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Infrastructure Australia

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Infrastructure Market Capacity

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Acknowledgement of Country

Infrastructure Australia proudly acknowledges the Traditional Owners and Custodians of Australia, and their continuing connections to the land, waters and communities. We pay our respects to them and to their Elders past, present and emerging. In preparing for the future of our infrastructure, we acknowledge the importance of looking beyond the immediate past to learn from Aboriginal and Torres Strait Islander peoples' unique history of land management and settlement, art, culture and society that began over 65,000 years ago.

As part of Infrastructure Australia's commitment to reconciliation, we will continue to develop strong, mutually beneficial relationships with Aboriginal and Torres Strait Islander partners who can help us to innovate and deliver better outcomes for Aboriginal and Torres Strait Islander communities, recognising their expertise in improving quality of life in their communities.

Chair's foreword

I am pleased to present Infrastructure Australia's first *Infrastructure Market Capacity* report reflecting a new capability to support decision makers to better understand the capacity of the market to deliver the forward infrastructure pipeline.

This work builds on Infrastructure Australia's increasing collaboration with state and territory governments, and industry. It lays a new foundation for all levels of government to work in partnership to better understand the national Major Public Infrastructure Pipeline and the markets it depends on for delivery.

In the aftermath of COVID-19, the ambition of a strong Major Public Infrastructure Pipeline to support our recovery, increase productivity and realise better outcomes and quality of life across our communities is even more critical.

Essential to realising this ambition is a comprehensive understanding of the supply and demand of the skills and materials critical to that pipeline, and associated risks in planning and delivery.

For the first time, Infrastructure Australia's market capacity report provides a new evidence base to increase that understanding, to support decision making, and help ensure value for money outcomes from our future infrastructure investments.

The challenges and opportunities highlighted through this report underscore the importance of continuing to drive productivity and innovation across government and industry. Infrastructure Australia's parallel delivery of the *2021 Australian Infrastructure Plan* and our forthcoming *Deliverability Roadmap* reports establish a best practice agenda to support these outcomes in the short-, medium-, and long-term.

This report demonstrates the potential of Infrastructure Australia's Market Capacity Program to inform investment and help mitigate risks across sectors. As is clear in this report, foundational to the authority and strength of this capability is the data that underpins it, and the timely sharing of that data by state and territory governments.

We look forward to working collaboratively across government to ensure we continue to build on this first foundation, and enhance our capability to support your decisions in the years ahead.

Mark Balnaves

Chair, Infrastructure Australia

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Infrastructure Australia wishes to acknowledge the support and assistance we received from state and territory governments, industry participants and peak bodies in developing the Market Capacity Program, our associated analysis, and this initial report.

Australasian Railway Association

Australian Constructors Association

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Australian Local Government Association

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Infrastructure VIC (Vic Government)

Infrastructure WA (WA Government)

Main Roads Western Australia (WA Government)

Major Projects Canberra (ACT Government)

National Infrastructure Commission (United Kingdom)

National Skills Commission (Australian Government)

National Water Grid Authority (Australian Government)

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Executive summary

At a glance

Australia is currently experiencing a record level of investment in infrastructure.

- Known investment will peak at $52 billion in 2023, however absence of certainty on expenditure – not a real reduction – is likely to characterise 2024 and beyond.

Average annual growth rate to 33% outstrips industry's confidence of their capacity to deliver on-time and on-budget.

- Industry has a high confidence of delivering 10-15% annual growth.
- The industry has a low confidence in delivering growth over 18%.

Shortages are expected in skills, labour and materials.

- Demand for plant, labour, equipment and materials will be two-thirds higher than the previous five years.
- 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%.
- 34 of the 50 public infrastructure occupations are potentially in shortage.
- Over the next three years it is expected there will be:
  - 120% average growth in demand for materials (across 10 categories, highest in rock/bluestone).
  - 125% growth in demand for equipment (across 3 categories, highest in control equipment).
  - 140% growth in demand for plant (across 11 categories, highest in speciality plant).

COVID-19 border closures and social distancing restrictions are compounding other challenges.

- Border closures have impacted access to skills and labour.
- Some plant and equipment have also been impacted due to supply chain constraints.
- Material shortages, such as steel, have been created or compounded.

The *2021 Australian Infrastructure Plan* proposes a reform agenda to drive industry productivity and innovation in response to these challenges. Key reforms include:

- Active portfolio and pipeline management to smooth investment and manage resource constraints.
- Improved front-end engineering and design to avoid waste
- Increased collaboration with industry to support capacity and capability development.
- Embedding digital practices, including supporting definitions, systems and processes.
- Increased public sector capacity and capability to act as a model, mature client.

Forecasting a new wave of public infrastructure investment

Australia is on the cusp of an unprecedented wave of investment in public infrastructure projects. Investment in major public infrastructure over the next five years across Australia will exceed $218 billion. This scale of investment, and the rate of growth to achieve it, has never before been seen.

The new record investment builds substantially on waves of investment committed in past years. The level of activity represented by the Major Public Infrastructure Pipeline reflects a 100% growth rate as compared to current activity. The peak of annual investment, estimated at over $52 billion in 2023, has not previously been delivered, and reflects many multiples beyond spending rates experienced in response to the Global Financial Crisis. Such a trend is likely to create hyper-localised shortages of skills and materials, and risks that are difficult to predict or plan for.

Parallel activity forecast in residential and non-residential building and private engineering construction presents a multiplier for the risks and constraints created by this scale of investment. The Major Public Infrastructure Pipeline reflects just part of the picture when considering the supply and demand for associated skills and resource inputs alongside those created by mining, defence, infrastructure maintenance, non-public infrastructure construction and building.

Past peaks in investment, alongside industry soundings, indicate potential limits on the ability of the market to efficiently accommodate this growth. Relative to current activity, the confidence of the market to deliver new investment decreases with the rate of growth forecast. Nearly 50% of industry participants were not confident, or not at all confident in their ability to accommodate a 50% increase in growth over the next twelve months. Access to skills and workers, increased demand for key materials and manufacturing limits were all cited as constraints to growth.

Unprecedented demand and constraints in supply

The scale of demand for skills and resources is highly likely to exceed the normal capacity increases expected in the market. Demand for plant, labour, equipment and materials to deliver the Major Public Infrastructure Pipeline over the next five years will be two-thirds higher than the previous five years (to 2019-2020).

The most intense resource pressures are labour and materials, accounting for 60% and 30% of resource demands over the next five years, respectively.

This report identifies approximately 182,000 people are currently engaged in the Major Public Infrastructure Pipeline across Australia. There are a further 1.18 million people in adjacent industries.

Between 2021 and 2024 shortages are anticipated in all public infrastructure-related occupational groups. 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% over this period.

Some shortages appear to be ongoing and systemic, for example building surveyors. Engineering occupations are currently most at risk of shortage.

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. For example, while few indicators suggest an overall shortage of plumbers, there are potential shortages in specialist roles including drainer, maintenance plumber and pipefitters.

By their nature these more senior or specialist roles are likely to be filled by older workers, with shortages exacerbated as those with highly specialised occupational knowledge retire. The public infrastructure workforce retires young. 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%.

Beyond the immediately engaged workforce, there are another 1.18 million individuals working in relevant occupations that may, to varying degrees, be able to transition into the workforce engaged in public infrastructure, though noting the cascading impacts on those parts of the economy from which they are drawn. Any increase in capacity drawn from these sources will require the development of scalable training and transition pathways alongside initiatives to maximise workforce participation.

For many positions however, the reality is that occupations needed to support future public infrastructure delivery have limited capacity to draw on any adjacent workforce.

Immigration and border restrictions require consideration

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.

Plant, Materials and Equipment will also come under pressure

Materials demand accounts for the second largest proportion of expenditure in the pipeline over the next five years. Demand for materials is projected to grow for three consecutive years representing annual average growth of just over 30% per annum between 2021 and 2023.

Demand for quarried material and cement are likely to produce the most significant challenges due to their reliance on local supply chains. Steel, bitumen and electrical control equipment are likely to be exposed to international demand and supply chain pressures.

The increasing and significant concentration of mega-projects, transport and rail investment drives unprecedented demand for associated skills and materials. For example, an average annual growth rate for rock/bluestone approaching 60% over the next three years.

Interdependencies and risks for escalation and delivery

The Major Public Infrastructure Pipeline is being delivered in an increasingly complex risk environment. New risks are emerging, converging and interdependencies between infrastructure sectors are growing.

Market capacity constraints in the supply of skills and resources, and associated risks for escalation and delivery present an additional and growing risk category. This environment is heightening risk exposure for major projects in planning or delivery over the next five years.

More broadly, systemic risks associated with the increasing incidence and severity of natural disasters, cyber-security, community and user risks are manifesting differently across sectors and geographies. Systemic risks including those arising from market capacity and economic constraints act as multipliers for a range of project-level risks throughout the project lifecycle in planning, design, construction and operation.

Critical sectoral risks are identified, for example, in transport (related to tunnelling and land acquisition), energy (issues with connection and transmission infrastructure), water (investment environment uncertainty), social infrastructure (business case problems), waste (inadequate coordination of waste cycle stages, and ineffective engagement) and digital infrastructure (scope and cost overruns).

Increasing the visibility of these risks across projects, both geographically and by sector, is critical to managing complexity and identifying mitigation options. Infrastructure Australia's Market Capacity Program provides that increased visibility through a new analysis of infrastructure risk, supported by a new interactive risk dashboard and mapping tool.

Transforming infrastructure delivery

These risks, the scale of the forecast pipeline, the associated demand for skills and materials and future supply constraints are part of a new evidence base to inform infrastructure decisions and policy reform. These insights further reinforce the importance of governments unlocking productivity and innovation to support infrastructure delivery in a constrained environment.

A collaborative commitment with industry to support workforce participation, outcomes-focused procurement and effective risk management will help transform infrastructure delivery and maximise the opportunities created through this pipeline.

These outcomes are supported by Infrastructure Australia's *2021 Australian Infrastructure Plan (the 2021 Plan)* as it establishes a practical and actionable roadmap for reform through to 2036. The *2021 Plan* will be supplemented with *Deliverability: a Roadmap for Infrastructure Industry and Productivity.* This *Deliverability Roadmap* will support new ways of working in the sector for industry and government, and together provide practical recommendations for all industry participants to work together to increase productivity and innovation in the short-, medium-, and longer-term.

Sharing data to deepen and build on this first report

The ongoing ambition of the Market Capacity Program, and the authority of the insights it generates, depends on the quality and depth of data shared by state and territory governments. This first Market Capacity report demonstrates the benefits of a comprehensive national view of the Major Public Infrastructure Pipeline.

Increasing risks to delivery, interdependencies across states and territories, and shared markets for the supply of plant, labour, equipment and materials underscore the importance of this new capability to inform policy at every level of government.

Ongoing commitments to data sharing will strengthen Infrastructure Australia's future analysis and enable new insights to be generated. Infrastructure Australia is committed to expanding the scope and depth of this analysis in future years. To this end, as we consider future capabilities as part of Phase 2 of the Market Capacity Program, our ongoing collaboration with state and territory governments and industry will continue to be central to maximise the value of this work.

Key market capacity findings

Market participants have a low degree of confidence in responding to change in growth of 18% or more.

The sector has a high degree of confidence that it can deliver growth of 10-15% year on year.

Approximately 434 projects worth $218 billion will be completed by 2025.

Over the next 3 years the investment in infrastructure will likely – at least – double current spending.

NSW, Queensland and Victoria account for 87% of activity over the next 5 years. These projects will consume more than 85% of projected resource demands.

2 in 5 megaprojects are delivered within 5km of another megaproject, increasing the risks of local constraints.

A strong residential building market and record levels of non-oil and gas construction activity from 2022-2023 will cause additional input challenges.

The transport sector will dominate demand– 4 out of 5 dollars are allocated to transport projects over the next five years.

While demand is expected to rise strongly, past evidence suggests imports can augment local supply for steel, bitumen and electrical bulk materials.

An increasing reliance on imports may lead to rising quality and global supply chain risks, including price escalation risks in the near term.

Strong growth in demand for quarry products, cement, and concrete may present the greatest risk given challenges in quickly increasing supply.

There are approximately 182,000 people currently working on public infrastructure projects across Australia.

Of the 50 public infrastructure occupations 34 are potentially in shortage.

By 2023, demand for labour and skills will be 48% higher than supply, 3x higher than shortages experienced in 2017-2018.

The number of women in construction roles increased by 34% between 2015 and 2020, however females make up only 12% of the overall public infrastructure workforce.

There will be a peak deficit of 70,000 engineers, scientists and architects; 15,000 structural and civil trades; and 19,000 project management professionals.

Demands for labour will rise around 75% over the next three years compared to current activity. Greatest demand will be for finishing trades and labour (around 140%) and structures and civil trades and labour (around 130%).

Key infrastructure sector facts

Total engineering and construction expenditure over 2020 to 2025 will equal $1,095 billion.

Major public infrastructure expenditure will account for 20% of engineering and construction expenditure across all sectors over 2020 to 2025.

On average $1 spent on public infrastructure has a multiplier of $4.

Over 20% of GDP is attributed to the infrastructure sector.

The average construction worker is six times more likely to commit suicide than be the subject of a workplace fatality.[1]

Over the past 30 years, the infrastructure sector has become 25% less productive compared to other Australian sectors such as mining, manufacturing, retail and transport.[2]

Construction is the most male dominated industry in Australia.

The construction industry regularly accounts for over 20% of all insolvencies in Australia.[3]

1. Introduction

This Market Capacity Report is the first report on this issue by Infrastructure Australia. This report responds to the request made by the Prime Minister and First Ministers at the COAG meeting of 13 March 2020:

> ‘Leaders considered analysis on the market’s capacity to deliver Australia’s record pipeline of infrastructure investment to support the country’s growing population. This analysis highlighted the importance of monitoring infrastructure market conditions and capacity at regular intervals to inform government policies and project pipeline development.
>
> Leaders agreed that Infrastructure Australia will work with jurisdictions and relevant industry peak bodies to monitor this sector.’
>
> COAG Communique, March 2020

In meeting this request, Infrastructure Australia has worked collaboratively with state and territory governments and industry across Australia and internationally. This partnership has facilitated a new national capability to understand and analyse the Major Public Infrastructure Pipeline through the newly established Market Capacity Program.

This report and the broader Market Capacity Program reflect a new world-leading capability for governments and industry. This report, and the associated tools, present a cohesive and scalable platform of evidence and analysis to inform future investment decisions and industry policy.

The scope of this first phase of the Market Capacity Program is informed by those challenges identified in the *2019 Australian Infrastructure Audit*. As has been documented across the states and territories, an increasingly complex risk environment for project delivery, constraints in the supply of skills and resources, market volatility, and poor project and portfolio planning are all increasing the risk of cost escalations and project delays across sectors.

There have been clear constraints in the market, with particular issues associated with skills, quarry-based materials and plant. This has also been felt in project commercial terms, where there have been fewer potential bidders, a rise in non-compliant bids, and in some cases, no bids at all. COVID-19 is materially compounding these challenges both through an expansion in the size and rate of growth in the pipeline, and also through additional constraints in the supply of labour and resources. Key areas of constraint include disruptions to interstate and global supply-chains, impacts on worksite productivity, alongside a greater reliance on digital and remote operations.

A new capability to optimise infrastructure pipeline delivery

The Market Capacity Program reflects a new data-driven capability to comprehensively understand the capacity of the market to deliver the Major Public Infrastructure Pipeline. Infrastructure Australia has worked with national and international experts to design and develop what is a data-driven solution to monitor and report.

A new National Infrastructure Project Database aggregates and organises project data and is supported by a Market Capacity Intelligence System (MCIS). The MCIS applies a comprehensive suite of analytical and system-based tools to interrogate and visualise capacity across sectors, by project type and resource inputs.

This system includes a suite of fully interactive dashboards that enable the full depth of the pipeline to be interrogated geographically, across sectors, by resource input, or project type. This first phase of the Market Capacity Program reflects a capability that will only deepen over time with additional and ongoing data inputs and more detailed, project and sector specific analysis.

This first phase of the Market Capacity Program builds a new evidence base to understand the Major Public Infrastructure Pipeline and associated demand for 73 separate resource inputs across plant, labour equipment and materials.

This demand-side analysis is supported by a public infrastructure occupation taxonomy used to map the demand for skills and occupations against supply, and consider current and future constraints geographically and across sectors.

Alongside this analysis of supply and demand the Program also establishes a new framework to increase the identification and transparency of key risks across the pipeline at a systemic, sectoral and project level.

In totality, this first phase of the Market Capacity Program establishes a new and comprehensive capability through a suite of tools, data and reporting to provide both a current and ongoing evidence base to better understand the Major Public Infrastructure Pipeline and the capacity of the market to deliver in the years ahead.

Expanding this capability

This initial report is an output of the first phase of the Market Capacity Intelligence System. The authority and depth of the insights captured reflect the quality of the data incorporated as part of the National Infrastructure Project Database.

Direct and complete data sharing by state and territory governments will continue to enhance the capability of this system over time. Access to high quality data is critical to the robustness of analysis.

Additional options are being considered depending on the data available from state and territory governments. This will determine opportunities to establish new and deeper capability, for example:

- expanding into more infrastructure sub-sectors and building a larger and more representative data set.
- deep-dives into materials and opportunities with non-virgin replacements, embodied carbon, or construction and demolition waste.
- greater understanding about sector-specific constraints and opportunities, for example in relation to mega-project delivery, or the rail project pipeline.

2. Methodology and constraints

At a glance:

Infrastructure Australia has engaged extensively to produce this initial report, drawing on subject-matter experts, real data, and best practice approaches to unlock insight.

Any empirical assessment relies on a range of analytical techniques, methodology and assumptions. Transparency is critical to decision-making confidence. All assumptions and approaches have been provided.

Analysis and insights are drawn from characteristics of capital projects. Plant, labour, equipment and materials (PLEM) are the major drivers of cost in any project and can often be the source of issues when supply and demand are misaligned.

The project pipeline is determined by budget cycles. Insights and analysis in 2024 and beyond should be considerate of this fact.

How we produced this report

As the nation's independent infrastructure adviser, Infrastructure Australia has worked collaboratively with a range of key stakeholders to develop this initial report. The collaborative approach and support from government agencies, departments and key individuals has been critical to developing this analysis.

Infrastructure Australia has also benefitted from industry support and engagement. In many circumstances, industry insight has provided the complementary 'real world' story behind the data. Complementing empirical evidence with real-world insights has been critical in further developing our understanding.

Analysis limitations and assumptions

Due to the complexity of our analysis, there are limitations and considerations that should be understood. In applying the analysis from this initial report, it is critical that users and decision-makers understand the methodology and assumptions we used.

Infrastructure Australia has drawn upon a range of inputs including external consultant reports and data providers. Although all efforts have been undertaken to ensure the accuracy of inputs, there is a degree of reliance on external suppliers. For example, Australian Bureau of Statistics (ABS) *construction work done* data is referenced throughout this report as it provides a consistent, historical context to the Major Public Infrastructure Pipeline data generated as part of this study[4]. It is important to recognise, however, that it is not completely comparable with Major Public Infrastructure Pipeline activity data. In particular, construction activity does not represent total project costs (which also include purchases of equipment, for example) nor does it include related non-construction activities which may form part of total project cost (such as planning and procurement costs).

In creating the Market Capacity Intelligence System, it is important to note that our data capture is not total. To mitigate this risk, a range of analysis techniques and quality-control measures have been employed. Where required, assumptions in analysis have been conservative.

While there are challenges in measurement there is a high degree of confidence in the direction of the analysis and insights. This has been confirmed through a number of means, most notably confirmation with external experts on the approach, alongside the cohesion of findings from industry.

More data in the future may facilitate a finer degree of analysis of our market conditions and capacity. All assumptions and details on methodology for each chapter are captured in Appendix A of the supporting report.

Skills analysis limitations

The data sources used in the skills supply analysis – the 2016 Census, the ongoing *Labour Force Survey* and job advertisement data from Burning Glass Technologies – have their own strengths and weaknesses leading to limitations in the conclusions that can be drawn.

The Census is comprehensive but infrequent; it is self-completed and depends on respondents identifying their own occupation and industry.

The Labour Force Survey is carefully calibrated to definitive population totals, has higher quality consistent use of classifications but is based on a sample.

The job advertisements are also a sample but of a varying and unknown proportion of the full quantum of demand – varying not just over time but also by occupation and industry. The classification of job advertisements to industry and occupation is done by a statistical/machine learning algorithm based on analysis of the original text, introducing its own statistical noise.

Key limitations of the analysis can be understood categorized as:

- Measurement noise – such as Census respondents misclassifying their industry or occupation, in a way different to any misclassification that takes place in the Labour Force survey.
- Processing noise – such as the Burning Glass Technologies machine learning algorithm misclassifying the occupation of a job advert.
- Analytical assumptions – such as assuming that the proportions of detailed job titles within an Australian and New Zealand Standard Classification of Occupations (ANZSCO) unit Group in the workforce reflect the proportion of those titles appearing in job adverts for that ANZSCO unit group; or that the proportion of people in each industry working in each occupation at the time of the Census (the best source at that level of granularity) has not changed materially since.

Appendix A, in the supporting report, outlines the efforts made to control for these problems but significant uncertainty and limitations are inevitable.

Analysis methodology

Demand-side

The demand-side analysis presented in this report is based on aggregations of project-level data to inform a pipeline view of Australia public infrastructure. Project-level data was provided by BIS Oxford Economics in conjunction with Infrastructure Australia. This data was current for the 2020-2021 budgets of all jurisdictions as at March 2021 (it does not include, for example, any additional projects anticipated or considered for acceleration following the successful Brisbane 2032 Olympics bid). Due to the variation in budget cycles across jurisdictions, mid-2020 is taken in this report as the beginning of the forecast period. This forecast period is indicated as such on all relevant figures.

For this initial report the criteria for inclusion in the project-level database was funding source (majority public sector funded) and project capital cost (over $50 million for Tasmania, the Northern Territory (NT) and the Australian Capital Territory (ACT), and over $100 million for all other Australian states). It does not include smaller projects, nor minor capital works, programmed works or infrastructure maintenance, limitations that are targeted for future improvement in future phases.

The public pipeline beyond 2024 has increasingly less confidence due to the budgeting process. This does not mean that major project activity will necessarily decline beyond 2024, however shows the pool of uncommitted funds is higher. The low certainty beyond year three of the forecasts, highlights the need for longer term (ten year plus) project funding pipelines.

The following project-level fields have been captured in the Market Capacity Intelligence System:

- Location (including state or territory)
- Investment cost
- Land acquisition cost
- Funding status
- Typecast
- Project stage (preconstruction stages, under construction or completed)
- Project timing (across the various project stages)
- Delivery agency
- Contracting model

A description of the methodology used to find and collate this data can be found in Appendix A.

Major Public Infrastructure Pipeline activity to resource demands

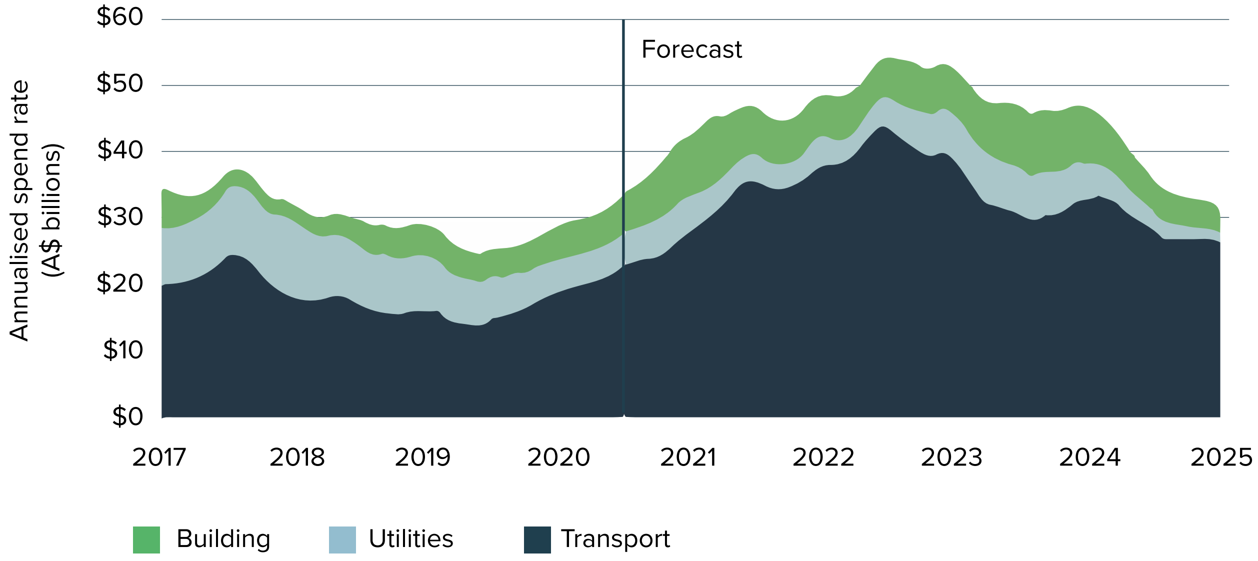
Infrastructure Australia has translated individual projects into individual components using typecasting. Each project is considered against more than 30 different asset types – ranging from brownfield hospitals to low-use roads. Timing of each project is also considered.

For each typecast a detailed breakdown of project cost information and resource demands is developed based on real data from Australian infrastructure projects. Detailed cost breakdowns follow the International Construction Measurement Standards.

Detailed project cost information and resource demands are provided with appropriate confidence ranges. Project costs are in 2020-2021 dollars, while unit rates for resources are based on current market rates.

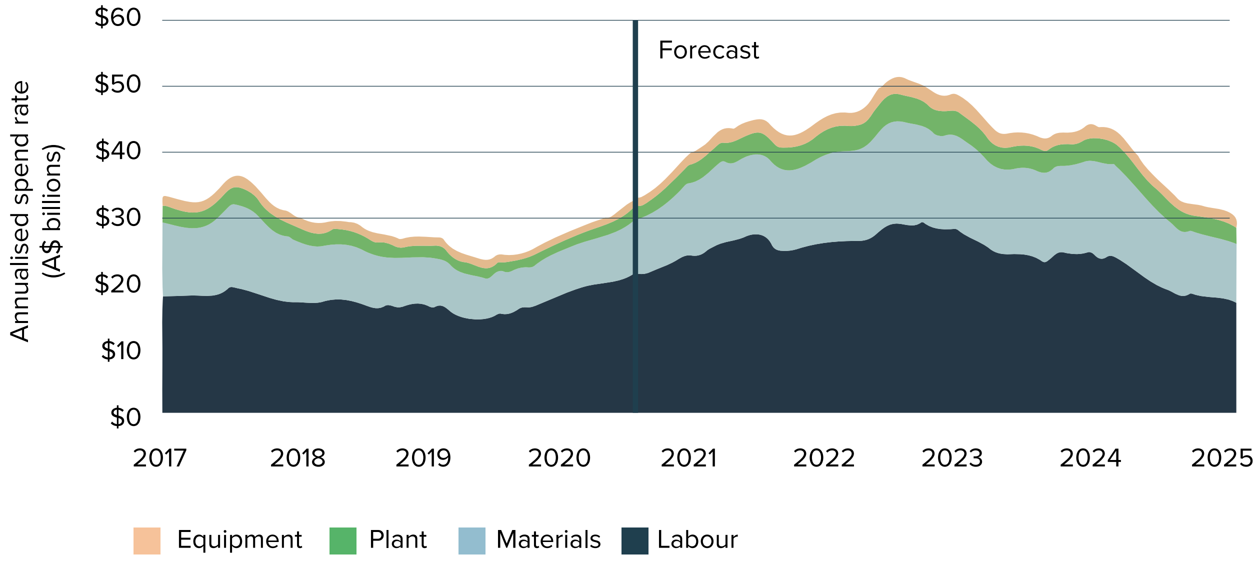
The methodology outlined above allows a high degree of flexibility. Very detailed project resources and costs can be interrogated across any number of market segments, jurisdictions, or project types as shown in Figure 1 and Figure 2. Note that to better represent the detail of investment trends, the costs presented in these figures are annualised spend rates calculated on a monthly basis.

Figure 1: Infrastructure costs by sector



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 2: Infrastructure investment by major project resource



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Detailed insight into the inputs of infrastructure demand

Resource categories are established across four key accounts: plant, labour, equipment, and materials.

Plant covers 11 individually distinct (and mostly mobile) capital items typically used in the implementation of major projects, including:

- site plant, which includes cranes, scaffolding and scissor lifts
- temporary site facilities, including site offices and other infrastructure such as lunchrooms and toilets
- civil plant, which includes mobile plant such as excavators, graders, bulldozers and compactors
- speciality plant, which refers non-standard items or plant which is purpose built, modified or manufactured for a specific application/use (including tunnel boring machines, modified excavators and pile driving plant, augers, heavy transportation and low loaders).

Labour includes 50 occupations most commonly engaged in infrastructure, including:

- project management professionals: risk management, project management, commercial management, construction management and environmental and occupational health professionals
- engineering, science and architecture: including a range of professional non-management roles including different types of engineers, surveyors, architects, IT professionals, geologists, maintenance planners, safety officers and procurement roles.
- structures and civil trades and labour: including plant operators, concreters, bricklayers, carpenters and joiners, drillers, rail track workers and structural steel erectors amongst other roles.
- finishing trades and labour: including telecommunications field staff and cablers, plumbers, electricians, electrical line workers, tilers, glazers, plasterers and painters.

Equipment reflects the three generally non-distinct capital investment items and have been categorised as either control, electrical or mechanical equipment. Being non-distinct (and often bespoke) items, demand for equipment is expressed in dollar terms rather than units.

Materials include the following distinct items:

- concrete: including aggregates, sand and cement
- rock / bluestone
- steel: including structural, reinforcing steel, and rail track
- bitumen binders and asphalt
- electrical bulk, representing mainly electrical cables, accessories and fittings, conductors, insulators, transformers, switches and other related items.

The full breakdown of resources provided in this analysis is detailed in Appendix A.

Supply-side – Skills

The skills supply analysis addresses to what extent the current and projected supply of labour can support Australia's proposed investment in public infrastructure.

To understand this, it was necessary to clearly define the occupations and skills that underpin this workforce and estimate the numbers available at different points in time, including projections for the future. The broad approach was to:

- Estimate numbers of people in or near the workforce as determined by official statistics (e.g. the 2016 Census and the ongoing Labour Force Survey) and our own forecasts or modelling based on those statistics.
- Confront those estimates with additional data (such as job advertisements from Burning Glass Technologies) that provides extra information on variables (such as skills) not covered by the official statistics.
- Add extra granularity (than exists in the ANZSCO and Australia and New Zealand Standard Industrial Classifications (ANZSIC)) on variables which required further detail than official statistics provided.

Greater detail on the approach to understanding skills supply can be found in Appendix A

Market constraints and risk

The risk analysis presented in this report is based on empirical evidence sourced from numerous sources and compiled for the Australian infrastructure sector. A multi-dimensional approach to risk evaluation and analysis has been employed. Spatial, sectoral, asset- and project-specific risks have been captured and considered alongside a best practice risk management framework.

Empirical evidence has been complemented by global benchmarking, industry sounding, expert interviews/surveys, and spatial risk data.

Global benchmarking of infrastructure project risk

This initial report includes a statistical analysis of thousands of projects to increase the understanding of risk through cost and schedule overruns and deviations in benefits realisation using Oxford Global Projects' Infrastructure Project Database including:

Transport
877 Projects

Energy
765 Projects

This has been supported by reviews of relevant and contemporary reports on infrastructure project risk. This includes the *2019 Australian Infrastructure Audit*, industry publications, business cases, and Auditor-General reviews. It also includes a detailed review of project risk registers as completed by proponents as captured in the Infrastructure Australia *2021 Infrastructure Priority List*.

Project risk data from the front-line of projects

This initial report includes analysis arising from 40 interviews with individuals, peak industry, and stakeholders across the infrastructure sector. Interview findings have been consolidated into risk registers including activities to mitigate and avoid risk.

Risk registers have been complemented by de-identified risk data sourced through Dispute Resolution Boards Australia. This data provides considerable detail into sources of risk through project claims prior to them reaching court.

Industry sounding to better contextualise infrastructure risk

Complementing global benchmarking data and risk registers captured from the front-line of projects, an additional 50 individuals have been surveyed to capture a range of perspectives on project, sector, and risk.

Increasing awareness about spatial and environmental risk

The risk analysis presented in this report is further complemented by a range of spatial datasets as known drivers of location-based risk. These include datasets that capture the likelihood and magnitude of temperature, flood, bushfire, and sea-level rise.

3. A new wave of public infrastructure investment

At a glance:

This initial report is delivered on the cusp of an unprecedented wave of investment in public infrastructure projects. Although visibility of upcoming demand is limited by budget processes and the limit of forward views afforded by budget estimate periods.

In total the sector now accounts for around 2% of Gross Domestic Product. The volume at the peak of the investment, expected in 2023, has never before been delivered by the Australian infrastructure market.

The Australian infrastructure market has responded to peaks and troughs before, however, market soundings have emphasised deliverability issues with both the unprecedented magnitude and the speed of this upcoming wave.

Industry confidence in their capacity to deliver against increased activity in the Major Public Infrastructure Pipeline indicate potential capacity limits on efficient growth. One in four actors in the supply chain highlighted a near impossibility in being able to respond to an increase of more than 30% in any given year.

This initial report represents a new paradigm in capability for senior decision-makers across the Australian infrastructure sector. Phase 2 of Infrastructure Australia's Market Capacity Intelligence System will enhance insight, and likely unlock better portfolio and project outcomes.

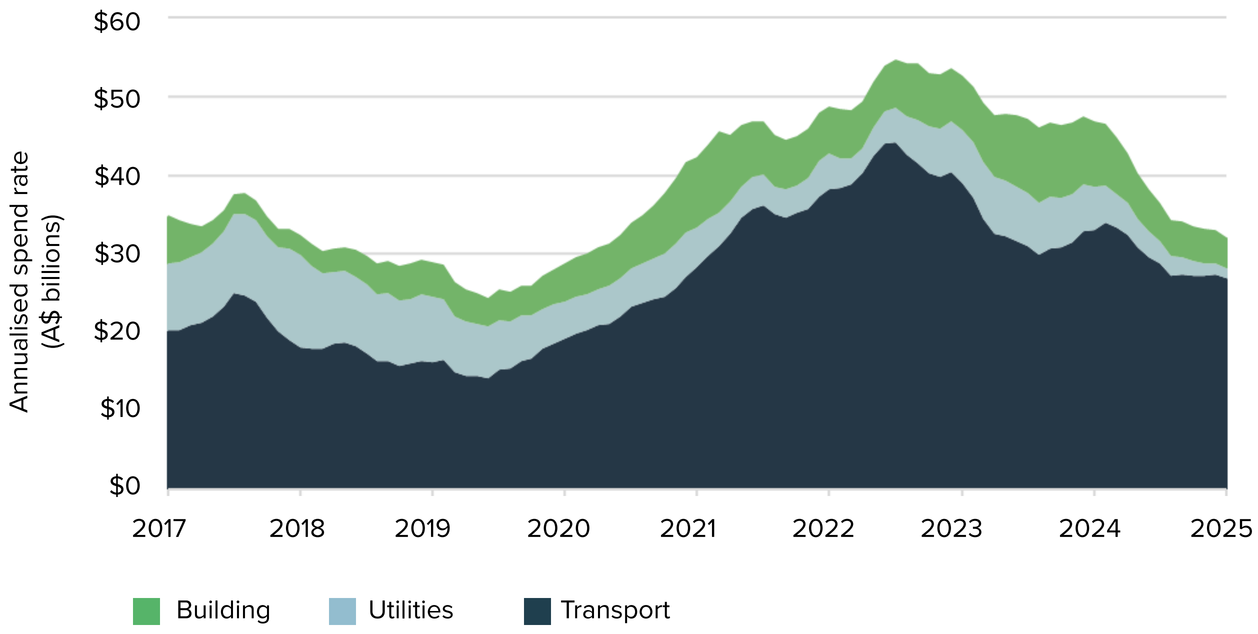
78% of the current public infrastructure workforce is in NSW, Victoria and Queensland, and 78% is in major cities. In a buoyant market, this creates difficulties for non-metropolitan areas to source labour. Efforts to grow the workforce are being constrained by a range of cultural, geographical, diversity and education issues.

Labour shortages are anticipated to be three times greater than in 2017-2018, peaking at a likely shortfall of 105,000 unfilled roles in mid-2023 or 48% higher than projected supply. Victoria, Queensland and Tasmania will experience the greatest risk of labour shortage. At points between 2021-2025, all three states will require a workforce that is approximately twice the size of projected supply available within their borders.

A doubling of investment in three years

Australian Governments have made commitments toward an unprecedented wave of infrastructure investment across transport, utilities, and social infrastructure, Figure 3. An expected $290 billion investment is planned over the next 10 years, including an approximate doubling of investment over the next three years.

Figure 3: Major public infrastructure activity will approximately double over the next three years

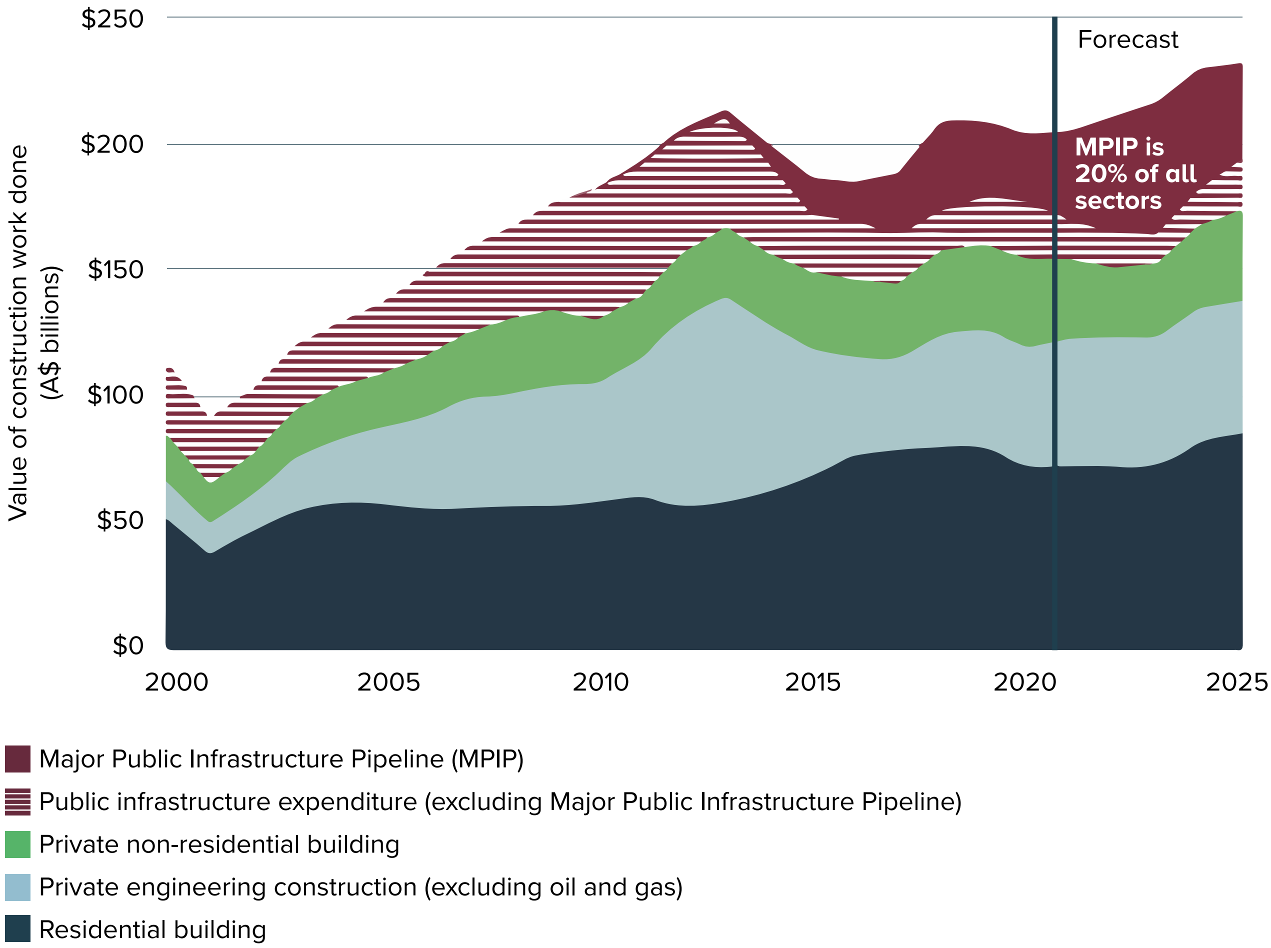


Note: the visibility of forward infrastructure spending is limited by available data. Only publicly known projects are included, and therefore generally occur within the forward estimates. As a result, future expenditure is likely to be larger than forecast beyond the forward estimates as new projects are announced. Increased clarity of the long-term pipeline is highly desired to support this understanding.

Annual spending will peak in 2023 at over $52 billion. This represents approximately twice the current (2020) expenditure rates. It is many multiples beyond spend rates experienced as a response to the Global Financial Crisis. The investment path to these record levels of spend is lumpy, with finite periods of aggressive growth leading to multiple peaks and troughs.

Forecast concurrent activity in residential and non-residential building and private engineering construction presents a multiplier for the risks and constraints created by this scale of investment. The Major Public Infrastructure Pipeline reflects just part of the picture when considering the supply and demand for associated skills and resource inputs alongside those created by mining, defence, maintenance and non-public infrastructure construction (Figure 4).

Figure 4: Public infrastructure projects are only part of the picture relative to investment across residential and non-residential building



Note: Public infrastructure expenditure data is sourced from the Australian National Accounts published by the ABS. Major public infrastructure projects data is only reported separately from public infrastructure expenditure data from 2010.

Adding further difficulty for stakeholders in supporting and managing this pipeline, the visibility of upcoming demand is limited by budget processes and the limited visibility beyond the future estimate periods (Figure 5). As charted in Figure 6, the current acceleration of investment is at a rate that is beyond what the market has expressed confidence in being able to deliver (Figure 7). The annual rate of growth in expenditure between 2020 and 2023 is expected to average 30%, while around 25% of actors in the supply chain have very low confidence in being able to respond to an increase of more than 30% in any given year.

Figure 5: Investment in infrastructure is lumpy and unpredictable

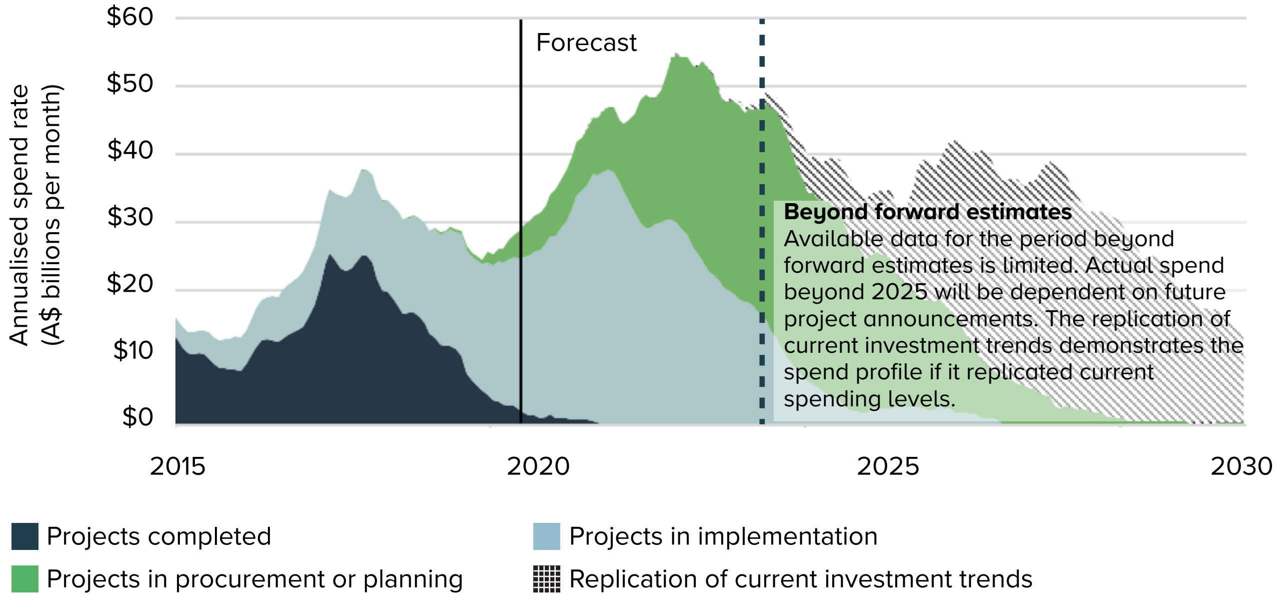
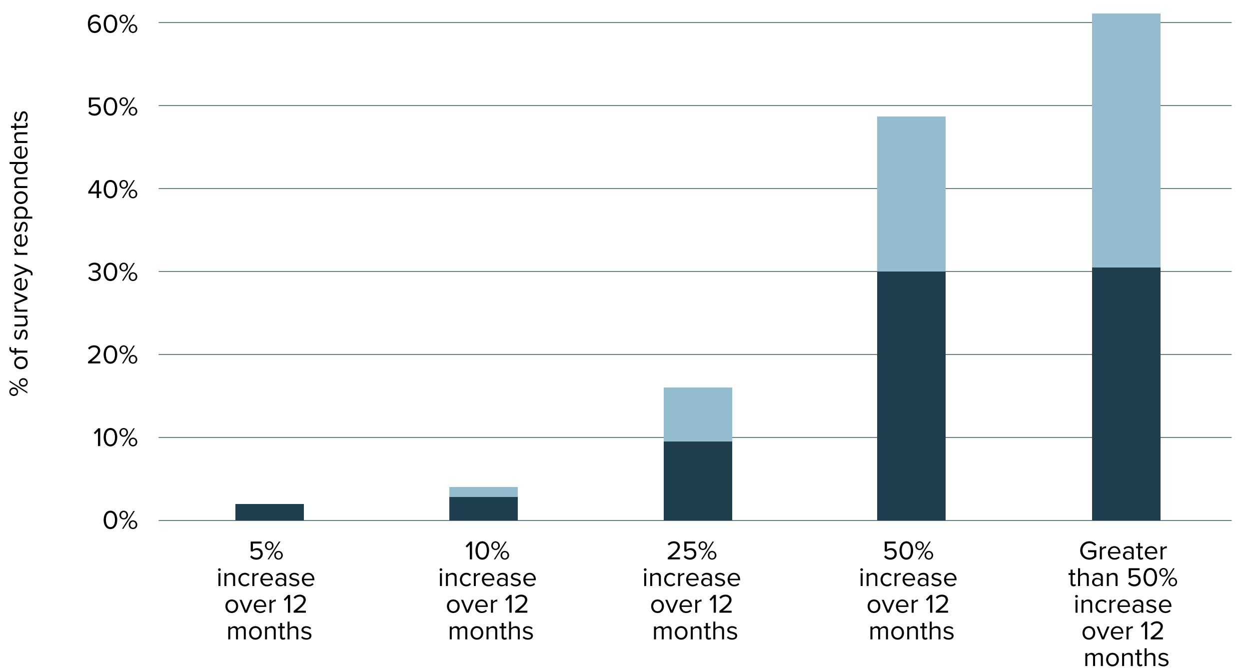


Figure 6: Forecast investment in the pipeline is accelerating at a rate that the market lacks confidence to deliver



Note: the visibility of forward infrastructure spending is limited by available data. Only publicly known projects are included, and therefore generally occur within the forward estimates. As a result, future expenditure is likely to be larger than forecast beyond the forward estimates as new projects are announced. Increased clarity of the long-term pipeline is highly desired to support this understanding.

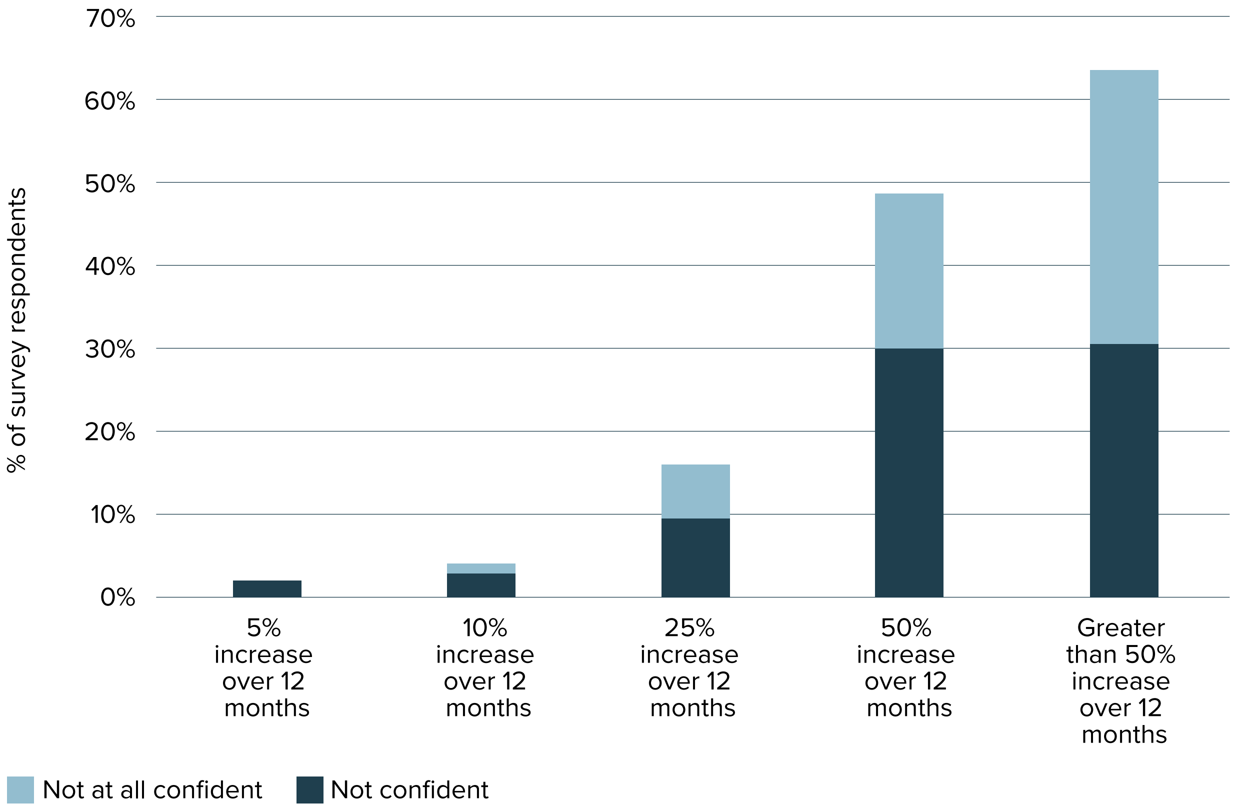
Market confidence weakens in response to large increases in investment in short periods of time

> "Current infrastructure projects are already showing signs of not meeting demand, with the borders closed and no immigration or migrant workers. I can't see how industry will complete existing and new projects without serious delays or cost blowouts."
> -Market survey participant, 2021

Feedback from over 100 stakeholders representing a wide-range of the infrastructure supply-chain have highlighted concerns with deliverability of the forward pipeline. The majority of those concerns stem from issues associated with deliverability and long-term sustainability.

One in four actors in the supply chain highlighted very low confidence in being able to respond to an increase of more than 30% in any given year. This increases to 1 in 2 actors when infrastructure investment increases by more than 50% in a 12-month period. Such insight is critical when thinking about infrastructure deliverability. The loss of access to half the market when bidding, tendering, and delivering any infrastructure project is a key consideration for future decision-making.

Figure 7: Industry confidence in its ability to deliver deteriorates after an 18% uplift



A pipeline dependent on people for delivery

Ultimately, infrastructure delivery requires more than steel and concrete. It is also about the workers, engineers and project teams who design and build it, in addition to the users who rely on it for their needs. Infrastructure planners, financiers, operators and community engagement teams are all part of the tens of thousands of people that make up the sector. In total, the sector accounts for around 21% of Gross Domestic Product (GDP).[10]

Of the 50 occupations identified as relevant to public infrastructure, 16 occupations are rated as currently likely in shortage and 18 rated as potentially in shortage. Shortages are likely being compounded by changing skills needs that lead to the existing workforce no longer having the right skills. Occupations identified with a high degree of skill change also indicate a strong likelihood of being in shortage, including employers seeking workers with more generalist skills.

Of note, 78% of the current public infrastructure workforce is in New South Wales (NSW), Victoria or Queensland and 78% in major cities. In a buoyant market, this creates difficulties for non-metropolitan areas to source labour. Smaller states and territories or regional areas also face higher risks to workforce retention. 27% of the Northern Territory (NT) infrastructure workforce is engaged in public infrastructure compared with just 12% in Queensland or Victoria.

Over the next three years demand for infrastructure-connected labour is anticipated to reach unprecedented levels. The consequences are significant with labour shortages anticipated to be three times greater than in 2017-2018, peaking at a likely shortfall of up to 105,000 roles by mid-2023 or 48% higher than projected supply. Victoria, Queensland and Tasmania will experience the greatest risk of shortage. At points between 2021-2025, all three states will require a workforce that is approximately twice the size of projected supply available within their borders.

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.

In a sector where up to 40% of the workforce is set to retire in the next 15 years, business as usual may not be an option. Current regulatory and procurement practices may result in workforce inefficiencies just as the sector is attempting to cope with escalating demand.

Efforts to grow the workforce are being constrained by a range of cultural, geographical, diversity and education issues. Further, due to COVID-induced restrictions, migration can no longer be relied upon alone to meet the gap. Continued investment in public infrastructure without significant expansion of workforce supply will likely compound shortages already evident in the workforce. This may put the delivery of the infrastructure investment pipeline at risk in the years to come.

4. Understanding demand

At a glance:

The Market Capacity Intelligence System includes detailed information over 630 projects across transport, utilities and building infrastructure. Approximately two thirds of those (434 projects worth $218 billion) will be implemented in the next five years (2021 to 2025).

Annual infrastructure expenditure will double by 2023 to $54 billion.

The committed cumulative value of investment over the next five years represents a 68% growth rate as compared to activity over the preceding five years.

Such a rate of growth and height in infrastructure investment has never been seen in Australia. Successful delivery of this level of investment remains untested.

Investment rates expected over the next five years exceed capacity limits identified as ‘deliverable’ by more than a quarter of the surveyed infrastructure market.

Market sounding is well supported by empirical evidence. Resource demands over the next five years will be two-thirds higher than the previous five years (to 2019-2020).

Demand volatility appears to be a trait that is characteristic across the public infrastructure sector. The most intense resource pressures are labour and materials, accounting for 60% and 30% of expenditure (resource demand) over the next five years, respectively.

Australia’s largest east coast states – NSW, Queensland and Victoria – are the biggest drivers of infrastructure expenditure, accounting for 87% of all activity over the next five years.

Increasing delivery of mega-projects, transport and rail, drives concentration in demand for skills and materials.

Transport activity over the next five years will be 68% higher than the previous five. At its peak in 2022-2023 the transport sector will consume over 80% of all resource demands. The vast majority of this activity and resource demand will be focused on road and rail.

Rural spends will increase from $6.9 billion to $15.6 billion between in 2019-2020 to 2022-2023.

Major findings

Timeline risk factors

Over the next three years the investment in infrastructure will likely – at least – double current spending.

The transport sector will dominate demand over the next five years – 4 out of 5 dollars are allocated to transport projects.

Approximately two-thirds of the Major Public Infrastructure Pipeline (434 projects worth $218 billion) will be undertaken within the next five years (2021-2025).

Risks to the rail sector extend beyond skills to labour. Demand for rail track workers will increase by approximately 375% in the next three years.

Demands on infrastructure plant and equipment are expected to rise by 145% and 125%, respectively, over the next three years.

Demands for labour will rise around 75% over the next 3 years compared to current activity. Greatest demand will be for finishing trades and labour (around 140%) and structures and civil trades and labour (around 130%)

Headcount of telecommunications field staff, cablers, electrical line workers, and safety officers will need to increase by a minimum of 50%

Portfolio demand for rail track grows faster than any other material, with demand more than tripling in coming years.

Material demands are expected to rise by c.120% over the next three years. Rock and bluestone (+240%), steel (160%) and concrete (110%) will be the biggest material risks.

Location risk factors

NSW, Queensland and Victoria account for 87% of activity over the next five years. These projects will consume more than 85% of projected resource demands.

Queensland, Tasmania, the NT, and the ACT will experience the strongest growth for resources.

The ACT is projected to average more than 100% growth in resource demands each year for the next five years.

Materials demands will rise by around 215% per annum on average. This represents a 32-fold increase in material demands when compounding across the next five years

73 of the 81 megaprojects over the next five years are located on the eastern seaboard.

A greater concentration of work in megaproject activity is likely to introduce unpredictable hyper-localised cost escalation and capacity risks.

Sectoral risk factors

Transport projects represent 74% of the activity over the next five years. Tunnelling projects represent a smaller share of the Major Public Infrastructure Pipeline than non-tunnel works but are more intensive in their use of steel, concrete and equipment.

Transport projects use more labour and plant resources compared to utilities and building projects. Major road projects account for 41% of total labour demand over the next five years.

The capacity of the Australian infrastructure market

This section presents quantitative analysis of the market's ability to respond to infrastructure investment demands when considering capacity of the market.

Australia's infrastructure market has a natural level of equilibrium. Market feedback underscored that volatility translates to difficulties in delivering the forward infrastructure pipeline (as seen in Figure 7). Investments that change beyond 18% in any given year have a low degree of deliverability.

Demand volatility appears to be a trait that is specific to the public infrastructure sector. Other market sectors, such as defence and manufacturing, appear to be more stable and predictable and therefore more sustainable and productive over the longer term.

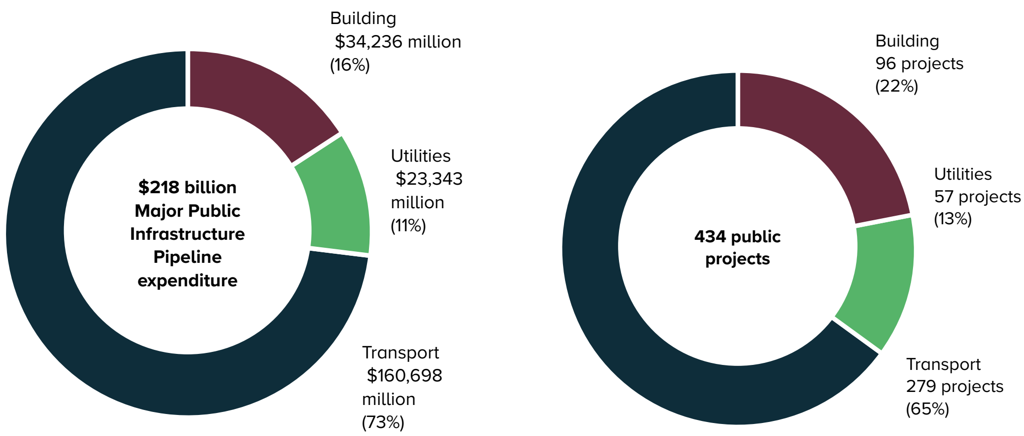
Major project activity trends and outlook

The Market Capacity Intelligence System includes detailed information about 634 projects across transport, utilities and building infrastructure. Approximately two-thirds of those (434 projects worth $218 billion) will be implemented within the next five years (2021-2025). The 634 projects include all public infrastructure over $100 million, and those over $50 million in NT, ACT and Tasmania.

The transport sector will dominate demand over the next five years. As seen in Figure 8 four out of five dollars are allocated to transport projects.

Building and utilities account for smaller proportions of the expected spend. The building sector, predominantly made up of social infrastructure projects, is expected to be spending $34.2 billion over the next five years. This is followed by utilities comprising 11% of total investment ($23.3 billion) over the next five years.

Figure 8: The transport sector will dominate demand over the next five years



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021))

Project activity in the Major Public Infrastructure Pipeline is set to grow 98% over the next three years and is expected to peak at $52.3 billion in 2022-2023. As highlighted in Figure 1 this rise in activity represents an average growth 30% year on year. Transport projects are the main driver of this growth where activity over the next five years will be 68% higher than the previous five.

Building activity is expected to grow the fastest in the near-term particularly 2020-2021 where it will rise by 60% before peaking in 2021-2022 at $7.3 billion. Health projects account for the majority of this investment.

Smaller public-sector building projects, such as education, arts, and justice facilities, have high growth forecasts – above 80%. These projects have the greatest cross-over with residential and small-scale commercial sub-sectors. It's unlikely these sub-sectors will experience downward trends in activity likely resulting in upward pressure in costs and shortages for common inputs, such as materials.

The transport sector's growth trajectory is similarly aggressive. It is planned to increase three consecutive years at 37%. The estimated level of activity in 2024-2025 is 80% above 2019-2020 levels. Rail activity will be the largest driver of growth as it rises by 150% in 2021-2022 alone. The severity of outcomes as a result of this level of growth are difficult to predict.

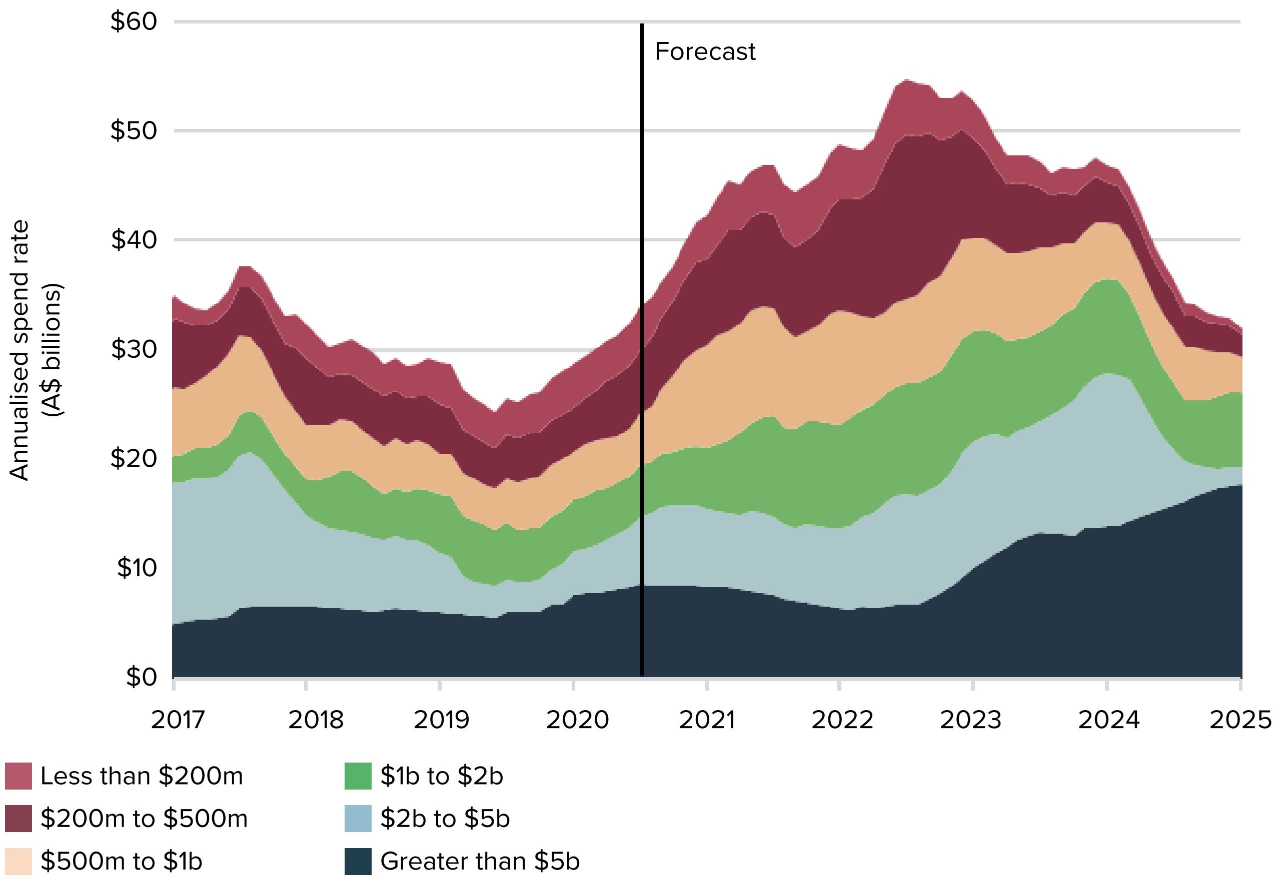
Activity in the utilities sector is projected to decline for two consecutive years at an average annual rate of 19%. This decline is mostly driven by finalisation of investment in the National Broadband Network (NBN). It also may be an effect of the data, which does not include project activity conducted by government-based water and energy providers.

Megaprojects continue to dominate public infrastructure activity

Infrastructure Australia's Market Capacity Intelligence System includes 80 megaprojects and represent less than 20% of the total number of projects in the Major Public Infrastructure Pipeline.[11] Cumulatively, these projects are worth 80% of the total Major Public Infrastructure Pipeline investment over the next five years.

Looking ahead the value of megaprojects will continue to grow. Very large megaprojects represent a disproportionately large component of the Major Public Infrastructure Pipeline, particularly in 2025, Figure 9.

Figure 9: Megaprojects will represent a large component of the future Major Public Infrastructure Pipeline



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Increasing the representation of megaprojects presents two major risks for governments:

- **Megaprojects, particularly megacontracts, are harder to cost and deliver** There is a growing body of evidence that megaprojects are inherently more difficult to cost and deliver. These challenges result from the paucity of information during competitive tender processes, which may lead to imperfect planning and costing challenges.[12]
- **Market capacity, tolerance, and appetite to deliver them is low** Infrastructure Australia analysis of market capacity to deliver megaprojects highlights a relative decline over the past decade by parties servicing megaprojects. As contract sizes increase, so too does the need for organisations to joint venture. This lowers the number of effective bidders and introduces hidden interface risks.

An increasing number of megacontracts increases the risk of cost and schedule 'blow outs'. For more information about market density, particularly Tier 1 contractors, see *Market capacity risks* (page 2).

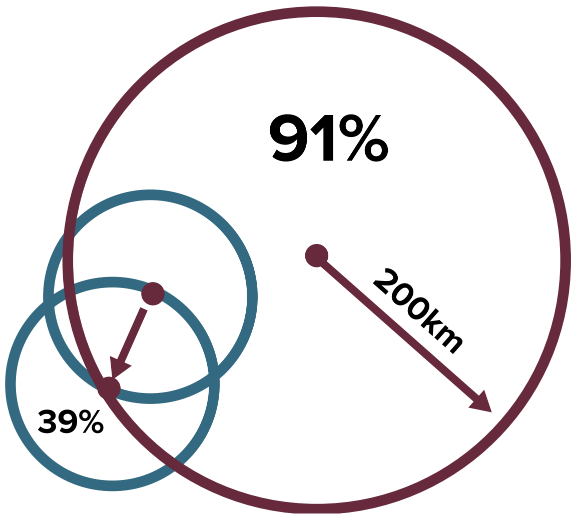
Megaprojects are being delivered on top of one another

Infrastructure Australia analysis has highlighted a growing risk that megaprojects are increasingly being delivered on top of one another. Figure 10 highlights two out of every five megaprojects are planned to be delivered within five kilometres of another. Such a trend is likely to create hyper-localised shortages and risk effects that are difficult to predict or plan for.

Figure 10: Megaprojects are clustering together

91% of all megaprojects will have at least one more within 200km

39% of all megaprojects will have at least one more within 5km

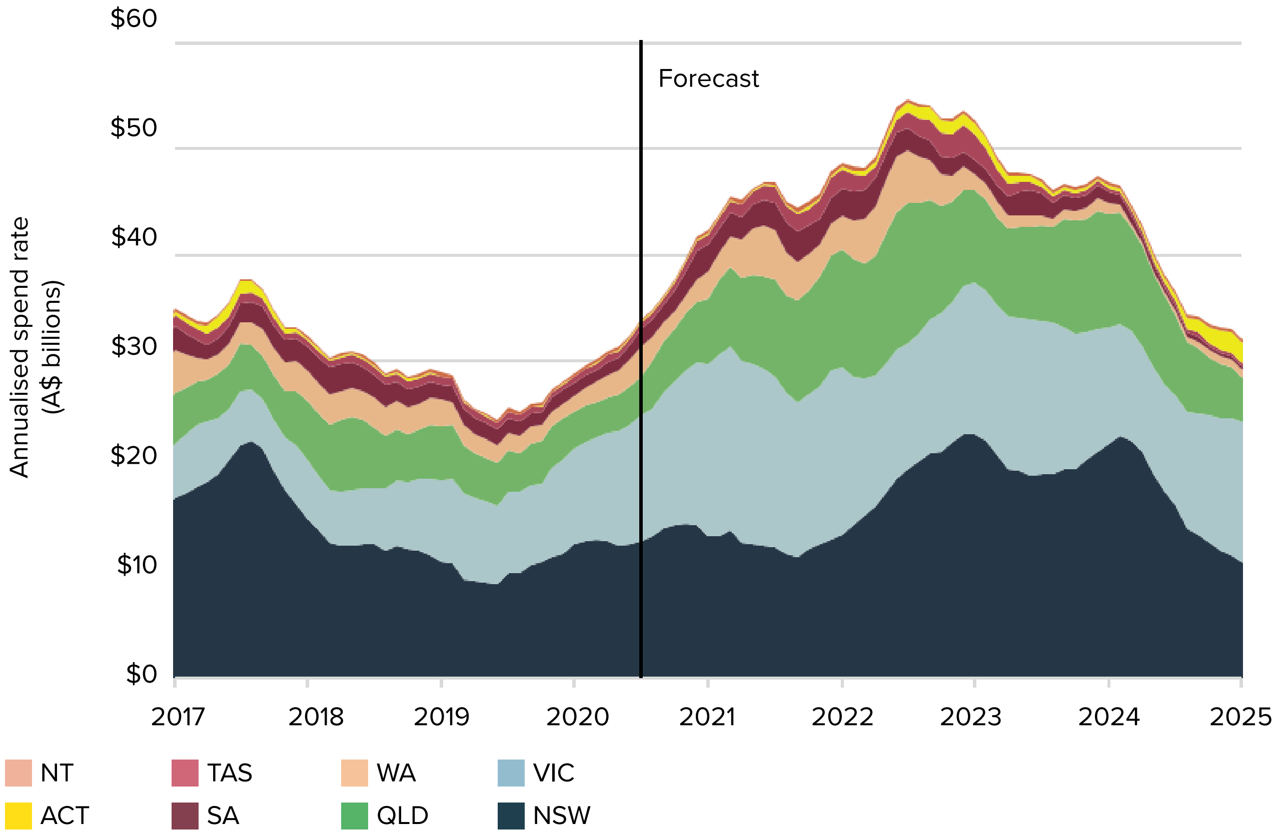


Australia's east coast dominates the spend over the next five years

NSW, Victoria and Queensland account for 87% of the Major Public Infrastructure Pipeline over the next five years. As seen in Figure 11, the majority of that activity is concentrated in NSW and Victoria.

NSW activity is poised to increase substantially at almost 40% more investment in the next five years. The largest proportion of this activity is in major public transport projects. Proportionally, NSW is forecasted to invest more heavily in public infrastructure buildings. Such an investment increases risk if activity in similar sectors, such as large-scale residential and small-scale commercial, continue to rise.

Figure 11: Pipeline expenditure is dominated by the mainland east coast states



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

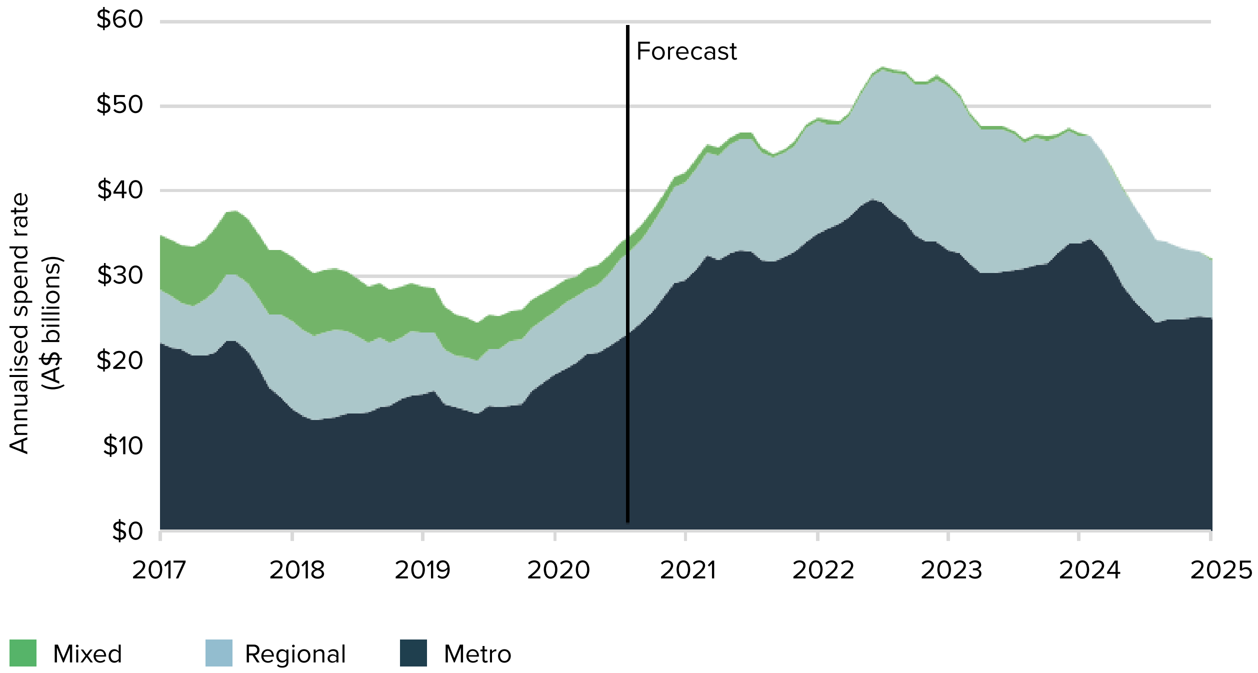
While the magnitude of investment in smaller states do not rival the east coast, the rate of growth in investment does. For example, the rate of investment in the ACT is projected to grow at an average of 124% per year over the next five years. Isolating this just to transport in the ACT, it will rise an unprecedented 227%.

Detailed market sounding highlighted that such rates of growth will likely be difficult to achieve without trade-offs. Sustained periods of activity beyond 36% each year had a ‘near zero’ likelihood of deliverability.

Regional infrastructure activity is increasing

Each individual project in the Major Public Infrastructure Pipeline has been assigned to metropolitan areas, regional areas or a mixture of both. Over the next five years the proportion of expenditure in regional areas across Australia is pegged to rise. As seen in Figure 12 rural spends will increase from $6.9 billion to $15.6 billion between in 2019-2020 to 2022-2023.

Figure 12: Infrastructure investment in regions is forecast to rapidly rise

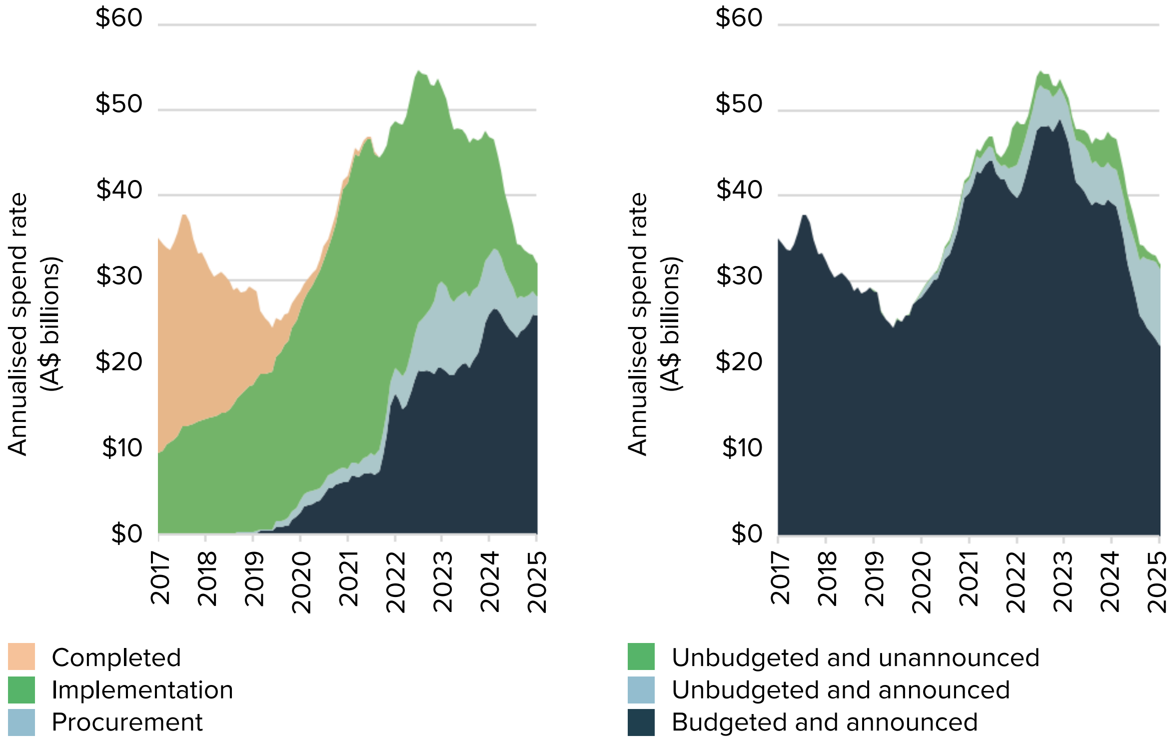


Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

The bulk of this rise is driven by regional transport projects, such as Inland Rail, although building and utilities sectors will experience sharp growth also. The risk ahead is the capability and capacity of regions to deliver such aggressive growth. Infrastructure Australia research into market capacity, particularly in skills, highlights skills for many regional infrastructure projects are often sourced from metro areas. Competition for skills in both markets will remain tight through to 2024.

Infrastructure investment is uncertain beyond 2023

Figure 13: Major Public Infrastructure Pipeline expenditure by project stage and project status



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

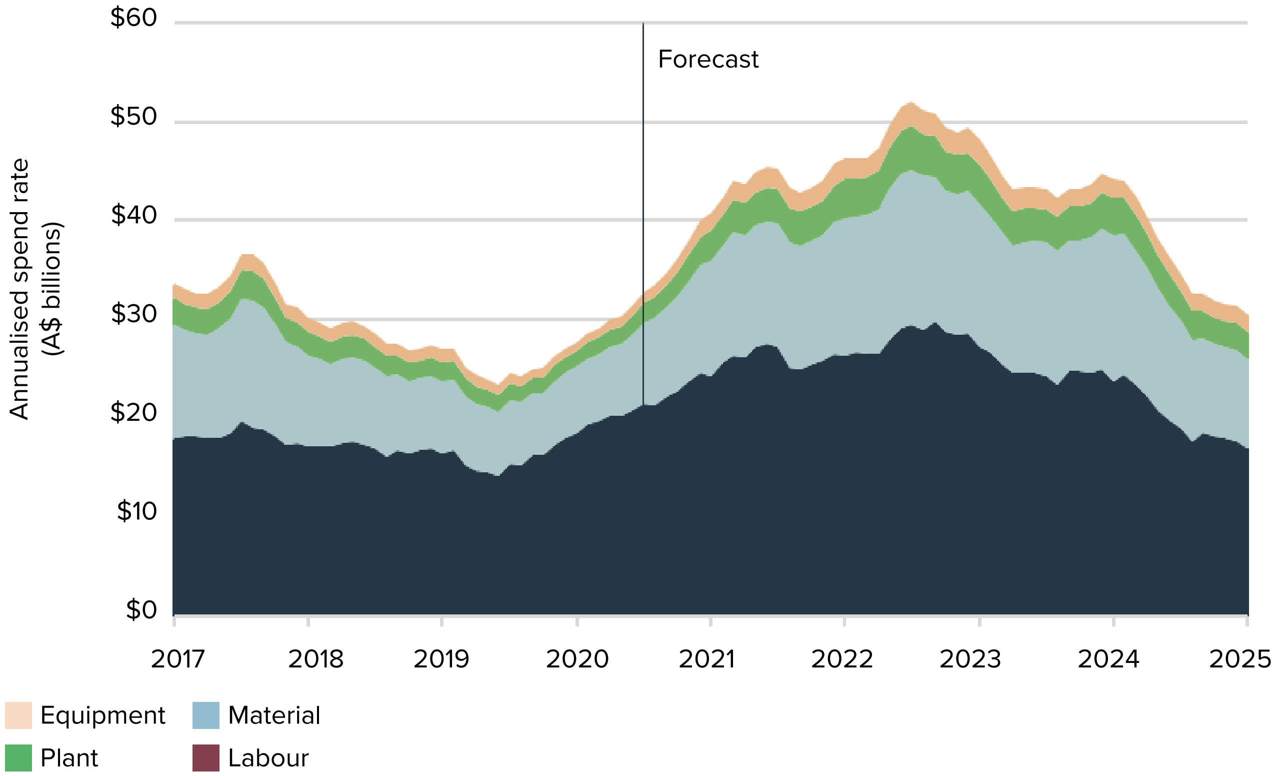
Figure 13 highlights that the majority (88%) of infrastructure investment in the next five years has been budgeted and announced. Such a high figure provides certainty to the market. It enables a greater level of planning with their supply chain to prepare for bidding and delivery. While transparency in government infrastructure investment is a positive development there are clear periods of volatility. Examples of this include Q2 2022 and the 'cliff' of investment beginning in Q3 2023. While the latter is connected to current budget cycles it does highlight the difficulty in market planning around 'certain' investment.

Another critical takeaway from the analysis was that the resource requirements in each infrastructure 'stage' – planning, engineering, construction, and through to operations and maintenance – are notably different. For instance, there are near-zero materials requirements in planning, engineering, operations and maintenance. The vast bulk of materials are consumed during construction phases. Such insight only amplifies the intensity of resources requirements.

Infrastructure needs a considerable volume of plant, labour, equipment and material

The focus of the section is to quantify demand for critical resources in future infrastructure investment. Through a robust peer reviewed methodology, Infrastructure Australia has translated project investment into more than 70 different resource demands across four broad categories: plant, labour, equipment and materials (PLEM).

Figure 14: Material and labour are the largest consumer of infrastructure investment



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As seen in Figure 14 labour and materials are the biggest consumers of investment as they account for approximately 60% and 30%, respectively, of every dollar. Investment in labour alone ranges from $91 - $151 billion, or 173,000 to 290,000 individuals each year on a full-time basis. The magnitude of investment in materials is similarly large at $45 - $75 billion representing between 190 and 320 million tonnes.

The transport sector is the biggest consumer of materials. Although the sector represents 75% of total spend it accounts for 92% of all materials consumed. High material consumption rates drive proportionately bigger demands for resources, such as rail track, asphalt and crushed rock. While this is discussed in greater detail in

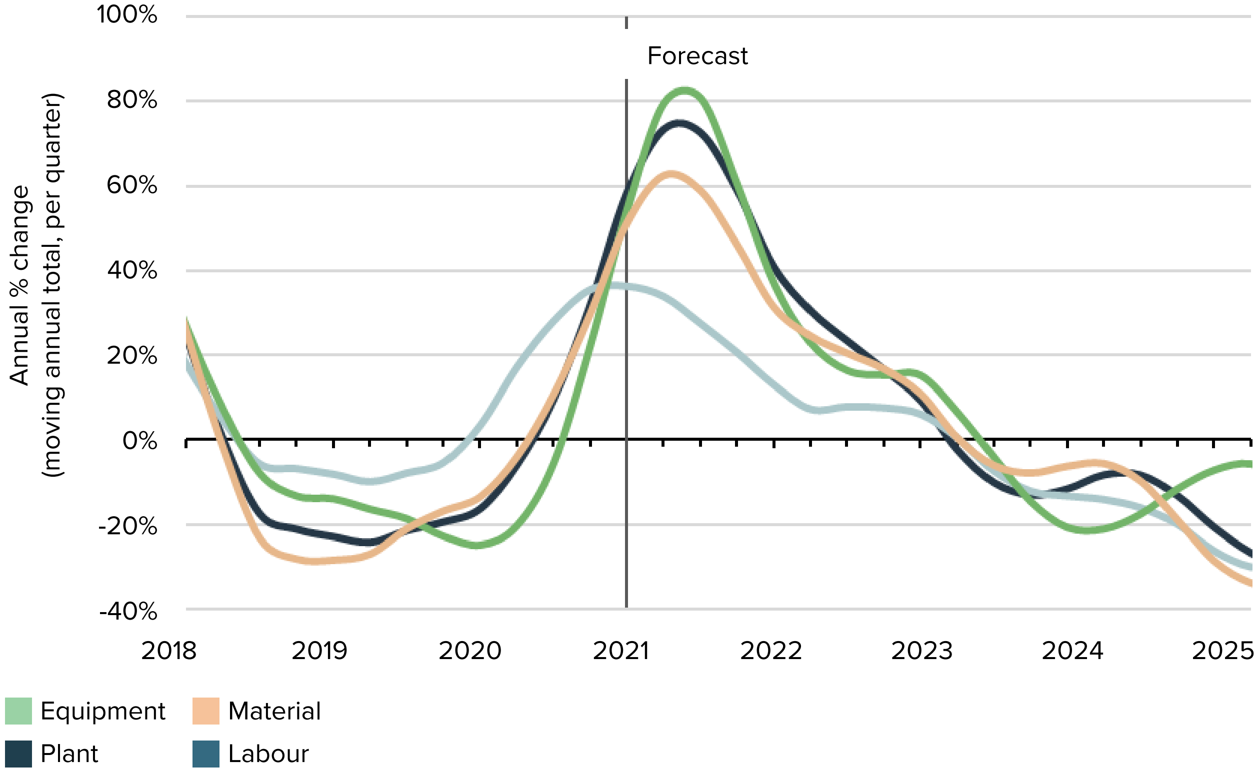
Resource demand trends and outlook by sector, below, it is critical to highlight that government is often the only buyer of these materials. As such, these materials are supplied to only one market: public infrastructure.

This represents a risk as there is no spare capacity that can be diverted from other markets.

Infrastructure resource demands are volatile

Analysis has highlighted that infrastructure investment is volatile. It becomes more volatile when isolating a specific sector and location. Drilling down further it becomes increasingly volatile when resource requirements are considered.

Figure 15: Volatility is most pronounced in infrastructure equipment, material, and plant



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 15 highlights the volatility across plant, labour, equipment and material. Volatility is most pronounced in specific resources, such as equipment, plant and material. Peaks in volatility are reached in 2022-2023 with increases of specific resources 80% year on year.

Of greatest risk is material. Investment in materials not only represent a large proportion of total investment (approximately 30%) but they are characterised by a high degree of volatility. Volatility and magnitude combine to create a large risk as the supply-chain depth of infrastructure materials is relatively long. For example, releasing more supply of crushed rock requires planning approvals for quarries to be approved decades ahead of when materials are in demand. Similarly, quarries must have the appropriate licenses, labour, and blasting equipment available – all subject to considerable investment and timelines in their own right.

Figure 15 highlights proportionately lower volatility in labour. This should not detract from greater consideration as the supply-side of labour is particularly complicated and difficult to influence. For example, a 40% increase in labour demand represents approximately 40% more individuals. Sourcing such an increase in labour in such a short period of time is difficult and not without trade-off. Long-term, such trends are unsustainable.

Resource demand trends and outlook by sector

The Pipeline is dominated by transport (mainly road and rail) projects, which represent 74% of the total investment over the next five years. Therefore, the resource demands for these projects tend to drive the majority of PLEM demands. Within transport, tunnel projects represent a smaller share of the Pipeline than non-tunnel works but are more intensive in their use of steel and equipment.

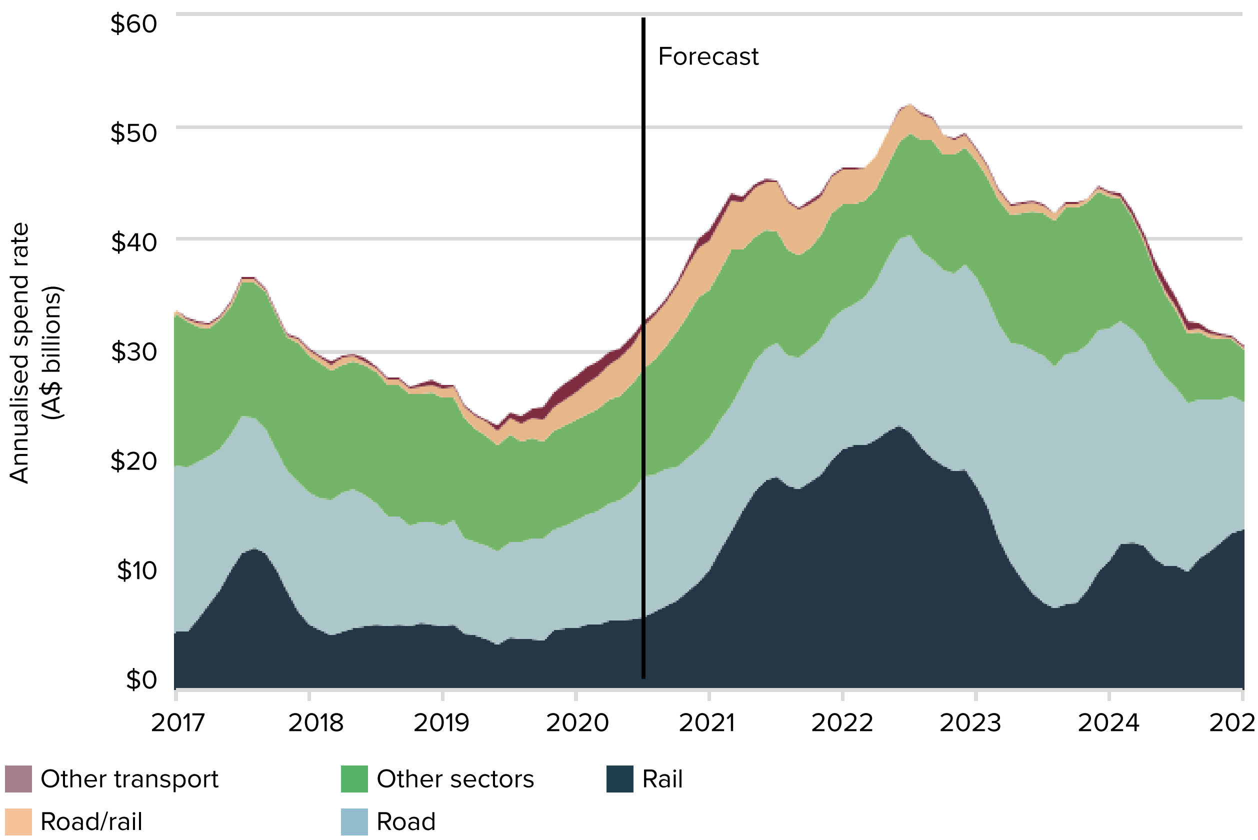
Transport projects overall tend to be relatively more intense in their use of labour and plant resources compared to utilities and building projects. Combined with the high level of transport activity in the Pipeline, this sector counts for 78% and 80% of total Pipeline demand respectively for these resources. Major road projects alone account for 41% of total labour demand among all Pipeline sectors over the next five years.

Demand for plant, labour, equipment and material is different for each sub-sector. Overviews of transport, utilities and buildings are provided below.

Transport sector resource demands

The transport sector is the principal recipient of infrastructure expenditure over the next five years. Major public transport project activity over the next five years is approximately $161 billion, peaking at $41 billion in 2022-2023. High spend rates in the transport sector is expected to drive strong demand growth for resources, particularly in materials.

Figure 16: The two major subsectors within transport (road and rail) account for around 75% of total Major Public Infrastructure Pipeline resource demand

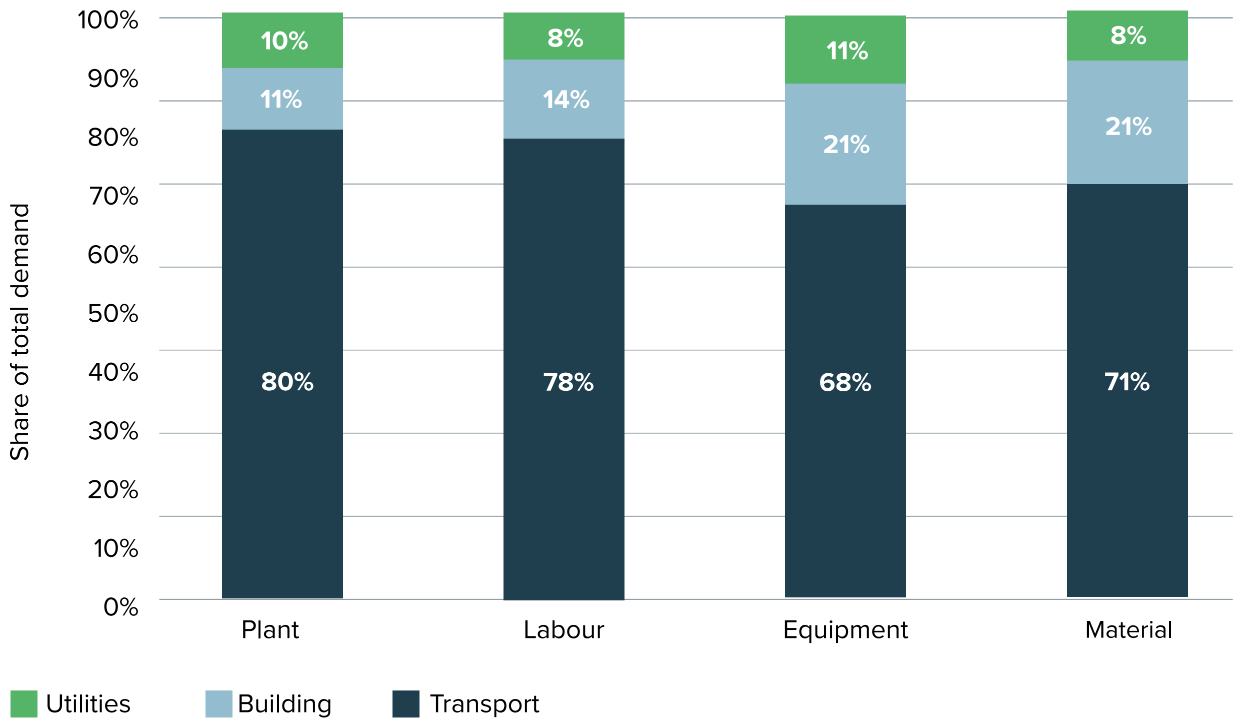


Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

At its peak in 2022-2023 the transport sector will consume over 80% of all resource demands. The vast majority of this activity and resource demand will be focussed on rail and road as shown in Figure 16.

State roads (such as highways and freeways) account for around 25% of total resource demand while mainline rail works account for just under 20% of demand over the next five years.

Figure 17: Transport is a major consumer of plant and labour



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021). Period of analysis is 2021-2025.

As seen in Figure 17, each sector draws down on resources differently. Transport, by way of example, draws a higher proportion of resources from the plant and labour resource categories, responsible for approximately 80% of both plant and labour demand over the next five years.

Analysis of transport demand over the next five years by Infrastructure Australia highlights the criticality of understanding supply-side capacity for specific 'at risk' resources. This is particularly critical if suppliers of those resources solely service the public works transport sector. A clear example of this is the supply of crude oils for the production of asphalt and bitumen for road construction where inputs are not sourced from Australia at scale. As such, any disruptions to this supply-chain, including geopolitical or foreign exchange will have a large bearing on cost and supply.

Utilities sector resource demands

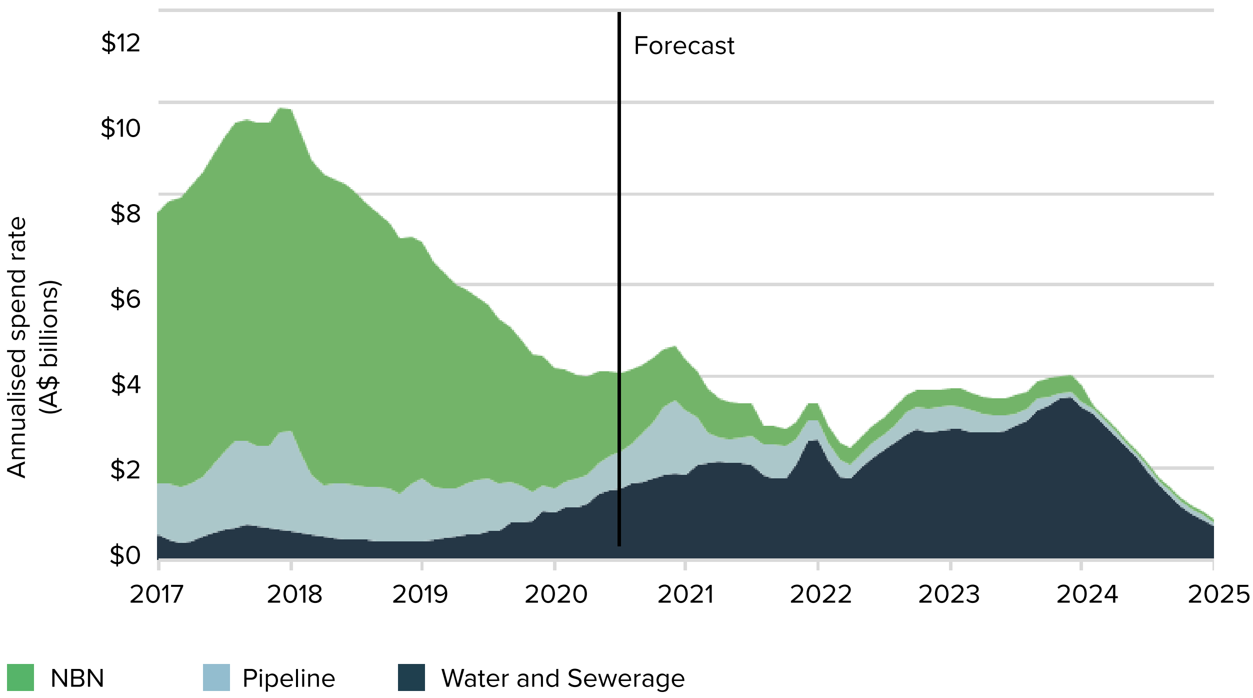
The utilities sector forms the smallest sector within the Major Public Infrastructure Pipeline, and as a result, places the least demand pressures across the input resource categories. Analysis examining resource demands in the energy and fuels sector is based on a different method of analysis. This analysis examines publicly funded projects in this sector above the threshold value.

Over the next five years, major utilities project activity is estimated at $23.3 billion – almost seven times smaller than activity in the transport sector. The disparity between utilities (and building) resource demands and those of the transport sector is highlighted in Figure 17. Overall, utilities accounts for only a small proportion (between 8% to 11%, depending on the resource) of overall Major Public Infrastructure Pipeline resource demands in the next five years.

The utilities sector further differs from the other sectors in terms of its expenditure profile over time. Transport and building are expected to see significant growth in activity in the near-term, whereas utilities is not expected to undergo growth in Major Public Infrastructure Pipeline activity until 2022-2023. In turn, this drives a relatively delayed resource requirement compared to the transport and building sectors. In any case, the overall impact on input demands is of a much lower order of magnitude due to the smaller size of the sector. Overall, the sector demands only around 8% of total PLEM resources over the next five years, which increases marginally to 9% in the peak year of utilities activity (2023-2024).

Resource demands from the utilities sector are relatively plant and equipment intensive, accounting for 10% and 11% respectively of total resource demands over the next five years (seen in Figure 17). Although falling NBN rollout work is driving generally lower levels of activity from the recent peak, forward estimates of utilities activity is being driven by water and sewerage work, as illustrated in Figure 18. Water and sewerage comprises 67% of total resource demand within the utilities sector over the next five years and is a relatively heavy user of plant, accounting for 78% of total plant demand.

Figure 18: Water and sewerage comprises 67% of total resource demand for the utilities sector over the next 5 years and is a relatively heavy user of plant



Building sector resource demands

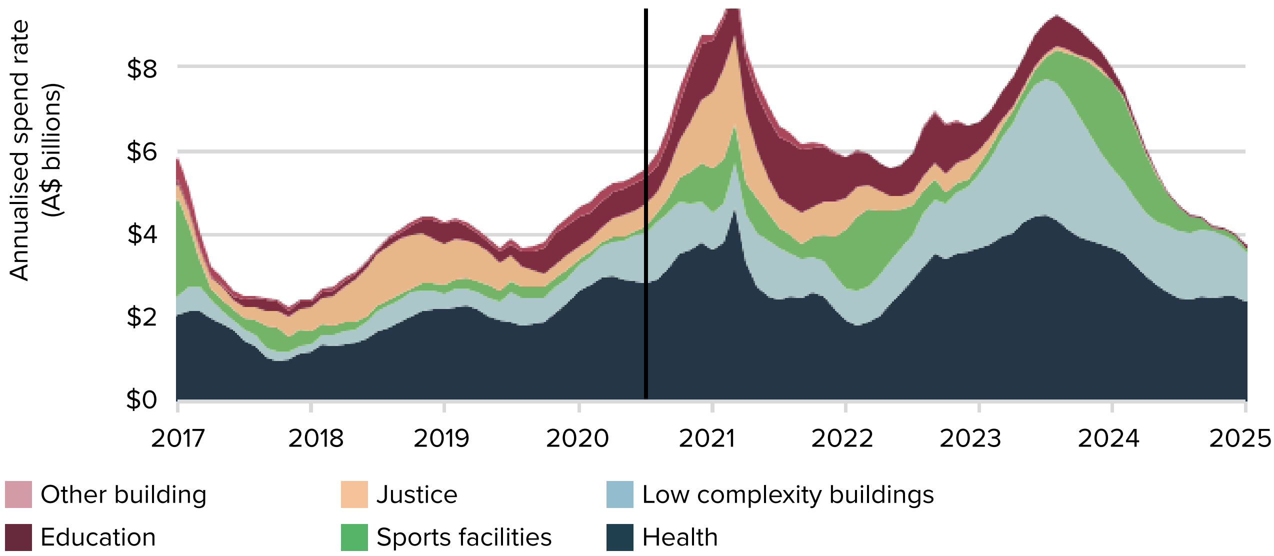
The building sector has the second largest expenditure profile of the three major sectors, but still forms only around 16% of Major Public Infrastructure Pipeline activity over the next five years. Overall, resource demands from the building sector are estimated to range between $24.9 to $41.6 billion over the next five years. Resource demands in the building sector differ from other sectors in two major ways. Firstly, Major Public Infrastructure Pipeline activity rises very quickly in the near term (increasing nearly 60% in 2020-2021).

Secondly, the building sector is substantially more equipment and material intensive than the other sectors. As a result, the building sector has the highest proportion of resource demand focused on the next two years (just over 40%) and, over the next five years, the building sector's share of material demand (around 38%) is larger than the transport or utilities sectors.

The building sector inputs expenditure profile exhibits two spikes in activity over time (as seen in Figure 19). On a monthly basis resource demands are projected to peak in the second half of 2021-2022 but there is a further spike in activity in 2023-2024, which represents the peak in the total annual resource demands. This second wave of demand is brought on by a series of new projects which are expected to commence in the second half of the next five years, the largest of these include Stage 1 of the Western Sydney Airport, and a number of hospital projects.

The largest building subsectors, health and low complexity buildings (the latter including offices, arts facilities and airport buildings), account for the majority of resource demands – including around 67% of material demands and just over 80% of equipment demands. Even so, resource usage among the different building subsectors is the most uniform out of all the sectors. Structural materials such as steel and concrete account for large proportions of project expenditure, while the use of mechanical and electrical equipment is also ubiquitous among each building subsector.

Figure 19: The building sector inputs expenditure profile shows two spikes, the second of which is brought on by a series of new projects including Stage 1 of the Western Sydney Airport.



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Demand trends and outlook by resource type

Labour demands from the Pipeline rise approximately 75% over the next three years. The strongest growth in demand over the next three years is expected for Finishing Trades and Labour (around 140%), Structures and Civil Trades and Labour (around 130%) and Project Management Professional (+65%). Within these segments the strongest demand growth is expected to be for rail track workers (+375%), telecommunications field staff and cablers (190% and 250% respectively), concreters (165%), carpenters and joiners (+160%), electrical line workers (155%) and safety officers (+135%).

Material demands from the Pipeline are expected to rise around 120% over the next three years. Particularly strong growth in demand is anticipated for rock and bluestone (+240%), steel (160%) and concrete (110%). Pipeline demand for rail track, specifically, grows faster than any other material, with demand more than tripling in coming years.

Plant and equipment demands from the Pipeline are expected to rise around 145% and 125% respectively over the next three years

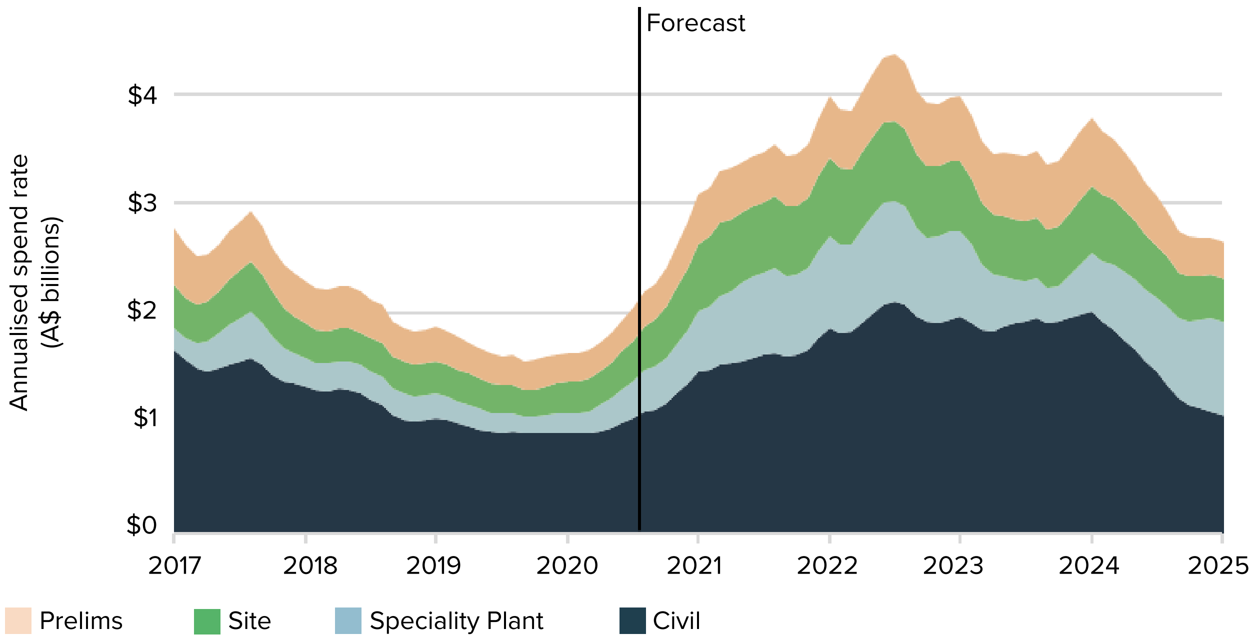
From a review of resource demands by sector, this section reviews demand for each of the PLEM resources – plant, labour, equipment and materials – across all sectors. Due to the more specialised uses of some of these resources, this analysis captures prominent asymmetries in demand among these detailed resources.

Trends and outlook: Plant demand

In infrastructure, plant refers to heavy machinery and equipment used during construction works. For the purposes of this report plant has been categorised over site, preliminaries (including pre-construction tasks, reports, etc.), civil machinery, and speciality plant.

Civil plant accounts for nearly 50% of total plant demand with remaining plant categories accounting for less than 20%. Further breakdowns among the four categories can be found in Appendix A.

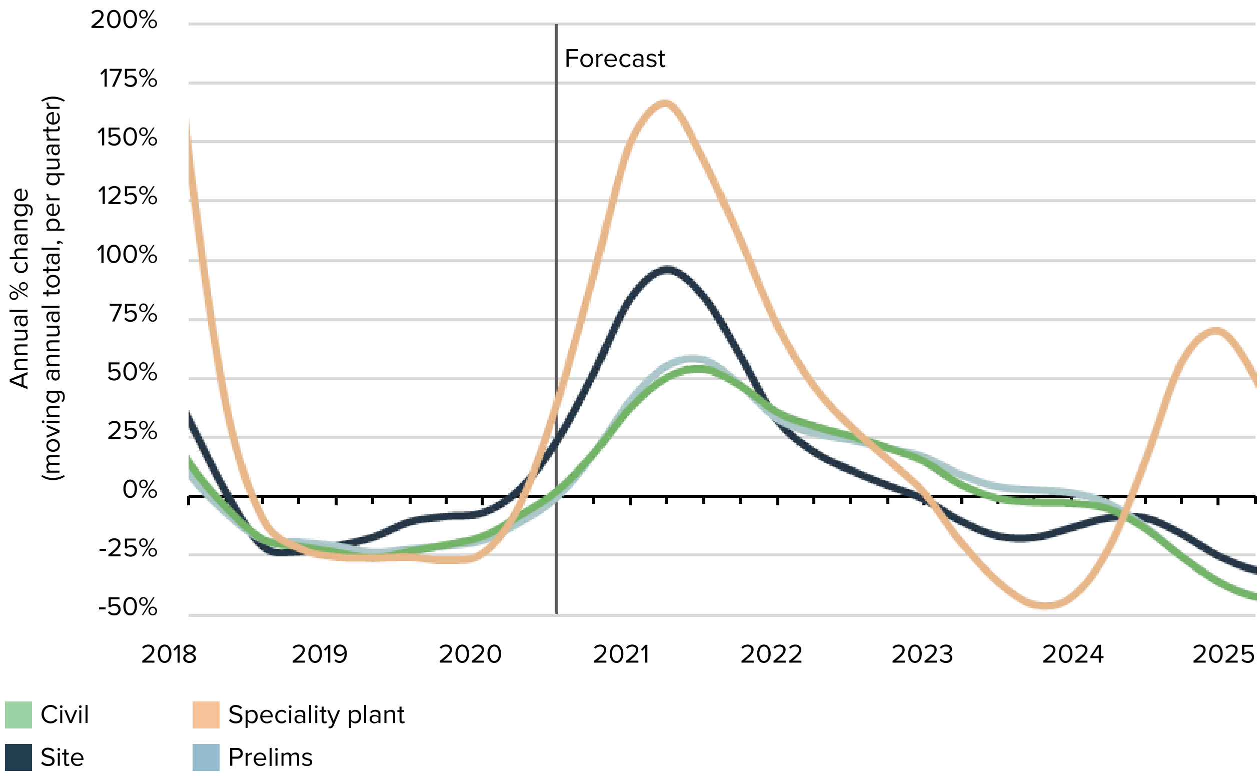
Figure 20: Plant demand is expected to rise strongly



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As illustrated in Figure 20, demand for plant is projected to grow by $12.2 - $20.4 billion over the next five years, with a sharp rise over the next three years.

Figure 21: Specialty plant likely to experience considerable growth in the next three years



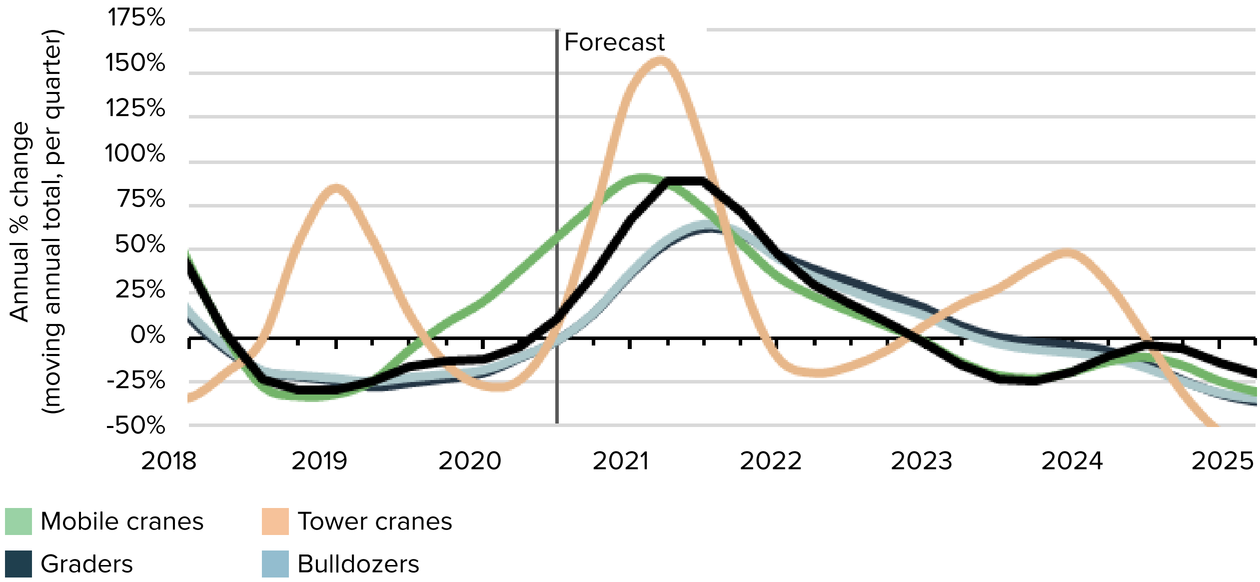
Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As highlighted in Figure 21 increases in plant demand are largely by speciality plant, linked to increasing demands of transport infrastructure. Demand for speciality plant is expected to almost double for two consecutive years in 2020-2021 and again in 2021-2022.

Aggressive growth in specialty plant may pose a risk if unmitigated. Specialty plant, which includes heavy cranes and tunnel boring machines, is often difficult to source and typically controlled and operated by specific organisations and individuals. Unavailability in specialty plant has been a risk in other periods of high demand often resulting in costly outcomes and delays. Examples of this include unavailability of drilling and completions rigs for the coal seam gas activity in Queensland.

There is likely to be less severe volatility and growth in other categories of plant. Demand is still projected to increase by an average of nearly 30% per annum over the next three years, peaking at around 45% growth in 2021-2022.

Figure 22: Cranes are likely to experience considerable growth through to 2022



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Reviewing demands on specific types of plant highlights considerable growth in tower and mobile cranes, bulldozers, and graders. Figure 22 highlights a challenging period of growth in next two years, with particular growth in in mobile cranes and tower cranes which are both projected experience growth of over 70% in 2020-2021. Availability of cranes are often tied to the critical path of any given major infrastructure project – as such, any delays in sourcing this plant is likely to have an effect on project timelines.

Other plant, such as scaffolding and scissor lifts, have relatively softer growth in 2020-2021 but rising to over 70% and 60% respectively in 2021-2022. It should be noted that these resources are shared with other sub-sectors, such as residential and commercial construction and logistics/warehousing. Increased activity in these sectors may have a bearing on availability and cost to public infrastructure projects.

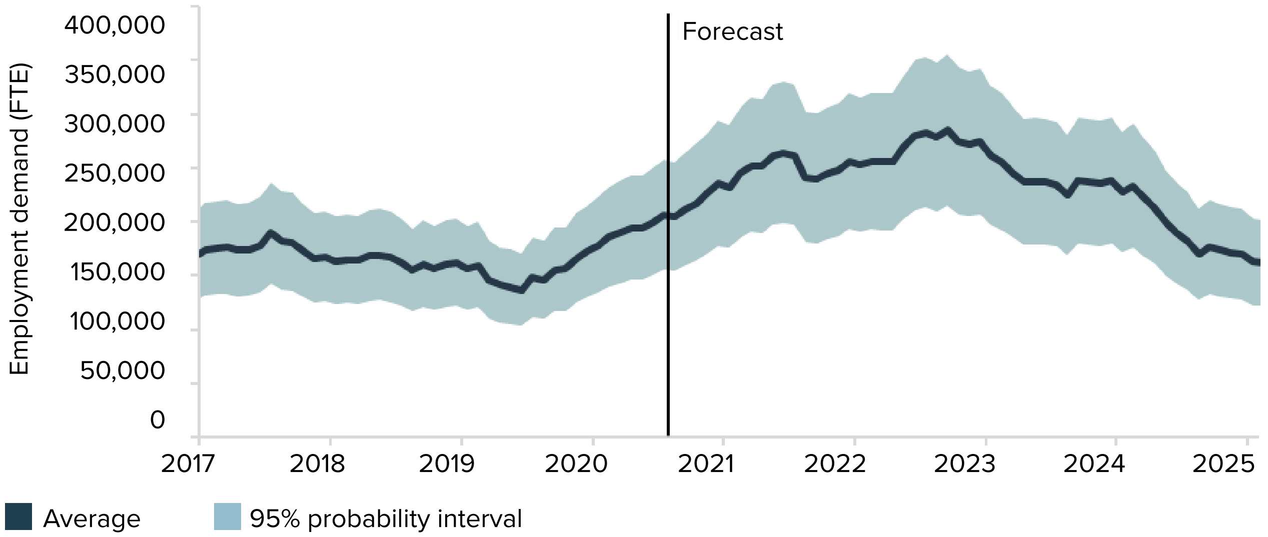
This heightened level of growth in demand for site resources over the next few years is driven by the building sector – site resources comprise almost 35% of total material demands within the sector but only around 20% for utilities and 15% for transport. This disproportionate spending and the short-term spike in building activity (growth of nearly 60% in 2020-2021, the highest among all sectors) is helping to establish current demand pressures on site resources.

Trends and outlook: Labour demand

Labour requirements on major infrastructure projects are sourced through a range of highly specialised occupations with specific skills, experience, and knowledge. For the purposes of this report, labour is categorised into project management professionals, engineers, scientists and architects, finishing trades and labour, and structures and civils trades. These broad occupational categories are further split into a detailed list of occupations and can be found in Appendix A.

Between 2017 and 2025 the cumulative value of labour demand is estimated between $10.8 billion to $37.2 billion. This represents 103,000 to 356,000 roles on an annual full time equivalent (FTE) basis.

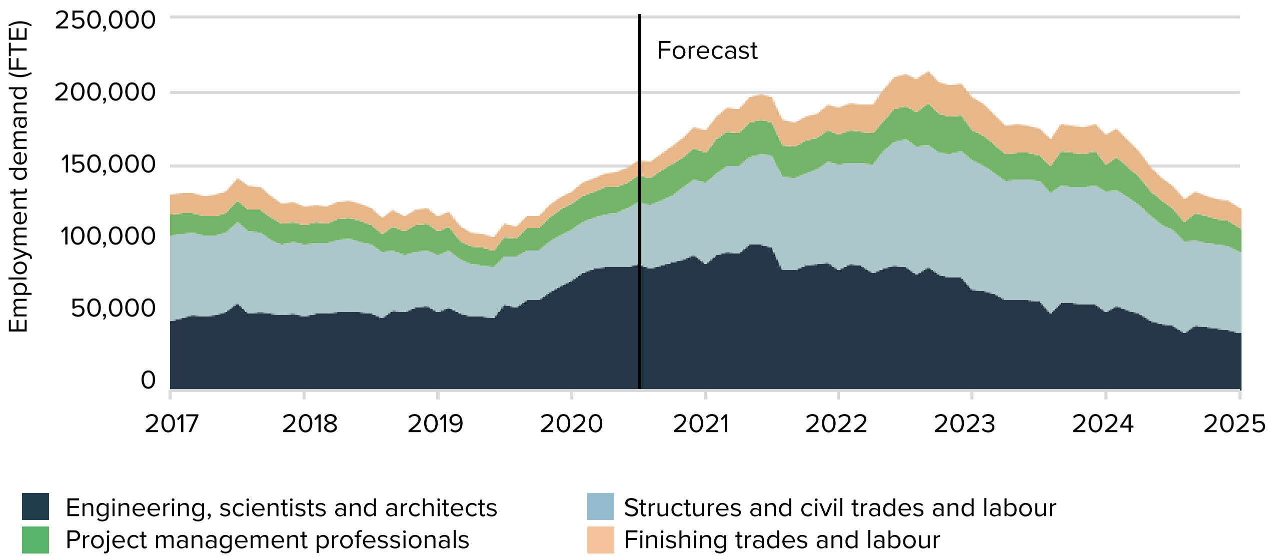
Figure 23: Infrastructure labour demand to increase then plateau at 2022 to 2023



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 23 illustrates the growth profile of labour. In dollar terms at the peak of demand Australian governments will be investing $29.8 billion in 2022-2023. Labour growth is pegged at 20% per year between 2021 and 2023. In this three-year period an additional 39,000 in FTE will need to be sourced to meet demand.

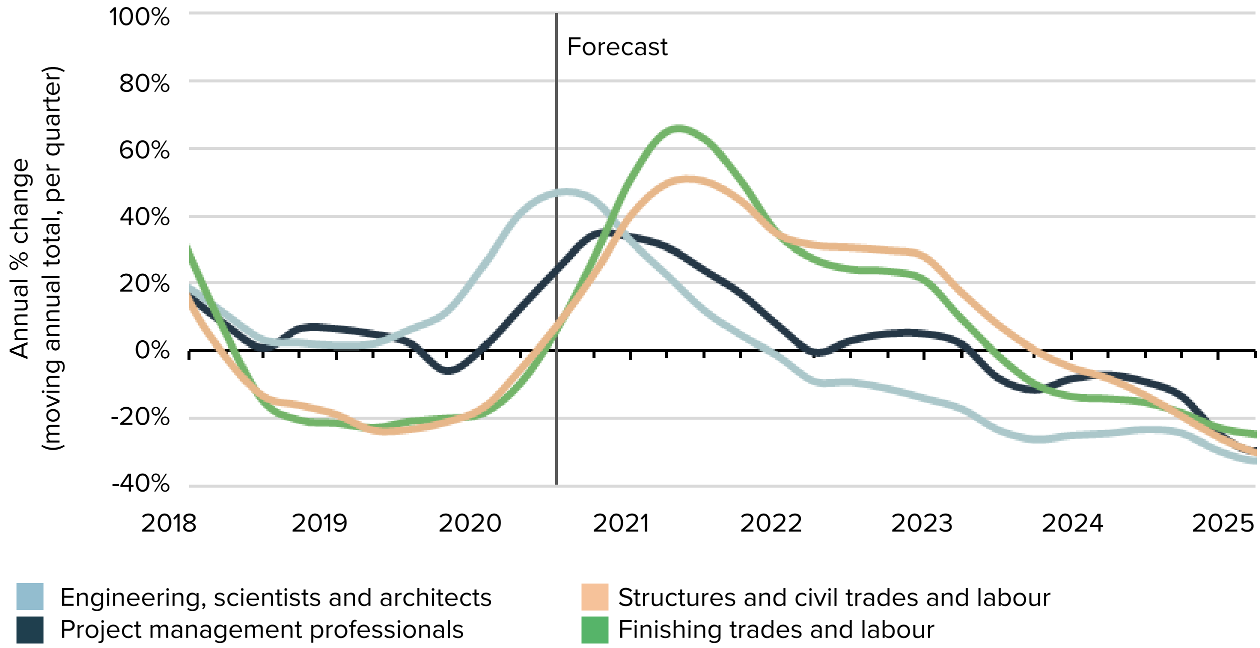
Figure 24: Labour demand is expected to be driven by engineers, scientists, and architects, structures and civils trades, and general labour.



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As seen in Figure 24, wholesale demands for labour will be driven by engineering, science and architecture. Similar demands will be felt in structures and civil trades, and labour. In the next five years these two categories represent 39% and 37% respectively of all infrastructure labour demand. An average of approximately 180,000 FTE will be required in these two categories per year.

Figure 25: Finishing trades, structures and civil trades, and labour will experience the highest volatility between 2019 and 2022.



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As highlighted in Figure 25, between 2020 to 2022 there will be rapid increases in three major infrastructure labour categories.

The first, finishing trades and labour, is expected to see an average annual growth rate of just under 35% per annum over the next three years. This will peak at 50% in a 2021-2022 representing an additional 7,500 FTE jobs in a single year. The risk for rapid increases in finishing trades and labour is that they're often shared with other sub-sectors, such as commercial and high-rise residential. As such, any rises in activity in these sectors may increase upward pressure on costs.

The second, structures and civil trades and labour, are anticipated to grow at an average annual rate of around 32% per annum over the next three years. This category will peak at around 45% in 2021-2022. An additional 26,000 FTE jobs will need to be found in this year alone. Individuals within the category of structures, civil trades and labour are often uniquely dedicated to the infrastructure sector. As such, there is a risk that these individuals cannot be sourced or diverted from another sub-sector.

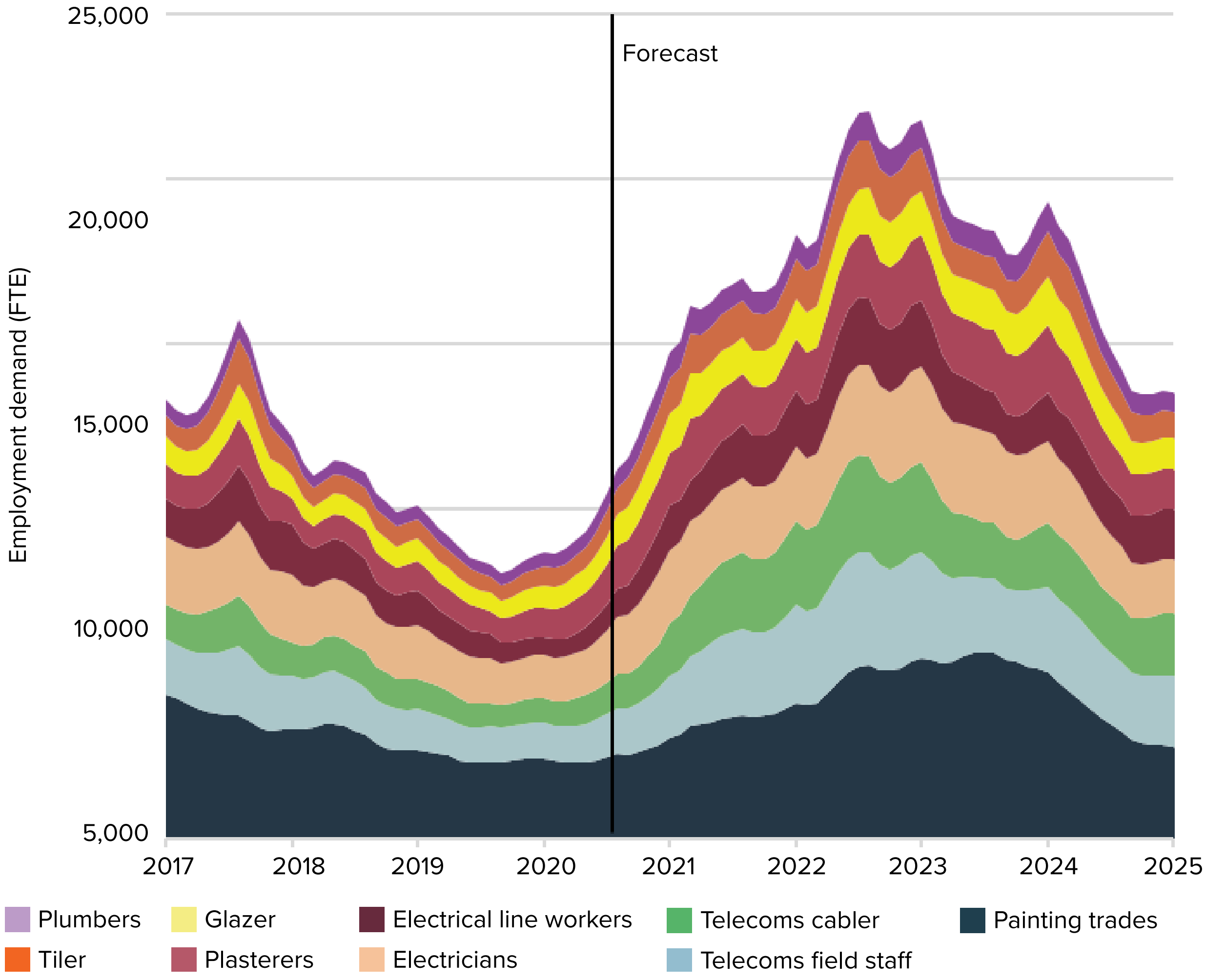
The third, engineering, scientist and architects, are one of the most volatile. In the next two years, this category will call for an additional 20,000 FTE jobs. Sharp rises are followed by a sharp drop in 2022 to 2025. Its estimated that approximately 19,500 FTE jobs will be shed in this period.

Infrastructure Australia cautions conclusions that may be drawn about the manageability of labour demand through peaks and troughs. The risk stems from the fact that labour demand is difficult to source through diversion and upskilling alone. The second reason is that 'troughs' beyond 2022 are likely an artefact of the government budget forecast periods. Newer projects, although they are not captured, are likely to emerge in coming years.

Labour demand should be considered on sectoral basis

Infrastructure labour and occupations are not all the same. Electricians engaged on major hospital developments are typically not the same electricians utilised on rail projects. It is not uncommon for many sub-sectors, for example, road, rail or water, to draw down a unique sub-set of an occupation. As such, labour within an occupation should not be perceived as a 'common pool' from which all government projects can access.

Figure 26: Painters, electricians and telecommunications workers likely to be in high demand over the next 3 years



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Between 2021 to 2023, there are sharp rises across all finishing trades and labour occupations. An additional 12,000 FTE will be required between mid-2020, and peaks in 2023. As seen in Figure 26, painting trades, electricians and electrical line workers account for the bulk of demand.

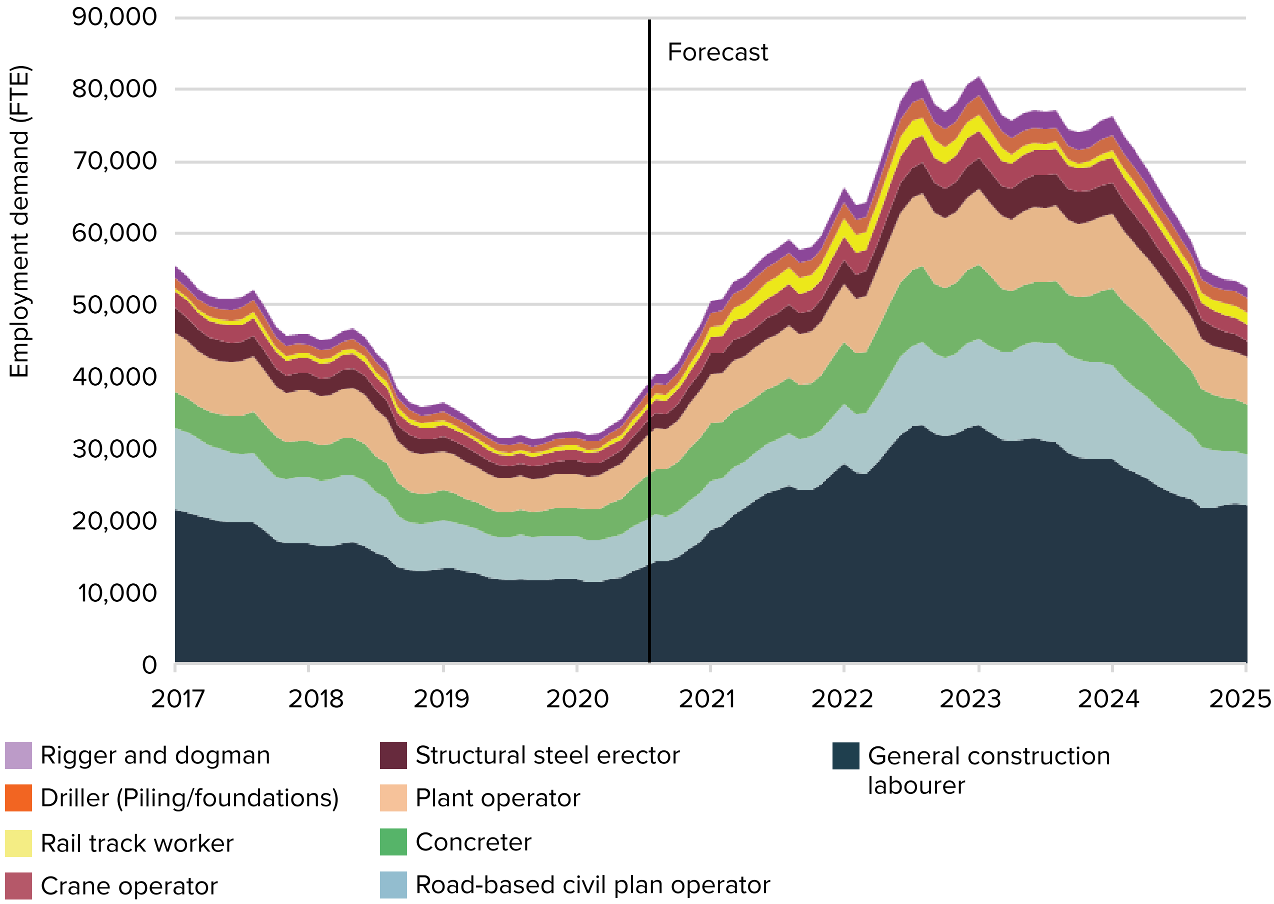
Steep growth figures in finishing trades and labour are largely driven by the need for telecommunications workers. While there is some activity remaining as part of the NBN, there will be considerable demand emanating from the transport sector. It remains to be seen whether telecommunications works are highly transferrable across these two sectors.

Demand for telecommunication cablers is expected to rise by over 100% in 2021-2022. This represents a three-fold increase in growth from previous years. Demand for telecommunications field workers is projected to rise around 85% in 2021-2022, followed by an additional 30% in 2022-2023.

Over the next three years, the transport sector is expected to demand an average of 1,800 more telecommunications trades each year.

Finishing trades and labour more heavily tied to the building sector, such as plumbers, tilers, glazers and plasters, are expected to see a significant spike in demand in 2020-2021. As shown in Figure 27, demand across all of these occupations is pegged to increase by 50% in 2020-2021. An additional 1,600 FTE in these occupations will need to be sourced each year. As mentioned above many of these occupations are not sharable across sub-sectors. For example, there is limited transferability between a plumber that works on single storey residential projects to those that are involved in stormwater drainage scope of major civil projects. As such, the constraints between supply and demand are likely bigger than portrayed and present a risk for deliverability of major projects.

Figure 27: Demand for concreters, bricklayers, carpenters, joiners, and rail track workers likely to be difficult to source



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

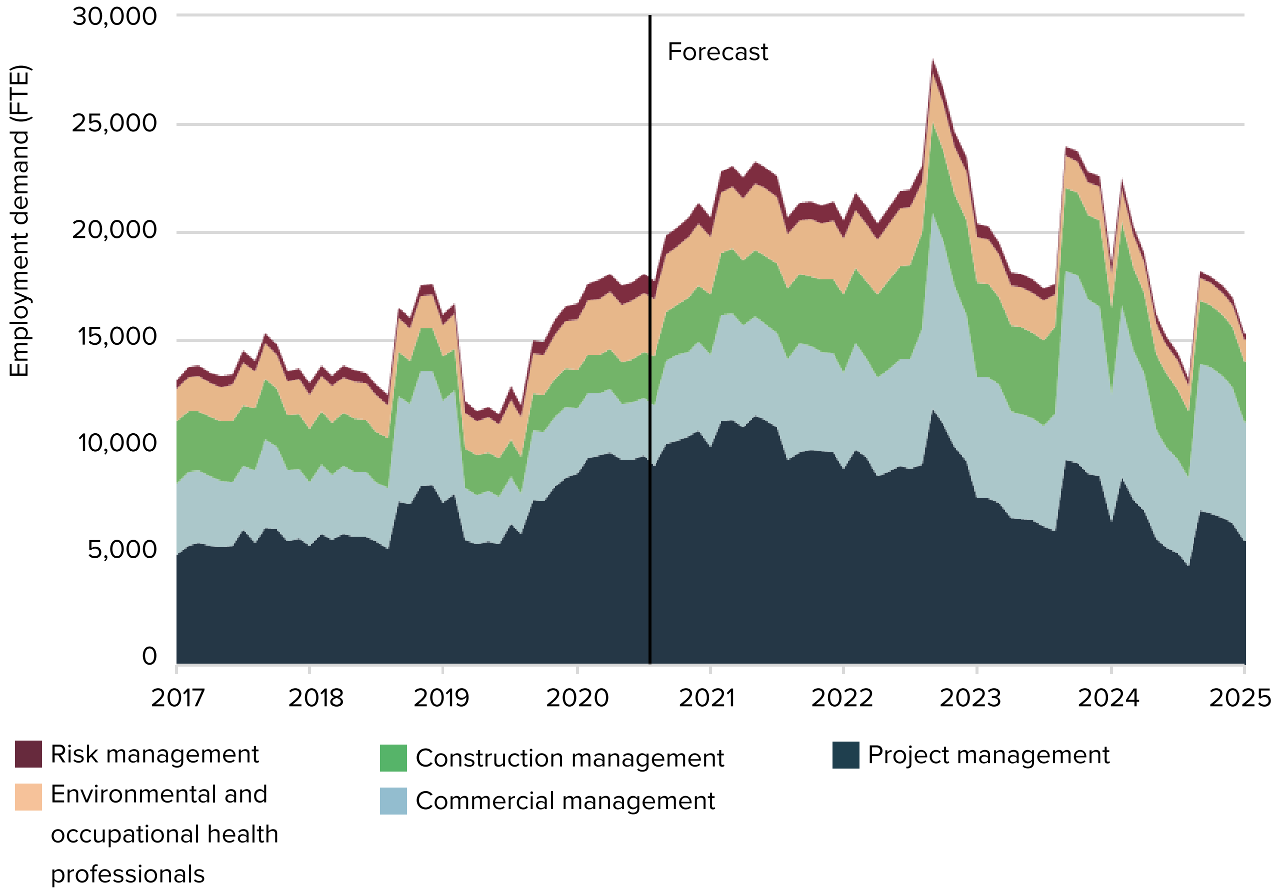
Demand for structures and civil workers is predominately driven by demand in the building and transport sectors. Structures and civils workers that are required on building sector projects are expected to experience large increases in demand in 2020-2021. Occupations with high growth in demand across the building sector include concreters, bricklayers, carpenters and joiners. Demand for these trades is expected to rise more than 50% in 2020-2021 representing an increase of 3,700 in FTE jobs.

Many structures and civil workers are also required in the transport sector. Demand for carpenters, joiners and concreters growing at an average annual rate of nearly 40% per annum over the next three years.

One of the biggest areas of demand is among rail track workers. This is driven by the steep rise in rail activity over the next three years. Demand in rail track workers is expected to peak in 2021-2022. This peak represents a 2.5-fold increase in demand as compared to current activity levels; an additional 1,700 FTE jobs will need to be sourced.

Project management professionals and engineers, scientists and architects are not expected to experience as strong growth in demand as occupations within trades and labour. These occupations do require more formal experience and training. Even small increases in demand are likely to place upward pressures on project costs.

Figure 28: Project managers, program managers, and commercial managers account for around 70% of demand over the next 5 years



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As seen in Figure 28 the demand for project management professionals is largely driven by project managers, program managers, and commercial managers. Together, these occupations account for around 70% of demand over the next five years.

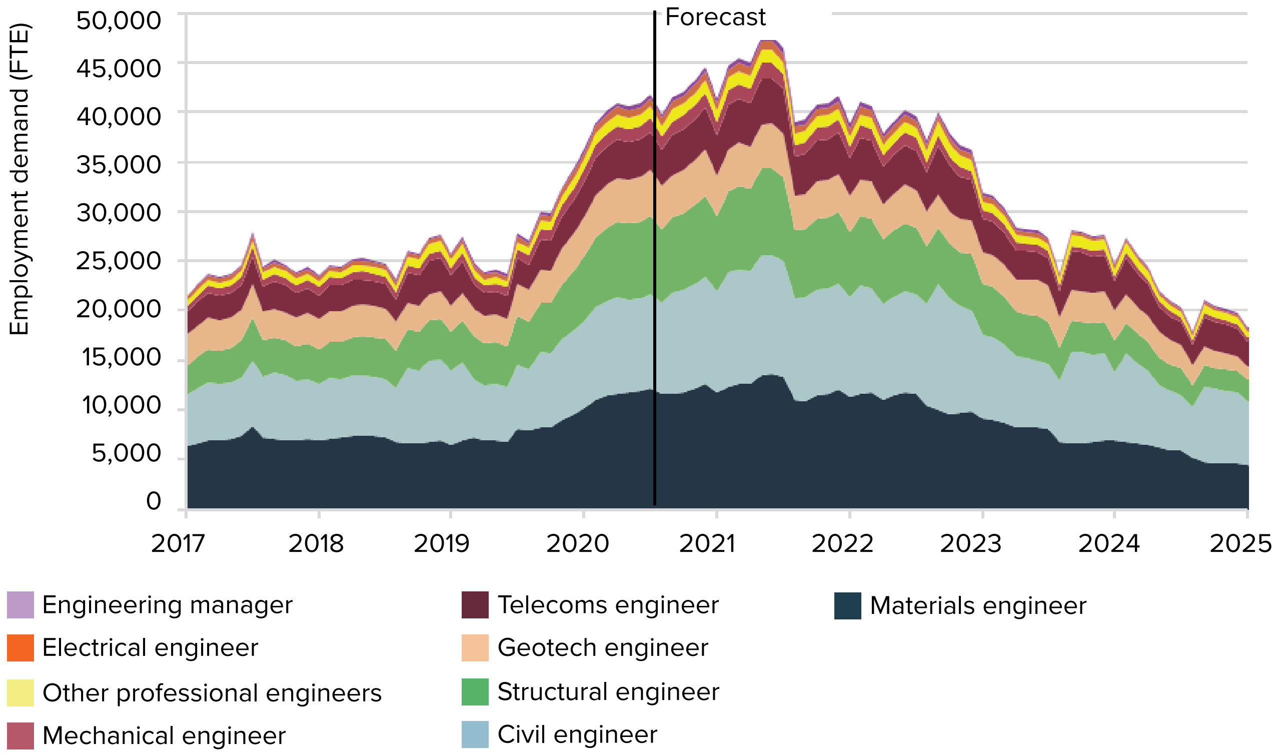
Demand for risk managers is also tipped to rise. Demand for this occupation is projected to grow by over 40% in the current financial year. While this growth is high, it is of low risk as risk managers have a reasonably transferrable skillset. Application of risk management techniques and frameworks, such as ISO 31000, can be applied to most infrastructure sectors. The key opportunity for risk managers in public infrastructure is to begin to systematically capture risks including any mitigating actions.

Project and program managers will also likely experience growth over the next two years. An additional 4,000 FTE jobs will be required. Growth in project management presents as a risk.

If a sufficient number of these resources cannot be sourced it is likely that individuals with less experience or training will likely have to step up. It is difficult to predict the outcomes in this situation, but it is likely less favourable than outcomes under a more sustained growth trajectory.

Rapid growth in the next two years extends to other occupations. Commercial and construction management are each pegged to grow by 35% to 40% each year towards 2022-2023. It is important that government and industry both have access to high-quality commercial skills. This is particularly poignant given the rise in complexity of major infrastructure projects.

Figure 29: Occupational demand profile for engineers



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

As seen in Figure 29 engineering, science and architecture are largest drivers of infrastructure employment. In 2021-2022 the category accounts for approximately 118,000 FTE jobs.

As seen in Figure 29, engineers are in the highest demand. Approximately 57,000 FTE jobs in engineering are required in 2021-2022. Demand for civil engineers is the largest at 30% of total engineering demand. This is closely followed by structural engineers at 20%. As seen in

Skills supply to meet the *Major Public Infrastructure Pipeline*, below, rapid engineering demand is difficult to source. This is largely driven by long training periods and hyper-unique skillsets to particular sub-sectors. A good example of this is electronic or electrical engineers in the context of rail projects often becoming rail signalling engineers. This example demonstrates the hyper-bespoke nature of these engineering disciplines underscoring the importance of long-term workforce planning.

Volatility in skill demand across states and territories

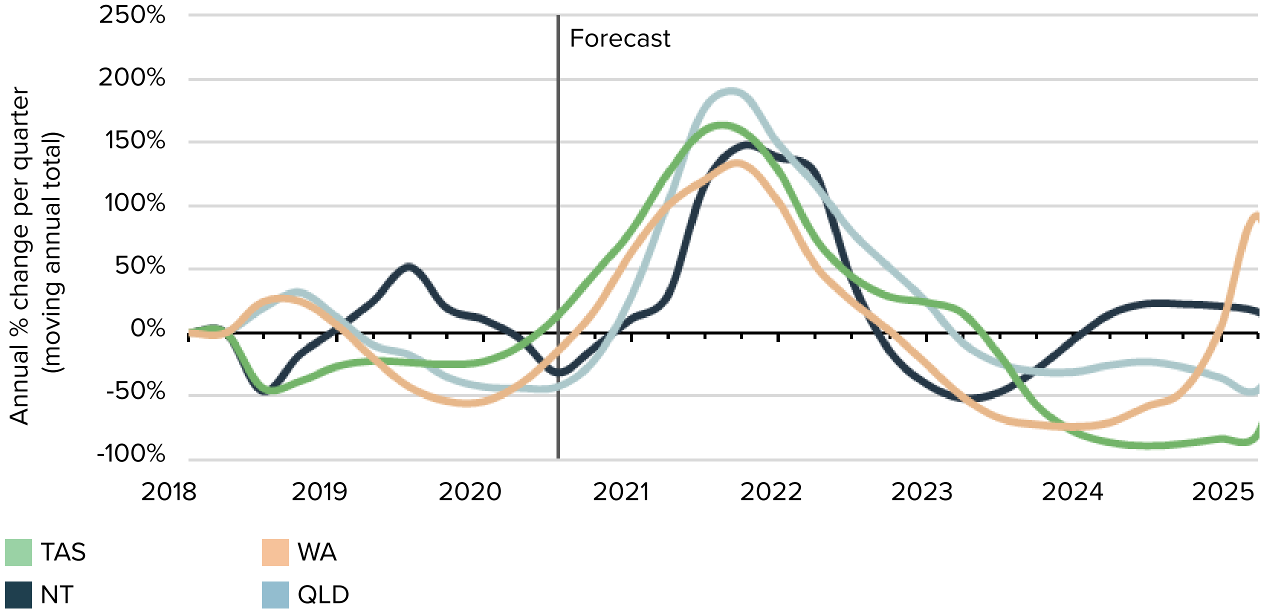
Peaks and troughs of infrastructure skill demand are further exaggerated when reviewing investment in a given state or territory.

The three larger states, New South Wales, Queensland and Victoria, account for more than 85% of all demand for Australia's infrastructure skills. Two out of five individuals employed in the Australian infrastructure sector over the next five years will be required in New South Wales projects.

New South Wales, Queensland, and Victoria consuming the magnitude of infrastructure labour complicates matters for smaller states. This is particularly true as competition for labour will increase in response to increase in activity amongst smaller states. For example, the Australian Capital Territory has made project plans that demand an average of 200% each year for the next three years. Australian Capital Territory will likely compete for resources from Victoria and New South Wales which already have elevated activity levels.

Of specific note is the strong demand for finishing trades and labour in specific states. As illustrated in Figure 30 Northern Territory, Queensland, Tasmania, and Western Australia have all made project commitments that require twice as many FTE jobs through to 2022.

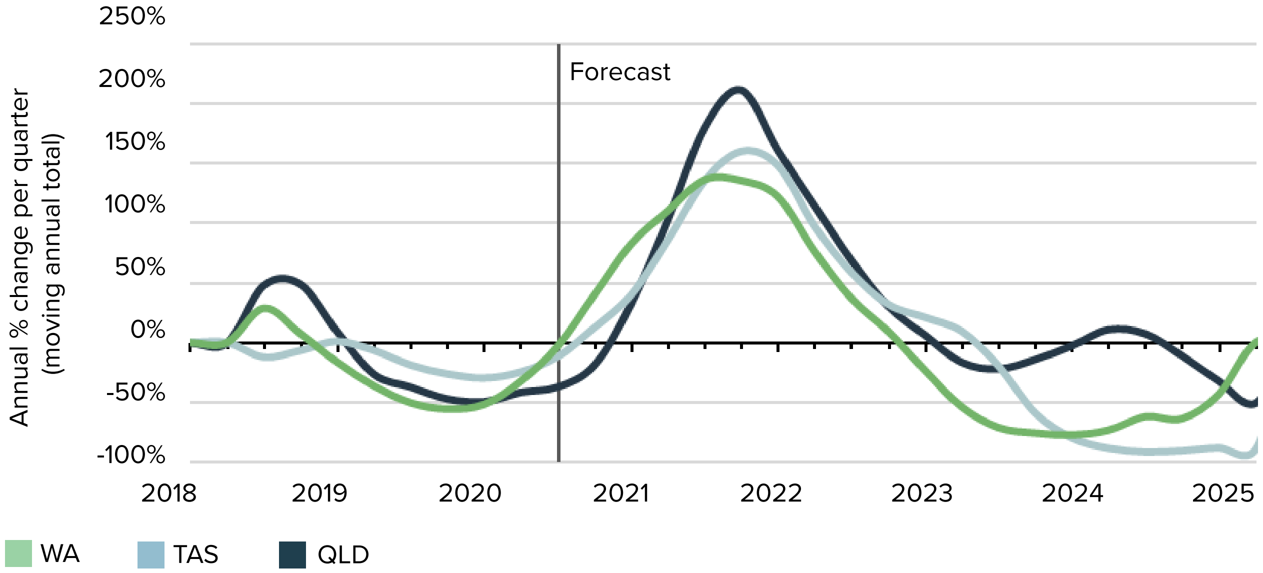
Figure 30: Finishing trades and labour are in high demand in a number of Australian states and territories



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)
Note: A moving annual total has been provided to control for quarterly volatility.

Queensland, Tasmania and Western Australia have made project commitments requiring large supply in structures and civil trades and labour. Figure 31 underscores the magnitude of growth in these states and territories – often upward of 150 percent through to 2022.

Figure 31: Structures and civil trades and labour are in high demand across a number of Australian states and territories



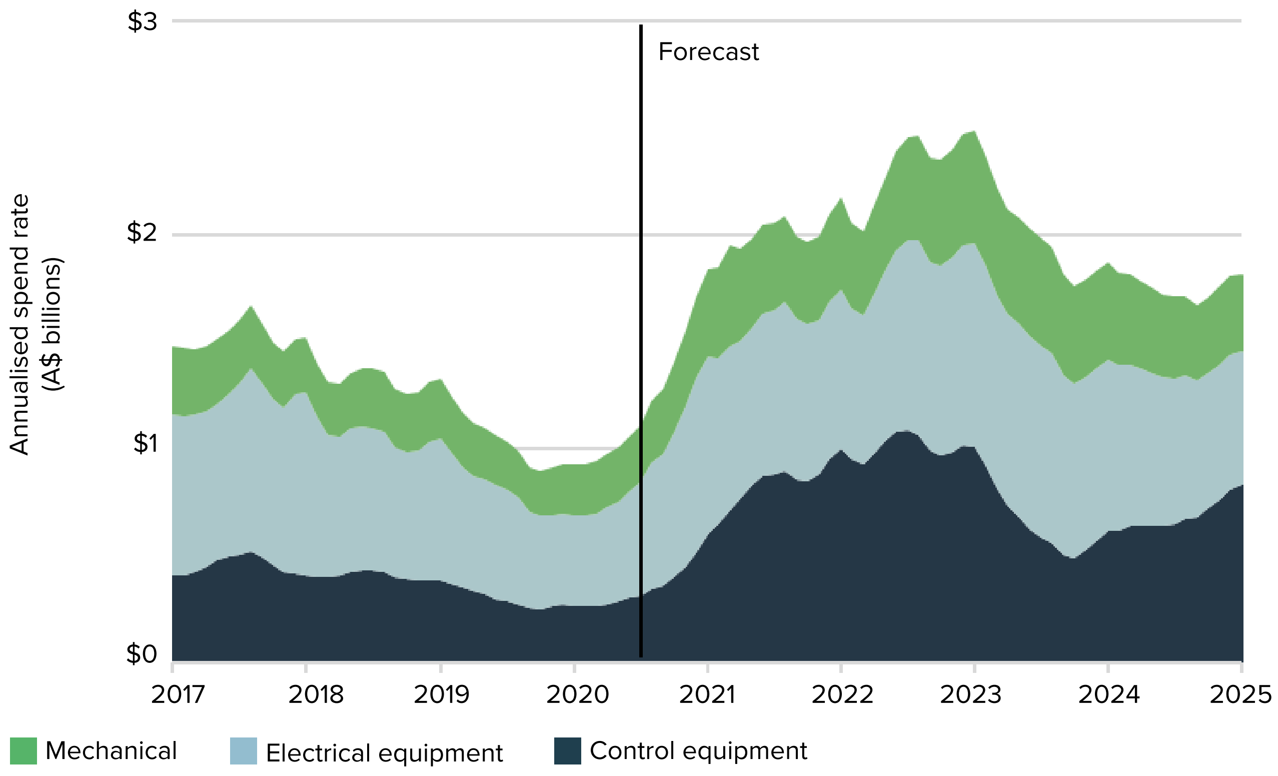
Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)
Note: A moving annual total has been provided to control for quarterly volatility.

Trends and outlook: Equipment demand

In the context of infrastructure projects equipment is often permanent and standalone when installed. This is distinct from materials which are often combined together to make a final product (i.e. steel combined with concrete to make structural columns). For the purposes of this report, equipment includes sub-categories of control, electrical, and mechanical equipment.

Equipment has the smallest profile of demand among the four resource categories. A total value of demand between $7 to $12 billion is planned over the next five years. The majority of capital spent on equipment is dedicated to control and electrical equipment at 38% and 40% respectively.

Figure 32: Equipment demand will build strongly

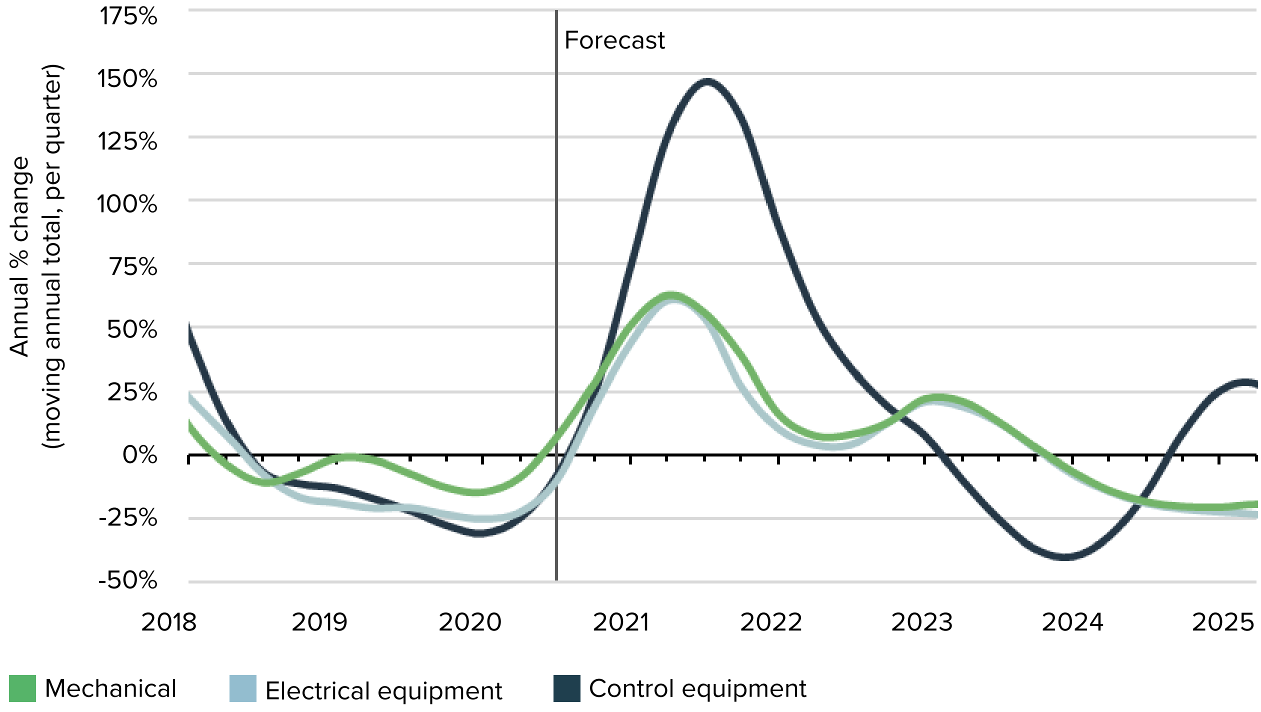


Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Demand for equipment rises strongly over 2020-2021 and 2021-2022 as illustrated in Figure 32. Equipment demand has the highest single year growth among all resources at 60% in 2021-2022. Demand for control equipment will be the greatest of the three reflecting increasing transport project activity. The transport sector accounts for 90% of demand on control equipment – much of this lying within the rail subsector which accounts for 70% of control equipment demand.

Record-breaking levels of Major Public Infrastructure Pipeline rail activity expected over the next five years is propelling substantially inflated growth rates among transport-specific construction resources. As highlighted in Figure 33, demand for control equipment is projected to rise over three consecutive years, with annual growth peaking at over 130% in 2021-2022, before rising again by nearly 20% in 2022-2023. When restricted solely to the transport sector, growth in the demand for control and mechanical equipment is expected to peak at around 170% and 145% respectively in 2021-2022. Particularly strong growth occurs in the rail subsector, where demand is projected to almost triple.

Figure 33: Demand for control equipment is expected to rise to over 130% in 2021-2022



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Trends and outlook: Materials demand

Materials demand considered in this analysis include:

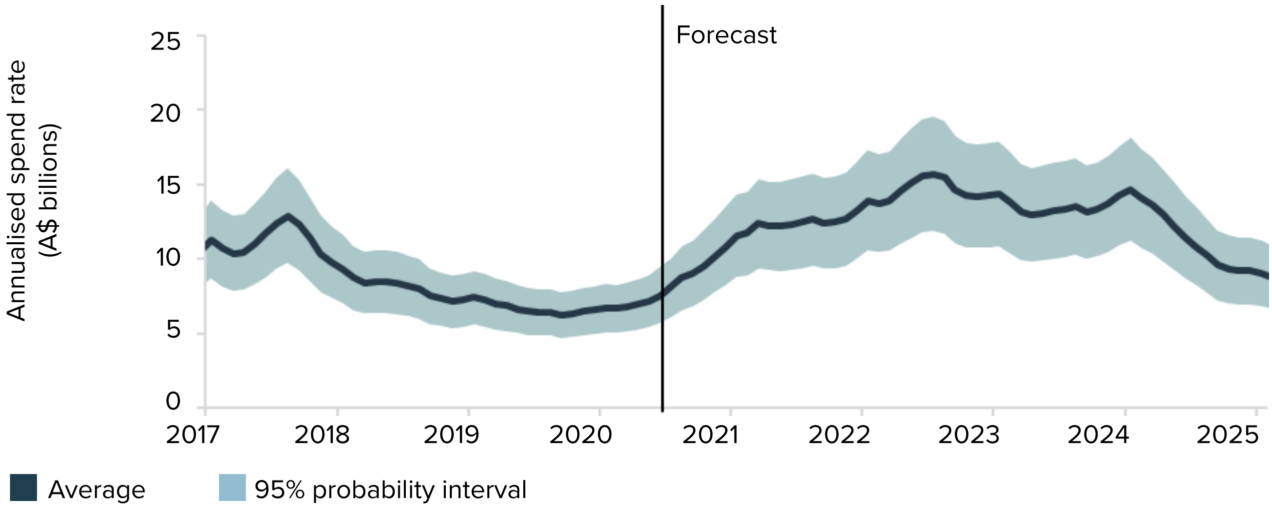
- concrete and quarry products
- steel products
- asphalt
- electrical bulk.

These categories are further subclassified to account for differences in resource types within each group – this includes aggregate, sand, cement and rock/bluestone which comprise the concrete and quarry products grouping, while reinforcing steel, structural steel and rail track comprise the steel products grouping. The full list of breakdowns developed for this report can be found in Appendix A.

In total, materials demand accounts for the second largest proportion of expenditure in the Major Public Infrastructure Pipeline – estimated in the range of $45.3- $75.4 billion over the next five years. This demand estimate represents a range of 190 - 320 million tonnes of material. As illustrated in Figure 34, demand for materials is projected to grow for three consecutive years to a peak in 2022-2023 (representing annual average growth of just over 30% per annum between 2021-2023). The peak year itself represents an estimated expenditure of $11 - $18.3 billion or 50 - 80 million tonnes of material. The largest jump in a single year is in 2021-2022 where materials demand rises by approximately 45%).

Due to the disparities in growth among the sectors, and the unique combination of materials used in each sector, material tonnages grow at a slightly different rate to expenditure demand. Material tonnages are also expected to peak in 2022-2023, but the average growth over the three previous years is equal to around 35% per annum, and the peak growth rate sits just shy of 50% in 2021-2022.

Figure 34: Materials demand ($) showing the 95% probability interval

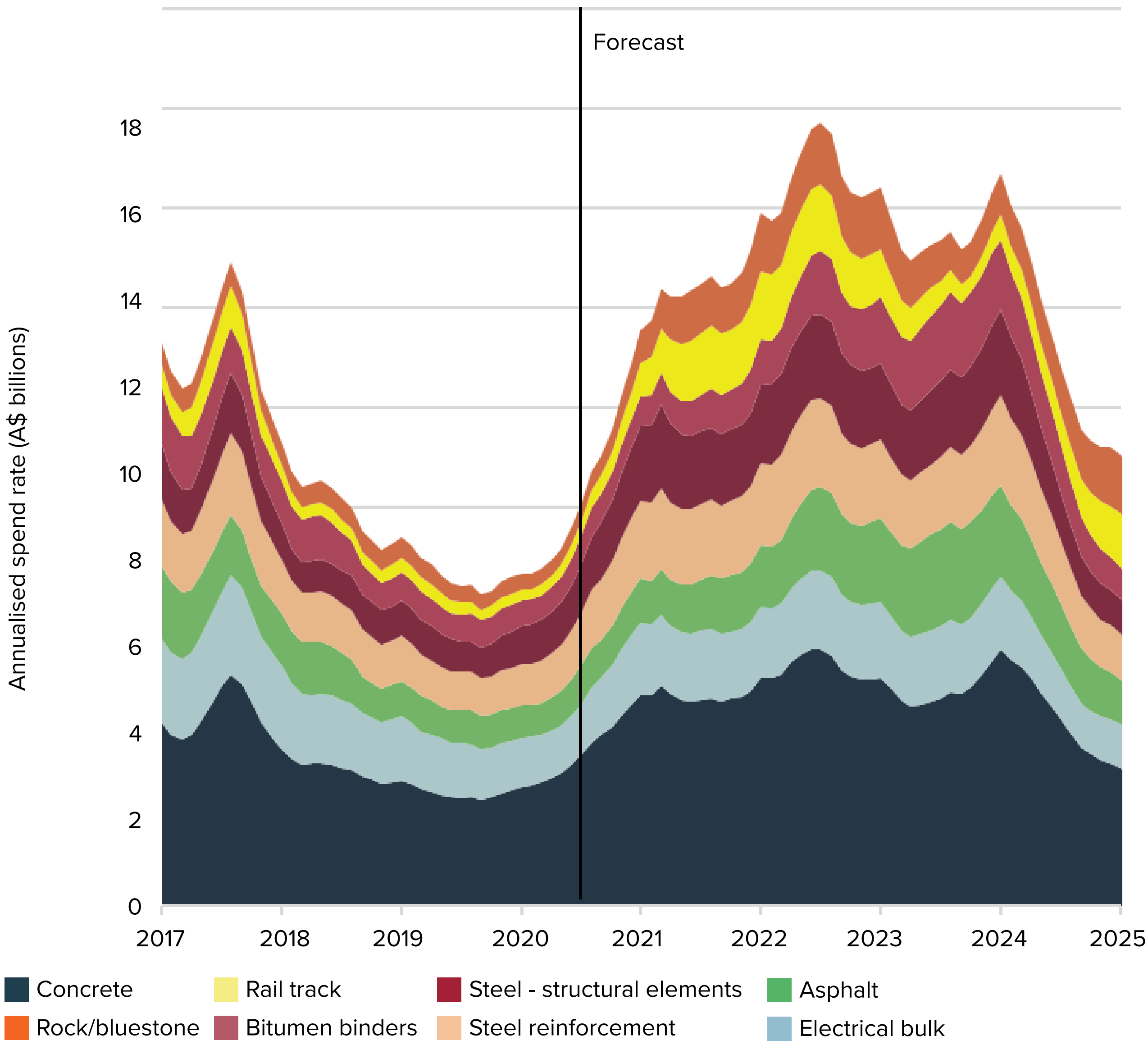


Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Within the materials demand classification, concrete and quarry products, and steel are the two largest sub-categories in expenditure terms. Over the next five years, in expenditure terms, these categories represent around 40% and 30% respectively of the overall material demands, which corresponds to approximately 230 million tonnes over both categories. Concrete and quarry products represent the majority of demand by volume, accounting for almost 85% of the total material demand category. The second largest materials category in volume terms is asphalt, accounting for around 11% of the total, while steel only comprises a mere 3% of total demand in volume terms.

This disparity is highlighted by the demand profiles in Figure 35.

Figure 35: Materials demand breakdown



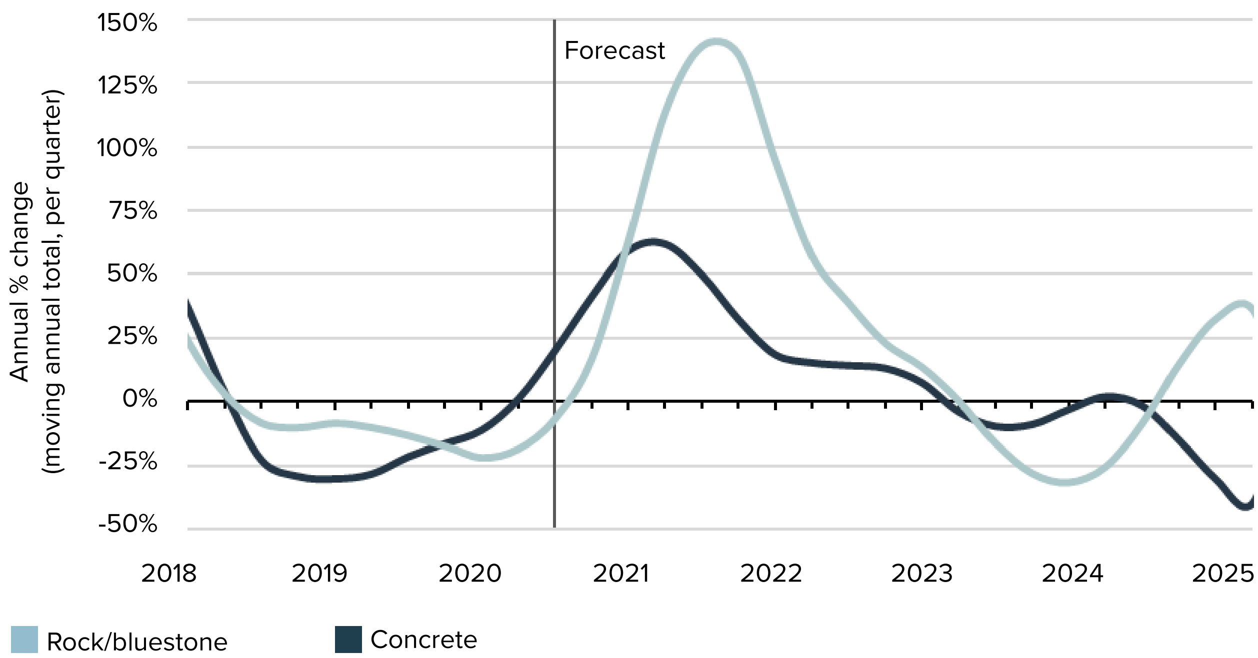
Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Concrete growth overshadowed by fast rise in quarry products demand

Within concrete and quarry products, it is demand for rock/bluestone that is expected to grow the fastest in coming years. Concrete and its constituent components (aggregate, sand and cement) are demanded disproportionately by the building and utilities sectors – accounting for around 40% and 45% respectively of material demands in these sectors, compared to around 35% of material demands across all sectors. As such, the sharp rise in building project activity in 2020-2021 is driving strong concrete demand growth in 2020-2021 (representing an approximate 40% rise in expenditure, or around 7-8 million tonnes increase) but growth is relatively slow in later years of the Major Public Infrastructure Pipeline – averaging just under 30% per annum over the next three years.

However, in the case of rock/bluestone – which is heavily tied to the transport sector, particularly the rail subsector which accounts for nearly 65% of all quarry product demand – a significantly inflated rate of growth in demand is projected over the next three years due to the rise in rail project activity. Demand for rock/bluestone is expected to more than double in 2021-2022, as depicted in Figure 36, with an average annual growth rate approaching 60% per annum over the next three years (an average yearly increase of around four million tonnes of material). Strong demand growth for rock/bluestone from the rail sector, particularly, is driving this outcome.

Figure 36: Concrete and quarry products demand growth profile



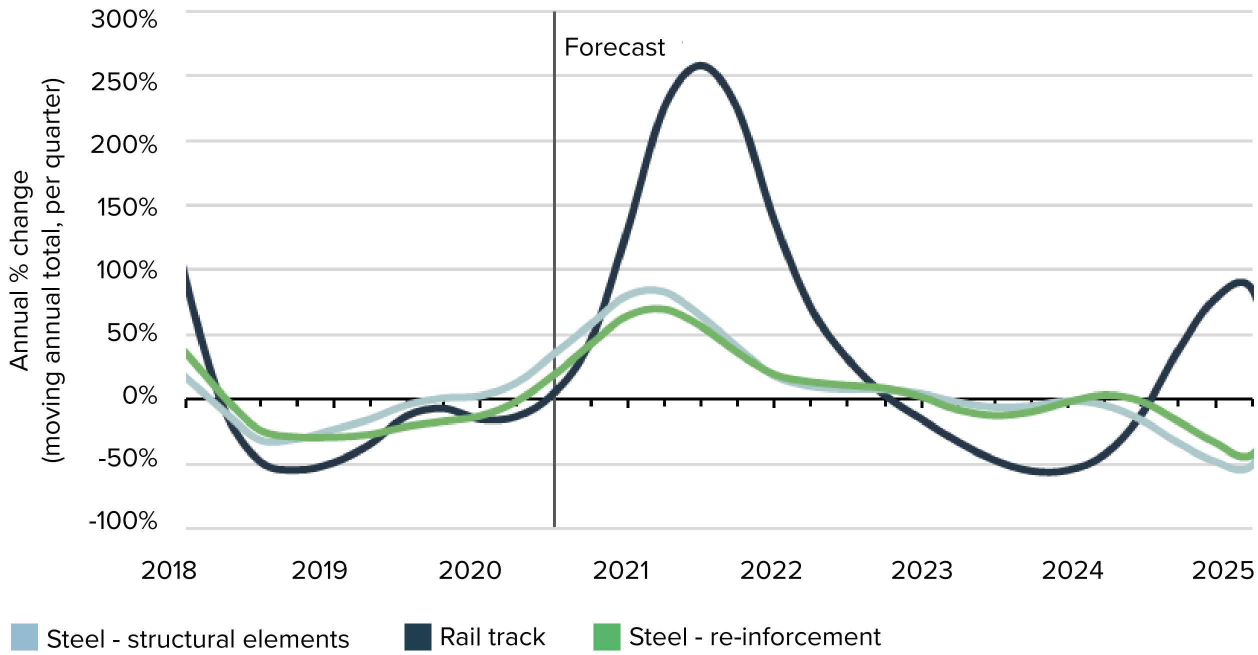
Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Transport projects continue to drive strong growth outcomes for steel products

As with concrete and quarry products, significant growth in transport Major Public Infrastructure Pipeline activity is driving strong growth in steel products demand – and these rates are even higher when considering materials that are specialised to the rail or road industries. Rail track is a key example (see Figure 37). Demand growth over the next three years is the highest among all materials due to its strong links with the fast growing rail sector in the Major Public Infrastructure Pipeline. Rail track demand growth is projected to surge in 2021-2022 and 2022-2023 as activity on a number of rail projects ramps up. Over the next three years, this equates to an increase of more than 300,000 tonnes of rail track steel.

Other steel products (reinforcing and structural) are demanded relatively more heavily in the building sector – accounting for around 40% of material demands in the sector, compared to around 25% of material demands across all sectors of the Major Public Infrastructure Pipeline. As a result, the remaining steel products are projected to see strong growth in demand in the near term (averaging a growth of just under 40% and 50% per annum over the next two years respectively for reinforcement and structural) but not to the same degree as those resources which are more closely tied to transport sectors.

Figure 37: Steel products demand growth profile



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

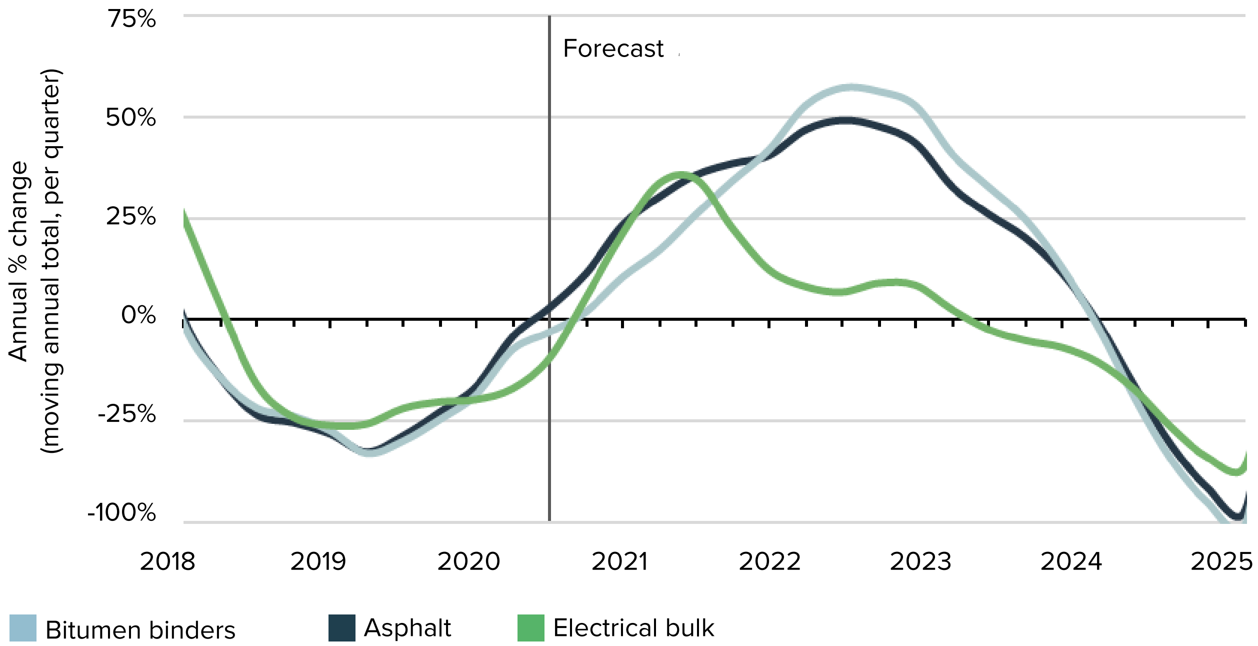
Asphalt demand tracks road activity while electrical bulk is less volatile

Of the remaining materials, asphalt is expected to see a long growth period that lasts over the next four years due to the strength in road project activity. Transport accounts for over 90% of asphalt and bitumen binder demand across the Major Public Infrastructure Pipeline, with road projects alone accounting for around 80% of total asphalt demand over the next five years. Meanwhile, electrical bulk is projected to undergo the slowest growth in demand among all materials, a direct result of its relatively higher usage in the slower growing utilities sector.

Unlike most other resources, asphalt demand is expected to peak in 2023-2024 due to a relatively longer growth phase in road project activity in the Major Public Infrastructure Pipeline. Specifically, asphalt and bitumen binder demand from Major Public Infrastructure Pipeline activity is expected to grow at an average annual rate of just under 30% per annum over the next four years, peaking at a combined $2.5 to $4.1 billion in 2023-2024 (representing an estimated range of 4.7 - 7.8 million tonnes as highlighted in Figure 38).

Electrical bulk is projected to grow the slowest among all material demands over the next five years of Major Public Infrastructure Pipeline activity. The resources usage in the transport sector is pulling up demand, but at a reduced rate, growing at an average annual rate of only 12% per annum over the next three years. Growth is limited by the material's relatively higher usage in the utilities sector which is set to decline over the next three years, mostly due to weaker levels of telecommunications (NBN) activity.

Figure 38: Other material demand growth profiles



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

State/ territory demand for plant, equipment and materials

The eastern states of mainland Australia - New South Wales, Queensland and Victoria - dominate the Pipeline, accounting for 87% of major public project activity over the next five years. Consequently, these three states are responsible for more than 85% of projected PLEM input demands.

The high proportion of megaprojects in these states is another reason why these states dominate the Pipeline and resulting input demands. Of the 81 megaprojects in the Pipeline over the next five years, 73 are located in these states. A greater concentration of work in megaproject activity may, in turn, bring other capacity risks.

New South Wales and Victoria are expected to experience record levels of input demands from the Pipeline over the next three years.

The strongest growth in PLEM demands is expected in Queensland and smaller states and territories such as Tasmania, the Northern Territory and the Australian Capital Territory given a lower base of Pipeline activity in recent years.

Exceptional growth in Pipeline activity in smaller states and territories leads to exceptional growth in input demands. The Australian Capital Territory is projected to average more than 100% growth in Pipeline demands each year for the next five years across all resource categories, with materials rising an extraordinary 215% per annum on average. This is equivalent to a more than 32-fold increase in material demands in five years.

This section provides analysis that describes how plant, equipment and material demands are expected to vary by the different states and territories. Once again, variations in sectoral growth within each state or territory is projected to lead to significant variations in resource demands.

The low base of activity among certain states and territories in previous years of the Major Public Infrastructure Pipeline is driving relatively strong demand growth among particular resources in different regions across the country.

Generally, these stronger growth rates are concentrated on resources which are already projected to undergo significant rises in demand across Australia – but the rapid rise in project activity in some states and territories is imparting a magnifying effect on the projected demand.

The rapid growth in transport Major Public Infrastructure Pipeline activity in some states and territories – particularly the ACT, Queensland and WA – is driving very strong growth outcomes among certain plant, equipment and material resources. The key resources that are tied to road or rail activity – such as speciality plant, asphalt, rail track and rock/bluestone – are all expected to see large increases in demand among these states and territories. Strong growth in road work in WA is driving Major Public Infrastructure Pipeline demand for asphalt up by an average annual rate of nearly 175% over the next two years (and over 180% for bitumen binders). Similarly, very strong growth in Major Public Infrastructure Pipeline rail activity in the ACT produces extraordinary (over 1,000%) growth in steel and site plant demands. However, it is important to note again that these examples of large growth in the smaller states and territories may exaggerate the actual change in expenditure – the rise in steel and site plant demands, for instance, represents an increase in expenditure of around $16 million and $2 million respectively.

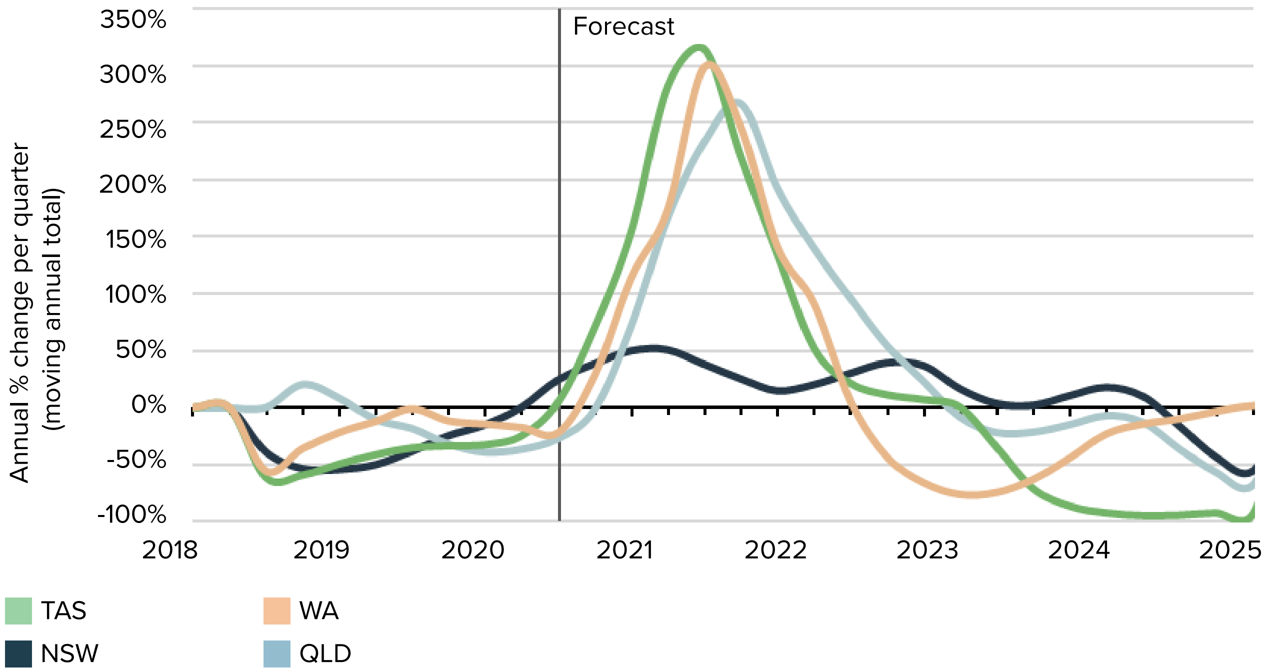
The disparity of resource demand between the states and territories is further illustrated in Table 1, which shows the total demand for key plant, material or equipment resources over the next three years. In the context of absolute demand values of

Table 1, Figure 39 to Figure 42 chart the jurisdictional growth in demand for those key resources. These charts highlight the significant rises in resource demands among different jurisdictions, particularly since the resources charted – rock/bluestone (rail), asphalt (road), control equipment (rail) and steel (rail) – are those that are closely tied to the rapidly growing transport sector. For each Figure, the fastest growing states and territories were plotted (with the exception of outlier states which have at least a 5 to 10 times increase in demand in a single year due to a small base of expenditure). The figures provide annual growth rates of the moving annual total to smooth out quarterly volatility.

Table 1: The total demand over the next three years for select key resources by state and territory

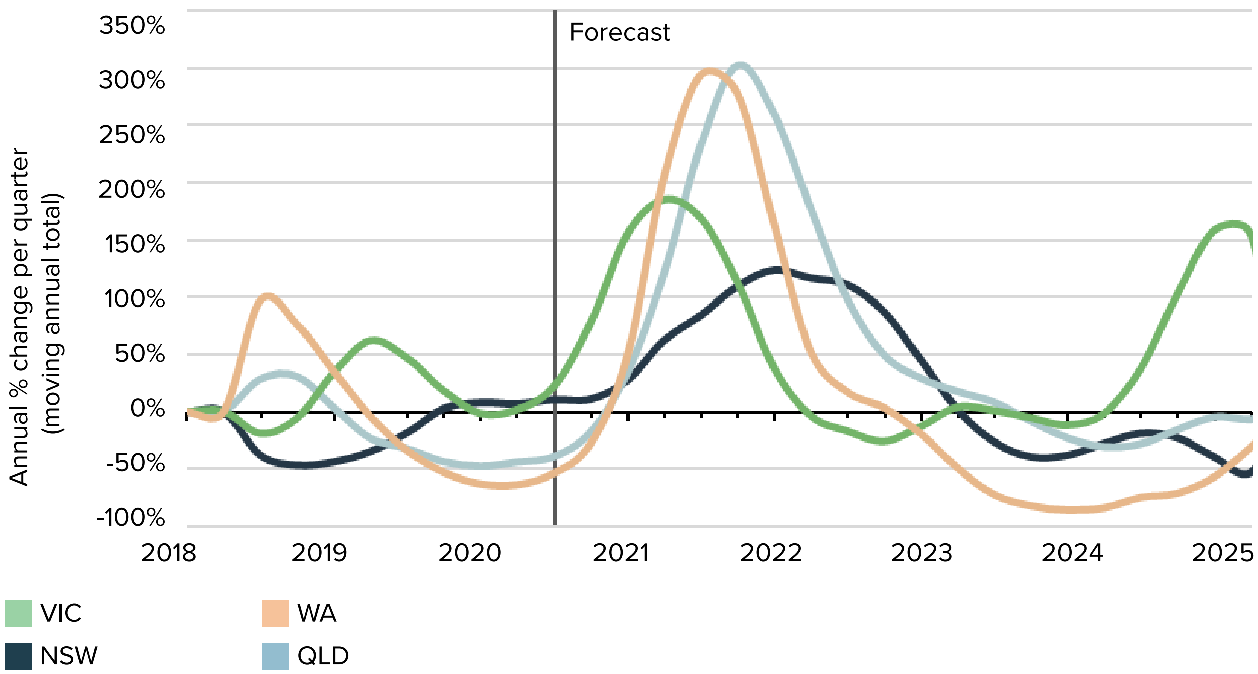
	Steel (tonnes)	Rock/bluestone (tonnes)	Control equipment (AU$)	Asphalt (tonnes)
ACT	56,800	121,200	$5 million	129,200
NSW	1,765,900	12,545,500	$667 million	4,406,400
NT	46,700	127,800	$4 million	169,500
Qld	870,600	4,747,100	$365 million	3,418,800
SA	315,800	701,000	$36 million	749,100
Tas	200,500	689,400	$29 million	547,100
Vic	1,919,500	11,364,400	$935 million	4,165,700
WA	250,600	3,458,200	$178 million	1,627,300
Total 3-year Pipeline	5,426,400	33,754,600	$2,219 million	15,213,100

Figure 39: Growth in steel demand by selected states and territories



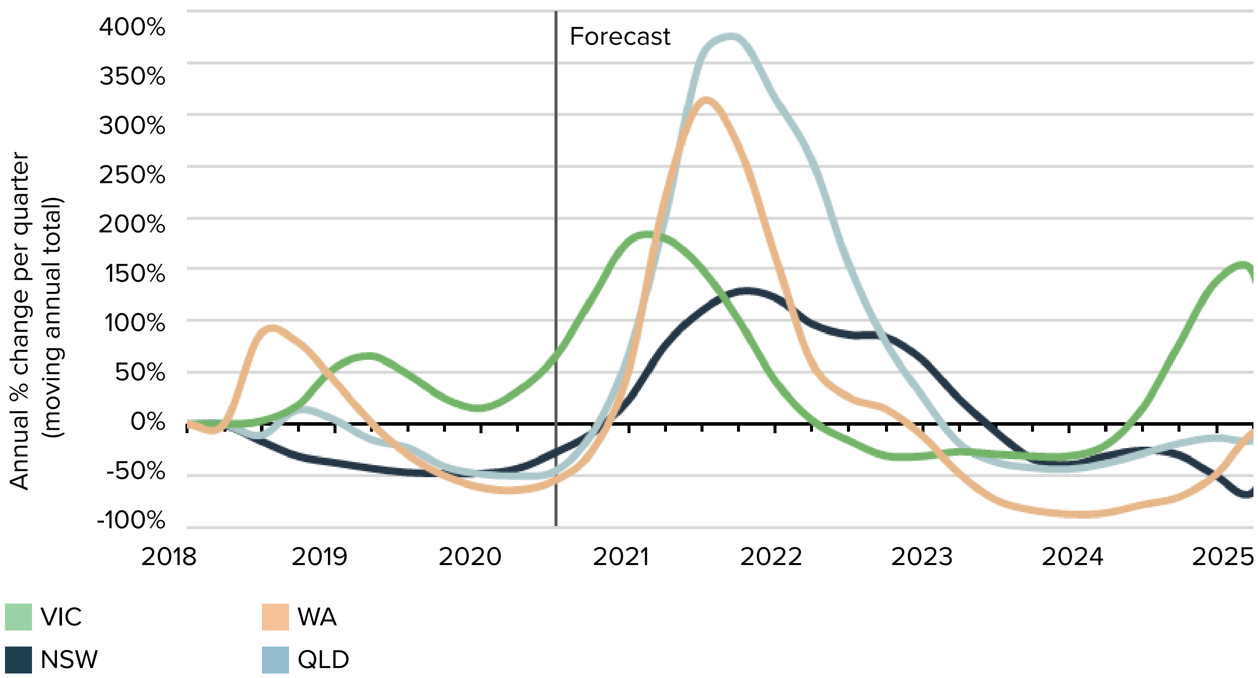
Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 40: Growth in rock/bluestone demand by selected states and territories



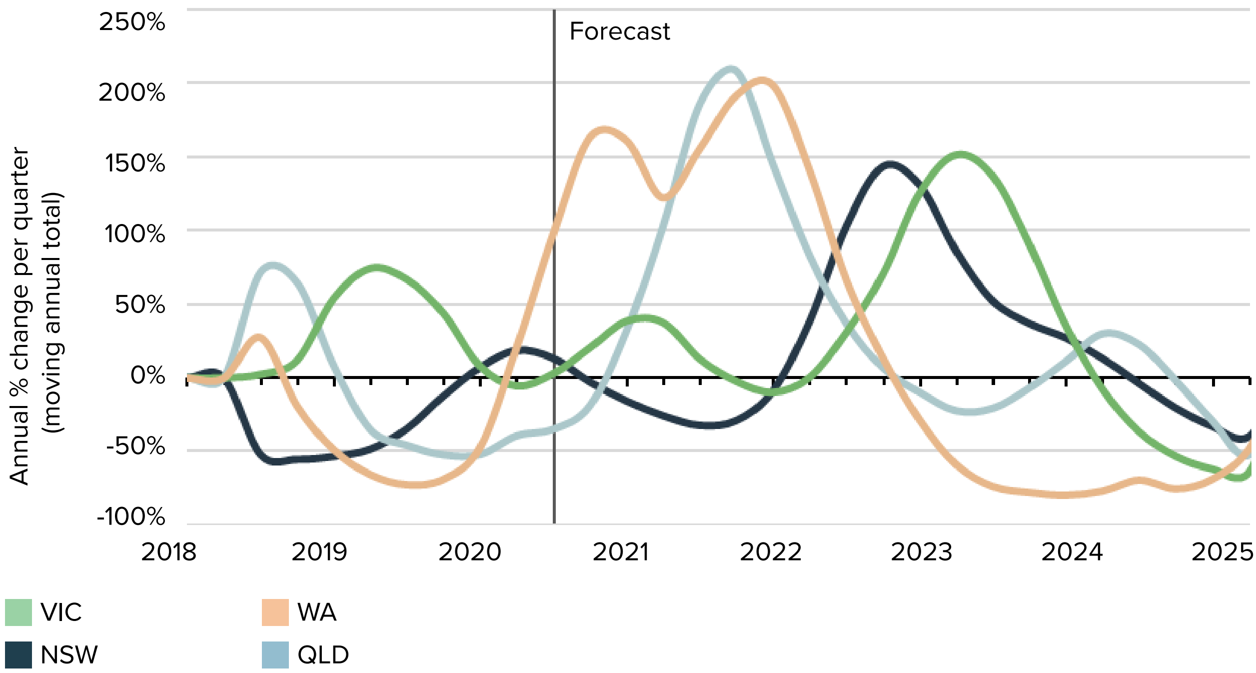
Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 41: Growth in control equipment demand by selected states and territories



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 42: Growth in asphalt demand by selected states and territories



Source: Turner & Townsend and BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Projects in Australia's energy market

Data derived from the Australian Energy Market Operator's 2020 Integrated System Plan (ISP) indicate that under the Step Change scenario, an estimated $66 billion will be invested in large-scale renewable energy generation and storage (mostly in regional areas) and $27 billion in rooftop solar and battery storage. The build-out of electricity generation and transmission infrastructure will create pressures on market capacity to deliver the supply of labour and materials required for a smooth, efficient energy system transition.

A series of Renewable Energy Zones (REZs) in regional areas have been identified by the Australian Energy Market Operator (AEMO) as the best locations for large-scale renewable energy generation and storage. In addition to inter-state transmission connections to enable power flows across states, investment in new transmission and generation capacity will be coordinated to unlock resources within the REZs and connect them with population and demand centres. The NSW, Queensland and Victorian Governments are each developing programs to implement REZs within their states.

Infrastructure Australia has commissioned a study of labour and material requirements for electricity generation, storage and transmission as part of our market capacity analysis. The AEMO has contributed to defining the scope of work for this study, and recognises the benefits of assessing the employment and material requirements for the transmission and generation projects identified in the 2020 Integrated System Plan. In supporting Infrastructure Australia's study, AEMO hopes to improve understanding of labour and material requirements to inform and assist governments, transmission network providers, project developers and market bodies.

The following analysis is additive to all the preceding analysis. It does not represent a combined assessment with the resource demands of the broader Major Public Infrastructure Pipeline.

Key findings

The key findings of this analysis, based on different growth scenarios for renewable energy, are:

- Employment demand in the electricity sector grows over time, fluctuating from 80,000 to 95,000 with the primary source of growth in large-scale renewable energy. Growth occurs across all major occupation groups except machine operators.
- There is significant volatility forecast in employment demand (reflecting primarily the peaks and troughs in construction), especially within states and regions.
- Labour and skill shortages may become a significant factor for the build out of renewable generation and transmission infrastructure, especially in regions with tight labour markets.
- Key risks for shortages and constraints are identified both in the larger occupational groups (such as electricians, construction managers, electrical and grid engineers), but also some more specialised jobs (such as line workers for transmission construction or crane operators for wind power construction).
- Occupations currently listed on skills shortage and skills needs lists (electricians, telecommunications engineers) present a higher level of risk where prolonged border closures or limits on skilled migration present supply constraints.
- Industry stakeholders identified a range of challenges and barriers for skill development through the Renewable Energy Zones, but also opportunities for better co-ordination of training, skills and workforce development to reduce the labour supply risks, improve regional economic outcomes and job quality.
- The current projections for labour demand in the energy sector could significantly underestimate growth, especially under ‘energy superpower’ scenarios where there is mass electrification and growth in renewable hydrogen for heavy industry, transport fuels and export with associated demand on labour and materials. For example, in the National Hydrogen Strategy, electricity requirements for renewable hydrogen are projected to range from 65 terawatt hours to 912 terawatt hours or around one-third to over four and a half times the current size of the National Electricity Market (NEM).[15] AEMO is currently developing a scenario to model the implications of mass electrification and hydrogen growth for the 2022 ISP.
- Renewable energy will significantly increase consumption of steel and concrete. Australia produces 29 million m^3 of concrete per year and 5.6 million tonnes of crude steel per year (in 2018).[16] [17] Electricity generation and transmission demand for steel peaks at just over 1 million tonnes, reaching about a fifth of the Australian yearly production, and demand for concrete peaks at just over 4 million m^3. The largest source of steel consumption is wind turbine towers but solar farms, rooftop solar, pumped hydro storage and transmission towers are all notable sources of demand for steel. Importantly, most of the steel is currently imported although there are local wind tower manufacturers and a transmission tower factory is being established. For concrete, the primary source of consumption is pumped hydro storage and secondarily wind turbines.
- Based on a case study of NSW, State REZ programs could significantly bring forward material requirements with the peak consumption of steel more than double and concrete consumption over 50% higher in the mid-2020s.

Background and approach

In 2019-2020, the Institute for Sustainable Futures at the University of Technology Sydney conducted a large-scale survey of renewable energy employment to generate employment estimates based on Integrated System Plan (ISP) scenarios.[18] This work has been extended to develop an integrated analysis of energy generation and transmission construction by undertaking:

- Surveys with transmission networks and construction firms to generate employment indicators for transmission construction, collect data on recruitment difficulties and qualitative information on barriers and issues for skill and labour development (March-April 2021).
- Desktop research to include fossil fuel generation and fuel supply to enable employment projections, for the entire energy sector, including coal and gas generation and fuel supply, clean energy generation, storage, and transmission construction.
- Research on the concrete and steel requirements for rooftop solar photovoltaics (PV), solar farms (PV), wind farms, hydroelectricity and pumped hydro storage and transmission construction to generate volume estimates under ISP scenarios.
- An industry workshop (featuring renewable energy, transmission, training providers, and TAFE stakeholders) was held in April 2021 on the challenges, opportunities and barriers for employment and skill development for the REZs and transmission construction.

Resource demand is projected for the electricity sector as a whole, renewable energy generation technologies and transmission construction, both by states in the NEM (that is, not including WA and the NT) and by occupation. Note that the assumptions within the ISP based model predate the Australian Government's gas-fired recovery policy, which will affect the projections of resource demands within the coal and gas energy sub-sector.[19]

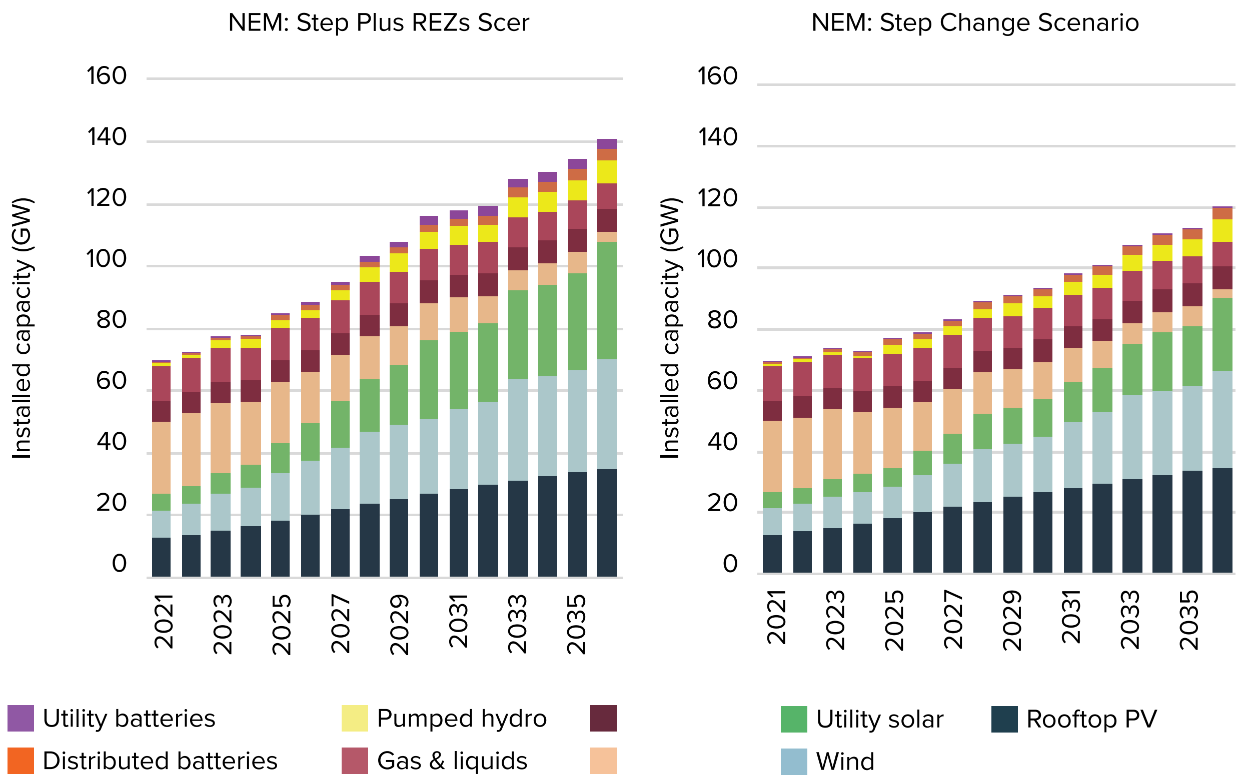
Employment demand in the energy sector is uncertain and volatile

The pace of change within the electricity sector and uncertainty over the development of renewable energy makes forecasting employment challenging. If the direction of change is clear – all of the scenarios considered by AEMO end with 80 to 95% renewable energy by 2040 – however there are many different transition pathways. For example, the clean energy transition could be faster or slower, or there could be a higher or lower share of distributed or large-scale renewable energy. The employment and material requirements for energy generation and transmission will depend in part on which pathway is taken. Consequently, the starting point here is the energy transition scenarios of AEMO which underpins the employment and material projections.

Under the most rapid scenario in the 2020 ISP, the Step Change scenario, the market share of renewable energy would grow to 90% by 2035. In reality, the current and planned development of renewable energy is occurring even more rapidly. The Clean Energy Regulator has identified nearly 7 gigawatts (GW) of committed and probable projects which are likely to be built in the next few years.[20] The NSW, Victorian and Queensland Governments are each developing programs to implement large volumes of renewable energy and storage in Renewable Energy Zones before 2030 (see Appendix A) with the result that renewable energy growth is likely to occur faster than forecast even in the Step Change scenario in the 2020 ISP.

Consequently, a Step Plus REZs scenario is included and the projections in this report are mostly based on this scenario. The installed capacity for each technology under the two scenarios is shown in Figure 43.

Figure 43: Forecasts of total capacity, Step Plus REZs and Step Change Scenario (2021–2036)



The key differences between the two scenarios are:

AEMO's Step Change scenario: renewable energy generation and storage grows modestly during the 2020s and then rapidly from the late 2020s and early 2030s based on coal-fired power station closures, emissions reductions and cost reductions for renewable energy technologies.

Step Plus REZs scenario: this is based on the Step Change scenario which has been modified based on the State REZ targets for NSW, Queensland and Victoria. Only NSW has released detailed modelling for its REZ program and therefore the volume and timing for wind power generation, solar, pumped hydro and large scale batteries is based on the NSW Government Infrastructure Roadmap modelling, which brings forward development and increases the overall volume of renewable capacity. Adjustments are made for Victoria and Queensland in line with their targets:

- The scenario assumes that Victoria will install 75% of the NSW wind and solar generation capacity, adding 9.5 GW by 2030 which is close to the Victorian target of 10 GW in the REZ Development Plan.
- Queensland is assumed to install 50% of the NSW additions towards the 50% 2030 Queensland Renewable Energy Target.
- In 2036 the capacity in Queensland is just 0.5 GW greater than the Step Change, while in Victoria capacity is 11.5 GW greater.

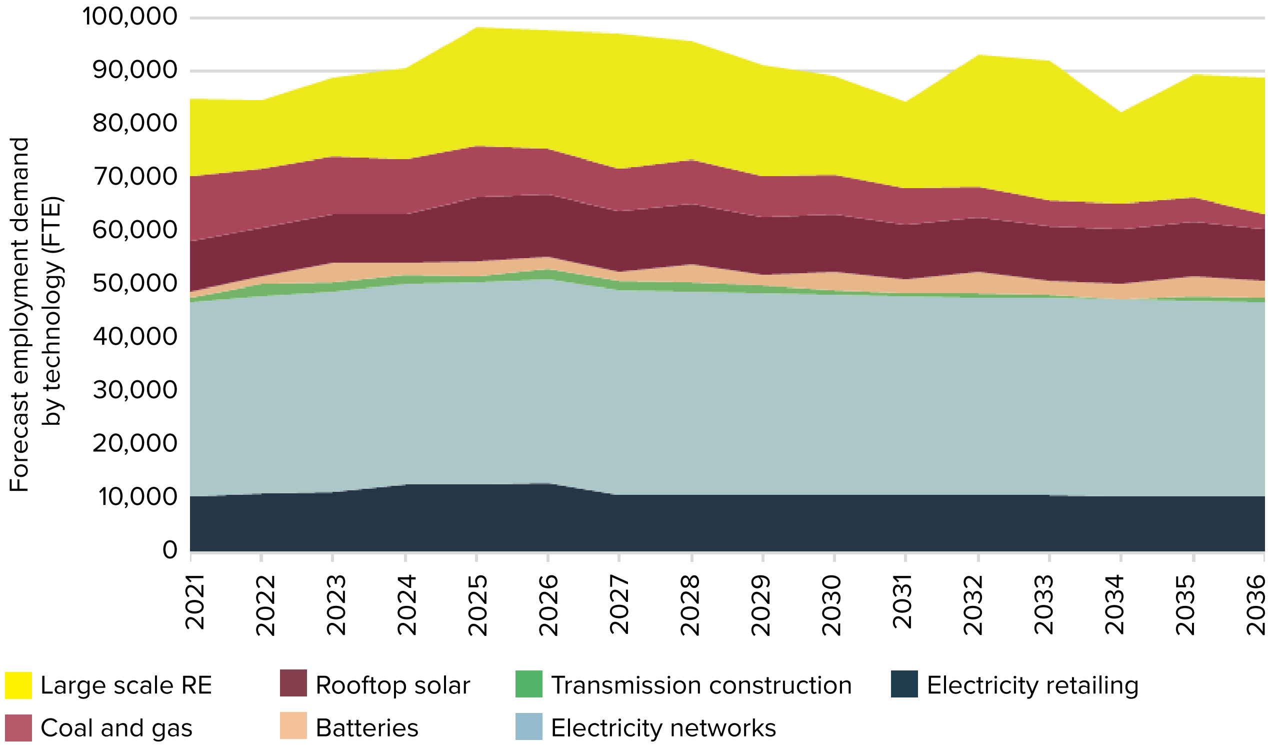
The projection for rooftop PV in both the Step Change and the Step Plus REZs scenarios has been increased in line with more recent projections from Green Energy Markets, which were commissioned for the 2022 ISP by AEMO.[21]

This scenario is not a prediction – AEMO is currently preparing the next iteration of the ISP for 2022. The purpose is to illustrate the trajectory of employment demand that could occur if the REZs are implemented under this scenario which is broadly aligned with State government targets for 2030.

Power sector employment demand grows over time, driven primarily by large-scale renewable energy

Total power sector employment increases over time, albeit with some major fluctuations between 80,000 and 95,000. As shown in Figure 44, the largest source of employment is the operation of the electricity networks, primarily the distribution network which employs around 33,000 people. Electricity retailing employs around 11,000 people.

Figure 44: Forecast total employment demand, power sector (by sub-sector), Step Plus REZs (2021-2036)

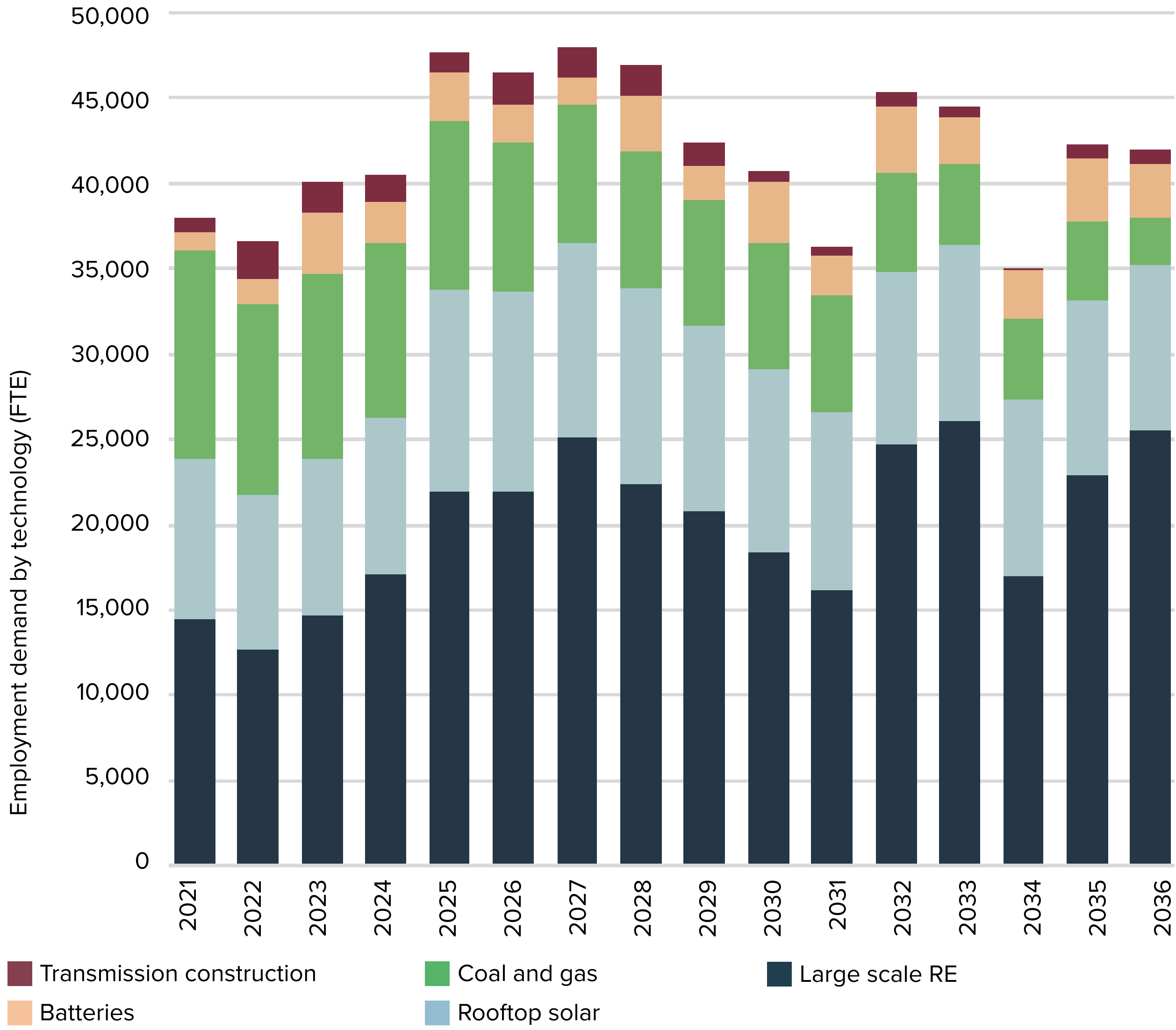


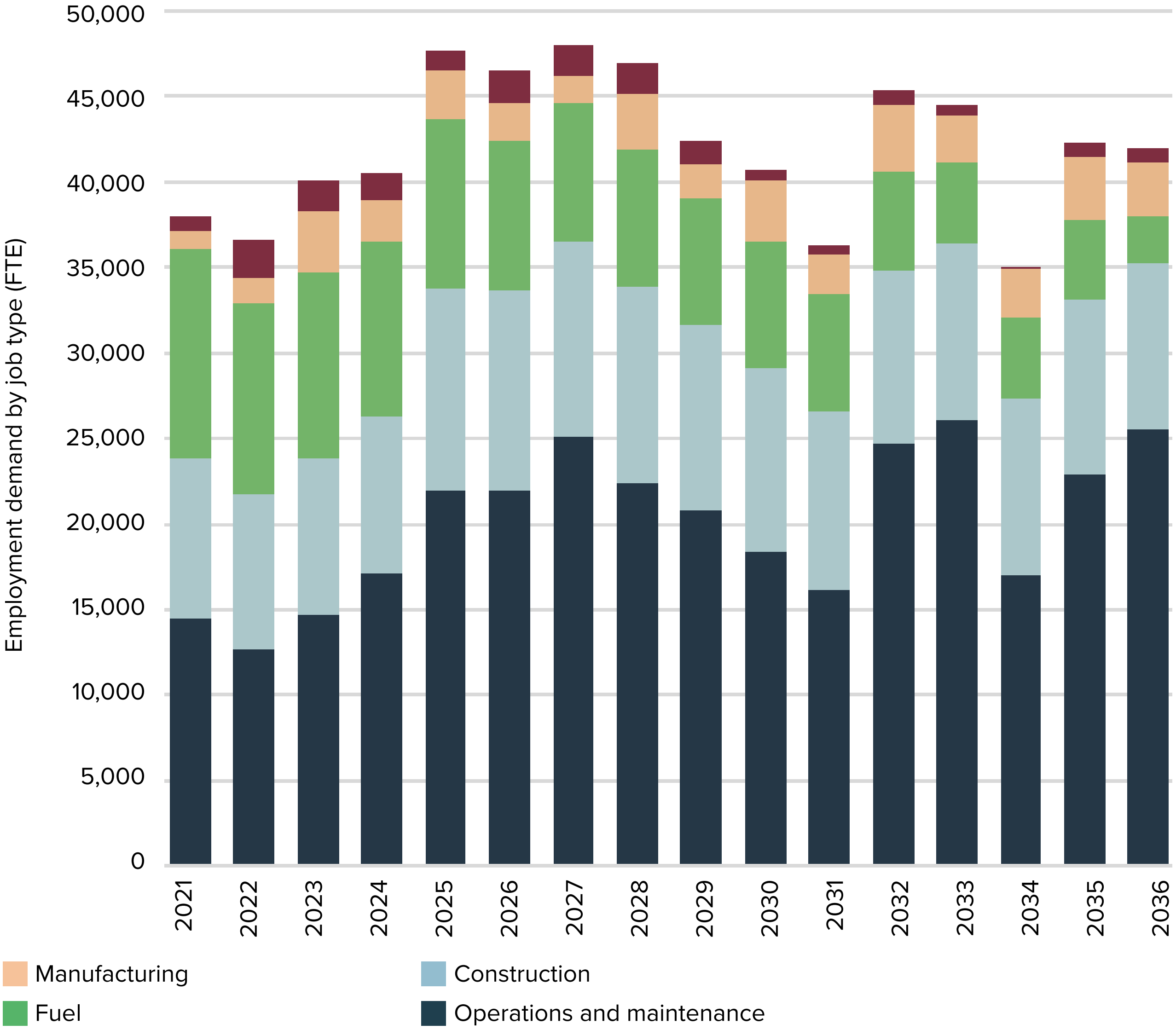
Note: the source for employment in the operation of the transmission and distribution network and electricity retailing are IBIS projections, as these sub-sectors were not included in the study. [22] IBIS projects employment until the mid-2020s, after which employment is assumed to decline in line with trend for each at the average rate for the preceding decade (-0.7% p.a. for electricity distribution, -0.3% p.a. for transmission and -0.1% for electricity retailing).

Key features related to the demand for skills and labour highlighted by this analysis across the electricity generation and transmission construction sector include (Figure 45):

- Growth in demand for employment within large-scale renewable energy, rooftop solar, battery storage and transmission construction is projected to climb to over 40,000 for most of the study period and towards 50,000 jobs.
- There is high volatility across all the growth sectors apart from rooftop solar. The volatility primarily reflects the high proportion of employment in construction which scales up rapidly and then subsides as projects are completed. The volatility in employment presents challenges for suppliers, Engineering, Procurement and Construction firms (EPCs), workers and local communities. Attracting and retaining skilled workers across cycles is difficult. Although there is a core workforce with ongoing employment, many workers and contractors are engaged project-to-project. Strategies to reduce and manage volatility are an important consideration for the industry to reduce skill shortages, improve the quality of jobs and regional economic outcomes.
- As the asset base of the energy market grows steadily over time, so too does the demand for operation and maintenance labour required to run these facilities. Employment in operation and maintenance in coal and gas is currently around 11,000. At the level of a single project, renewable energy does not employ large numbers of operation and maintenance staff but the growth in the volume of operating projects means that by the mid-2030s there are over 20,000 jobs in operation and maintenance. Over time, as renewable energy grows, the level and proportion of people employed in operation and maintenance increases from one-third to over half of electricity generation employment (Figure 45).

Figure 45: Forecast employment demand by technology and job type, transmission construction and electricity generation (Step Plus REZs) (2021–2036)





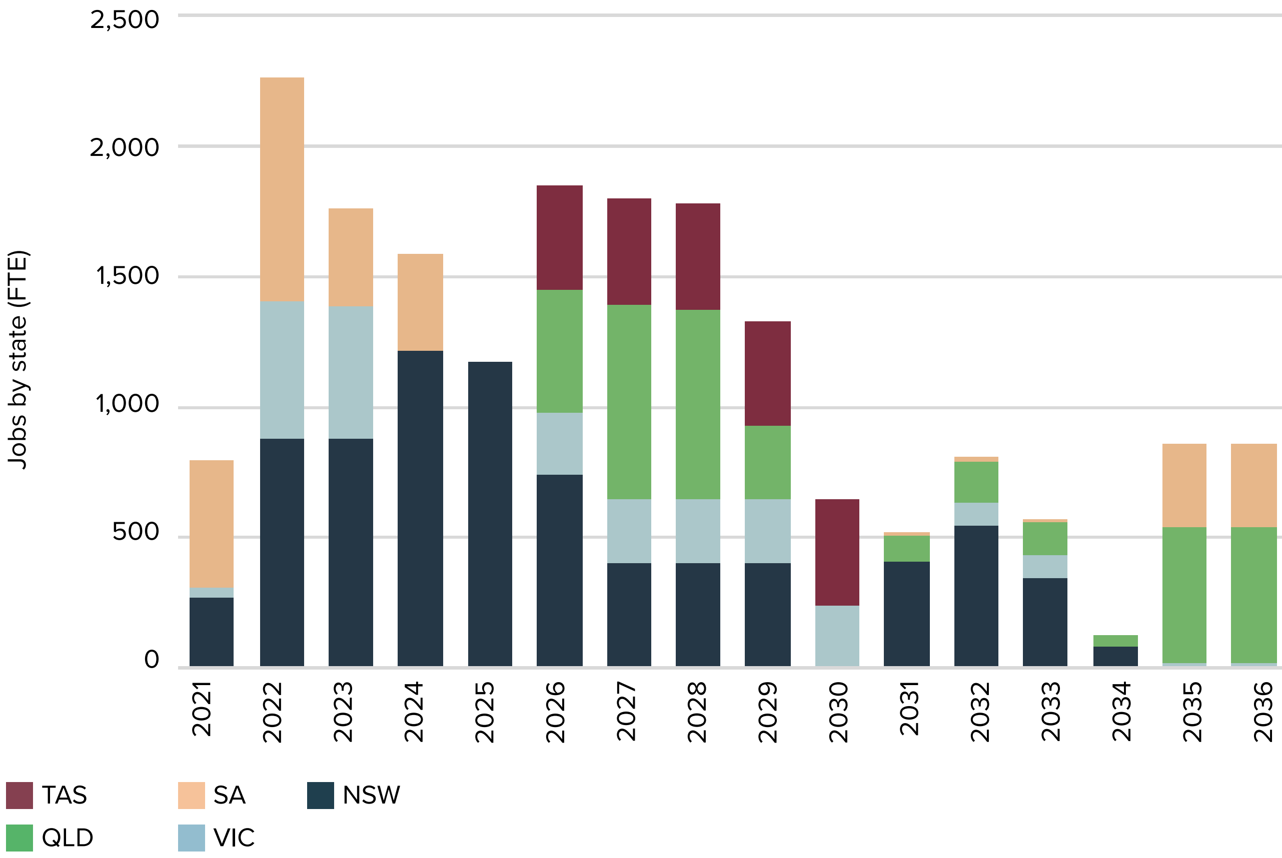
There are major variations between the technologies underpinning the trends in energy sector employment (Figure 45):

- The key source of growth in employment demand is large-scale solar and wind farms (utility-scale renewable energy). Employment climbs sharply to 25,000 by 2027, subsiding after a wave of construction before a series of sharp cycles of growth and decline during the 2030s (around 25%).
- Rooftop solar employment demand is relatively stable. Historically, rooftop solar employment was highly volatile as activity was heavily influenced by government programs. Rooftop solar is now a cost-effective technology with high demand from consumers. The forecast of Green Energy Markets which underpins this employment projection assumes gradually declining demand, falling slowly from just under 2 GW per annum through much of the 2020s to closer to 1 GW per annum by 2036.[23] This decline is compensated by an increase in employment in domestic batteries associated with PV systems.
- As Australia's energy mix pivots to renewables, demand in the domestic coal and gas sector (including fuel supply for electricity production) is projected to decline from around 11,000 throughout the 2020s and more rapidly in the 2030s. As there is expected to be less project activity relative to other energy sub-sectors, most of these jobs are in operation and maintenance of power stations with a smaller level of demand in mining and gas supply. It is important to note that the assumptions within the 2020 ISP on which this report is based predate the Australian Government's gas-fired recovery policy, which will affect the projections of resource demands within the coal and gas energy sub-sector.[24]

- There are several thousand workers employed in battery storage construction, operation and maintenance. These numbers are indicative only as the data on employment intensity was collected in 2019 when it was an emergent sector. Although there is a decline factor applied to account for increased scale and productivity, it may be conservative.

  The growth in battery storage is also sensitive to assumptions about the costs relative to pumped hydro storage, which are competing for market share as sources of storage to complement intermittent renewable energy.
- Transmission construction is a smaller source of employment but there are also some significant fluctuations with the workforce forecast to scale up rapidly to over 2,000 in the early 2020s (Figure 46).

Figure 46: Forecast transmission construction employment by state, Step Plus REZs (2021–2036)

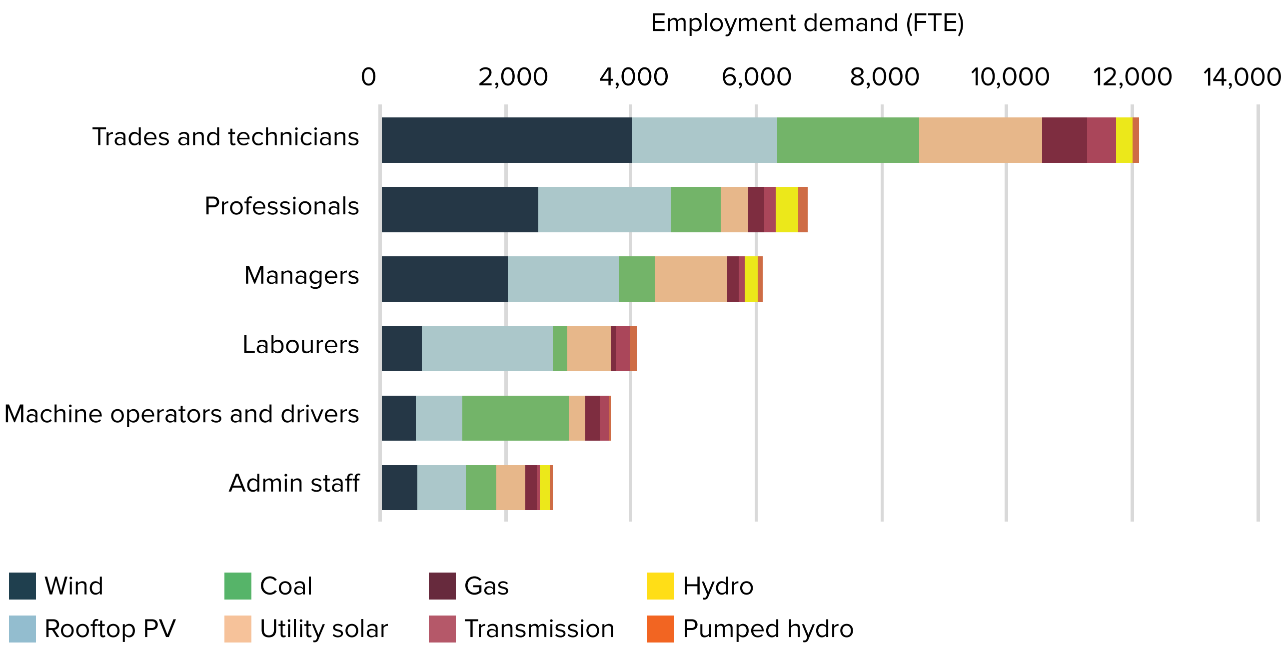


Employment growth occurs across all occupational groups except machine operators, led by trades and technicians

There is a spread of employment between occupational groups across the energy sector (Figure 47) with:

- The largest grouping of trades and technicians average around 12,000 per annum (around one-third of total employment).
- Professionals (an average of over 6,000 per annum) and managers (over 5,000 per annum), together comprise just over one-third of total employment.
- Machine operators (4,000 per annum) and labourers (3,500 per annum) which together account for just over one-quarter of total employment.
- Just under 3,000 administrative staff are employed on average.

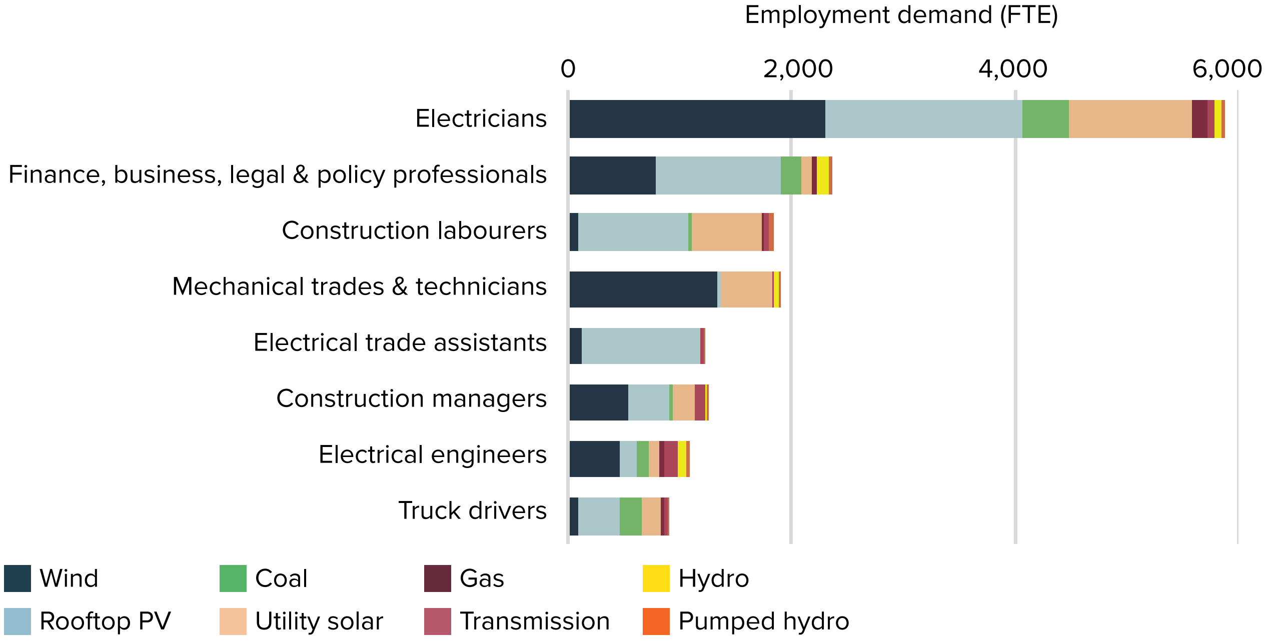
Figure 47: Forecast average employment demand, grouped occupations (2021-2036)



Machine operators are the only group which experiences decline over the forecast period (40%) reflecting the higher volume of current employment in coal and gas (e.g. drillers).

The occupations in the energy sector projected to have the highest growth include electricians, construction managers, finance and business professionals, electrical engineers (including grid engineers), mechanical trades and truck and van drivers (Figure 48).

Figure 48: Forecast average employment demand, key occupations (2021–2036)



There is a risk of skill shortages with the scale-up to deliver Renewable Energy Zones and transmission infrastructure

The build-out of renewable energy generation, storage and transmission under the Integrated System Plan and the Renewable Energy Zones represent a major scale-up for the industry. Very few major transmission lines have been built in recent decades. As one transmission industry participant noted, *'$100 million used to be a large contract, now a large contract would be $1 billion.'* The rapid growth and peakiness of the employment profile for both generation and transmission construction creates a higher risk of skill shortages.

Through surveys of recruitment difficulties with generation and transmission companies and an industry workshop, the major jobs at risk of shortages were identified (Table 2).

Table 2: Recruitment difficulty and skill shortage assessments, selected occupations

Occupation	Solar and wind survey (2019)	Transmission survey (2020)	Industry trends and observations
Construction managers	High	High	High competition has been observed across infrastructure sectors for construction managers.
Electrical and grid engineers	High	High	One wind power company estimated there were less than 150 grid engineers in Australia with the full suite of skills required.
Civil engineers	High	Medium	National skill shortage status changes from year to year illustrating fluctuations in supply-demand balance.
Telecommunications engineers	High	Medium	Listed on the National Skills Needs List with eligibility for the Rural and Regional Skills Shortage List.
Electricians	Medium	Low	Listed on the National Skills Needs List with eligibility for the Rural and Regional Skills Shortage List.
Mechanical technicians	Medium	Low	Industry reports wind blade technicians are recruited internationally (an apprenticeship is being established in Victoria).
Transmission lineworkers	n/a	High	All survey respondents noted these were in shortage in Australia and a heavy reliance on international recruitment.
Riggers	Low	Medium	Transmission EPCs were recruiting riggers internationally.
Crane operators	Medium	Low	Not all wind generation developers experienced shortages, but some said high crane operator shortages had delayed projects.

Note: The classification of jobs is based on the responses to surveys conducted by Institute for Sustainable Futures.[25]

It is not always the occupations with the largest demand volumes (e.g. electricians) that can create constraints. High-crane operators were not a widespread shortage for wind farms during the boom conditions of 2018-2019 but where they did occur they created project delays. Industry concerns in relation to shortages were especially acute in relation to transmission lineworkers and electrical specialists for substations due to a combination of factors:

- a rapid scale-up in construction projects and a strong reliance on international and inter-state recruitment.
- Significant lead-times for retraining lineworkers from other sources (e.g. electricity distribution workers, electricians) or new entrants.
- Limited training providers and training packages which have been identified as requiring updates.
- Disincentives to on-the-job training (e.g. project length is shorter than apprenticeship length).
- A fragmented approach to skill development between industry and public agencies without an overriding plan.

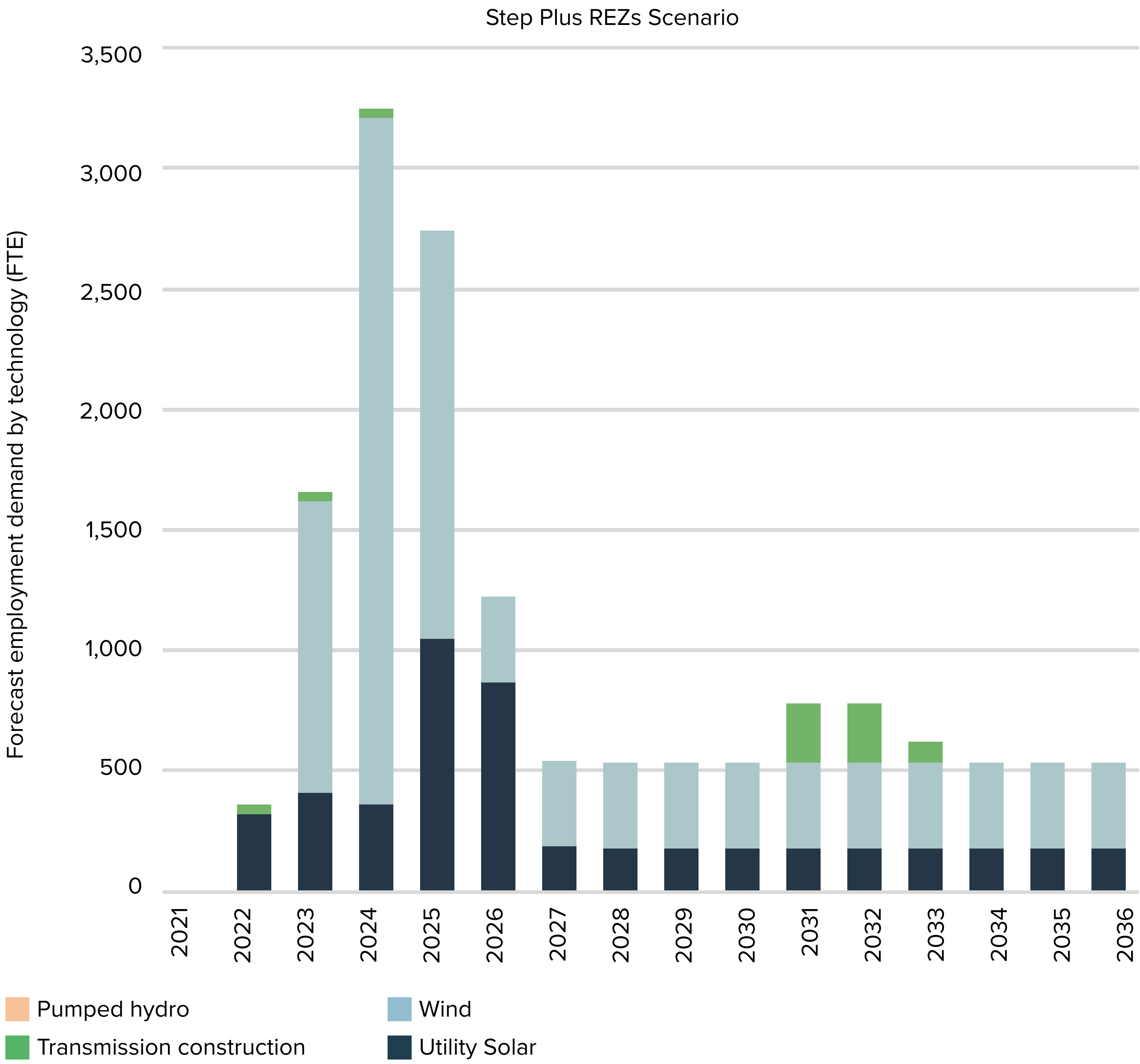
Stakeholders identified a number of key factors shaping skill development in the generation sector including:

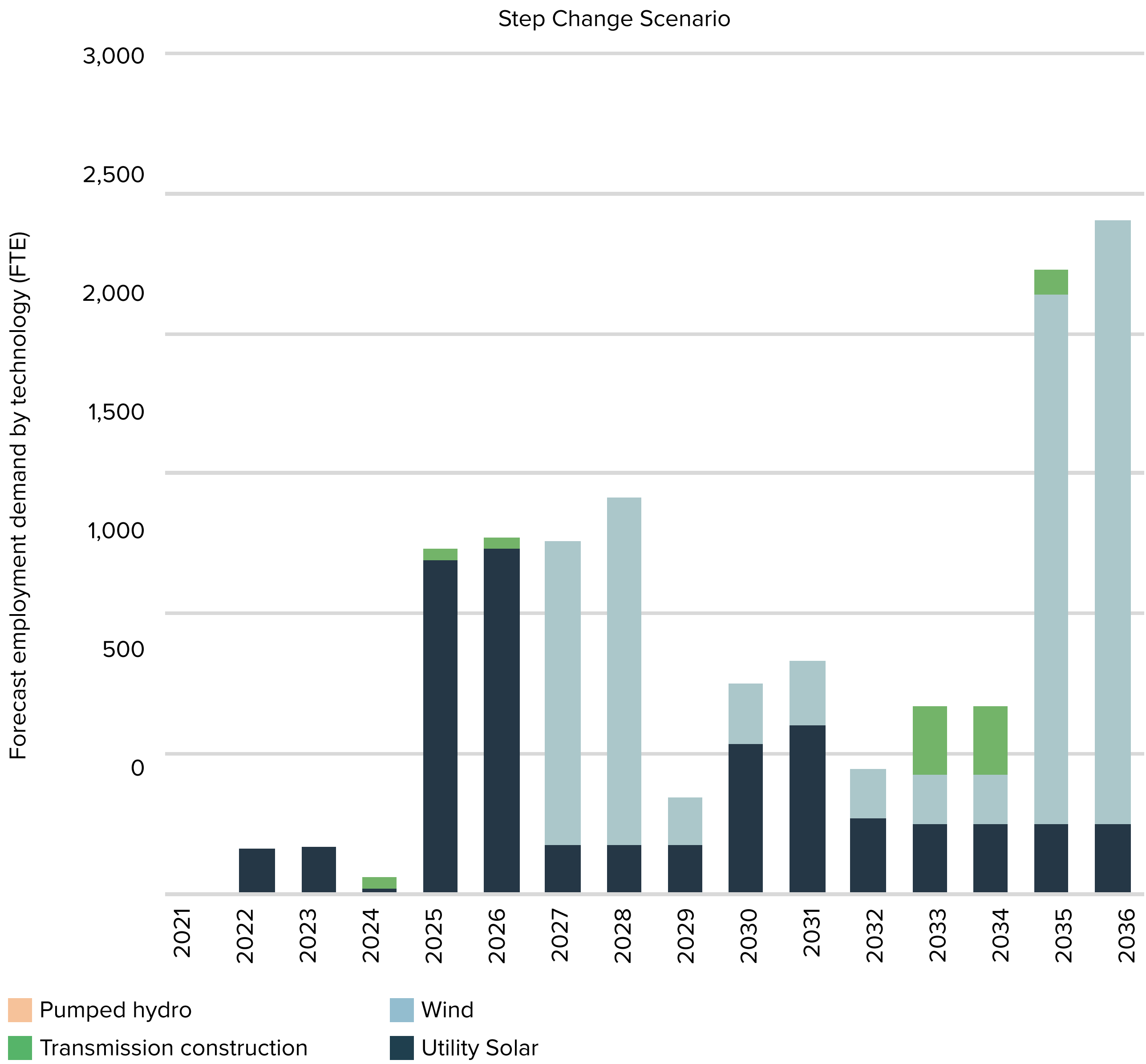
- A decline in the role of public sector training of apprenticeships without a reciprocal increase from the private sector.
- Disincentives leading to insufficient training investment at firm level such as short project lead times, policy and labour demand uncertainty, projects of shorter duration than the length of apprenticeships, and the risks of not realising the value of training investment and high levels of cost competition.
- Labour retention challenges such as competition from other sectors that pay higher wages (e.g. mining), and short-term construction project employment without career paths leads to workers pursuing alternative options.
- Issues with training system capacity for key occupations (e.g. electricians, lineworkers, turbine technicians) – some of which are being currently addressed, though it was observed that the investment in training system capacity has been low.

Case-Study: Central-West Orana Renewable Energy Zone

The case study of the Central-West Orana Renewable Energy Zone (CWO REZ) illustrates both the challenges and opportunities for local employment. The CWO REZ will be the first REZ to be rolled out under the NSW Government's Electricity Infrastructure Roadmap. Consequently, as seen in Figure 49, whereas employment fluctuates from 500 to almost 1,500 in the next few years under the Step Change scenario, demand for labour scales up very rapidly to annual employment of over 2,000 with a peak close to 3,000 under the State REZ scenario.

Figure 49: Forecast transmission construction and renewable energy employment, Central West Orana REZ





Note: The transmission construction employment includes only the Central West transmission project

The challenge for creating local jobs is that the labour market in the CWO REZ is relatively tight (the unemployment rate in Orana and Central West region is 1.8% and 4.2% respectively), the workforce is ageing (around half are over 55) and there could be significant competition for trades and technicians, machine operators and labourers with other industries like civil construction and mining.

The REZs offer an opportunity for greater industry, government and training system collaboration – a skill ecosystem approach

Renewable energy, transmission and training stakeholders agreed that there is a need for greater coordination and collaboration between industry, government and training authorities to improve local skill formation and employment:

> *"The industry does not have a collective vision… there is a need for an organised, long-term and unified approach with strategies and actions that are supported by industry… a collaborative system to education, training with industry playing a part in guiding course development and providing spaces for workplace experience is necessary to support workforce development"*[26]

> *"We want to have that partnership at regional level to be able to attract staff … there is incredible scope for the long-term opportunity to develop workforce – but it needs a holistic view. A collaborative approach to industry and training workforce. We have a highly fragmented workforce in Australia. An additional layer of consideration is project work within a fragmented industry – people try to stitch together careers or otherwise we seek the international workforce."*[27]

A range of opportunities were highlighted in an industry workshop (featuring renewable energy, transmission, training providers, and TAFE stakeholders) for improving local and regional labour supply and job quality including:

- Improved project sequencing, smoothing the development pipeline and visibility of worker skills (e.g. digital passports) to facilitate redeployment between projects.
- Worker transition from declining industries through skill mapping, micro-credentials and coordinated programs.
- Increased use of apprenticeships models such as Group Training which reduce the risks and costs for host employers.
- Creating better pathways into the industry from schools and under-represented groups in the labour force (e.g. local indigenous community).
- Collaboration between the states to efficiently develop training capacity to cover key skill requirements across generation and transmission to accelerate development and reduce overall costs.
- Investing in core skills and creating pathways between clusters of energy, construction and manufacturing business to create career paths, labour sharing and retention.

As the International Labour Organisation has noted:

> *"Training targeted on the renewable energy sector should invest in skills that are portable. Even with efforts taken to adopt a smooth transition approach, employment in development, construction and installation may be volatile. In occupations linked to operations and maintenance, there may also be periods when scope to employ newly trained workers will be limited. Education and training courses should therefore be built around a core qualification that will be useful in a broader range of sectors."*[28]

The REZs create a platform for a more collaborative approach – what has elsewhere been described as a skill ecosystem approach which typically includes the following key elements:[29]

- Collaboration between the training sector and industry to improve workforce sustainability and align training with industry needs.
- An approach to skill development that includes not just increasing training supply but also workforce development to encompass the acquisition, use and renewal of skills on-site and in the workplace.
- A holistic perspective that includes other labour market and workplace dimensions that impact on labour supply and skill development, such as influences on labour retention (e.g. career paths, job quality). It is no use increasing training supply if there are other workplace or labour market features that means the sector cannot develop and retain labour.
- Designing interventions across an industry and/or region – not just at an individual firm level.
- Building the capacity of industry and training organisations to more systematically plan and manage skill development to avoid skill shortages.

The best example of this type of approach to date in the energy sector is the *Energising Tasmania* initiative which could serve as a model for other states. *Energising Tasmania* is a cross-sectoral, regional initiative which aims to develop the workforce within and across wind power, hydro, transmission, hydrogen, civil construction and advanced manufacturing. The goal is to build a workforce with nationally accredited qualifications that reflect the project pipeline of the next decade and build career paths for workers that can move across sectors with shared core skillsets.

Stakeholders agree that there is no one-size-fits-all solution to the skills and labour development needs of the renewable energy and transmission sector. There are common elements and scope for greater collaboration across the industry and states, but the mix will vary depending on the regional and industry context. Whatever the exact solutions, greater collaboration is essential, and the Renewable Energy Zones were seen as creating a platform for a skill ecosystem approach.

It is important to note this estimate of energy-sector jobs does not include all Australian energy sector employment (e.g. end-of-life, recycling and circular economy for renewable energy technologies) and there are significant other demand drivers.

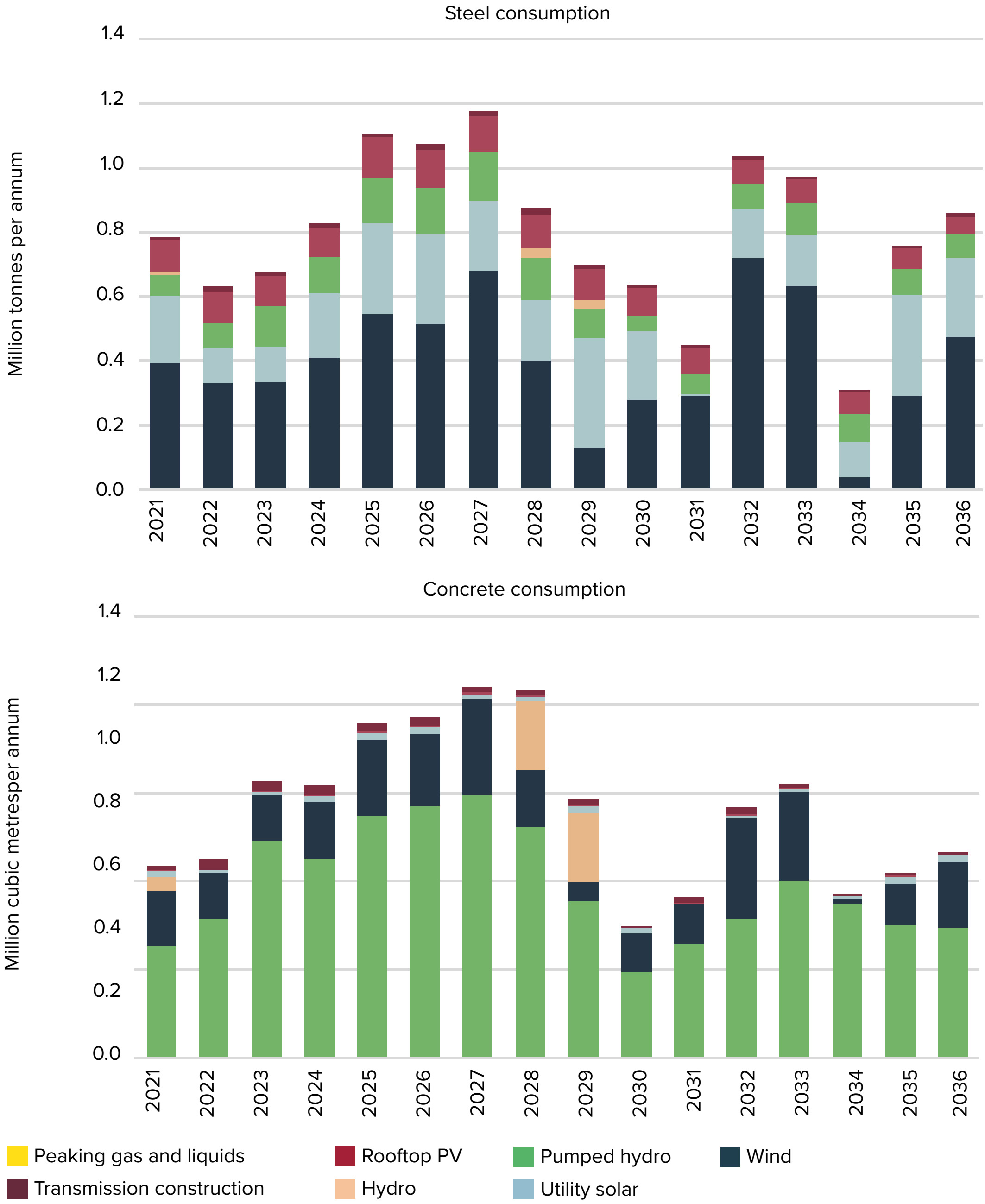
Electricity demand and growth opportunities for large scale renewable energy could be several times larger under scenarios currently being developed by electricity market forecasters (including AEMO for the 2022 ISP) in which there is large-scale electrification (industry, homes, transport) and/or the development of renewable hydrogen for heavy industry, transport fuels and export. In the National Hydrogen Strategy, electricity requirements for renewable hydrogen are projected to range from 65 terawatt hours to 912 terawatt hours, or around one-third to over four and a half times the current size of the NEM.[30] ,[31]. If this occurs, the employment creation would also be correspondingly higher, most likely during the 2030s and into the 2040s.

The scope of this study is the NEM which covers the Eastern Seaboard across to South Australia (SA) and Tasmania. There are significant renewable generation plans in both the NT and WA with large-scale projects under development to connect undersea cables to South-East Asia.

Renewable energy will significantly increase consumption of steel and concrete

Australia produces 29 million m^3 of concrete per year 5.6 million tonnes of crude steel per year (in 2018) (see Figure 50)..[32] .[33] The demand for steel peaks at just over 1 million tonnes, reaching about a fifth of the annual production in Australia.

Figure 50: Forecast steel and concrete consumption by technology (NEM, Step Plus REZs)

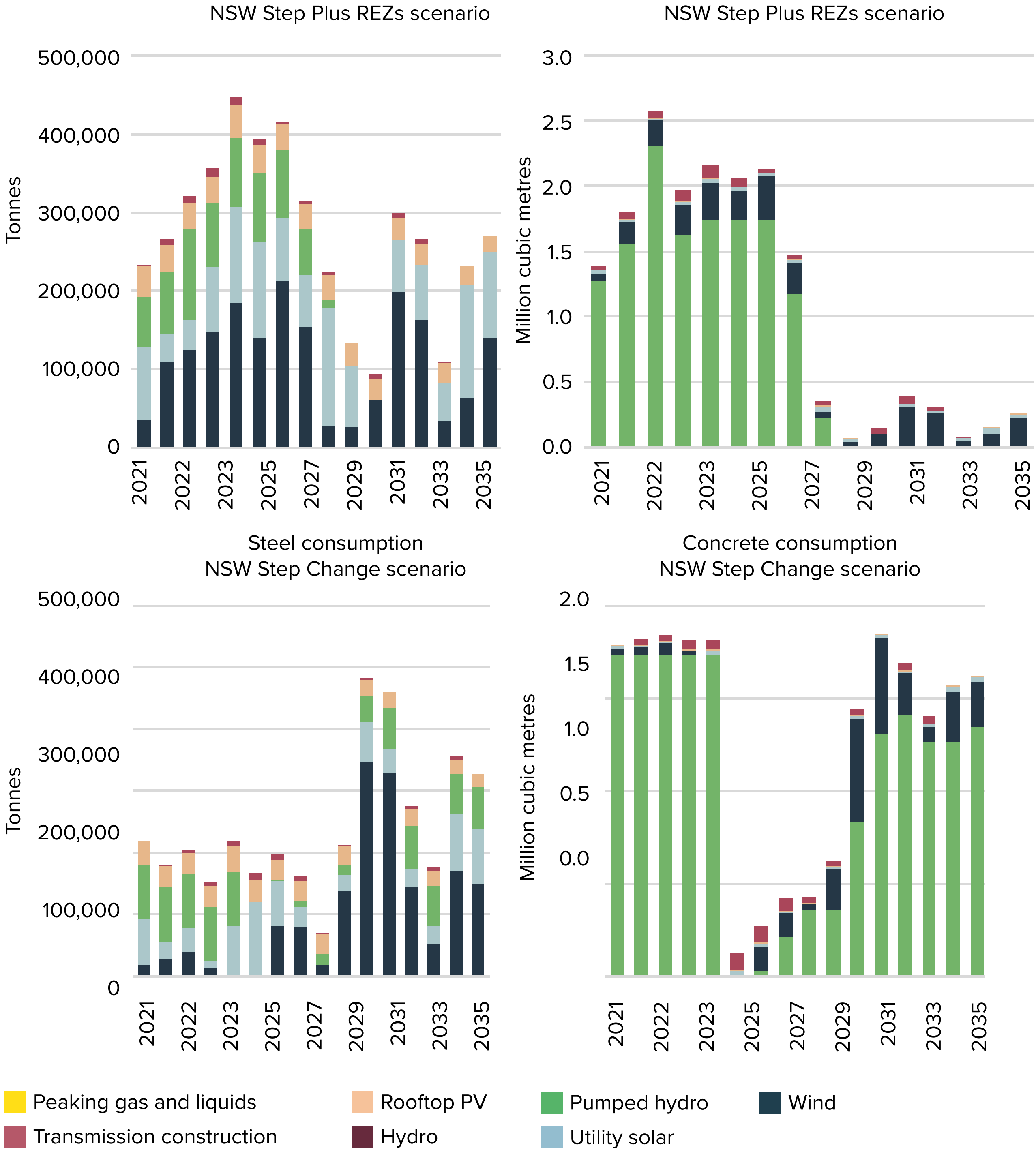


For concrete, the main source of demand in energy sector in the next 15 years is for pumped hydro (1 million – 3 million m^3 annually). Wind turbines also use significant volumes of concrete for their foundations (500,000 – 1 million m^3 annually). Smaller quantities are used for utility-scale solar.

For steel, the major source of demand is wind turbines (ranging from around 300,000 – 700,000 tonnes), but there is a greater diversity of demand across technologies. Most of the steel demand for wind farms is for towers with a small proportion for the concrete foundations. There are two wind tower manufacturing facilities in Australia, but most towers are imported (up to around 15-20% of turbine towers are made locally) due to lower cost. Solar farms use significant amounts of structural steel (e.g. mounting structures), generally 150,000 – 300,000 tonnes, which was manufactured locally in the early stages of the industry but is now imported. Pumped hydro (100,000 – 150,000 tonnes) and commercial and industrial rooftop solar (50,000 – 125,000 tonnes) also generate steel demand. Transmission towers are a smaller demand source (15,000 – 20,000 tonnes) which has been imported but a transmission fabrication factory is being established in SA.

Focussing on NSW to illustrate the impact of REZ developments at a state level, consumption of both steel and concrete is brought forward with major peaks in the mid-2020s under the Step Plus REZs scenario (see Figure 51). Steel consumption is double at 450,000 tonnes by 2025. The increase in concrete requirements is less pronounced but rises from a flat profile of 1.8 million m^3 to 2.5 million m^3. The major drop-off in concrete consumption in the mid-2020s reflects the forecast end of Snowy 2.0 construction.

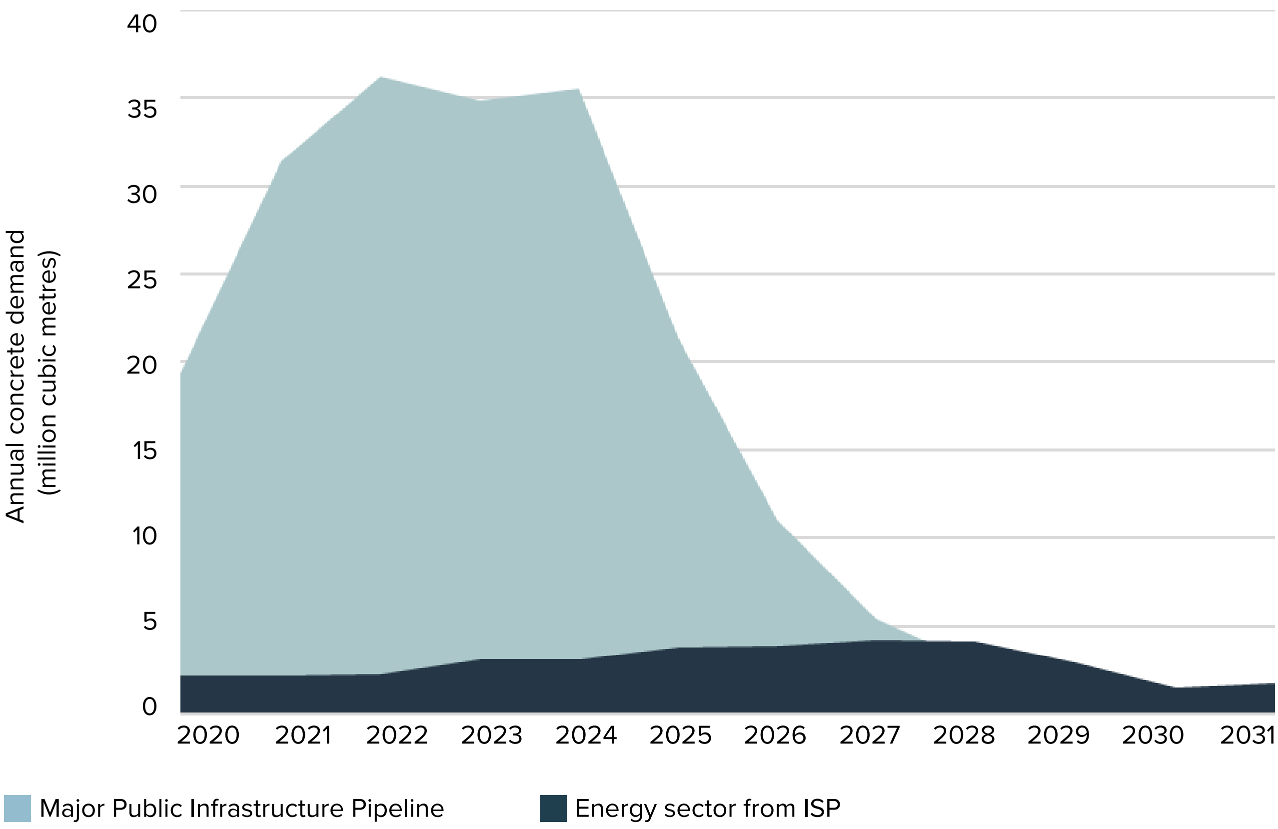
Figure 51: REZ scenarios with forecast material demands for NSW



The importance of an integrated portfolio view

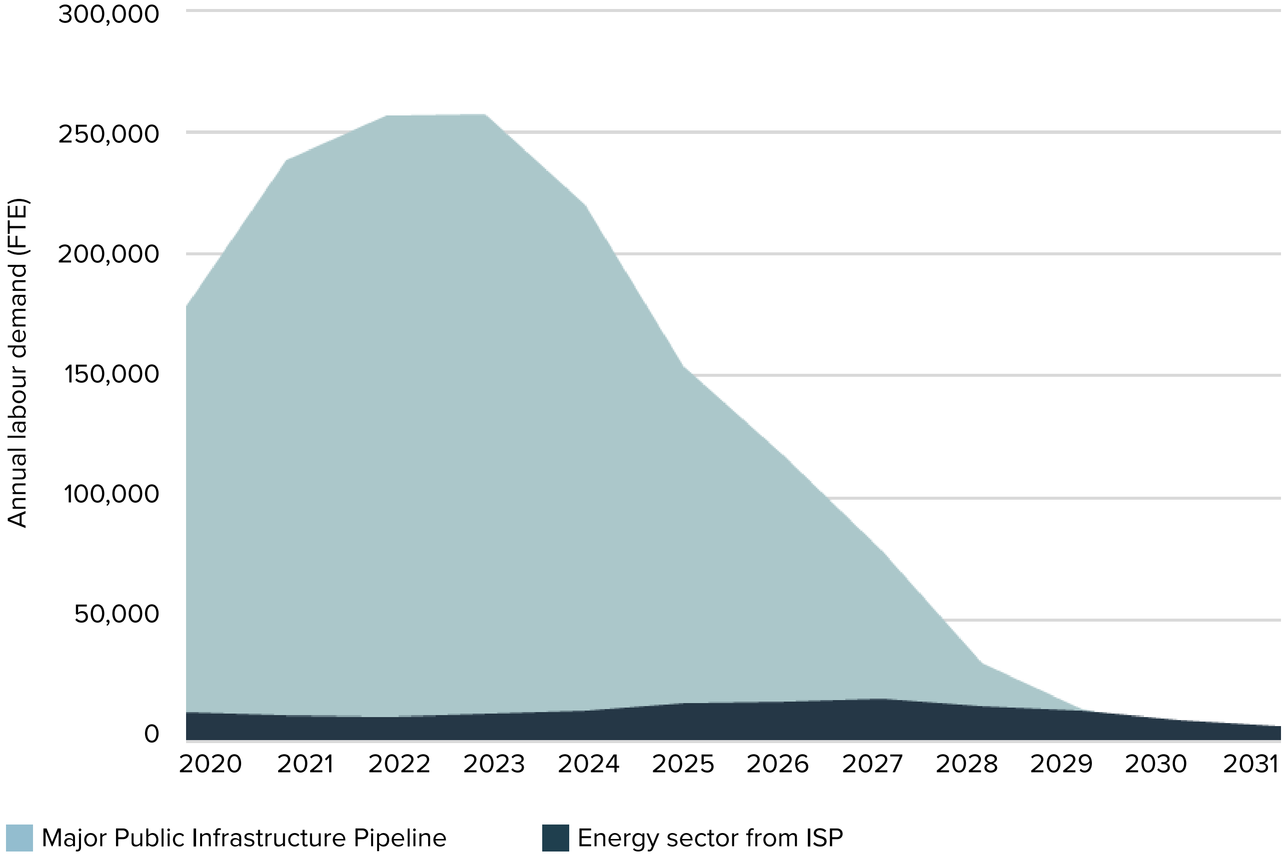
In the preceding analysis, the resource demands of the energy sector as projected using the ISP methodology has not been combined with the resource demands of the broader Major Public Infrastructure Pipeline of public infrastructure works. A combined view of the portfolio with the energy sector highlights risks not clear in isolation. When viewed in isolation, the demand for resources of the energy sector can provide a false sense of security in the market's ability to supply that sector. For example, considering the volume of concrete demanded by the energy sector in 2022 in isolation, one could reasonably conclude that the market will be able to supply the 2.2 million cubic metres, given that the total national concrete production was 29 million cubic metres. However, when viewed in combination with the broader Major Public Infrastructure Pipeline, as in Figure 52, the demand in 2022 exceed previous levels of supply, denoting a capacity risk to all sectors.

Figure 52: Forecasted demand for concrete in energy sector appears small in isolation, but a combined view shows more demand than recent production



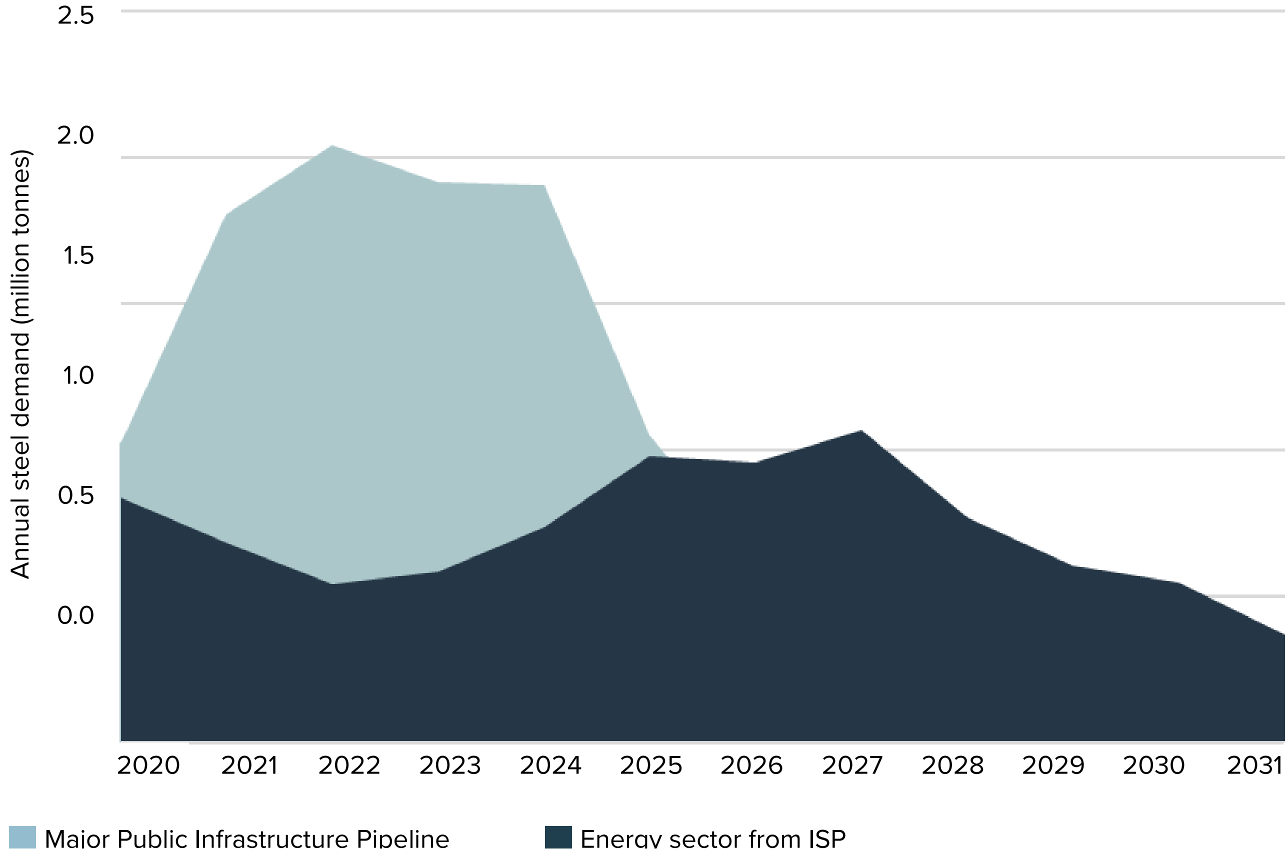
Similarly, the demand for project-based (i.e. exclusive of operations and maintenance) labour resources in the energy sector is relatively small compared to the Pipeline, averaging 10,000-11,000 FTEs over the next three years. However, when viewed in combination with the labour resource demands of the broader Major Public Infrastructure Pipeline, as in Figure 53, it is important to note that these sectors will be competing for many of the same general skill resources to deliver their projects. Furthermore, although the energy sector adds a relatively small incremental labour demand in total, nuanced risks exist when considering that it is comprised of specialised skill resources, such as electrical line workers, which are common between transmission line projects and electrified rail projects. As already identified earlier in this report, electrical line workers are at risk of short supply, so is a risk to both energy and transport sectors.

Figure 53: Forecasted labour demand of the energy sector is proportionally small but specialised, for example electrical line workers are shared across energy and rail.



The energy sector has a requirement for steel that is disproportionate to its demand for other resources. Figure 54 shows that in 2020 the demand for steel in the energy sector dominated the demand for steel in the broader Major Public Infrastructure Pipeline. At no point in the periods considered is steel demand from the energy sector projected to be less than 20% of the combined demand. Intuitively this does not make sense, given the relative volume of total project activity in both sectors. However, this disproportionately large appetite for steel is driven by the steel requirements in the construction of wind turbine towers, that each require 120 tonnes of steel per megawatt of installed capacity (see Appendix A). This combined view for steel demand illustrates the importance of considering the Major Public Infrastructure Pipeline in the context of other sectors.

Figure 54: Energy has a surprisingly disproportionate requirement for steel, driven by wind turbine towers



5. Understanding supply

At a glance:

Quarry materials (stone, gravel and sand) are one of the most-transported commodities by volume in Australia, with around 160 million tonnes transported to/from construction and industry sites each year. Unlike high-volume primary commodities such as iron ore, coal and grain that are mainly transported in rural areas by rail in large train configurations, a large proportion of quarry materials are transported in urban areas, by road.

There are approximately 182,000 people currently working on public infrastructure projects across Australia, classified as the engaged workforce.

Beyond the immediately engaged workforce, there are another 1.18 million individuals working in relevant occupations that may to varying degrees be able to transition into the Major Public Infrastructure Pipeline workforce.

However, for many of these workers there will be significant training needs before they can be deployed to support the Major Public Infrastructure Pipeline delivery

Between 2021 and 2024 shortages are anticipated in all infrastructure-related occupational groups.

In 2024, NSW and Victoria show signs of continued workforce shortage as other jurisdictions wrap up their currently confirmed projects.

States and territories are projected to need to increase their workforce by 47% or more beyond projected supply to meet peak demand.

Victoria, Queensland and Tasmania all have points where they will need workforces approximately double what is projected to be available within their borders. The timing of workforce shortages is also varied – Victoria is already in a shortage that will continue until 2026, while SA's most significant shortage is not until 2027.

There are significant barriers to fully utilising the adjacent workforce including low female representation in the workforce, education and training leakages and cultural issues.

There are also significant barriers to importing workers to fill any labour resource gaps, including likely permanent impacts from COVID-19 migration restrictions.

Existing migrants struggle to get into the public infrastructure sector – 28% of migrant qualified civil engineers were unable to find work in the occupation.

Major findings

Key findings for plant, equipment and materials supply

Quarry material requirements can vary significantly year on year depending upon the mosaic of infrastructure investments and construction sites.

Infrastructure Australia is working with CSIRO on a Phase 2 project, using the Transport Network Strategic Investment Tool (TraNSIT).

We will map different types of materials from quarries through to processing facilities (e.g. cement manufacturers) and then construction sites.

Key findings for skills supply

There are approximately 182,000 people currently working on public infrastructure projects across Australia.

16 of 50 public infrastructure occupations are rated as currently likely in shortage, and another 18 rated as potentially in shortage.

Between 2021 and 2024 shortages are anticipated in all four occupational groups in the sector.

Women currently make up less than 12.7% of the workforce in construction occupations and less than 2% of related trade jobs.

At its peak, workforce demand is projected to be 48% higher than supply in the next 3 years and approximately 1/3 of jobs advertised could remain unfilled.

Victoria, Queensland and Tasmania will experience the greatest risk of shortage during this period and at points are projected to require a workforce approximately twice the size of the available supply within their borders.

Migration is only projected to provide 6% of new workers in the public infrastructure industry over the next 15 years.

Women are likely to be paid less (between 20-26% based on average weekly earnings) and less likely to be in senior positions (3x less likely than other industries).

An ageing workforce is a key risk - 40% in the sector to potentially retire in next 15 years.

The supply chain for plant, equipment and materials

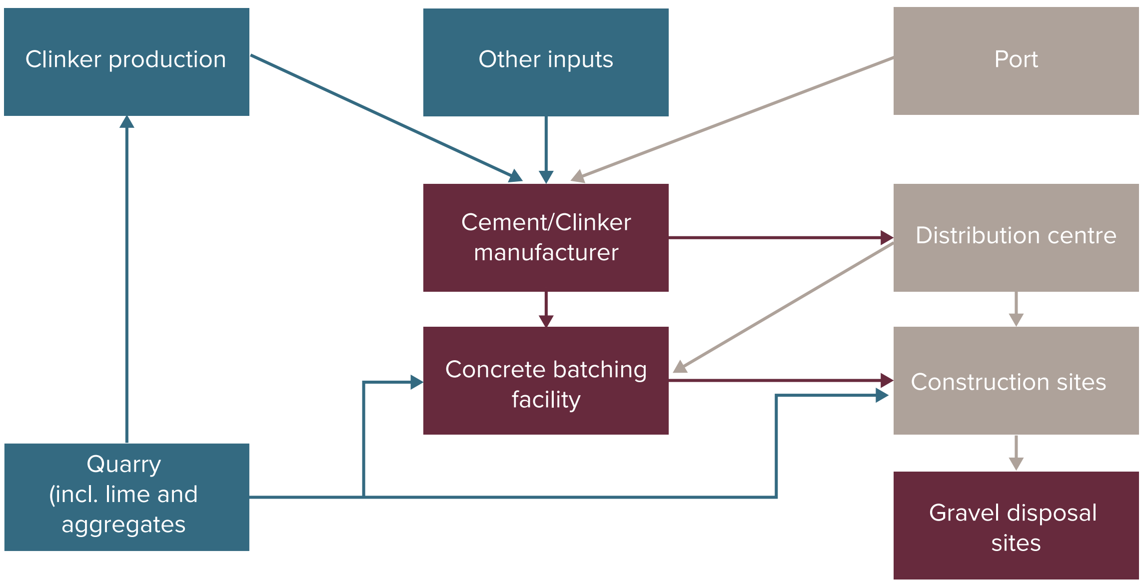
Quarry materials (stone, gravel and sand) are one of the most-transported commodities by volume in Australia, with around 160 million tonnes transported to/from construction and industry sites each year. Unlike high-volume primary commodities such as iron ore, coal and grain that are mainly transported in rural areas and by rail in large train configurations, a large proportion of quarry materials are transported in urban areas, by road. Freight paths and capacity planning for quarry material requirements can vary significantly from year to year depending upon the mosaic of infrastructure investments and construction sites. These impact source provider, transport distances, routes and freight volumes. Supply routes are also geographically impacted depending on the capacity of quarries for different types of aggregates used in cement, concrete, asphalt, rail track ballast etc. For many large urban markets, there is a growing necessity to source suitable aggregates from further away, since closer suppliers have reached their operating capacity. This increases the tonnes-kilometre freight task of quarry materials along the road network, but also opens up opportunities for interventions to reduce this impact.

Infrastructure Australia is working with CSIRO on a project that will to provide a freight analysis and capacity planning capability for different types of materials from quarries through to processing facilities (e.g. cement manufacturers) and to construction sites, using the TraNSIT, developed by CSIRO. It will map supply chains and quarry material freight volumes for projected future developments (e.g. a target year such as 2025), and the corresponding quarry material requirements between years and produce scenarios based on future requirements.

The proposed scope of the quarry materials supply chain is shown in Figure 55 and includes the cement/concrete supply chains. Both locally produced and imported inputs are included. Road and rail are considered, as well as coastal shipping which is extensively used for clinker and other materials. The scope tentatively includes gravel disposal which represents a large percentage of the total freight for quarry materials, but will depend on data availability.

Further outcomes from this project will form part of Phase 2 of Infrastructure Australia's market capability analysis.

Figure 55: Proposed supply chain map for quarry materials



Skills supply to meet the Major Public Infrastructure Pipeline

As noted, Australia has ambitious plans when it comes to investing in public infrastructure. Major public infrastructure activity across transport, utilities and buildings is expected to nearly double over the next 3 years. A skilled workforce that is available when required will be pivotal in realising these plans.

The proposed rapid expansion of public infrastructure is testing the limits of the existing workforce capacity and capability, with signs of shortages already prevalent.

Occupations, roles and skills needed to deliver public infrastructure

Occupations

The infrastructure workforce consists of four main occupational groups:

1. **Project management professionals** are involved in the planning, organisation, direction, control and coordination of the construction process. These occupations are typically responsible for the physical and human resources engaged across the construction lifecycle, including planning, procurement, risk and compliance.
2. **Engineers, scientists and architects** are engaged on infrastructure projects to design, plan, organise and manage the detailed specifications of the construction and maintenance. These occupations are typically engaged early in the construction process, for the duration of the build, and include many subspecialists that have specialised knowledge.
3. **Structures and civil trades and labour** includes individuals experienced in the pre-construction preparation and construction works. It includes most occupations that assist a project to get 'out of the ground'. It includes excavation, steelwork, concreting, carpentry, and drilling. It also includes activities that underpin these tasks, such as cranes and trucks.
4. **Finishing trades and labourers** includes individuals who move infrastructure projects from construction to completion. They develop the fit out for construction projects and ensure infrastructure is operational and can be used for their intended purpose.

Each group contains discrete occupations, as set out in Figure 56.

Figure 56: Public infrastructure occupational taxonomy

Project management professionals

- Risk management
- Project management
- Commercial management
- Procurement
- Environmental and occupational health professionals (e.g. HESQ)
- Construction management

Engineers, scientists and architects

- Engineering manager
- Materials engineer
- Electronic and electrical engineer
- Mechanical engineer
- Production engineer
- Civil engineer
- Geotech engineer
- Quantity surveyor
- Structural engineer
- Telecommunications engineer
- Draftsperson
- Architect
- Landscape architect
- Environmental professionals
- Geologists, Geophysicists and Hydrogeologists
- Land surveyor
- Building surveyor
- IT professionals/engineers
- Maintenance planner
- Other professional engineers, scientists etc.

Structural and civil trades and labour

- Rigger & dogman
- Structural steel erector
- Plant operator
- Road based civil plant operator
- Bricklayer
- Carpenters and joiners
- Concreter
- Rail track worker
- Crane op
- Truck drivers
- Driller (piling/foundations)

Finishing trades and labourers

- Telecoms field staff
- Plumbers
- Mechanical trades workers
- Painting trades
- Tiler
- Plasterer
- Glazier
- Electricians
- Electrical line workers
- Telecoms cabler
- Telecommunications trade assistant
- General construction labourer
- Safety officer

Note: These occupations were informed by ANZSCO and through consultation with Infrastructure Australia's industry experts and key stakeholders. This classification was developed to account for the limitations of the existing ANZSCO taxonomy.

Source: Nous Group commissioned by Infrastructure Australia (2021)

Outside of the four main occupational groups there are other occupations that make public infrastructure possible. This fifth group of individuals includes individuals that support general business operations in any organisation – for example human resources, administration and accounting as well as specialists in other industries like bankers, lawyers and economists. This group of individuals has been excluded from this analysis but are no less important to the functioning of the infrastructure industry and represent an opportunity for future research and analysis of supply constraints.

Roles

Each occupation also includes a range of roles that reflect the different specialisations or experiences that distinguish positions within a given occupation. This provides a greater level of specificity on the workforce needed to support the delivery of the infrastructure pipeline that would otherwise be masked by utilising only ANZSCO.

Skill sets

Public infrastructure relies on a large workforce with a broad range of skills. These range from long-practiced and common skillsets to those that are niche and at the cutting-edge of technology.

At the most granular level, every occupation and role represent a portfolio of skills. Skills are combined in different ways to perform specific jobs or tasks. For the purposes of this analysis three categories of skills have been identified:

- **Generalist skills** are often referred to as enterprise or soft skills and include skills or attributes that are common to most occupations such as communication, problem solving and time management.
- **Technical skills** are required to perform specific, practical tasks that are necessary for many occupations, but are not confined to construction. These may include skills such as project management, stakeholder management or quality assurance and control.
- **Specialist skills** are required by a specific profession and often require a certain qualification or accreditation. Construction related specialist skills are often distinct to the industry. These include types of engineering, construction management and construction labour skills.

Analysis of the skills employers are seeking in job ads shows that most roles require a combination of these skills, with generalist and technical skills to provide breadth, and specialist skills the depth. This is illustrated in Figure 57, which is based on analysis of Burning Glass data for each occupational group.

Figure 57: Skill profiles by occupational group

	Project management professionals	Engineers, scientists and architects	Structural and civil trades and labour	Finishing trades and labourers
	Communication Skills	Planning	Teamwork / Collaboration	Detail Orientation
General skills and attributes	• Building effective relationships • Problem solving • Organisational skills • Time management • Computer literacy • Leadership	• Building effective relationships • Problem solving • Mentoring • Written communication • Verbal/oral Communication • Time management	• Time management • Customer service • Computer literacy • Positive disposition • Problem solving • Organisational skills	• Time management • Customer service • Computer literacy • Preventive maintenance • Energetic • Leadership
Technical skills	• Project management • Scheduling and budgeting • Stakeholder management • Quality assurance and Control • Contract management	• Project management • Scheduling and budgeting • Commissioning • Report and proposal writing • Quality assurance and control	• Scheduling and budgeting • Quality assurance and control • Logistics • Procedure development • Occupational health and safety	• Scheduling and budgeting • Cardiopulmonary resuscitation • Quality assurance and control • Logistics • Procedure development
Specialist skills	• ISO 14001 standards • Construction management • Managing subcontractors • Construction industry knowledge • Rail safety	• Environmental consulting • Engineering design • Engineering (civil, electrical, mechanical, geotechnical etc) • Structural design • Digital engineering e.g. BIM	• Carpentry • Mobile plant operation • Delivery unload and breakdown • Power tools • Road construction	• Electrical • Plumbing • Roofing • Tools (hand and power) • Painting • Welding

7

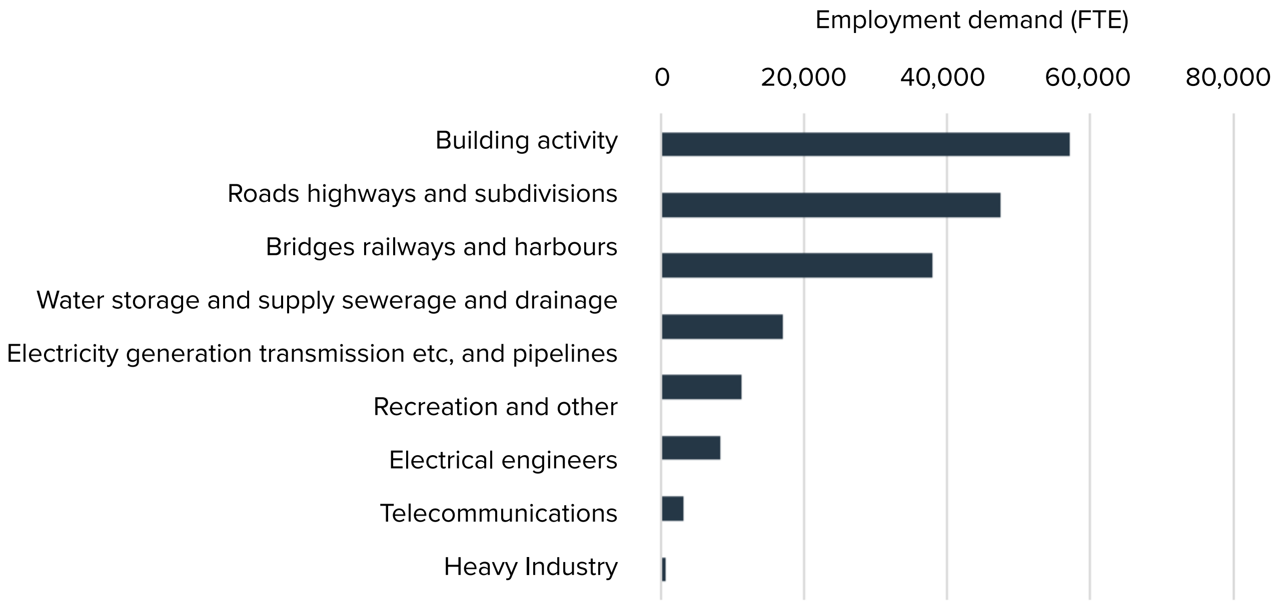
Source: Nous Group commissioned by Infrastructure Australia (2021)

The current public infrastructure workforce

There are approximately 182,000 people currently working on public infrastructure projects across Australia, classified as the engaged workforce.

Figure 58 shows most of the engaged workforce is in building activity (residential and commercial construction), roads highways and subdivisions, and bridges, railways and harbours.

Figure 58: Engaged workforce activity



Source: Nous Group commissioned by Infrastructure Australia (2021)

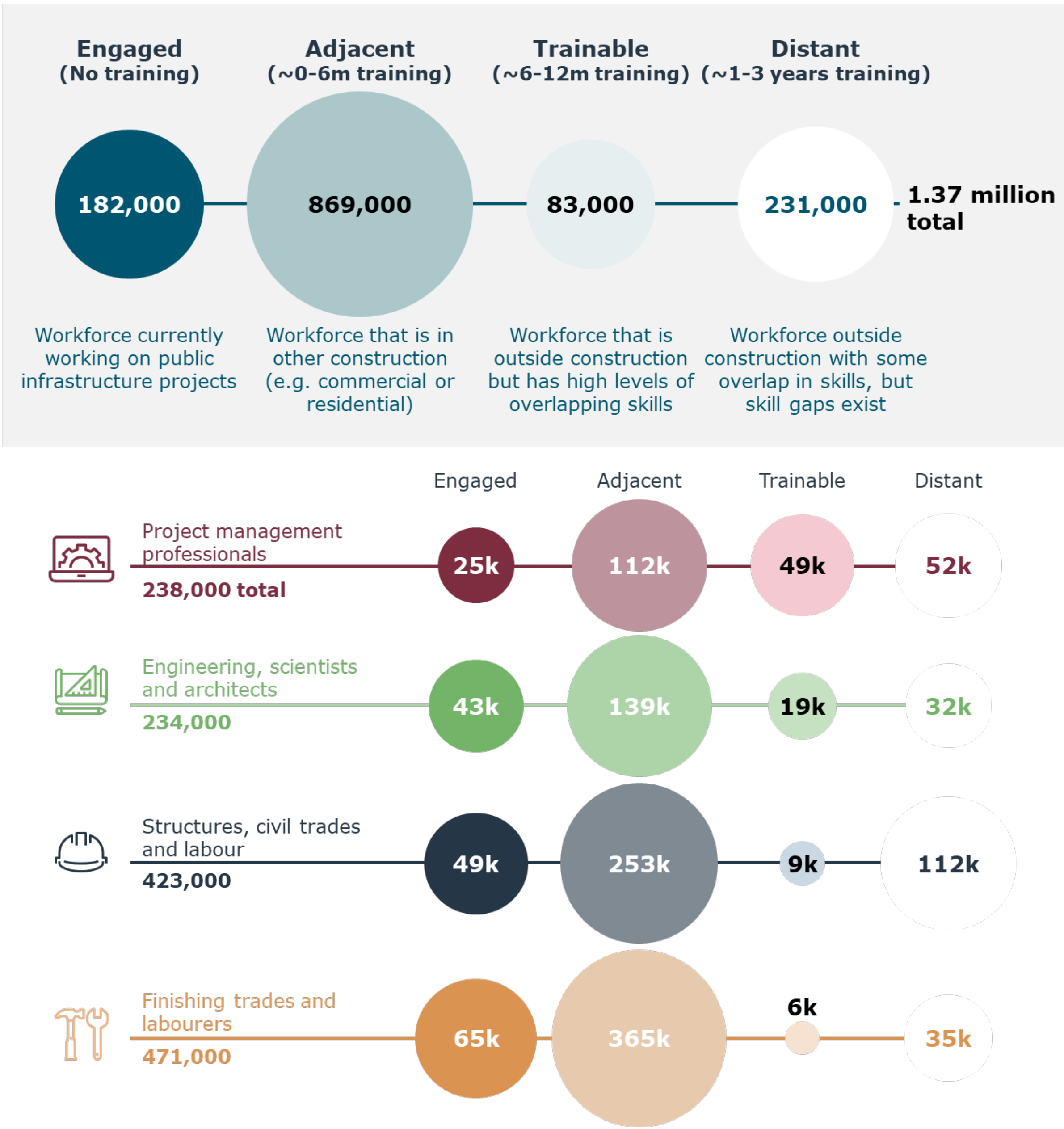
The total workforce with infrastructure relevant occupations

Beyond the engaged workforce, there are another 1.18 million individuals working in infrastructure relevant occupations (seen in Figure 56). They can be classified into three further categories differentiated by their readiness to transition to the engaged workforce: adjacent, trainable and distant.

The adjacent category includes people working in other construction sectors, while the trainable and distant groups have been defined based on the similarity of the skills requested by employers. The closer a worker is to engaged, the less additional training would be required to be ready to work on public infrastructure. Estimates range from 0-6 months for adjacent through to 1-3 years if distant.

Figure 59 provides definitions of the readiness categories and a snapshot of the total workforce. It shows that while there is a large adjacent workforce in other construction sectors, only project management professionals have significant numbers in the trainable category. While there is a large distant category, these individuals will likely require significant retraining before they could be redeployed to public infrastructure projects.

Figure 59: Total workforce in infrastructure relevant occupations



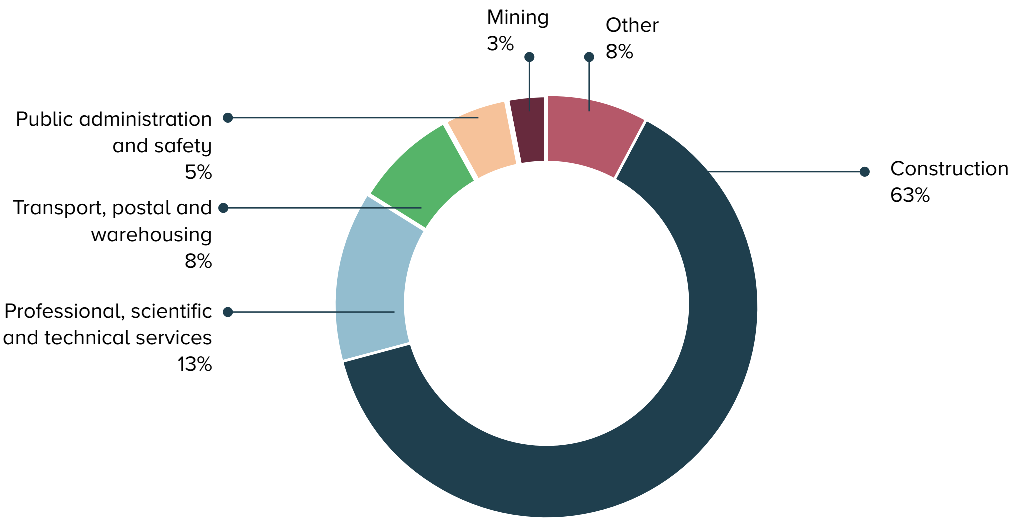
Source: Nous Group commissioned by Infrastructure Australia (2021)

Limitations of the total workforce

Of the 1.37 million people working in infrastructure relevant occupations, 63% are in the construction industry (using the ANZSIC), which includes public infrastructure, along with residential construction, civil construction and private industrial and commercial construction.[34] The remaining 37% work in other industries such as professional, scientific and technical services; transport, postal and warehousing; public administration and safety; and mining.

Figure 60 shows how these individuals are distributed by industry.

Figure 60: Distribution of infrastructure relevant occupations by industry



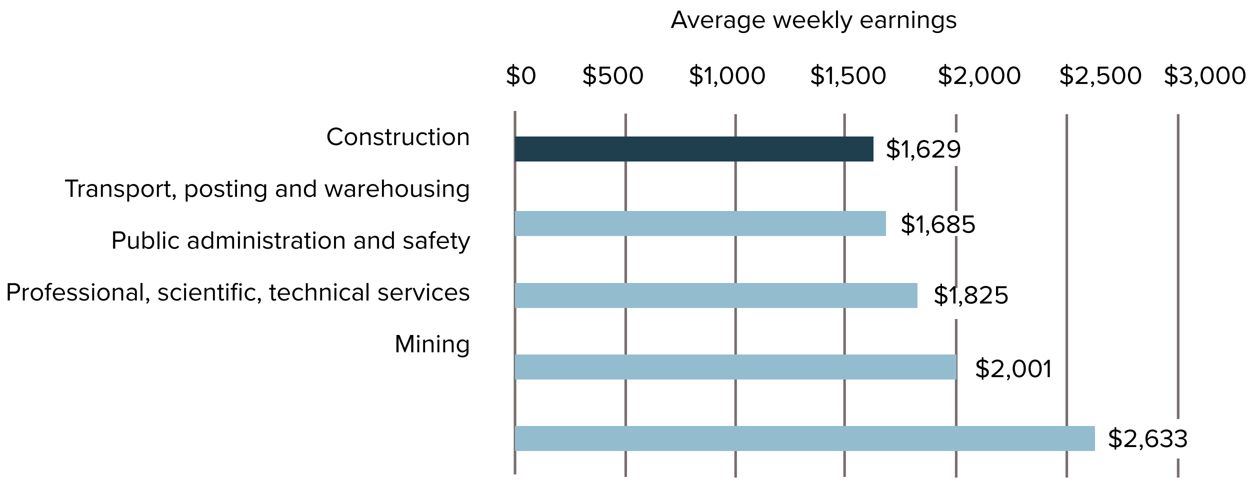
Source: Nous Group commissioned by Infrastructure Australia (2021)

This shows that large portions of the 1.18 million workforce in the adjacent, trainable and distant categories are in fundamentally different roles and may not actually have the skills needed to work in public infrastructure, although they could be retrained with sufficient time and resources. While this presents as an opportunity to address changing workforce requirements of public infrastructure it will not be a realistic solution in many cases.

Most of the adjacent, trainable and distant workforce is already gainfully employed, and so the individual must want to leave to attract them to public infrastructure. Overcoming this hurdle is not insignificant, as industry consultations repeatedly referenced the difficulty of managing workforces through boom and bust periods, which are hard to predict and make the industry unappealing to new entrants.

Many other industries that rely on similar skillsets often pay more and are more likely to keep or attract individuals. Figure 61 shows that construction has relatively low average earnings compared to other industries, suggesting that attracting individuals may not be a reliable approach and would likely result in escalating costs.[35]

Figure 61: Average weekly earnings of industries that employ infrastructure relevant occupations

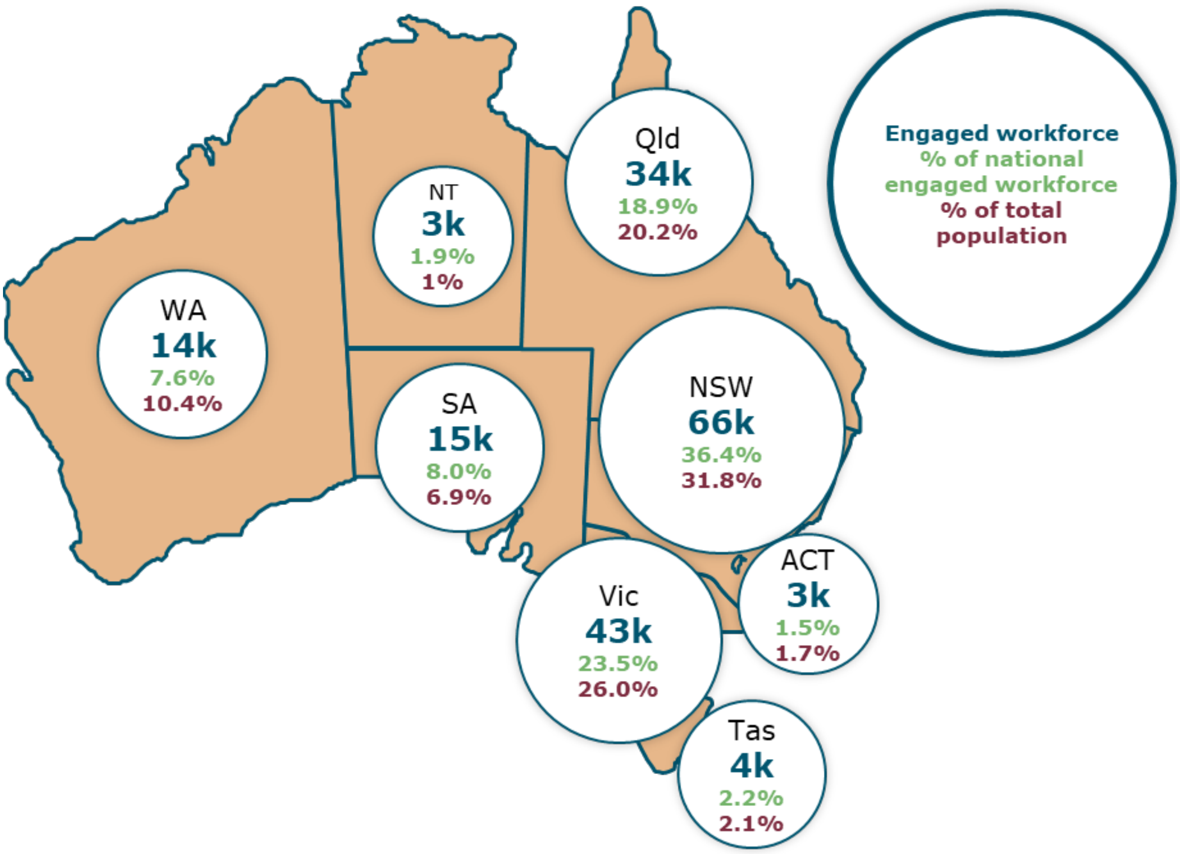


Source: ABS (2021)

The workforce resides in cities and larger states

The engaged workforce is geographically concentrated, reflecting the location dependent nature of public infrastructure projects. Figure 62 shows that three states dominate, with 79% of individuals based in NSW, Victoria and Queensland.[36]

Figure 62: Distribution of engaged workforce by state and territory



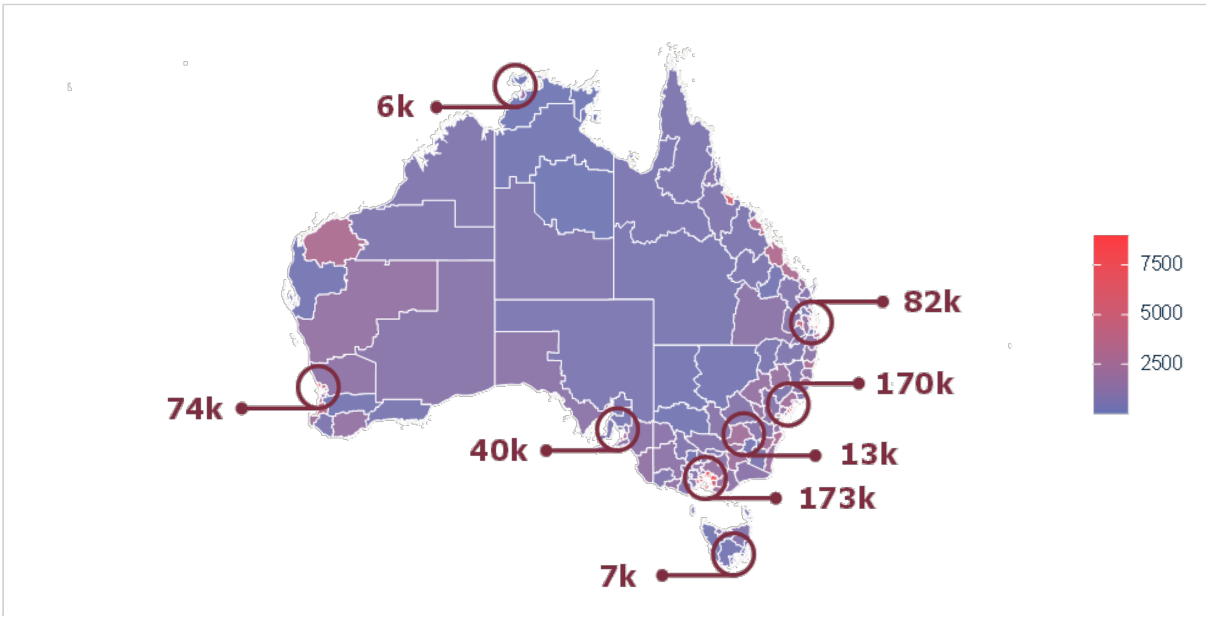
Source: Nous Group commissioned by Infrastructure Australia (2021)

The distribution of occupations across states and territories also differs markedly. For example, nearly two-thirds of engaged engineers, scientists and architects live in NSW and Victoria, while WA has a much higher proportion of finishing trades and labour than other occupational groups..[37] The NT is the largest outlier, with a very strong skew towards both structural and finishing trades, and very few professional roles relative to their workforce. This is likely reflective of the fact that detailed design is something that can be done remotely but physical construction cannot.

The NT is the jurisdiction most concentrated on public infrastructure in 2021, with 28% of individuals in relevant occupations classified as engaged. No other state has more than 20% of the relevant workforce engaged in public infrastructure, and some of the largest workforces in Victoria and Queensland have among the lowest focus on infrastructure, with just 1213% of each state's workforce classified as engaged. This indicates that smaller jurisdictions do not have the diversity in construction work to accommodate significant shifts in demand for public infrastructure. This may exacerbate the imbalance between the public infrastructure workforce concentration in larger states and the population spread across the country as individuals migrate to where opportunities are greater when projects conclude.

Figure 63 shows that the construction workforce is also concentrated in urban areas, more so than the Australian workforce overall. This includes both the engaged and the adjacent workforces as they cannot accurately be separated at this granular level. 78% of the construction workforce live in major cities, as defined by the ABS' Remoteness Area classifications, 3% higher than the share of Australia's total population that lives in these areas.[38]

Figure 63: Distribution of Australia's construction workforce (engaged and adjacent)



Source: Nous Group commissioned by Infrastructure Australia (2021)

From a market perspective, the 3% overrepresentation in major cities can have a significant impact on the ability to deliver public infrastructure outside of metropolitan areas due to the challenges incentivising individuals to move to regional areas. This becomes even harder in a buoyant market.

While competition for labour is impacted by many factors including role specifications and externalities, understanding and implementing methods to enable worker mobility may help to overcome geographical impediments.

Emerging workforce pressures

Of the 50 occupations identified in Figure 56, 16 are likely already in shortage, 18 are potentially in shortage and only 16 are estimated to have sufficient capacity to meet existing demand. These are illustrated in Table 3.

Table 3: Current occupational shortages

	Likely Shortages	Potential Shortages	Unlikely Shortages
Project management professionals	• Procurement management	• Construction management • Risk management	• Commercial management • Environmental and occupational health professionals • Project management
Engineers, scientists and architects	• Building surveyor • Civil engineer • Electrical engineer • Engineering manager • Environmental professionals • Geologists, geophysicists and hydrogeologists • Geotechnical engineer • Land surveyor • Materials engineer • Quantity surveyor • Other professional engineers, scientists, etc.	• Electronic engineer • IT professionals/engineers • Maintenance planner • Production engineer • Structural engineer • Telecommunications engineer • Mechanical engineer	• Architect • Landscape architect • Draftsperson
Structural and civil trades and labour	• Driller (piling/foundation)	• Bricklayer • Carpenters and joiners • Concreter • Crane operator • Rail track worker • Road based civil plant Operator	• Plant operator • Rigger and dogman • Structural steel erector • Truck drivers
Finishing trades and abour	• Electrical line workers • Telecommunications cabler • Telecommunications field staff • Tiler	• Electricians • Glazier • Painting trades • General construction labourer	• Electrical or telecommunications trades assistant • Mechanical engineering trades workers • Plasterers • Plumbers • Safety officers

Note: Each occupation has been assessed for signs of current shortages using four distinct and independent methods (1. Are they on a relevant migration shortlist? 2. Are they recognised by industry through literature or stakeholder consultation? 3. Is there a shortfall of between the currently modelled supply and demand? 4. Do a set of labour market indicators show shortage?). Occupations have been classified as likely to be in shortage if three or more of these assessments showed a shortage, potentially in shortage in two assessments suggested a shortage but the other two did not or were unclear, and unlikely to be in shortage if only one or none of the assessments identified a shortage.

Source: Nous Group commissioned by Infrastructure Australia (2021)

Engineering occupations are currently most at risk of shortage. This is consistent with the feedback from industry stakeholders such as Engineers Australia and Consult Australia. Geophysicists, geotechnical engineers, structural engineers and civil engineers are identified as shortages in most assessment methods. Some of the main drivers of shortages are flagged as lack of applicants with technical skills and experience, and lack of applicants altogether. Master Builders Australia raise similar concerns noting that capital cities as well as regional NSW and Queensland are experiencing difficulties recruiting sufficiently skilled civil engineers.[39] These shortages are typically difficult to address through short-term measures because they require technical expertise and long training periods.

Some shortages appear to be ongoing and systemic, for example building surveyors. The 2018 *Building Confidence Report* indicated an extreme workforce supply issue in the building surveying profession due to an ageing workforce and ill-defined career pathway.[40] Similar concerns were raised by Consulting Surveyors National which noted a workforce shortfall of over 600 surveyors and spatial scientists nationally. This shortfall is expected to continue to increase due to retirements as the average age of surveyors is around 52 years.[41]

The project management professionals occupational group show mixed signs of shortage. Construction managers and procurement managers are on skilled migration lists, while analysis of supply and demand shows shortfalls in most occupations, but only procurement management is consistently identified as an area of shortage.[42] Industry associations have recognised current challenges with capacity to support the delivery of projects in Australia.[43] The specific shortages identified are generally for senior roles.

Indicators of shortages for occupations in structural and civil trades and finishing trades and labour are much more varied. Labour market analysis of skilled occupations indicates a shortage of bricklayers in all states except for WA and the NT. This is also supported by a 2020 job report by Hays.[44] However, most of the potential shortages indicated under structural and civil trades and labour were recognised by industry or by demand supply analysis but not reflected in the migration lists or labour market indicators. This may mean shortages are felt more acutely in specific regions or specific specialisations.

Conversely, many of the potential shortages flagged in finishing trades and labour are recognised by various migration lists and stakeholder feedback but do not appear in labour market indicators or supply and demand data. This includes electricians, glaziers, and electrical line workers so may be due to heightened demand in other sectors.

Hidden workforce challenges

Just as assessment of the overall market can mask shortages for specific occupations, assessment at an occupational level masks challenges at the more granular level of specific roles.

Shortages can be found amongst specialist roles within an occupation or at more senior levels, even if overall there appears to be enough people in the occupation. Just because demand for a role is small does not mean it is any less critical to the delivery of public infrastructure. The absence of one worker with a specific skill set can have significant implications for a project and a debilitating impact on the industry if not addressed.

Analysis of shortages at role level has to date been limited to qualitative insights from industry with limited data available. However, non-traditional data sources such as Burning Glass job advertisement data can shed light on sub occupational trends.

Table 4: Roles likely in shortage

	Role shortages within occupations that are likely in shortage	Role shortages within occupations that are unlikely or potentially in shortage
Project management professionals	• Procurement specialist • Purchasing officer • Construction supervisor • Procurement officer • Senior procurement officer	• Risk and compliance manager • HSE advisor • Safety advisor • Senior strategic planner
Engineers, scientists and architects	• Senior software engineer • Senior estimator • Environmental advisor • Senior environmental advisor • Ecologist • Application support analyst • Head of engineering • Geologist • Hydrogeologist • Principal geotechnical engineer • Electronic engineer • Senior signalling engineer • Telecommunications engineer • Building inspector • Building certifier	• Mechanical engineering technician • Automation tester
Structural and civil trades and labour	• Joiner • Apprentice carpenter • Concreter • •Crane operator • Driller • Blast hole driller	• Multi combination driver • Grader operator • Dozer operator • Reach forklift driver • Excavator operator • Backhoe operator • Final trim grader operator
Finishing trades and labour	• Electrician • Industrial electrician • Electrical supervisor • Industrial painter • Apprentice painter • Powder coater • Linesperson • Tiler • Wall and floor tiler	• Diesel fitter • Fitter • Mechanical fitter • Drainer • Electrical trade assistant • Maintenance plumber • Pipefitter • Solid plasterer

Between 2021 and 2024 shortages are anticipated in all four occupational groups. The scale of anticipated shortages is outlined in Figure 64 which compares the projected supply and demand currently to the peak shortage in 2023.

Some roles that are likely to be in shortage are outlined in Table 4, above. Details on projected shortfalls are noted in Figure 64 below.

Figure 64: Projected shortages by occupational group

Occupation groups	Current shortfall	Peak projected shortfall (2021-2025)	Occupation groups	Current shortfall	Peak projected shortfall (2021-2025)
Project management professionals	13,700	19,100	Structures, civil trades and labour	-6,200	Up to 15,700
Engineers, scientists and architects	63,900	70,200	Finishing trades and labourers	-20,700	Up to 13,600

Note: Analysis shows the highest total difference between demand and supply for an occupation group in any month between 2021 and 2024.

Source: Nous Group commissioned by Infrastructure Australia (2021)

Our analysis shows a range of shortages in specific roles within each occupational group. Many of the role shortages identified through analysis and stakeholder consultation exist in senior, experienced positions. For example, principal geotechnical engineers, senior signalling engineers, and heads of engineering (in the engineers, scientists and architects occupational group) have been identified as roles that are likely to be in shortage.

A general comparison of senior roles (i.e. those requiring five or more years of experience) to more junior roles shows that they have different skill profiles.[45] Across all four occupation groups, senior roles have a slightly less emphasis on generalist skills, suggesting they are expected to provide more specialised value. For example, junior project management professionals are required to be detail-orientated and show organisational skills (both generalist skills), while senior roles in the same occupations require technical skills in budgeting, scheduling and risk management. Among engineers, scientists and architects, leadership skills such as mentoring become important at the senior levels.

Similar trends appear for roles that require greater technical specialisation. For example, while few indicators suggest an overall shortage of plumbers, there are potential shortages in specialist roles including drainer, maintenance plumber and pipefitters. This is also seen in plant operator roles, including grader operator, excavator operator and backhoe operator.[46] By their nature these more senior or specialist roles are likely to be filled by older workers. Shortages could be exacerbated as those with highly specialised occupational knowledge retire.

Systems engineers are flagged by industry stakeholders as an area of extreme current shortage, despite quantitative indicators showing an adequate supply of the broader occupation production engineers. Systems engineers are a niche and highly experienced role that is small enough to be outweighed by other roles but can be a key dependency risk for projects.

Conversely, potential shortages exist in some apprentice and junior roles. This includes potential shortages in apprentice carpenters and painters and electrical trade assistants. For carpenters and painters that are categorised as potentially in shortage, this may indicate that existing shortages are driven by a weak pipeline for entry level workers.

In addition, industry stakeholders working in rail suggest a worsening shortage of roles integral to rail infrastructure, in particular rail signallers and systems engineers. Consultation with industry bodies suggested that these shortages are worse in WA where similar roles are utilised by the mining sector. Specialist rail worker positions, including rail surveying or rail construction management, require large amounts of technical knowledge. Therefore, a shortage of only a few individuals can have a significant impact on a jurisdiction's ability to meet rail project milestones. Rail track workers were also flagged as an area of potential shortage due to unprecedented demand and competition for entry level workers. Shortages in rail are expected to increase in light of international travel restrictions due to the COVID-19 pandemic as the sector heavily relies on overseas skilled workers.[47]

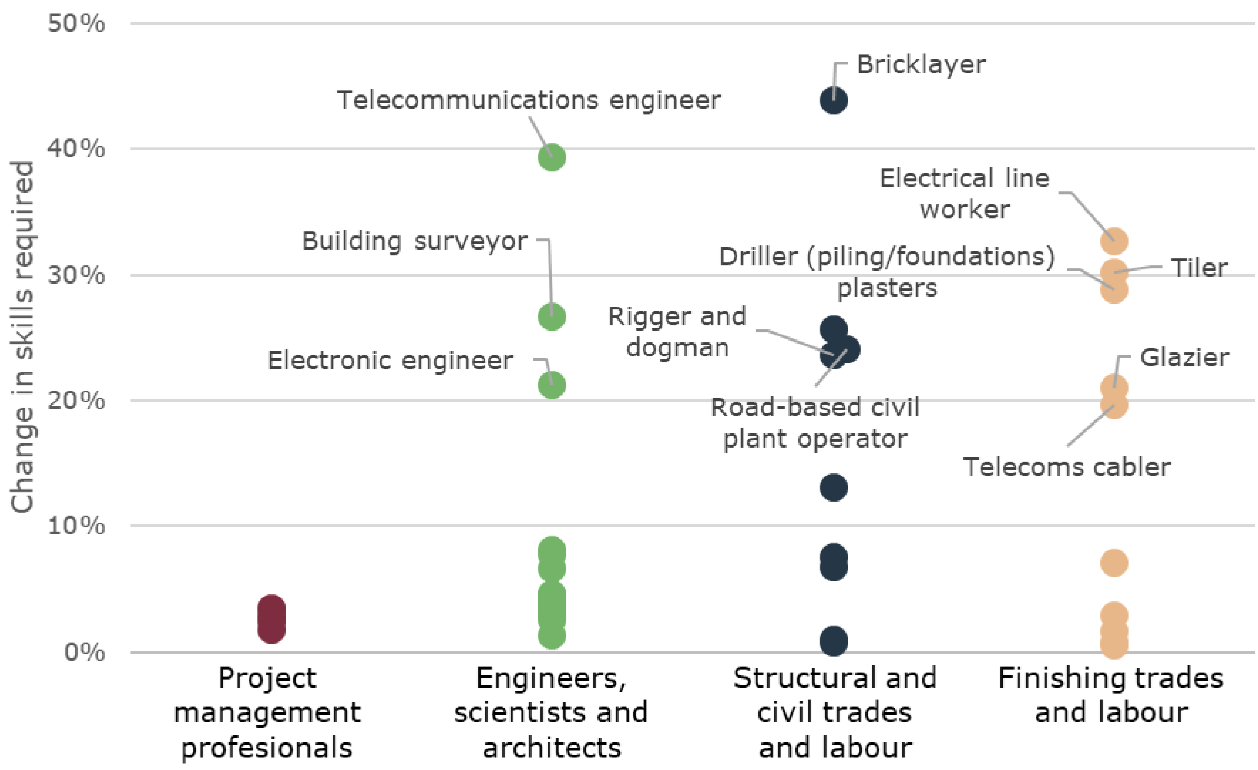
Changing skill needs compound shortages

When the skills needed for an occupation change rapidly, large proportions of the workforce may find their skills are out of date. This can result in employers struggling to find appropriately skilled staff, not because there are not enough people in the occupation but because those people no longer have the relevant skills. This situation is a result of a skills mismatch as opposed to shortage.

Figure 65 highlights the occupations that have experienced the largest shift in required skills in recent years, so are at the greatest risk of a skills shortage.

Almost all the occupations identified have been assessed as potentially or likely in shortage, suggesting that they are experiencing skills shortages or that this is driving labour shortages.

Figure 65: Change in skills required by occupation (2017–2020)



Source: Nous Group commissioned by Infrastructure Australia (2021)

Some of these changes are reflective of changes in the industry, where occupations increasingly require a stronger mix of generalist, technical and specialist skills. Bricklayers and telecommunications engineers have had some of the largest increases in requirements for generalist skills among all occupations, while tilers, plasterers, glaziers and building surveyors were already some of the most focused on generalist skills. On the other hand, drillers (piling/foundations) have substantially increased their focus on specialist skills. Electronic engineers are one of the occupations most focused on specialist skills, even after experiencing one of the largest shifts towards generalist skills in recent years.

The desire for a greater combination of generalist and technical, and specialist skills is strongest in science, technology, engineering and mathematics (STEM) orientated occupations such as engineering. Just 24% of skills required for engineers, scientists and architects are generalist, compared to 32% in other infrastructure occupations.[48] This may be changing, as digitisation and automation across the construction sector has introduced a new set of skills along with increasingly complex project arrangements that place a premium on effective communication and multidisciplinary understanding.[49] This is not restricted to specialist skills. A similar trend is occurring with trades and labour where multiskilled individuals are highly valued.[50]

Change across the industry is also seen in the emerging skills that make use of new technologies and processes and eventually replace obsolete skills. Figure 66 identifies the top emerging skills across the industry.

These emerging skills show increasing trends such as a greater priority on skills in logistics and procedure development and technologies like asset management software. Emerging skills also often relate to roles in with skills shortages due to the lag between demand and workers developing the new skills. This lag comes firstly from the delay in demand becoming widespread enough that the workforce must respond and then in the time taken to train and develop the relevant skills.

Figure 66: Skills emerging over the last five years by occupational group

	Project management professionals	Engineers, scientists and architects	Structural and civil trades and labour	Finishing trades and labourers
Emerging skills	• Logistics • Asset management software (e.g. Maximo) • Procedure development • Scheduling • Quality assurance and control	• Brownfields • Systems engineering • Geotechnical engineering • Logistics • Engineering management	• Quality assurance and control • Asset management software (e.g. Maximo) • Budgeting • Delivery unload and breakdown	• Logistics • Procedure development • Asset management software (e.g. Maximo) • Budgeting • Planning

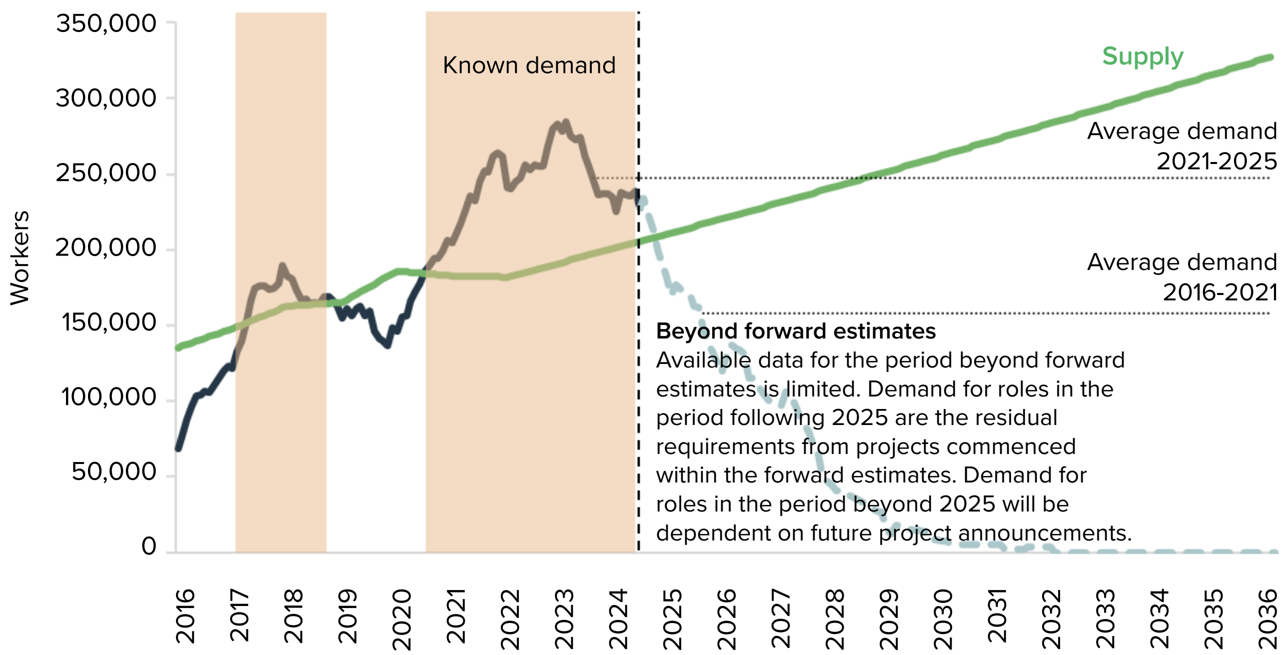
Source: Nous Group commissioned by Infrastructure Australia (2021)

The future workforce supply challenge

Australia's demand for public infrastructure is forecast to reach unprecedented levels over the next three years. The workforce consequences are significant with labour shortages anticipated to be almost three times more than that in 2017–2018.

Figure 67 shows historical and projected supply and demand with projected labour shortages lasting from late 2020 to late 2024, peaking at a gap of almost 93,000 additional roles being required in early 2023.[51] An additional demand for approximately 12,000 project-based roles forecast in the energy sector lifts this total to 105,000 additional roles being required by mid-2023 (see Figure 53). At this peak demand 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% over the same period.

Figure 67: National supply and demand for public infrastructure workers, historical (2016–2021) and projected (2021–2032)



Source: Nous Group commissioned by Infrastructure Australia (2021)

Note: the visibility of forward infrastructure spending is limited by available data. Only publicly known projects are included, and therefore generally occur within the forward estimates. As a result, future expenditure is likely to be larger than forecast beyond the forward estimates as new projects are announced. Increased clarity of the long-term pipeline is highly desired to support this understanding.

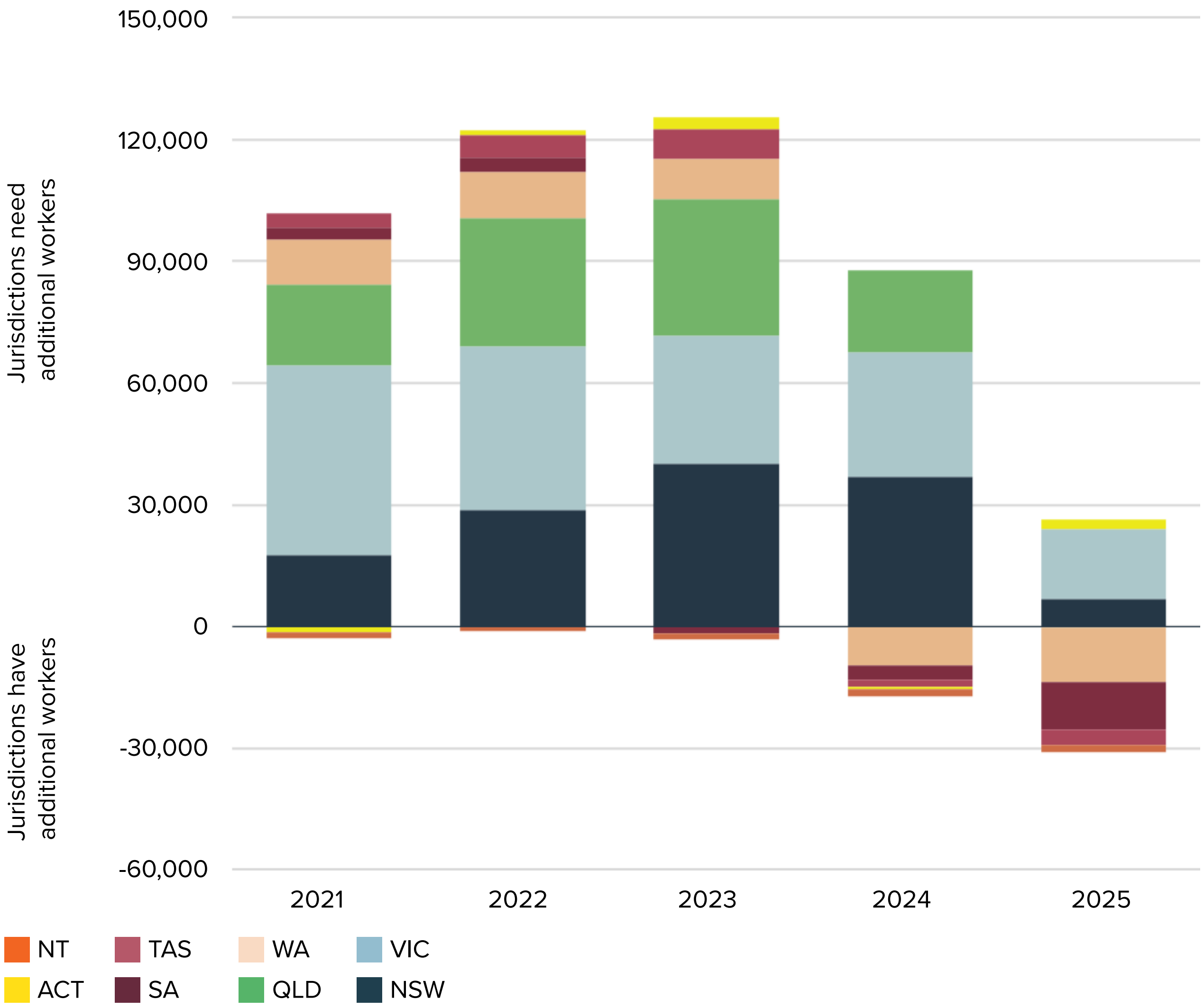
While Figure 67 illustrates an equilibrium of sorts being reached by late 2024, projections only account for projects confirmed as of 30 April 2021. The decline in known demand shown after late 2024 is not a reliable forecast. Recent announcements and new infrastructure projects over coming years will push demand up in future years.

The national picture also masks significant variation across the country. Figure 68 is based on the same analysis as Figure 67 and shows that NSW, Victoria and Queensland face the greatest risk of shortage. In every year from 2021 to 2024 demand is anticipated to outpace supply for these three states. In 2024, NSW and Victoria show signs of continued shortage as other jurisdictions wrap up their currently confirmed projects.

All states and territories except the NT are projected to need to increase their workforce by 47% or more beyond projected supply to meet peak demand. In considering potential shortages across states and territories it is important to note also the potential impact from competing sectors of the economy, for example oil and gas construction, not captured through this analysis as it is focused on major public infrastructure. Victoria, Queensland and Tasmania all have points where they will need workforces approximately double (or more in Tasmania's case) what is projected to be available within their borders. The timing of shortages is also varied – Victoria is already in a shortage that will continue until 2026, while SA's most significant shortage is not until 2027.

The variation between states means there will be some opportunity to resolve specific local shortages by reallocating individuals across the country. However, this will not address the major national shortages across 2021–2024.

Figure 68: Net additional Major Public Infrastructure Pipeline workers required by state and territory



Source: Nous Group commissioned by Infrastructure Australia (2021)

Future shortages

Between 2021 and 2024 shortages are anticipated in all four occupational groups. The scale of anticipated shortages is outlined in Figure 64 which compares the projected supply and demand currently to the peak shortage in 2023.

The projections underlying this figure show that pressure on the supply of all occupations will increase over the next few years. This will exacerbate the difficulties in sourcing occupations identified as already experiencing shortages (seen in Figure 67).

Occupations in engineering, science and architecture that are currently experiencing shortages are generally experiencing or soon to experience the most extreme peak of their potential shortage. For example, while existing shortages in geotechnical engineers, geologists, geophysicists and hydrogeologists and quantity surveyors will grow, the growth will not be exponential. Shortages in land surveyors and civil engineers on the other hand are likely to continue to increase incrementally over the next few years.

Over 41,000 further individuals are estimated to be required to fill engineering occupations including positions in civil, geotechnical, structural and materials engineers. Of all the occupations, materials engineers have the largest projected workforce shortage and will require the profession to increase fivefold to meet demand.

The land surveyor profession will need to double and almost all building surveyors who are currently working in other industries (such as residential construction) would need to transition to public infrastructure to meet demand. Much of this demand is driven by infrastructure work in NSW and Victoria. Shortages in quantity surveyors are anticipated to be concentrated in Queensland and Victoria.

While most project management occupations are not currently experiencing shortages, there will be an increased pressure on supply in the next few years as shortages in commercial management and project management are expected to develop. Targeted measures to increase current supply of these professions will be required soon to avoid significant future constraints.

Likewise, occupations in finishing trades and labour will experience more severe shortages in the coming years than are currently experienced. This includes in occupations such as general construction labourers, plumbers, painting trades and tilers.

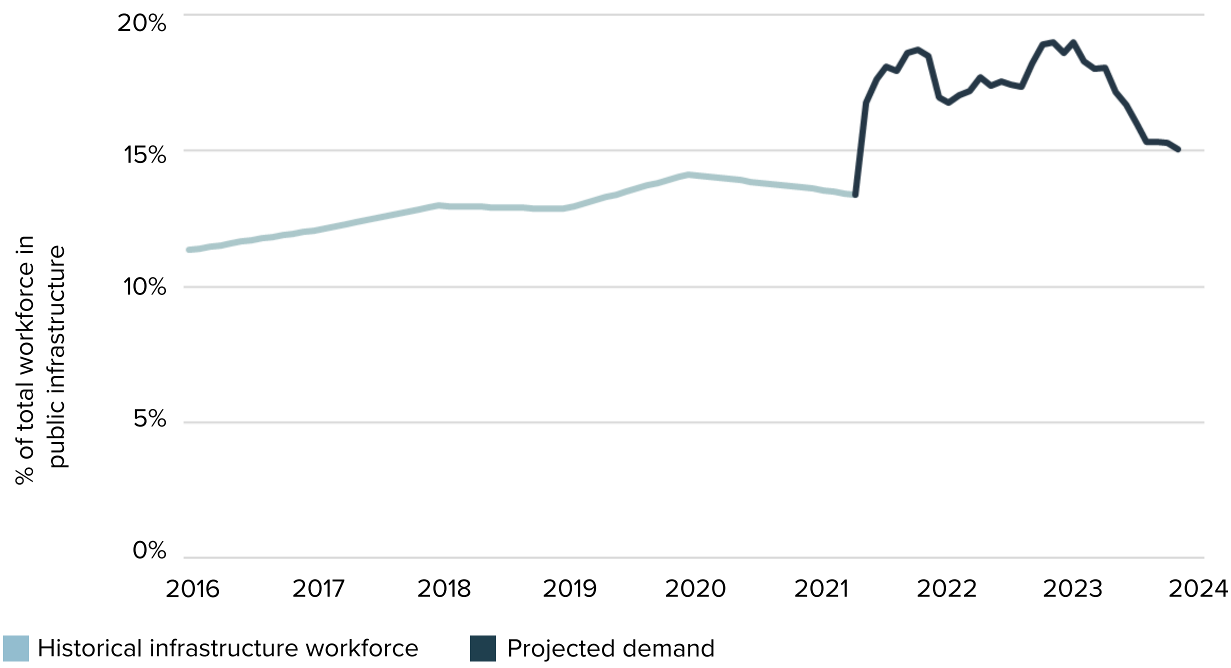
Projected shortages in structures, civil trades and labour are more evenly spread across most of the sub-occupations. There are projected shortages in concreters, crane operators, drillers, rail track workers and structural steel erectors. There is however significant diversity at the jurisdictional level for these occupations. For example, there are no projected shortages for concreters in WA, SA and the NT. For shortages in concreters, projects would only need to draw on approximately 10% of individuals working in other industries to fill potential shortages.

Shortages in drillers and rail track workers on the other hand cannot be filled by transitioning workers in similar occupations in adjacent professions. These may be drawn on by the larger states who will potentially experience future shortages. Plant operators and road based civil plant operators will experience the largest growth in shortages over the next five years.

Consequences for the total workforce with infrastructure relevant occupations

As noted earlier, public infrastructure shares a workforce with other industries (seen in Figure 60). Significant increases in workforce demand for public infrastructure has potential widespread consequences to the general availability of labour. Historically, public infrastructure has utilised around 12-14% of the total workforce in relevant occupations, and currently sits at 13%..[52] If demand estimates are realised this would require the percentage of the workforce supporting public infrastructure to increase to 19% by 2023, as illustrated in Figure 69.

Figure 69: Proportion of total workforce in public infrastructure 2016–2024

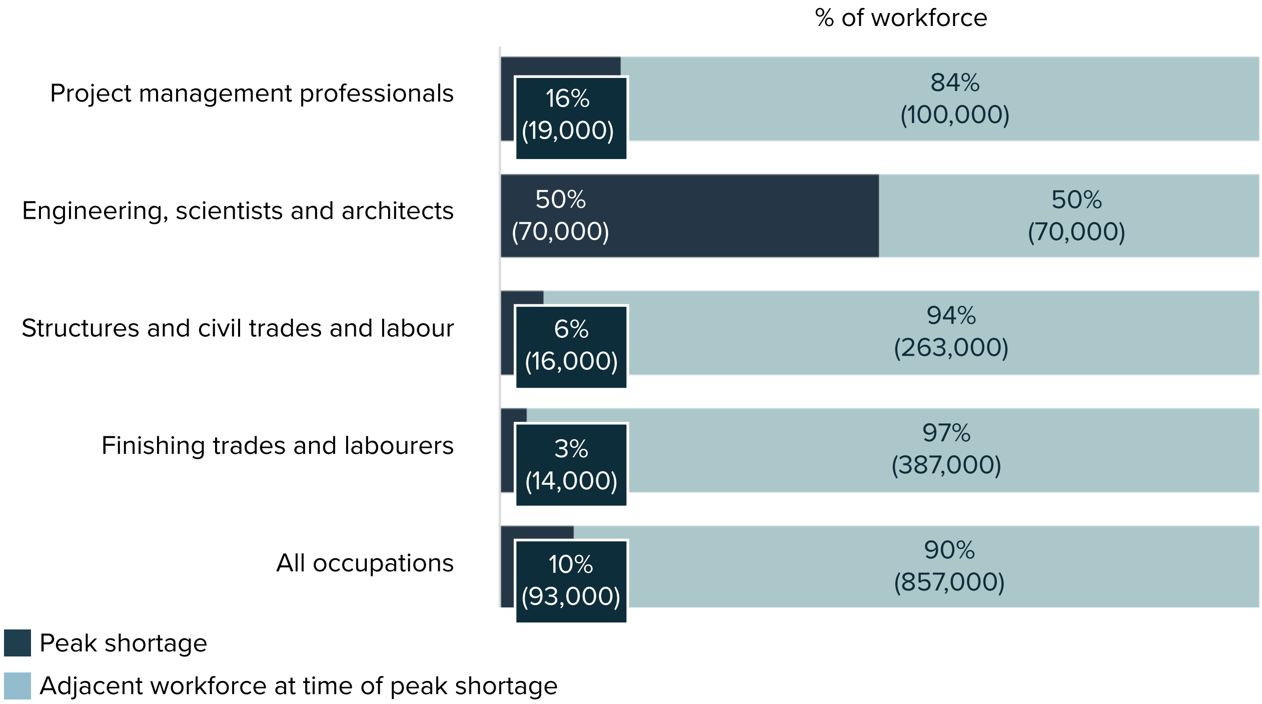


Source: Nous Group commissioned by Infrastructure Australia (2021)

While the share of individuals engaged on public infrastructure has generally increased since 2016, a 5.7% jump in share of workers would be unprecedented. Further, each worker that takes a job delivering public infrastructure will likely leave a vacancy elsewhere that must be filled with cascading impacts across sectors and escalating costs.

Figure 70 shows that the peak projected shortages would require around 10% of the adjacent workforce (those most easily retrained) to move to public infrastructure. This compares to total movement in the past 5 years of only 3.5% of adjacent workers to engaged, or about a third of what would be required to meet the projected peak. This problem is significantly worse for engineers, scientists and architects, where the peak shortage is over 50% of the adjacent workforce, which is projected to occur towards the end of 2021.

Figure 70: Workforce movement required from adjacent to engaged



Note: Adjacent workforce refers to construction, excluding public infrastructure. The adjacent workforce is projected to grow faster than the engaged workforce for all occupation groups except engineering, science and architecture.

Source: Nous Group commissioned by Infrastructure Australia (2021)

Many occupations needed to support future public infrastructure delivery have limited capacity to draw on an adjacent workforce. Over 41% of rail track workers are already classified as engaged suggesting there is little opportunity to increase the engaged supply by retraining people from the adjacent workforce. Amongst occupations already classified as being in shortage, 27% of drillers (piling/foundations) and 25% of building surveyors are already classified as engaged.

Migration will have a role in addressing workforce demand but while it may be the difference between capacity or shortage for some occupations like electrical engineers or specific highly skilled individuals at senior levels, it is unlikely to be sufficient to grapple with the demand for civil engineers, particularly in the face of global demand for these skills as countries around the world leverage infrastructure as part of post-COVID stimulus strategies.

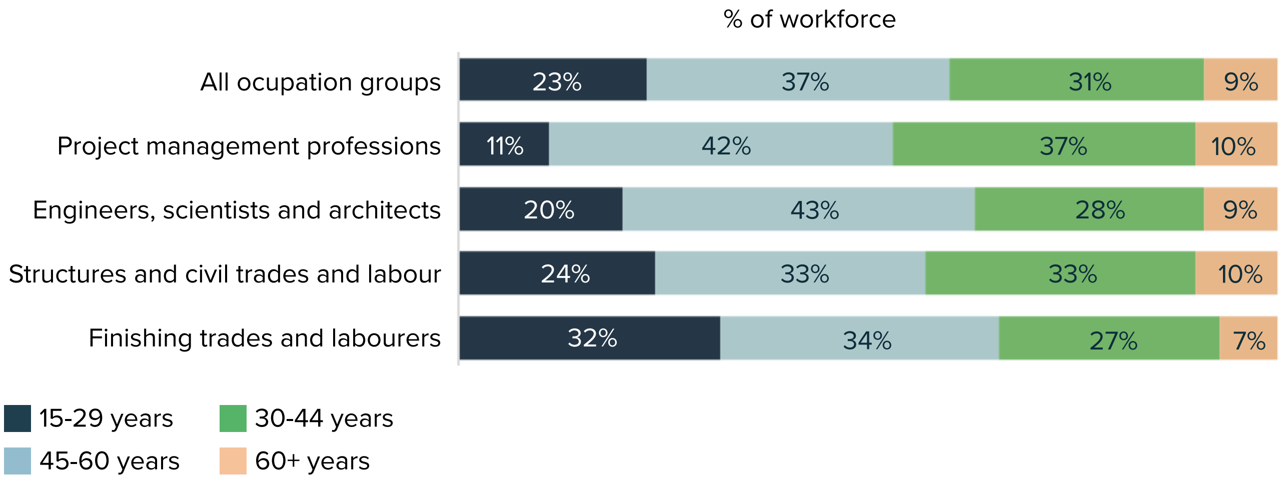
Constraints to addressing the supply challenge

Challenges to retaining the current public infrastructure workforce

The public infrastructure workforce retires young

Over the next 15 years the sector could lose over 40% of its potential workforce due to early retirement. The average age of retirement for a construction worker is 60 years, and labourers even younger at 58.[53] When compared to Australia-wide recent retiree age of 63 years, the construction industry has a significantly greater risk to the availability of skilled and experienced public infrastructure workers, above the broader workforce.[54] In considering this, Figure 71 shows the risk to the potential infrastructure workforce given the substantial portion of the population over 45 years of age.

Figure 71: Distribution of age by occupational group



Source: Nous Group commissioned by Infrastructure Australia (2021)

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% (those in non-labouring roles are likely to retire slightly later). In contrast the workforce for finishing trades and labour and engineering, scientist and architects are younger, with nearly one third of the finishing trades and labour workforce in the 15 to 29 age group. Beneath the high-level occupational groups, the greatest risk from an ageing workforce can be found in building surveyors, crane operators, drivers, safety officers and rail track workers.

Public infrastructure work can be physically demanding. Older, blue-collar workers in the construction industry are more likely to suffer from physical impediments to ongoing work than white-collar professions.[55] While project management professionals, engineers, scientists and architects are less likely to retire for physical reasons, losing the depth of experience in these occupational groups can be devastating to the industry.

How roles are crafted for older team members as they near retirement will be a key determinant in whether the sector will be able to continue to leverage their substantial expertise for an extended duration of years.

Regulation can restrict workforce mobility

States and territories have responsibility for deciding which occupations require registration or licencing, and on what basis. Consequently, differences can emerge between states and territories. Jurisdictions currently maintain a range of regulatory requirements for individuals to practice within their borders.

This is established for architects, building surveyors, land surveyors, plumbers and electricians with moves by a number of states and territories to extend to other occupations such as civil, mechanical, electrical and fire safety engineers.

Occupations which are registered or licensed in one jurisdiction are not automatically recognised elsewhere. Interstate licensing and registration schemes are only accepted under mutual recognition laws, sometimes with conditions on registration equivalents. In practice this means that individuals looking to move may be required to undertake a registration process in one jurisdiction despite already being registered in another.

NSW, Victoria, Northern Territory and the ACT have recently established an automatic mutual recognition scheme for most electrician roles to reduce the regulatory burden for those wishing to move interstate..[56] A national automatic mutual recognition scheme has also passed the federal parliament and received royal assent in 2021, which will enable licensed workers to operate across two jurisdictions (home and one other) using automatic notification.[57] Further enabling mobility between states and territories could benefit states and territories experiencing shortages when others are not, and potentially lead to improved national productivity within existing resources.

Complex procurement processes can consume resources

Public infrastructure procurement approaches in Australia have become increasingly sophisticated, driven by buyer desires to manage cost and risk, and increased transparency required to deliver to policy objectives.

The consequence is a process that requires extensive resources to respond to and manage these obligations. This requires costly resources to be diverted away from other areas. Consultation with industry identified multiple incidences of individuals leaving the sector because of the long hours required to respond to requirements in designated timeframes. Industry consultation also identified excessive information and documentation requirements (Australian bid costs are 25-45% higher than Canadian equivalents, largely driven by increased design focus and purchaser requests), and an emphasis on architectural design and design innovation increasing the required workforce for large projects.[58]

These procurement costs have a direct effect, both from a financial and effort perspective, that have the potential to drive businesses and individuals away from public infrastructure construction to industries that have less arduous procurement processes.

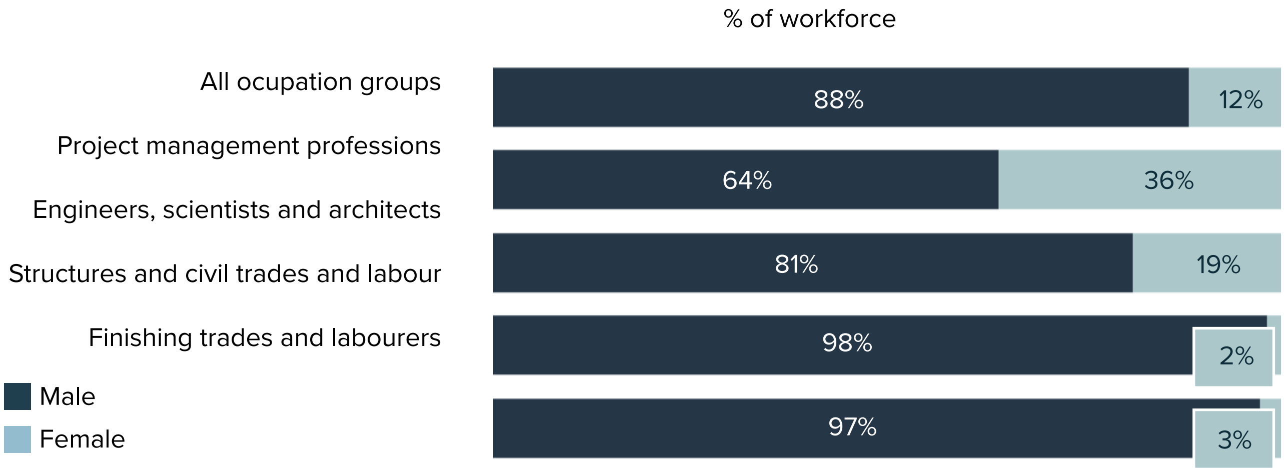
Challenges to growing the future public infrastructure workforce

Female underrepresentation

Women currently make up less than 12.7% of the workforce in construction occupations and less than 2% of related trade jobs.[59] This is a result of historic gender imbalance, insufficient pathways for women into the industry and a lack of strategies to attract and retain women. Further, females are likely to be paid less (between 20% and 26% based on average weekly earnings) and less likely to be in senior positions (three times less likely than other industries).[60]

The extent of this imbalance is represented in Figure 72 which illustrates the male dominated nature of the occupation groups that are relevant to public infrastructure.

Figure 72: Gender by occupational group

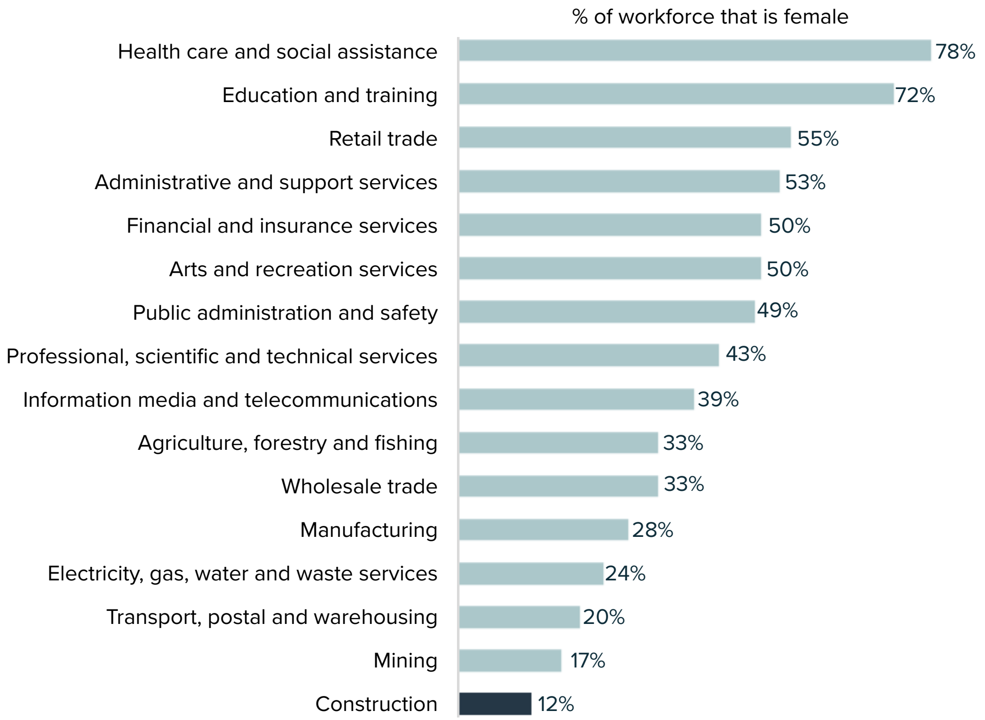


Note: Information for individual occupations is available in Modelling methodology

Source: Nous Group commissioned by Infrastructure Australia (2021)

The gender disparity in the public infrastructure and construction workforce is improving, though very slowly. The overall number of women in construction roles increased by 34% between 2015 and 2020, but is still a small portion of the workforce.[61] As shown in Figure 73, construction has the lowest proportion of female workforce of any industry included in ABS industry benchmarks.[62]

Figure 73: Female proportion of workforce by industry



Source: ABS (2021)

These challenges are not confined to a single occupational group or jurisdiction. Project management professionals appear to have a larger proportion of women than other infrastructure-relevant professions. However, this is likely driven by a large percentage of workforce in those occupations working outside of construction (44%). In contrast construction management as a sub-occupation has a female workforce of 8% which aligns with industry commentary on female participation.[63]

The engineers, scientists and architects group also has greater participation of women. The female workforce in this occupational group is skewed by three specific occupations – architects, landscape architects and environmental professions, three occupations not experiencing shortages – all which have approximately equal participation by women and men.

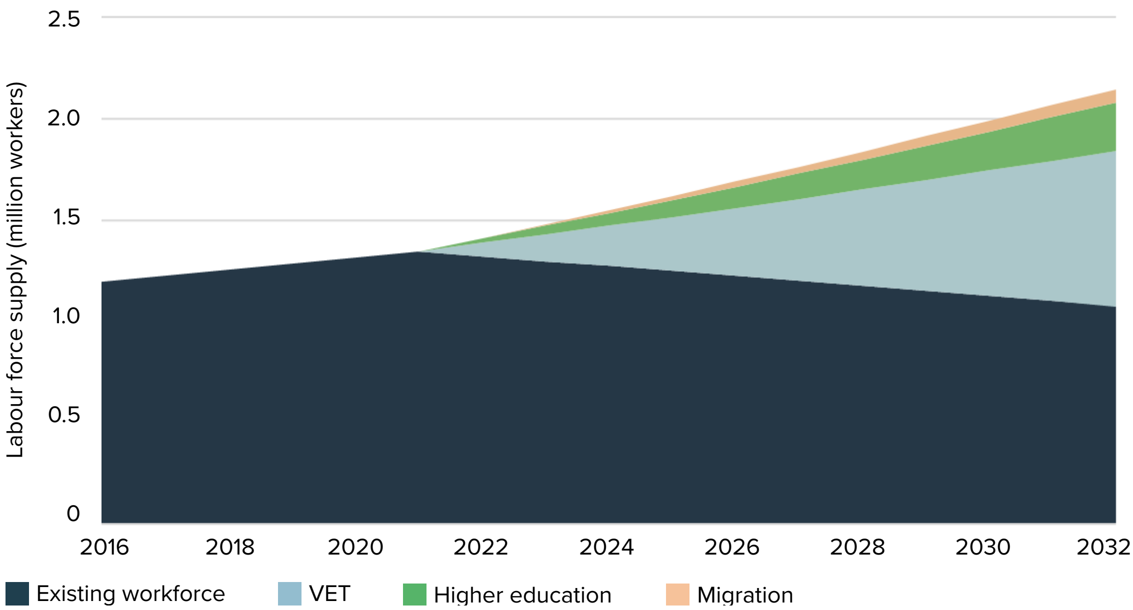
The constraints for women are multifaceted from stereotypes and attitudinal bias through to remuneration and work conditions. Addressing the current imbalance to harness all of the population could assist infrastructure in meeting supply challenges and allow the workforce and industry to benefit fully from the advantages of diverse workforces, such as improved communications, better teamwork and problem solving.[64]

Governments are acting with several programs aimed at increasing female participation in trades and infrastructure, including the NSW Government's Construction Industry Leadership Forum (CILF) and Construction Industry Culture Taskforce (CICT), but a concerted effort will be required given the limited progress achieved over the last 6 years.[65] Investment in trade training is a gateway to increased female participation in the workforce. The NSW Government's 'Built for Women' fee-free training program, which will provide 3,000 training places for women in trades, is an example of how policies are being used to drive a long-term shift in the industry.[66] Similar programs exist in other jurisdictions. These programs are beginning to have an impact with increased numbers of women in apprenticeships, for example Queensland nearly doubled the number of women construction apprentices between 2010 and 2020.[67]

Leakage from educational pathways

Around 94% of new workers are forecast to come through either the higher education (22%) or vocational education and training (VET) sector (72%). Without these additional workers the total workforce would shrink as current employees retired or moved to other areas of the economy. Figure 74 shows the estimated labour supply for the workforce by source.

Figure 74: Estimated future labour supply by source



Note: Analysis of future labour supply based on education inflows of individuals that will graduate as workforce-ready in the case of VET and Higher Education, using a field of education to ANZSCO mapping to estimate the supply of infrastructure workers. Migration figures use Department of Home Affairs data, at an ANZSCO unit group level, focusing on permanent visa classes and assumes consistent migration from 2023 onwards. These growth figures would have some variance in occupation over time. For additional information, see Appendix A, section 2. Migration estimates include individuals who migrate to Australia without declaring skills relevant for public infrastructure on entry. Migrants who subsequently gain the skills to work in public infrastructure after arriving in Australia are included in higher education, VET and existing workforce estimates.

Source: Nous Group commissioned by Infrastructure Australia (2021)

The ability to access the right course, receive high quality training and graduate into a job in the sector all present key challenges. In the current environment any lost potential worker has an immediate cost to the sector and potential downstream consequences for more experienced roles for years to come.

Effective educational pathways start with access. In the case of public infrastructure access to relevant courses is inconsistent. People in regional and remote areas often do not have a local option for tertiary education, which reduces participation.[68] Delivery costs can be two to five times higher where training numbers are low, so even if there is an accessible training provider, they are unlikely to have a full suite of courses unless subsidised to do so.[69] Similar impacts are also seen in specialist areas, for example there are very limited rail specific courses in Australia. This lack of access creates a form of leakage at the start of the training pipeline, with potential students prevented from pursuing qualifications that could lead them to the public infrastructure workforce.

Once engaged in training the next challenge is retention. Many students in infrastructure relevant qualifications do not complete their training or go on to work in other industries – for example 38% of qualified engineers work in other industries.[70] While there will always be people in both these groups due to different interests and capabilities, they can be minimised through better quality training and better development and articulation of pathways into the public infrastructure workforce.

The final challenge is alignment of what is learnt and what is valued by the sector. Employers regularly report that graduates are not work ready and that additional on-the-job training is required. This contributes to the direct leakage from the training pipeline by making it harder to get work and also limits productivity of the workforce at junior levels. It can affect the pace of career progression, further increasing leakage while reducing the rate of new people in senior and experienced roles.

Cultural challenges

Despite unprecedented demand, reports continue to emerge of employers having difficulty attracting and retaining suitable entry level workers to the sector due to perceptions around jobs or careers, long and irregular hours, travel and inconsistent work. Calls are often loudest in traditional trades outside of electrical and plumbing such as apprentice painters.

Working in public infrastructure can be demanding and involve shifts of 12 to 14 hours, more than double contracted hours.[71] The pipeline of work can fluctuate, and to minimise disruption to the public, work is often done in off-peak times, such as nights, weekends and holidays. In addition, there can be a need to travel long distances to the location of required work.

The perception of excessive workloads, "dog-eat-dog environments", and an unhealthy work culture all weigh into the limited ability to fill the future workforce pipeline.[72] Combatting these perceptions will be critical to attracting a new generation of public infrastructure workers.

Migration alone cannot address labour shortages

Australia has historically relied on skilled migrants to fill workforce shortages across public and private infrastructure projects. However, migration is only projected to provide 6% of new workers in the public infrastructure industry over the next 15 years (seen in Figure 74). This is based on Department of Home Affairs migration data of permanent visa classes, based on ANSZCO unit group level, and assumed the same migration numbers from 2023 onwards.

As borders begin to open there will be a greater focus from the public infrastructure sector on obtaining skilled migrants.[73] However, migration cannot resolve all shortages – policy responses will be required across migration, education and training, and facilitating transition of existing workers into public infrastructure delivery.[74]

Between 2017-2018 and 2020-2021 Australia increased its intake of migrants in infrastructure relevant occupations by approximately 40% or 4,409 individuals. The increase was primarily driven by an additional 5,669 individuals on temporary visas which more than offset a decrease of 1,260 individuals being granted permanent visas.

Historically, public infrastructure has utilised around 12-14% of the overall workforce in relevant occupations. In this case additional migration would represent a minimum increase of 530 workers for public infrastructure projects, although may be higher.

Most temporary visas were granted to engineers, scientists and architects who received approximately two thirds of new temporary visas with the remainder split across the other occupational groups. Despite growth across most occupations, fewer visas were granted to civil, electrical and material engineers, due to a reduction in permanent visas. Overall, there were 1,124 fewer permanent visas granted to engineers, scientists and architects in 2020-2021 compared to 2017-2018.

Migration can be time consuming and risky for businesses

Australia's skilled migration program sets out the key occupations and skills required to fill short- and medium-term shortages. However, restrictions such as age limitations and number of migrant workers per business prevents businesses from flexibly utilising the program to meet their needs.

Stakeholders note the program's current age limitation of 45 limits the ability for businesses to fill gaps where substantial technical skill and seniority is required. The process is also costly for small and medium businesses. In particular, the cost involved in sponsorship of skilled workers and the level of Temporary Skilled Migration Income Threshold can be prohibitive.[75] This leads many employers, particularly smaller and more regional organisations, to decide that it is not worth pursuing and is particularly true for sponsorship of construction workers and tradespeople.[76]

Further, the occupations list is drawn from ANZCO classifications and does not adequately reflect growing workforces and emerging skills such as rail systems or digital engineering.[77] Of the roles earlier identified as likely in shortage (seen in Table 4), 22 are not identified in the existing skills shortage lists.

Existing migrants are not well utilised

Not all migrants are equally effective in addressing workforce shortages. While businesses often sponsor highly skilled migrants, those that arrive through other visas do not always have the same impact. Our migration estimates exclude individuals who migrate to Australia without declaring skills relevant for public infrastructure on entry.

Migrants are more likely to work in areas that are outside and below their qualifications and skill set. In the case of migrants with engineering qualifications, they are more likely to work in industries such as retail trade, accommodation and food services. The Committee for Economic Development of Australia (CEDA) similarly found that despite indicators civil engineers are in shortage, 28% of migrant qualified civil engineers were unable to find work in the occupation.[78] The reasons for this are lack of recognition of overseas skills and qualifications, employer reluctance to employ individuals without local experience, lack of understanding of Australian standards and English language barriers. Migrants who subsequently gain the skills to work in public infrastructure after arriving in Australia are included in this report under higher education, VET and existing workforce estimates.

Border closures will have long-term impacts

Ongoing border closures have substantially limited the inflow of international students, who are major contributors to the public infrastructure workforce. In 2019, international students made up 34% of undergraduate enrolments in engineering and 23% in architecture and building.[79]

Between study and post-study visas, they are eligible to spend up to twelve years in the country before applying for permanent visas, which means they can contribute substantially to workforce supply.

They are also better placed to overcome the barriers to migrant employment identified above, as they are more likely than other skilled migrants to have strong English-language skills, understanding of Australian standards and experience in Australian contexts.

Priority Migration Skilled Occupation List

Travel restrictions have protected the health of Australians and ensured that Australia's borders remain strong and protected from the transmission of COVID-19.

The Government has worked closely with Australian businesses to support the entry of critical workers to help Australia's economic recovery, including by introducing a Priority Migration Skilled Occupation List (PMSOL)

The PMSOL identifies 44 occupations that fill critical skills needs to support Australia's economic recovery from COVID-19.[80] The list is based on advice from the National Skills Commission and consultation across the Australian Government. This list currently includes a number of those occupations identified as relevant to the public infrastructure workforce, including construction project managers, surveyors, and engineering occupations.

The Australian Government has announced that employer sponsored nomination and visa applications with an occupation on the PMSOL will be given priority processing. All other skilled occupation lists will remain active, but the PMSOL occupations will take priority.

The list is temporary and priority occupations may change as Australia recovers from the pandemic. The Australian Government and the National Skills Commission will continue to monitor the impact of COVID-19 on the Australian labour market and assess Australia's skills needs as they evolve and new sources of data emerge.

National Skills Commission

The NSC provides expert advice and national leadership on Australia's labour market and current, emerging and future workforce skills needs. Understanding where the jobs in demand are, and what skills are needed to do those jobs, will help more Australians get back to work and build a strong economy for the future.

The NSC monitors, researches and analyses employment dynamics across different demographic groups, industries, occupations and regions.

The Skills Priority List (SPL) is key deliverable for the NSC that provides a detailed view of shortages as well as the future demand for occupations across Australia.

The SPL uses a range of inputs to deliver labour market assessments for occupations based on labour market data analysis, employer surveys, industry consultation and federal and state/territory government input. This list provides the backbone piece of labour market analysis on occupations that will be a key input to a range of Australian Government policy initiatives, including targeting of skilled migration, apprenticeship incentives and training funding. Noting that each of these measures will also need to consider other inputs relevant to their specific policy needs. The SPL is reviewed and updated annually and is published on the NSC website at https://www.nationalskillscommission.gov.au/2021-skills-priority-list

Infrastructure Australia acknowledges the support of, and looks forward to continuing to work with, the NSC to support this work through the ongoing analysis provided through the Market Capacity Program.

6. Risks and constraints

At a glance:

The scale of demand growth expected by the Major Public Infrastructure Pipeline over the next three years is highly likely to exceed the normal capacity increases expected in the market.

Meeting Major Public Infrastructure Pipeline demand will require drawing in capacity from other sectors or importing capacity.

The Major Public Infrastructure Pipeline is part of a much larger market, with mining, defence, maintenance, transport and other non-Major Public Infrastructure Pipeline construction segments over the next three years possible amplifiers of risks.

The intensity of activity is increasing risk around meeting the input requirements to deliver the Major Public Infrastructure Pipeline.

Increasing reliance on importing capacity is likely to be difficult, for example current migration restrictions due to COVID-19. This may also increase other risk categories, including sovereign risk.

Over the decade between 1994-1995 to 2004-2005, multifactor productivity in the construction industry rose 18%, effectively allowing industry to do more with existing resources. Productivity surged a further 14% between 2010-2011 to 2013-2014.

Since 2013-2014, productivity in the construction industry has slumped 17%. As with falling net overseas migration from COVID-19 border closures, falling productivity growth is a key risk factor for market capacity in delivering the Major Public Infrastructure Pipeline.

Market capacity risks across the Major Public Infrastructure Pipeline are amplified by other delivery risks, including those at a systemic level such as climate change and cyber security, and those at the individual project level such as policy uncertainty and land acquisition challenges.

Major findings

The scale of demand for the Pipeline over the next 3 years is highly likely to exceed the normal accumulation of capacity through investment in inputs

Mining and other construction activities such as defence which competes for input resources may present additional risks.

Record levels of non-oil and gas construction activity from 2022-2023 causes additional input challenges.

The larger, east coast states may monopolise the highest quality professional skills, causing capability risks to increase for smaller projects in other areas.

Risks are emerging around access to professional skills associated with project management professionals and engineers, scientists and architects.

While demand is expected to rise strongly, past evidence suggests imports can augment local supply for steel, bitumen and electrical bulk materials.

Given the higher propensity to import construction plant and equipment, these present relatively lower challenges to market capacity.

Strong growth in demand for quarry products, cement, and concrete may present the greatest risk given challenges in quickly increasing supply.

An increasing reliance on imports may lead to rising quality and global supply chain risks, including price escalation risks in the near term.

Risk and infrastructure delivery

Market capacity challenges and broader deliverability issues represent a convergence of risks. Analysis commissioned from Oxford Business School points to a correlation between the size of a project and its level of risk, with Australian energy projects over $350 million more than twice as likely to run over cost, and digital projects almost three times as likely. In concordance with the findings of quantitative analysis of market capacity in this report, industry consultation reported that constraints are emerging due to the size of the Major Public Infrastructure Pipeline.

The COVID-19 pandemic and 2019-2020 bushfires underscore the significant risk context for delivering major infrastructure projects. There is evidence of growing quantum of risk, from contractor failure to increased disputes, to material shortages, and evidence of *new* risk categories such as:

- **Cyber** – operators manage significantly more cyber attacks daily that are individually more disruptive, sometimes managing thousands of attacks daily.
- **Technology –** energy, transport, waste and health technology changes create complexity and uncertainty around design, use, and commissioning.
- **Climate change –** as catastrophic weather events become more frequent, investment settings have switched to support a transitioning energy market and new green asset classes.
- **COVID-19** – the pandemic has changed customer behaviour, constrained workforce responses, and driven a desire to diversify supply chains.
- **Urban growth –** major urban site and long corridor development is exposing major contamination and geotechnical risks, in projects that have higher interface and integration risks.

This report compiles a range of evidence and insights on risk trends across the Australian infrastructure sector, which point to heightened risk exposure for major projects in planning or delivery over the next five years. The data points shown in

Figure 75 shows symptoms of risk drivers and demonstrates the breadth of data needed to derive a clear picture of strategic risk across the infrastructure market.

Figure 75: Infrastructure delivery is impacted by a range of risk drivers

Declining contractor profitability

Tier 1 contractor profits, historically ~4-5%, dropped steeply in 2019, in one case to -7.5%, while winning significant new work.

Climate risk impacts on insurance

Insurance premiums in some cases increased by 400% following the 2019-2020 bushfire season.

Price escalation of construction materials

While 2020 ABS data shows rising steel costs, proponents noted acute recent price increases of timber and steel.22 One lender reported a contractor had an 80-90% steel price increase from tender submission to award.

Decarbonisation costs to construction

One estimate is that the cost of decarbonising construction would be 0.4-0.6% of global GDP.

Rapid decline in Professional Indemnity

Proponents noted that price of PI insurance had escalated up to three times in two years, with a 50% drop in insurance capacity.

Cybersecurity risks increased sharply

35% of cyber incidents impact critical infrastructure providers, with one metro water utility observing thousands occur daily.

Labour shortages are evident

Shortages in experienced project managers are evident across all sectors, with 33.5% drop in skilled migration through COVID, and with 40-75% national vacancy rates for critical skills such as civil engineering.

Utilities risk

An estimated 128 projects would deal with utilities risk over the next five years. The Sydney Gateway project will manage 487 utility connection points.

Social license issues could increase project delays and cost

One report estimates that community opposition to projects over the next decade could amount to a $40 billion cost.

Cost optimism bias is significant

On the future pipeline, the projected cost uplift required could amount to $~90 billion nationally.

Risk transfer and sharing

68% of survey respondents indicated that traditional contracting methods did not adequately manage for emerging risks.

Project complexity and size are a driver of cost overruns

The Grattan Institute estimates that every 10% increase in project size represents a 6% higher chance of cost overrun.

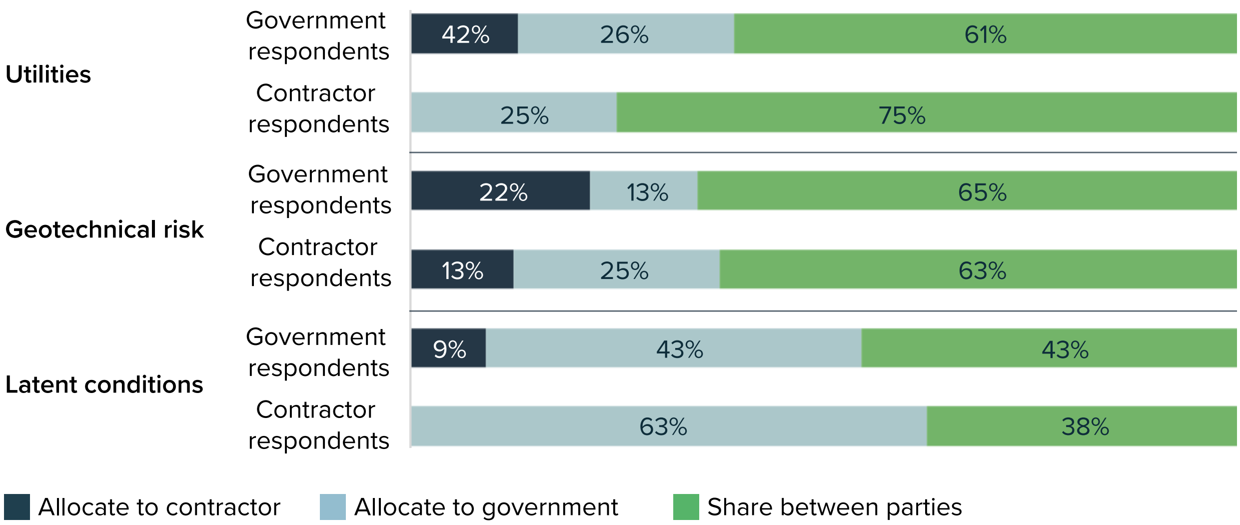
Market sounding – Risk allocation

> "The complexity of the megaprojects underway at present are difficult to adequately price risk exposure and equally to get a fair balance between client and contractor."
> Market sounding participant, 2021

In order to assess how contractors and government perceive the most effective allocation of risks, and thus are best placed to implement risk controls, Infrastructure Australia undertook a market sounding exercise with key stakeholders. Results from a market sounding survey (see Figure 76) shows areas of convergence on risk allocation, however they diverge on planning, integration and utilities.

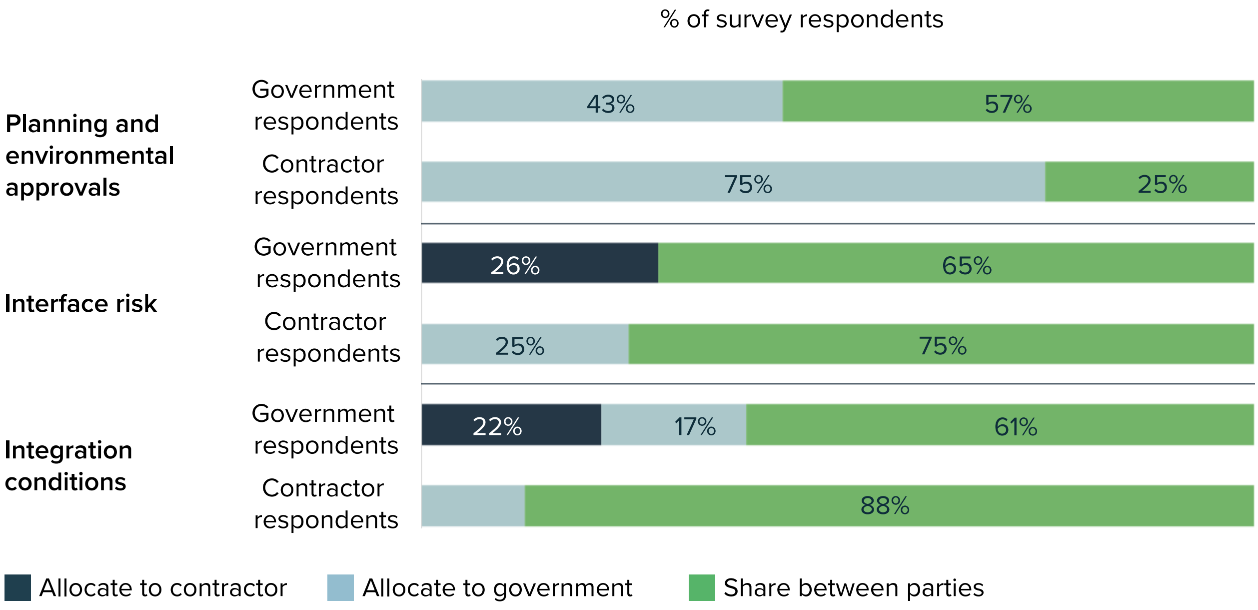
While contractor and government proponents largely agree that utilities, geotechnical and latent condition risks should be shared, there remains some bias in how proponents suggest these risks should be shared. Contractors who did not think risks should be shared were more likely to suggest government to bear these risks.

Figure 76: Government and contractors diverge on how to allocate risk



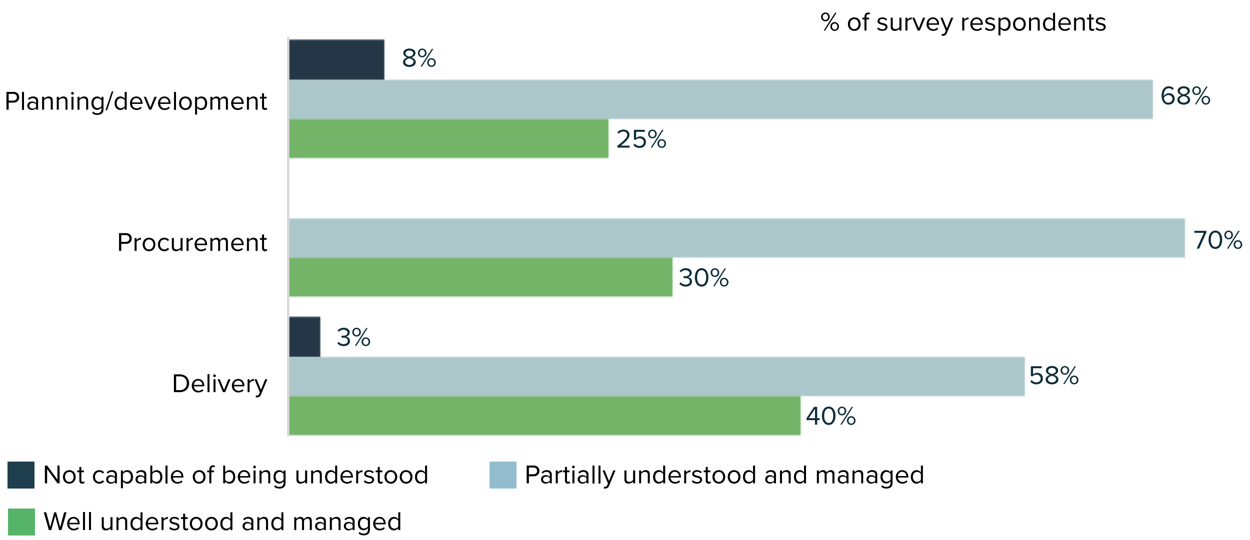
Proponents suggested that planning and environmental approvals should be either shared or borne by government (see Figure 77), however contractors were more insistent that this risk is a government risk. The majority of contractor and government proponents agreed that interface and integration risks should be shared.

Figure 77: Contractors want government to bear risks



Our market sounding survey has broadly indicated that risks are only "partially understood and managed" across the lifecycle with planning phase most problematic (see Figure 78). The majority of market sounding survey responses indicated that risks were "partially understood and managed" across the major phases. Confidence that critical risks are understood and can be managed was strongest during project delivery stage, and weakest during project planning and development (see Figure 78).

Figure 78: Risks are only "partially understood and managed" across the lifecycle



Market capacity risks

Given that the Major Public Infrastructure Pipeline represents a part of a much broader market, in identifying market capacity risks from Major Public Infrastructure Pipeline demands the following risk factor 'red flags' are each considered below in turn:

- The growth rate of forward Major Public Infrastructure Pipeline activity and consequent demands.
- Whether this growth occurs alongside growth in other parts of the market.
- Whether this contributes to record levels of total construction activity (implying the need for capacity-enhancing investments such as new quarries or upstream manufacturing or processing facilities), and if so, when these record levels of activity are reached.
- Whether Major Public Infrastructure Pipeline resource demands are focused domestically (where supply flexibility may be limited), or through imports (which may trigger other risks, such as the ability to access the global market – which is currently difficult for skills given border closures – and the broader health and resilience of global supply chains).

Risks from rising Major Public Infrastructure Pipeline activity

The following risk factors are clear from examining the Major Public Infrastructure Pipeline, namely:

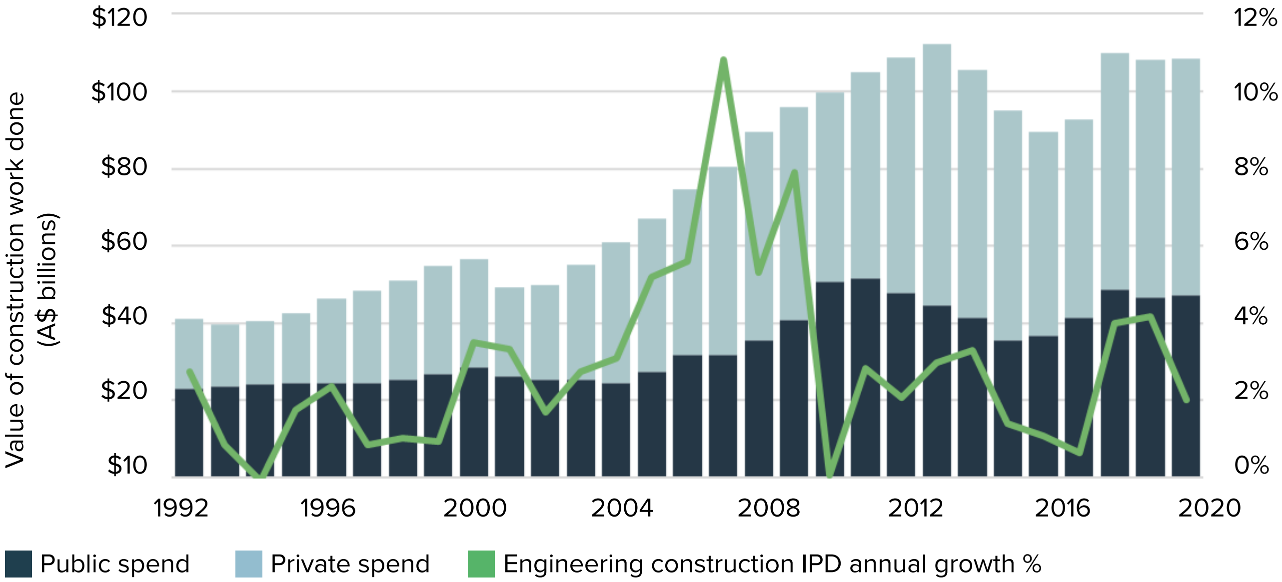
- The sheer scale of demand growth for inputs from the Major Public Infrastructure Pipeline over the next three years is highly likely to exceed natural accumulation of capacity in the market, necessitating resources to be drawn from other sectors and regions.
- Growth in demands vary by sector and state. State-specific supply constraints may present particular challenges for those states where input demand growth is acute.
- Rising competition from mining, defence, maintenance, transport and other non-Major Public Infrastructure Pipeline construction segments over the next three years may amplify risks.
- From 2022-2023, potentially record levels of broader construction activity could present further market capacity risks and challenges.
- The following PLEM resource categories are considered to present the greatest risks:
    - Project management professionals
    - Structural and civil trades
    - Engineers, scientists and architects
    - Quarry products and concrete
    - Rail track

Critically, this report has found that a 98% increase in Major Public Infrastructure Pipeline activity is expected over the next 3 years. In turn, overall resource demands driven by the Major Public Infrastructure Pipeline is entering uncharted, record territory.

A rising level of public infrastructure investment is not, in itself, a new or necessarily risky phenomena in the context of overall market capacity or capability.

Figure 79 presents the sum of historical Australian transport, utilities and building construction work done data from the ABS. This data is presented in constant (2018-2019) prices and so reflects changes in the quantity of construction activity over time, not changes in its price, and excludes mining and heavy industry construction. This data shows a rising trend of real public infrastructure investment particularly across the last two decades, combined with large cycles (on a rising trend) in the construction of privately funded transport, utilities and building infrastructure.

Figure 79: Transport, utilities and building construction work done, $ billions (1992-2020)



Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Overall, the construction of transport, utilities and building infrastructure for the public sector rose 123% between 1991-1992 (the previous trough) and 2010-2011 (a historical peak). That it grew during periods when privately-funded activity was also rising strongly suggests that the market found a way to address market capacity challenges through this period – particularly as overall levels of activity reached new peaks.

Undoubtedly, in meeting periods of stronger growth in public infrastructure construction, the market adjusted to utilise any existing spare market capacity available as well as drawing in resources from other sectors. However, reaching new levels of activity – such as during the long growth phase during the 2000s and early 2010s would have required significantly increasing overall market capacity and/or market productivity. The former refers to increasing the quantity of resources available to meet demand, while the latter refers to improvements in efficiency in the way resources are used.

Determining the specific range of factors which allowed the market to deliver sharply rising levels of infrastructure during this period is outside the scope of this analysis, however there are two factors which may have been critical to boosting market capacity at this time:

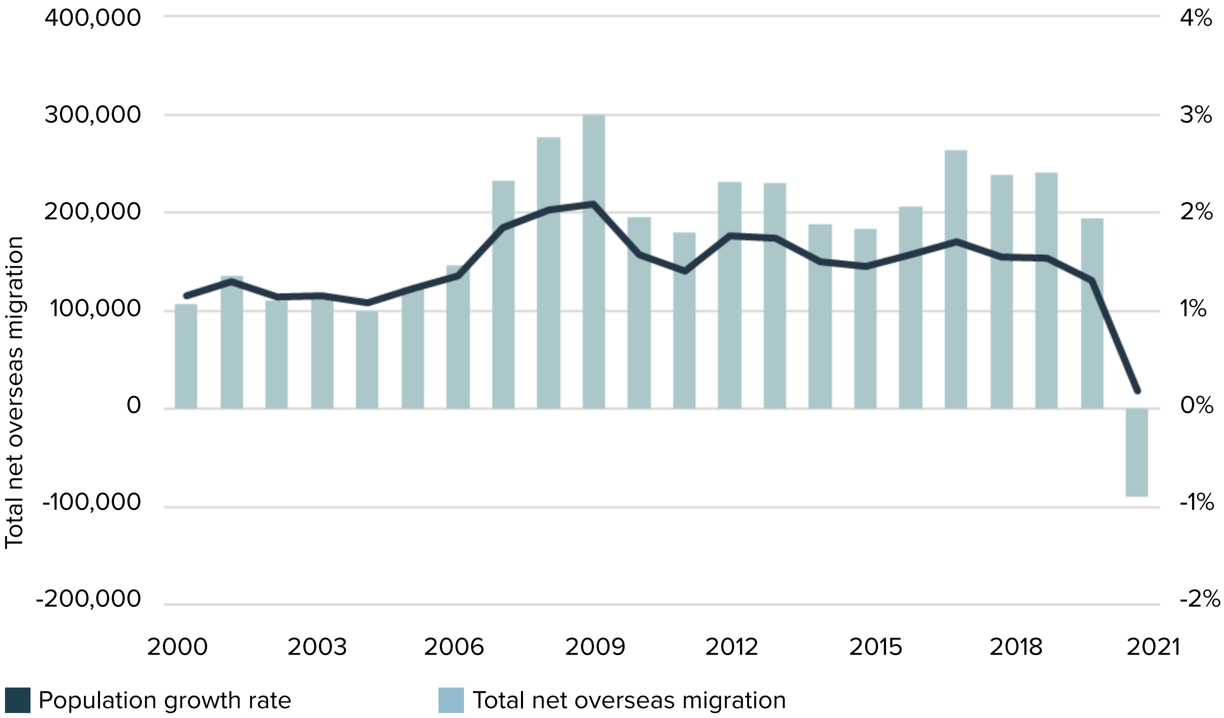
- **Strong population growth** driven by net overseas migration (and particularly the role played by temporary and permanent skilled migration programs) and
- **An upward shift in construction industry productivity** between 2001 and 2014.

The strong, sustained growth in infrastructure construction activity shown in Figure 79 neatly coincides with a sharp acceleration in Australia's population growth rate, as shown in Figure 80. From just 1.1% growth in 2003-2004, Australia's population growth accelerated to 2.1% by 2008-2009 and remained at rates above that seen in the early 2000s thereafter. Rising annual net overseas migration (NOM) was a significant factor.

In 2003-2004, NOM was just beneath 100,000 persons. By 2008-2009, this had near tripled to just under 300,000 persons, increasing labour on temporary visas as well as via the skilled migration program. Annual skilled NOM from these sources rose from 38,840 persons in 2004-2005 to 77,580 persons in 2007-2008 and remained at relatively higher levels thereafter.

With the onset of COVID-19, the closure of international borders saw skilled migration slump 40% in 2019-2020. The 2021-2022 Commonwealth Budget projects that NOM is expected to turn negative by 97,000 persons in 2020-2021 and a further negative of 77,000 persons in 2021-2022.,[81] The latest quarterly ABS population data (September 2020) showed that NOM had already turned negative by 40,000 persons in that quarter alone.[82]

Figure 80: Population growth and net overseas migration

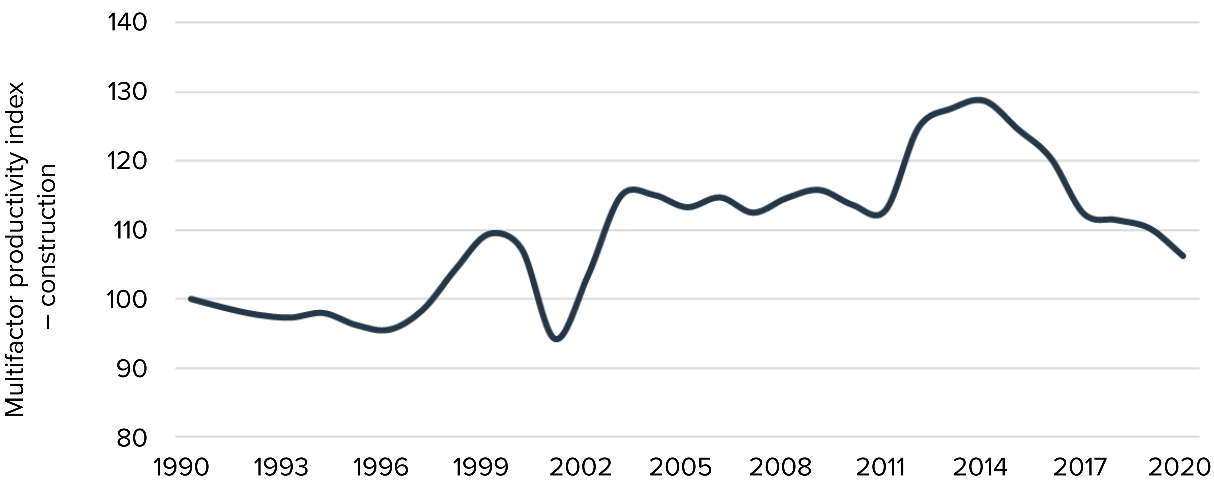


Source: Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Another critical factor which likely assisted market capacity in the 2000s was rising industry productivity, as shown in Figure 81. Over the decade between 1994-1995 to 2004-2005, multifactor productivity in the construction industry rose 18%, effectively allowing industry to do more with existing resources.

Productivity surged a further 14% between 2010-2011 to 2013-2014. However, since 2013-2014, productivity in the construction industry has slumped 17%, meaning that more resources need to be employed for a given level of construction industry output. As with slumping net overseas migration from COVID-19 border closures, falling productivity growth is a key risk factor for market capacity in delivering the Major Public Infrastructure Pipeline.

Figure 81: Multifactor productivity index, construction industry (1990–2020)



Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

While rising resource capacity through skilled migration and stronger productivity growth has helped the market deliver rising levels of public infrastructure, this did not come without additional cost. In particular, the three major public infrastructure investment growth phase periods over the past 30 years – 1997 to 2000, 2005 to 2011 and 2016 to 2018 – also corresponded with periods of heightened acceleration in construction costs as measured by growth in the engineering construction implicit price deflator (IPD), shown graphically in Figure 82.

Table 5 summarises these public infrastructure growth phases. Each phase coincided with an acceleration in construction costs. The long growth phase between 2005 and 2011 (which also occurred alongside strong growth in privately funded investment) drove the strongest period of construction cost growth – peaking at 10.8% in 2006-2007 alone. Outside of these growth phases, the engineering construction IPD has averaged only 1.8% per annum growth since 1990.

Table 5: Public infrastructure growth phases and construction costs, 1990-1991 to 2019-2020

Public infrastructure growth phase	Public sector focus	Public sector activity growtha	Construction cost growthb
1998 to 2000	Utilities	16.1% (5.1% p.a.)	7.9% (2.6% p.a.)
2005 to 2021	All	110.3% (11.2% p.a.)	43.9% (5.3% p.a.)
2016 to 2018	Transport, building	36.8% (11.0% p.a.)	9.0% (2.9% p.a.)

a: Cumulative growth in non-residential construction activity for the public sector as measured by ABS construction data

b: As measured by cumulative and annual average movements in the ABS engineering construction IPD including 1-year lagged impacts.

Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Higher rates of growth in construction costs during growth phases of construction activity may flag increasing capacity and capability pressures. This is because rising activity and resource demands places pressure on the existing supply of resources (including the provision of services relating to this activity), potentially boosting resource prices. Where capacity constraints exist, rising activity can lead to strong increases in resource prices as investment in new capacity is itself costly and takes time to come on stream.

However, it is also important to recognise that construction costs may also vary due to changes in globally determined commodity prices for key imports (including steel and oil), as well as variations in exchange rates. These price changes may occur independent of growth in public and private domestic infrastructure activity. Consequently, accelerating construction costs, while potentially flagging market capacity constraints, are themselves only a partial indicator.

As outlined in *Major project activity trends and outlook*, above, Major Public Infrastructure Pipeline activity is anticipated to grow 98% over the three years to 2022-2023, with known Major Public Infrastructure Pipeline activity receding in 2023-2024 and 2024-2025.

In growth terms, the three years to 2022-2023 represents a similarly strong growth phase for total public infrastructure activity (including Major Public Infrastructure Pipeline and non-Pipeline work) which occurred over 2016 to 2018 (following slightly lower levels of activity the previous two years) as well as the 2005 to 2011 growth phase (which occurred alongside a boom in resources-related investment).

In turn, this growth is likely to fuel very strong growth in resources demand. As detailed in *Demand trends and outlook* by resource type, above, resources demand from the Major Public Infrastructure Pipeline over the next three years is expected to realise:

- 75% growth in FTE demand for skills.
- 122% growth in demand for materials.
- 127% growth in demand for equipment.
- 144% growth in demand for plant.

Such strong growth over a short period of time will be very unlikely to be met through a natural, flexible supply response. Rather, if Major Public Infrastructure Pipeline activity proceeds as planned it will likely need to compete for resources from other sectors and regions.

Figure 82: Growth in transport, utilities and building construction and construction costs

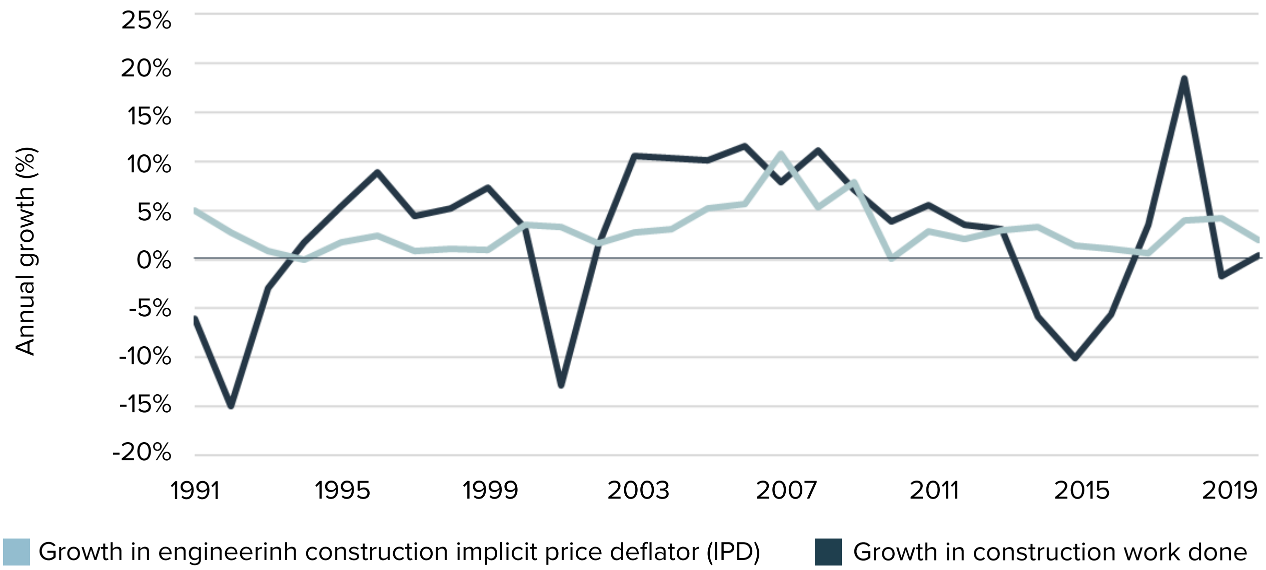


Figure 82 illustrates that there is likely to be a lagged connection between growth in infrastructure market activity (transport, utilities and building construction) and an acceleration in construction costs which could be indicative of market capacity being stretched. In particular, sustained market growth of 10% per annum between 2002-2003 and 2007-2008 eventually saw an acceleration in construction cost growth (despite strong increases in skilled labour and industry productivity) which was eventually punctured by the global financial crisis in 2008-2009. Falling infrastructure activity between 2013-2014 and 2015-2016, conversely, produced a slowing in cost growth.

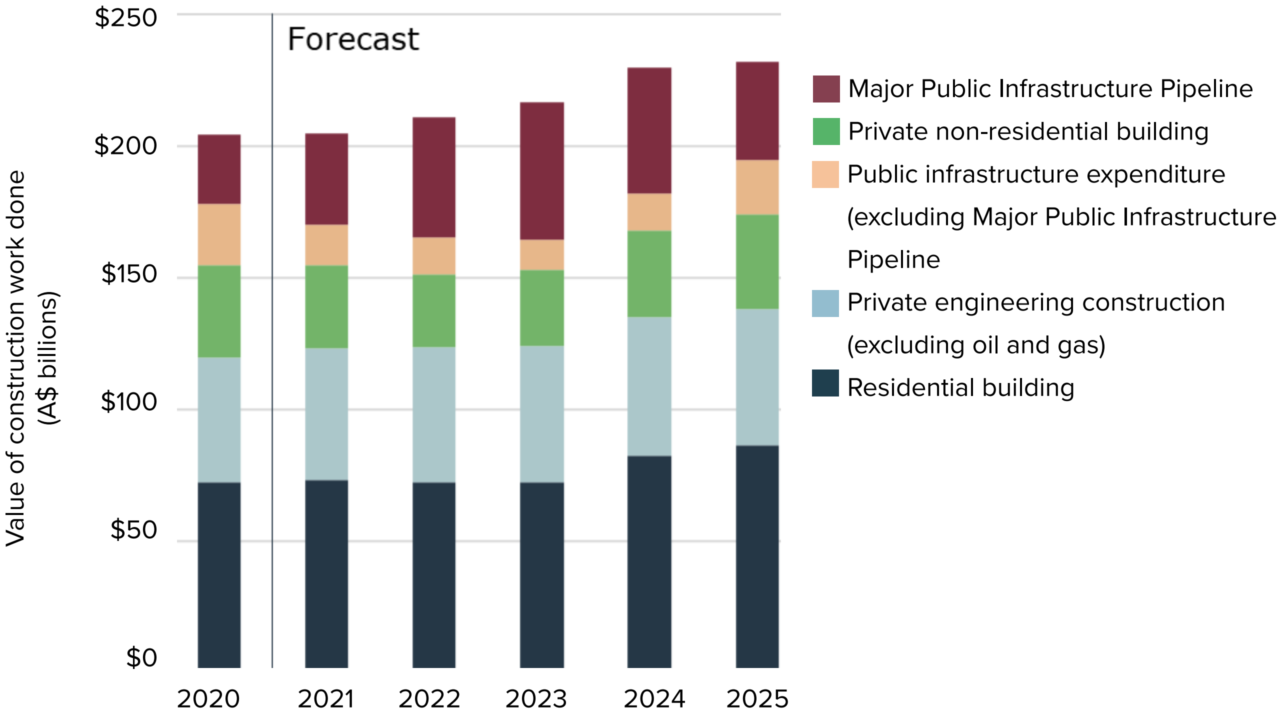
Of note, the engineering construction IPD rarely falls in absolute terms over time, even with falling activity. This likely reflects downwards stickiness in wages and other resource prices. Consequently, a longer term negative from a stretching in market capacity is that resultant price increases will likely form a new price floor for future activity.

Risks from growth in competing demands

Whether the Major Public Infrastructure Pipeline increases market capacity and capability risk in the near term may rest on whether there is spare market capacity which can be drawn on. This, in turn, critically depends on the strength of activity in competing sectors. Where strong Major Public Infrastructure Pipeline growth occurs alongside growth in other parts of the market or related industry sectors, this will effectively amplify competition for potentially scarce resources.

When the Major Public Infrastructure Pipeline is compared against forecasts of construction market activity (excluding oil and gas construction) supplied by BIS Oxford Economics in Figure 83, two main risk factors emerge. Firstly, the Major Public Infrastructure Pipeline itself is the fastest growing segment of the market over the next three years. Secondly, however, growth is also expected over this period from privately funded engineering construction.

Figure 83: Annual construction work done in all sectors (excluding oil and gas construction)



Private funded engineering construction is forecast to rise 12% in real terms over the four years to 2023-2024. This mainly reflects sustained mining and heavy industry construction activity – excluding oil and gas construction – and the delivery of resources-related infrastructure such as railways, ports and roads as the global economy recovers from the COVID-19-induced recession and increases demand for metals, minerals and energy. It also reflects rising private investment in local electricity and energy markets and further upgrades to Australia's telecommunications networks. While growth in resources-related activity is not expected to be as strong as seen during the previous boom years (which covered much of the decade to 2013-2014) it is still likely to present risks to capacity and capability, particularly WA or resource-rich regions, when joined with a strong Major Public Infrastructure Pipeline.

By contrast, privately funded non-residential building activity is projected to continue to weaken until mid-2023, as many segments of the market including accommodation, retail, offices and aged care take time to see a recovery in confidence and investment in the wake of COVID-19. For the period between 2020-2021 to 2022-2023, this may potentially provide spare market capacity, particularly for public building projects. Many Australian non-residential building segments with considerable private sector involvement are not expected to fully recover until later this decade.

While there has been considerably strong growth in house prices and detached house approvals over the past year, residential building activity is expected to remain relatively flat in aggregate over the next three years as rising activity on detached housing (supported by stimulus policies such as *HomeBuilder*) is offset by falling work on higher density projects. With population growth a fundamental driver of residential building activity, a sustainable recovery in residential building activity is not anticipated until closer to the middle of the decade. This, combined with relatively lesser resource competition between Major Public Infrastructure Pipeline projects and the residential building market, is likely to see only mild market capacity risks to the Major Public Infrastructure Pipeline from residential building demands.

Overall, rising construction industry activity may represent a risk to market capacity. That a strengthening outlook for broader market activity is already underway is evidenced by recent industry surveys. Consult Australia, for example – representing small, medium, and large businesses in design, advisory, and engineering – reported in April 2021 that 48% of their members are experiencing an overall upturn in work, a significant improvement from 2020, with roads and mining, schools and childcare facilities amongst the top sectors experiencing an upturn in work.[83] A majority of their members also raised concerns about pressures on workforce capacity to deliver the anticipated volume of work over the next six months.

Outside of the construction industry, the growth outlook for other Australian industries may also present risks to market capacity and capability. In particular:

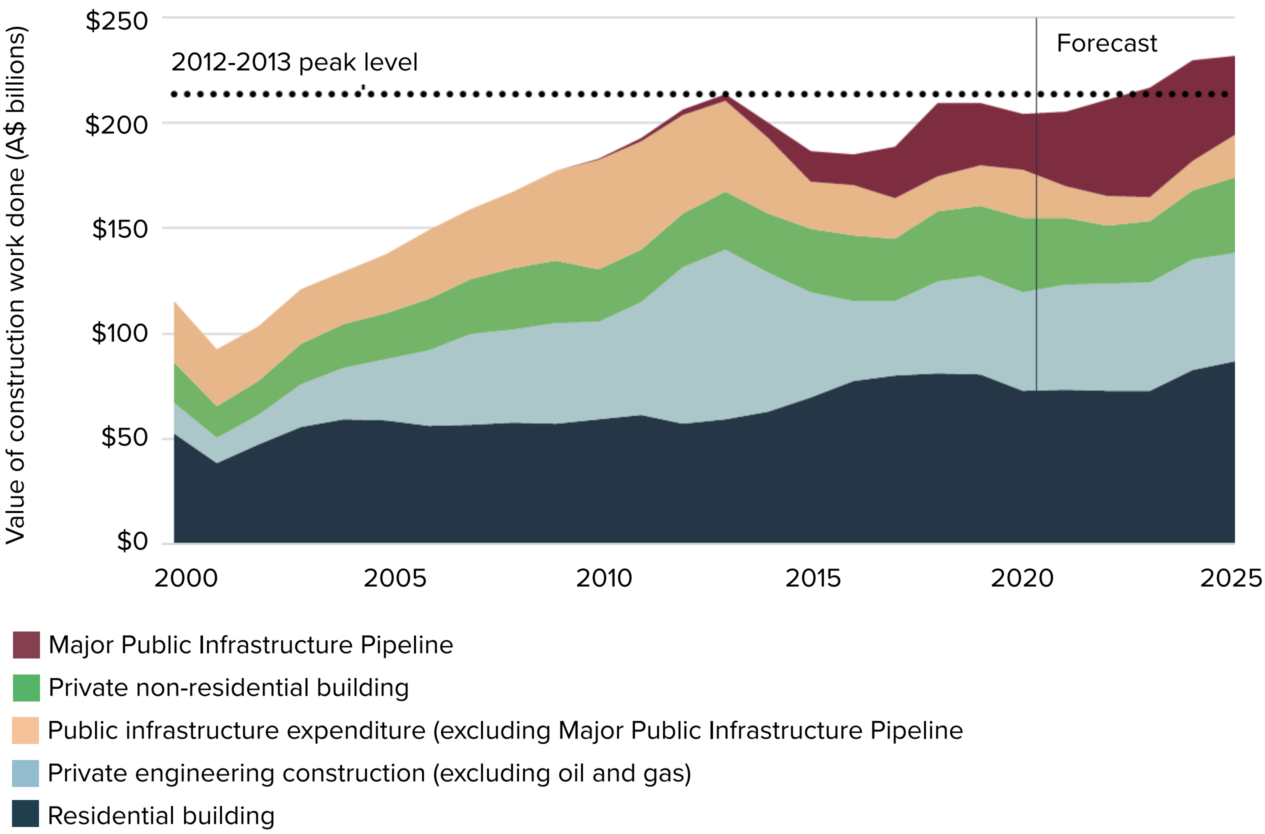
- **Maintenance**: Total maintenance activity is expected to be 12% higher in real terms over the five years to 2024-2025 compared to the five years to 2019-2020, according to industry forecasts.[84] The strongest growth in the near term is expected to be in mining and heavy industry segments (led by oil and gas, where over $300 billion in new assets has been developed over the past decade), transport (particularly roads) and parts of the building and utilities segments. It is important to note that while there has been significant offshoring of oil and gas *construction* over the past decade, the same offshoring potential is not available for oil and gas *maintenance* which must be done on-site, utilising similar skills and equipment which could also be employed on the Major Public Infrastructure Pipeline.
- **Defence**: Defence-related infrastructure has been specifically excluded from this analysis, but it is important to note that previous infrastructure industry research has identified the defence sector as a key competitor for skills and other resources.[85] In this context, the 2021-2022 Commonwealth Budget provides $270 billion in new capability investment to implement the July 2020 Defence Strategic Update to meet the Australian Government's key strategic objectives over the next decade. This includes "investments in the supporting infrastructure required to build and sustain military power; including a robust, resilient and internationally competitive defence industrial base".[86]
- **Transport**: Strong investment in public and private transport infrastructure over the past decade is driving rising levels of operations and maintenance activity in the sector and may potentially draw resources away from the delivery of new transport infrastructure. This effect may be amplified by new behaviours in response to COVID-19 which may be accelerating shifts to e-commerce and retailing.

Risks from record levels of market activity

Overall, strong growth in Major Public Infrastructure Pipeline activity alongside growth in other parts of the market could result in record levels of total construction activity (excluding oil and gas activity) by 2022-2023. This may be a critical risk factor as, in the absence of robust increases in productivity, supporting record levels of construction activity requires increasing resources beyond that which were previously supplied. Boosting supply requires either increasing imports or developing new local market capacity (such as quarries or manufacturing facilities, or the training and development of specialist labour) which may take time to come on stream. With closed international borders likely to prevent a large intake of skilled labour (as happened during the 2000s construction boom) and productivity growth continuing to deteriorate, increasing pressure is likely to fall on local labour and capital intensive delivery methods to support market capacity.

The previous analysis of historical infrastructure market activity (illustrated in Figure 82) identified a link between market growth and accelerating construction cost growth. Figure 84 reveals that cost growth also accelerates as the market moves to new peak levels of activity. Looking ahead, total market activity (excluding oil and gas) is expected to reach new record levels again by 2022-2023, with the next peak in activity forecast for 2024-2025. Based on past experience, this may be accompanied by a re-acceleration in construction costs around this time which itself may flag that market capacity is under increasing pressure.

Figure 84: Construction work done (excluding oil and gas construction)



Risks associated with local or imported supply

Finally, there are also market capacity risks associated with the *source* of supply. Primarily, the strong Major Public Infrastructure Pipeline outlook can be considered to hold risks for market capacity if the resultant resource demands are more likely to be sourced within Australia (i.e. are more domestically focused) and cannot be met easily by increasing imports. Even where capacity can be augmented through imports, however, this potentially increases other risks, such as quality and global supply chain risks (including sovereign risk). As an obvious example, the international border closures and restrictions necessary to control the COVID-19 pandemic have restricted the international movement of skills and therefore have increased market capacity risks.

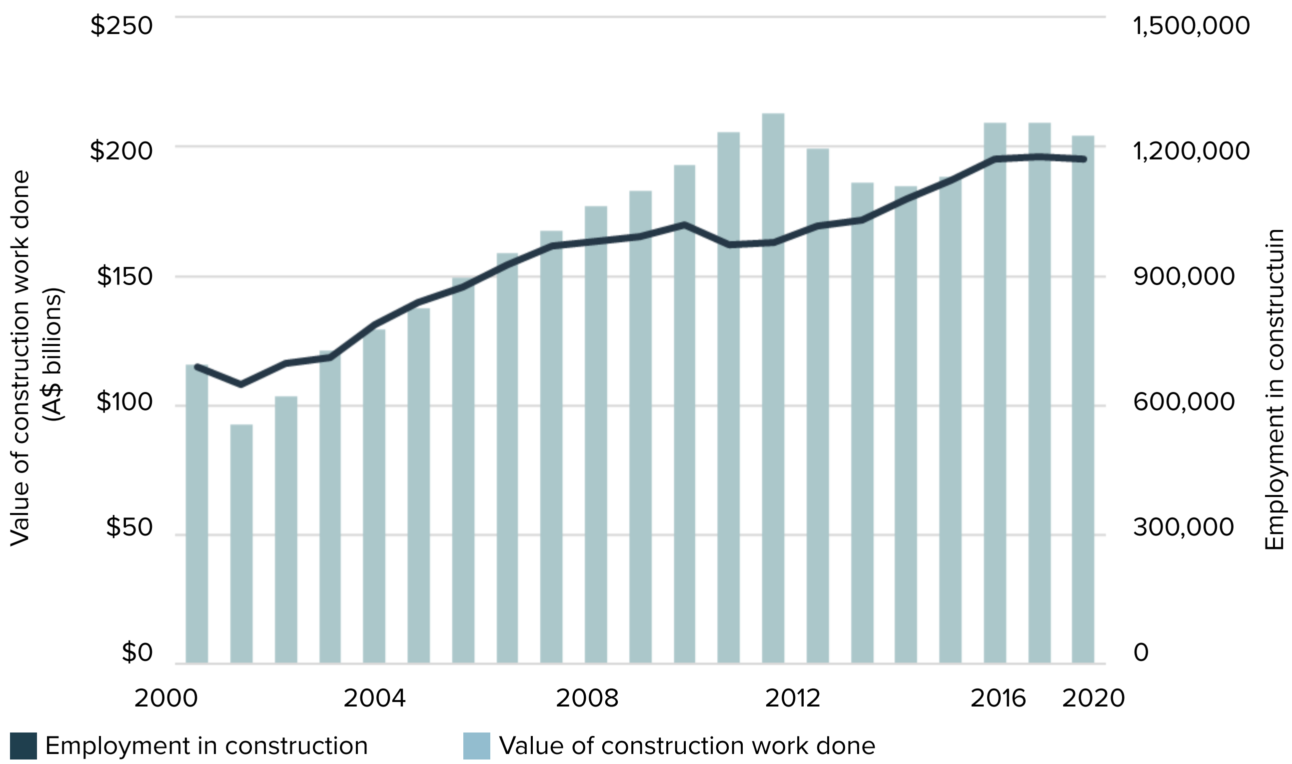
Resources used for Major Public Infrastructure Pipeline projects are ultimately sourced from a network of local and international suppliers and their respective supply chains. In turn, deeper understanding of the quality and flexibility of the supply chain to meet the strong growth in Major Public Infrastructure Pipeline demand predicted by this report is required. As a starting point, previous industry research indicates that a greater proportion of labour (with the exception of higher skilled or specialist roles) and construction materials (sand and aggregates, as well as concrete) tends to be sourced from within Australia (and often close to where construction activity takes place) while plant, equipment and commodities such as oil, bitumen and steel have been increasingly imported into Australia to meet rising domestic demand (and local supply gaps).[87] Around 50% of clinker, the raw material used to make cement, is also now imported following closures of kilns around Australia, as well approximately 1 million tonnes of cement (representing 8% of total consumption).[88] Consequently, the rapid growth in demand for skills and construction materials indicated by the Major Public Infrastructure Pipeline analysis may represent a potential market capacity risk, particularly in the context of record levels of total construction activity.

The following discussion highlights potential supply risks and challenges facing each of the PLEM resource categories, and the potential risks these may hold in turn for market capacity.

Labour

The resource demand analysis provided in this report indicates that the most intense Major Public Infrastructure Pipeline resource pressure will be focused on labour and materials, which account for 58% and 29% of resource demand for the Major Public Infrastructure Pipeline over the next five years. The transport sector accounts for 78% of labour demand, with road projects alone responsible for 41% of the total demand. Strongly increasing activity in the sector is likely to drive large increases in demand for certain occupations. In particular, demand for project management professionals and engineers, scientists and architects are projected to rise by 34% and 45% respectively in 2020-2021 (equivalent to 6,500 and 34,500 FTE positions), with further growth in subsequent years. The Major Public Infrastructure Pipeline also drives very strong demand for structural engineers, architects and safety officers.

Figure 85: Construction activity (less oil and gas) and construction employment



Historically, construction employment is highly linked to construction activity – indicating a substantial local labour supply footprint for the infrastructure market – with ABS data indicating nearly 1.2 million people were employed in the industry in 2019-2020, as shown in Figure 85. Of note, there was a fall in construction employment between 2010-2011 and 2013-2014 – when total market activity rose on the back of the LNG investment boom, providing further evidence that LNG investment was relatively less labour intensive. The planning, provision and operation of infrastructure also draws in skills from a range of other industry sectors including professional, scientific and technical services (such as engineers, architects and surveyors), transport (truck and rail drivers), manufacturing (steel and concrete products), mining (including construction materials quarrying) and government itself.

Previous infrastructure workforce capability studies have highlighted that growth in local skills supply is already at risk from an ageing workforce, weak (or declining) growth in infrastructure-related education commencements and completions, and a stark lack of industry diversity, with female representation in the construction industry and related professions and trades very low.[89 90 91] This may in turn present market capacity risks given the strong increases in labour supply required to meet projected demands – and should be examined in more detail in further studies.

While general and construction trades labour remains traditionally locally sourced (and limited by growth in supply through education and training), an increasing share of technical and professional skills is being sourced from overseas to help manage local skills shortages. A recent survey by the Australasian Railways Association, for example, revealed that 68% of its member organisations sourced international workers through the skilled migration program prior to the onset of COVID-19, with over 60% stating that those skilled workers were necessary for the delivery of high value projects and operational roles.[92] These have included signalling, track maintenance, train drivers and controllers as well as educators, trainers and assessors.

While the closure of Australia's international borders to control the spread of COVID-19 is a critical risk to skills, pre-existing inefficiencies and skills mismatches in Australia's skilled migration programs are another..[93] Industry has reported that relatively newer construction techniques (including tunnelling), and the implementation of new technologies or bespoke systems often means that new specialist roles are demanded which are not necessarily reflected in skill shortage lists that feed into these programs. Accessing labour through skilled migration programs is often costly in terms of time and money, impacting flexibility..[94]

Materials, plant and equipment

Previous industry research has highlighted significant differences in perceived supply side risk associated with various materials resources..[95] The extraction and transport of quarry materials (including sand and aggregates) has considerable supply side risks, as the cost of these materials rises significantly the further they are located from construction activity, thereby necessitating a particularly local supply response. This also extends to the manufacture and delivery of concrete and concrete products. Furthermore, the closure of longstanding quarries coupled with the time it takes to develop new quarry capacity (often over 10 years) presents further significant market capacity risks that should be further examined given the strong growth in demand for these products engendered in the Major Public Infrastructure Pipeline.

By contrast, the supply of resources such as steel, oil, bitumen, clinker – and as well as plant and equipment (including electrical equipment) – has been increasingly augmented via imports given the reduction in local manufacturing over recent decades and the difficulty in quickly scaling up remaining local capacity to meet demand.

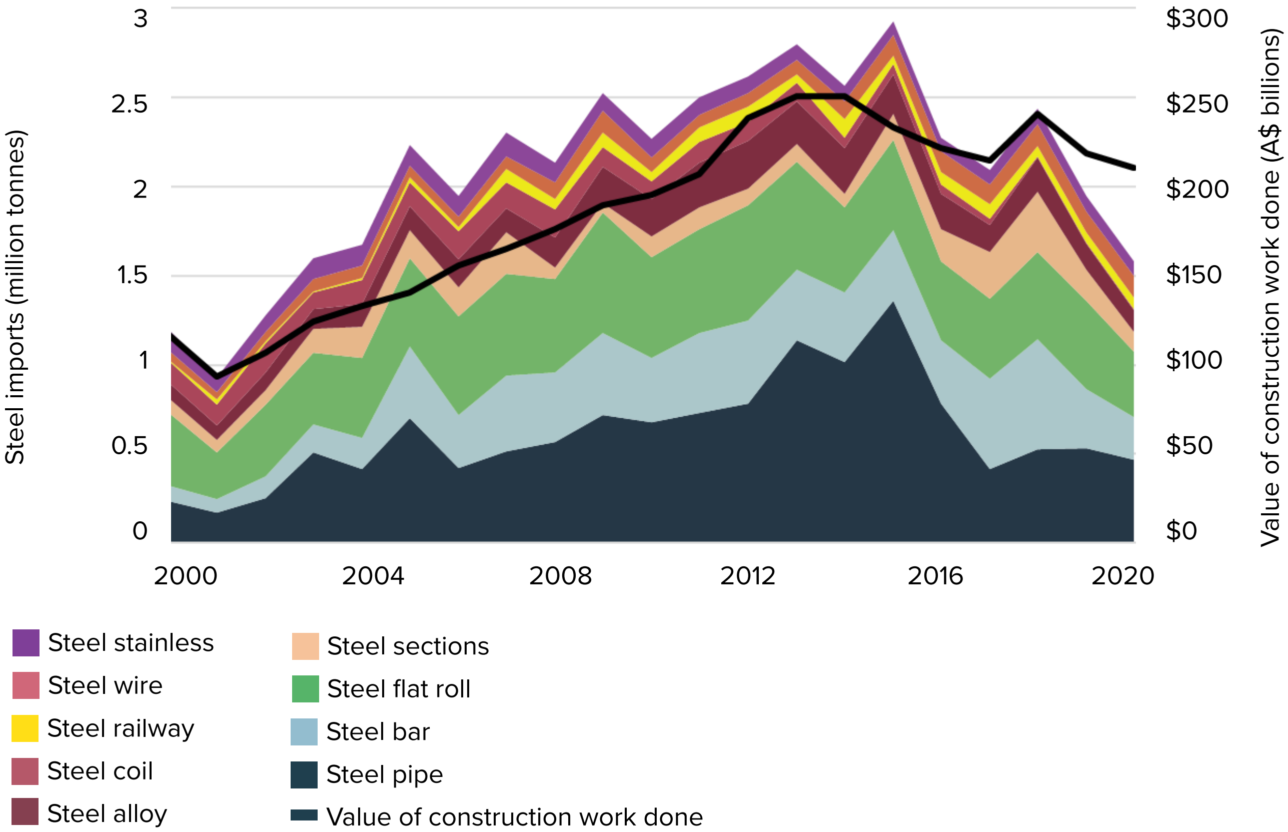
While potential shortages in these resources from Major Public Infrastructure Pipeline and broader market activity over the next five years is likely to be addressed through rising imports, it is important to recognise that this raises other risks, including potential quality concerns as well as global supply chain risks and exposure to import price shocks. In the near term, rising global steel demand and constraints on the supply of raw inputs, particularly iron ore, exposes Australia to rising price risks for steel imports. Meanwhile, recovering oil prices is also driving up the cost of diesel fuel and bitumen, which are now almost entirely imported by Australian industry.

Concerns are also being raised regarding longer term supply risks for copper and other raw materials for electrical equipment manufacture as major economies accelerate demands for greener energy..[96] These import risks, may all lead to higher than expected import prices and therefore higher infrastructure delivery costs. In turn, rising prices for imports have implications for the potential scale and scope of future government infrastructure commitments. Conversely, the presence of rising import price and non-price risks also highlights that there may be strong and rising benefits in encouraging domestic supply chain development.

Steel: Australia still produces approximately 5.3-5.5 million tonnes of steel annually..[97] This production is split roughly equally between the Liberty Steel Group (formerly OneSteel/Arrium) and BlueScope which were both spun out of BHP. Liberty's steel production is focused at its blast furnace in Whyalla in SA and electric arc furnaces at Rooty Hill (NSW) and Laverton (Victoria). It is Australia's only producer of long steel products (wire, rods, rails and rebar, including structural and reinforcing steel sections). Bluescope is focused on flat steel products for the building and construction industry, including sheet and rolled coil products and coated and plate steel, sourced from its blast furnace at Port Kembla Steelworks.

Local steel production also provides important low cost waste materials such as slag which is an important input to cement and concrete production. While local steel-making capacity has been critical for servicing market demand, growth in demand has been increasingly augmented by imports, as shown in Figure 86. This in turn generates other risks including ensuring high import steel quality for infrastructure projects as well as managing other global supply chain risks.

Figure 86: Australian steel imports

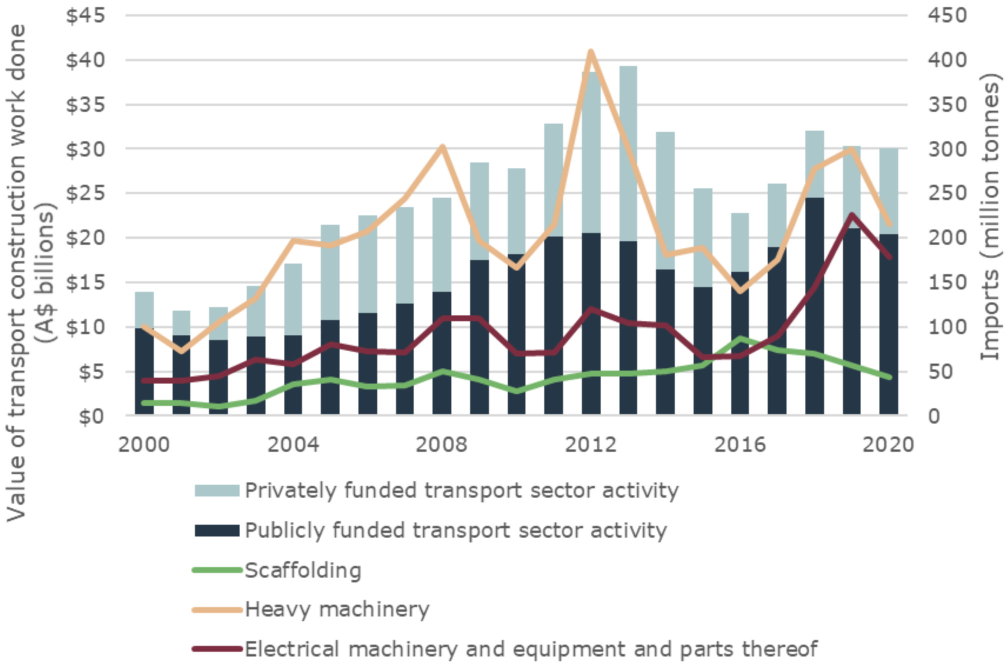


Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Fuel and bitumen: Australia now mostly imports the oil products used in the construction industry, notably diesel fuel (for mobile construction plant) and bitumen. This process has accelerated with the closure of three oil refineries in Australia since 2012, including the Clyde Shell and Kurnell Caltex refineries in NSW in 2012 and 2014 respectively, as well as the closure of the Bulwer Island BP refinery in Queensland in 2015. In October 2020, BP announced the closure of its Kwinana refinery, and this was followed in February 2021 with Exxon's announcement it was also to close its Altona refinery. With the Port Stanvac ExxonMobil refinery closed in 2009, the only remaining refineries operating in Australia will be at Geelong (Vitol) and Lytton (Caltex). The reduction of local refining capacity is increasing Australia's reliance on global supply chains for valuable oil products such as diesel fuel, as well as the "waste product" of bitumen which is used to make asphalt commonly applied in road construction. Consequently, fuel and bitumen are now fully exposed to global supply risks.

Other plant and equipment: Over the past two decades, the closure of Australian manufacturing facilities and strong growth in construction industry demand has seen supply increasingly augmented by imports. As shown in Figure 87, heavy machinery imports (which include mobile and fixed plant used in the construction industry) is highly correlated with transport activity, indicating a strong propensity to satisfy demands through imports. Scaffolding imports also moved higher from 2015-2016 in line with rising non-residential building (and high-density residential building) activity. The strong surge in electrical equipment from 2016-2017 to 2018-2019 was likely linked to sharply increasing activity on renewable electricity generation projects during this period to meet Australia's 2020 Renewable Energy Target.

Figure 87: Heavy machinery imports is highly correlated with transport activity



Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

The Major Public Infrastructure Pipeline is part of a much larger market

Examining the Major Public Infrastructure Pipeline's call on resources as undertaken in this report is only a partial analysis of risk to market capacity – the overall level of market demand is a critical factor.

In examining the impact of demands from the Major Public Infrastructure Pipeline, it is important to recognise the call on the same resources from other competing market demands. In particular, the combination of strong, simultaneous growth in total infrastructure investment during the 2005 to 2011 growth phase (including infrastructure to support new resources capacity, such as new or upgraded railways and ports) spurred record growth in construction costs, indicating there may have been severe challenges to market capacity and capability to deliver during this time.

With regards to whole-of-market demands, however, it is possible to contextualise the Major Public Infrastructure Pipeline's share of overall market demand (excluding oil and gas construction – see the related text box for why this sector has been excluded in the historical analysis) as per Figure 88.

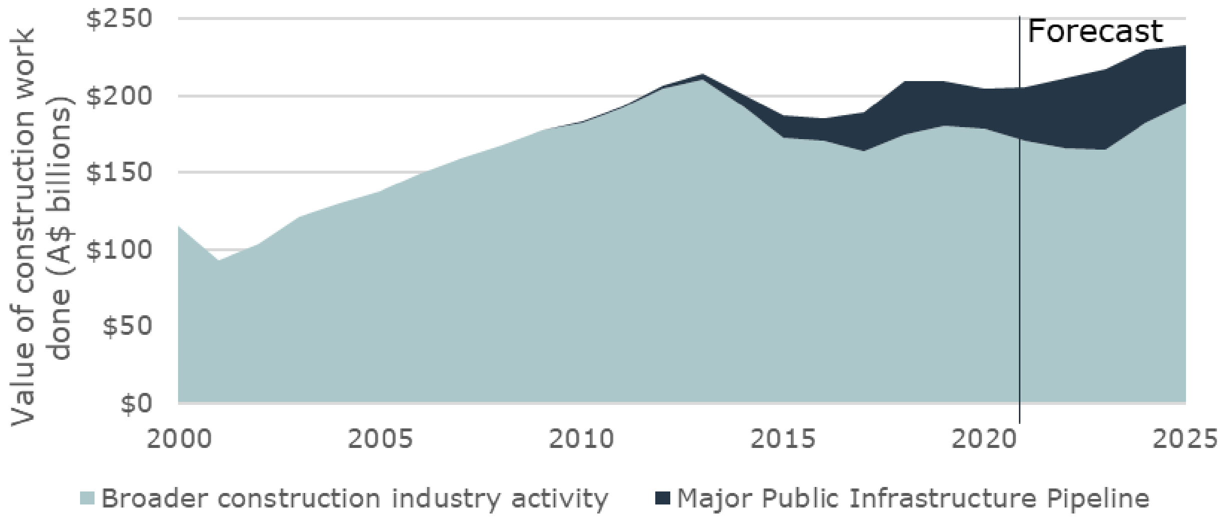
Oil and gas construction in Australia

Oil and gas construction is excluded from the analysis of historical ABS construction data in this report. This is because much of the activity included in the construction data did not occur domestically and so gives a misleading impression of local demand-side pressures. While rising oil and gas construction will still likely add to demand pressure, the experience of the previous oil and gas boom was somewhat unique in its focus on LNG facilities and showed that industry was able to make transformational adjustments to accommodate very steep increases in activity (which may also have contributed to a step up in industry productivity during this period).

This involved much greater overseas outsourcing of professional services in the planning, procurement and implementation stages of several simultaneous multi-billion dollar projects as well as a heavy reliance on overseas steel fabrication (and imports of materials generally). This was assisted by the coastal or offshore location of the new LNG facilities, which made overseas sourcing of large fabricated modules and other components more attractive. For example, Bechtel notes that, in delivering six LNG production trains on Curtis Island in Queensland for three separate clients, the plant design (from engineers based in Houston, New Delhi and Shanghai) was geared at the start to modular construction. Bechtel facilities in the Philippines, Indonesia, and Thailand, constructed more than 260 modules, many of which weighed more than 5,000 tons.[98] In measuring construction work done, the ABS included the value of these (and other) LNG modules upon arrival in Australia. This led to substantial volatility in measured construction activity in the ABS's engineering construction survey.

Consequently, while measured oil and gas construction rose nearly 10-fold (from $5.8 billion in 2006-2007 to $51.2 billion by 2013-2014) its call on local resources was likely significantly lower than these figures suggest. Analysis by BIS Oxford Economics suggests that of the $288 billion in measured engineering construction work done in the oil and gas sector between 2009-2010 and 2017-2018 approximately $150 billion (53%) represented offshored construction activity.

Figure 88: Annual activity captured in the Major Public Infrastructure Pipeline against the broader total construction industry activity (excluding oil and gas)



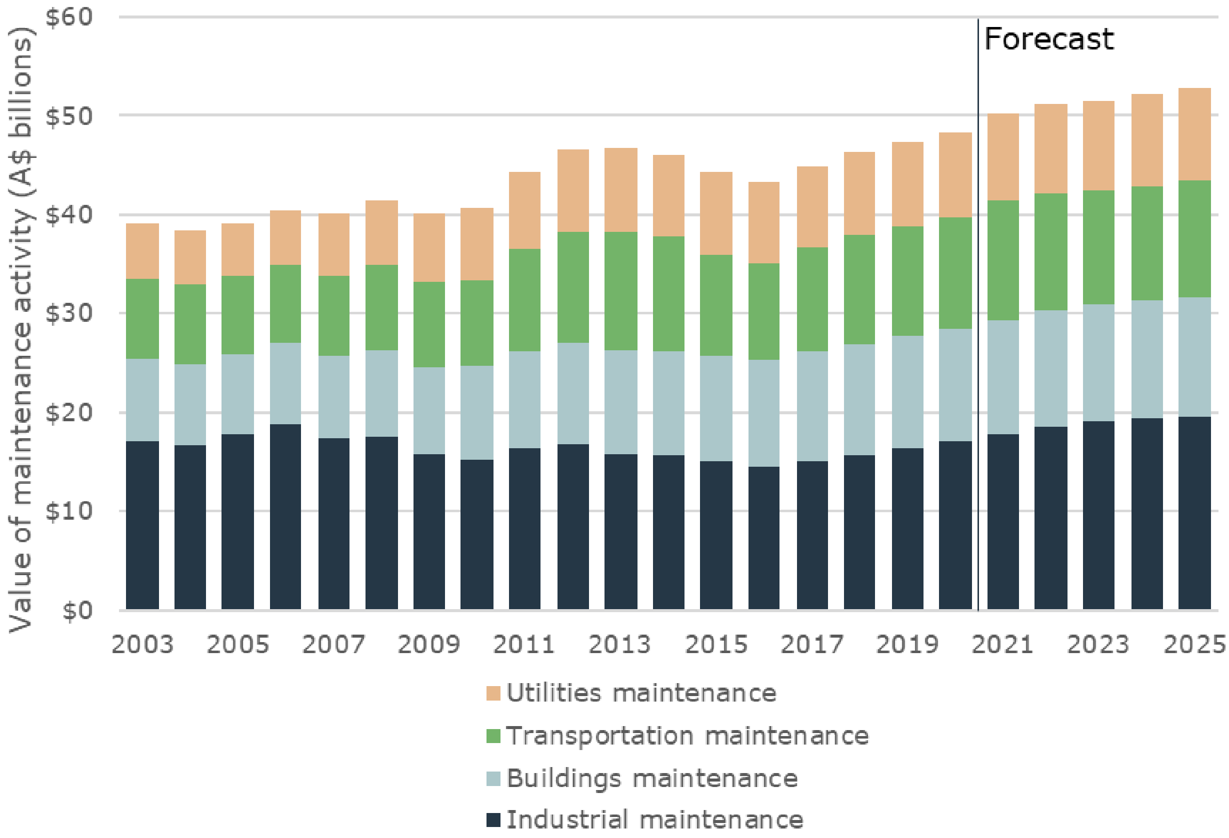
Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

Figure 88 puts into historical context the size of construction activity captured in the Major Public Infrastructure Pipeline with broader total construction industry activity (noting the limited history of Major Public Infrastructure Pipeline projects in this initial dataset), as well as the context of future spend. This illustrates that Major Public Infrastructure Pipeline – while itself significant – is just the tip of a much larger iceberg in overall construction industry activity across residential building, non-residential building and engineering construction (the latter of which includes non-building construction across transport, utilities and mining and heavy industry sectors).

As at 2019-2020, the Major Public Infrastructure Pipeline is estimated to have captured just over 53% of total public infrastructure construction activity. The gap between Major Public Infrastructure Pipeline activity and total public sector activity mainly represents construction activity that occurred in projects less than the threshold values considered for inclusion in the Major Public Infrastructure Pipeline. This includes substantial programmed activity in sectors such as water, sewerage, roads, rail, education and other buildings as evidenced in Commonwealth and state budgets. Once private sector funded activity is included as well the share of the Major Public Infrastructure Pipeline of total activity falls to just 13% in 2019-2020..[99]

To this could also be added the call on market resources from maintenance activity, which is not included in ABS construction work done statistics, nor this analysis and report. As shown in Figure 89, according to estimates prepared by BIS Oxford Economics, maintenance activity in Australia was valued at $48 billion in 2019-2020 and this is expected to grow in real terms over the next five years to 2024-2025, averaging nearly $52 billion per annum during this period..[100] This lift in maintenance activity over the next five years is being driven predominantly by the industrial and transport sectors. Rising industrial activity is being driven by the growing maintenance needs of the resources industry as a consequence of the sector's investment boom during the 2000s and 2010s. Rising transport maintenance, meanwhile, is being driven by a combination of a growing and ageing asset base, as well as additional public funding for maintenance by Commonwealth and state governments to provide support to the economy following the COVID-19 induced recession in 2020.

Figure 89: Annual maintenance activity (2003-2025)



Source: BIS Oxford Economics commissioned by Infrastructure Australia (2021)

While maintenance in some sectors, such as buildings, is likely to be less resource-intensive than construction activity, this is certainly not true of all sectors. Indeed, elements of road maintenance (such as major rehabilitation work) as well as utilities maintenance (such as network renewals) can be just as resource intensive as original construction work and can play a significant role in driving market demands.

The contractor market in Australia has grown, however there is fragility relating to the sustainability of contractors

The growing size and complexity of tender offerings poses a high risk to tier 1 contractors, who have taken on greater risk with reduced profitability, ultimately reducing the competitiveness of the bidding process.

The result is poor competitiveness in the market, with contractors unable to bid for increasingly large tenders, forcing collaborative bids to be placed. This results in additional risk as there is an increasing interconnectedness across the market, increasing the impact of a firm failing. This places an extreme risk on the competitiveness tender processes and is likely that the future pipeline will continue to be exposed to this risk as projects get larger and more frequent. This risk can be transferred across market participants, by breaking up major projects into more manageable tenders A failure to mitigate will see this risk continue to grow and accelerate as the pipeline delivery grows.

Market capacity risks are amplified by other delivery risks

In addition to the specific market capacity concerns outlined above, there are a range of broader risks that are latent for any infrastructure project, namely systemic risks and project-delivery risks.

Systemic risks

All infrastructure development is extensively exposed to systemic risks – large scale, external conditions that are uncontrolled or difficult to influence. A significant contributor to risk levels for infrastructure delivery is the extent of external and systemic risk. Systemic risks for this analysis have been identified through a macroscopic driven analysis, calibrated through the market sounding interviews and validated through subject-matter expert (SME) interviews and data analysis. This section presents the major systemic risk categories and scopes the potential impact on cost, schedule and benefits outcomes for infrastructure delivery. The identified systemic risk categories are in Table 6.

Table 6: Most systemic risks are trending upwards

Category	Risks	0-5 year assessment	
		Rating	Trend
Climate and natural hazards	Increasing extreme weather events and a changing climate represent a risk to major network infrastructure.	**Critical**	↑
	The global shift to a low carbon future will impact infrastructure investments, delivery requirements and the supply chain, driving up costs.	**High**	↑
Community and user risks	COVID is resulting in lasting changes in both living and working patterns as longer term population growth changes underpinning demand.	**Medium**	↓
	Social license issues and community fatigue are leading to additional project costs and delays.	**High**	↑
Technology and cyber risks	The increasing reliance on technology within infrastructure is resulting in greater cyber security risks.	**Medium**	↑
	Failure to accommodate for design for new and emerging technologies pose a risk to asset investments and usage.	**Medium**	↑

Climate and natural hazards

Extreme weather events and a changing climate represent a critical risk to major network infrastructure. The increasing intensity and frequency of adverse weather events poses an episodic but extreme risk to developing and to existing infrastructure, including in the near term.

Climate change experts have highlighted the lack of centralised and transparent data to support planning. Climate resilient infrastructure can be built by incorporating this data in developing structural adaptations, such as changing the composition of road surfaces so they do not deform in high temperatures.

The global shift to a low carbon future will impact infrastructure investments, delivery requirements and the supply chain. Participants in the market sounding identified Environmental, Social, and Governance factors (ESG) as a major recent shift in investment settings, and a driver of investment appetite for lenders and equity investors in the infrastructure sector. However, it was noted that uncertainty over future policy settings was creating investment uncertainty. Further, domestic climate policies and global climate accords could impact future cost of construction materials and the infrastructure supply chain. This will likely be moderate in the short term, with more significant impacts beyond the 5 years.

Community and user risks

The COVID-19 pandemic, bushfires, northern cyclones and recent storm events are creating uninsurable risks. The pandemic, floods, bushfires and even cyber attacks involved a single extreme event generating many losses at once, and increasing loss factors and interruptions risk for many. The annual level of insured losses for weather related events show exponential growth from the beginning of this century, to more than $4 billion in 2011.[101]

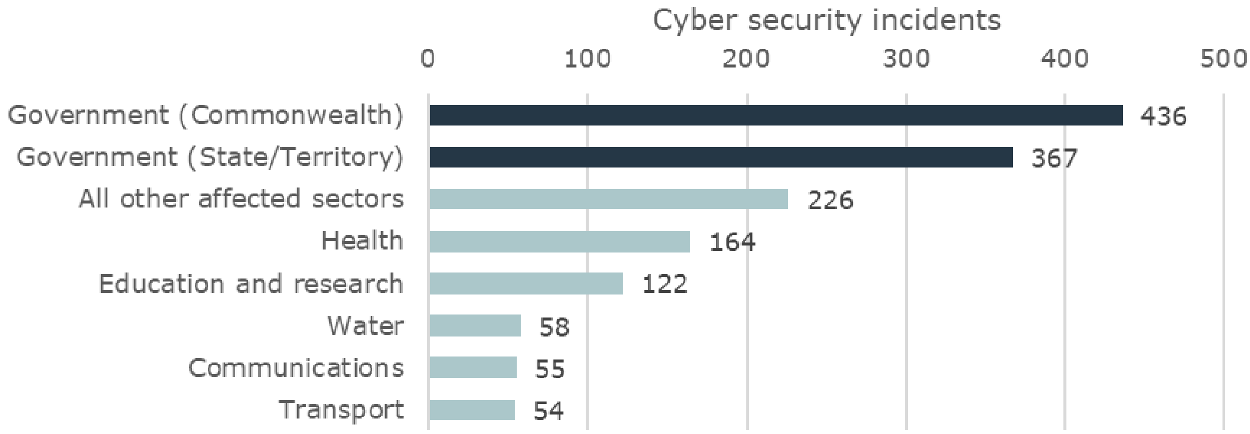
Further the increasing severity and frequency of natural disasters in Australia has resulted in exponentially growing insurance payouts which manifest in being passed through to insurance premiums for following years. As these climate risks worsen, becoming more frequent and causing greater damage to infrastructure, insurers will no longer be willing to insure housing and buildings in high risk regions, or will only be able to insure them at unaffordable rates. This will create insurance "red zones" through major cities, regional centres, and small towns across Australia, as has already been occurring in recent years.[102]

Social licence issues and community fatigue are leading to additional project costs and delay. There almost 200 large sale and mega projects being delivered in Australia's major cities, impacting 71% of the population.[103] [104] The result is that many of the country's most complex engineering projects also experience high levels of community opposition and concern. It has been estimated that $20 billion worth of infrastructure has been cancelled over the last decade as a result of community opposition. This risk can be reduced; however it requires a strong community involvement and coordination across projects to ensure projects are completed quickly and with minimum disruption to the communities impacted.

Technology and cyber risks

The increasing reliance on technology within infrastructure is resulting in greater cyber security risks. There has been a substantial increase in cyber attacks in recent years, with over 2000 cyber security incidents reported in 2019, and over 1000 of these targeting government and critical infrastructure providers (see Figure 90).

Figure 90: Cyber security incidents by sector (2019)



In Australia, the severity of most cyber threats to date have been low and there have been no reportable incidents where critical infrastructure has had to shut down as a result of a reported cyber attack. Globally however cyber attacks have resulted in significant disruption including such incidents as the 2015 disruption to power facilities in Ukraine, the 2017 Triton attacks on Saudi petrochemical facilities and the 2021 ransomware attack on Colonial Pipeline in the United States. Whilst rare, cyber security risks have the ability to have extreme impacts on infrastructure. Our growing dependence on technology and the need to embed technology into infrastructure means this risk will continue to grow. This risk can be reduced by strongly considering cyber security risks at the planning stage and continued investment in security measures.

Technology continues to grow at an accelerated pace. Whilst it is difficult to predict the technologies which will define the future, the continued acceleration of the Internet of Things, emergence of the electric vehicle grid and rise of automation are all rapidly growing trends which will likely define the next 30 years and pose a moderate risk to infrastructure obsolescence.[105] Given the immense investment made in infrastructure development, it is important to protect infrastructure from obsolescence. As such infrastructure will need to be designed to be more technologically adept. Poorly integrated infrastructure will be most at risk of lower than expected demand, risking a benefit underrun and reduced economic viability of infrastructure. The failure to design for new and emerging technologies poses a low risk to the infrastructure over the future pipeline. However this risk will grow with time and thus decisions need to be made at the planning stage to future proof infrastructure.

Project risks

Project risks, applicable to the Major Public Infrastructure Pipeline, were identified through a macroscopic driven analysis, calibrated through the market sounding interviews and validated through SME interviews and data analysis. These views were tested with SME interviews in technology, environment, social, geo-political and economics, transport, social, energy, water, waste and digital. These risks were further tested against the publicly available data sources. Finally, market sounding interviews and results from the market sounding survey were used to determine the relevance of the risks identified in Table 7.

Table 7: Project-level risks common to all sectors

Category	Risks	0-5 year assessment	
		Rating	Trend
Planning and governance	Optimism bias in cost estimation is creating budgetary constraints and delivery risk as cost pressures mount in delivery.	**Critical**	↑
	The size of the pipeline is amplifying the cumbersome and fragmented nature of planning approval process, slowing down projects and adding costs.	**High**	↑
Geography	Utilities relocation risk will continue to be a key issue in the delivery of the infrastructure pipeline with potentially significant consequences.	**Critical**	↑
Construction and delivery	Integration risks is increasing due to new infrastructure projects and technologies requiring integration into existing systems.	**Critical**	↑
	Unpredictable ground conditions can lead to significant impacts during project delivery.	**High**	↑
	Interface risk is becoming more pronounced with the increasing size, scale and complexity of the infrastructure pipeline.	**Critical**	↑
Procurement	The capacity in the insurance market has significantly dropped with increased premiums and reduced coverage.	**Medium**	↓
	As projects get larger the increased complexity results in more frequent and proportionally larger cost overruns.	**High**	↑

Key risks within the planning phase, such as optimism bias and approval process delays were identified as major risks, with unexpected schedule and cost overruns threatening project deliveries. Physical risks such as geotechnical risks, integration risks, and utilities risks were also identified. The increasing complexity and size of projects paired with growing interface risks was problematic and likely to result in greater cost overruns and delays.

All project delivery parties – banks and lenders, contractors, investors, insurers – expressed confidence in their ability to deliver and invest in the current environment, however the key risk is the level of construction risk borne by contractors in two areas:

- Market capacity: The increased size and scale of projects, have limited the number of market entrants, however the competition between Tier 1 contractors is driving down profit margins. The increasing project size also means contractors are forced into Joint Ventures. With the value of projects getting larger, and an increased government push to onforward risk to contractors, there is a critical market exposure in that a single contractor failure can be catastrophic to the infrastructure sector as a whole.
- Resourcing constraints impacting quality: There is a limited capacity for Tier 1 contractors to bring their 'A team' to each project due to the volume of projects concurrently running in Australia. This poses a threat to the quality of build of such projects.

Planning and governance

Optimism bias in cost estimation is creating budgetary constraints and delivery risk as cost pressures mount in delivery. This is compounded by the sheer size, scale and complexity of the Major Public Infrastructure Pipeline and government announcements to fast track $110 billion of infrastructure.

Research by Oxford Global Projects has found that optimism bias exists for costs, schedules, and benefit forecasts throughout all project stages. [106] Optimism bias can manifest during the planning phase of a project (e.g. cost and schedule estimation undertaken during business case development) and during procurement of a project (e.g. a contractor's tender price).

Accordingly, optimism bias can lead to:

- over-estimation of net benefit results in cost-benefit analysis.
- the actual costs of delivering a project exceeding the forecast expected costs, leading to budgetary stress.
- an erosion of the public's confidence in infrastructure planning, assessment and delivery processes.

To mitigate the risks associated with optimism bias, in particular for highly complex mega projects:

- The public sector can reduce the level of uncertainty in design development (e.g. in respect of ground conditions and utilities locations) therefore improving price certainty through greater emphasis on pre-tender Project Development and Due Diligence.
- Adopt techniques such as reference class forecasting – a method to remove optimism bias and strategic misrepresentation in infrastructure projects in order to create more accurate forecasts.

Market sounding feedback identified that major contractors and some investment firms view planning and environmental approval processes as an unpredictable risk to project timelines and a key driver of delays. The need for contractors to coordinate across multiple layers of government to obtain approvals, and the requirement to meet increasingly onerous conditions attached to many approvals (e.g. in relation environmental approvals) has led to concern over project delivery times.

Although a lack of efficiency and efficacy within the planning and approvals space is not a new issue, the scale of the Major Public Infrastructure Pipeline will magnify its impacts and potentially delay the desired economic benefits of the $300 billion of spending.

Planning and environmental approvals are typically allocated between the State and private sector. While key approvals are typically obtained by the State, with minor and technical approvals often allocated to the contractor, issues arise where:

- Key decisions around design requirements are not made early in the process and mandatory approval requirements are unable to be clearly defined and articulated. This creates a risk that the final design is likely to have elements requiring rework after contract reward, leading to potentially significant time and cost overruns.
- During delivery some smaller approvals require the contactor to consult or obtain consents from numerous stakeholders that the State is better positioned to manage, for example local governments or environment protection authorities for disposal of spoil, with consequent delays to obtaining these approvals resulting in potentially significant time and cost overruns.

Geography

Utilities relocation risk represent a significant risk in the delivery of major projects. This is particularly evident given the number of brownfields projects in developed areas with multiple and varying utility infrastructure that is often not well mapped or able to be easily identified. Accordingly, it is often difficult to price accurately.

This risk is challenging for any project party. Market soundings indicate that traditionally States have sought to transfer this risk to the private sector. However, the ability for any party to effectively manage this risk is limited by the absence of any meaningful commercial incentives or bargaining power that can be leveraged in negotiations with the relevant utility companies.

Private sector participants have limited means to manage utility company demands and can often be forced to absorb the pricing and program implications of any demands. Given the likely magnitude of time and cost delays in the context of the current Major Public Infrastructure Pipeline, we are likely to see a trend where the market will either not accept this risk, or engage in disputes with the State in order to recover significant losses.

The well publicised dispute between the contractor and the NSW Government on the Sydney CBD Light Rail demonstrates the significant cost and time impacts when utilities relocation risk manifests to disrupt a project's time and cost profile. The project ended up with a cost overrun of $1 billion and a significantly delayed start to services, for which the contractor brought various claims against the NSW Government. Some headway is being made to mitigate risks associated with utilities relocations. For example, early works packages have proven effective in mitigating this risk. In particular, early works packages procured under collaborative contracting models have been a useful mechanism for minimising the risks associated with utilities relocation.

Construction and delivery

Integration risk is the risk associated with commissioning and integrating a completed major project/asset into the broader network or existing asset base.

This risk will become more prevalent given the scale and concurrency of the Major Public Infrastructure Pipeline, with significant brownfields projects meaning new infrastructure and technology is required to integrate into existing systems.

This is a major risk in complex brownfield rail projects and in energy projects:

- Brownfield Rail – Integration risk can be seen in relation to introduction of new high capacity, digital train control systems, new rolling stock, faster and additional rail services;
- Energy – Integration risk is increasing with the shift underway to a more distributed network driven by localised renewables like solar.

The integration component of the project can often be overshadowed by the construction component, which is usually the largest portion of the project's cost. However the integration piece is often the most challenging and there needs to be a strong focus from the client to ensure its considered at key points in the broader program development. Pipeline planning also has a role to play in mitigating integration risk. Where multiple projects are being delivered on related parts of a network, the sequencing of their design, specification, procurement and delivery is important. Where there is a significant integration component to multiple projects, the client must take a holistic view during the design phase in order to minimise potentially significant integration issues later in the project lifecycle.

Information from the market sounding and SMEs identified unpredictable ground conditions as a common challenge for all major projects, and in particular transport projects that involve tunnelling using tunnel boring machines. The risk arises because:

- It is often not feasible or even possible to fully understand ground conditions ahead of the commencement of construction.
- Environmental challenges associated with groundwater and contamination, particularly in developed areas.
- The need to resolve issues relatively early in the construction phase (meaning that where unexpected issues later arise they will have a knock on effect over the whole project).

The extent to which unknown ground conditions are an issue is dependent on the specific geology of a region. For example, Melbourne's geology makes this issue particularly acute because its ground conditions are changeable and inconsistent. In these circumstances even the most comprehensive pre-construction sampling has the potential to miss important features that could cause issues during delivery. A key issue for contractors is the fact that they are often provided with extensive documentation during the tender phase which includes geotechnical reports and investigations on a 'no-reliance' basis. Contractors argue they should be entitled to rely on information provided to them during tender phase and accordingly should be provided with time and cost relief in the event the ground conditions turn out to be different than what the relevant reports concluded. Major contractors are also indicating they are less willing to accept ground conditions risks moving forward. This means that effective management and collaboration between States and contractors will be critical to effectively mitigate unknown ground conditions risks where it manifests.

Interface risk is becoming more pronounced with the increasing size, scale and complexity of the Major Public Infrastructure Pipeline. Interface risk arises where multiple projects (or packages of a single project) interfere with one another during the design and construction phase. This risk is becoming more prevalent due to the volume and concurrency of major projects within the same geographical location (see Figure 10) resulting in more complex interactions across projects and project stakeholders. Some examples of key interface risks include traffic switching, design inconsistency, community messaging and temporary road connections. The risk manifests when stakeholders cannot reach agreements, or cannot effectively coordinate, resulting in project delays, cost overruns, legal disputes, and potential reputational harm. Overly aggressive program schedules significantly amplify interface risk. Where there are issues on one project or package, the change of a consequential impact on interfacing works is minimised if there is time to remediate problems without altering the program for other works. Packaging should deliver the simplest interfaces possible. Overly complex interfaces increase risk. Packages should also be defined to ensure that interfaces are at points with the minimum technical and engineering complexity.

Procurement

Leading contractors and insurers in the market sounding highlighted that changes in the insurance market are having significant impact on the delivery component of the infrastructure value chain. These changes are being driven by the size and complexity of the infrastructure program and the desire to transfer 100% of the risk and insure against delay risk. Market proponents have estimated a 50% reduction in the capacity of insurance for the construction market as the costs continue to rise.

The impact is most pronounced within professional indemnity where there is challenge in understanding the contractor requirements, with market proponents having seen the amount of PI insurance decrease from $150-$200 million to around $50-$60 million. There is a shift to more defined policies with less coverage, while contractors are being influenced by their insurance coverage in their decisions to bid.

There are particular impact points:

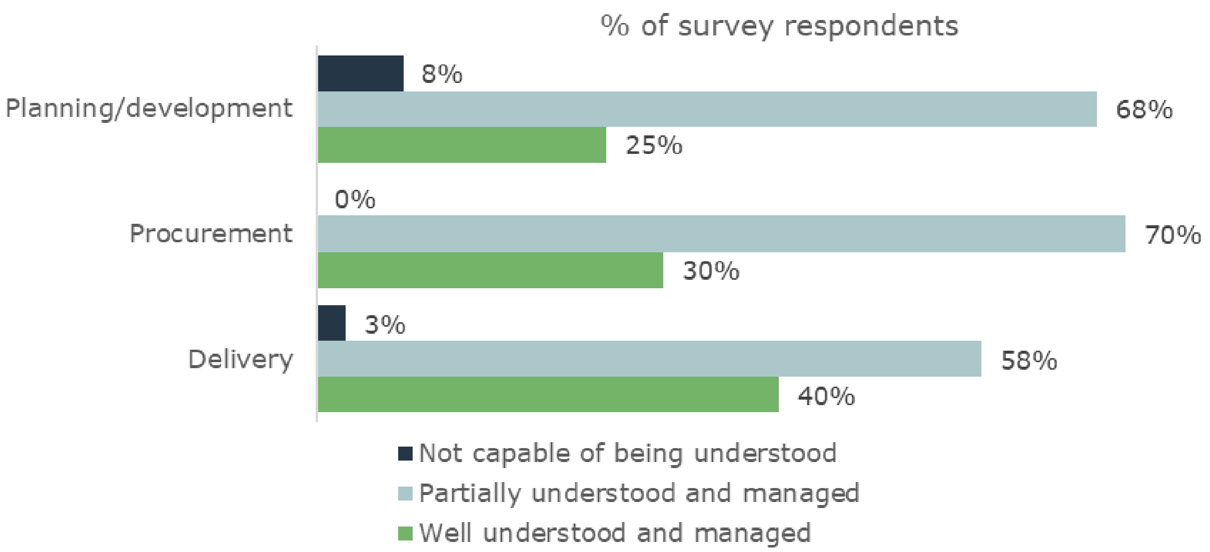
- Contracting model impacts – traditional risk transfer procurement models (e.g. design and construct) have a higher exposure compared with an alliance model which shares the risk across parties;
- Asset type – a single site (e.g. a hospital) has more exposed risk in a single location as compared to a rail line where the risk is spread across the line. Renewable energy assets also have higher claims relative to other asset types;
- Social change – insurance for projects involving thermal coal is almost impossible. .[107]

As projects get larger the increased complexity results in more frequent and proportionally larger cost overruns. The number of megaprojects (projects valued at over $1 billion) has increased ninefold over the past decade, with two thirds of infrastructure spending going to towards these projects. 102 [108] The complexity of these projects allows for greater optimism bias in costing, as the many interconnected risks are often ignored and missed. Post execution was found to be a major cause of time and cost extensions as the ripple effect of small delays on megaprojects can have large impacts which are not as well understood when compared to smaller projects.

Market survey for project risks

Market participants believe critical project risks are only partially understood and managed across the project lifecycle as shown in Figure 91.

Figure 91: Critical risks are only partially understood across the project lifecycle



The market sounding participants identified the top five critical risks to delivery as:

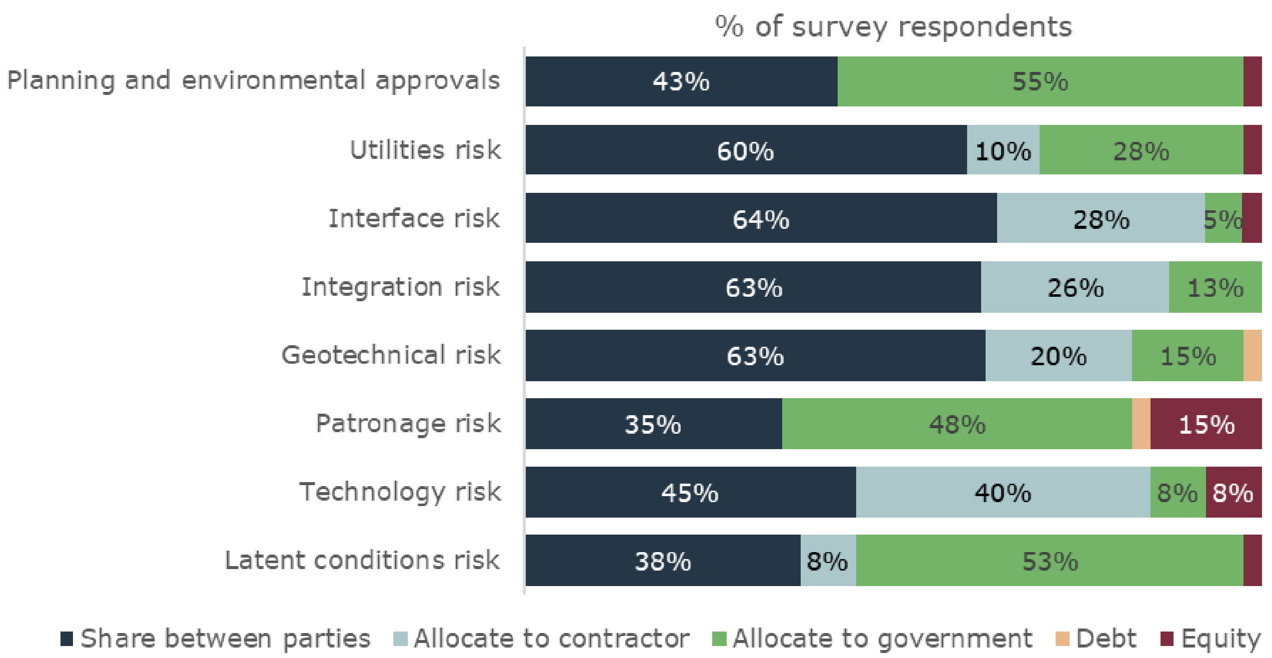
- Contractor capacity.
- Labour shortage across blue collar, white collar and managerial positions.
- Utilities and ground condition risks.
- Availability and cost of insurance.
- Contamination risk.

The poor understanding of these critical risks in delivery has contributed to uncertainty in the market, particularly with respect to the doubling of the pipeline. Market survey participants have largely agreed that traditional procurement models are effective, but have suggested that certain parties are more appropriately positioned to take on particular risk, as shown in Figure 92. In summary:

- Greater risk sharing across parties is required for risks related to utilities, interfacing, integration, and geotechnical issues;
- Technology risk should be fully or partially borne by the project contractor;
- Patronage and latent conditions risk should be fully or partially borne by government.
- Risks related to delays from the planning and approval process should be taken on by government.

While delivery models are relatively effective, changing critical project risks are poorly understood and require revised risk sharing approaches.

Figure 92: Distribution of who should bear risk



There are also risks specific to each sector

How risks impact sector and asset type is a key consideration in delivering the Major Public Infrastructure Pipeline. In addition to systemic risks and project level risks common to all projects, there are sector specific risks that require consideration.

Additionally, systemic and project risks will have a greater impact on some specific sectors than others. For example, wind farms and solar are more exposed to foreign trade risks because they are heavily reliant on imported materials. They are particularly exposed to global supply chain disruptions leading to project delays and cost increases.

Infrastructure Australia analysis on the critical risks per sector is included at Table 8.

Table 8: Critical risks by sector

Sector	Risk	Risk rating
Transport	Increasing prevalence of tunneling in projects will require greater specialist capability nationally, to manage increasing risks on ground movements as well as geotechnical issues.	**Critical**
Transport	Land acquisition challenges will result in increased project costs due to underestimated compensation costs to landowners, and/or late changes affecting project scope and design.	**Critical**
Energy	Underlying connection and transmission infrastructure to support renewable energy is underdeveloped, creating potential for low grid resilience and 'orphan infrastructure' unable to connect into the network.	**Critical**
Energy	Lack of policy coordination is disbursing investment focus, leading to lower investment effectiveness and less efficient investment parametres.	**Critical**
Water	Lack of national policy framework creates uncertainty for investment.	**Critical**
Social	Business cases for social infrastructure are frequently without adequate O&M funding resulting in significant unscoped financial burden for governments.	**Critical**
Waste	Inadequate infrastructure development coordination for all stages of the waste cycle, from collection to aggregation to treatment, will cause cost overruns and benefits underruns.	**Critical**
Waste	Ineffective community engagement continues to lead to social license problems causing project delays and increased costs.	**Critical**
Digital	Poor understanding of existing utility infrastructure, leading to scope growth and cost overruns.	**Critical**

Further detail on how risks can be analysed for each sector – transport, energy, water, social, waste and digital - is available in Attachment C.

7. Next steps

At a glance:

This initial market capacity report identifies potential resource challenges and risks from estimated demands from the Major Public Infrastructure Pipeline.

Mitigating market capacity risks is critical if the rollout of the Major Public Infrastructure Pipeline is to be successfully delivered on time, on budget and in scope.

These risks, the scale of the forecast pipeline, the associated demand for skills and materials and future supply constraints further reinforce the importance of governments unlocking productivity to support infrastructure delivery through transformative policy and leadership.

These outcomes are supported by Infrastructure Australia's *2021 Australian Infrastructure Plan* as it establishes a practical and actionable roadmap for reform through to 2036.

The ongoing ambition of the Market Capacity Program, and the authority of the insights it generates, depends on the quality and depth of data shared by state and territory governments.

Infrastructure Australia is committed to expanding the scope and depth of this analysis in future years.

Responding to risks & identifying opportunities for reform

This initial *Market Capacity Program* report identifies potential resource challenges and risks from estimated demands from the Major Public Infrastructure Pipeline.

Managing these risks effectively will in turn require further research into the key risk areas and, in collaboration with industry and governments, the development of appropriate risk mitigation strategies. Ultimately, the aim of these strategies should be to enhance existing and future market capacity, and the market's flexibility to respond to what may be significant changes in demand. Some strategies are already well known or are being developed, including:

- Better mapping and auditing of quarrying resources, supply and demand, as well as the transport and logistics challenge associated with transporting these construction materials and the removal of spoil – as well as accelerating timeframes for the development of new quarries.[109]
- Improving incentives for (or mandating) industry education and training initiatives (such as the Infrastructure Skills Legacy Program in NSW), boosting public funding for new training facilities (such as the Victorian Tunnelling Centre), as well as considering funding additional tertiary course places.[110]
- Deeper workforce capability modelling by state governments as well as state infrastructure agencies, such as Sydney Metro for critical or bespoke roles.
- Reviewing whether existing skills shortage lists and processes surrounding skilled migration programs are fit for purpose for the infrastructure industry.
- Redressing the lack of diversity in many engineering, building and construction-facing industries.
- Transparent communications regarding the Major Public Infrastructure Pipeline so that industry has the best chance to gear up to meet demand.
- Better understanding the longer-term operations and maintenance demands from infrastructure that may also impact on market capacity.
- Choosing procurement models which more efficiently allocate risk (depending on the project) as well as broader measures to encourage industry innovation vital for lifting productivity in the delivery of major projects and hence minimising resource demands.[111]
- Undertaking further research into the quality, price, strategic and security resource risks associated with Australia's increasing reliance on overseas supply chains for key materials, plant and equipment, and skills – and the opportunity a strong Major Public Infrastructure Pipeline presents for building local industries and supply chains, and providing a more diverse array of sustainable employment opportunities.

Mitigating market capacity risks is critical if the rollout of the Major Public Infrastructure Pipeline is to be successfully delivered on time, on budget and in scope (including quality). Conversely, failure to meet market capacity and capability challenges is likely to have a range of deleterious impacts including:

- Increasing cost overruns on major projects or project failures (including costly litigation, rectification works and social costs).
- Increasing failures in the infrastructure industry (including increasing closures and bankruptcies in infrastructure-related businesses as well as failure of projects to meet desired business, economic or social objectives).
- Delays to projects and the broader construction and engineering pipeline.
- Worsening industry productivity.
- Higher cost escalation and generally higher costs in delivering the Major Public Infrastructure Pipeline which in turn may risk project quality.

Emerging capacity constraints, worsening industry productivity and higher construction costs all have the potential to negatively impact the scope and scale of future infrastructure commitments, either requiring projects to be delayed or other spending foregone. With constraints on key skills, higher quality skills run the risk of being quarantined to the highest bidder which is likely to see them focused on larger infrastructure projects in the larger states, with reduced capability available for smaller projects and smaller state and territory governments, as well as local government, and particularly in regional areas. Ignoring risks to the supply of critical materials, plant and equipment is likely to place greater reliance on global supply chains

Transforming infrastructure delivery

These risks, the scale of the forecast pipeline, the associated demand for skills and materials and future supply constraints further reinforce the importance of governments unlocking productivity to support infrastructure delivery through policies supporting increasing portfolio management, digitalisation, front-end engagement and innovation. A collaborative commitment with industry to support workforce participation, outcomes-focused procurement and effective risk management will help transform infrastructure delivery and maximise the opportunities created through this pipeline in the years ahead.

These outcomes are supported by Infrastructure Australia's *2021 Australian Infrastructure Plan* as it establishes a practical and actionable roadmap for reform through to 2036. The *2021 Plan*, delivered alongside a new *Deliverability Roadmap* for industry and government, together provide practical recommendations for all industry participants to work together to increase productivity and innovation in the short-, medium-, and longer-term.

Sharing data to deepen and build on this understanding

The ongoing ambition of the Market Capacity Program, and the authority of the insights it generates, depends on the quality and depth of data shared by state and territory governments. This first Market Capacity Report demonstrates the benefits of a comprehensive national view of the Major Public Infrastructure Pipeline.

Ongoing commitments to data sharing will strengthen Infrastructure Australia's future analysis and enable new insights to be generated. Infrastructure Australia is committed to expanding the scope and depth of this analysis in future years. To this end, as we consider future capabilities as part of Phase 2 of the Market Capacity Program, our ongoing collaboration with state and territory governments and industry will continue to be central to maximise the value of this work.

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Table of tables

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