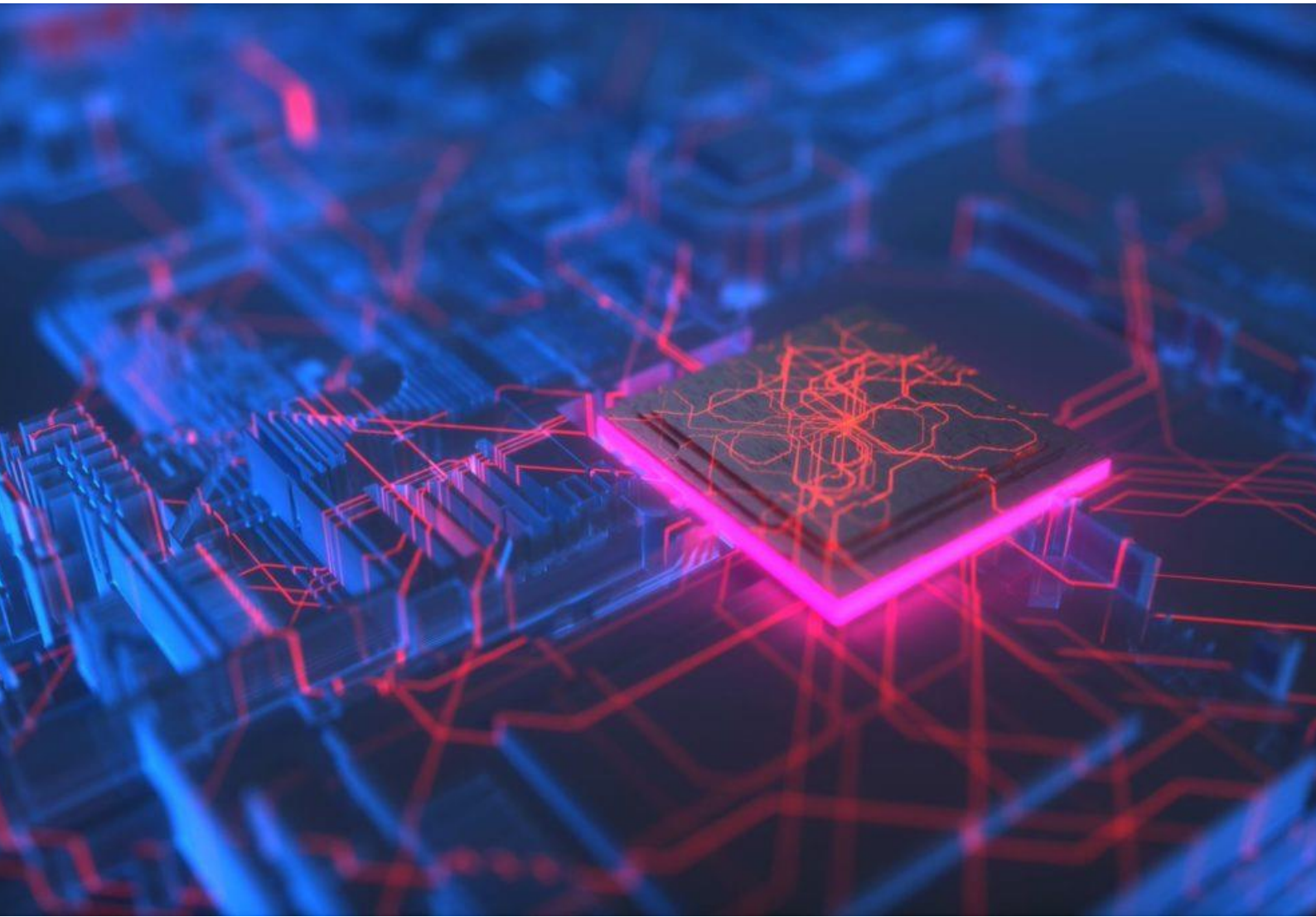
Australia's National
Science Agency

Growing Australia's Quantum Technology Industry: Updated economic modelling

Revised economic estimates to the 2020 report

October 2022



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Contents

Summary

Context and approach

Reflecting recent domestic and global developments in quantum technology opportunities, this report updates the market projections from the **CSIRO (2020) Growing Australia's Quantum Technology Industry** report. It provides estimates for potential Australian revenue and jobs in quantum computing, sensing and measurement, and communications for the years 2030, 2035, 2040, and 2045.

This project used the original economic model framework, with updated model inputs for calculating the global market figure and the growth rates. While key modelling parameters – namely, the quantum technology's share of the total addressable markets and Australia's assumed market share of the global quantum opportunity – are unchanged from the original model, other aspects were significantly revised, including the use of variable growth rates over time to size each market opportunity.

Findings

By 2030, Australia's quantum technology opportunity could reach **$2.2 billion**. By 2045, Australia's quantum technology opportunity could almost reach **nearly $6 billion** in total.

Australia's quantum opportunity ($B, AUD, 2021 dollars)

	Computing	Sensing and measurement	Communications	Total
2030	1.3	0.4	0.4	**2.2**
2035	2.0	0.6	0.7	**3.3**
2040	2.8	0.9	0.9	**4.6**
2045	3.6	1.1	1.2	**5.9**

By 2030, the sector could generate around **8,700 jobs**. This could more than double to **19,400 jobs** by 2045.

Australia's quantum opportunity (jobs, 000's)

	Computing	Sensing and measurement	Communications	Total
2030	5.4	1.5	1.8	**8.7**
2035	7.8	1.9	2.7	**12.4**
2040	10.3	2.3	3.5	**16.1**
2045	12.7	2.5	4.2	**19.4**

Discussion

These results are conservative estimates and are refinements of the original modelling. The figures presented are not a large departure from the estimates in the original report, reflecting that no major changes have occurred in the quantum technology space in recent years to significantly alter the modelling parameters.

There are still high levels of uncertainty as to how quantum technology will be commercialised around the world. However, some recent developments, such as public and private investment announcements and new policy initiatives and focused funding, provide optimism. Other indicators, such as a recent slowdown in the founding of quantum technology companies, suggest a more moderate market outlook is warranted.

1 Introduction

1.1 Project background

Acknowledging Australia's world-class and cutting-edge capabilities in the advancement of quantum technology research and development, the **CSIRO (2020) Growing Australia's Quantum Technology Industry** report set out to estimate the potential market size of Australia's quantum technology industry by the year 2040. Based on available data at the time, the report estimated that in 2040 the quantum technology industry could generate over $4 billion in revenue and 16,000 new jobs in Australia in three main domains:[1]

1. **Computing:** $2.5 billion and 10,000 jobs
2. **Sensing and measurement:** $0.9 billion and 3,000 jobs
3. **Communications:** $0.8 billion and 3,000 jobs.

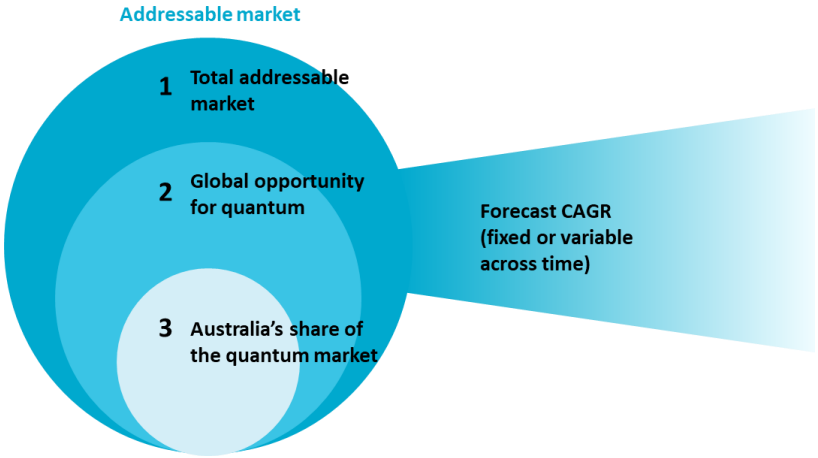
Since the release of this report, there have been major Australian policy initiatives related to quantum technology. For instance, in November 2021 the Australian Government announced measures to invest $111 million in quantum technology, including $70 million for a Quantum Commercialisation Hub to form strategic international partnerships, commercialise Australia's quantum research, and help Australian businesses access new markets and investors.[2]

As part of its ongoing promotion of quantum technology capabilities development in Australia, the Department of Industry, Science and Resources (DISR) contracted CSIRO to provide an update of the market projections in the 2020 CSIRO report. This is to reflect recent domestic and global developments in the expansion and maturation of quantum technology opportunities.

1.2 Goal and approach

This report provides an update to the 2040 market estimate for the quantum computing, sensing and measurement, and communications opportunity from the original CSIRO report with updated data inputs. The report also provides estimates for the years 2030, 2035 and 2045 to show how these opportunities for Australia in quantum technology could change in magnitude overtime.

Figure 1: Approach to market sizing



Source: CSIRO Futures.

[1] CSIRO (2020) Growing Australia's Quantum Technology Industry.
[2] Australian Government (2021) '$111 million investment to back Australia's quantum technology future', <https://ministers.treasury.gov.au/ministers/jane-hume-2020/media-releases/111-million-investment-back-australias-quantum-technology>.

In terms of a general approach, this project used the original economic model framework from the 2020 CSIRO report, with updated model inputs for calculating the global market figure and the growth rates.

As depicted in Figure 1, this framework begins with an estimation of the current global, addressable markets in computing, sensing and measurement, and communications that quantum technology could potentially command in the absence of competing technologies or services.

This estimation is then projected out to 2030, 2035, 2040, and 2045 using variable growth rates over time. These growth rates are an extension of the original model framework. This is followed by an estimate of the quantum technology's potential share of the larger total addressable markets, and then by an estimate of Australia's potential share of that global quantum opportunity.

1.3 This report

The remainder of the report is structured as follows. Chapter 2 further details the methodology, including the updated data inputs for the economic modelling. Chapter 3 details the key findings from the market sizing exercise. Chapter 4 provides a brief analysis and discussion on market changes to the quantum technology opportunity since 2020.

2 Methodology

2.1 Addressable markets and opportunity shares

The following data sources and parameters were used for estimating the total addressable markets in the three key domains:

- **Computing:** The update used the same data sources from the original report because they remain the most recent sources available. These were market report estimates for advanced computation, analytics, and simulation, as well as for edge and distributed computing-related operations.[3]
- **Sensing and measurement:** For the same reasons as above, the same data sources and approach as the original report were used. These were based on market report estimates for advanced sensing in image, biosensors, chemical, RADAR, position, flow, level, wireless and fibre optic, among others.[4]
- **Communications:** This was revised from the original report and is estimated from updated AustCyber research on global cyber security expenditure.[5]

Quantum technology's share of the total addressable markets and Australia's assumed market share of the global quantum opportunity remain unchanged as parameters from the original modelling. This is because these parameters were guided by an expert consultation process which were not repeated as part of this shorter re-estimation exercise. These parameters are as follows:

- **Quantum's share of global addressable markets:** 4% for computing, 3% for sensing, and 2% for communications. As with the original report, the analysis assumes a scenario where quantum technologies account for 2–4% of the addressable markets while acknowledging high technical and economic uncertainty surrounding the long-term commercialisation and market penetration of these technologies.
- **Australia's share of quantum markets:** This analysis continues to assume Australia can capture 5% of the global quantum technology market opportunity, informed by its current share of annual global investment into non-classified quantum-technology research, and the global quantum-technology research workforce.

A review of recent market reports and other developments in the quantum technology space indicate that no major changes have occurred recently to warrant a change to these parameters (see section 4 for further commentary). To realise this share, Australia must maintain its research strength and industry activity through targeted planning and investment.

Lastly, **exchange rates** from the RBA and **inflation rates** from the ABS were used to convert figures to 2021 Australian dollars.[6]

2.2 Variable growth rates

In the 2020 CSIRO report, a fixed compound annual growth rate (CAGR) out to 2040 of 6% was used. This was based on a review of growth forecasts for advanced computing and analytics, sensing, secure communications, and cyber security across several sources, as well as the assumption that in the long-term, global demand for these technologies will converge towards long-run real GDP growth of advanced economies (of around 1.6% per annum).

[3] BCC Research (2019) Analytics Markets: A Global Outlook; BCC Research (2018) Global Markets and Technologies for Edge Computing Through 2023.
[4] BCC Research (2019) Sensors Markets: A Global Outlook.
[5] AustCyber (2020) Australia's Cyber Security Sector Competitiveness Plan: 2020 Update.
[6] RBA (2022) Historical Data – exchange rates, <https://www.rba.gov.au/statistics/historical-data.html#exchange-rates>; ABS (2022) Consumer Price Index, Australia, <https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/latest-release>.

In a departure from the original modelling, this report uses variable growth rates over time to estimate Australia's quantum technology opportunity over 2030, 2035, 2040, and 2045 (please see section 2.3 below for a discussion about why this growth modelling approach was used). An exponential decay function was constructed for the CAGR of each addressable market opportunity to create (downward) changing rates across the years.

This function has the following general form:

$$\boldsymbol{G(t) = G_i\, e^{-kt}}$$

$$\boldsymbol{t = \{0,\ 1,\ 2, \ldots\}}$$

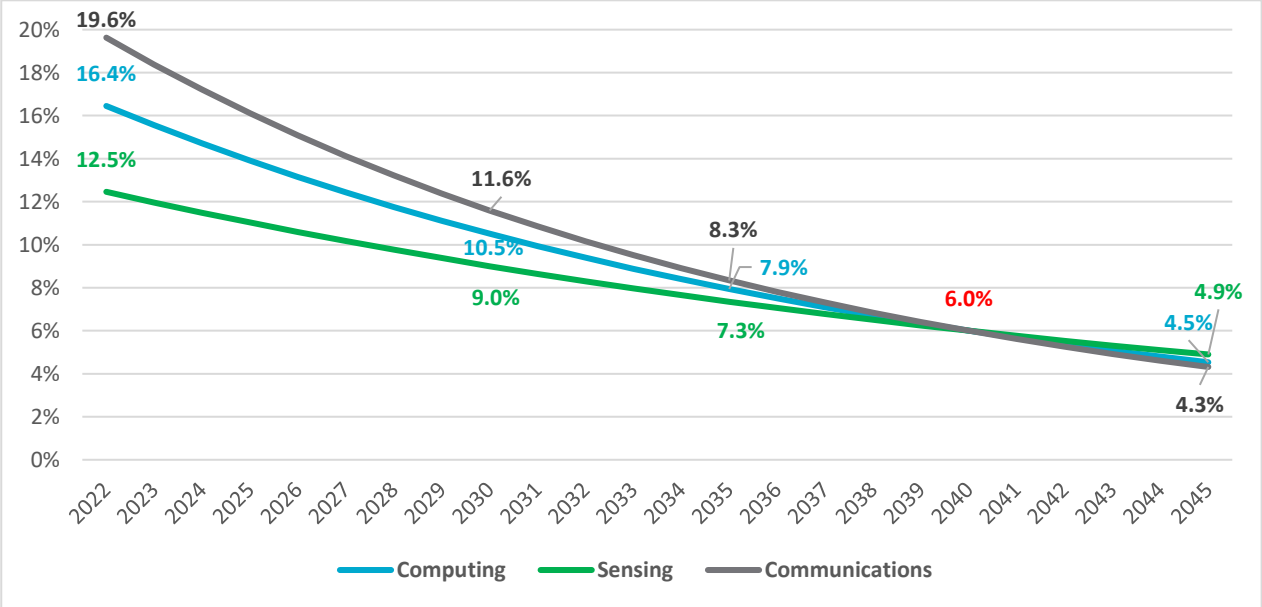
where $\boldsymbol{t}$ is the time variable and $\boldsymbol{t = 0}$ refers to the starting year of 2021, $\boldsymbol{k}$ is a constant unique to each opportunity domain that adjusts the argument of the exponential decay function, $\boldsymbol{G_i}$ is the 2021 growth estimate for each addressable market opportunity as informed from the latest market report estimates, and $\boldsymbol{G(t)}$ is the forecast CAGR for each year.

The starting growth rates for each of the opportunities was derived from conservative forecasts in recently published market reports:

- **Computing:** The 2022 CAGR for the global quantum computing market.[7]
- **Sensing and measurement:** The 2022 CAGR for the global quantum sensors market.[8]
- **Communications:** The 2022 CAGR for the global cyber security market.[9]

It is assumed that all growth rates reach 6% by 2040 as per the long-run CAGR assumed in the original CSIRO report. Based on this project's updated understanding of developments in the quantum technology industry, no new information was identified to alter the assumption that a 6% CAGR is realistic in the longer term. Furthermore, this assumption allows $\boldsymbol{k}$ to be solved computationally in the formula for each market opportunity.

Chart 1: Variable growth rates (CAGR) used for modelling



Source: CSIRO Futures modelling.

[7] Technavio (2021) Global Quantum Computing Market 2021-2025.
[8] Technavio (2022) Global Quantum Sensors Market 2021-2025.
[9] BCC Research (2022) Cybersecurity: Technologies and Global Markets. Cyber security more broadly defined was selected given the relatively limited scope of other reports on quantum-specific communications technologies and services (e.g., quantum cryptography).

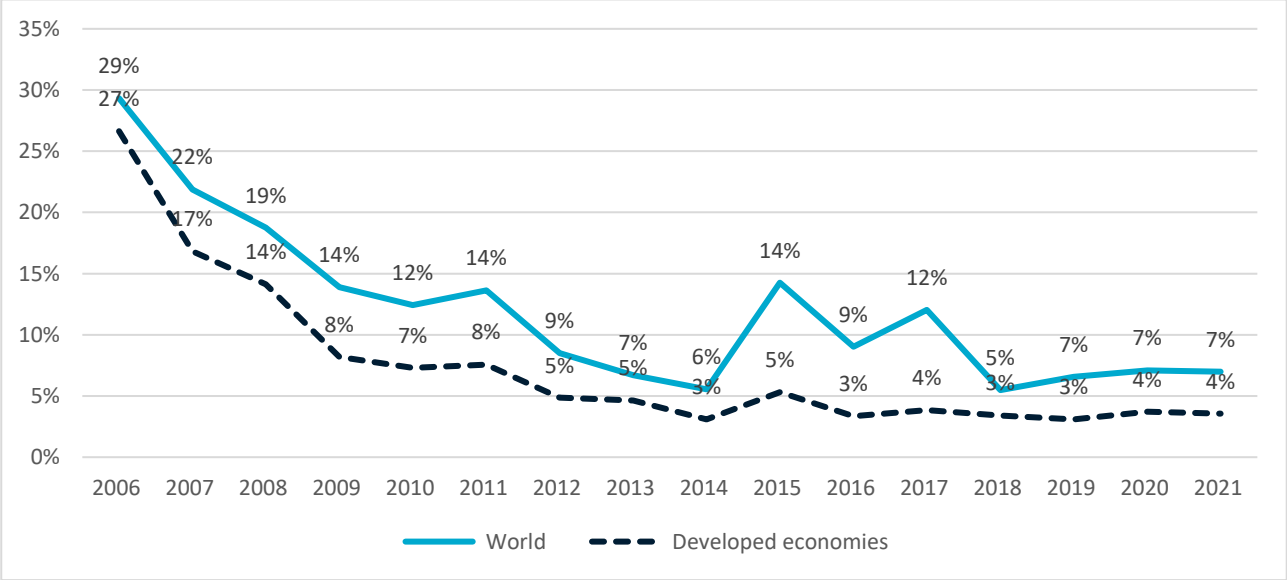
Chart 1 above shows the variable CAGRs used for projecting out the quantum technology opportunities to 2045. It should be emphasised that these should be interpreted as the growth rate of the total addressable markets of which the three quantum technology domains will take a share.

2.3 Justification of declining growth rates

An exponential decay function is a common feature in economic models. It is used as a simple mathematical approach to describe processes where an amount diminishes consistently at a set rate over time. For instance, it can be used to model a diminishing market growth rate over time, reflecting rapid growth in a new commercial area that tapers off as the novel technology or service offering becomes mature. Quantum technology will likely experience a similar growth trajectory, at least under conservative assumptions.

One real-world example that parallels the variable growth rates presented in section 2.2 is the CAGR experienced by some telecommunication technologies. Chart 2 shows the declining CAGR of fixed-broadband subscriptions. Broadband was a technology first widely introduced in the early 2000s which experienced double-digit growth which declined on average from 2006 through to 2021 in a non-linear fashion until it reached a CAGR of around 5%.[10]

Chart 2: Example of fixed-broadband subscriptions CAGR over time



Source: International Telecommunications Union statistics.

Additionally, many of the market reports reviewed for this project indicate downward revisions of previously more optimistic growth forecasts. For example, a 2017 market report for global quantum computing indicated a 2021 CAGR of over 250%. In contrast, a 2021 update revised this figure significantly down to a near-term estimate of around 16%. Similarly, a 2019 quantum cryptography solutions report indicated a 2021 CAGR of over 40% and its 2022 update revised this down to 8% estimated growth in 2021.

Moreover, a 2022 market report on quantum sensors indicates consistent year-on-year growth will vary between a narrow range of around 12-13%, indicating “environmental stability in the market”.

[10] International Telecommunications Union (2022) Statistics, <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>. While this depicts consumers/subscription growth and not revenue, it remains a reasonable proxy for market size. Similar trends can also be seen in other telecommunications technology areas such as mobile-broadband subscriptions.

As such, for the modelling to remain on the conservative side, declining growth rates have been selected for the quantum technology opportunities.

2.4 Variable revenue per employee figures

The modelling also reports on the potential job figures for Australia's quantum technology industry. This is done by calculating the sector's revenue per employee ratio similarly as the previous CSIRO report. The following methods were used for estimating the revenue/employee ratio in the three key domains:

- **Computing:** This is assumed at $274,000 per employee in 2040 based on the rounded average ratio for Australian companies in computer systems design, systems integration, software simulation, and related hardware and software services between 2012-2021 (a historic ten-year average).[11]
- **Sensing and measurement:** This is assumed to be $387,000 per employee in 2040 based on the rounded average ratio for Australian companies in navigational, measuring, and scientific equipment development and manufacturing between 2012-2021.[12]
- **Communications:** This is assumed to be $260,000 per employee in 2040 based on the rounded average ratio for Australian companies in cyber security between 2012-2021.[13]

These 2040 revenue/employee ratios were varied across years using a linear growth estimation approach. The historic ten-year average growth in the revenue/employee ratio was calculated for the three key domains (approximately 1% for computing, 3% for sensing and measurement, and 1% for communications) using market reports.

This was linearly projected into 2030, 2035, 2040 and 2045 to generate (rounded) revenue/employee ratios. These ratios across the various years used for the modelling are listed below in Table 1.

Table 1: Revenue/employee ratios applied in modelling (AUD, 000's)

	2030	2035	2040	*2040 (original)*	2045
Computing	249	261	274	*255*	287
Sensing and measurement	287	333	387	*325*	449
Communications	227	243	260	*244*	278

Source: CSIRO Futures modelling.

[11] IBISWorld (2022) Computer System Design Services in Australia. This is similar to the 2020 CSIRO report which used the then-current version of this report to derive an average ratio from 2010 to 2019.
[12] IBISWorld (2022) Measurement and Other Scientific Equipment Manufacturing in Australia. This is similar to the 2020 CSIRO report which used the then-current version of this report to derive an average ratio from 2010 to 2019.
[13] IBISWorld (2022) Cybersecurity Software Services in Australia. This is an update on the approach used in the 2020 CSIRO report which, due to data limitations, derived a ratio from Australia's national cyber security expenditure and the size of its workforce at the time.

3 Findings

3.1 Australia's revenue opportunity

The results of the updated economic modelling are shown below in Table 2. It is found that by 2030, Australia's quantum technology opportunity in revenue terms could conservatively reach **$2.2 billion**. In five years, this could rise by an additional $1.1 billion to reach **$3.3 billion** by 2035, and then rise by another $1.3 billion to reach **$4.6 billion** by 2040. By 2045, Australia's quantum technology opportunity could almost reach **nearly $6 billion** in total.

In each of the years modelled, the quantum computing opportunity is the most dominant. The communications and sensing and measurement opportunity are notably smaller, with communications slightly exceeding sensing and measurement in some years.

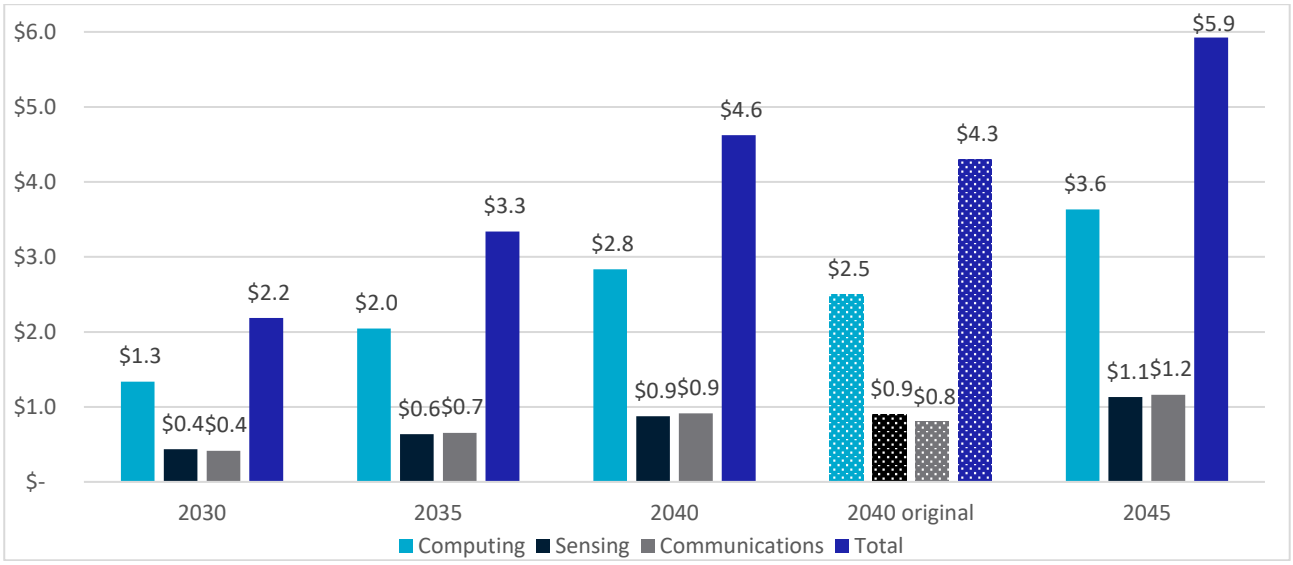
Table 2: Australia's quantum opportunity ($B, AUD, 2021 dollars)

	Computing	Sensing and measurement	Communications	Total
2030	1.3	0.4	0.4	**2.2**
2035	2.0	0.6	0.7	**3.3**
2040	2.8	0.9	0.9	**4.6**
2045	3.6	1.1	1.2	**5.9**

Source: CSIRO Futures modelling.

Chart 3 illustrates the results, alongside the 2040 revenue estimates from the original CSIRO report. It shows that the updated estimates for 2040 are strongly comparable to the original 2040 estimates ($4.6 billion compared to $4.3 billion, with similarly proportioned opportunity sizes across the three domains).

Chart 3: Australia's quantum opportunity ($B, AUD, 2021 dollars)



Source: CSIRO Futures modelling.

As a point of comparison with the updated 2040 estimate provided, internet publishing and broadcasting achieved a total sales and service income of $3.2 billion in 2020-21. Likewise, forestry and logging achieved around $3.8 billion in sales and service income in 2020-21.[14]

3.2 Australia's employment opportunity

The job estimates in headcount employment terms are shown below in Table 3. The modelling estimates that by 2030, Australia's quantum technology sector could conservatively generate around **8,700 jobs**. This could rise to **19,400 jobs** by 2045.

As with the estimates for the revenue sizes, the quantum computing employment opportunity is the largest across the four years modelled. This is followed by communications, and then by sensing and measurement.

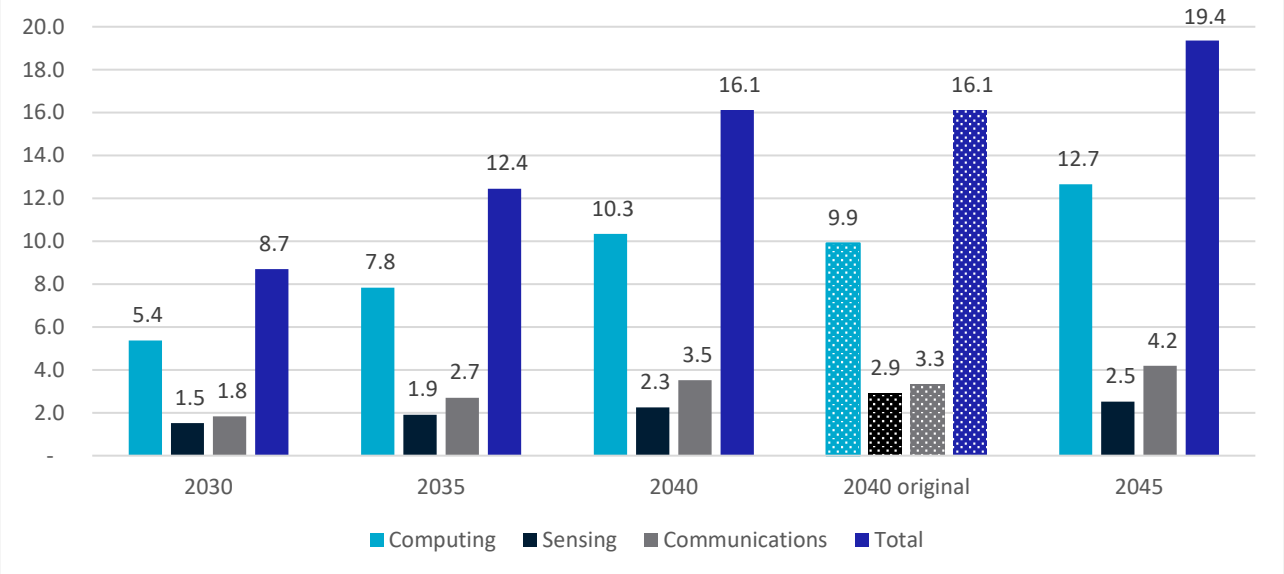
Table 3: Australia's quantum opportunity (jobs, 000's)

	Computing	Sensing and measurement	Communications	Total
2030	5.4	1.5	1.8	**8.7**
2035	7.8	1.9	2.7	**12.4**
2040	10.3	2.3	3.5	**16.1**
2045	12.7	2.5	4.2	**19.4**

Source: CSIRO Futures modelling.

Chart 4 visualises the results, alongside the original 2040 job estimate. As was the case with the revenue estimates, the updated 2040 job estimate is identical to the original estimate in aggregate terms (both being 16,100 jobs), and the job sizes for computing, sensing and measurement, and communications are also equally similar in size.

Chart 4: Australia's quantum opportunity (jobs, 000's)



Source: CSIRO Futures modelling.

[14] ABS (2022) Australian Industry by division, < https://www.abs.gov.au/statistics/industry/industry-overview/australian-industry/latest-release#data-download>.

As a point of comparison with the updated 2040 job estimate provided above, this figure is comparable to oil and gas extraction employment in 2020-21 which was approximately 17,000 employees. Pulp, paper and converted paper product manufacturing in Australia also employed approximately 16,000 jobs in 2020-21.[15]

[15] ABS (2022) Australian Industry by division, < https://www.abs.gov.au/statistics/industry/industry-overview/australian-industry/latest-release#data-download>.

4 Discussion

This report has used the same economic framework as the 2020 CSIRO Growing Australia's Quantum Technology Industry report, with updated inputs, and a new CAGR and job estimation approach to provide Australian quantum technology market sizing estimates for the years 2030, 2035, 2040, and 2045. In providing an expanded view of the potential opportunity in the coming years, it has also affirmed the economic results from the original report.

The results should be seen as conservative estimates and refinements of the original modelling based on an updated dataset and methodology. The revenue and jobs figures presented are not a large departure from the estimates in the original report. This is supported by desktop research, including a review of recent market reports and news articles in this space, which indicates that no major changes have occurred in the quantum technology space in the last two years to significantly alter the underlying modelling parameters.

Some recent developments do provide signs of an optimistic outlook. For instance, quantum technology start-up funding and investment activity in 2021 surpassed 1.4 billion USD, more than twice that in 2020.[16] As of early 2021, 17 countries have a national initiative/strategy to support quantum technology R&D.[17] Additionally, there have been recent announcements such as Fujitsu's plans to sell 64-qubit research computers in 2023, IBM's goal of building an over 4,000 qubit computer by 2025, and Baidu's development of a 10-qubit quantum computer for public use.[18]

However, a more moderate market outlook might be warranted despite these promising indicators. As noted in section 2.3, some recent market reports on quantum technologies have downgraded their forecasts significantly.

In their June 2022 Quantum Technology Monitor, McKinsey notes low overall investment in quantum sensors with most hardware at the prototype level, and quantum computing and communications having a fairly immature software space.[19] Further, they observe a slowdown in the past three years in quantum technology start-ups being founded, despite high levels of investment, which they suggest could be due to a specialist talent bottleneck, high cost of entry for newcomers, and few working use cases with current hardware. They also provide an incredibly high range for the 2040 global market size for quantum computing (from $9 billion up to $93 billion), citing technology challenges in hardware development as one factor.

Ultimately, there are still high levels of uncertainty as to how quantum technology will be commercialised both around the world and domestically. The revenue and job estimates presented in this report are contingent on cutting-edge and – to some degree – still speculative technologies, such as quantum computing hardware and services, to realise wider, commercial applications in the near term.

For Australia itself to realise these opportunity sizes, and as already discussed in detail in the original CSIRO report, it will need to maintain its standing in quantum technology research, as well as sustain industry activities to promote market commercialisation. As a fundamental element of this, Australia will need to implement a focused and nationally coordinated approach to enhancing capability and collaboration to position the domestic industry for continued growth.

[16] McKinsey & Company (2022) Quantum Technology Monitor – June 2022.
[17] CIFAR (2021) A Quantum Revolution: Report on Global Policies for Quantum Technology.
[18] Reuters (2022) 'For hype-wary IBM, quantum-computing sales are close, but not too close', <https://www.reuters.com/technology/hype-wary-ibm-quantum-computing-sales-are-close-not-too-close-2022-05-10/>; Reuters (2022) 'China's Baidu reveals its first quantum computer called Qianshi', <https://www.reuters.com/technology/chinas-baidu-reveals-its-first-quantum-computer-called-qianshi-2022-08-25/>.
[19] McKinsey & Company (2022) Quantum Technology Monitor – June 2022.

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