RACE for 2030

RELIABLE AFFORDABLE CLEAN ENERGY

E3 Fast track

The Australian Electricity Workforce for the 2022 Integrated System Plan: Projections to 2050

UTS Institute for Sustainable Futures

AEMO

Australian Government Department of Industry, Science and Resources

AusIndustry Cooperative Research Centres Program

RACE for Everyone
Research Theme E3: Future Energy Workforce

ISBN 978-1-922746-18-4

Industry Report
The Australian Electricity Workforce for the 2022 Integrated System Plan: Projections to 2050

Citation

Rutovitz, J., Langdon., R, Mey, F., Briggs, C. (2022) The Australian Electricity Workforce for the 2022 Integrated System Plan: Projections to 2050. Prepared by the Institute for Sustainable Futures for RACE for 2030

November 2022

Contributors

Acknowledgements

We would like to thank the NSW and Victorian State governments for making this work possible. We would also like to thank our project partner the Australian Energy Market Operator (AEMO) for their invaluable help, and the Industry Reference Group: the Australian Power Institute, Clean Energy Council, Department of Climate Change Energy & Water (Commonwealth of Australia), Department of Energy and Public Works (Queensland), Department for Energy and Mining (South Australia), Energy Consumers Association, Energy Networks Association, Office of Energy and Climate Change (NSW Treasury), the University of NSW, and the Department of Environment Water Land and Planning (Victoria) for their insights, which have made this work much better. Any errors and omissions are, however, entirely the responsibility of the authors.

What is RACE for 2030?

RACE for 2030 CRC is a 10-year co-operative research program with AUD350 million of resources to fund research towards a reliable, affordable, and clean energy future: https://www.racefor2030.com.au

Acknowledgement of Country

The authors of this report would like to respectfully acknowledge the Traditional Owners of the ancestral lands throughout Australia and their connection to land, sea and community. We recognise their continuing connection to the land, waters and culture and pay our respects to them, their cultures and to their Elders past, present, and emerging.

Key Findings

- A rapid scale up of the energy workforce is needed to implement the optimal development path in the Integrated System Plan (ISP) for all scenarios except the Slow Change. Under the Step Change – considered 'most likely' by energy stakeholders and well-aligned with recent policy commitments by State Governments - the combined workforce for renewable generation, storage, and transmission construction needs to increase by 12,000 in just two years to 2025. Overall electricity sector employment grows by 37,000 from 2023 to peak at 81,000 in 2049.
- If Australia becomes a major exporter of renewable energy (the 'Hydrogen Superpower' scenario), the workforce needed would be up to twice as high in the 2030s and up to three times higher in the 2040s, with a peak of 237,000. The scale up of the workforce needs to start now, as implementing this scenario would need 31,000 extra workers by 2025 compared to 2023[1].
- In the Offshore Wind scenario, jobs increase by 29,000 to peak at 73,000 in 2049, less than the Step Change, reflecting the displacement of more labour-intensive onshore wind and solar farms. In the Slow Change scenario employment would fall, although this scenario is considered unlikely in the light of recent policy development and would not deliver Australia's emissions commitments.
- Under all scenarios, construction dominates the employment profile through the 2020s as the build-out of renewable energy, transmission and storage accelerates. Ongoing operations and maintenance (O&M) employment gradually increases as the fleet of renewable energy generation increases, reaching over 50% in all scenarios by 2040.
- Construction employment in large scale technologies is subject to major upswings and downswings, with increases of 13,000 in just two years in the Step Change scenario (45,000 in the Hydrogen Superpower), followed by drop offs which can be very sharp. This 'boom-bust' pattern creates significant risks for labour supply, exacerbated by competing demands for infrastructure build in other parts of the economy and the fact that much of the energy infrastructure is in rural areas.
- The rapid increase in requirements for in-demand occupations brings a high risk of skill shortages which could impact on the achievement of the ISP's optimal development path. Skill shortages create the risks of delays, increased project costs (wage inflation, recruitment costs and liquidated damages), and increased cost of capital to reflect increased risk.
- Most of the electricity sector job growth is in renewable energy, with average annual employment of 39,000 in the Step Change scenario. The combined workforce for rooftop solar and distributed batteries accounts for between 26% and 45% of average electricity sector employment in all scenarios.
- Fossil fuel employment in power stations or producing gas or coal for Australian electricity generation declines steadily to around 2,000 jobs in the late 2040s, regardless of scenario. This decline is outstripped by the increase in other electricity sector jobs, offering some opportunities for transition employment. However, these jobs may not be in similar occupations or locations, and additional planning and diversification is needed to ensure a smooth and just transition for coal regions and communities.
- The electricity workforce needed nationally to deliver the energy transformation is far larger and more diverse than outlined in this report. The modelling does not include Western Australia or the Northern Territory, both with significant renewable growth projected, as the ISP only covers the National Electricity Market (NEM). These projections also do not include the workforce needed in mining or mineral processing for renewable energy technologies, decommissioning and recycling of energy infrastructure, or any of the jobs in energy efficiency, demand-side and energy management, or electrification, which could more than double the workforce projections.

[1] Compares the Hydrogen Superpower requirement in renewables, storage and transmission construction for 2025 (61,000) to the Step Change requirement for 2023 (30,000).

Executive Summary

This report provides electricity sector workforce projections for the 2022 Integrated System Plan (ISP) developed by the Australian Energy Market Operator (AEMO). The study was undertaken by the Institute for Sustainable Futures, University of Technology Sydney (ISF) in collaboration with AEMO and was funded by the RACE for 2030 Cooperative Research Centre and by the New South Wales and Victorian State governments.

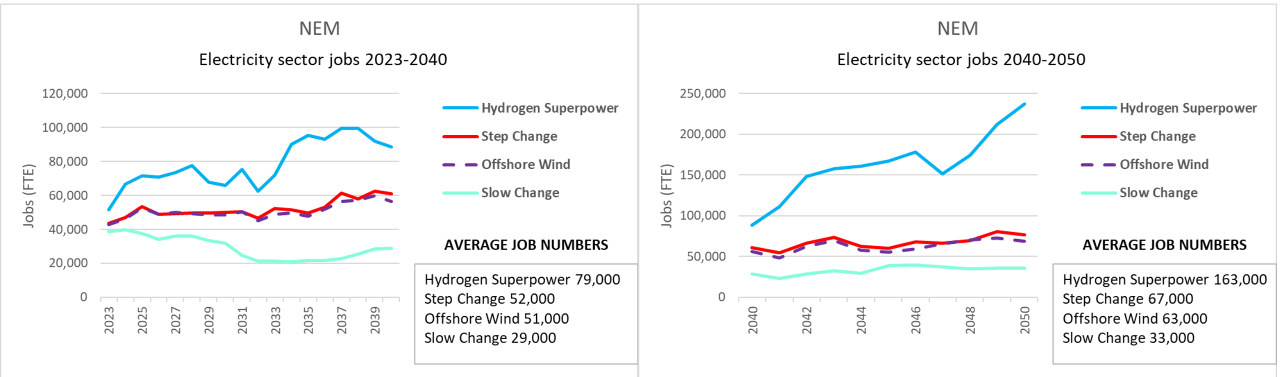
The workforce projections cover electricity generation, storage, and transmission construction for three 2022 ISP scenarios[2] and one sensitivity;

- **The Step Change scenario**: includes rapid consumer-led transformation of the energy sector and coordinated economy-wide action moving fast to fulfil Australia's net zero policy commitments. Energy stakeholders consider this the most likely scenario. The NSW Electricity Infrastructure Roadmap is broadly aligned with this scenario, and during this project Victoria and Queensland released energy plans with some alignment.
- **The Hydrogen Superpower scenario:** includes strong global action, significant technological breakthroughs, and a near quadrupling of NEM energy consumption to support a hydrogen export industry. There is large-scale development of the renewable energy sector, especially in the 2030s and 2040s.
- **The Slow Change scenario**: features a slow pace of policy and technology change, assuming a challenging economy following the COVID-19 pandemic, with the risk of industrial load closures. This scenario is considered unlikely and would not reach Australia's decarbonisation targets.
- **The Offshore Wind sensitivity**: the ISP includes a sensitivity to the Step Change scenario that takes account of the Victorian target to build 9GW of offshore wind by 2040[1] and assumes a lower capital cost for offshore wind relative to other scenarios. Offshore wind displaces onshore wind and utility-scale solar and reduces the overall capacity needed (by 2050 there is 13 GW (10%) less generation capacity in the NEM in this scenario). No offshore capacity is projected until the late 2040s in other scenarios.

Jobs are presented as full time equivalent (FTE) for each year and are the sum of people working on construction projects, operations and maintenance, manufacturing, and fuel supply for coal and gas generation. One FTE could be one person working full time just for that year, two people working full time for six months, or an ongoing full-time job in operations and maintenance. Construction jobs are by nature temporary, although workers may move from one project to another and be in continuous employment.

Electricity sector jobs increase in all but the Slow Change scenario, with employment in the Hydrogen Superpower scenario increasing nearly fivefold

Figure E1 NEM: total job numbers by scenario



[2] The Progressive Change scenario was not included as the workforce profile is very similar to the Step Change.

The peak electricity sector workforce under the Hydrogen Superpower scenario would be up to double the peak workforce under Step Change and Offshore Wind scenarios in the 2030s and up to three times higher in the 2040s.

- Under the Step Change scenario, employment averages 52,000 from 2023 to 2040, increasing by 19,000 from 2023 to peak at 63,000 jobs in 2039. Jobs average 67,000 from 2040 to 2050, increasing gradually to a peak of 81,000 in 2049.
- Under the Hydrogen Superpower scenario, employment averages 79,000 up to 2040, with a peak of 100,000 in 2037. Even more dramatic growth occurs in the 2040s, reaching an employment peak of 237,000 in 2050. Planning for this scenario would need to start very rapidly, as the workforce in 2023 would already need to be 8,000 higher than the Step Change to deliver the increase in capacity in 2024 shown in the ISP.
- Under the Slow Change scenario, employment falls from close to 40,000 to a low of 21,000, averaging 29,000 from 2023 to 2040 as the pace of energy transition slows. Job numbers increase slightly during the 2040s, with an average of 33,000.
- Offshore Wind has almost the same total employment as the Step Change scenario, with a lower average of 51,000 up until 2040, and 63,000 from 2040 to 2050. This reflects displacement of a somewhat larger quantity of more labour intensive onshore wind and utility-scale solar.

While this report includes workforce projections from 2023 to 2050 in line with the ISP, later years should be treated as indicative only as they are 27 years hence. There may be step changes in labour productivity in that timescale, for example resulting from construction automation, rather than the gradual increase anticipated in these projections.

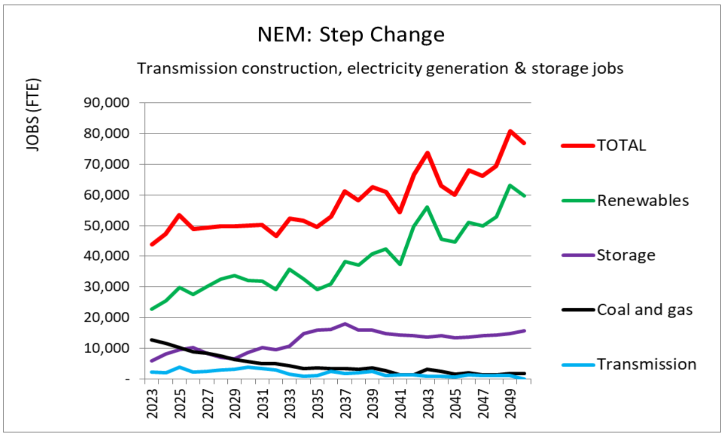
A rapid scale-up in the electricity workforce will be required to implement the ISP

Under the three growth scenarios, a rapid workforce increase will be required to implement the optimal development path in the ISP. An increase in the combined workforce for renewable energy, storage, and transmission construction of 12,000 is needed in just two years to 2025 under the Step Change scenario (Figure E2). The ramp up needed for the Hydrogen Superpower scenario is far steeper, with a combined increase of 31,000 needed by 2025[3].

Most of the job growth is in renewable energy, with an increase of 7,000 by 2025 in the Step Change. Whilst overall renewable energy employment grows until the end of the period, there are years with sudden drops. Jobs drop by 4,000 in 2031 and 2040, and by 13,000 over the two years prior to 2045.

The proportion of renewable energy jobs is close to 50% in 2023 and above 77% in 2050 in the Step Change scenario. Storage employment increases from 14% in 2023 to 20% in 2050, with a peak employment of 18,000 in the mid-2030s. Transmission construction (including lines and substations) reaches peaks of 4,000 in 2025 and again in 2030.

Figure E2 National Electricity Market, jobs by technology group (Step Change scenario)



Fossil fuel employment in power stations or producing gas or coal for Australian electricity generation[4] declines steadily over the period to 2,000 jobs in 2050[5]. This decline is outstripped by the increase in other electricity sector jobs, which may offer some opportunities for transition employment. However, these jobs will not necessarily be in similar occupations or locations, so additional planning and diversification will be needed to ensure a smooth and just transition for coal regions and communities.

[3] This includes the additional 8,000 workers needed in the Hydrogen Superpower compared to the Step Change in 2023.
[4] This does not include coal mining for export or LNG production for export.
[5] This includes a construction workforce of 1,000 projected to be constructing an open-cycle gas plant.

The electricity workforce needed nationally to deliver the energy transformation is even larger than outlined here. These projections do not include the workforce needed in mining or mineral processing for renewable energy technologies, decommissioning, or any of the jobs in energy efficiency, demand-side and energy management, or electrification. The modelling does not include Western Australia or the Northern Territory, as the ISP only covers the National Electricity Market (NEM).

The workforce required for energy efficiency, demand-side and energy management, and electrification will be significant, with further requirements for workforce planning, particularly where the skill sets of these employees overlaps with those required to deliver outcomes aligned with the ISP scenarios. There is a lack of information on the current and future scale of this workforce, with estimates for 2030 varying from 200,000 to 400,000[2]. Even the lower end of this range would be four times the 2030 electricity sector projection here. In order to make reasonable projections of the labour requirement, employment indicators should be developed in tandem with ensuring that the energy efficiency and electrification tasks are sufficiently defined to allow their application.

Wind and solar farms are the primary drivers of employment growth

Under all scenarios, most employment growth occurs in solar and wind farms. Figure E3 shows the average employment by technology over the period in the Step Change and the Hydrogen Superpower scenarios, while Figure E4 shows the annual employment.

- Wind accounts for an average of one-third of employment in the Step Change and nearly half in the Hydrogen Superpower scenario. In Step Change, wind farm employment grows by 26,000 to peak at 33,000 in 2048. In Hydrogen Superpower, wind farm employment grows very strongly, nearly doubling by 2033, and exploding through the 2030s and 2040s to peak at 121,000 in 2049.
- Solar farms account for 11% of employment in the Step Change and 18% in the Hydrogen Superpower scenario. Utility-scale PV employment grows very strongly in this scenario, increasing by 85,000 from 2023 to peak at 88,000 in 2050 (in the Step Change the peak is 21,000 in 2049).
- The combined workforce for rooftop PV and distributed batteries accounts for more than 40% of electricity sector employment in the Step Change, and for 26% in the Hydrogen Superpower scenario. Rooftop PV is a steady source of employment, with average annual employment staying between 14,000 and 22,000 in both scenarios.

- Jobs in distributed batteries generally increase steadily over the period, from close to 4,000 in 2023 to 14,000 in 2050 (16,000 in the Hydrogen Superpower scenario). Distributed batteries contribute to more than 97% of the battery jobs shown.
- Coal and gas account for 8% of average employment in the Step Change scenario (3% in the Hydrogen Superpower), while hydro accounts for 3-5% and transmission construction for 3% in both the Step Change and the Hydrogen Superpower scenarios.

Figure E3 National Electricity Market, average job numbers by technology and scenario

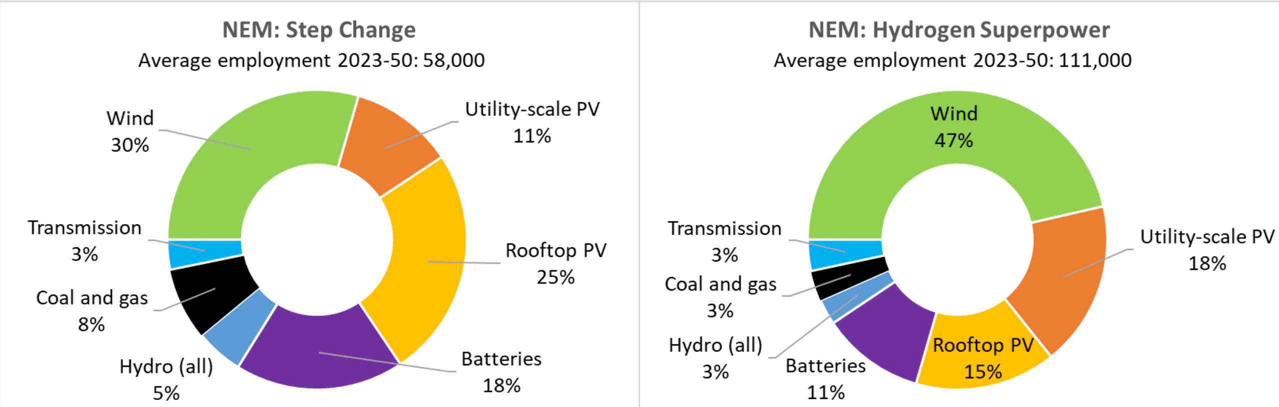
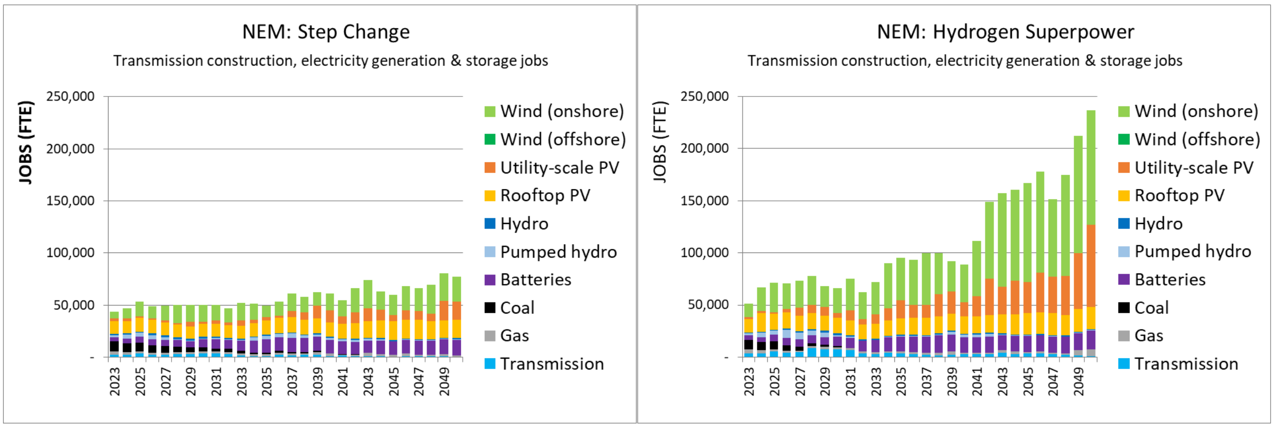


Figure E4 National Electricity Market, annual jobs by technology and scenario



Most jobs in the electricity sector will be in operations and maintenance by the 2030s

Under all scenarios, construction dominates the employment profile through the 2020s but ongoing operations and maintenance (O&M) employment gradually increases as the fleet of renewable energy generation and storage increase. O&M employment reaches just over 50% in the Hydrogen Superpower and over 60% in the Step Change scenario (Figure E5).

Australian governments and other stakeholders are considering policies to increase the proportion of manufacturing which occurs onshore. The proportion included in these projections is based on current levels from the findings of an industry survey in 2020[3], and vary from 2% for solar to 23% for onshore wind. Increasing the share of onshore manufacturing to 30% for all technologies could add 3,300 jobs on average over the period, mainly in solar manufacturing (Figure E6).

Figure E5 National Electricity Market, jobs by phase (Step Change & Hydrogen Superpower)

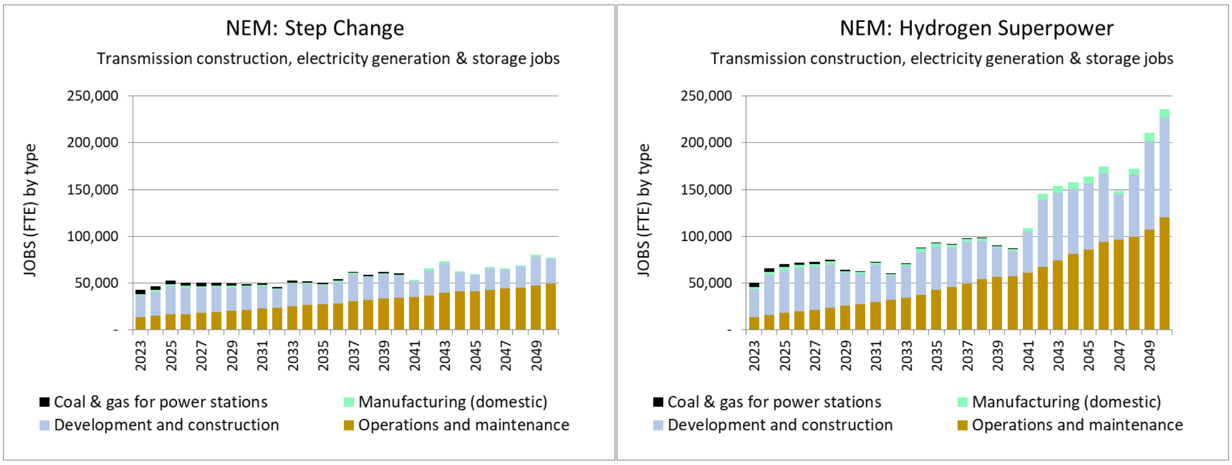
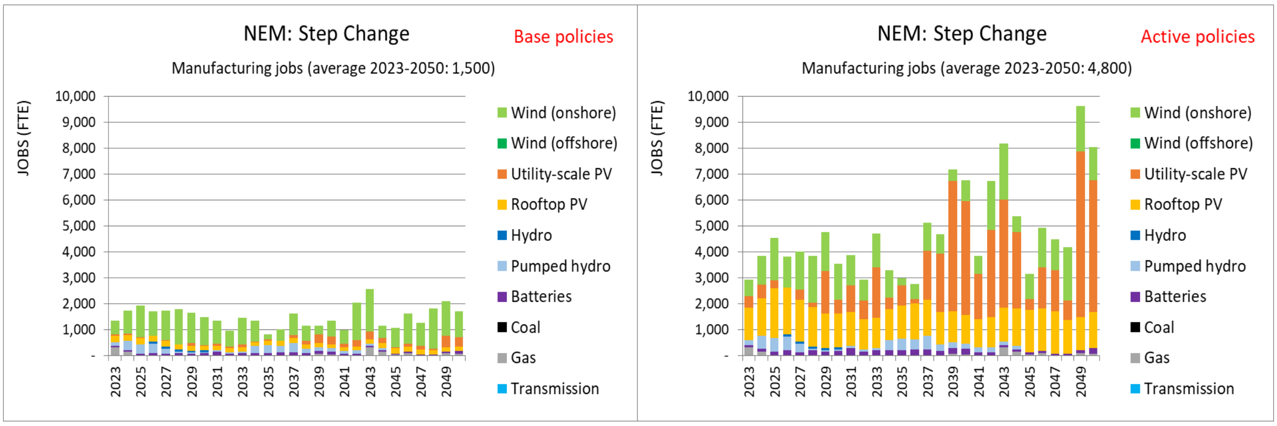


Figure E6 Change in manufacturing employment with active policies



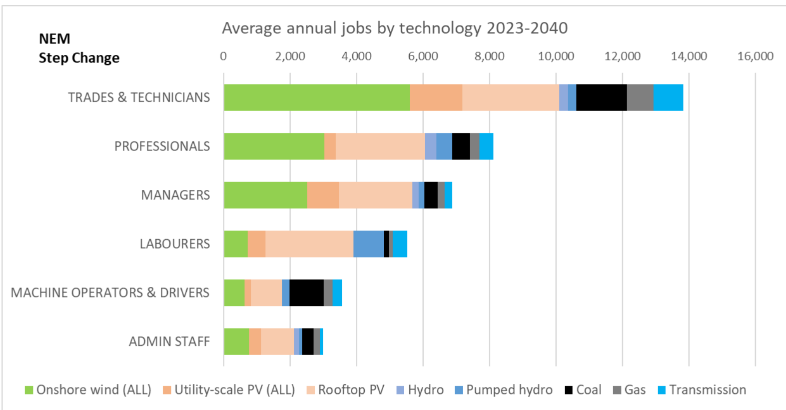
Demand is highest for trades & technicians, with almost 14,000 needed each year until 2040

The largest group of occupations is trades and technicians which average at almost 14,000 per year until 2040 under the Step Change scenario (Figure E7) [6]. The pattern of occupational demand is similar in the Hydrogen Superpower scenario, although the required numbers are consistently higher. The key trends across other occupational groups are:

- Professionals: around 8,000 per year until 2040 across a wide range of occupations including engineers, finance, health, and safety
- Managers (e.g., construction or operations managers): around 7,000 per year
- Labourers: over 5,500 per year, especially mechanical labourers
- Machine operators and drivers (e.g., truck drivers or crane operators): over 3,500 per year
- Administrative staff: 3,000 per year.

Occupational employment trends are important for the training sector and the community to understand what types of jobs will be required as a result of the energy transition.

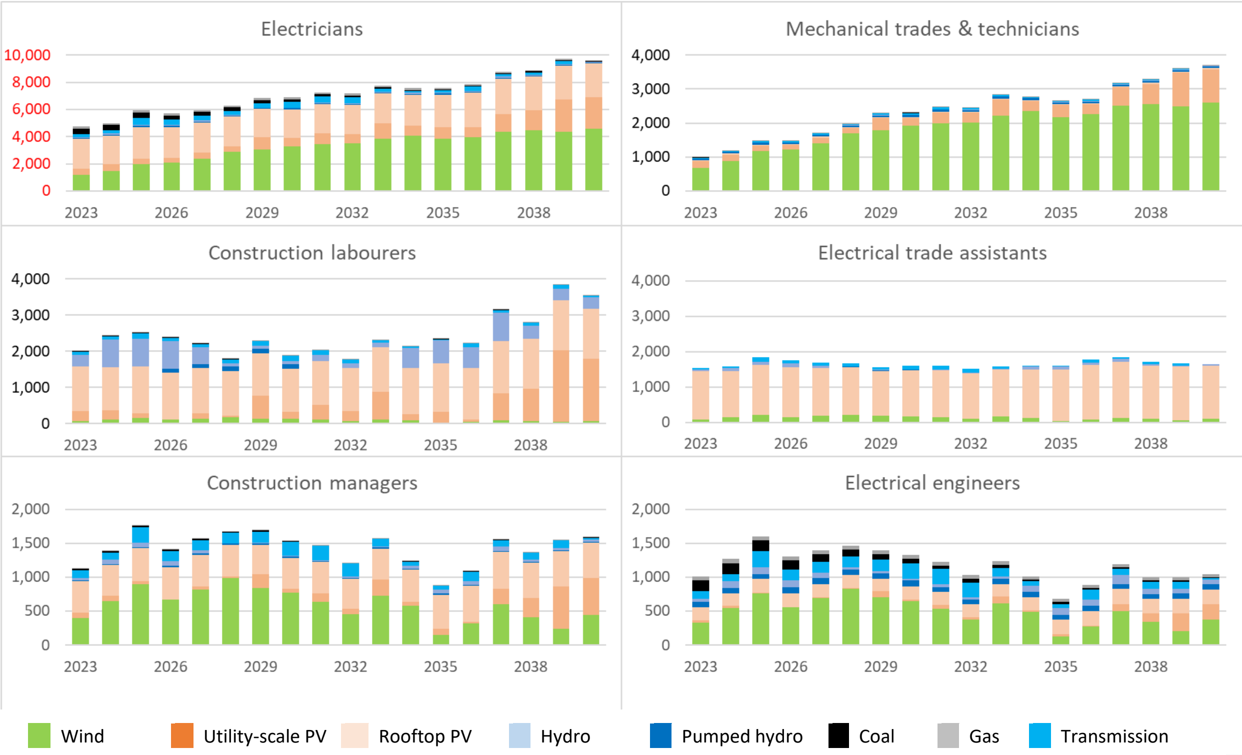
Figure E7 NEM, average occupational structure 2023 – 2040



[6] Overall numbers include both offshore wind and batteries, but these technologies are not included in the detailed occupational breakdowns, as robust data are not available for these technologies.

Average employment projections illustrate the bulk distribution of jobs between technologies but from the perspective of skills, training, and labour supply, the peaks in employment are the most important.

Figure E8 National Electricity Market, in-demand occupations annual employment, Step Change



Note different scales: electricians 0-10,000, construction managers/ electrical engineers 0-2,000, remainder 0-4,000

Annual requirements for the most in-demand occupations under the Step Change are shown in Figure E8. Those occupations needed in large numbers primarily during construction (such as construction labourers and electrical engineers) are very volatile. By 2040, there are nearly 10,000 electricians, almost 4,000 mechanical trades and technicians and around 3,500 construction labourers needed in the Step Change scenario. In the Hydrogen Superpower scenarios, these requirements are much higher, with more than 15,000 electricians and 7,000 mechanical trades needed.

NSW is the leading state for renewable jobs – but under a hydrogen superpower scenario most employment growth would occur in Queensland, South Australia, and Tasmania

NSW is the leading state for renewable energy employment, averaging 20,600 full-time jobs per year, followed by Queensland (18,000) and Victoria (11,800). The share by technology is very similar for the three largest states, with solar contributing 37%, wind 27%-30% and batteries 17%-22%. South Australia has a higher proportion of wind (37%), while Tasmania has a very different distribution, with 29% of jobs in hydro (Figure E9).

In the Step Change, Offshore Wind, and Slow Change scenarios, the distribution of total jobs between the States follow a similar pattern, with NSW having the greatest share, followed by Queensland, Victoria, South Australia and Tasmania. In the Slow Change scenario, average employment is lower across all states with NSW leading with just over 11,000 full-time jobs per year (Figure E10).

However, under the Hydrogen Superpower scenario, most of the employment growth is projected to occur in Queensland, South Australia and Tasmania and the employment distribution between states is notably different. Queensland has the highest average employment (41,000), more than doubling compared to the Step Change. Employment in South Australia more than triples compared to the Step Change scenario, with an average of 19,000 jobs, and South Australia overtakes Victoria and NSW from the early 2040s. Tasmania increases average employment by a staggering four times, from 2,100 to 9,400. By contrast, additional employment in NSW and Victoria in the Hydrogen Scenario compared to the Step Change is relatively modest (4000 to 5000).

Under the Offshore Wind scenario, the average employment is slightly lower overall than in the Step Change scenario, as more labour-intensive onshore wind and some solar farms are displaced.

Figure E9 National Electricity Market, average electricity jobs by State, 2023-2050 (Step Change)

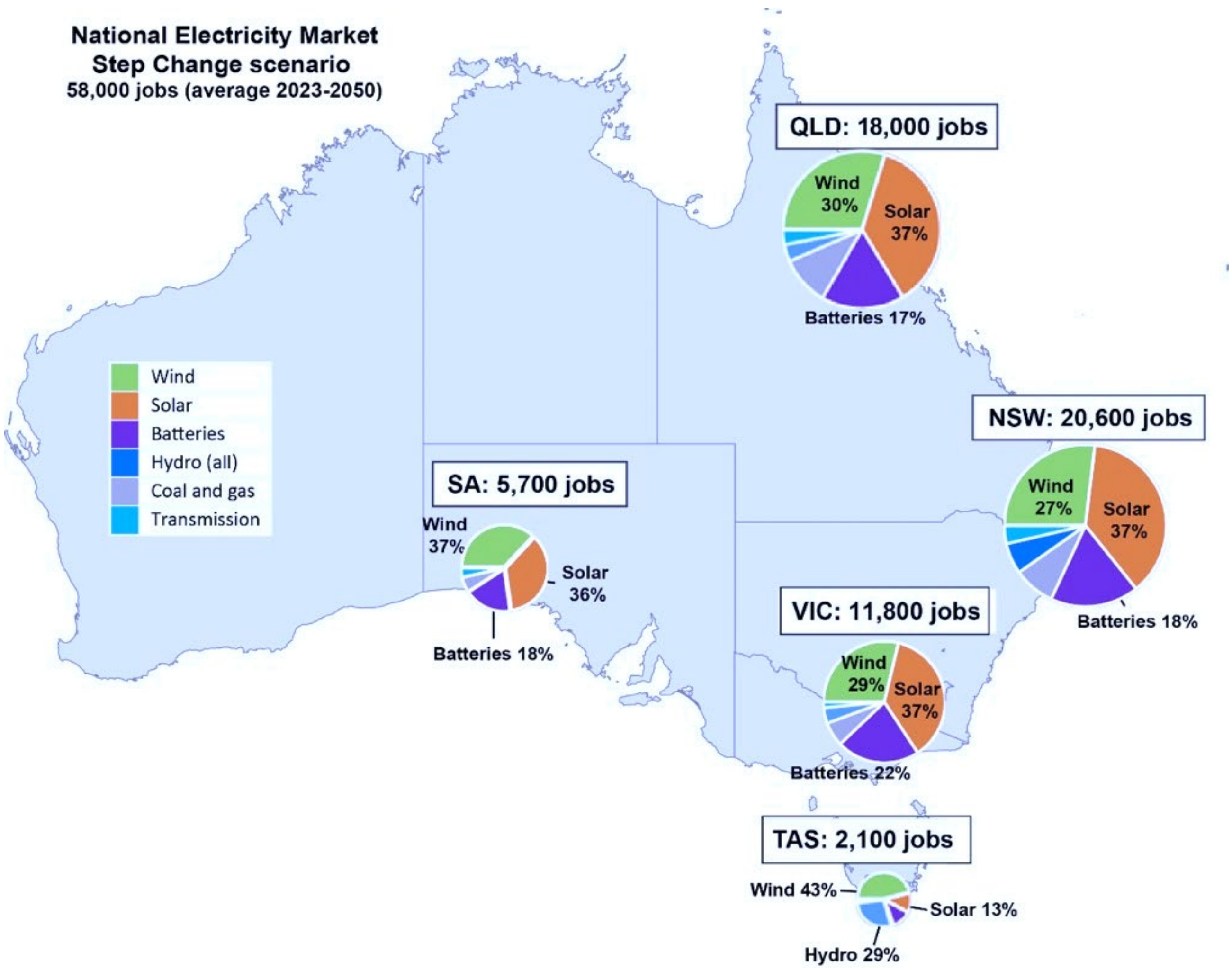
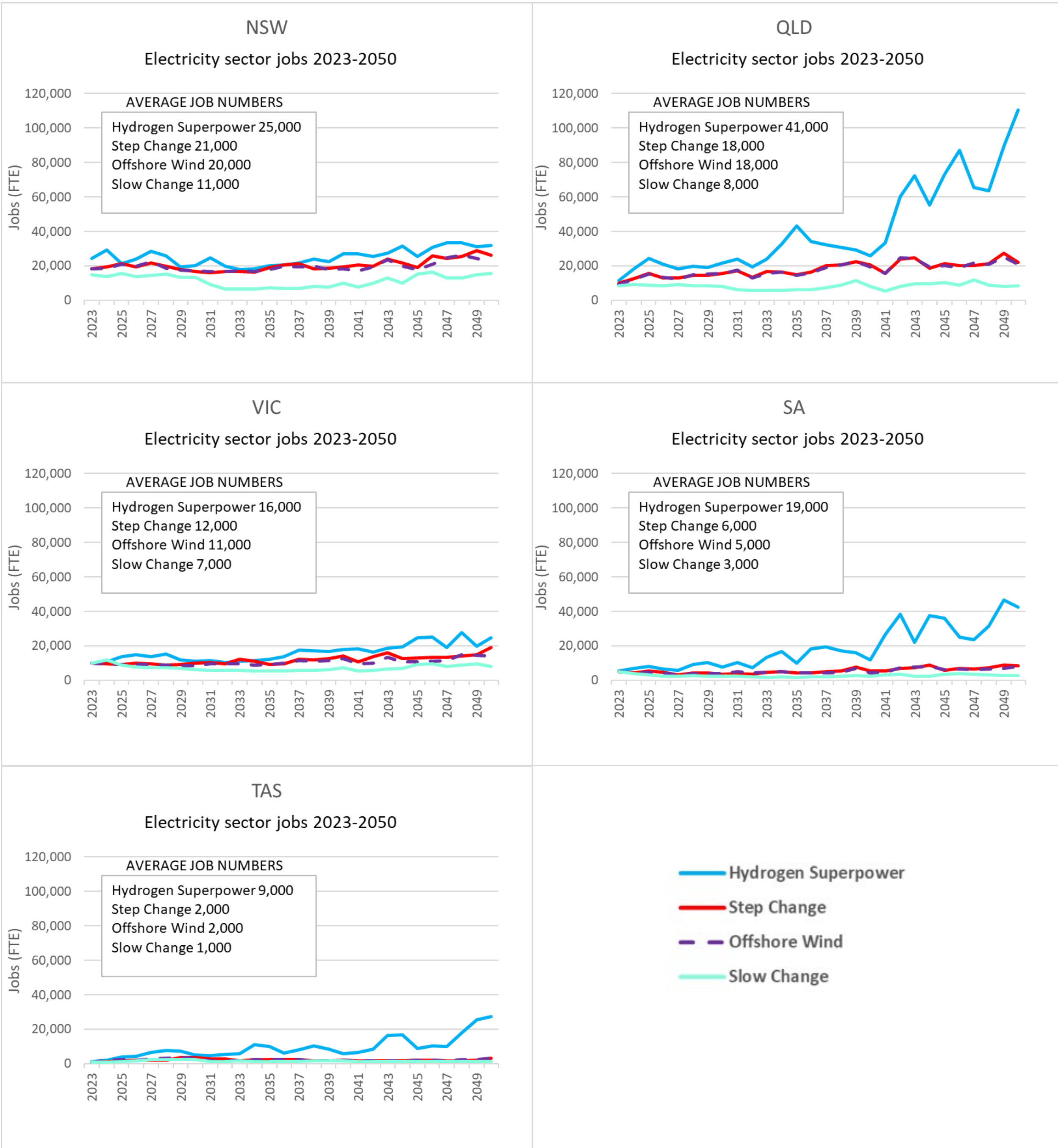


Figure E10 State electricity sector jobs by scenario



There is a major risk of skill shortages which will impact on the timing and cost of the ISP

The rapid increase in requirements for in-demand occupations brings with it a high risk of skill shortages which could impact on the achievement of the ISP's optimal development path. Skill shortages create the risks of delays, increased project costs (wage inflation, recruitment costs and liquidated damages), and increased cost of capital to reflect increased risk.

The build-out of renewable energy, transmission and storage infrastructure is occurring in the context of widespread skill shortages. Industry surveys and the National Skill Shortage Priority List have identified current shortages across a range of key occupations within renewable energy, including civil, electrical, and mechanical engineers, construction managers, electricians, and transmission lineworkers. In recent fieldwork[4] there was extensive testimony about current shortages from renewable energy and transmission industry and training stakeholders in NSW. Demand for electricians across the NEM rises by 1,000 in the Step Change scenario in the next two years, and by 2,000 in the Hydrogen Superpower. The labour market context for the development of renewable energy is also challenging:

- **Low unemployment** – unemployment rates are currently the lowest for decades, including in many of the Renewable Energy Zones (REZ).
- **Competing infrastructure builds** – Australia is in the midst of an 'unprecedented infrastructure boom', with shortages projected across 34 out of 50 public infrastructure occupations and peak demand for skills is 48% higher than supply[5]. This includes a peak deficit of 41,000 engineers and 15,000 structural and civil trades. The renewable energy sector will be competing with projects able to offer higher paying employment in capital cities, instead of remote locations.
- **Demand outstrips labour market supply in some REZs** – analysis of the NSW Renewable Energy Zones (REZs) found the peak demand for key occupations outstrips the entire workforce in some REZs[6]. Whilst regional labour markets vary, it is likely to be the case in many REZs that renewable energy employment demand in key occupational groups is very large relative to the existing local workforce. Low unemployment and occupational structure in regional labour markets will make it challenging to recruit labour from adjacent sectors.
- **The training gap** – rapidly increasing the labour supply in line with what is needed will be very challenging. The renewable energy and transmission sector is what is known in the training sector as a 'thin market' (low demand for training spread across geographically dispersed regions). It has also been subject to high levels of policy uncertainty which makes the economics of specialised training difficult and creates gaps in access to training. Even where there are established training pathways (e.g., electrical apprentices) there is a need for investment to increase capacity.

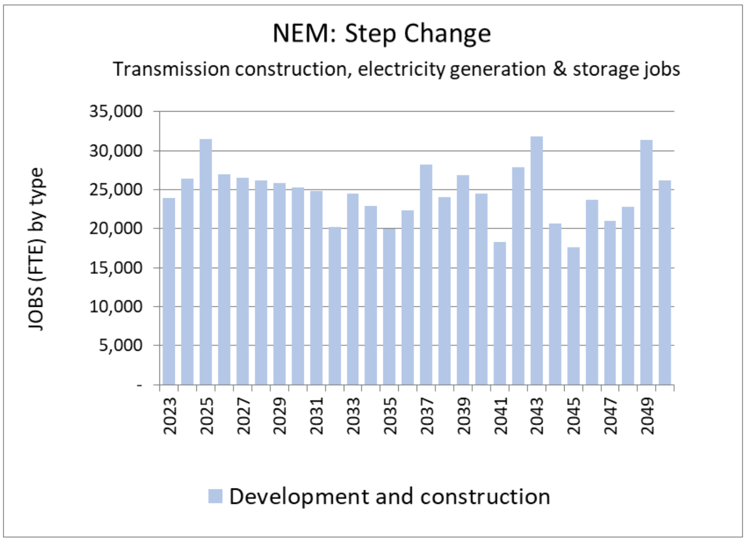
The REZs create a platform for government-industry collaboration on skills and workforce development but the states and regions are starting from a base of relatively low training capacity. Investment in training, workforce development and labour market programs are urgently required to increase the supply of skilled labour and local employment.

The boom/bust pattern of construction is a key risk factor for labour supply

The trajectory of the construction workforce needed to deliver the energy infrastructure for the energy transition in the Step Change scenario is subject to major upswings and downswings (Figure E11). Employment increases by 8,000 in just two years to 2025, again in the late 2030s, and has even greater jumps in the 2040s. These peaks are followed by drop offs, which can be very sharp. The Hydrogen Superpower has similarly volatile demand, only more extreme as the jumps and dips can be up to three times greater with variations of up to 46,000 in the space of two years.

This "lumpiness" creates significant risks for labour supply, as evidenced at present with the difficulties finding personnel to deliver projects. Risks are exacerbated by the competing demands for infrastructure build in other parts of the economy, and by the fact that much of the infrastructure is in rural areas. The peaks and troughs are disruptive for local economies with risks to social licence as communities experience the costs of sharp booms, such as housing shortages and inflation, with fewer ongoing jobs and economic growth. Analysis undertaken by AEMO Services Ltd for the NSW Government recommended a 'supply-chain adjusted' development pathway that included a maximum and minimum annual build to reduce volatility as the least-risk model[7].

Figure E11 Construction employment, Step Change scenario



In NSW, the schedule for the Long-Term Energy Supply Agreement auctions is being designed to reduce the volatility of renewable development. In Queensland and Victoria, state-owned entities offer an opportunity to explore smoothing the employment profile (reducing the scale of upswings and downturns) to reduce supply chain risks and support workforce development and local economic development.

Recommendations

There are several recommendations that could assist in reducing the boom/bust cycles that have characterised the development of renewable energy, and provide the information needed to develop the workforce for the energy transition. These are for:

1) AEMO to consult with ISP stakeholders on integrating employment profiles into the ISP.

2) AEMO to consult with ISP stakeholders on including sensitivities for capacity development that results in smoothed employment profiles in the ISP. This would allow a better understanding of the costs and benefits of reducing the volatility of employment demand.

3) Research bodies to undertake the required research to address gaps and maintain the accuracy of workforce projections, including:

   - Developing detailed occupational indicators for batteries and offshore wind to support training strategies
   - Regularly revisiting the employment indicators for major technologies, in particular wind and solar, with reference to the Australian industry
   - Developing better employment indicators for onshore manufacturing for key technologies (solar, wind, batteries), including occupational indicators to support training strategies
   - Undertaking supply chain analysis to determine more accurate projections for onshore manufacturing
   - Developing employment indicators where these are not currently available, including hydrogen production; renewable energy and fossil fuel decommissioning; and extraction and processing of critical minerals associated with the energy transition, in particular battery minerals (noting that employment creation in this sub-sector will be primarily driven by global rather than onshore demand)
   - Developing employment indicators, in tandem with suitable data sets for the energy efficiency and electrification tasks, to enable the inclusion of energy efficiency, demand and energy management, and electrification in the workforce projections.

Beyond the delivery of information to facilitate planning for workforce development, there is an urgent need for governments, training providers, and industry to take coordinated action to develop and implement skills, training, and workforce development strategies. This is particularly important in regional areas and the REZs to increase labour supply and create local employment and training opportunities. Employment and training should be designed to facilitate a rapid build-out and increase the equity of the energy transition, with any training or development initiatives including opportunities for First Nations people and communities most impacted by the energy transition.

Finally, it is worth noting that the energy transition is unlikely to align exactly with any one of the ISP scenarios, so policies development to prepare for the future energy workforce should be tested against a diversity of potential directions for the energy sector.

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1.1 List of abbreviations

Acronym	Term
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BAU	Business As Usual
CDPs	Candidate Development Paths
DER	Distributed Energy Resources
FTE	Full Time Equivalent
GW/GWh	Gigawatt / Gigawatt Hours
ISF	Institute for Sustainable Futures
ISP	Integrated System Plan
kW/kWh	Kilowatt / Kilowatt Hours
MW/MWh	Megawatt /Megawatt Hours
n/a	Not applicable
NEM	National Electricity Market
O&M	Operations & Maintenance
PV	Solar Photovoltaic
REZ	Renewable Energy Zones

1 Introduction

This report provides electricity sector workforce projections broken down by technology, occupation, and location for the 2022 Integrated System Plan (ISP) developed by the Australian Energy Market Operator (AEMO). Projections cover electricity generation, storage, and transmission construction.

The study was undertaken by the Institute for Sustainable Futures, University of Technology Sydney (ISF) in collaboration with AEMO. The project was funded by the RACE for 2030 Co-operative Research Centre and by the NSW and Victorian State governments. The project has benefited from an Industry Reference Group made up of state government, industry, and university representatives.

The report aims to give stakeholders, including state governments, training providers, and the electricity industry a better understanding of the employment implications of alternative electricity scenarios. This will enable the development of appropriate training plans, allow policy development to maximise regional and local benefits, allow planning to avoid skill shortages, and inform choices on alternative development paths associated with different scenarios. There is widespread consensus that we need good quality projections of energy sector employment by occupation and location in order to manage the energy transition and maximise benefits to the Australian economy[8].

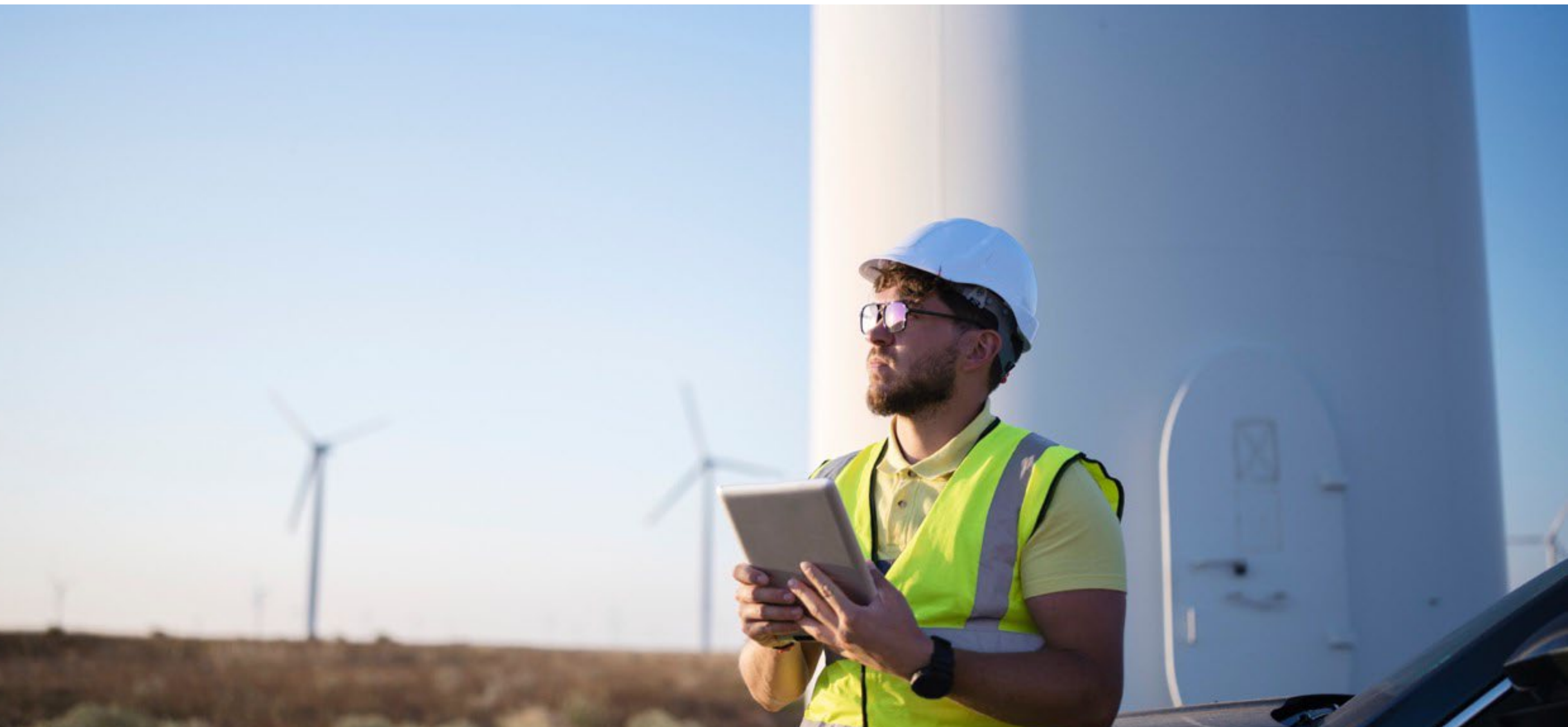
The workforce projections are for the 2022 Integrated System Plan, for three ISP scenarios and one sensitivity, namely the Step Change, Hydrogen Superpower, and Slow Change scenario, and the Offshore Wind sensitivity analysis. The projections cover the following:

- Coal generation (black and brown coal)
- Gas generation
- Wind (on and offshore)
- Solar (utility-scale and rooftop)
- Storage (batteries and pumped hydro)
- Hydro
- Transmission construction (but not maintenance).

The report is structured as follows:

- Section 2 gives the methodology, with supplementary information in Appendices A – D.
- Section 3 presents the results for the National Electricity Market (NEM), focussing on the comparison between scenarios.
- Section 4 presents the NEM results, focussing on a technology comparison
- Section 5 presents the results by state.
- Section 6 discusses the next steps and recommendations.

Accompanying this report are five summary documents giving the results for each state, including selected Renewable Energy Zones (REZs) within that state.



2 Methodology

2.1 Overview

The methodology undertaken in this study is consistent with standard techniques used to estimate energy sector employment internationally. An employment factor (full-time equivalent job-years/megawatt of installed capacity) is applied to the capacity (MW) constructed each year to estimate manufacturing and construction and development employment, while a factor for jobs per MW is applied to the cumulative capacity to determine operations and maintenance employment. The employment factors are reduced over time to reflect productivity improvements. This approach is summarised in Figure 1.

Figure 1 Employment calculation: methodological overview

Manufacturing employment for year	=	MW installed per year	x	Manufacturing employment factor for that year (job-years/MW)	x	% Onshore manufacturing
Construction employment for year	=	MW installed per year	x	Construction employment factor for that year (job-years/MW)	/	Average construction time
Operation and Maintenance jobs	=	Cumulative capacity	x	O&M employment factor for that year (jobs/MW)		
Fuel employment	=	GWh used per year	x	Fuel employment factor for that year (job-years/GWh)		
Employment factor for year	=	Base year employment factor	x	Technology decline factor for year (equals CAPEX for year / CAPEX for base year)		

The calculation itself is simple, although the robustness of the results is entirely dependent on the accuracy of the employment factors (Section 2.4) and the capacity projections (Section 2.2).

What is a job and a job-year?

When we calculate jobs, it is done differently for work that is linked to a time-limited project (construction) and work that is ongoing.

Construction and manufacturing jobs depend on what is being built, and finish once it is complete. Of course, construction workers may move from one project to another and be in continuous employment, but that depends on more of whatever it is being built. These jobs are calculated in job-years per MW, where one job-year could be one person working full time for a year, four people working full time for three months, or six people working full time for two months. They are full time equivalent (FTE).

Maintenance jobs are presented as jobs per MW and are also presented as FTE. One job per MW could be one person full time or two people half time, but it is assumed that these continue indefinitely each year, so they are calculated in jobs per MW.

Fuel supply jobs are calculated using jobs/GWh. This is the employment created by coal mining or gas production to produce one GWh of electricity and will vary depending on how much the power station generates, unlike the operations and maintenance workforce, which is likely to be fixed.

The total jobs given for each year considered is the FTE sum of people working on construction projects, operations and maintenance, manufacturing, and fuel supply for coal and gas generation in that year, regardless of whether that job will continue the next year.

2.2 The energy scenarios

This report develops electricity sector workforce projections based on AEMO's 2022 ISP. The ISP provides a comprehensive roadmap for the NEM to support Australia's highly complex and rapid energy transformation towards net zero emissions. It serves the regulatory purpose of identifying actionable and future ISP projects, as well as the broader purposes of informing market participants, investors, policy decision makers, and consumers.

The ISP draws on extensive stakeholder engagement and power system expertise to develop a roadmap that optimises consumer benefits through a transition period of great complexity and uncertainty. A Draft 2022 ISP was published in December 2021, receiving broad endorsement along with valuable suggestions for input assumptions and other improvements. The final 2022 ISP was published on 30 June 2022.

The ISP considered four scenarios for energy transformation on the path to reach net zero by 2050: Slow Change, Step Change, Progressive Change and Hydrogen Superpower.

This report presents four scenarios for the electricity sector workforce:

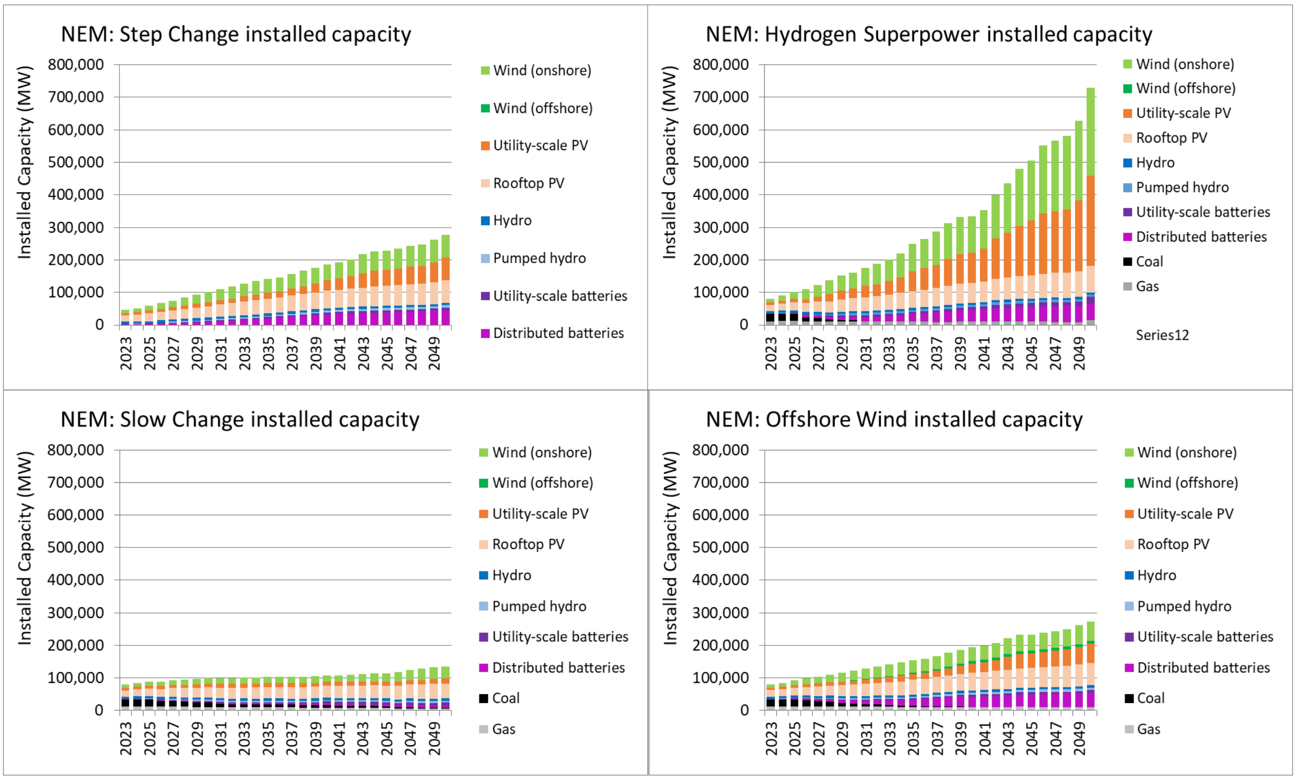
- **Step Change**: renewables generate 83% of NEM electricity by 2030. This scenario initially moves fast to align with the Paris agreement to limit global temperature rise to below 2°C and considers stronger global policy commitments and favourable market developments (for example rapidly falling technology costs and increased digitalisation). By 2050, electrification of heating and transport is almost complete while domestic hydrogen production scales up after 2040. Energy stakeholders consider this the most likely scenario. The NSW Electricity Infrastructure Roadmap is broadly aligned with this scenario and during this project, Victoria and Queensland released energy plans similarly aligned.
- **Hydrogen Superpower**: this scenario is the most ambitious and is included to show the most extreme end of projected workforce requirements. The energy scenario anticipates strong global action and significant technological breakthroughs. The Hydrogen Superpower nearly quadruples NEM energy consumption to support both a hydrogen export industry and decarbonising the country's domestic industry and household consumption.
- **Slow Change:** this is the least ambitious scenario and assumes a challenging economic environment following the COVID-19 pandemic, with much slower net zero emissions action failing to meet national and international climate commitments. Consumers continue to manage their energy needs through distributed energy resources (DER), particularly distributed PV. The Slow Change scenario is considered unlikely but was included as it offers the greatest contrast to the other scenarios.

- **Offshore-wind:** this is a sensitivity of the Step Change scenario in the ISP, rather than a standalone ISP scenario. The scenario takes account of the Victorian Government's Offshore Wind Policy Directions Paper[9] and their target to build 9GW of offshore wind by 2040 and assumes a lower cost for offshore wind. Offshore wind displaces onshore wind and utility-scale solar and reduces the overall capacity needed (by 2050 there is 13 GW (10%) less generation capacity in the NEM in this scenario).

The installed capacities for each workforce scenario are shown in Figure 2, and are available in AEMO's generation outlook[10].

The **Progressive Change ISP** scenario was not included in the workforce projection as initial modelling indicated very similar employment outcomes to the Step Change scenario.

Figure 2 Capacities installed under the four ISP scenarios



2.2.1 Additional data on capacities

Some additional data is required for the employment calculations which are not contained in the ISP:

- **Historical data to calculate yearly installed capacity:** the previous years' cumulative capacity for each technology is required in order to calculate construction employment, as the ISP only commences in 2023-24. The installed capacity for each technology and region is entered into the model for 2024, sourced from the 2022 ISP[11], and is common to every scenario. The 2023 total is taken as the average between the 2022 data and the 2023-24 projected total for the Step Change scenario.

- **Historical data to calculate fuel employment:** 2023 fuel use is required in order to calculate fuel employment for coal and gas generation in 2023. This is calculated by projecting the average change between 2024 and 2026 for one year (in all cases this has resulted in increased fuel use in 2023).

- **Disaggregated pumped hydro and utility batteries data:** while the ISP projections combine totals for utility storage, the employment projections require capacities separated into pumped hydro and utility batteries, as the employment profiles for the two differ. AEMO supplied the data in disaggregated form by state and scenario, based on a high-level assumption that long-duration storage would be pumped hydro and short-duration storage would be battery[12].

- **REZ project data:** cumulative capacity is given in the ISP for wind and solar by REZ[13]. However, this does not include utility-scale storage or pumped hydro, nor give an indication of historic capacity already installed in the REZs. Historic capacity has been sourced from AEMO's generation information dataset, with projects identified as 'existing plant' allocated to historic capacity[14]. Project capacities have been allocated to individual REZs as far as possible by examining 'committed' and 'publicly announced' projects noted in the AEMO dataset, identifying their locations via google search, and comparing these capacities to the ISP projections. Where it has not been possible to match ISP projections to identified projects – either due to a capacity mismatch or where multiple projects have the same capacity but are associated with different REZs – the additional capacity will appear in "Rest of State". Appendix C – Additional information – REZ project allocation gives the allocations of ISP projected capacity to individual REZs.
- **Post ISP data:** capacity increases post 2050 are needed in order to calculate construction and manufacturing employment for 2045 to 2050[7], while the ISP gives a projection to 2050. Capacities for all technologies have been extended forward to 2055 using the average growth rate for 2046 to 2050.

2.3 Transmission construction

Transmission construction has been modelled based on AEMO's 2022 ISP least cost Candidate Development Paths (CDPs) for the Step Change, Hydrogen Superpower, and Slow Change scenarios. These are CDP2 for the Step Change, CDP12 for the Hydrogen Superpower, and CDP5 for the Slow Change. CDP2 is also used for the Offshore Wind employment scenario as the Offshore Wind is a sensitivity to the Step Change scenario.

Transmission projects have been allocated to REZs if they are directly related to the establishment of new renewable energy generation in a REZ. For example, the Central-West Orana loop is a transmission line that is constructed specifically for the Central-West Orana REZ and so has been allocated to this REZ. Interconnectors that run across

[7] The longest construction period is for pumped hydro, so pumped hydro capacity coming online up to 2050 would impact the workforce projection, while wind and solar only draw on data to 2053.

state borders, like Energy Connect or QNI connect, have been divided between states according to the kilometres of line in each state, and the location of substations have been allocated to states and REZs accordingly. The construction end date for transmission line and non-line asset construction has been allocated according to project commissioning dates provided by AEMO; start dates are assumed to be 4 years prior to commissioning.

Employment factors have been derived for transmission lines (FTE jobs per km of line) and non-line assets (FTE job-years per $ million) and then multiplied by the total kilometres of line or the cost of assets constructed in each location. Data on total kilometres of line for each transmission project was provided by AEMO, with some additional data provided by network participants. For more information on the transmission line and non-line methodology, and the derivation of the employment indicators, refer to Briggs et al. (2022)[15].

2.4 Employment indicators – summary

Table 1 details the employment factors and construction time for the generation and storage technologies modelled in this study, while Table 2 lists the transmission employment factors.

Only offshore wind and utility batteries have been materially changed for this work; most of the other employment factors come from a series of surveys undertaken for the Clean Energy Council in 2020[16] and Infrastructure Australia in 2021[17]. Appendix A gives information on the derivation of the utility batteries employment factor and compares the offshore wind employment factor used here to others.

The factors used in 2020 have been reduced to reflect the CAPEX reduction in the intervening two years, using the decline shown in the table (see Section 2.5 for a discussion of decline factors).

Table 1 Employment factors – all generation and storage technologies

	Build time	Decline relative to 2020 EF	Construction/ installation	Manufacturing		O&M	FUEL
				Total	On-shore		
	Years		Job-years/MW			Jobs/MW	Jobs/GWh
Black coal [a, b]	5	1%	11.1	5.4	3.32	0.22	0.04
Brown coal [a, b]	5	1%	11.1	5.4	3.32	0.22	0.01
Mid-merit gas [a, b]	2	1%	1.3	0.9	0.38	0.14	0.07
Peaking gas & liquids [a, b]	2	1%	1.3	0.9	0.38	0.14	0.11
Wind (onshore) [c, b]	2	6%	2.7	1.6	0.38	0.22	0.00
Wind (offshore) [d]	3	n/a	1.4	5.3	0.38	0.08	
Utility-scale PV [e, b]	1	10%	2.1	3.9	0.09	0.11	
Rooftop PV [e, b]	1	9%	5.2	3.6	0.15	0.16	
Utility-scale batteries [f]	1	n/a	0.6	0.6	0.09	0.04	
Distributed batteries [g, b]	1	6%	5.3	0.6	0.09	0.27	
Pumped hydro [h, b]	4	0%	7.2	3.5	0.70	0.08	
Hydro [h, b]	5	0%	7.4	3.5	2.21	0.14	

Employment factors notes

a) Coal and gas factors from Rutovitz et al. (2015)[18] assume 30% of manufacturing occurs onshore.

b) Construction and manufacturing factors are reduced by the decline listed. O&M factors are not reduced.

c) Onshore wind construction, O&M, and domestic manufacturing factors from Rutovitz et al. (2020)[19]. International manufacturing factors from IRENA (2017)[20].

d) Offshore wind factors for construction and installation and O&M from Sylvest (2020)21. Construction time from BVG Associates, 201922. Proportion of Australian manufacturing assumed to be 17.5%, midway between upper and lower bound in Briggs et al. (2021)[23].

e) PV factors for construction, O&M, and domestic manufacturing factors from Rutovitz et al. (2020)[24]. International manufacturing factor from IRENA (2017)[25]
f) Utility batteries employment factors for construction and O&M derived from data for 14 Australian projects, and for manufacturing from eight studies (see Appendix A). Assumes 15% of manufacturing occurs onshore.

g) Distributed batteries construction and O&M from Rutovitz et al. (2020)[26]. International manufacturing derived from eight studies (see Appendix A). Assumes 15% of manufacturing occurs onshore.

h) Pumped hydro factors for construction and O&M from Rutovitz et al. (2020)[27]. Hydro construction and international manufacturing from Rutovitz et al. (2015). Assumes 20% of manufacturing occurs onshore.

Table 2 Employment factors – transmission construction

	Unit	Construction/ installation
Transmission line: single circuit	job-years/km	0.66
Transmission line: double circuit	job-years/km	3.68
Transmission (other)	job-years/$m	1.85

Source: Employment factors from a 2021 survey for Infrastructure Australia, described in Briggs et al. (2022)[28]

2.5 Decline factors

Renewable energy technologies are still experiencing significant cost declines. While there may not be an exact correspondence with employment creation, experience suggests that construction and manufacturing employment broadly declines in line with overall cost reductions. Note that this does not imply that wages decline, but the time taken to install (or manufacture, or maintain) each MW goes down alongside the cost.

For example, one of the major drivers of the decline in wind technology cost is the size of the turbine, which have gone from around 0.5 MW per turbine to closer to 3 MW in the last two decades. The employment created per MW will have an associated decline; while there will be additional work to install the larger turbine, it will certainly not be six times as great.

As determining the exact relationship between overall cost decline and employment would be subject to many assumptions, we instead apply the cost decline to the calculated employment factors for construction and manufacturing. The employment factor for a particular year is then equal to the base year factor multiplied by the decline factor, or the percentage of CAPEX remaining in that year.

$$Decline\ factor\ for\ year\ X = \left(\frac{technology\ cost\ (yr\ x)}{technology\ cost\ (base\ yr)}\right)$$

This is then used to calculate an employment factor for each year:

$$Employment\ factor\ (yr\ x) = Employment\ factor\ (base\ yr)\ \text{x decline factor (year x)}$$

The decline factors are calculated from the AEMO cost projections for each technology and scenario. We note that the declines are greater in those scenarios which install more capacity. For example, the cost of utility-scale solar declines by 28% by 2040 in the Step Change scenario, compared to a 63% decline in the Hydrogen Superpower scenario and only 42% in the Slow Change scenario. We assume that this decline also applies to the job creation per MW. The actual values calculated are given in Appendix B, Table 10 to Table 12.

Where the employment factor is based on a 2020 datapoint, the cost decline between 2020 and 2022 is used to adjust the 2020 factor. This cost variation is based on CSIRO GenCost 2021-22[29], as the current AEMO ISP does not give historic CAPEX. The calculated declines for the two years are shown in Table 1.

2.6 Occupational structure

The occupational employment projections are based on indicators developed in the 2020 renewable energy survey[30] and the 2021 transmission construction survey[31]. Survey data was used to estimate the proportion of total employment accounted for by each of the identified occupations. These occupational employment factors are only available for the following technologies:

- Onshore wind
- Utility-scale PV
- Rooftop PV
- Pumped hydro (hydro is assumed to be the same)
- Coal and gas (covering fuel supply and power station operations and maintenance)
- Transmission line, sub-station, and associated asset construction

Occupational indicators were not calculated for manufacturing.

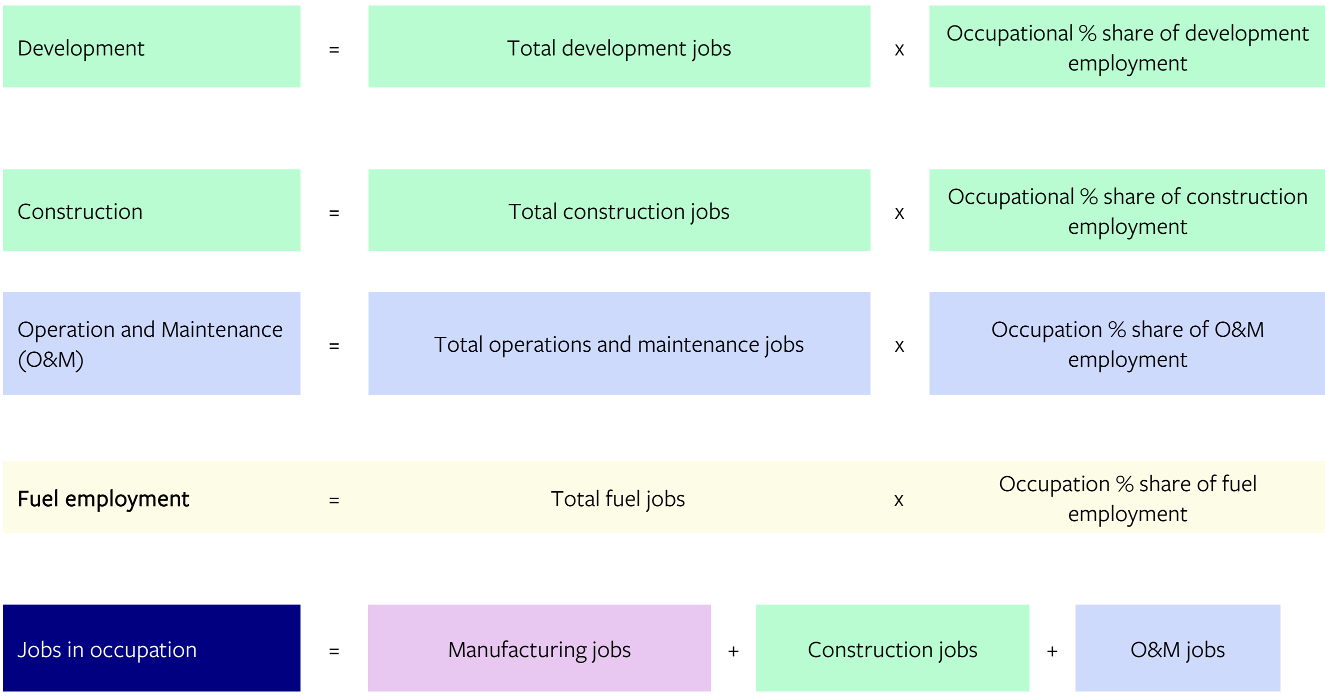
A weighting was applied to the occupational breakdowns for each project phase based on their share of the employment factor. Construction, for example, is a larger share of total employment so a higher weighting was applied to its occupational mix in calculating the overall occupational composition for each technology.

Occupational employment was estimated at two levels based on the Australian and New Zealand Standard Classification of Occupations (ANZSCO):

- 1-digit (managers, professionals etc);
- Composite: either a 2-digit, 3-digit or 4-digit level occupation was selected depending on size and common understanding (e.g. electrician)

The occupational employment indicator is applied to the total jobs for each phase and technology to calculate, for example, the number of electricians working on pumped hydro construction (as illustrated in Figure 2). The indicators are applied to the total employment numbers for each technology by phase, to calculate the occupational mix for the renewable energy industry as a whole (noting that this does not include batteries or offshore wind, nor manufacturing employment).

Figure 3 Occupational employment calculation overview



2.7 Repowering

Repowering is replacing wind turbines or solar panels, either at the end of their life, or because technology improvements mean that the replacements are sufficiently higher performance to make replacement economic.

Repowering has been included in the model for onshore wind, utility-scale PV, and rooftop PV. Employment factors and construction times are assumed to remain the same.

Calculating the capacity to be repowered requires using historic data for these technologies for the relevant repowering time. This has been taken as 20 years for large scale wind and solar. All previously installed capacity is assumed to be repowered, as it is likely that any utility-scale facilities will be actively managed to maximise output. While some repowering may occur later than 20 years, it is reasonably likely that some repowering will occur earlier in order to take advantage of improvements in turbine efficiency.

Rooftop solar has not been included in repowering calculations previously, and examination of the literature found no reference to domestic repowering. It is difficult to determine the proportion that will be repowered, and at what time interval. A review of recycling put the likely lifetime at 30 years, and the proportion to be recycled at greater than 99%[32], although there was no discussion of whether those installations would be repowered. We have assumed 80% repowering and a lifetime of 25 years. Varying the lifetime from 25 to 30 changes the time at which repowering comes into effect, from 2032 to 2037 (we do have installation data pre-2007). The impact of changing the lifetime is not great, as prior to 2010 the annual solar capacity installed was below 100 MW (about 200 job-years of employment for repowering), followed by seven years where it was relatively level between 600 to 900 MW/year. By 2042, the employment created is almost the same whether 25 or 30 years is used.

2.8 Caveats and omissions

This report includes a workforce projection from 2023 to 2050, while ISF's earlier employment projections have generally gone no more than 15 years into the future[33,34]. In this work, as the ISP projects capacity to 2050, it was determined to include employment projections to 2050. These should be treated as indicative only, as any inaccuracy in either inputs or assumptions is likely to be exaggerated by a projection of 27 years. Workforce productivity changes over the next three decades may well go beyond the declines projected for cost; for example, the introduction of robotics in solar farm installation[35] may reduce the associated labour in a step change rather than a gradual decline. The projections here do not take account of this type of technological change, which may have a significant impact 27 years hence.

The report assumes that the current level of onshore manufacturing for the included technologies will persist for the study period. However, the opportunities offered by increasing onshore manufacturing as part of the energy transition are being actively investigated by Australian governments and other stakeholders. A sensitivity for an increased share of manufacturing is explored in Section 3.2.

The projections here are specifically for the ISP scenarios, so any limitations in those scenarios will be carried through to the workforce projection. State renewable plans or targets published after the ISP completion are not included.

The ISP only covers the National Electricity Market, so the employment modelling does not include Western Australia or the Northern Territory, nor the off-grid renewable energy developments associated with energy exports or mine sites. Both WA and NT have similar net zero trajectories, and off-grid renewables are projected to grow dramatically, further increasing the workforce demand for the energy transition.

There are several modelling omissions:

- Occupational forecasts do not include occupational breakdowns for offshore wind or batteries, as these are not available at sufficient granularity to include these technologies. It would be beneficial if these sectors were surveyed in order to collect data on the occupational composition. The breakdown of occupations for manufacturing is also not included for any technologies, as these breakdowns are not available.
- The employment projections do not include the mining or mineral processing for renewable energy technologies, professional services outside the renewable energy industry (for example regulators), nor the employment associated with decommissioning and recycling.
- Hydrogen is only partially included. The bulk of employment associated with the development of green hydrogen is likely to be associated with the renewable energy (primarily wind and solar) used as the energy input. That employment is included here as it is part of the ISP scenarios. However, the additional employment associated with the hydrogen production process and supply-chain (for example, electrolysers to produce the hydrogen, transport, and distribution) is not included. Robust employment indicators are not available as the industry is at an early stage of development, and the specific characteristics of the hydrogen landscape are still unknown – for example, the means of transport, or the proportion of onshore use.
- Employment projections do not include energy efficiency, energy and demand management, and electrification, although this workforce would be very significant. Energy efficiency and electrification are inputs to the ISP and feed into determination of electricity consumption in each scenario as GWh/year electricity savings (energy efficiency) or GWh/year consumption (for electrification)36. Determining the associated employment would need the development of a set of suitable indicators, such as employment per GWh or per $m by sector and broad category of action. Sufficient data on the actual efficiency actions envisaged would also be needed. This is a challenging task, as the labour requirement will differ both by sector and by implementation.

3 Sector workforce projections for the National Electricity Market

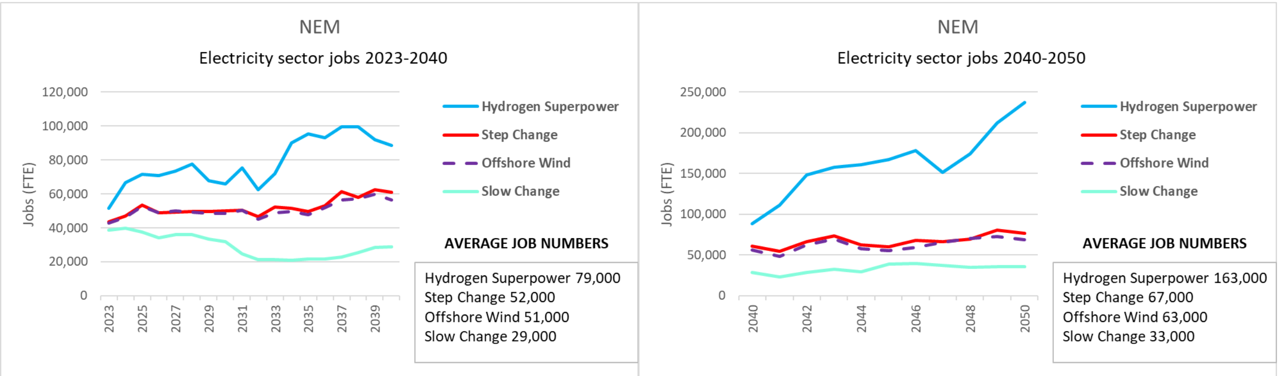
3.1 Electricity Sector Workforce Projections – by scenario

The peak electricity sector workforce under the Hydrogen Superpower scenario would be up to double the peak workforce under Step Change and Offshore Wind scenarios in the 2030s and up to three times higher in the 2040s. Employment projections for each of the four workforce scenarios are presented in Figure 4:

- Under the Step Change scenario, employment averages 52,000 from 2023 to 2040, increasing by 19,000 from 2023 to peak at 63,000 jobs in 2039. Jobs average 67,000 from 2040 to 2050, increasing gradually to a peak of 81,000 in 2049.
- Under the Hydrogen Superpower scenario, employment averages 79,000 up to 2040, with a peak of 100,000 in 2037. Even more dramatic growth occurs in the 2040s, reaching an employment peak of 237,000 in 2050. Planning for this scenario would need to start very rapidly, as the workforce in 2023 would already need to be 8,000 higher than the Step Change to deliver the increase in capacity in 2024 shown in the ISP.
- Under the Slow Change scenario, employment falls from close to 40,000 to a low of 21,000, averaging 29,000 from 2023 to 2040 as the pace of energy transition slows. Job numbers increase slightly during the 2040s, with an average of 33,000.
- Offshore Wind has almost the same total employment as the Step Change scenario, with a lower average of 51,000 up until 2040, and 63,000 from 2040 to 2050. This reflects displacement of a somewhat larger quantity of more labour intensive onshore wind and utility-scale solar.

While this report includes workforce projections from 2023 to 2050 in line with the ISP, later years should be treated as indicative only as they are 27 years hence. There may be step changes in labour productivity in that timescale, for example resulting from construction automation, rather than the gradual increase anticipated in these projections.

Figure 4 National Electricity Market, electricity sector jobs by scenario



Peak employment in the Hydrogen Superpower is between three and five times greater than in the other scenarios, so it is difficult to see variations in those scenarios if all are compared side by side. The rest of this section will compare the Step Change to the Slow Change and then to the Hydrogen Superpower in graphical representations, noting that the Step Change scenario is widely considerd the most likely. The variation between the Step Change and the Offshore Wind scenarios is extremely small when considering the National Electricity Market as a whole, so the the rest of this section will not present graphical results for the Offshore Wind scenario (results for the Offshore Wind scenario are presented in Section 4.1 and Section 5).

Figure 5 and Figure 6 show the total employment by whether it is construction, manufacturing, operations and maintenance, or fuel supply for Australian coal and gas generation (note that this does not include coal or gas production for export). Under all scenarios, construction dominates the employment profile through the 2020s but ongoing operations and maintenance (O&M) employment gradually increases as the fleet of renewable energy generation and storage increases.

In all scenarios, O&M employment is greater than 50% by 2050, varying from 51% in the Hydrogen Superpower to 64% in the Step Change scenario.

Manufacturing is projected to contribute only a small proportion of employment, around 3% on average in all scenarios, as very little manufacturing occurs onshore at present. In the Step Change scenario, manufacturing varies between 800 and 2,500, as the amount of construction varies. The effect of increasing onshore manufacturing is explored in section 3.2.

Employment in gas and coal production for Australian power generation is also shown and declines over the period as fossil fuel generation declines in all scenarios, from about 4,000 currently, to close to zero (noting that this does not include employment associated with coal and gas for export).

Figure 7 and Figure 8 show the breakdown between renewable generation, fossil fuel generation, storage, and transmission construction. Most of the employment growth in all scenarios is produced by renewable energy. The proportion of renewable energy jobs is close to 50% in all scenarios in 2023 and reaches between 80% and 90% by 2050.

Figure 5 National Electricity Market, jobs by phase (Step Change & Slow Change)

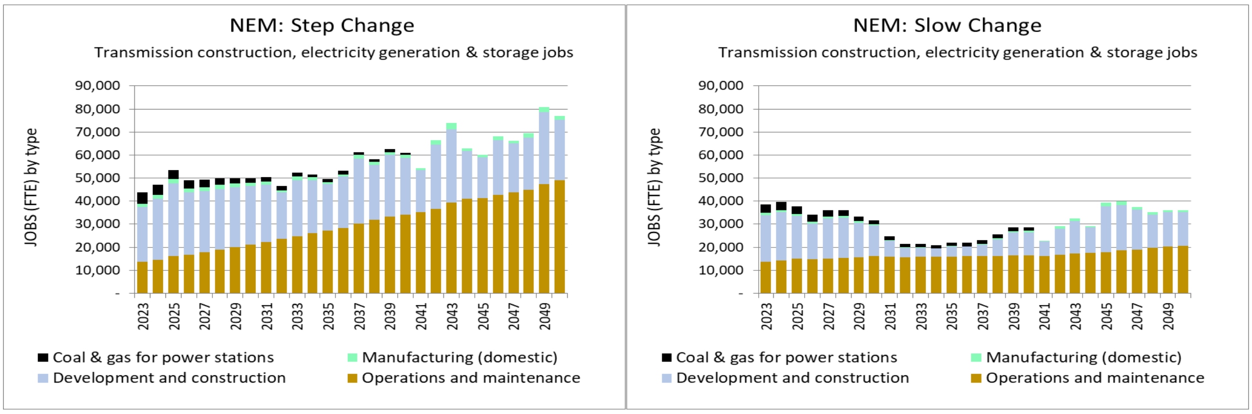


Figure 6 National Electricity Market, jobs by phase (Step Change & Hydrogen Superpower)

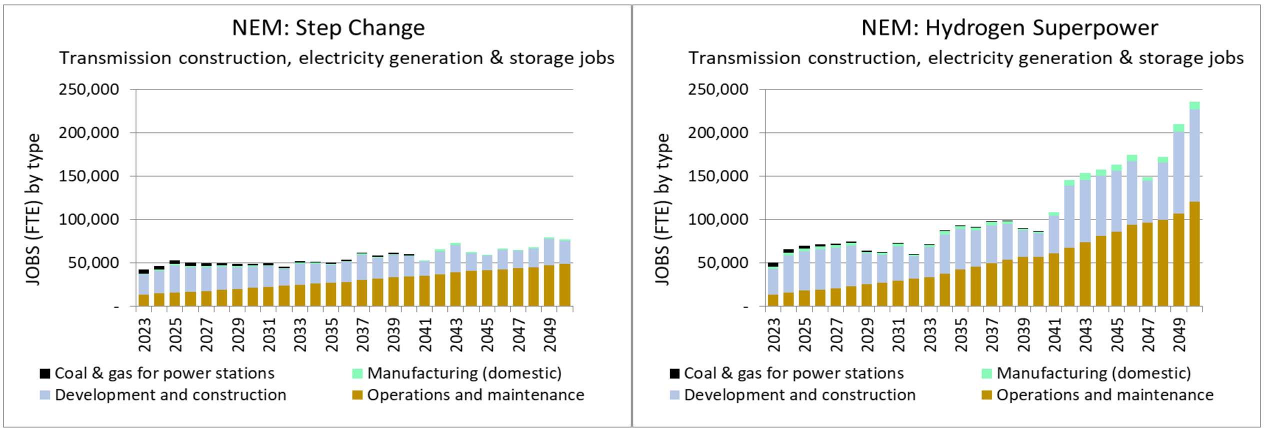


Figure 7 National Electricity Market, jobs by technology group (Step Change & Slow Change)

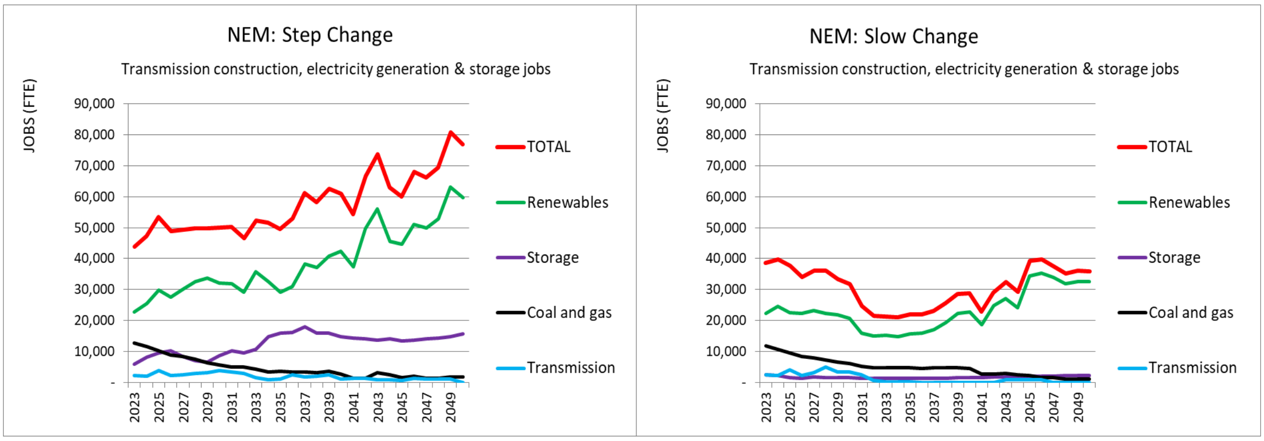
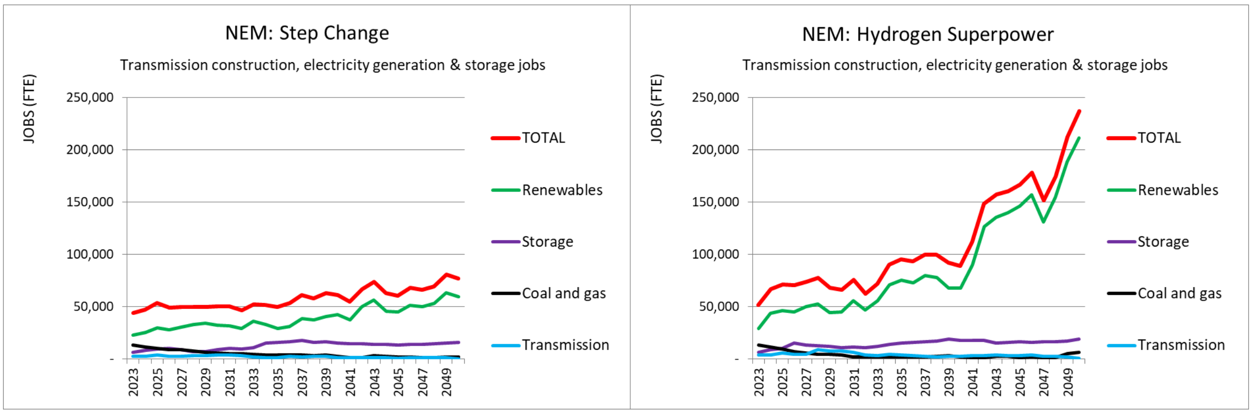


Figure 8 National Electricity Market, jobs by technology group (Step Change & Hydrogen Superpower)



The numbers of jobs added varies significantly by scenario, particularly by the end of the projection period. Taking the 2023 total in the Step Change scenario (44,000) as the reference point for all scenarios, in 2030 in the Step Change there are 6,000 additional jobs (33,000 by 2050), in the Hydrogen Superpower scenario there are 22,000 additional jobs in 2030 (193,000 by 2050), in the Slow Change scenario there are 12,000 **fewer** jobs in 2030 (8,000 fewer by 2050), and in the Offshore Wind scenario there are 5,000 additional jobs in 2030 (25,000 by 2050). Fossil fuel employment falls in all scenarios, to close to 1,000 jobs by 2050.

3.2 Manufacturing: sensitivity with active policies to increase onshore share

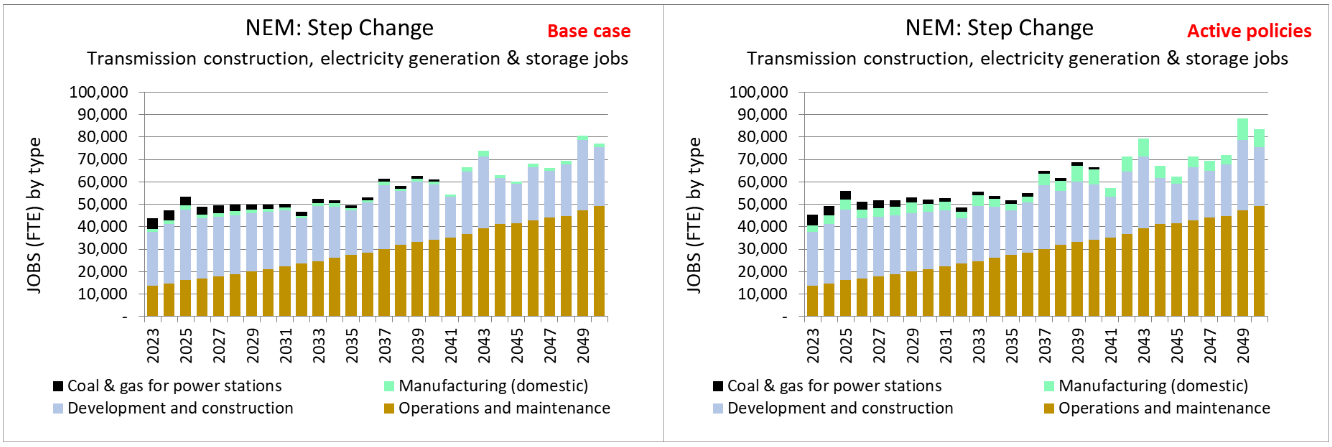
The proportion of total manufacturing for each technology that occurs onshore in the projections presented here is based on the findings of an industry survey in 2020[37], and are conservative numbers. Australian governments and other stakeholders are considering implementing policies to increase the proportion of manufacturing which occurs onshore. For example, the tender guidelines for the NSW REZs require a baseline of 40% of the value up to commissioning for wind and 49% for solar, with a stretch target of between 72% and 81% and specific targets for steel components[38], and the NSW government has announced they will establish a Renewable Manufacturing Fund[39].

We have therefore considered a sensitivity where the onshore manufacturing is increased. Table 3 gives the base case and enhanced proportion for onshore manufacturing. In the base case, the proportion remains constant throughout the study period, while in the 'active policies' results, the proportion is assumed to increase gradually until 2030, and then remain constant.

Table 3 Base case and enhanced manufacturing (percentage of total occurring onshore)

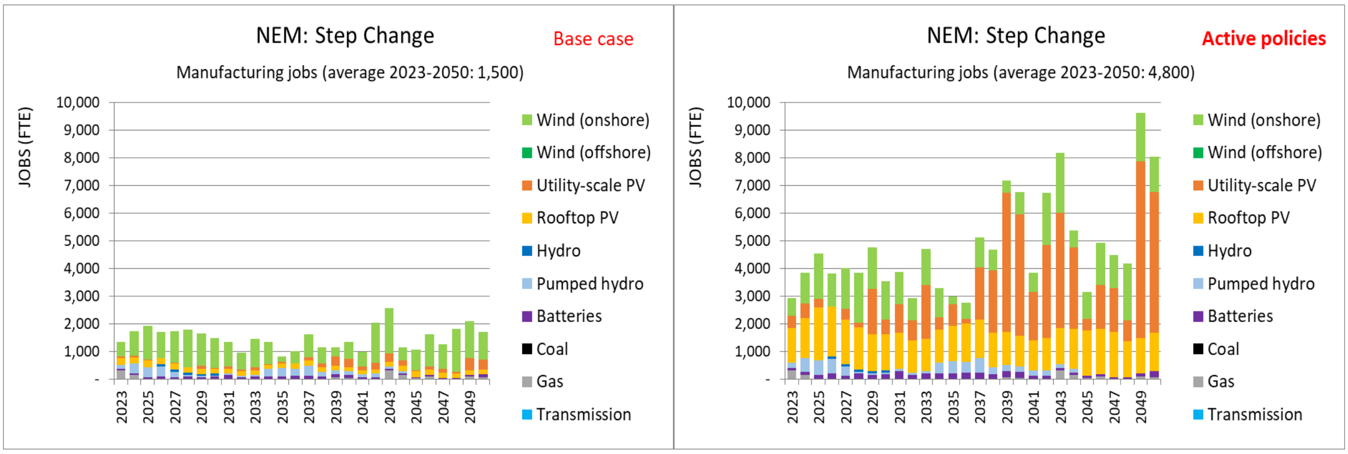
	Base case		Increased manufacturing	
	2020-2050	2020	2025	2030-2050
Coal	30%	30%	30%	30%
Gas	30%	30%	30%	30%
Wind (onshore)	23%	23%	26%	30%
Wind (offshore)	18%	18%	24%	30%
Utility-scale PV	2%	2%	16%	30%
Rooftop PV	4%	4%	17%	30%
Utility-scale batteries	15%	15%	23%	30%
Distributed batteries	15%	15%	23%	30%
Pumped hydro	20%	20%	25%	30%

Figure 9 Change in overall employment with active policies to increase onshore manufacturing



Increasing the share of onshore manufacturing adds about 6,000 jobs on average over the period, mainly in solar manufacturing. Figure 9 shows the overall change in the share of manufacturing jobs compared to all electricity sector employment, while Figure 10 shows what this means by technology (Figure 10 only includes manufacturing employment, while Figure 9 shows all employment).

Figure 10 Change in manufacturing employment with active policies

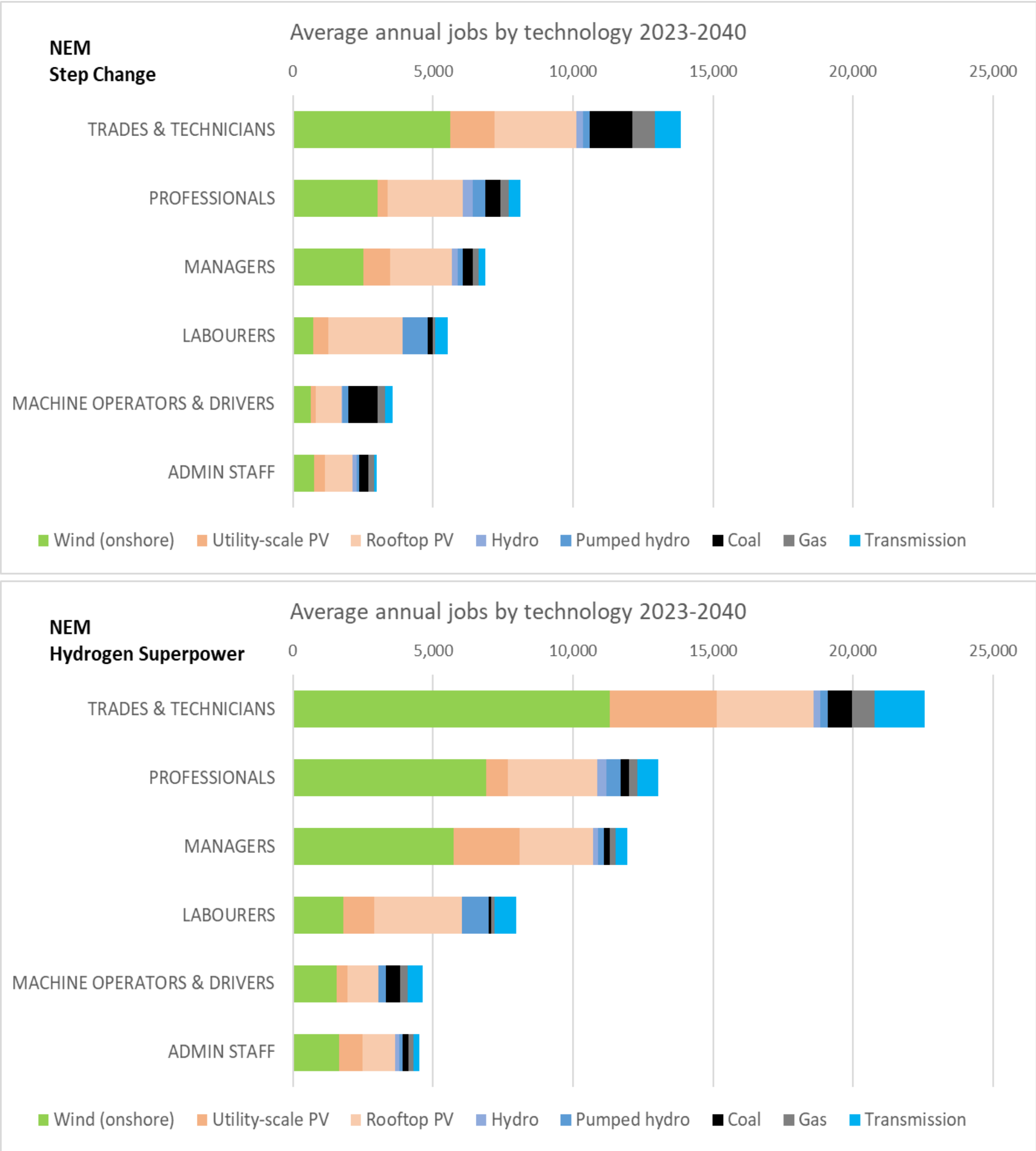


3.3 National Electricity Market – employment by occupation

Occupational employment trends are important for government, industry, the training sector, and the community to understand what type of jobs will be required as a result of the energy transition. Average annual employment projections illustrate the bulk distribution of jobs between technologies, and the occupations that are most in demand overall. Figure 11 shows the average annual employment breakdown from 2023 until 2040 by employment grouping for the Step Change and the Hydrogen Superpower scenarios:

- The largest group is trades and technicians, which average almost 14,000 per year until 2040 under the Step Change scenario and around 23,000 under the Hydrogen Superpower scenario.
- The next largest groups are professionals (around 8,000 per year across a wide range of occupations including finance, health and safety, engineers – or 13,000 for Hydrogen Superpower) and managers (7,000 per year led by construction managers – or over 12,000 for the Hydrogen Superpower scenario)
- Nearly 6,000 labourers are projected per year (especially construction labourers), over 3,500 machine operators and drivers (e.g. truck drivers, crane operators) and around 3,000 administrative staff. Under the Hydrogen Superpower scenario, there would be demand for around 8,000 labourers, 5,000 machine operators and drivers, and 4,000 administrative staff.

Figure 11 National Electricity Market, average occupational structure 2023-2040



From the perspective of skills, training, and labour supply, the peaks in employment are the most important, with training provision in the medium term likely to be designed to cater for the next ten to fifteen years. The peak labour requirement year in this period is chosen to illustrate peaks for the most in-demand occupations.

Labour requirements in 2033 (the peak year before 2035 in the Step Change scenario) are shown in Figure 12. There are nearly 8,000 electricians and nearly 3,000 mechanical trades and technicians needed in the Step Change scenario.

In the Hydrogen Superpower scenarios, these requirements are much higher, with more than 12,000 electricians and 5,000 mechanical trades needed in 2033. Those occupations needed in large numbers primarily during construction (such as construction labourers, construction managers, and electrical engineers) are very volatile, while occupations such as electricians and mechanical trades increase steadily over the entire period.

Requirements for in-demand occupations in the Hydrogen Superpower scenario are shown in Appendix E – Additional results by occupational mix.

Figure 12 National Electricity Market, in-demand occupations during peak year (2033)

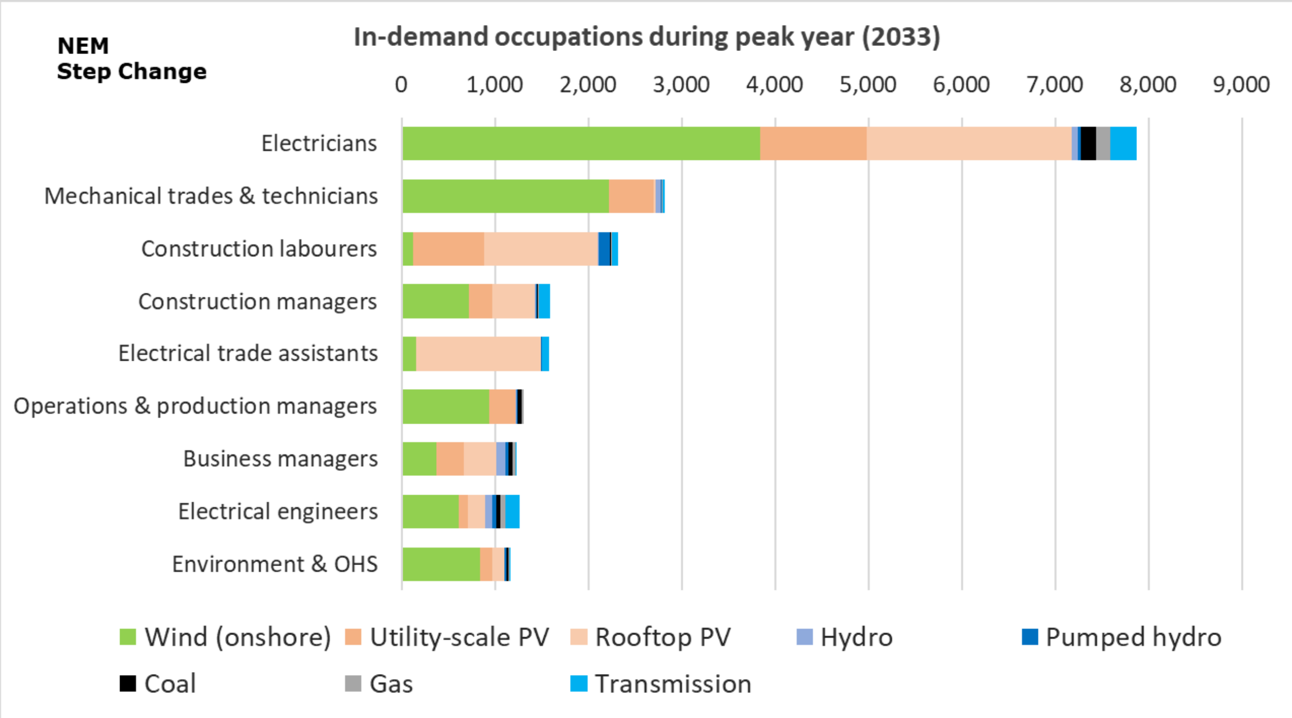
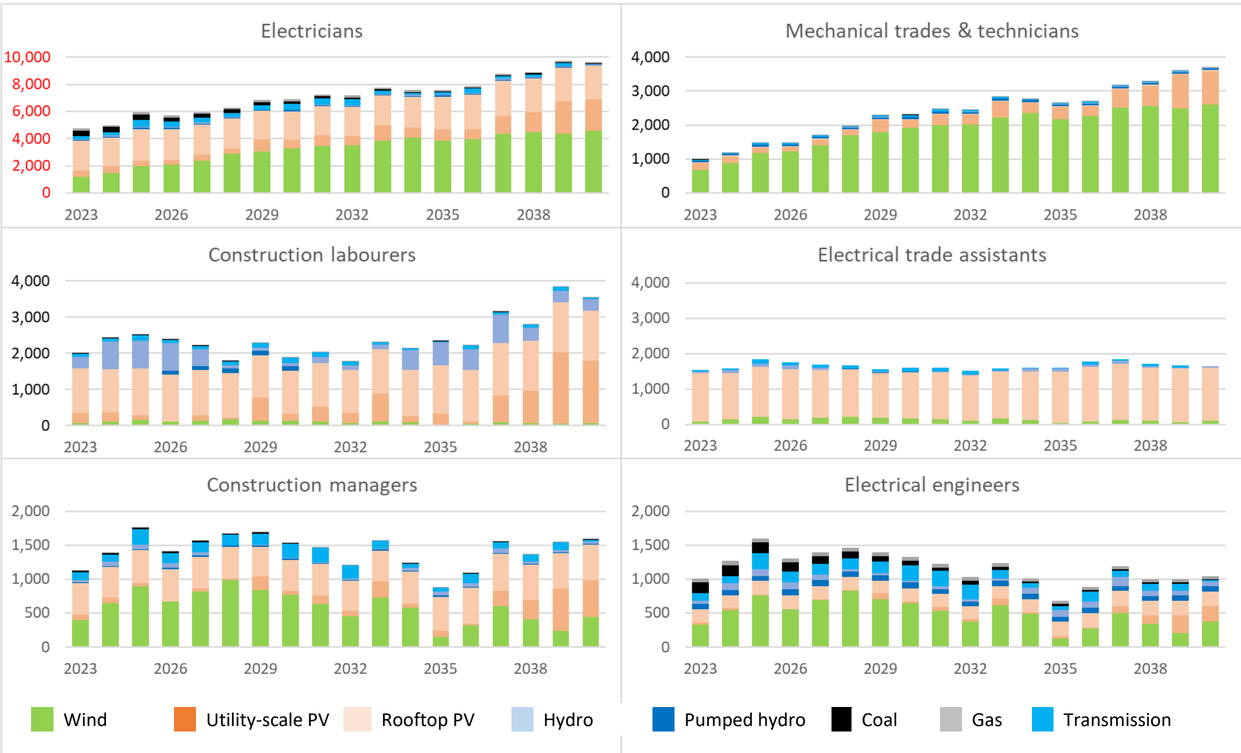


Figure 13 National Electricity Market, in-demand occupations annual requirement by technology, Step Change

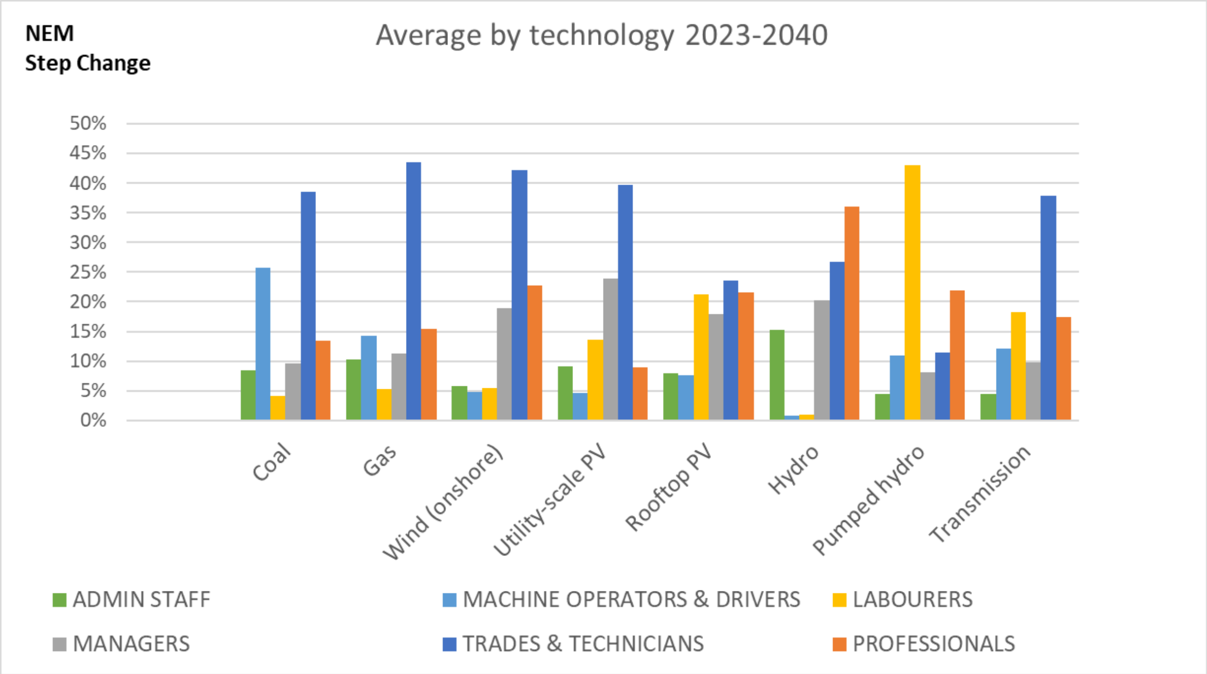


Note different scales: electricians 0-10,000, construction managers/ electrical engineers 0-2,000, remainder 0-4,000

Occupational mix by technology

The high-level occupational mix for various technologies varies considerably (Figure 14). Trades and technical roles account for close to 40% of employment for most of the large-scale technologies, with the exception of pumped hydro and hydro. Rooftop solar is quite different, with a relatively even spread of roles with labourers, managers, professionals, and trades all accounting for about 20%. Pumped hydro employment is dominated by the need for labourers, reflecting the extensive siteworks involved. Appendix E – Additional results by occupational mix gives the average occupational mix for wind and solar.

Figure 14 National Electricity Market, average occupational mix by technology, 2023-2040



4 Electricity sector workforce projections by technology

Under all scenarios, most employment growth occurs in solar and wind farms. Figure 15 shows the average employment by technology over the period, while Figure 16 shows the annual variation.

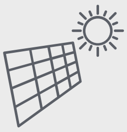
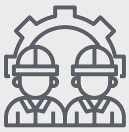
Technology	About
	Wind accounts for an average of one-third of electricity sector employment in the Step Change and nearly half in the Hydrogen Superpower scenario. In Step Change, wind farm employment grows by 26,000 to peak in at 33,000 in 2048. In Hydrogen Superpower, wind farm employment grows very strongly, nearly doubling by 2033, and exploding through the 2030s and 2040s to peak at 121,000 in 2049. Wind accounts for a slightly lower proportion of the total employment in the Offshore Wind scenario (27% compared to 30%), reflecting the fact that offshore wind displaces more labour-intensive onshore wind or solar farms. Offshore wind itself accounts for a very small percentage of employment, reaching just 1% in this scenario.
	Utility-scale PV accounts for 11% of employment in the Step Change and 18% in the Hydrogen Superpower scenario. Utility-scale PV employment grows very strongly in this scenario, increasing by 85,000 from 2023 to peak at 88,000 in 2050 (in the Step Change the peak is 21,000 in 2049).
	The combined workforce for rooftop solar and distributed batteries accounts for more than 40% of electricity sector employment in the Step Change, Offshore Wind, and Slow change scenarios, and 26% in the Hydrogen Superpower scenario. Rooftop solar is a steady source of employment, with average annual employment staying between 13,000 and 21,000 in all but the Slow Change scenario; in Slow Change rooftop solar employment varies between 7,000 and 17,000. Jobs in distributed batteries generally increase steadily over the period, from close to 4,000 in 2023 to 14,000 in 2050 in the Step Change and Offshore Wind scenarios, and 16,000 in the Hydrogen Superpower scenario. In the Slow Change scenario there is much less installation of batteries, and employment is only 2,000 at the end of the period. Distributed batteries contribute more than 97% of the battery jobs shown.
	Coal and gas account for 8% of average employment in the Step Change and Offshore Wind scenarios, 3% in the Hydrogen Superpower, and 16% in the Slow Change scenario.
	Hydro accounts for between 3% and 6% of electricity sector employment in all scenarios.
	Transmission construction accounts for between 2% and 4% of electricity sector employment in all scenarios.

Figure 15 National Electricity Market, average electricity sector jobs by technology and scenario

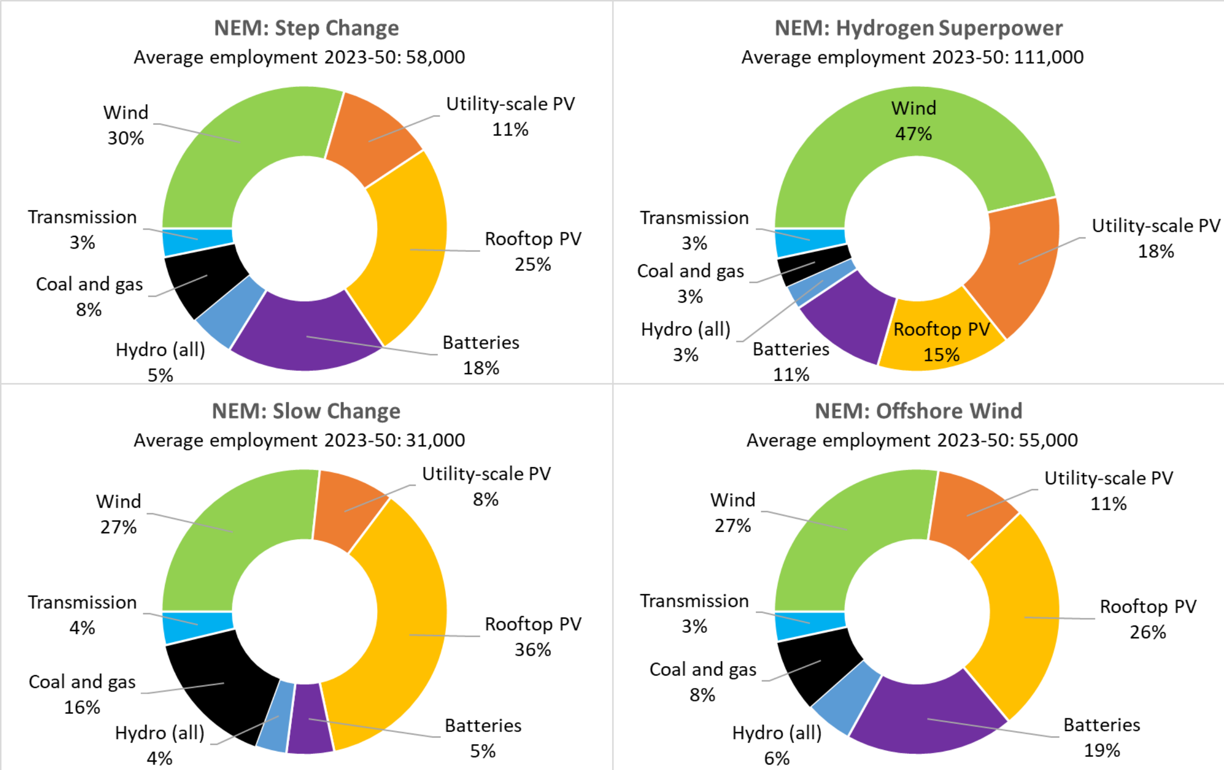
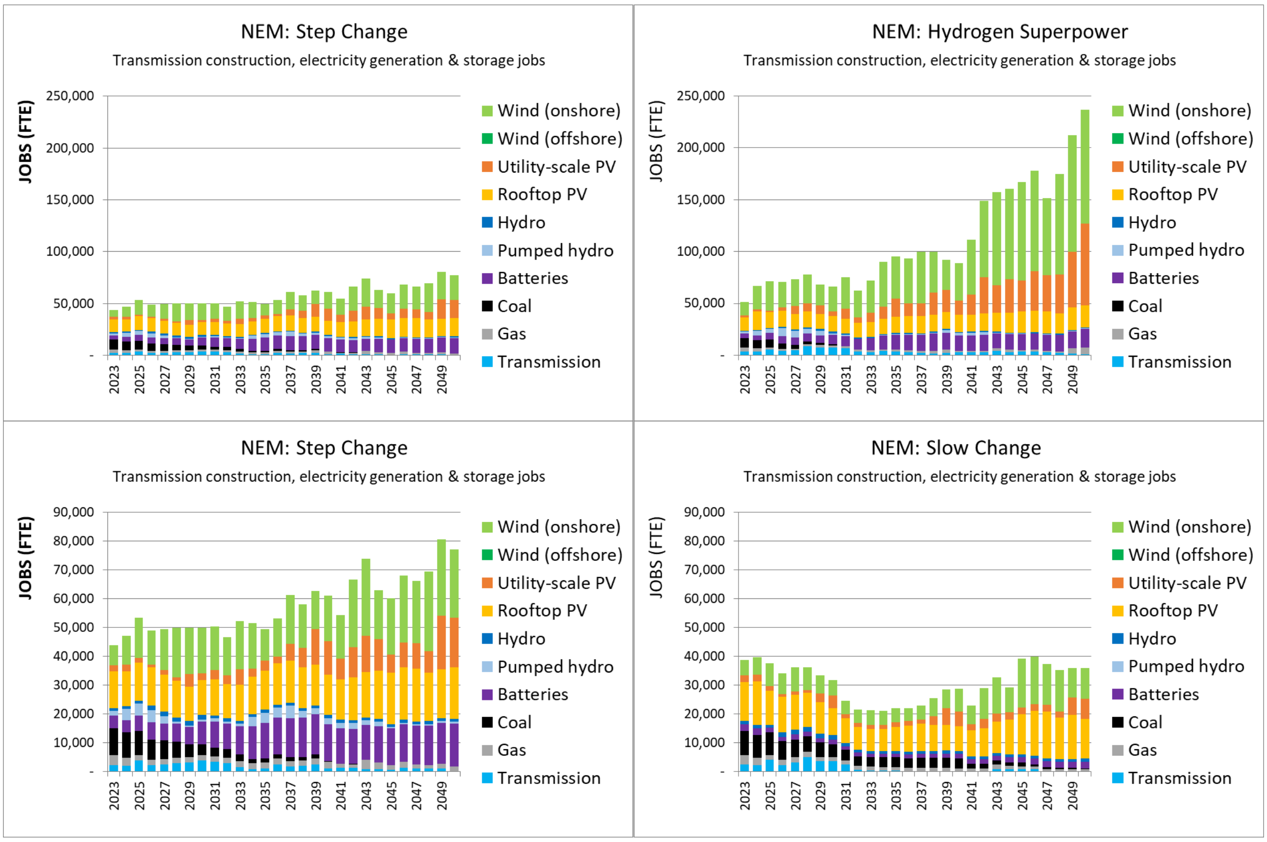


Figure 16 NEM, annual jobs by technology (Step Change, Hydrogen Superpower, Slow Change)



4.1 Wind

Total jobs in wind power are shown in Figure 17 for the Step Change and Offshore Wind scenarios. Employment climbs reasonably steadily through the 2020s and fluctuates in the 2030s, before climbing again in the 2040s. Repowering starts playing a noticeable role in the late 2030s and is a significant post 2045, with close to 10,000 jobs.

Average wind employment is almost 2,000 lower in the Offshore Wind compared to the Step Change scenario, 14,900 compared to 16,800, reflecting the lower labour intensity of offshore compared to onshore wind and the fact that offshore tends to displace somewhat more onshore wind capacity than is installed offshore. Total wind capacity is 10.7 GW lower in 2050 in the Offshore Wind compared to the Step Change scenario.

Figure 17 National Electricity Market, jobs in wind (Step Change and Offshore Wind)

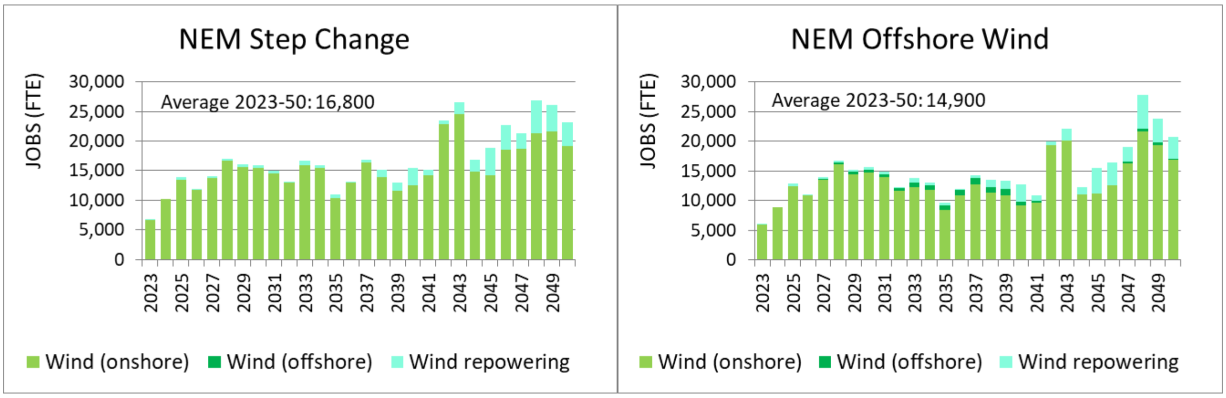
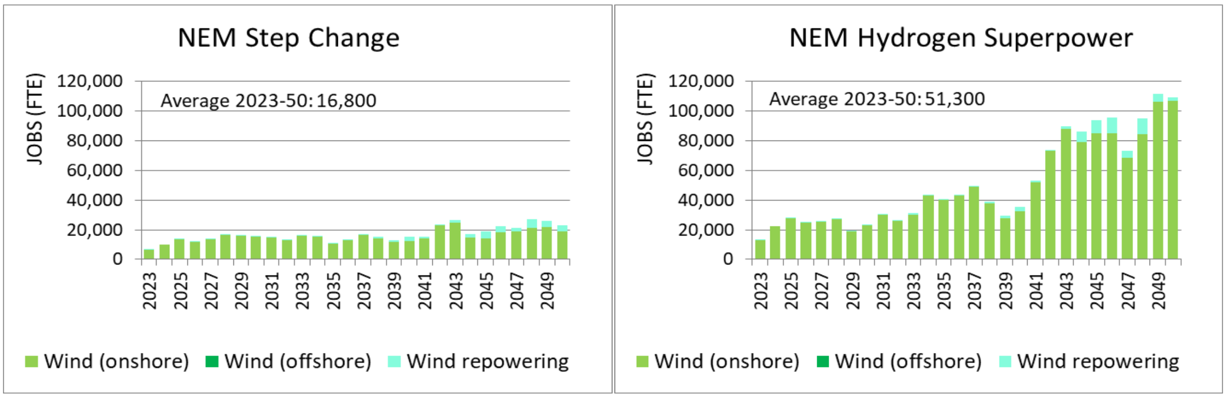


Figure 18 National Electricity Market, jobs in wind (Step Change and Hydrogen Superpower)



Wind employment averages 51,300 in the Hydrogen Superpower scenario, with repowering less significant because the capacity expansion is so great. Average employment in the Slow Change is only 9,000.

The enhanced manufacturing case described in Section 3.2 would add an average of 200 jobs per year in the Step Change (1,000 in the Hydrogen Superpower).

Appendix D gives results for wind employment in each scenario.

4.2 Utility-scale solar

Total jobs in utility-scale solar are shown in Figure 19 for the Step Change and Offshore Wind scenarios.

Employment climbs reasonably steadily through the 2020s and 2030s, before dipping and then climbing again in the 2040s. Repowering starts playing a noticeable role in the late 2030s and averages 1,500 jobs per year after 2035.

Average annual utility-scale solar employment is just under 1,000 lower in the Offshore Wind compared to the Step Change scenario, 5,700 compared to 6,400, reflecting the displacement of utility-scale solar by offshore capacity. Utility-scale solar is 12 GW lower by 2050 in the Offshore Wind compared to the Step Change scenario.

In the Hydrogen Superpower scenario (Figure 20), utility-scale solar grows very strongly, taking the average annual employment to nearly 20,000 jobs.

The enhanced manufacturing case described in Section 3.2 would add an average of 1,000 jobs per year in the Step Change (4,000 in the Hydrogen Superpower).

Figure 19 National Electricity Market, jobs in utility-scale PV (Step Change and Offshore Wind)

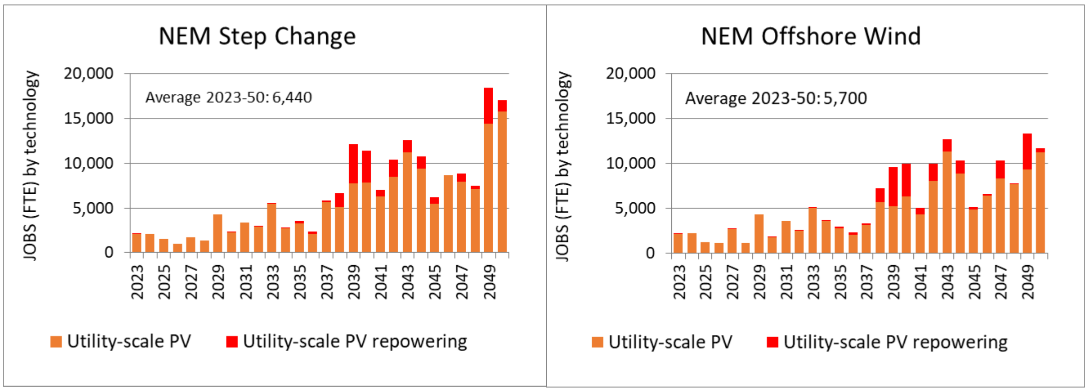
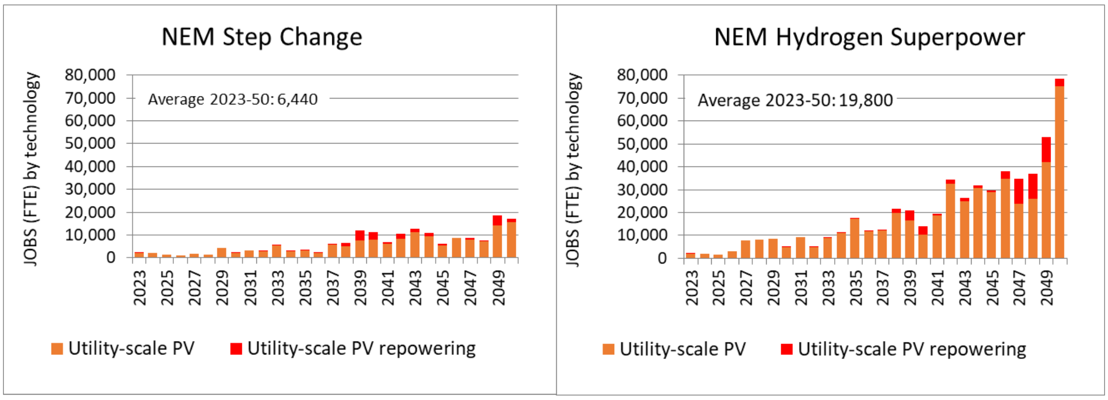


Figure 20 National Electricity Market, jobs in utility-scale PV (Step Change and Hydrogen Superpower)



4.3 Rooftop solar and distributed batteries

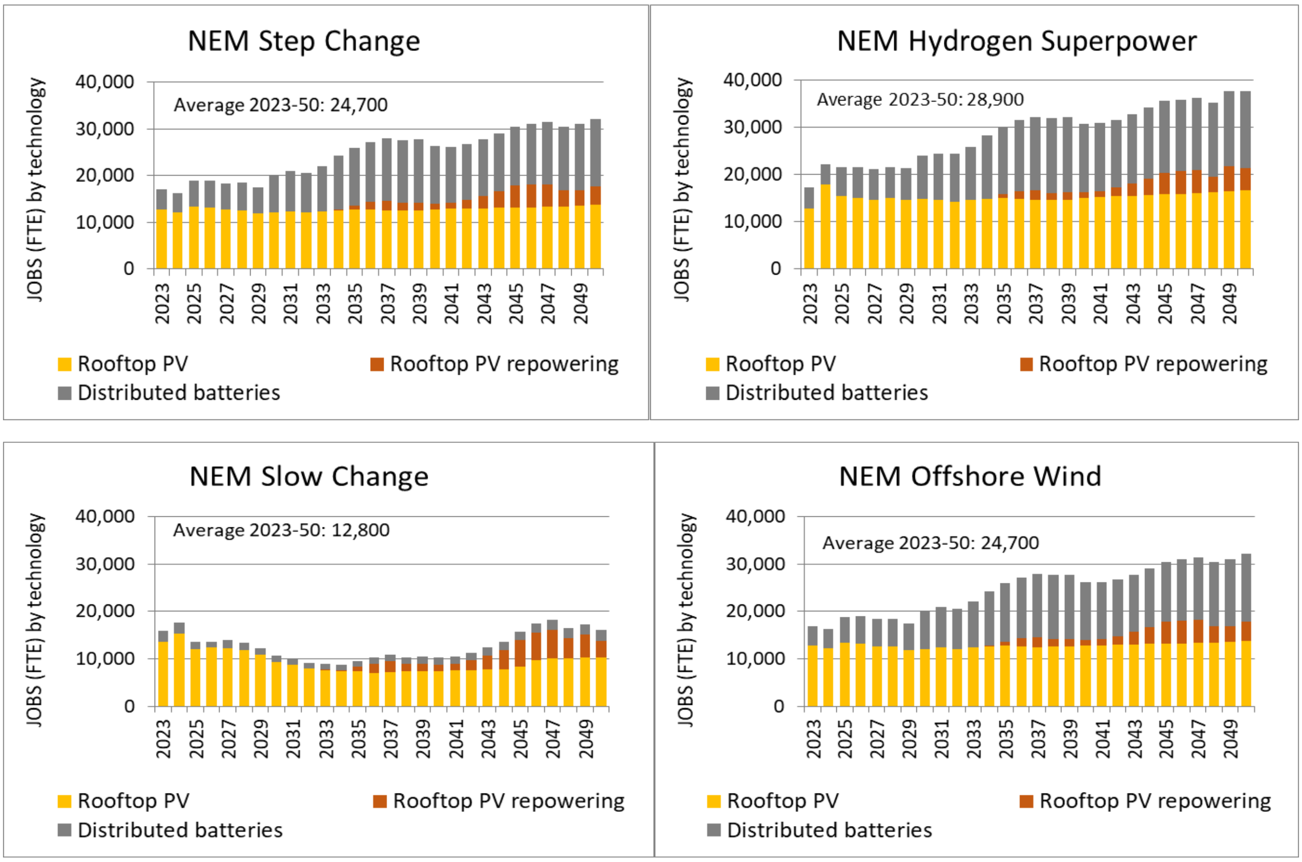
In the Step Change scenario, rooftop solar employment is virtually constant through the entire period, at 13,000 (Figure 21). When combined with distributed batteries employment, annual employment averages nearly 25,000, with a reasonably steady increase over the period, from 17,000 in 2023 to 32,000 in 2050. Repowering plays a noticeable role from the mid-2030s, reaching a maximum of 5,000 in 2045. The profile of employment in these technologies is identical in the Offshore Wind scenario.

In the Hydrogen Superpower scenario, average annual employment averages nearly 30,000, and both rooftop solar and distributed battery employment are slightly higher than the Step Change.

The enhanced manufacturing case described in Section 3.2 would add an average of 1,000 jobs per year in the Step Change and the Hydrogen Superpower scenarios.

The Slow Change scenario is the only one in which employment drops, to a minimum of 9,000 in 2034, and combined employment averages just under 13,000. After this, employment climbs again, to a maximum of 18,000 in 2047. Distributed batteries employment is very much lower than the Step Change scenario, with an average of 2,000 compared to 10,000 in the Step Change.

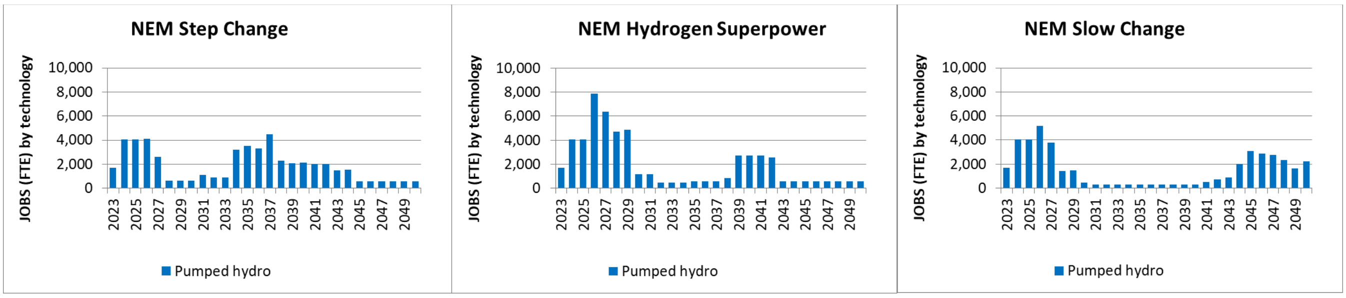
Figure 21 National Electricity Market, rooftop solar and distributed batteries employment (all scenarios)



4.4 Large scale storage

Large scale storage jobs are shown in Figure 22 and Figure 23 for the Step Change, Hydrogen Superpower, and Slow Change scenarios, noting that the scale for pumped hydro (Figure 22) goes from 0-10,000 and the scale for batteries employment (Figure 23) goes from 0-2,000. Offshore Wind is not shown as the profile is the same as the Step Change scenario.

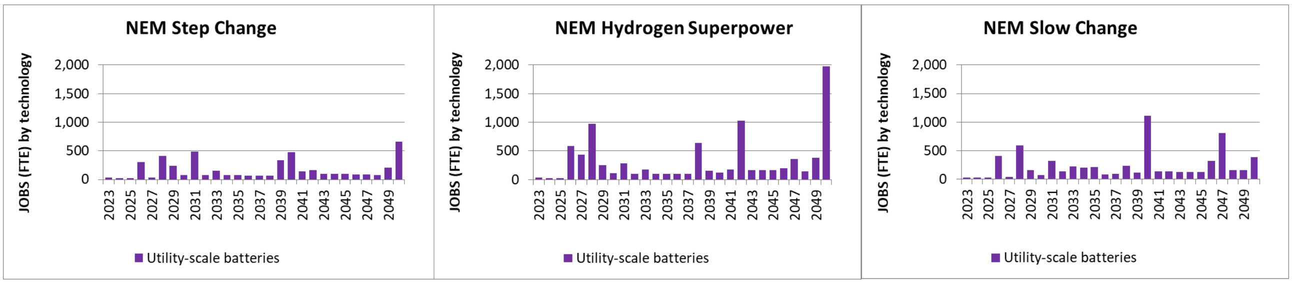
Figure 22 National Electricity Market, jobs in pumped hydro (Step Change, Hydrogen Superpower, Slow Change)



Jobs in pumped hydro are volatile, reflecting the periods when new facilities are constructed. The Step Change is the least variable and the Hydrogen Superpower the most variable, as construction of additional facilities occurs earlier in this scenario. In between construction periods employment is close to 600 in the Step Change, and close to 500 and 300 in the Hydrogen Superpower and Slow Change respectively. The peaks, reflecting construction periods, vary from 4,400 in the Step Change to nearly 8,000 in the Hydrogen Superpower.

Figure 23 shows employment in utility batteries in the three scenarios. The annual average employment is between 200 and 300 in all scenarios.

Figure 23 National Electricity Market, jobs in utility batteries (Step Change, Hydro Superpower, Slow Change)

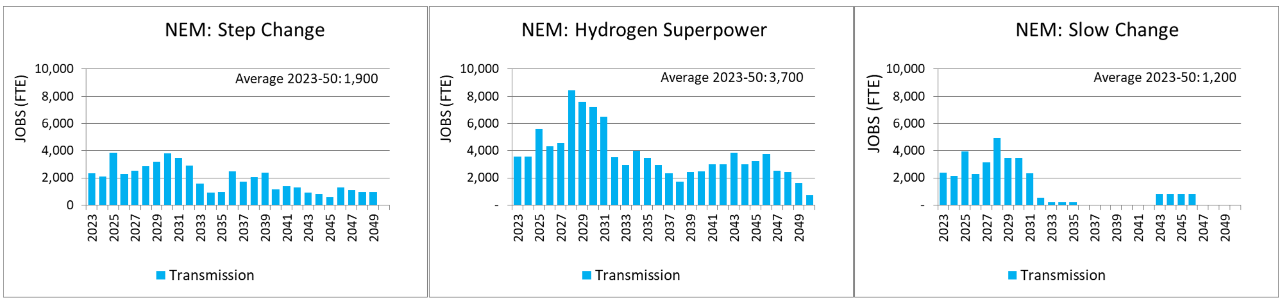


4.5 Transmission construction

Employment in transmission construction is compared for three scenarios in Figure 24 (Offshore Wind is identical to the Step Change scenario). This employment includes both transmission lines and the associated substations, which may require quite different skillsets.

Transmission employment averages 1,900 jobs for the Step Change scenario, 3,700 jobs for the Hydrogen Superpower scenario, and 1,200 jobs for the Slow Change scenario. The greatest peaks in employment occur in the mid-2020s to early 2030s across all scenarios, reaching just over 8,000 jobs in the Hydrogen Superpower scenario in 2028. Step Change transmission employment peaks at just under 4,000 jobs in 2025 and again in 2030, with smaller peaks occurring in the late 2030s. Much of the employment demand falls off after 2035 in the Slow Change scenario, with transmission construction employment reaching a peak of around 4,500 jobs in 2028. All scenarios peak in the late 2020s. It should be noted that actual employment is likely to be more variable than shown here, as these calculations assume that employment is spread evenly across the construction period for each project.

Figure 24 National Electricity Market, jobs in transmission (Step Change, Hydrogen Superpower, Slow Change)



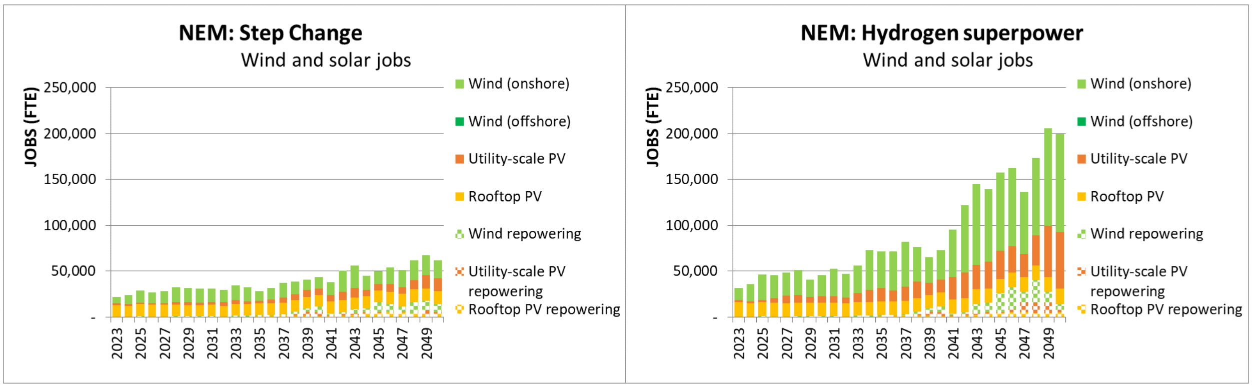
4.6 Hydrogen

Hydrogen employment is not modelled as such, but the increase in wind and solar employment in the Hydrogen Superpower scenario relative to the Step Change (Figure 25) is entirely as a result of increasing capacity for hydrogen production. This adds a total of 136,000 to the peak employment, and 51,000 to the average employment compared to the Step Change.

While it has not been possible to include jobs in hydrogen production as such, the jobs in the associated wind and solar are likely to be considerably larger than the direct hydrogen employment.

Hydrogen production and transport jobs are likely to require an entirely different set of skills, so it is important that these are quantified alongside the renewable energy employment in future work.

Figure 25 National Electricity Market, wind and solar jobs (Step Change and Hydrogen Superpower)

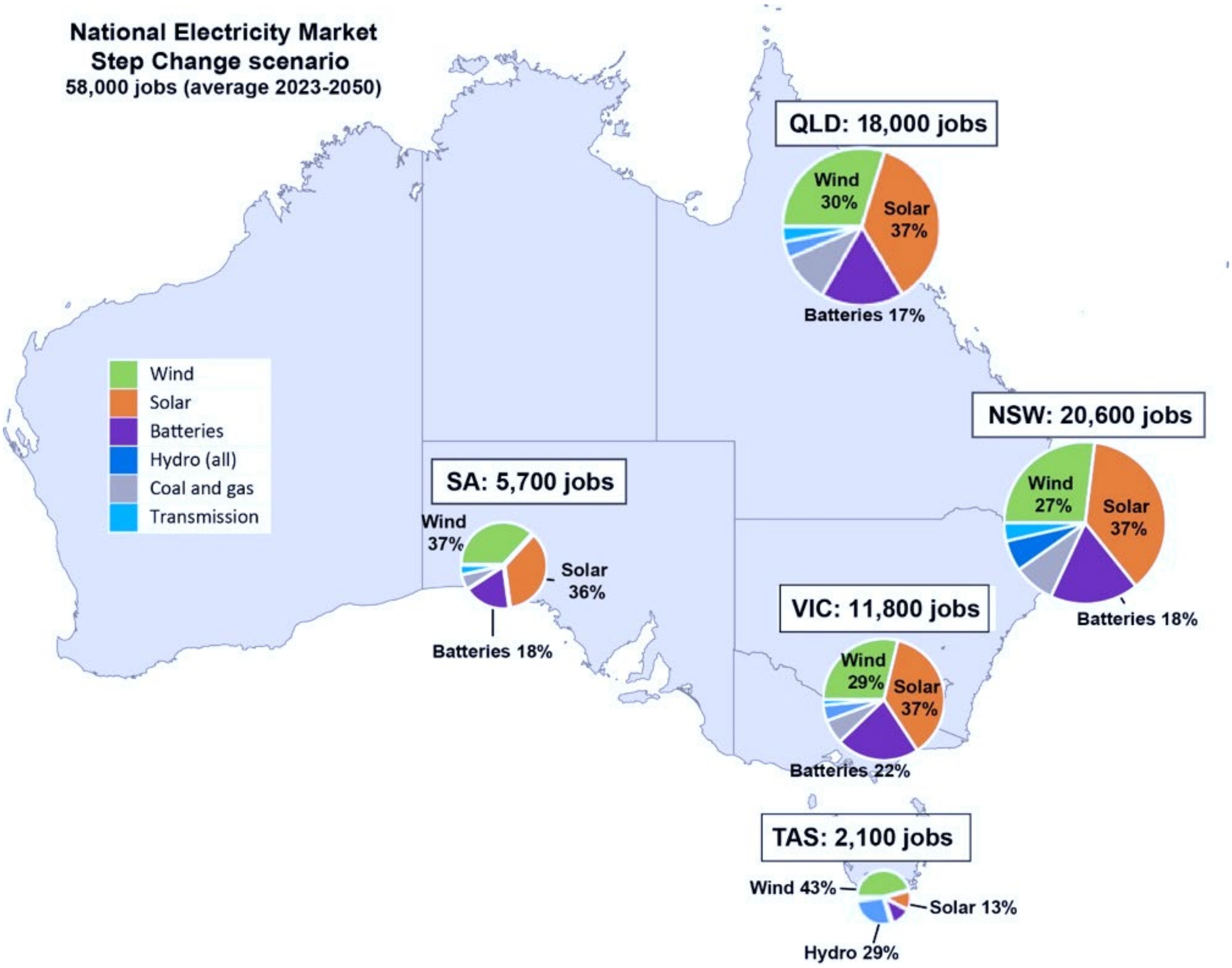


5 Electricity sector workforce projections – by State

Figure 26 gives the average electricity sector employment by state and technology from 2023-40 in the Step Change scenario. NSW is the leading state for renewable energy employment, averaging 20,600 full-time jobs per year, followed by Queensland (18,000) and Victoria (11,800).

The share by technology is very similar for the three largest states, with solar contributing 37%, wind 27%-30% and batteries 17%-22%. South Australia has a higher proportion of wind (37%), while Tasmania has a very different distribution, with 29% of jobs in hydro.

Figure 26 National Electricity Market average electricity jobs by State, 2023-2050 (Step Change)



The distribution of employment growth between the states varies considerably by scenario, with the Hydrogen Superpower scenario particularly different.

Figure 27 and Figure 28 compare each scenario for each state. In all states, the Hydrogen Superpower has the most employment, although the difference is not that great in NSW and Victoria.

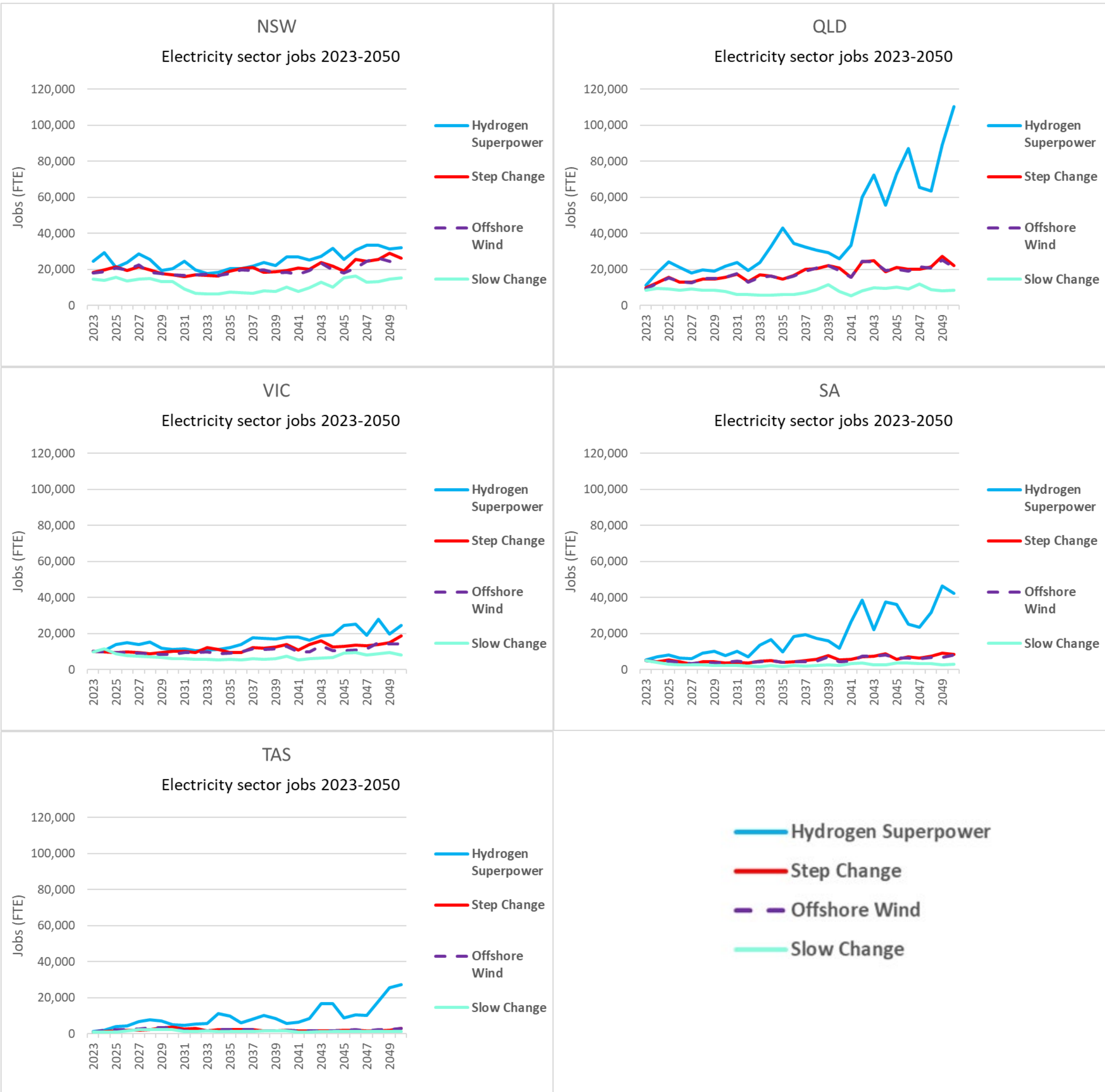
In the Step Change, Offshore Wind and Slow Change scenarios, the distribution of total jobs between the States follows a similar pattern, with NSW having the greatest share, followed by Queensland, Victoria, South Australia and Tasmania. In the Slow Change scenario, average employment is lower across all states with NSW leading with 11,400 full-time jobs per year.

Under the Hydrogen Superpower scenario, most of the employment growth is projected to occur in Queensland, South Australia and Tasmania, and the employment distribution between states is notably different. Queensland has the highest average employment (41,400), more than doubling compared to Step Change employment (18,000). Employment in South Australia more than trebles compared to the Step Change scenario, with an increase of 13,000 jobs, and South Australia overtakes Victoria and NSW from the early 2040s. Tasmania increases employment by a staggering four times, from 2,210 to 9,400. By contrast, additional employment in NSW and Victoria in the Hydrogen Scenario is relatively modest (4,000-5,000).

See the "Focus on.." reports for New South Wales, Queensland, South Australia, Tasmania, and Victoria. These provide detailed results for each state, including employment by candidate REZ, and occupational and technology employment breakdowns for the state.

racefor2030.com.au/fast-track-reports

Figure 27 State comparison by scenario, jobs to 2050



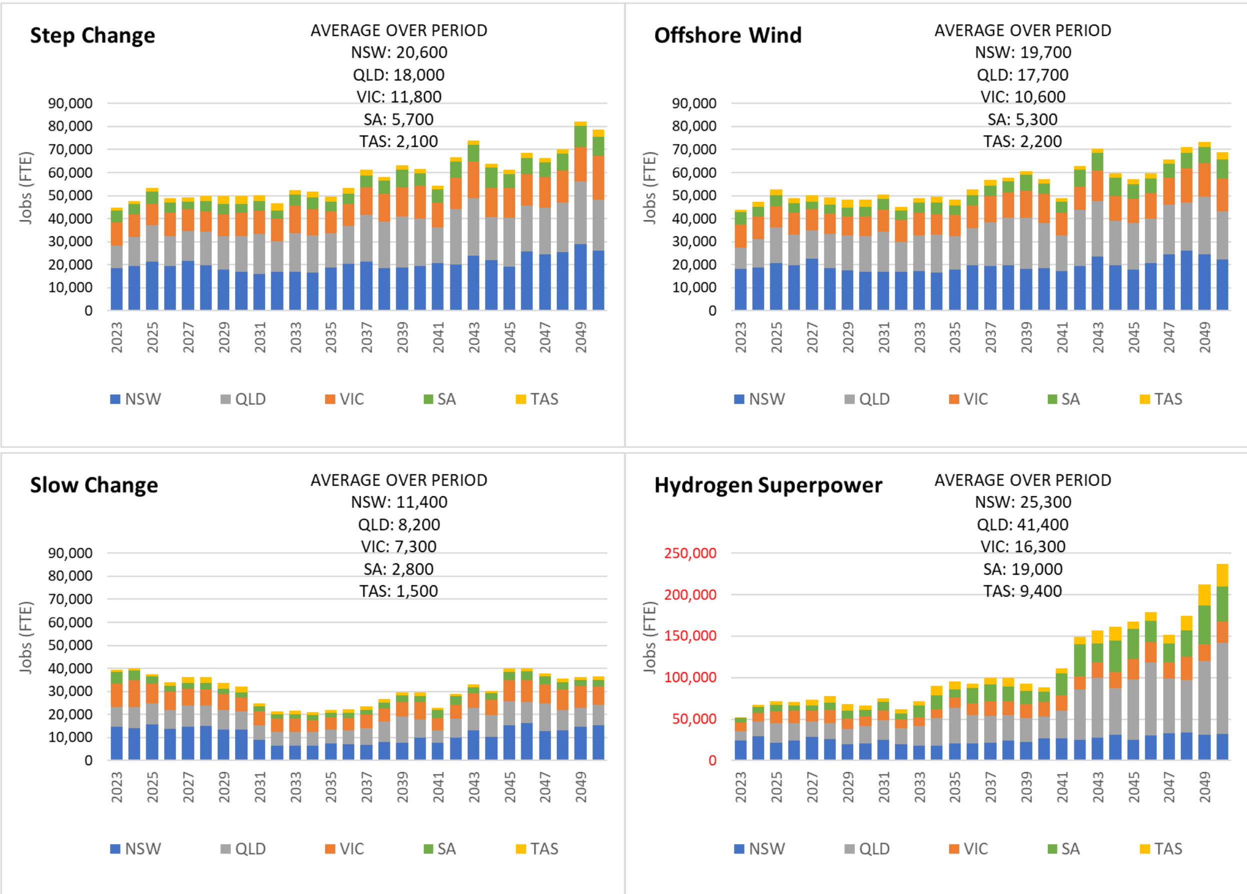
Under the Offshore Wind scenario, average employment is somewhat lower overall than in the Step Change scenario, as more labour-intensive onshore wind and some solar farms are displaced (Figure 28). In Victoria average employment is 1,200 lower than in the Step Change; in NSW it is 900 lower, in Queensland and South Australia 300 and 400 lower respectively.

Unpacking these results by technology highlights some of the underlying factors. Under the Step Change scenario, the dominant mix along the east coast is a mix of onshore wind, utility-scale PV and rooftop PV and battery storage. NSW and Queensland dominate the profile of transmission construction employment which occurs in phases firstly within NSW and then Queensland. Pumped hydro storage employment also occurs early in NSW followed by Queensland. Tasmania stands apart from the other sites with a mix dominated by onshore wind, hydro and pumped hydro storage.

Under the Hydrogen Superpower scenario, there is a surge in wind farm employment in Queensland to over 50,000 full-time jobs in peak years. In South Australia, most of the growth is also in wind farms but there is stronger growth in solar farms.

Additional results by technology and state are given in Appendix F, and there are accompanying summaries of employment projections by state, which include some breakdowns by the individual REZs.

Figure 28 State comparison by scenario, jobs to 2050 (all scenarios)



Note different scale for Hydrogen Superpower (0-250,000, remainder 0-90,000

5.1 Occupational mix by state

The demand for selected occupations by state, in the peak year for each state (2028 in NSW, 2031 in QLD, 2033 in VIC, 2034 in SA, and 2030 in TAS) is given in Figure 29 for the Step Change scenario.

Labour demand is dominated by the need for electricians in all states. Annual demand for electricians across the NEM is shown in Figure 30, with the year of peak labour demand indicated for each state (noting this is peak labour demand across all occupations). Demand for electricians across the NEM is just under 8,000 by 2033, which is close to the sum of demand in the peak years for each state. Demand for electricians is predominantly driven by new wind, and utility scale solar construction and rooftop PV installations in the late 2020s to mid-2030s. A smaller share of electrician jobs will be driven by transmission construction in NSW and QLD, peaking at around 300 jobs each.

Figure 29 In-demand occupations by state in peak years (2028-2034), Step Change scenario

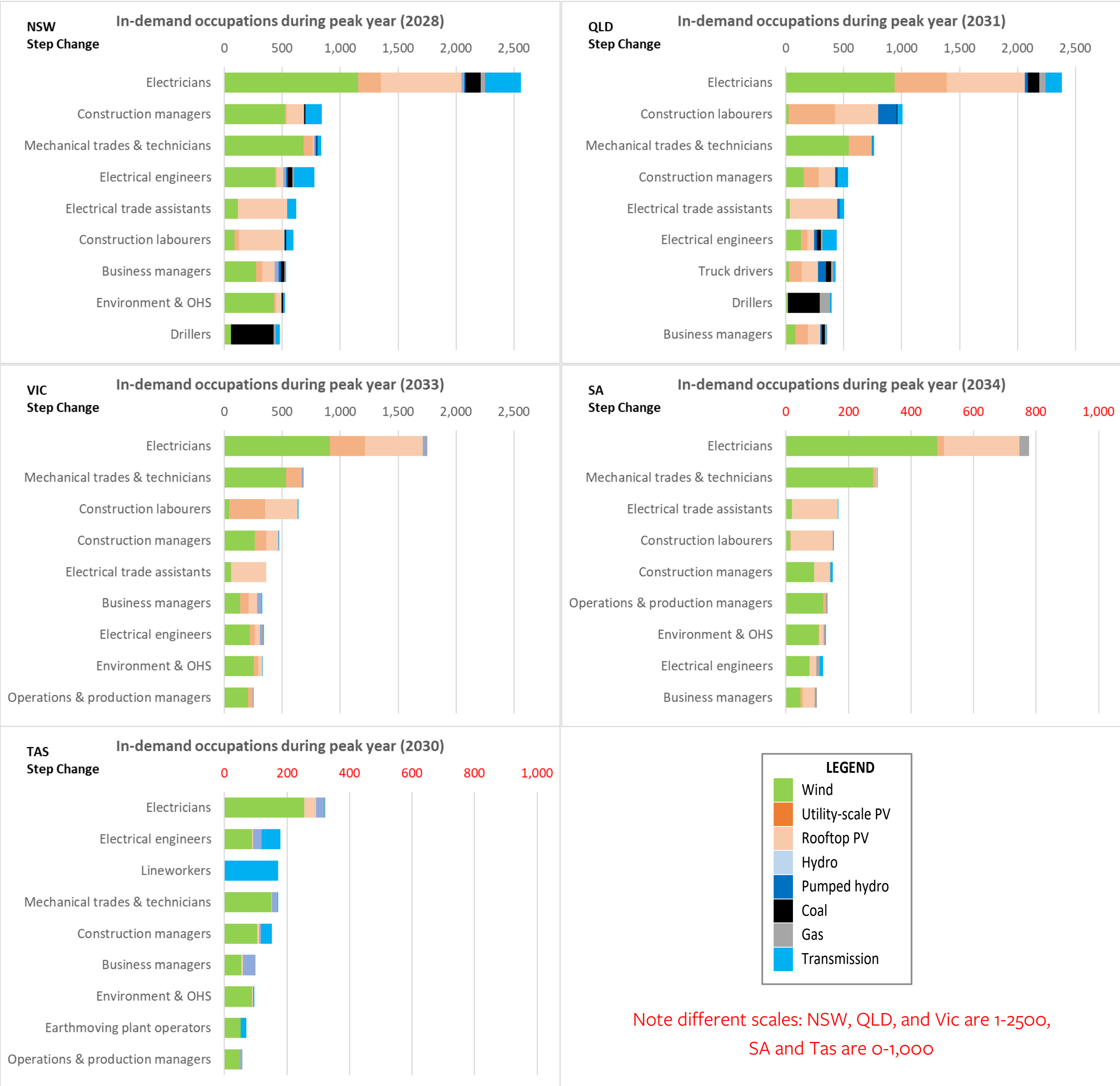
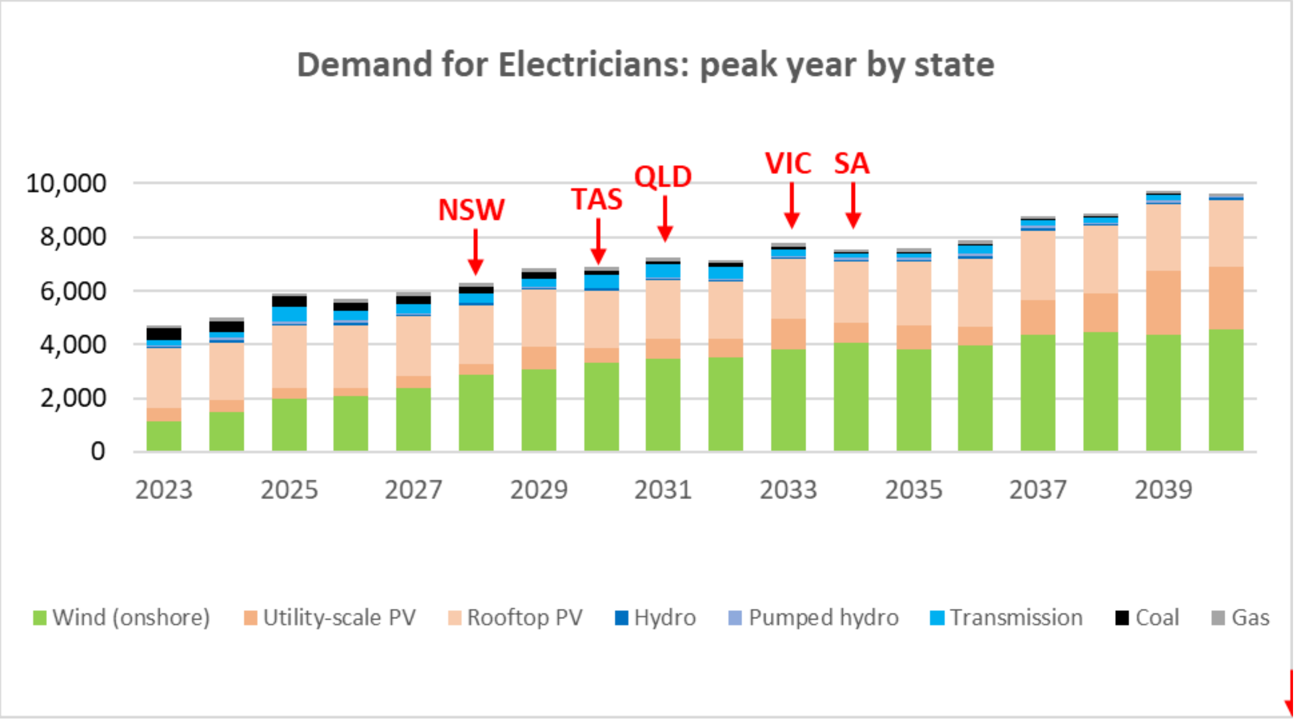


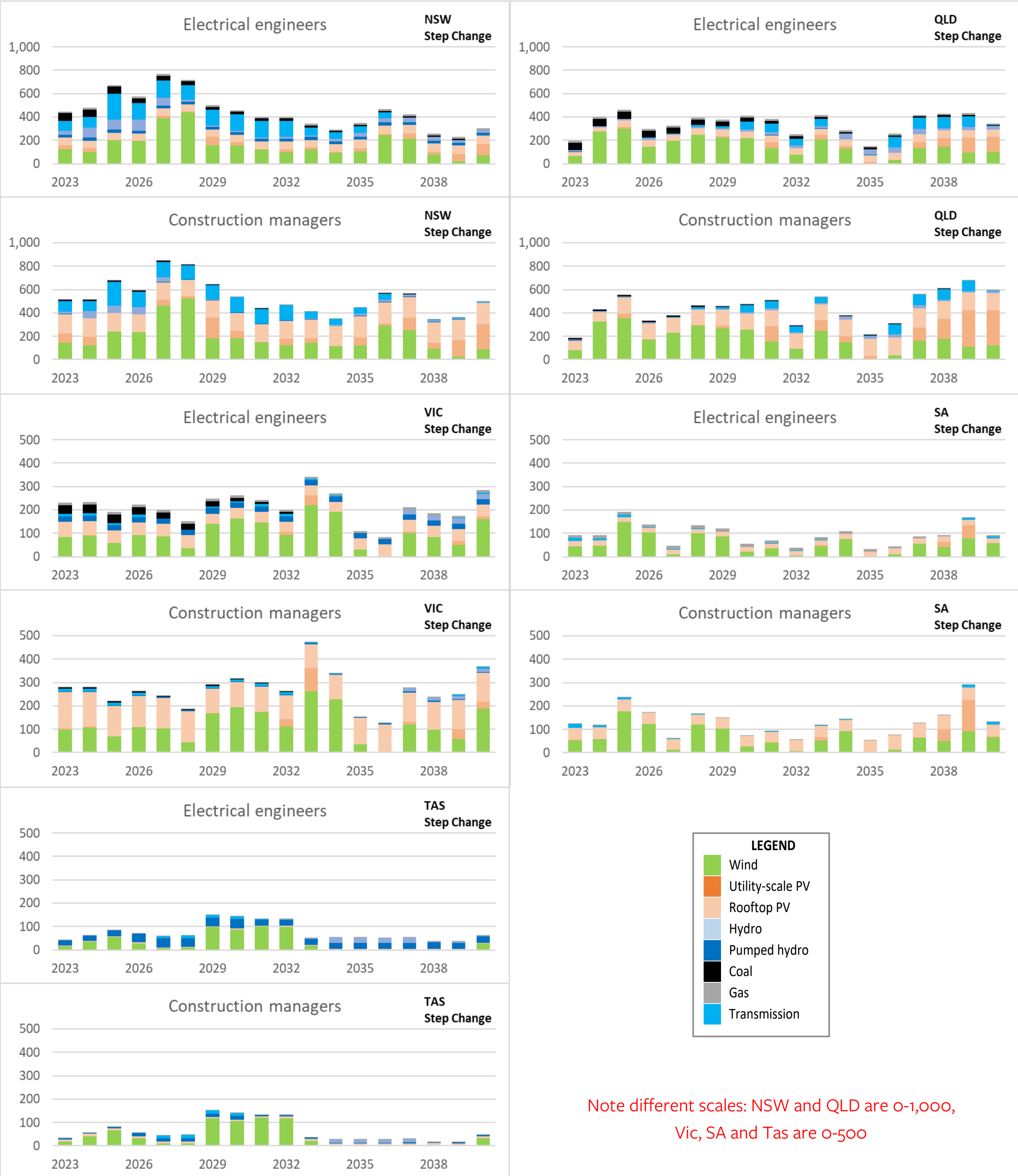
Figure 30 NEM annual demand for electricians, showing peak labour demand years for each state



Growth is steady for electricians, as electricians are required both for construction and for operations and maintenance. For occupations which are primarily involved in construction (e.g. construction managers or electrical engineers), demand is highly volatile across all states, as shown in Figure 31. Taking the example of electrical engineers, demand doubles in both Queensland and NSW in just two years (2023-2035); these spikes are repeated in the mid-2030s. While variations are smaller in South Australia and Tasmania, the relative changes are just as great.

These volatile employment profiles bring high risks of skill shortages which could impact on the achievement of the development pathways set out in the ISP. These risks are exacerbated by the fact that construction will be highly concentrated in the REZs. Comparison of employment demand with the underlying labour supply in NSW found that in some cases the annual demand for labour for renewable energy developments outstripped the entire existing workforce[40]. While labour will certainly be brought in from outside the immediate REZs, ensuring that local opportunities are maximised will be crucial to retain social license for these developments.

Figure 31 In-demand construction occupations, annual variation by state, Step Change scenario



Note different scales: NSW and QLD are 0-1,000, Vic, SA and Tas are 0-500

6 Discussion and Recommendations

6.1 Skill shortage risks

The rapid increase in requirements for in-demand occupations brings with it a high risk of skill shortages which could impact on the achievement of the optimal development pathways under the ISP. Skills shortages create the risks of delays, increased project costs (wage inflation, recruitment costs and liquidated damages), and increase the cost of capital for future projects to reflect increased risk.

The timetable for the delivery of renewable energy generation, transmission, and storage to maintain energy security as coal-fired power stations retire is tight. In the 2022 Electricity Statement of Opportunities AEMO signalled[41]:

'a need to urgently progress anticipated generation, storage and transmission ... with the NEM expected to experience a cluster of five announced coal-fired generator retirements in the next decade, and needing resilience for potential future closures as well, the investment need is pressing and widespread'.

Industry surveys and the National Skill Shortage Priority List have identified current shortages across a range of key occupations within renewable energy, including all classes of engineers, construction managers, electricians, and transmission lineworkers.

Table 4 Recruitment difficulty and skill shortages, selected occupations

Occupation	ISF Solar & Wind Farms Survey (2019-20)	ISF Transmission Construction Survey (2021)	National Skills Priority List (current NSW status/ future national demand)
Construction manager	High	High	Shortage/Moderate
Mechanical technician	Medium	Low	Shortage/Strong
Electrical engineer	High	High	Shortage/Moderate
Civil engineer	High	Medium	Shortage/Moderate
Electricians (1)	Medium	Low	Shortage/Strong
Transmission lineworker (2)	n/a	High	Shortage/Moderate
Rigger	Low	Medium	Shortage/Moderate
Crane operators	Medium	Low	Shortage/Moderate

Note 1: there are some specialised occupations in shortage that are not well-reflected in these categories. For example, commissioning technicians for substations are consistently identified in our industry surveys and engagement as being in shortage and difficult to address due to long training periods (6-8 years). In the employment projections, electrical trades and technicians are grouped and described as 'electricians' even though the skill level of a commissioning technician is beyond a licenced electrician. It is not possible to differentiate as the occupational employment factor does not go beyond the category of 'electrician'.

Note 2: this includes electrical lineworkers, technical cable jointers and telecommunications lineworkers.

In recent fieldwork, there was extensive testimony about current skill shortages from renewable energy and transmission industry and training stakeholders in NSW. For example:

"Skill shortages have arrived – they've well and truly arrived from the civil projects (roads, foundations) to standing up towers (doggers, riggers) to overhead transmission workers. You are absolutely bidding for top dollar for a small pool of people that are busy building projects" (training provider, project interview)[42]

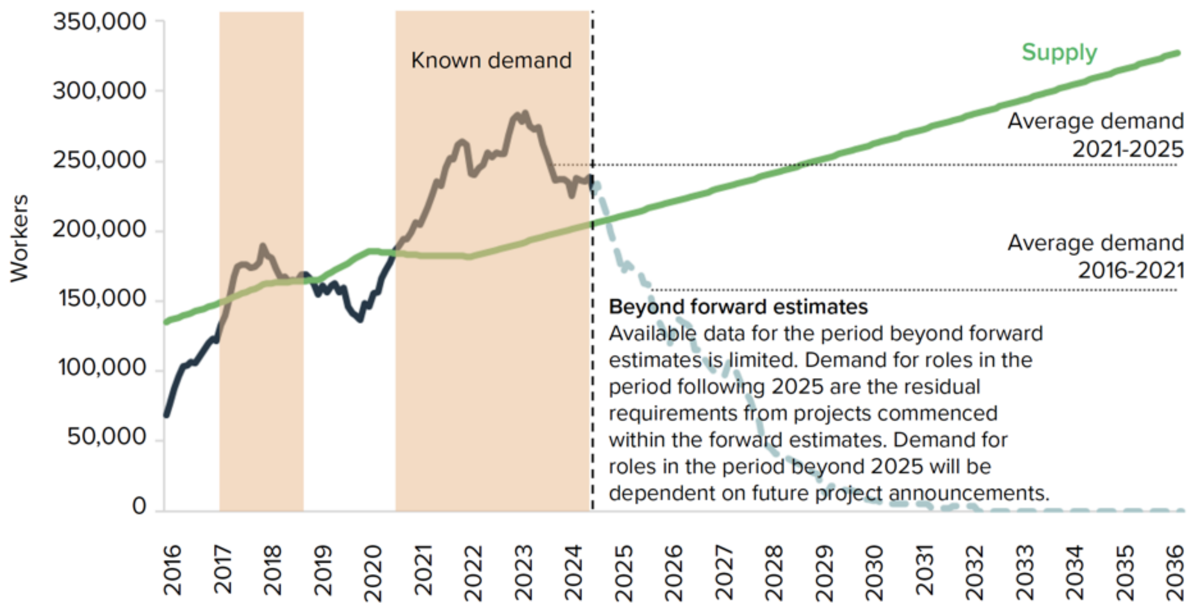
The labour market context for the development of renewable energy is also challenging due to a number of factors, including low unemployment and the current infrastructure pipeline, regional labour markets, and the training gap.

Low unemployment and the infrastructure pipeline

Unemployment rates are currently the lowest for decades, including in many of the regions where renewable energy, transmission, and storage infrastructure will be built and maintained. Whilst labour market conditions can change rapidly, there is a record pipeline of infrastructure investment. Australia is in the midst of what Infrastructure Australia has described as an unprecedented boom in infrastructure that 'has not previously been delivered and reflects many multiples beyond spending rates experienced in response to the Global Financial Crisis'[43]. Infrastructure Australia is projecting shortages across 34 out of 50 public infrastructure occupations with the peak demand for skills 48% higher than supply. This includes a peak deficit of 41,000 engineers and 15,000 structural and civil trades. In addition to major labour shortfalls in coming years (Figure 32), it is important to note that Infrastructure Australia does not project supply catching up with demand by 2024; rather it is only including financially committed projects in the projection so there is no information beyond that point. Project delays and additional investment are likely to create ongoing labour scarcity across the infrastructure sector into the mid-2020s and beyond.

Consequently, the renewable energy sector will be competing for professionals, trades, and technicians against infrastructure projects, in particular 'mega-transport' projects able to offer employment in capital cities (instead of remote and regional locations) and generally higher pay.

Figure 32 National supply and demand for public infrastructure workers



Source: Infrastructure Australia 2021, p.108.[43]

Regional Labour Markets

Analysis by ISF and SGS Economics for the NSW REZs found the peak employment demand for key occupations outstrips the entire size of the workforce in some REZs (New England, South West), whilst in the Central-West Orana peak demand is around two-thirds of the existing workforce[44]. Only in the Hunter-Central Coast REZ does the existing workforce clearly exceed employment demand. Whilst regional labour markets vary, it is likely to be the case in many REZs that renewable energy employment demand in key occupational groups is large relative to the existing local workforce. Low unemployment and occupational structure in regional labour markets will make it challenging to recruit labour from adjacent sectors.

Training gaps

The renewable energy and transmission sector is what is known in the training sector as a 'thin market' (with low demand for training spread across geographically dispersed regions). It is also subject to high levels of policy uncertainty which makes the economics of specialised training challenging and creates gaps in access to training. Even where there are established training pathways (e.g., electrical apprentices) there is a need for investment to increase capacity.

The REZs create a platform for government-industry collaboration on skills and workforce development but the states and regions are starting from a base of relatively low training capacity. Consequently, investment in training, workforce development and labour market programs is urgently required to increase the supply of skilled labour and local employment.

6.2 Boom and bust cycles

The expected trajectory of the construction workforce requirements to deliver the energy infrastructure needed for the energy transition is shown in Figure 33. The profile is highly variable, with increases of 8,000 in just two years in the early 2020s, again in the late 2030s, and with even greater jumps in the 2040s. These peaks are followed by drop offs, which can be very sharp.

This "lumpiness" creates significant risks for the supply chain, as evidenced at present with the difficulty to find the personnel to deliver projects. Risks are exacerbated by the competing demands for infrastructure build in other parts of the economy, and by the fact that much of the infrastructure is in rural areas with restricted labour supply. The troughs increase the difficulty of putting effective training programmes in place as the pipeline is not steady. These profiles are for all technologies, while specialist skills that are technology specific, and requirements within a state, are likely to be even more volatile.

The Hydrogen Superpower has a very similar pattern in terms of volatility of demand; however the scale of the jumps and dips are almost three times greater, with variations of up to 46,000 in the space of two years. The numbers projected for 2023 shows the scale of the challenge: the workforce in 2023 would need to already be 8,000 larger relative to the Step Change to deliver the increase in capacity in 2024 shown in the ISP.

Figure 33 National Electricity Market, development and construction employment, Step Change

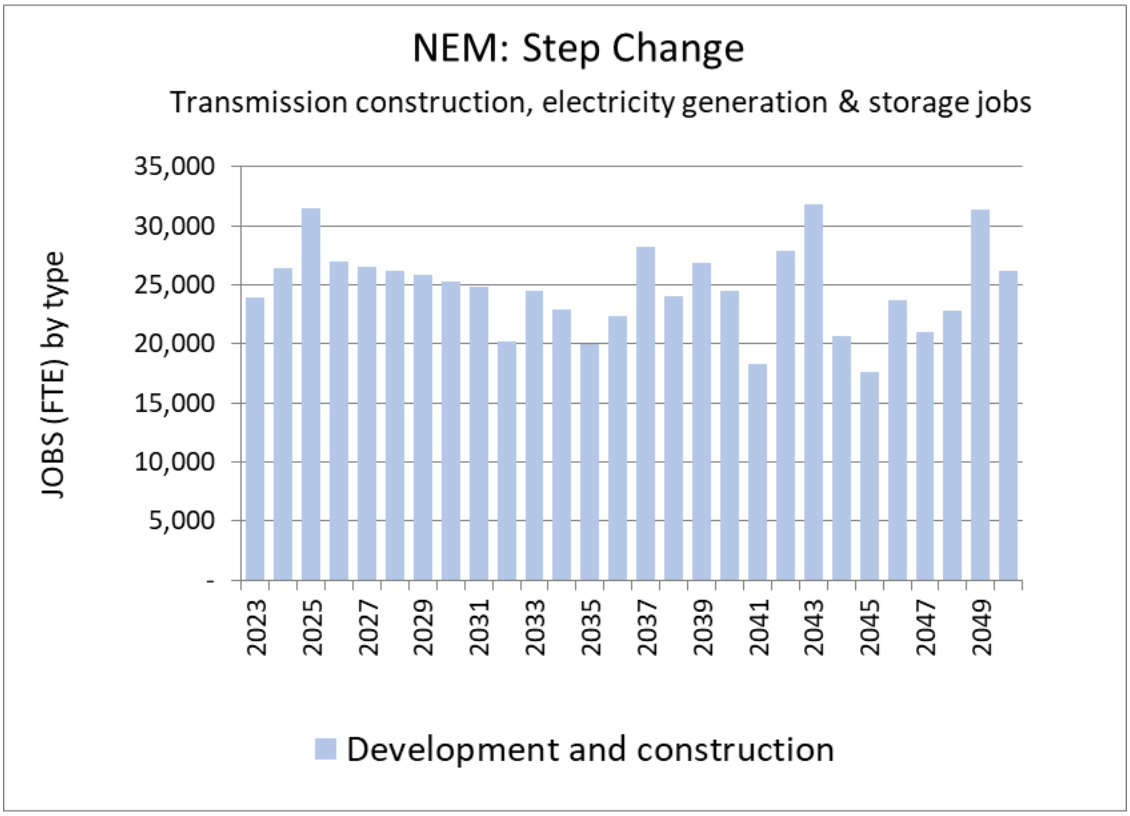


Figure 34 National Electricity Market, in-demand construction occupations, Step Change

Note different scales: construction labourers 0-2,500, others 0-1,500

Figure 34 shows how this profile plays out for some occupations that are needed in high numbers for construction but not required so much for operations and maintenance[8]. These include construction labourers and managers, truck drivers, and electrical engineers. The sharp surges in demand are reflected in these occupations.

There are some efforts underway to limit the volatility of renewable development. The NSW Government commissioned AEMO services to compare various development paths, including a "supply adjusted" pathway that imposed a maximum and minimum annual build, which was found to be the least cost[45]. The work did not specifically set out to produce a smoothed employment profile, although this would be an effect, nor did it present the employment outcomes of the four scenarios tested. It would be advantageous to explore the option of smoothing the employment profile to both reduce supply chain risks and assist efforts to ensure that opportunities for workforce development are put in place.

Recommendations

There are several recommendations for next steps that could assist in both providing the information needed to develop the workforce for the energy transition, and avoiding the boom bust cycles that have hampered industry development of the industry. These are:

1) AEMO to consult with ISP stakeholders on integrating employment profiles into the ISP.

2) AEMO to consult with ISP stakeholders on including sensitivities for capacity development that results in smoothed employment profiles in the ISP. This would allow a better understanding of the costs and benefits of reducing the volatility of employment demand.

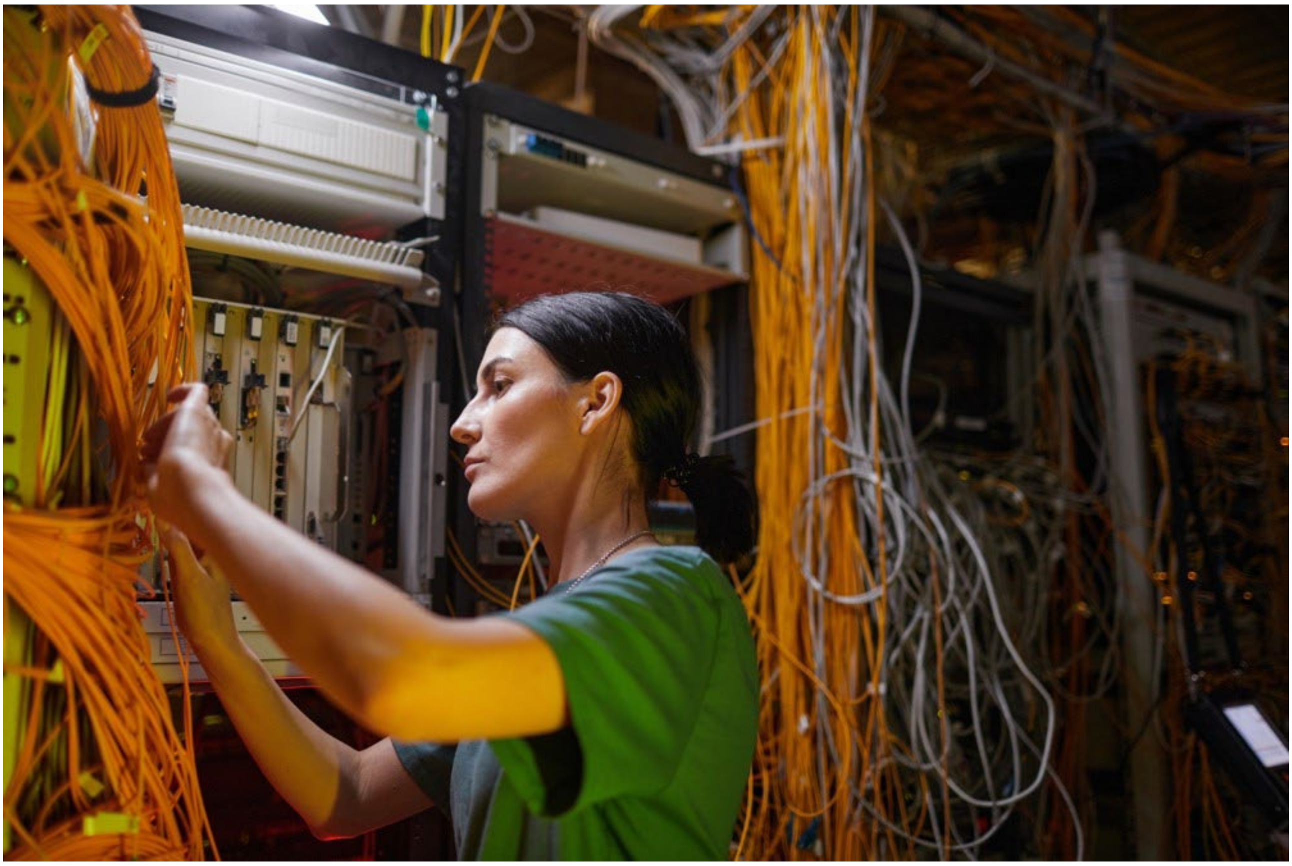
3) Research bodies to undertake the required research to address gaps and maintain the accuracy of workforce projections, including:

- Developing detailed occupational indicators for batteries and offshore wind to support training strategies.
- Regularly revisiting the employment indicators for major technologies, in particular wind and solar, with reference to the Australian industry to ensure accurate projections.
- Developing better employment indicators for onshore manufacturing for key technologies (solar, wind, batteries), including occupational indicators to support training strategies
- Undertaking supply chain analysis to determine more accurate projections for onshore manufacturing.

[8] The demand profile for electricians, for example, is much smoother, as electricians are also required in high numbers for operations and maintenance.

- Developing employment indicators where these are not currently available, including hydrogen production; renewable energy and fossil fuel decommissioning; extraction and processing of critical minerals associated with the energy transition, in particular battery minerals (noting that employment creation in this sub-sector will be primarily driven by global rather than onshore demand).
- Developing employment indicators in tandem with suitable data sets for the energy efficiency and electrification tasks to enable the inclusion of energy efficiency, demand management and energy management, and electrification in the workforce projections.

Beyond the delivery of information to facilitate planning for workforce development, there is an urgent need for governments, training providers, and industry to take coordinated action to develop and implement skills, training, and workforce development strategies. This is particularly important in regional areas and the REZs to increase labour supply and create local employment and training opportunities. Employment and training should be designed to facilitate a rapid build-out and increase the equity of the energy transition, with any training or development initiatives including opportunities for First Nations people and communities most impacted by the energy transition.



Appendix A – Employment indicators – Additional information

Utility batteries

In 2020, the ISF undertook the first large-scale study of renewable energy employment in Australia, covering a large proportion of the wind and solar industries, and with a reasonable return for distributed batteries and pumped hydro[46]. The surveys collect data on total employment across the supply-chain, including development, construction and operation and maintenance. The data was used to calculate employment factors. However, there was insufficient data to derive employment factors for utility-scale batteries, as there were few completed utility-scale projects in Australia. The information on detailed occupational breakdowns was also not sufficiently robust to include those breakdowns for battery employment. While it was beyond the scope of this study to repeat the survey, we sought to address this gap by conducting another literature review, focussed on reported employment from Australian projects.

The battery storage industry is growing fast with more than 21 GW installed globally, including rapid development in Australia[47]. Australia's largest battery, the 300 MW/450 MWh Victorian Big Battery has been in operation since late 2021, with even larger projects approved (for example the Mornington Peninsula Maoneng battery)[48].

The literature review aimed to find international employment data for battery storage both at distributed and utility-scale, but there is little which allows for derivation of an energy factor (for example, employment for utility-scale and distributed batteries disaggregated into installation and operation). In Australia, there is similarly a paucity of aggregated figures for battery storage employment at both distributed and utility scale.

However, there is estimated employment data associated with an increasing number of utility scale battery projects. Table 6 lists project data available from 14 utility scale Australian projects on construction and operations and maintenance employment collected for this review. The data includes projects at various stages of development and covers 3.2 GW of capacity.

We collected the project name, company, size (MW and MWh) and either employment projections or actual numbers for installation/construction, and operations and maintenance (O&M). To calculate the employment factors, the FTE employment is divided by the project capacity (MW). We then took the average of the calculated employment factors. This gives a figure of 0.61 job-years/MW (range 0.18-1.5) in construction and 0.04 jobs/MW (range 0.02-0.10) in operations and maintenance. The average value has been used in this project. As expected, this is considerably lower than the factors derived for distributed batteries in the 2020 survey, reflecting the large battery size.

As a comparison, we calculated the construction employment using the NREL cost breakdowns between labour and capital, and the AEMO projection of costs for batteries with 4 hours storage and with 8 hours storage (Table 5). The labour cost was converted to job years using an average employment cost for an electrical contractor of $119,300[9]. While the range of the employment factors derived from project data (Table 6) is quite high, the average value fits well into the factor calculated using the cost data.

Table 5 Calculation of batteries employment factor from capital costs (2, 4 and 8 hour storage)

	Capital cost for 2021-22, $/kW (2021 real Au$)[49]	Labour % of capital cost (NREL data)	Labour $/MW	Employment factor Job-years per MW
Battery storage (8hrs)	$2,856	3.7%	$106,324	0.89
Battery storage (4hrs)	$1,628	4.5%	$73,950	0.62
Battery storage (2hrs)	$1,054	5.8%	$61,494	0.52

[9] Calculated from average salary of $91,800 from https://www.traderisk.com.au/how-much-do-electricians-earn (2018 data) plus on-costs of 30%.

Table 6. Utility batteries employment: project data

Project	Company	Year	Status	Capacity			Employment		Employment Factor	
				MW	MWh	Storage hours	Installation Job-years	O&M Jobs	Installation Job-years/ MW	O&M Jobs/MW
Orana Battery Energy Storage System (BESS)	Akaysha Pty Ltd	2022	Scoping	300	1600	5.3	78 (1)	n/a	0.26	n/a
Apsley BESS	Acenergy PTY LTD	2022	Scoping	160	640	4.0	50	5	0.31	0.03
Gould Creek BESS	Maoneng Group	2022	Approved	225	450	2.0	131 (1)	n/a	0.58	n/a
Hornsdale Power Reserve	NEOEN	2022	Operating	150	194	1.3	158	6	1.05	0.04
Victoria Big Battery	NEOEN	2022	Operating	300	450	1.5	125 (1)	6	0.42	0.02
Mornington BEES	Maoneng Group	2022	Approved	240	480	2.0	160	n/a	0.67	n/a
Hunter Energy Hub	AGL	2022	Approved	500	2000	1.0	100	n/a	0.20	n/a
Maoneng BESS	Maoeng Group	2022	Approved	240	480	4.0	160	n/a	0.67	n/a
Earing Big Battery 1-3	Origin Energy Earing Pty Limited (Origin)	2021	Approved	700	2800	4.0	128	n/a	0.18	n/a
Awaba BESS	Firm Power	2021	Scoping	50	200	2.0	20	1.5	0.40	0.03
Broken Hill BEES	AGL Energy Limited	2021	Approved	50	100	2.0	50	2	1.00	0.04
Muswellbrook BESS	Firm Power	2021	Scoping	150	600	4.0	75	2.5	0.50	0.02
Tamworth BESS	Maoneng Group	2021	Scoping	200	400	2.0	150	0	0.75	n/a
Hume BESS Project	Meridian Energy Australia Pty Ltd	2020	Approved	20	40	4.0	30	2	1.50	0.1
Average/ TOTAL				3285	10434	2.8			0.61	0.04

Notes

[1] The average is used when either a range of FTE employment or employment period was provided (for example, 100-140 people employed for 4-6 months would be converted to 50 job-years).

Table 7 Utility batteries: employment factors comparisons

	Unit	Australian 2022 project review	Calculated	ISF 2020	NREL (for 2020)
Manufacturing	Job-years/MW	n/a	n/a	6.6 (global), 0.38 (Australian)	3
Construction & development	Job-years/MW	0.61	0.52 – 0.62	4.7 (1)	11.5 (distributed & utility combined)
O&M	Jobs/MW	0.04	n/a	1.4 (1)	

Note 1: utility battery factors were not derived in the 2020 survey, so these data points are the distributed commercial battery factors.

Batteries manufacturing

The ISF 2020 survey found an international value for batteries manufacturing employment of 6.6 job-years/MW or 3.36 job-years/MWh. Reviewing international literature, this figure is very high[50,51], so we have derived a new figure from literature, which we use in this work. The capacities were given in all reports in GWh, so we have converted to MW using the using the average value of 2.7MW / MWh from the 14 Australian battery projects listed in Table 6. The average value found is 0.57 job-years/MW, which is used for both distributed and utility batteries.

Table 8 Batteries manufacturing employment

Project	Year	Annual production (GWh)	Employment	Manufacturing employment factor (1)	
			Jobs	Job-years/MWh	Job-years/MW
Germany case study - company CATL[52]	2021	100	2000	0.20	n/a
Swiss case study, Swiss Clean Battery (SCB) AG[53]	2022	1.2 - 7	180-1100	0.16	n/a
Thielmann et al (2021) [54]	2021	32	2900-5800	0.14	n/a
BVES 2022 Sector Analysis [55]	2022	40	16900	0.42	n/a
Tesla's Nevada Gigafactory[56]	2018	20	7059	0.35	n/a
Usai et al, 2022 [57]	2022	n/a	n/a	0.12	n/a
Faraday Institute, 2020[58]	2020	n/a	n/a	0.18	n/a
Steen M, et al, 2017[59]	2017	n/a	n/a	0.11	n/a
Average				**0.21**	**0.57**

Offshore wind

Table 9 Offshore wind employment factor: comparison with other studies

Source/ project	Year	Information type	Development & construction Job-years/MW	Manufacturing Job-years/MW	Operations & maintenance Jobs/MW
QBIS (Sylvest, T.) [60] (employment factor used in this work)	2020	Study	1.4	5.3	0.08
Star of the South [61]	2021	Project			0.09
Knol & Coolen [62]	2020	Study	0.4	3.3	0.07
Beatrice [63]	2019	Project			0.15
Arklow Bank [64]	2018	Project			0.10
BVG [65]	2017	Study	0.7		
IRENA [66]	2017	Study	2.2	10.5	0.17
East Anglia [67]	2014	Project	3.1	7.3	0.13

Appendix B – Decline factors for employment indicators

Table 10 to Table 12 give the calculated decline factors for each technology and scenario. A value of 1 indicates there is no decline in CAPEX, so the employment factor is assumed to remain the same. The decline factor for hydro is assumed to be the same as for pumped hydro (this has negligible impact on the employment projections as there is no hydro construction expected).

Table 10 Decline factors (technology and year) for the Step Change and Offshore Wind scenarios

Citation
Rutovitz, J., Langdon., R, Mey, F., Briggs, C. (2022) Electricity Sector Workforce Projections for the 2022 ISP: Focus on New South Wales. Prepared by the Institute for Sustainable Futures for RACE for 2030
November 2022
Contributors

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Black coal	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Peaking gas & liquids	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Mid-merit gas	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95
Utility-scale PV	1	0.84	0.78	0.75	0.72	0.70	0.68	0.67	0.65	0.63	0.63	0.61	0.60	0.58	0.56	0.53	0.51	0.49	0.47	0.47	0.47	0.47	0.46	0.46	0.46	0.46	0.45	0.45	0.44
Solar Thermal	1	0.99	0.97	0.95	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.78	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.67	0.67	0.66	0.66	0.65	0.65	0.64
Distributed batteries	1	0.92	0.84	0.78	0.73	0.69	0.65	0.63	0.59	0.56	0.53	0.52	0.51	0.49	0.48	0.46	0.45	0.44	0.42	0.41	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30
Utility-scale batteries	1	0.90	0.79	0.71	0.65	0.60	0.56	0.53	0.49	0.46	0.43	0.42	0.42	0.41	0.40	0.40	0.39	0.38	0.37	0.37	0.36	0.36	0.35	0.34	0.34	0.33	0.32	0.32	0.31
Wind (onshore)	1	0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.90	0.89	0.89	0.88	0.88	0.87	0.86	0.86	0.85	0.84	0.84	0.83	0.83	0.82	0.82	0.81
Wind (offshore)	1	0.97	0.95	0.92	0.90	0.88	0.87	0.85	0.83	0.82	0.81	0.79	0.78	0.77	0.76	0.75	0.74	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66
Pumped hydro	1	1	1	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95
Rooftop PV	1	0.88	0.80	0.72	0.66	0.64	0.62	0.60	0.59	0.58	0.57	0.56	0.55	0.55	0.54	0.54	0.52	0.51	0.49	0.48	0.47	0.46	0.44	0.42	0.41	0.40	0.39	0.39	0.38
Brown coal	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95

Table 11 Decline factors (technology and year) for the Hydrogen Superpower

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Black coal	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Peaking gas & liquids	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Mid-merit gas	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95
Utility-scale PV	1	0.81	0.64	0.58	0.54	0.50	0.47	0.45	0.43	0.41	0.41	0.39	0.39	0.38	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.34
Solar Thermal	1	0.99	0.97	0.95	0.91	0.89	0.87	0.85	0.83	0.81	0.79	0.78	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71	0.70	0.69	0.67	0.67	0.66	0.66	0.65	0.65	0.64
Distributed batteries	1	0.92	0.84	0.78	0.73	0.69	0.65	0.63	0.59	0.56	0.53	0.52	0.51	0.49	0.48	0.46	0.45	0.44	0.42	0.41	0.40	0.39	0.37	0.36	0.35	0.33	0.32	0.31	0.30
Utility-scale batteries	1	0.90	0.79	0.71	0.65	0.60	0.56	0.53	0.49	0.46	0.43	0.42	0.42	0.41	0.40	0.40	0.39	0.38	0.37	0.37	0.36	0.36	0.35	0.34	0.34	0.33	0.32	0.32	0.31
Wind (onshore)	1	0.99	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.90	0.89	0.89	0.88	0.88	0.87	0.86	0.86	0.85	0.84	0.84	0.83	0.83	0.82	0.82	0.81
Wind (offshore)	1	0.97	0.95	0.92	0.90	0.88	0.87	0.85	0.83	0.82	0.81	0.79	0.78	0.77	0.76	0.75	0.74	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.66	0.66
Pumped hydro	1	1	1	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95
Rooftop PV	1	0.88	0.80	0.72	0.66	0.64	0.62	0.60	0.59	0.58	0.57	0.56	0.55	0.55	0.54	0.54	0.52	0.51	0.49	0.48	0.47	0.46	0.44	0.42	0.41	0.40	0.39	0.39	0.38
Brown coal	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95

Table 12 Decline factors (technology and year) for the Slow Change

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Black coal	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Peaking gas & liquids	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
Mid-merit gas	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95
Utility-scale PV	1	0.93	0.89	0.85	0.82	0.79	0.76	0.73	0.71	0.69	0.67	0.66	0.65	0.64	0.62	0.61	0.59	0.59	0.58	0.57	0.56	0.54	0.53	0.51	0.50	0.49	0.48	0.47	0.46
Solar Thermal	1	0.99	0.98	0.97	0.96	0.95	0.93	0.91	0.90	0.89	0.88	0.88	0.87	0.86	0.86	0.85	0.85	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.78	0.77	0.76
Distributed batteries	1	0.97	0.94	0.91	0.88	0.86	0.83	0.80	0.76	0.72	0.68	0.64	0.62	0.60	0.58	0.56	0.54	0.53	0.51	0.50	0.49	0.48	0.46	0.45	0.44	0.43	0.42	0.41	0.40
Utility-scale batteries	1	0.96	0.92	0.90	0.87	0.84	0.82	0.77	0.72	0.68	0.63	0.59	0.56	0.55	0.52	0.51	0.49	0.47	0.46	0.45	0.44	0.44	0.43	0.42	0.41	0.40	0.40	0.40	0.39
Wind (onshore)	1	0.99	0.99	0.98	0.97	0.97	0.96	0.96	0.95	0.94	0.94	0.93	0.93	0.92	0.92	0.91	0.90	0.90	0.89	0.88	0.88	0.87	0.87	0.86	0.86	0.85	0.85	0.84	0.84
Wind (offshore)	1	0.97	0.94	0.93	0.91	0.90	0.88	0.87	0.86	0.94	0.94	0.93	0.93	0.92	0.92	0.91	0.90	0.90	0.89	0.88	0.88	0.87	0.87	0.86	0.86	0.85	0.85	0.84	0.84
Pumped hydro	1	1	1	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95
Rooftop PV	1	0.96	0.93	0.90	0.87	0.84	0.82	0.80	0.77	0.74	0.70	0.67	0.65	0.63	0.60	0.58	0.56	0.55	0.54	0.53	0.53	0.52	0.52	0.51	0.50	0.50	0.49	0.48	0.48
Brown coal	1	1	1	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95

Appendix C – Additional information – REZ project allocation

Table 13 to Table 18 give the REZ capacity allocations by state and scenario that are used for modelling employment outcomes. When there is no entry for a particular REZ, we have not included any of the state capacity in the employment projections for that particular REZ. There are no pumped hydro tables for Victoria or South Australia because the modelled REZs do not have any project allocations. There are no tables for Tasmania as it was not clear that any of the state large scale storage projections would be built in the modelled REZs.

Table 13 NSW REZ capacity allocation – pumped hydro

Pumped Hydro	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
All scenarios																													
NSW total	240	240	240	920	2280	2280	2280	2280	2280	2280	2280	2280	2280	2280	2486	2780	2780	2881	2881	2881	2881	3280	3280	3280	3280	3280	3280	3280	3280
Tumut		240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240
Illawarra		-	-	680	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040
Rest of NSW	240	-	-	-	-	-	-	-	-	-	-	-	-	-	206	500	500	601	601	601	601	1000	1000	1000	1000	1000	1000	1000	1000

Table 14 NSW REZ capacity allocation – utility batteries

Utility Batteries	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Step Change, Offshore Wind and Hydrogen Superpower scenarios																													
NSW total	50	50	50	650	650	1575	1975	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	2050	1450	1450	525	148	465	465
Central-West Orana	-	-	-	-	-	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	-	-	-	-
Hunter	-	-	-	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	-	-	-	-	-	-
Rest of NSW	50	50	50	50	50	50	450	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	148	465	465
Slow Change scenario																													
NSW total	50	50	50	650	1162	1575	1612	1612	1612	1612	1612	1612	1612	1612	1612	1612	1612	1612	1749	1749	1749	1749	1749	1149	638	224	806	806	806
Central-West Orana	-	-	-	-	512	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	925	413	-	-	-	-	-
Hunter	-	-	-	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	-	-	-	-	-
Rest of NSW	50	50	50	50	50	50	87	87	87	87	87	87	87	87	87	87	87	87	224	224	224	224	224	136	638	224	806	806	806

Table 15 QLD REZ capacity allocation – pumped hydro

Pumped Hydro	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Step Change, Offshore Wind scenarios																													
QLD total	570	570	570	820	820	820	820	820	1046	1046	1046	1293	1375	1375	2023	2174	2174	2207	2207	2529	2529	2529	2529	2529	2529	2529	2529	2529	2529
Darling Downs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	403	403	403	403	403	403	403	403	403	403	403	403	403	403	403
Rest of QLD	570	570	570	820	820	820	820	820	1046	1046	1046	1293	1375	1375	1620	1771	1771	1804	1804	2126	2126	2126	2126	2126	2126	2126	2126	2126	2126
Hydrogen Superpower scenario																													
QLD total	570	570	570	820	820	820	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	2263	2263	2263	2263	2263	2263	2263	2263	2263	2263
Darling Downs	-	-	-	-	-	-	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635	635
Rest of QLD	570	570	570	820	820	820	549	549	549	549	549	549	549	549	549	549	549	549	549	1628	1628	1628	1628	1628	1628	1628	1628	1628	1628
Slow Change scenario																													
QLD total	570	570	570	820	820	820	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1153	1153	1793	1804	1804	1804	1845
Darling Downs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	21	662	662	662	679	679
Rest of QLD	570	570	570	820	820	820	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1132	1132	1131	1142	1142	1125	1166

Table 16 QLD REZ capacity allocation – utility batteries

Utility batteries	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Step Change, Offshore Wind scenarios																													
QLD total	100	100	100	100	100	100	186	186	902	902	902	902	902	902	902	902	1809	2997	3170	3409	3409	3409	3409	3409	3409	3409	4344	5857	5140
Wide Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188	1188
Darling Downs	100	100	100	100	100	100	100	100	816	816	816	816	816	816	816	816	1723	1723	1723	1962	1962	1962	1962	1962	1962	1962	1962	1962	1962
Rest of QLD	-	-	-	-	-	-	86	86	86	86	86	86	86	86	86	86	86	86	259	259	259	259	259	259	259	259	1194	2707	1990

Utility batteries	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Hydrogen Superpower scenario																													
QLD total	100	100	100	406	782	1851	2180	2180	2719	2719	2719	2719	2719	2719	2719	4623	4721	4721	4806	8240	8240	8240	8240	9257	10614	9837	9785	13901	13362
Wide Bay	-	-	-	-	-	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068	1068
Darling Downs	100	100	100	100	100	100	100	100	100	100	100	100	100	100	964	964	964	964	1655	1655	1655	1655	1655	1655	1655	1655	1655	1655	1655
Rest of QLD	-	-	-	306	682	683	1012	1012	1551	1551	1551	1551	1551	1551	687	2591	2689	2689	2083	5517	5517	5517	5517	6534	7891	7114	7062	11178	10639
Slow Change scenario																													
QLD total	100	100	100	100	100	100	265	265	779	917	1021	1322	1605	1605	1605	1605	1605	2548	2548	2548	2548	2548	2548	3287	3287	3287	3122	3954	4088
Wide Bay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	942	942	942	942	942	942	942	942	942	942	942	942
Darling Downs	100	100	100	100	100	100	100	100	100	100	100	400	400	400	400	400	400	400	400	400	400	400	400	1440	1440	1440	1440	2272	2272
Rest of QLD	-	-	-	-	-	-	165	165	679	817	921	922	1205	1205	1205	1205	1205	1206	1206	1206	1206	1206	1206	905	905	905	740	740	874

Table 17 VIC REZ capacity allocation – utility batteries

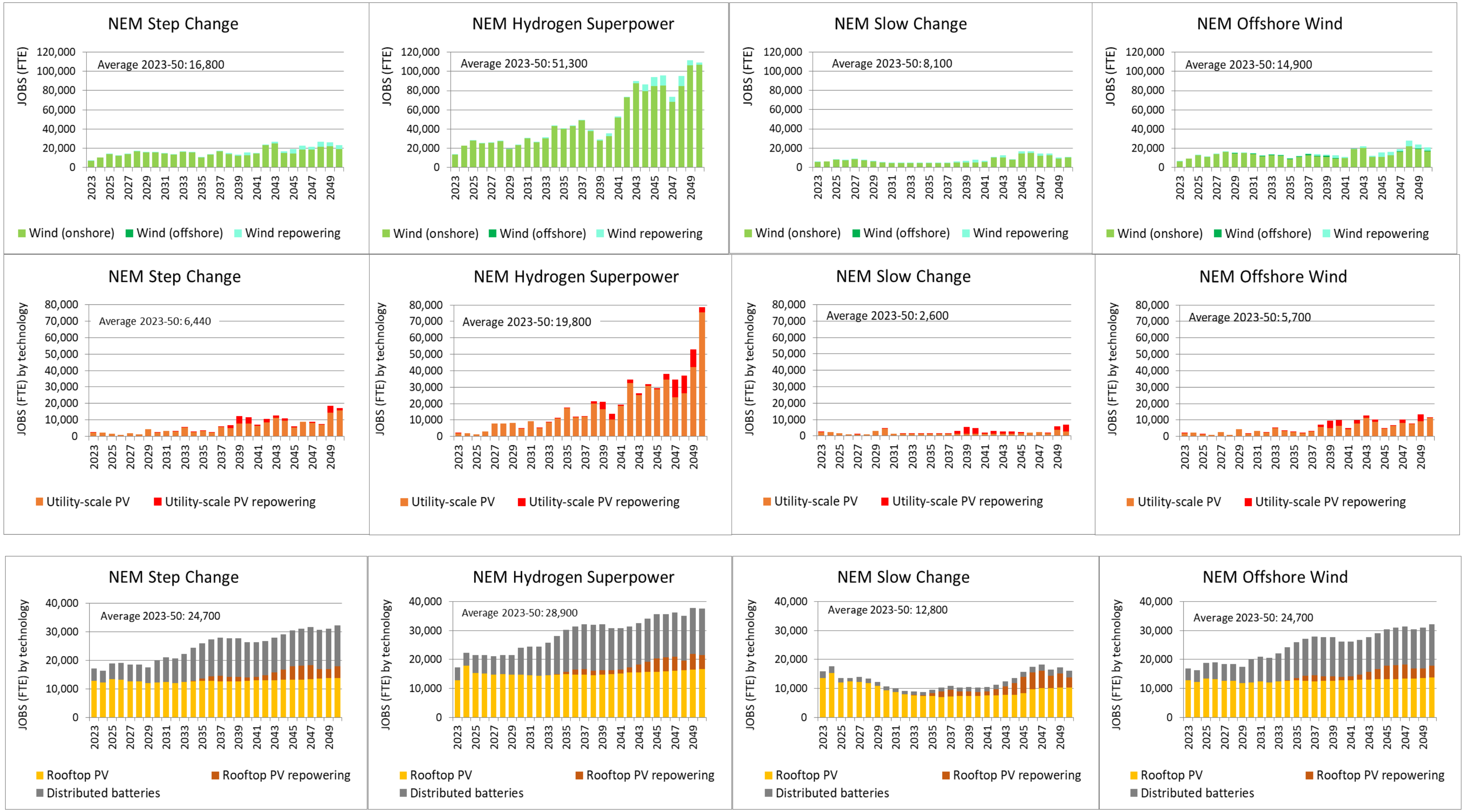
Utility batteries	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Step Change, Offshore Wind scenarios																													
VIC total	250	125	124	124	124	125	124	124	710	710	961	960	961	960	961	961	961	961	961	961	961	961	961	961	961	961	961	961	375
Western Victoria	-	-	-	-	-	-	-	-	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Rest of VIC	250	125	124	124	124	125	124	124	460	460	711	710	711	710	711	711	711	711	711	711	711	711	711	711	711	711	711	711	125
Hydrogen Superpower scenario																													
VIC total	250	125	124	396	396	1121	1120	1120	1120	1120	1371	1370	1371	1370	1370	1370	1371	1370	1370	1370	1370	1371	1371	1099	1099	375	375	375	375
Western Victoria	-	-	-	-	-	233	233	233	483	483	483	483	483	483	483	483	483	483	483	483	483	483	483	483	483	250	250	250	250
Rest of VIC	250	125	124	396	396	888	887	887	637	637	888	887	888	887	887	887	888	887	887	887	887	888	888	616	616	125	125	125	125
Slow Change scenario																													
VIC total	250	125	124	124	124	125	124	124	124	124	375	375	375	374	374	374	375	651	651	651	651	652	651	652	1809	2180	2180	2181	2243
Western Victoria	-	-	-	-	-	-	-	-	-	-	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251	251
Rest of VIC	250	125	124	124	124	125	124	124	124	124	124	124	124	123	123	123	124	400	400	400	400	401	400	401	1558	1929	1929	1930	1992

Table 18 SA REZ capacity allocation – utility batteries

Utility batteries	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
Step Change, Offshore Wind scenarios																													
SA total	342	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	531	781	781	781	781	781	783	781	781	781	781	1484	1484
Mid-North SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	350	350	350	350	350	350	350	350	350	350	350	350
Rest of SA	342	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	481	431	431	431	431	431	433	431	431	431	431	1134	1134
Hydrogen Superpower scenario																													
SA total	342	473	473	476	476	476	476	476	476	476	476	476	476	476	476	476	476	476	476	476	476	476	479	473	473	473	973	4893	4893
Mid-North SA	-	-	-	53	53	53	53	53	53	53	53	53	53	53	53	351	351	351	351	351	351	351	351	351	351	351	351	351	351
Rest of SA	342	473	473	423	423	423	423	423	423	423	423	423	423	423	423	125	125	125	125	125	125	125	128	122	122	122	622	4542	4542
Slow Change scenario																													
SA total	342	473	473	473	473	473	473	473	473	473	473	473	520	520	546	998	1041	1256	1256	1256	1256	1256	1256	1256	1450	1450	1450	1450	1450
Mid-North SA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
Rest of SA	342	473	473	473	473	473	473	473	473	473	473	473	520	520	408	860	903	1118	1118	1118	1118	1118	1118	1118	1312	1312	1312	1312	1312

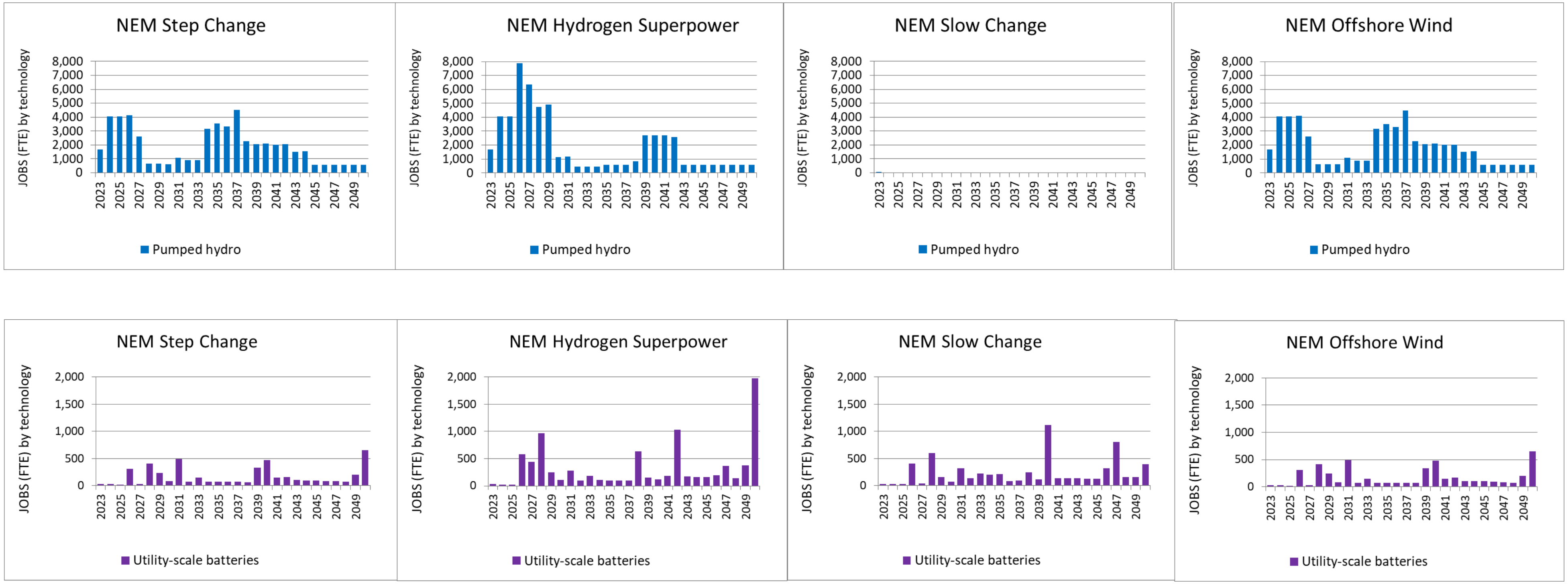
Appendix D – Additional results by technology and scenario

Figure 35 National Electricity Market, wind, solar and distributed battery jobs by scenario



Note scale for wind is 0-120,000, for utility solar is 0-80,000, and for rooftop solar and batteries is 0-40,000

Figure 36 National Electricity Market, pumped hydro and batteries jobs by scenario



Note scale for pumped hydro is 0-8,000, scale for batteries is 0-2,000 FTE jobs

Appendix E – Additional results by occupational mix

Figure 37 NEM, in-demand occupations for 2031, Hydrogen Superpower

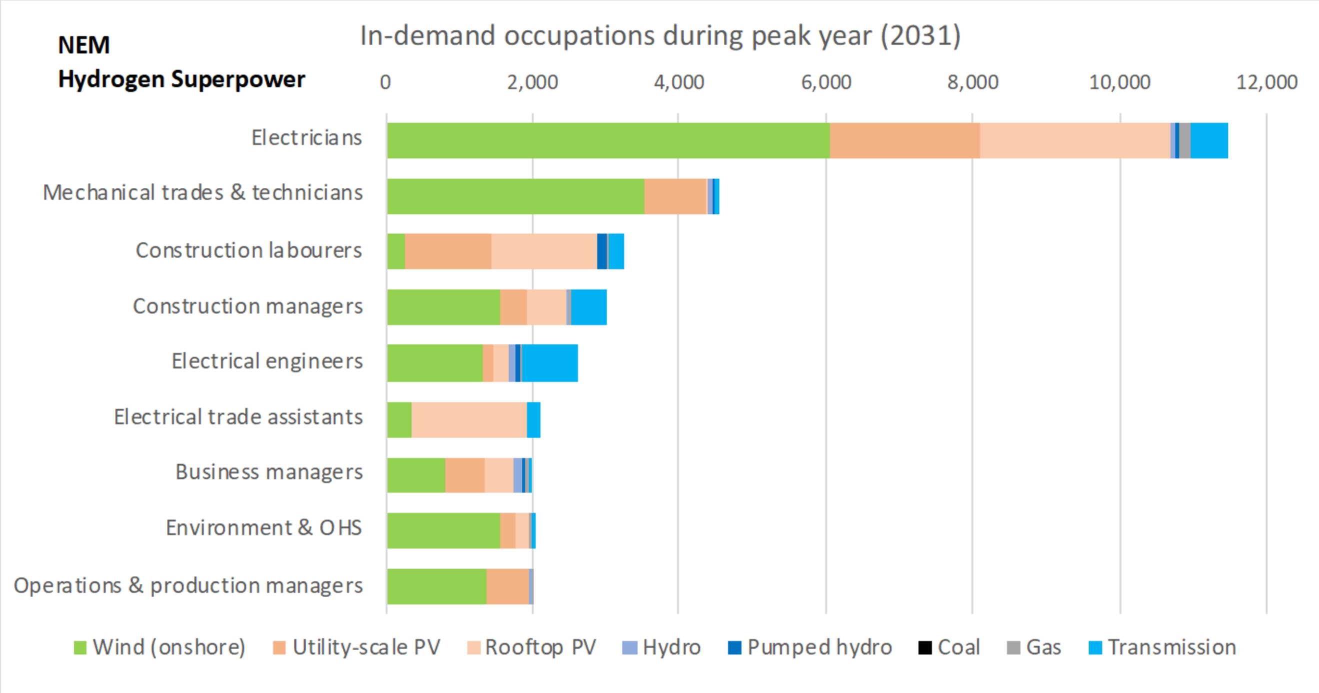


Figure 38 Annual requirements for in-demand occupations, Hydrogen Superpower

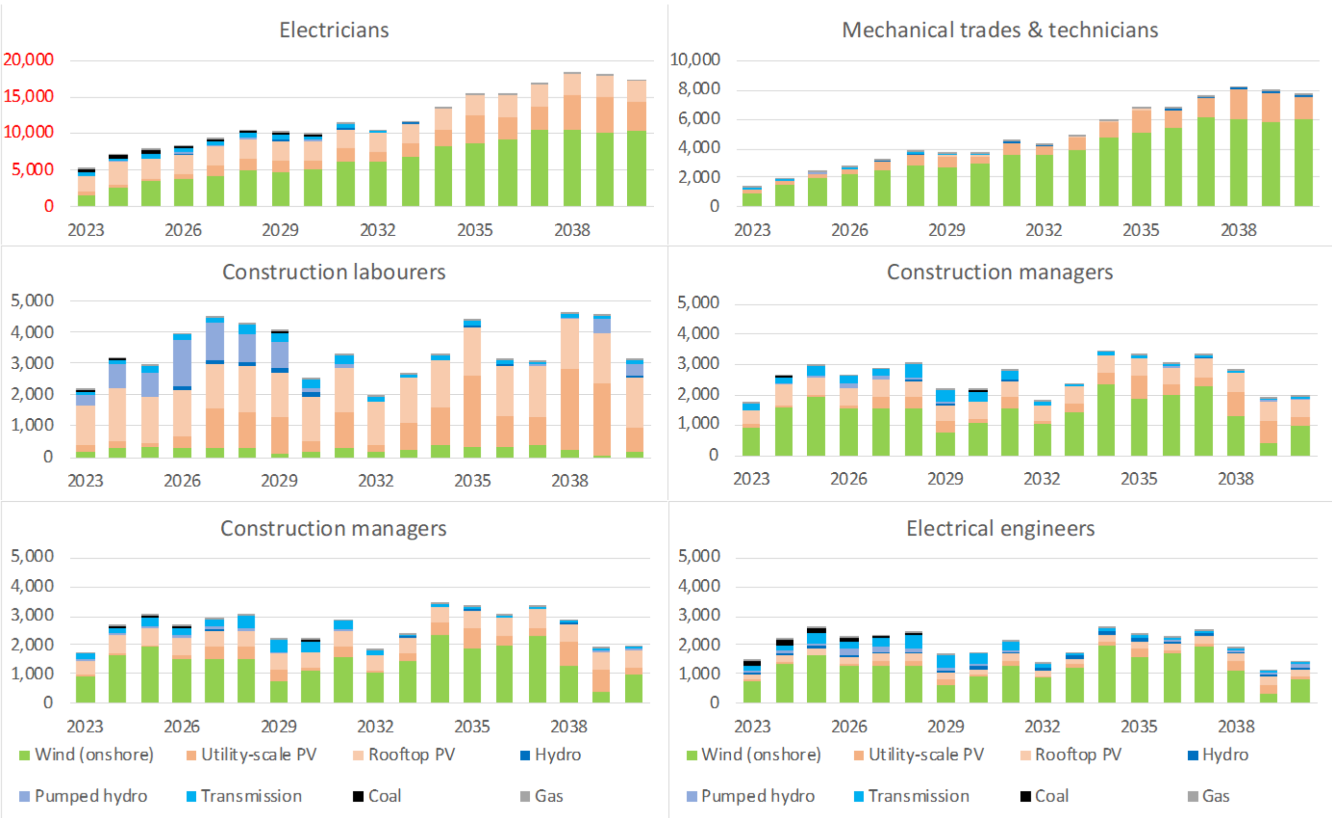
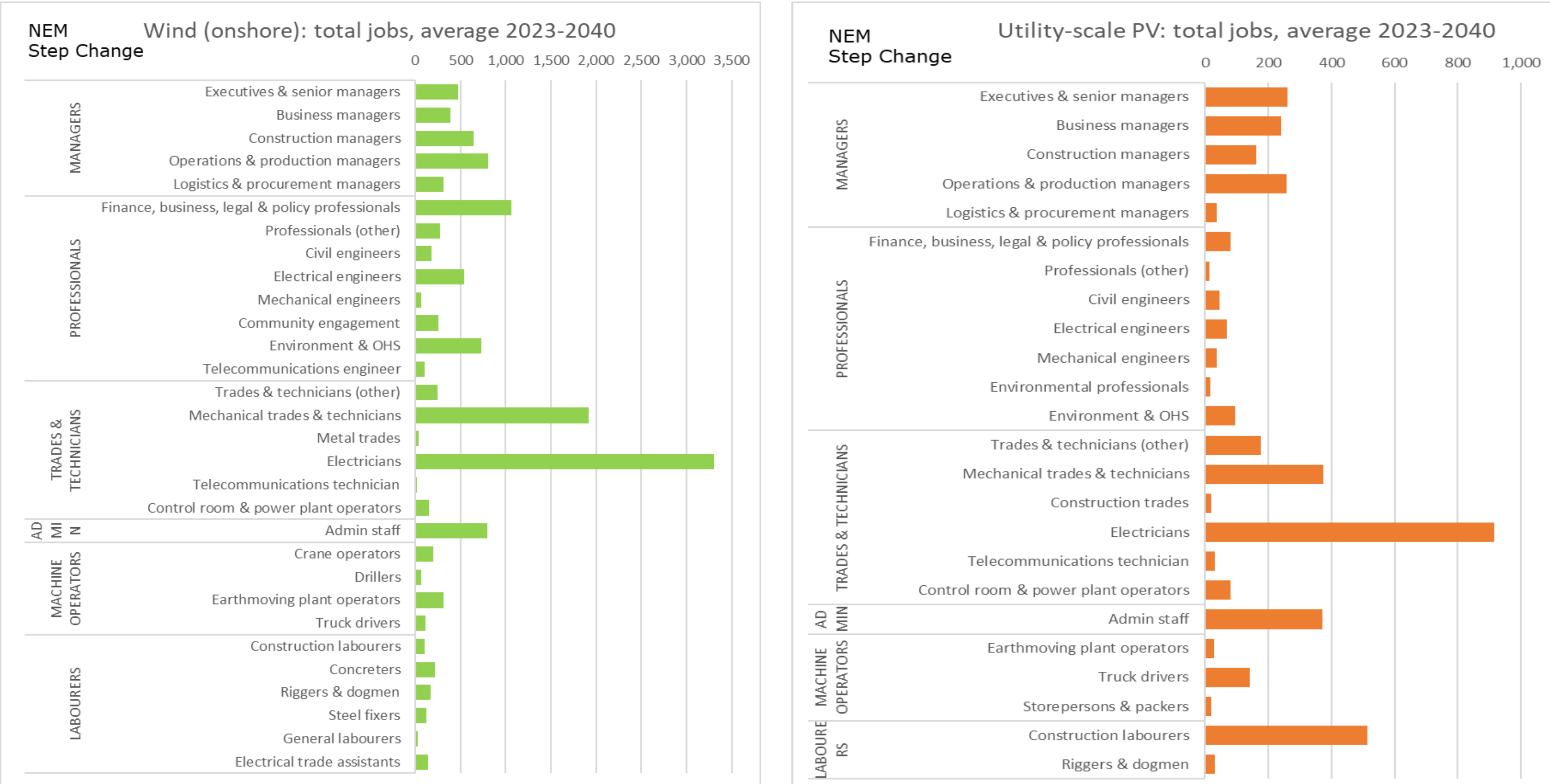


Figure 39 Average occupational mix for wind and solar, 2023 - 2040



Note different scales – wind from 0-3,500, solar from 0-1000

Appendix F – Additional results by State

Figure 40 State by state technology summary by scenario

Note: Hydrogen Superpower Scenario the maximum is 120,000 FTE while the other three scenarios have a maximum of 35,000 FTE.

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