20-Year NSW R&D Roadmap – Supplement

The *20-Year NSW R&D Roadmap – Supplement* ('the Supplement') provides further detail on the methodology and selected underlying data used in the development of the *20-Year NSW R&D Roadmap* ('the Roadmap'). Most of the data is available from public sources.

Methodology for developing the Roadmap

Competitive advantage

The Roadmap assesses NSW's competitive advantages. Competitive advantages are attributes that allow a business or state to outperform its competitors. Competitive advantages can be general (for example in a sector or technology) or specific (for example in a particular application). The Roadmap considers data on six categories of competitive advantage.

Table 1: Categories of competitive advantage

Competitive advantage		**Example indicators**
R&D	Research and development capabilities such as centres, facilities, equipment and teams in universities, businesses, research organisations and government.	Number and quality of publications Amount of R&D investment and grants attracted Number and quality of researchers Critical facilities
Education	Education pathways and capacity through universities and other training providers.	Undergraduate and graduate course completions Domestic and international course enrolments University rankings
Workforce	Workforce capacity including skilled workers and employment opportunities.	Employment data Migration data
Industry	Businesses' capacity including local activities and investment and exports.	Business Expenditure on R&D (BERD) Export data Sector Gross Value Added (GVA)
Innovation	Business creation, scaling and early stage investment and entrepreneurship.	Number and quality of patents Number of startups Venture capital investment data
Natural	Access to critical natural resources and assets.	Critical natural resources Critical natural assets

The competitive advantages are used to benchmark NSW against the rest of the world, selected peer geographies (countries, states or cities), or in some cases against other Australian States and Territories. NSW is competing in a global marketplace for goods and services. Therefore it is preferable to benchmark NSW internationally. However, in some cases there is insufficient robust data to develop a global benchmark. In these cases, where Australian data is available, it is used to benchmark NSW against other Australian States and Territories. While inferior to an global benchmark, an understand of NSW's competitive advantages in a domestic context is still helpful, particularly for Australian companies, international companies and investors intending to do business in Australia, and the Australian Government.

The Roadmap identifies NSW's areas of competitive advantages in:

- **Technologies:** Methods, systems and devices with common attributes and functions that can be applied in a variety of applications across different sectors. For example, 'software' that describes computer scripts, applications and programs – essentially all virtual function aspects of computers.

This can be used for any application involving computers and electronics, from control systems to word processing, video games and graphic design.

- **Applications**: The use of technology for a specified purpose, generally in a specific sector. For example, 'robotic agriculture', which comprises the use of robotics to perform tasks in the agricultural sector such as planting and harvesting.

An aggregation of sufficient competitive advantages in a technology or application can make that technology or application 'an area of competitive advantage for NSW'. For example, Australia has leveraged its competitive advantages in natural resources, people and skills, technology, regulatory support, infrastructure, markets, industry, and supply chains to develop a world leading and highly productive resources sector.

Although competitive advantages assist businesses or states in competing against other businesses and states, they are only leveraged into actual industry strength in some cases. For example, Australia could (but is yet to) leverage its competitive advantages in natural and low-cost renewable energy resources, R&D capability, people and skills, infrastructure, markets, and supply chains to develop a large and competitive controlled environment horticulture industry.

While NSW needs to prioritise areas where it has competitive advantages, NSW also needs capabilities in certain sectors, technologies and applications that are critical for economic and national security. For example:

- The Covid-19 pandemic has demonstrated how having a local mRNA industry has been critical for countries to rapidly access to sufficient supplies of highly effective vaccines.
- The semiconductor shortage and the geopolitical sensitivity surrounding the semiconductor industry has demonstrated how local industry, including defence and manufacturing, can be critically impacted by developments in the international semiconductor industry.

NSW may or may not have competitive advantages in these critical areas. For example, NSW already has R&D capability and people and skills for RNA industry, but arguably has limited global competitive advantages in the semiconductor sector. However, it may still make sense to prioritise R&D investments to these areas to ensure NSW develops local capabilities and industry and manages economic and national security risks.

Therefore, the R&D Roadmap also identifies and assesses technologies and applications that NSW needs for strategic reasons. These could become areas of competitive advantage over time, with deliberate effort and investment.

Data analysis

Data relating to each category of competitive advantage was collected and analysed from a range of official sources such as the Australian Government and United Nations agencies. Private data sources, such as selection of well-known university ranking publications and Crunchbase (an international database for private company data) were also used. These sources are outlined in Table 2.

Descriptive statistics and Revealed Comparative Advantage methodology were used to identify areas of competitive advantage. Technology themes were identified through synthesis of competitive advantages identified across the range of data sources examined and consideration of the insights provided by experts and stakeholders through consultation.

Data sources were separately analysed looking for NSW advantage in terms of rank, total volumes and/or percentage share in measures such as output, investment, industry, in categories (such as industry sector, occupations, fields of research or education), compared to other Australian jurisdictions or international

jurisdictions (dependent on dataset). As listed below in Table 2, the reference periods varied depending on data availability and the periods defined by the original research methodology. For example, the 2018 ERA outcomes used a reference period ranging from 2011 to 2016. For most datasets, the most recently available year, or series of years up to the most recently available, was used. In some cases, particularly where the COVID-19 pandemic had large and likely temporary impacts on the data, a pre-2020 reference period was used even where more recent data was available.

Highlights from each data source were explored to identify technologies and applications with clusters of advantages. These were then considered alongside insights and feedback from a consultation and public survey to inform the draft Roadmap. The findings of the draft Roadmap were tested with experts at the Competitive Advantage Summit, hosted by the NSW Chief Scientist & Engineer and the NSW Chief Economist in February 2022. The feedback from the Competitive Advantage Summit was used to refine the draft and finalise the Roadmap.

Commentary on data sources

- Many official statistics are presented using the Australian and New Zealand standard classification structures. In particular, the industry and occupation classification standards are aligned to traditional sectors and occupations and make it harder to identify the segments of the economy or labour force that relate to technologies and applications. Additionally, while data is available at State/Territory level, it is often only available at the highest level of the classification such that it is not possible to examine subdivision contributions.
- Trade data is impacted by 'Confidential Items of Trade' for which the Australian Bureau of Statistics (ABS) suppresses selected details (such as the commodity code, receiving country, etc.) to protect confidentiality of the reporter. The value of all confidential exports is aggregated into the category 'Confidential Items of Trade' causing the value of some commodity classes to be undervalued. The ABS produces a list of confidential items which can be used to determine the impact on reported statistics.[1] As noted below in Table 2, this analysis did not attempt to quantify the impact of confidential data.
- The notes on use of data from the Australian Research Council's (ARC) Excellence in Research for Australia (ERA) Outcomes report state that the outcomes data should not be used for between-field of research comparisons. Therefore, the analysis for this report has restricted conclusions about the ERA Outcomes scores to within-field comparisons between jurisdictions. The ratings in the ERA Outcomes are based on results across several R&D indicators.
- In the detailed Higher Education dataset obtained from the Department of Education, Skills and Employment (DESE), the actual numbers of course completions were supressed for fields with less than 5 completions at the institution level and replaced with '<5'. To enable summary analysis, '<5' was replaced with a value of 1 with the expected general impact of underestimating totals across the data. The impact at the broad field of education level was seen to be minimal when totals from the detailed dataset were compared against the publicly available data in the DESE Higher Education uCube. For narrow and detailed fields of education, where completions are much lower, the impact of any truncated data was considered prior to the inclusion of any statistics in the report, to determine if the interpretation could be materially affected. For example, in the detailed field of Mechanical Engineering, NSW had a calculated total of 64 Doctorate by Research completions, Victoria had 4, Queensland had 3. NSW had 2 rows impacted by truncated data, Victoria had 4 and Queensland had 3. If Victoria and Queensland both had the maximum of 4 actual completions in each of those affected rows, their total completions would have been 16 and 12

[1] ABS (2021), *International Merchandise Trade: Confidential Commodities List*, accessed 25 January 2021.

respectively. This does not change NSW having the lead or majority share. Reported completions are given as approximations to reflect this uncertainty.

Commentary on composite indicators

Composite indicators simplify information across a range of factors related to a phenomenon to enable comparisons between geographical entities (such as countries, states, cities) or organisational entities (such as hospitals, universities, businesses), generally into a single numeric value that enables entities to be ranked. Composite indicators therefore are a popular tool for reducing multi-dimensional data in the process of policy and decision making as they enable an audience to easily make comparisons between the evaluated entities.

Several well-known composite indicators exist for the measurement of Innovation, Technology and Information. These include:

- Technology Achievement Index[2]
- Summary Innovation Index[3]
- General Indicator of Science and Technology[4]

The formation of composite indicators is a complex process that involves carefully weighed judgement at several steps and requires robust theoretical and statistical frameworks. The utility of the final indicator is subject to acceptance by the audience by which it will be used. The *Handbook on Constructing Composite Indicators Methodology and User Guide* cautions that composite indicators may "invite users (especially policy-makers) to draw simplistic analytical or policy conclusion" and that they have potential to mislead if not well constructed or if poor quality data is used.[5]

Authors of the Handbook also emphasise that composite indicators should be merely the starting point, prompting deeper analysis into the underlying sub-components and drivers of the results.[6] There is a temptation to boil down complex dimensions into a single output and not explore more deeply once the result has been achieved.

Considering the range of limitations found in the data sources used in the Roadmap, and the variety of comparisons and categories of competitive advantage that were considered as part of the Roadmap methodology, it considered inappropriate to develop a composite indictor of overall competitive advantage. Rather, the Roadmap focuses on understanding the details which underly the observed clusters of competitive advantage, which assist readers to understand the basis for why a technology or application has been identified.

Revealed Comparative Advantage

The Revealed Comparative Advantage (RCA) Index was first introduced by Bela Balassa in 1965 and is a commonly used calculation in economics to compute relative advantages between jurisdictions in trade exports.[7] It can be thought of as a normalised proportion, for example:

$$RCA\ Australian\ coal\ exports = \frac{Ratio\ of\ Australia's\ coal\ exports\ to\ Australia's\ total\ exports}{Ratio\ of\ world's\ coal\ exports\ to\ world's\ total\ exports}$$

[2] United Nations (2001), *Making New Technologies Work for Human Development*, accessed 4 February 2022.
[3] European Commission (2021), *European Innovation Scoreboard 2021 Methodology Report*, accessed 4 February 2022.
[4] National Institute for Science and Technology Policy Japan, "Science and Technology Indicators, and Scientometrics", accessed 4 February 2022.
[5] OECD and Joint Research Committee of the European Commission (2008), *Handbook on Constructing Composite Indicators Methodology and User Guide*, accessed September 2021.
[6] OECD and Joint Research Committee of the European Commission (2008), *Handbook on Constructing Composite Indicators Methodology and User Guide*, accessed September 2021.
[7] Balassa, B. (1965), *Trade Liberalisation and 'Revealed' Comparative Advantage,* The Manchester School, 33 (2), 99–123.

An RCA > 1 indicates a relative advantage or specialisation in exporting the product compared to a country that exports the product at or below the world average level. According to the UNCTADstat RCA Radar, Australia's RCA for coal is 26.1, revealing a substantial relative strength in coal exports.[8] As part of the Roadmap development, the RCA concept was used to examine NSW specialisations in merchandise exports, patenting and technology businesses relative to other Australian jurisdictions and the world. The term Revealed Technology Advantage (RTA) has been used to describe the RCA index calculated for patent data.

Data sources

Table 2 shows the main data sources used to assess NSW's competitive advantages compared to other countries, peer geographies, and Australian States and Territories. Other sources are referenced in the Roadmap.

Table 2: Data sources analysed in development of the NSW R&D Roadmap.

Competitive advantage	Data sources	Analysis notes / Reference period
R&D capability	Excellence in Research Australia Outcomes 2018-19	Data included ranges from 2011 to 2016, staff census date 31 March 2017
	Australian Research Council National Competitive Grants Program Projects dataset	Funding from all programs in the National Competitive Grants Program 2012-2021
	CWTS Leiden Ranking 2021	Indicators included were total volume of publications, publications in top 1% of citations, publications co-authored with industry Citations cover period 2016 to 2019
Education	QS University Rankings by Subject 2021	Publication year 2021
	Shanghai Ranking's Global Ranking of Academic Subjects	Publication year 2021
	Australian Higher Education Completions Data, provided by Department of Education, Skills and Employment	Period included 2015 to 2019
Workforce	ABS Australian Labour Force, Detailed[9]	Reference date August 2021
	Temporary Resident (Skilled) reports, Department of Home Affairs	Reports from 2018 to 2021
Industry	ABS Research and Experimental Development, Businesses, Australia[10]	Reference years 2011-12, 2013-14, 2015-16, 2017-18, 2019-20.
	DFAT Trade Statistical Pivot Tables[11] based on ABS International Trade in Goods and Services, Australia ABS International Trade: Supplementary Information, Calendar Year[12] RCA 2019 - International commodity exports data (SITC Rev. 4, 2016 to 2020), UN Comtrade RCA 2019 - International service exports data (EBOPS 2002, 2016 to 2020), UN Comtrade	Exports are recorded by the port of export and may not truly reflect industry output of the state. RCA analysis for merchandise exports at State & Territory level used data curated by DFAT based on ABS Merchandise Exports data for 2019. State to International RCA analysis compared NSW data (DFAT) to international data from UN Comtrade with commodities aligned using 3-digit commodity codes of the SITC revision 4 classification. RCA for service exports used State/Territory-level service credits data from the ABS. Differences between the EBOPS 2002 classification used by the UN Comtrade and 2010 version used by ABS created challenges in aligning NSW and international data. The results are not reported in the Roadmap.
	ABS Australian State Accounts[13]	Reference date June 2021

[8] UNCTADstat, *Revealed Comparative Advantage*, accessed 31 January 2022.
[9] Table EQ08 - Employed persons by Occupation unit group of main job (ANZSCO), Sex, State and Territory, August 1986 onwards and Table EQ09 - Employed persons by Industry division (ANZSIC) and Occupation major group (ANZSCO) of main job and Sex, August 1986 onwards.
[10] Business expenditure on R&D, by ANZSIC06 industry subdivision, by location of expenditure, financial years 2011-12 to 2019-20.
[11] State by country and SITC pivot table 2011 to 2020 (June 2021 data).
[12] Table 3. International trade in services, credits, state by calendar year, $m.
[13] Table 2 Expenditure, Income and Industry Components of Gross State Product, New South Wales, Chain volume measures and current prices' (June 2021 data).

Competitive advantage	Data sources	Analysis notes / Reference period
Innovation	IP Government Open Data (IPGOD) 2021 from IP Australia PATENTSCOPE from the World Intellectual Property Organisation (WIPO)	RTA index was calculated based on Balassa's RCA methodology, as described above, to normalise NSW's share of filed patents over the period 2016-19. Data from the 3 years was included to smooth patent activity over several years. The international reference data of global patent filings was obtained from WIPO.
	Crunchbase, Startup data	Reference date January 2022
	Department of Industry, Science, Energy & Resources Venture Capital Dashboard, NSW data provided.	Reference date November 2021

Stakeholder consultation

The Office of the NSW Chief Scientist & Engineer (OCSE) conducted a phased consultation process on the Roadmap, involving stakeholders from industry, research and government sectors:

- **Phase 1:** From October to December 2021, a series of roundtables were held with industry and research leaders from sectors across the NSW economy. Targeted interviews were also held with experts with specialised expertise in particular industries or technologies.
- **Phase 2:** From November to December 2021, an online survey was conducted to collect feedback from the broader community.
- **Phase 3:** In February 2022, the findings of the draft Roadmap were presented at the Competitive Advantage Summit hosted by the NSW Chief Scientist & Engineer and the NSW Chief Economist.

Phase 1: Roundtables and targeted interviews

The OCSE and selected strategic partners hosted roundtables to consult with key stakeholders from the business, investor, research and startup communities in NSW. The OCSE also hosted roundtables focused on key sectors (technology, biomedical, construction, agriculture and food, decarbonisation and manufacturing) and a series of interviews and in-depth discussions with individual experts, business leaders and executives, investors and technology innovators.

Phase 2: Online survey

The OCSE ran a survey open to all research and industry stakeholders and the public, with 176 survey responses received. The NSW Government 'Have Your Say' platform was used for a public consultation survey to engage a wider range of stakeholders and the community. The survey was open from 5 November 2021 to 16 December 2021 and received strong interest from the NSW R&D community and public:

- 31.4% engagement rate[14]
- 967 total visits by 741 unique visitors
- 176 surveys completed
- 108 quick poll responses.

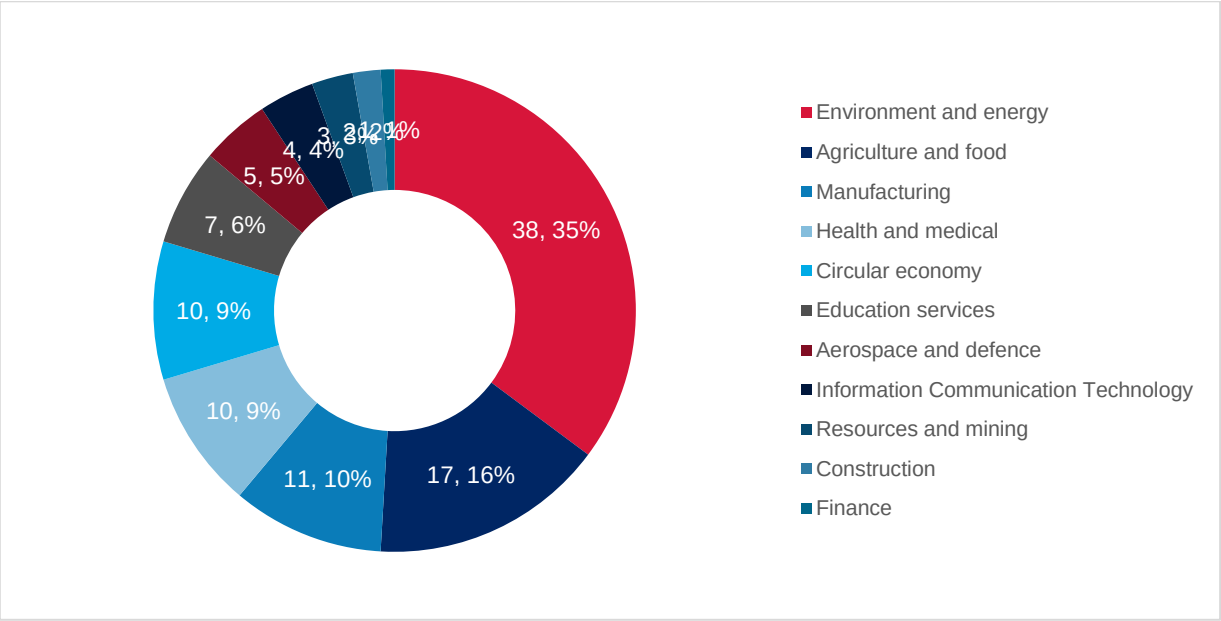
The Have Your Say survey was promoted by direct email campaign, NSW Government official LinkedIn pages, and to representatives of participating organisations in the Roadmap roundtable sessions. Most survey respondents were from an academic background (42%), followed by Industry (25%) and Government (17%). A summary of some of the survey findings is detailed below.

[14] Compared to an average engagement rate of ~10% for NSW Government Have Your Say consultations.

Survey Results

Quick Poll: "Which sector should NSW invest in to build capability and capacity over the next 20 years?"

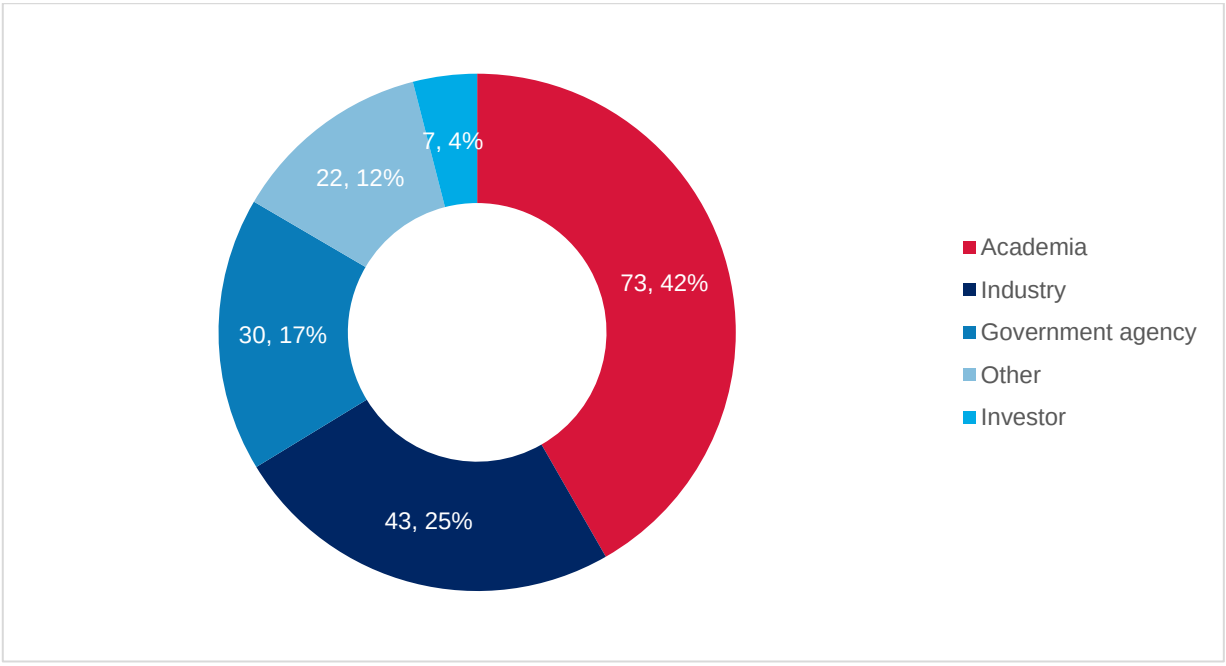
Number of responses = 108



The leading response to the Quick Poll was 'Environment and Energy', which received more than double the votes compared to the second highest category, 'Agriculture and food'. This preference was reinforced by the results from the full survey, where 'Energy technologies' ranked highest both as the technology category in which NSW had competitive advantages and should invest in.

Question 1: "What best describes you?"

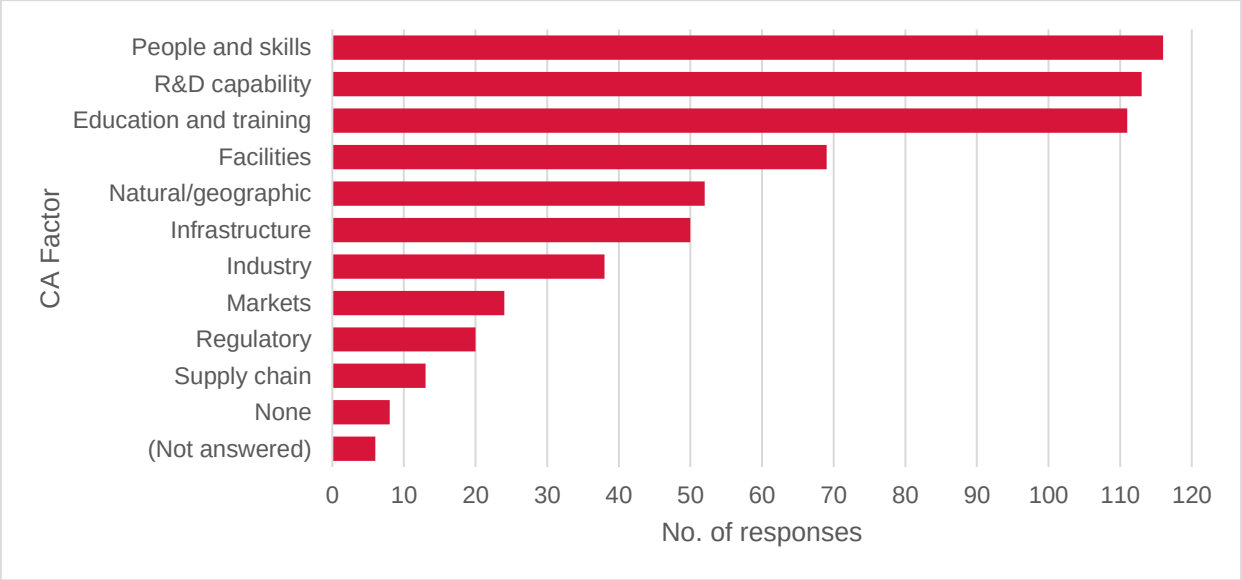
Number of responses = 175



This question aimed to understand the professional background of respondents. The largest group represented in the survey was 'Academia', followed by participants from 'Industry'.

Question 2: "What are NSW's competitive advantages in research and industry development?"

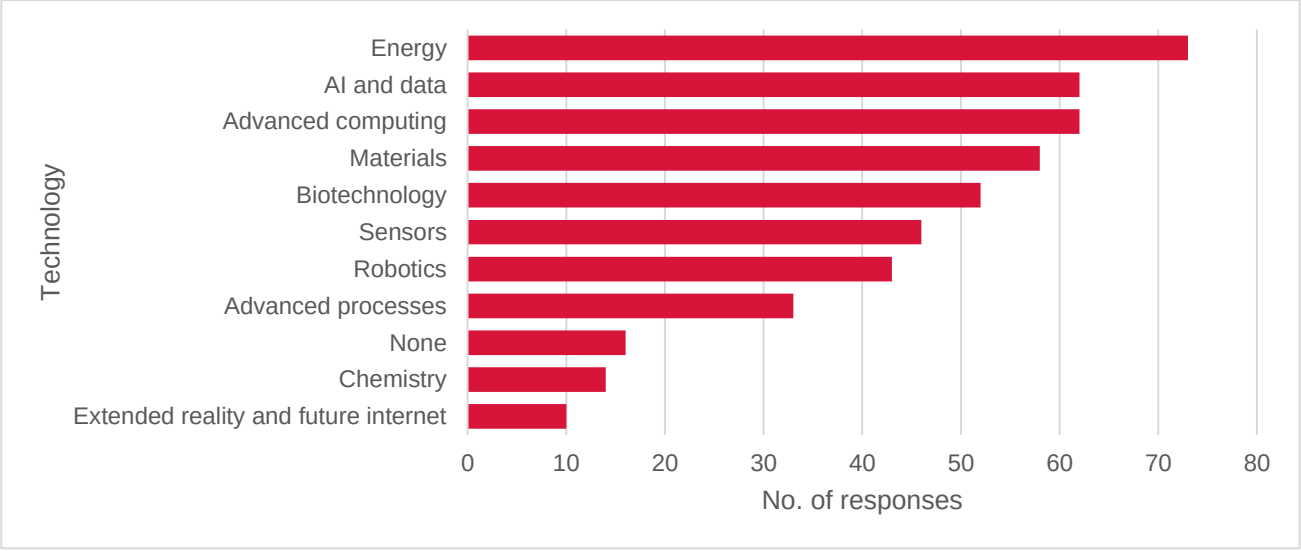
Number of respondents[15] = 168



This question aimed to understand NSW's competitive advantages. Across all respondent categories, the top 3 competitive advantage factors included 'People and skills', 'R&D capability' and 'Education and training'. For respondents in the 'Investor' category, 'Facilities' tied equal second with 'R&D capability' and 'Education and training'.

Question 3: "What technologies does NSW have a competitive advantage in?"

Number of respondents = 169

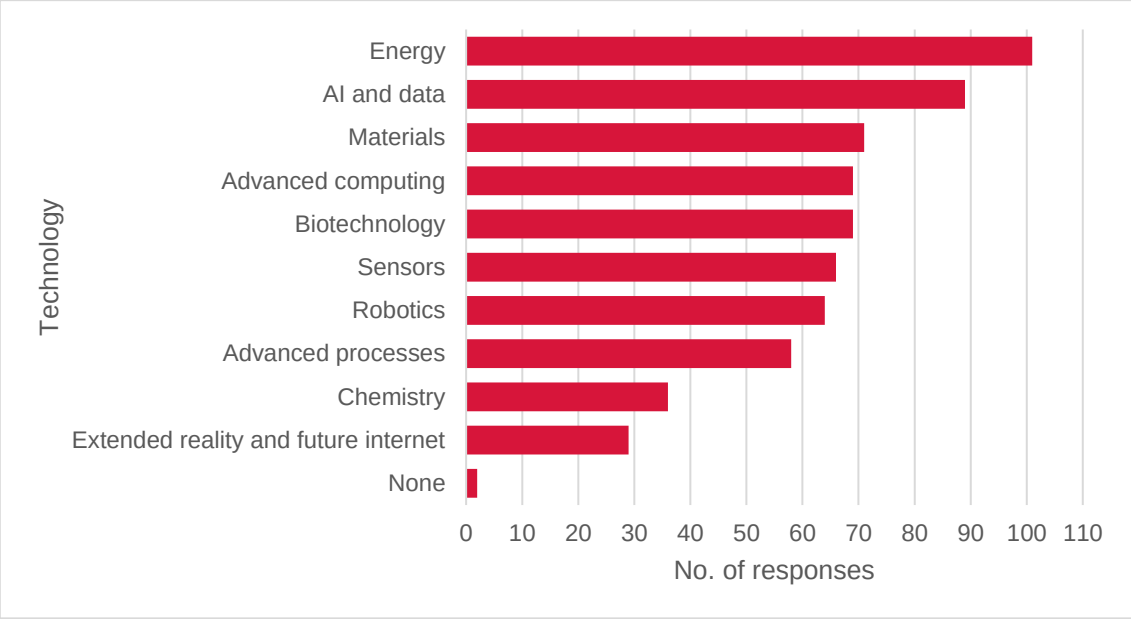


This question aimed to understand the technologies that respondents consider NSW to have a clear competitive advantage in. Definitions and examples of these ten technology clusters were provided to the respondents for reference. The 'Energy' technology was ranked first across all respondent categories, except amongst the 'Other' respondent category where it was ranked fifth.

[15] Respondents were allowed to select more than one response to the question.

Question 4: "Which technologies should NSW invest in?"

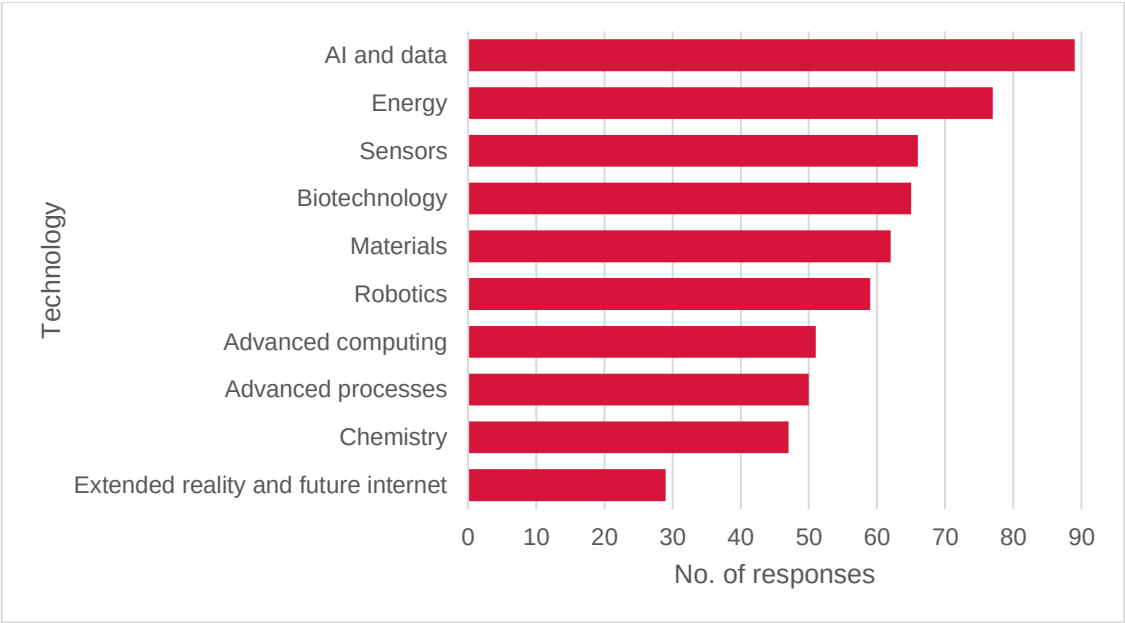
Number of respondents = 169



This question aimed to understand which technology cluster stakeholders think NSW should support with targeted investment, public funding and resources to leverage their existing competitive advantages or grow the capabilities required to fulfil strategic needs. Amongst investors, the 'Energy' technology cluster was ranked first, followed by 'Biotechnology', 'Chemistry' and 'Materials'.

Question 5: "Which technologies are you currently developing or adopting?"

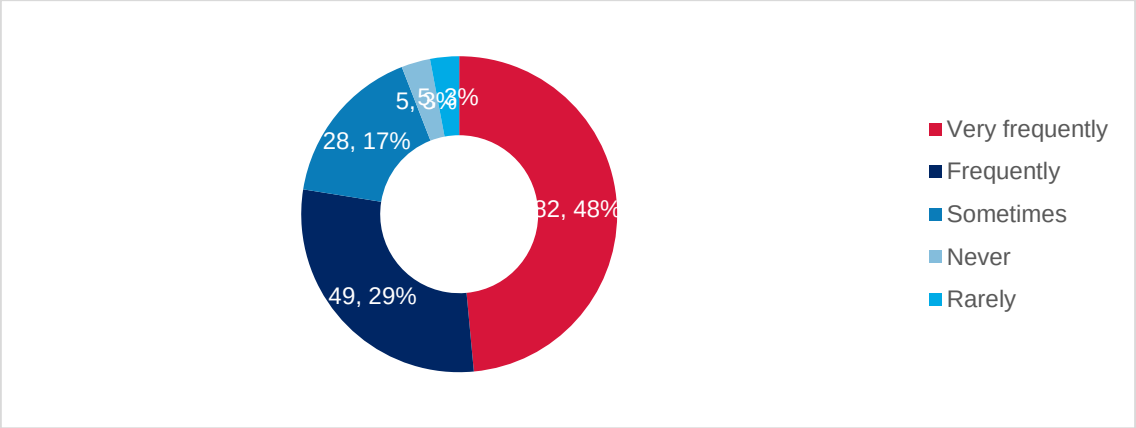
Number of respondents = 169



This question aimed to understand how respondents are currently investing their resources in the ten technology clusters for technology development, commercialisation and deployment. 'AI and data' ranked first across all respondent categories, except for 'Investors' who ranked 'Robotics' the highest.

Question 6: "How is your organisation collaborating with others?"

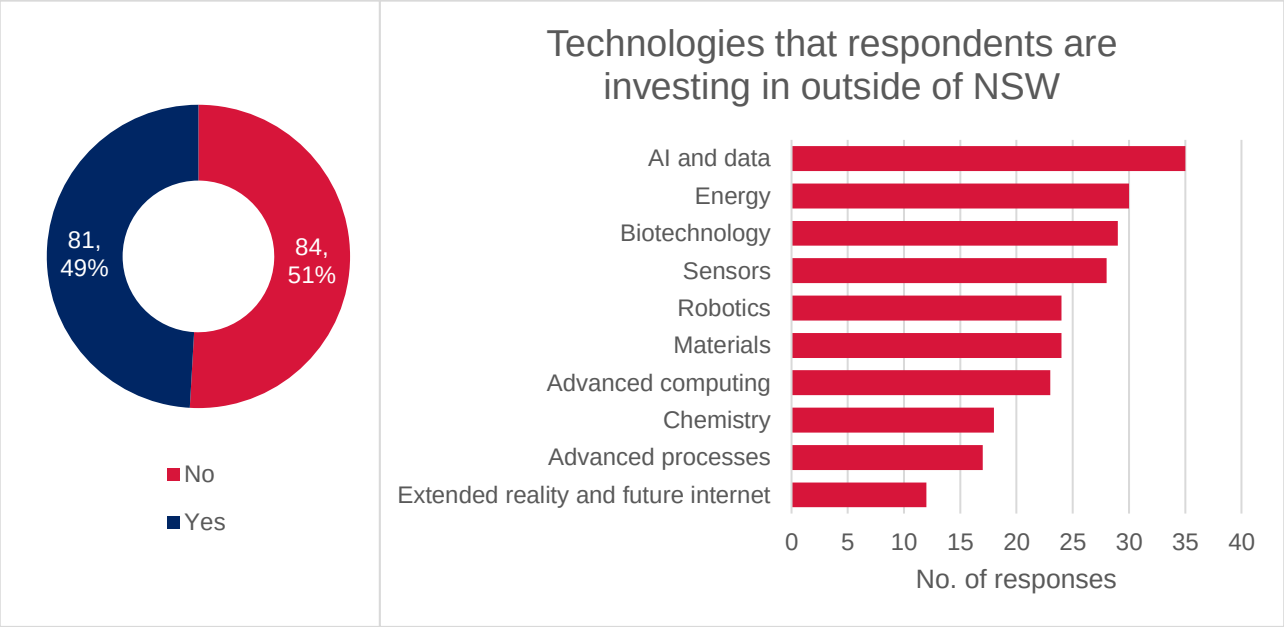
Number of respondents = 169



This question aimed to understand how respondents are collaborating with other organisations. Many of the survey respondents were involved in a frequent collaborations. 131 respondents (78%) reported collaborating either frequently or very frequently. Only 10 respondents (6%) reported never or rarely collaborating with others.

Questions 7 and 8: "Is your organisation investing in other regions (outside NSW) and if so, which technology group are you investing in?"

Number of respondents = 165



This question aimed to understand the competitiveness and attractiveness of NSW for investment in the ten technology clusters compared to other jurisdictions.

Phase 3: Competitive Advantage Summit

The findings of the draft Roadmap were tested with industry and research sector leaders at the Competitive Advantage Summit, hosted by the NSW Chief Scientist & Engineer and the NSW Chief Economist in February 2022. The feedback from the Competitive Advantage Summit was used to refine the draft and finalise the Roadmap.

Approach to competitive advantage strategies in other jurisdictions

Methodology of innovation and future industry strategies

Prior to developing the Roadmap, a review of similar R&D strategies and future industries policies of selected jurisdictions was undertaken. This review informed the methodology for the Roadmap. Key findings are summarised:

- Stakeholder consultation is the most common assessment methodology. Surveys targeting the industry and research sector were used by some strategies to identify competitiveness and future industries.
- Most strategies assess competitive advantages at a 'sector' or 'industry' level. Very few have undertaken a systematic review across the entire economy. Most comprehensive assessments were not conducted at the 'technology' level with consideration of their cross-cutting applications. Supply and value chain assessment was selected by very few strategies and only at a high level (i.e. product, transport and use) without the support of extensive datasets.
- There was generally a lack of quantitative assessment in supporting the claims of 'competitiveness' in many strategies. Very few strategies have combined qualitative and quantitative assessments for their competitiveness and most of those that have are industry-specific strategies rather than economy-wide strategies (for example, U.S. Advanced Manufacturing). For those adopting quantitative assessment, detailed methodologies and analytical results were not published by the strategies.
- Some strategies commissioned independent analysis of elements of the innovation ecosystem (such as research infrastructure requirement, domestic and overseas market demand for technology/commodities, or sovereignty issues in the global value chain), as part of the competitive assessment. Most of this analysis were carried out by experts from local research institutions.
- Most strategies were not embedded with the periodical reviews on the progress of recommendations. Some strategic policies lack specific and actionable items to implement recommendations.
- Summits, workshops and roundtables were hosted by many strategies that brought together thoughts leaders including experts, government officials and industry executives to validate and test initial findings during their development process.

Case studies

Four case studies of R&D strategies and future industries policies that the Roadmap considered are summarised below. Three Organisation for Economic Co-operation and Development reviews of innovation policies in specific countries were also considered (Table 3).

Table 3: Case studies

	UK Industrial Strategy (2017)	UK Innovation Strategy (2021)	U.S. Advanced Manufacturing (2014)	Qld Science and Research Priorities (2015)	Finland, China and Sweden OECD Reviews
Quantitative assessment (e.g. data and analytical results)	No	Yes	Yes	No	No
Qualitative assessment (e.g. stakeholder consultations, surveys or interviews)	Yes	Yes	Yes	Yes	Yes
Competitive advantages assessment level (sector/industry/technology/application)	Sector, industry	Industry, technology	Application	Industry	Sector, industry
Competitive advantages assessment using a value chain framework	No	No	Yes	No	No
Periodical Review	No	No	No	No	No

Case study 1: UK Innovation Strategy (2021): Leading the future by creating it

The United Kingdom's (UK) strategy offered recommendations under four pillars on business, people, places and institutions, and missions and technologies.

On the missions and technologies pillar:

- A combined missions and technology approach to innovation can bring industry and research stakeholders together around challenges and industry development priorities.
- Transformational deep technology should be supported that can make fundamental contributions to missions
- A framework of 'own, collaborate or access' should be adopted, and stakeholders should make judicious decisions on what technologies to invest locally, to work with international partners on, and to deploy as technology users.
- A range of recommendations were provided for the pillar focusing on Government's role in building R&D capabilities, investing in transformative deep technologies, building industry-research-government relationships.
- Forthcoming industry strategies will guide the development of priorities technologies identified in the strategy, including AI, Space, Semiconductors, Cyber-physical infrastructure and Robotics.

The strategy identified seven technology families that the UK has strength, opportunities to attain a world-leading capability, and to prioritise investment in. The technology families are Advanced Materials and Manufacturing, AI, Digital and Advanced Computing, Bioinformatics and Genomics, Engineering Biology, Electronics, Photonics and Quantum, Energy and Environment Technologies and Robotics and Smart Machines.

These technology families are derived from an analysis of other reports undertaken by UK government agencies. The methodology considered R&D strength, industrial capacity and global opportunities. Detailed methodology and data sources are not published in the strategy itself.

Case study 2: UK Industrial Strategy: Building a Britain fit for the Future (2017)

This white paper identified five 'Foundations of Productivity' aligning with the UK's vision for a transformed economy: ideas, people, infrastructure, business environment and places. Key policies and funding programs were proposed under each foundation. For example, to raise of total R&D investment to 2.4 per cent of GDP by 2027. Four 'Grand Challenges' were set for future industries: AI & Data Economy, Future of Mobility, Clean Growth and Aging Society. An independent Industrial Strategy Council was proposed to asset the progress of advancement in future industry and development of productivity foundations.

The Foundations of Productivity and Grand Challenges were identified through stakeholder consultation across industry, research and government. The Grand Challenges were further refined by scientific leaders including the Government Office of Science, research and innovation councils and academies. Quantitative assessment or supporting data in competitive advantages were not reported in the white paper.

Case study 3: US Advanced Manufacturing Partnership Report: Accelerating Advanced Manufacturing (2014)[16]

The report was commissioned by President Obama to provide recommendations to increase competitiveness in advanced manufacturing. It was the second phase of the Advanced Manufacturing

Partnership initiative following the first set of recommendations made in 2012. Recommendations were framed under three pillars: 'enabling innovation in critical emerging manufacturing technologies', 'securing the talent pipeline' and 'improving the business climate for innovative manufacturing firms'. The strategy identified several opportunities outside the original scope, such as regulatory, tax and policy based on stakeholder consultation.

The strategy consulted with advanced manufacturing experts from 43 college and university faculties and administrators, 51 industry leaders and employees, and four labour group representatives. Stakeholder meeting summaries were published in the final report.

The strategy was delivered through five workstreams: technology development, infrastructure, education and workforce, policy and outreach. The methodology of each workstream differs slightly but generally was a combination stakeholder consultation and research.

The technology development workstream undertook the following activities:

- A qualitative survey with industry and university to identify top industries and list of 'game-changing' technologies. This was followed by some in-depth industry interviews on technology potential and local competitiveness.
- A comparative study surveyed the research on partnerships and mechanisms in other jurisdictions for technology development
- Analysis of key factors that will influence the new industry formation: energy efficiency, sustainability, productivity, new technology, globalisation and customisation.
- A framework was developed to prioritise investment in advanced manufacturing technologies. The framework considered national need, global demand, local competitiveness and technology readiness level.

Case study 4: Queensland Science and Research Priorities (2015)

The policy developed science and research investment decision rules (REDS): real future impact, external commitment, distinctive angle, and scaling toward critical mass. These rules can be used for the assessment of entire portfolio or a single project. The policy identified the following R&D priorities:

- Delivering productivity growth and jobs by developing enhanced production technologies, tools and practices particularly in the agricultural, mining, advanced manufacturing and supporting sectors including engineering services.
- Growing knowledge intensive services through science, research and innovation.
- Protecting biodiversity and heritage, marine and terrestrial, with particular focus on the Great Barrier Reef.
- Cleaner and renewable energy technologies development.
- Ensuring the sustainability of physical and especially digital infrastructure critical for research and strategically leveraging national programs.
- Building resilience and managing climate risk, through the design and development of construction technologies for extreme weather event resistance.
- Supporting the translation of health and biotechnology research where Queensland has a particular interest or specific expertise, such as vaccine/drug development, age related and tropical diseases, and skin cancer.
- Improving health data management and services delivery (including telemedicine).
- Ensuring sustainable water use and delivering quality water and water security in a variable climate and in a resources-intensive economy.

- Digitally-enabled technologies, for example the development and application of advanced modelling, visualisation, sensing and simulation technologies, tools and practices, including robotics.

The REDS and R&D priorities were developed through consultation with industry and research sector.

Case studies 5 to 7: OECD Reviews of Innovation Policy

The OECD Reviews of Innovation Policies provides assessments of the innovation systems of individual OECD members and non-OECD countries of interest. An OECD Review has not yet been conducted for Australia. The reviews offer recommendations on how to improve on innovation performance and R&D policies. In general, OECD Reviews are carried out through partnerships between the OECD Directorate for Science Technology and Innovation (DSTI) the member countries' government. Non-OECD reviews were conducted by local research institutions commissioned by OECD DSTI with financial support from OECD members. The OECD Reviews draw on findings from desktop studies, literature reviews, stakeholder consultation through interviews, workshops and meetings hosted by member country's government. The Roadmap assessed the OECD Reviews of Finland, Sweden and China (Table 4).

Table 4: OECD Reviews of Innovation Policies

Finland 2017 Review	The review aims to provide an independent and comparative assessment of the Finnish innovation system and recommendations for improvement. The review was peer reviewed by a working party under OECD DSTI. A survey of macroeconomic literature on the role of R&D in fostering economic performance was commissioned by OECD DSTI to inform the review. A workshop was hosted with experts from Finland, the European Union and the US to validate findings from review and recommendations.
Sweden 2016 Review	The review focused on six policy initiatives central to the 2008 and 2012 Swedish Research and Innovation Bills as requested by the Swedish Government. The 2016 review also assessed the progress of those policy initiatives since introduced in 2008 and from the last 2012 review. A stakeholder survey was organized by a Swedish industry peak body and followed by targeted interviews, workshops and panel discussions.
China 2008 Review	The review was carried out by OECD DSTI and Chinese Government with experts from China and OECD members. The review focused on four modules which are policy and institutional analysis, globalisation of R&D, human resources for science and technology and science and technology indicators. The review process involved scoping and roadmaps, background information gathering and fact-finding, workshops and a symposium to present the findings. The analytical work was carried out by expert groups for each module.

Representative data and graphs

The following data and graphs summarise some of the data sets used in the development of the Roadmap.

Gross Domestic Product and population Size

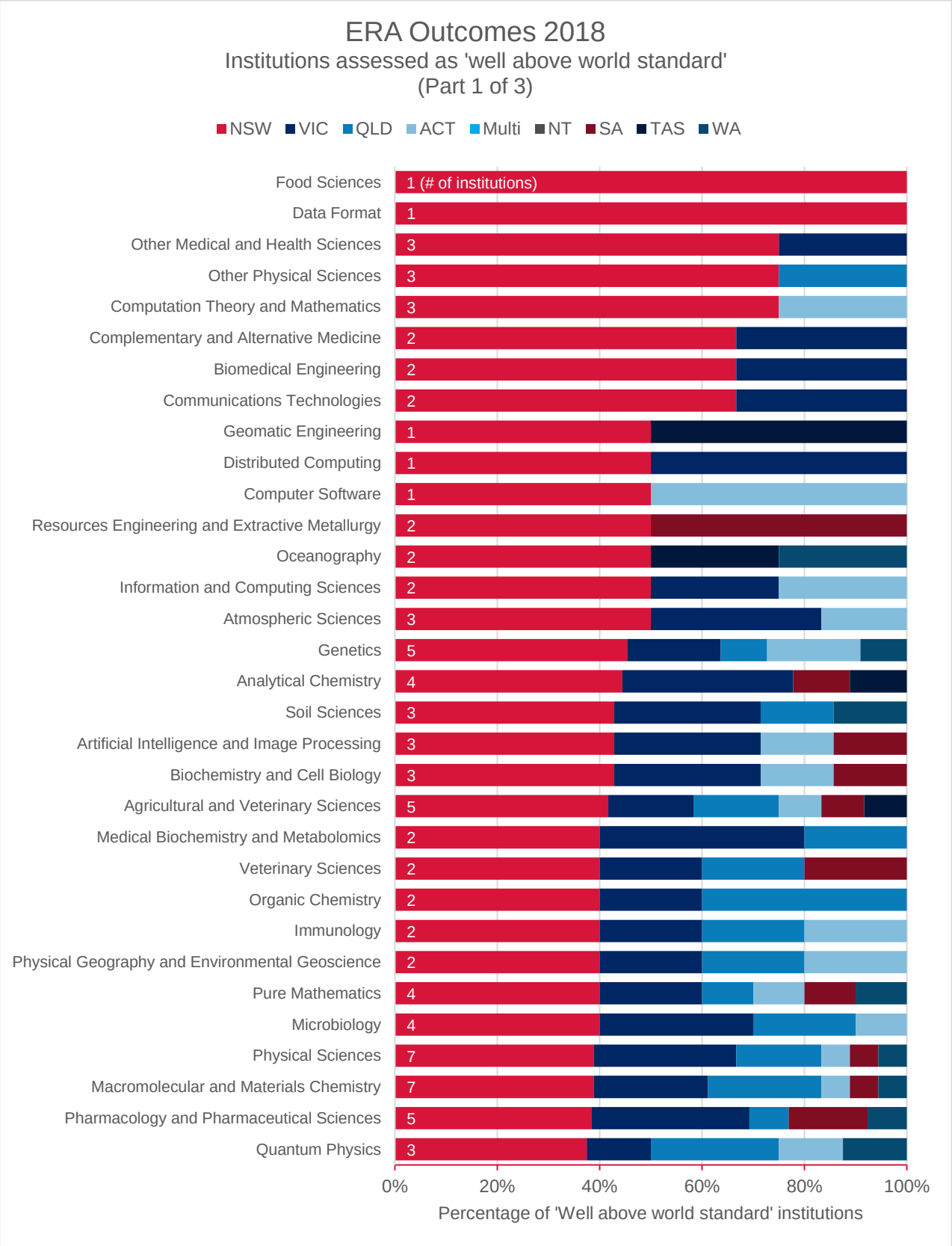
The contribution of NSW, Victoria and Queensland to Australian Gross Domestic Product (GDP) and population are provided for reference.

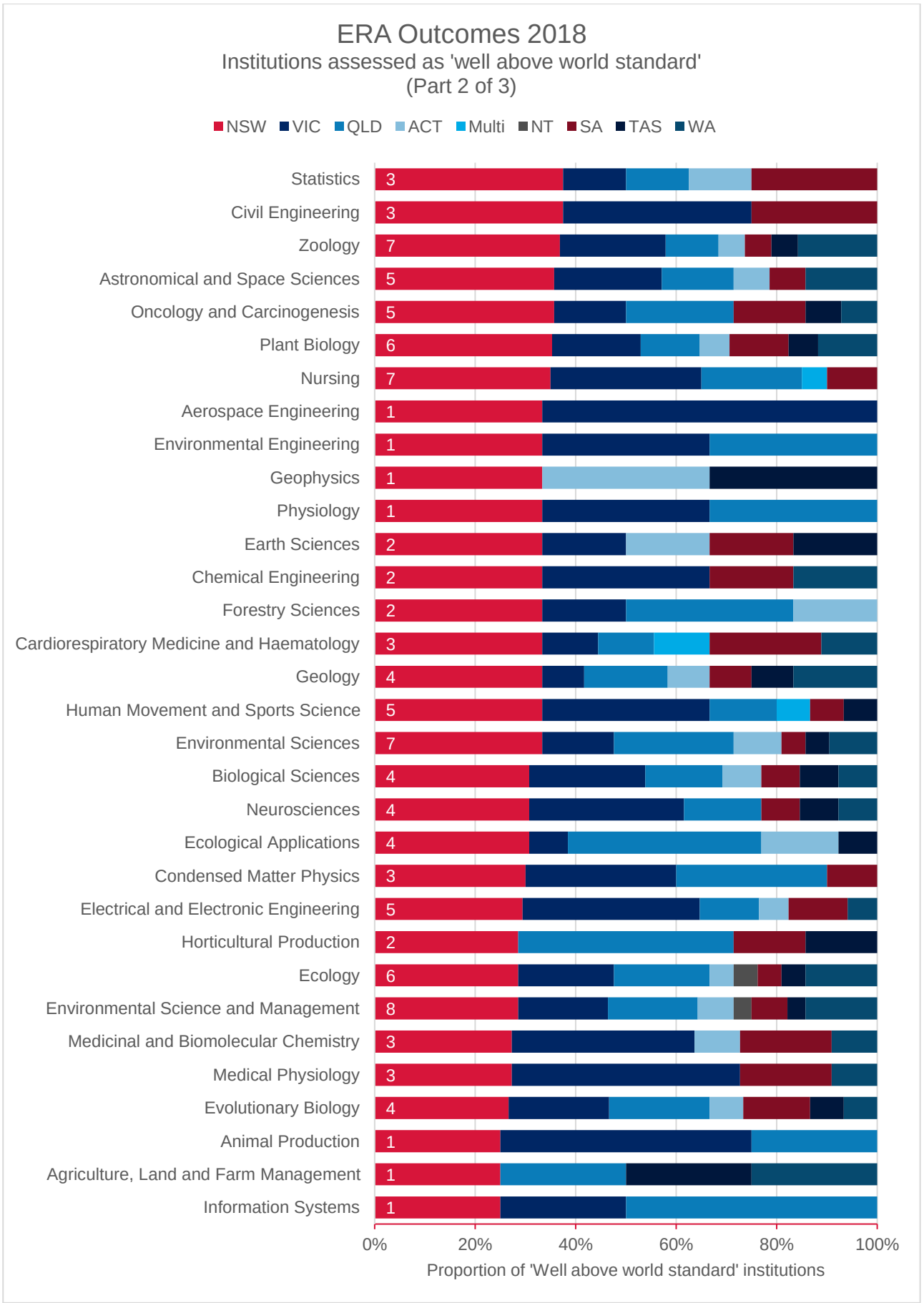
State	% of GDP [17]	% of Aust. Pop[18]
NSW	32	32
VIC	24	26
QLD	19	20

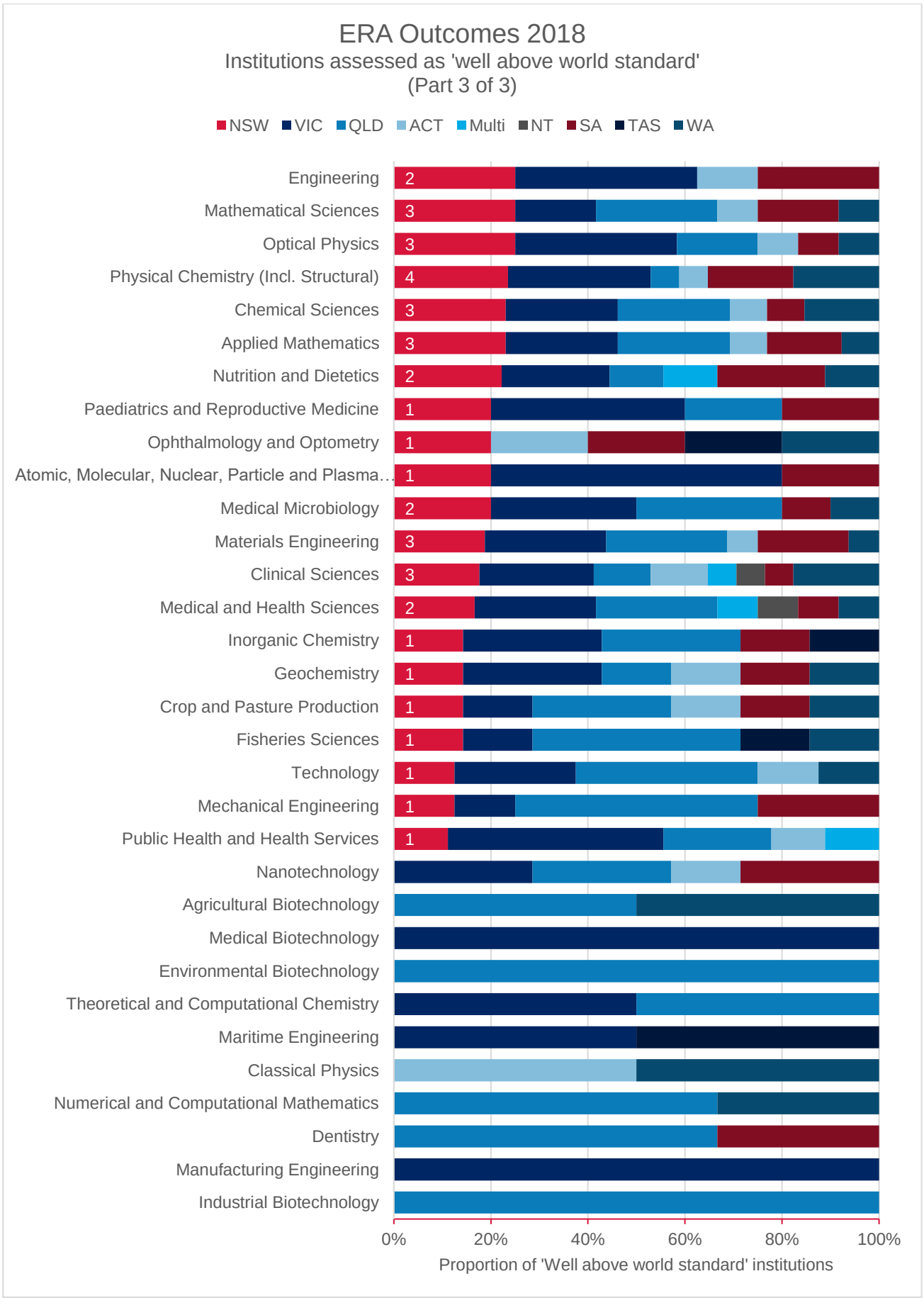
[17] ABS (2020-21), *Australian National Accounts: State Accounts*, accessed 23 December 2021.
[18] ABS (June 2021), *National, state and territory population*, accessed 23 December 2021.

Excellence in Research Australia Report 2018 (Australian Research Council)

The Excellence in Research in Australia (ERA) Outcome reports by the Australian Research Council (ARC) assess the quality of research at institutions across Australia for different fields of research.

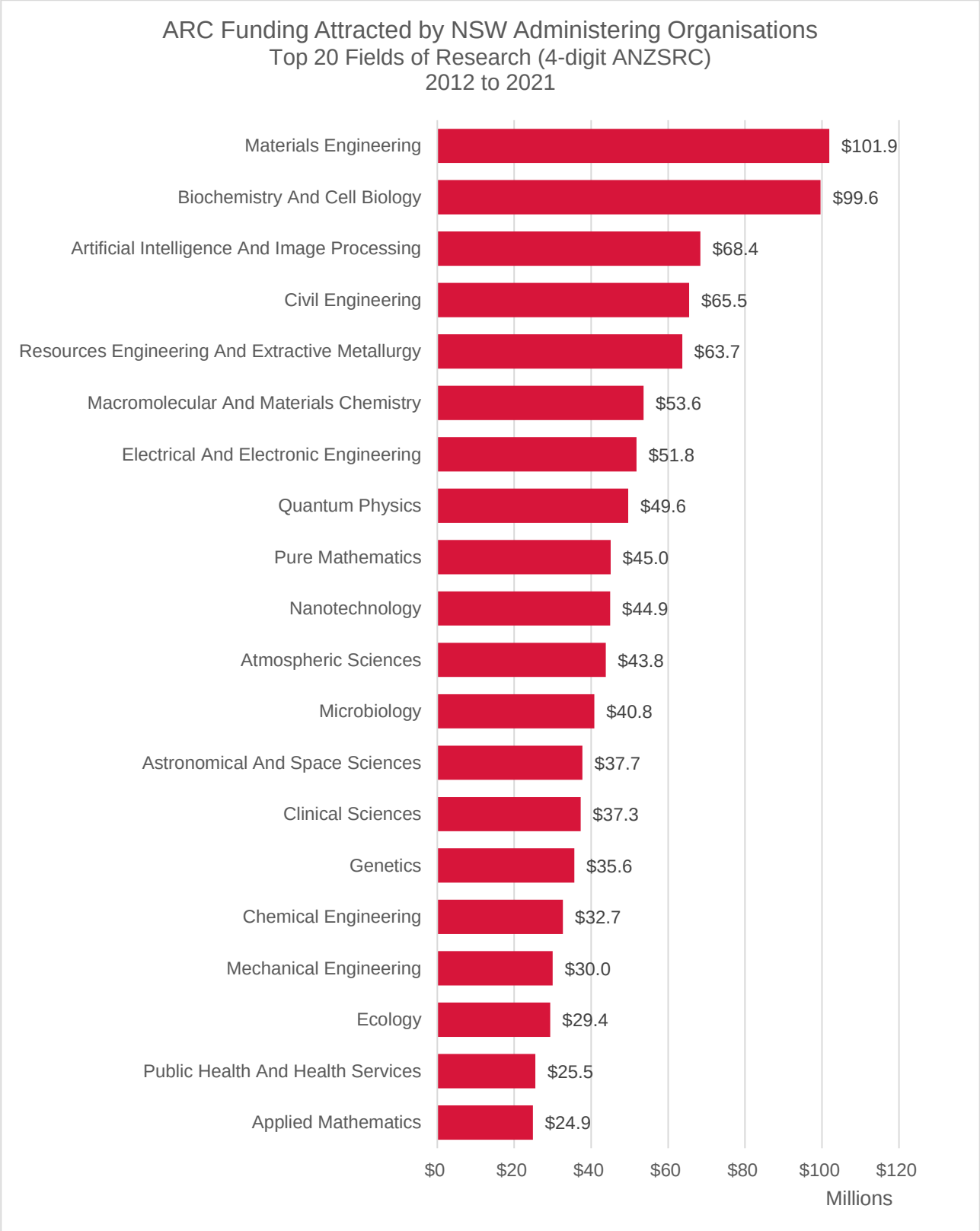


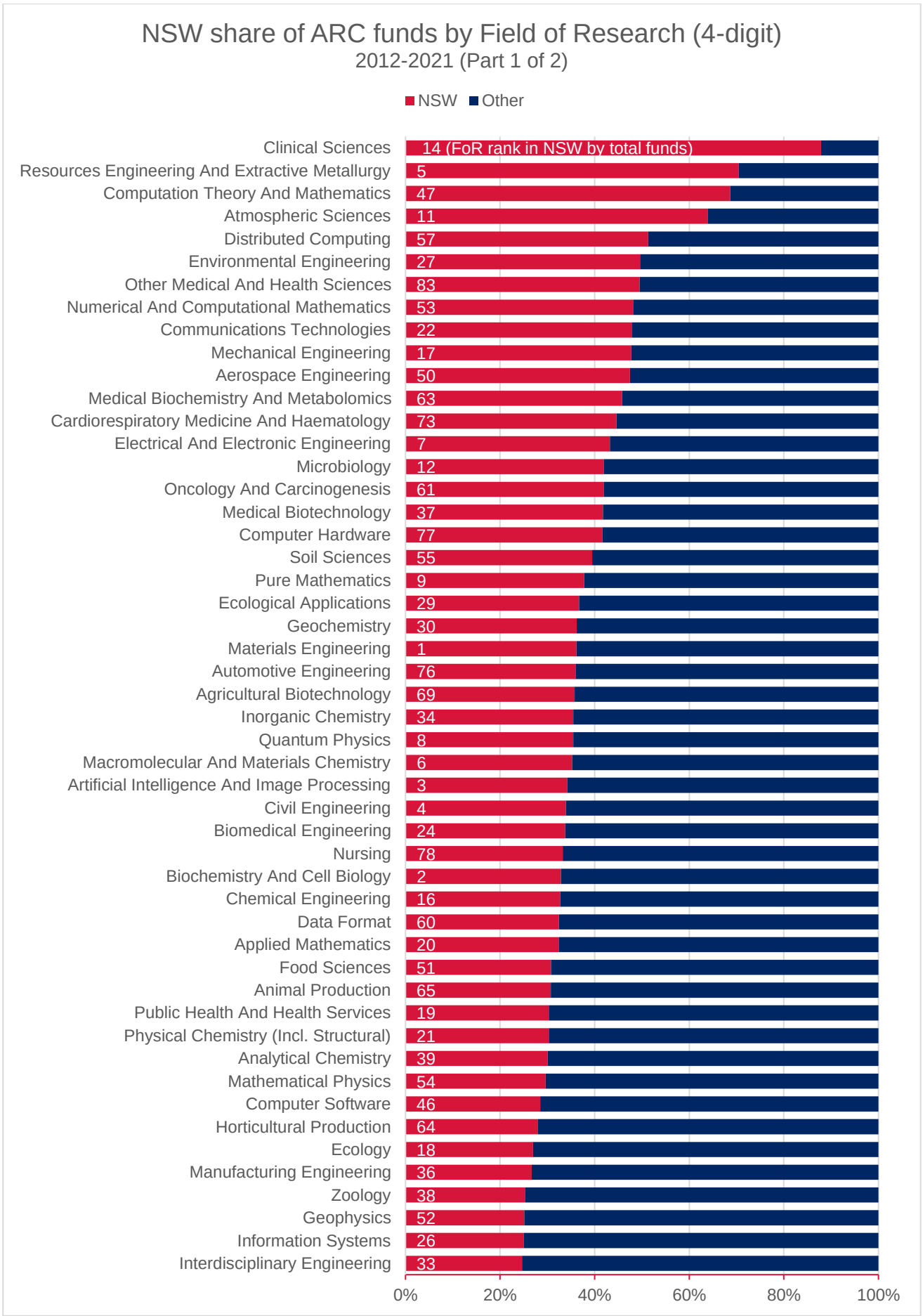

ERA Outcomes 2018
Institutions assessed as 'well above world standard'
(Part 2 of 3)
NSW
VIC
QLD
ACT
Multi
NT
SA
TAS
WA
Statistics 3
Civil Engineering 3
Zoology 7
Astronomical and Space Sciences 5
Oncology and Carcinogenesis 5
Plant Biology 6
Nursing 7
Aerospace Engineering 1
Environmental Engineering 1
Geophysics 1
Physiology 1
Earth Sciences 2
Chemical Engineering 2
Forestry Sciences 2
Cardiorespiratory Medicine and Haematology 3
Geology 4
Human Movement and Sports Science 5
Environmental Sciences 7
Biological Sciences 4
Neurosciences 4
Ecological Applications 4
Condensed Matter Physics 3
Electrical and Electronic Engineering 5
Horticultural Production 2
Ecology 6
Environmental Science and Management 8
Medicinal and Biomolecular Chemistry 3
Medical Physiology 3
Evolutionary Biology 4
Animal Production 1
Agriculture, Land and Farm Management 1
Information Systems 1
0%
20%
40%
60%
80%
100%
Proportion of 'Well above world standard' institutions

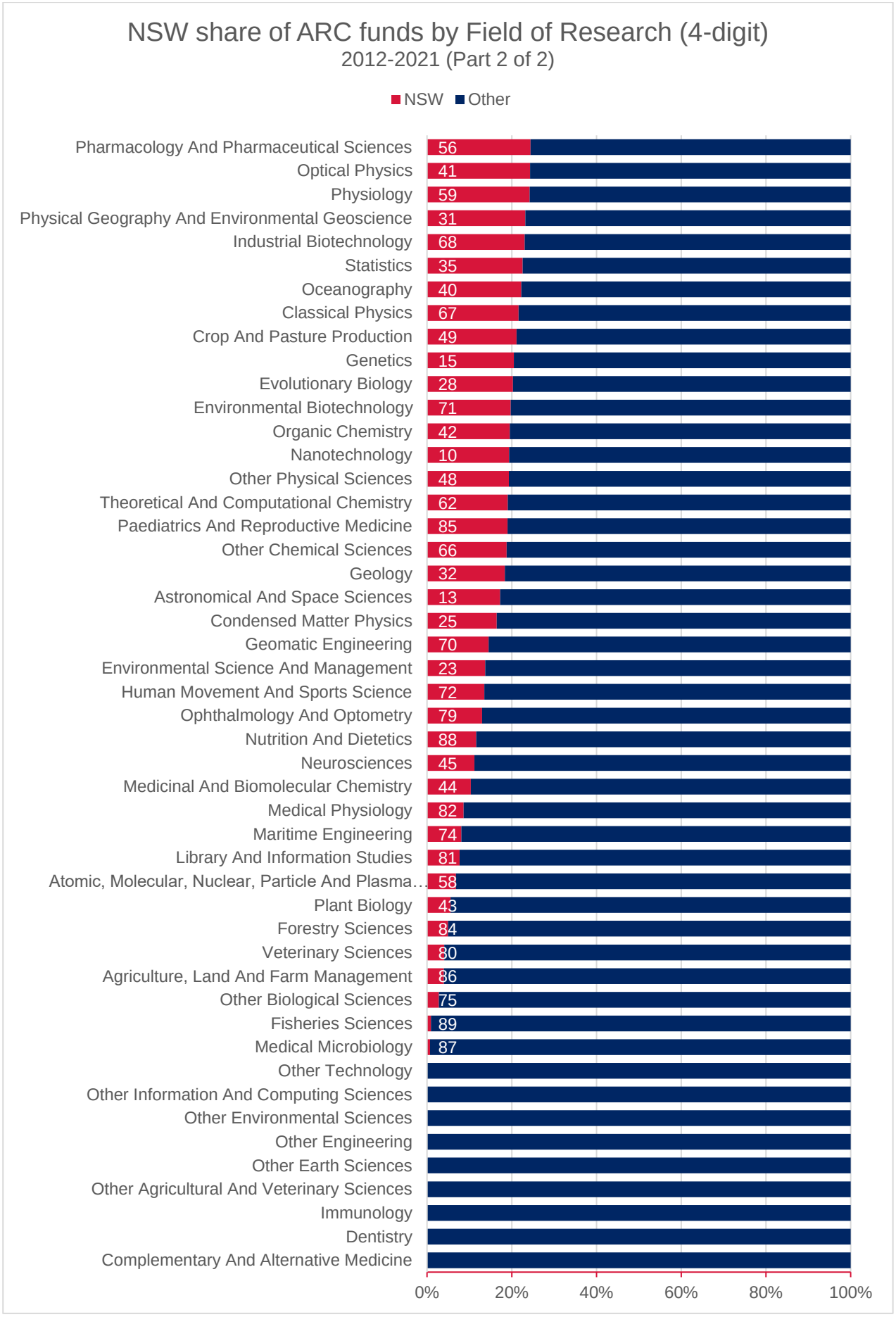

ERA Outcomes 2018
Institutions assessed as 'well above world standard'
(Part 3 of 3)
NSW VIC QLD ACT Multi NT SA TAS WA
Engineering 2
Mathematical Sciences 3
Optical Physics 3
Physical Chemistry (Incl. Structural) 4
Chemical Sciences 3
Applied Mathematics 3
Nutrition and Dietetics 2
Paediatrics and Reproductive Medicine 1
Ophthalmology and Optometry 1
Atomic, Molecular, Nuclear, Particle and Plasma… 1
Medical Microbiology 2
Materials Engineering 3
Clinical Sciences 3
Medical and Health Sciences 2
Inorganic Chemistry 1
Geochemistry 1
Crop and Pasture Production 1
Fisheries Sciences 1
Technology 1
Mechanical Engineering 1
Public Health and Health Services 1
Nanotechnology
Agricultural Biotechnology
Medical Biotechnology
Environmental Biotechnology
Theoretical and Computational Chemistry
Maritime Engineering
Classical Physics
Numerical and Computational Mathematics
Dentistry
Manufacturing Engineering
Industrial Biotechnology
0% 20% 40% 60% 80% 100%
Proportion of 'Well above world standard' institutions

ARC grant funding

The ARC Grant Funding database reflects the distribution of ARC grants to institutions across Australia and the purpose of those grants. For reference, the percentage of total funds that were granted to NSW administering organisations over the period from 2012 to 2021 was 27.8 per cent ($1.56 billion).

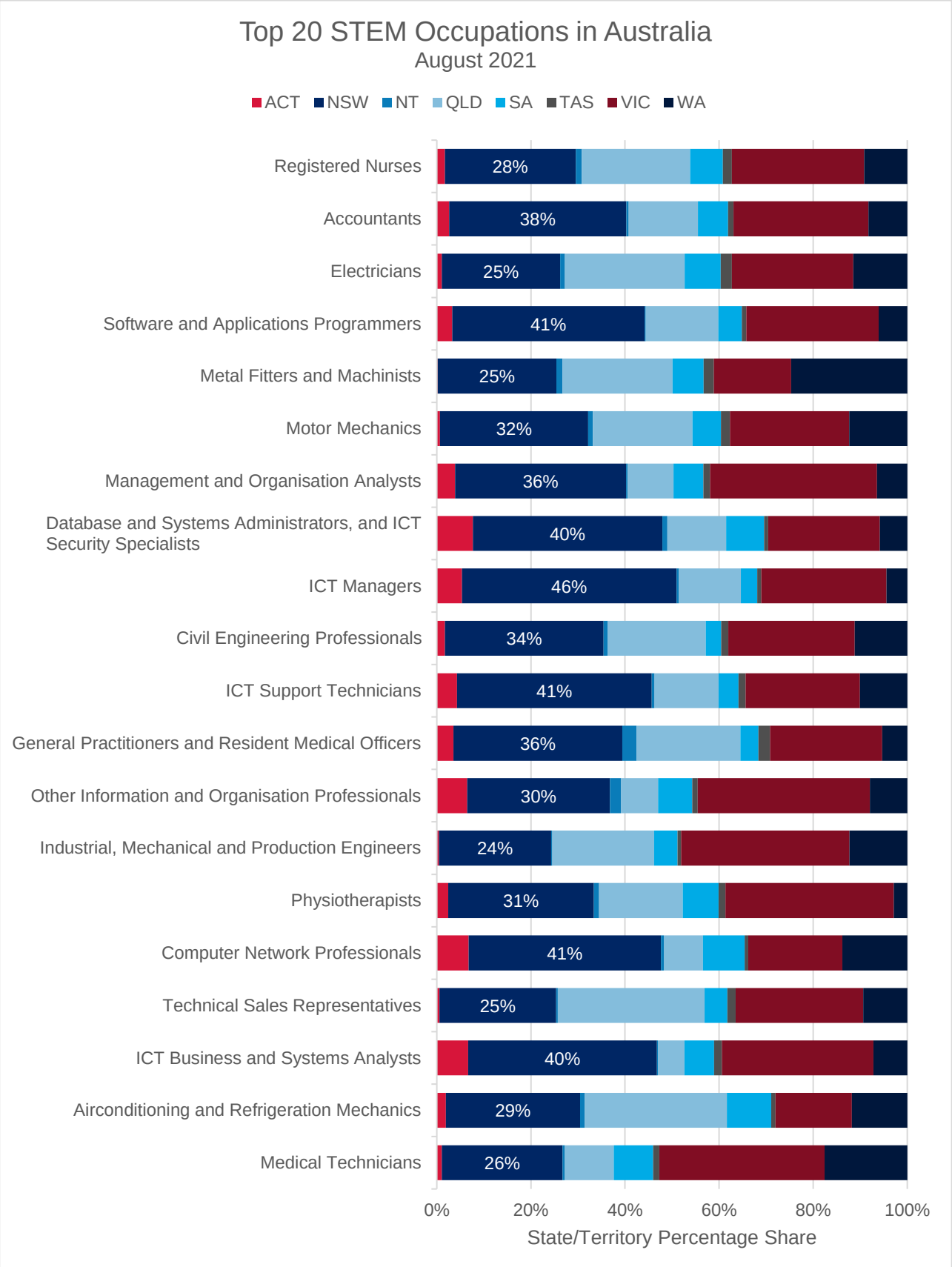



NSW share of ARC funds by Field of Research (4-digit)
2012-2021 (Part 1 of 2)
NSW
Other
Clinical Sciences 14 (FoR rank in NSW by total funds)
Resources Engineering And Extractive Metallurgy 5
Computation Theory And Mathematics 47
Atmospheric Sciences 11
Distributed Computing 57
Environmental Engineering 27
Other Medical And Health Sciences 83
Numerical And Computational Mathematics 53
Communications Technologies 22
Mechanical Engineering 17
Aerospace Engineering 50
Medical Biochemistry And Metabolomics 63
Cardiorespiratory Medicine And Haematology 73
Electrical And Electronic Engineering 7
Microbiology 12
Oncology And Carcinogenesis 61
Medical Biotechnology 37
Computer Hardware 77
Soil Sciences 55
Pure Mathematics 9
Ecological Applications 29
Geochemistry 30
Materials Engineering 1
Automotive Engineering 76
Agricultural Biotechnology 69
Inorganic Chemistry 34
Quantum Physics 8
Macromolecular And Materials Chemistry 6
Artificial Intelligence And Image Processing 3
Civil Engineering 4
Biomedical Engineering 24
Nursing 78
Biochemistry And Cell Biology 2
Chemical Engineering 16
Data Format 60
Applied Mathematics 20
Food Sciences 51
Animal Production 65
Public Health And Health Services 19
Physical Chemistry (Incl. Structural) 21
Analytical Chemistry 39
Mathematical Physics 54
Computer Software 46
Horticultural Production 64
Ecology 18
Manufacturing Engineering 36
Zoology 38
Geophysics 52
Information Systems 26
Interdisciplinary Engineering 33
0%
20%
40%
60%
80%
100%


NSW share of ARC funds by Field of Research (4-digit)
2012-2021 (Part 2 of 2)
NSW
Other
Pharmacology And Pharmaceutical Sciences 56
Optical Physics 41
Physiology 59
Physical Geography And Environmental Geoscience 31
Industrial Biotechnology 68
Statistics 35
Oceanography 40
Classical Physics 67
Crop And Pasture Production 49
Genetics 15
Evolutionary Biology 28
Environmental Biotechnology 71
Organic Chemistry 42
Nanotechnology 10
Other Physical Sciences 48
Theoretical And Computational Chemistry 62
Paediatrics And Reproductive Medicine 85
Other Chemical Sciences 66
Geology 32
Astronomical And Space Sciences 13
Condensed Matter Physics 25
Geomatic Engineering 70
Environmental Science And Management 23
Human Movement And Sports Science 72
Ophthalmology And Optometry 79
Nutrition And Dietetics 88
Neurosciences 45
Medicinal And Biomolecular Chemistry 44
Medical Physiology 82
Maritime Engineering 74
Library And Information Studies 81
Atomic, Molecular, Nuclear, Particle And Plasma… 58
Plant Biology 43
Forestry Sciences 84
Veterinary Sciences 80
Agriculture, Land And Farm Management 86
Other Biological Sciences 75
Fisheries Sciences 89
Medical Microbiology 87
Other Technology
Other Information And Computing Sciences
Other Environmental Sciences
Other Engineering
Other Earth Sciences
Other Agricultural And Veterinary Sciences
Immunology
Dentistry
Complementary And Alternative Medicine
0%
20%
40%
60%
80%
100%

ABS Labour Force survey – STEM Occupations

The Australian Bureau of Statistics (ABS) Labour Force data provides insight into the labour force across different occupations and jurisdictions in Australia.



Merchandise trade data (DFAT, UN Comtrade)

United Nations Comtrade data and NSW export data (from the Department of Foreign Affairs and Trade (DFAT)) can be used to undertake a Revealed Comparative Advantage (RCA) of exports where NSW has RCA compared to the world (Table 5) and Australia (Table 6).

Table 5: NSW vs. World Revealed Comparative Advantage Index 2019

SITC Code	Commodity Description	2019 RCA
321	Coal, whether or not pulverized, but not agglomerated	56.17
268	Wool and other animal hair (including wool tops)	39.00
283	Copper ores and concentrates; copper mattes; cement copper	18.33
11	Meat of bovine animals, fresh, chilled or frozen	13.87
345	Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons	9.67
211	Hides and skins (except furskins), raw	8.40
12	Other meat and edible meat offal, fresh, chilled or frozen (except meat and meat offal unfit or unsuitable for human consumption)	5.81
883	Cinematographic film, exposed and developed, whether or not incorporating soundtrack or consisting only of soundtrack	5.35
287	Ores and concentrates of base metals, n.e.s.[19]	5.31
592	Starches, inulin and wheat gluten; albuminoidal substances; glues	5.21
685	Lead	5.10
684	Aluminium	4.92
291	Crude animal materials, n.e.s.	3.96
247	Wood in the rough, whether or not stripped of bark or sapwood, or roughly squared	3.85
288	Non-ferrous base metal waste and scrap, n.e.s.	3.71
98	Edible products and preparations, n.e.s.	3.44
872	Instruments and appliances, n.e.s., for medical, surgical, dental or veterinary purposes	3.04
971	Gold, non-monetary (excluding gold ores and concentrates)	3.03
269	Worn clothing and other worn textile articles; rags	2.35
1	Live animals other than animals of division 03	2.29
112	Alcoholic beverages	2.29
891	Arms and ammunition	2.26
673	Flat-rolled products of iron or non-alloy steel, not clad, plated or coated	2.04
641	Paper and paperboard	2.00
48	Cereal preparations and preparations of flour or starch of fruits or vegetables	1.81
411	Animal oils and fats	1.69
542	Medicaments (including veterinary medicaments)	1.56
874	Measuring, checking, analysing and controlling instruments and apparatus, n.e.s.	1.55
579	Waste, parings and scrap, of plastics	1.51
282	Ferrous waste and scrap; remelting scrap ingots of iron or steel	1.50
289	Ores and concentrates of precious metals; waste, scrap and sweepings of precious metals (other than of gold)	1.47
57	Fruit and nuts (not including oil nuts), fresh or dried	1.24
62	Sugar confectionery	1.19
611	Leather	1.17
47	Other cereal meals and flours	1.16
46	Meal and flour of wheat and flour of meslin	1.11
677	Rails or railway track construction material, of iron or steel	1.06
581	Tubes, pipes and hoses, and fittings therefor, of plastics	1.02

[19] N.e.s stands for “not elsewhere specified”.

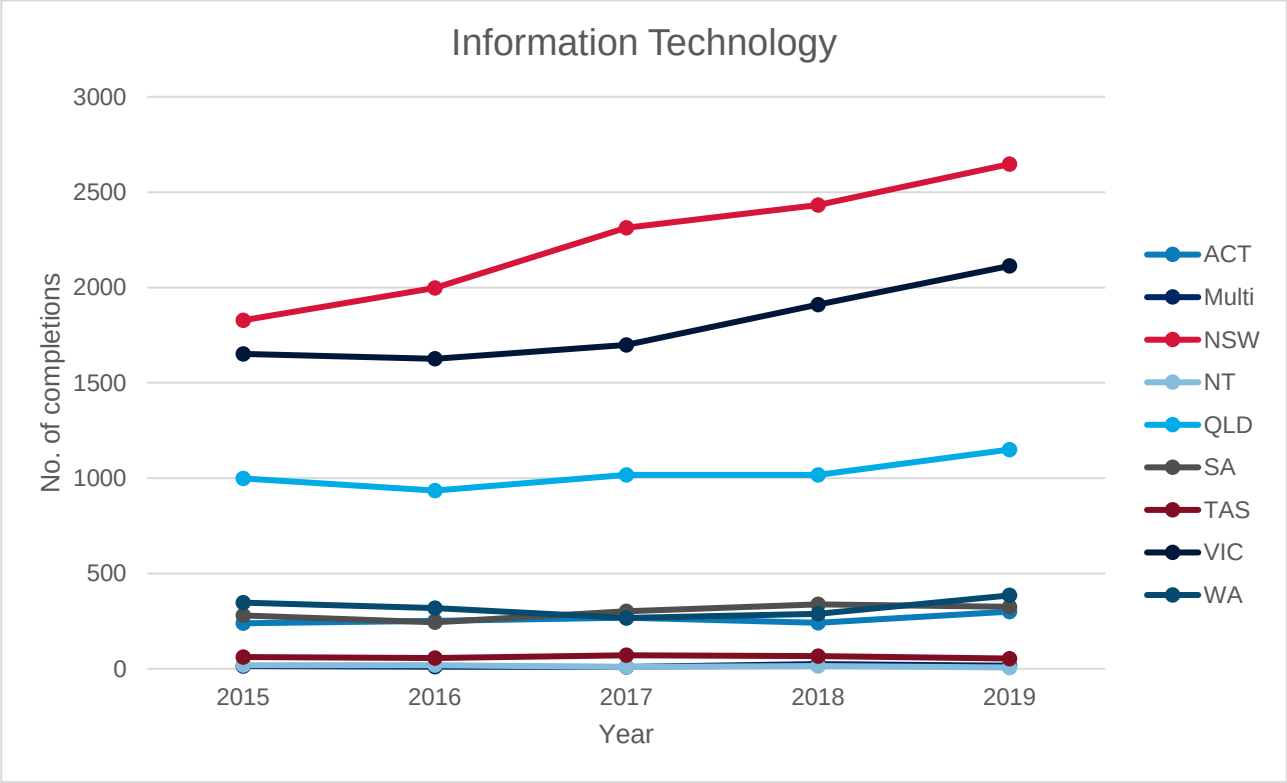
Table 6: NSW vs. Australia Revealed Comparative Advantage Index 2019[20]

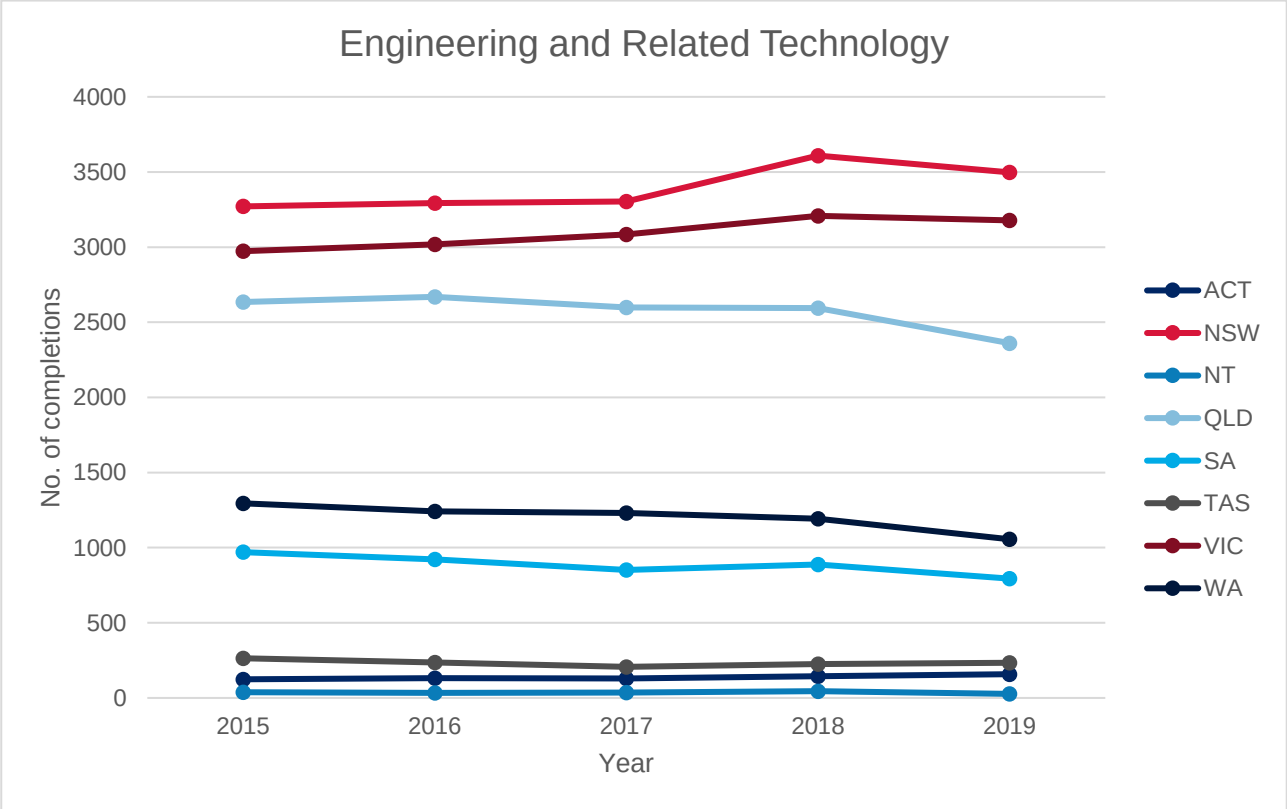
SITC Code and Description	2019 RCA
988 Confidential items of trade	8.31
345 Coal gas, water gas & similar gases	7.55
711 Steam boilers & parts	6.51
525 Radioactive materials	5.93
046 Wheat flour	5.79
673 Uncoated flat-rolled iron & steel	5.61
512 Alcohols, phenols & derivatives	5.58
891 Arms & ammunition	5.53
671 Pig-iron	5.45
524 Other inorganic chemicals	5.08
071 Coffee & substitutes	4.94
883 Cinematographic film, developed	4.93
592 Starches, inulin & wheat gluten	4.92
265 Other vegetable textile fibres	4.91
872 Medical instruments (incl veterinary)	4.87
961 Coin (excl gold coin) not legal tender	4.76
641 Paper & paperboard	4.70
681 Silver & platinum	4.59
573 Primary vinyl chloride polymers	4.58
791 Railway vehicles (incl hovertrains)	4.51
882 Photo & cinematographic supplies	4.47
335 Residual petroleum products, nes	4.39
542 Medicaments (incl veterinary)	4.34
675 Flat-rolled alloy steel	4.26
062 Sugar confectionery	4.25
016 Meat, salted or dried	3.87
334 Refined petroleum	3.78
894 Prams, toys, games & sporting goods	3.74
898 Musical instruments & parts	3.74
283 Copper ores & concentrates	3.69
581 Plastic tubes, pipes & hoses	3.55
511 Hydrocarbons & derivatives	3.53
874 Measuring & analysing instruments	3.53
422 Fixed vegetable oils & fats, hard	3.51
047 Other cereal flours	3.44
075 Spices	3.41
322 Briquettes, lignite & peat	3.31
873 Meters & counters	3.24
694 Nails, screws, nuts, bolts & rivets	3.21
737 Metalworking machinery & parts	3.17
763 Sound & video recorders	3.16
642 Paper & paperboard, cut to size	3.09
684 Aluminium	3.02
899 Misc manufactured articles, nes	3.01
074 Tea & mate	3.01

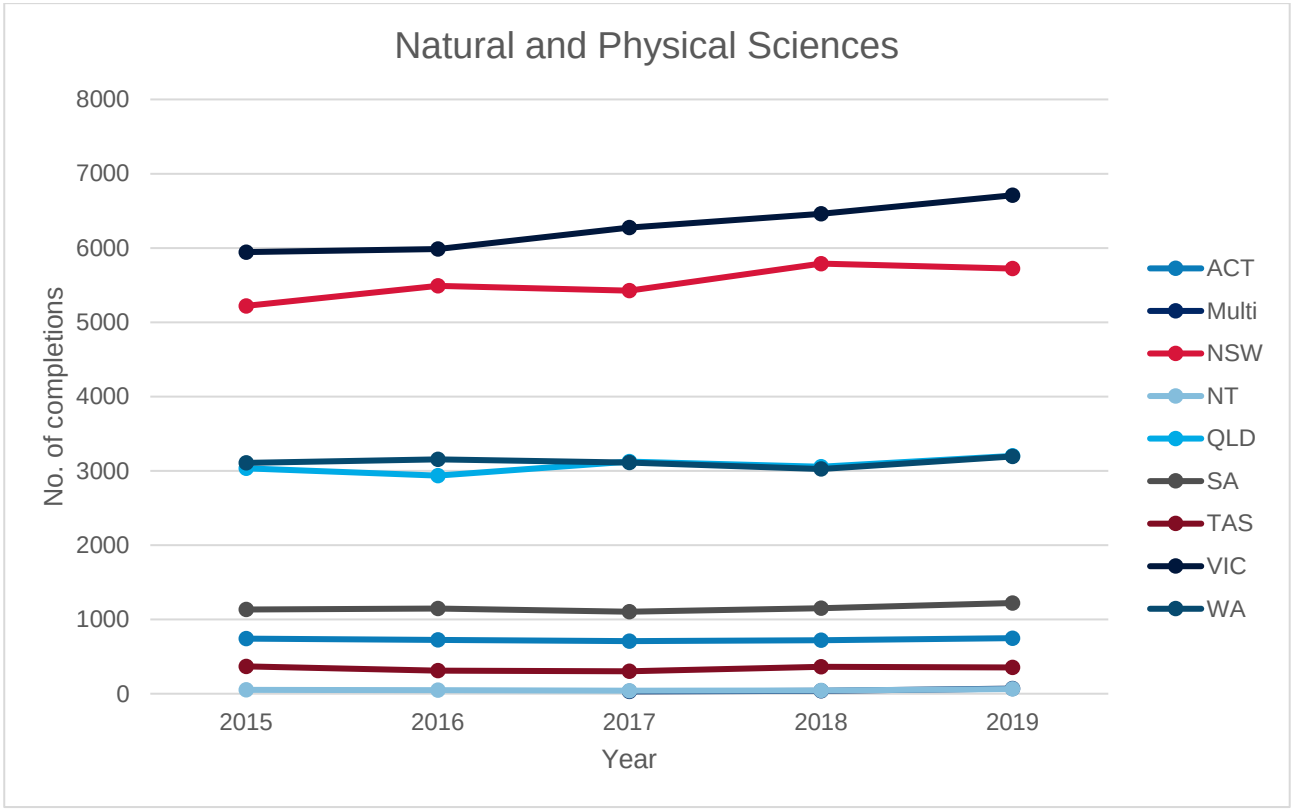
[20] For brevity, table restricted to items with RCA > 3.

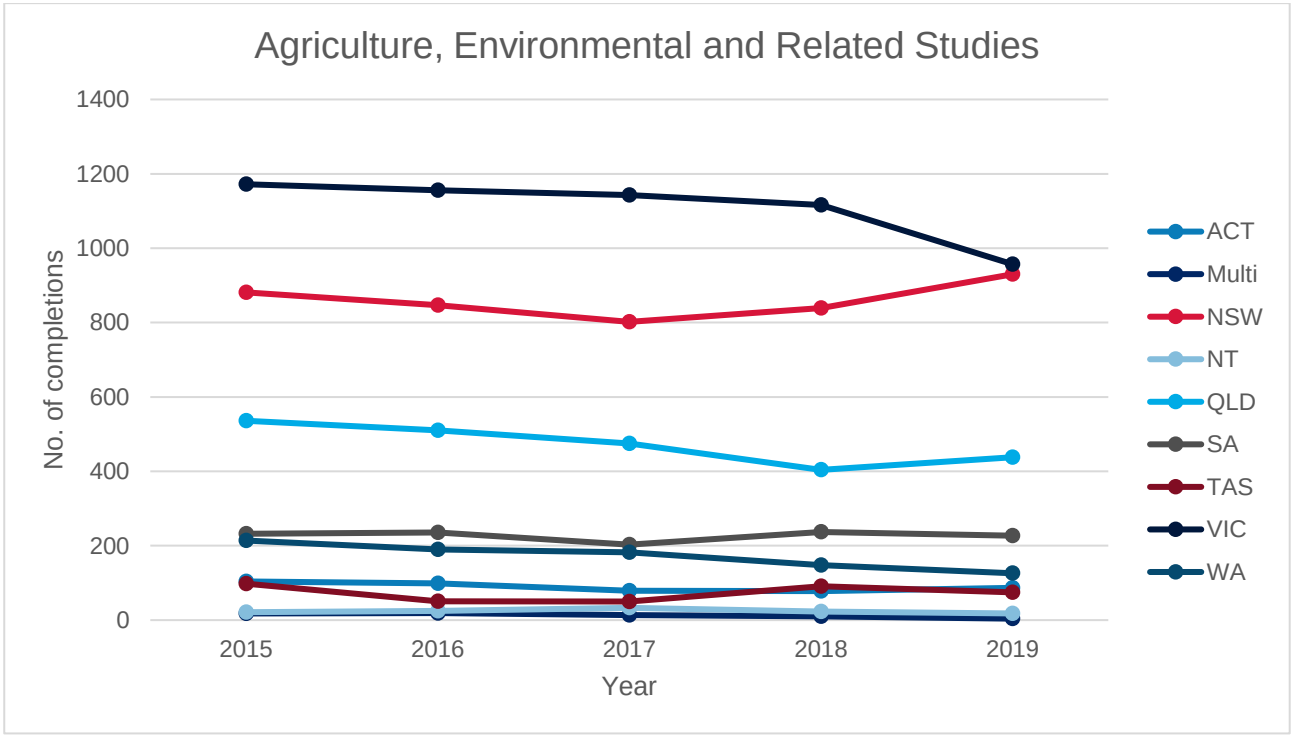
Higher education completions by domestic enrolments

The Australian Government's Department of Education, Skills and Employment provides a detailed dataset on higher education completions by student type, state and subject.



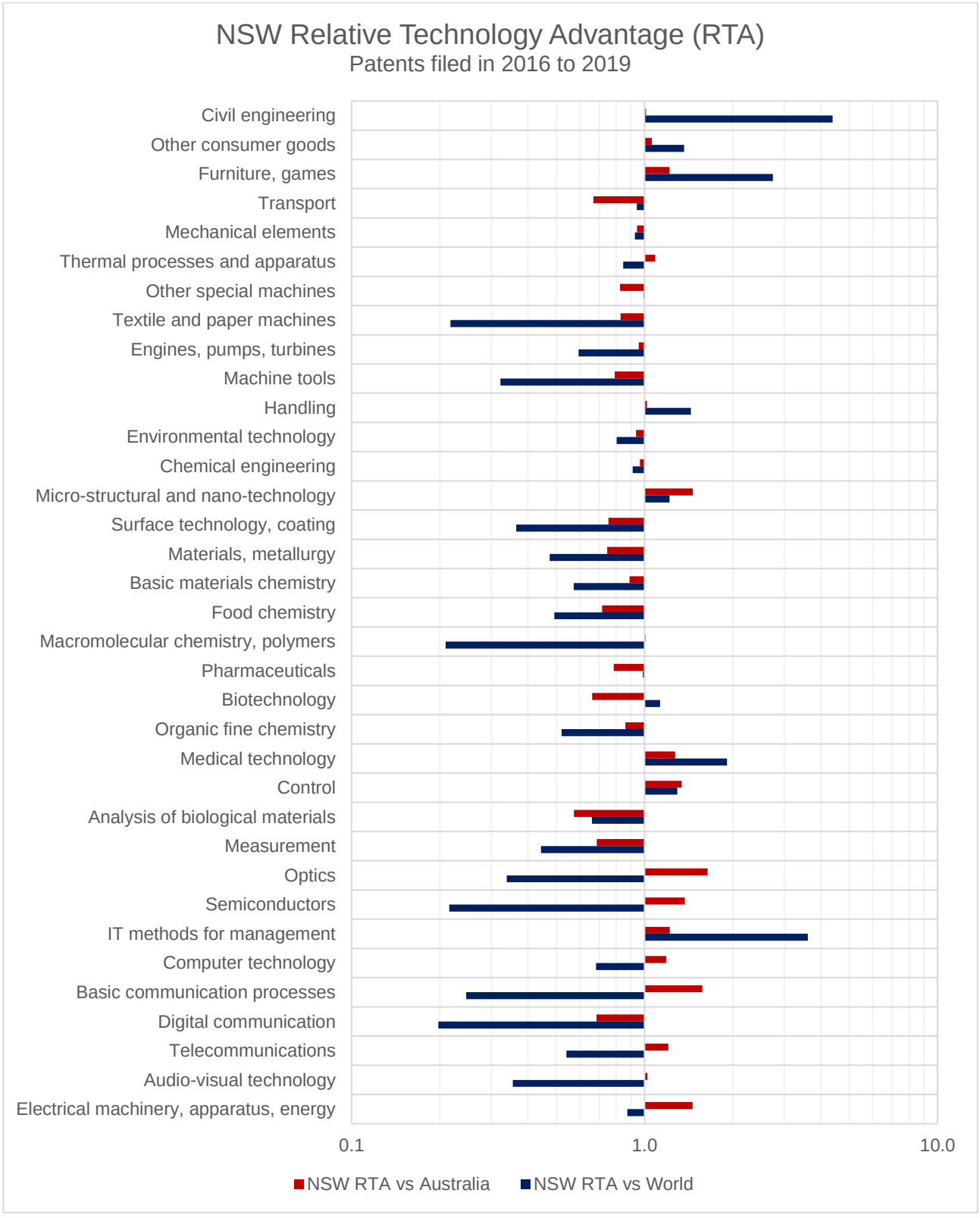



Natural and Physical Sciences
8000
7000
6000
5000
4000
3000
2000
1000
0
No. of completions
2015
2016
2017
2018
2019
Year
ACT
Multi
NSW
NT
QLD
SA
TAS
VIC
WA


Agriculture, Environmental and Related Studies
1400
1200
1000
800
600
400
200
0
No. of completions
2015
2016
2017
2018
2019
Year
ACT
Multi
NSW
NT
QLD
SA
TAS
VIC
WA

Patent data

World Intellectual Property Organisation (WIPO) data and IP Australia data can be used to undertake a Revealed Technology Advantage (RTA) of patent filings and identify where NSW has RTA compared to the world and Australia.[21]



[21] For this RTA analysis, one NSW-based organisation who files a disproportionate amount of patents (22 per cent) was excluded from the analysis.

Further data

Further data was used to develop the Roadmap and may be available upon request. If you wish to access other data not provided in the Supplement, please contact the OCSE.