Working Paper

Shortages of Engineers and Supply Projections

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This paper brings together published evidence on current and projected shortages of Australia's degree qualified engineer workforce. It appears that approximately 100,000 more engineers will be required by 2030, a 50% increase on current numbers, in order to deliver on government initiatives in energy, transport and built infrastructure, advanced manufacturing, minerals, defence, etc.

The current supply of domestic graduates into engineering employment is roughly equivalent to the loss of engineers through retirement and normal attrition. The future engineer workforce will therefore continue to require both permanent migration of overseas-educated engineers, and temporary skills-based migration programs. The paper models projections for future supply that include a rapid increase in domestic engineering graduates.

Introduction

This paper presents data from Australian government and other trusted sources that refer to, or imply, current and prospective shortages in Engineering, technical IT, and related occupations that would be expected to be filled by graduates with at least 3-year Bachelor degrees. These occupations are at Level 1 (Managers) and Level 2 (Professionals) in the ANZSCO classification.

Sections 1 and 2 summarise reports from the National Skills Commission, and the Australian government's initiatives in modern manufacturing, low-emissions technologies, naval shipbuilding, and infrastructure. These, and other initiatives being pursued by State governments (not reported here), indicate strong prospective opportunities for future engineers and IT[1] professionals[2]. A summary of the influential Ai Group's concerns about prospective engineer shortages – and their member companies' perspectives on supply – is provided in Section 4.

Section 5 provides two international comparisons. The numbers of working engineers per 1,000 population in Australia, and Germany and UK show clearly that Germany has a much higher proportion of engineers than Australia, particularly in mechanical, industrial and production engineering. Secondly, across the OECD countries, Australia produces the second lowest proportion of engineers amongst its tertiary graduates.

Taken together, these reports and data indicate that Australia needs to increase its professional engineering workforce. Section 6 of the paper explores increasing this to about 300,000 by 2030, from its current base of about 200,000. An illustrative supply projection model is described with three components: domestic graduates, permanent migrants, and temporary visa holders. The importance of maintaining (and growing) the pool of temporary migrants to supply the majority of permanent migrants is discussed. The model includes a 10% per annum (compounding) increase of domestic

[1] Note that 'ICT' is used in ANZSCO classifications. The term 'IT' is used in the text of this paper.

[2] Some sources refer to shortages of (or the need for) engineering Technicians and Tradespeople (Level 3 ANZSCO occupations). These are mentioned for context, but are not quantified in the paper, as their education and training are not the responsibility of the higher education sector.

graduates from as early as possible in order to ensure greater sovereignty of the Australian engineering workforce for the identified areas of national importance.

1. National Skills Commission reports

Three documents from the National Skills Commission (NSC) are summarised here. First is the most recent skills priority list, published in June 2021. This is followed by a short summary of the December 2020 NSC report on post-Covid-19 economic recovery. Third, the NSC employment predictions for November 2025 in the occupations of interest here, are presented.

1.1 NSC Skills Priority List (June 2021)[3]

This annual report classifies occupations by current shortage (shortage/no shortage) and strong/ moderate/soft future demand. The report is based on job vacancies and employers' recruitment experiences. Shortages exist *"when employers are unable to fill or have considerable difficulty filling vacancies for an occupation, or significant specialised skill needs within that occupation, at current levels of remuneration and conditions of employment, and in reasonably accessible locations*". 'No shortage' is the default for includes occupations for which there is a lack of evidence.

The June 2021 list identifies 153 occupations in current shortage and 646 in future shortage. Table 1 summarises the counts of total occupations that are in Engineering and related, and technical IT occupations at ANZSCO Levels 1 and 2. The corresponding named occupations of interest to ACED with strong and moderate future demand are listed in Appendix 1.

Table 1 Summary of National Skills Priority List, June 2021

Current Labour Market Assessment	Future Demand indicator	Count of occupations				
		Total	Engineering* and related		IT (technical)	
			Level 1	Level 2	Level 1	Level 2
Shortage	strong	57	-	10	-	3
Shortage	moderate	87	2	-		3
Shortage	soft	9	-	-	-	-
No Shortage	strong	208	3	11	1	8
No Shortage	moderate	394	2	7	-	-
No Shortage	soft	44	-	-	-	-

*Computer, Network and Telecommunications Engineering occupations are included in Engineering

These data indicate that:

- engineering and IT occupations are almost one quarter of all occupations in *current shortage*
- almost all engineering and technical IT occupations have *at least moderate future demand*.

1.2 The shape of the Australian Post COVID-19 Workforce[4]

This report examines a number of scenario variations for post-2020 economic recovery, with broad predictions for employment to 2025.

[3] Australian Government National Skills Commission (June 2021). *Skills Priority List.* https://www.nationalskillscommission.gov.au/sites/default/files/2021-06/Skills%20Priority%20List%20Occupation%20List_0.pdf

[4] Australian Government National Skills Commission (Dec 2020). *The shape of the Australian Post COVID-19 Workforce.* https://www.nationalskillscommission.gov.au/shape-australias-post-covid-19-workforce

The basic *Economic Restoration* scenario shows employment growth projections over Q1 2021 to Q1 2025 in two industry sectors in which engineers are employed:

- Professional, Scientific and Technical Services: up 65,800 (5.7%)
- Information Media and Telecommunications: up 10,800 (per cent increase not stated)

but decline in three:

- Manufacturing: down 23,200 (2.5%)
- Construction: down 25,000 (2.1%), due to lower population growth
- Mining: down 27,000 (2.3%), due to fall in world economic growth forecasts by the IMF.

Occupations that require a Bachelor degree or higher will continue to have high growth expectations, with 'Information and Organisation Professionals' predicted for 11.6% growth over 5 years to 2025.

The report examines three variants of the basic scenario. Under the '*Accelerated Digitisation'* variant, Professional, Scientific and Technical Services, Manufacturing, Mining and Construction sectors all gain employment share by Q2 2023 (relative to the baseline of Q1 2020). IT professionals and technical occupations are predicted to grow more rapidly than non-technical roles, with IT Network and Support Professionals having 5-year growth of about 12%. The '*Fortress Australia*' variant depresses the changes in employment share in all sectors of interest except for Manufacturing. Even in this sector the change by Q2 2023 is slightly negative.

1.3 NSC Labour Market Projections

The NSC produces annual employment projections by industry, occupation, skill level and region for the following five-years. NSC warns that COVID-19 makes the 2020 projections more uncertain than usual.

The NSC's five-year employment outlook to Nov 2025[5] predicts continued structural shift in employment towards service industries. *Professional, Scientific and Technical Services*, *Education and Training,* and *Construction* will make up the 3rd, 4th and 5th largest contributions to employment growth. By contrast, *Information Media and Telecommunications,* and *Manufacturing* are predicted to be the only industry sectors (of 19) that will experience employment shrinkage.

The report projects employment growth in *Computer System Design and Related Services by 47,200 (16.0%),* and *Architectural, Engineering and Technical Services by 25,700 (9.0%).* The *Construction* sector growth (overall 6.8%) takes into account government stimulus in residential building and above average growth of 8.8% in *Heavy and Civil Engineering Construction* as a result of infrastructure investment.

Table 2 provides projections for degree-level occupations in Engineering, IT and related areas[6]. The occupations with the greatest percentage projections of demand (> 30%) are in the IT area. The named *Telecommunications, Civil, Mechanical & Manufacturing, Mining, and Electrical Engineers* all have projections of demand greater than 10%. These figures are all greater than the 7.8% average projection of across all occupations.

[5] Australian Government National Skills Commission (Mar 2021). *Industry Employment Outlook – five years to November 2025.* Downloaded from https://lmip.gov.au/default.aspx?LMIP/GainInsights/EmploymentProjections
[6] Australian Government Labour Market Information Portal. *Occupation Projections – five years to November 2025*. Downloaded from https://lmip.gov.au/default.aspx?LMIP/GainInsights/EmploymentProjections

Table 2 Selected occupation projections – five years to Nov 2025

Occupation Code	Occupation	Employment Nov 2020 ('000)	NSC Projections		
			number ('000)	increase ('000)	increase (%)
1332	Engineering Managers	26.8	29.3	2.4	9.0
1334	Manufacturers	22.1	21.7	-0.4	-1.8
1335	Production Managers	70.3	73.0	2.6	3.8
135	ICT Managers	65.6	71.0	5.4	8.3
	Managers (above)	**184.8**	**194.9**	**10.1**	**5.5**
2331	Chemical & Materials Engineers	7.0	7.4	0.4	5.7
2332	Civil Engineering Professionals	67.0	77.1	10.2	15.2
2333	Electrical Engineers	26.8	29.9	3.1	11.4
2334	Electronics Engineers	5.4	5.9	0.5	9.1
2335	Industrial, Mech. and Prod. Eng's	45.5	52.8	7.3	15.9
2336	Mining Engineers	11.0	12.5	1.5	13.9
2339	Other Engineering Professionals	13.2	14.6	1.4	10.8
2330	Engineering Professionals nfd	19.2	21.8	2.7	14.0
233	**Engineering Professionals**	**196.8**	**223.8**	**27.0**	**13.7**
2613	Software and Apps. Programmers (inc. Software Engineers*)	157.3	199.8	46.1	30.0
2631	Computer Network Professionals	49.1	64.0	14.9	30.4
2632	ICT Support and Test Engineers	12.1	16.3	4.1	34.0
2633	Telecomm. Eng. Professionals	13.1	15.2	2.1	16.3
	Technical IT Professionals	**228.0**	**295.3**	**67.2**	**29.5**
	ALL OCCUPATIONS	**12,740.6**	**13,732.3**	**991.6**	**7.8**

* Most graduates would have 3-year Computer Science degrees. The proportion with an accredited 4-year Software Engineering degrees is small. ACED members graduated < 300 such domestic graduates in 2019.

2. Commonwealth Government Initiatives

Several of the Commonwealth government's current initiatives are explicit about increasing jobs in Engineering and IT and related fields. Other initiatives imply jobs expansion and the need for new engineering capabilities. The government's technological focus has recently been reinforced in a Blueprint[7] and Action Plan[8] for Critical Technologies in the national interest, emphasising the technologies that "*enable military modernisation [and mitigate] economic coercion, foreign interference and cyber threats.*" Many of the 63 technologies listed also underpin the broader range of initiatives referred to in Section 1 – 3. mentioned above, and many, if not most, lie at the leading edges of engineering and IT.

This following comments and quotes are mostly from initiatives' websites.

[7] Australian Government Nov 2021. *Blueprint for Critical Technologies*. https://www.pmc.gov.au/sites/default/files/publications/ctpco-blueprint-critical-technology.pdf

[8] Australian Government Nov 2021. *Action Plan for Critical Technologies.* https://www.pmc.gov.au/sites/default/files/publications/ctpco-action-plan-for-critical-technology-amalgamated.pdf. This document contains the list of technologies.

2.1 Modern Manufacturing Strategy

As ACED members heard from then Industry Minister Hon Karen Andrews MP in 2019, the Australian government's ***Modern Manufacturing Strategy***[9] will focus on areas of comparative advantage and strategic importance through the National Manufacturing Priorities. There are six priorities. Statements relating to increased job opportunities for engineers and ICT and related education and training, include the following:

Resources Technology & Critical Minerals Processing: 10-year goals include

- "*driving increased jobs in the sector and delivering transformational economic outcomes for local communities*"
- "*the number of high-tech, highly-skilled jobs in the sector is growing and Australia is attracting international talent based on the industry's reputation for quality and innovation"*
- a benchmark of success will be (subject to data availability) the "*number and value of jobs in resources technology manufacturing and critical minerals processing*"

Food & Beverage: 5-year and 10-year goals include

- "*digitalised production equipment and predictive data analytics*"
- "*a highly skilled workforce that is agile and adaptive*"
- "*a thriving, innovative ecosystem, with a sustained increase in R&D and number of business incubators*"

Medical Products: statements include

- [the plan] "*will achieve growth through increasing rates of research translation and commercialisation. Successful firms will translate ideas into high-value medical products manufactured in Australia"*.
- "*The medical products ecosystem will be underpinned by a vibrant and collaborative sector with large, medium and small businesses*."
- Progress on the "*number of new jobs in medical product manufacturing*" will be monitored (subject to data availability) as data as one of the benchmarks of success.

Recycling & Clean Energy: amongst many actions proposed are:

- "*attracting global suppliers of manufacturing inputs to Australia, like electronics contract manufacturing, to offer products and services to Australian manufacturers*", and
- "*improving the quality and depth of advanced trades*".

Defence:

- the actions for growth are focussed on co-investment (government and industry) to "*bring parts of supply chains back to Australia ('onshoring') where domestic manufacturers have the capability to meet ADF requirements or serve civilian sectors, where this is economically viable*"
- there is an emphasis on Industry 4.0 and "*Transformative technologies such as robotics, sensors, big data analytics and artificial intelligence [to] provide the opportunity for defence manufacturers to upgrade their operations and protect themselves against cyber attacks*".
- Benchmarks of success include monitoring "the number of new jobs".

The Australian Space manufacturing program: "*will support a globally recognised Australian space sector with the capability, capacity and expertise to locally design, develop, manufacture and deploy specialised*

[9] Australian Government 2019. https://www.industry.gov.au/data-and-publications/make-it-happen-the-australian-governments-modern-manufacturing-strategy)

products, equipment, systems and services for exporting to international markets and to support national and international space missions".

Specific 10-year goals are to:

- "*develop expertise in providing and producing qualification solutions and products with increasing numbers of manufacturers bringing their projects to market more quickly*"
- "*achieve year-on-year growth of direct and indirect jobs that would meet a target of 20,000 additional jobs by 2030*"

2.2 The Low emissions Technologies and the Plan for Net-Zero by 2050

The government's 2020 low emission technology statement[10] charted "*a strategy to accelerate development and commercialisation of low emissions technologies*".

- the top-level statement has a 'Big Technology Challenge', "*Expanding production and increasing productivity, creating jobs and substantially reducing emissions from Australia's primary industries*". The statement refers to the Grattan Institute's report of the export potential of green steel, "*creating 25,000 manufacturing jobs in Queensland and New South Wales*".
- part of the Strategic intent is to: "*attract and retain the best minds in priority low emissions technology research fields*", and
- anticipates impact of "*support over 130,000 jobs by 2030 with more than half in regional communities*"

The roadmap has recently been updated in the low emission technology statement 2021[11] to align with the government's commitment to net-zero emissions by 2050. The Minister's introductory statement refers to "*investing more than $20 billion in new energy technologies over the coming decade, to drive between $80 billion and up to $120 billion of combined public and private investment and creating 160,000 jobs*".

The government's long-term economic modelling and analysis[12] for net-zero carbon emissions by 2050, headlines that "*jobs gained from new economic opportunities exceed job losses associated with changes in demand*". This is based on separate assessments of electrification of the energy sector for transport and industry, and export-related heavy industries.

Summarising, these assessments project large growth in jobs in the following industry sectors and technologies, particularly in the regions, but without any specific references to occupations and skills:

- for minerals needed for clean energy technologies - up to 52,000 new jobs by 2050;
- for hydrogen production - up to 16,000 new jobs by 2050, plus up to 13,000 and associated construction of renewable energy projects;
- low-emissions iron and alumina – up to 18,000 new jobs;
- in the domestic energy sector – net growth of 35,000 to 40,000 new jobs by 2050, sustained beyond the construction phase, for operation and maintenance.

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[10] Australian Government Department of Industry, Science, Energy and Resources. *Technology Investment Roadmap: First Low Emissions Technology Statement 2020* https://www.industry.gov.au/data-and-publications/technology-investment-roadmap-first-low-emissions-technology-statement-2020

[11] Australian Government Department of Industry, Science, Energy and Resources. *Technology Investment Roadmap: First Low Emissions Technology Statement 2021.* https://www.industry.gov.au/data-and-publications/technology-investment-roadmap-low-emissions-technology-statement-2021

[12] Australian Government (Nov 2021). Australia's Long-Term Emissions Reduction Plan: Modelling and Analysis. https://www.industry.gov.au/sites/default/files/November%202021/document/australias-long-term-emissions-reduction-plan-modelling.pdf

The report also references further job opportunities in "*low-cost renewable energy manufacturing, … upstream energy generation manufacturing like wind turbines and hydrogen electrolysers, … and downstream manufacturing and export of green ammonia and hot briquette iron*".

it must be assumed that a significant minority of the new jobs foreshadowed in all of these reports will be for higher education qualified engineers and technologists[13].

For the energy sector, the RACE for 2030 CRC (RACE stands for Reliable, Affordable, Clean Energy) has recently published a report on Developing the future energy workforce[14]. This recommends setting up three work packages to track and forecast energy sector jobs, identify new skills development, and leveraging innovation to enable the decarbonisation transformation. The report quotes other studies to estimate the current size of the clean energy employment as "*somewhere between 90,000 and 266,000, with 59,000 to 236,000 of those working in energy efficiency. By 2030, the sector could increase by somewhere between 130,000 and 200,000 jobs*".

2.3 Naval Shipbuilding

The Naval Shipbuilding Plan[15] was released on 16 May 2017, to lay "*the foundations for an Australia-wide, continuous National Naval Shipbuilding Enterprise*". It will "*provide direct and indirect employment opportunities for generations to come.*" At inception, the Government envisaged investing $90B in new naval ships and submarines, more than $1B in shipyard infrastructure, and $62M of workforce growth and skilling. The Plan investment is now stated to be $183B and involve up to 23 classes of Defence maritime vessels by the 2050s. Up to 15,000 jobs nationally are envisioned.

The Naval Shipbuilding College[16] opened in 2018 and operates through approved RTOs or higher education providers across Australia. The College website refers to Engineering Roles (Electrical Engineer, Electronics Engineer, Mechanical Engineer, Software Engineer, Combat Systems Engineer, Systems Engineer, Structural Engineer, Designer, Naval Architect, and ILS Engineer), and Trade Roles (Electrician, Welder, Boilermaker, Pipe Fitter, Machinist, Sheet Metal Worker, Light Fabricator, and Heavy Fabricator). No 'Technician' toles are mentioned despite their importance in complex engineering design and manufacturing. Neither is there any information on the specific certificate, diploma or degree programs being sponsored by the College.

3. The 2021 Australian Infrastructure Plan (launched 3 Sep 2021) and Infrastructure Market Capacity Report (launched 21 October 2021)

The Plan[17] is a comprehensive 15-year roadmap for "*infrastructure reform to leverage the Australian Government's historic $110 billion infrastructure spend and drive the national COVID-19 recovery*".

The investment will be leveraged to deliver better infrastructure in traditional areas - Energy, Transport, Telecommunications – plus Waste and Social Infrastructure. The Plan also focuses on three cross-

[13] Further information is being sought at the time of writing this paper.
[14] RACE for 2030 CRC, 2021. E3 Opportunity Assessment: Developing the future energy workforce. https://www.racefor2030.com.au/wp-content/uploads/2021/10/RACE-E3-Opportunity-Assessment-FINAL-REPORT-October-2021.pdf
[15] Australian Government. Department of Defence (May 2017) *Naval Shipbuilding Plan*. https://www1.defence.gov.au/business-industry/naval-shipbuilding/plan
[16] Naval Shipbuilding College website https://www.navalshipbuildingcollege.com.au/
[17] Infrastructure Australia (Sep 2021). Australian Infrastructure Plan https://www.infrastructureaustralia.gov.au/publications/2021-australian-infrastructure-plan

cutting key themes - Place (Cities, Regions, Rural and Remote Areas, and Northern Australia), Sustainability and Resilience, and the infrastructure Industry itself.

The Plan has been highly consultative, and is strongly focussed on putting customers (e.g. service users) and community sustainability at the heart of the reform agenda and impact assessment.

Three of the six themes - *dealing with change and uncertainty*, *harnessing digitisation*, and *customer empowerment through data* - are consistent with the attributes of 'new engineers' elaborated in ACED's Engineering Change report.

The Plan contains impact summaries[18] for each area of reform. Some of these refer to the capacity and skills needed by government and industry. See Appendix 2.

The Infrastructure Australia Market Capacity Report[19] provides a detailed analysis of the shortfall of engineers and other professionals, and technicians, tradespeople and labourers, required to implement the Plan. The headline message is that "*the peak of demand for skills is 48% higher than supply. Meeting this demand would require annual growth of 25% over the next two years, which is more than eight times higher than the projected annual growth rate of 3.3%. Engineering occupations are currently most at risk of shortage."*

The following quotes from the report indicate the depth and breadth of skills shortages:

"*Over 41,000 further individuals are estimated to be required to fill engineering occupations including positions in civil, geotechnical, structural and materials engineering. Shortages are particularly acute for a range of senior, experienced positions. For example, principal geotechnical engineers, senior signalling engineers, and heads of engineering. Similar trends appear for other roles that require greater technical specialisation.*" (p10)

"*Shortages are anticipated to peak at 19,000 project management professionals, 70,000 engineers, scientists and architects, 16,000 structural and civil trades and labour and 14,000 finishing trades and labour at different points across the next three years. The country is nearing peak demand for engineers, scientists and architects now*." (p29)

"*Over the next 15 years the sector could lose over 40% of its potential workforce due to early retirement. The risk is greatest in project management professionals, who have nearly half of their workforce over 45, and in structures, civil trades and labour with 43%."* (p10)

Employment volatility is also noted in graphs and in these terms. "*The third [occupation group], engineering, scientist and architects, are one of the most volatile. In the next two years, this category will call for an additional 20,000 FTE jobs. Sharp rises are followed by a sharp drop in 2022 to 2025. Its estimated that approximately 19,500 FTE jobs will be shed in this period*." (p48-49)

The challenge of meeting demand is expressed in these terms: "*Migration will have a role in addressing workforce demand, and may be the difference between capacity or shortage for some occupations like electrical engineers or specific highly skilled individuals at senior levels. However, even with migration playing a significant role, access to some skills, such as to civil engineers, are still likely to be inadequate. This is due to the global nature of the talent pool, and strong global demand for these skills as countries around the world leverage infrastructure as part of post-COVID stimulus strategies."*

[18] https://www.infrastructureaustralia.gov.au/sites/default/files/2021-09/2021%20Reform%20Priority%20List.pdf
[19] https://www.infrastructureaustralia.gov.au/sites/default/files/2021-10/Infrastructure%20Market%20Capacity%20Report%20%281%29.pdf

4. Ai Group CET report: 'The Skills Urgency – transforming Australia's Workplaces'

This Ai Group report[20] is intended to be a "*thought starter for encouraging bigger change around skills in Australia*", and calls for action on "*digital skills development, a re-imagined apprenticeship system, work-based learning as a core principle in qualifications, and more flexible qualifications*".

The report reflects on gaps between current Australian skills development and the business-driven *Future of Jobs 2020* report by the World Economic Forum. The required directions for change in graduate capabilities are strongly reflected in ACED's Engineering Change report[21].

During 2020, Ai Group surveyed its member companies CEOs, and received 115 responses from companies employing nearly 40,000 people. The sectors covered were Manufacturing (with 58.5% of the responses), Services (13%), Construction (9%), Mining (3%) and Others made up the remaining 16%. Large, medium and small companies made up 31%, 45% and 24% of the responses, respectively.

The survey reported that the three occupations for which there was the most "*difficulty in meeting skills need*" were: Technicians and Trades workers (39% of respondents), Managers (30%) and Professionals (22%). For "*increased skills requirements*", these three occupational groups received 49%, 30% and 39% responses respectively. The hardest to fill roles were:

- Engineers - maintenance, mechanical, mechatronic, electronic, process, aerospace and sales engineers.
- Managers - operations, production and project, supply chain, logistics, water, marketing and business development managers.
- Digital roles - 'digital experts', software engineer, RFID, solutions architect and SAP business analyst.

Manager and Professional occupations were also prioritised for urgent digital skills training. Substantially increased demand for so-called 'soft skills (problem solving, adaptability, creativity, communication, initiative) in these occupations was reported by more than 72% of respondents.

Employers reported their preferred actions to meet skill needs in the next 12 months is by re-skilling existing staff, or employing experienced people. Fifth ranked, only 27% of respondents reported that they would employ university graduates and interns, and 'employing skilled migrants' was preferred by only 7% of respondents.

In the longer-term re-skilling is also most strongly favoured, but employers would "*increase employees' skills levels by taking take on university and TAFE students as higher apprentices, cadets or interns*". Some employers would adopt this approach only if government support is available.

The report also outlines employers' preferences for training and development through short courses (although amongst providers, "*universities will be least used to them*"), and to invest in formal qualifications mostly from TAFE and private RTOs. There is little knowledge of microcredentials.

The report discusses employers increasing their stock of trade/apprentices, and strengthening relationships with VET/TAFE. Also 27% of employers with an existing relationship with higher education/university providers intend to increase the number of relationships, and 15% indicate they will establish new links.

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[20] Ai Group's Centre for Education and Training (April 2021). *The Skills Urgency – transforming Australia's Workplace*. https://cdn.aigroup.com.au/Reports/2021/CET_skills_urgency_report_apr2021.pdf.

[21] Australian Council of Engineering Deans (2021). *Engineering Change the future of engineering education in Australia*. https://www.aced.edu.au/downloads/2021%20Engineering%20Change%20-%20The%20future%20of%20engineering%20education%20in%20Australia.pdf

The report includes seven case studies/stories about company action on skills development and staff retention. Two relate to Professional Engineers:

- BAESystems Australia expects to employ about 650 (new) people into the business each year to 2024. The company is a major STEM employer with 40% engineers, and 20% in trades. In 2020 in the UK, over 250 of the company's 800 apprentice recruits were in degree apprenticeship programs. This model will be promoted Degree Apprenticeships in Australia to meet workforce requirements.
- Agilent recruits (via a partnership with ACS) an annual cohort of around 10 students in the third or fourth year of their bachelor degree as interns in areas of software, mechanical, computer science, technical services, application scientist, and field service engineering. Future plans include creative coding and digital marketing.

This Ai Group report states the survey is not representative of the Australian economy; neither is it representative of the industry sectors in which engineers are employed. Its emphasis on the needs of manufacturing companies does however demonstrate the range and depth of concerns that must be addressed if initiatives in modern manufacturing, etc. are going to be pursued towards their goals.

5. International Comparisons

5.1 Engineers working in the field

A further way of looking at shortages in the Australian engineering workforce is to compare our numbers and distributions with those of other countries. Table 3 provides a comparison of Australian numbers in the main branches of (professional) engineering with Germany and UK, using the 'numbers per 1,000 of population' metric.

The comparison shows that with 12.5 engineers per 1,000 population Germany has nearly twice the engineer population of Australia that were 'working in-field' in the occupations listed in Appendix 2. (These do not include the 5% of working graduate engineers in education and training.)

The main difference is in the high German figure (5.29 per 1,000) for the combination of Mechanical and Industrial & Production engineers, compared with Australia's 1.04 per 1,000 population. (This obviously reflects the much greater importance of high-end equipment and consumer-oriented manufacturing in the German economy, compared with Australia.)

There appear to be only slightly more engineers per 1,000 population in the UK workforce than are working 'in field' in Australia, but the mixed UK classification of engineering branch and occupational activity makes comparisons difficult.

Table 3 Comparison of Engineers per '000 population, Australia, Germany and UK

Branch of engineering or other occupational description	Australia, 2016			Germany, 2010		UK, 2018	
	number in-field	out of field	in-field per 1,000*	number	per 1,000	number	per 1,000
Civil	21,919	7,895	1.72	157,895	1.97	87,379	1.32
Mechanical	13,229	10,312	1.04	220,971	2.76	82,547	1.25
Industrial & Production				202,500	2.53		
Electrical	29,335	17,728	2.3	136,800	1.71	38,595	0.58
Electronics & Telecommunications				47,320	0.59	31,150	0.47
Chemical	11,116	8,553	0.87	37,125	0.46		
Mining				5,262	0.07		
Aerospace	3,846	2,678	0.3				
Maritime	788	990	0.06				
Geomatic	1,762	6,037	0.14				
Automotive	101	462	0.01				
Other	2,903	462	0.23	192,050	2.40		
*details not provided**	*77,287**	*37,491*					
Design & development engineers						73,278	1.11
Production and process engineers						47,549	0.72
Engineering professionals						104.260	1.59
Total Engineers	**162,286**	**94,382**	**6.65**	**999,923**	**12.50**	**464,949**	**7.04**
National Population	24,400k			80,000k		66,000k	

* the 'details not provided' total is distributed across the reported branches

Sources:

Australia - *STEM Workforce Report* (2020). Office of Australia's Chief Scientist https://www.chiefscientist.gov.au/news-and-media/2020-australias-stem-workforce-report

Germany - *Engineering Labour Force in Germany* - Alberta Government (2010) https://open.alberta.ca/dataset/91651b5a-d220-4466-9d8e-bea7373fcbeb/resource/2d2e330a-a003-496b-ba6e-61afcb5dc1e7/download/Ger-EngCFS-w.pdf

UK - *The Supply and demand for Engineers in the UK* (2018). ECITB. https://www.ecitb.org.uk/wp-content/uploads/2018/12/EC03-ECITB-ET-Report-FINAL-23.01.18.pdf

5.2 Australia's 'out of field' problem and engineering graduation rates

The data in Table 5 shows that approximately one third of the population with engineering qualifications is not working in the field. Arguably, if Australia had sufficient engineers to eliminate its shortage, this would not be a problem. Indeed, several ACED reports (including those supporting reference 21) have suggested that having more engineering-educated individuals in society at large would be a good thing, because of the quantitative, science-based, problem-solving, and teamwork orientation of their qualifications. Palmer and Campbell[22] reinforce this view and suggest that a greater proportion of the engineering curriculum should be dedicated to the transferable skills that engineering graduates can take to occupations outside engineering, and that these would be especially valuable to women, who tend to leave engineering occupations earlier than men.

The 'out-of-field' problem for Australia of concern here relates to the projected skills shortages. Can more Australian engineers be persuaded to stay in the engineering workforce longer, or return to it.

[22] Palmer, S. and Campbell, M. (Sep 2021) *The short- and long-term relationships between gender and occupational outcomes for Australian engineering bachelor graduates*, https://spalm.home.exetel.com.au/sp210901.pdf

These are largely questions for employers, although educators may have a role to play in providing updating and upskilling short courses (and microcredentials) in specific areas.

The second critical (and comparative) question is the size of the Australian engineer graduate cohort. OECD data reports[23] that in 2019 Australia had 8.2% of tertiary graduates in the engineering field, the second lowest in the OECD countries. This rate is greater that the USA, and slightly below UK, Netherlands, New Zealand and Ireland. Several European countries and Canada are at 12-13%. Germany tops these rankings at 24%. For Australia's size and population, and with the aspirations for engineering outlined in earlier sections of this paper, it would seem reasonable to strive to increase this proportion to at least 12%.

6. Projections of engineer demand and supply pipelines to 2030

6.1 Demand profile

Preceding sections of this paper point to significant growth in the demand for engineering professionals. Unfortunately, most of the enumerated new jobs foreshadowed are not classified by occupation level. The exceptions are the National Skills Commission projections (Table 2), and (less specifically) the Infrastructure Australia Market Capacity Report outlined in Sec. 3.

The NSC report projects a five-year employment increase of 7.8% for All Occupations. Professional occupations are projected to grow by 13.2%, while Managers' occupations will grow by only 6.1%.

NSC's 5-year predictions in ACED's occupations of interest are:

- Engineer employment growth of approximately 30,000 (14%) in most branches (including Telecommunications), apart from Chemical & Materials which is much lower (5.7%).
- More than 60,000 additional people (around 29% growth) as Software and Application Programmers and Computer Network professionals. This rate of increase is the largest amongst all occupation groups. Software Engineers are a subset of this group and are 'hidden' in a 6-figure ANZSCO code.

Clearly then, according to NSC, employment of professionals in Engineering is expected to grow slightly more rapidly than professionals as a whole. Employment of technical IT professionals will grow much more rapidly.

The expected employment growth rate of 15.9% in Industrial, Mechanical and Production Engineers is actually the highest growth rate amongst non-IT engineering occupations, and amounts to 7,300 more individuals. They would clearly contribute to the jobs growth envisaged in the Modern Manufacturing initiative.

Overall, having NSC's additional 30,000 Engineers (in branches other than IT) by the end of 2025, and approximately 10,000 IT Engineers (Software, Computer and Telecommunications), would clearly be able to contribute to all streams of the Modern Manufacturing initiative and the other programs referred to in this paper. Whether 40,000 would be sufficient needs further research. The engineering needs for defence and the low energy transition (with ramifications for transport and hydrogen), and IT systems across the economy need quantification, in particular. The NSC prediction of a low growth rate for Chemical and Materials Engineers needs examination.

The Infrastructure Australia Market Capacity Report records needing 41,000 engineers over the next few years, greatly exceeding the NSC's 10,200 prediction to 2025.

[23] OECD (2021), Tertiary graduates by field (indicator). doi: 10.1787/9af26c71-en
https://data.oecd.org/students/tertiary-graduates-by-field.htm (Accessed 17 Nov 2021)

Looking to 2030 and beyond, the Space and Naval Shipbuilding programs have quantified their employment demand at 35,000. Arguably, based on the BAeSystems Australia example, one-third of these could be for professional engineers.

6.2 Workforce supply projections

These initiatives and projections point to expanding the demand for engineer professionals in all branches. For illustrative purposes, the remainder of this paper explores increasing the workforce of engineering professionals from about 220,000 (in FY2019-20) to 300,000 in 2029-30.

Table 4 shows the 2019-20 baseline and growth for each of the supply pipelines – graduates, temporary visa holders, and permanent migrants – to meet these goals. Recent trends in these pipelines are discussed in more detail in an accompanying ACED paper[24].

Table 4 Projections of professional engineer workforce from new graduates and migrants

components of engineer supply	2019-20	2021-22	2023-24	2025-26	2027-28	2029-30
Engineer stock at start of year	**200,000**	**208,503**	**217,252**	**229,686**	**246,092**	**267,24**
Attrition during year	-6,000	-6,255	-6,518	-6,891	-7,383	-8,035
Domestic PE graduates in engineering work						
BEng(Hons) + current MEng	6,242	6,442	6,642	7,417	8,974	10,859
new stream MEng graduates			850	937	1,033	1,139
Permanent migrants (PMs)	4,394	4,000	4,840	5,956	7,086	8,574
including 'new to Australia' PMs	895	1,200	1,452	1,757	2,126	2,572
Engineer stock at end of year	**204,636**	**212,690**	**223,067**	**236,664**	**254,887**	**278,584**
Temp Grad visas granted	3,599	3,200	3,395	3,602	3,821	4,054
Temp Skills (TSS) visas granted	4,410	4,000	4,500	5,446	6,588	7,972
including 'new to Australia' TSS	1,688	2,000	2,250	2,723	3,294	3,986
Pool of Temp. visa holders	**17,346**	**13,323**	**15,191**	**17,493**	**20,109**	**23,209**
Total workforce at end of year	**221,982**	**225,927**	**238,507**	**254,157**	**274,996**	**301,793**

This workforce projection model has the following components:

The 'Engineer stock' – is the number of individuals with a secure place in the Australian engineering workforce. This grows from 200,00 to 278,584 in 2029-30, alongside retirements and other attrition.

Attrition: the rate of retirement and other departures from the workforce is estimated to be 3% of the 'engineer stock' at the start of the year.

Domestic professional engineer (PE) graduates – it is assumed that nominally 85% of the BEng(Hons) graduates and current entry-to-practice MEng graduates enter the workforce. These numbers estimated to increase by 100 per year until 2024-25 (due to increased demand for engineers) and by 10% per annum from 2025-26) from a corresponding major increase of commencing enrollments in BEng(Hons) programs. Working engineers from domestic MEng graduations are increased from 850 in 2023-24 and then by 5% per annum, from a new pipeline of domestic BSc graduates. (There were 17,000 domestic BSc graduates in 2019.)

Permanent migrants – the estimates are for Primary applicant engineers in the skills stream of the Permanent migration program. Numbers are assumed to recover from their current low values. Most of these migrants are drawn from the pool of engineers on Temporary visas. The 'new-to-Australia'

[24] King, R. (Dec 2021). *Pipelines into Professional Engineering Occupations*. ACED website

cohort is assumed to grow at 10% per annum from 2022-23, as the pool of temporary visa holders increases.

Temporary Graduate (TG) visas are granted each year to international students who have completed their degree in Australia. The number of engineers in this category is estimated to have been 3,599 in 2019, falling to 3,037 in 2020, and is then reset to 3,200 for FY 2021-22, followed by 3% annual growth. These visas are typically held for two years, and their holders may be eligible for Temporary Skills Shortage visas and Permanent migration.

Temporary Skills Shortage (TSS) visas are granted to experienced engineers to fill skills shortages, some highly specialised. These visas are issued for two years or four years, but may be renewed. The model estimates that half of the number of visas issued each year are to individuals who are 'new to Australia', with 10% growth from 2024-25, after post-COVID recovery.

The Pool of Temporary visa holders is the sum of the two consecutive year's visas issued to the TG and TSS visa classes. This pool is estimated to have increased from 14,000 to 16,332 in the three years to FY2018-19. Over the period of the projection, the pool increases to 23,000. The supply into this pool could be further increased by reducing the barriers[25] into engineering employment to other migrants (e.g. those on humanitarian visas and family members) with engineering qualifications and experience.

The Total workforce of engineering professionals is the sum of the stock of engineers (as defined above) and pool of temporary visa holders. The model delivers an engineering workforce just over 300,000 in FY2029-30.

Figure 1 charts the key components of these projections – engineer attrition, graduates, permanent migrants and new entrants into the temporary visa pool, consistent with the data in Table 4.

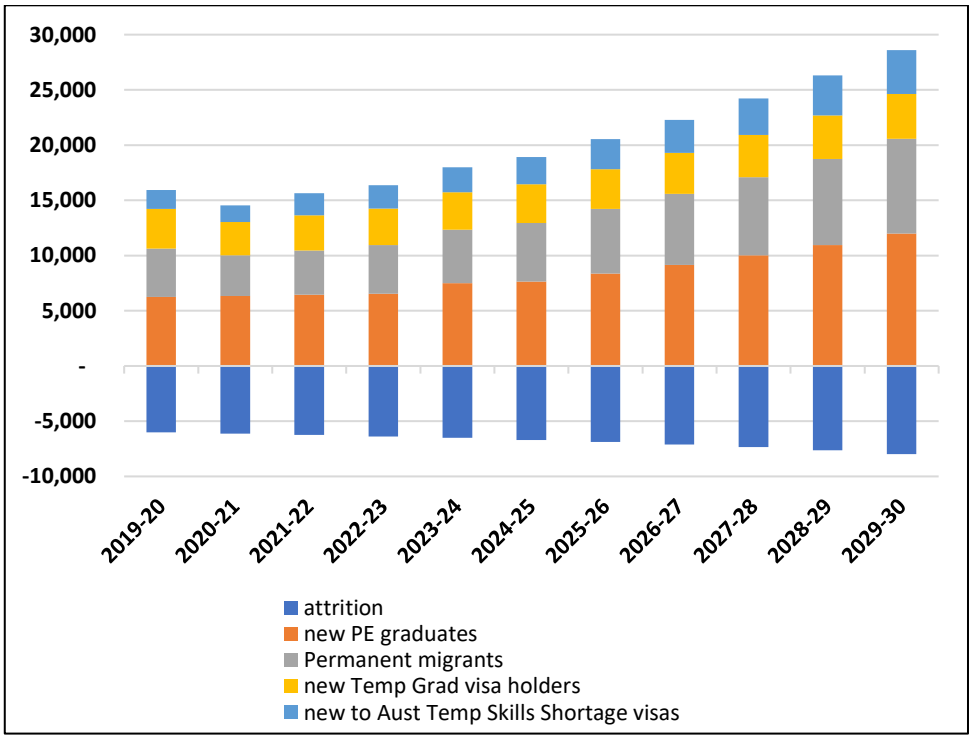

Figure 1 Projections of attrition and supply of graduates and new migrants into engineering, FY 2019-20 to FY 2029-30

[25] Engineers Australia (Oct 2021). Barriers to employment for migrant engineers (engineersaustralia.org.au) (Accessed 16 Dec 2021)

The chart shows that by the end of the period, the projected increase in the numbers of domestic graduates in engineering work are contributing more significantly to the net growth of professional engineering capability. Such growth will not be possible without at least the following measures:

- a major domestic undergraduate student recruitment campaign that emphasises the service/social dimensions of engineering as well as the technological, and that significantly lifts the participation rates of women from the current 20%. This increased demand (which aspires to be 10% per annum for five years) will need government support for fully-funded places;
- a major campaign to recruit domestic BSc graduates (e.g. those with majors in mathematics, physical and chemical sciences, and computer science) into entry-to-practice MEng degrees, from 2022. This demand would also have to be supported by fully-funded places. This pathway could be further enhanced by offering an engineering major or minor in science degrees.
- increased commitment and support from engineering employers, particularly in areas of projected skills shortages, to support all engineering students with opportunities for workplace learning and other industry engagement.

Figure 2 shows the accumulation of these projections. From the FY2019-20 baseline, over the decade nearly 70,000 engineers will retire or leave the engineering workforce, while more than 80,000 new domestic graduates will join it. In addition, there will be nearly 60,000 permanent migrants. The pool of temporary visa holders in engineering work grows fairly slowly, as it is replenished by holders of Temporary Graduate visa and Temporary Skills Shortage visas, and feeds the supply of Permanent migrants.

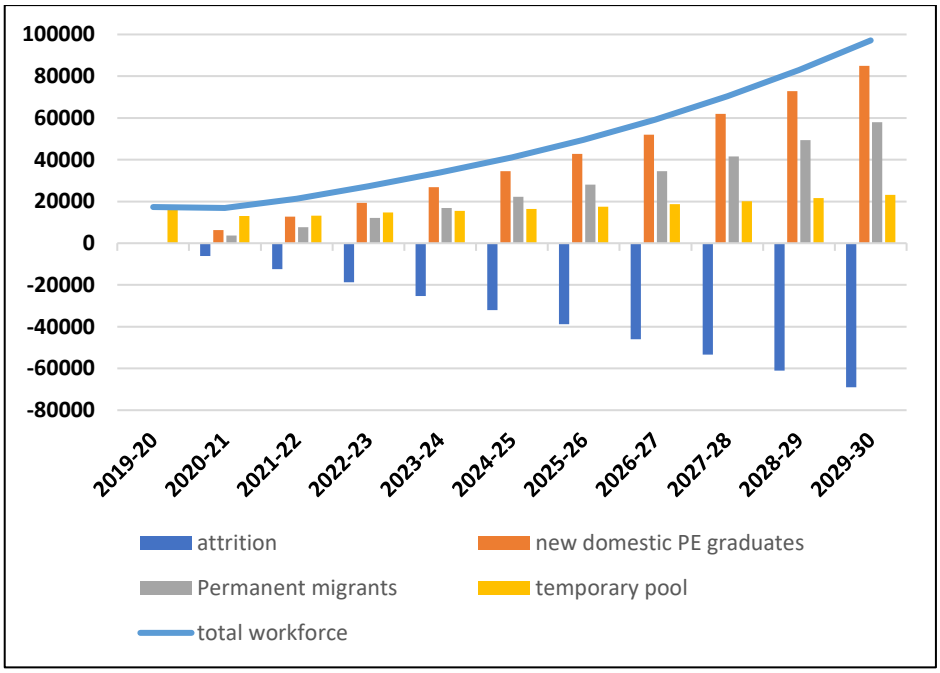

Figure 2 Cumulative projected growth of the engineering workforce, from domestic graduates and migration, FY2019-20 to FY2029-30.

It must be stressed that the projections in this model are based on many estimates and assumptions that need to be examined further. Furthermore, the projections have not included any differentiation of demand and supply by branch of engineering and IT, but it is evident from the NSC and other data Computer and Software Engineering should be prioritised, followed by Mechanical and Production Engineering, Civil, and Mining Engineering.

Author's Note

The author thanks members of the ACED Executive for their constructive comments in earlier versions of this working paper, and takes responsibility for the interpretation of the data used in this report. He acknowledges that some of the estimates used in the model (such as the attrition engineers) have not been adequately tested because of lack of data. There is plenty of scope for further work.

The author would appreciate contact with individuals who reference and use the content of the paper.

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Appendix 1 Extracts from National Skills Shortage lists

Level 1 and 2 Occupations in current national shortage, with strong or moderate future demand

ANZSCO	Occupation	future demand
1 MANAGERS		
135112	ICT Project Manager	strong
133111	Construction Project Manager	moderate
133211	Engineering Manager	moderate
2 PROFESSIONALS		
233211	Civil Engineer	strong
233212	Geotechnical Engineer	strong
233213	Quantity Surveyor	strong
233214	Structural Engineer	strong
233215	Transport Engineer	strong
233311	Electrical Engineer	strong
233512	Mechanical Engineer	strong
233611	Mining Engineer (excluding Petroleum)	strong
233612	Petroleum Engineer	strong
261312	Developer Programmer	strong
261313	Software Engineer	strong
262112	ICT Security Specialist	strong

Level 1 and 2 Occupations not in current national shortage, with strong or moderate future demand

ANZSCO	Occupation	future demand
1 MANAGERS		
132511	Research and Development Manager	strong
133512	Production Manager (Manufacturing)	moderate
133513	Production Manager (Mining)	moderate
135111	Chief Information Officer	strong
139912	Environmental Manager	strong
139913	Laboratory Manager	strong
2 PROFESSIONALS		
224914	Patents Examiner	strong
232213	Cartographer	strong
232214	Other Spatial Scientist	strong
232312	Industrial Designer	strong
233111	Chemical Engineer	strong
233312	Materials Engineer	strong
233411	Electronics Engineer	moderate
233511	Industrial Engineer	strong
233513	Production or Plant Engineer	strong
233911	Aeronautical Engineer	moderate
233912	Agricultural Engineer	moderate
233913	Biomedical Engineer	moderate
233914	Engineering Technologist	moderate
233915	Environmental Engineer	moderate
233916	Naval Architect	moderate
261212	Web Developer	strong
261311	Analyst Programmer	strong
261314	Software Tester	strong
263111	Computer Network and Systems Engineer	strong
263112	Network Administrator	strong
263113	Network Analyst	strong
263211	ICT Quality Assurance Engineer	strong
263212	ICT Support Engineer	strong
263213	ICT Systems Test Engineer	strong
263311	Telecommunications Engineer	strong
263312	Telecommunications Network Engineer	strong

Appendix 2 Extracts from the Australia Infrastructure Plan impact summaries

The following Table identifies areas of skills shortage and capability that have a bearing on the implementation of the Infrastructure Plan.

Reform Theme and specific recommendation	Extracts from the reform impact summaries – principally from 'ease of implementation'
1 Place-based outcomes for communities Recommendation 1.4 Ensure Northern Australia and Developing Regions fulfil their economic role, attract and retain skilled workers and enable participation of Aboriginal and Torres Strait Islander people through greater collaboration between governments on infrastructure needs across the region.	With the exception of large-scale resources projects, Northern Australia has limited capacity in the private sector to deliver infrastructure projects. Government will need to develop policies to attract and retain skilled workers to enhance local business capacity. (The detailed Implementation plan refers to DESE supporting skills formation in NT and in 10-15 years, developing an essential skills training academy, and also to support VET capacity to align with industry-specific skills and jobs growth objectives.)
2 Sustainability and Resilience Recommendation 2.1 Build community resilience to all hazards by considering systemic risks, interdependencies and vulnerabilities in infrastructure planning and decision-making. Recommendation 2.2 Meet Australia's present and future needs by establishing the quadruple bottom line as a goal for all infrastructure policy and investment.	While skills and resources are generally available, governments and industry may experience capacity constraints requiring large upskilling of staff to ensure consistency and better application of new scenarios. Industry and governments have capacity and are well-positioned to play a role in both social infrastructure upgrades and the rollout of electric vehicles at the right scale and time.
3 Industry productivity and innovation Recommendation 3.3 Increase productivity and embed a culture of innovation in the infrastructure sector by adopting an evidence-based digital by default approach to infrastructure planning, delivery and operations Recommendation 3.4 Deliver a greater return on investment by ensuring governments act as model clients and custodians of industry health and productivity.	The infrastructure and construction sector has one of the slowest adoption rates of technology, innovation and digitally supported ways of working. While there is a strong appetite for innovation and digital tools in Australia, many actions such as digital twins are at the pilot level. Significant upfront and ongoing cost reductions from the reform should deliver future infrastructure investments for less, although the actions will require developing new capabilities, which will involve a moderate degree of complexity.
4 Transport Recommendation 4.2 Improve the liveability and economic sustainability of regional, rural and remote areas by developing, maintaining and operating integrated freight and passenger	Delivering faster rail services, especially high-speed rail, will present complex economic and technological challenges that are new to Australia. However, there should be enough lead time for the growing domestic rail industry to pivot from urban to regional priorities.

transport networks that meet end-to-end access needs.	
5 Energy Recommendation 5.2 Transition to a smart, affordable, reliable future grid by implementing regulatory reforms, introducing incentives for customer participation in energy system management and planning cross-sector integration Recommendation 5.3 Transition Australia's exports and domestic energy demand to high-tech, low-cost, low-emission energy sources by coordinating national strategy.	Governments have the capacity in skills and expertise needed to build on concurrent coordination and reform programs – particularly by the market bodies – but additional resources may be needed to fully implement this smarter grid. Australia is building world-leading capacity to harness this transformation and can implement this future with the right investments in emerging industries, skills, and systems.
9 Waste Recommendation 9.2 Encourage market development through government and industry partnerships to accelerate and extend the implementation of the National Waste Policy's data actions and bring national consistency to the household waste collection and landfill levy system.	Industry lacks the knowledge, capacity and data to make informed decisions. However, recent joint initiatives such as the response to the national waste export ban show coordination is achievable in the long-term.

Section 3 of the main document picks up the capability shortfalls in more detail.

Appendix 3 Engineers Australia occupations used in the Australia's STEM Workforce report

1 MANAGERS	**233 Engineering Professionals**
11 CHIEF EXECUTIVES, GENERAL MANAGERS AND LEGISLATORS	2331 Chemical and Materials Engineers
111 Chief Executives, General Managers and Legislators	2332 Civil Engineers
1111 Chief Executives and Managing Directors	2333 Electrical Engineers
1112 General Managers	2334 Electronic Engineer
13 SPECIALIST MANAGERS	2335 Industrial, Mechanical and Production Engineers
132 Business Administration Managers	2336 Mining Engineers
1324 Policy and Planning Manager	2339 Other Engineers
1325 Research and Development Manager	**234 Natural and Physical Science Professionals**
133 Construction, Distribution and Production Managers	2343 Environmental Scientist
1331 Construction Manager	2349 Other Physical Sciences
1332 Engineering Manager	**242 Tertiary Education Teachers**
1334 Manufacturers	2421 University Lecturers and Tutors
1335 Production Manager	2422 Vocational Education Teachers
1336 Supply and Distribution Manager	**26 ICT PROFESSIONALS**
134 Education, Health and Welfare Services Managers	**261 Business and Systems Analysts, and Programmers**
1344 Other Education Managers	2611 ICT Business and Systems Analysts
135 ICT Managers	2613 Software Developers
1351 ICT Managers	**262 Database and Systems Administrators, and ICT Security Specialists**
139 Miscellaneous Specialist Managers	2621 Database and Systems Administrators
1391 Commissioned Officers	**263 ICT Network and Support Professionals**
1392 Senior Non-commissioned Defense Officer	2631 Computer Network Professionals
1399 Other Specialist Managers	2632 ICT Support and Test Engineers
2 PROFESSIONALS	2633 Telecommunications Engineering Professionals
22 BUSINESS, HUMAN RESOURCE AND MARKETING PROFESSIONALS	**3 TECHNICIANS AND TRADES WORKERS**
224 Information and Organisation Professionals	**31 ENGINEERING, ICT AND SCIENCE TECHNICIANS**
2241 Actuaries, Mathematicians and Statisticians	**312 Building and Engineering Technicians**
2242 Intelligence and Policy Analysts	3121 Architectural, Building and Surveying Technicians
2247 Management and Organisational Analysts	3122 Civil Engineering Draftspersons and Technicians
225 Sales, Marketing and Public Relations Professionals	3123 Electrical Engineering Draftspersons and Technicians
2252 ICT Sales Professionals	3124 Electronic Engineering Draftspersons and Technicians
2254 Technical Sales Professionals	3125 Mechanical Engineering Draftspersons and Technicians
23 DESIGN, ENGINEERING, SCIENCE AND TRANSPORT PROFESSIONALS	3126 Safety Inspectors
231 Air and Marine Transport Professionals	3129 Other Engineering Technicians
2311 Air Transport Professionals	**313 ICT and Telecommunications Technicians**
2312 Marine Transport Professionals	3131 ICT Support Technicians
232 Architects, Designers, Planners and Surveyors	3132 Telecommunications Technical Specialists
2326 Urban and Regional Planners	**5 CLERICAL AND ADMINISTRATIVE WORKERS**
	51 OFFICE MANAGERS AND PROGRAM ADMINISTRATORS
	511 Contract, Program and Project Administrators
	5111 Contract, Program and Project Administrators

Copied from Appendix A https://www.chiefscientist.gov.au/news-and-media/2020-australias-stem-workforce-report