

Strong policy action can catalyse investment in up to six large new smelters with access to cost competitive renewable electricity

With policy support, Australia will be able to increase its output of aluminium to 5.0 Mt, requiring investment in up to four large new smelters. Additional funding will help Australia to shift downstream in its metal refining capability, from bauxite ore exports to alumina and finished aluminium using renewable energy. Green alumina exports are assumed to reach 21.9 Mt under the policy scenario. Employment increases from 3.2k in the aluminium industry in 2021 to 10.8k from exports in 2040 and revenue increases from \$10.7 billion³ in 2021 to \$16.6 billion in 2040.

Volume of output 2019: 1.59 Mt aluminium, 21.2 Mt alumina
Volume of green output 2040: 5.0 Mt aluminium; 26.3 Mt alumina
Energy input required: 123 TWh
Share of global market: 6% aluminium market



\$16.6B
Revenue



\$10.1B
GVA¹



10.8k
Jobs²

Notes: 1. GVA includes direct and indirect GVA. 2. Jobs includes only direct jobs 3. 2020 revenue and jobs figures are representative of the total alumina and aluminium industry in Australia since there is no current green metals industry in Australia. This employment is inclusive of domestic activity. 4. Revenue for green alumina and aluminium decreases from 2020 since only 30% of total alumina and aluminium is assumed to be green in a BAU scenario. Hence, the remaining production of non-green alumina and aluminium cannot be counted towards the revenue in 2040.

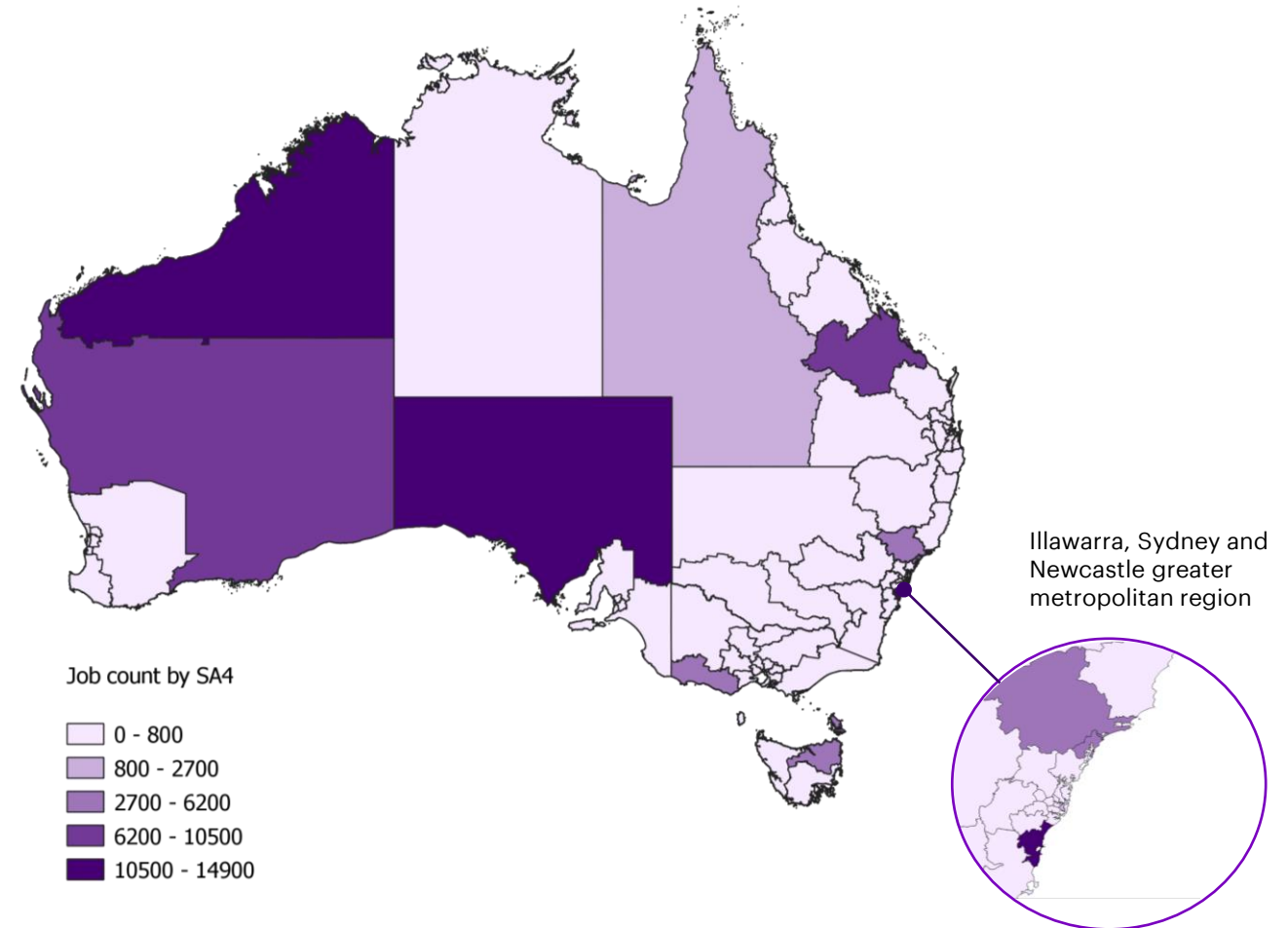
The majority of jobs for both green aluminium and steel could be supported in regions that are currently carbon intensive

The key regions that will benefit include Illawarra, Western Australia Outback, South Australia and Central Queensland. These regions include existing carbon intensive activities in steel and aluminium production. They have the industrial infrastructure and labour skill base for a future low carbon metals industry. Specifically, Illawarra and Newcastle areas are currently carbon intensive employment regions.

The green metals opportunity will support more jobs in these regions because of the collocation of ports, smelter and refining facilities and the skills base that workers have there. Similarly, Whyalla in the South Australia – Outback SA4 is currently home to one of Australia’s largest steel works, and port infrastructure for ease of shipping products. This part of South Australia is also home to good solar and wind capability that could be utilised for renewable energy based for green metal refining plants.

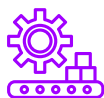
Figure 39: Distribution of green metals jobs by SA4

Heat map



Source: Accenture analysis

Three preconditions will be critical to the green alumina and aluminium opportunity



Production ramp-up

Australia has 5 bauxite mines, 6 alumina refineries and 4 aluminium smelters. Australia's smelters process 15% of the alumina output, producing ~1.6 Mt of aluminium each year.

Raising Australia's aluminium output to 5 Mt per year would consume 50% of Australia's current bauxite output and 100% of its alumina production. This would be a three-fold increase on current levels, requiring four new large aluminium smelters, based on an assumed annual production capacity of 0.84 Mt.¹

To produce green alumina, it is assumed that existing production is greened.

Scenario	Production (Mt)	Electricity required	New smelters
No policy	2.03	44 TWh	1
Policy	5.00	123 TWh	4



Cost-competitive clean energy

Energy costs represent ~38% of total aluminium production costs. Cost-competitive exports will depend on access to low-cost, firm clean electricity.

Recent CSIRO analysis² indicates that the long-term levelised cost of firm renewable electricity is potentially in the range of \$53-83/MWh by 2040, bringing firm renewables into line with electricity prices paid by large industrial customers today.

Processing more bauxite into alumina and increasing aluminium production would add significantly to electricity demand. A major build-out of renewable energy capacity would be required to meet increased demand.



Access to export markets

Key markets for Australia's aluminium exports today are South Korea, Japan, Taiwan, Thailand and the United States. China is the world's largest aluminium producer, responsible for more than half of global supply.

Producers report a small premium for green alumina and aluminium, with automakers BMW and Audi among leading customers.

Global demand for green aluminium and alumina is expected to increase as customers increasingly prioritise low-carbon supply.

Four policy and actions are critical to the success of Australia's green metals opportunity



Coordinated investment in Renewable Energy Zones

Reliable and affordable firming renewable electricity is an important enabler for competitive green metals production in Australia. Coordinated investment in renewable energy zones is currently under development at a small scale in New South Wales, Queensland and Victoria. This would help to align generation, transmission and storage investment to take advantage of high-quality renewable energy resources, using auctions and CCfDs to drive least cost new capacity.



Government co-investment

Government co-investment in green metal production facilities may have high upfront investment costs but are effective in catalysing development. Co-investment in flagship refineries and smelters for proof-of-concept green metal production can enable the industry to grow. Government could also mandate requiring a rising percentage of steel and aluminium to come from zero-carbon sources.



Green public procurement

For example, mandating an increasing share of green steel and aluminium in infrastructure and buildings. This could be implemented subject to a cost-benefit analysis.

Publicly funded infrastructure can also play a key role in boosting demand for clean energy.

There are numerous European precedents and models for green public procurement policies. For detail see Policy section 5.



Carbon contracts for difference

A carbon contract for difference (CCfD) policy can incentivise investment in green metals by providing price support to enable greater predictability of future revenue streams, providing a more attractive risk profile for investors. This policy is highly effective but can be expensive in the early stages of market development. The cost to government will decline over time as the cost gap diminishes. To minimise costs, CCfDs could be competitively awarded via auction.

Battery manufacturing



Battery manufacturing

Australia produces roughly half of global lithium and is a dominant player in other raw materials that are used as batteries inputs. There is large potential for the batteries market as demand for electric vehicles and stationary storage grows around the world.

While we have access to the raw materials, Australia has a small manufacturing base and does not currently compete in downstream assembly and production. If Australia can engage in additional parts of the value chain, there is opportunity to tap into a large global market, but barriers exist in our supply capabilities and required investment costs. To diversify downstream, Australia will need to address capital availability, improve collaboration and build a skilled workforce. By doing so Australia will be able to capitalise on the growth of the global batteries industry, expected to reach \$432 billion by 2040.

Scale of barriers: High Low

Opportunity drivers

Summary of findings

Opportunity drivers		Summary of findings	
Demand-side drivers	1 Global market size by 2040		The global batteries market is estimated to be \$432 billion by 2040¹ It is estimated that the total market for Li-ion batteries will reach 1,840GWh by 2029, growing at 26% pa between 2019 and 2029. ² The forecasted growth in battery pack sales over the next decade is driven by three applications of energy storage: electrification of transport, renewable energy storage systems, and consumer electronics.
	2 Demand for Australian exports		
Supply-side drivers	3 Australia's current production		Australia has a small manufacturing base in battery assembly. Currently, downstream production of batteries is worth \$0.3 billion.
	4 Technology		Lithium-ion batteries are already used globally in electric vehicles, stationary storage and other industrial applications.
	5 Supply capabilities		Australia is a dominant producer of battery raw materials including lithium and cobalt. However, Australia has limited scale in manufacturing and currently relies on migrant labour.
	6 Investment/infrastructure		Australia would need large billion additional capital investment than is already available to realise a downstream battery opportunity, which may be supported by government intervention.

Source: 1. Bloomberg NEF (2021), New Energy Outlook; Accenture analysis. 2 Roskill (2020), Lithium Ion Batteries: Outlook to 2029.

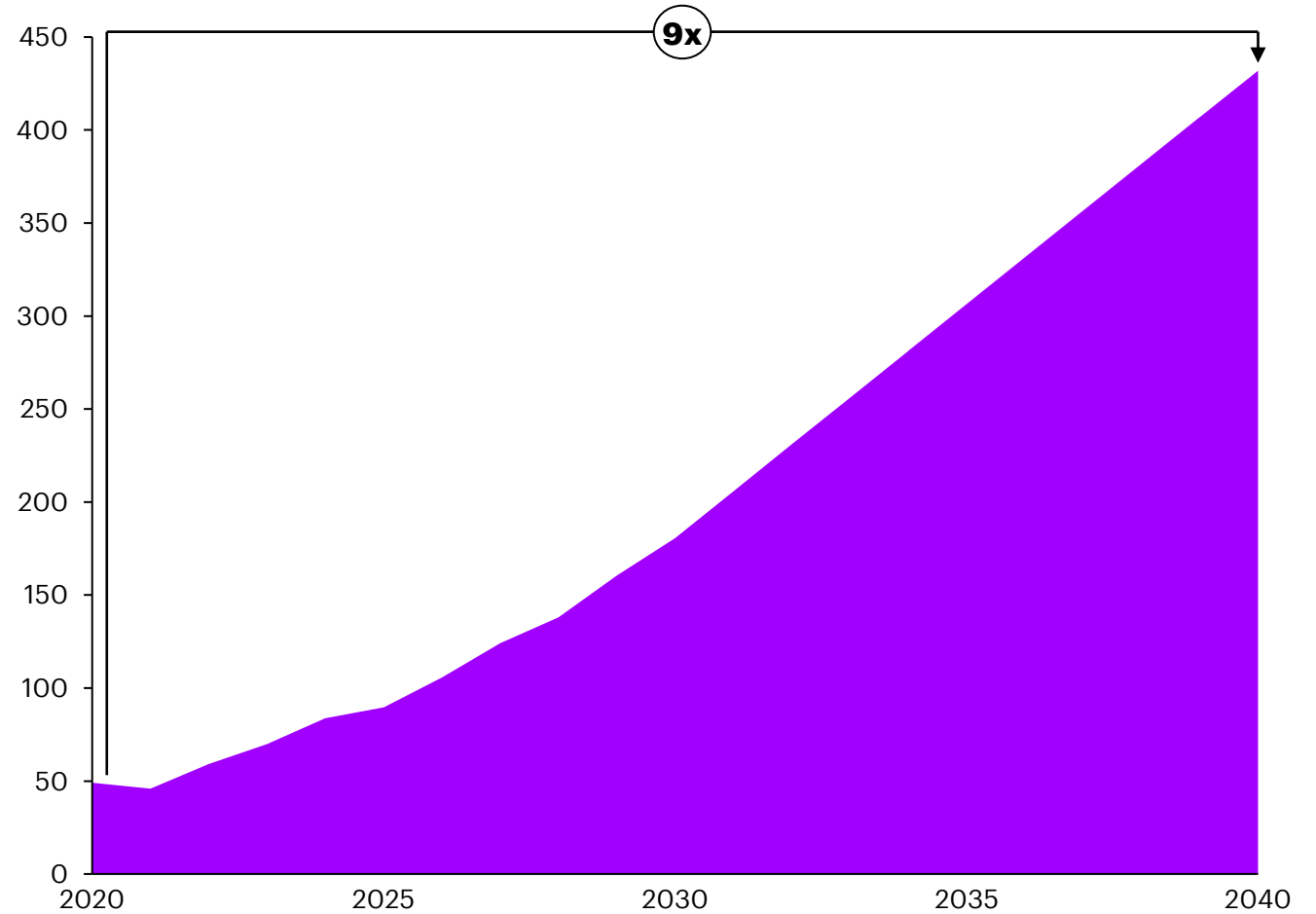
Strong growth is forecast for the batteries market from now until 2040

Under this scenario, with demand growing for renewable energy storage, batteries are projected to be increasingly important to the global energy transition. Technology improvements have rendered batteries more affordable and useable, which are now the preferred technology in electric vehicles over fuel cells and internal combustion engines. Batteries are increasingly favoured as a stationary energy storage technology. Of the 53,535MWh of grid-connected (excluding pumped hydro) energy storage that was operational globally in 2020, just 7.1% relied on batteries. However, batteries make up 43.3% of the 6,397 MWh of projects that are currently under construction or contracted globally. By 2030, global battery demand is expected to reach 2,300-2,600 GWh per annum, from just 263 GWh in 2020.

Despite continued falls in prices, soaring demand over the next two decades is expected to precipitate an increase in the global batteries market to AU \$432 billion in 2040, a 9-fold increase from today.

Figure 40: Global batteries market

Revenue, AU \$ bn



Source: Accenture (2021) *Future Charge: Building Australia's Battery Industries*

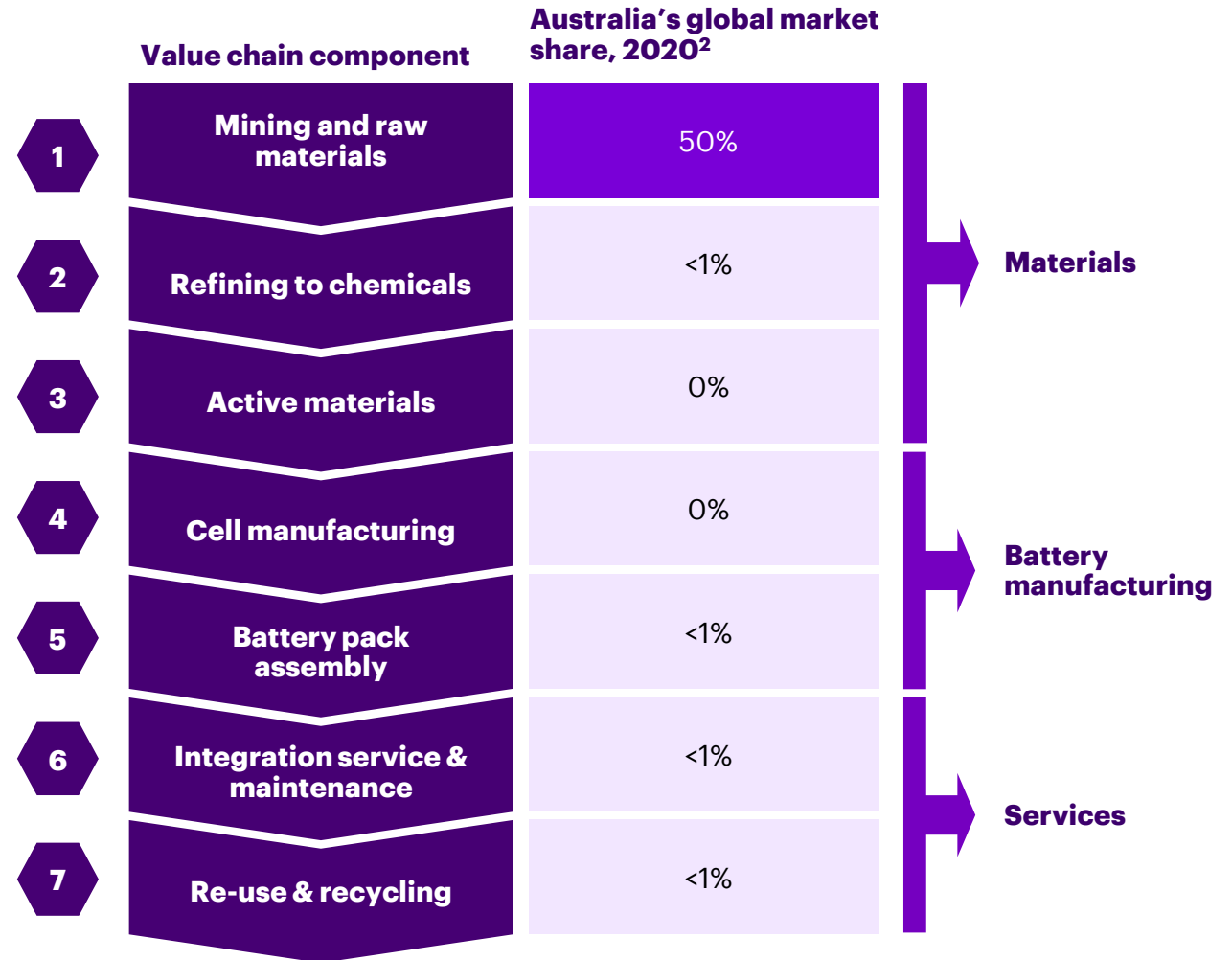
Australia's current production capacity focuses on battery raw materials

With its natural advantages in lithium mining and renewable energy potential, Australia has room to capture more of the battery manufacturing and assembly components of the value chain. Australia is a key market for both on-grid and off-grid energy storage systems, and already ranks fifth in the world by market size according to the International Energy Agency (IEA). This is because Australia's strong investment in renewables needs to be supported by energy storage. It has already established several large-scale renewables projects, and there is very high uptake of rooftop solar PV.

Several investments are underway to expand Australia's capacity in downstream activities, including Magnis Energy's feasibility study to produce 15GWh of lithium-ion cells annually at a plant in Townsville.¹ as well as Australian government's new \$ 1.5B Modern Manufacturing initiative which includes processing of critical minerals and clean energy as key priorities.

Figure 41: Australia's position in the global value chain

% market share



Source: 1. Magnis Energy (2020), [Queensland Government approves Townsville feasibility study](#) 2. Accenture (2021), *Future Charge: Building Australia's Battery Industries*

Declining global battery prices reflect lower input costs, but Australia would need to be cost competitive with global peers

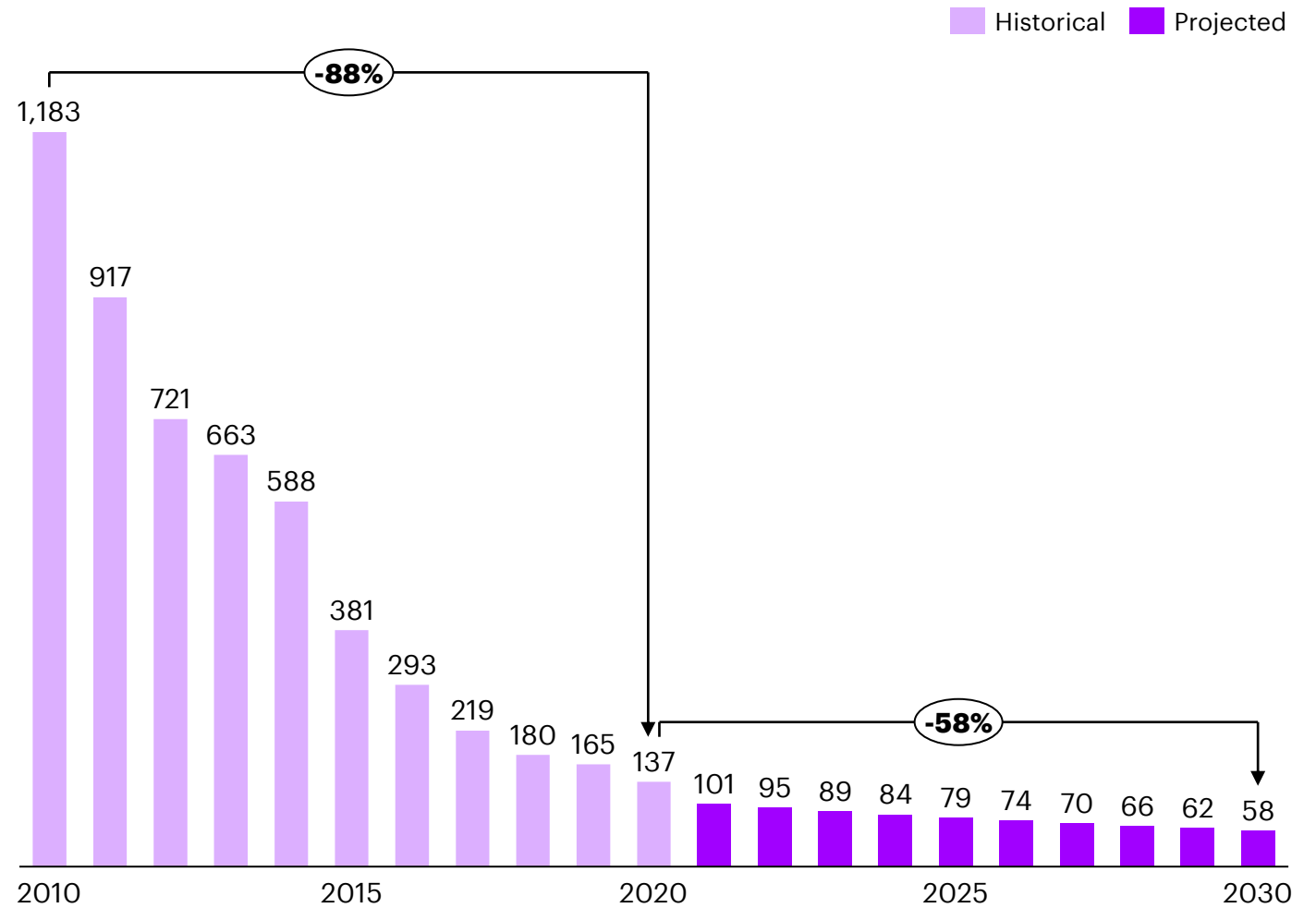
Technological and manufacturing improvements and increasing scale in production have led to dramatic reductions in battery prices of 88% between 2010 and 2020.

Over the next decade, battery production improvements are expected to be more modest, with price forecast to fall 58% from 2020 to 2030. The slowing price reductions indicates the industry is now at an inflection point – most cost savings have been achieved, and further savings will be more difficult. This greater stability in the cost of technology makes it more attractive for mainstream investors and suggests the importance of this moment for industry development.

However, to scale a domestic batteries manufacturing industry, Australia will need to be globally competitive on cost (including raw materials, labour, energy, and others). Australia will have some cost advantages from its dominant role in the extraction of raw materials. Australia's labour costs while relatively high to the global average are comparable to those of our OECD peers such as Germany, Japan or South Korea – each of which are growing their batteries industry. Availability of skilled labour is likely to be a greater barrier than cost.

Figure 42: Projected global price of lithium-ion batteries

Real US\$ per kWh



Source: Accenture (2021), *Future Charge: Building Australia's Battery Industries*

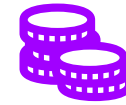
Australia has the potential to capture \$27.6 billion export revenue from batteries in 2040 in a policy scenario

BAU

In a BAU scenario, Australia is assumed to take a smaller share of the global battery market

Australia continues to be dominant in upstream mining of battery materials like lithium, with limited manufacturing and assembly. Global revenue in batteries is estimated to be \$431 bn by 2040, \$16.66 to be captured by Australia in the BAU case, representing revenue for active materials, cell manufacturing and battery assembly. Australia's presence in the battery value chain is currently limited to mining raw materials with planned projects underway in both cell manufacturing and battery pack assembly.

Volume of output: N/A
Energy input required: N/A
Share of global batteries market: 3.9%



\$16.6B
Revenue



\$3.9B
GVA¹



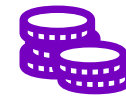
14.8k
Jobs²

POLICY SCENARIO

In a policy scenario, Australia can expand activity in value added cell manufacturing and battery pack assembly

Funding to support flagship factories and investment in assembly capacity to capture a wider share of downstream battery activities. By 2040, the policy case projects Australia will capture \$27.62 billion in revenue, and \$6.94 billion in value added. This value added total only captures the manufacturing part of the value chain as mining is covered by critical minerals.

Volume of output: N/A
Energy input required: N/A
Share of global batteries market: 6.4%



\$27.6B
Revenue



\$6.9B
GVA¹



24.9k
Jobs²



Notes: 1. GVA includes direct and indirect GVA. 2. Jobs includes only direct jobs. 3. This opportunity assumes there will be supply chain impacts for mining of lithium as it relates to batteries raw material inputs, the value add of which is included in indirect GVA

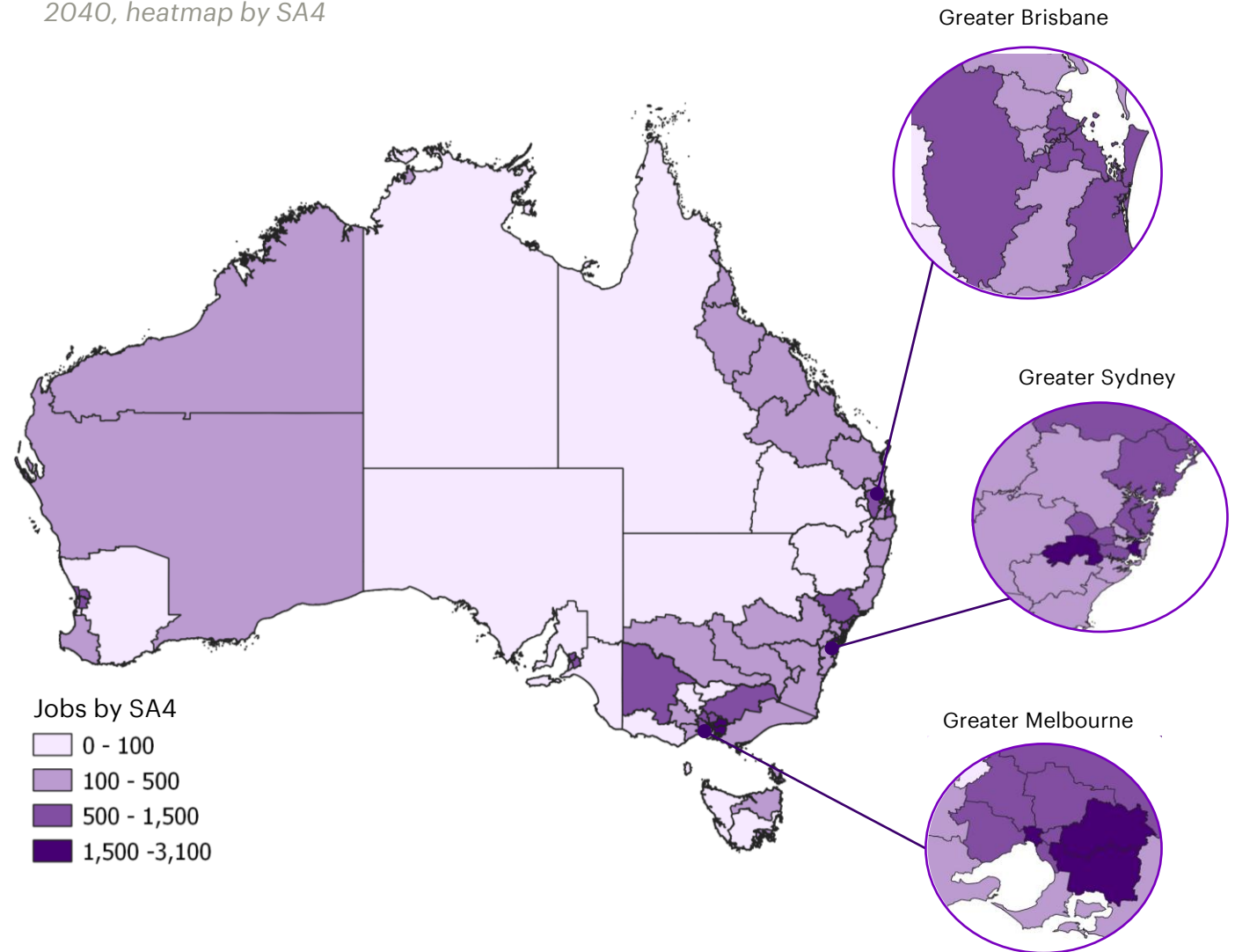
Jobs will be supported near lithium mine operations in WA, as well as manufacturing hubs in the east coast capital cities

Chemical, cell and electrical manufacturing are strong in the major metropolitan regions of Australia. Jobs for batteries will capitalise on colocation of warehousing, shipping and transport infrastructure and high skilled labour in the electrical and battery manufacturing sectors. This will mean that a significant number of jobs will be supported in Brisbane, Sydney and Melbourne.

The additional jobs supported by the batteries opportunity will support a skilled work force, with 35% of jobs for people with a bachelor's degree or higher, and 27% with a Cert III qualification. Approximately 5% of jobs will support people with 'other' types of qualifications and 32.% for no post school qualification.

Figure 43: Clean export jobs created by the batteries opportunity

2040, heatmap by SA4



Source: Accenture analysis

Three preconditions will be critical to the battery manufacturing opportunity



Diversification of global supply chains

Batteries are manufactured through a complex global value chain from mining and then refining of raw materials, through manufacturing of cells into assembly, service and maintenance.

Considering recent geopolitical tensions and physical disruption of supply chain due to COVID-19, global businesses and governments are reconsidering their reliance on highly concentrated supply chains.

As global leaders seek to diversify, new sources of supply will be required and could drive demand for batteries manufacturing in Australia.



Shift in our electricity supply from coal and gas to renewable energy

While growth of electric vehicles will drive a high portion of the demand for batteries, Australia could develop specialisation by targeting battery use cases.

Strong global growth in variable renewable energy generation has increased the need for energy storage to match supply and demand. Australia already has a higher uptake in energy storage systems than other OECD countries.

As countries further scale renewable energy generation, demand for batteries is forecast to grow exponentially. Australia's more developed demand in off-grid energy storage systems could help local producers build a competitive advantage within targeted use cases.



Coordinated batteries strategy

State governments have implemented a range of schemes incentivising the installation of household batteries and driving demand through a number of mechanisms including electrification of their public transport fleets. Additionally, the Federal Government addresses batteries in a range of different roadmaps, strategies and policies (for e.g. Modern Manufacturing Initiative).

Australia could benefit from a more coordinated vision to scale its batteries industry. A national strategy would enable focused investment in batteries research and commercialisation, improve coordination across supply chain, and define pathways to develop a globally trusted Australian batteries brand.

Four policy enablers are critical to the success of the batteries opportunity



Increase access to capital and intensify promotion of foreign direct investment opportunities

The total investment required to support diversified industries is likely \$17-23 billion. Battery projects currently face challenges in accessing the necessary capital investment required to scale, especially in manufacturing.

- Make grant funding available for Australian-based battery businesses to develop their products and scale-up
- Increase access to government sponsored capital by broadening the mandate of the CEFC and ARENA to include battery industry development
- Increase investment attraction activities to promote Australia's battery industries to key foreign direct investment markets



Skilled workforce

Industry professionals are concerned about a skills gap facing Australia's battery industries.

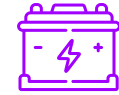
- Establish and fund, in partnership with universities, TAFE and industry, specialist battery training programmes at leading universities and TAFE.
- Work with industry and VET providers to identify opportunities to upskill existing workforce and reskill workers from declining industries, informed by the Future Battery Industries Cooperative Research Centre (FBICRC) national workforce development strategy



Develop Australian battery brand

While there is strong demand for Australia's battery materials, demand for downstream battery products needs to be fostered as the industry develops.

Assist industry to develop and market the "Green, Reliable, Ethical" Australian battery brand and simplify the credentialling process



Establishing battery hubs

Coordination across the supply chain is an essential element of diversified battery industries, to enable sourcing of supply from trusted suppliers.

Work with state and territory governments to identify sites for battery materials and manufacturing hubs. Co-locating steps of the value chain can yield several benefits, from reduced logistical costs (e.g. transportation), certainty of demand (e.g. through assured offtake), coordination across the business (e.g. when deciding to suspend and restart operations, and more flexible use of personnel between integrated business units).

Clean energy education & training



Education and training

Australia is one of the highest recipients of overseas higher education students due to its high quality of educators and researchers and post-graduate employment opportunities. Though revenue has plummeted due to the COVID-19 pandemic which has damaged the higher education sector and international enrolments, the international education sector's contribution to export earnings in 2020 was \$30 bn, making it Australia's fourth largest export.¹

Majority of international student enrolments are driven by Asia – in particular China, India, Nepal, Vietnam and Thailand. With increasing emphasis on climate change, sustainability and energy consumption in Asia, there is a growing demand for skills and expertise in these fields to drive research and scale new industries.

Australia is home to some of the world-class research centres on solar and wind energy. Building on its strength, Australia has the opportunity to double down on its investment in clean energy related research and education to train a workforce that will be required to scale new clean industries globally.

Scale of barriers: High Low

Opportunity drivers

Summary of findings

Category	Opportunity Driver	Barrier Scale	Summary of Findings
Demand-side drivers	1 Global market size by 2040	Low	In 2020, there were ~6m international students in tertiary education programmes globally. It is estimated enrolments will continue to grow by ~3% annually. With strong growth outlook and targets in clean energy sectors, there is a growing demand for skilled expertise. Skills shortages already exist within the renewable energy labour market, leading to project delays and lowered efficiency that drive up cost. Demand is likely to grow as other sectors such as transport and industry begin to decarbonise.
	2 Demand for Australian exports	Medium	
Supply-side drivers	3 Australia's current production	Low	Australia's University of New South Wales was also the first organisation internationally to offer undergraduate training in the area of Photovoltaics and Solar Energy. Currently, Australian universities and institutions offer ~200 undergraduate, postgraduate and VET courses in environmental science offered in Australia ³
	4 Technology	Medium	
	5 Supply capabilities	Low	
	6 Investment/infrastructure	High	

Source: 1. DFAT (2018-19), Trade in services 2. Inputs from OECD, ABS, Austrade, DFAT. 3: IDP Australia

Capturing ~11% of global student mobility, Australia is one of the highest recipients of overseas students

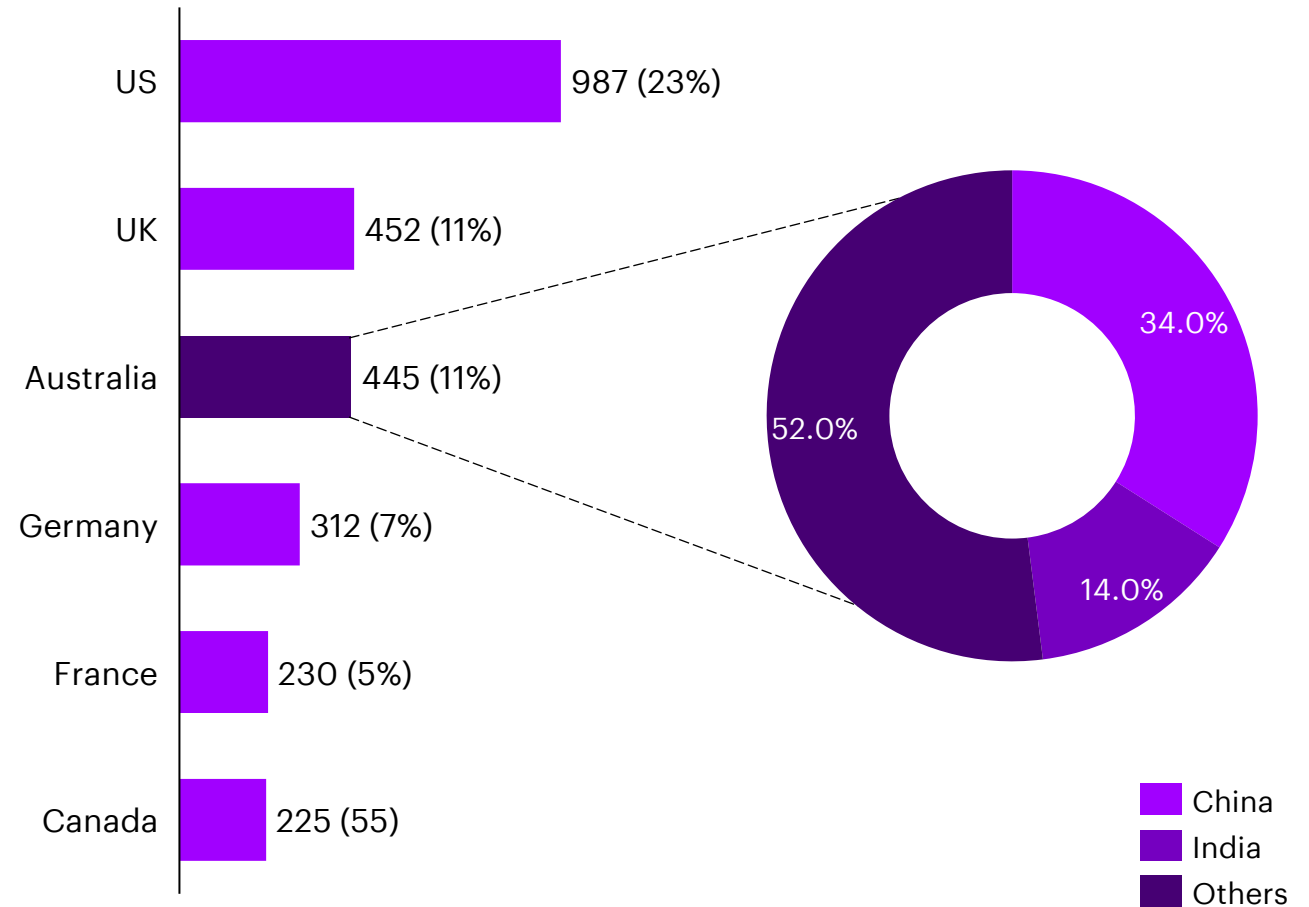
Australia is one of the highest recipients of overseas higher education students due to its high quality of educators and researchers and post-graduate employment opportunities. Australia ranked as the fifth largest recipient of overseas students among OECD countries.¹

Students from Asia form the largest group of international students in Australia. About 34% of international students studying in Australia come from China and 14% from India.¹

International students make up 21% of all students enrolled in tertiary education in Australia.¹

Figure 44: International student enrolments

'000 and % of global enrolments



Source: 1. OECD (2019), [Education at a glance](#)

Rapidly growing need for clean energy specialists will fuel demand for education & training in related fields of study

Decarbonisation is expected to generate up to 18 million net green jobs globally by 2030, the majority of which will be in Asia. Three million new green jobs could be created in India alone.¹

In the next decade, there will be a rapidly growing demand for clean energy specialists across the globe to scale planned renewable and decarbonisation projects. Several countries have identified shortage of skills and training as a leading barrier to realising the full potential from renewables.²

The US Bureau of Labour Statistics forecasts that America's two fastest-growing jobs through 2029 will be solar installers (projected to grow by 51 percent) and wind technicians (projected to grow by 61 percent) and occupation such as environmental scientists, technicians and geoscientists to grow much faster than the average jobs growth rate.³

Figure 45: New green jobs by 2030¹

% of total, 2030

- Americas
- Asia
- Pacific and Europe

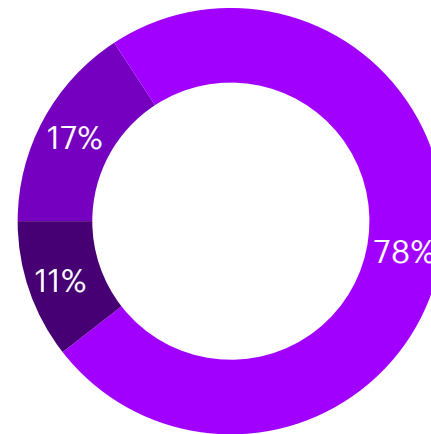
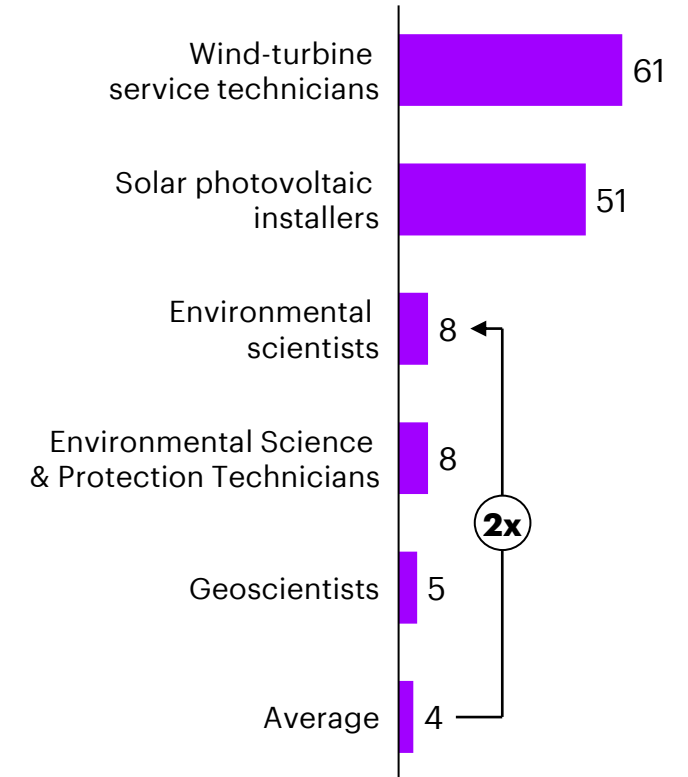


Figure 46: Example of high growth occupations in the United States

Growth rate (%), 2019-2029



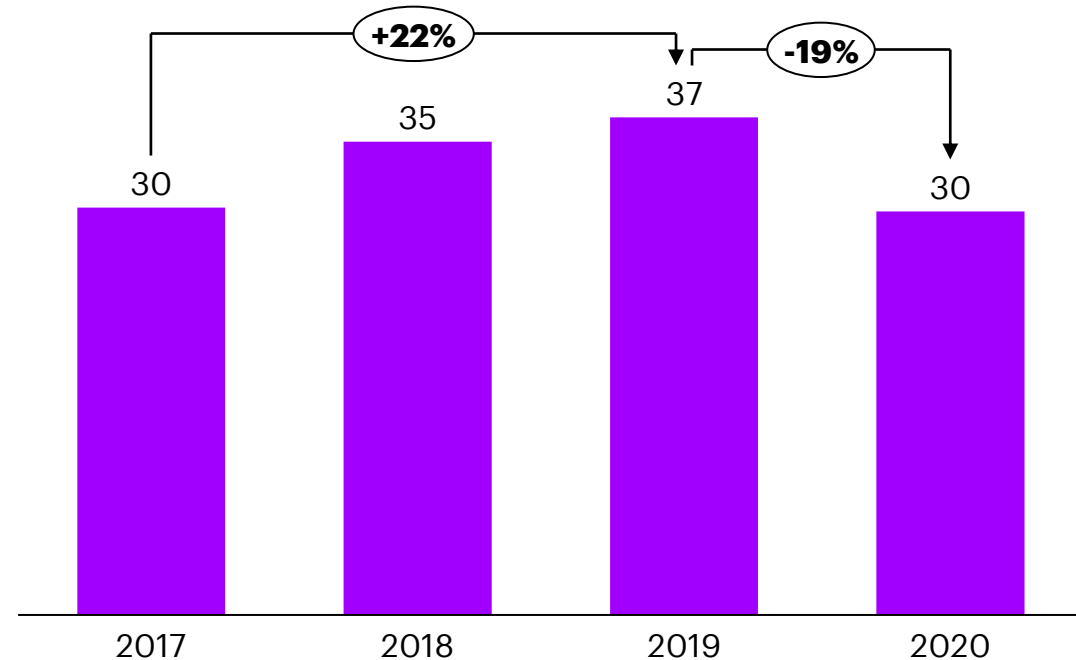
Source: 1. ILO (2018) [Regional study on green jobs policy readiness in ASEAN](#) 2. ILO (2019), [Skills for a greener future](#). 3. US Bureau of Labor Statistics (2019), [Occupational Outlook Handbook](#)

Clean energy focused economic growth can contribute towards education sector's long-term recovery

Australia has experienced a significant growth in solar photovoltaic development in the last 5 years. In 2019, Australia ranked first on world's highest solar capacity per capita with a total of 644 Watt/capita.¹ One of the key reasons for the rapid growth is Australia's world-class research and innovation capability. Australia is home to some of the world-class research centres on PV. University of New South Wales (UNSW) School of Photovoltaic and Renewable Energy Engineering, for example, holds the world record in silicon solar cell efficiency.² Building on its strength, Australia has the ability to expand its research and innovation capability to other clean energy areas such as renewable hydrogen. Universities and TAFEs could utilise their research and industry linkages to inform new academic curriculum and courses, driving global demand for Australian education services and contributing to recovery of the education sector.

International education is Australia's fourth largest export. Prior to 2020, value of education related exports was as high as \$37bn.³ With border closures and restricted mobility due to the pandemic, value of education related export decreased significantly to \$30bn in 2020⁴ and the sector will need support to recover and then grow.

Figure 47: Value of education related exports^{3,4}
2017-2020, \$B



Source: 1. Department of Industry, Science, Energy and Resources 2. IEA (2020), [Trends in photovoltaic applications](#) 3. DFAT 4. Department of Education, Skills, and Employment (2018), [Export income to Australia from international education activity in 2017](#)

Australia has the potential to capture \$11 billion export revenue from international enrolments in clean energy related fields of study in 2040

BAU

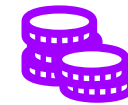
Limited policy support to rebuild the education sector after the impacts of Covid-19

Limited support resulting in lower quality and capacity to scale new academic courses and research. Australia has a flat growth (CAGR - 2%) in education related exports, impacted by slow recovery from impact of COVID. Limited expertise and slow jobs growth in clean energy sector results in declining proportion of enrolment in natural sciences, engineering and environmental courses (10%).

Volume of output: N/A

Energy input required: N/A

CAGR: 2%



\$4.8B
Revenue



\$4.2B
GVA¹



18.9k
Jobs²

POLICY SCENARIO

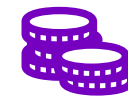
Long-term growth of education sector fuelled by strong policy support and demand for skills in new industries

Injection of new funding available for academic research, new courses and research and training institutes, focusing on specific fields and employment pathways for skilled / specialised graduates in certain areas of study to work in Australia. Australia will see a medium-term growth (CAGR - 4%) in education related exports, making a recovery back to half a million enrolments by 2030 and faster growth to 2040. Demand for academic courses in natural sciences, engineering and environment will grow driven by high demand for jobs and skills in these areas (17%)

Volume of output: N/A

Energy input required: N/A

CAGR: 4%



\$11.9B
Revenue



\$10.5B
GVA¹



47.4k
Jobs²



Three policy enablers would support clean energy focused recovery and growth of education exports by 2040



Growth of clean energy industries

This opportunity will depend on the pace of energy transition globally and Australia's ability to scale clean industries domestically and driving demand for new jobs and skills.

Skills and workforce strategy

National and regional skills assessments and access to timely labour market information will be essential as first steps to identify new skills and inform new training programmes and academic curriculum in collaboration with industry, universities and VET institutions.



World-class research & training capabilities

Australia's competitive advantage lies in its high-quality education and research. Therefore, the scale of this opportunity will depend on Australia's ability to support the recovery of the education and training sectors from the COVID pandemic, as well as attract the best faculty and researchers, fund research in specific fields of study such as natural and physical sciences, engineering and the environment, and invest in new curriculum.

Strengthening our research and training institutions and aligning with clean energy export opportunities

Provide additional funding for universities and other research institutions (such as CSIRO, Bureau of Meteorology, etc.) to scale research and new academic curriculum. Attract "high potential" PhD candidates by providing government sponsored scholarships in targeted clean energy research areas, linking a portion of scholarships to industry collaboration.



Opportunities for international students

This opportunity will also depend on easing of travel restrictions in a post-pandemic world and the ability of international students to study and work in Australia.

Pathways for international students to return to Australia

Explore safe pathways for international students to return to Australia. Retain global talent by scaling new visas/work permits/pathways for "high-potential" individuals in areas where there is high demand and low domestic expertise.

Engineering, ICT and consulting services



Engineering, ICT and consulting services

In 2019, Australia exported \$11.8B of engineering, ICT, consulting, and mining services.¹ As the world transitions to clean energy, engineering and consulting services will increasingly be used as a mode of delivery for technologies across the energy supply chain globally – from generation, transmission and distribution to retail.

Similarly, deploying smart technologies that enable capabilities such as distribution flexibility, resiliency, enhanced security, and storage will be needed to run more efficient systems.

There are 100+ Australian firms with capability in exporting environmental, renewable energy and energy efficiency services globally. As Australia scales its clean energy industries and builds capabilities, it has the opportunity to monetise that expertise as services to other countries. For example, expertise in hydrogen project development could be monetised in the same way as mining expertise in Australia or oil and gas expertise in Houston, Texas.²

Scale of barriers: High Low

Opportunity drivers

Summary of findings

Opportunity drivers		Summary of findings	
Demand-side drivers	1 Global market size by 2040	High	IEA projects up to ~\$2.3 trillion will be invested in clean energy projects annually by 2040. ³ Scaling such projects will require highly specialised capabilities. Countries where domestic capabilities are limited will drive the demand for services exports. Key services that will be required in future include renewable energy operations and maintenance, grid integration, systems design and operations, financial, advisory, and engineering services to support new clean energy infrastructure projects.
	2 Demand for Australian exports	Medium	Australia has the opportunity to monetise the expertise and capabilities as services to other countries that are trying to scale clean energy projects.
Supply-side drivers	3 Australia's current production	High	In 2019, Australia exported \$11.8B of engineering, scientific, and technical services, \$5B of ICT services, \$5.6B of consulting services and, \$0.3B of mining related services ¹
	4 Technology	Medium	Growth of 'green' services will depend on Australia's ability to scale other clean energy opportunities and develop capabilities in advisory, project design and build, and smart technologies that enable effective management and distribution of renewable energy
	5 Supply capabilities	Medium	117+ companies in Australia are involved in exporting clean energy and environmental services. ⁴
	6 Investment/infrastructure	High	Although this opportunity is a by-product of Australia scaling its clean energy industries such as renewable energy hydrogen or batteries manufacturing, additional investment and strategy will be required to develop and promote a highly specialised workforce

Source: 1: DFAT (2019) *Trade in Services* 2: Hydrogen Strategy Group (2018), *Hydrogen for Australia's future* 3: IEA (2021), *Net zero by 2050 report* 4: Austrade



Growth of renewables and clean energy industries globally will inevitably drive the demand for clean energy services

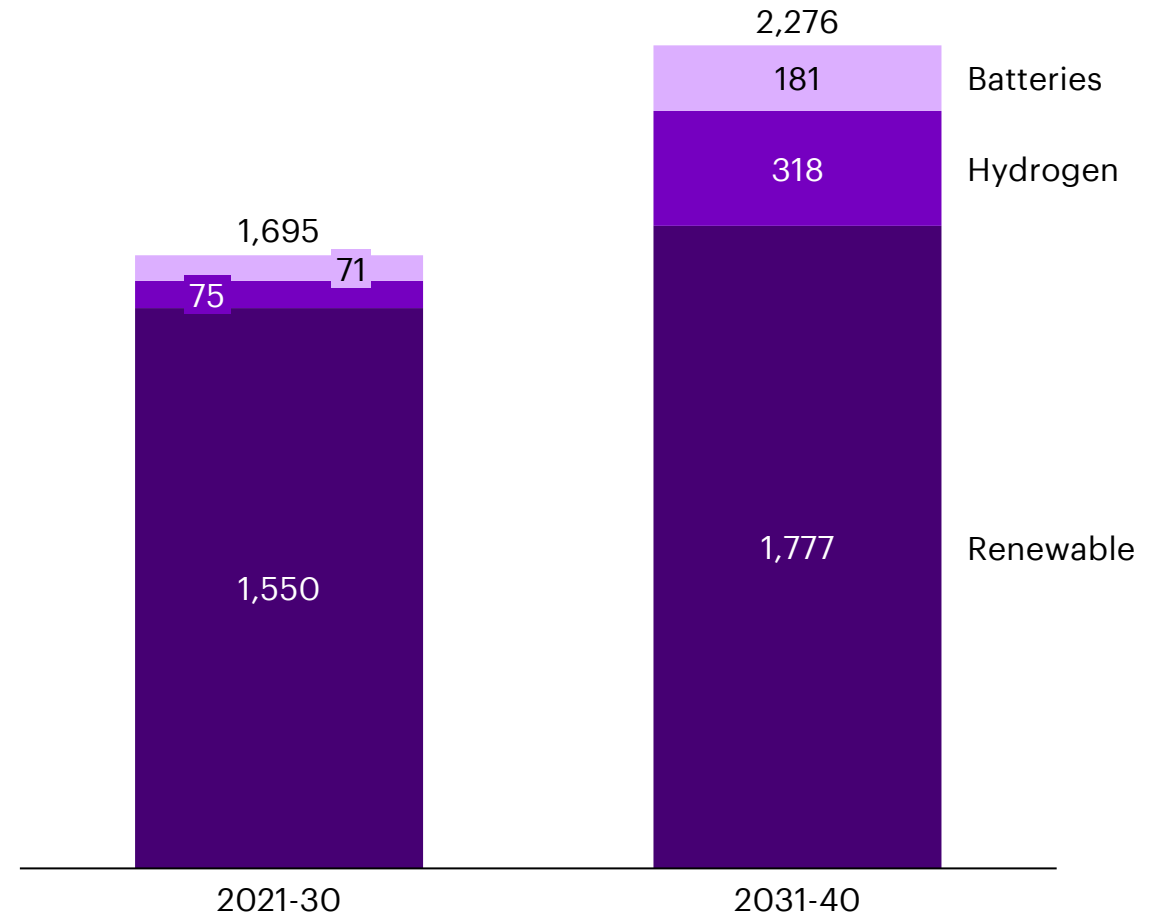
Investment in renewable energy and clean energy technologies such as batteries manufacturing globally will drive up the demand for specialised services to scale projects. IEA projects up to ~\$2.3 trillion will be invested in clean energy projects annually by 2040.

There are many services which would be incidental to clean energy transition, such as:

- Renewable energy build and operations
- Grid build, management and maintenance
- Energy systems design and operations
- Battery integration, recycling and re-use
- Mining support services
- Smart technologies and other ICT services
- Clean energy legal, advisory and financial services for large infrastructure projects
- Other design and engineering services

Figure 48: Global average annual investment by technology ¹

A\$ billion, 2050, IEA net zero estimates



Source: 1: IEA (2021), Net zero by 2050

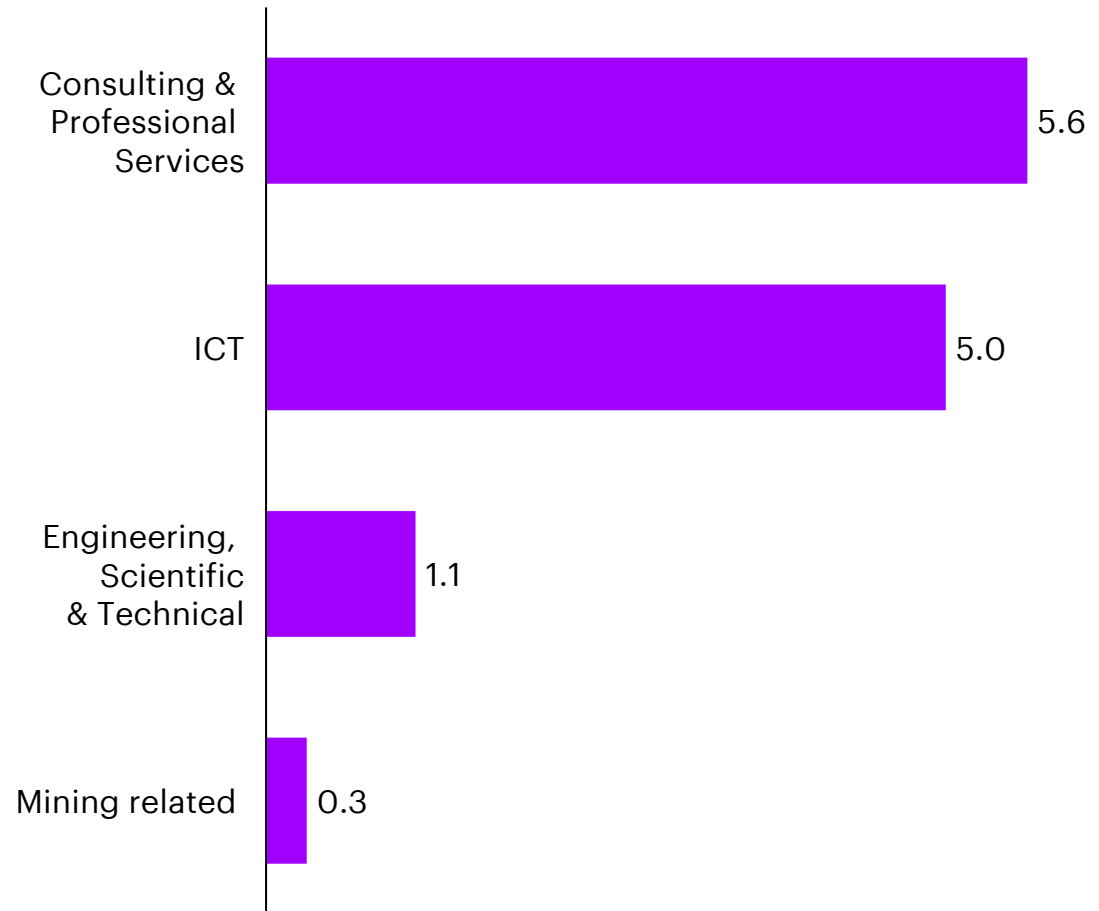
Australia exports ~\$12B of engineering, ICT, consulting, and mining services annually

Australia exported ~\$12 bn worth of engineering, ICT, consulting and mining services in 2018-19. Australia's ICT exports particularly have been growing significantly with a 5-year average annual growth rate of 14.6%. Australian software companies now generate revenue all over the world, with the US, Canada, South Africa, Indonesia and Chile currently the main international markets. Key growth markets include Russia, India, China, Mexico and Brazil, with strong prospects also in Southern and West Africa, Central Asia, Scandinavia and South-East Asia

In addition, there are a growing number of Australian companies exporting environmental, renewable energy and energy efficiency services globally. Australian trade commission has identified 100+ Australian companies currently providing clean energy related engineering, consulting, and other professional services to key export markets in Asia as well as the Americas, Europe and the Middle East,

Figure 49: Trade in services by type of activity

\$B, 2018-19



Source: 1: DFAT (2019), [Trade in Services](#)

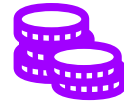
As Australia scales clean energy projects, there are opportunities to export that expertise to other countries

Australia has the opportunity to monetise the expertise and capabilities as services to other countries. For example, expertise in hydrogen project development could be monetised in the same way as mining expertise in Australia. Mining Equipment and Technology Services (METS) provide a wide range of technology and services to companies across the mining value chain including equipment manufacturing, project management, communication services, computer design systems, mining support and professional services.

The sector experienced a period of significant growth in Australia during the last two decades due to:

- Growth of mining industry domestically driven by urbanisation and rising demand for resources in Asia
- The experience and established expertise of METS companies developed over time by engagement with domestic mining operation
- The necessity to innovate to increase productivity and lower to stay globally competitive, thereby helping to build specialist expertise.

Australian mining equipment and technology sector¹



\$27B

Annual exports²



~31.3k

Jobs²



600+

Businesses²

Case study: Metallurgical Systems

An example of Australian business that has been scaling clean energy services globally is Metallurgical Systems. Founded in 2010 and 100% Australian owned, Metallurgical Systems is a technology company with a specific focus on improving outcomes for minerals processing plants. Their software enables site engineers and managers to easily access plant data, enhancing decision making and improving the operating efficiency of their plants. The software is currently used in processing plants globally in 7 countries (US, Peru, Kazakhstan, Laos, Namibia, Democratic Republic of Congo, South Africa, Malawi).³

Note: 1: Australia's METS sector comprises of businesses participating in sale and maintenance of capital equipment and mining consumable as well as contract mining and exploration services, professional services including engineering and consulting, and Software and advanced technologies.

Sources: 2. [Austrade](#), 3. [Metallurgical Systems](#)

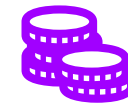
With additional policy support, where share of global services is ramped up, Australia has the potential to capture \$5.9 billion export revenue from clean energy services in 2040

BAU

Australia does not scale clean energy opportunities as described in the policy case for each

Australia does not scale clean energy opportunities and develop domestic expertise and capabilities in deploying clean energy projects. Australia has some expertise in renewables and grid management but there is limited specialised expertise for clean energy technologies such as renewable energy hydrogen or battery technology. Australia therefore has limited comparative advantage to export clean energy related services to other countries and therefore captures only 0.5% market share of \$5.9B in export revenue. To compare, Australia exported \$11.8B of engineering, scientific, and technical services in 2019 however there is no data to estimate the % relating to clean energy services.

Volume of output: N/A
Energy input required: N/A
Share of global market: 0.5%



\$1.2B
Revenue



\$0.9B
GVA¹



3.6k
Jobs²

POLICY SCENARIO

Australia scales clean energy opportunities as described in the policy case for each

Australia scales clean energy opportunities as described in the policy case and develops specialised expertise and capabilities in deploying clean energy projects. Australia conservatively capture 3% of market share³

Volume of output: N/A
Energy input required: N/A
Share of global market: 3%



\$5.9B
Revenue



\$5.0B
GVA¹



10.8k
Jobs²



The scale of clean energy services exports will depend on two factors - growth of the domestic clean energy industry and a highly specialised and skilled workforce



Growth of clean energy industries

Export of clean energy services will depend on Australia's ability to scale other clean energy opportunities and build domestic capabilities in clean energy project delivery, management and operations.

The pace at which Australia transitions to clean energy compared to other countries will determine Australia's comparative advantage in providing clean energy services to other countries.



Skilled workforce

Another factor that will underpin growth of services sector is supply of skilled workforce. Policies to scale education, research and training in renewable and other clean energy fields of study will be needed to build a highly specialised and innovative workforce.

Skills assessments and access to timely labour market information will be required to identify new skills and inform new academic and training programmes. Additional funding for universities and VET institutes would be needed to develop new education and training programs. See the Education and Training section for a detailed policy consideration.

Ambition and policy action are needed to seize Australia's clean export opportunity



Unlocking clean exports at this scale would require 6x Australia's current electricity output by 2040

A dramatic increase in renewable electricity generation would be required to take advantage of the opportunities identified in this report. To meet additional demand for new clean exports at the same time as electrifying other energy demand, renewable electricity in the order of 6x the current total electricity generation across Australia would be required.

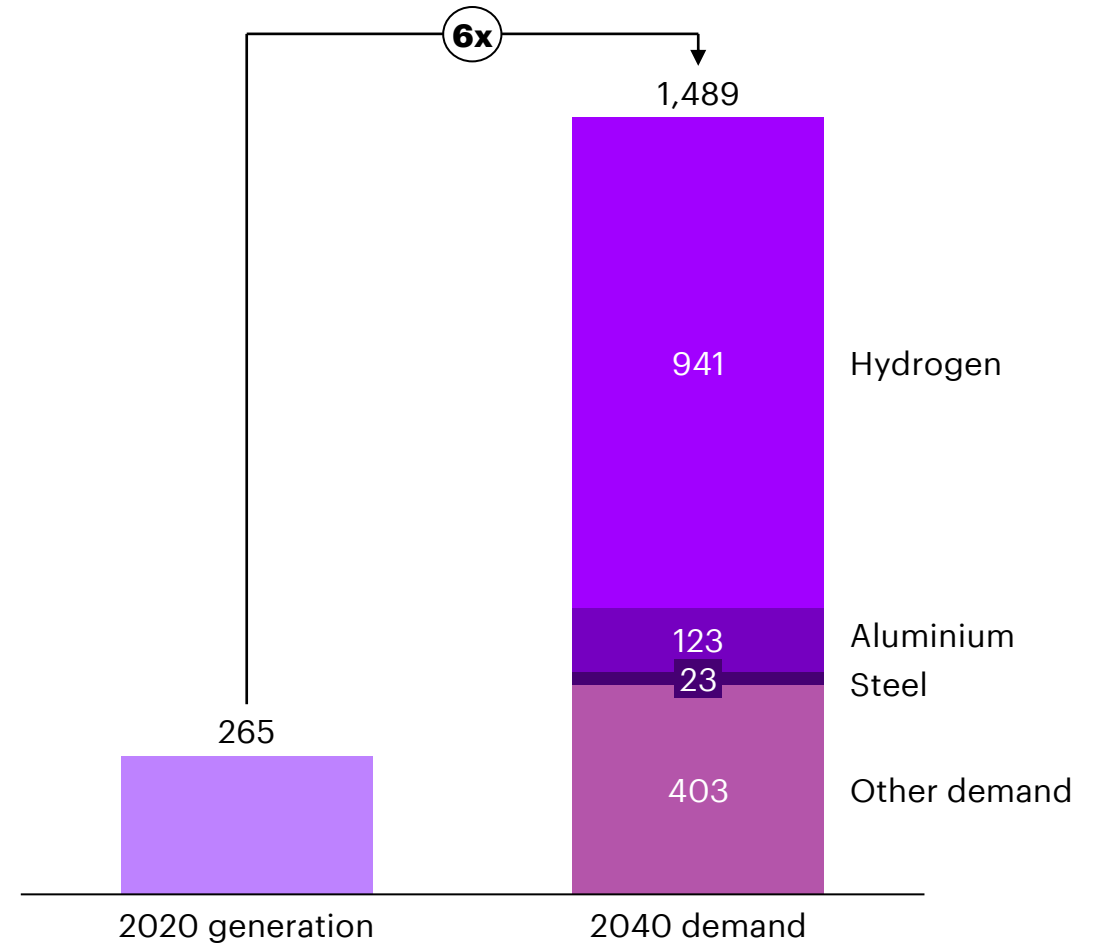
In the past 3 years, Australia has seen average growth of 8.4 TWh of renewable electricity each year. **To reach the 2040 renewable energy demand in the policy scenario, the annual rate of additional renewable electricity would have to jump to around 75 TWh every year until 2040 – a 9x increase on recent growth.**

Delivering clean energy at this scale around the country will require connecting diverse renewable energy resources with investment in new and strengthened transmission networks supported by intraday and long-duration energy storage. This renewable energy build will create many new construction jobs, and over time, a significant ongoing operational and maintenance workforce. These new jobs are additional to the jobs potential outlined across the six clean export opportunities.

To meet the scale of renewable energy expansion required, vast areas of land, and potentially ocean, will be needed. The free prior and informed consent of First Nations people must be obtained, along with their continued effective and meaningful participation.

Figure 50: A 6x increase in electricity generation would be required by 2040¹

Australian electricity 2020 generation, 2040 demand, TWh



Source: 1. DISER (2021), *Australian Energy Statistics, Table O 2*. AEMO (2021) *Inputs, Assumptions and Scenarios Report*, Accenture analysis

Note: 2040 demand incorporates AEMO's estimate of NEM underlying demand and Accenture estimates of the additional Australia-wide electricity demand including the green steel, aluminium and hydrogen opportunities identified in this report

Clean energy exports depend on low-cost, firm renewable electricity

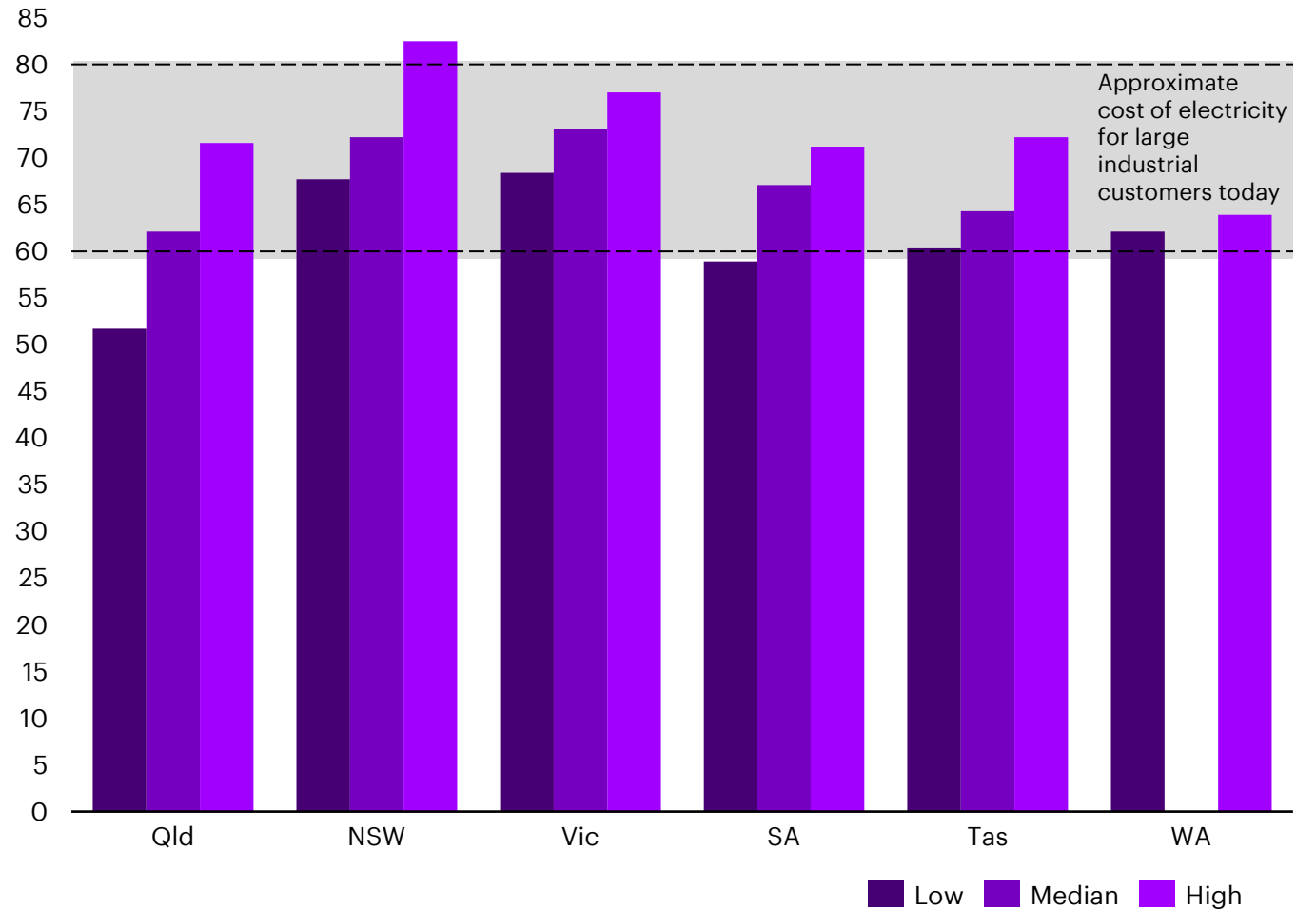
Recent CSIRO analysis indicates that the long-term levelised cost of firm renewable electricity is potentially in the range of \$53-83/MWh by 2040, bringing firmed renewables into line with electricity prices paid by the largest industrial customers today.

CSIRO has also flagged opportunities to develop the electricity system in ways that would push costs even lower:

- Using batteries in electric vehicles to balance the grid ('vehicle-to-grid') would see lower overall system costs.
- Flexible hydrogen production connected to the National Electricity Network could lower the overall storage needs of the system, resulting in even lower overall long-term electricity costs.

Figure 52: Australian locations are expected to provide firmed renewable energy at competitive costs

Levelised cost of firmed renewables, 2040, by state and zone (A\$/MWh)¹



Source: 1. Energy Transition Initiative / CSIRO (2021), Accenture analysis

Australia's renewable energy growth is slowing

Renewable electricity is critical for attracting investment into clean export production in Australia, but the rate of new large-scale renewables connecting to the grid appears to be slowing.

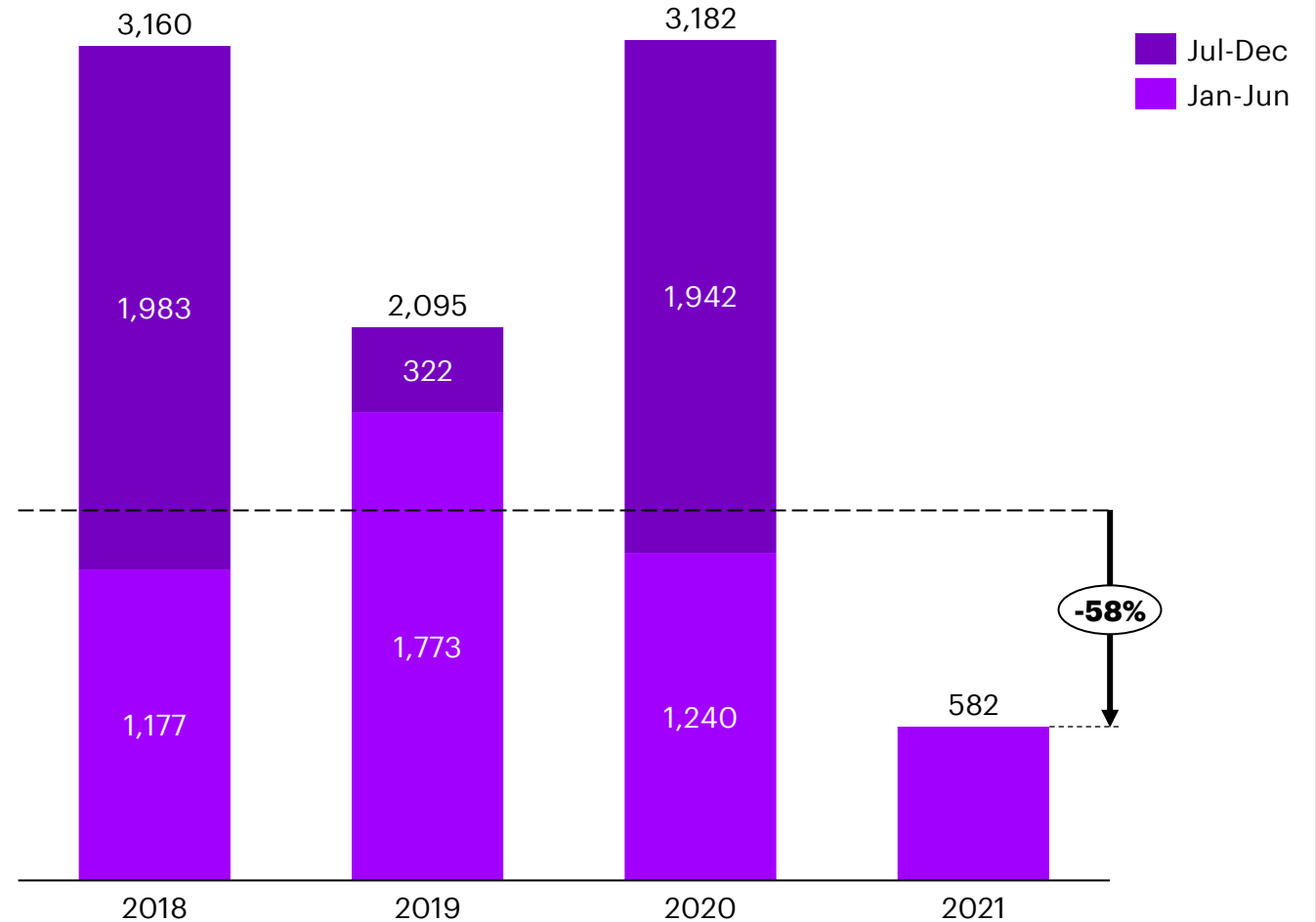
New renewables connecting to the National Electricity Market in the first half of this year fell to their lowest level in recent years.

Investment data tells a similar story. The Clean Energy Council reports that investment in large-scale renewable energy projects slowed from 51 projects worth \$10.7B in 2018 to 28 projects worth \$4.5B in 2019.²

Lack of a clear policy framework and recent challenges with grid connections and network constraints have contributed to this slowdown.

Figure 53: New renewable energy capacity connected to the NEM¹

MW



Source: 1. AEMO (2021), [Quarterly Energy Dynamics \(2018-2021\)](#), Accenture analysis 2. Clean Energy Council (2020), [Clean Energy Investment collapses as risks and uncertainty mount](#)

A cost gap remains between traditional and clean technologies today

Hydrogen from renewables is nearly twice as expensive as fossil fuel derived hydrogen today.

In Australia, it costs \$2.20 per kg to produce hydrogen from natural gas. In comparison, producing hydrogen from renewables costs around \$5.20 per kg today.

Achieving lower costs for renewable hydrogen will be driven by three factors: declining costs for renewables, higher deployment of electrolyzers, and technical improvements in electrolyser efficiency.

Producing green steel using hydrogen is around 20% more expensive than the typical market price for steel.

In steel production, hydrogen is used for process heat but can also act as a reductant. At an electricity cost of \$50/MWh, hydrogen DRI is around 20% more expensive than the typical market price of steel. Where electricity costs are close to \$20/MWh or less, green steel can be cost competitive. Using hydrogen in steel production requires an uptake of lower emissions manufacturing, a premium for green metals, or lower electricity costs from hydrogen.

Figure 54: Cost gap for renewables-based hydrogen in Australia¹

2020, A\$/kg

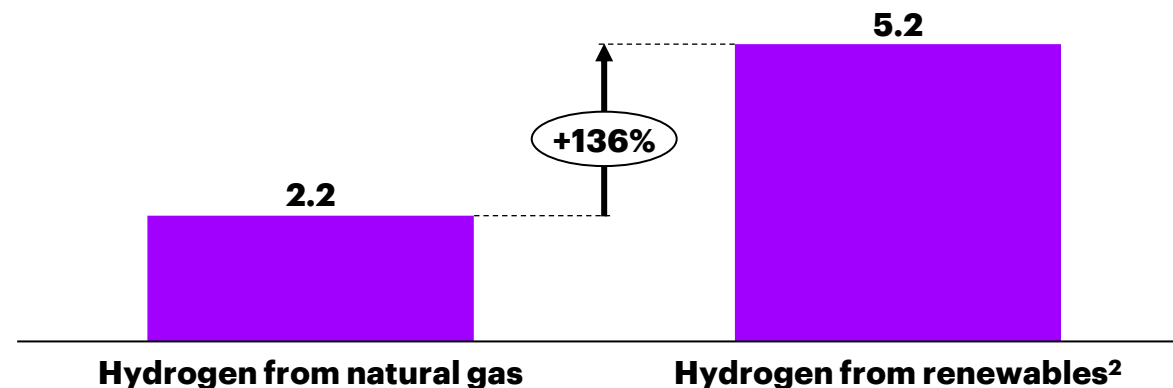
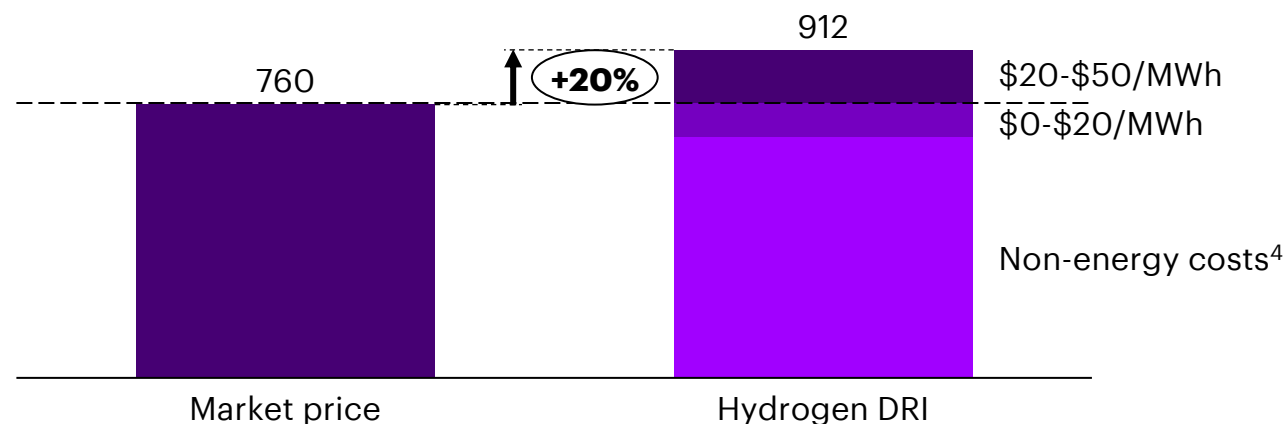


Figure 55: Cost gap for steel produced with hydrogen³

2020, A\$/tonne



Sources: 1. Energy Transitions Initiative (2021), *Phase 1 Technical Report* 3. Rocky Mountain Institute (2019), *The disruptive potential of green steel*

Notes: 2. Assumes PEM electrolysis using renewables PPA 4. Non-energy costs include the cost of iron ore and labour.

There is some policy support for clean energy exports, but no comprehensive strategy and few measurable targets

Australia has a range of policies to support clean energy exports, though there are gaps.

Hydrogen has the most comprehensive policy support, underpinned by the National Hydrogen Strategy and state strategies in NSW, WA and VIC. The Commonwealth has set a target of “H2 under \$2” and ARENA’s new Investment Plan targets support for hydrogen.

Batteries is the least progressed opportunity area. The main initiative by the Commonwealth is the creation of the FBICRC. WA is the only state with a battery industry strategy.







Green steel is included in the Low Emissions Technology Roadmap with cost targets for production (less than \$900 per tonne). The federal government has provided some funding for feasibility studies and ARENA’s latest Investment Plan includes support for green metals.

Critical minerals has a strategy at the national level, focused on attracting investment into Australia. Various forms of financial support have been provided, but there are no specific targets.

None of the policies are at the level required to unlock the potential discussed in this report. Existing policies have been factored into the BAU scenario.

Figure 56: Current policy landscape in Australia

In clean export sectors covered by this report

Opportunity	Government	Strategy	Measurable targets	Financial support		Example policies and actions ³
				Targeted ¹	Volume ²	
 Renewable energy hydrogen & ammonia	Federal	✓	✓	✓	\$\$	• National Hydrogen Strategy, CEFC Advancing Hydrogen fund, ARENA Investment Plan
	NSW	✓	✗	✓	\$\$	• Net Zero Industry and Innovation Program
	VIC	✓	✓	✓	\$	• Renewable Hydrogen Industry Development Plan
	WA	✓	✓	✓	\$	• Renewable Hydrogen Strategy
	QLD	✓	✗	✓	\$	• Queensland Hydrogen Industry Strategy
 Green steel	Federal	✓	✓	✓	\$\$	• Low Emissions Technology Roadmap, ARENA Investment Plan
 Batteries	Federal	✗	✗	✗	\$	• Establishment of FBICRC
	QLD	✗	✗	✗	-	• N/A
	VIC	✗	✗	✗	-	• N/A
	WA	✓	✗	✓	\$	• Future Battery Industry Strategy
 Critical minerals	Federal	✓	✗	✗	\$	• Critical Minerals Strategy
	NSW	✓	✓	✓	\$	• Minerals Strategy
 Services	Federal, state and territories	✗	✗	✗	-	• There are few strategies, targets or financial incentives to support services or education and training exports
 Education & training	Federal, state and territories	✗	✗	✗	-	

Notes: 1. Targeted evaluates whether the financial support is specific to the export opportunity. 2. Level of available funding where ‘\$\$\$’ indicated funding is level aligned to policy case and ‘-’ indicates no or minimal funding. 3. See appendix for more details.

Source: Accenture analysis

A national clean exports strategy is required

Given the **cost gaps** today between clean and fossil fuel technologies and the **scale** of the required renewable energy build, we need a **package** of policies and actions.

A national strategy with clear targets would put in place the fundamentals for the clean exports sector to develop.

A national strategy would:

- catalyse investment in renewables and the full range of export opportunities
- put in place the necessary infrastructure
- support research and development
- develop the long-term skills required

to take advantage of growing global demand for clean energy commodities, goods and services.

The vision: a national strategy



A **national clean exports strategy**



A cooperative, unifying national approach bringing together governments, industry, unions, First Nations people, R&D and the education sector



with **clear targets**



Growth targets to galvanise the industry and signal our national ambition to the world



backed up by **credible policies**



Co-investment, financial incentives and innovative policy solutions to catalyse investment in clean exports at scale

Five major policies and actions are required for Australia to capture \$89 billion and support 395k jobs in clean exports by 2040

01

Coordinated investment in 7 clean export precincts

By coordinating investment in clean energy and export industries, governments can link Australia's low-cost renewable energy resources to clean exports at precincts around the country.



02

\$10 billion co-investment in new industries

By co-investing using grants, debt, equity or carbon contracts for difference (CCfDs), governments can directly support flagship projects to accelerate the scale-up of Australia's clean export industries.



03

\$5 billion fund for workers and regions delivered by a new energy transition authority

A new fund overseen by a dedicated authority with representatives from government, industry and unions will help manage the disruptive impacts of the transition on workers and regions with carbon-intensive industries.



04

Support for low-carbon materials in major infrastructure projects

An immediate new program to support the use of low-carbon materials in buildings and major infrastructure projects would boost domestic demand, supporting new manufacturing capacity and laying the foundation for exports.



05

An interim target of 6 GW of hydrogen capacity and 3 green metals plants by 2027

Setting an ambitious target as part of a national strategy will galvanise collaboration between governments, industry, unions and the research and education sector to grow Australia's clean export industry.



Coordinated investment in 7 clean export precincts

By coordinating investment in clean energy and export industries, governments can link Australia's low-cost renewable energy resources to power clean exports at precincts around the country.



What are clean export precincts?

Clean export precincts connect renewable energy and hydrogen production with new and existing industries and transport links. Sometimes referred to as renewable energy industrial clusters, clean export precincts can facilitate new export industries as well as renewables-powered production for local industry.

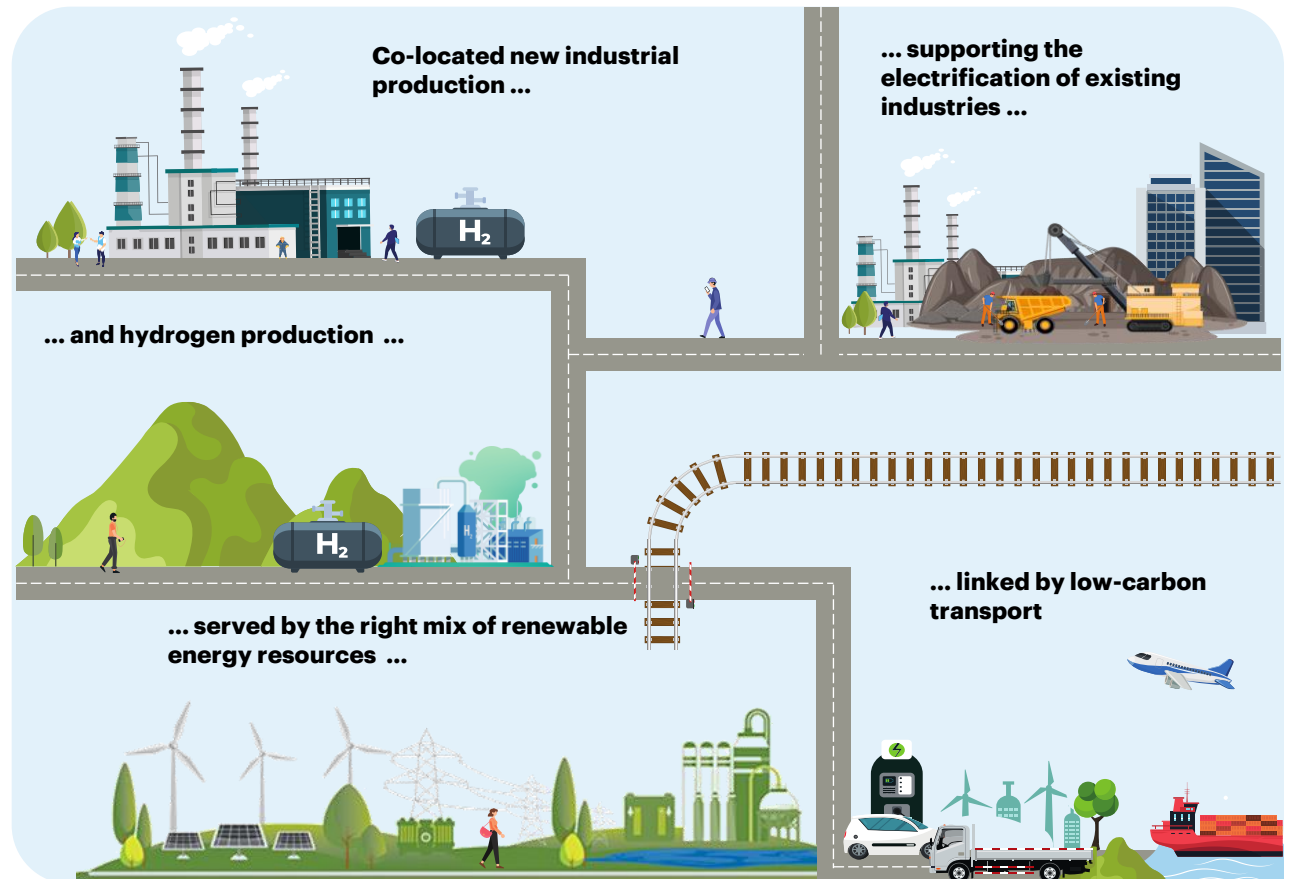
Why is the policy needed?

A coordinated approach to clean export precincts would use **renewable energy zones, financial incentives, shared infrastructure investment, strategic land-use and marine planning and other policy levers** to build clusters at a scale that attracts significant investment, potentially in or near regions with existing carbon-intensive industry.

By coordinating investment in clean energy supply (including renewables, storage and transmission) and demand (for new and existing energy-intensive manufacturing, processing and production), governments can **unlock Australia's low-cost renewable energy resources** and deliver low-cost, firm clean electricity to **power clean exports**.

How would the policy work?

Clean export precincts link renewables and H₂ with industry and transport



Coordinated investment in 7 clean export precincts

By coordinating investment in clean energy and export industries, governments can link Australia's low-cost renewable energy resources to power clean exports at precincts around the country.



Global case studies



Hydrogen clusters in the United Kingdom

The UK is building a set of hydrogen clusters that will aim to deliver 9.7GW of new capacity by 2030.¹ The program will deliver four carbon capture, storage and utilisation (CCUS) projects that will assist industrial decarbonisation, enable hydrogen to be integrated into gas networks and provide flexible power generation and transportation.

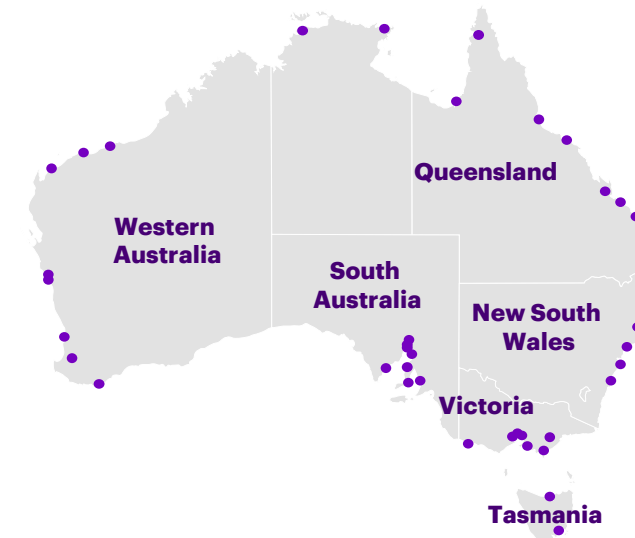


Europe's clusters connected by a 'Hydrogen Backbone'

23 European gas Transmission System Operators have drafted a proposal for the European Hydrogen Backbone which would connect industrial clusters across 21 countries and accelerate energy industry decarbonisation.² The proposed pipeline could connect hydrogen valleys across 11,600km by 2030, and grow to a length of 39,700km by 2040.

Potential Australian clean energy precincts

Candidate clean export precinct locations^{3,4,5}



Queensland	New South Wales	Victoria	Western Australia	South Australia	Tasmania
Abbot Point	Hunter Valley	Altona	Ashburton/Onslow	Myponie Point	Bell Bay
Brisbane	Newcastle	Latrobe Valley	Albany	Port Adelaide	Hobart
Bundaberg	Port Botany /	Geelong	Collie	Port Augusta	
Gladstone	Kurnell	Port Anthony	Dampier	Port Bonython	Northern Territory
Karumba	Port Kembla	Port of	Geraldton	Port Giles	
Port Alma		Melbourne	Kwinana	Port Lincoln /	Darwin
Townsville		Port of Hastings	Oakajee	Cape Hardy	(Middle Arm)
Weipa		Portland	Port Hedland	Port Pirie	Gove
				Whyalla	

Coordinated investment in 7 clean export precincts

By coordinating investment in clean energy and export industries, governments can link Australia's low-cost renewable energy resources to power clean exports at precincts around the country.



Engagement with and consent from First Nations people

Clean energy precincts involve significant changes to land use and will require long-term collaborative planning involving a wide range of stakeholders. To meet the scale of renewable energy expansion required, vast areas of land will be needed. Australian law recognises that First Nations people are the Traditional Owners and have a critical decision making role.

Activities that require significant land and water use, such as clean energy precincts and critical minerals mining, must be cognisant of the human rights impacts projects can have such as forced displacement or destruction of the environment.¹ Furthermore, it is important that First Nations People benefit from the projects on Aboriginal Land. This benefit may take the form of agreements for access to energy, financial compensation, or a stake in ownership.²

Since the mineral deposits and prospective hubs may lie on Aboriginal Land, the free prior and informed consent (FPIC) of Traditional Owners must be obtained to protect these human rights. FPIC is explicitly recognised in the United Nations Declaration of the Rights of Indigenous Peoples (UNDRIP) which was endorsed by Australia in 2009.

Beyond consent, First Nations people should be engaged in partnerships that involve effective and meaningful participation. The Western Green Energy Hub can be looked towards as an example of a project moving beyond obtaining consent, and entering into a partnership with the Traditional Owners.

Case Study: Western Green Energy Hub

The proposed Western Green Energy Hub (WGEH) in Western Australia is the largest Traditional Owner and commercial partnership in Australian history. The project consortium includes InterContinental Energy, CWP Global, and the Mirning People.

The WGEH is planned to be 15,000 km² with a combined wind and solar capacity of up to 50 GW. At completion, the hub expected to produce up to 20 Mtpa of green ammonia from hydrogen.³

The partnership with the Mirning people involves providing the Traditional Owners with equity in the project as well as a permanent board seat.



\$10 billion co-investment in new industries

By co-investing using grants, debt, equity or carbon contracts for difference (CCfDs), governments can directly support flagship projects to accelerate the scale-up of Australia's clean export industries.



What is co-investment?

Co-investment is an arrangement between the government and one or more eligible parties to fund and support flagship projects. Co-investment could take the form of grants, debt, equity, CCfDs, or other financial instruments.

Co-investment has a track record of success in Australia, particularly in the form of grants from the Australian Renewable Energy Agency and financial investments from the Clean Energy Finance Corporation and Export Finance Australia.

Why is the policy needed?

Through co-investment, **governments can directly catalyse flagship projects** in Australia's clean export industries such as hydrogen, green metals and battery manufacturing by sharing risk with other investors.

Government investment can also **play a role in attracting global investment** to accelerate the diversification of Australia's exports.

Government co-investment may also **support earlier stage projects** to scale and commercialise research and innovation.

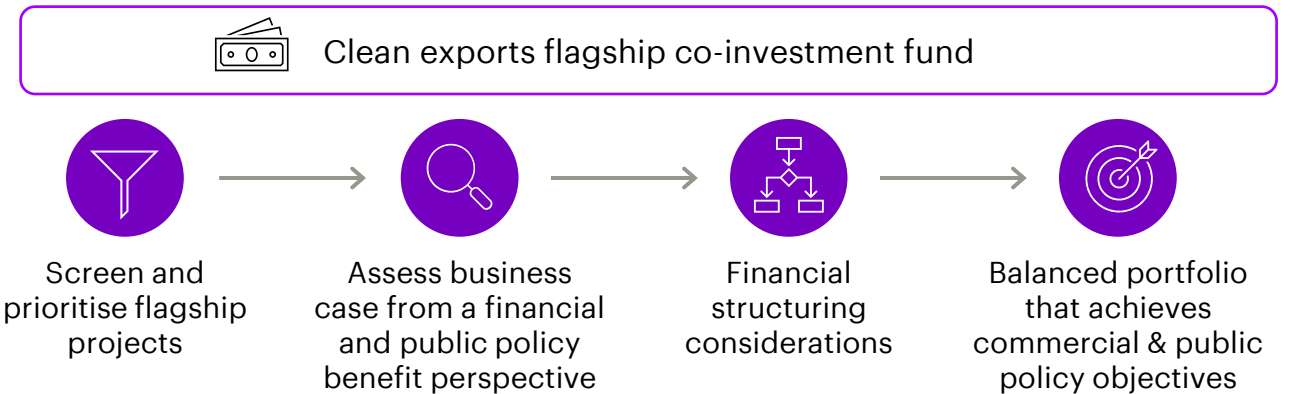
How would the policy work?

Co-investment should be delivered by an independent government body.

Agencies such as ARENA and the CEFC provide financial support for clean energy initiatives. These agencies are responsible for assessing the business case and financing needs of proposed projects.

This disciplined process is important when considering co-investment in new clean export industries to maximise the value of public finance.

Co-investment through CCfDs for hydrogen or green metals would cover the price differential between fossil fuel-derived commodities and green commodities. This provides greater predictability of future revenue streams and provides a more attractive risk profile to investors.



Source: Adapted from CEFC's Investment Screening Process

\$10 billion co-investment in new industries

By co-investing using grants, debt, equity or carbon contracts for difference (CCfDs), governments can directly support flagship projects to accelerate the scale-up of Australia's clean export industries.



Global case studies

Germany



Co-investment is widely used to support emerging clean energy industries.

- The German government is building on EUR 2.9 billion of EU funding for battery innovation with significant investments to support the development of battery manufacturing.
- The German government will contribute to EUR 55 million towards a hydrogen-DRI green steel plant in Hamburg, covering half the cost of the new plant.

Sweden



In 2016, the Hydrogen Breakthrough Ironmaking Technology (HYBRIT) initiative was launched as a joint venture between SSAB (steel producer), LKAB (iron ore producer), and Vattenfall (energy company). The HYBRIT initiative was developed due to the growing need to decarbonize the steel manufacturing industry.

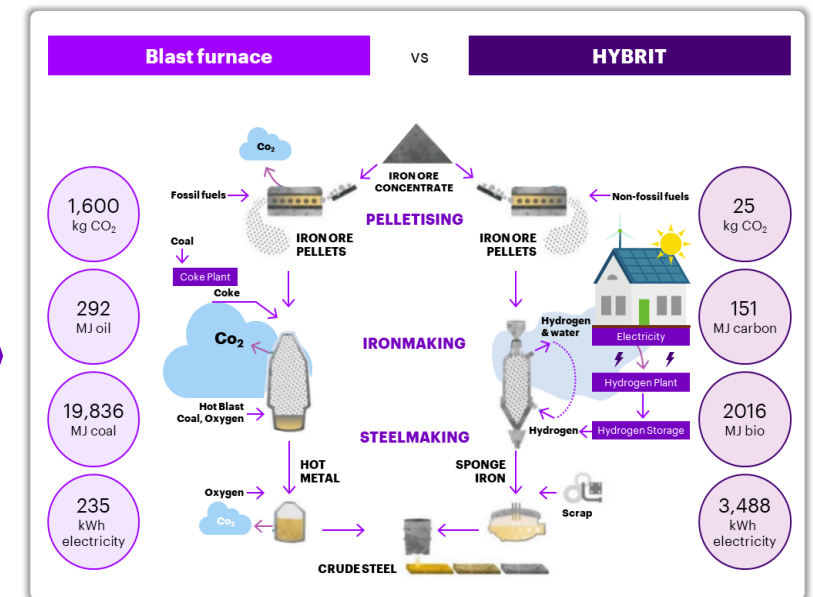
The initiative has been supported at several stages of development by grants from the Swedish Energy Agency (SEA):

- EUR 6.9m to fund a pre-feasibility study in 2016 and 2017
- EUR 51.3m to fund two pilot plants (largest funding in the history of the SEA).¹

With the support of these government grants, the joint venture had two pilot plants operational by 2020.

In August 2021, SSAB delivered green steel to carmaker Volvo.^{2,3} SSAB is aiming to put green steel on the market at commercial scale by 2026.⁴

Sweden—developing HYBRIT through co-investment



\$5 billion fund for workers and regions delivered by a new energy transition authority

A new fund overseen by a dedicated authority with representatives from government, industry and unions will help manage the disruptive impacts of the transition on workers and regional economies with carbon-intensive industries.



What is the policy?

With targeted local policy solutions, governments can ensure that **workers can transition to new clean exports jobs** and new projects have the **right mix of skills** available as the clean exports industry takes off.

A national, independent statutory authority with significant resources is required to plan and coordinate an orderly, just transition for workers and communities and to help regional economies diversify.

Why is the policy needed?

Australia's energy transition will have a significant and disruptive impact on workers in carbon-based industries and their communities and local economies.

Large scale worker retraining programs are expensive, and the **cost burden should be shared** between federal and state governments.

Consistent, engaged coordination will be required across all levels of government, working with regional coordinating bodies where these exist. **Institutions with regional expertise** working with local employment and training organisations can deliver solutions based around local conditions and needs.

How would the policy work?

The transition authority would be an independent, statutory body with a tripartite structure and a budget of \$5 billion. It will work with regional transition authorities, plan for the clean energy workforce and administer and provide advice to government on the best use of the fund.

Transition authority + transition fund



The transition authority can provide **access to training for clean energy jobs** for workers with transferable skills. Many existing VET and university training courses can be adapted for clean energy qualifications.



The transition authority can support projects that allow workers to obtain **clean energy skills on mixed energy projects**. For example, supported low-emission steel manufacturing project that used technology such as gas-based direct reduction could equip workers with the skills required for a hydrogen-based production process.¹



The transition authority can coordinate **pooled redundancies** to ensure that workers in carbon jobs have timely opportunities at other sites or in other companies.



Clean energy precincts can be created in existing carbon-intensive areas, creating a demand for workers in areas likely to see job losses as high-carbon industries decline. When planning REZs and clean export precincts, governments should **aim for scale** to facilitate highly skilled, permanent, local workforces.



The transition authority can coordinate **regular transparent disclosures** about the number and types of jobs that will be created, and the required qualifications and expected wages.¹ This will enable communities and local organisations to accurately prepare for the energy transition.

\$5 billion fund for workers and regions delivered by a new energy transition authority

A new fund overseen by a dedicated authority with representatives from government, industry and unions will help manage the disruptive impacts of the transition on workers and regional economies with carbon-intensive industries.



Global case studies

European Union



The Just Transition Mechanism (JTM) has been set up to address the **social and economic effects** of the clean energy transition.

The JMT aims to mobilise **€65-75 billion** between 2021-2027 available to EU member countries. The funds will be used to assist with economic diversification, research and development, environmental rehabilitation, re-skilling and job search aid for workers.¹

Germany



In 2018, the Commission for Growth, Structural Change and Employment was established in Germany, mandated with ensuring **minimal social and economic problems** as coal-fired power stations are phased out over the next 20 years.²

The Commission's recommended measures include training and recruitment programs, early retirement pension deficit funding for older workers, price mechanisms to suppress energy prices during the transition, and compensation payouts to coal-fired plant operators.

Support for low-carbon materials in major infrastructure projects

An immediate new program to support the use of low-carbon materials in buildings and major infrastructure projects would boost domestic demand, supporting new manufacturing capacity and laying the foundation for exports.



What is green procurement?

Green procurement involves policies to promote the use of low-carbon materials in buildings and infrastructure that are paid for or financed using public resources.

Government policies and programs could support moving over time towards 100% use of low-carbon cement and steel in buildings and infrastructure projects.

Why is the policy needed?

Policy support is required to help bridge the cost gap between low and high-carbon materials as technology costs decline.

By promoting domestic demand, green procurement policies would support new production capacity for clean energy and materials, laying the foundation for future exports.

How would the policy work?

Promoting domestic demand for low-carbon materials encourages the development of a domestic industry and drives down costs through economies of scale. Without this policy, cost gaps between emissions intensive and low-emissions products would inhibit the adoption of low-emission products.

There is a history of using procurement to drive changes such as addressing modern slavery, advancing vaccine development, and more recently to encourage the uptake of electric vehicles.¹

The Australian Government spent \$6.2 billion in 2019-20 on building construction, support, maintenance and repair services, and nationally nearly \$225 billion has been allocated for general government sector infrastructure funding over the four years to 2023-24.^{2,3} Supporting the use of low-carbon materials through these investments would accelerate domestic demand and lay the foundations for clean exports.

There are already commitments by Australian states to drive emissions reduction through procurement. For example, Victoria has committed to adding 400 EVs to the government fleet and Western Australia has recently set a 25% EV target for their government fleet. Setting targets or mandates for publicly funded procurement is an established policy mechanism.

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Global case studies

Netherlands



The Dutch Ministry of Infrastructure **quantifies the environmental components of private bids** for infrastructure projects. The monetary value of the environmental contribution is then subtracted from the offered price, incentivising companies to compete along environmental dimensions.¹

Italy



The City of Rome has Green Purchasing Policies (GPP) that cover **98% of the City's purchases**. In 2016 the City introduced a digital monitoring system linked to their public procurement electronic information system that increased transparency around GPP as part of their aim to reduce the City's CO₂ contribution by 20%.²

Scotland



Scotland embedded sustainable procurement duty into the Procurement Reform Act of 2014.³ The Act applies to public infrastructure projects with significant steel composition and capital costs greater than £2 million. It specifies that **purchased steel must have been produced a "responsible and sustainable way."**⁴

An interim target of 6 GW of hydrogen capacity and 3 green metals plants by 2027

Setting an ambitious target as part of a national strategy will galvanise collaboration between governments, industry, unions and the research and education sector to grow Australia's clean export industry.



Why is a target needed?

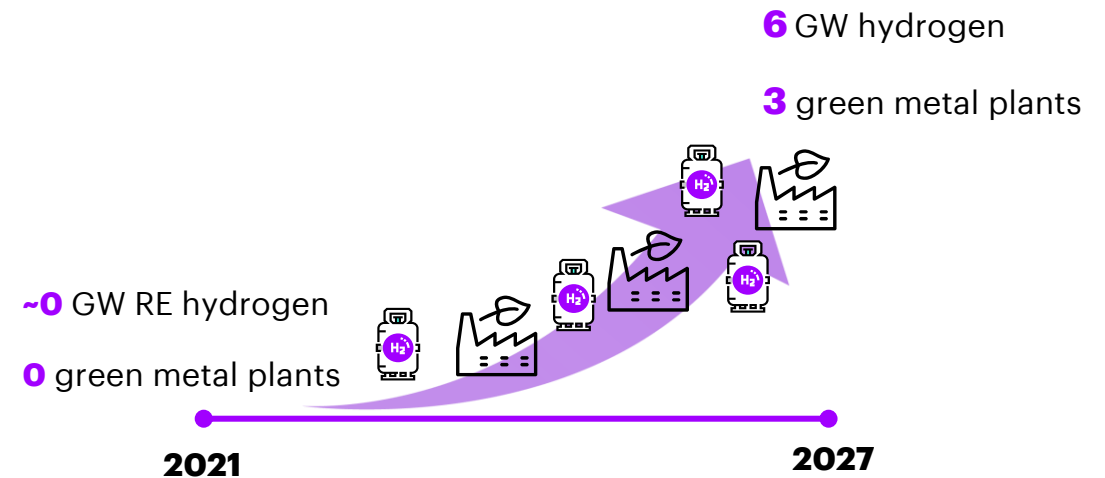
Targets are required where reaching outcomes requires coordinated effort between stakeholders to achieve. In this case, targets serve as a coordination mechanism that signals intent and provides certainty about national priorities. This certainty helps stakeholders to work collaboratively towards the announced goal.

Timebound targets allow other parties to transparently assess progress towards the goal.

How would the target work?

For a target to be effective, it must be clear and timebound, and supported by credible policies and actions.

An interim target of 6 GW of renewable energy hydrogen production and 3 green metal plants by 2027 would signal Australia's commitment to building a significant clean export industry.



An interim target of 6 GW of hydrogen capacity and 3 green metals plants by 2027

Setting an ambitious target as part of a national strategy will galvanise collaboration between governments, industry, unions and the research and education sector to grow Australia's clean export industry.



Global case studies

Chile



Chile announced a national hydrogen strategy in 2020 that set an ambitious **target of 5 GW of electrolysis capacity operation and under development by 2025 and 25 GW of electrolyser capacity by 2030.**¹ The strategy includes an action plan to reach these targets such as through a promotion of domestic and export markets and capacity building and innovation. The strategy includes policy such as a funding round of up to USD\$50 million to close the production cost gap and a national council to monitor the strategy.

Germany



Germany announced a national hydrogen strategy in 2020 that set a **target of 5 GW of electrolyser capacity by 2030.** To reach this target, 38 measures across hydrogen production, fields of application, research, education and innovation are introduced. Several examples of these measures include funding for hydrogen and fuel cell technologies, Carbon Contracts for Difference (CCfD) to target steel and chemical industries and increasing demand for low-emissions products.²

European Union



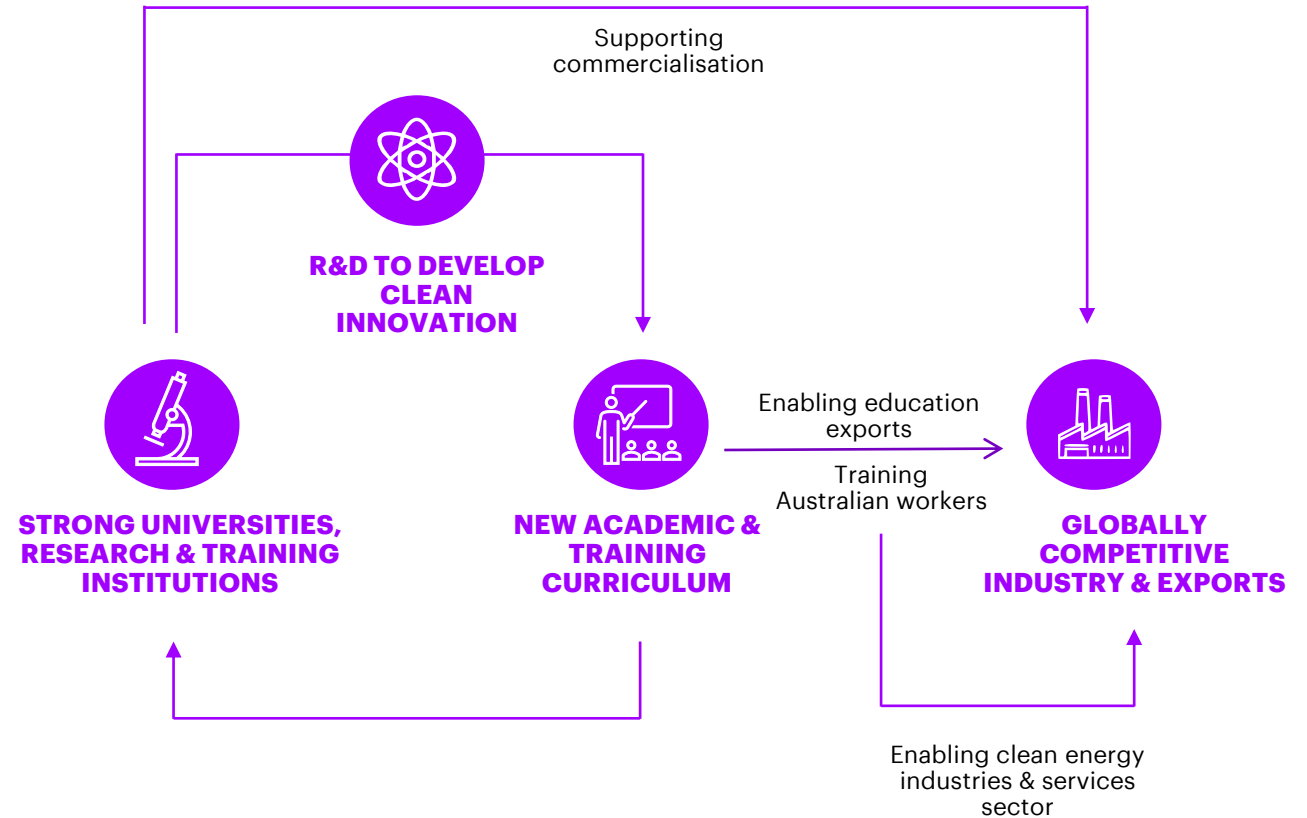
The European Union published a hydrogen strategy in 2020 that set a target for electrolyser capacity of **6 GW by 2024 and 40 GW by 2030.**³ This strategy outlines 6 key priorities such as boosting demand for clean hydrogen, the need for a supportive framework and well-functioning markets, and promoting research and innovation to reach these targets.³

Strong research and education institutions will be essential to delivering the national clean exports strategy

Universities and research institutions have a critical role to play as key clean energy stakeholders. Universities enable new capacity through new research and insights and can provide effective solutions to complex clean energy problems.¹ Australian universities have a strong legacy in leading renewable energy research, with the establishment of the University of New South Wales' Solar Photovoltaics Group and beginning of solar energy research at Australian National University in the 1970s. In addition, Australian universities provide a regular supply of highly skilled people who develop and implement solutions to clean energy barriers.

A holistic approach to scaling new clean industries must include strong investment and coordination with Australian universities and key research institutions such as CSIRO to promote cutting-edge research and innovation, develop new academic and training curriculum, and enable a skilled clean energy workforce.

Role of Australian Universities, training and research institutions



Source: 1. European Universities Association (2017), [Energy Transition and the Future of Energy Research, Innovation, and Education](#)



Appendix I: Methodology



A long list of export opportunities was considered to identify key opportunities

Sectors		Long-list of opportunities		Aggregated short- list	
Energy & materials	Clean energy	1	Green hydrogen & ammonia	Green hydrogen / ammonia Export of hydrogen / ammonia	
		2	Biofuels	Biofuels Export of biofuels and related technologies	
		3	Direct electricity (via undersea cables)		
	Clean metals	4	Green iron & steel	Green metals Processing & export of higher-value metals using renewable energy	
		5	Green alumina and aluminium		
		6	Manganese		
		7	Critical minerals (e.g. copper, cobalt, nickel, lithium, rare earths)	Critical minerals mining & refining Export of minerals critical for production of clean energy products and technologies	
Technologies	Energy storage	8	Batteries	Direct electricity transfer International transmission of renewable electricity via subsea cables	
	Transport	9	Battery electric vehicles		
		10	Hydrogen fuel cell vehicles		
	Devices & components	11	Heating and cooling technologies	Batteries Export of Australian-made batteries	
		12	Wind turbine/ Solar PV components		
	Services	Recycling	13	Recycling of clean energy technologies	Electric vehicles Export of Australian-made vehicles
ICT & data		14	Software to operate clean energy systems		
		15	Data-driven industrial operations		
		16	Finance & investment		
Professional services		17	Legal, accounting & consulting	Engineering , ICT & consulting services Expertise to support design & operation of clean energy systems, demand management, grid management, etc	
		18	Design & engineering (e.g. microgrids)		
		19	Education & training	Education & Training Education and training services for clean energy related fields of study	

Top six opportunities were prioritised for further exploration based on market attractiveness and Australia's competitive advantage

Prioritisation Criteria

Attractiveness



Potential export value
size of the opportunity



Carbon abatement and other externalities such as impact on regions, jobs, etc

Competitive advantage



Supply and input conditions
existing production in Australia and key barriers to supply



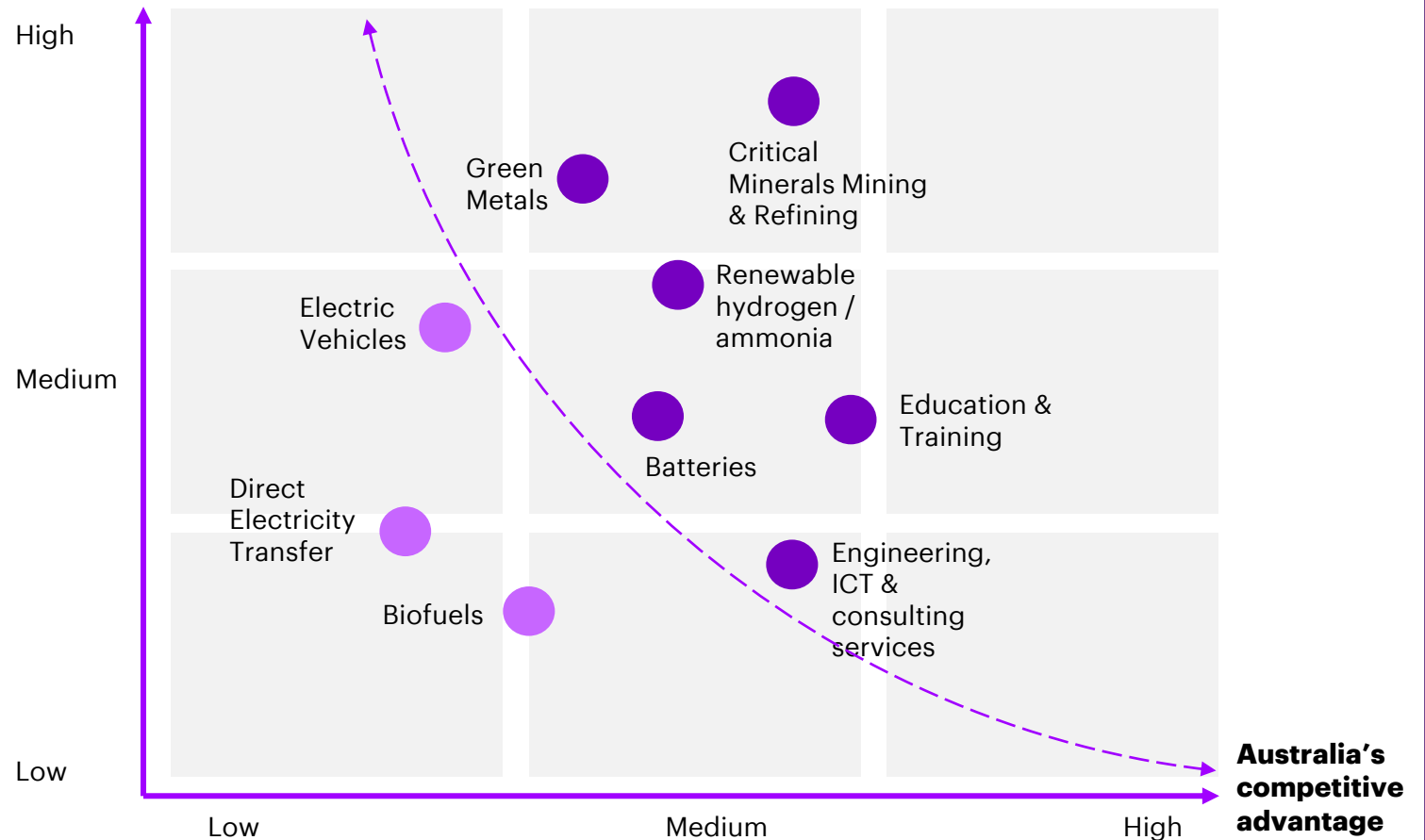
Demand and market conditions
key competitors, barriers to entry



Feasibility
Viability and commercial uptake of opportunity by 2040

Market Attractiveness

Key opportunities selected for further deep-dive



Key inputs and assumptions for calculation of revenue, GVA and jobs in BAU and Policy scenarios (1/2)

Category	Assumption	Scenario	Source
GVA and Jobs	Input – output tables were used to estimate direct and indirect gross value added and employment generated in the economy due to additional output (revenue) generated within each of the six export opportunities.		ABS, REMPLAN
Revenue Projections:			
Critical Minerals	Global demand and value of critical minerals as per IEA	BAU and Policy	IEA 2021, Net Zero by 2050, IEA 2021, Role of Critical Minerals in Clean Energy Transitions
	Australia's % share of global mining production for all critical minerals except lithium constant from 2020	BAU and Policy	USGS
	Australia's % share of lithium mining decreases from 50% to 31% by 2030 and remains constant	BAU and Policy	Roskill projection 2020, Global Lithium demand is expected to climb to 1.79Mt by 2030
	% share of mined lithium refined in Australia = 20%, % share of mined remaining critical minerals refined in Australia = 0%.	BAU	Accenture analysis
	% share of mined critical minerals refined in Australia = 60%	Policy	Accenture analysis
	Location of jobs informed by the location of known deposits of critical minerals	BAU and Policy	Geoscience Australia 2021 <i>Mines Atlas</i>
Hydrogen	Global demand for hydrogen in 2040 = 520Mt	BAU and Policy	IEA Net Zero by 2050
	Australia's % share of global hydrogen/ammonia constant from existing share of global ammonia production. Australia's share = 1.2%	BAU	World Bank WITS
	Australia's volume of hydrogen produced = 15 Mt. Informed by AEMO's inputs and assumptions of hydrogen produced in Australia in 2040 Hydrogen Superpower scenario reaching 1800 PJ.	Policy	AEMO 2021 <i>Inputs, Assumptions and Scenarios</i>
	Location of jobs informed by the prospectus hydrogen hubs identified by Arup and the existing or proposed export focused projects according to CSIRO	BAU and Policy	ARUP 2019, Australian Hydrogen Hubs Study ; CSIRO 2021, Industry: Hydrogen Large-scale, demonstration and pilot projects
Green Alumina & Aluminium	Global demand for alumina and aluminium	BAU and Policy	World Aluminium Institute 2019 Alucycle
	Australia's production of green alumina and aluminium – maintain current market share of global aluminium production	BAU	Australian Aluminium Council (2020), Australian Alumina 3. Grattan Institute (2014) Less cost, less coal 4. Geoscience Australia (2016), Bauxite
	Australia's production of green alumina and aluminium – increase share of global aluminium production to 6%	Policy	Accenture analysis



Key inputs and assumptions for calculation of revenue, GVA and jobs in BAU and Policy scenarios (2/2)

Category	Assumption	Scenario	Source
Green Iron & Steel	Global demand for iron and steel	BAU and Policy	World Steel Organisation
	Australia's production of HBI and green steel	BAU and Policy	Accenture analysis based on demand and supply barriers, and informed by: Grattan Institute, Start with Steel report, 2020 Energy Transition Hub, From mining to making report, 2019
Green Metals	Location of jobs for green metals is based on current location of mines, steel plants, and aluminium smelters as well as regions with high solar and wind capabilities.	Policy	Geoscience Australia 2021 Mines Atlas Desktop research on current aluminium smelters and steel plants locations and production capacities
Batteries	Global demand for batteries industry	BAU and Policy	Accenture, Future Charge report, 2021 Bloomberg NEF 2021, New Energy Outlook Roskill 2020, Lithium Ion Batteries: Outlook to 2029
	Australia's market share	BAU and Policy	Accenture, Future Charge report, 2021 Accenture analysis to estimate market share in 2040
	Location of jobs based on current manufacturing hubs and location of lithium mines	Policy	Geoscience Australia, ABS
Education & Training	CAGR for Australia's education related exports	BAU	Average of various sources adjusted for impact of COVID: Austrade, Growth and Opportunity in Australian International Education ICEF Monitor, 2018
	CAGR for Australia's education related exports - Recovery to pre-COVID CAGR	Policy	
	Proportion attributed to clean energy files of study <i>based on current international enrolment in natural sciences, engineering and environmental courses, 2020.</i>	Policy	2020 estimates, Department of Education, Skills, and Employment
	Location of jobs informed by the international student enrolments by SA4	Policy	Department of Education, Skills, and Employment, ABS
Engineering, ICT & Consulting Services	Global investment in clean energy as per IEA	BAU and Policy	IEA 2021, Net Zero by 2050
	Value-added component of services in output generated by global clean energy industry: ICT: 1% Other professions services: 7%	BAU and Policy	World Bank, ABS I-O estimates
	Australia's market share as per growth seen in other new industries such as cybersecurity services market	BAU and Policy	Expert interviews, Accenture analysis

Appendix II: Policy analysis



At both the federal and state level, governments are taking some policy steps in the right direction (I/III)

Renewable energy hydrogen and ammonia

Federal Government

'18: CSIRO National Hydrogen Roadmap

Nov'19: Australia's National Hydrogen Strategy

The key actions of the strategy include national coordination, developing production capacity, responsive regulation that supports innovation and R&D, international engagement, and developing skills, workforce and community confidence. In addition, a key element of the approach will be the development of hydrogen hubs to support the industry in early development stages.

Post strategy release there have been several major funding announcements:

- Sep '20: AUS Gov invested \$1.9bn for emissions reduction technology, including \$70m for creation of regional hydrogen export hub, research collaboration and supply chain studies and \$75m for a future fuels package, prompting the release of a [discussion paper](#) in Feb '21
- May '20: CEFC launched \$300m advancing hydrogen fund
- May '21: [ARENA awarded \\$103m](#) for 3 commercial hydrogen projects

Sep'20: Technology Investment Roadmap: First Low Emissions Technology Statement

- "H2 under \$2" stretch goal set

Jun'21: Guarantee of Origin hydrogen certification scheme, discussion paper released

The purpose of the scheme is to guarantee the origin of clean hydrogen from the 3 main production paths: electrolysis, coal gasification with CCS, and steam methane reforming with CCS.

International Partnerships

- Sep'20: German-Australian supply chain [feasibility study](#) of renewable hydrogen
- Apr'21: 2021-2022 budget will include \$566m to establish low emissions [international tech partnerships](#), including clean hydrogen

Regional Hydrogen Hub Development

- Apr'21: 2021-2022 budget will include \$276m to [accelerate development of four additional clean hydrogen hubs](#)

State Government (Non-exhaustive)

WA

In June 2019 The WA government launched a [renewable hydrogen strategy](#), with a [roadmap of initiatives](#) focusing on four strategic focus areas: Exports, remote application, hydrogen blending in natural gas networks and transport.

By 2030 WA has set clear policy objectives, aiming to achieve the following key targets (Previously 2040 targets, with \$22m invested in 2020 to bring forward):

- WA's market share of hydrogen exports is similar to LNG today
- WA's gas pipelines and networks contain up to 10% renewable hydrogen
- Renewable hydrogen is widely used in mining haulage vehicles
- Renewable hydrogen is a significant fuel source for transportation in regional WA

VIC

The Victorian Government has developed several policy initiatives to address renewable hydrogen, however there are few quantified targets set for their strategies to achieve.

Key initiatives include the [Renewable Hydrogen Industry Development Plan](#) that has set 18 qualitative outcomes that span across three focus areas: Laying a foundation for renewable hydrogen, connecting the economy and leading the way

Additionally, the [Zero Emission Vehicle \(ZEV\) Roadmap](#) includes subsidies for resident and public transport purchase of ZEVs, including hydrogen fuel cell cars. Key targets:

- 50% of light vehicle sales to be ZEV by 2030

NSW

The overarching policy framework to support the development of the hydrogen industry in NSW is still in development, however several key policies are underway.

- Mar'21: The [Net Zero Industry and Innovation Program](#) will commit \$750m support the commercialisation of hydrogen as an emerging and innovative technology, specifically with the development of hydrogen hubs in the Hunter and Illawarra.
- May'21: Announced development of [Australia's first renewable hydrogen & gas power plant](#)

At both the federal and state level, governments are taking some policy steps in the right direction (II/III)

Federal Government

State Government

Green metals

Sep'20 : [Technology Investment Roadmap: First Low Emissions Technology](#)

Low emissions steel and aluminum were flagged as priorities in the roadmap, setting economic stretch goals for the price/tonne of both:

- Low emissions steel production under \$900 per tonne
- Low emissions aluminum under \$2,700 per tonne

Relevant funding announcements:

- Jan'21: \$11.3m [ARENA funding grant](#) to Alcoa for low carbon alumina refining feasibility project
- Apr'21: 2021-2022 budget will include \$566m to establish low emissions [international tech partnerships](#), including low carbon metals
- Jun'21: \$600k [grant to Rio Tinto](#) for technology trial to use renewable hydrogen to refine aluminum

WA

- Currently MRIWA has an outstanding tender for a [green steel value chain assessment](#)

Batteries

Mar'19: [Australia's Critical Minerals Strategy](#)

- Key action is for AUS to deliver international roadshows on the potential for more lithium-ion battery manufacturing in Australia

Sep'20 : [Technology Investment Roadmap: First Low Emissions Technology Statement](#)

- Apr '19: [Committed \\$25m over six years](#) for the Future Battery Industries Cooperative Research Centre (FBICRC)

Oct'20: [National Manufacturing Priority Road Map](#)

- [Recycling and Clean Energy](#): Overview of opportunity with no direct policy
- [Resources Technology and Critical Minerals Processing](#): Identifies key opportunities in Australia across the battery value chain

WA

- [Future Battery Industry Strategy](#) (Jan'19 with Nov '20 update)
- \$5m Exploration Incentive Scheme

QLD

- \$3.1m for Imperium3 manufacturing plant
- \$2.5m to Tritium EV charging
- \$1.96m to RedEarth energy storage

VIC

- \$200k to envirostream battery recycling

[Source for states](#)



At both the federal and state level, governments are taking some policy steps in the right direction (III/III)

Federal Government

Mar'19: [Australia's Critical Minerals Strategy](#)

Critical minerals strategy has set 3 goals to:

- Attract investment into Australia's critical minerals sector
- Spur innovation in the critical minerals sector
 - Mar'19: Aus Cooperative Research Centre projects (CRC-P) provides [\\$20m grant funding to for critical minerals](#)
- Infrastructure Investment
 - Numerous investments in roads & infrastructure (p.g. 18-19 of critical minerals strategy)

Jan'20: Establishment of [Critical Minerals Facilitation Office](#)

Jun'20: \$125m into [Exploring for the future \(EFTF\) program over 4 years](#)

Nov'20: [Critical Minerals Prospectus](#) (Support from Geoscience Australia)

- Supports knowledge projects and greenfield investment opportunities as well as technical, commercial and geological data for investors. Includes overview of current policy initiatives.

May '21: [Critical Energy Minerals Roadmap for Australia \(CSIRO\)](#)

State Government

NSW

Feb'19: Released [NSW Minerals Strategy](#):

Focused on growing investment in metals and rare earth elements, particularly as greenfield sites. Key targets include:

- NSW Govt will halve assessment time for state significant development projects
- NSW share of total AUS Greenfields exploration will average 9%
- The proportion of greenfield exploration relative to brownfield exploration don within NSW increases by 10% on 2018 levels by 2025
- Contributing \$16m to the development of future deep exploration technologies

Apr'20: Lithium [Valley Strategic Plan](#)

- Ambition is to achieve 'industrial symbiosis'
- Focus points include but are not limited to; tailings and byproduct disposal, access to raw materials and reagents, dark factories, inputs for batteries etc

Critical minerals

Services

No evident direct policy for technical, engineering or ICT services, or education and training.

AusTrade – [Clean Energy and Environments Directory](#): Innovative clean energy companies

Same as Federal

Feb'19: Report on the value and need for innovation and policy in the environmental good and services sector in NSW [here](#)

What policies could scale up clean electricity supply?

A very rapid scale-up to support clean energy export growth would require policies that go beyond decarbonising the existing electricity generation mix to driving significant expansion of capacity in renewables-rich regions.

Potential clean energy supply policies

Goal	Policy	Policy effectiveness	Cost	Incidence
Scale up Australia's clean electricity supply	Coordinated investment in renewable energy zones to align generation, transmission and storage investment to take advantage of high-quality renewable energy resources, using auctions and CfDs to drive least cost new capacity	High	Moderate	Government budget or electricity consumers
	Carbon price to change the relative cost of carbon-intensive generation and renewables	Depends on price level	Least cost	Electricity consumers, carbon-intensive electricity generators
	Retailer carbon standard to require electricity retailers to supply an increasing share of zero-emissions energy	Effective but insufficient by itself	Moderate	Electricity consumers
	Coal retirement mechanism to provide a clear timetable for coal capacity exits	Effective but insufficient by itself	Moderate	Depends on mechanism design
	Electricity market reforms to support efficient investment and dispatch as the electricity system grows rapidly	Enabler	Reduces costs overall	Electricity consumers

What policies could support a renewable hydrogen export industry?

Policies will be required to stimulate demand and supply of renewable hydrogen and support the development and deployment of new hydrogen technologies.

Potential renewable hydrogen policies

Goal	Policy	Policy effectiveness	Cost	Incidence
Stimulate Australian hydrogen supply	Targets for electrolyser capacity (underpinned by credible policies)	Depends on policies	No direct costs	No direct incidence
	Co-investment for renewable hydrogen production facilities	High	High	Government budget
Stimulate Australian hydrogen demand	Mandates requiring a rising percentage of fuels to come from zero-carbon sources (e.g. in shipping, aviation, existing H ₂ uses)	High	High, declining	Industry, customers
	Product carbon standards (e.g. declining carbon intensity standards for products – e.g. cars)	High	High, declining	Industry, customers
	Voluntary green product commitments	NA	Low	Industry, customers
	Green public procurement policies (e.g. mandating an increasing share of green steel in infrastructure and buildings)	Limited	Low	Government budgets
	Contracts for difference bridge the cost gap between renewable hydrogen and fossil fuel-derived hydrogen	High	High, declining	Government budget or industry
Develop and deploy new hydrogen technologies	Support electrolyser technology improvements	Potentially high		Government budget
	Mandate hydrogen-ready gas turbines	Moderate	Low	Industry

What policies could drive green metals?

Stimulating green metals production can be achieved through co-investment, carbon pricing and mandates.

Potential green metals policies

Goal	Policy	Policy effectiveness	Cost	Incidence
Stimulate green metal production	Co-investment in green metal production facilities	High	High	Government budget
	Carbon price to improve the competitiveness of hydrogen-DRI vs blast furnace steelmaking	High	Least cost	Industry, consumers
	Mandates requiring a rising percentage of steel to come from zero-carbon sources	High	Moderate	Industry
Stimulate Australian green metal demand	Carbon contracts for difference to bridge the cost gap to zero-carbon metals and for current and new domestic metal customers	High	Moderate	Government budget
	Green public procurement to boost domestic demand	High	Moderate	Government budget



Disclaimer

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