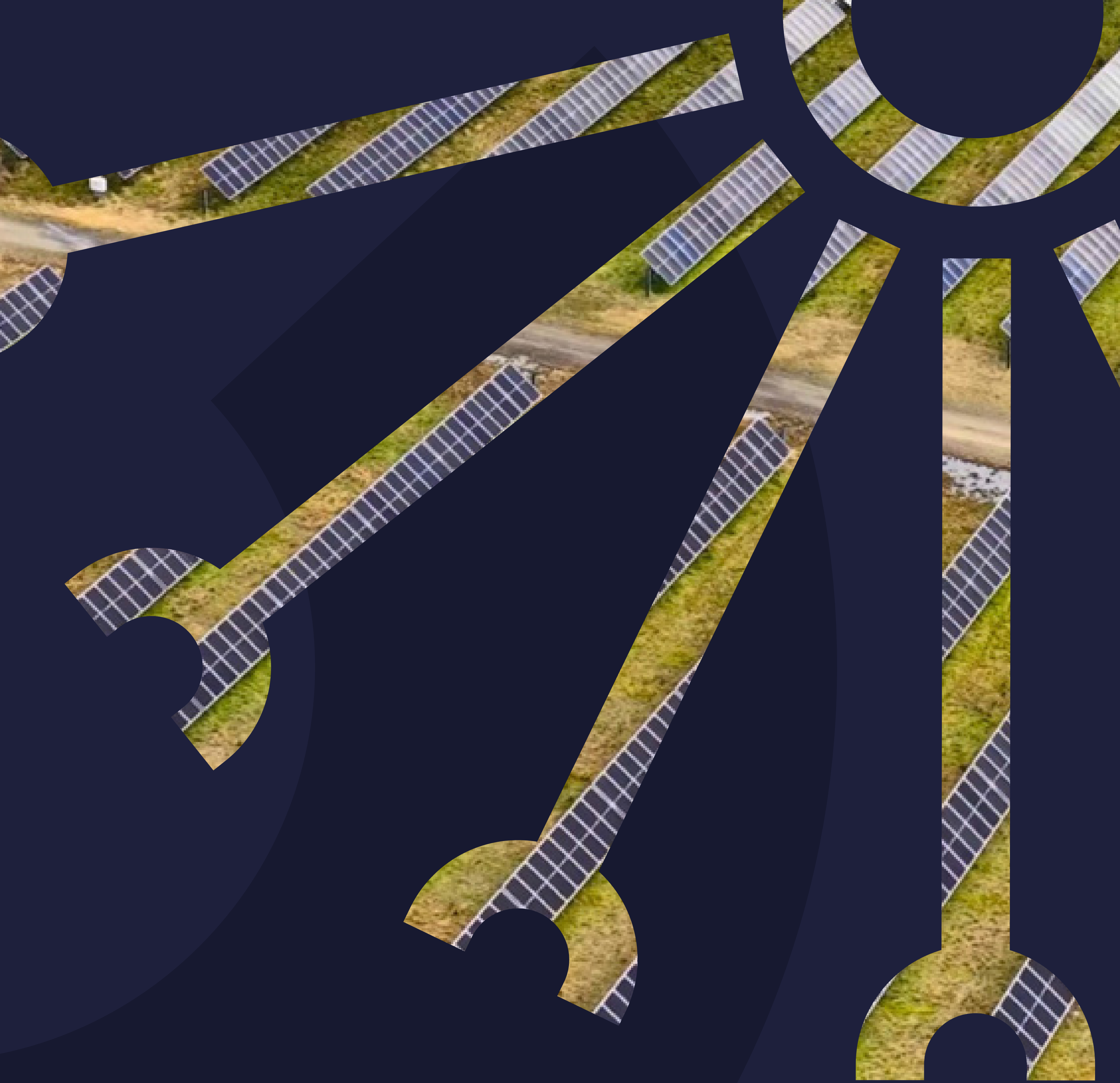

THE FUTURE GENERATION WORKFORCE

A development plan

RACE for 2030

UTS

POWERING AUSTRALIA

ACKNOWLEDGEMENTS

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CITATION

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ACKNOWLEDGMENT OF COUNTRY

Powering Australia wishes to acknowledge the First Nations of Australia and recognise their enduring connection to Country through culture, people, place and story. We honour the knowledge systems that have sustained these lands and waters for thousands of generations and recognise the vital role of First Nations leadership and self-determination in shaping a just and sustainable future. As Australia undergoes a significant clean energy and industrial transition, we acknowledge the importance of respectful partnership, cultural integrity, and shared purpose to realise the full opportunity of the Clean Energy Transition.

PROJECT CONTEXT

Australia is well placed to take advantage of many clean-tech opportunities by leveraging its global leadership in critical minerals and renewable energy resources. There are also challenges including a sparse industrial ecosystem, a relatively small workforce, sectoral fragmentation and international competition.

The project aims to contribute to the development of Australia's clean-tech manufacturing sector by:

- Growing Australian manufacturing capability in a way that drives exports and ensures domestic energy security.
- Identifying potential skill shortages and priority actions to provide a suitably skilled workforce for clean-tech manufacturing.
- Growing jobs and providing pathways to secure employment for those in priority cohorts or who are transitioning from carbon-intensive industries.
- Accelerating the commercialisation of Australian technologies related to clean-tech manufacturing.
- Accelerating the path to a decarbonised future.
- Delivering better economic outcomes for First Nations communities.

SECTOR COMPETITIVENESS PLANS (SCPS) – CYAN VENTURES AND DELOITTE

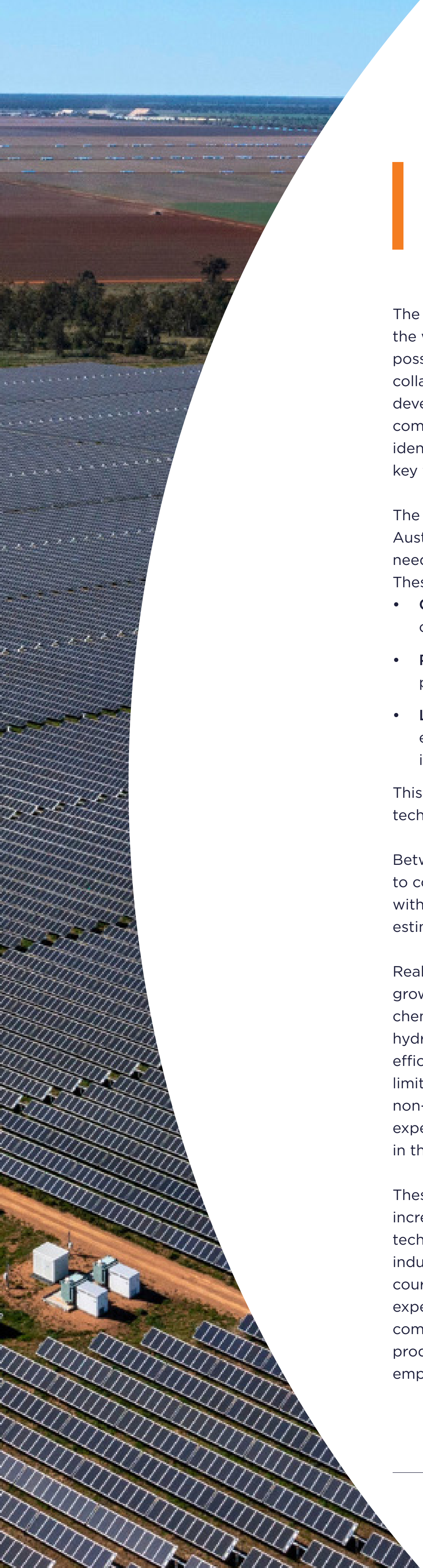
Powering Australia has developed sector competitiveness plans (SCPs) to identify opportunities where Australia has a unique advantage to foster clean-tech manufacturing across six areas:

1. Renewable Energy Generation
2. Industrial Decarbonisation
3. Transport
4. Electricity Transmission and Distribution
5. Carbon Capture and Storage
6. Opportunities for First Nations businesses and workers across these sectors.

Each SCP identifies anchor opportunities based on national need and likelihood of success, outlines workforce requirements, and recommends targeted actions to leverage Australia's strengths and build resilient supply chains.

WORKFORCE DEVELOPMENT PLANS (WDPS) – INSTITUTE FOR SUSTAINABLE FUTURES, UNIVERSITY OF TECHNOLOGY SYDNEY, RACE FOR 2030 COOPERATIVE RESEARCH CENTRE

One of the key challenges to building clean-tech manufacturing in Australia is developing the workforce amidst widespread skill shortages. Responding to this challenge, Powering Australia has partnered with the RACE for 2030 Cooperative Research Centre and commissioned the Institute for Sustainable Futures at the University of Technology Sydney to develop Workforce Development Plans (WDPs). The WDPs are focused on the anchor opportunities and begin with the workforce requirements identified in the SCP.



Executive summary

The Clean Tech Manufacturing Workforce Development Plans (WDPs) aim to profile the workforce requirements for fostering a thriving green industrial base, identify possible workforce challenges and solutions, and set the foundations for innovative collaboration between industry, government, education, and training providers to develop a robust workforce, supporting the ambitions of the Future Made in Australia comprehensive $22.7 billion investment plan. The WDPs take the anchor opportunities identified by Powering Australia and the expected demand for labour and look at the key factors that influence workforce development

The Sector Competitiveness Plan (SCP) identified three areas in the sector where Australia is cost-competitive, offers market differentiation, or where local resilience needs to be built due to supply chain risks.
These are:

- **Critical mineral refining:** a strategic opportunity for Australia to move up the value chain and reduce reliance on offshore processing for battery production minerals.
- **Polysilicon:** opportunity for sale into international markets, produced in partnership with a foreign technology partner.
- **Large-scale renewable deployment/ balance of plant (BOP):** key pieces of equipment that help drive down the levelised cost of renewable energy production in Australia.

This report steps out a plan for developing the workforce to grow Australia's clean tech manufacturing capabilities in the renewable energy generation sector.

Between 11,000 and 27,000 additional workers are projected to be required in 2035 to construct and operate new critical minerals and polysilicon manufacturing facilities, with requirements for between 21,000 and 33,000 additional workers in 2050. Jobs estimates were not provided for BOP manufacturing.

Realising this depends on resolving several workforce constraints. Much of the growth can draw on skillsets already available within non-ferrous metal and chemical manufacturing, but new and enhanced skillsets are needed, including hydrometallurgical processes, plant and equipment knowledge, and ensuring safe and efficient manufacturing environments. The domestic labour pool for operations roles is limited: Australian workforce capability is in its infancy in critical minerals refining, and non-existent in polysilicon production. Consequently, the sector may need to draw on experience from market leaders like China to establish and train a domestic workforce in the specific processing techniques.

These facilities will be highly automated, changing the nature of the work and increasing demand for shift-based operation, process control and facility-specific technical skills. Building the domestic pipeline will also require change beyond industry itself: closer alignment between industry and the training sector on course content and awareness, intergenerational transfer of knowledge before experienced workers retire, and both regional attraction and skilled migration to compete for workers against mining and construction. Strong demand for Australian product, including through local content requirements, will be needed to secure the employment pipeline while domestic manufacturers scale up to competitiveness.

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Introduction

The clean tech manufacturing Workforce Development Plans (WDPs) aim to profile the workforce requirements for a thriving green industrial base for the clean energy sector, identify possible workforce challenges and solutions, and set the foundations for collaboration between industry, government, the education sector, and training providers to develop a robust workforce.

The WDPs support the ambitions of Future Made in Australia, an Australian Government strategy aimed at transforming Australia into a clean energy superpower and strengthening its economic resilience (Australian Government, 2024). Establishing and growing clean-tech manufacturing in Australia requires people to build and operate the manufacturing plants, and the advanced skills to design and market those products with a competitive advantage.

The WDPs investigate the anchor opportunities identified by Powering Australia in the Sector Competitiveness Plans (SCPs) and the expected demand for labour, and investigate the key factors that could influence workforce development, including the current state of the labour market, the adequacy of the training system, and anticipated technological change.

The current workforce in the most comparable industry is analysed, supplemented by information from stakeholder interviews, to gain insight in the projected new workers and identify an initial set of in-demand occupations. The key in-demand occupations of these proxy industries are examined for training and employment pathways, as are the key trends and challenges shaping workforce demand and workforce supply. Relevant opportunities and initiatives are identified, and recommendations are given for developing the necessary skills.

The work is informed by literature review, stakeholder interviews, and an Industry Reference Group (IRG). ISF conducted fourteen stakeholder interviews overall, with eight in renewable energy generation and six with cross sector stakeholders. The insights gained from stakeholder interviews and from the IRG are invaluable, however the conclusions and recommendations are the responsibility of the authors alone.

1. Sector competitiveness plans: anchor opportunities for clean-tech manufacturing in renewable energy

The Renewable Energy Generation Sector Competitiveness Plan (SCP) [1] identified three "anchor" opportunities – areas where Australia is cost-competitive, offers market differentiation, or where local resilience needs to be built due to supply chain risks. These are:

- **Critical mineral refining:** a strategic opportunity for Australia to move up the value chain and reduce reliance on offshore processing for battery production minerals. Australia has a strong competitive edge due to its abundant reserves of lithium, nickel, cobalt, and rare earths and the potential for vertical integration.
- **Polysilicon:** opportunity for sale into international markets, produced in partnership with a foreign technology partner. Key enablers include access to ultra-low-cost renewable electricity, automation to offset labour costs, and supply chain integration with international partners that will positively impact cross-border tariffs.
- **Deployment/ balance of plant (BOP):** key pieces of equipment that help drive down the levelised cost of renewable energy production in Australia. There are manufacturing niches forecast to be competitive in Australia due to unique conditions and the need for locally developed solutions to overcome key cost barriers related to labour and remoteness challenges.

These anchor opportunities reflect existing areas where there is strong potential for long-term competitiveness, growth and ancillary resilience benefits. Acknowledging they exist within a wider eco-system of a future green industrial base, the SCP identified adjacent value-chain opportunities and wider supply-chain ecosystem opportunities (Figure 1). Developing these wider ecosystem opportunities will increase availability of inputs, allow for common infrastructure, cluster skills, reduce transport costs, and foster knowledge sharing.

Figure 2: Anchor opportunities and their associated ecosystems for renewable generation

Anchor opportunities: Specific focus areas within priority value-chains.	**Adjacent value-chain:** Complimentary segments up or downstream from the anchor opportunity.	**Wider supply-chain ecosystem** Supporting services, equipment and feedstock that Australia can deliver competitively to support the leading opportunities.

Anchor/leading opportunities	Polysilicon	
	Critical mineral refining	
	Deployment/BoP (ultra-low-cost renewable energy)	
Adjacent value chain (non-exhaustive)	Active Material manufacturing (new anode/cathose technology)	
	Metallurgical silicon (Mg-Si)	
	Renewable recycling	
	Wind tower manufacturing	
Wider supply chain ecosystem (Non-exhaustive[1])	Innovative solar cells	Pre-fab anchor cages
	Innovative solar modules	Flow batteries
	Automated deployment/BOP solutions	

Ultra low-cost renewable energy has opportunities that will require domestic manufacturing of innovative balance of plant and deployment systems but is also an important enabler for all opportunities downstream

The SCP estimates a range of economic value and employment associated with each of the opportunities, with a lower bound 'Current Trajectory' scenario (modelled on the AEMO Step Change scenario) and an upper bound 'Focused Ambition' scenario (modelled on the AEMO Green Energy Exports scenario) [2].

Two of the anchor opportunities identified – critical minerals and polysilicon - are estimated to generate gross value added (GVA) of between A$3.7 billion (Current Trajectories) and A$7.1 billion (Focused Ambition) in 2035, and between $9.2 billion and $15.4 billion in 2050. A correspondingly large range of new jobs is forecast, with new jobs across the economy, including supporting services and impacts from wages, estimated between 22,000-54,000 in 2035, and between 43,000-66,000 in 2050.

Direct jobs for the anchor opportunities are the focus of this workforce development plan. The SCP projects between 11,000 and 27,000 additional workers are required in 2035 to construct and operate new critical minerals and polysilicon manufacturing facilities, with requirements for between 21,000 and 33,000 in 2050 (the lower and upper bounds from the Current Trajectory and Focused Ambition scenarios respectively) (Figure 2). GVA and jobs estimates were not provided for BOP manufacturing.

Notes/Sources: Source: Powering Australia, Generation Sector Competitiveness Plan, 2025, p.22

Figure 1: Workforce demand and GVA for renewable generation clean tech manufacturing anchor opportunities

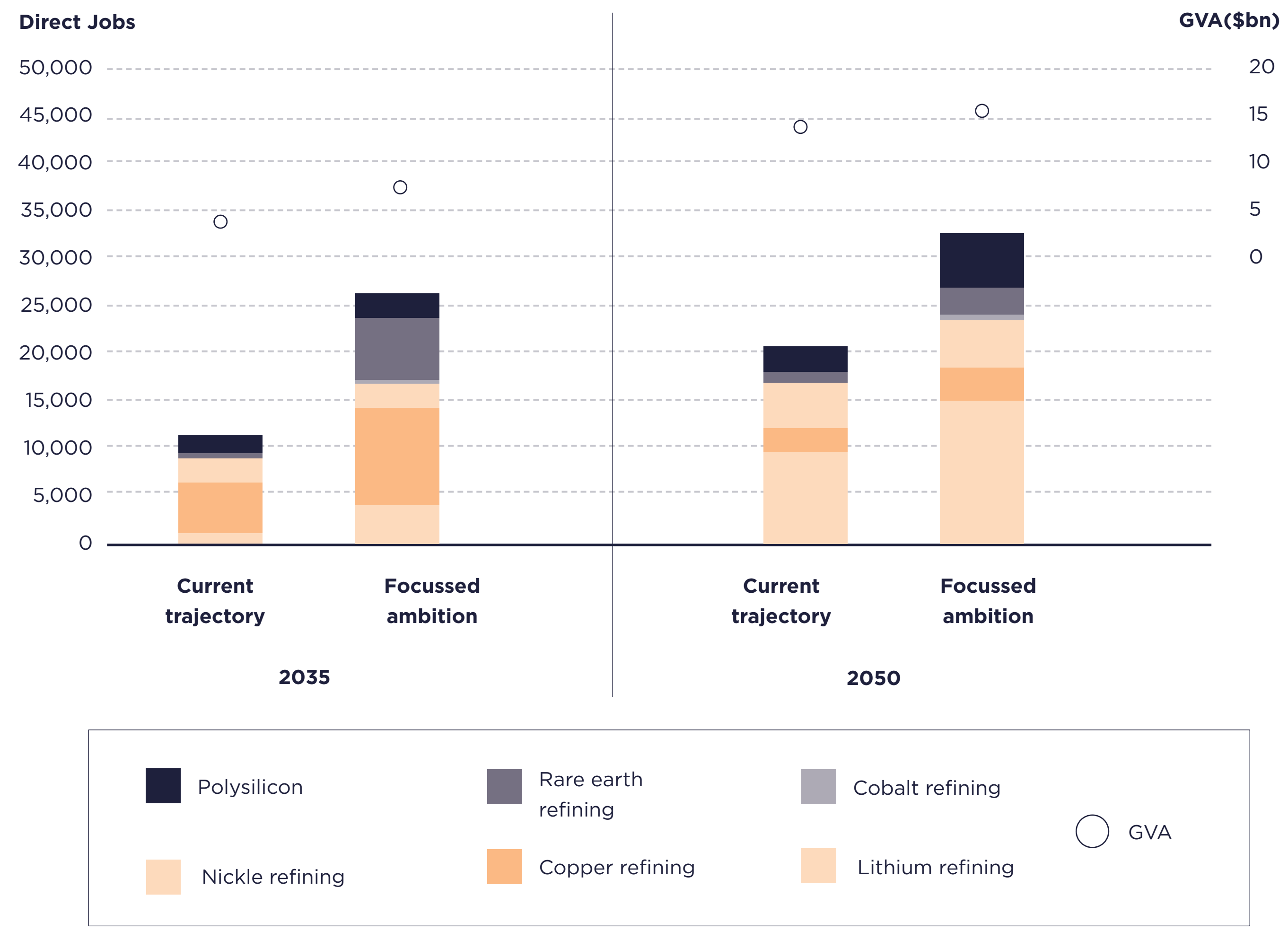
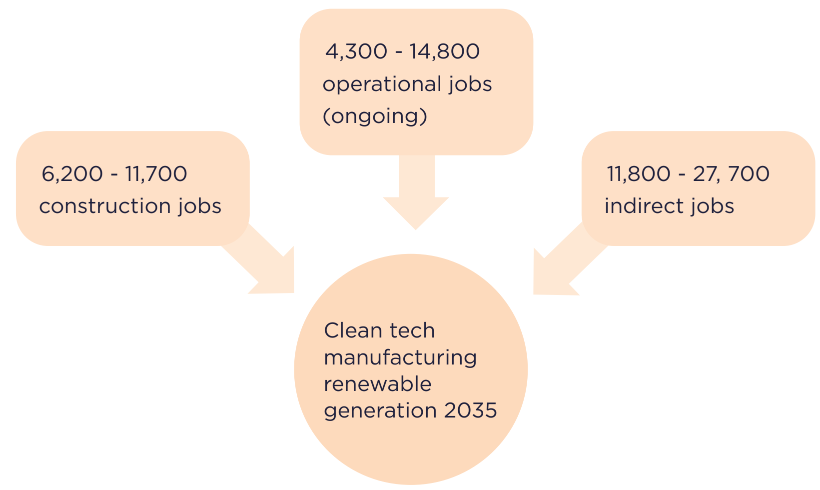


Figure 3: Workforce demand and GVA for renewable generation clean tech manufacturing anchor opportunities



Notes/Sources: Source: Powering Australia, Generation Sector Competitiveness Plan, 2025, p.22

2. The current construction workforce: critical minerals and polysilicon

The construction workforce required to construct advanced critical minerals and polysilicon processing facilities is estimated at between 6,200 and 11,700 in 2035 and between 9,700 and 12,700 in 2050. Most of the workforce demand is anticipated before 2035 to construct facilities capable of producing a range of critical minerals commodities including lithium, copper, nickel, cobalt, rare earths and polysilicon. Between 2035 and 2050, continued demand for the construction workforce is projected to be focused in lithium, nickel and polysilicon.

The composition of occupations and skill sets for construction are similar across critical minerals and polysilicon refining facilities and could be leveraged in future workforce development. Several facilities were constructed in Western Australia between 2019 and 2022, after stakeholder engagement on key construction roles and detailed review of Census data from 2021, this construction workforce is well reflected in the 'basic non-ferrous metal manufacturing NFD' sector; therefore, this sector has been used as a proxy for the construction workforce. There will also be a large pool of construction workers that would construct the building elements of manufacturing facilities, these workers would likely sit within the 'heavy civil engineering construction' sector but are considered secondary to the specialised workforce required to design, fabricate, test and commission processing plant pipes, vessels, tanks and associated processing equipment.[4]

Census data was combined with insights from stakeholder interviews to inform an overview of critical construction occupations in Table 1. Metal trades are the most in-demand occupation, making up 61% of the workforce in combination.

Key occupations include:

- **Structural steel and welding trades workers** make up 46% of the current workforce, fabricating processing plant equipment such as pipes, pressure vessels, and tanks. Stakeholders noted that welding and fabrication needs to be completed to a high quality and according to precise tolerances, with employment pathways from LNG or equivalent refining facility construction. Stakeholders interviewed considered these skills to be readily available in Australia, but structural steel and welding trades are listed in national shortage by the Occupational Skills Shortage list published by Jobs and Skills Australia.
- **Metal fitters and machinists** make up 6% of the current construction workforce and are also in national shortage.
- **Industrial, mechanical and production engineers** represent a relatively small proportion of the workforce at 1%. However, industrial and mechanical engineers are in shortage in Western Australia, Queensland, and South Australia, where significant construction activity is projected to occur.
- **Truck drivers** are required to transport equipment and materials to site and are listed as in national shortage.

Notes/Sources: [4]Additional occupations are metal engineering process workers (3%) and sheetmetal trades workers (1%). [5]https://www.jobsandskills.gov.au/data/occupation-shortage/occupation-shortage-list

Table 1: Key occupations in critical minerals and polysilicon construction

Occupation	Current volume (% of proxy industry)	2035 additional demand (Focused ambition scenario)	Current shortage status (2025)	Key training and employment pathways
Structural Steel and Welding Trades Workers **322311 Metal fabricator** **322313 Welder (First Class)**	3633 (46%) *80%* *20%*	5,400	Shortage	MEM31925 – Cert III in Engineering – Fabrication Trade or extensive experience.[6] MEM31925 – Cert III in Engineering – Fabrication Trade + Welding trade specialisations or extensive experience. AWCR certification may be useful[7].
Metal Engineering Process Workers	449 (6%)	704	Not specified	No formal training required. Cert I or II in engineering or engineering production may be useful.[8]
Metal Fitters and Machinists **323211 Fitter (General)** **323212 Fitter and Turner** **323214 Metal Machinist (First Class)** **323213 Fitter-Welder**	447 (6%) *40%* *36%* *15%* *6%*	704	Shortage	MEM30219 Cert III in engineering – mechanical trade or extensive experience.[9]
Engineering Production Workers	385 (5%)	587	No shortage	No formal qualifications required, Cert II or III in engineering studies may be useful.[10]
Sheetmetal Trades Workers	3%	352	Shortage	MEM31925 Cert III in Engineering – fabrication trade.[11]
Managers (office, production, managing directors)	5%	587	No shortage	No formal qualifications required, Cert III in process plant operations or diploma in process plant technology may be useful.[12]
Industrial, Mechanical and Production Engineers **233512 Mechanical engineer** **233511 Industrial Engineer**	58 (1%) *88%* *12%*	117	State/territory shortage (QLD, SA, NT, ACT) State/territory shortage (WA, SA, NT)	Bachelor of mechanical engineering. Membership with Engineers Australia highly regarded.[13]
Truck Drivers	55 (1%)	117	Shortage	Heavy vehicle drivers license training.

Notes/Sources: Source: [6] https://www.yourcareer.gov.au/occupations/322313/welder-first-class?tab=how-to-become
[7] https://awcr.org.au/about/how-it-works/
[8] https://www.yourcareer.gov.au/occupations/839111/metal-engineering-process-worker?tab=how-to-become
[9] https://www.yourcareer.gov.au/occupations/323211/fitter-general?tab=how-to-become
[10] https://www.yourcareer.gov.au/occupations/712311/engineering-production-worker?tab=how-to-become
[11] https://www.yourcareer.gov.au/occupations/322211/sheetmetal-trades-worker?tab=how-to-become
[12] https://www.yourcareer.gov.au/occupations/133512/manufacturing-production-manager?tab=how-to-become
[13] https://www.yourcareer.gov.au/occupations/233512/mechanical-engineer?tab=how-to-become

3. The operations and maintenance workforce: critical minerals refining and polysilicon manufacturing

Critical minerals refining capability in Australia is still emerging; limited manufacturing is happening that processes material to the high purity required for renewable energy products. Current industry capability is largely structured around basic material processing after the mining stage, along with a handful of remaining pyrometallurgical / smelting operations. Advanced mineral refining to a very high purity requires different manufacturing plant and equipment and the associated skills to manage and operate these facilities requires experience in similar operating environments over many years. There is a significant amount of activity happening at the research development stage – at a pilot plant scale – often linked with university PhDs. However, only a small number of facilities are emerging at a commercial scale for critical minerals and rare earth advanced processing. There are no facilities currently producing polysilicon in Australia.

Critical mineral refining and polysilicon manufacturing environments are similar in workforce composition. Stakeholder engagement insights highlighted that this workforce composition was most similar to the Copper, Silver, Lead and Zinc Smelting and Refining sector. Therefore, this sector was used as the proxy industry for occupational analysis, using ABS census data.

The top occupation for both critical mineral refining and polysilicon is projected to be engineering production workers, with mobile plant operators, metal fitters and machinists, electricians and a broad cross-section of technicians and trades all being significant. Of these occupations, electricians, metallurgical/materials technicians (sitting in the trades and technicians category), electronic instrument technicians, mechanical engineers, and chemical engineers are all listed in shortage either at a state or national level by JSA in 2025.

Census data from 2021 indicates that the current workforce for smelting and refining is concentrated around existing facilities in South Australia (44%), Queensland (20%) and Tasmania (30%). However, this is likely to look very different in future census data, with new critical minerals and rare earth processing capacity emerging in Western Australia.

There is projected to be a baseline workforce growth of 22% across the broader Basic Non-Ferrous Metal Manufacturing industry from May 2025 to May 2035. This does not include the potential growth from critical minerals and polysilicon manufacturing opportunities if realised. The current workforce features below average gender diversity, with only 8% of the workforce being female and slightly above average First Nations workforce share at 3.75%.

The median age for the industry is 45, somewhat above the median age for the general population (39). This indicates that an ageing workforce could be a barrier in the future. 10% of the workforce is below the age of 24 and 11% above the age of 60.

Figure 4: Critical minerals and polysilicon, operations and maintenance workforce dashboard

The workforce reflects a diverse skills level profile, with highest educational attainment distributed as follows:

- 39% Certificate III or Certificate IV
- 37% Year 12 or below
- 21% Diploma or University Degree

Over the past 20 years, employment within the broader Basic Non-Ferrous Metal Manufacturing industry peaked in 2012 at approximately 33,000 workers. While this has fluctuated since this peak, it has been on an overall downwards trend, with employment at 18,000 workers in 2025.

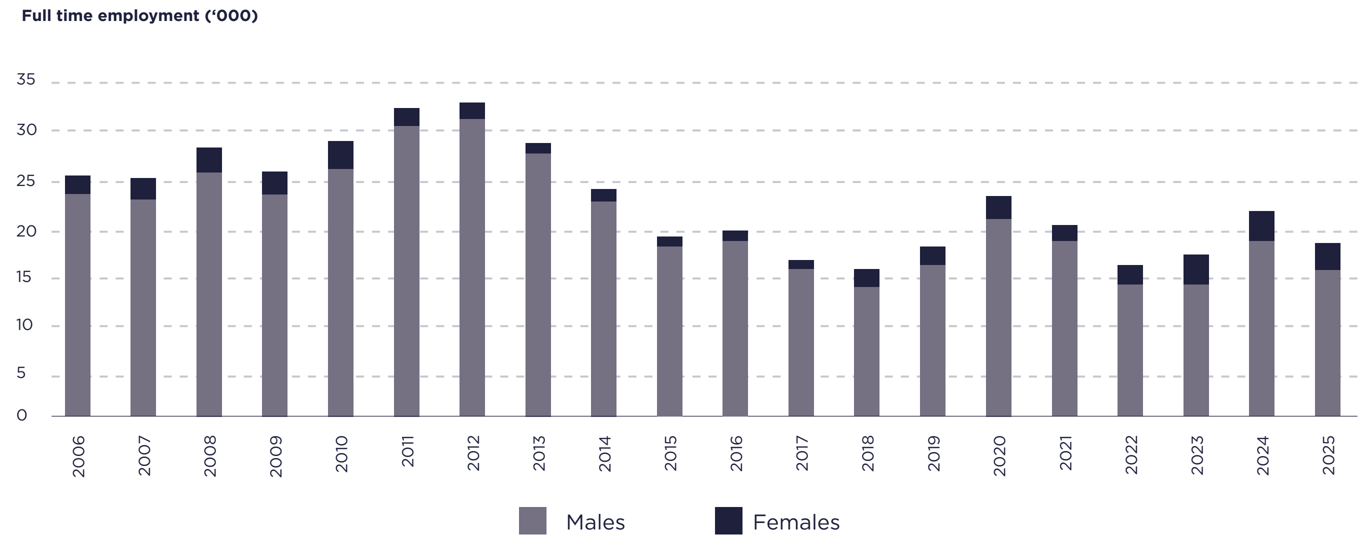
The term 'critical minerals' includes lithium, nickel, cobalt, graphite, rare earths, and copper (not directly critical but essential in many clean energy use cases).[14] While Copper, Zinc and Lead Smelting and Refining was used as the best proximate industry, it is important to note that the more essential and developed critical minerals such as nickel and lithium are not captured in this classification. Therefore, workforce dynamics may vary, most notably with the geographic spread of workers and the sector, as Western Australia is home to Australia's largest critical mineral deposits and mines.[15]

Total workforce by state or territory [3]

Projected growth to 2035*	% Female workforce	% Workforce First Nations [4]
2%	22% (43% for general workforce)	0.86% (3.3% for general workforce)

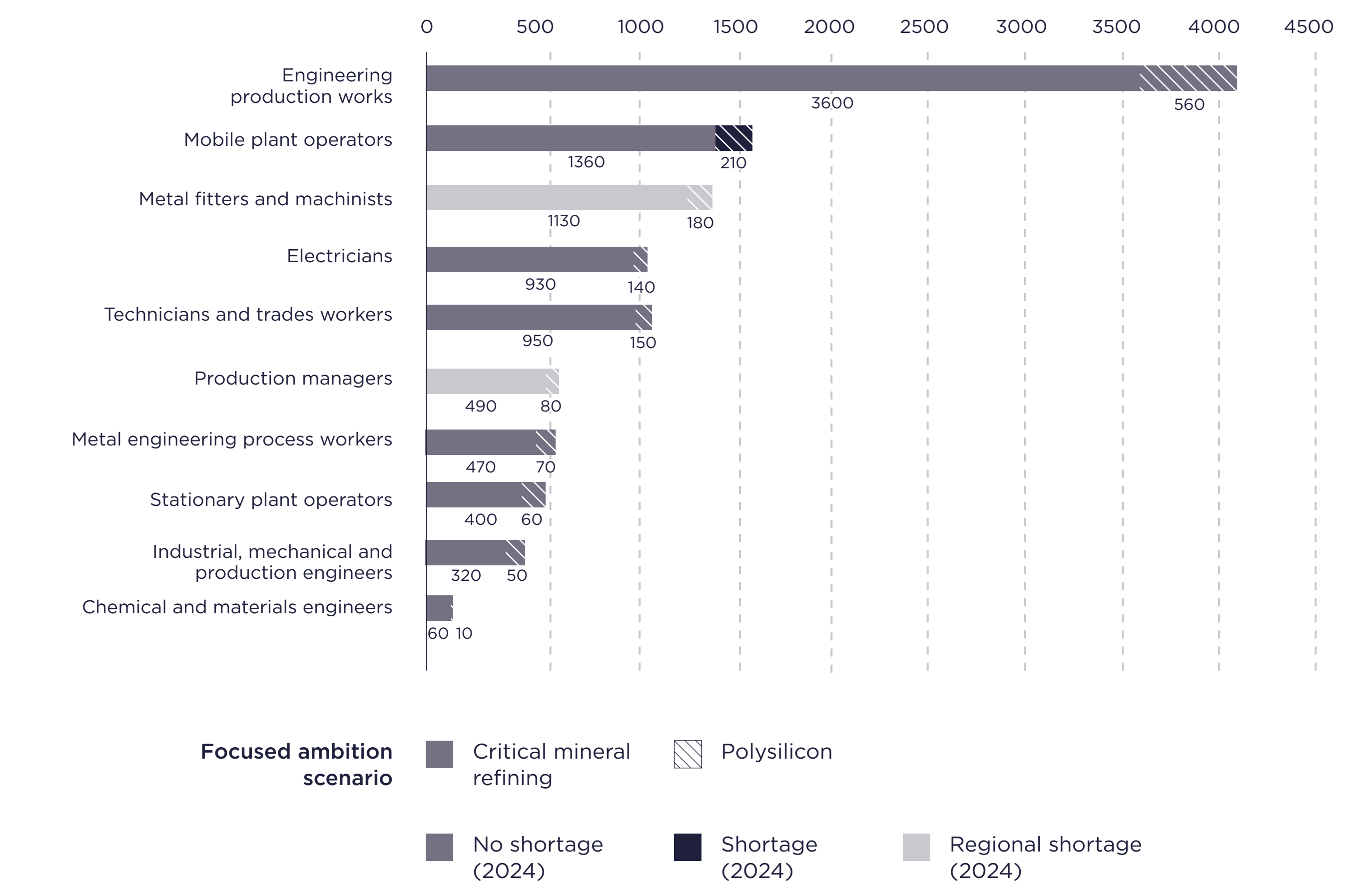
Median age	% Workforce aged 24 or below	% Workforce aged 60 and over [5]
45 (39 for general workforce)	7%	15%

Employment trends [6]

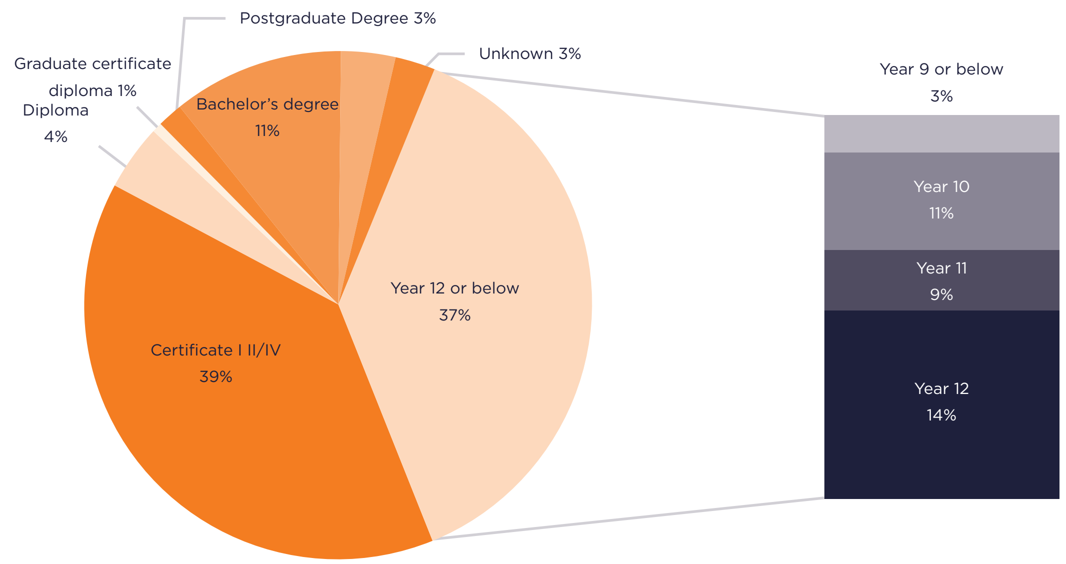


Notes/Sources: [14]Stinson, H. and Cam, I. for the Reserve Bank of Australia (2025). The Global Energy Transition and Critical Minerals. https://www.rba.gov.au/publications/bulletin/2025/oct/the-global-energy-transition-and-critical-minerals.html
[15]Ibid

Top 10 ANZSCO occupations: jobs projected in 2050 (Focused Ambition scenario) [1]



Education level [3]



Sources: [1] Jobs and Skills Australia, Occupation Shortage List, 2025; ABS (2021), Census Table Builder. [2] Cyan Ventures & Deloitte, Transmission Sector Competitiveness Plan. [3] ABS (2021), Census TableBuilder. [4] Jobs and Skills Australia, Jobs and Skills Atlas, Industry Profiles. [5] ABS, Labour Force, Australia, Detailed, Table EQ06 - Employed persons by Industry group of main job (ANZSIC), Sex, State and Territory, November 1984 onwards (Pivot Table). [6] In demand occupations from UTS research, stakeholder consultation, 2026.

4. Developing the future workforce: critical minerals refining and polysilicon

Australian minerals production is moving from an industry dominated by mining, processing, and smelting towards advanced processing capabilities that will manufacture the high purity minerals needed for renewable energy technologies. The development and expansion of industrial capability in Australia to produce highly refined minerals will change the nature of future workforce demand and skills mixes.

Much of the current workforce in Australian refining and smelting facilities will be needed to support an expansion of downstream processing capability. Demand for the key occupations needed to operate and maintain these facilities will change, reflecting the transition or expansion from pyrometallurgical processing environments to hydrometallurgical or chemical-based processing environment.

At scale, critical minerals and polysilicon manufacturing facilities will integrate increasing automation. This will influence the technical skill requirements within occupational cohorts, change the nature of work for production and process workers, and impact the scale of workforce demand.

Key occupations

A summary of the key occupations in demand in critical minerals and polysilicon is provided in Table 2 alongside information on the current workforce volume (based on the closest ANZSIC proxy sector - copper, silver, lead and zinc smelting and refining) as well as SCP workforce projections and key training and employment pathways. Key occupations were selected based on a combination of occupational volumes in the proxy sector and stakeholder insights on critical occupations.

Table 2: Key occupations in critical minerals and polysilicon operations and maintenance

Occupation	Current volume/ (% of proxy industry)	2035 additional demand (Focused ambition)	Current shortage status	Key training and employment pathways	Role/ comments
Engineering Production Workers	358 (21%)	3061	No shortage	No formal qualifications required, cert II or III in engineering studies may be useful.[6]	Production workers are directly involved in the basic operations on the factory floor. Currently workers are more likely to be experienced in pyrometallurgical/ smelting production pathways due to the dominance and size of these industries in the Australian manufacturing mix. Stakeholders noted that: • Workers could be trained in the manufacturing processes, although previous experience in chemical manufacturing would be highly desirable. • Highly automated production environments reduce the demand for production workers.
Electricians	92 (5%)	787	National shortage	Certificate III or IV in Electrotechnology or Electrical Trade, often completed as part of an apprenticeship. An electrical license is also required[19].	High demand in manufacturing environments due to 24-hour operational requirements and necessity of ensuring that any equipment faults are addressed promptly to reducing downtime. Wage levels tend to be lower than in construction, exacerbating the difficulties in attracting and retaining electricians.

Table 2: Continued

Occupation	Current volume/ (% of proxy industry)	2035 additional demand (Focused ambition)	Current shortage status	Key training and employment pathways	Role/ comments
Technicians and Trades Workers[20] (% for key occupations)	117 (7%)	1000	Varies across occupations		
312912 Metallurgical or Materials Technician	*15 (12%)*	*120*	National shortage	Extensive experience, or a cert IV in manufacturing technology or another related field to work as a Metallurgical or Materials Technician[21].	A mix of skills and occupations sit within this broad category and have been combined to represent demand for various trades, including: building technicians; engineering, ICT and science technicians; electrical and electronic engineering technicians; and metallurgical/ materials technicians. Stakeholders noted that specialised technicians would be needed to support operations (metallurgical/materials technicians, chemistry technicians), and different technicians for maintenance (electrical, electronic, and mechanical technicians). Key occupations like metallurgical, electrical and electronic technicians are already in shortage nationally.
311411 Chemistry Technician	*9 (7%)*	*70*	No shortage	A formal qualification in chemistry, laboratory skills, laboratory technology or another related field to work as a Chemistry Technician. VET and university are both common study pathways[22].	
342314 Electronic Instrument Trades Worker	*9 (7%)*	*70*	National shortage	Cert III or IV in instrumentation and control or similar to work as an Electronic Instrument Trades Worker (General), e.g. Certificate III in Engineering - Electrical/ Electronic Trade[23].	
Production Managers	49 (3%)	419	State/territory shortage (in the NT	No formal qualifications, but a cert III in process plant operations or a diploma in process plant technology may be useful. Also, Cert II in Manufacturing Technology is related[24].	Production managers oversee the operation of the manufacturing facility. They require direct experience in a similar processing environment to be able to run the plant safely and efficiently.
Stationary Plant Operators	40 (2%)	342	No shortage	There are multiple pathways, but it is common to complete a Certificate III in Process Plant Operations[25].	Stationary plant operators directly control, monitor, and operate machinery on the factory floor. These workers need to be experienced with the manufacturing and safety procedures specific to minerals and polysilicon chemical manufacturing environments. Workers will also need to be prepared with the skills and knowledge to safely and efficiently work with automated plant and equipment.

Table 2: Continued

Mechanical and Production Engineers	32 (2%)	274	State/territory shortage for mechanical engineers (SA, WA, NT)	Bachelor of mechanical engineering. Membership with Engineers Australia highly regarded.[9]	Design, test, oversee the operation and maintenance of mechanical processing equipment. Future skills development may be needed to ensure these occupations are prepared for the needs of robotic and automated manufacturing environments.
Chemical and Materials Engineers	6 (0.3%)	51	State/territory shortage (VIC, QLD, NT, TAS)	Bachelor's degree in chemical, biochemical or process engineering to work as a Chemical or Materials Engineer. It is also common to complete postgraduate studies. Registration may be required in some jurisdictions. Membership with Engineers Australia highly regarded[26].	Critical role in the establishment of new manufacturing plants, and in operations and maintenance. Stakeholders noted that training pathways for hydrometallurgical production processes are thin, highlighting technical skills not available in broad chemical engineering training packages. Chemical engineers are in shortage in Australian states and territories where increased demand is anticipated due to the establishment of new industrial facilities. Long lead times for training completions means that manufacturers may need to rely on skilled migration to meet workforce needs in the short term.
Chemists	18 (1%)	154	No shortage	Bachelor's degree in science majoring in chemistry to work as a Chemist. It is also common to complete postgraduate studies[27].	Play a critical role in sampling, testing and preparing reports to ensure high quality manufacturing outputs. Although not currently in shortage, a pipeline of these critical occupations may need to be managed, particularly as demand increases.
Chemistry Technicians	16 (1%)	137	No shortage		
Chemical Plant Operators	13 (1%)	111	No shortage	Formal qualifications are not required if you are able to demonstrate your technical competency to employers. A certificate III or IV in process plant operations is recommended though[28].	Control the operation of manufacturing plant equipment and associated utilities equipment, analyse and record test data, inspect and schedule maintenance. In a highly automated environment, these procedures are increasingly via remote operation in a control room with integration of AI.

Sources: [24]https://www.yourcareer.gov.au/occupations/133512/manufacturing-production-manager?tab=how-to-become [25]https://www.yourcareer.gov.au/occupations/712999/stationary-plant-operator-not-covered-elsewhere?tab=how-to-become [26]https://www.yourcareer.gov.au/occupations/233112/materials-engineer?tab=how-to-become, https://www.yourcareer.gov.au/occupations/233111/chemical-engineer?tab=how-to-become [27]https://www.yourcareer.gov.au/occupations/234211/chemist?tab=how-to-become [28]https://www.yourcareer.gov.au/occupations/399211/chemical-plant-operator?tab=how-to-become

5. Key trends and challenges shaping workforce demand and skills

The future demand for workers in the critical minerals and polysilicon manufacturing industries projected by the SCP is small relative to both current workforce volumes in key occupations and projected future demand across Australian industries by Jobs and Skills Australia. For key occupations, the current supply and the supply pipeline is compared to forward demand projections to identify where the supply-demand ratio is tight (Table 3). Notwithstanding the modest level of labour demand overall, the workforce dynamics of some key occupations highlight the potential for future industry competition and labour supply pinch points. Key trends include:

- Engineering production workers are a relatively small cohort across all Australian industries; projected growth in demand from critical minerals and polysilicon production is large relative to the current workforce size, with approximately 14% workforce growth expected by 2035.
- The current workforce volume in Australia for technicians and trades workers with the baseline skill sets relevant to critical minerals and polysilicon manufacturing is large. However, a significant proportion of these workers (just over 60%) are concentrated in the construction industry. Higher wages in construction and the mobile nature of employment opportunities may attract new entrants to construction rather than manufacturing. Job experience is important and workers without experience in a manufacturing environment will require upskilling on the plant, systems and equipment used to effectively transition.
- Electricians, electrical technicians and electrical trades assistants are in high demand in construction, mining, and other manufacturing sectors, and are in national shortage. Competition for workers is likely to occur as stakeholders noted higher wages are achievable in both mining and construction compared to manufacturing.
- Low training commencements and completions in chemistry and chemistry technician related training will impact volumes of new entrants to the workforce and may lead to labour constraints

Sources: [29]https://www.jobsandskills.gov.au/data/employment-projections. [30]Relevant sectors used to determine total workforce volume include mining; manufacturing; electricity, gas, water and waste services; construction; and professional, scientific and technical services sectors. ABS Census data 2021

Table 3: Supply pipeline for critical minerals and polysilicon operations and maintenance

	Current supply and JSA growth projection		Projected growth 2035		Supply pipeline (all industeries)			
	Current workforce – all industries	Current workforce – proxy industry	JSA growth projection (2035)[32]	SCP demand projection (2035)	Commencements (2025)[33]	Completions (2025)	Net exit/entry	Median age
Engineering Production Workers (7123)	20,500	358 (21%)	+2,700 (12%)	+3061	330	140	30	43
Electricians	195,900	92 (5%)	+23,400 (12%)	+787	13085	7765		32
Technicians and Trades Workers	786,200	117 (7%)	-	+1000	-			
312912 Metallurgical or Materials Technician	4,100	15	Unknown[34]	+120	Unknown[35]			38
311411 Chemistry Technician	4,200	9		+70				39
342314 Electronic Instrument Trades Worker	1,400	9		+70	660	350	Unknown[28]	34
Production Managers	64,900	49 (3%)	+10,500 (17%)	+419	Low – see note[36]	Low – see note	Low – see note	47
Stationary Plant Operators	13,600[37]	40 (2%)		+342	455	380		40
Mechanical and Production Engineers	40,100[38]	32 (2%)	9,200 (23%)	+274	Unknown[39]			
Chemical and Materials Engineers	7,100[40]	6 (0%)	+1,700 (23%)	+51				34
Chemists	3,700[41]	18 (1%)		+154	10[42]	5[27]	40[27]	
Chemistry Technicians	42,000[25]	16 (1%)		+137				
Chemical Plant Operators	1,800[43]	13 (1%)		+111	310[29]	240[29]		47[29]

Notes: [31]Proxy industry is the Copper, Silver, Lead and Zinc Smelting and Refining sector. [32]JSA projected growth figures are based on historic trends of commencements and completions; they are not a projection of workforce demand. [33]Commencements and completions are for the occupation across all industries (not the proxy industry. [34]No sufficient data for 6-digit occupation. [35]No sufficient data for 6-digit occupation. [36]Production managers enter the workforce from a range of backgrounds and usually find their way into a managerial role from another professional or experience-based pathway. [37]Occupational concentration in relevant sectors only (mining, manufacturing, electricity, gas, water and waste services, construction, and professional, scientific and technical services sectors. ABS Census data 2021. [38]https://www.jobsandskills.gov.au/jobs-and-skills-atlas/occupation?regionType=state&regionValue=aus&occupationFocus=2335&occupationMetric=summary data not available. [39]https://www.jobsandskills.gov.au/jobs-and-skills-atlas/occupation?regionType=state&regionValue=aus&occupationFocus=2331&occupationMetric=summary. [40]ABS Census 2021, count of persons, place of enumeration, 6-digit occupation, all Australian industries. [41]Represents ANZSIC code 2342 - Chemists, and Food and Wine Scientists. [43]Represents ANZSIC code 3992 - Chemical, Gas, Petroleum and Power Generation Plant Operators

6. Developing the future workforce: balance of plant manufacturing

Australia is aiming to rapidly scale renewable generation, with the potential to support niche manufacturing opportunities for balance of plant (BOP) elements, that in turn enable rapid deployment of renewables capacity. Opportunities identified in the SCP include solar PV racking, power management and electrical systems, foundations, and software to automate operations and maintenance. Total employment estimates were not estimated in the SCP for BOP manufacturing, however, stakeholders currently operating in Australia were interviewed to understand current labour market opportunities and challenges, including any workforce related barriers to industry growth. Case studies of niche market operators have been provided to illustrate the nature of current and future workforce characteristics, and where there may be need for interventions for future workforce development.

Case study 1: 5b (Solar Farm Arrays - Balance of Plant)

About 5b

Established in 2013, 5B is an Australian company based in Sydney that designs and manufactures a prefabricated, pre-wired, ground-mounted solar solution. These large-scale solar systems are assembled in a factory and then deployed in the field, with the goal of reducing time and labour for on-site construction. 5B's flagship product, the Maverick, is a modular, East-West array that packs rows of solar modules into a compact, self-ballasted structure. To date, the Maverick has primarily been deployed in off-grid mining contexts in Australia. In 2026, 5B finished deployment of its first utility-scale project – 69 MW in Puerto Rico. This type of solution could have a big role to play in large-scale deployment contexts and behind-the-meter installations for data centres.

Current workforce

5B's current workforce is mainly split between a Sydney-based HQ and R&D Facility and an Adelaide-based production facility, with distinct skills, challenges, and future changes emerging from increasing automation and expansion plans.

- Company headquarters in Sydney houses the tech and product (engineering and R&D), delivery, supply chain and corporate functions.
- The Adelaide facility includes a supply chain, logistics, and production workforce with a range of skills.
- Production workers do not need formal qualifications to assemble Maverick arrays, which are built on a semi-automated proprietary assembly line; 5B trains these workers in-house and has drawn on the local area's manufacturing history to recruit workers, including some who used to work at Holden. Due to ergonomic design decisions that 5B has taken, 5B has a significant proportion of women who work on the production line.

The deployment of 5B's solar arrays also has implications for the construction workforce. 5B can deploy roughly 1–1.25 MW per day with two crews of four (about eight workers), with less electrician labour required as pre-wiring of modules takes place in the factory.

Workforce issues

5B has experienced challenges in recruitment across a range of its teams. As an innovative clean tech manufacturer, the company has experienced specific challenges finding the workers with the right mix of skills. For example, solar PV engineers in Australia typically work for developers and EPCs, rather than coming from a tech hardware background. Finding mechanical/structural and electrical engineers with experience in this area has historically been difficult. Overseas candidates that have backgrounds working in hardware are less likely to be familiar with Australian standards and certification requirements, which is critical for working in a necessarily highly regulated industry. 5B has a strong partnership with UNSW and has hosted a number of interns that have gone on to employment, which has worked well but does not solve the fundamental challenge.

Case study 2: Magellan – Battery Energy Storage System (BESS) balance of plant

About Magellan

Established in Western Australia in 1991, Magellan Power is an Australian designer and manufacturer of advanced power electronics and energy storage systems critical to the nation's energy transition. The company delivers AC and DC uninterruptible power supplies (UPS), battery energy storage systems (BESS), stand-alone power systems (SAPS), and grid-support technologies to sectors including mining, utilities, defence, transport, and healthcare.

Magellan manufacturing capability sits within a strategically critical domain—power conversion and energy storage integration—where Australia is currently highly dependent on imports. A core innovation is Magellan's 4R battery lifecycle ecosystem, which integrates power electronics to enable reuse of lithium batteries, via repair and refurbishment. This innovative capability directly aligns with national priorities in sustainability, critical minerals and waste reduction.

Magellan designs and manufactures systems specifically for harsh, remote environments, positioning the company as a key enabler of energy reliability in regions such as the Pilbara and other off-grid or weak-grid locations.

The company operates from Western Australia with a growing national footprint in Brisbane, Sydney and Melbourne and is actively scaling manufacturing to meet rapidly increasing demand driven by decarbonisation and electrification.

Current workforce

Magellan employs approximately 85 people across engineering, manufacturing, testing, service, and R&D functions. The current workforce includes:

- Power electronics and control systems engineers
- Electrical engineers and technicians
- Electricians and apprentices
- R&D and test engineers
- Quality assurance and compliance specialists
- Field service and commissioning teams

Magellan's production model is highly customised, engineering-intensive, and system-integrated. There is no existing workforce in Australia that is pre-trained for Magellan's bespoke manufacturing environment. Therefore, all employees require structured, on-the-job training to develop the necessary capabilities, particularly in:

- System-level integration (battery + power electronics + controls)
- Quality controlled manufacturing practices
- Safety in high-energy electrical systems
- Customer-specific engineering solutions

Apprenticeships and internal training programs are therefore foundational to workforce creation.

Workforce issues

Magellan has experienced a range of issues related to workforce recruitment and retainment. Magellan's experience highlights several structural challenges across emerging renewable manufacturing sectors, these challenges are elaborated below.

Australia is not producing "job-ready" workers for advanced manufacturing

Graduates and tradespeople have baseline qualifications but lack practical systems integration skills, exposure to real manufacturing environments, and understanding of quality control procedures for production environments. Internal training requirements to bring new employees up to speed results in 6–12 months of productivity lag time per hire, placing a significant burden on growing companies.

Training responsibility is falling on individual companies

Due to the bespoke nature of Magellan's manufacturing processes and the suitability gap of new workforce entrants, Magellan invests heavily in training workers across four areas of competency, including:

- Technical training
- Safety systems
- Quality culture
- Customer-focused behaviours

These areas of competency are considered essential to Magellan's strategic and operational requirements and are not yet adequately embedded in current training systems.

Competition for talent from large industrial players

Magellan experiences competition for workers from the mining sector, utilities, and major industrial firms. These larger players are able to offer higher wages, have established workforce pipelines and benefit from existing regionally embedded labour ecosystems. Innovative emerging manufacturers are disadvantaged due to their inability to compete on wages alone.

Absence of manufacturing ecosystems

Unlike traditional industries, emerging renewable manufacturers like Magellan operate without established supplier networks, skilled labour clusters, or coordinated training pipelines. The Magellan workforce and associated supply chain ecosystem is being built from scratch.

Critical shortage of automation and advanced manufacturing skills

Scaled manufacturing will result in automation that demands critical skills in robotics, digital manufacturing systems (MES, automation), and advanced testing and quality assurance systems. However, Australia currently lacks a workforce trained in these environments, limiting the ability of manufacturers like Magellan to scale local manufacturing competitively.

7. Key findings

The downstream expansion of critical minerals manufacturing capability and the establishment of polysilicon manufacturing capability in Australia will result in workforce growth in skillsets that are already available within the broader non-ferrous metal manufacturing sector, such as mineral ore processing, aluminium smelting, and the copper, silver, lead, and zinc smelting and refining sectors. Relevant skillsets can also be found in existing chemical manufacturing industries in Australia, such as petrochemical refineries, explosives and fertiliser manufacturers.

New and enhanced skillsets needed for safe and efficient manufacturing environments

Advanced critical minerals and polysilicon processing capability will also demand new and enhanced skillsets to support specific hydrometallurgical processes, plant and equipment, and ensure safe and efficient manufacturing environments. Several key trends are emerging that cut across both critical minerals processing and polysilicon manufacturing facilities, impacting demand for key skills and changing the nature of workforce competencies. These trends are explored below.

Skilled chemical workers able to work in complex safety and quality-controlled environments could become a shortage

Chemical manufacturing environments and associated chemical focused occupations and skillsets are critical for manufacturing quality control and safe production practices. Although many of these roles are not currently reported on the skills shortage list, these critical skills may be pushed into shortage if projected demand is realised. Chemical manufacturing environments require a high level of safety and quality control to ensure material purity levels are achieved. A proportion of the operational workforce could be sourced from similar chemical manufacturing environments; however, stakeholders highlighted the importance of workers with previous experience operating advanced processing facilities, particularly in the establishment phase of the facility.

There is a limited domestic labour pool for operations roles in advanced critical minerals and polysilicon manufacturing

There is a limited domestic workforce with the skills required to operate advanced critical minerals and polysilicon manufacturing facilities when built. Stakeholders noted that workers needed experience using the specific plant and technologies that would be used in their facilities. Australian workforce capability is in its infancy in critical minerals refining, and non-existent in polysilicon production. China is the world leader in this manufacturing capability and stakeholders noted they will need to draw on China's experience to establish and train a domestic workforce in the specific processing techniques.

Workers will need to be reskilled for the automated manufacturing environments necessary for Australian manufacturers to be globally competitive

Automation of manufacturing environments is needed to scale production capacity and achieve market competitiveness. Automated manufacturing environments will change the nature of work as well as demand for key occupations:

- Automation results in manufacturing environments that run 24 hours, increasing the reliance on shift-workers.
- Use of robots reduces the reliance on mobile plant operators to move material from one process to another.
- The current operations and maintenance workforce in Australia has limited experience with highly automated manufacturing environments and will need to be trained in the bespoke set-ups of individual facility processes and procedures.
- As manufacturing becomes more efficient – producing more product over less time – demand for some workforce cohorts, particularly factory floor workers, will likely decrease.

The timing of automation could provide challenges for workforce development. Some manufacturers will invest in advanced automation from the outset, while others may stage or delay automation dependent on facility size and investment opportunity. A workforce development strategy will need to time the development of automation skills so that they align with the timing and scale of automation in industry. Staged or delayed automation, which may suit existing facilities, will increase production output efficiency and will result in reduced demand for some occupations.

Balance of plant manufacturers working in battery and electrical component manufacturing noted the need for specific skills and experience in semi-automated manufacturing environments and processes, including:

- Electromechanical assembly in automated environments: where operators work alongside conveyors, using torque tools and test rigs
- Automated testing systems: where workers run, interpret, and troubleshoot testing sequencies for electronic equipment associated with battery systems (e.g., inverters, battery modules)
- Quality control: includes checklists, traceability, and defect identification and prevention
- Introduction to robotics and cobotics: workers learn basic programming, safe interaction with robots and experience relevant use cases
- Battery manufacturing and handling: workers learn cell and module assembly, safety and handling, high voltage awareness (up to 1000V DC)

Micro credentials were recommended in the following areas:

- Manufacturing execution systems (MES) and digital manufacturing systems (DMS) (operator level)
- Basic PLC and industry control systems (operator level)
- Thermal management & reliability in power electronics systems
- Data-driven manufacturing and predictive maintenance (advanced)
- Design for manufacture and test (DFM/DFT) (advanced)
- Integration of power electronics and battery systems in production environments (advanced)

Intergenerational skills and knowledge transfer is required to ensure knowledge is not lost as critical cohorts retire
Critical cohorts of occupations are approaching retirement in the manufacturing industry in Australia, with a closing opportunity to leverage the embedded knowledge in these workers acquired over decades of experience. New workforce entrants will take time to build this level of experience. However, younger workers differ in their career goals and expectations, prioritising career progression and a variety of employment experiences to build their career rather than staying with one employer for an extended period.

Competitive wages, regional attraction measures and skilled migration is needed to build an available and skilled workforce

- Regional attraction is paramount to ensure that a skilled manufacturing workforce remains near facilities. Stakeholders noted challenges in overcoming regional attraction issues, where capital cities were favoured with key occupational cohorts, like engineers, over regional locations.
- Competition for key occupations is likely to occur between manufacturing, mining and construction. Stakeholders noted the higher wages that may be achieved in some cases in the mining and construction industries, particularly on big infrastructure projects.
- Skilled migration will be critical to enable the establishment of completely new industries and manufacturing facilities.

Stakeholders consider improved alignments is required between industry and the education and training sector to ensure a pipeline of job ready graduates
Better coordination between industry and training organisations is needed to optimise training pathways so they align with employment pathways. Stakeholders perceived that young graduate awareness of opportunities in manufacturing was low or non-existent and suggested that targeted marketing may be needed to engage and guide new entrants through appropriate training pathways. Stakeholders also noted a decline in the ability for graduates to demonstrate the skills commensurate with their qualifications. Training offerings for critical occupations, like chemical/metallurgical engineering, are perceived to be too broad and lack the technical focus on hydrometallurgical and pyrometallurgical processing.

Greater demand and investment certainty for Australian product is needed to secure future employment pipeline
Australian manufacturers may take time to be competitive in the global market. Support for Australian production, from Australian infrastructure developers, is needed to fill the demand gap during early stages of production ramp up, until such time that market competitiveness can be reached.

Local content requirements embedded within procurement processes for major infrastructure projects need to be strengthened. Where Australian manufacturing capability is available for technology, components, or materials, tender documents should specify that Australian production is either favoured or required and should be a material consideration when awarding contracts.

Stakeholders noted that in many cases local content requirements are not strong enough and may be circumvented if local manufacturers cannot meet cost, output, or timeline expectations. Off-takers frequently favour international manufacturing partners because they are ready to go with large manufacturing capacity. However, without the support of a large off-taker, domestic manufacturers will not reach the scale of production where they could be competitive with international offerings. Local content requirements are one route to enable the expansion to achieve competitiveness.

8. Recommendations and actions

Stakeholder interviews and literature were analysed for common barriers, opportunities and policy recommendations. A literature review was completed to identify workforce policies, actions, barriers and risks relevant to each sector. The review focused on reports produced by Jobs and Skills Councils, industry bodies and government agencies. Recommended actions were synthesised by grouping proposed actions into common policy themes, while current policies were recorded separately to distinguish existing initiatives from proposed reforms. Policies and actions that addressed the constraints identified through the stakeholder analysis, and that were repeated across the literature, were then selected as the recommended options presented below. Findings from the literature review were combined with thematic summaries of stakeholder interviews to identify key recurring challenges and opportunities and align with policy recommendations.

The recommendations cover four key actions to build and develop the workforce and skills:

1. **Building domestic polysilicon manufacturing and critical mineral processing capability by strengthening skilled migration pathways and/or international investment partnerships**
2. **Building the pipeline of chemical and metallurgical engineers**
3. **Developing training capacity to reskill workers to operate in automated and chemical manufacturing environments**
4. **Building clusters of firms for renewable energy balance of plant deployment, to enable skills transfer and workforce development**

These recommendations are detailed below, with a list of the key actions required.

Recommendation 1: Build domestic polysilicon manufacturing and critical mineral processing capability by strengthening skilled migration pathways and/or international investment partnerships

'Sector-specific shortages not addressed by general migration; need embedded operational knowledge from global leaders' (Clean tech manufacturing stakeholder)

'Processing delays slow facility commissioning' (Clean tech manufacturing stakeholder)

'No domestic polysilicon capability; specialist hydromet skills; start-up knowledge transfer' (Clean tech manufacturing stakeholder)

Rationale: There are no polysilicon production facilities operating in Australia currently. Consequently, there is likely to be a gap in domestic workforce capability to establish and run polysilicon manufacturing facilities in the future which needs to be addressed. Similarly, advanced critical minerals processing capacity in Australia is just emerging and is likely to experience the same capability gaps.

Discussion: The workforce required to design, construct and run processing facilities in the short term will need prior experience in a similar manufacturing environment. For polysilicon production, this capability is only available in countries with established polysilicon production capacity, in particular China.

The workforce required to design, construct and run processing facilities in the short term will need prior experience in a similar manufacturing environment. For polysilicon production, this capability is only available in countries with established polysilicon production capacity, in particular China.

Consequently, arrangements will need to be put in place either for skilled migration to establish and run production facilities and build domestic capability or partnerships for investment by international manufacturers that enable skills transfer. There is experience in Australia and globally with co-investment programs to encourage the establishment of facilities by international firms with skills transfer.

The Skills in Demand visa would be an appropriate migration pathway for skilled migrants with an advanced TVET or bachelor's degree qualification to work in Australia, particularly for operations and maintenance workforce if sponsorship arrangements can be established with employers. Skilled working visa opportunities are anchored to occupations on the Skilled Occupation List (SOL) and key occupations in critical minerals and polysilicon manufacturing are well represented on this list. However, workers need to undergo occupational skills assessments with the relevant organisation for their occupation (for example, Engineers Australia, Trades Recognition Australia) and in some cases these requirements are a significant barrier to employment opportunities (for example, electricians are required to spend 12 months under the supervision of a qualified electrician). Visa costs are also significant for workers migrating with families, with fees up to $10,000 depending on the number of dependents. This barrier could be overcome if employers are willing to embed the full cost of migration (both employer/sponsor and visa applicant costs) into salary agreements, particularly for specialised in demand skillsets. Global competition for green skills across engineering, metallurgical, and electrical trades and professionals could result in a migration attraction issue for Australia if visa pathways are perceived to be a barrier in Australia compared with other migration opportunities.

Key capabilities needed to establish critical minerals and polysilicon manufacturing in Australia should be prioritised in skilled visa pathways – potentially through specific labour agreements, formal arrangements negotiated between the Australian Government and an employer, industry body, or state or territory government that allow departure from standard skilled visa conditions. Barriers to migration or delays in the migration process could slow the commissioning timeline of critical minerals and polysilicon production facilities and impact the speed at which Australia can realise manufacturing capability and market competitiveness. A portion of this migrating workforce will remain in Australia to help run manufacturing facilities and train a domestic workforce in operational procedures; therefore, long-term migration pathways are necessary for some roles.

Co-investment initiatives with international partners to establish new manufacturing facilities should be aligned with Australian labour mobility agreements. Clean tech manufacturing labour migration agreements should be explored to ensure that short term skills gaps are filled whilst long term domestic skills transfer is prioritised. The U.S features several temporary skilled visa pathways that could be adopted in an approach to international partnership. These include L1 A and B visas which focus on temporary work visas for managers and specialist professionals for up to 1 year initially in a new business/operation, or 3 years, if supporting an existing business. This timeframe could be suitable to support the establishment of a new manufacturing facility and increase domestic capacity through skills and knowledge sharing. A similar pathway may need to be explored for TVET pathways to fill plant operational skills gaps.

Actions:

- **1.1 Review the Skilled Occupation List for key clean tech manufacturing occupations:** Ensure the Skilled Occupation List anchored to the Skills in Demand visa reflects the list of occupations identified in renewable energy and other clean tech manufacturing opportunities.
- **1.2 Streamline skills assessments for priority occupations and minimise unnecessary barriers to skills recognition:** Skills / competency assessments should be streamlined where possible, whilst ensuring safe work practices can be maintained. This should be achieved in close collaboration with workers unions to ensure minimum workplace conditions and safety procedures are being met.
- **1.3 Investigate the development of co-investment initiatives for the establishment of polysilicon and critical minerals processing facilities with aligned labour mobility agreements.**

Recommendation 2: Build the pipeline of chemical and metallurgical engineers

Rationale: The supply and quality of graduates for critical occupations, notably chemical and metallurgical engineers, needs to be increased.

Discussion: Stakeholders from smaller or emerging enterprises noted a decline in the ability of graduates to demonstrate the skills commensurate with their qualifications. Training offerings for critical occupations, like chemical/metallurgical engineering, are perceived to be too broad in some institutions and lack the technical focus on hydrometallurgical and pyrometallurgical processing. Apprenticeships were also claimed to not always cover the key relevant skills needed. In contrast, larger multinationals do not expect graduates to enter the workforce with the full skill set ready to start work, these companies anticipate at least a 6-12 month upskill investment in their bespoke manufacturing processes and have a range of international facilities to train graduates onsite.

There is a decline in enrolments in core disciplines such as chemical and metallurgical engineering. In a recent study on workforce requirements for carbon dioxide removal technologies, industry and university sources noted chemical engineering degrees had an image problem because of the association with fossil fuel sectors (a 'gas degree'). Similar issues have been observed with engineering degrees for mining.

Funding was allocated as part of the 2024-25 budget for careers promotion focused on engagement with women and First Nations people to STEM training programs. Additional engagement campaigns and evaluations are required to address perceptions of these degrees, the link to energy transition and career prospects.

An associated priority is to develop work-based learning options and placements with companies for university students in foundational technical degrees. Work-integrated training is less common for the university sector than the VET sector and employers have observed there are less graduates with the right knowledge and skills that fit workplace requirements. For emerging sectors with specialised skill requirements such as polysilicon and critical minerals, the gap between formal qualifications and work skills could be acute. Developing work-based learning positions in partnerships between universities and firms such as internships and cadetships should be considered.

Actions:

- **2.1 Expand STEM promotional campaigns to improve the attraction of students to core engineering degrees for polysilicon and critical minerals:** Review and expansion of the STEM attraction programs to increase candidates for engineering degrees associated with fossil fuels to underline pathways and careers for energy transition.
- **2.2 Engineers Australia and AUSMASA to investigate how to increase work-based learning programs with emerging polysilicon and critical minerals processing facilities for university students**

Recommendation 3: Investigate the development of training capacity and delivery mechanisms for the reskilling of workers for automated manufacturing environments and process changes

'Automated manufacturing environments require new control, data and maintenance skills; existing [Australian] workforce under-skilled in these areas.' (Clean tech manufacturing stakeholder)

'Full qualifications too slow for rapid technology change; need modular upskilling for hydrometallurgical and chemical safety.' (Clean tech manufacturing stakeholder)

Rationale: The critical minerals and polysilicon manufacturing workforce will need to work in highly automated, chemical manufacturing environments which differ significantly from today's Australian manufacturing environments.

Electromechanical assemblers require experience in semi-automated, high reliability balance of plant (BOP) manufacturing environments.

The knowledge and skills of trainers need to be kept relevant through emersion in industrial environments, but this can result in trainers eventually leaving training institutions, 'trainer drain'.

Discussion: Industry stakeholders noted that the Australian manufacturing workforce has low engagement with highly automated and chemical manufacturing environments. Australian workers will need to be upskilled to prepare for working in these environments and trainers need to be continually developing their expertise to deliver the knowledge and capabilities required.

Balance of plant (BOP) manufacturers noted that environments are moving from manual assembly environments and skills towards semi-automated manufacturing that requires process control and system supervision skills.

Manufacturers listed a range of competencies which in their view should be better embedded into units within training package:

- Safety and handling requirements of new industries such as polysilicon.
- Electromechanical assembly in automated environments: where operators work alongside conveyors, using torque tools and test rigs
- Automated testing systems: where workers run, interpret, and troubleshoot testing sequencies for electronic equipment associated with battery systems (e.g., inverters, battery modules)
- Quality control: includes checklists, traceability, and defect identification and prevention
- Introduction to robotics and cobotics: workers learn basic programming, safe interaction with robots and experience relevant use cases
- Battery manufacturing and handling: workers learn cell and module assembly, safety and handling, high voltage awareness (up to 1000V DC)

Additionally, micro-credentials and post-trade units were identified to upskill workers in the requirements of programming and control for automated and robotic environments, working with robots and automated production lines, working in chemical manufacturing environments and safe chemical handling practices.

Actions:

- **3.1 Review training packages to integrate competencies required for new automated manufacturing environments:** Ensure training institutions are embedding relevant digital, automation and data competencies into clean tech aligned training packages.
- **3.2 Develop micro-credentials and post-trade competency units for the existing workforce:**
  - MES and digital manufacturing systems (operator level)
  - Basic PLC and industry control systems (operator level)
  - Thermal management & reliability in power electronics systems
  - Data-driven manufacturing and predictive maintenance (advanced)
  - Design for manufacture and test (DFM/DFT) (advanced)
  - Integration of power electronics and battery systems in production environments (advanced)

Recommendation 4: Build clusters of firms and training hubs to enable skills transfer and workforce development

Rationale: One of the learnings from global international manufacturing is that clusters or ecosystems of firms underpin growth and workforce development and shared training infrastructure could support the building of ecosystems – and these need to be nurtured through industry policy and associated workforce development.

Discussion: There is a large body of studies and experience that have identified that manufacturing sectors develop where clusters and ecosystems of inter-locking firms, supply-chains and workforces are created. It is notable that Australia has some innovative balance-of-plant firms like solar array manufacturer 5b but they tend to be isolated – which creates challenges for workforce recruitment and skills as there is a gap in workers with experience in firms and contexts like them and therefore the skills alignment.

There are innovative solar firms that are aiming to scale globally using Future Made in Australia (FMIA) initiatives such as production tax incentives, but there is also scale through domestic deployment that could be leveraged. Australia is on the brink of a large-scale build-out in renewable energy, storage and transmission. In some regions, such as the Pilbara, there are multiple mega-projects (e.g. 20 GW solar farms) under development linked to industrialisation and decarbonisation. There is an opportunity for FMIA funding to target the development of clusters or multiple firms in balance-of-plant niches linked to renewable energy development, but it requires a joined-up strategy that uses funding to develop clusters instead of grants to single firms. Workforce development is one of the barriers to development of local firms and can be targeted through integrated industry policy and workforce development that focuses on opportunities associated with large-scale deployment.

In emerging sectors with smaller firms such as critical mineral refining, polysilicon manufacturing and balance of plant manufacturing, shared training infrastructure could reduce the burden on training institutions to purchase capital intensive training equipment and improve access for smaller businesses. One stakeholder suggested partnerships with equipment vendors with a lease or subscription model for access to equipment and software for training purposes. This would ensure that training infrastructure remains relevant to industry practice.

Actions:

- **4.1 Investigate the development of FMIA funding round for renewable energy balance of plant sector development integrating workforce development:** the renewable energy manufacturing fund is open to applications on an individual basis. Whilst this suits some firms aiming to scale innovations rapidly to a global scale, there could also be opportunities to develop industry and skill ecosystems associated with domestic deployment. A funding round would need to be targeted at developing multiple local firms to service large deployments in a region such as the Pilbara and integrate commitments to workforce development from firms in alignment with the community benefit principles under development for FMIA.
- **4.2 Investigate the potential of industry-government-training co-funding to support shared training infrastructure for smaller enterprises:**
  Leverage existing TAFE-led National Centres of Excellence and other regional training infrastructure as the foundation for co-funded industry, government and training-sector hubs.

Appendix 1
Industry reference group members

Australian Industry Group (AIG)

Mining and Automotive Skills Alliance (AUSMASA)

Powering Skills Organisation (PSO)

Manufacturing Skills Alliance (MISA)

Electrical Trade Union (ETU)

Australian Manufacturing Workers Union

TAFE NSW – Manufacturing Centre of Excellence

TAFE QLD – Centre of Excellence, Clean Energy Batteries

Department of Training and Workforce Development (WA) Clean Energy Skills National Centre of Excellence (CESNCE)

Jobs and Skills Australia

Dr Mark Apthorpe

List of tables and figures

Table of abbreviations

Name	Abbreviations
Australian Bureau of Statistics	ABS
Australian Energy Market Operator	AEMO
Australian Manufacturing Skills Association	AUSMASA
Australian and New Zealand Standard Industrial Classification	ANZSIC
Balance of Plant	BOP
Battery Energy Storage System	BESS
Distributed Variable	DV
Future Made in Australia	FMIA
Gross Value Added	GVA
Industry Reference Group	IRG
Jobs and Skills Australia	JSA
Liquified Natural Gas	LNG
Not Further Defined	NFD
Original Equipment Manufacturer	OEM
Industry Reference Group	IRG
Photovoltaic	PV
Research and Development	R&D
Registered Training Organisation	RTO
Science, Technology, Engineering and Maths	STEM
Sector Competitiveness Plan	SCP
Technical and Further Education	TAFE
Vocational Education and Training	VET
Workforce Development Plan	WDP