THE FUTURE NETWORKS WORKFORCE

A development plan

RACE for 2030

UTS

POWERING AUSTRALIA

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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 fragmentation, a sparse industrial ecosystem, a relatively small workforce, and fierce international competition. Quick and effective action is needed for Australia to build thriving clean-tech industries.

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
6. And the cross-cutting study of opportunities for First Nations businesses.

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

One of the key challenges to building clean-tech manufacturing in Australia is developing the workforce amidst 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 aim to profile the workforce requirements for fostering a thriving green industrial base, identify possible workforce challenges and solutions, and set the foundations for innovation and collaboration between industry, government, education, and training providers to develop a robust workforce. They are focused on the anchor opportunities and begin with the workforce requirements identified in the relevant 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 Networks Sector Competitiveness Plan (SCP) identified three anchor opportunities based on an assessment of areas where Australia is cost-competitive, offers market differentiation, or there is a need to build local resilience due to supply chain risk. The three opportunities identified are:

- Expanding transformers capability to higher voltage (HV) classes: building on its strong base in lower voltage transformers, Australia could extend production into higher voltage classes (up to 330kV) with similar cost structures and strong demand from both grid expansion and off-grid projects.
- Distributed integration services: Australia's early leadership in rooftop solar has driven it to develop advanced capabilities in service-based solutions, combining software and hardware such as dynamic operating envelopes, monitoring, and automation.
- Custom solutions for off-grid and remote deployment: Australia can leverage its specialised expertise in harsh environments and unique customer needs (e.g. mining) to expand manufacturing of modular skid-mounted substations, modular towers, and standalone power systems.

These opportunities include two associated with physical manufacturing opportunities and one service- based opportunity. This workforce development plan focuses on the single opportunity for which workforce requirements and gross value added are identified, namely expansion of high voltage transformers and noting only one anchor opportunity is modelled due to available data. There is also some discussion on the opportunities for growth in integration services for distributed energy resources.

The SCP estimates 2,400 to 8,900 additional direct jobs by 2035, growing the electrical equipment manufacturing industry by around 150% in under a decade.

Realising this depends on resolving several workforce constraints. In the short term, the most senior transformer engineering roles will need to be filled through skilled migration, as the depth of experience does not yet exist locally in sufficient numbers. Over the longer term, the larger challenge is trades: projected demand for skilled welders far outstrips the current pool, in an occupation already in national shortage.

Building the domestic pipeline will also require change beyond industry itself. Both the education system and the public perception of manufacturing need to shift to attract people into these careers.

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Introduction

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.

The WDPs support the ambitions of the Future Made in Australia comprehensive $22.7 billion investment plan, spanning the coming decade and 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 plant, and the advanced skills to design and market those products with a competitive advantage.

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, including the current state of the labour market, the adequacy of the training system, and anticipated technological change.

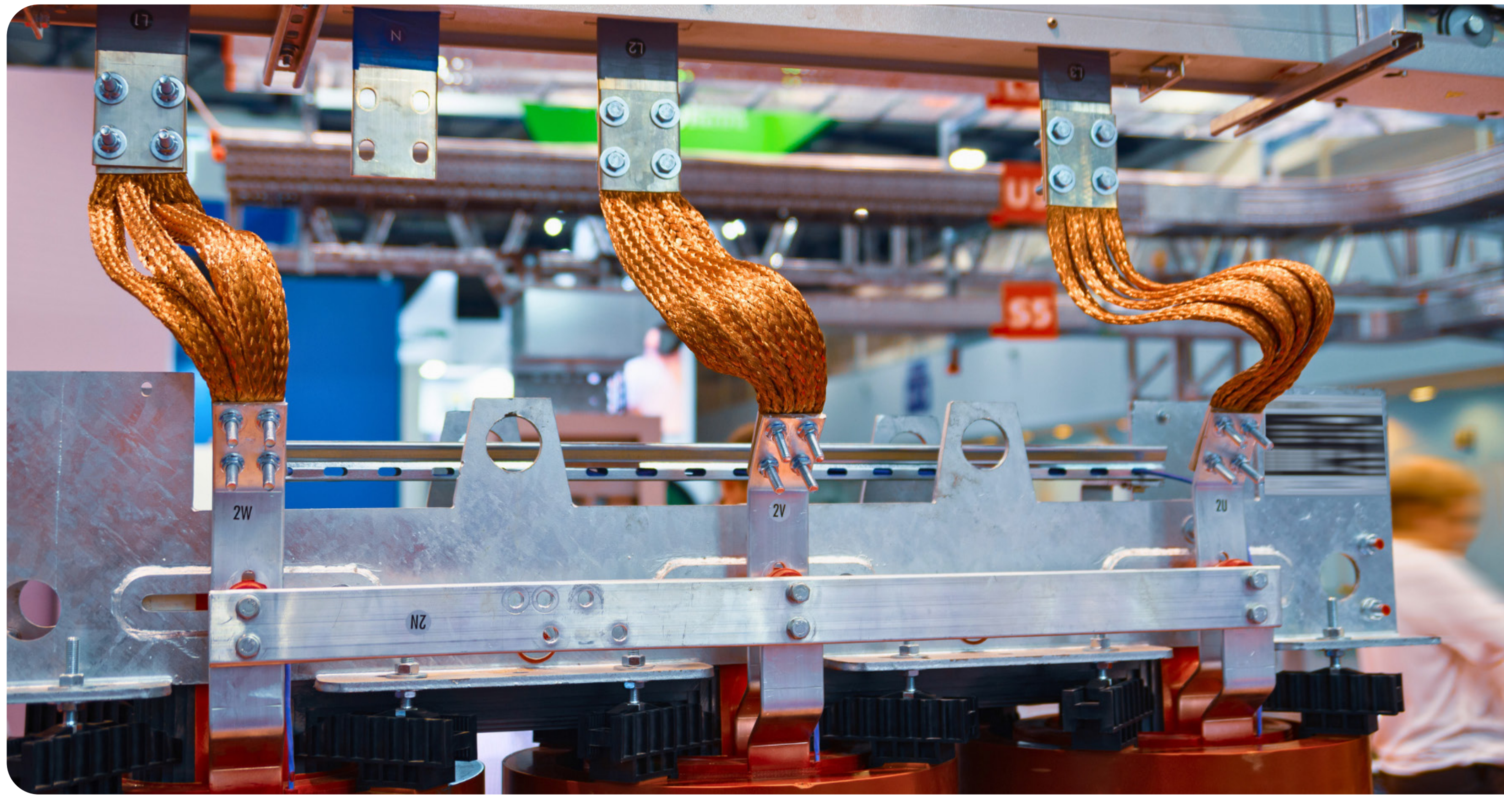
The current workforce in the most comparable industry is analysed to gain insight in the projected new workers and identify an initial set of in-demand occupations, supplemented by information from stakeholder interviews. The key in-demand occupations are examined for training and employment pathways and 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 workforce.

The work is informed by literature review, stakeholder interviews, and an Industry Reference Group (IRG). ISF conducted seven stakeholder interviews overall, with four focused on the identified anchor opportunities for transmission and distribution and three cross-sector interviews. 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 electricity transmission and distribution

The Networks Sector Competitiveness Plan considered opportunities across the transmission and distribution value chain. The SCP identified three anchor opportunities based on an assessment of areas where Australia is cost-competitive, offers market differentiation, or there is a need to build local resilience due to supply chain risk. The three opportunities identified are:

- **Expanding transformers capability to higher voltage classes:** building on its strong base in lower voltage transformers, Australia could extend production into higher voltage classes with similar cost structures and strong demand from both grid expansion and off-grid projects. Domestic manufacturing would reduce current lead times and supply-chain bottlenecks while meeting international demand.
- **Distributed integration services:** Australia's early leadership in rooftop solar has driven it to develop advanced capabilities in Distributed Energy Resource (DER) integration and orchestration. These service-based solutions, combining software and hardware such as dynamic operating envelopes, monitoring, and automation, could be exported globally.
- **Custom solutions for off-grid and remote deployment:** Australia can leverage its specialised expertise in harsh environments and unique customer needs (e.g. mining) to expand manufacturing of modular skid-mounted substations, modular towers, and standalone power systems. With two-thirds of clean sector manufacturing opportunities dependent on off-grid solutions, this is a key opportunity for differentiated competitiveness.



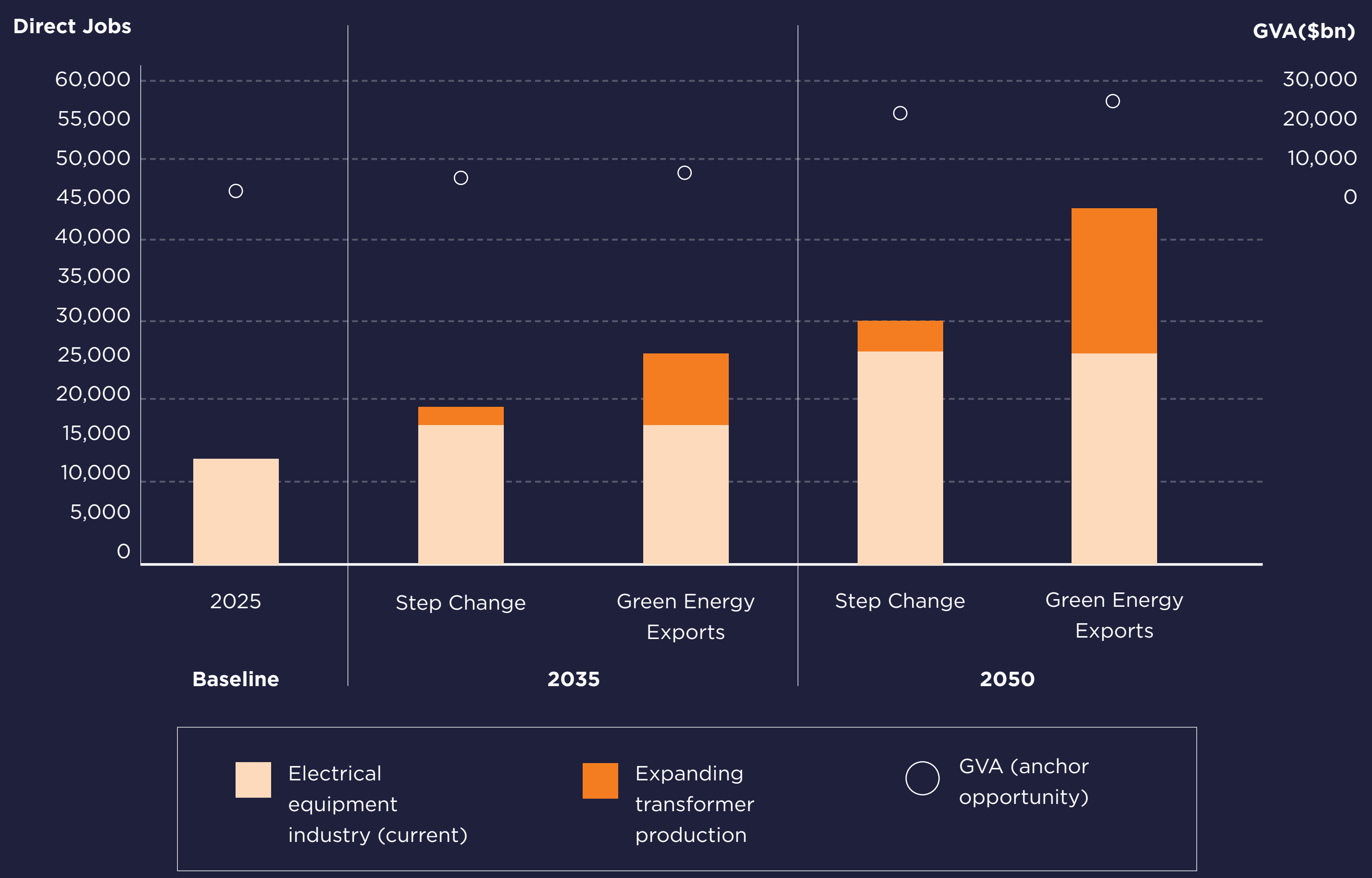
The anchor opportunities include two associated with physical manufacturing opportunities and one service-based opportunity and were identified after evaluating 15 transmission and distribution opportunities.

The SCP only estimates job requirements and GVA growth for one anchor opportunity, extending transformer capability to higher voltage classes. Job numbers are estimated for 2035 and 2050 under a business-as-usual scenario, and for low and high scenarios of extending transformer capability (Figure 3). Lower and upper bound estimates use the assumption that transformer production would increase to either 50% or 75% of domestic demand respectively, with demand estimated from the Step Change and Green Energy Export scenarios from the Australian Energy Market Operators 2024 Integrated System Plan. The SCP estimates 2,400 – 8,900 additional direct jobs in 2035, and 3,800-18,200 additional direct jobs in 2050[1].

The SCP does not estimate the workforce or GVA for the custom off-grid solutions anchor opportunity separately, though the calculation includes both on-grid and off-grid generation estimates. The third anchor opportunity, for distributed integration services, is not quantified at all, although support measures are identified.

This workforce development plan focuses on the single opportunity for which workforce requirements are identified (expansion of high voltage transformers), with some analysis of the opportunities for growth in integration services for distributed energy resources.

Figure 1 Additional direct jobs and GVA from extending transformer capability to higher voltage classes



Source data: Powering Australia, Networks Sector Competitiveness Plan, 2025, p..41-42.

Notes/Sources: 1: The Step Change estimates are used in calculations of potential workforce in the rest of this work.

2. The current operations workforce for transformer manufacture

Figure 3 provides a high-level snapshot of the projected operational workforce profile. The list of in-demand occupations come from stakeholder consultation on the existing transformer manufacturing industry, while the demographic and geographic information, education levels and longer-term industry trends come from ABS data on the entire electrical equipment manufacturing industry.

The current industry is growing strongly, with the business-as-usual growth projection expecting to add 33% by 2035 and to double by 2050 according to the SCP[2]. The potential growth from expanding transformer production is substantial even within this context, with a further 14% added to the projected industry size in 2035 and an additional 15% by 2050 in the Step Change scenario (53% and 71% in the Green Exports scenario) (Figure 3). The electrical equipment manufacturing sector is distributed throughout the country, with New South Wales (35%), Victoria (34%), Queensland (16%) and Western Australia (7%) the leading states. Long-term employment trends from ABS data show that electrical equipment manufacturing employment has remained relatively stable over the past two decades at around 15,000 workers, other than fluctuations around the COVID outbreak.

Stakeholders do not anticipate the makeup of the current operational workforces will change significantly, although skills will increase to adapt to technological change. The top occupations are product assemblers and structural steel and welding trades, with employment numbers potentially reaching 1500 and 450 respectively by 2050. While the highest occupation by volume is product assemblers, this is unlikely to be a constraint on industry growth. Several occupations were identified as being critical and difficult to recruit:

- Skilled welders, such as those holding an advanced welding qualification (AS1554), and with skills in arc welding.
- Electrical design engineers with experience in power transformers.
- Specialist engineers (controls engineers, test engineers).
- Test managers.
- Quality managers (transformer experience preferred).

Skilled welders are the second most in-demand occupation and are both high volume (12% of the workforce requirement) and in shortage. Within transformer manufacture the shortage will be much more acute than the general workforce shortage, as proficient welders in this application need transformer experience, and it can take three years to train a qualified welder to a sufficient skill level:

> *"The transformer is a very significant lump of steel, weighing 30 plus ton on its own. So, it's not like we're welding something superfluous" (Industry stakeholder).*

Stakeholders noted that competition from the construction sector, and in particular large infrastructure projects, could make sourcing welders nigh on impossible. The manufacturing sector simply cannot compete on wages. This situation has eased somewhat as the post-COVID boom in infrastructure construction has reduced. The remaining critical roles are professional and are not high-volume[3]. However, these roles are frequently impossible to recruit within Australia owing to the lack of high voltage transformer manufacturing. Planning to increase the domestic supply, or for expansion of the skilled migration pathways, may be necessary.

Notes/Sources: 2: Cyan Ventures & Deloitte, Networks Sector Competitiveness Plan, 2025, Figure B1 and B2, p54. The current industry is described as including cable, transformers, and substations. 3: Combining relevant engineering roles accounts for just under 10% of the workforce.

Figure 2: Operational workforce for HV transformer manufacturing (Step Change scenario)

The current workforce has below average diversity, with only 22% of the workforce being female and 0.1% First Nations workers, compared to 43% and 3.3% in the general workforce. The industry has a similar educational profile to the general working population, other than a somewhat lower level of university education:

- 27% of workers highest qualification is Year 12 or below, compared to 29% for all employed persons.
- 70% of workers have non-school qualifications (71% for all employed persons).
- 32% of the workforce completed a diploma or a university degree (45% for all employed persons).

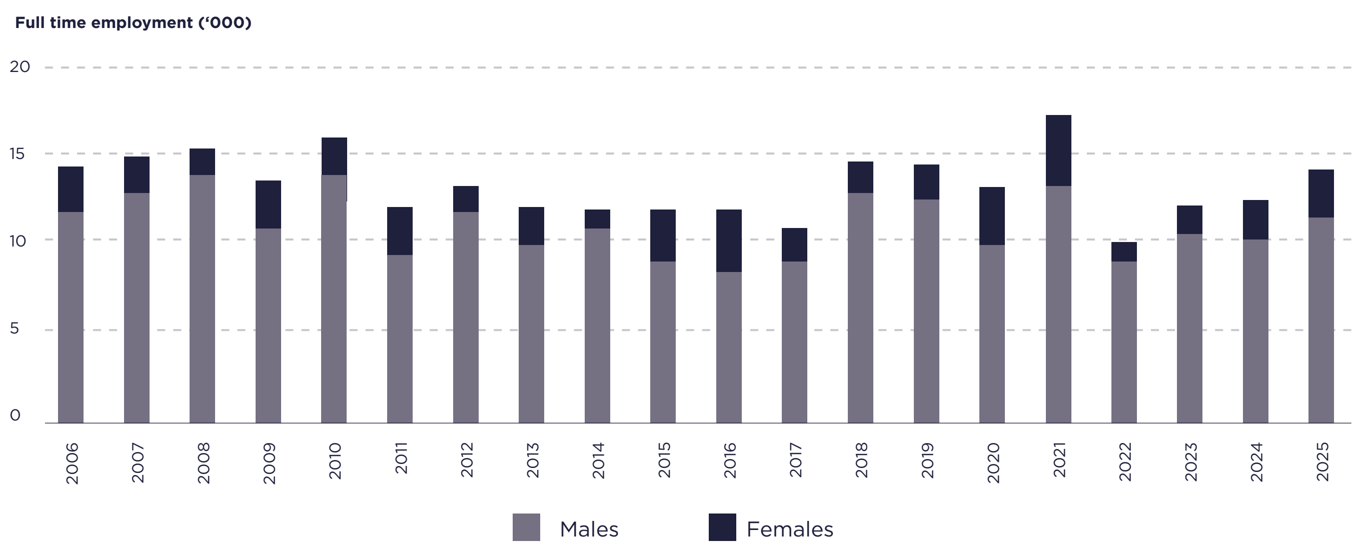
Age profile data shows that 27% of the workforce is aged 55 or over, suggesting an ageing workforce. Conversely, 15% of workers are aged 29 or below, indicating some level of early-career participation. Stakeholders reported a generational issue, with a significant gap in the workforce from the mid-30s up to the 50s. The cohort of experienced engineers are coming up to retirement, and while the supply of graduates entering is seen as adequate, experience is only gained over time.

Total workforce by state or territory [3]

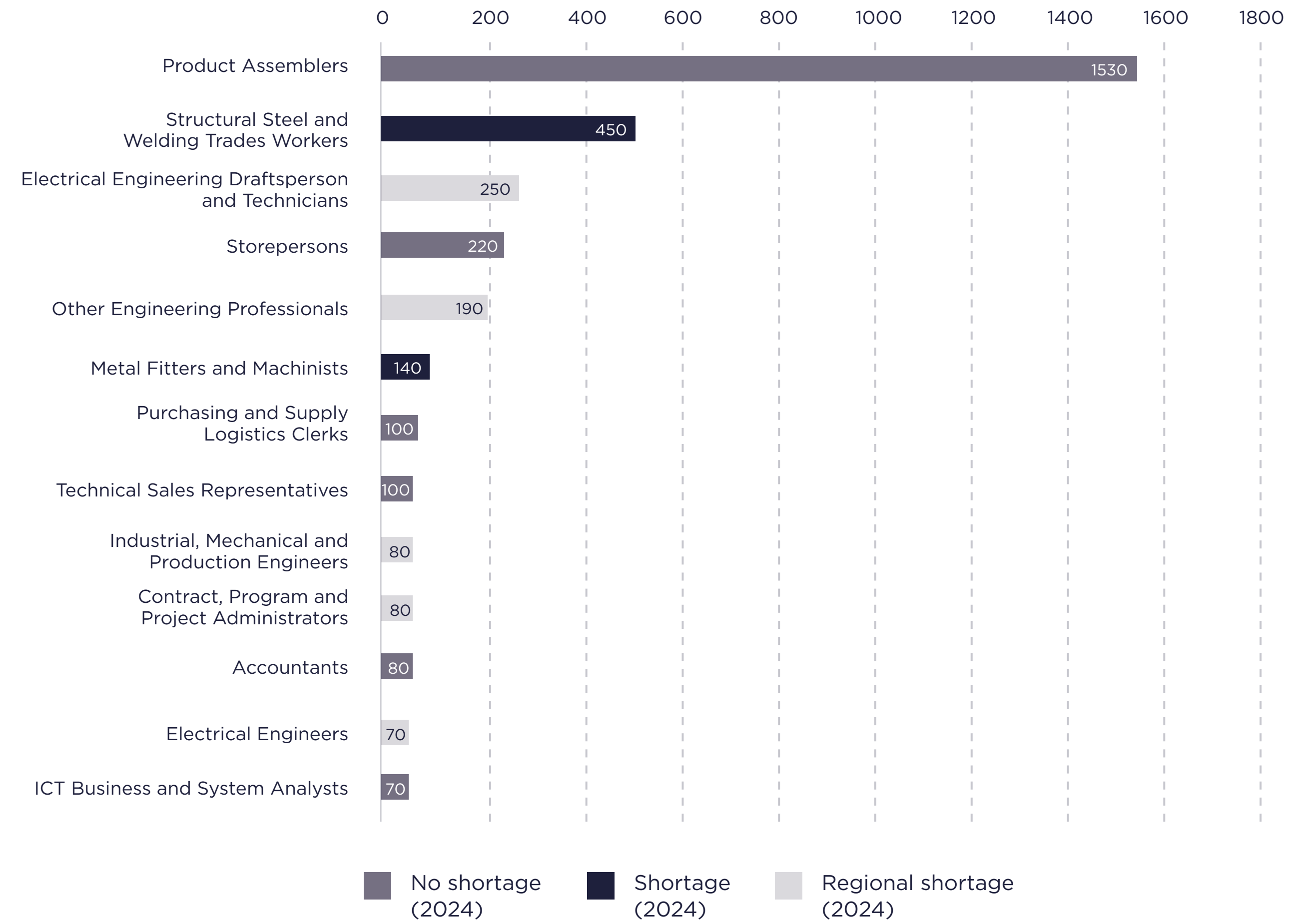
Projected growth to 2034 [4]	% Female workforce [3]	% Workforce First Nations [3]
2%	22% (43% for general workforce)	0.86% (3.3% for general workforce)

Median age [4]	% Workforce aged 24 or below [3]	% Workforce aged 60 and over [3]
45 (39 for general workforce)	7%	15%

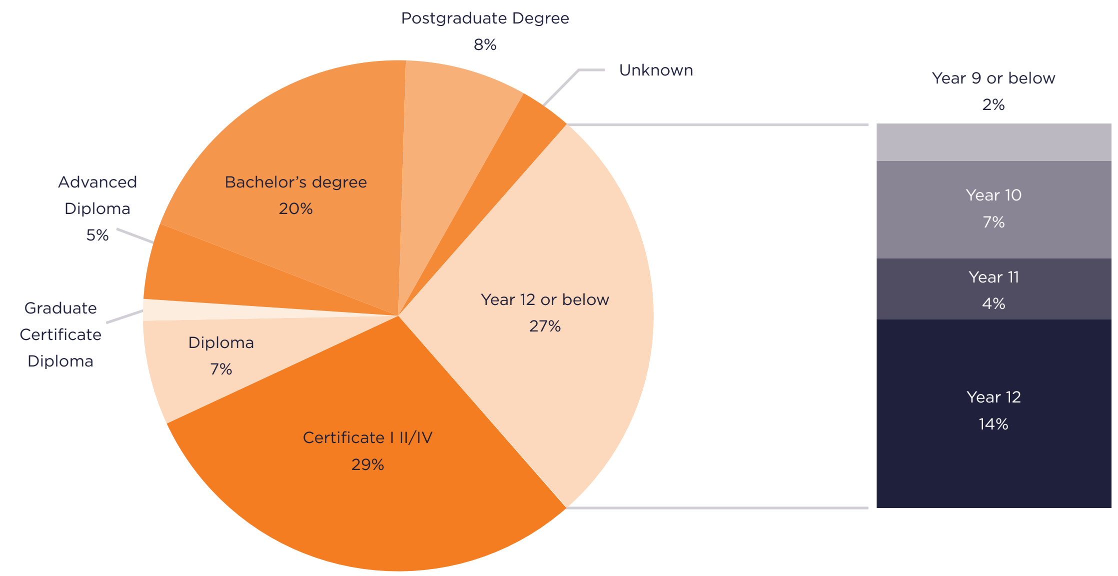
Employment trends [5]



In demand occupations: jobs projected for opportunity in 2050 (Focused Ambition scenario) [1,2,6]



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.

3. Developing the future workforce for transformer manufacturing

There are crucial skill shortages for the expansion of HV transformer manufacturing because the small size and scale of the current Australian industry mean there is a lack of experience outside the current companies. The skill bottleneck is most acute for electrical design engineers, test and quality managers, and product managers, who all need experience with high voltage transformers. This experience is in shortage globally, and the labour pool is very small.

> *"Even strong skills can't replace experience in this space. If we want to move quickly, we need to import experience because it simply doesn't exist locally in sufficient numbers." Industry stakeholder.*

Stakeholders reported that international recruitment is required and could easily extend over several years to attract the right experience. Providing the industry expansion is realised, this may be a temporary problem, as once these engineers are recruited then local engineers can gain the experience. However, skilled migration will be required in the short term.

> *"The advantage is that we don't need large numbers - we might only need one or two highly experienced individuals, and they can train 50 or 60 others." Industry stakeholder.*

Trades are seen as a long-term problem, with the improvements in the general pipeline and in retention both crucial. The general aptitude for practical and manual skills that comes with trade training was seen as vital, even if the specific skills required for transformer production workers can only be acquired in house.

Skilled welders are in national shortage, and it can take a further three years intensive training for a qualified welder to gain enough experience. The labour market for these trades is very tight, with competition from construction, although it was also reported that a slowdown in mining may be helping attraction.

Stakeholders identified both a lack of attraction into trades, although this was described as improving, and a cultural issue with expectations of working conditions. This led to low completion rates for training and to low worker retention, problematic considering the extended requirement for in-house training. Expectations of workplace flexibility were seen as very difficult to manage in younger workers; as one industry stakeholder put it, "You can't weld from home".

3.1 Projected workforce demand compared to the current industry and pipeline

Key occupations for the operational workforce in high voltage transformer manufacturing are listed in Table 1, based on stakeholder consultation and the current workforce for electrical equipment manufacturing. Core professions are electrical and mechanical engineering, particularly power engineering, while core trades are welders, boilermakers, fabricators, and spray painters. Electrical fitters who combine mechanical and electrical knowledge were seen as an ideal hybrid trade within the production setting but were no longer formally trained.

The table lists the number of workers in the most comparable occupation for the current parent industry (electrical equipment manufacturing), their projected growth, and the additional demand for those roles in 2035 if the Focused Ambition scenario for the expansion of HV transformer manufacturing is achieved. Three occupations are currently in national or regional shortage: structural steel and welding trades, electrical engineers and other specialist engineers, and electrical engineering draftspersons are in metropolitan shortage[4].

Notes/Sources: 4: Jobs Skills Australia (2026). 2025 Unit group Shortage List (ANZSCO 2022)

Table 1: Key occupations supply pipeline HV transformer manufacture

	Current supply and JSA growth projection			Projected growth 2035 (Step Change scenario)			Supply pipeline (all industries)[5]			Median Age
	Current Volume									
	All Industries	Parent industry[9]	JSA growth projection (2035)[6]	SCP demand projection[7]	SCP demand/ parent industry	SCP demand/ JSA growth	Shortage status	Commencements [Completions][8]	Net exit/ entry	All Industries
Skilled welders[10]	79,100	201	5993 (7.5%)	282	140%	5%	National Shortage	25 [12]	280	37
Electrical design engineers with experience in power transformers[11]	33,100	395	7,029 (22%)	43	11%	1%	Shortage in Shortage in NSW, SA, WA, NT	Unknown (too small)	445	35
Electrical Engineering Draftspersons and Technicians	10,500	316	1,197 (12%)	154	49%	13%	Metropolitan shortage	Unknown (too small)	80	41
Specialist engineers (controls engineers, test engineers)	3,800	76	5,482 (21%)	120	157%	2%	Shortage except WA	Unknown (too small)	-	36
Quality manager (transformer experience preferred)	12,400	56	231 (2%)	26	46%	11%	No shortage	285 [50]	10	46
Test managers	72,200	75	14,054 (20%)	17	23%	0.1%	No shortage	50 [30]	390	45
Electricians	197,300	1366	23,360 (12%)	17	1%	0.1%	National shortage		2980	32

Sources: [5] Jobs and Skills Atlas data https://www.jobsandskills.gov.au/jobs-and-skills-atlas/occupation [6] Employment Projections (May 2025 - May 2035), produced by Victoria University for Jobs and Skills Australia. Table 6. [7] Growth projection for the Focused Ambition scenario in 2035 [8] NCVER Data Builder, Apprentice completion rates five-year average 2021-2025, https://www.ncver.edu.au/research-and-statistics/data/databuilder# [9] Electrical Equipment Manufacturing [10] The general ANZSIC code for structural steel and welding trades is used except for the SCP growth projection; note that qualified welders require up to three years further training. [11] The general ANZSIC code for electrical engineers is used here, however the requirement is far more specific than an electrical engineer.

The additional workforce required in 2035 under the Step Change scenario for expanding transformer manufacture is estimated to add 19% to the current electrical equipment industry. The SCP anticipates the parent industry increasing by 33% without this expansion, so realising the opportunity would mean that electrical equipment manufacturing grows by 51% in just nine years to 19,000 compared to the current 10,200.

The workforce demand for specific occupations is compared to the current expectations of occupational growth from JSA for 2035 and to the current pool in the parent industry in Table 1. Three roles, welding, draftspersons, and quality managers, would account for a significant proportion of the total projected growth in these occupations. To support attraction and retention, technical traineeships supporting trade progression into technical roles as CAD modellers and draftspersons should be included.

One of the critical occupations, skilled welders, is worthy of particular attention. The SCP projection under the Step Change scenario results in an increase from 200 in the current industry to nearly 500 in 2035, accounting for 5% of the projected JSA growth. This is particularly challenging because demand in this case is for a much higher skill and experience level than is present in the general pool of metal fabricators and welders. There is potential for this to become a significant bottleneck if the labour supply is not increased and the projected expansion is to be realised.

The projected need for electrical engineering draftspersons/technicians and for quality managers is also high compared to the parent industry and to the projected JSA growth. The projection would lead to increasing numbers in the parent industry by nearly 50% in both cases, and account for between 10% and 15% of the projected JSA growth. For quality managers in particular, the actual pool of people is much lower than it appears as transformer experience is a strong preference.

3.2 Education and training pathways

Table 2: Key occupations and qualifications for expanding HV transformer manufacturing

Occupation	Key training and employment pathways
Skilled welders	MEM31925 – Cert III in Engineering – Fabrication Trade / welding trade specialisations/ extensive experience.[12] AWCR certification may be useful[13], as would AS 1796 welding certifications.
Electrical design engineers with experience in power transformers	A bachelor's degree in engineering or science with a major in electrical engineering is required. Postgraduate studies are common. Membership with Electrical Energy Society of Australia (EESA)
Electrical Engineering Draftspersons and Technicians	A diploma or advanced diploma in electrical engineering or another related field is usually needed to work as an Electrical Engineering Draftsperson. Some workers have qualifications such as Certificate IV in Engineering Drafting or an Advanced Diploma of Engineering Technology – Electrical.
Specialist engineers (controls engineers, test engineers)	A bachelor's degree in engineering or science with a relevant major. This group includes jobs that might have different study pathways. Postgraduate studies may also be useful.
Quality manager (transformer experience preferred)	You can work as a product examiner without formal qualifications, however, a course in a related field, such as manufacturing, engineering trades, sciences or technology may be useful. E.g. Diploma of Quality Auditing
Test managers	Extensive experience, or a formal qualification in a related field to work as a Specialist Manager. E.g. Bachelor or Cert IV in Management,
Electricians	Certificate III or IV in Electrotechnology or Electrical Trade, often completed as part of an apprenticeship.[14] An electrical license is also required.[15]

Vocational education and training is seen to be broadly working, other than requiring strengthening on the throughput, and initiatives for co-operation between industry, TAFE and GTOs were seen as very positive.

However, all stakeholders identified the need for a significant effort to improve the public perception of trade careers, starting with schools, and to encourage young people to go into trades. A cultural shift is needed to see these careers as meaningful, stable, and secure, and not as second best compared to university education. The need to be direct about working practices was identified, so young people entering manufacturing would not have unrealistic expectations.

University education was seen as varied, with some stakeholders reporting general satisfaction and others a lack of some important content. Mechanical engineering was generally seen as adequate. Electrical engineering could benefit from the inclusion of core transformer design elements and additional power engineering; a potential solution was identified in the development of additional units.

Sources: [12] https://www.yourcareer.gov.au/occupations/322313/welder-first-class?tab=how-to-become [13] https://awcr.org.au/about/how-it-works/ [14] https://www.yourcareer.gov.au/occupations/341111/electrician-general?tab=how-to-become [15] https://www.nsw.gov.au/business-and-economy/licences-and-credentials/building-and-trade-licences-and-registrations/electrical

3.3 Key findings: extending transformer manufacturing

1. **Policies are needed to support local industry development:**
   While the expansion of transformer manufacturing has potential, policies and procurement practices are needed to support production. While out of scope of this research, stakeholders mentioned both policies to support sovereign capability, and the need to introduce lifecycle costing when purchasing decisions were taken. This could be applied initially to Commonwealth funded projects.
2. **Key professional roles will have to be recruited from overseas:**
   There is a need for highly skilled professionals with experience in high voltage transformer manufacture, including electrical design engineers, test engineers, and production managers. This is a very small pool internationally, so recruitment is difficult. Australia requires a small number of individuals, who will train local staff; a skilled migration route is preferred.
   > *"Even strong skills can't replace experience in this space. If we want to move quickly, we need to import experience because it simply doesn't exist locally in sufficient numbers." – Industry stakeholder.*
3. **Key trade roles could become serious constraints on industry expansion:**
   Projected growth in the requirement for skilled welders represents five times the numbers in the current parent industry and nearly 20% of projected growth in an occupation already in national shortage. The situation is exacerbated as candidates will require further intensive training to meet the rigorous requirements of high voltage transformers. These pressures are significantly exacerbated by demands from large infrastructure construction.
4. **A campaign to support trade careers is needed in schools:**
   Science, technology and engineering and mathematics (STEM) programs in schools are critical and should be expanded. Importantly, students should recognise that STEM creates both university and trades pathways that are both valuable and fulfilling careers. Higher apprenticeships also create a hybrid pathway. Interest in STEM should be enough to create access to the many technical careers that offer a secure future and do not require top academic performance:
   > *"Science, technology, and engineering can be delivered through hands-on trade careers. Interest in STEM is more important than high marks" – Industry stakeholder.*
5. **An attraction campaign for energy sector manufacturing is needed:**
   Public perception of manufacturing is both poor and outdated. Community expectations are that manufacturing means a dirty, large workplace with mainly unskilled work, while transformer manufacturing is skilled and occurs in a clean and controlled environment. It can offer a long-term secure career, technically interesting work, and a direct contribution to the energy transition and sustainability. It is important that this communication creates realistic expectations, particularly with regards to working arrangements – technical manufacturing roles cannot be done from home.
6. **Power transformer design modules should be included in electrical engineering courses:**
   As onshore manufacturing of this equipment has declined in Australia, courses have reduced their coverage to the extent that electrical engineers may not cover transformer design at all. Tuition should be offered in these specialist areas, and content should further be developed to give mechanical engineers some insight into power engineering:
   > *"Universities are generally adequate for mechanical engineering, but electrical engineering is woefully inadequate for transformer design." – Industry stakeholder.*
7. **The impact of automation and robotics is already in train:**
   And likely to become embedded in every role across the workforce from human resources to the factory floor. This transition is already underway, and likely to accelerate:
   > *"The key will be the ability to use technology. For example, boilermakers now graduate with the ability to program robotics. Ten years ago, that would have been a specialist engineering task." – Industry stakeholder.*

4. The opportunity for distributed energy resources (DER) integration

Australia's competitive advantage in the area of distributed energy resource integration services was identified in the SCP, although not quantified. Australia is a global leader in distributed energy deployment and integration, largely driven by its uptake of rooftop solar. The following opportunities were identified:

- Virtual power plant aggregation and community battery services for Frequency Control Ancillary Services (FCAS) and energy;
- Flexible trading enablement;
- Dynamic export orchestration using dynamic operating envelopes (DOEs);
- Gateway and fleet control services;
- Low voltage network analytics and hosting capacity services.

While not a manufacturing opportunity, some stakeholder engagement was undertaken to see whether workforce might become a barrier for development, and some surprising commonalities were found with workforce issues in other areas of clean-tech manufacturing.

Firstly, the need for an attractiveness campaign was identified, in common with every other area of the energy sector workforce. This sub-sector did go one step further and identify a need for the power sector to bring in storytellers and creatives to address this issue.

Secondly, the need for power system experience is a common thread with transformer manufacturing, albeit there is a very different specificity of experience required. Both emphasised the hard reality that experience is only gained by time in the industry, and that qualifications cannot substitute for experience.

Thirdly, the benefits of aligning university education with industry realities came out with all stakeholders, although in some cases this was about highly specific industry issues, while with DER integration improvements are focused on increasing cross disciplinary working in both the technology and power sectors.

4.1 DER integration: key findings

1. **There is an acute need for a cross-disciplinary approach and expertise across the power and the technology domains:**
   Developing and offering integration services needs at least a working knowledge in both areas, and the ability to communicate between the two. The power sector is complex and manages physical flows that are different to telecommunications or monetary trading. Offering these integration services requires understanding of the complex regulation and market systems and an understanding of the physics of power flows.
   > *"The biggest hurdle is domain expertise. DER integration brings together the tech side with the power system side in a way that hasn't really happened before. The power sector is used to managing voltages and stability limits, but the challenge of scale is different. The (power) sector isn't used to actively managing millions of devices, whereas the people who know how to manage systems at that scale don't know anything about the power sector. So we have to upskill in both directions." – Industry stakeholder.*
   >
   > *"We've got people who have come from a tech or telco background where there's deep expertise in building software systems and scalable systems, and they're running into the power system is complicated. The regulatory environment is convoluted and the rules are different. It's one thing to have a packet collision in a TCP/IP network; you don't want that with large power flows." – Industry stakeholder.*

2. **Artificial intelligence is reshaping workforce needs and hiring behaviour:** AI is already having a significant impact and changing hiring practices. Requirements are changing rapidly from needing coders and software engineers to needing AI managers with far more extensive knowledge and skills. Staff need to understand both the context and have the ability to review, and quality assure the AI coding. This has meant a sharp drop in the number of graduate hires, and a rise in the experience needed on the tech side. The long-term effect is unknown, although it may be more difficult for new entrants to gain experience if those entry level jobs do not reappear.

3. **There is a need to attract a broader set of skills extending beyond both the energy and technology sectors:** the industry needs to actively attract new types of talent, in particular creatives and storytellers. The aim is to increase attractiveness and counter perceptions of a dinosaur industry which are a recruitment barrier and an obstacle to customer engagement. The significant and accelerating switch to distributed resources is requiring an entirely different type of engagement, and that needs storytelling. This is both to engage potential customers and to attract more and diverse recruits to the industry. For example, tech talent is often drawn to finance, AI, or other more high-profile or paying sectors rather than energy, and women do not see it as an industry for them.

   > *"We need to recognise the value of storytelling and invite those skills into the industry. This isn't an advertising problem. Storytellers need to sit inside organisations, not outside as consultants." – Industry stakeholder.*

4. **More cross disciplinary options in university courses and in ongoing learning forums would be beneficial:** the need for integration between disciplines extends to education and to working environments. It would be beneficial for software engineers to have some understanding of the power system, and vice versa, with modules on distributed energy systems and the role of software offered in both disciplines. In addition to tertiary education, the need for cross disciplinary programs between the power sector, the technology sector, and the finance sector was identified, as all three are crucial players in a growing number of applications (for example, virtual power plants) that sit between managing actual power flows and monetary flows, and do so in real time.

   > *"By the time you're overlapping technology, power systems, and economics, that's a very small subset of people. It is that overlap that creates interesting problems to be solved. Rather than it being a formal university program, if there was a semi-independent program that grabbed final-year students or early-career people from academia and industry." – Industry stakeholder.*

5. **There is a need for global alignment of DER standards:** while Australia has historically been a leader in developing DER standards simply because of the advanced level of DER implementation, there is a need to balance this leadership with greater international harmonisation. Export opportunities will require harmonisation.

   > *"Australia was facing challenges ahead of the rest of the world, so there was no international standard we could use. But we don't want to stay isolated. We should bring ourselves back into alignment with international standards." – Industry stakeholder.*

5. Recommendations and actions

Stakeholder interviews and literature were analysed for common barriers, opportunities and policy recommendations, with some common themes emerging. Firstly, the importance of experience over qualifications, with an uncompromising need for experience in high voltage transformers on the one hand, and in the power sector more generally on the other. Development of the anchor opportunities is unlikely to be achieved without international recruitment of specific skilled roles. Secondly, the need to strengthen the workforce supply pipeline with better communication to the general public and in schools, and specifically re-emphasis of trade pathways in STEM education.

Recommendation 1: Ensure skilled migration pathways are facilitated for strategic professionals in transformer engineering

Rationale: skilled migration is required in the short term to enable industry growth as high voltage transformer experience is not available in Australia outside the existing workforce.

Discussion: Stakeholders noted the requirement to bring in engineering professionals because experience in a necessity over and above skill and qualification levels. The primary obstacle is availability, globally as well as nationally, so it is important that the visa and migration process is as smooth as possible. Stakeholders noted that the requirement will not persist beyond the set up or expansion phase.

Actions:

- **1.1 Review the Skilled Occupation List:** ensure the Skilled Occupation List anchored to the Skills in Demand visa incorporates transformer engineers and skilled migration pathways for transformer engineers ensure local manufacturers can access international expertise where not available within Australia.

Recommendation 2: Undertake trades attraction campaign in schools and increase workforce diversity

Rationale: Manufacturing has lost prominence as a career pathway and is seen as old school.

Discussion: Manufacturing, and clean-tech manufacturing in particular, needs to be re-discovered as a secure and sustainable career path. There needs to be campaigns to reassert it as an important part of Australia's future, and part of making Australia and the energy system sustainable.

Actions:

- **2.1 Expand the 'Make It Manufacturing' initiative** and schools' attraction campaigns that position manufacturing jobs as clean, secure careers playing an important role in the energy transition, including place-based outreach in targeted regions and roles in shortage such as welding and electrical draftspersons.
- **2.2 Implement industry-led diversity initiatives** including women's pre-apprenticeship programs, funded mentoring, flexible work arrangements and co-designed First Nations pathways.

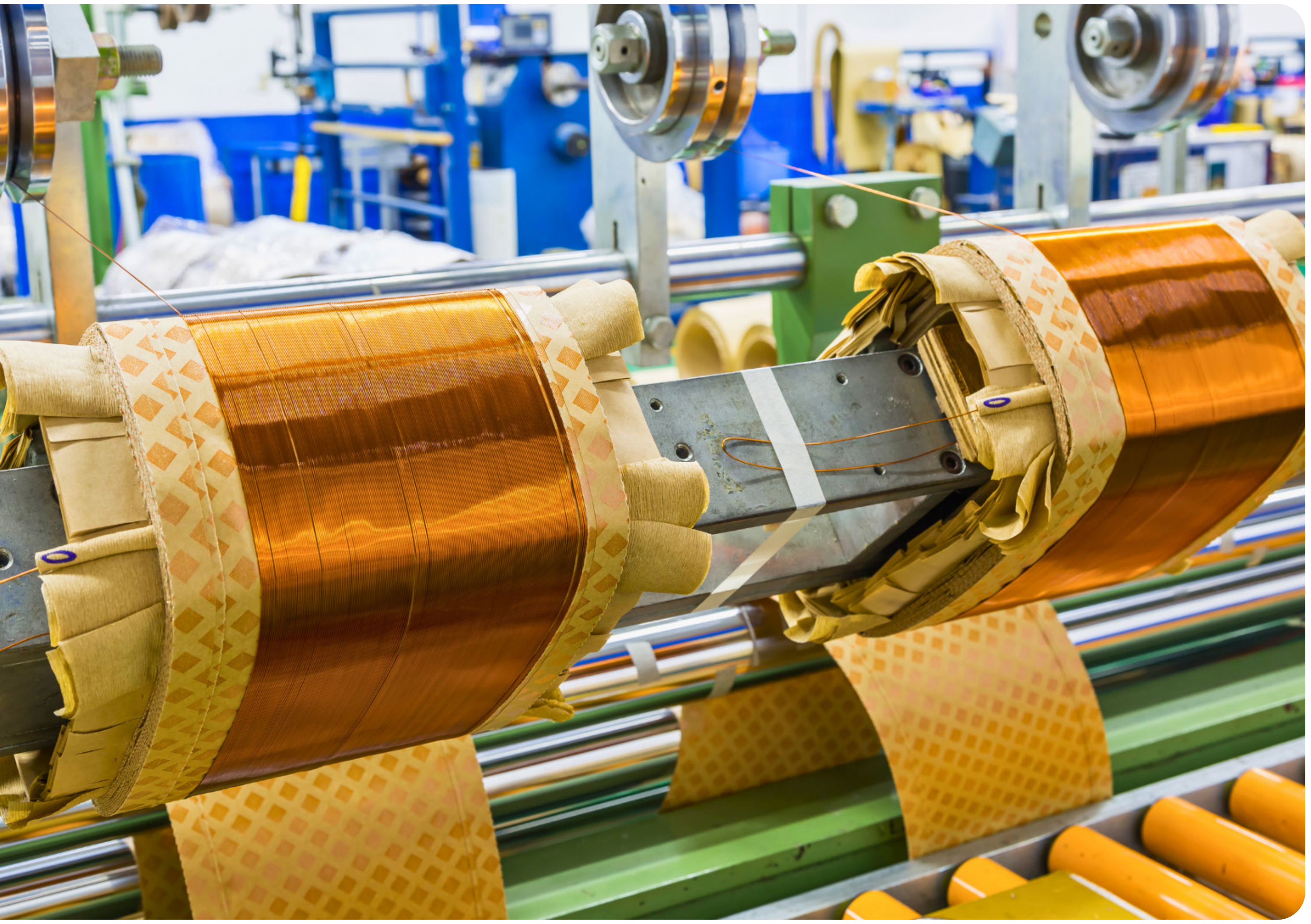
Recommendation 3: Review course content in schools and university to improve alignment with transformer manufacturing

Rationale: The emphasis on university pathways and professional roles has meant that young people are less likely to consider trade routes. STEM programmes should establish a well-defined route into trades within schools. The skills and knowledge for power system engineering and transformer design are critical to the industry and are currently not included as options in electrical engineering courses.

Discussion: The immediate concern is STEM education, which has become associated with high academic achievers. Programmes need to be redefined to emphasise technical aspects, so that an interest in STEM is sufficient for inclusion in these programmes. There should be clear mapping for trade pathways from STEM programmes. University modules should be co-designed with industry and offered within university courses. This would sit well with internship programs which stakeholders were already participating and/ or familiar with.

Actions:

- 3.1 **Engineers Australia to investigate university partnerships** to introduce transformer design modules into electrical engineering courses.
- 3.2 **Review school STEM programmes** to ensure the inclusion of clear, accessible pathways into trades.



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 Net Zero Manufacturing Centres 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

List of tables and figures

Table of abbreviations

Name	Abbreviations
Australian Bureau of Statistics	ABS
Artificial Intelligence	AI
Distributed Energy Resources	DER
Dynamic Operating Envelope(s)	DOE(s)
Electrical Energy Society of Australia	EESA
Frequency Control Ancillary Services	FCAS
Group Training Organisation	GTO
Gross Value Added	GVA
High Voltage	HV
Industry Reference Group	IRG
Jobs and Skills Australia	JSA
Megavolt ampere	MVA
Sector Competitiveness Plan	SCP
Science, Technology, Engineering and Mathematics	STEM
University of Technology Sydney / Institute for Sustainable Futures	UTS / ISF
Workforce Development Plan	WDP