

30 November 2021

The Department of Industry, Science, Energy and Resources

Cooperative Research Centres Program

Impact Evaluation



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ACIL Allen acknowledges Aboriginal and Torres Strait Islander peoples as the Traditional Custodians of the land and its waters. We pay our respects to Elders, past and present, and to the youth, for the future. We extend this to all Aboriginal and Torres Strait Islander peoples reading this report.



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Abbreviations

ABS	Australia Bureau of Statistics
ACOLA	Australian Council of Learned Academies
CBA	Cost-benefit analysis
CGE	Computed General Equilibrium (modelling)
CO2	Carbon dioxide
CRC Program	Refers to both streams of the Program: the CRC element and the CRC-P element.
CRC	Cooperative Research Centre
CRC-P	Cooperative Research Centre Project
DALYs	Death adjusted life years
DISER	Department of Industry, Science, Energy and Resources
DNA	Developing Northern Australia (CRC-P)
D2D	Data to Decision (CRC)
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GHG	Greenhouse gas
GPS	Global Positioning System
GT	Giga tonnes
GVP	Gross Value of Production
ICT	Information and Communications Technology
KPIs	Key Performance Indicators
MDQ	Management Data Questionnaire (CRCs)
Med-Tech	Medical Technology
METS	Mining Equipment, Technology and Services
MT	Mega tonnes

MTP	Medical Technology and Pharmaceutical
NASA	National Aeronautics and Space Administration (USA)
nec	Not elsewhere categorised
OECD	Organisation for Economic Cooperation and Development
PDQ	Program Data Questionnaire (CRC-Ps)
QALYs	Quality-adjusted life years
R&D	Research and development
RD&E	Research, development and extension
SME	Small and medium-sized enterprises
VC	Venture capital
WIPO	World Intellectual Property Organisation



The Cooperative Research Centres (CRC) Program was established in 1990 and is regarded as a flagship initiative of the Australian Government. The Program establishes collaborations between industry and the research sector. It is of high strategic importance to the Government, involves significant funding and has a high public profile. In 2015, a second Program element, CRC Projects, was introduced to encourage greater SME involvement in collaborative research.

Over the Program's life, the Australian Government has invested \$5.1 billion (nominal)¹ in CRC Program — \$4.8 billion in the CRCs alone — not including the recent \$158 million announced for Round 22 on 30 June 2021.

Grants to CRCs have averaged around \$150 million per year. Over the life of the Program, CRC partners have contributed \$3 billion in cash and an estimated \$12 billion through in-kind contributions.

Over the 29 years of the Program's operation, CRC funding has induced around \$200 million per year of new private R&D. The estimated average additionality of investment in CRCs is 1.47. As a result, CRCs have increased GDP by \$32.5 billion.

The Department commissioned ACIL Allen to undertake a new impact evaluation in 2021. ACIL Allen was asked to evaluate the Program's success in meeting its stated policy objectives by reviewing the Program's high-level design and the Program's short-, and long-term outcomes from 2012 to 2020.

The economic impacts of CRCs supported by the Program have been assessed using ACIL Allen's in-house Computable General Equilibrium (CGE) model, Tasman Global. This model takes into account the economy-wide supply constraints and productivity aspects of industry-researcher collaboration. It also allows the economic impacts of human capital development and knowledge spillovers to be modelled.

In assessing the economic contribution and impact of the CRC Program, ACIL Allen has drawn on data provided by the CRCs, CRC-Ps and the Department. For CRCs active in the period 2012-20, 191 economic impacts have been reviewed, validated as necessary and catalogued. For CRC-Ps, this evaluation has assessed the impact of the thirty projects completed at the time of the review.

¹ A nominal value is one expressed in terms of money, whereas a real value is one which has been adjusted for inflation

The Cooperative Research Centres



\$4.8 billion invested in the CRCs by the Australian Government over the life of the Program



\$14.9 billion invested by partners

For the 2012-20 period, **\$1.5 billion** invested by the Australian Government and **\$4.9 billion** by partners



Number of CRCs active by sector (2012-20):



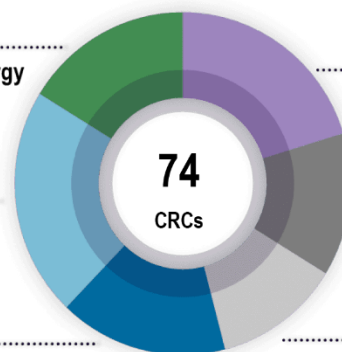
12 Mining and energy



16 Medical



12 Manufacturing and technology



15 Agriculture and food



10 Environment



9 ICT

CRC Projects



11 Eleven grant rounds since 2015



154 CRC Projects grants awarded



\$329 million from the Australian Government



\$768 million from project partners

Impact of CRCs

SINCE
1992

\$32.5 billion of present and anticipated economic impacts over the life of the Program (NPV 7%)

For the period 2012-20



GDP is **\$13.3** billion higher as a result of the Program (NPV 7%), with projections to 2025

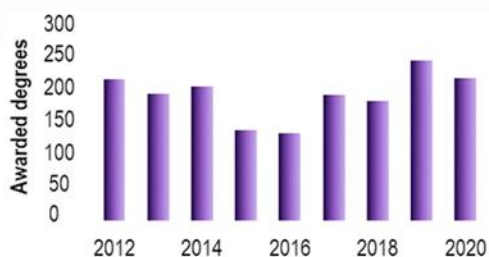


GDP has increased **\$5.61** for every dollar of government funding received since 2005, with projections to 2025

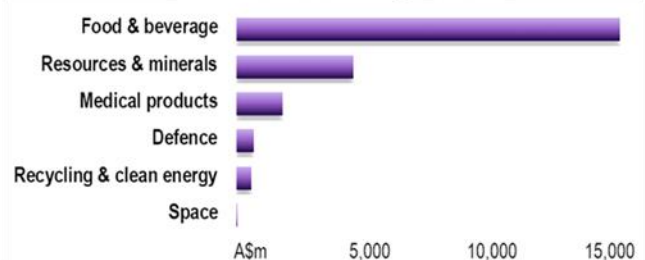


22,007 full time equivalent jobs-years created because of the CRC Program

Post-Graduates trained



Alignment of economic impacts identified with National Manufacturing Priorities



Note: Tier 4 preparedness impacts are not included in this analysis

Impacts for completed CRC Projects



From **30** completed CRC Projects:

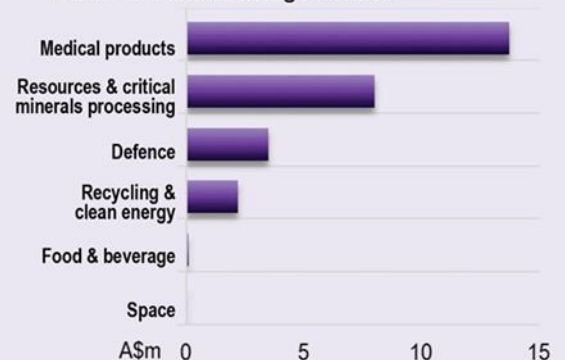


\$514 million net present value of completed CRC Projects



Completed CRC Projects have returned **\$7.73** for every dollar of Australian Government funding

Alignment of economic impacts identified with National Manufacturing Priorities



Evaluating CRCs

This evaluation focuses on the period since the last impact evaluation report (2012-20). It also provides an impact evaluation for the Program since it commenced in 1991.

The broad aims for this impact evaluation have been to:

1. Analyse the Program's intended and unintended outcomes and consider their alignment with the Government's broad strategic priorities, including job creation, the National Manufacturing Priorities, commercialisation, innovation, export opportunities and the economy
2. Assess the overall impacts and value for money of the Program
3. Consider Program impacts compared to an estimate of what would have happened in the Program's absence (counterfactual and additionality), and
4. Summarise the additional impacts of the Program and provide case studies demonstrating why these are important.

In the 2012-20 period, the Australian Government granted CRCs \$1.5 billion (nominal). For this period, ACIL Allen identified 191 economic impacts from the CRCs active in this period.

Economic impacts were classified into four categories:

- Fully attributable to CRCs
- Partly attributable to CRCs
- Imminent impacts (2021-25)
- Preparedness impacts

Excluding preparedness impacts, CRCs active in the period 2012-2020 generated economic impacts exceeding \$32.2 billion in 2021 dollars. This figure includes impacts that are anticipated to occur in the next five years. Some 2,445 full-time equivalent job-years were created. The average annual increase in consumption was \$171 million, investment of \$67 million and trade of \$120 million (all in 2021 dollars).

This impact analysis is based on 57 CRCs active in the period 2012-20. These CRCs comprise around 77 per cent of those participating in the Program over the period — it was not possible to identify and verify the impacts of all relevant CRCs. However, the CRCs included in this analysis provide a representative sample across sectors and disciplines. The absence of the other CRCs does, however, contribute to an underestimate of total economic impacts.

The impacts of CRCs are based on outputs, including new technologies, cost-saving measures, revenue for partners, spin-off companies, efficiency gains and income from licencing of intellectual property. Historically, the CRC Program has extensively supported the agriculture, mining and manufacturing sectors.

In addition to the positive impact on GDP, CRCs also achieved environmental and social impacts. These types of impacts can be significant but are difficult to value and have not been monetised. Examples from the 2012 to 2020 period include:

- Health – improvements in health and well-being from improved cancer therapeutics to asthma diagnostic products
- Education and training – around 2,600 doctorate and masters' degrees awards and research careers started in applied research

- Labour force participation – 2,445 full-time equivalent job-years were created.
- Business development – CRCs create spin-off businesses, assist start-ups, and generate relationships with business incubators
- Safety and security – significant preparedness and security measures
- Social costs avoided – improved schooling in remote areas
- International collaboration – CRCs report international collaboration including with EU Framework Programme and NASA
- Environmental – significant environmental impacts such as reduced greenhouse gas emissions, reduced water consumption and protection of endangered species.

Examples of these types of impacts are presented in this report, including some case studies.

Preparedness outputs address and seeks to mitigate or avoid risks. In some cases, these outputs provide forewarning of impending events with high economic and social costs, depending on particular circumstances or combinations of circumstances. However, if they occur, the timing of such avoided costs cannot be predicted with certainty. Examples of these costs potentially avoided include accident avoidance in rail transport, losses due to bushfires and avoided damage to assets in space.

Evaluating CRC Projects

Since 2015, ten regular and one special round of CRC Projects (CRC-Ps) grants have been awarded to 154 projects. These CRC-Ps received \$329 million in Australian Government support. In addition, their partners invested \$239 million in cash and provided around \$530 million of in-kind contributions.

At the time of this evaluation, only thirty CRC-Ps had been completed. The analysis presented in this report is based on these thirty CRC-Ps who have completed their project and filed end of project reports with the Department. This group of CRC-Ps align well with National Manufacturing Priorities and Government priorities more generally.

These thirty CRC-Ps have reported economic benefits, valued by ACIL Allen at \$514 million in net present value terms. This results in a benefit-cost ratio of 7.7. Considering the entire project costs gives a benefit-cost ratio of 2.5.

CRC-Ps are still a relatively new element of the CRC Program. Only 17 per cent of grants by dollar value have been completed. The COVID-19 pandemic has delayed some project completions and realisation of expected impacts. It is relatively early in the life of the CRC-Ps to make a proper appraisal of this element of the Program — however, indications to date are very promising.

Evaluation conclusions

The impacts catalogued and analysed show that the CRC Program continues to meet its Program objectives, with solid support from Program partners and stakeholders. As a result, the CRCs have demonstrable positive impacts at their local level and drive GDP growth and jobs throughout the economy.

This evaluation finds that the Program is working well, delivering on its objectives, and meeting an identified need. ACIL Allen recommends the Program be continued and funding increased, with only minor adjustments to strengthen and improve outcomes (see page xiv).

This impact evaluation has concluded that the CRC Program:

- continues to be fit for purpose and able to continue driving outcomes
- is an appropriate Government intervention in the view of stakeholders and continues to fulfil a need, addressing Australia's low-level of industry-researcher collaboration
- is consistent with the Government's strategic policy priorities, including the National Manufacturing Priorities
- is being administered and delivered efficiently with appropriate data collection arrangements
- is effectively advised by the CRC Advisory Committee, and the CRCs would benefit if this were expanded
- can address emerging issues, with recent CRCs and CRC-Ps addressing issues such as future energy exports, cyber security and food waste
- has been impacted by the COVID-19 pandemic, which has delayed some outcomes, but partners appear to be managing the crisis
- is assisting SMEs, particularly through the CRC-Ps
- is considered by stakeholders and Program partners to be achieving its intended outcomes, contributing to industry competitiveness, sustainability and productivity
- is also considered by stakeholders and Program partners to be increasing the quality and strength of industry-research collaboration, improving commercialisation and enhancing the capability of the research workforce

CRC-Ps are relatively new, and COVID-19 has delayed some outcomes, making it challenging to undertake a full-scale assessment of their impact. A future evaluation should examine the extent to which they induce additional research. The future evaluation will benefit greatly if CRC-P reporting is improved.

Recommendations

ACIL Allen has reviewed the CRC Program, its impacts and stakeholder views of its function. The clear evidence is that CRCs continue to be a success — both the measurable impacts and stakeholder views of the Program.

Accordingly, our recommendations either suggest expansions of the Program or push for marginal improvements in the structure delivery of the Program. Our recommendations, including page numbers, are given in the order that they appear:

Recommendation 1

The CRC Program is achieving excellent economic, employment, research and commercialisation outcomes as shown by this impact analysis. New opportunities could be addressed by the CRCs and stakeholders see significant opportunities for further investment. There are opportunities for CRCs to be established in new areas (such as proposals that involve the application of synthetic biology or artificial intelligence) and in areas which are currently under-served. This evaluation recommends that future efforts to drive industry growth and innovation should leverage the Program's success and consider further investment in both CRCs and CRC-Ps, as proven ways to drive industry-research collaboration. 82

Recommendation 2

From time to time, Governments have decided to commit a funding round to a priority area. The very nature of these priorities makes it likely that consortia will take time to form. It is important that there is sufficient time for the strongest possible proposals to be developed. It is therefore recommended that, should the Government decide to have a grant round on a priority area, then it should provide some additional lead time. 84

Recommendation 3

The success of the program is contingent on the Advisory Committee determining which proposals should be recommended for funding across a wide range of technologies for both CRCs and CRC-Ps. The Committee is challenged by the numbers of grant applications (especially since the start of CRC-Ps) and new areas of research. It is important that the range of experience, knowledge and skills available to the Committee is sufficient to perform its work credibly without making undue demands on the time of its members. It is therefore recommended that the Government consider increasing the size of the Advisory Committee. This evaluation recommends that the Committee size be increased to around fifteen members. The Committee should also be encouraged to continue to seek external advice, particularly where specialist expertise may be required. 85

Recommendation 4

Currently, CRCs are funded for a period of up to 10 years. However, in some circumstances, particularly in medical research (e.g. where clinical trials are involved), exceptional circumstances arise where a longer funding period is desirable to secure the best return on investment. It is recommended that the Government should allow for a degree of flexibility, in limited circumstances, to provide scope for CRCs to be extended with additional funding. It is suggested that such extensions of funding should be for up to five years where a clear case can be made. 88

Recommendation 5

In some CRCs, particularly those with larger numbers of partners, keeping everyone 'on the same page' can be a challenge. This is important to achieving optimal returns. It is therefore recommended that CRC partners aim to appoint liaison officers to improve the relationship between industry and research partners and help to span the boundaries between them. 89

Recommendation 6

Commencement processes for new CRCs can be difficult. Given the long lead times to impact, it is important that CRCs achieve a rapid start to maximise their productivity. It is recommended that the Department continue to work closely with CRCs at early stages of their funding to reduce the time spent on start-up. The Department should continue to allow the CRC early access to funding support once the contract is signed. 90

Recommendation 7

Winding up a CRC should have been planned from the earliest stages. However, circumstances can change during the life of a CRC, making wind-up or transition to a new entity complex. Loss of key CRC personnel and momentum behind the endeavour can also complicate the exit process. It is recommended that the Department continue to work closely with the CRCs on the wind-up process and including providing advice on exit options. In addition, Exit Reports — which clearly identify outcomes and impacts — should be systematically collected and stored by the department for future research and evaluation purposes. 90

Recommendation 8

The application process for securing a new CRC can be quite long. Delays in the period between submission of proposals and announcement of successful applications can result in a loss of impetus on the part of applicants. It is recommended that the Department should make every effort to ensure that the time between Stage 1 applications closing and an announcement of successful CRCs is as short as possible. Ideally, this should be no more than ten to twelve months. 91

Recommendation 9

Success of the CRC-P element of the program can be bolstered from early learnings from the outcomes on early-round CRC-Ps. At this stage, it appears CRC-Ps may have trouble articulating impacts and communicating challenges faced. It is recommended that reporting is made as straightforward as possible, that the Department continue to improve reporting tools (aligned with the evaluation needs of DISER), and that Departmental staff should continue efforts to assist CRC-Ps in meeting their monitoring and reporting requirements. 92

Recommendation 10

The COVID-19 pandemic has had a significant adverse impact on the CRC-P element of the Program. Additionally, the number of completed CRC-Ps are low. The current cohort is therefore not optimal to form a definitive view of the success of this element. This evaluation recommends that there should be a further evaluation of the impact of the CRC-P element of the Program when at least 80 CRC-Ps have been completed and impacts can be assessed. 92

Recommendation 11

With any grants scheme, it is important to establish that the activities being funded are substantially additional to what might have happened in the scheme's absence. The CRC-P element of the Program will have its greatest impact where it is encouraging innovation that could not have occurred without a grant. It is recommended that any future evaluation of the CRC-P program element should also test the extent to which the activities undertaken by the CRC-Ps would have occurred without government support. 93

1 Introduction

This Chapter sets out the history and the context of the CRC Program since it began operating in 1991.

ACIL Allen has been commissioned by the Department of Industry, Science, Energy and Resources (the Department) to undertake this impact evaluation of the Cooperative Research Centres (CRC) Program (including both CRCs and CRC Projects).

The CRC Program has been operating since 1991 and is an ongoing, merit-based grant program supporting industry-driven, multi-year research collaborations. The CRC Program has two elements:

- CRCs, which undertake medium to long term industry-researcher collaborations for up to ten years. There is no limit set on funding for CRCs
- CRC Projects (CRC-Ps), which were introduced in 2015, undertake short term, industry-led collaborative research for up to three years. CRC-P grants have a maximum limit of \$3 million.

As of April 2021, the Australian Government had provided approximately \$5.1 billion to support 230 CRCs and 154 CRC-Ps over the life of the Program.² In addition, program partners have contributed a further \$15.8 billion in cash and in-kind. At the time of preparing this report, there were 25 active CRCs and around 107 active CRC-Ps.

The CRC Program's objectives have been amended over the years. However, the primary objective has remained constant throughout the life of the Program, namely to encourage collaboration between industry and researchers. As noted above, the CRC Program now comprises two elements: grants to CRCs and grants for CRC Projects (CRC-Ps)

1.1 CRC grants

Under the current provisions, CRC grants support medium to long-term (up to ten years) collaborative research intended to identify solutions to problems that have been identified by industry. CRCs must:

- be a medium to long-term industry-led collaborative research program
- aim to solve industry identified problems and improve the competitiveness, productivity and sustainability of Australian industries
- include an industry-focused education and training program, including a PhD program that builds capability and capacity
- increase research and development (R&D) capacity in small to medium enterprises (SMEs)
- encourage industry take-up of research results.

² On 30 June 2021, a further \$158 million was announced by the Australian Government for three successful Round 22 applicants.

There is no specified limit to funding for each CRC. The number of CRC grants funded in each selection round depends on the relative merit of the applications received and available funding. Applicants must at least match the amount of grant funding sought through cash and in-kind contributions.

1.2 CRC Project grants

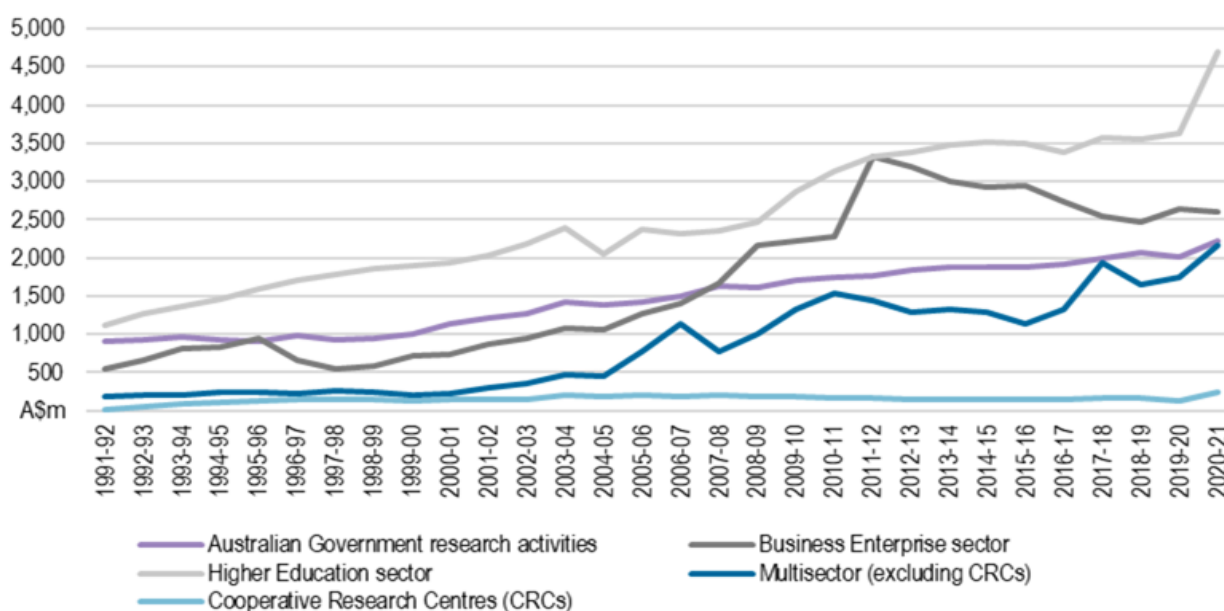
The CRC Project (CRC-P) grants support short-term collaborative research and are a relatively recent addition to the Program. CRC-Ps receive between \$100,000 and \$3 million to support research projects for up to three years. CRC-Ps include at least two businesses (including one small- or medium-sized enterprise) and one research organisation. CRC-Ps must:

- be a short-term industry-led collaborative research project
- develop a product or service, or process that will solve industry problems and drive industry outcomes
- benefit small to medium enterprises (SMEs)
- include education and training activities.

1.3 The funding context

Public funding support for RD&E is an important input into innovation. The Australian Government plays the most prominent role, as shown in Figure 1.1. Nearly \$12 billion was committed to RD&E by the Australian Government in 2020-21, of which \$234 million was for the CRC Program.³

Figure 1.1 Investment in R&D in Australia by sub-sector, 1991-92 to 2020-21 (\$m, nominal)

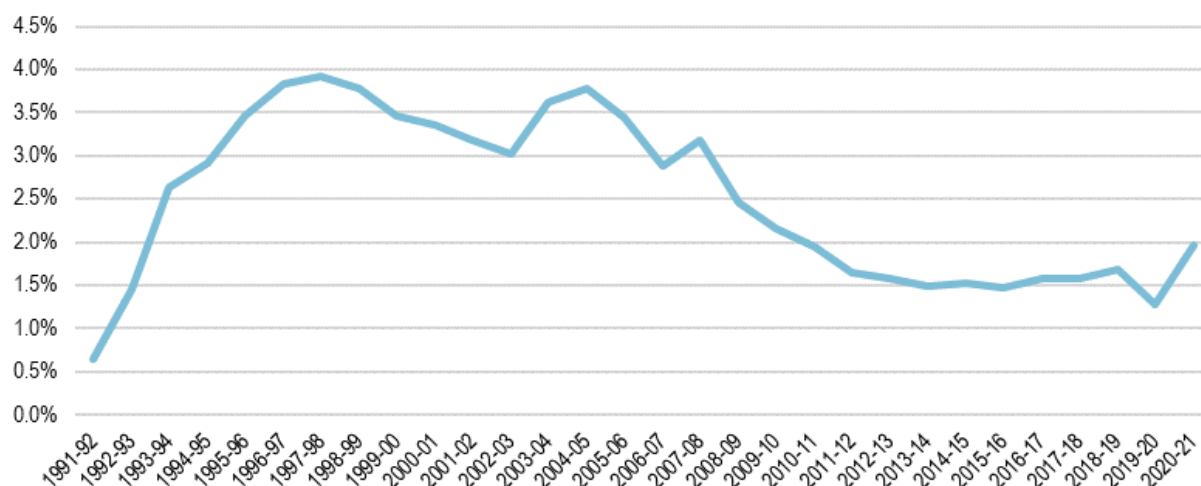


Source: DISER, 2020-21 SRI Budget Tables as at April 2021

³ CRC Program funding has been revised to \$222.77 million in the 2021-22 Portfolio Budget Statement.

CRC Program funding constitutes around 2 per cent of total Australian Government funding for RD&E in 2020-21 (see Figure 1.2). The CRC Program's share in total funding was higher in the late 1990s and mid-2000s. However, it declined to around 1.6 per cent, averaged over 2019-20 and 2020-21 from a high point of 3.8 per cent in 2004-05. For the last ten years, the CRC Program's share was around 1.5 per cent of total Australian Government RD&E funding. In real terms, the annual funding to the CRC Program has decreased year-on-year since the early 2000s.

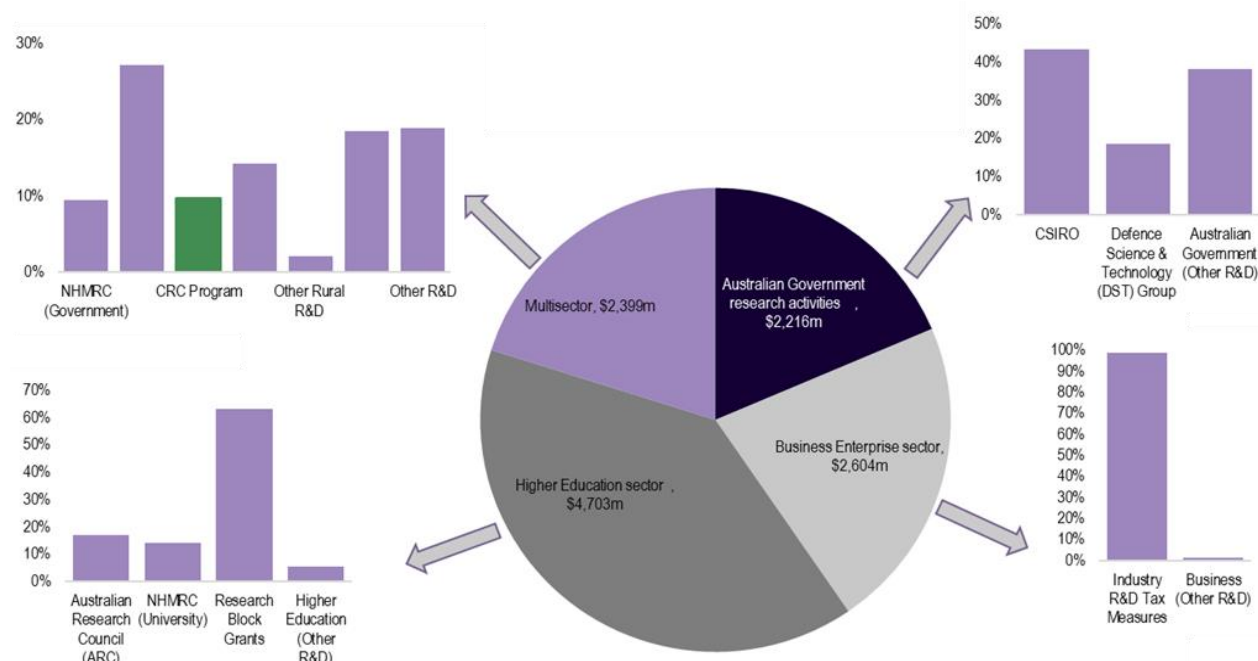
Figure 1.2 CRC Program share in Australian Government RD&E funding (per cent)



Source: DISER, 2020-21 SRI Budget Tables as at April 2021

The CRC Program's current funding position relative to the other Australian Government RD&E funding are summarised in Figure 1.3. The green bar shows where the CRC Program is positioned in this funding ecosystem.

Figure 1.3 Australian Government funding of R&D in 2020-21



Source: DISER, 2020-21 SRI Budget Tables as at April 2021

Note: National Health and Medical Research Council (NHMRC) funding come through multiple channels. Its grants are divided between universities' funding and NHMRC funding other than that provided through universities within the SRI Budget Tables.

1.4 Program funding

Overall funding to date, to both the CRCs and CRC-Ps, is summarised in Table 1.1.

Table 1.1 Summary of total CRC Program funding 1991-2020

	Units	CRCs	CRC-Ps	TOTAL
Total funded to date	number	230	154	384
Currently active (includes committed but not yet contracted)	number	25	107	132
Total value of CRC Program grant funds	\$m	4,793.6	329.3	5,122.9
Total value of partner contributions	\$m	14,992.9	767.5	15,760.5
– Value of partner cash	\$m	3,068.6	239.2	3,307.8
– Value of partner non-staff in-kind	\$m	5,659.4	237.9	5,897.2
– Value of partner staff in-kind	\$m	6,265.0	290.4	6,555.4
Value of grant funds for active CRCs and CRC-Ps	\$m	1,021.3	216.8	1,238.1
Value of partner contributions for active CRCs and CRC-Ps	\$m	3,344.5	523.1	3,867.5

Source: DISER as at April 2021

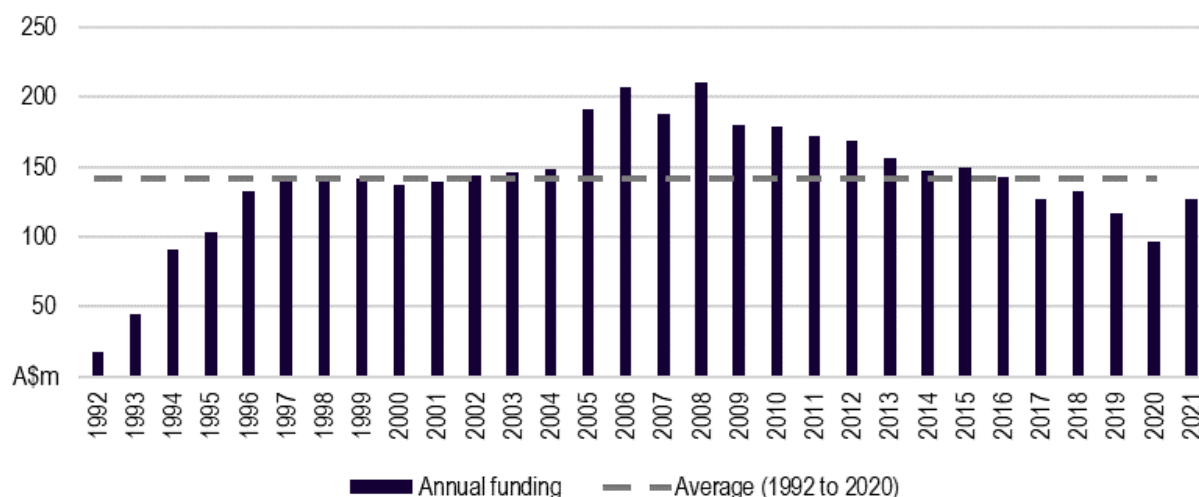
Note: On 30 June 2021, Round 22 was announced with \$158 million committed to three applications.

1.4.1 CRC funding

Australian Government CRCs payments, not inclusive of CRC-Ps, by financial year are summarised in Figure 1.4. Between 1992 and 2020, the Australian Government provided nearly \$4.7 billion (nominal) in grants to 230 CRCs.

Based on CRC grant contracts in place as of August 2021, the Government is committed to investing a further \$700 million in the CRC Program in the period to 2030. On average, over the past 29 years, the Australian Government has provided around \$141 million per year to CRCs (shown as a dashed line in Figure 1.4). However, CRC funding has decreased year on year since its peak in the mid-2000s, both in nominal and real terms (see section 7.1.1 for a discussion of CRC Program funding).

Figure 1.4 Grant payments to CRCs by year, 1992-2030 (\$m, nominal)

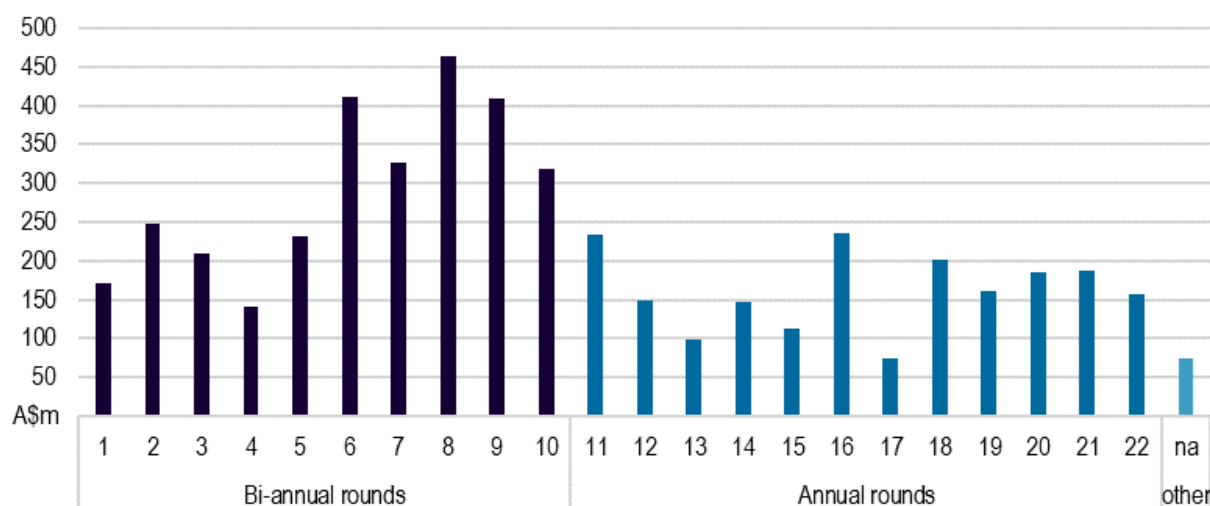


Source: ACIL Allen based on DISER data as at April 2021

Note: This data does not include Round 22 grant funding.

Applications are currently sought for the 23rd round of funding. Since 1991, twenty-two selection rounds of CRC grants have been provided. Funding by round is summarised in Figure 1.5. There is no fixed amount of funding in each round. For the first ten rounds, grants were announced on a bi-annual basis. For round 11 onwards, grants are announced on an annual basis. Over the past five rounds, the total funding provided to successful applicants in each round has been between \$150 million and \$200 million — averaging \$161.8 million.

Figure 1.5 CRC selection rounds (\$m, nominal)

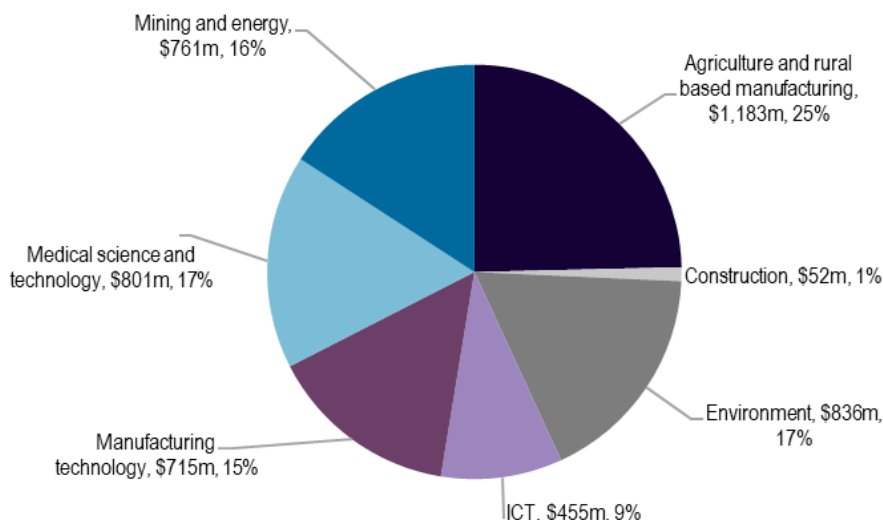


Source: ACIL Allen based on DISER data as at April 2021

Note: The Government committed \$75 million for a CRC for Developing Northern Australia through the 2015 White Paper on Developing Northern Australia, outside a CRC grants round process.

CRC grants by sector are summarised in Figure 1.6. A quarter of total CRCs funding went to agriculture and rural-based manufacturing research, followed by environment (17.4 per cent), medical sciences (16.7 per cent), mining and energy (15.8 per cent) and manufacturing technologies (14.9 per cent).

Figure 1.6 Australian Government support for CRCs, by sector 1991-2020



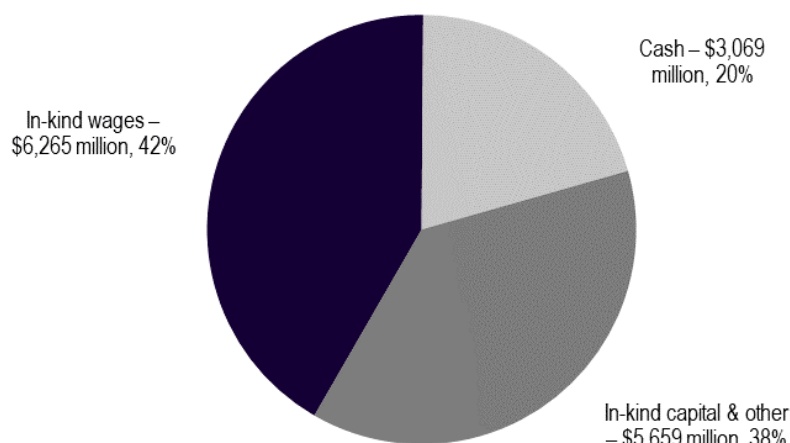
Source: ACIL Allen based on DISER data as at April 2021

1.4.2 CRC partner contributions

The CRC Program supports collaborations between industry and researchers. A CRC must have among its partners at least one Australian industry entity and one Australian research organisation. The partner contributions include cash payments and in-kind contributions (capital, staff and non-staff costs, and others).

Partner contributions by type are shown in Figure 1.7. Around 42 per cent of partner contributions are wages, 38 per cent are in-kind (including capital), and the remaining 20 per cent are cash contributions. On average, each dollar of a CRC grant attracts around three dollars of cash and in-kind contributions from CRC partners.

Figure 1.7 Partner contributions to CRCs by type, 1991-92 to 2020-21



Note: During the period 2012-20, there have been changes in the way some of this data has been collected. In addition, the salary figures used in the calculation were changed in the middle of this period. The most recent data has been recorded in a new database. Attempts to bring all this data together to provide an in-kind contribution figure for each CRC, by year, have been problematic, with some anomalies in the data.

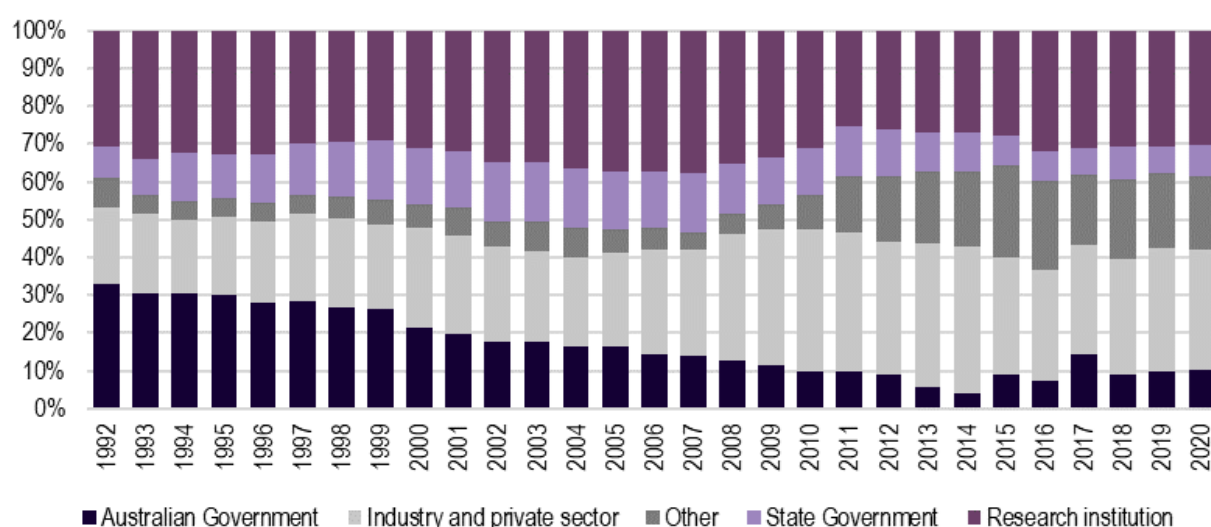
Source: ACIL Allen based on DISER data as at April 2021

Partner contributions by source are summarised in Figure 1.8. In 2020:

- Over 10 per cent of contributions were from Australian Government bodies such as CSIRO and Departments
- Industry and the private sector contributed around 32 per cent
- Other (mainly aggregated supporting partners along with research organisations and industry associations) contributed around 19 per cent
- State governments contributed around 8 per cent, and
- Research institution partners contributed around 30 per cent.

These shares of partner contributions vary between CRCs depending on the nature of the research being undertaken and the willingness of partners to contribute.

Figure 1.8 Total partner contributions to CRCs by source, 1992-2020



Source: ACIL Allen based on DISER data as at April 2021

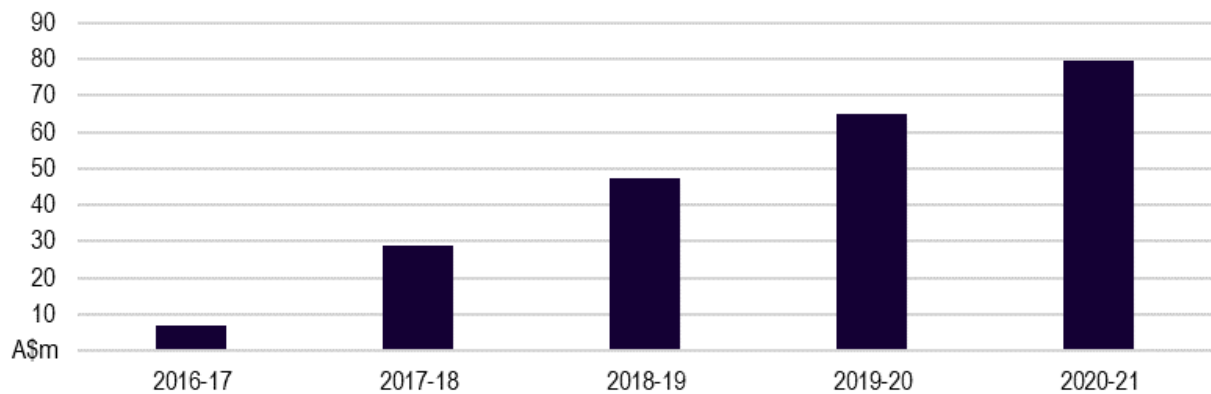
1.4.3 CRC-P funding

CRC-Ps were introduced following the Government's agreement to the recommendations of the 2015 Miles Report. CRC-P grants provide funding for short-term research collaborations. They provide matched funding of between \$100,000 and \$3 million for a period of up to three years to develop a new technology, product or service. CRC-P grants are awarded to industry-led research collaborations involving at least two Australian industry partners, at least one of which must be a small to medium-sized enterprise (SME) and an Australian research organisation. Projects must develop a product, service or process that will solve a problem identified by industry and deliver actual outcomes, benefits to SMEs and include education and training activities.

Grant funds can be used to cover project costs, including research, proof of concept activities, pre-commercialisation of research outcomes, industry-focused education and training activities, conferences, workshops, symposia related to the joint research, and information-sharing and communications related to the research.

Australian Government funding for *all* CRC-Ps is summarised in Figure 1.9. Based on CRC-P contracts in place as at August 2021, the total committed funding between 2016-17 and 2023-24 is around \$300 million. To date, there have been 11 rounds of funding awarded, including the special Developing Northern Australia (DNA) round between Rounds 3 and 4. Grants have been awarded to 154 CRC-Ps. An average of \$30 million has been awarded per round. The average funding for each project is around \$2 million.

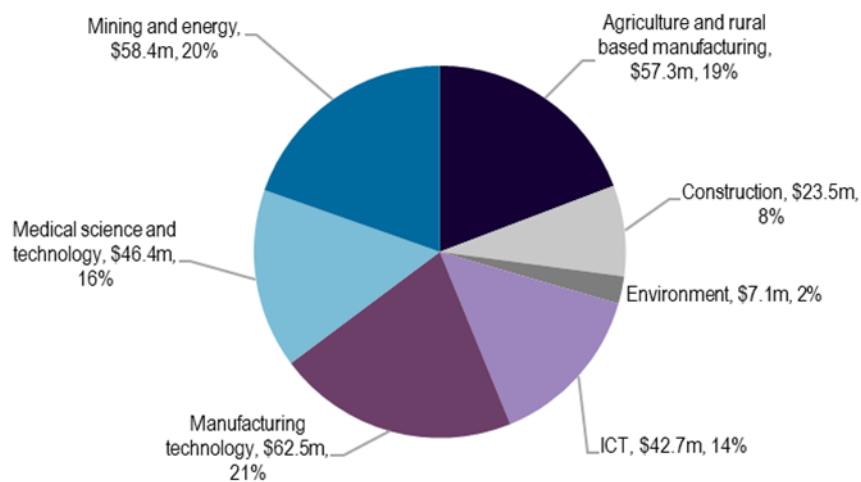
Figure 1.9 Contracted Australian Government funding to CRC-Ps by year (\$m, nominal)



Source: ACIL Allen based on DISER data as at April 2021

Figure 1.10 shows the sectoral breakdown for funding provided to all CRC-Ps.

Figure 1.10 Total CRC-Ps funding by sector



Source: ACIL Allen based on DISER data

The CRC-Ps are a relatively recent addition to the CRC Program. The initial CRC-Ps that received funding were only completing their three-year grants in 2018, not long before the start of the COVID-19 pandemic. As a consequence, most CRC-P grant recipients are yet to deliver impacts from their work. In addition, a few businesses involved have not survived the pandemic.

1.5 Structure of this report

The remainder of this report consists of:

- Chapter 2 – which provides details of this evaluation, including research questions, data sources, and outputs reported
- Chapter 3 – which presents the economic analysis undertaken of the CRCs
- Chapter 4 – which describes the social benefits from the CRCs
- Chapter 5 – which describes the environmental benefits that have flowed from the CRCs
- Chapter 6 – which presents details of the analysis for the completed CRC Projects
- Chapter 7 – which presents an assessment of the Program in its totality and includes a discussion of its issues
- Chapter 8 – which presents conclusions, findings and recommendations from this impact evaluation

2 This impact evaluation

This Chapter sets the purpose of this evaluation, including review objectives, and data and methods used.

The Department commissioned ACIL Allen to undertake an impact evaluation of the CRC Program, including an analysis of CRC Program impacts. This impact evaluation analyses the operations of the Program in the period up to June 2020. At the time of analysis, the Australian Government has provided approximately \$5.1 billion to support 230 CRCs and 154 CRC-Ps since the Program's start. On 30 June 2021, \$158 million was announced for three successful Round 22 CRC applications. This funding has not been included in the impact evaluation. CRC Program partners have contributed a further \$15.7 billion in cash and in-kind.

The CRC Program has a current budget appropriation of \$773 million over the four years from the 2021-22 financial year. Economic impacts were identified, verified and catalogued in the period between April and June 2021.

The CRC Program is a flagship initiative of the Australian Government. It is of high strategic importance to the Government, involves significant funding and has a high public profile. As such, it was assigned Tier One status on the Department's Evaluation Plan 2020-21, signifying the strategic importance of both the initiative and its evaluation.

ACIL Allen was asked to evaluate the Program's success in meeting its stated policy objectives by reviewing the Program's high-level design and its short, medium and long-term outcomes. Additionality analysis was required to assess the impacts of the Program and its value for money.

The broad aims for this evaluation were to:

1. Analyse the Program's intended and unintended outcomes and consider their alignment with the Government's broad strategic priorities, including job creation, the National Manufacturing Priorities, commercialisation, innovation, export opportunities and the economy
2. Assess the overall impacts and value for money of the Program
3. Consider Program impacts compared to an estimate of what would have happened in the Program's absence (counterfactual and additionality); and
4. Summarise the additional impacts of the Program and provide case studies demonstrating why these are important.

The Department asked ACIL Allen to address a number of questions as part of this project. These are listed in

Box 2.1.

Where relevant, views on these questions were sought from stakeholders. CRCs and CRC-Ps were also invited to express their views.

Box 2.1 Questions to be addressed by this evaluation**Design**

1. What is the nature, magnitude and distribution of the problem or opportunity that the CRC Program is designed to address?
 - a) Was federal government intervention appropriate? Is it still appropriate?
2. Is the CRC Program consistent with the Government's current strategic policy priorities (Science and Research Priorities, Industry Knowledge Priorities, CRC-P priority areas) and forward priorities (e.g. National Manufacturing Priorities)?
 - a) Is the CRC Program well integrated and positioned alongside other Government programs?
3. Is the CRC Program an appropriate mechanism to address the problem or opportunity it was designed to address, or the Government's current and forward priorities?
4. Does the CRC Program's design still address the need? What changes or improvements have been made to the CRC Program over time? How effective have these changes been? What, if any, changes could be made to better align the CRC Program with the Government's current and forward priorities?

Efficiency

5. Have CRC Program funding rounds been administered and delivered efficiently by the department?
6. How efficient have CRC Program entities been at delivering their outcomes?
7. Does the CRC Program have sound data collection methodologies?
8. How effective has been the role of the CRC Advisory Committee?
9. How well has the Program been able to identify and address emerging issues or concerns and support its participants?
10. What impact has the COVID-19 pandemic had on CRC Program entities and participating research organisations and industry partners?

Outcomes and Impact

11. Is the CRC Program achieving its intended outcomes? What is the magnitude of the changes that occurred?
 - a) To what extent has the CRC Program increased the strength and quality of business-research collaboration in Australia?
 - b) To what extent has the CRC Program generated a culture of industry-research collaboration, with firms and researchers seeing value in collaborative partnerships?
 - c) To what extent has the CRC Program contributed to the competitiveness, sustainability and productivity of Australian industry and supported commercial outcomes?
 - d) Has the CRC Program improved commercialisation and business performance?
 - e) To what extent has the CRC Program increased research training and improved the capability of the research workforce?
12. What are the intended and unintended outcomes achieved by the CRC Program relevant to the Government's strategic priorities?
 - a) Are the CRC Program outcomes achieved to date in line with the Government's current and forward priorities?

13. How well do the CRC Program's participants match the intended target group and is the reach sufficient to realise the required scale of change?
 - a) Are there any groups negatively affected by the CRC Program?
14. Does the actual distribution of the outcomes differ from that which was intended?
15. What are the main factors contributing to the outcomes?
16. Are there any other impacts and unintended consequences?
17. What is the Government's return on investment for the CRC Program? How has this changed since the last assessment (Allen Consulting, 2012)?
18. How much does the CRC Program contribute to economic growth (GDP), real consumption, real investment and taxation revenue?
19. What would happen to the level of business-research collaboration in Australia in the absence of the CRC Program?
 - a) What impact would this have on economic growth (GDP)?
20. What, if any, lessons can be drawn from the CRC Program to improve the efficiency or effectiveness of this initiative and future initiatives or programs?

Source: DISER

2.1.1 Previous reviews and evaluations

Previous evaluations and reviews of the CRC Program are listed in Table 2.1.

Table 2.1 Previous reviews of the CRC Program

Year	Evaluator	Type
2018	ARTD Consultants	Monitoring evaluation; post-commencement evaluation of the implementation of Miles Review recommendations
2015	Mr David Miles AM	Policy review
2012	Allen Consulting Group	Impact evaluation
2008	Professor Mary O'Kane	Program review
2007	Productivity Commission	Research report on science and innovation
2006	Insight Economics	Impact evaluation
2005	Allen Consulting Group	Impact evaluation
2003	Howard Partners	Program review
2000	Dr Robin Batterham	Program review
1997	Mr David Mortimer AO	Program review
1997	Mr Don Mercer, Professor John Stocker	Program review
1995	Sir Rupert Myers KBE, AO, FTSE	Program review

Source: DISER

2.2 CRC data and information sources

CRC data and information for this project was sourced from:

Existing sources

- CRC Exit Reports
- Impact analyses commissioned or undertaken by some CRCs
- CRC Annual Reports
- CRC Management Data Questionnaire (MDQ) returns
- CRC Association material

Material gathered for this evaluation

- ACIL Allen data request survey similar to that used in the Allen Consulting Group in 2012
- ACIL Allen survey of CRC views of the Department's research questions
- Consultations with stakeholders (listed in Appendix A)
- Discussions with CRC partners.

CRC Exit Reports, where available, varied in their usefulness. Some Exit Reports were accompanied by independent impact analyses. ACIL Allen contacted the authors of a number of these Exit Reports and impact studies to obtain the data used for our economic assessments and seek clarifications of material in these documents.

The ACIL Allen project team sought to contact all CRCs active in the period 2012-20 to request the completion of a data request survey. Like the Allen Consulting Group 2012 evaluation, survey respondents were provided with an evaluation framework to classify their outputs and impacts. The evaluation framework helped to provide consistency in the evaluation process and that all outputs were assessed comparably. The survey questions allow consideration of the effects of a range of factors, such as:

- Nature and scale of outputs/impacts
- Timing of outputs/impacts
- Attribution of outputs/impacts

The data request survey responses were the most satisfactory source of data, although it was still necessary to speak with a number of those responding to clarify the information provided. Unfortunately, it was not possible to contact personnel from CRCs that had concluded their funding period in many cases. In some cases, persons contacted no longer had access to the required data and information. In other cases, contacts provided reports and other material, but these often lacked the detail needed.

A list of quantifiable and non-quantifiable outputs assembled from the sources noted above are summarised in Table 2.2.

In some cases, impacts were substantial or imminent but were difficult to quantify. For example, valuing a start-up company is difficult when there has been no recent purchases of shares. In other cases, negotiations on sales of IP are currently not finalised, making a valuation impossible. Some data was provided on a confidential basis.

Table 2.2 Types of outputs generated by the CRCs

Economic outputs (quantifiable)	Social outputs (non-quantifiable)	Environmental outputs (non-quantifiable)
– Potential costs saved/avoided – Costs saved or avoided – Contract income – Increased capital value for CRC partners – Increased sales/revenue – Licenses granted – Other – Other revenues – Value of patents sold – Value of spin-off companies	– Business diversity – Business success – Change in character of the local community (positive and negative), maintenance of heritage, cultural development events or change in crime patterns – Education and training provided – Expected social costs avoided – Improved health and well being – Improved safety – Intangibles – International collaborations – Labour force participation – Other – Participation in community activities – Savings on government expenditure	– Reduction in the amount of waste produced – Reduction in energy consumption – Area of environment protected – Reduced GHG emissions – Other – Water consumption reduced

Source: ACIL Allen Survey Questionnaire.

The outputs and impacts used in this analysis are summarised in Appendix B.

- Table B.1 summarises outputs and impacts that are 100 per cent attributable to CRCs in the period 2012-20.
- Table B.2 summarises outputs and impacts where CRCs share the attribution with other parties.
- Table B.3 summarises outputs and impacts which are expected in the next five years.

2.3 CRC-P data and information sources

CRC-P data and information was sourced from:

- CRC-P end of project reports
- CRC-P Program Data Questionnaire (PDQ) returns
- An ACIL Allen data survey request
- Consultations with stakeholders and partners

To the end of May 2021 — the time the analysis was completed — only 30 CRC-Ps had completed their projects.⁴ As a result, the response to the data survey was small and, in some cases, only partial, but it was used where possible. To obtain complete information and verify outcomes and estimated impacts, the ACIL Allen team sought to contact recipients of those grants where projects had been completed.

A list of the quantifiable and non-quantifiable outputs identified from the survey and other sources is provided in Table 2.3. Details on how impacts were assessed can be found in section 6.2.

Table 2.3 Types of outputs generated by the CRC-Ps

Economic outputs (quantifiable)	Social outputs (non-quantifiable)	Environmental outputs (non-quantifiable)
– Licenses granted – Contract income – Value of patents sold – Value of spin-off companies – Other revenues – Funding/ in-kind benefits – Costs saved or avoided – Potential costs saved/avoided – Increased sales/revenue – Increased capital value for CRC-P partners	– Education and training provided – International collaborations – Labour force participation – Business diversity – Business success – Tourism development – Improved health and well-being (QALYs) – Improved safety (DALYs) – Expected social costs avoided – Savings on government expenditure – Participation in community activities – Change in character of the local community	– Reductions in environmental costs – Number of endangered species saved – Reduced GHG emissions – Emission of pollutants avoided – Water consumption reduced – Reduction in use of natural resources – Reduction in the amount of waste produced – Reduction in energy consumption – Reduction in usage of transport and commuting – Reduction in contamination of natural resources, including soil, water, air, etc – Area of environment protected

Source: ACIL Allen Survey Questionnaire.

The evaluation of the CRC-Ps has focussed on the 30 CRC-P grants, which have been completed. These CRC-Ps provide a representative spread across sectors. They are listed in Appendix B.2. These grants' outputs, outcomes, and impacts have been reviewed and subject to a cost-benefit analysis (CBA).

⁴ An increasing number of CRC-Ps are finishing. By mid-2022, enough CRC-Ps will have finished and provided project outcomes to make more meaningful evaluation of this aspect of the Program. However the impact of the COVID-19 pandemic may have adversely impacted on these outcomes.

2.4 Evaluation approach/methodology

2.4.1 CRCs

The general approach adopted for this impact evaluation is purposely very similar to that used in the 2012 Allen Consulting Group report to support comparisons. The evaluation draws on data and information from the Government, CRCs and their partners, and other stakeholders.

Central to the evaluation has been identifying economic impacts arising from CRC research and commercialisation activities. These have been categorised, as in the 2012 report, under four tiers:

- **Tier 1: CRC outputs** — fully delivered by and attributable to CRCs
- **Tier 2: Collaborative outputs** — where these are partly attributable to CRCs and partly to other parties
- **Tier 3: Imminent outputs** — these are expected to occur over the next five years (2021-25)
- **Tier 4: Preparedness outputs** — which address potential risks.

Tiers 1, 2 and 3 outputs, outcomes and impacts are included in the CGE analysis for this evaluation. Tier 4 has been excluded from the quantified impacts, though are listed given their potential for large benefits.

This evaluation has focussed on those CRCs which were in receipt of funding during the period 2012 to 2020. Some 74 CRCs were active in this period. Of these:

- 59 completed their funding during this period
- 39 were new CRCs commencing in this period.⁵

Only twenty CRCs provided data survey responses, although a number of others provided material, reports and other information. ACIL Allen experienced difficulty in contacting senior staff of CRCs that had completed their funding period, especially those that had finished in the early years of the period under evaluation.

Where there was no survey response provided, ACIL Allen has relied on Exit Reports to identify impacts. Exit Reports provide a snapshot at the time that Government funding has ceased. To get a more up-to-date picture of impacts identified in Exit Reports, the ACIL Allen team contacted senior managers and CRC partners as necessary. Particular attention was given to verifying claimed high-value impacts.

As a result of these investigations, ACIL Allen has obtained information from 77 per cent of the CRCs active in the period 2012-20 and has catalogued 191 economic impacts (these are catalogued in Appendix B).

Where significant projected impacts could not be verified, they have been excluded from the analysis. Impacts projected beyond 2024 have not been included. Some estimated impacts have been scaled back where — in the view of the ACIL Allen team — they are unlikely to be fully realised (at least in the time frame proposed in Exit Report) because of the COVID pandemic or for other reasons.

⁵ Note some CRCs both commenced and concluded during this time, for example the CRC for Polymers commenced a new period of funding on 1 July 2012 and concluded on 30 June 2017.

Other estimated impacts have been risk-adjusted. This has occurred where the impact could be large in certain circumstances, but the chance of these circumstances occurring is slight.

Review of impacts projected as imminent in 2012

A number of CRCs which had projected impacts in the period 2012-17 were re-examined. Some of these had completed their funding before 2012. The ACIL Allen team sought to contact personnel and partners from CRCs whose imminent impacts had been included in the Allen Consulting Group 2012 report to re-assess these projections. Some CRCs reported that actual outcomes in the 2012-17 period were much greater than expected, while others reported shortcomings in their resulting impacts. Most CRCs reported outcomes consistent with original projections.

Return on Government investment as a measure of Program impact

This report, like its predecessors, focuses on the return on the Australian Government's investment in CRCs. However, unlike individual CRC endeavours, the impact of the CRC Program is measured at the economy-wide level. The return-on-investment approach is used in preference to cost-benefit analysis (CBA), which is often used in deciding whether or not to proceed with an individual project or in the review of small- to medium-scale projects.

Because of the scale of the CRC Program, measures of change in GDP have to account for market-distorting effects such as changes in the flow of investment, changing employment and changes in Government spending. These factors, which drive GDP outcomes, are not strictly benefits, nor are they strictly costs — they would appear in both the numerator and the denominator, depending on modelling assumptions. Accordingly, a strict benefit-cost ratio is not necessarily a useful way of characterising the overall impact of the CRC Program and, in ACIL Allen's view, would be more misleading than useful in understanding the impact of the CRC Program.

2.4.2 CRC-Ps

Unlike CRCs, CRC-Ps usually involve just one project. While CRCs can still achieve significant impacts when one project fails, CRC-Ps that have only one project are more at risk of failing to achieve impacts. Therefore, it was apparent that using the same approach to evaluating CRC-Ps as described above for the CRCs would not be appropriate.

CRC-P Completion Reports were of variable usefulness. ACIL Allen was able to contact the authors of a number of these Completion Reports and impact studies to obtain data that could be used for our economic assessments and to seek clarifications of the information provided in these documents.

The ACIL Allen project team sought to contact all completed CRC-Ps to complete the data request survey or to provide other data. Unfortunately, it was not possible to contact personnel from CRC-Ps where the funding period had concluded in several cases. The publicly available information and documents submitted to the Department, such as the end of project reports and grant applications, have been drawn on for all completed CRC-Ps.

The data request survey responses were the most satisfactory source of data, although, as with the CRCs, it was still necessary to speak with a number of the survey respondents to clarify the information provided. In some cases, impacts were substantial or imminent but were difficult to quantify. Some data was provided on a confidential basis.

As with any survey, not all the CRC-Ps that responded provided answers to all the questions. Of the 154 CRC-Ps, 19 responded to the ACIL Allen's data survey. This represents 12.3 per cent of the survey response. Of the 30 completed CRC-Ps, analysed in this report, only six returned surveys – a response rate of 20 per cent.

The outputs and impacts used in this analysis for the 30 completed CRC-Ps are summarised in Appendix B, Table B.4 and Table B.5.

3 Economic impact assessment of CRCs

This Chapter outlines the economic impacts of the CRCs and the sectors they operate in; and outlines the estimated economy-wide impacts on GDP, human capital, and employment. CRCs are the major element of the CRC Program.

The CRCs have been a positive driver of the Australian Economy for close to thirty years. The scale of the impact of the CRCs is measured in the tens of billions, with impacts across sectors such as agriculture, the environment, manufacturing, mining, energy, construction, information and communications technology, and medical science and technology.

This section characterises two aspects of the CRCs economic impact:

- the direct economic impacts which have been identified and catalogued by ACIL Allen
- the estimated impact on Australian GDP when considering spending, alternative uses of the funding, and labour impacts

3.1 Economic impacts

In this analysis, impacts have been classified as economic, social or environmental. Economic impacts are those to which can be given a measurable and specific asset value captured by economic actors. This category is subdivided into two groups:

- Direct impacts of the CRCs (or in collaboration with others), where the benefit may be either as direct benefits or as costs saved (for example, a cheaper production method).
- Economy-wide impacts where the economic benefit is propagated throughout the economy, and the CRC activity stimulates investment, jobs and further economic growth.

Most social and environmental impacts have not been monetised. Monetary values, where reported, have not been included in the economic analysis. This is because the monetisation of many of the social and environmental impacts is often not reliable. As a result, impacts determined from CGE analysis for this project understate the overall benefits of the CRCs. Information on the CGE model is included in Appendix D.

3.1.1 Demand-side

Demand-side impacts include the goods and services used by the CRCs. As with any other economic activity, CRCs contribute to the economy through their day-to-day operations and through their capital expenditure.

CRCs receive income from various sources — mainly Australian Government funding, partner contributions, sale of services and IP and consulting income. CRCs spend this income in generating research outputs and attracting researchers who also spend on goods and services. This spending has a direct effect on economic activity, raising demand for goods and services and driving wider economic growth through second (and subsequent) indirect effects.

An important aspect in analysing the demand side of CRCs impacts is the opportunity cost of government spending for CRCs against other government spending or saving. Unlike other government spending, such as unemployment benefits which are transfers, expenditure by CRCs through their operations generates positive impacts, mainly through the accumulation of physical, human and intellectual capital that would otherwise not be possible.

3.1.2 Supply-side

Supply-side impacts of CRCs are generated through the beneficial research outputs they produce from research activities — R&D and industry collaborations. As noted in the previous Chapter, these supply-side benefits include:

- **Tier 1** are *solely* delivered by CRC research activities. These include cost savings in the production and sale of goods and services. These impacts could be quantifiable based on the information provided by CRCs.
- **Tier 2** are *jointly* delivered by CRCs and their collaborative partners. These impacts could be quantifiable with an appropriate attribution rate based on the information provided by CRCs. Each collaborative impact has been assigned an attribution factor, which may have been reported by the CRC or, in some cases, assigned by ACIL Allen based on discussions with relevant parties and analysis.
- **Tier 3** are *potentially* delivered by CRCs and their collaborative partners in the near future, for example, the next five years. These impacts could be quantifiable with reasonable probabilities based on the information provided by *existing* CRCs. These include technology that is proven but where there are uncertainties associated with the market and its uptake. These can be partly quantifiable by using appropriate probabilities of expected benefits provided by CRCs. Incorporating Tier 3 anticipated impacts necessarily adds a degree of uncertainty. It is difficult for CRCs to estimate their future impact and also difficult for ACIL Allen to verify. ACIL Allen has therefore been conservative in assessing them.
- **Tier 4** are delivered by CRCs and their collaborative partners, which will be revealed only if certain circumstances occur — for example, preparing for bushfires and the management of non-recurrent pests and diseases. Tier 4 benefits, though extremely important and the focus of some CRCs, are not included in the economic impact analysis given the difficulty in attributing the time and scale of their economic impacts.

The *incidence* and reporting of these benefits can vary by tier and by CRC. For example, CRCs which have closed may have realised benefits through the sale or licensing of intellectual property. Continuing CRCs may categorise these benefits as a value-add to the CRC (through revenues or improved capital value). While many benefits are reported as specific impacts, other common benefits include:

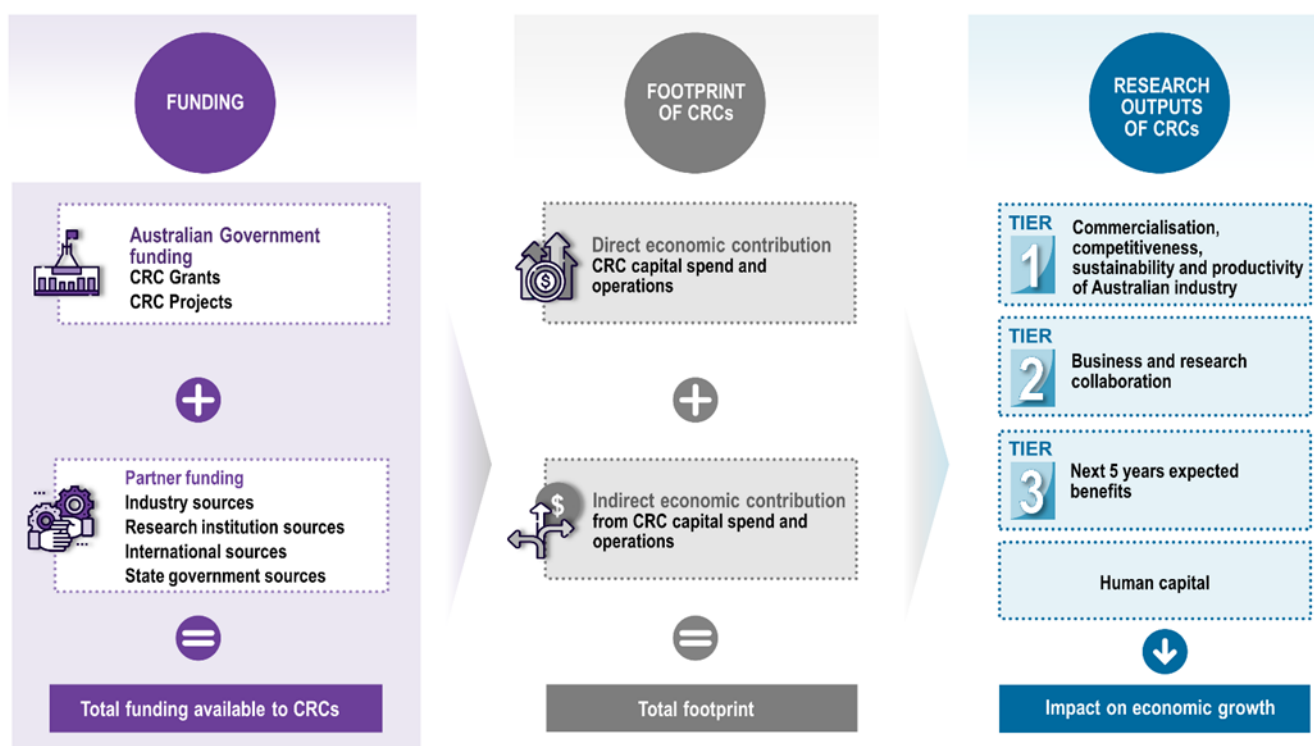
- benefits through the sale of Intellectual Property
- benefits from enhanced skills formation:
 - through the development of highly skilled post-graduates that build a critical mass of skills that either attract private companies to invest or help retain existing business activity levels
 - through the development of highly skilled post-graduates who then work in industry and allow industry to be smart adopters and adapters of CRC generated technology/knowledge
 - through industry and academic researchers interacting and increasing their skills, and hence their future productivity, via this interaction.

- through collaboration across sectors and disciplines encourages researchers to develop an understanding of both research provider and end-user perspectives, maintaining focus on the active planning for and management of pathways to application.
- benefits through the increased market value of participating organisations
- benefits through an organisation established to continue the work CRCs
- benefits through the creation of spin-off companies.

3.2 Analytical framework for economic impact analysis

ACIL Allen has used an analytical framework to assess the impact of CRCs on the Australian economy. This framework is based on previous CRC Program evaluations undertaken by the Allen Consulting Group and used in various ACIL Allen R&D evaluation studies. The framework is summarised in Figure 3.1. This framework shows the main channels through which the CRCs impact the Australian economy. It also provides the context for counterfactual, additionality and attribution issues in analysing the CRCs' impacts.

Figure 3.1 Analytical framework

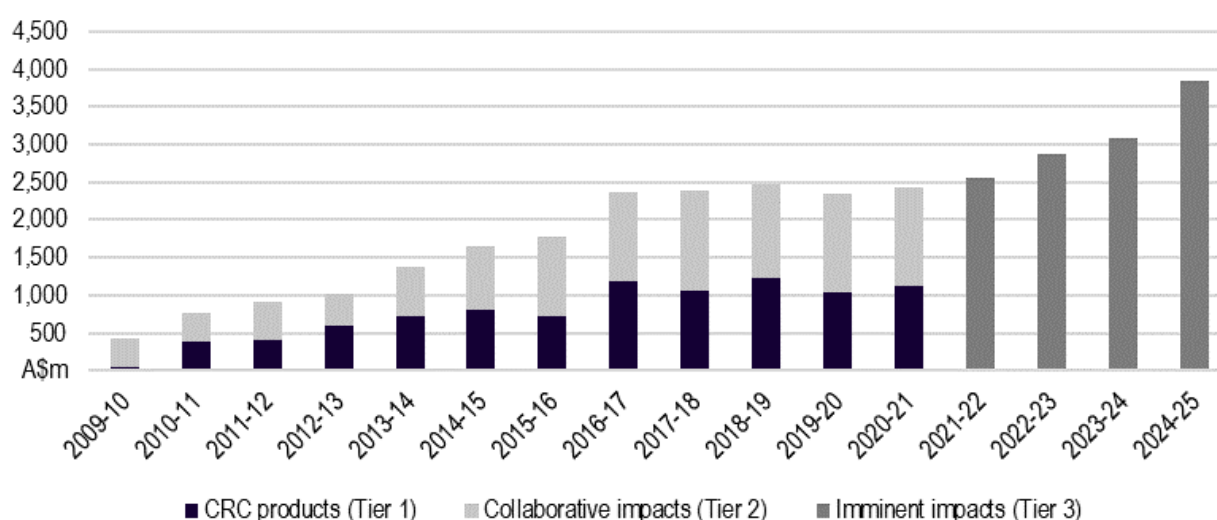


Source: ACIL Allen

3.3 Measured economic impacts

ACIL Allen has drawn on details on 191 economic impacts of 54 CRCs in the years since 2005. This includes 30 CRCs which report imminent benefits between 2021 and 2025. These impacts, along with the data collected for the 2012 Allen Consulting review of the CRC Program, provide a long-term and detailed picture of the economic contribution of the CRCs. The total economic impacts catalogued as part of this review for the period from 2012 to 2025 are \$32.2 billion (2021 dollars) and a further \$13.7 billion (in nominal terms) in the years after 2025. These benefits, by year, are given in Figure 3.2.

Figure 3.2 Reported quantifiable benefits in the year accrued, by tier (\$m, 2021 dollars)



Source: ACIL Allen

These impacts are made up of:

- 29 per cent *Tier 1* benefits (\$9.3 billion in 2021 dollars)
- 33 per cent *Tier 2* benefits (\$10.6 billion, reflecting benefits attributable to the CRCs, in 2021 dollars), and
- 38 per cent *Tier 3* benefits (\$13 billion of anticipated benefits in 2021 dollars).

A full list of economic impacts identified, by tier, is provided in Appendix B.

3.3.1 Previously predicted benefits for 2012-17

In 2012, Allen Consulting estimated that the economic impacts over the period 2013 to 2017 would be \$6.98 billion (in 2021 dollars). From the economic impacts quantified in this report, we estimate the Tier 1 and Tier 2 impacts over the period was \$8.18 billion (in 2021 dollars). The current estimate is 18.7 per cent larger than the Allen Consulting report estimates (see Table 3.1).

Table 3.1 Comparison to 2012 Allen Consulting estimates, 2013-2017

	2012 Allen Consulting Group Report economic benefits anticipated 2013-17 (2021 dollars)	Tier 1 and Tier 2 benefits quantified 2013-17 (2021 dollars)
2013-17 reported benefits	\$6.89 billion	\$8.18 billion

Source: Allen Consulting 2012 and ACIL Allen

There are multiple reasons for the difference:

- Both reports are limited in the number of CRCs which have been reported; and in the types and scale of economic impacts they can provide. The CRCs which provided numbers are different.
- Some CRCs were starting just before 2012 or started during the period which would have been unavailable for inclusion in the estimates
- Anticipated impacts are more difficult to measure than retrospective economic impacts.

3.3.2 Impact by sector

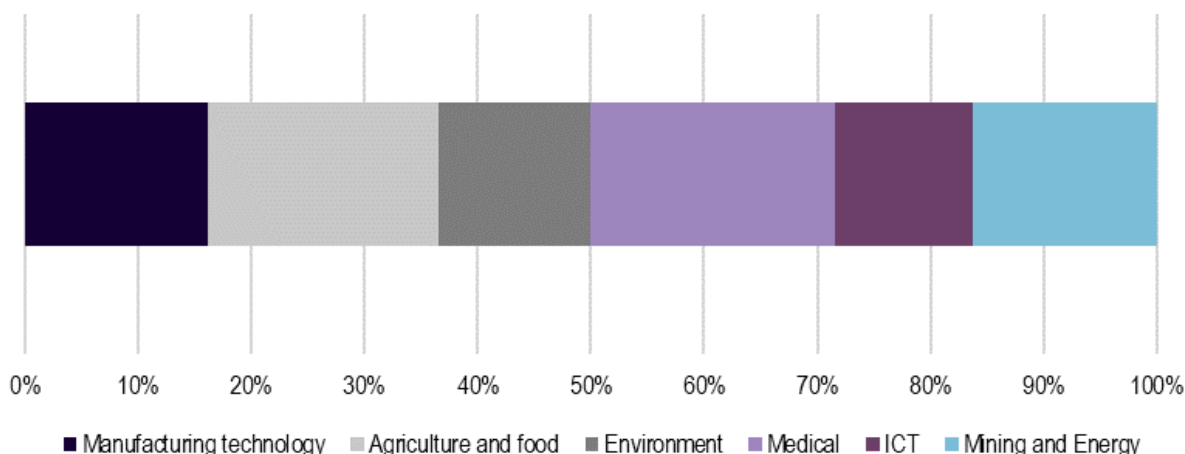
CRCs have contributed widely throughout the Australian economy. Almost every CRC services a separate industry or market, which makes it a naturally far-reaching program. Historically, the CRC Program has extensively supported the agriculture, mining and manufacturing sectors. In the period from 2012, CRC focus has diversified, reflecting a changing economy.

As part of this review, CRCs were categorised by the following sectors:

- Agriculture (and rural-based manufacturing) – examples include the *Blue Economy CRC* and the *CRC for Beef Genetic Technologies*
- Environment – examples include the *CRC for Water Sensitive Cities* and the *Bushfire and Natural Hazards CRC*
- ICT – examples include the *Cyber Security CRC* and the *Data to Decisions CRC*
- Manufacturing – examples include *CRC for Advanced Composite Structures* and the *Innovative Manufacturing CRC*
- Medical science and technology –examples include the *Cancer Therapeutics CRC* and the *CRC for Asthma and Airways*; and
- Mining and energy –examples include the *CRC for Optimising Resource Extraction* and the *CRC Mining*.

Agriculture was the largest group of CRCs for which impacts were identified — 16 of the 56 CRCs (29 per cent) were from this sector. In addition, there were ten medical science and technology CRCs, ten manufacturing CRCs, eight mining and energy CRCs, and seven environment CRCs. The breakdown of CRCs by sector is shown in Figure 3.3.

Figure 3.3 CRCs by sector for which economic benefits were identified

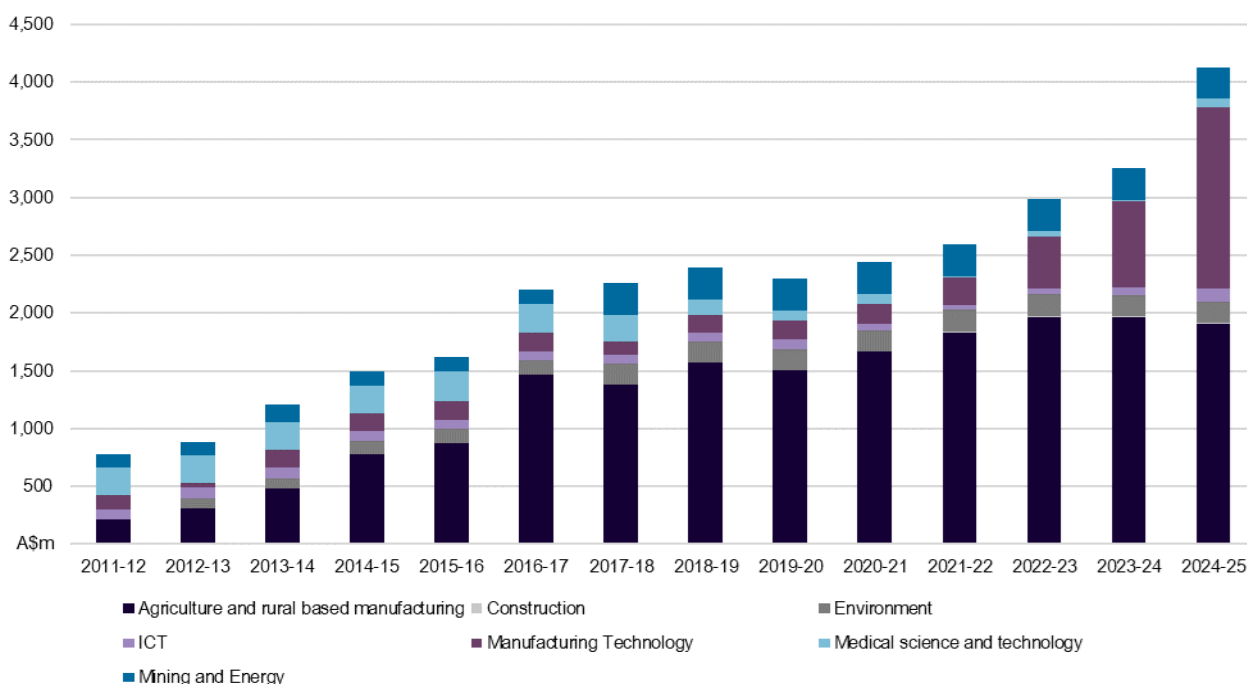


Source: ACIL Allen

Although we have categorised the CRCs by these sector groups, we note the diversity and breadth of the CRCs. It is not uncommon for an environment CRC to have economic impacts which result in agriculture benefits; or for a construction CRC to have economic impacts for the manufacturing sector.

Of the economic impacts catalogued, the sector with the largest impacts is the agriculture sector, with over 57 per cent of direct economic impacts identified. The next largest sector is manufacturing, with 15 per cent of economic impacts. The breakdown of economic impacts by sector is given in Figure 3.4.

Figure 3.4 CRC economic impacts, by sector (\$m)



Source: ACIL Allen

Agriculture sector

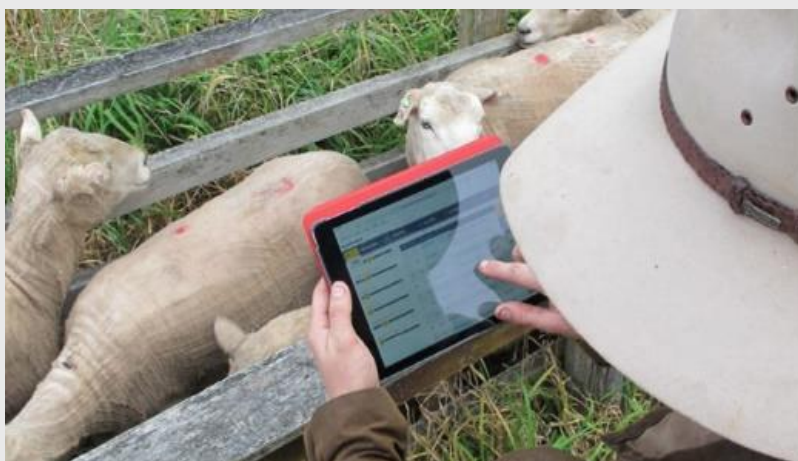
The agriculture sector is an important part of Australia's economy, accounting for 11 per cent of goods and services exports, 1.9 per cent of GDP and 2.6 per cent of employment in 2019-20.⁶

From 2012 to 2020, direct economic benefits of \$9.1 billion (2021 dollars) were identified. These benefits are shown in Figure 3.5. Economic benefits from agriculture CRCs make up 57 per cent of benefits, despite making up only 29 per cent of CRCs for which benefits were identified. However, it is important to note that agriculture CRCs were relatively more common in the earlier part of the period. Therefore, they have had more opportunities to develop economic benefits, many of which are reported to be substantial and ongoing.

Examples of these substantial, ongoing benefits include those reported by the Fight Food Waste CRC, the CRC for Contamination Assessment and Remediation of the Environment, and the CRC for High Integrity Australian Pork. Fight Food Waste CRC alone reports impacts of over \$1.4 billion between 2019-20 to 2024-25, resulting from its research programs into food waste reduction and transformation.

Box 3.1 RamSelect from the CRC for Sheep Innovation — helping sheep farming achieve faster genetic gain

Program funding for the CRC for Sheep Industry Innovation (Sheep CRC, 2014-19) has helped RamSelect Plus take the guesswork out of breeding sheep through digital technology. Success in the sheep industry depends on picking the right ram for breeding. In an industry-first innovation from the Sheep CRC, digital technology has been combined with DNA testing to ensure that farmers can make the best choices. RamSelect Plus is an enhanced version of the Sheep CRC's popular web-based genetic selection app. RamSelect Plus takes the guesswork out of selecting rams with the genetics which match the farmer's purpose – whether that be wool production, meat quality or a range of other factors which impact the profitability of a flock. Farmers can compare sheep from a range of sources via an intuitive and easy-to-use platform, with RamSelect Plus using plain English terminology for the desired traits.



⁶ ABARES, 2021, *Snapshot of Australian Agriculture 2021*, available online at: <https://www.agriculture.gov.au/abares/products/insights/snapshot-of-australian-agriculture-2021>

The success of RamSelect Plus can be best gauged by its rapid uptake by sheep breeders. About 14,000 rams from 180 studs were listed on the website in the first five months. Ram breeders who list their sales catalogues pay a small charge to advertise their animals on the site for three months.

There are no charges for ram buyers conducting online searches of catalogues listed on the RamSelect site, and users can view/print lists of rams that meet their breeding objectives. Users who wish to save their breeding objective, together with a sale list and ram information or genomic profiling information, have to become a registered user for a small annual cost.

RamSelect uses Australian Sheep Breeding Values (ASBVs), which are an estimate of an animal's genetic merit based on pedigree, performance recorded and DNA information. They provide an estimate of how the animal's progeny will perform. ASBVs are available for all the traits that are economically important to a sheep business. Selecting the right rams can have a significant positive impact on a sheep farmer's income — the genetics that farmers buy will last in their flock for many years. The RamSelect tool:

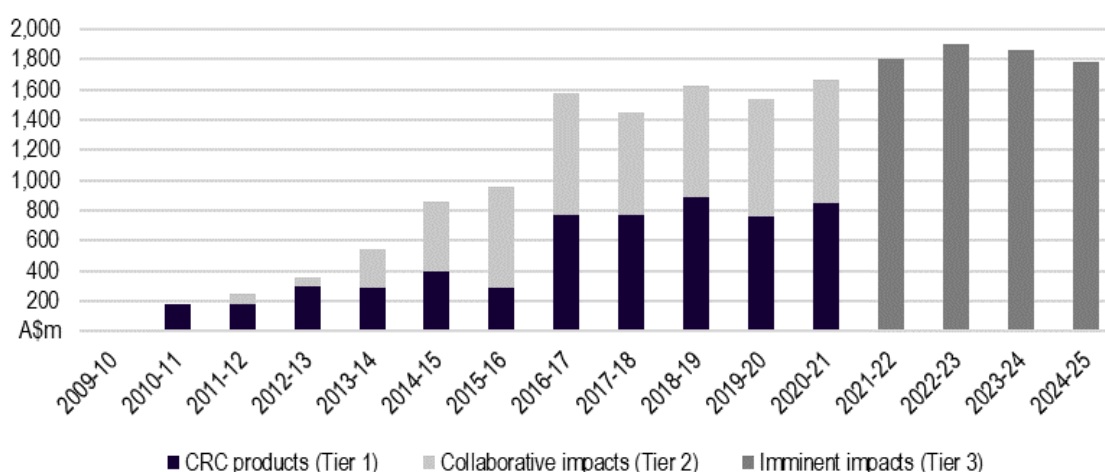
- Searches all rams with ASBVs that are listed for sale by breeders
- Allows commercial producers to specify their breeding objective in a direct way, by specifying how much emphasis they wish to place on different commercial traits — default settings, using standard industry indices (Merino, Terminal, Maternal, Dohne), are provided as a first step and are a reference point for those developing a customised objective
- Ranks available sale rams according to their suitability relative to the producer's breeding objective
- Provides advanced filters for setting additional search criteria
- Provides easy access to additional ASBV details
- Stores and tracks ram data over time and provide accurate benchmarks of genetic merit, and
- Stores and tracks DNA flock profiling results over time and for use in purchasing future rams. This innovation has the potential to change the sheep meat industry. Producers can now be rewarded for delivering superior eating quality by selecting for traits such as growth, tenderness and intramuscular fat.

The Sheep CRC received \$68.8 million in Australian Government funding and over \$259 million in industry support (cash and in-kind contributions) between its first iteration in 2007 and the end of its funding period ending in 2019.

RamSelect Plus is available on laptops, mobile, and tablets at www.ramselect.com.au and was developed with Telstra, NSW Department of Primary Industries and Pivotal Labs.

The Sheep CRC won an Innovation Award for its RamSelect training program. Since the completion of its funding, RamSelect is has been taken over by the University of New England.

Source: *Business.gov.au*, *Sheep CRC*, *RamSelect* viewed on 6 August 2021 at <http://www.ramselect.com.au/> ; picture credit *Sheep CRC*

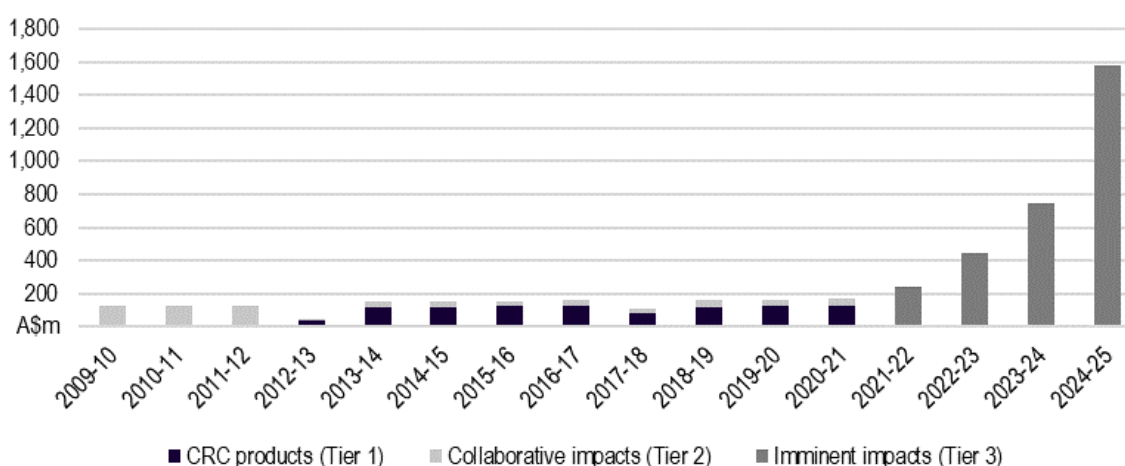
Figure 3.5 Economic impacts, agriculture and rural manufacturing sector (\$m, 2021 dollars)

Source: ACIL Allen

Manufacturing sector

The manufacturing sector employs approximately 831,000 people⁷ and makes up around 5.9 per cent of Australian GDP. The sector also contributes 26.4 per cent (\$4,599 million) of business expenditure to research and development (R&D), making it the second-highest contributor following the professional, scientific and technical services industry.⁸

ACIL Allen identified \$4.6 billion (2021 dollars) of direct economic impacts to the manufacturing sector from CRCs in the period 2009-10 to 2024-25, making it the sector with the second largest proportion of impacts from the Program. From 2012 to 2020, direct economic benefits of \$1.3 billion in 2021 dollars were identified, shown in Figure 3.6.

Figure 3.6 Economic impacts, manufacturing sector (\$m, 2021 dollars)

Source: ACIL Allen

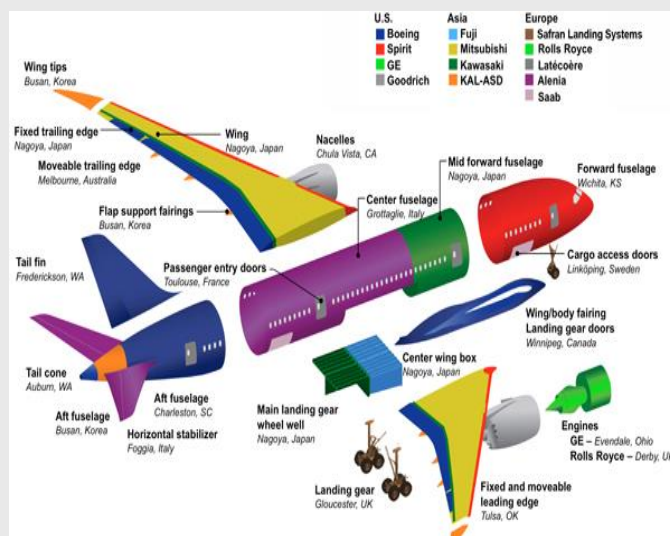
⁷ ABS, 2021, *Australian Industry*, available online at: <https://www.abs.gov.au/statistics/industry/industry-overview/australian-industry/latest-release>

⁸ ABS, 2019, *Research and Experimental Development, Businesses, Australia*, available online at: <https://www.abs.gov.au/statistics/industry/technology-and-innovation/research-and-experimental-development-businesses-australia/latest-release>

Box 3.2 The CRC for Advanced Composite Structures — applications ranging from aerospace to oil & gas

The CRC for Advanced Composite Structures (CRC-ACS, 1991-2015) was one of the longest-running CRCs and one of the most successful. It operated in a period when there was strongly increasing interest in the use of new composite, lightweight, high-performance materials in manufacturing. Composites are being used in sectors including aerospace, automotive, defence, infrastructure, oil and gas. The use of composites requires a very high level of engineering capability, along with highly developed manufacturing and technical skills. CRC-ACS brought together Australia's leaders in composites, building a centre with an international reputation for excellence and reinforcing Australia's reputation as a successful innovator in composite structures.

From its beginnings, CRC-ACS employed a large staff to engage in collaborative programs, reaching a peak of 40 employees. The staff worked with researchers and industry personnel, promoting education and becoming experts in the technology. Half of the CRC's more than 100 postgraduate students were employed by industry or research organisations. There was also a focus on demonstrating the technology, with CRC-ACS striving to reduce the gap between new technology and its adoption by industry partners. CRC-ACS adopted limited royalty-free licensing of IP for major investors in 2010 while increasing SME engagement and commercial contracting through its new spin-out company – Advanced Composite Structures Australia Pty Ltd.



The major success of CRC-ACS was technology and expertise development in collaborative projects involving Hawker de Havilland, which became Boeing Aerostructures Australia (BAA) and secured a sole supplier contract for the Boeing 787 Dreamliner worth up to \$5 billion over 25 years.

The CRC was vital to Australia remaining as a significant supplier to major aircraft manufacturers, with technology developed inside CRC-ACS, allowing BAA to put forward innovative manufacturing and engineering approaches. These were central to helping it secure Tier 1 supplier status with Boeing, as well as a major package of advanced design and manufacturing work. International engagement was a significant feature of CRC-ACS. Their participation in EU Framework Program projects led to further significant work with Airbus and others.



CRC-ACS engaged with the international Oil & Gas (O&G) industry by developing novel repair technologies using composites. The development of a lightweight, corrosion-resistant customisable pipeline clamp for the O&G industry offers the potential of significant economic and environmental benefits through rapid, inexpensive installation and long-life performance.

The clamp is a highlight of the collaboration achieved through Australian and international universities and SMEs, and PETRONAS – Malaysia's national O&G company.

This novel composite clamp was awarded the prestigious JEC 2014 Innovation Award in the O&G category. With massive weight savings (one-sixth the weight of the equivalent steel clamp), the technology can save significant costs through minimising requirements for divers and support infrastructure. It combines fast customisation capability and is not subject to corrosion. PETRONAS licensed the technology for the deployment of the clamp locally and internationally.

CRC-ACS helped its partners make substantial contributions to the Australian economy. While the details of these remain confidential, one partnership alone is understood to have contributed more than \$1 billion to Australia's GDP. By the close of funding, CRC-ACS and its collaborators had received four international awards for composites as well as four CRC Association awards.

Source: CRC-ACS Exit Report, CRC Association

Manufacturing CRCs made up 18 per cent of the CRCs for which economic benefits were identified and made up 15 per cent of economic benefits. It is important to note that many of the most substantial economic benefits are imminent impacts, expected to mature in the years from 2021. For example, Innovative Manufacturing CRC reported significant collaborative impacts occurring in 2024-25 – an expected \$310 million in costs avoided and \$282 million in increased revenue.

Alignment of CRCs with National Manufacturing Priorities

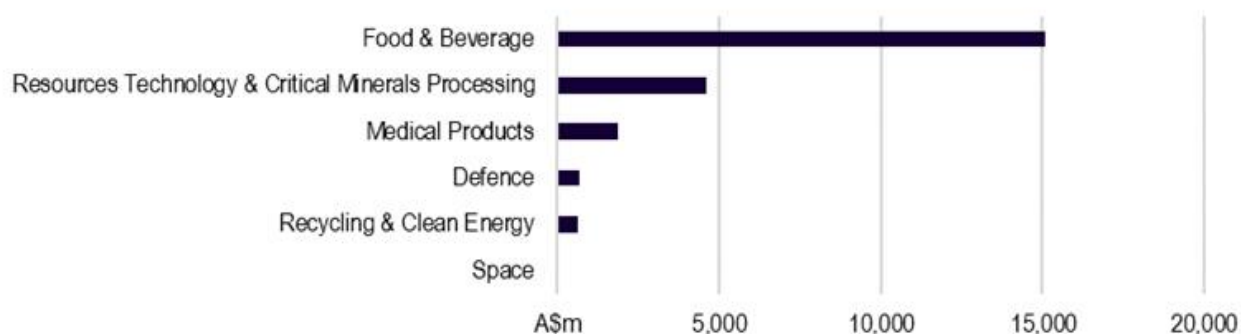
In October 2020, the Australian Government announced the National Manufacturing Priorities. These priorities are:

1. Resource Technology & Critical Minerals Processing
2. Food & Beverage
3. Medical Products
4. Recycling & Clean Energy
5. Defence
6. Space

These priorities are all represented in the CRCs. The priorities are a recent addition, and the degree to which they are represented throughout the CRC Program depends on how well they have been represented in the status quo.

Accordingly, Food and Beverage (through agricultural CRCs) and Resource Technology & Critical Minerals Processing (through mining and energy CRCs) are both very well represented in the economic impacts measured, with 65.7 per cent and 20.2 per cent of measured economic impacts, respectively. Space — still emerging within the CRCs — only represented 0.27 per cent of economic impacts identified (see Figure 3.7). Given the lag in economic impacts, the Food & Beverage-aligned economic impacts are anticipated to decline as other priorities grow.

Figure 3.7 CRC economic impact alignment with National Manufacturing Priorities



Note: Tier 4 preparedness impacts are not included in this analysis

Source: ACIL Allen

Mining and energy

The mining sector accounted for \$202 billion of Australia's GDP (10.4 per cent), making it the largest contributor to the Australian economy in 2019-20.⁹ It was identified that the CRCs would produce \$3.2 billion (2021 dollars) of direct economic impacts to the sector from 2009-10 to 2024-25. From 2012 to 2020, direct economic benefits of \$1.7 billion in 2021 dollars were identified. These benefits are shown in Figure 3.8. Mining and energy CRCs made up 14 per cent of the CRCs for which economic benefits were identified and made up 10 per cent of economic benefits.

The figure shows a large number of collaborative impacts from 2017-18 onwards. This is the result of the development of Deep Exploration Technologies CRC's coiled tubing drilling system, which was a significant collaborative effort involving drillers, driller assistants, technicians, scientists and engineers from various companies and institutions. The CRC reported that the drilling system is expected to generate impacts of over \$200 million per annum.

Box 3.3 Deep Exploration Technologies CRC — Revolutionising minerals exploration

The RoXplorer® is a revolutionary drill rig for minerals exploration that was developed by the Deep Exploration Technologies CRC (DET CRC, 2010-18). It utilises a continuous, malleable steel coil, removing the need to add individual drill rods as a drill hole deepens. This makes drilling faster, cheaper and safer. The technology is estimated to be one-sixth the cost of diamond drilling and a third of the cost of reverse circulation drilling. The RoXplorer®'s drill bit is driven by a motor within the drill string near the base of the hole as opposed to conventional rotation of the entire drill string by the drill rig at the surface.



The RoXplorer® rig is small and lightweight. It has a small drill pad, fluid recycling, and lower consumables (e.g. fuel). This means coiled tubing drilling has a lower environmental impact than conventional drilling methods.

The RoXplorer® coiled tubing drill rig, combined with DET CRC's other new technologies, will open up the almost three-quarters of Australia where mineral deposits are hidden by covering rocks, such as in the Gawler Craton and the Murray Basin, to 'prospecting drilling'. This will enable progressive vectoring towards concealed mineral deposits using multiple, cheap holes in a single drilling campaign.

⁹ ABS, 2021, *Australian National Accounts: National Income, Expenditure and Product*, available online at: <https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-national-income-expenditure-and-product/latest-release#data-download>

RoXplorer® is expected to lead to a significant increase in exploratory drilling in Australia each year. If this results in a 10 per cent improvement in productivity over conventional diamond drilling, the estimated benefits to the Australian economy will be \$38 million per annum.

DET CRC has identified the types of economic benefits from the coiled tube drilling system:

- Savings of \$140 million a year by replacing half of Australia's diamond drilling
- The potential to find over \$250 million in additional mineral discoveries per annum, and
- A 50 per cent reduction in workplace injuries.

These impacts will be further enhanced by DET CRC's contribution to improved knowledge of distal footprints, mineral deposits, economic benefits from the development of AutoSonde and AutoShuttle (which provide a real-time down-hole determination of rock properties), and Lab-at-Rig, which provides real-time top-of-hole geochemistry and mineralogy.

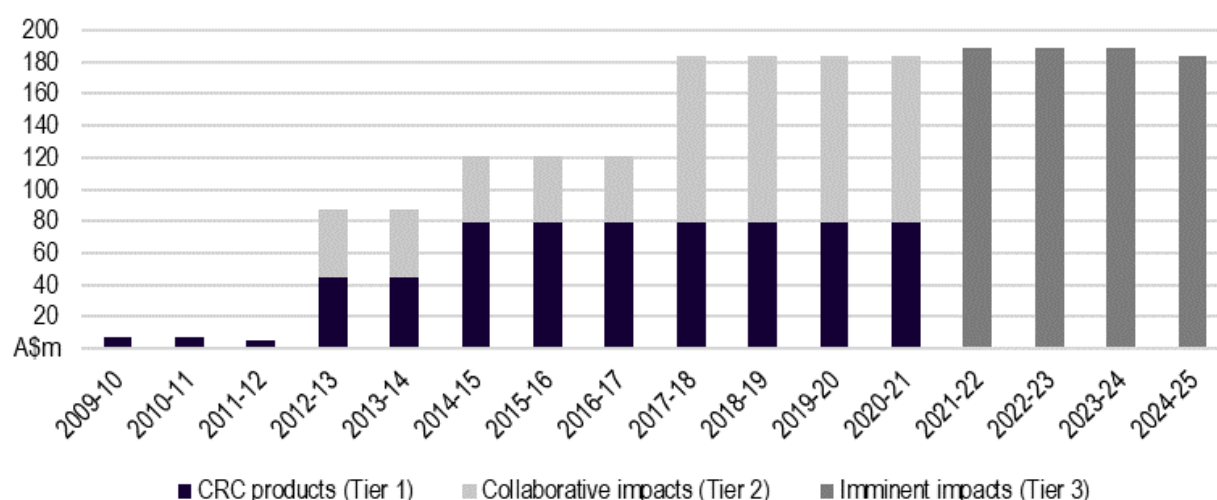
The DET CRC received \$28 million from the CRC Program, \$34 million in cash from industry and other end-users and an estimated \$93 million in-kind from its research providers, industry and other end-users. Commenting on DET CRC's contribution to minerals exploration, one explorer said:

The way industry has interacted, and CRC management / researchers have responded to industry priorities was a major highlight compared to historical industry-university interactions.
Tony Belperio, Minotaur Exploration

The RoXplorer® coiled tubing drilling system was the recipient of a CRC Association Excellence in Innovation Award in 2018.

Source: DET CRC, 2018, *Economic Impact Finance Snapshot*. Photo credit – DET CRC

Figure 3.8 Economic impacts, mining and energy sector (\$m, 2021 dollars)



Source: ACIL Allen

Box 3.4 Power Ledger — enabling electricity trading between renewable generators and users

Power Ledger is a spin-out company from the CRC for Low Carbon Living (2012-19). Power Ledger's technology enables efficient data capture and trade in renewable energy. The CRC's Dr Jemma Green's PhD research with the Centre was the catalyst for the launch of this successful international energy-sharing company. The Power Ledger platform uses real-time data from existing smart meters to enable electricity trading between buyer and seller using low-cost technology. Power Ledger hopes to make a big contribution to achieving the Paris climate goals.



Dr Green's research with the Centre used blockchain technology to monitor how residents in Perth could share and trade electricity from shared solar power and battery storage technology. Dr Green's research has disrupted the dominant way of thinking by advancing a shared ownership model of renewable energy assets between developers, owners, tenants, strata bodies and utilities. The model enables greater uptake of solar PV and energy storage within medium density housing establishments across Australia, reducing energy costs and carbon emissions.

In 2017 the Australian Government awarded the City of Fremantle an \$8 million Smart Cities and Suburbs Program grant to trial the use of blockchain-powered distributed energy and water systems. In partnership with Curtin University, Western Power and Synergy, Power Ledger's platform is being used at Gen Y Demonstration House at White Gum Valley. This residential development in Fremantle aims to provide sustainable and affordable housing attractive to young buyers.

Power Ledger now has clients in more than nine countries. The company has partnered with US-based Silicon Valley Power to encourage electric vehicle owners to charge their cars from solar during the day in return for carbon credits via blockchain.

In Japan, Power Ledger is being used by the country's privately-owned power utility, KEPCO, to support a Virtual Power Plant in Osaka. Power Ledger has also partnered with the Thai Government-backed renewable energy company BCPG.

In the USA, Power Ledger and Silicon Valley Power — the City of Santa Clara's Municipal Electric Utility — successfully completed a trial of a blockchain-based solution for measuring and monetising renewable electricity discharged to electric vehicles.

Following a successful trial with Power Ledger, American PowerNet (APN) is also considering a rollout of energy trading technology in the North American market. The APN trial was the first time Power Ledger's peer-to-peer energy trading platform was deployed in the largest US wholesale electricity market, the PJM Interconnection, which provides power to 65 million people across thirteen states and the District of Columbia. Using Power Ledger's blockchain-enabled xGrid platform, APN was able to trade solar power generated from the rooftop of its headquarters in Wyomissing, Pennsylvania, with two commercial neighbours across the grid. A total of 43 MWh of energy was traded on the platform, resulting in a 17 per cent renewable energy mix for the buying participants, who were able to access renewable energy at 5 per cent lower rates compared to grid rates.

Power Ledger won Richard Branson's Extreme Tech Challenge in 2018. The company also received a 2019 Excellence in Innovation Award from the CRC Association in recognition of its innovative energy sharing technology.

Source: CRC Association, 2019 Awards <http://www.lowcarbonlivingcrc.com.au/news/news-archive/2019/05/excellence-innovation-award-recognises-blockchain-research-and> ; Power Ledger viewed on 6 August 2021 at <https://www.powerledger.io/>; picture credits Power Ledger and Low carbon CRC

Medical science and technology

ACIL Allen identified \$2.6 billion (2021 dollars) of direct economic impacts in the medical sector from CRCs in the period 2009-10 to 2024-25. Health care makes up around 8.1 per cent of Australian GDP.

Box 3.5 Vision CRC — a flagship of the CRC Program

The Vision CRC (2003-15) and its predecessor, the CRC for Eye Research Technology (CRCERT, 1991-2002), provide one of the real success stories of the CRC Program. Collectively these CRCs have delivered measurable impacts across all objectives of the CRC Program. Through extensive collaboration, Vision CRC has transformed the innovation system within the eye health industry and the way it is delivered around the world. Through the activities and investment of Vision CRC, Australia is now positioned as a leader in the industry.

Vision CRC was responsible for one of Australia's innovation success stories, Silicone Hydrogel contact lenses. Commercialising technology developed by CRCERT and commercialised through Vision CRC; Silicone Hydrogel makes up 60 per cent of the world contact lens market. This product has brought more than US\$270 million in royalty income to Australia. The Vision CRC has advised that, without CRC Program support, this would not have been possible. Over the period 2010 to 2015, Vision CRC has developed new products and processes that have provided significant economic and social benefits, including:

Myopia control spectacles (MyoVision) — commercialised by Carl Zeiss Vision, Vision CRC's MyoVision spectacles have generated approximately US\$500,000 in royalties for its partners. The uptake of this Australian technology is resulting in significant economic benefit by slowing the progression of myopia.

A more comfortable contact lens — a high per cent of current users' experience dryness and discomfort, disrupting the preferred wearing schedule and causing premature lens removal or even total cessation of wear. Vision CRC piloted lens designs and an eye drop formulation which have been licensed to the Brien Holden Vision Institute for validation and commercialisation.



AIR OPTIX® AQUA multifocals — successful commercialisation of multifocal contact lenses. Vision CRC was involved in the development of this product, which is now the largest selling soft multifocal contact lens in the US. It is estimated that it will deliver around US\$6 billion in sales to Alcon (previously Ciba Vision) over 15 years.

The CRC's Models of Vision Care was an Aboriginal and Torres Strait Islander Community project focussed on improving systems, processes and ultimately eye care outcomes for people living in rural and remote Aboriginal communities and accessing primary health care through participating study sites (health services) in the Northern Territory and New South Wales. The CRC's Vision Centre Effectiveness Program developed and evaluated models of vision care that can be used throughout the world to alleviate avoidable vision impairment. It also worked to improve postgraduate education opportunities to create sustainable eye care services in developing countries.

One of the most striking features of the Vision CRC was its international engagement with both researchers and industry. Its Exit Report presents a long list of both Australian and international collaborators. To quote that report:

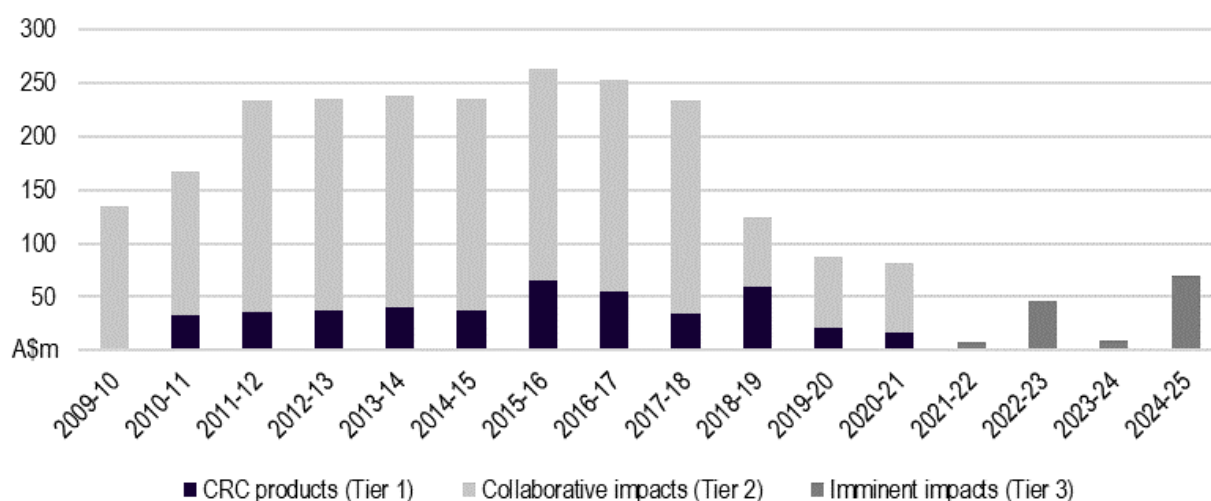
Vision CRC attributes much of its success to the collaborations forged through the CRC Program. The exceptional and prolonged partnerships are testament to the effective collaboration and management of research to deliver outputs and achieve substantial benefits.

Professor Brien Holden OAM, who led the Vision CRC, died in 2015. He and his colleagues have been the recipients of many awards. In 2013 Prof Holden was awarded the James Cook Medal from Royal Society of NSW for outstanding contributions to science and human welfare, and, in 2014, he received optometry's highest award for Research Excellence in Optometry, the Charles F Prentice Medal. The work of the Vision CRC continues through the Brien Holden Vision Institute and Foundation.

Source: Vision CRC; picture credit Vision CRC

From 2012 to 2020, direct economic benefits of \$2.1 billion in 2021 dollars were identified. These benefits are shown in Figure 3.9. Economic benefits from medical research CRCs make up 8 per cent of benefits, despite making up 18 per cent of CRCs for which benefits were identified. Many of the economic benefits were collaborative (52 per cent), with relatively few imminent impacts. This partly reflects that many of the most successful medical science and technology CRCs ended or transitioned out of the Program early in the review period.

Figure 3.9 Economic impacts, medical science and technology sector (\$m, 2021 dollars)



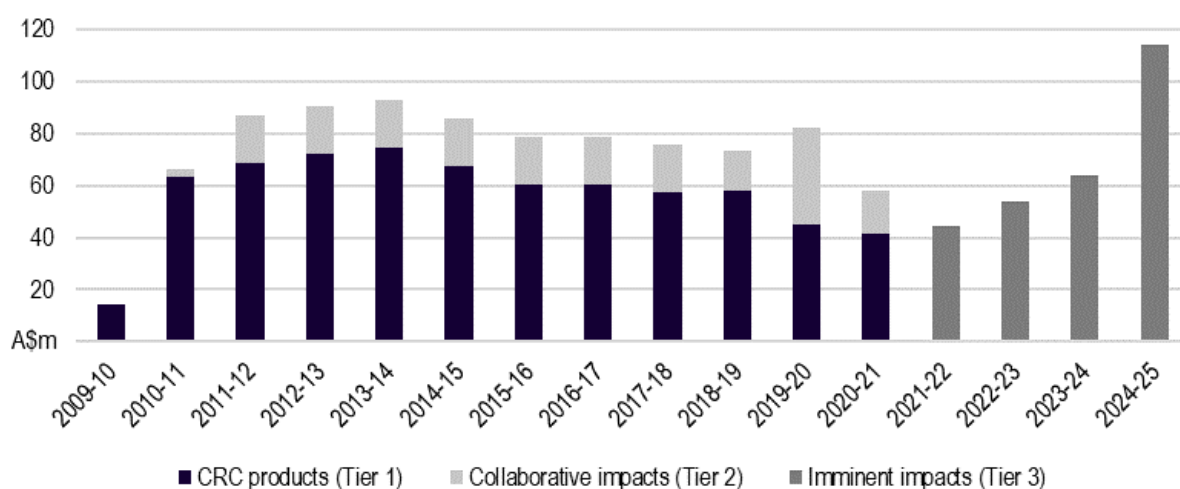
Source: ACIL Allen

ICT and environment sectors

The direct impacts in the ICT and environment sectors were less than those in the other sectors described above. Nevertheless, the CRCs resulted in \$3.3 billion (2021 dollars) in the ICT and environment sectors combined from 2009-10 to 2024-25.

From 2012 to 2020, direct economic benefits of \$1.9 billion (2021 dollars) in the ICT sector and the environment sector combined — as shown in Figure 3.10 and Figure 3.11. These two sectors together accounted for 21 per cent of the CRCs for which economic benefits were identified and made up 10 per cent of economic benefits.

Figure 3.10 Economic impacts, ICT sector (\$m, 2021 dollars)



Source: ACIL Allen

Box 3.6 Capital Markets SMARTS software — ensuring fairer stock market trading

Capital Markets CRC (2001-19) developed SMARTS, a real-time surveillance software that services regulators, exchanges and brokers of capital markets. In Europe, this surveillance solution has helped to reduce instances of insider trading by 26 per cent. SMARTS has been adopted by more than 40 national exchanges and regulators and 150 brokers across 50 countries. SMARTS was subsequently sold to NASDAQ, with a significant proportion of the proceeds used to fund a venture firm now funding technology start-ups and research scholarships in Australia. Global stock markets are fairer and more efficient as a result of the work of the Capital Markets CRC.



SMARTS surveillance software provides a good example of how CRC research can be successfully commercialised. ASX Data had two questions: ‘Is it possible to replay a trading market from historical data?’ and ‘Can this be used to monitor a market for illegal trading practices?’ The Capital Markets CRC established a research project to gather historical trading data from ASX Data. The CRC’s PhD Researchers applied all rules governing market trading to reconstruct the full order book and created rules/algorithms to identify illegal trading practices. The SMARTS technology was built to create meaningful alerts that analyse complexities in trading across asset classes and trading venues – automating the detection, investigation and analysis of potentially abusive or disorderly trading.

Key aspects of SMARTS include that it:

- Enables compliance teams at sell-side firms to take a multifaceted approach to surveillance
- Provides a combination of traditional alerts-based monitoring and risk-based discovery
- Establishes an industry benchmark for real-time and T+1 cross-market surveillance
- Has a library of 210 pre-configured detection algorithms, and
- Offers risk-based discovery approach providing deep information on an individual’s behaviours in the context of market conditions, peer groups and individual’s own norms.

The SMARTS technology was spun out into its own company and subsequently sold to NASDAQ for approximately \$100 million.

An article in the Australian Financial Review of 8 June 2016, headlined “NASDAQ extends market surveillance technology based on CMCRC’S SMARTS” reported:

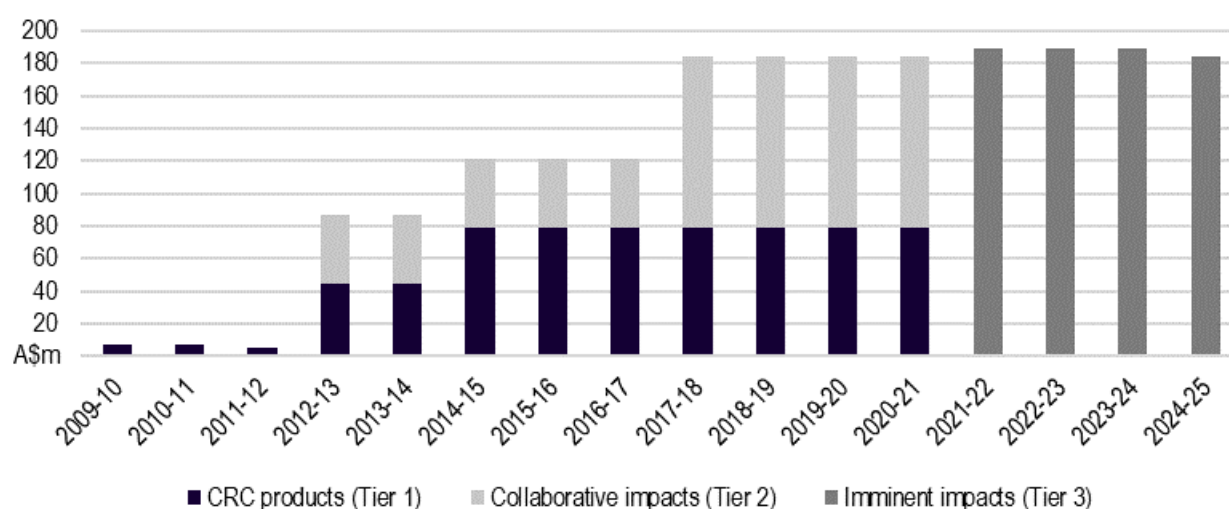
Nasdaq Inc says CMCRC’s Australian surveillance technology, SMARTS remains the foundation to identify manipulation and insider trading in markets. The Australian Financial Review, reports Nasdaq Chief executive Bob Greifeld, who lives in New Jersey and has run the global exchange business since 2003, described SMARTS as a deal that went “phenomenally well. Nasdaq aims to roll out “machine learned” market surveillance using SMARTS as its foundation technology in two years to detect suspicious trading patterns.

Professor Michael Aitken, the founding CEO of the Capital Markets CRC, was awarded the 2016 Prime Minister's Prize for Innovation for creating and commercialising tools that are making markets fair and efficient.

Following completion of its CRC funding, the Capital Markets CRC became the Rozetta Institute, another example of research collaboration extending beyond the end of the life of the CRC.

Source: Prime Minister's Innovation Prize 2016, accessed on 8 August 2021 at <https://www.industry.gov.au/sites/default/files/2018-10/2016-pm-prize-for-innovation-michael-aitken.pdf>, Rozetta Institute, accessed on 8 August 2021 at <https://www.rozetta.com.au/institute/our-work/> Photo credit Reuters/Shannon Stapleton

Figure 3.11 Economic impacts, environment sector (\$m, 2021 dollars)



Source: ACIL Allen

3.3.3 Economic benefits of education and training

The CRCs have a strong track record of educating and training postgraduate students. Each CRC will train numerous Masters' or PhD students in the course of undertaking their mission. Crucially, the CRCs expose postgraduate students to industry-focused research — potentially cementing a career of research that will benefit the industry and the wider economy. Between 2010-11 and 2017-18¹⁰, approximately 2,615 doctorate and Masters' degrees — by research — were awarded to students with the support of a CRC.

The 2012 Allen Consulting Group report estimated an output premium of around \$43,500 per annum per research postgraduate in Australia (in 2021 dollars). The cumulative value of education outcomes achieved under the Program between 2010 and 2017 is \$113.7 million in total. Figure 3.12 shows how this has been distributed across the sectors over time. Further discussion on the skill formation and social benefits of the CRCs' education and training programs is discussed in section 4.2.

¹⁰ The data collection method of the MDQ survey changed from 2018-19. This section only describes postgraduate figures up to 2017-18, for consistent comparison to the 2012 Allen Consulting review.

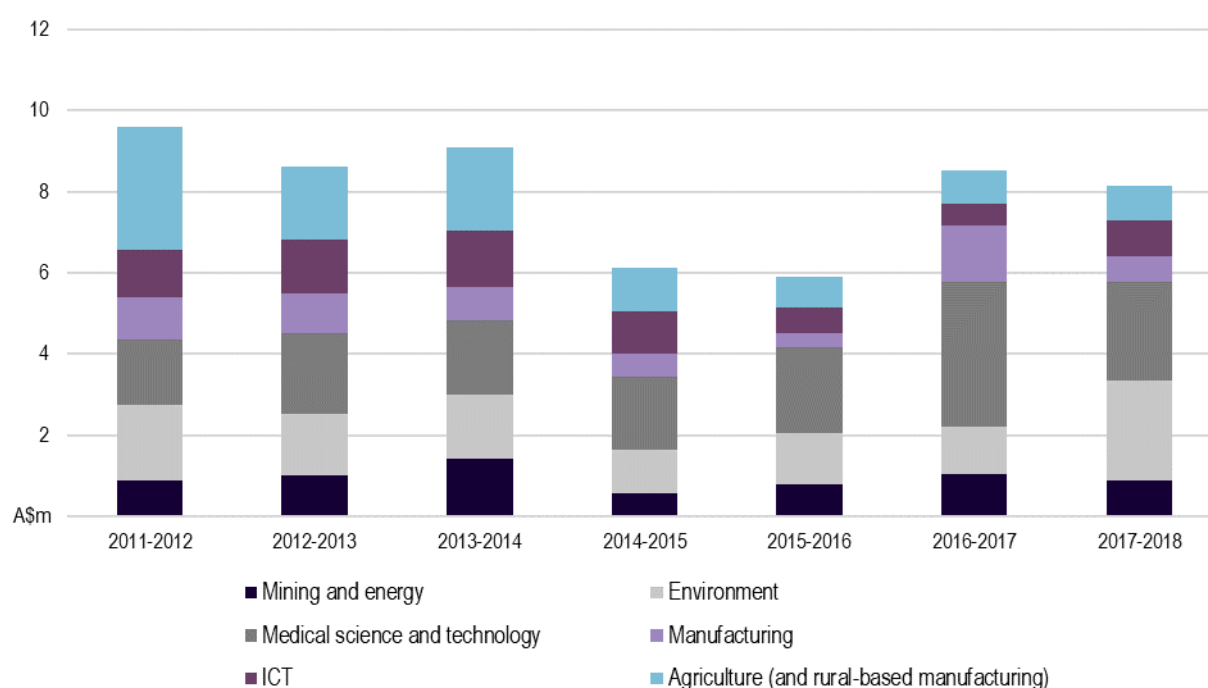
3.4 Total economic impact

The total economic impact of the CRCs extends beyond the direct impacts, as noted in section 3.1. Economy-wide impacts include increased investment in research, capital, human capital, spending, jobs, imports and exports. The economic impacts of CRCs are ultimately measured in improvements to the gross domestic product.

3.4.1 Modelling the total economic impact

The method used to analyse the GDP contribution of the CRCs is computable general equilibrium (CGE) modelling. ACIL Allen's CGE model, Tasman Global, calculates impacts on prices, production, consumption and investment across different industries when resources are directed into alternative uses (see Appendix D). For a program to be considered successful at the economy-wide level, it must cause real GDP and income to rise.

Figure 3.12 Value of CRC supported education outcomes (2021 dollars)



Source: ACIL Allen

Building a counterfactual

A key challenge for this study has been the counterfactual — a comparison between what actually happened to the research sector in Australia and what would have happened in the absence of Australian Government funding to CRCs. The economic modelling conducted in this study estimated benefits under two scenarios: 'with the CRCs' and 'without CRCs'. In the 'without CRCs' scenario, it was assumed that other than the Australian Government CRC funding, all the cash and in-kind resources allocated to the CRC activities would have been allocated by the funding providers to some alternative R&D activities.

Comparison of the ‘with CRCs’ scenario to the ‘without CRCs counterfactual’ allows the net effect of the Australian Government funding for CRCs on Australian economic performance to be estimated. If the Government had not funded CRCs, it is assumed that the grant funding would have been allocated across other Government expenditures (potentially having positive impacts elsewhere). This approach is similar to the Allen Consulting Group 2005 and 2012 evaluation of the CRC Program.

An alternative counterfactual assumption could be that taxes could have been lowered by the amount of CRC funding. This assumption was used in the 2006 Insight Economics evaluation of the CRC Program. However, given the scale of CRC funding in the overall Australian Government budget, it is more likely that the funds would have just been differently allocated out of consolidated government revenue.

The key finding from this modelling is that, as a result of the provision of Australian Government funding for CRCs, over the 1992 to 2025 period, the Australian economy’s overall performance has been enhanced when compared to the performance that would have occurred in the absence of funding to the CRCs, specifically, over the 1992 to 2025 period.¹¹

3.4.2 Total economic output between 2005 and 2025

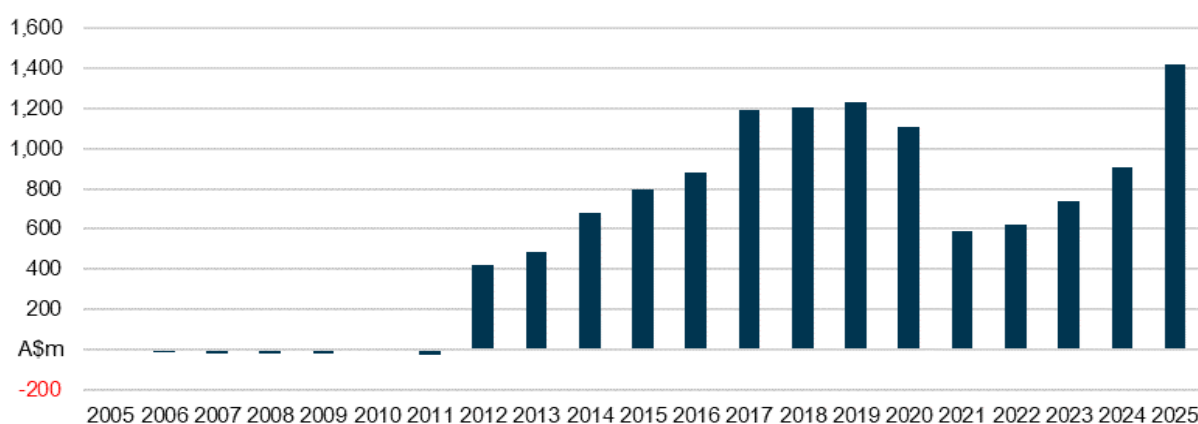
Figure 3.13 shows the impacts of CRCs on the real economic output of Australia. This has been measured as the change between actual economic outcomes compared with a model of the economy where the CRC impacts have been removed (the counterfactual or Reference Case). While our focus here is on the outcomes in the period 2012-20, the modelling needs to take into account some of the funding prior to 2012, which contributed to outcomes during 2012-20. The analysis extends to 2025 because Australian Government funding is committed to existing CRCs up to 2025.

The key finding from this modelling is that, as a result of the provision of \$1.5 billion in nominal dollars (and \$1.7 billion in 2021 dollars) of Australian Government funding for the CRCs reporting benefits in this study, over the 2012 to 2025 period, the Australian economy’s overall performance has been enhanced when compared to the performance that would have occurred in the absence of the CRCs grants to these CRCs.

The peak (and subsequent dip) in economic activity is a result of the changing number and intensity of CRC activities over time. A large number of CRCs completed their work the early 2010s, with a number of their economic impacts accrued towards the end of that period. Further, new CRC grants were suspended in 2015 for the Miles review and then slowly restarted. The first round of CRC grants after the Miles Review (2017) was a relatively small round and had relatively fewer partner contributions. These impacts throughout the 2010s left a tail of economic impacts until the early 2020s.

Real GDP (total economic output) cumulatively between 2005 and 2025 (in 2021 dollars) is \$12.2 billion higher than would occur if the funding of CRCs had instead been used for general government expenditure (which would have itself contributed to GDP, but lower levels).

¹¹ The modelling scenario is run out to 2025 as some of the benefits that have already commenced from the CRCs are possibly going to continue to be accrued out to at least 2025 (imminent or Tier 3 benefits).

Figure 3.13 Real economic output relative to the Reference Case, 2005–25 (2021 dollars)

Source: ACIL Allen

Table 3.2 summarises the estimated cumulative change in the real economic output of the CRCs under various net present value discount rates. This also compares with the Australian Government funding to CRCs. Based on the economic modelling, the CRCs reported benefits to outweigh the costs to the Australian Government. Table 3.2 presents 5, 7 and 10 per cent discount rates to show the sensitivity of the results to this variable. A seven per cent discount rate is commonly used in analyses of government policy, for instance, in the Australian Government Office of Best Practice Regulation guide to cost-benefit analysis.

Table 3.2 Cumulative total increase in real economic output from Australian Government CRC funding 2005–25

	Total 2005- 2025	Annual average	At 5% discount rate	At 7% discount rate	At 10% discount rate
	\$m	\$m	\$m	\$m	\$m
GDP	12,189	359	12,712	13,308	14,348
Australian Government funding to the CRCs who reported benefits	1,714	50	2,070	2,374	2,951
Ratio of increase in GDP to govt funding	7.11	7.11	6.14	5.61	4.86

Note: All dollars in 2021 prices. Non-government partner contributions include contributions by the private sector and other research institutes. Discount rates of 5% and 10% are used to show sensitivity to this rate.

Source: ACIL Allen

Based on the economic modelling, the CRCs reported net economy-wide benefits outweigh the costs to the Australian Government between 2005 and 2025.

- In 2021 dollars, the Australian Government funding to the CRCs, which reported benefits, totals \$1.7 billion in 2021 prices (\$2.4 billion at a 7 per cent discount rate).
- The cumulative net impact of those CRCs on GDP is \$12.2 billion (\$13.3 billion at a 7 per cent discount rate).
- It is estimated that for every \$1 spent by the Australian Government on the CRCs which reported benefits between 2012 and 2025 (from Australian Government funding received since 2005), GDP is cumulatively \$5.61 higher than it would have been had that \$1 instead been allocated to general government expenditure.

The 2012 Allen Consulting Group Review found that the CRCs had a net benefit ratio of 3.1 to 1. The analysis in this review is now 5.61 to 1, indicating that the CRCs are generating more GDP for every dollar of Australian Government spending. There are several possible reasons for this:

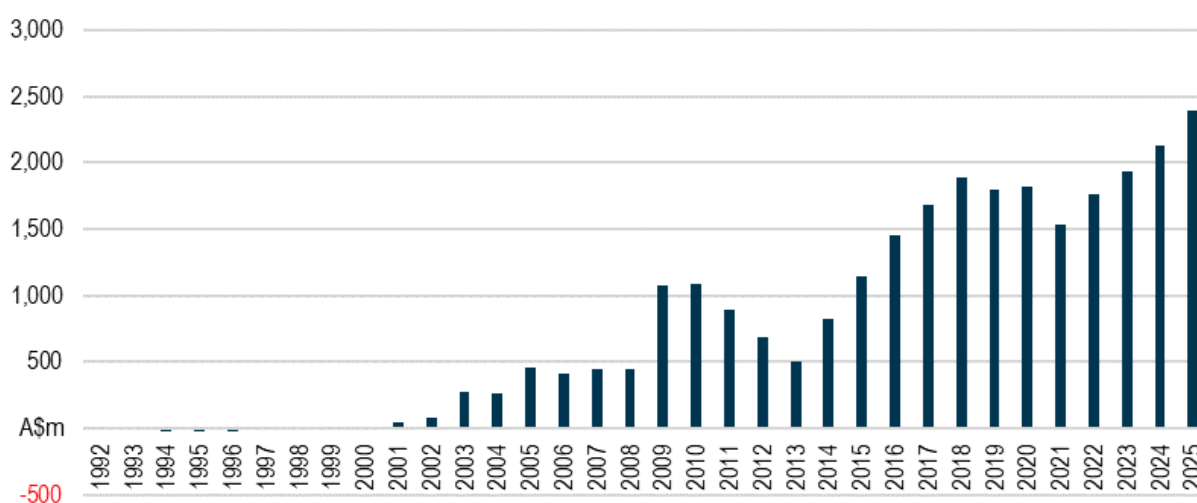
- After the Miles Review, CRCs which focused on economic outcomes were prioritised, increasing the economic benefits relative to government spending, and
- The current review period included significantly more spending per year, early in the period. This means relatively more benefits were generated early in the period, increasing the value in real terms.

3.4.3 Total economic output between 1992 and 2025

This evaluation has also calculated the total economic output of the CRCs from the beginning of the Program in 1991. Figure 3.14 shows the impacts of the CRCs on the real economic output of Australia. This has been measured as the change between the actual economic history (with all funded programs) compared to a model of the economy where the funded programs and the impacts were removed (the counterfactual or Reference Case).

Real Gross Domestic Product (total economic output or GDP) cumulatively between 1992 and 2025 (in 2021 dollars) is \$26.9 billion higher than would occur had the money spent on CRCs instead gone to general government expenditure.

Figure 3.14 Real economic output relative to the Reference Case, 1992–2025 (2021 dollars)



Source: ACIL Allen

Table 3.3 summarises the estimated cumulative change in the real economic output of the CRCs under various net present value discount rates. This also compares with the Australian Government funding to CRCs. Based on the economic modelling, the CRCs reported benefits outweigh the costs to the Australian Government.

Table 3.3 Cumulative total change relative to a baseline in real economic output and Australian Government funding to CRCs, 1992–2025

	Total 1992-2025	Annual average	At 5% discount rate	At 7% discount rate	At 10% discount rate
	\$m	\$m	\$m	\$m	\$m
GDP	\$26,910	\$791	\$29,654	\$32,524	\$38,072
Australian Government total funding to the CRCs	\$6,405	\$202	\$9,166	\$12,467	\$20,334
Ratio of increase in GDP to govt funding	4.20	3.92	3.24	2.61	1.87

Note: All dollars in 2021 prices. Non-government partner contributions include contributions by the private sector and other research institutes. Discount rates of 5% and 10% are used to show sensitivity to this rate.

Source: ACIL Allen

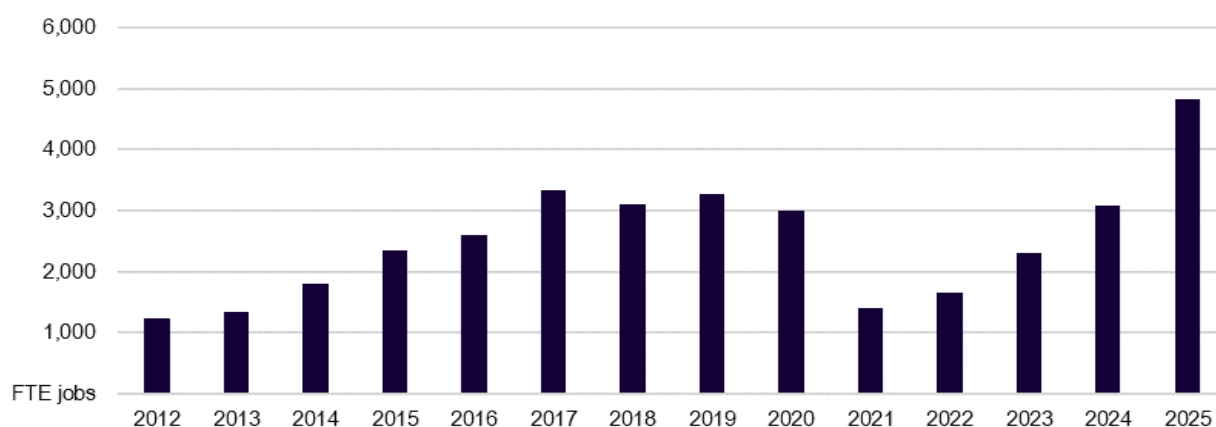
Based on the economic modelling, the CRCs reported net economy-wide benefits outweigh the costs to the Australian Government between 1992 and 2025.

- In 2021 dollars, the Australian Government funding to the CRCs totals \$6,405 million in 2021 prices (\$12.5 billion at a 7 per cent discount rate).
- The cumulative net impact of Australian Government investment in CRCs on GDP is \$26.9 billion (\$32.5 billion at a 7 per cent discount rate).
- It is estimated that for every \$1 spent by the Australian Government on the CRCs between 1992 and 2025, GDP is cumulatively \$2.61 higher than it would have been had that \$1 instead been allocated to general government expenditure.

The lower ratio over the whole period is a result of the discounting rate used. Higher discount rates increase the real value of early investments relative to later received benefits. At a seven per cent discount rate, early CRC funding is larger in real terms, which negatively affect the benefit ratio.

3.4.4 Impacts on jobs

CRCs are a net job creator. Early on, the diversion of funding and resources has a net cost to the economy. However, as CRCs combine capital with human ingenuity, they start to produce economic, social and environmental impacts. Over time, these create more and more employment. Over the period from 2012 to 2020, the CRCs are estimated to have created 22,007 FTE-years. This is an average of 2,445 jobs in each year of the Program (see Figure 3.15). As with the economic impact, the peak of CRCs active in the early 2010s, followed by a pause in new CRC grants during the Miles Review period partly created the dip in economic activity and jobs in the early 2020s.

Figure 3.15 Full-time employment creation attributable to the CRCs

Source: ACIL Allen

3.5 Additionality

A key question in assessing the impact of CRC funding is how the funding elicited private investment that would not otherwise have been made – additionality. This additionality can generate total private and spill-over returns that are still sufficiently positive to exceed the Australian Government CRC funding costs. The CRC funding costs include:

- the marginal excess burden of taxation required to fund the CRCs by the Australian Government
- the utilisation of resources on administration and compliance of CRCs by the Australian Government and the CRC funding recipients
- consequences of selecting non-strategically important CRCs

Additionality on the investment side is critical to the issue of CRC impact evaluation since the R&D can potentially produce economic, social or environmental impacts. The additionality issue stems from the fact that Australian Government support to CRCs may, directly or indirectly, substitute for R&D that would otherwise be financed by others (crowding out). Additionality is important because beneficial impacts can only be generated by truly additional R&D, while the taxation distortions imposed by financing the transfers still produce costs.

Box 3.7 Additionality

Additionality has been defined in several ways. At one level, additionality has been referred to the extent to which R&D eligible for at least partial public support is truly additional. At a higher level, additionality as 'leverage', measured as the ratio of the change in privately funded R&D to the subsidy level (α in equation 2 below). Leverage is positive if a subsidy, say CRC funding, induces complementary private R&D ('crowding in'), minus 1, if there is complete crowding out, and between -1 and 0 if there is partial crowding out. Another definition of additionality is the ratio of total new R&D stimulated by a CRC to its subsidy cost. This is $(1+\alpha)$ in equation 3.

$$CRC\ impact = CRC\ funding\ (1 + \vartheta) + \Delta\ private\ R\&D\ (1 + r) \quad (1)$$

ϑ is spillover rate from public R&D

r is spillover rate from private R&D

We can represent the change in private R&D as a constant fraction of supported R&D.

$\Delta\ private\ R\&D = \alpha\ CRC\ funding$ and ϑ as an excess return, $\vartheta = r + \rho$

Where ρ is the premium rate of return, re-writing equation 1 is:

$$\begin{aligned} CRC\ impact &= CRC\ funding\ \{(1 + \vartheta)\ (1 + \alpha) + \rho\} \\ &= CRC\ funding\ \{(1 + \vartheta)\ additionality + \rho\} \end{aligned} \quad (2)$$

Where additionality:

$$\begin{aligned} Additionality &= (1 + \alpha) \\ &= \frac{CRC\ funding + \Delta\ private\ R\&D}{CRC\ funding} \\ &= \frac{Net\ new\ R\&D}{CRC\ funding} \end{aligned} \quad (3)$$

Source: Based on Productivity Commission 2007

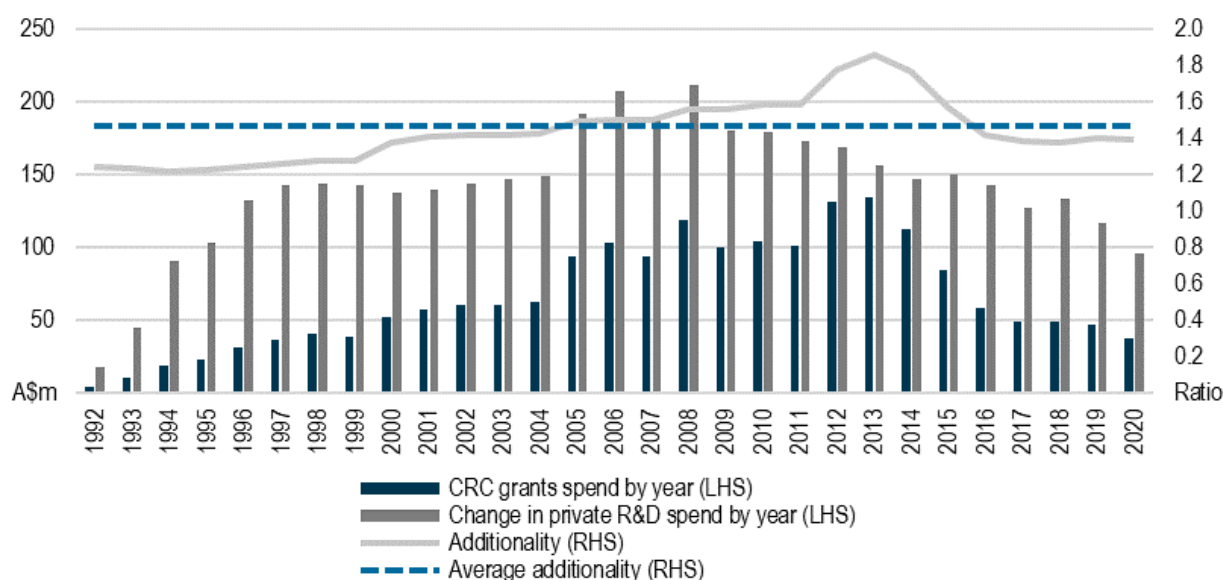
For this study, it has been important to assess which partner contributions are truly additional and provide economies of scale benefits the CRCs, while crowding-in and not crowding-out other R&D investments. Based on the data provided by CRCs, it is difficult to quantify what is truly additional in the case of CRCs — partners do not record what funding they would have spent without the CRCs. Therefore, it has been assumed that around 50 per cent of the industry and private sector contributions may have been truly additional. This is the same assumption used in the 2012 Allen Consulting review. This is still positive and provides crowd-in (complementary) rather than crowd-out industry and private sector investments.

The estimated annual additionality — the ratio of total new R&D stimulated by the Australian Government's CRC funding — is provided in Figure 3.16.

Over 29 years, CRC funding has induced around \$2 billion of new private R&D than otherwise would have been not invested somewhere in the economy. The estimated average additionality of funding the CRCs is 1.47. Then the estimated 'bang for buck' is about 47 per cent, crowding out would be 53 cents in the dollar.

When government funding of one dollar to CRC causes an increase in business-funded R&D by 47 cents (complementary), the effect is called crowding-in. Considering a marginal excess burden of corporate taxation of around 50 cents on the dollar,¹² the spill-over rate required to achieve a net social benefit from the CRC funding is anything greater than 27 per cent (a relatively low rate). This means that the crowding-in from CRC funding is resulting in a net social benefit. As noted by the Productivity Commission in 2007,¹³ the lower the crowding out, the better, but some crowding out *per se* is not that damaging to R&D policy, particular for the CRC Program.

Figure 3.16 Estimated CRCs scale benefits, 1992-2020 (\$m)



Source: ACIL Allen estimates based on the DISER data

3.6 Preparedness impacts

Some CRC outputs relate to preparedness. These are outputs that seek to ensure that risks are mitigated or avoided. In some cases, these outputs provide forewarning of impending events with significant economic and social costs. Such events may be dependent on particular circumstances or combinations of circumstances. The timing of such avoided costs, if they occur at all, cannot be predicted with certainty. These impacts are discussed as preparedness impacts.

Preparedness impacts from some CRCs which continued to operate in the period 2012-20 include:

- Rail Manufacturing CRC, whose work on safety and security could avert a major transport disaster, and
- Bushfire and Natural Hazards CRC, where this CRC has contributed to a reduction in loss of life, property losses and other fire-related costs which cannot be predicted or monetised.

¹² Treasury 2015, Understanding the economy-wide efficiency and incidence of major Australian taxes. Treasury Working Paper 2015-01. <https://treasury.gov.au/sites/default/files/2019-03/TWP2015-01.pdf>

¹³ Productivity Commission 2007, Public Support for Science and Innovation, Productivity Commission Research Report. <https://www.pc.gov.au/inquiries/completed/science>

As in the 2012 Allen Consulting report, in this impact evaluation, we are providing examples that have not been previously reported. Other examples can be found in section 4.1, where, for example, the impact of the development of some vaccines and other medical treatments may depend on the arrival of a human or animal virus in Australia. Preparedness impacts are best examined through examples. It is not possible to incorporate them in CGE modelling.

The Space Environment Management CRC has undertaken valuable research in understanding space debris. Space debris is any human-made object in orbit that does not serve a purpose. It includes retired satellites, spent rocket bodies and fragments of satellites resulting from collisions and break up events. It is estimated that 500,000 marble-sized pieces are orbiting the earth, as well as 30,000 pieces the size of a softball or larger. Space debris moves at a high velocity, so its potential to do damage on impact with valuable space assets is considerable. For example, the International Space Station has to manoeuvre away from a possible space debris collision 1 to 3 times per year.

The mounting risk of collisions between satellites and space debris threatens individual spacecraft and, ultimately, the viability of the entire space environment. Although this is a global problem, Australia is a world leader in optical space tracking, which has emerged as a key technology for protecting satellites. Australian infrastructure and debris data now offer the most expeditious route for research, development and feasibility testing of diverse global efforts to protect satellites from debris. The Space Environment Management CRC's work is helping to protect assets worth many billions of dollars.

The Data to Decisions (D2D) CRC's vision was to be a leading provider of capability, resulting in a safer and more secure nation and a sustainable big data workforce for Australia. The CRC's spin-off company, Fivecast, has developed software called Insight that can monitor images, text and video, identifying key terms, phrases, quotes and objects. It provides public and private organisations worldwide with the capability to explore masses of digital data, gaining insights that are critical in protecting our communities. It utilises leading-edge AI-enabled technology with the ability to solve the most complex intelligence challenges.

Developed with the CRC's spin-out company, Insight is a world-first data collection and analysis platform that provides threat analytics for law enforcement and national security. D2D CRC received a CRC Association award in 2019 for this development. Austrade reports:

Fivecast is a scaleup Australian technology company that is winning contracts at the heart of America's huge defence and national security community. Fivecast has gained strategic new clients in the US less than two years after setting up in Washington.

Austrade, accessed on 14 August 2021 at <https://www.austrade.gov.au/news/success-stories/new-defence-innovation-agency-helps-adelaide-ai-spinoff-enter-us-market>

Putting a preparedness value on Insight is not possible. But just avoiding one major terrorist incident would likely be worth millions of dollars.

CRC Mining has undertaken valuable work in exploring the use of fibre optic sensing technology to revolutionise the way mines are monitored and controlled. Costly surveys and conventional measurement systems, unpredicted incidents, lack of data for decision making, and late diagnostics of hazards and faults are issues that mining operations (particularly coal mining) are currently facing. The optical fibre technology offers an intrinsically safe, rapid, reliable, accurate and cheaper method of sensing and monitoring.

CRC Mining has undertaken investigations into fibre optic sensing technology to identify the potential high-value mining applications and assess at a high level the technology gap for each application. The CRC has demonstrated the benefits of remote sensing through a passive optical fibre without the need for power distribution or discrete sensors. A collaborative CRC and University of Queensland research team developed fibre-optic based gas sensors with financial support from the Australia Coal Association Research Program.

The presence of methane gas in underground coal mines poses many challenges for the mineworkers and companies, including health and safety and impact on the greenhouse. Optical fibre technology provides a means of fast, remote sensing without the requirement for electrical equipment in the mine. The future global benefits of this technology, in terms of mine fires and deaths-avoided is very large but difficult to value.

The CRC for Advanced Automotive Technology has undertaken research in safety and intelligent vehicle systems, aiming to improve vehicle safety and reduce crash frequencies through new and intelligent vehicle product systems. These improvements will make onboard systems easier to use, increase comfort and performance and reduce driver distraction. Collectively they increase customer satisfaction and reduce the social and economic costs associated with road accidents. Highlights of this theme's research program have included:

- More effective crash avoidance systems using sensor fusion of optical systems, including speed sign recognition technology
- Better strategies and systems to enhance driver awareness and reduce distraction, including voice command technology
- Road traffic flow prediction technology, enabled by advanced modelling algorithms
- Establishment of a self-sustaining industry group to standardise wireless communication between vehicles and infrastructure operators
- New lightweight, highly-fuel efficient vehicle designs to improve occupant safety in crashes
- Developing collision avoidance strategies using wireless communications for improved rail level crossing safety
- Improved vehicle security systems using speaker authentication algorithms embedded within a vehicle's computing systems
- Establishment of a human factors research laboratory initially targeting automotive user ergonomics and comfort, with broader cross-industry application

The results of this work are flowing through to motor vehicles sold in Australia and around the world. But like all safety improvements, it is difficult to predict impact and value by the year in which impact is likely to occur. In 2015, the Australian Automobile Association commissioned Economic Connections (ECON) to quantify the cost that the Australian community incurs each year as a result of road crashes. The cost of road trauma was more than \$22 billion per annum. Thus, any reduction results from the work of this CRC could have a significant value even though it is not possible to include an estimate in this evaluation.

3.7 Government impacts

In addition, to sectoral impacts, CRCs also have impacts on government. Some examples identified in this evaluation include:

- Reduced health system costs as a result of CRC discoveries
- Increases tax revenues from successful CRC-involved companies and their employees
- Help for government agencies facing cyber security threats
- Benefits to urban and local government areas from the CRCs such as the CRC for Water Sensitive Cities
- Benefits from the application of CRC outputs to rail transport services

Quantifying these impacts is not generally possible, but they are potentially large.

4 Social impacts of CRCs

This Chapter sets out the social impacts of the CRCs in parallel to the economic effects. It provides several case studies of CRCs which have positively affected social outcomes.

Social impacts flowing from CRC research are identified below. They have been grouped under the following categories:

- Health
- Education and training
- Labour force participation
- Business development
- Safety and security, and
- Costs avoided.

However, the CRCs discussed in this Chapter have delivered economic benefits and have also delivered meaningful social impacts. Unfortunately, these are generally difficult to quantify because they mostly occur after the CRC's funding has ceased, are difficult to predict and are contingent on factors that are difficult to assess.

4.1 Health

In the period 2012-20, there have been around fifteen CRCs that have focussed on health and medical outcomes. Some of these have resulted in the commercialisation of new products and services. Many have resulted in cost savings to Australia's health system. Major examples are listed in Table 4.1. Five case studies are presented in Boxes.

Table 4.1 CRCs providing health and medical outcomes.

CRC	Activity	Outcome
Digital Health CRC	Digital health innovation and commercialisation	Improvements in health and healthcare
The Lowitja Institute Aboriginal and Torres Strait Islander Health CRC	Enhanced health outcomes for Aboriginal and Torres Strait Islander people	Reduced incidence of disease, improved education outcome for children, increased QALYs and DALYs
CRC for Cancer Therapeutics	Development of new treatments for a range of cancers. Improved treatment for children with cancer	Discovery and development of clinical drug candidates to target cancer cells. Increased QALYs and DALYs for patients treated with these new drugs (see Box 4.1).
The Hearing CRC	Development of new technologies such as electrodes for cochlear implants	Increase in QALYs for persons with impaired hearing

CRC	Activity	Outcome
CRC for Cell Therapy Manufacturing	Improved affordability and accessibility of cell therapies in Australia	Increase in QALYs for patients that receive cell therapy treatment
CRC for Living with Autism	Improved lifetime for individuals with Autism and improved family support	Improved education outcome for children with Autism and a more normal life for them
CRC for Mental Health	Identification of biomarkers for early treatment of neurodegenerative disorders and psychoses	Early identification of these disorders can result in more successful treatment
Vision CRC	Development and commercialisation of soft contact lenses and spectacles to slow the progress of myopia	Innovative solutions for common eye conditions resulting in increased QALYs (see Box 3.5).
Wound Management Innovation CRC	Strategies and interventions to treat wounds more successfully and reduce the incidence of wounds in aged care	Improved wound care and healing resulting in increased QALYs and DALYs
Oral Health CRC	Development and commercialisation of a product to strengthen tooth enamel	Reductions in oral disease, with improved QALYs (see Box 4.2).
CRC for Asthma and Airways	Discovery and development of therapeutic and diagnostic products for asthmatics	Increase in QALYs and DALYs for asthmatics and reduction in healthcare costs
CRC for Biomedical Imaging Development	Develop novel radiopharmaceuticals and better detection equipment	Improved diagnostics, leading to better treatment of medical conditions with increased QALYs and DALYs

Source: ACIL Allen

The health-related CRCs listed in Table 4.1 tend to involve:

- multidisciplinary teams
- expertise drawn from across Australia
- international linkages, and
- addressing major health issues.

For example, the long-term impacts of the Wound Management CRC's research, educational and translation outputs include:

- A substantial contribution to the molecular and biochemical understanding of wound biology, including characterising the metabolome, proteome and microbiome of healing and non-healing wounds, will further underpin research, potentially leading to new diagnostic and therapeutics beyond the CRC
- A passionate and skilled group of next-generation wound researchers graduating from the CRC's student program
- Risk assessment tools for venous leg ulcers, surgical wound dehiscence and skin tears
- Improved wound prevention strategies, reduced care costs and improved quality-of-life including skin and pressure injury prevention in residential aged care facilities, pressure injury prevention in Intensive Care Units, burn first-aid and venous leg ulcer recurrence

- Health economic research and up to date data on wound care costs providing the financial evidence to support program-level clinical decision making in hospital and health systems with strategy papers from Diabetic Foot Australia and the CRC's health economics team outlining the path to achieving further impacts, and
- Health system savings and liberation of valuable resources resulting from decreased nursing hours and bed days required for wound management.

Box 4.1 Cancer therapeutics — promising new approaches

The Cancer Therapeutics CRC (CTx, 2007-20) recently completed its CRC Program funding period. Over more than a decade, the CRC developed a reputation as Australia's leading oncology-focused small molecule drug discovery organisation, bringing together leading researchers and organisations from industry and academia to find cures for cancer.

Characterised by successful collaboration and innovation, CTx made its mark on the drug discovery landscape with a multitude of achievements, including more than twenty drug discovery projects across areas including epigenetics, immuno-oncology and RNA biology.

CTx has an impressive track record of success and has commercialised multiple drug discovery projects, including two of the largest preclinical licensing deals in Australia with international pharmaceutical companies, Merck Sharp & Dohme (MSD) and Pfizer. Each of these deals has given rise to further research collaboration agreements between the CRC, participant organisations and the pharmaceutical company providing tangible financial and scientific benefits to the local biomedical research sector. More than 185 patents have been filed globally in relation to intellectual property originating from CTx.



In 2016, CTx signed an exclusive multi-million-dollar global deal for PRMT5 inhibitors with MSD/Merck in one of the biggest pre-clinical drug licensing deals in Australian history. The project involved the enzyme PRMT5, which was identified as a potential drug target offering therapeutic benefits for both cancer and blood disorders. In recognition of its excellence in innovation, CTx won a CRC Association Innovation Award in 2017 for its work on PRMT5, modulating cancer gene signals to deliver promising new treatments.

The work of CTx was also recognised in a comment from MSD:

“Our collaboration with Cancer Therapeutics CRC in Australia is a great example of the type of partnerships we seek, and we are hopeful that together we will impact cancer patients in the future.”

Ben Thorner, Senior Vice President, MSD, 2016

Previously thought as undruggable, CTx's multi-disciplinary team discovered small molecule inhibitors against two chromatin-modifying enzymes, which are particularly cancer-relevant targets. The two programs were licensed to Pfizer in 2018, in a deal worth \$20 million upfront, \$648 million in potential milestone payments, plus royalties (some of the CTx participants re-invested some of their share in the CRC). As a demonstration of the high-quality assets licensed to Pfizer, the MOZ (KAT6A) program entered Phase 1 clinical trials in November 2020 for the potential treatment of patients with advanced or metastatic breast, prostate, or lung cancer. Commenting about the deal on behalf of Pfizer:

"We are constantly searching the globe for the best science that has the potential to change the way we can treat people with cancer in the future. What we have found at CTx with these two chromatin-modifying enzyme targets are very promising, differentiated programs that have the potential to provide new treatment options for patients."

Dr. Robert Abraham, then Senior Vice President and Head of Oncology Research & Development Group. Pfizer, 2018

The MOZ program was the second CTx project to reach clinical trials. AMP945, a Focal Adhesion Kinase inhibitor invented by CTx, was licensed to Australian biotech company Amplia Therapeutics. In July 2021, Amplia announced the successful completion of its Phase 1 clinical trials in healthy volunteers and is now preparing for Phase 2 trials of AMP945 in patients with pancreatic cancer later this year. Additionally, STING, one of two promising immuno-oncology programs licensed to Aculeus Therapeutics in 2020, is currently in pre-clinical development.

The CRC also led a number of key initiatives: the ALIDC consortium that designed and built a drug discovery library of more than 329,000 compounds; seed funding for ZERO Childhood Cancer program — a precision medicine trial for paediatric patients with personalised treatment options; and an international working group with the USA FDA to discuss the regulation of drugs for the treatment of early metastasis. In 2016, working with BioMedVic, CTx created STEMM Bootcamp to provide early career researchers and late-stage postgraduate students with an understanding of the skills required to translate and commercialise their research. More than 115 students registered for the course, and this program was handed over to the Faculty of Medicine, Dentistry and Health Sciences at the University of Melbourne.

Since the completion of CRC funding, CTx is evolving into a new organisation, Canthera Discovery, with the objective of continuing the legacy of the CRC via this successor organisation.

Source: Cancer Therapeutics CRC, 2020, Highlights and achievements report; picture credit Cancer Therapeutics

Box 4.2 The Oral Health CRC's Recaldent™ — strengthening tooth enamel

The Oral Health CRC (2003-18) combined Australian research expertise, Australian biotechnology/bioscience manufacturing experience, and global market knowledge and access to develop and grow the domestic oral health industry, create novel and commercially viable oral health therapies and preventive strategies and improve oral health in Australia and worldwide. The Oral Health CRC achieved these outcomes through:

- Establishing links between local and international companies that have facilitated the development of oral health and consumer products from the laboratory to end-user markets
- Training a new cohort of researchers and upgrading the commercial skills of existing researchers providing human capital for economic and social development
- Expanding the capacity of the dental workforce through enabling the adoption of evidence-based policies, access to new strategies and techniques, and access to the most effective products and tools to treat oral health problems
- Continuing research and development into applications for casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), diagnostics, epidemiology, and treatment and management of oral diseases
- Expansion of traditional oral health research areas into oral-systemic health links, regeneration and reconstruction projects, and biomarkers of disease
- Improved understanding of the demographics of oral diseases
- Intervention strategies to improve the delivery of oral health services
- Taking novel therapies for the treatment of oral diseases to global markets, and
- Ensuring knowledge transfer of the results of the CRC through publications, conference presentations and commercialisation of products.

One of the major achievements of the Oral Health CRC in the funding period 2010-18 has been growing the sales of products developed by the CRC to improve oral health. This was acknowledged in late 2017 by the award of the Prime Minister's Prize for Innovation to recognise global sales exceeding \$2 billion of products containing CPP-ACP developed by the CRC.



Recaldent™ is the trademark name of the naturally occurring protein known as CPP-ACP. Dental decay, or caries, start when bacteria in plaque produce an organic acid that dissolves the tooth enamel, breaking down the calcium and phosphate in tooth enamel.

Recaldent™ works by delivering calcium and phosphate ions into the tooth, repairing and strengthening areas of enamel previously damaged by the action of bacteria.

Recaldent™ is manufactured in Victoria and used around the world in oral care and confectionary products.

The scientific research which led to the development of Recaldent™ began in the 1980's. Researchers at the Melbourne Dental School (University of Melbourne), led by Professor Eric Reynolds, investigated the casein protein in milk until they were able to identify and isolate the CPP-ACP complex. Research in the Oral Health CRC and its predecessor, the CRC for Oral Health Science, has focused on new ways of using the therapeutic and preventive properties of Recaldent™.

Another major achievement of the CRC was the preparation of the *P. gingivalis* vaccine Clinical Development Plan with commercial partner, CSL Limited, in late 2017.

Products from the Oral Health CRC and its predecessor the CRC for Oral Health Science are estimated to have saved more than A\$12 billion in dental treatment costs worldwide.

The Oral Health CRC provides a good example of CRC partners deciding to continue their collaboration beyond the end of the CRC funding period. The parties' commercialisation rights and ownership of intellectual property have been maintained, as has the joint venture structure.

Source: Oral Health CRC, Annual report 2017-2018

In addition to impacts improving human health, some CRCs have sought to improve animal health and welfare. The CRC for High Integrity Australian Pork and the Beef CRC provide relevant examples.

4.2 Education and training

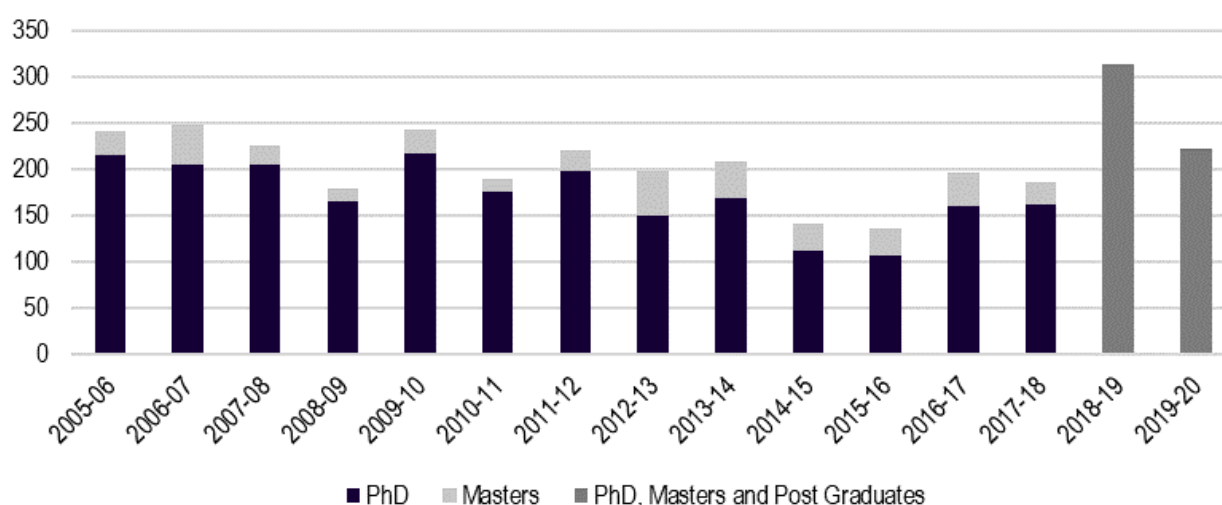
The CRCs have a strong role in the training of postgraduate students and exposing those students to industry researchers, and opening up career opportunities. The number of students trained by the CRCs has grown significantly over the life of the Program. The number of students who have completed their studies from within the CRCs are shown in Figure 4.1. More of these students will have completed their studies in the period following cessation of funding. The skills formation that occurs within CRCs delivers a number of benefits for Australia. They include:

- benefits through the development of highly skilled post-graduates that build a critical mass of skills in a region that either attracts multinational companies to invest in the location or helps retain existing business activity levels
- benefits through the development of highly skilled post-graduates who then work in industry and allow industry to be smart adopters and adapters of internationally generated technology/knowledge, and
- benefits through industry and academic researchers interacting and increasing their skills, and hence their future productivity, via this interaction. Collaboration across sectors and disciplines encourages researchers to understand both research provider and end-user perspectives and to maintain focus on the active planning for and management of pathways to application.

The CRC for Infrastructure and Engineering Asset Management provides an example of the role of CRCs in education and training. This CRC increased the numbers of Masters' and PhD students in its particular area of focus. At the time of the completion of funding for this CRC in 2013, 26 students undertaking postgraduate research studies had completed their degrees. A further 36 were in progress with arrangements for them to complete their studies following the closing of the CRC. These students would not have enrolled in these studies without scholarships and top-ups provided by the CRC. The graduates from this CRC are now employed in companies such as Bechtel, Downer Rail, GHD, SKF, SunWater and Western Power.

Stakeholders report that researchers trained in CRCs often find employment in the private sector and take the knowledge and experience of working with researchers in universities with them. In the long term, this should help to build industry-researcher cooperation in Australia.

Figure 4.1 Awarded degrees at CRCs 2005-6 to 2017-18



Source: MDQ data from DISER

Note: The questions underpinning the data was changed in 2018-19. As a consequence, the number of post-graduate participants for 2018-19 and 2019-20 may have been affected by survey design and CRC responses.

The contribution of the educational activities undertaken by the CRCs is taken into account in this analysis by estimating the effect of these graduates on the future productivity of the Australian workforce via its output of graduates (expressed as annual changes in the wage bills of Australia). The impacts of the CRC's educational activities are measured over the Program period (although graduate impacts go beyond this time period).

Many CRCs have reported that more than half of the students who have worked in their CRC have found subsequent employment in partner companies.

4.3 Labour force participation

Nearly all CRCs have reported increases in employment as a result of their work. In some cases, these increases have occurred in CRC partner companies where new products and services have created jobs. In other cases, CRCs have created jobs through the establishment of spin-off companies. CRC work that has improved the productivity of their stakeholders has, in some sectors, resulted in increased employment as a result of the improved competitiveness of the sector leading to expanded domestic or overseas markets.

Labour force participation impacts arising from involvement in CRCs are diffuse and, in most cases, are not easy to quantify. It can also be challenging to attribute increases in employment in a company to the Program. Often there are numerous factors behind an increase in employment in a business. Some companies appear to have been able to increase their exports as a result of CRC participation. However, such increases are often gradual and spread over a number of years beyond the life of the CRC. When CRC spin-off companies create jobs, they appear to generally require high skills levels and tend to grow slowly in numbers.

Noting the complexities of providing an accurate figure, ACIL Allen estimates that CRCs have created 22,007 FTE-years on employment over the period from 2012 to 2020. This is an average of 2,445 jobs in each year of the Program (see section 3.4.4) for further detail on this analysis).

4.4 Business development

A number of CRCs have reported that their partners have been able to expand their businesses as a result of the outcomes of CRC research. In addition, CRCs have created start-up companies to commercialise their research. In assisting business expansion and creating start-ups, CRCs are contributing to business development in Australia and to the diversification of the Australian economy.

Some CRCs have a close relationship with business incubators (e.g. Cicada Innovations in central Sydney), and CRC spin-offs sometimes start their life in a business incubator. At least one CRC, on completing its funding period, has evolved into a business that supports start-ups.

4.5 Safety and security

Some CRCs have addressed safety and security issues. Examples include:

- The Cyber Security CRC, which is delivering solutions to increase the security of critical infrastructure and provide cyber security solutions for businesses and their customers
- Space Environment Management CRC
- Data to Decisions (D2D) CRC
- MinEx CRC (see Box 3.3)
- CRC for National Plant Biosecurity CRC, which has helped to safeguard Australia from damaging pest incursions
- CRC for Infrastructure and Engineering Asset Management, which has contributed to a higher standard of asset management in Australia, reducing the risk of failures, and
- CRC for Advanced Automotive Technology, which has contributed to increased vehicle safety.

4.6 Social costs avoided

Examples of CRC research that has resulted in avoided social costs include:

- Capital Markets CRC – detecting fraud (see Box 3.6)
- Bushfire and Natural Hazards CRC – reduced social disruption
- CRC for Remote Economic Participation – improved schooling in remote areas.

Some of these impacts have been discussed in section 3.6 (Preparedness).

4.7 International collaboration

The 2012 Allen Consulting Group report noted that CRCs were involved in 545 international alliances in 2009-10. Since then, that number has varied with the number of active CRCs but remains significant. Many CRCs active in the period 2012-20 have reported international alliances. A simple count of such alliances is not particularly meaningful because of their range of size and significance. The largest include engagement in European Union Framework Programmes and participation in NASA projects. However, many smaller-scale alliances are proving valuable to CRCs and are contributing to their outputs and impact.

5 Environmental impacts of CRCs

This Chapter discusses key environmental impacts achieved by the CRCs in the period 2012-20.

CRCs have generated a range of environmental benefits. These benefits are often difficult to express in monetary terms. The environmental benefits arising from the CRCs are wide-ranging: from reducing greenhouse gas (GHG) emissions and energy consumption to protecting areas of land and endangered species. As with economic outputs, environmental outputs range from those that have been delivered and directly attributable to the CRC, to anticipated outputs and those that relate to preparedness. For some CRCs, their primary objective is to achieve positive environmental impacts. For others, this is secondary to commercial objectives, with impacts occurring as a result of a broader research program. Some of the positive environmental impacts of CRCs, listed below, are discussed in this Chapter. It should be noted that this list is not exhaustive or definitive given the broad scope of the Program.

- Reduced GHG emissions.
- Reduced energy consumption.
- Reduced water consumption.
- Protection of areas of the environment.
- Protection of animal species.
- Reduction in the amount of waste produced.
- Reduced environmental costs.

These impacts have not been quantified or monetised. They are additional to the economic impacts discussed in Chapter 3.

5.1 Reduced GHG emissions

To address global warming, world leaders agreed in 2008 to the target of halving global carbon dioxide (CO₂) emissions by 2050. Successive Australian governments have set targets to limit greenhouse gas emissions and subsequently implemented plans to achieve this outcome.¹⁴ A range of responses will be required to achieve these emission reduction targets, including initiatives such as increased use of renewable energy, greater energy efficiency, fuel switching, and carbon capture and storage. One example is the CRC for Greenhouse Gas Technologies (CO₂CRC), which operated between 2003 and 2014, focusing on addressing the major scientific and technology issues related to carbon capture and storage (CCS) as a key mitigation technology for reducing CO₂ emissions to the atmosphere. Low Carbon Living CRC is another example of a CRC whose core objective relates to the reduction of emissions. Examples of its work, as well as some background on the CRC, are provided in Box 5.1.

¹⁴ Cooperative Research Centre for Greenhouse Gas Technologies, 2015, *Exit Report*.

Box 5.1 Low Carbon Living CRC

The Low Carbon Living CRC commenced in 2012 with \$28 million in funding from the Australian Government. The objective of this CRC was to provide government and industry with technological and policy tools to overcome identified market barriers that prevent the adoption of cost-effective, low carbon products and services. The CRC had 45 active partners across a multitude of disciplines. They spanned three essential sectors: industry, government, and research. The key partners of the CRC were AECOM, BlueScope, Multiplex, CSIRO, Curtin University, Swinburne University of Technology, Sydney Water, The University of Melbourne, UNSW Sydney and the University of South Australia.

The CRC operated for seven years, from 2012 to 2019, over which time it applied \$116.95 million in resources: \$49.68 million was received by the CRC as cash, and \$67.27 million was received as in-kind funding. The CRC's three research streams were:

- Integrated building systems
- Low carbon precincts
- Engaged communities.

UNSW Sydney verified cumulative CO₂e savings of 12.8Mt across the CRC's research streams over the life of the CRC. Examples of the CRC's achievements under each research stream is provided below.

Integrated building systems

The integrated building system project aimed to develop new low-embodied-carbon products and services and establish ways to communicate best practice design through rating tools, standards, display homes and buildings. As part of this program, the Centre worked with BlueScope, CSIRO and UNSW to put solar photovoltaic (PV) cooling to the test, using a prototype solar desiccant air conditioning unit. The solar cooling unit requires air at a much lower temperature compared to alternative systems, which need higher temperature air via a more powerful heat source at a greater energy expense. With the significant fall in PV prices in recent years, it was a good time to test the system and demonstrate its potential to industry and government.

Low carbon precincts

The low carbon precincts project aimed to develop planning techniques and data for delivering low carbon developments at a precinct level. The CRC developed the Urban Heat Island Mitigation Decision-Support Tool as part of this program. The tool brings together scientific models, case studies and guidelines to help government and built environment professionals plan top heat mitigation strategies and effects for their city.



Figure: Urban Heat Island Mitigation Decision-Support Tool.

Engaged communities

The aim of this program was to capture a new community appetite for low carbon living through research and communication with businesses, in particular with the tourism industry, which represents around 5 per cent of Australia's carbon emissions. The Centre's Low Carbon Living Australia program, which started at the Blue Mountains World Heritage Institute and has now launched nationally, brings Australian communities and businesses together to collectively lower carbon emissions. By 2019, participating businesses had reduced their annual carbon emissions by 19 per cent on average after two years in the program.

These are just three examples of the achievements reported by the Low Carbon Living CRC. Its work will continue through its six Nodes of Excellence established in Australian universities and the BuiltBetter knowledge hub, a website established by the Centre that collates low carbon-built environment research for ongoing use in the sector.

Source: Content and images sourced from Low Carbon Living CRC Exit and Highlights Report 2012-2019.

For other CRCs, reducing GHG emissions is a secondary issue. For example, the Innovative Manufacturing CRC is involved in a range of projects that aim to improve manufacturing technology. Its ultra-sustainable concrete project is an example of a project that has emissions reduction benefits. Announced in July of 2020, the two-year project is being co-funded by Innovative Manufacturing CRC and building material company Boral.¹⁵ The project aims to overcome current technological barriers of low-carbon concrete manufacturing and accelerate the development of Boral's lower carbon ENVISIA® concrete.

CRCs reported various contributions to reductions in GHG emissions. Some examples are provided in Table 5.1.

Table 5.1 CRCs reported contributions to GHG emission reduction

CRC	Details	GHG reduction
CRC for High Integrity Australian Pork	The CRC for High Integrity Australian Pork has contributed to a reduction in Greenhouse Gas emissions. Research by the CRC included the establishment of commercial quantities of algae products to replace 10 per cent of existing feed and alternative approaches to waste management that mitigate carbon outputs.	The CRC reported a reduction of greenhouse gas emissions from 3.6 kg to 1.3kg CO ₂ e/kg of pork produced by 2019, with pathways to reduce this further to the CRC target of 1.0kg CO ₂ e/kg of pork produced.
Food Agility CRC	Food Agility CRC has delivered a scientifically credible framework for the food industry to support cropping farmers in the reduction of GHG emissions. This should lead to increased long-term sustainability and yield stability.	Grain farming currently emits 10m tonnes of GHG. Assuming a cost of \$50 per tonne, an expected improvement of 5 per cent will save \$25m per year.
Food Agility CRC	Food Agility CRC's Cool Soil project is anticipated to reduce GHG emissions and improve soil carbon sequestration in the cereal grain industry by 5 per cent from 2021 onwards. Emissions are currently estimated at 10m tonnes of CO ₂ per year.	Reduction of CO ₂ e emissions by 500,000 tonnes per annum.

¹⁵ Innovative Manufacturing CRC, 2020, *Research collaboration pushes the boundaries of low-carbon concrete technology*, available at: https://www.imcrc.org/2020/07/29/research_pushes_the-boundaries_of_low-carbon_concrete_technology/.

CRC	Details	GHG reduction
Fight Food Waste CRC	Reduced GHG emissions, in particular methane, as a result of reduction in food waste that would have otherwise ended up in landfill.	Reduction of around 18Mt of CO ₂ between 2019 and 2048.
CAST CRC	Emissions reductions delivered by CAST CRC through the adoption of the AM-cover technology and reduced energy consumption associated with improved energy efficiencies in production and the elimination of waste.	Emissions reduction of 108,000 tonnes of CO ₂ e from CAST activities between 2005-12.
SmartCrete CRC	The cement and concrete industry in Australia has a largely unquantified number of options for carbon reduction. The SmartCrete CRC is co-funding the development of a decarbonisation Roadmap for the industry. This will inform the technology options and indicate the quantum of emissions reduction from each option.	SmartCrete CRC is funding 40 per cent of the Roadmap.
iMove CRC	Efficient transport systems and less use of private vehicles will deliver emissions reductions. iMove CRC is currently planning to extend CRC activities to include a stream on sustainable transport, including alternative fuels.	The CRC's research is likely to result in reduced car use, the introduction of more efficient transport options, and the increased use of other modes of transport. The CRC has not attempted to quantify its emission reduction impacts at this stage.

Source: Survey responses from CRCs, 2021

5.2 Avoiding the emission of pollutants

Pollution control is another major environmental issue addressed by some CRCs. The Innovative Manufacturing CRC reports impacts related to reducing the emission of pollutants. An example of this work, as well as some background on the CRC, is provided in Box 5.2 below.

Box 5.2 Innovative Manufacturing CRC

The Innovative Manufacturing CRC commenced in 2015 with the objective to accelerate Australia's rapid transition into high value, high knowledge-based manufacturing through leadership, support and facilitation of innovative manufacturing organisations and entrepreneurs. Since its launch, Innovative Manufacturing CRC has invested \$31 million of Government and other funding to advance Australian manufacturing, catalysing over \$200m investment in collaborative research, manufacturing, innovation and education across Australia.

The CRC has 47 partners, including 28 industry partners, 12 research partners, six government and industry associations, and one collaborator. The CRC has invested significantly in these partnerships to support innovation and deliver commercial outcomes that ensure the Australian manufacturing sector can meet the challenges and opportunities of the global economy.

The CRC's supports four core research programs:

1. Additive manufacturing processes
2. Automated and assistive technologies
3. High-value product development
4. Industrial transformation

These multidisciplinary research programs comprise a series of projects that aim to deliver benefits to partners and create important insights to share with the broader manufacturing community.

In June 2019, Innovative Manufacturing CRC partnered with Xefco and Deakin University to develop an atmospheric plasma coating system as part of research program 3. This project aims to advance conventional coating equipment and develop a commercially viable plasma deposition solution that improves current coating and treatment methods for textiles and substrates used in the garment, geotextiles, packaging and medical industry. This coating is expected to address known functional and environmental issues, such as water contamination, pollution and use of harmful chemicals, within the textile manufacturing and processing industries.

This is just one example of the CRC's initiatives, with many other projects in areas such as health, robotics, electric vehicles, shipbuilding, and automation.

Source: Innovative Manufacturing CRC, 2020, Annual Highlights Report 2019-2020,

5.3 Reduced energy consumption

Reducing energy consumption helps to reduce costs and protect the environment by reducing GHG emissions. Research activities can develop technologies that reduce the consumption of energy in different industries.

Several CRCs have had an impact on energy consumption. For example, the Blue Economy CRC (BECRC) brings together expertise in the seafood, marine renewable energy and offshore marine engineering sectors to deliver innovative solutions for Australia's aquaculture sector.¹⁶ BECRC has installed 1 MW of renewable energy generation to date and expects that its R&D initiatives will generate 2 GW of energy savings between 2024 and 2029. Renewable sources being explored by BECRC include wave energy, wind energy, solar energy and hydrogen storage and usage. The implementation of renewable energy in the sector will lead to lower operating costs and thus reductions in production costs. BECRC is expecting a reduction in production costs of up to 20 per cent associated with the:

- Reduction in the use of diesel to support offshore operations, for example, powering offshore platforms, freshwater desalination, transporting and shipping of products. For context, the current cost of diesel for the salmon industry is \$184 million per year.
- Potential for excess energy to support the processing of products offshore, the refuelling for transport and delivery, exports via conversion to hydrogen.

Another example of a CRC with energy consumption impacts is Minex CRC, the world's largest mineral exploration collaboration between industry, government and research organisations.¹⁷ MinEx CRC is developing more productive, safer and environmentally friendly drilling methods, including coiled tubing drilling technology (see Box 3.3). The increased energy efficiency in coiled tubing rigs from additional electronics and reduced hydraulic usage significantly reduces fuel consumption. Further, drilling with a continuous coil reduces the environmental footprint by drilling smaller holes with a lighter and more mobile drilling platform. The MinEx CRC expects its RoXplorer® coiled tubing technology will lead to energy savings of 1.32 GJ between 2023 and 2032.

¹⁶ BECRC, 2019, *About BECRC*, available at: <https://blueeconomycrc.com.au/about/>

¹⁷ MinExCRC, 2020, *What is MinExCRC?*, available at: <https://minexcrc.com.au/about-minex-crc/what-is-minex-crc/>

5.4 Reduced water consumption

Total water use is an important indicator of the extent to which human activity draws upon Australia's finite water resources. Given the pressures placed on water systems by society, it is important that methods of reducing water consumption are investigated.

CRCs can have an impact on the amount of water consumed. For example, BECRC expects savings of 8300 m³ (8.3 megalitres) of freshwater on fish farms per bathing cycle¹⁸ through its research into localised renewable energy generation and desalination at offshore operational sites.

A further example is provided by the Food Agility CRC, which is researching the optimisation of irrigation in Western Australia based on environmental inputs. Food Agility CRC reports that its research is expected to reduce the amount of water applied in WA by 5 per cent, equating to 520 megalitres of annual water savings.

Finally, the CRC for Water Sensitive Cities reports impacts related to reducing the emission of pollutants. An example of this work, as well as some background on the CRC, is provided in Box 5.3.

5.5 Protecting areas of environmental significance

With many areas of national environmental significance in Australia, the protection of these areas is a key outcome of the research of many CRCs that are working to protect or conserve large areas of land.

For example, the CRC for Contamination Assessment and Remediation of the Environment (CRC CARE) is an independent organisation that performs research, develops technologies, and provides policy guidance for assessing, cleaning up, and preventing soil, water, and air contamination.¹⁹

Box 5.3 Cooperative Research Centre for Water Sensitive Cities

The CRC for Water Sensitive Cities (CRCWSC) operated from July 2012 to June 2021 with \$30 million in funding from the Australian Government. The objective of the CRC was to deliver the socio-technical urban water management solutions, education and training programs, and industry engagement required to make towns and cities water sensitive. The CRCWSC defines a water sensitive city as a place that:

- serves as a potential water supply catchment, providing a range of different water sources at a range of different scales and for a range of different uses
- provides ecosystem services and a healthy natural environment, thereby offering a range of social, ecological, and economic benefits, and
- consist of water sensitive communities where citizens have the knowledge and desire to make wise choices about water, are actively engaged in decision-making and demonstrate positive behaviours such as conserving water at home and not tipping chemicals down the drain.

The CRCWSC had 60 partners across state and local government, the water utility sector, research organisations, and private industry. The CRC's eight essential partners were the Department of Communities (Housing) WA, Department of Water and Environmental Regulation

¹⁸ According to BECRC, this estimate is based on fish requiring 5 evenly spaced bathing cycles during the 11 month grow-out phase. Assuming 4 full pens being sequentially bathed, 8,300 m³ of freshwater would need to be produced approximately every 16 days.

¹⁹ CRC CARE, 2021, *About CRC CARE*, available at: <https://www.crccare.com/about>

WA, Monash University, The University of Queensland, Department of Environment, Land, Water and Planning (VIC), Melbourne Water Corporation, South East Water and the University of Western Australia.

In December 2020, the CRCWSC reported that it expected to end its term in June 2021 with:

- 1,700+ IP assets, including 48 case studies, 95 guidelines and industry resources
- 47 cities benchmarked using the WSC Index
- \$11 million + of commercial income generated
- 29 research synthesis reports applying WSC insights to real-world challenges
- 5 states with established WSC communities of practice
- 47 students who successfully completed their PhD

The Aquarevo residential development in Lyndhurst, 42 km southeast of central Melbourne, is the location of an interesting CRCWSC project. The decommissioning of the former wastewater treatment plant provided South East Water with an opportunity to demonstrate advances in water management. The CRCWSC provided in-kind research time and a research synthesis workshop in 2014, producing the ideas document for Aquarevo and contributing to the development of the landscape plan for the project. An example of a water-saving measure on this project is the conversion of rainwater for use with household appliances. A rainwater harvesting system was designed to minimise any health risks associated with the use of rainwater for hot water use. The rainwater from each home's roof undergoes screening, filtration, ultraviolet (UV) and heat treatment before it is supplied to hot water taps in the shower, bath, laundry trough and clothes washing machine via a separate plumbed supply system. Drinking water is automatically supplied to the hot water system as a backup if there is no rainwater in the tank.



Aquarevo incorporated a range of water management initiatives such as the one described above, as well as some energy management initiatives. These initiatives were incorporated into the promotional material for the land, which was well received and understood by buyers. The first land release of 44 lots (10% of the development) sold out within a day in November 2016, whereas the sale of that number of lots would usually take three months.

Above is an example of one of the major projects that CRCWSC was involved in during its operation period. The Water Sensitive Cities Institute (WSCI) is the CRCWSC's legacy vehicle and will continue to support the mainstreaming of WSC practices and further develop intellectual property developed through the CRCWSC. The Institute is partnering with public, private and academic organisations to bid for the next generation of WSC research.

Figure: Trialling of rainwater to hot water connections at Holmesglen TAFE

Source: Water Sensitive Cities CRC, 2020, Stakeholder Annual Report FY1920, accessed on 8 August 2021 at https://watersensitivecities.org.au/wp-content/uploads/2020/12/201216_V8_CRCWSC-Annual-Report-FY1920.pdf; Water Sensitive Cities, 2017, Aquarevo, available at: <https://watersensitivecities.org.au/solutions/case-studies/aquarevo/>

CRC CARE has developed health screening levels (HSLs) for petroleum hydrocarbon remediation, which provide a minimum concentration of contaminants that triggers further action (including monitoring and clean-up). The HSLs, as well as other best practice strategies for managing petroleum hydrocarbon contamination, were incorporated into national legislation known as the National Environment Protection (Assessment of Site Contamination) Measure and adopted by all environment protection authorities across Australia.

In addition, Invasive Animals CRC (IA CRC) was Australia's largest integrated invasive animal research and management collaboration with 27 participating organisations, operating from 2005 to 2017. The IA CRC developed new technologies and integrated strategies to reduce the impact of invasive animals on Australia's economy, environment, and people. IA CRC has reported one of its key achievements as the recovery of land and water regions from rabbit, wild dog and carp impacts. In particular, the lead researcher on the IA CRC's carp herpesvirus registration and release project is now leading the Australian Government's \$15 million National Carp Control Plan (NCCP).²⁰ Carp have major negative impacts on water quality and the amenity value of Australia's freshwater rivers and lakes; thus, the work of the CRC, which will feed into the NCCP, will be a key part of protecting Australian waterways from invasive carp.

Further, BECRC has reported that its offshore seaweed production, which covers 5000 hectares of ocean, will provide new habitat and rejuvenate the depleted seaweed forests in Australia and New Zealand. This project is still in the research and development stage.

5.6 Protecting endangered species

The protection of endangered species is of primary concern to some CRCs, while for others it is secondary.

For example, the Plant Biosecurity CRC operated from 2012 to 2018 and was established to strengthen Australia's plant biosecurity scientific capacity.²¹ Some of the CRC's key research was on myrtle rust, a disease caused by the exotic fungus *Austropuccinia psidii*, which can lead to deformed leaves, heavy defoliation of branches, reduced fertility, dieback, stunted growth, and plant death.²² The Plant Biosecurity CRC developed methods to assess the impacts of myrtle rust in native ecosystems, documenting native species and plant communities at risk of significant short to long-term impacts. These efforts have led to myrtle rust being declared a Threatening Process in NSW and a priority for the Australian Government's National Environmental Science Program (NESP) projects. Two common species, *Rhodomyrtus psidioides* and *Rhodamnia rubescens*, have been recommended for listing as critically endangered due to the impacts of myrtle rust. An extensive network of national and international research partners has been forged, awareness generated in government and industry about the biosecurity risk posed by myrtle rust, and a significant contribution made to the scientific literature. The extensive body of knowledge and relationships developed through the CRC has culminated in developing a draft National Action Plan for myrtle rust.

²⁰ CRC CARE, 2020, *Annual Report 2019/2020*

²¹ Plant Biosecurity CRC, 2018, *Legacy website*, available at: <https://www.pbccrc.com.au/>

²² Department of Agriculture, Water and the Environment, 2016, *Myrtle rust (Austropuccinia psidii)*, available at: <https://www.environment.gov.au/biodiversity/invasive-species/diseases-fungi-and-parasites/myrtle-rust>

Cotton Catchment Communities CRC was an example of a CRC whose protection of endangered species was secondary but still contributed to the research and awareness of the issue. For example, the CRC's Rivers Program aimed to increase the cotton industry's understanding of integrated management of river flows to ensure profitable irrigation industries and sustainable ecological conditions of floodplain ecosystems. According to Cotton Catchment Communities CRC, 90 per cent of the nation's cotton comes from the northern Murray Darling. This area experiences flooding in response to summer rainfall events in upper catchments and is one of the country's most extensive, fertile, and productive croplands. However, the area is also among the most extensively and intensively farmed, and the ecosystems and flora and fauna it supports are among the most threatened and least conserved in the national reserve system. For example, the nationally endangered Coolibah can be found on many cotton farms. Cotton growers are therefore in a unique position to influence the conservation of some of Australia's most endangered ecosystems and species, and they can also significantly impact on the environmental wellbeing of the entire Murray Darling system. A key goal of the Rivers Program was to raise awareness of the conditions and management regimes needed to trigger floodplain vegetation species responses and enable these communities and species to persist in these landscapes.

5.7 Reducing waste

Waste is a significant and growing issue in Australia – the country produced approximately 75.8 million tonnes of solid waste in 2018-19, an increase of 10 per cent since 2016-17.²³ A number of CRC's have conducted research in order to reduce the amount of waste produced.

For example, BECRC has been examining ways to capture waste produced from salmon farming to be utilised in the circular economy. Salmon is part of BECRC's strategy for the long-term development of integrated aquaculture systems. These temperate integrated systems would include salmon production at the core, and take advantage of renewable energy, oxygen by-products, and will recycle salmon waste streams to increase efficiency.²⁴

Another example is the Food Agility CRC, which is also conducting research on ways to reincorporate waste into the circular economy. For example, the Food Agility CRC has partnered with the construction company Lendlease and the Queensland University of Technology to roll out the Yarrabilba Circular Food Economy Project. Using smart sensors, education and food waste collection, Yarrabilba in Southeast Queensland will become Australia's first *sustainable food city*, meaning that the community's food and green waste will be used to support community growing activities and small-scale food enterprises.²⁵ The Food Agility CRC expects this will result in an annual reduction of 345,000 kg of food waste from 2020.

²³ ABS, 2020, *Waste Account, Australia, Experimental Estimates*, available at: [https://www.abs.gov.au/statistics/environment/environmental-management/waste-account-australia-experimental-estimates/latest-release#:~:text=Australia%20generated%2075.8%20million%20tonnes,disposal%20\(20.5%20million%20tonnes\)](https://www.abs.gov.au/statistics/environment/environmental-management/waste-account-australia-experimental-estimates/latest-release#:~:text=Australia%20generated%2075.8%20million%20tonnes,disposal%20(20.5%20million%20tonnes)).

²⁴ Blue Economy CRC, 2020, *Key Challenges for Offshore/High Energy Salmon Aquaculture Production*, available at: https://blueeconomycrc.com.au/wp-content/uploads/2021/03/BECRC_Flyer_2.20.002_e160321.pdf

²⁵ Food Agility CRC, 2021, *Yarrabilba Circular Food Economy*, available at: <https://www.foodagility.com/research/yarrabilba-circular-food-economy>

Further, the Fight Food Waste CRC is estimating a saving of 9.7 million tonnes of food waste between 2019 and 2048 through its research and initiatives. An example of the Fight Food Waste CRC's work, as well as some background on the CRC, is provided in Box 5.4.

Box 5.4 Fight Food Waste CRC

The Fight Food Waste CRC commenced in 2018 with \$30 million in Australian Government funding. The objective of the CRC is to reduce food waste throughout the supply chain, transform unavoidable waste into innovative high-value co-products and engage with industry and consumers to deliver behavioural change. The CRC is ongoing with a planned operation period of 10 years, until 2028.

The Fight Food Waste Cooperative Research Centre brings together 48 industry and ten research partners, contributing \$33 million cash and \$57 million in-kind contributions. The CRC's partners include research institutions such as the South Australian Research and Development Institute, Central Queensland University, RMIT University, Swinburne University of Technology, and the University of Adelaide, and industry partners such as Oz Harvest, Australian Council of Prawn Fisheries, the Australian Food and Grocery Council, the Australian Institute of Packaging, and Woolworths.

The Fight Food Waste CRC's grant agreement targets for 2018-28 are as follows:

- 30 MT of reduced food waste
- \$2 billion increase in industry profitability
- 20 M Kg of rescued food distributed
- 5200 circular economy jobs
- 40 future leaders graduated across the PhD, masters and honours levels, and
- 250 industry people trained per annum.

The CRC reported significant headway in terms of research output in its 2019/2020 Annual Report, published October 2020. By the end of June 2020, the Fight Food Waste CRC had 34 projects approved across the following three research streams: **reduce** food waste throughout the supply chain; **transform** unavoidable waste into innovative products; and **engage** with industry and consumers to deliver behavioural change. This is an increase of 20 projects from June 2019 and equates to a contracted total project value (cash and in-kind) of \$17.7 million.

An example of one of the CRC's research projects is the onboard processing and packaging innovation project in Australian wild harvest prawn fisheries. This project commenced in August 2019 and is scheduled to be completed by August 2022.

The CRC states that the wild prawn industry currently reports 20,500 tonnes of wild prawn catch valued at \$305.8 million, averaging at \$14.90/kg across all grades. The project is expected to lead to more efficient and optimal processing of larger volumes of prawns under periods of high-volume catch, plus new onboard processing automation (such as peeling) to enhance product value. These will increase profitability and the ability to supply a premium grade product as a result of faster processing times. Potential new on-board processing techniques aim to improve shelf-life, enhance market access and reduce discard in supermarkets/retail.

Despite the challenges of COVID-19 in the 2019/20 financial year, the CRC's Board reported an achievement level of 90 per cent against company KPIs. The CRC expects that it is well-positioned to deliver the goals outlined in its grant agreement.

Source: Fight Food Waste CRC, 2020, 2019/2020 Annual Report

5.8 Other environmental impacts

The activities of many industries incur costs attempting to mitigate their environmental impact in terms of GHG emissions, energy consumption and water consumption, for example. Therefore, it is important to find innovative ways to reduce the costs associated with environmentally friendly operations.

For example, the BECRC reported on initiatives to reduce costs associated with addressing negative environmental impacts. It expects that its research on improved environmental management and the incident response would lead to a reduction in production costs associated with:

- Improvements in the management of environmental risks
- Lower risk of environmental incidents, for example, pollution, fire, explosions, contaminations
- A reduction in clean-up costs and reputational damage, and
- Improved consumer and stakeholder confidence in offshore operations, including price premiums associated with industry products.

A specific cost-saving measure reported by BECRC relates to its research on amoebic gill disease (AGD). BECRC is examining methods to reduce or completely eradicate AGD in salmon farming by moving production further offshore. Managing AGD is estimated to cost the local industry \$40 million a year in treatment and lost productivity as it affects fish growth, and frequent freshwater bathing is required to detach the amoeba. The freshwater is in limited supply, and bathing is labour-intensive. Thus, moving further offshore will reduce the biosecurity cost associated with onshore operations, and reduce freshwater usage on these farms. These benefits are also likely to improve consumer and stakeholder perceptions of offshore operations.

5.9 Conclusions

The environmental impacts of the CRCs are wide-ranging. For some CRCs, the primary objective is to achieve positive environmental impacts. For others, this is secondary to other objectives, with environmental impacts occurring as a result of a broader research program. Reducing GHG emissions is a common impact of CRCs across all sectors. Reducing energy, water consumption, and waste is also common. Some CRCs were negatively affected by the COVID-19 pandemic, which is likely to continue to change how collaboration occurs.

The environmental impacts discussed in this Chapter have not been quantified or monetised. They are additional to the economic impacts.

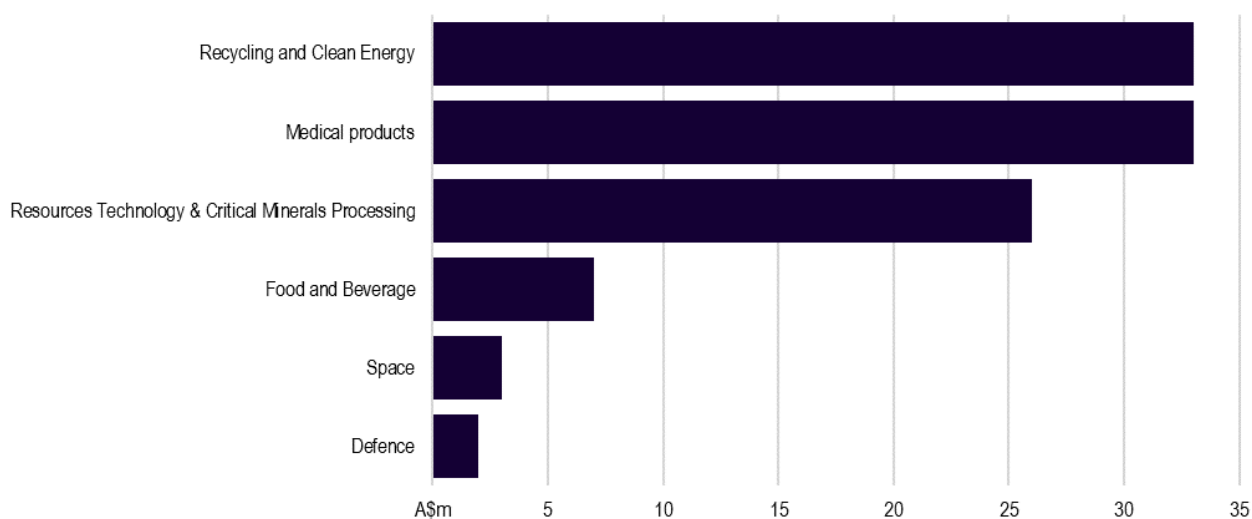
6 Impact of CRC Project grants

This Chapter looks at the early impacts of the CRC Projects, including a cost-benefit analysis of the impacts of the 30 completed CRC-Ps at the time of the review.

Due to the small number of CRC-Ps that have completed their project and the impact of COVID-19 on the realisation of benefits, the analysis of CRC-Ps could not be satisfactorily undertaken using the methodology that has been used for the CRCs. An assessment of 30 completed CRC-Ps was therefore used to inform the cost-benefit analysis. Only completed CRC-Ps were used because, in the circumstances, it would not have been credible to attempt to assess benefits from projects that are ongoing. This sample is broadly representative of the sectors where CRC-P grants have been awarded.

The National Manufacturing Priorities (NMP) were announced by the then Minister, the Hon Karen Andrews, and Prime Minister Scott Morrison in October 2020 — after Round 9 had been announced. Accordingly, many of the grants were not made intentionally to support the NMP. However, analysis of the CRC Project grants from rounds 1-10 shows that approximately two-thirds align with NMP. Because outcomes are not available, it is impossible to know how much impacts align with NMP; however, the value of CRC P grants as they align is shown in Figure 6.1.

Figure 6.1 Alignment of CRC-Ps grant funding (rounds 1-10) with National Manufacturing Priorities, (\$m, nominal)



Source: ACIL Allen

Box 6.1 Targeted therapy for sleep apnoea: A novel personalised approach

Oventus Medical Ltd is an Australian ASX-listed medical device company with a proprietary technology for the treatment of obstructive sleep apnoea (OSA) and snoring. Oventus was awarded a CRC-P grant in 2017 of \$2.95 million over three years. The aim of the project was to commercialise and improve the efficacy, compliance and monitoring of sleep apnoea therapy using a tailored suite of treatments. The range of therapies was designed to be used, singularly or in combination, and include oral appliances with or without a positive airway pressure machine (with reduced pressure and airflow), supplemental oxygen delivery or a sleep consolidation aid. CRC-P partners included Medical Monitoring Solutions Pty Ltd, CSIRO, Western Sydney University, Neuroscience Research Australia and Flinders University. Some 40 per cent of Australian adults have sleep issues, and OSA affects at least 4 million Australians. Inadequate sleep was expected to have a financial and welfare cost of \$66 billion (2016-17), equating to just under \$9,000 per capita.

Oventus and its partners invested more than \$750,000 in cash (as well as in-kind contributions) in the project. As part of the project, three new sleep apnoea treatment products were developed and launched in local and international markets (with supporting clinical evidence that the product is viable). This has led to a growth in sales and jobs created. Six patent applications have been lodged.



Oventus estimates their technology will reduce costs to the Australian healthcare system from OSA by more than \$200 million in 2021. In addition, demand in the global market for these technologies was growing, with a compound annual growth rate of 15-20 per cent per annum in 2019.

Customer testimonials note the success of the technology, the difference it has made to the quality of their lives and the lives of their family, and the cost savings relative to the incumbent Continuous Positive Airway Pressure (CPAP) machine.

Other realised and expected benefits include:

- Improved health and wellbeing – a reduction in obstructive sleep apnoea and potential applications for COVID-19 monitoring.
- Savings on government expenditure – sleep monitoring will be included in the device delivery fee at a reduced total, resulting in a saving for Medicare.
- Education, training and publications – more than 20 conference and journal publications and two research projects delivered. Three PhD students have completed their research and delivered their theses.
- International collaboration – Oventus have set up an International Clinical Advisory Committee.

Source: Completion Report, ACIL Allen analysis, related reports, websites such as <https://investors.o2vent.com/>, <https://investors.o2vent.com/testimonials/>, Oventus Medical Ltd Annual Report, 2019 and Deloitte Access Economics. Asleep on the job: costs of inadequate sleep in Australia. Canberra 2017; picture credit Rodrigo Pereira on Unsplash

Box 6.2 A big health data analytics & insights platform for the Medical Technologies and Pharmaceuticals sector

Prospection Pty Ltd is a healthcare data analytics provider in the Asia Pacific and is a leader in producing data insights that inform decisions to improve health. It was founded at Sydney's Cicada Innovations in 2012. In 2017, Prospection was awarded nearly \$2 million in a CRC-P grant over two years. The project aimed to develop a commercial analytics platform integrating multiple linked health datasets for the Medical Technologies and Pharmaceuticals (MTP) sector to address data access, integration and analytics capacity issues. CRC-P partners included Janssen-Cilag Pty Ltd and the University of NSW. Prospection and its partners invested \$525,000 in cash (as well as in-kind contributions) in the project. Revenues attributable to the CRC-P are expected to be \$8 million in 2021 and forecast to be around \$11 million in 2022. Investors were influenced by the CRC-P grant, with \$10 million raised in 2019.



Prospection notes the following impacts its technology makes:

Patient insights — provided through AI-based algorithms from millions of patients that can be used to develop individual treatments.

Tactics and patient findings — analytics allow for early identification of untreated and undertreated patients for more than 90 diseases.

Real-world evidence — more data across larger demographic cohorts allows for better decision-making using Prospection statistical software.

Decision support — provided to clinicians on therapeutic information and other supports directly through clinician software.

Other realised and expected benefits include:

- Increased return on investment – increased returns on the \$1 billion per year R&D investment made by the local MTP sector boosting submission success, cost savings, new product launches, health benefits, and profitability.
- Increased licence income – MTP firms will have stronger evidence of the value of their products and R&D projects, increasing the potential for economic inflows through licensing, partnering and third-party investment.
- Increased capital value of CRC-P partners – successful capital raise due to CRC-P collaboration, expansion into Asia, and platform development.
- Improved health and well-being – health benefits arising from the increased success of R&D investments made by the MPT sector.
- Increased employment – the CRC-P contributed to a doubling in full-time equivalents (FTE) from 30 to 60, and they now employ approximately 100 FTE.

Source: Completion Report, ACIL Allen analysis, related reports and websites such as <https://www.prospection.com/>; picture credit National Cancer Institute on Unsplash

6.1 Completed CRC-Ps

Table 6.1 presents an overview of the 30 completed CRC-Ps included in this assessment. On average, each CRC-P received a grant of \$1.9 million and, collectively, there was a total of \$57.13 million in government funding across the 30 CRC-Ps (total project value across the 30 CRC-Ps was \$173.7 million with an average project value of \$5.8 million). The average project duration was 2.63 years, with most projects given a duration of three years.

Table 6.1 Overview of assessed CRC-P grants

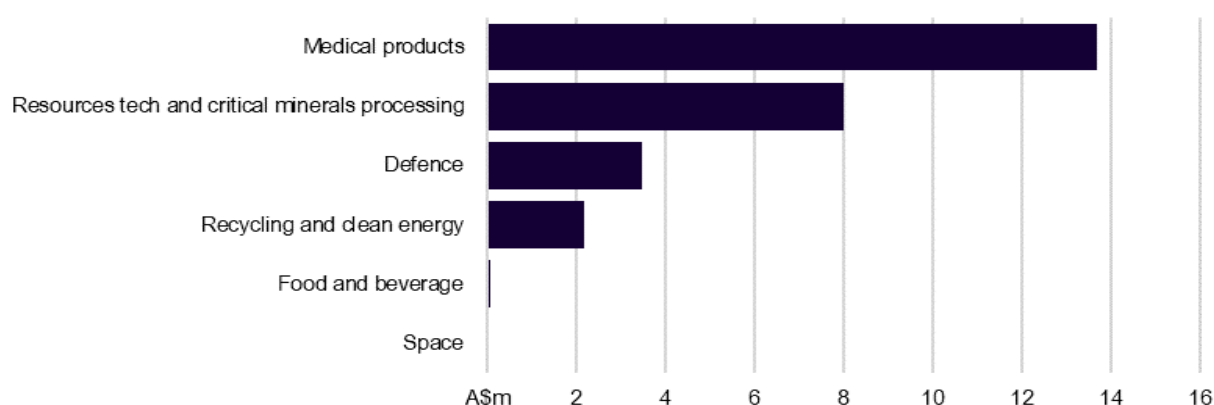
Metric	Measure
Number of completed CRC-Ps analysed	30
Average CRC-P grant amount	\$1.9 million
Total CRC-P grant amount	\$57.13 million
Average project duration	2.63 years

Note: 30 CRC-Ps were complete at the time of analysis in May 2021.

Source: ACIL Allen; CRC-P Selection Round Applications

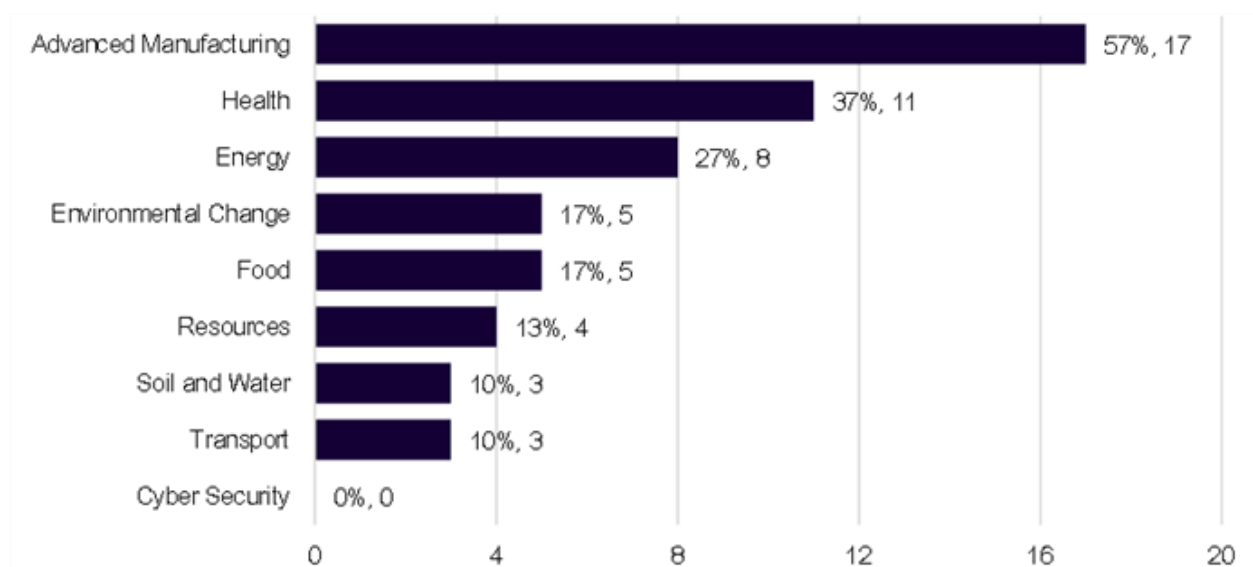
The alignment of the 30 completed CRC-Ps with the Government's National Manufacturing Priorities has been analysed. Six were characterised as medical products (20 per cent), and four with resources, technology and critical minerals processing (13 per cent). Projects had a lower level of alignment with the recycling and clean energy (7 per cent), defence (7 per cent), and food and beverage (3 per cent) sectors, and no CRC-Ps aligned to the space sector. Half of the CRC-Ps did not align with the National Manufacturing Priorities (see Figure 6.2).

Figure 6.2 Alignment of the 30 completed CRC-Ps outcomes with National Manufacturing Priorities



Source: ACIL Allen.

CRC-P alignment with the Government's Science and Research Priorities was also analysed, noting that CRC-Ps could align with multiple priorities. More than half of the 30 CRC-Ps aligned with advanced manufacturing (57 per cent). There was also a strong level of alignment with the health sector (37 per cent), and the energy sector (27 per cent). Five of the 30 CRC-Ps (17 per cent) aligned with both the environmental change and food sectors. There have been no CRC-P completions linked to the cyber security sector (see Figure 6.3).

Figure 6.3 Alignment of completed CRC-Ps with Science and Research Priorities (30 projects)

Source: ACIL Allen; CRC-P Grant Applications. Note: Some CRC-Ps aligned with more than one priority, and some projects didn't align with any priorities.

Box 6.3 Future Oysters CRC-P

Australian Seafood Industries (ASI) is an industry-owned research and development company formed in 2000, specialising in an Australia-wide Pacific Oyster selective breeding program. In 2016, ASI was awarded a \$3 million grant over three years. The project aimed to rebuild and evolve the Australian oyster aquaculture industry by accelerating the breeding of disease-resistant oysters, disease management and productivity. CRC-P partners included:

- Select Oyster Company Pty Ltd, Oysters Australia Ltd, The Yield Technology Solutions
- SA Department of Primary Industries and Regions, NSW Department of Industry
- Fisheries Research & Development Corporation (FRDC), CSIRO, and
- The University of Tasmania, Flinders University, The University of Newcastle, The University of Adelaide, University of Technology Sydney, University of the Sunshine Coast, Macquarie University.

ASI and its partners invested more than an additional \$2 million in cash (as well as in-kind contributions) in the project.

In conjunction with other research projects – this selective breeding program enabled the Tasmanian industry to recover from Pacific Oyster Mortality Syndrome (POMS) in under three years. This is considered a resounding success, essentially 'saving' the Tasmanian oyster industry, which, in 2017-18, had a gross value of production of \$23 million.



ASI's breeding programs have been accelerated for disease resistance leading to the supply of broodstock for Pacific Oysters, with 95 per cent of seed derived from the seeding program developed through the CRC-P.

The breeding program has protected the South Australian oyster industry from POMS by making resistant broodstock available.

Benefits for Australian oyster growers are expected to be \$64 million over the years 2019-2025, with 80 per cent of this benefit attributable to the CRC-P.

Other realised and expected benefits include:

- Business success – better farm management strategies and more resilient farming systems leading to improved profitability.
- Education and training – five scientific journal articles have been published, seven FRDC final project reports and 36 short newsletters and reports produced for the industry, and 130 industry communications (presentations, newsletters, website). There were also seven work experience, graduate and postgraduate students engaged.
- Change in character of the local community – increased confidence of Pacific Oyster growers in the aftermath of POMS to reinvest in their business. This also led to positive mental health outcomes for owners and employees by providing hope for profitability and sustainability.
- International collaboration – collaboration between researchers and international industry and colleagues that have experienced POMS plus a number of presentations at international conferences overseas.
- Reduction in environmental costs – through improved biosecurity and surveillance outcomes.

ASI won a Research, Development & Extension award in the Tasmanian and National Seafood Industry Awards.

Source: *End of Project Report, ACIL Allen analysis and related reports and websites such as <https://www.asioysters.com.au/> <https://www.frdc.com.au/fish-vol-27-3/poms-where-pacific-oyster-industry-now> https://www.imas.utas.edu.au/data/assets/pdf_file/0007/1308067/Economic-Contributions_TAS-Summary_NOV2019.pdf; picture credit Sarah Ugalde, IMAS.*

Box 6.4 Translational R&D to accelerate sustainable omega-3 production

Qponics is an agritech company aiming to produce high-value nutraceutical and food supplements and food protein from marine microalgae. In 2016 Qponics was awarded a \$1 million CRC-P grant over two years to commercialise high-quality algal omega-3 products. The project aimed to translate proof-of-concept technologies to achieve sustainable, organic production of omega-3 fatty acids. CRC-P partners included Nutrition Care Pharmaceuticals Pty Ltd and The University of Queensland.

Qponics and its partners invested more than \$354,000 in cash (as well as in-kind contributions) in the project. CRC-P funds allowed for Qponics to expand from an R&D-scale pilot algae farm to a small, commercial operation, and Qponics has continued to fund the facility. In 2021, Qponics was announced as an industry partner in the \$270 million CRC for Marine Bioproducts (MB-CRC).



John Gunn, Chair of the MB-CRC has stated:

“Qponics is an excellent example of a new generation of the emerging marine bioproducts industry, having already collaborated with the University of Queensland and invested in building their capability to grow commercial quantities of microalgae to scale up production and invest in the development of market-ready products to value add to their business”.

Estimated economic benefits from the sale of products are approximately \$170 million, largely to be realised between 2022 and 2025. Of this, approximately 90 per cent is attributable to the CRC-P investment.

Other realised and expected benefits include:

- Education, training and labour force participation – new employment and training due to the establishment of new farms near cities and regional areas.
- Improved health outcomes – health benefits from an increase in the availability of algal omega-3 oil for vegetarians and people who choose not to consume fish or fish oil.
- Education and training – various site visits, an international visiting chemical engineer, support to graduate students and visiting scientists to carry out projects.
- Business diversity and resilience – the project has demonstrated that marine microalgae farming as a drought-proof form of agriculture for Australia that can produce 30-70 and 10,000 times more protein per hectare than livestock or conventional crops, respectively. There is also potential to create a future educational and tourism facility in the region.
- International collaboration – the CRC-P has engaged with Australian and global food producers with an interest in securing a future supply of algal omega-3 oil and algal high-protein biomass as new vegetarian food ingredients.
- Reductions in environmental costs – environmentally sustainable production of food ingredient products from algae.

Source: End of Project Report, ACIL Allen analysis and related reports and websites such as <https://qponics.com/> , <https://cloud.hitservices.com.au/index.php/s/oThNbA1nkKr1rgm> ; picture credit Qponics

Box 6.5 Universal Solar Module Inspection and Data Storage System

A spin-off from the University of NSW's Photovoltaic (PV) and Renewable Energy Engineering School, BT Imaging Pty Ltd is a global leader in materials and device inspection solutions for solar modules. Awarded a CRC-P grant of just over \$1.8 million in January 2017 for 23 months, BT Imaging designed a Universal Solar Module Inspection and Data Storage System. The CRC-P partners included PV Lighthouse Pty Ltd, 5B, and the University of NSW. The system is aimed at improving the performance of large-scale PV installations, reducing costs and improving the reliability and bankability of PV power.



BT Imaging and its partners invested more than \$1.4 million in cash (as well as in-kind contributions) in the project. In 2019, BT Imaging was awarded an ARENA Program grant of \$1 million to take this system to large-scale field trials and assist with commercial development.

The economic benefit is estimated at around \$26 million. The CRC-P has taken the system from the design stage to commercialisation. This economic benefit is largely due to sales with \$17 million anticipated for 2022-25. As a result of the CRC-P BT Imaging capital value has increased.

Other realised and expected benefits include:

- Training and education – new postgraduate degrees awarded, and one Postdoctoral Fellow engaged on a full-time basis on the project as well as the funding of a PhD student.
- International collaboration – new collaborations established with organisations outside Australia to test the concept and product prototypes.
- Publications – two publications or reports for industry users published.
- Reductions in environmental costs – reduced manufacturing costs will escalate the take-up of PV globally.

The University of NSW lists BT Imaging as a collaborating industry participant with an exchange of ideas, research collaboration and shared student supervision. Several conference papers have been presented and a journal paper issued (under review), with 69 patents maintained during the funding period.

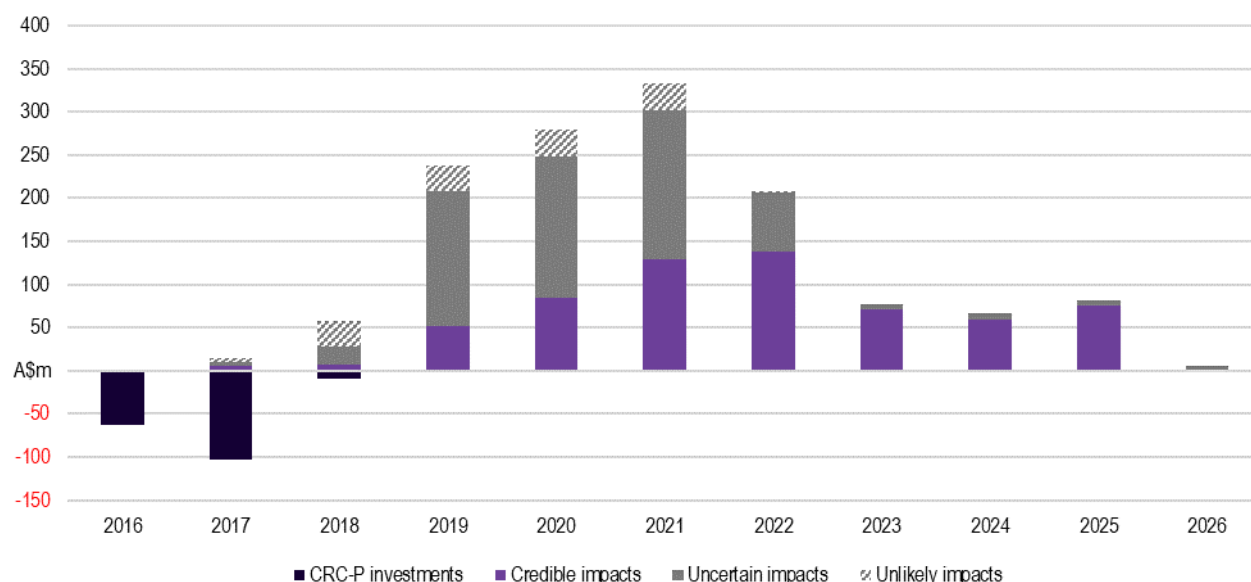
Source: End of Project Report, ACIL Allen analysis and related reports and websites such as <https://www.btimaging.com/about> , <https://arena.gov.au/projects/bt-imaging-lis-m1-solar-module-inspection-system/> ; picture credit Science in HD on Unsplash

6.2 Impact of CRC-Ps

ACIL Allen conducted a cost-benefit analysis based on the government investment (CRC-P grants) for 30 completed projects. Two analyses were undertaken — one which focused on the government contribution (\$57,129,219) and one which focused on the full project costs (\$173,726,667).

The economic benefits were estimated from a variety of sources, including end of project reports, applications, survey responses and discussions with stakeholders.²⁶ In a manner similar to the CRCs, the impacts have been assessed based on the probability and have been classified as being credible impacts, uncertain impacts, and unlikely impacts. This has been done as it is often difficult to determine the efficacy of benefits and also to determine whether they have been realised or not. A breakdown of impacts is presented in Figure 6.4.

Figure 6.4 CRC-P distribution of impacts by year (government costs only) for completed CRC-Ps, realised and imminent



Source: ACIL Allen

With a focus only on credible impacts (see Appendix B, Table B.4, the analysis gives a ratio of 7.73:1 for impacts versus government investment and a benefit-cost ratio (BCR) of 2.54 when all project costs are taken into account (see Table 6.2).

Table 6.2 Benefit-cost analysis and sensitivity (provisional)

	BCR (7% discount rate)	Net present value (NPV) (5% discount rate)	Net present value (NPV) (7% discount rate)	Net present value (NPV) (10% discount rate)
Government contribution only	7.73	\$527,732,231	\$514,442,033	\$495,467,769
Full project costs	2.54	\$383,703,559	\$358,120,125	\$319,175,228

Note: All dollars in 2021 prices. Non-government partner contributions include contributions by the private sector and other research institutes. Discount rates of 5% and 10% are used to show sensitivity to this rate.

Source: ACIL Allen

These estimates are conservative as they only focus on credible economic impacts. In addition to the economic benefits, there are social and environmental impacts (see Appendix B, Table B.5) which, if quantified and included in the analysis, would increase these BCRs.

²⁶ Social and environmental benefits are hard to quantify and would require significant caveats to be made. They have been excluded from this analysis.

6.2.1 Educational outcomes of CRC-Ps

The 30 completed CRC-Ps have produced various educational outcomes, including postgraduate researchers, publications and other forms of training. A summary of these outcomes across the 30 CRC-Ps is provided below:

- 47 internships, secondments or student placements facilitated
- 90 publication reports for industry users and scientific journals published
- 85 structured professional training courses/conferences/workshops delivered, and
- 14 PhD students or Postdoctoral Fellows funded.

A detailed breakdown of educational outcomes by CRC-Ps is provided in Appendix Table B.5.

6.2.2 Future evaluation of the CRC-P element

Evaluating the CRC-P program element early into its life and in the midst of an ongoing pandemic can provide only a limited view of its success. Completed CRC-Ps have been granted about 17 per cent of all the funds announced under the CRC-P element to date. A more thorough review of the CRC-P element will need to occur once more projects have been completed, and in the context of the coincidental COVID-19 pandemic.

Of those CRC-Ps investigated — the 30 completed, and those who provided survey information on anticipated impacts — a common theme was that they had difficulty tracking and articulating the benefits they were anticipating generating. There were sizable and unexplainable differences in the anticipated benefits listed in grant applications, End of project reports, and survey responses. CRC-P partners appear to view reporting on economic benefits generated as either a secondary requirement, or that gathering the information is too time-consuming.

Having a better understanding of the reasons why actual outcomes were different from those anticipated could, over time, help to identify any common issues that led to better (or worse) outcomes.

It should be noted that the CRC Association is increasingly engaging with CRC-Ps. The Association provides workshops and information sessions to CRCs on measuring research impacts, and it is expected that the Association will increasingly offer these sessions to CRC-Ps. These engagements are expected to increase CRC-Ps awareness of the importance of documenting project benefits and provide guidance on the calculation of impacts.

If CRC-Ps still experience difficulty articulating project benefits following guidance from the CRC Association, the Department could consider implementing processes to further support CRC-Ps in identifying impacts. As just one example, a tailored impact tool, similar to the tool provided to CRC applicants, could be developed to assist CRC-Ps to collect and document benefits over the course of the project. The quality of the information gathered on CRC-P outcomes will be fundamental for understanding the success or failure of the CRC Projects element of the CRC Program. Department CRC-P liaison officers can also assist CRC-Ps with measuring and documenting benefits.

7 Program assessment

This Chapter discusses issues that influence the quantity and quality of the outcomes and impact achieved by the CRC Program. It discusses issues raised by CRC Program stakeholders and partners during consultations.

7.1 Program-wide issues

7.1.1 The need to encourage industry-researcher collaboration

Australia is widely regarded as having strengths in basic research. This is reflected in international awards such as Nobel Prizes. Australian postdoctoral researchers are sought after by research organisations in other countries. ARC analysis indicates that most research funded through Discovery Grants is world-class. However, OECD and WIPO²⁷ data show Australia's track record in commercialising research outcomes is weak.

Australia has a higher proportion of research undertaken in higher education institutions than other OECD countries.²⁸ Commercialising research outcomes is essential if Australia is to capitalise on its research strengths and drive industry innovation. OECD data on the extent of collaboration indicates that Australia needs to improve its industry-researcher collaboration performance if we want better commercial outcomes.

The latest ABS data²⁹ confirm that Australian industry R&D is weak by OECD standards. Only 1.6 per cent of innovating businesses in Australia collaborate with university researchers. Thus, there is considerable scope to gain significant national benefits from increasing researcher-industry collaboration.

Stakeholders identified an ongoing opportunity and need for the Australian economy to secure greater benefits from collaboration between industry and researchers. OECD data shows that Australia underperforms in this area. However, the CRC Program funding, on its own, is insufficient to address this issue. Stakeholders agree that Australian Government intervention is justified and want to see more funding for the Program. For example:

"This is a crucial program to retain" (State Govt Chief Scientist)

"CRCs address long term systemic problems that industry needs research to address" (Growth Centre CEO)

Some have pointed to larger interventions in support of research cooperation and collaboration in other countries. Others referenced the ACOLA SAF09 report, which shows how Australia lags behind other countries in the range of measures to encourage university-industry interaction. An Australian Bureau of Statistics report found that total spending by Australian businesses on

²⁷ WIPO 2020, Global Innovation Index: Australia.

²⁸ Innovation and Science Australia 2017, Australia 2030: prosperity through innovation.

²⁹ ABS 2021, Research and Experimental Development, Businesses, Australia, released 3 September 2021.

research and development remains at 2012 levels.³⁰ Business expenditure on R&D (BERD) was \$18.17 billion in 2019-20, slightly below the \$18.32 billion that businesses spent in 2011-12 in today's prices.

The ABS found Australia's overall spending on R&D — by governments, businesses, universities and not-for-profits — as a percentage of GDP fell dramatically from 2.11 per cent in 2011-12 to 1.79 per cent in 2019-20. This compares with comparable OECD nations, with countries like Germany, South Korea and Switzerland spending more than 3 per cent of GDP on R&D.

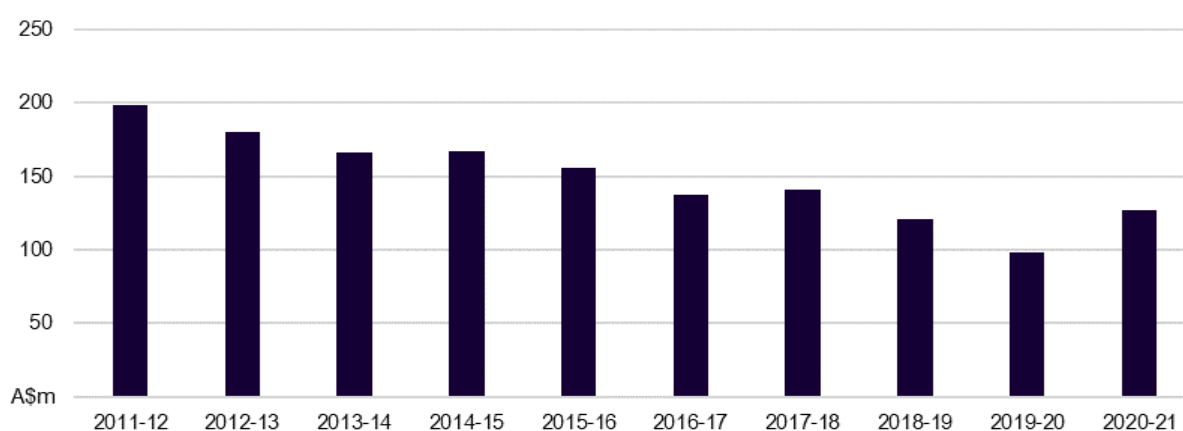
Professor Roy Green, a special innovation advisor to the University of Technology Sydney and the author of a seminal report on Australia's innovation system for a Senate inquiry, noted that other advanced economies were increasing investment in research and innovation; however, the latest ABS data suggests that Australia has not followed suit.³¹

He went on to say that:

The overall picture would have been even worse but for higher education expenditure on R&D increasing by around a third over this period, as both business and government spending flat-lined. This was largely due to the contribution of international student fees to university revenues, a contribution which can no longer be counted on to support the otherwise strong performance of Australian universities in either research or teaching.

Real annual funding for the CRCs is shown in Figure 7.1. Real funding has decreased year-on-year over the period. The high point of the funding for the Program was in 2008, when \$266.1 million of funding was made to the CRCs — approximately 2.7 times as much as the amount available in 2020.

Figure 7.1 Government funding to CRCs, 2021 dollars



Source: ACIL Allen

As shown in the economic impacts (see Chapter 3), the direct economic impacts of CRCs and their impact on GDP are substantial and continues to generate high returns. Evidence gathered as part of their review, including stakeholder views, give no reason to question whether this performance could continue.

³⁰ <https://www.abs.gov.au/statistics/industry/technology-and-innovation/research-and-experimental-development-businesses-australia/latest-release>, accessed September 2021.

³¹ <https://www.aumanufacturing.com.au/business-spending-on-rd-has-flatlined-in-australia> accessed September 2021.

RECOMMENDATION 1

The CRC Program is achieving excellent economic, employment, research and commercialisation outcomes as shown by this impact analysis. New opportunities could be addressed by the CRCs and stakeholders see significant opportunities for further investment. There are opportunities for CRCs to be established in new areas (such as proposals that involve the application of synthetic biology or artificial intelligence) and in areas which are currently under-served. **This evaluation recommends that future efforts to drive industry growth and innovation should leverage the Program's success and consider further investment in both CRCs and CRC-Ps, as proven ways to drive industry-research collaboration.**

7.1.2 Mechanisms to encourage industry-research collaboration

ACOLA (2015) has identified a range of measures used in other countries to encourage industry-researcher collaboration. These include government procurement such as the US SBIR Program; business incubators and accelerators, which, with government backing, have grown in numbers over the last two decades; large-scale international consortia such as those found in the EU; and national grant-based programs similar to the Australian CRC Program. Australia's CRC Program is well-known among OECD country policymakers and has inspired several similar initiatives.

The ability of the CRC Program to lift industry-researcher collaboration is largely a function of the funding allocated to it. And as the Miles Report noted:

"While the CRC Programme attracted some criticism from stakeholders for failing to lift Australia's industry and research collaboration, it needs to be understood that it is only one component of the Australian science, research and innovation landscape."

Miles 2015, Op Cit, page 24

Although no one single government initiative is suitable for driving industry-researcher collaboration across the economy, the 'generally available' nature of the CRC Program has proved able to meet the requirements of sectors such as agriculture and services. In Australian agriculture, farmers have traditionally relied on research organised through the Rural R&D Corporations. However agricultural CRCs have found niches and have achieved outcomes that demonstrate the Program's usefulness in this sector. In the services sector, R&D is sometimes difficult to define (for example, in software development). However, there have been very successful CRCs in this area too.

The conclusion from the above is that the CRC Program is versatile, flexible and able to address the needs of the various sector of the Australian economy.

7.1.3 Other factors that create a need for collaboration incentives

Most public sector researchers know that their promotion prospects and their next job often depends on their publication and citation record. Recognition of research work by peers is widely considered to be a valuable measure of research novelty and quality. Public sector researchers perceive that research collaboration reduces their prospects for publications because industry partners tend to want to keep research outcomes for themselves (especially when they have contributed to research costs). In addition, it is sometimes perceived that ideas are being taken by industry without adequate recognition of researcher inputs.

These sorts of issues have been successfully addressed by CRCs, but they continue to inhibit industry-researcher collaboration.

7.1.4 Is the CRC Program fully addressing the need?

The need for the CRC Program can be gauged, in part, from the demand for funding. The number of high-quality applications per round for both CRCs and CRC-Ps indicates the level of interest in industry-researcher collaboration. However, low success rates for applications may discourage applications (i.e. application numbers could be higher if there were a greater chance of receiving a grant).

High transaction costs are also a barrier to attracting proposals. The cost of preparing a successful CRC application is relatively high. It requires a significant commitment of time and resources to engage in discussions with potential partners and prepare the application. In addition, partners are asked to make 7 to 10-year commitments, which can also be a barrier, especially for SMEs.

7.1.5 To what extent should the CRC Program reflect government priorities?

The Australian Government has a range of research priorities in different areas of the economy. They can be found in agriculture, manufacturing, cybersecurity, health and the environment. A 'generally available' measure such as the CRC Program can potentially address government priorities across the economy. ACIL Allen agrees with the Miles Report, which, while recognising the importance of priorities, commented that:

"... the (CRC) programme should continue to be available to all industry sectors."

Miles 2015, op cit. page 8

Setting priorities has been seen as a means of focussing limited government resources on areas of importance. However, priorities are often described in terms that are so broad that they can accommodate an extensive range of proposals.

Government priorities change from time to time. However, the CRCs are designed to support longer-term collaborations. A CRC established in 2012 may well not reflect the priorities of 2021. In ACIL Allen's view does not diminish the relevance or usefulness of a CRC established in 2012. But it does make it difficult to comment on how well the CRCs active in the period 2012-20 have met government priorities, given the changes over the period.

Some priorities were a feature of CRC selection rounds 13 to 16, such as priorities including lean manufacturing, social innovation and sustainable regional communities. Likewise, CRC-P priorities have included: Round 4 (Advanced Manufacturing), Round 6 (Artificial Intelligence), Round 7 (Critical Minerals), Round 8 (Plastics waste and recycling, and critical minerals), Round 10 (waste and recycling), as well as the Developing Northern Australia Round.

In comments to this evaluation, some stakeholders saw merit in having special rounds on topics that the Government had identified as high priorities. However, a number of stakeholders were critical of the inadequate lead time for the preparation of proposals. This could make it difficult to prepare a high-quality application and, at worst, lead to applications for potentially highly relevant work not even being submitted.

This problem was already noted in the Miles Report:

"... stakeholders questioned the value of having priority areas in this way, particularly as they are unpredictable and typically announced at the same time as the opening of the selection round which leaves minimal time to develop quality applications."

Miles 2015, Op Cit. page 22.

RECOMMENDATION 2

From time to time, Governments have decided to commit a funding round to a priority area. The very nature of these priorities makes it likely that consortia will take time to form. It is important that there is sufficient time for the strongest possible proposals to be developed. **It is therefore recommended that, should the Government decide to have a grant round on a priority area, then it should provide some additional lead time.**

Australia's National Manufacturing Priorities are relatively recent and intended to deliver long-term, transformational outcomes for the Australian economy:

- Resources Technology & Critical Minerals Processing
- Food & Beverage
- Medical Products
- Recycling & Clean Energy
- Defence
- Space

Since their introduction, these priorities have applied to CRC-P Round 11 and CRC Round 23, so it would be premature to form a view on their impact. But arguably, with the possible exception of space, they are well covered by existing CRCs. In CRC-P Round 11, 70 per cent of the funding was available for projects with a focus on NMPs. CRC-Ps appear to generally reflect the NMPs (see Figure 6.2).

Other relevant priorities include Australia's Science and Research Priorities dating from 2015. They include Food, Soil and water, Transport, Cybersecurity, Energy, Resources, Advanced manufacturing, Environmental change and Health. Although these appear very broad, more detail was provided to define each priority more precisely. There are also Industry Knowledge Priorities that relate to the Industry Growth Centres.

7.1.6 Selection processes

Selecting the best proposals is critical to the success of the Program. The Advisory Committee charged with this role is significantly smaller than its predecessors and has the additional workload of the CRC-P element of the Program. A number of stakeholders and partners feel that the Committee should have more members to cover the wide range of research activities being put forward in proposals. ACIL Allen shares this view.

There is also concern that the Advisory Committee is advised by the Industry Growth Centres, some of which are conflicted because they are involved in supporting some proposals. This issue is well known in the research community and is a source of concern. The Miles Report also saw this as an issue:

"... where a Growth Centre is involved in assembling the consortia, or driving the application, independent review will be an imperative."

Miles 2015, Op Cit, page 29

In addition, if the Growth Centres cease to operate, that source of advice for the Advisory Committee would no longer be available. The Advisory Committee should have the ability to seek expert advice from persons who are not otherwise involved in CRC or CRC-P proposals. This is important as it would be difficult for Advisory Committee members to have expertise across the entire range of topics the Committee might need to assess applications on. This could be particularly relevant if the Government decides to hold a special round in an emerging area where specialised advice may be needed to assess the applications.

ACIL Allen's experience with other grant selection committees supports the view that the size of the Advisory Committee should be increased and recommends that it should have around fifteen members to reduce the workload on individual members and provide a broader range of expertise. In addition, the Committee should be encouraged to seek expert advice from independent external sources when necessary.

RECOMMENDATION 3

The success of the program is contingent on the Advisory Committee determining which proposals should be recommended for funding across a wide range of technologies for both CRCs and CRC-Ps. The Committee is challenged by the numbers of grant applications (especially since the start of CRC-Ps) and new areas of research. It is important that the range of experience, knowledge and skills available to the Committee is sufficient to perform its work credibly without making undue demands on the time of its members. **It is therefore recommended that the Government consider increasing the size of the Advisory Committee. This evaluation recommends that the Committee size be increased to around fifteen members.** The Committee should also be encouraged to continue to seek external advice, particularly where specialist expertise may be required.

7.1.7 Impact of COVID-19 on CRCs and CRC-Ps

ACIL Allen asked CRCs and CRC-Ps about the impact of the COVID pandemic on their work. The most common responses were project delays due to:

- Lack of access to research facilities
- Partners (both industry and research) experiencing cash flow problems
- Supply chain problems with the importation of materials
- Inability to travel both domestically and internationally
- Delays in postgraduate student recruitment
- Partner's staff diverted from CRC work to other activities
- Difficulties in attracting qualified staff from overseas
- Some research activity diverted to addressing COVID-related medical equipment needs

The extent of the impact on CRCs varied from very little to quite severe, with about 20 per cent of survey respondents reporting effects at each end of that spectrum. The consequences of delays will be reflected by delays in outputs and impacts in future years.

A number of CRCs³² reported negative impacts of COVID-19 on their research in their Annual and Exit reports, such as the inability for partners to meet and host research forums and collaborative events.

For example, CRC CARE, whose work was mentioned earlier in this report, advised that COVID-19 was the major impediment to its activities in 2019/20. The closure of campuses in response to the COVID-19 pandemic compromised the ability of CRC CARE to meet a number of its remaining milestones, even leading to a 12-month protracted wind-up of the CRC to 30 June 2021.

It is also essential to consider how the COVID-19 pandemic may have changed the context of some CRC's research or even provided insights into research affecting the environment.

For example, congestion reduction is a key objective of iMove CRC. iMove CRC has reported that COVID has impacted on how it understands congestion and public transportation use, and it is now running a suite of projects on how COVID experience can be used to create working and transport arrangements that reduce peak and overall traffic. The iMove CRC has committed to furthering its understanding of working arrangements gained through and post-COVID, which will produce findings with potential impacts.

7.1.8 Program administrative efficiency

Administrative overheads for research grant programs can vary, depending on:

- Number of grants being administered at any one time
- Reporting/monitoring requirements
- Numbers of applications received, and
- Whether or not assessors and selection committee members are paid.

Some high-profile programs are labour intensive, requiring frequent Ministerial briefings, site visits and negotiations with grant recipients. When there are significant numbers of applications, but a low success rate, the cost of reviewing unsuccessful proposals drives up the overhead costs in relation to grant funds allocated. Some programs, such as those of the ARC, rely on the goodwill of previous grant recipients to review applications without receiving payment. On the other hand, applications to the former Industry R&D Board required expert assessment of business plans, due diligence on the companies involved and technical review. Some of these assessment activities had to be commissioned from outside the Department at a cost to the grants program.

ACIL Allen has reviewed a large number of research grant programs at federal, state and R&D Corporation levels. Departmental administrative costs tend to fall in the range of 4-10 per cent. From an analysis of the appropriations in the period 2012-20 and feedback from stakeholders, it appears that the Program is being administered efficiently.

³² For example, Rail Manufacturing CRC, SmartSat CRC, Bushfire and Natural Hazards CRC and Future Battery Industries CRC reported on disruptions due to the COVID-19 pandemic.

7.2 CRCs

7.2.1 Should CRCs be granted extensions?

Following the 2008 O’Kane Review, the Government decided to limit CRC funding to 15 Years. The 2015 Miles Report’s recommended:

“CRC funding should be limited to a maximum of up to 10 years with no extension of funding. Given the focus on shorter term research, CRC-P funding should be limited to a maximum of up to 3 years with no extension of funding.”

Miles 2015, Growth through Innovation and Collaboration: A Review of the Cooperative Research Centres Programme, Recommendation 11

One factor that appears to have influenced this Miles Report recommendation was that the review took place “against a backdrop of fiscal restraint”. Stakeholders and partners consulted for this impact evaluation have argued that extensions should be permitted in some circumstances, such as when clinical trials are required to achieve commercialisation. They have also suggested that the current ‘no extension’ policy inhibits CRCs from undertaking larger scale, and more ambitious longer-term projects because of the risk of not reaching a point where research outcomes can be licensed or transferred to a start-up before funding ceases.

Such premature closing of a CRC can also result in the impact of the research collaboration not being well captured by the partners. An example was cited where one CRC closed with no real economic outcomes as a result of the no-extensions policy. One of the most successful CRCs, which was working in a challenging technology (Photonics), had a relatively long lifetime, and this enabled it to achieve some very significant outcomes that arguably could not have been realised in a ten-year period.

The challenges of delivering impact may be more acute for CRCs that are only granted funding for around six years. Considering the time needed for a CRC to start-up and wrap-up, the time realistically available for research could be reduced by as much as 30 per cent. In addition, if unexpected events (such as the COVID-19 pandemic) occur and delay or hinder research, then this could further reduce the ability of the CRC to deliver impact (see section 7.1.7).

The difficulty with the no extensions policy is that it is a one-size-fits-all approach. ACIL Allen considers that the policy to not allow extensions may discourage CRC applications from more ambitious research collaborations and, in some cases, prevent or limit the full realisation of impact. There should be scope for CRCs that can make a convincing case for an extension, to be granted an additional period of funding for up to five years (which would provide a balance between the Miles Report comments and the needs discussed above).

RECOMMENDATION 4

Currently, CRCs are funded for a period of up to 10 years. However, in some circumstances, particularly in medical research (e.g. where clinical trials are involved), exceptional circumstances arise where a longer funding period is desirable to secure the best return on investment. **It is recommended that the Government should allow for a degree of flexibility, in limited circumstances, to provide scope for CRCs to be extended with additional funding.** It is suggested that such extensions of funding should be for up to five years where a clear case can be made.

7.2.2 What factors contribute to a successful CRC?

ACIL Allen was asked to consider the main factors contributing to (CRC and CRC-P) outcomes. Stakeholders and partners identified a variety of possible factors, based on their personal experience with CRCs. The major factors identified were:

- Funding — partners emphasised that, without this funding, the outcomes achieved would likely have not happened
- CRC leadership — the management team of a CRC is considered to be critical in driving outcomes. This is probably less relevant for CRC-Ps, which operate on a much smaller scale with fewer partners. Some partners and stakeholders consider that an industry background is an asset for a CRC CEO. However, others point to successful CEOs that came from a research background.
- A history of collaboration – If there is a history of collaboration between the parties prior to the CRC application, then this suggests that there is a high level of trust and understanding between the parties, which would bode well for the commercialisation of any eventual useful outcomes from the CRC. For example, the successful completion of a CRC-P would demonstrate the partners' ability to collaborate with each other to deliver the desired outcome (see also discussion in section 0)
- Industry role in proposal development — some commentators have suggested that successful CRCs often have had a strong industry involvement in developing their grant applications. The Advanced Automotive CRC has been cited as an example. However, some successful CRCs have operated in fields involving emerging technologies where there is little Australian existing industry. The Cancer Therapeutics and Photonics CRCs are examples of this.

The literature review (See Appendix C) identified that a liaison officer within both the research organisation and industry to take responsibility for industry-research relationships and 'span the boundaries' of the difference in both structural and cultural alignment is one approach to improve industry-researcher collaboration that has been successful elsewhere.

RECOMMENDATION 5

In some CRCs, particularly those with larger numbers of partners, keeping everyone 'on the same page' can be a challenge. This is important to achieving optimal returns. **It is therefore recommended that CRC partners aim to appoint liaison officers to improve the relationship between industry and research partners and help to span the boundaries between them.**

7.2.3 CRC starting and finishing periods

There are concerns about the processes involved in the start and finish of CRCs. Stakeholders believe that these could be made more efficient, allowing more time and resources to be applied to achieving impacts. ACIL Allen is aware of documentation available from the Department to assist in these processes. However, it is clear from our discussions that the existence of this material is not as widely known as it needs to be. Material on the Department's website goes part of the way to addressing this issue. However, partners appear to be unaware of what is available or whether it is appropriate to ask the Department for help and advice.

One stakeholder suggested that the Department should try to get the universities to agree on two or three models for sharing intellectual property.

One jurisdiction said that if they were part of a CRC that successfully obtained CRC funding, they would often provide some up-front funding support to help the CRCs navigate the start-up process. This initial support had helped to accelerate the commencement of CRC activity. Other new CRCs would also benefit from such support.

Several former CRC partners who were consulted complained about the difficulties and time involved in winding up a CRC. These partners spoke of some of the difficulties they faced in the wind-up process, particularly where there was a need for further work before research results could be fully commercialised. In more than one case, the Department had to be asked for extra time to complete wind-ups. However, there was a lack of knowledge of the different options available or what information might be available from the Department.

The Department should consult with CRCs at the early and late stages of their funding to ensure that they are aware of Departmental support material and should explore other ways to ensure that the existence of this material is better publicised.

Expediting start-up and wind-up processes is important. These processes:

- Take time and resources away from core CRC activity
- Delay the start of benefits
- Can result in reduced industry interest in the CRCs
- Put commercialisation of CRC outputs at risk
- Impact on the information gathered by the Department on CRC management and activities

The CRC Association may be a channel to get the availability of help in starting and finishing a CRC more widely known. In these discussions, the Department should seek to identify and fill any identified gaps in the information material that they make available.

RECOMMENDATION 6

Commencement processes for new CRCs can be difficult. Given the long lead times to impact, it is important that CRCs achieve a rapid start to maximise their productivity. **It is recommended that the Department continue to work closely with CRCs at early stages of their funding to reduce the time spent on start-up.** The Department should continue to allow the CRC early access to funding support once the contract is signed.

Some cases of long and complex wind-ups also appear to be affecting information gathered by CRCs on their activities. In looking into the economic impacts of the CRCs which have closed or are in the process of closing, it is clear that there is a significant variation in the quality and quantity of information and documentation collected and archived by the CRCs. This directly impacts the information available for impact evaluations in future years and outcomes after the close of the CRC.

RECOMMENDATION 7

Winding up a CRC should have been planned from the earliest stages. However, circumstances can change during the life of a CRC, making wind-up or transition to a new entity complex. Loss of key CRC personnel and momentum behind the endeavour can also complicate the exit process. **It is recommended that the Department continue to work closely with the CRCs on the wind-up process and including providing advice on exit options.** In addition, Exit Reports — which clearly identify outcomes and impacts — should be systematically collected and stored by the department for future research and evaluation purposes.

7.2.4 CRC selection process

Multiple stakeholders expressed concerns about low success rates in the CRC application process. Changes to the application process following the Miles Report were noted. But stakeholders and partners feel that the costs involved in preparing a bid are still significant and that too often, this effort is wasted. Examples of stakeholder comments on this issue include:

“... (when) success rates are too low, then industry will question value of putting in the effort required to apply. Funding is insufficient.”

CEO of a national science organisation

“If quality of applications is high, but success rate is low, then this suggests that more funding is needed.”

CEO, university organisation

Stakeholders speaking for the wider research community have particular concerns about this issue. There is a view among stakeholders that some high-quality applications are missing out because of a lack of funds. Low success rates may also be a barrier to industry, particularly SMEs, being willing to commit the time required to complete an application for funding.

There are also concerns about the time it takes from Stage 1 applications closing to an announcement of decisions on new CRCs. When this time period gets too long, industry partners can start to lose interest, which can hamper the eventual impact of the CRC. Having a long hiatus can also increase the time required to start-up a CRC in the event the application is ultimately successful.

RECOMMENDATION 8

The application process for securing a new CRC can be quite long. Delays in the period between submission of proposals and announcement of successful applications can result in a loss of impetus on the part of applicants. **It is recommended that the Department should make every effort to ensure that the time between Stage 1 applications closing and an announcement of successful CRCs is as short as possible.** Ideally, this should be no more than ten to twelve months.

7.3 CRC Projects

Miles suggested the creation of the CRC-P element of the Program to provide “a simpler entry mechanism and lower cost threshold to enable participation in the programme”. CRC-P applications involve much less cost and a shorter duration commitment. They are intended to deliver outcomes more rapidly and address specific and immediate needs of industry. CRC-Ps appear to be particularly well suited to SMEs, which often have limited resources and little research capacity.

Typical CRC-P partner comments included:

“Our industry was inspired by our CRC-P project.”

“The CRC-P program was seismic for our business.”

It has been suggested that some CRC-P partners may discover the benefits of research collaboration and subsequently become partners in CRC bids. That would be a useful outcome because it would signal a willingness to move from short term projects to more ambitious, longer-term collaboration. Only time will tell if this outcome is realised. However, the numbers of applications for CRC-Ps demonstrate that CRC-Ps are addressing an otherwise unmet demand.

CRC-Ps are not smaller CRCs — they have limited capacity to undertake administration on the grantee end. Our review of benefits showed that many CRC-Ps had trouble clearly identifying and quantifying their outcomes (for example, “improved profitability”). While CRCs may have residual resources to prepare Exit Reports, resources amongst CRC-Ps may be limited, as can be an understanding of the task. Some CRC-Ps were unable to articulate impacts.

The information on impacts of CRC-Ps appears mixed for this reason — some had limited information available or were unwilling to provide it to this review. One way to address this is for the Department to lower the costs of administrative activities by simplifying the reporting tool, providing more guidance, or make resources available to CRC-Ps.

RECOMMENDATION 9

Success of the CRC-P element of the program can be bolstered from early learnings from the outcomes on early-round CRC-Ps. At this stage, it appears CRC-Ps may have trouble articulating impacts and communicating challenges faced. **It is recommended that reporting is made as straightforward as possible, that the Department continue to improve reporting tools (aligned with the evaluation needs of DISER), and that Departmental staff should continue efforts to assist CRC-Ps in meeting their monitoring and reporting requirements.**

As only 30 CRC-Ps have been completed their projects and filed Completion Reports, it is too soon to fully assess the impacts of this element of the Program. However, the findings from the 30 completed and relatively representative CRC-Ps are positive. At this early stage, the results suggest that for every dollar invested by the Australian Government, there is a \$7.73 return in economic benefits. Some of the CRC-Ps reported outcomes different to those anticipated for a range of reasons. There is a case to investigate project failures early to understand CRC-P risks better and support future grant success.

From the completed CRC-Ps, and the grants issued by the time of this review, interim findings in relation to this element of the Program are as follows:

- There is a good mix of sectors represented in CRC-Ps
- CRC-Ps are catering for SMEs as well as larger businesses
- CRC-Ps enjoy strong stakeholder support
- These projects have increased collaboration between industry and researchers.
- The effects of COVID have further distorted recent CRC-P progress.
- As only 30 CRC-Ps have been completed their projects and filed Completion Reports it is too soon to assess the impacts of CRC-Ps fully.

RECOMMENDATION 10

The COVID-19 pandemic has had a significant adverse impact on the CRC-P element of the Program. Additionally, the number of completed CRC-Ps are low. The current cohort is therefore not optimal to form a definitive view of the success of this element. **This evaluation recommends that there should be a further evaluation of the impact of the CRC-P element of the Program when at least 80 CRC-Ps have been completed and impacts can be assessed.**

7.3.1 Additionality of the CRC-P program element

Unlike the CRC stream, the additionality of the CRC-P element is less clear; that is, the degree to which it encourages investment that would not have occurred otherwise. Whereas it would be difficult, if not impossible, to create CRCs without Australian Government support, smaller industrial research is carried out constantly.

The CRC-P program element encourages research partnerships (i.e. one small-to-medium, (typically) one large, and one Australian research organisation) that are somewhat unique. The main objective is to encourage SMEs to work collaboratively with researchers. However, additionality is still an issue, and measuring the extent of additionality of the CRC-P element is difficult.

One method to evaluate the additionality of CRC-Ps could be to conduct a survey of applicants who were close to receiving the grant but were unsuccessful. The survey could examine whether the project was carried out despite the absence of government funding. However, unsuccessful CRC-P applicants may be a difficult and sensitive stakeholder group to engage, especially since even successful CRC-Ps had limited capacity to respond to this study.

If a future evaluation were to test the extent to which CRC-Ps would have occurred without government support, a considered approach would need to be developed to engage unsuccessful CRC-P applicants. This process would need to be informed by the Department's awareness of any key stakeholder sensitivities. Previous ACIL Allen experience is that unsuccessful applicants are often very reluctant to engage with consultants to respond to questions about whether they went ahead with the research in the absence of a grant. To make it possible to have these conversations, the application guidelines need to make it clear that applicants have to agree that if they are unsuccessful that they can be contacted for a follow-up interview.

Recommendation 11

With any grants scheme, it is important to establish that the activities being funded are substantially additional to what might have happened in the scheme's absence. The CRC-P element of the Program will have its greatest impact where it is encouraging innovation that could not have occurred without a grant. **It is recommended that any future evaluation of the CRC-P program element should also test the extent to which the activities undertaken by the CRC-Ps would have occurred without government support.**

8 Conclusions, findings and recommendations

This Chapter summarises the high-level impacts of the CRC Program. It addresses questions posed by the Department and provides a summary of recommendations to strengthen the Program.

8.1 Overall findings

This evaluation has found the following impacts based on our economic analysis for both CRCs and CRC-Ps:

Economic impacts of CRCs

ACIL Allen has identified \$32.2 billion (2021 dollars) in economic impacts between 2012 and 2025. These impacts are made up of:

- 29 per cent *Tier 1* benefits (\$9.3 billion in 2021 dollars)
- 33 per cent *Tier 2* benefits (\$10.6 billion, reflecting benefits attributable to the CRCs, in 2021 dollars), and
- 38 per cent *Tier 3* benefits (\$13 billion of anticipated benefits in 2021 dollars).

This is based on government funding to the CRCs analysed in this evaluation of \$1.7 billion (2021 dollars).

ACIL Allen has also modelled a counter-factual in which the CRCs did not exist, and government funding could be used for other purposes. This CGE modelling provides an insight into the change in GDP over the period attributable to the CRC Program, and is inclusive of impacts measured in prior reports, which were still accrued in the 2012-2025 period. Based on the economic impacts reported above and residual economic impacts from prior to 2012, the Program, through its funding of CRCs, has increased GDP by \$13.3 billion using a seven per cent discount rate, typically used in government reviews. This is based on \$2.4 billion of government funding — resulting in returns of 5.61 to one. This compares with an equivalent ratio of 3.1 to one in the 2012 Allen Consulting Group Review. Over this same period, the Program has created an average of 2,445 FTE per year.

Since the CRC Program began operating in 1991, the counterfactual modelling shows that CRCs have delivered \$32.5 billion in current terms based on \$12.4 billion of CRC funding — resulting in returns of 2.61 to one, using a seven per cent discount rate.

Economic impact of CRC-Ps

The results of the CRC-P program element are still preliminary. Only 30 of the CRC-P grants have been completed, equivalent to about 17 per cent of grants allocated by dollar value. Many of the CRC-Ps have been further interrupted by the ongoing COVID-19 pandemic. A cost-benefit analysis of these 30 completed CRC-Ps shows that the credible economic impacts have resulted in \$514 million in net present value terms for a benefit-cost ratio of 7.7. Considering the full project costs has resulted in a net present value of \$358 million, for a benefit-cost ratio of 2.5.

8.2 Findings in relation to the evaluation questions

The research questions which were posed by the Department for this impact evaluation were listed in

Box 2.1. ACIL Allen’s findings in response to these questions are summarised in the Tables below, based on the analysis in the preceding Chapters.

Table 8.1 Program design

No	Question	Finding
1	What is the nature, magnitude and distribution of the problem or opportunity that the CRC Program is designed to address? Was federal government intervention appropriate? Is it still appropriate?	There is an ongoing opportunity and need for the Australian economy to secure greater benefits from collaboration between industry and researchers. Many stakeholders provided comments consistent with this finding. OECD data ³³ shows that Australia underperforms in this area. However, the CRC Program funding, on its own, is insufficient to address this issue (see section 7.1.1). Stakeholders agree that federal government intervention is justified and want to see more of it. For example: <i>“This is a crucial program to retain” (State Govt Chief Scientist)</i> <i>“The CRC Program is great. CRCs address long term systemic problems that industry needs research to address” (Growth Centre CEO)</i> There are larger interventions in support of research cooperation and collaboration in other countries (see literature review). The ACOLA SAF09 report ³⁴ show how Australia lags behind other countries in the range of measures used to encourage university-industry interaction.
2	Is the CRC Program consistent with the Government’s current strategic policy priorities (Science and Research Priorities, Industry Knowledge Priorities, CRC-P priority areas) and forward priorities (e.g. National Manufacturing Priorities)? Is the CRC Program well integrated and positioned alongside other Government programs?	Stakeholders and CRC partners consider that nearly all the CRCs awarded since 2012 relate to a government-identified priority. Since their introduction, National Manufacturing Priorities have been well addressed by both CRCs and CRC-Ps. ACIL Allen analysis supports this view (see sections 3.3.2, 6.1 and 7.1.5). The Advisory Committee has recognised CRC-P priorities, including artificial Intelligence, critical minerals, waste and recycling when recommending projects for funding. The CRC Program does not duplicate other Government programs. Other programs are smaller in scale (ARC) or do not focus on industry-research collaboration (Manufacturing Collaborative Grants). A senior university group representative of noted: <i>“There are no other programs that successfully deliver university-industry collaboration like the CRC Program”</i>
3	Is the CRC Program an appropriate mechanism to address the problem or opportunity it was designed to address, or the Government’s current and forward priorities?	The CRC Program is widely considered to be appropriate and capable of addressing current and forward priorities. ACIL Allen notes that on occasions when the Government wanted a CRC or a CRC-P in a particular sector or technology, that it has sought applications accordingly. Some stakeholders are critical of such selection rounds, pointing to unnecessary competition in areas where research capabilities are limited, resulting in strong partners from

³³ OECD, 2021, OECD Science, Technology and Innovation Scoreboard, accessed on 15 August 2021 at <https://www.oecd.org/sti/scoreboard.htm>

³⁴ ACOLA, 2015, Translating research for economic and social benefit: country comparisons. Accessed on 15 August 2021 at <https://acola.org/wp-content/uploads/2018/08/saf09-research-economic-social-benefit-report.pdf>

No	Question	Finding
		unsuccessful applicants being excluded from the successful CRC. Other stakeholders supported special rounds subject to more time to prepare proposals (see section 7.1.5).
4	Does the CRC Program's design still address the need? What changes or improvements have been made to the CRC Program over time? How effective have these changes been? What, if any, changes could be made to better align the CRC Program with the Government's current and forward priorities?	The need to encourage industry researcher cooperation still exists. Without it, researchers would not be motivated to seek to engage with industry. Industry is less likely to seek to address large scale research initiatives with researchers from the public sector (see section 7.1.1). Industry stakeholders and partners believe that, in some cases, CRC's grant term should be able to be extended beyond the current limit. ACIL Allen agrees. ACIL Allen believes that removal of 'public good' CRCs may have contributed to increased overall economic impacts (while diminishing social and environmental impacts). CRC-Ps are strongly supported by stakeholders, who consider them to be a useful addition to the Program. ACIL Allen considers that removing the possibility of extensions to CRC funding beyond 10 years may limit the scope of CRCs (see Section 7.2.1). Some relaxation of this provision is recommended. This evaluation considers the Program is already well aligned with Government priorities and has not identified any changes required to better align the Program. ACIL Allen considers, and stakeholders agree, that that the CRC Program should continue to be a generally available measure, supporting quality proposals that meet the Program's criteria.

Source: ACIL Allen

Table 8.2 Efficiency

No	Question	Finding
5	Have CRC Program funding rounds been administered and delivered efficiently by the department?	Stakeholders consider that the Program rounds have been administered and delivered efficiently. One stakeholder comment reflected the general view: <i>"Overall, the CRC Program runs well."</i> Industry Association CEO Department costs appear to be low compared with grant funds spent (section 7.1.8). Some stakeholders believe that the efficiency of the Program could be improved by the Department better publicising the material it has available to help applicants prepare proposals and help grant recipients get started faster. As an example of the sort of comments on this issue from stakeholders: <i>"The first year of a CRC is [often] wasted"</i> (CEO, Industry Association) They also suggest that the Department could give more guidance and support when CRCs come to the end of their funding period (see section 7.2.3).
6	How efficient have CRC Program entities been at delivering their outcomes?	The strong outcomes and impacts of their work suggest that CRCs are efficient in the outcome they are achieving. ACIL Allen notes that many Exit Reports are including benefit-cost calculations for individual projects undertaken by CRCs. This suggests that CRCs are taking a stronger interest in ensuring

No	Question	Finding
		positive outcomes. CRC-Ps generally have only one project and are therefore particularly motivated to achieve strong returns. Some CRCs report that their administration and reporting is labour intensive and cumbersome. ACIL Allen suggests that the Department, working with the CRC Association, could help to promote the adoption of best administrative practices.
7	Does the CRC Program have sound data collection methodologies?	The data collection methodologies have evolved appropriately. ACIL Allen considers that recent minor changes to the MDQ will help to ensure quality data for future evaluations.
8	How effective has been the role of the CRC Advisory Committee?	The Advisory Committee is generally considered by stakeholders to have been effective. However, stakeholders consider that the Advisory Committee faces a very large workload. The range of technologies that need to be considered is so broad that there may be difficulties for the Advisory Committee to have a sufficient degree of expertise available. For these reasons, stakeholders and CRC partners believe that there is a strong case for increasing the size of the Advisory Committee. ACIL Allen believes that there is a strong case for increasing the number of members of the Advisory Committee to fifteen. This issue is discussed in section 7.1.6.)
9	How well has the Program been able to identify and address emerging issues or concerns and support its participants?	Stakeholders believe, and ACIL Allen agrees that the Program has identified and addressed emerging issues/concerns and has supported its partners (section 7.1.6 and 7.2.2). Stakeholders note that the Department has been supportive of partners (particularly CRC-P grant recipients) during the COVID pandemic.
10	What impact has the COVID-19 pandemic had on CRC Program entities and participating research organisations and industry partners?	COVID has slowed/delayed CRC and CRC-P work. It has also reduced the capacity of university partners (and some industry partners) to contribute cash to CRCs (section 7.1.7).

Source: ACIL Allen

Table 8.3 Outcomes and impact

No	Question	Finding
11	Is the CRC Program achieving its intended outcomes? What is the magnitude of the changes that occurred? To what extent has the CRC Program increased the strength and quality of business-research collaboration in Australia? To what extent has the CRC Program generated a culture of industry-research collaboration, with firms and researchers seeing value in collaborative partnerships? To what extent has the CRC Program contributed to the competitiveness, sustainability and productivity of Australian industry and supported commercial outcomes? Has the CRC Program improved commercialisation and business performance? To what extent has the CRC Program increased research training and improved the capability of the research workforce?	The CRC Program is achieving its intended outcomes. Appendix B summarises outcomes being achieved by CRCs and CRC-Ps. The economic and social impacts of the Program reported in this evaluation attest to the increase in strength of industry-research collaboration. On the basis of comments from stakeholders and partners, ACIL Allen has concluded that the Program has generated a positive research cooperation culture and that firms value the partnerships involved. Numerous examples were provided to illustrate an improvement in research cooperation culture. The case studies in this report also demonstrate how collaboration culture has been enhanced. Many of the partners in CRCs had not been involved in collaboration prior to their involvement in the Program. See also response to Question 3. Program partners report improved competitiveness, sustainability, productivity and commercial outcomes as well as improved business performance (see section 4.3 and Appendix B summaries). CRC Exit Reports include examples of increased competitiveness, which have been verified by independent consultants. These reports also provide examples of commercialisation and improved business performance. Some stakeholders observe that commercialisation is not always necessary — the Rail Manufacturing CRC is an example where outcomes were adopted across Australia without being “commercialised”. CRCs and, to a lesser extent, CRC-Ps have made strong contributions to research training and capability (see section 4.2).
12	What are the intended and unintended outcomes achieved by the CRC Program relevant to the Government's strategic priorities? Are the CRC Program outcomes achieved to date in line with the Government's current and forward priorities?	The major intended outcomes are improved competitiveness, productivity, adoption of new technology and making use of university research capabilities. No unintended Program outcomes were identified. Outcomes are in line with the Government's priorities (see the response to Question 2 above).
13	How well do the CRC Program's participants match the intended target group and is the reach sufficient to realise the required scale of change? Are there any groups negatively affected by the CRC Program?	The intended target group (including SMEs) appears to have been well covered by CRCs and CRC-Ps (see sections 1.4.1 and 1.4.3). The reach may be sufficient, but additional funding would be needed to realise the scale of change needed to move Australia closer to the OECD median. No groups have been identified as negatively impacted.

No	Question	Finding
14	Does the actual distribution of the outcomes differ from that which was intended?	ACIL Allen is not aware of any intended distribution of outcomes. The distribution of outcomes is largely determined by the proposals selected for funding.
15	What are the main factors contributing to the outcomes?	This is discussed in section 7.2.2. CRC Program funding and the strength of CRC leadership have been identified as key factors by stakeholders. A strong industry role in formulating CRC proposals and in decisions on CRC research also appear to be important factors determining outcomes. Some stakeholders expressed views similar to the following statement: <i>"The key to a successful CRC is governance and strategy" (Academies representative)</i>
16	Are there any other impacts and unintended consequences?	No unintended consequences have been identified.
17	What is the Government's return on investment for the CRC Program? How has this changed since the last assessment (Allen Consulting, 2012)?	For every dollar that the Australian Government invested in CRCs active in the period 2012-20, the CRCs generated benefits of \$5.61 for every dollar of grants (see section 3.4). This is an increase on the level of returns found in the 2012 impact evaluation. Every Government dollar invested in the 30 CRC-Ps examined is estimated to have returned \$7.73 in benefits.
18	How much does the CRC Program contribute to economic growth (GDP), real consumption, real investment and taxation revenue?	The economic impact on GDP of CRCs active in the period 2012-20 was \$23.5 billion (see section 3.4). The 30 which have completed their CRC-P are projected to generate net benefits of \$358.1 million.
19	What would happen to the level of business-research collaboration in Australia in the absence of the CRC Program? What impact would this have on economic growth (GDP)?	Stakeholders believe that, without the CRC Program, the level of business research would be much lower, with serious negative impacts on economic growth. In particular, university researchers and their students would be less engaged with industry. In the absence of the CRC Program, GDP would be \$12.1 billion less (section 3.4.2).
20	What, if any, lessons can be drawn from the CRC Program to improve the efficiency or effectiveness of this initiative and future initiatives or programs?	Lessons learned are discussed throughout the report and reflected in the findings and recommendations (see section 8.3). ACIL Allen rates the efficiency and effectiveness of the CRC Program as high.

Source: ACIL Allen

8.3 Summary of recommendations

ACIL Allen has reviewed the CRC Program, its impacts and stakeholder views of its function. The clear evidence is that CRCs continue to be a success — both the measurable impacts and stakeholder views of the Program.

Accordingly, our recommendations either suggest expansions of the Program or push for marginal improvements in the structure delivery of the Program. Our recommendations, including page numbers, are given in the order that they appear:

Recommendation 1

The CRC Program is achieving excellent economic, employment, research and commercialisation outcomes as shown by this impact analysis. New opportunities could be addressed by the CRCs and stakeholders see significant opportunities for further investment. There are opportunities for CRCs to be established in new areas (such as proposals that involve the application of synthetic biology or artificial intelligence) and in areas which are currently under-served. This evaluation recommends that future efforts to drive industry growth and innovation should leverage the Program's success and consider further investment in both CRCs and CRC-Ps, as proven ways to drive industry-research collaboration. 82

Recommendation 2

From time to time, Governments have decided to commit a funding round to a priority area. The very nature of these priorities makes it likely that consortia will take time to form. It is important that there is sufficient time for the strongest possible proposals to be developed. It is therefore recommended that, should the Government decide to have a grant round on a priority area, then it should provide some additional lead time. 84

Recommendation 3

The success of the program is contingent on the Advisory Committee determining which proposals should be recommended for funding across a wide range of technologies for both CRCs and CRC-Ps. The Committee is challenged by the numbers of grant applications (especially since the start of CRC-Ps) and new areas of research. It is important that the range of experience, knowledge and skills available to the Committee is sufficient to perform its work credibly without making undue demands on the time of its members. It is therefore recommended that the Government consider increasing the size of the Advisory Committee. This evaluation recommends that the Committee size be increased to around fifteen members. The Committee should also be encouraged to continue to seek external advice, particularly where specialist expertise may be required. 85

Recommendation 4

Currently, CRCs are funded for a period of up to 10 years. However, in some circumstances, particularly in medical research (e.g. where clinical trials are involved), exceptional circumstances arise where a longer funding period is desirable to secure the best return on investment. It is recommended that the Government should allow for a degree of flexibility, in limited circumstances, to provide scope for CRCs to be extended with additional funding. It is suggested that such extensions of funding should be for up to five years where a clear case can be made. 88

Recommendation 5

In some CRCs, particularly those with larger numbers of partners, keeping everyone ‘on the same page’ can be a challenge. This is important to achieving optimal returns. It is therefore recommended that CRC partners aim to appoint liaison officers to improve the relationship between industry and research partners and help to span the boundaries between them. 89

Recommendation 6

Commencement processes for new CRCs can be difficult. Given the long lead times to impact, it is important that CRCs achieve a rapid start to maximise their productivity. It is recommended that the Department continue to work closely with CRCs at early stages of their funding to reduce the time spent on start-up. The Department should continue to allow the CRC early access to funding support once the contract is signed. 90

Recommendation 7

Winding up a CRC should have been planned from the earliest stages. However, circumstances can change during the life of a CRC, making wind-up or transition to a new entity complex. Loss of key CRC personnel and momentum behind the endeavour can also complicate the exit process. It is recommended that the Department continue to work closely with the CRCs on the wind-up process and including providing advice on exit options. In addition, Exit Reports — which clearly identify outcomes and impacts — should be systematically collected and stored by the department for future research and evaluation purposes. 90

Recommendation 8

The application process for securing a new CRC can be quite long. Delays in the period between submission of proposals and announcement of successful applications can result in a loss of impetus on the part of applicants. It is recommended that the Department should make every effort to ensure that the time between Stage 1 applications closing and an announcement of successful CRCs is as short as possible. Ideally, this should be no more than ten to twelve months. 91

Recommendation 9

Success of the CRC-P element of the program can be bolstered from early learnings from the outcomes on early-round CRC-Ps. At this stage, it appears CRC-Ps may have trouble articulating impacts and communicating challenges faced. It is recommended that reporting is made as straightforward as possible, that the Department continue to improve reporting tools (aligned with the evaluation needs of DISER), and that Departmental staff should continue efforts to assist CRC-Ps in meeting their monitoring and reporting requirements. 92

Recommendation 10

The COVID-19 pandemic has had a significant adverse impact on the CRC-P element of the Program. Additionally, the number of completed CRC-Ps are low. The current cohort is therefore not optimal to form a definitive view of the success of this element. This evaluation recommends that there should be a further evaluation of the impact of the CRC-P element of the Program when at least 80 CRC-Ps have been completed and impacts can be assessed. 92

Recommendation 11

With any grants scheme, it is important to establish that the activities being funded are substantially additional to what might have happened in the scheme's absence. The CRC-P element of the Program will have its greatest impact where it is encouraging innovation that could not have occurred without a grant. It is recommended that any future evaluation of the CRC-P program element should also test the extent to which the activities undertaken by the CRC-Ps would have occurred without government support. 93

A Consultations

Table A.1 Stakeholders consulted

Stakeholder	Affiliation
Andrew Stevens	Chair, Industry Innovation and Science Australia
Kate Cameron	Acting CEO, IISA
Kylie Sproston	Chair, CRC Advisory Committee
Bronwyn Harch	Member, CRC Advisory Committee
Denise Goldsworthy	Member, CRC Advisory Committee
Sue Thomas	Senior staff, Australian Research Council
Leah McKenzie	
Robert Munn	
Liz Visher	
Anne Kelso	CEO, NHMRC
Peter Appleford	ED, SARDI
Richard Day	Director Strategy, Policy & Communications
Joanne Galley	Grants Officer, Investment Program
Jason Olsen	Office of Chief Scientist, QLD
Allison Bambrick	Dept Environment & Science
Grant Woollett	Dept Environment & Science
Caroline McMillen	Chief Scientist, SA
Centine Wilbello	Senior staff, Chief Scientist's Office, NSW
Carl Thompson	
Christine Newman	
Peter Klinken	Chief Scientist, WA
Peter Bentley	Innovative Research Universities
Deborah Sweeney	
Vicki Thomson	Group of Eight Universities
Cheryl Kut	
Heiko Daniel	Regional Universities Network DVCRs
Michael Friend	
Luke Sheehy	Australian Technology Network
Catriona Jackson	Universities Australia
Anne-Marie Lansdown	
Sam Bucolo	Meat and Livestock Australia
Michael Crowley	
Dan Grant	MTPConnect
Mirjana Prica	FIAL
Adrian Beer	METS Ignited
Miranda Taylor	NERA

Stakeholder	Affiliation
Francis Norman	
Ryan Winn	CEO, ACOLA
Lauren Palmer	Director, ACOLA
Chris Anderson	Australian Academy of Science
Kylie Walker	Australian Academy of Technology and Engineering
Misha Schubert, Jeremy Brownlie, Sharath Sriram, Peter Derbyshire	Science and Technology Australia
Innes Willox	CEO, Australian Industry Group
Tim Boyle	Director, Knowledge Commercialisation Australasia
Sanjay Mazumdar	KPMG, formerly D2D CRC

Source: ACIL Allen

B Summary of economic outputs and impacts — 2012-20

The impact estimates presented in this Appendix are **ACIL Allen estimates**, based on data provided by CRCs and CRC-Ps as well as information from other sources. These estimates are intended:

- to be conservative
- to take into account partial attribution, and
- have been verified where possible.

References to a year are references to financial years (e.g. 2020 refers to 2019-20).

B.1 CRC economic outputs and impacts 2012-20

Table B.1 provides a summary of economic outputs and impact that are 100 per cent attributable to CRCs funded in the period 2012-20.

Table B.1 CRC products — economic outputs and impacts — summary

CRC name	Industry	Output	Impact
Antarctic Climate and Ecosystems CRC	Environment	Saving from restrictions to planning in coastal hazard zones identified by CRC's sea-level rise decision-support tool, Canute.	\$5.06 million over 15 years from 2010-2011
Bushfire and Natural Hazards CRC	Environment	CRC role in reducing loss of life and injury, reducing government costs, and reducing insurable losses.	\$34.2 million over 15 years from 2014 to 2028
Cancer Therapeutics CRC	Medical science and technology	Three licensing agreements signed for 5 oncology small molecular inhibitor programs to treat cancer.	\$639 million 2015-16 ongoing
Cancer Therapeutics CRC	Medical science and technology	Two spin-off companies have been formed from assets developed in the CRC.	\$10 million in 2019-20
Cancer Therapeutics CRC	Medical science and technology	Funding for research collaborations as part of licensing agreements.	\$11.5 million from 2016 to 2021
CAST CRC	Manufacturing technology	Expected value from productivity improvements and cost savings from CAST activities.	\$9 million between 2005 and 2012
CAST CRC	Manufacturing technology	Expected value from additional profit on sale of manufactured products from CAST activities.	\$60 million between 2005 and 2012

CRC name	Industry	Output	Impact
CAST CRC	Manufacturing technology	Expected value of savings from deferred capital investment from CAST activities.	\$15 million between 2005 and 2012
CAST CRC	Manufacturing technology	Expected value from sale of equipment incorporating technologies from CAST activities.	\$24 million between 2005 and 2012
CAST CRC	Manufacturing technology	Direct benefits of CAST activities to business (end users and licensees) are expected to continue to accumulate with an additional value over the next five years from 2012.	\$205 million from 2012 to 2017
Cell Therapy Manufacturing CRC	Medical science and technology	Carina, one of CTM CRC's spin-off companies, has IP rights to > \$5 million of research stemming from CTM CRC.	\$5 million as at 2018-19
CRC for Aboriginal and Torres Strait Islander Health	Medical science and technology	Total value of impact on health attributable to the LICRC and CRCATSIH's activity between 2010 and 2019 is likely to be at least \$49.9 million.	\$49.9 million between 2010 and 2019.
CRC Contamination Assessment and Remediation of the Environment (CRC CARE)	Agriculture and rural based manufacturing	CRC CARE's health screening levels for petroleum hydrocarbons have been incorporated into national regulatory frameworks and been adopted by all regulators nationally.	\$1.3 billion benefit to industry and government.
CRC Contamination Assessment and Remediation of the Environment (CRC CARE)	Agriculture and rural based manufacturing	CRC CARE's research on heavy metalloid bioavailability has reduced the need for remediation of some contaminants and allowed limited resources to be focused on priority sites.	Reduced costs of \$60 million
CRC Contamination Assessment and Remediation of the Environment (CRC CARE)	Agriculture and rural based manufacturing	CRC CARE has conceived and developed a wide range of assessment, monitoring and remediation technologies. These technologies have provided substantial benefits to CRC partners and end users.	\$950 million over a 15-year impact period
CRC Contamination Assessment and Remediation of the Environment (CRC CARE)	Agriculture and rural based manufacturing	Benefits from CRC CARE's development of Site Contamination Practitioners Australia, a professional certification scheme (now operated by a third-party).	\$63 million over a 15-year impact period
CRC for advanced composite structures	Manufacturing technology	Contract income of CRC ACS's spin-off company, ACS Australia.	Confidential benefit per annum from 2015
CRC for Forestry	Agriculture and rural based manufacturing	The overall value of four major research programs.	\$185.6m over a period of 30 years.

CRC name	Industry	Output	Impact
CRC for Living with Autism	Medical science and technology	Includes royalty revenue on licensed products, recovery on MTA and IP fees on consultancy.	\$4.14m between 2018 and 2025
CRC for Living with Autism	Medical science and technology	ACRC contracted revenue outside of the CRC Program, including research grants, consultancy and other contracts.	\$27.2m between 2015 to 2025
CRC for Living with Autism	Medical science and technology	Annual turnover of wholly owned subsidiary revenue forecast to FY25.	\$10.75m from 2015 to 2025
CRC for Living with Autism	Medical science and technology	Other revenue generated by ACRC, including gift fund receipts	\$601,800 between 2015 and 2021
CRC for Living with Autism	Medical science and technology	Participant revenue generated from ACRC activity including royalty payments, training courses and commercial products developed through the ACRC.	\$5.11m between 2015 to 2025
CRC for Living with Autism	Medical science and technology	Net difference Directors' valuation of Australian Autism Biobank at least \$5.5m less capitalised cost of development \$3.7m.	\$1.77m as at 2018-19
CRC for Living with Autism	Medical science and technology	Participant fee waiver on Australian Autism Biobank samples and data for the use in further research projects	\$638,782 in 2019-20
CRC for Polymers	Manufacturing technology	CRCP licensed technologies used in Qenos Engineering Plastics' (now Ixom) communication cables.	Cumulative sales exceeding \$3.75 million
CRC for Rail Innovation	Manufacturing technology	Benefits resulting from CRC research into level crossings, fatigue, bridge life cycle asset management, curve lubrication, noise and rail simulation.	Total benefit of \$80.3m per annum.
CRC for Spatial Information	ICT	Benefits to date from Spatial Infrastructures Program through the influence/adoption of policy through Creative Commons frameworks and adoption of new policies and tools by governments.	\$69m between 2010 and 2018
CRC for Spatial Information	ICT	Savings from increased staff efficiency and improved health services via new geospatial visualisation tools for staff who collate and analyse disease, risk factor and program information for preventative health and avoided monetary costs for early disease detection.	\$61m between 2010 and 2018
CRC for Spatial Information	ICT	Benefit from the introduction of tool sets by skilled government agencies and research organisations for spatial analysis purposes which avoid labour costs that would otherwise be required to prepare, manipulate and extract spatial information.	\$39m between 2010 and 2018

CRC name	Industry	Output	Impact
CRC for Spatial Information	ICT	Cost savings through the use of the sustainable urban development tool to avoid costs of capital infrastructure, greenhouse gas emissions, physical activity costs, private occupier costs and improved healthcare and productivity and efficiency improvement.	\$15m between 2010 and 2018
CRC for Water Sensitive Cities	Environment	CRCWSC and the actions of its partners are estimated to deliver over \$600 million in economic, social and environmental impacts when assessed over a 15-year period.	\$600 million over a 15-year period
CRC Mining	Mining and energy	Value of CRC Mining's 8 spin-off companies.	Valued at \$35m as at February 2014
Cyber Security CRC	ICT	Third Party Participants (such as SAP Australia) and other parties signed contracts with the CSCRC to undertake law and policy functions with the CRC.	\$775,000 from 2021 to 2025
Data to Decisions CRC	ICT	Commercial in confidence.	\$12m in 2018-19
Energy Pipelines CRC	Mining and energy	Sale of software licences from product developed through CRC funding.	\$54,000 between 2015 and 2019
Energy Pipelines CRC	Mining and energy	CRC activities contract income.	\$613,000 between 2015 and 2019
Energy Pipelines CRC	Mining and energy	Costs saved from Research Program 1, which explored more efficient use of materials for energy pipelines.	\$107.04m as at July 2016
Energy Pipelines CRC	Mining and energy	Costs saved from Research Program which explored the extension of the safe operating life of new and existing energy pipelines.	\$128.43m as at July 2016
Energy Pipelines CRC	Mining and energy	Costs saved from Research Program 3, which explored the advanced design and construction of energy pipelines.	\$40.59m as at July 2016
Energy Pipelines CRC	Mining and energy	Costs saved from Research Program 4, which explored the public safety and security of supply of energy pipelines.	\$70.52m as at July 2016
Energy Pipelines CRC	Mining and energy	Provided greater global understanding of impact of transporting CO2 through pipelines (2016-19 project was undertaken with an international partner).	\$4.93m between 2011 and 2016
eWater CRC	Environment	Licence sales for products.	\$1.14m from July 2005-January 2012
eWater CRC	Environment	Income from eWCRC research and development contracts.	\$13.65m from July 2005- June 2011

CRC name	Industry	Output	Impact
Fight Food Waste CRC	Agriculture and rural based manufacturing	Potential savings by businesses as a result of reducing food waste.	\$735.36m between 2021 to 2048
Fight Food Waste CRC	Agriculture and rural based manufacturing	Potential savings by households of reducing food waste.	\$2.1 billion between 2020 to 2048
Food Agility CRC	Agriculture and rural based manufacturing	The NSW Government partnered with our CRC, and UTS and The Yield to build sensors and methodologies to allow oyster farms to open after weather events.	\$4.2m per annum from 2020-21
Future Fuels CRC	Mining and energy	The value of contract income earned (either individually or through partnerships with other organisations).	\$273,500 in 2018-19
iMove CRC	Manufacturing technology	A reduction in avoidable congestion due to improved traffic management software/systems.	\$542.5m between 2020 to 2025
Parker CRC for Integrated Hydrometallurgy Solutions	Mining and energy	Delivered benefit derived from sub-set of 21 projects.	\$45.9m between 2005 and 2012
Plant Biosecurity CRC	Agriculture and rural based manufacturing	Total benefits generated by the Plant Biosecurity CRC's Grains Programs according to the Centre for International Economics (CIE).	\$340.36m over 30 years
Poultry CRC	Agriculture and rural based manufacturing	Enhanced gut health leads to improved feed efficiency and CRC research demonstrated that the appropriate use of different litter materials is highly beneficial for maintaining gut health in poultry.	Present value of \$66.8m as at February 2014
Poultry CRC	Agriculture and rural based manufacturing	Diagnostic technologies developed by CRC led to early and accurate diagnosis of diseases and less mortality and morbidity in the flock, which increased productivity.	Present value of \$8.9m as at February 2014
Poultry CRC	Agriculture and rural based manufacturing	Controlling infectious bronchitis was a difficult challenge as new strains emerged which did not respond to existing vaccines, requiring an in-depth investigation of the various strains, the efficacy of existing vaccines against them, and an industry-wide strategy for the issue.	Present value of \$7.8m as at February 2014
Poultry CRC	Agriculture and rural based manufacturing	CRC research into Eimeria vaccines reduced reliance on antibiotics.	Present value of \$4.1m as at February 2014
Poultry CRC	Agriculture and rural based manufacturing	CRC research into odour and dust led to a greater scientific understanding of environmental issues related to the poultry industry, which helped farmers	Present value of \$3.4m as at February 2014

CRC name	Industry	Output	Impact
		to implement strategies to minimise the impacts of poultry production on the environment.	
Poultry CRC	Agriculture and rural based manufacturing	CRC research into Coccidiosis vaccines reduced reliance on antibiotics.	Present value of \$1.2m as at February 2014
Seafood CRC	Agriculture and rural based manufacturing	Oyster selective breeding and management program expected to lead to more rapid growth with lower mortality.	Additional \$29m per annum in profit
Seafood CRC	Agriculture and rural based manufacturing	Prawn selective breeding and management expected to lead to more rapid growth with lower mortality.	Additional \$5m per annum in profit
Seafood CRC	Agriculture and rural based manufacturing	Yellowtail Kingfish disease and nutrition management expected to lead to increased production into export markets.	Additional \$60 million to GVP per annum
Seafood CRC	Agriculture and rural based manufacturing	Development of new rock lobster traps expected to lead to Improved capture rates with reduced fishing effort would reduce costs.	Reduced costs of production by \$20 million per annum
Seafood CRC	Agriculture and rural based manufacturing	Current fishery is limited by stock availability; Southern Rock Lobster translocation program expected to result in increased catch.	Additional \$18 million to GVP per annum
Seafood CRC	Agriculture and rural based manufacturing	Current fishery is limited by stock availability; bêche-de-mer (sea cucumber) fishery enhancement expected to lead to increased catch.	Additional \$90 million to GVP per annum
Seafood CRC	Agriculture and rural based manufacturing	Improved percentage recovery through development and implementation of industry standards for fillet recovery and frames utilisation would reduce costs	Cost reduction of \$34 million per annum
Seafood CRC	Agriculture and rural based manufacturing	Downgrading and loss of product is a major problem, accounting for between 15-50% of total GVP; CRC research may lead to 3% increase in recovery from improved handling of product.	Additional \$60m per annum in profit
Seafood CRC	Agriculture and rural based manufacturing	Technical market access of wild-harvest prawns project expected to lead to Price support in international markets from work demonstrating product integrity (with particular reference to quality standards and characteristics).	Additional \$30 million in profit per annum

CRC name	Industry	Output	Impact
Seafood CRC	Agriculture and rural based manufacturing	Increased price of Australian seafood through health claims made by CRC expected to give sector access to premium price markets through increased demand.	Additional \$100 million in profit per annum
Sheep CRC	Agriculture and rural based manufacturing	CRC training programs targeting better ewe management for improved reproductive efficiency.	\$74 million/year by 2014
Sheep CRC	Agriculture and rural based manufacturing	CRC developed the ParaBoss program, a web-based information product which provides best-practice advice on parasite management.	\$3.7 million/year in 2014
Sheep CRC	Agriculture and rural based manufacturing	CRC activities raised utilisation of the Australian Sheep Breeding Values (ASBVs) which assisted farmers to make better ram selections.	\$10 million in 2014
Sheep CRC	Agriculture and rural based manufacturing	The CRC's wool research Program focused on quality assurance for next-to-skin knitwear. This research was expected to increase demand for these wools and re-establish the micron price premium.	Increase in the value of the Australian wool clip of \$126 million by 2018.
Sheep CRC	Agriculture and rural based manufacturing	The CRC's research in fields of genetics, genomics and meat science has delivered new knowledge and new technologies that allow simultaneous improvement in lean meat yield and eating quality.	\$9 million per year on a cumulative basis to the value of Australian lamb production.
Smart Services CRC	ICT	Partners had a right to take non-exclusive licence to research outcomes - 26 licences were granted led to partners incorporating technologies into their media and financial services offerings.	\$4.95 million between 2010 and 2015
Smart Services CRC	ICT	Integration development and project trials for specific partners through establishment of Service Innovation Foundry as unit within the CRC.	\$2.45 million between 2012 and 2014
Smart Services CRC	ICT	Benefits from the development of CRC's CSN Technology.	\$2.2 million between 2009 and 2017
Smart Services CRC	ICT	Benefits from the development of CRC's New Services program led to a variety of technological advances.	\$94 million between 2007 and 2020
Smart Services CRC	ICT	The CRC's Foresight program produced a number of beneficial products including a toolkit to assist in integrating macro-based forecasting with strategic planning.	\$6.35 million between 2007 and 2015

CRC name	Industry	Output	Impact
Smart Services CRC	ICT	The CRC's Education program led to benefits including the creation of early-stage innovation pipeline for industry participants.	\$36 million between 2007 and 2020
Smart Services CRC	ICT	Benefits from the development of CRC's Isee VC.	\$1 million from 2012 to 2018, and \$400,000 per annum ongoing
Smart Services CRC	ICT	Benefits from the development of CRC's Tabletop Technology.	\$3.85 million from 2012 to 2023, and \$500,000 ongoing
SmartSat CRC	Manufacturing technology	South Australia Department of Environment and Water (DEW) signed a contract with SmartSat to undertake research on SatCom IoT-enabled Automatic Ground Water Collection and Aggregation Pilot.	\$0.74 million from 2020 to 2021
SmartSat CRC	Manufacturing technology	SA SAT1 Project - The SA Premier, as represented by the South Australian Space Industry Centre, commissioned the build and launch of a South Australian built and manufactured small satellite, along with provision for 3 years operation.	\$6.46 million from 2021 to 2026
Vision CRC	Medical science and technology	Royalties generated by CRCERT and Vision CRC Ltd (completed 30 June 2015) as of 30 June 2021.	\$369.26 million
Capital markets CRC	ICT	Commercial in confidence.	\$18.84 million

Table B.2 provides a summary of CRC collaborative outputs and impacts where some of the attribution is to other parties.

Table B.2 CRC collaborative products — economic outputs and impacts — summary

CRC name	Industry	Output	Impact
Cooperative Research Centre for High Integrity Australian Pork	Agriculture and rural based manufacturing	Benefits from Reduced Confinement Sow & Piglet Management Program, Herd Health Management Program and Carbon-Conscious Nutrient Inputs and Outputs Program, and partial benefits from Healthy Pork Consumption Program.	Undiscounted benefit of \$6.91 billion across this CRC's programs.
CRC for Advanced Automotive Technology	Manufacturing technology	Benefit from Improved fuel efficiency over 11 key projects	\$217.62 million
CRC for Advanced Automotive Technology	Manufacturing technology	Business benefit over 11 key projects	\$525.07 million

CRC name	Industry	Output	Impact
CRC for Asthma and Airways	Medical science and technology	Benefits from CRC research including development of commercialised IP, reduced healthcare expenditure and improved quality of life for asthmatics.	10-year returns to the Australian economy of \$640 million.
CRC for Beef Genetic Technologies	Agriculture and rural based manufacturing	Benefits for consumers from CRC.	\$308 million over 25 years
CRC for Beef Genetic Technologies	Agriculture and rural based manufacturing	Benefits for producers from CRC.	\$696 million over 25 years
CRC for Biomedical Imaging Development	Medical science and technology	Sale of 6 FlexLAB dual reactors developed by CRCBID	\$780,000.00
CRC for Infrastructure and Engineering Asset Management	ICT	Benefit from four major industry projects undertaken by the CIEAM CRC	Risk-adjusted expected value of \$156 million
CRC for Optimising Resource Extraction (ORE)	Mining and energy	Shared revenue from industry consulting projects for Quantitative Group (QG) for working alongside CRC ORE discipline specialists.	\$1.5 million as of 2015
CRC for Polymers	Manufacturing technology	Increased Australian made sale from ceramifying polymers.	Increased Australian made sales of over \$60 million
CRC for Rail Innovation	Manufacturing technology	CRC research into ballast led to reduced maintenance cost due to improved ballast maintenance scheduling and design.	Total benefit of \$21.9 million per annum
CRC for Rail Innovation	Manufacturing technology	CRC research into ballast led to reduced maintenance cost due to improved ballast maintenance scheduling and design.	Total benefit of \$6.8 million per annum
CRC for Remote Economic Participation	Environment	The work on population mobility led to an improved basis for enumerating Aboriginal people in remote areas, which enables more accurate allocation of government funding.	\$62.7 million per annum
CRC for Spatial Information	ICT	Benefits to date through improved use of infrastructure resulting from CRC's Positioning Program	\$22 million between 2010 and 2018
CRC Mining	Mining and energy	Latest technology adoption, from outcomes generated by the Centre, is predicted to increase revenue for Australian mining operations	Increase in revenue by \$1.96 billion from inception of the Centre to 2024
Cyber Security CRC	ICT	Productivity enhancements are driven from implementation of CSCRC projects such as IAM with NAB	\$67.25 million from 2020 into future years

CRC name	Industry	Output	Impact
Cyber Security CRC	ICT	CSCRC research and activities reduce costs for government, the community and industry through robust advice, awareness raising and examination of outcomes for complex problems.	\$134.5 million from 2019-20 into future years
Dairy Futures CRC	Agriculture and rural based manufacturing	Cumulative benefit of CRC's genomics innovations by 2030	\$265 million between 2016 and 2030
Deep Exploration Technologies CRC	Mining and energy	The CRC's coiled tubing drilling system will result in 2.5 times or 1.4 million metres per annum additional drilling in Australia.	A\$207.4 million per annum (2013 USD\$200m)
Food Agility CRC	Agriculture and rural based manufacturing	Western Australian Grains farmers have partnered with Food Agility and Curtin University to increase farmers' use of digital tools to determine the exact placement of fertiliser on their farms.	\$90 million between 2021 and 2031 from increased land productivity
Food Agility CRC	Agriculture and rural based manufacturing	Circular food economy digital infrastructure developed with Lendlease and QUT to be rolled out across Lendlease's planned communities globally. The project reduces household food budgets by 5% per annum through education about food and reduced food wastage.	\$78 million between 2021 and 2031, calculated based on Yarrabilba trial site of program
Food Agility CRC	Agriculture and rural based manufacturing	Food Agility, The Yield and researchers from UTS collaborated to conduct research on yield and timing optimisation, which identified improved cost savings and profitability opportunities for Costa and Treasury Wine Estate.	\$66 million between 2021 and 2031
Food Agility CRC	Agriculture and rural based manufacturing	Water usage for 6 irrigated commodities (representing > 90% of production) over three irrigation seasons. There has been a 5% decrease in irrigated water usage (currently \$266m per year) and a 2% project output adoption	\$6.65 million between 2021 and 2032
Food Agility CRC	Agriculture and rural based manufacturing	Research to improve the quality of avocados exported by selecting the fruit that will travel best and identifying the best freighting conditions.	\$320,000 per annum between 2021 and 2025
Food Agility CRC	Agriculture and rural based manufacturing	CRC data science models provide green bean farmers with predictions to improve on-farm operations and reduce loss of crop.	\$1.75 million per annum from 2021

CRC name	Industry	Output	Impact
Food Agility CRC	Agriculture and rural based manufacturing	Model has been created to identify high risk areas allowing producers to take action to mitigate cattle against liver fluke and increase profitability as a result of fluke reduction.	\$25 million per annum from 2021
Food Agility CRC	Agriculture and rural based manufacturing	Investment used digital infrastructure to ensure the Sydney Fish Market auction could move to online delivery and continue during the COVID shut down. The business would otherwise have closed down for an estimated 4 months.	\$8,100,000 in 2021
Future Farm Industries CRC	Agriculture and rural based manufacturing	The estimated net benefit of FFI CRC's headline farming systems	PVB of \$2,349 million by 2030
iMove CRC	Manufacturing technology	Improvements to existing traffic management software used by departments of transport.	\$128 million between 2019 and 2025
Innovative Manufacturing CRC	Manufacturing technology	Costs avoided within business/commercial operations of CRC industry partners.	\$2.01 billion from 2018 ongoing.
Innovative Manufacturing CRC	Manufacturing technology	Increased sales and revenue across a number of key projects.	\$3.00 billion from 2018 ongoing.
Innovative Manufacturing CRC	Manufacturing technology	Further Investment in technology and research within the company catalysed by IMCRC projects.	\$471 million from 2017 ongoing.
Invasive Animals CRC	Environment	Economic impact of the IA CRC's research	\$627.8 million from 2012 to 2027
Oral Health CRC	Medical science and technology	Sales resulting from research in the current and previous CRC	\$2 billion between 2003 and 2018
Wound Management Innovation CRC	Medical science and technology	Implementation of residential aged care interventions developed by CRC will reduce the cost of wound care by 39%.	Potential savings of \$1.5 million per annum

Table B.3 summarises CRC outputs and impacts which are expected over the next five years.

Table B.3 CRC imminent economic outputs and impacts — summary

CRC name	Industry	Output	Impact
Blue Economy CRC	Agriculture and rural based manufacturing	Aquaculture and renewable energy companies (or other technology developers) sign a contract with our CRC to undertake research at an identified offshore R&D site managed/licensed to the BE CRC.	Contract value of \$500,000. Contracts may be in place between 2024 and 2029.
Blue Economy CRC	Agriculture and rural based manufacturing	BE CRC grants license to aquaculture companies for use of improved collar-tie and other pen improvements.	Licence fee of \$5,000 per annum from 2023 onwards

CRC name	Industry	Output	Impact
Blue Economy CRC	Agriculture and rural based manufacturing	Companies sign a contract with the BE CRC to purchase its hydrogen and oxygen produced at its H2 facility.	Contract value of \$1.71 million between 2023 and 2025 with possibility of extension.
Blue Economy CRC	Agriculture and rural based manufacturing	Aquaculture companies' and renewable energy companies' use of autonomous systems in offshore exposed environments to undertake operations.	\$500,000 in 2024-25
Blue Economy CRC	Agriculture and rural based manufacturing	Aquaculture companies reduce diesel usage and CO2 emissions in their offshore operations by increased renewable energy utilisation. This also reduces production costs.	\$200,000 in 2024-25
Blue Economy CRC	Agriculture and rural based manufacturing	Aquaculture companies' increase in exports associated with new markets or access to markets.	\$30 million per annum expected from 2023/24 to 2029-30
Blue Economy CRC	Agriculture and rural based manufacturing	Aquaculture companies' increased production by 50% in offshore leases.	\$30 million per annum expected from 2024 to 2031
Cell Therapy Manufacturing CRC	Medical science and technology	By 2025, CTM CRC's spin-off company TekCyte is expected to generate revenue > \$10 million and employ up to 16 staff.	Revenue of \$10 million by 2025
Cooperative Research Centre for High Integrity Australian Pork	Agriculture and rural based manufacturing	Future benefits from Healthy Pork Consumption Program.	Undiscounted benefit of \$79.73 million
CRC for High Performance Soils	Agriculture and rural based manufacturing	Costs saved from CRC development of value chain and meta-analysis on incentives and adoption for good soil stewardship in agrifood and fibre industries.	\$51.18 million post 2024-25
CRC for High Performance Soils	Agriculture and rural based manufacturing	Costs saved from bio-economic analyses of soil management interventions across a range of livestock and cropping enterprise and regions.	\$9.34 million post 2024-25
CRC for High Performance Soils	Agriculture and rural based manufacturing	Higher yield from value chain and meta-analysis on incentives and adoption for good soil stewardship in agrifood and fibre industries.	\$88.46m post 2024-25
CRC for High Performance Soils	Agriculture and rural based manufacturing	Value created from establishment of innovation partnership agreements with farmer groups, SMEs and/or corporate CRC participants. Commercialise CRC research CRC by licencing IP and establishing spin-offs	\$3.41 million post 2024-25

CRC name	Industry	Output	Impact
CRC for High Performance Soils	Agriculture and rural based manufacturing	Costs saved from new methods and data to measure productive soils and development of sensor technologies to support soil management.	\$1.8 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Value from increased crop yield of CRC's soil health real time monitoring tool, which will enable farmers to implement higher precision fertilising	\$217.43 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Value created from mobile applications to support soil management and program to support innovative developments and their commercialisation	\$65.13 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Increased product sales from CRC research into new fertilisers, chemicals and soil enhancers	\$4.52 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Reduction of fertiliser, irrigation and chemical costs due to new soil improving products developed by CRC	\$30.3 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Higher crop yields due to improved fertiliser products. Estimated impact of chemical fertilisers on agricultural output is \$12.7 billion per annum (fertiliser Association).	\$33.6 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Costs saved from CRC research into reductions in productive agricultural land loss	\$110.75 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Costs saved from CRC research into reduced fertiliser and nutrient use	\$1.7 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Value from CRC research on increased land productivity (dollar income per area) from intercropping, dual purpose cropping practices and ability to expand crop types.	\$307,000 post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	Costs saved from CRC research on reduced water usage costs and associated benefits from higher availability of arable land.	\$3.7 million post 2025
CRC for High Performance Soils	Agriculture and rural based manufacturing	CRC research into greater soil productivity that translates to higher yield.	\$77 million post 2025
CRC for Remote Economic Participation	Environment	Precision Pastoral Management System developed by the CRC provides significant economic benefits for beef producers.	\$243.9 million per annum
CRC for Transformations in Mining Economies	Mining and energy	Cost saving from CRC development of roadmap for co-developed relinquishment policy to identify a policy reform pathway with a focus on	\$87.88 million post 2024-25

CRC name	Industry	Output	Impact
		removing constraints that are currently preventing relinquishment.	
CRC for Transformations in Mining Economies	Mining and energy	Cost saving from CRC development of decision tool for regional planning of post mine use and integrated decisions systems and engagement tools to integrate mine closure plans more effectively with development strategies.	\$16.96 million post 2024-25
CRC for Transformations in Mining Economies	Mining and energy	Cost savings from CRC education and training. Sector educated on how to better prepare high quality documentation for mine activity approval, saving time and costs.	\$1.5 million post 2024-25
CRC for Transformations in Mining Economies	Mining and energy	Cost saving from development of advanced evaluation framework for long life assets; and real time models which will predict the level of residual risk and liability remaining at a site upon completion of mining operations.	\$68.26 million post 2024-25
CRC for Transformations in Mining Economies	Mining and energy	Cost savings from CRC development of smart architecture database: A knowledge platform to address shared problems between miners, community and regulators, providing quicker access to relevant knowledge, tools and data.	\$212.03 million post 2024-25
CRC for Transformations in Mining Economies	Mining and energy	Costs saved from CRC development of smart architecture database. The Smart Architecture Databases can also in some cases reduce the average rehabilitation time and thus accelerate re-purposing.	\$84.33 million post 2024-25
CRC for Transformations in Mining Economies	Mining and energy	Costs saved from CRC development of business solutions for firms supplying goods and services to post-mine ventures to assist with making informed investment decisions. Potential to trigger additional job growth in regions through a 10% expansion in the demand for mine closure services.	\$4.94 million post 2024-25
CRCNA	Agriculture and rural based manufacturing	Establishing eye screening services in remote northern Australian communities.	Cost saving of \$6.4 million per annum due to reduced travel.
Cyber Security CRC	ICT	Ability to attract investment to patent purchasers (as new owners of IP) and ability to deliver benefit and impact to customers, improving cybersecurity levels in market.	\$1 million in future years

CRC name	Industry	Output	Impact
Cyber Security CRC	ICT	Economic benefits from a potential capital increase for participants. These will be born from new technologies, efficiencies and greater alignment to policy and regulation participants glean through their involvement in the CSCRC.	\$5 million between 2022-23 and 2024-25
Cyber Security CRC	ICT	Project IP utilised by Project Participants internally, and separately licensed to other Participants and Third Parties for broader utilisation and commercialisation. CSCRC is undertaking the first such licensing process for an output and expects to grow this activity in future years.	\$810,000 from 2021-22
Cyber Security CRC	ICT	The CSCRC successfully establishes a spin off company or companies as a result of increased industry research collaboration.	\$45 million from 2024-25 into future years
Food Agility CRC	Agriculture and rural based manufacturing	SunRice and Hitachi partnered with Food Agility to increase farmers' ability to predict the whole grain rice yield that comes from the annual crop. The productivity gains come from preventing rice cracking during production cycles.	\$14.5 million per annum from 2021-22
Food Agility CRC	Agriculture and rural based manufacturing	CRC involved in the development of 'Smart' sensor technologies that continuously measure environmental conditions and product quality monitor pre- and post-harvest quality and power 'models' to predict appearance of fruit for export.	\$7 million per annum from 2022-23
Fight Food Waste CRC	Agriculture and rural based manufacturing	Potential increased net revenue from conversion of food waste into alternate products	\$266.1 million between 2023 and 2048
iMove CRC	Manufacturing technology	Increased supply chain efficiency through optimisation using data, including supply chain visibility.	\$16 million between 2022-23 and 2024-25
iMove CRC	Manufacturing technology	Reduction in road congestion due to increased use of public transport due to better travel planning and multi-modal tools.	\$70 million between 2021-22 and 2024-25
CRC for Forestry	Agriculture and rural based manufacturing	The overall value of four major research programs	\$185.6 million over a period of 30 years
CRC for Rail Innovation	Manufacturing technology	CRC research into ballast led to reduced maintenance cost due to improved ballast maintenance scheduling and design.	Total benefit of \$21.9 million per annum

CRC name	Industry	Output	Impact
CRC for Rail Innovation	Manufacturing technology	CRC research into ballast led to reduced maintenance cost due to improved ballast maintenance scheduling and design.	Total benefit of \$6.8 million per annum
CRC for Spatial Information	ICT	Benefits resulting from the reduction of costs of the vegetation management program through the introduction of software and improved technology solutions Australia wide and internationally	\$285 million between 2010 and 2025
CRC for Spatial Information	ICT	Benefit from the Urban Digital Elevation Modelling in High Priority Regions (Urban Digital Elevation Model-UDem) project, use of elevation distribution tools, commercial receipts and the use of the Savanna Burning Abatement Tool (SavBAT) tool	\$198 million between 2010 and 2025
CRC for Spatial Information	ICT	Benefits resulting from savings in labour used from deploying more effective software solutions into organisations to process data more efficiently into information.	\$16 million between 2010 and 2025
CRC Mining	Mining and energy	Latest technology adoption, from outcomes generated by the Centre, is predicted to increase revenue for Australian mining operations	Increase in revenue by \$1.96 billion from inception of the Centre to 2024
Low Carbon Living CRC	Manufacturing technology	The CRC's biosolids resource recovery project is projected to lead to potential energy and costs savings in areas such as better plant digestors and reduced fertiliser costs for farmers.	\$3 million a year across Sydney Water's network
MinEx CRC	Mining and energy	Reduced costs of exploration drilling enable increased metres drilled at constant budgets.	Net Present Value of \$70.3 million over 15-year impact period (2024 to 2033), with initial impact commencing 2023-24
MinEx CRC	Mining and energy	Drilling costs decrease with CT drilling capturing 10% of total market share resulting in \$160M annual savings by FY32.	\$490.62 million between 2029 and 2033
MinEx CRC	Mining and energy	Drilling and support industries of the METS sector expand international footprint by 50% in 15 years based on usage of outputs from four projects.	\$30 million between 2028 and 2034
MinEx CRC	Mining and energy	Development of advanced exploration tools	\$63.3 million
MinEx CRC	Mining and energy	Discovery of new moderate or larger-sized deposits	\$183 million from 2032 onwards

CRC name	Industry	Output	Impact
SmartSat CRC	Manufacturing technology	Forecast: improvement, as a result of the SA SAT1 project and, after launch, to build additional 2-3 satellites per year.	\$35 million from 2023 to 2025
SmartSat CRC	Manufacturing technology	Forecast: Myriota to secure additional requests for sensors components and data integration for bore water measurement	\$7.5 million from 2022 to 2025
SmartSat CRC	Manufacturing technology	Forecast: Myriota to secure additional requests for data services from state governments	\$1.73 million from 2023 to 2025
Space Environment Management CRC	Environment	CRC research led to avoidance of the loss of an NBN satellite due to collision with debris.	\$500 million per annum between 2021 and 2025
Space Environment Management CRC	Environment	CRC's estimated revenue from debris tracking contracts	\$100,000 per annum between 2021 and 2025

B.2 CRC-P economic outputs and impacts

Table B.4 provides a summary of CRC-P economic outputs and impacts.

Table B.4 CRC-P— economic outputs and impacts — summary

CRC-P name	Industry	Output	Impact
High performance optical telemetry system for ocean monitoring	METS, manufacturing, resources	Commercialise new – classes of distributed array sonars for ocean monitoring purposes	– <u>Income/ revenue</u> - sales of new sensors in sonar, mining telemetry and new sensors as “replacement and upgrades” to reduce user operational processes and costs. These systems will reduce the cost of acquiring and deploying sonar, enabling faster, cheaper resource discovery, and new applications for fisheries and border security. – <u>Cost savings</u> - improved monitoring of conditions underground, saving money (i.e. for government through improved national maritime security) and potentially lives. – <u>Licences expected</u> – new licence agreement expected to be established to clarify commercial terms of new sales and exclusivity conditions. – <u>Funding expected</u> – an application to the Defence Innovation Hub is expected to be formulated resulting in a new project.

CRC-P name	Industry	Output	Impact
Strengthening Australia's radiopharmaceutical development capabilities	METS, manufacturing	Strengthen Australia's radiopharmaceutical capabilities by developing the infrastructure, processes and training needed to treat serious disease	– <u>Increased sales revenue/ licence income</u> - New national and international client business from product development enabling companies to grow, increase revenue and employ new staff. Currently, two products have been developed to the point of initiating clinical trials. – <u>Cost savings</u> – expected direct reductions in health care costs and avoidance of associated indirect costs, such as carer costs.
Innovation in Advanced Multi-Storey Housing Manufacturing	Manufacturing	Develop and commercialise an innovative housing system that will transform conventional housing construction towards an advanced manufacturing future	– <u>Increased sales revenue/ licence income</u> - commercialisation of an innovative housing system (Advanced Multi-Storey Housing) with a market potential assumed to reflect cost savings and higher yields. – <u>Cost savings</u> - reduced costs and build-times. – <u>Increased sales revenue</u> - the R&D has resulted in several new products, practices, processes and workflows and a new business entity has been established. Also, a major development deal with a global technology company which will lead to export fees earned by Australian entities and the potential for a long-term commercial engagement.
Future Oysters CRC-P	Food and agriculture	Rebuild and evolve the Australian oyster aquaculture industry by accelerating the breeding of disease resistant oysters, disease management and productivity	– <u>Increased sales revenue</u> - increased sales due to accelerated rate of breeding disease resistance, benefiting oyster growers. The CRC-P will support the industry to recover and expand production and evolve to supply domestic and global markets. – <u>Cost savings</u> - improved survival from disease resistance leading to reduced production losses. The Project is also expected to deliver productivity gains from improved oyster health through disease control. – <u>Cost savings</u> – production of new species and productivity gains of from better farm management and technological improvements from environmental monitoring.

CRC-P name	Industry	Output	Impact
The future integrated driver monitoring solution for heavy vehicles	Manufacturing	Commercialise a world-leading driver monitoring product that will enable the freight industry to monitor and improve driver safety and wellbeing	– <u>Increased sales revenue</u> - sales of monitoring units (generating a profit margin) and an increase in Seeing Machine's share price from new IP and patents. – <u>Cost savings</u> – large, expected reduction in fleet damage and increases in productivity for the industry (i.e. from more flexible mandated driver breaks). – <u>Potential cost savings</u> – the CRC-P program will empower drivers and fleet owners to make more informed decisions around shift scheduling and driver training.
Hydrocarbon fuel technology for hypersonic air breathing vehicles	Manufacturing	Develop new technology to fuel scramjets with liquid hydrocarbons to commercialise hypersonic air breathing engines	– <u>Increased revenue/ sales and employment</u> – new advanced manufacturing sector product sales if the technology is commercialised.
Printed solar films for value-added building products for Australia	Manufacturing	Commercialise a new-to-the-world premium roofing product for large-span commercial structures	– <u>Increased revenue/ sales</u> - industry expansion and new product development based on stand-alone power from IoT sensors to grid-connected facilities. – <u>Cost savings</u> - reduced electricity usage by commercial and industrial businesses. – <u>Engagement of SMEs</u> – the project engaged with five SMEs (i.e. engineering solutions, energy connection companies) although, no income was generated from these engagements.
Translational R&D to accelerate sustainable omega-3 production	Food and agriculture, Med-Tech and pharma.	Commercialise high-quality algal omega-3 products by translating proof-of-concept technologies to achieve sustainable, organic production of omega-3 fatty acids	– <u>Increased revenue/ sales</u> - licencing of an algal cultivar for large scale cost-effective production licensed for use in commercial algal farms. – <u>Industry development and productivity gains</u> - expansion of omega-3 oil production from the construction of additional farms. – <u>Potential increase in revenue/ sales</u> – the project has demonstrated that large-scale commercial outdoor raceway pond marine microalgae farming has a viable future in Australia and has identified a preferred location for a commercial-scale marine microalgae farm with around 100 new direct jobs projected within 7-10 years.

CRC-P name	Industry	Output	Impact
An antibody based in vitro diagnostic for metastatic cancer	Med-Tech and pharma.	Scale up production and characterise the Chemocopeia antibodies to develop a prognostic assay for metastatic disease (currently an unmet need)	– <u>Cost savings</u> – a reduction in costs to the health service by early diagnosis of cancer and savings per patient based on quality adjusted life years (QALY benefits). – <u>Increased sales/ revenue</u> – potential direct commercial value together with significant benefits to patients and the potential to improve the rational deployment of high value oncology medications.
Enhanced market agility for the Australian tea tree industry	Food and agriculture	Reduce response time by half to around four years by developing a clonal propagation system for tea tree and transforming the Australian industry	– <u>Increased revenue/ sales</u> - gross value of low ME oil sales into Europe for tea tree growers. Also, the gross value of an increase in global market share for Australian growers due to demand increase for oil. – <u>Increased revenue/ sales</u> - plant sales by propagators supplying clonal planting stock to tea tree growers less the displaced business of selling seedlings. – <u>Increased revenue/ sales</u> - market retention and expansion by being able to supply new product lines adjusted to regulatory and consumer preference change.
Power Efficient Wastewater Treatment Using Graphene Oxide Technology	Food and agriculture, METS, manufacturing and resources	Significantly reduce the energy intensity in converting wastewater to freshwater using graphene oxide-based water treatment technologies	– <u>Cost savings</u> - reduction in power consumption estimated to reduce power consumption by 50 per cent compared to current activated sludge process. – <u>Increased revenue/ sales</u> - increased profits to businesses assuming revenue of \$0.5m per ML from the adsorption and filtration processes. – <u>Cost savings</u> – the project has led to the potential to change the usefulness and cost basis of membrane nanofiltration as it is applied to water filtration and industrial separations.
Targeting tropomyosin as a novel anti-cancer therapy	Med-Tech/ pharma.	Provide improved chemotherapy for advanced metastatic disease through an Australian innovation to selectively destroy cancer cells using anti-tropomyosin (ATM) drugs	– <u>Increase private investment</u> - increased liquidity, demonstrable government support and the development of an additional drug asset will reduce risk and increase growth, impacting on stock price and investor sentiment. – <u>Increase in business reinvestment</u> - stable contract of work and predictable future income will enable ICP to reinvest in company infrastructure, develop a broader range of assays and skills, making it more profitable in the contract research organisation (market by attracting additional contracts).

CRC-P name	Industry	Output	Impact
			– <u>Other revenue</u> – allow the School of Medicine to acquire skills and demonstrate precedent for commercialisation in the pharmaceutical sector that will have an impact on a variety of income streams. – <u>Increased revenue/ sales</u> – the CRC-P is in discussion with Pharma and VC investors to secure the necessary funding to take the clinical leads to a Phase I trial.
Universal Solar Module Inspection and Data Storage System	Manufacturing, resources	Identification and removal of defective solar modules based on BT Imaging's proven & proprietary luminescence imaging platform	– <u>Cost savings</u> - net future savings to the global solar industry of rejecting modules that will fail. A reduction in global business insurance and finance costs of installing and operating a solar energy installation. Globally, preventing a price increase from the 'learning curve' by enabling researchers to target areas of activities to maintain the required rate of cost reductions. – <u>Increased revenue/ sales</u> – the development of products will increase the company's sales and revenue, benefiting BT Imaging. Incremental revenue has commenced coming in and will continue as the industry adopts the new products. – <u>Increased revenue/ sales</u> - commercial sales realised by BT imaging to a world leading manufacturer. – <u>Increased employment</u> - employment of five additional staff as a result of the program.
An integrated modelling system for navigational aid in tidal inlets	METS/ resources	Use new ocean physics to develop an integrated modelling system to improve navigational aid systems and maritime safety whilst providing economic benefits to shipping	– <u>Increased revenue/ sales</u> - increased revenue for shipping and associated industries. – <u>Cost savings</u> - improved accuracy in ship-handling, reducing costs for maintenance dredging. Secondly, more efficient operation of the simulator with a reduction of about 30 per cent of the costs associated to the use of this technology. – <u>Expected increased revenue/ licence income</u> – the operational hydrodynamic model has been implemented into MetOcean's Solutions' operational model suite. The simulator platform has also been demonstrated to senior international delegates (e.g. US Navy) and the commercial shipping industry.

CRC-P name	Industry	Output	Impact
Targeted therapy for sleep apnoea: A novel personalised approach	Med-Tech/ pharma, manufacturing	Commercialise and improve the efficacy, compliance and monitoring of sleep apnoea therapy using a tailored suite of treatments	– <u>Cost savings</u> – expected reduction in the cost of obstructive sleep apnoea to the health system from the treatment of patients in Australia. – <u>Cost savings</u> – sleep monitoring will be included in the device delivery fee at a reduced total, resulting in a saving for Medicare. – <u>Increased revenue/ increased capital value of CRC-P partners</u> – increased revenue and net profits for commercial partners from domestic and international sales. Relevant taxes will also be paid to the Australian government. – <u>Increased revenue/ sales</u> - three new products have been developed, trialled, transferred to production, regulatory cleared and launched in local and international markets leading to increased sales and job creation. Another sleep apnoea product is currently being evaluated.
Wear life extension via surface engineered laser cladding for mining	Food, METS, manufacturing, resources	Develop, deploy and commercialise new surface engineered materials and application technologies to the drilling tools and drill rig used for exploration and extraction of mining resources	– <u>Increased revenue/ sales</u> – conservative ramping of sales of drill bits and an expected increase in manufacturing jobs and gross profit. – <u>Cost savings</u> - direct cost saving of using an advanced (laser clad) conventional drill/ advanced drill system that has a superior wear-life. – <u>Cost savings</u> – an expected reduction in the cost of mine exploration due to lower cost drilling leading to mining expansion and a long-term mining impact for Australian resources sector. – <u>Increased revenue/ sales</u> – direct economic benefits have been delivered through the sales of new or improved coated products. – <u>Employment support</u> - the CRC-P has resulted in the employment of two international coating experts. – <u>Cost savings (potential)</u> – improved understanding for Boart Longyear and promise for future savings through the adoption of the identified technologies.

CRC-P name	Industry	Output	Impact
Graphene Supply Chain Certification	Manufacturing	Develop an Australian graphene characterisation and certification capability to underpin product development and enable Australian SMEs to access new global advanced manufacturing supply chains	– <u>Increased revenue/ sales</u> - forecast revenue growth based on Imagine IM's current product portfolio. The project may also fast track development of new products, creating value beyond the life of the project.
Field deployable unit for the detection of Perfluorinated contaminants	Services	Develop and commercialise an effective tool for swift contaminated site assessment, drinking water monitoring and wastewater treatment efficacy in relation to Perfluorinated environmental contaminants	– <u>Increased profit/ reduced costs</u> – increasing profitability of wastewater treatment facilities. Cost is associated with a significant reduction of down-time under current testing methodology. – <u>Cost savings</u> - rapidly reduced contaminated site assessment times and enable fast decisions reducing the time and number of samples required. Potential cost saving from a reduction in the likelihood of litigation, timely information for fishing communities of potential impact, irrigation concerns and agricultural exposure. – <u>Increased profit/ reduced costs</u> - ongoing discussions to determine full commercialisation continue and progress has been made with certain developed components should be of commercial interest for other non-PFAS applications.
Advanced Manufacturing of High Performance Building Envelope Systems	Manufacturing	Develop and commercialise safer, more sustainable and more durable facade systems, which exhibit significantly enhanced air/water tightness, resistance to extreme loads and life cycle energy performance.	– <u>Increased revenue/ sales</u> - sales of the new façade systems are assumed at a 15 per cent gross margin. – <u>Cost savings</u> - construction cost savings based on cheaper building facades (off-site manufacturing, ease of erection), increased lifespans and reduced maintenance costs. – <u>Cost savings</u> – assumed reduction in energy consumption of a building by up to 40 per cent.
Development of New and Unique Super High Oleic Biobased Oil	Food and agriculture	Develop and commercialise a new biodegradable and renewable oil produced from safflower to replace products produced	– <u>Increased revenue/ sales</u> – increased profits through the sales of new and superior products that would enable an increase in market share by the manufacturers. Plus, an economic return to the farmer (gross margin) for planting safflower over other crops.

CRC-P name	Industry	Output	Impact
		from fossil fuel oils such as lubricants and plastics	– <u>Higher education impact</u> – economic impact of higher education on the local economy from spending on higher education in the project. – <u>Increased capital value of CRC-P partners</u> - increased market valuation benefiting GO Resources via accelerated development program leading to earlier revenue. – <u>Increased revenue/ sales</u> – SHOSO has the potential to be a new long-term economically beneficial crop to Australian farmers and the world's "best in class" plant-derived biobased oil. – <u>Increased revenue/ sales</u> - new income for the agricultural community including farmers and associated supply and logistics businesses, tax revenue, export revenue and royalty revenue to CSIRO.
Industrialisation of a novel diagnostic biosensor for bladder cancer	Med-Tech/ pharma., manufacturing	Develop the manufacturing capability for a new point of care (POC) biosensors platform, conduct clinical trials and prepare a POC device for commercialisation.	– <u>Increased revenue/ sales</u> - domestic and international sales of new bladder sensor devices. – <u>Cost savings</u> - a reduction in national health care costs.
The Probio-TICK Initiative	Food and agriculture	To deliver and commercialise a sustainable microbial probiotic against cattle ticks and buffalo fly for northern Australia, boosting animal's innate resistance to pest invasion	– <u>Productivity gains/ cost savings</u> - cost savings from a reduction in cattle ticks and buffalo fly resulting in a return to producers (ticks and buffalo fly are estimated to cause major economic losses to the northern beef industry). – <u>Increased capital value of CRC-P participants</u> - industry development and commercialisation of IP will increase the product's commercial valuation. – <u>Cost savings</u> – potential to deliver a lower cost, sustainable, eco-friendly, long-term solution to cattle pests.
Strategies to prevent two viruses devaluing Australian crocodile skins	Food and agriculture	Develop and apply control strategies to prevent Kunjin virus and a new (porosus) poxvirus lesions on crocodile skins	– <u>Increased revenue/ sales</u> - lower incidence of Kunjin virus lesions on crocodile skins allowed more skins to be sold from an extension in average production times, and a decreased time for finishing crocodiles and increased acceptance rates. – <u>Increased capital for CRC partners</u> - enabling the inventors of the vaccine to realise a commercialisation pathway for this vaccine.

CRC-P name	Industry	Output	Impact
High-resolution Real-time Airborne Gravimetry	METS, resources	Improve the spatial resolution of airborne gravity data by integrating a new lightweight gravimeter with breakthrough NASA technology and remove range limitations of existing GPS-based technology	– <u>Increased revenue/ sales</u> – increase in combined net revenue to CMG Operations and clients, plus a net revenue increase for other project participants from uptake of technology. – <u>Cost savings</u> - projected savings for end users of the new gravity technology plus savings for end users from reduction in the need to 're-fly' parts of regional surveys.
Additive manufacturing of energetic materials	METS, manufacturing, resources	Deliver new processing methods for energetic materials in additive manufacturing with industrial potential in the field of 3D printed energetic materials for civil, mining, defence and construction industries	– <u>Increased revenue/ sales/ employment</u> - commercialisation of the technology and generation of advanced manufacturing employment. – <u>Cost savings</u> - increases in productivity due to safe manufacture of products closer to users, on demand with little waste. – <u>Other revenue</u> - enhanced research and industry capability position Australia as a knowledge leader in the field and bring new applications to civilian markets. – <u>Increased revenue/ business success</u> – the mining industry will remain globally competitive through the ability to access previously unviable resource deposits in a cost-effective manner delivering economic security.
Breaking the Mould: Making Australian Advanced Manufacturing Portable	METS, Med-Tech/ pharma., manufacturing, resources	Support SPEE3D and CDU's engineering, training, and remote area expertise to deliver a portable metal 3D printer targeting new manufacturing technology for remote housing	– <u>Cost savings</u> - direct savings for remote housing demonstration projects and additional saving for separate remote infrastructure projects. – <u>Increased revenue/ sales</u> - additional machine sales, consumable sales, and prototyping sales as a direct result of the accessibility, linkage, and promotional activities in the project. – <u>Other revenue</u> - increased technology consumption, research and innovation activity. – <u>Increased revenue/ sales/ business success</u> - the CRC-P lowered the barrier of entry to the technology by de-risking the investment which led to new products and services in a variety of markets (e.g. healthcare and manufacturing). – <u>Employment growth</u> - SPEE3D has seen substantial growth in employment over the project. – <u>Additional funding/ capital value of CRC-P partners</u> –\$2 million venture capital

CRC-P name	Industry	Output	Impact
			lead investment by PIIF in SPEE3D (leading to development in international markets) and a further \$2.75 million concessional loan from the NT Government (Local Jobs Fund) to establish a Research and Development Headquarters in Darwin.
A big health data analytics & insights platform for the MTP sector	Med-Tech/ pharmaceutical	Develop a commercial analytics platform integrating multiple linked health datasets for the MTP sector to address data access, integration and analytics capacity issues	– <u>Increased return on investment</u> - increased returns on the \$1 billion per year R&D investment made by the local MTP sector boosting submission success, cost savings, new product launches, health benefits, and profitability. – <u>Increased licence income</u> - MTP firms will have stronger evidence of the value of their products and R&D projects, increasing the potential for economic inflows through licensing, partnering and third-party investment. – <u>Increased capital value of CRC-P partners</u> - successful capital raise as a result of CRC-P collaboration, expansion into Asia, and platform development. – <u>Increased employment</u> – CRC-P has contributed to Prospection's FTE count nearly doubling from around 30 to 60. – <u>Increased revenue/ sales</u> – Prospection's revenue has increased significantly since the beginning of the CRC-P and now works across six countries and international revenue is equal to its Australian revenue.
Enabling Exosome Therapy: Developing an Advanced Manufacturing Process	Med-Tech/ pharmaceutical manufacturing	To develop a large-scale advanced manufacturing process for exosomes focussing on exosomes to treat peripheral vascular disease and enabling off-the-shelf medicine without the technical problems of cell therapies	– <u>Increased investment/ business activity</u> - significant business activity at the selected Australian clinical centres with an investment by VivaZome. – <u>Licence income</u> - licensing of the technology to non-competing companies provides the opportunity to generate significant new revenue for the IP holder. – <u>Industry development/ increased sales</u> – potential to develop a new high-tech industry with prospects for industry development and high-value employment.

CRC-P name	Industry	Output	Impact
A scalable detection tool for childhood inattention: TALI Detect™	Med-Tech/ pharma.	Deliver TALI Detect™, an accurate, low-cost inattention detection tool for individuals that is scalable to national screening of all children entering school	– <u>Increased revenue/ sales</u> - revenue from the domestic testing and treatment market and international usage test revenue.
Project Vaccinate Driving Innovation in Dairy Goat Vaccines	Food and agriculture, Med-Tech/ pharma.	Develop standardised protocols and operating procedures for the development and delivery of targeted vaccines for endemic disease prevention in large Australian dairy goat milking operations	– <u>Cost savings</u> - farm productivity gains through improved animal health management, lower mortality rates and higher milk yields. – <u>Increased profitability</u> - farm productivity gains and higher milk yields may increase farm profitability. – <u>Increased productivity and competitiveness</u> - in the Australian dairy goat industry from the newly developed vaccine and broader potential of the protocols.

Table B.5 presents social and environmental benefits from CRC-Ps.

Table B.5 CRC-P— social and environmental outputs and impacts — summary

CRC-P name	Industry	Output	Impact
High performance optical telemetry system for ocean monitoring	METS, manufacturing, resources	Commercialise new classes of distributed array sonars for ocean monitoring purposes	– <u>Improved safety</u> - potential lives saved in mining contexts. – <u>Business success</u> – enhanced competitiveness of Australian manufacturing and other industry. – <u>Expected social costs avoided/ savings on Government expenditure</u> – enhanced national security in the years to come. – <u>Education and training</u> – three new internships/ secondments provided. – <u>Reduction in contamination/ environmental costs</u> - improvements in ocean monitoring and fisheries security.
Strengthening Australia's radiopharmaceutical development capabilities	METS, manufacturing	Strengthen Australia's radiopharmaceutical capabilities by developing the infrastructure, processes and training needed to develop innovative products to treat serious disease (SARTATE)	– <u>Improved health and well-being</u> – expected decline in mortality rates, gains in wellbeing and decline in health care costs and potential for the development of other new cancer drugs. – <u>International collaboration</u> - engagement with and funded industry focused research at public research organisations such as the Memorial Sloan Kettering Cancer Center (USA). The project and products have gained international reach, with

CRC-P name	Industry	Output	Impact
			development of the products through the FDA in the USA for clinical development. – <u>Education, training and publications</u> – skills development in radiopharmaceutical drug development and subsequent projects and training programs. Plus, three publications, two training courses/ workshops and two internships/ secondments provided.
Innovation in Advanced Multi-Storey Housing Manufacturing	Manufacturing	Develop and commercialise an innovative housing system that will transform conventional housing construction towards an advanced manufacturing future	– <u>Sector/ industry success</u> - the project will spearhead the restructuring of the sector away from a low-margin, low-skill, and hierarchical sub-contracting model, towards a value-adding, high-skill, and vertically integrated manufacturing structure – <u>Improved safety</u> – improved safety benefits from the innovative housing system. – <u>Business success</u> – the project led to a new start-up, wholly-owned subsidiary company with the intent that this be spun-off in the future. – <u>Education and training</u> – 22 publications or reports for industry users produced, 14 structured professional courses/ conferences delivered and, two ongoing internships/ secondments and six Postdoctoral Fellows supported. – <u>International collaboration</u> – seven visiting international experts were hosted, and six international tours were conducted. – <u>Reduction in the amount of waste produced</u> - a reduction of building waste produced while also increasing housing sustainability (including the use of renewable engineered timber systems).
Future Oysters CRC-P	Food and agriculture	Rebuild and evolve the Australian oyster aquaculture industry by accelerating the breeding of disease resistant oysters, disease management and productivity	– <u>Business success</u> - better farm management strategies and more resilient farming systems leading to improved profitability. – <u>Education and training</u> – five scientific journal articles have been published, seven FRDC final project reports and 36 short newsletters and reports produced for the industry as well as 130 industry communications. There were also seven work experience, graduate and postgraduate students engaged. – <u>Change in character of local community</u> – increased confidence of Pacific Oyster growers in the aftermath of POMS to reinvest in their business. This also led to positive mental health outcomes for

CRC-P name	Industry	Output	Impact
			owners and employees of businesses by providing hope for profitability and sustainability. – <u>International collaboration</u> – collaboration between researchers and international industry and colleagues that have experienced POMS plus, a number of presentations at international conferences overseas. – <u>Reductions in environmental costs</u> - improved biosecurity and surveillance outcomes (e.g. POMS hasn't reached some growing regions in South Australia).
The future integrated driver monitoring solution for heavy vehicles	Manufacturing	Commercialise a world-leading driver monitoring product that will enable the freight industry to monitor and improve driver safety and wellbeing	– <u>Improved safety and improved health and well-being</u> - reductions in driver injuries from a reduction in fatigue, workload and distraction related incidents. – <u>Education and training</u> – four structured professional training courses/ conferences/ seminars/ workshops delivered, and two internships/ secondments provided
Hydrocarbon fuel technology for hypersonic air breathing vehicles	Manufacturing	Develop new technology to fuel scramjets with liquid hydrocarbons to commercialise hypersonic air breathing engines	– <u>Labour force participation</u> - employment generation caused by the commercialisation of the new technology in the advanced manufacturing sector. – <u>Education and training</u> - enhanced domestic research and industry capabilities, university education and further research and innovation. – <u>Savings on government expenditure</u> - new scramjet technology will protect Australia's strategic interests enabling low-cost launch services which affect communications and surveillance space assets. – <u>Education, training and publications</u> – more than 20 publications or reports for industry users (most by PhD students engaged in the project) and three structured professional training courses, conferences or workshops delivered (including lectures to students at RMIT and engagement with Bundeswehr University Munich). – <u>Education and training</u> – the CRC-P has enabled research into hydrocarbon fuel technology to take a practical leap forward, ensuring Australia continues its driving force as a leader in hypersonic flight and has paved the way for future research.

CRC-P name	Industry	Output	Impact
Printed solar films for value-added building products for Australia	Manufacturing	Commercialise a new-to-the-world premium roofing product for large-span commercial structures	– <u>Reduced GHG emissions</u> - environmental benefits from a reduction in fossil fuels and reduced electricity usage by commercial and industrial businesses with concomitant savings in the severity of climate mitigation actions.
Translational R&D to accelerate sustainable omega-3 production	Food and agriculture, Med-Tech and pharmaceutical	Commercialise high-quality algal omega-3 products by translating proof-of-concept technologies to achieve sustainable, organic production of omega-3 fatty acids See Box 6.4.	– <u>Education, training and labour force participation</u> - new employment and training due to the establishment of new farms near cities and regional areas. – <u>Improved health outcomes</u> - health benefits from an increase in availability of algal omega-3 oil for vegetarians and people who choose not to consume fish or fish oil. – <u>Education and training</u> – various site visits, an international visiting chemical engineer, support to graduate students and visiting scientists to carry out projects. – <u>Business diversity and resilience</u> – the project has demonstrated that marine microalgae farming as a drought-proof form of agriculture for Australia that can produce 30-70 times more protein per hectare than livestock or conventional crops respectively. Potential to create a future educational and tourism facility in the region. – <u>International collaboration</u> – the CRC-P has engaged with Australian and global food producers with an interest in securing future supply of algal omega-3 oil and algal high-protein biomass as new vegetarian food ingredients. – <u>Reductions in environmental costs</u> - environmentally sustainable production of food ingredient products from algae.
An antibody based in vitro diagnostic for metastatic cancer	Med-Tech and pharma.	Scale up production and characterise the Chemocopeia antibodies to develop a prognostic assay for metastatic disease (currently an unmet need)	– <u>Improved health and wellbeing</u> - a reduction in costs to the health service by early diagnosis of cancer and a reduction in lives lost (QALY benefits) from improved testing of Gastric cancer. – <u>Improved health and wellbeing</u> - saving per patient based on quality adjusted life years (QALY). – <u>Education and training/ international collaboration</u> - one student industry placement supported (from Burnet Institute and Federation University).

CRC-P name	Industry	Output	Impact
Enhanced market agility for the Australian tea tree industry	Food and agriculture	Reduce response time by half to around four years by developing a clonal propagation system for tea tree and transforming the Australian industry	– <u>Education, training and publications</u> – various blog updates, 11 technical reports and two scientific papers published, one internship/ secondment supported and the training of two post graduate students in agricultural science. – <u>Increased safety/ health</u> - safety concerns may be alleviated in cosmetic and other personal care formulations by producing oil with low levels of methyl eugenol. – <u>Potential reduction in contamination of natural resources</u> - more sustainable growing practices (e.g. use of pest resistant clonal cultivars that require fewer chemicals).
Power Efficient Wastewater Treatment Using Graphene Oxide Technology	Food and agriculture, METS, manufacturing and resources	Significantly reduce the energy intensity in converting wastewater to freshwater using graphene oxide-based water treatment technologies	– <u>Reduction in energy consumption</u> - reduction in power consumption estimated to reduce power consumption by 50 per cent. – <u>Reduction in greenhouse gas emissions</u> – from saved power consumption and avoided CO2 emissions.
Targeting tropomyosin as a novel anti-cancer therapy	Med-Tech/ pharma.	Provide improved chemotherapy for advanced metastatic disease through an Australian innovation to selectively destroy cancer cells using anti-tropomyosin (ATM) drugs	– <u>Potential improved health outcomes</u> - two clinical lead compounds that inhibit tumour growth in an animal model of ovarian cancer have been identified (which have improved patient compliance and more favourable commercial prospects). – <u>Education, training and publications</u> – four publications or reports for industry users published with a fifth manuscript currently under review. Also, there was one PhD student and post-doctoral researcher employed by this grant. – <u>Business success</u> - opportunity to set up a spin-off company to develop Tpm4.2-targeting therapeutics in the future. – <u>International collaboration</u> – the CRC-P's first publication was a result of a collaboration with Bill Lehman's group at Boston University.
Universal Solar Module Inspection and Data Storage System	Manufacturing , resources	Identification and removal of defective solar modules based on BT Imaging's proven & proprietary luminescence imaging platform	– <u>Training and education</u> - new postgraduate degrees created and one Postdoctoral Fellow engaged on a full-time basis on the project. – <u>International collaboration</u> - new collaborations established with organisations outside Australia. Established to test the concept and product prototypes.

CRC-P name	Industry	Output	Impact
			– <u>Education, training and publications</u> – two publications or reports for industry users published. – <u>Reductions in environmental costs</u> - reduced manufacturing costs will escalate the take up of PV globally.
An integrated modelling system for navigational aid in tidal inlets	METS/ resources	Use new ocean physics to develop an integrated modelling system to improve navigational aid systems and maritime safety whilst providing economic benefits to shipping	– <u>Education, training and publications</u> – one publication and one report for industry users, six graduate subjects within the Master of Civil and Master of Environmental Engineering (UoM) delivered, one international conference (organised by the UoM), one internship/ secondment supported, two research engineers trained, two PhD students and a Master-by-research student. – <u>International collaboration</u> – the project facilitated discussions between project partners and international shipping and oil and gas industry. Also contributed to an international conference.
Targeted therapy for sleep apnoea: A novel personalised approach	Med-Tech/ pharma, manufacturing	Commercialise and improve the efficacy, compliance and monitoring of sleep apnoea therapy using a tailored suite of treatments	– <u>Improved health and wellbeing</u> – a reduction in obstructive sleep apnoea and potential applications for COVID-19 monitoring. – <u>Savings on government expenditure</u> - sleep monitoring will be included in the device delivery fee at a reduced total, resulting in a saving for Medicare. – <u>Education, training and publications</u> – more than 20 conference and journal publications and two research projects delivered. Three PhD students have completed their research and delivered their theses. – <u>International collaboration</u> - Oventus have set up an International Clinical Advisory Committee.
Wear life extension via surface engineered laser cladding for mining	Food, METS, manufacturing , resources	Develop, deploy and commercialise new surface engineered materials and application technologies to the drilling tools and drill rig used for exploration and extraction of mining resources	– <u>Education, training and publications</u> – seven international interns, three undergraduate students, four publications for industry users published, two structured workshops delivered, and two internships/ secondments delivered and five university visits.

CRC-P name	Industry	Output	Impact
Graphene Supply Chain Certification	Manufacturing	Develop an Australian graphene characterisation and certification capability to underpin product development and enable Australian SMEs to access new global advanced manufacturing supply chains	– <u>Business success</u> – one subsidiary company was supported (Graphene Certification Labs) who have invested in staff, lab space, equipment and services utilising the knowledge developed in the CRC-P. – <u>Education, training and publications</u> – one publication for industry users published, three structured professional training courses, conferences/ seminars delivered. – <u>International collaboration</u> – the CRC-P has mapped global standardisation initiatives and spoken with large organisations internationally that are working towards this goal.
Field deployable unit for the detection of Perfluorinated contaminants	Services	Develop and commercialise an effective tool for swift contaminated site assessment, drinking water monitoring and wastewater treatment efficacy in relation to Perfluorinated environmental contaminants	– <u>Change in character of local community</u> - near real time monitoring for a water quality assessment in or near impacted sites in order to alleviate concerns for local communities (reduction of likelihood of litigation, timely information for fishing communities of potential impact, irrigation concerns and agricultural exposure, drinking water supply quality assurance). – <u>Potential improvement in health and wellbeing</u> – near real time monitoring for a water quality assessment which enhances drinking water supply quality assurance. – <u>Education, training and publications</u> – two structured professional training courses/ workshops delivered; two internships/ secondments supported. – <u>Reduction in contamination of natural resources</u> - timely information for fishing communities of potential impact, irrigation concerns and agricultural exposure.
Advanced Manufacturing of High Performance Building Envelope Systems	Manufacturing	Develop and commercialise safer, more sustainable and more durable facade systems, which exhibit significantly enhanced air/water tightness, resistance to extreme loads and life cycle energy performance.	– <u>Education, training and publications</u> – five PhD students contributed to the project and 15 masters group projects (more than 40 students) completed, one major symposium held consisting of 77 attendees plus 17 national, international conferences and forums. – <u>International engagement</u> – the project research provided an opportunity to work with Island Exterior Fabricator, LLC (Island) based in the USA who have since visited the Australian assembly plant. – <u>Reduction in energy consumption</u> - assumed reduction in energy consumption of a building by up to 40 per cent.

CRC-P name	Industry	Output	Impact
Development of New and Unique Super High Oleic Biobased Oil	Food and agriculture	Develop and commercialise a new biodegradable and renewable oil produced from safflower to replace products produced from fossil fuel oils such as lubricants and plastics	– <u>Business success/ labour force participation</u> - impact on rural communities through increase revenue to the farmer and potentially increased employment. – <u>Education, training and publications</u> – one publication for industry users published. – <u>International collaboration</u> – collaboration with an international participant in the project (Emery Oleochemicals LLC). – <u>Business success/ resilience</u> - SHO Safflower has been shown to be hardy in drought conditions and can be grown successfully on soils that affected by salt. The drought/sodic resistance brings another highly profitable crop into the farmer's rotational crop plans. – <u>Reduced GHG emissions/ waste/ energy</u> - new and unique biodegradable and renewable oil produced from safflower that has the potential to replace products produced from fossil fuel oils including lubricants such as engine and marine oils.
Industrialisation of a novel diagnostic biosensor for bladder cancer	Med-Tech/ pharma., manufacturing	Develop the manufacturing capability for a new point of care (POC) biosensors platform, conduct clinical trials and prepare a POC device for commercialisation.	– <u>Savings on government expenditure</u> - health care cost reductions including Medicare savings based on avoided services/ treatment requirements. – <u>Education, training and publications</u> – two publications for industry users, three structured professional courses delivered, and 10 scientific conferences supported (most international), upskilling of engineers in various disciplines. – <u>Improved health and wellbeing</u> – development of a novel cancer diagnostic product and a better patient experience which introduces a less invasive and risky procedure. – <u>Business success</u> – results achieved from this CRC-P has led to other commercial opportunities for SMR including cell therapy and other diagnostic technologies.
The Probio-TICK Initiative	Food and agriculture	To deliver and commercialise a sustainable microbial probiotic against cattle ticks and buffalo fly for northern Australia, boosting animal's innate resistance to pest invasion	– <u>Education, training and publications</u> – three publications or reports released for industry users.

CRC-P name	Industry	Output	Impact
Strategies to prevent two viruses devaluing Australian crocodile skins	Food and agriculture	Develop and apply control strategies to prevent Kunjin virus and a new (porosus) poxvirus lesions on crocodile skins	– <u>Education, training and publications</u> - one PhD student supported plus research assistants, three internships/ secondments, one publication or report for industry users (plus two more in draft form) and contributed to research knowledge and capability in the Northern Territory.
High-resolution Real-time Airborne Gravimetry	METS, resources	Improve the spatial resolution of airborne gravity data by integrating a new lightweight gravimeter with breakthrough NASA technology and remove range limitations of existing GPS-based technology	– <u>Education, training and publications</u> – introduction of an annual lecture and field visit, one PhD student supported. – <u>International collaboration</u> – engagement with Intuitive Machines LLC (USA) and NASA after receiving a contract.
Additive manufacturing of energetic materials	METS, manufacturing, resources	Deliver new processing methods for energetic materials in additive manufacturing with industrial potential in the field of 3D printed energetic materials for civil, mining, defence and construction industries	– <u>Savings on government expenditure</u> - national security and strategic intent implications from a revolutionised military planning, logistics and safety through in-situ, on demand mission specific manufacture of ordinance and maintain technological superiority. – <u>Education, training, publications</u> – four publications or reports for industry users, one structured professional course.
Breaking the Mould: Making Australian Advanced Manufacturing Portable	METS, Med-Tech/ pharma., manufacturing, resources	Support SPEE3D and CDU's engineering, training, and remote area expertise to deliver a portable metal 3D printer targeting new manufacturing technology for remote housing	– <u>Savings on government expenditure</u> – reduced costs for the Northern Territory government from savings on remote housing demonstration projects, future projects and separate remote infrastructure projects. – <u>Savings on government expenditure</u> - increasing the capability of the Australian Army and Navy through projects designed to increase supply chain resilience, adaptability, and self-sufficiency. – <u>Education, training, publications</u> – eight structured professional training courses delivered, one internship projected, seven industry targeted case studies, five journal articles, nine conference proceedings, 13 student theses delivered, seven internships and secondments facilitated. – <u>Education/ business success</u> - the CRC-P led to increased manufacturing capabilities, increased industry knowledge and the delivery of a unique training program.

CRC-P name	Industry	Output	Impact
A big health data analytics & insights platform for the MTP sector	Med-Tech/ pharmaceutical	Develop a commercial analytics platform integrating multiple linked health datasets for the MTP sector to address data access, integration and analytics capacity issues	– <u>Improved health and wellbeing</u> – health benefits arising from the increased success of R&D investment made by the MTP sector.
Enabling Exosome Therapy: Developing an Advanced Manufacturing Process	Med-Tech/ pharmaceutical manufacturing	To develop a large-scale advanced manufacturing process for exosomes focussing on exosomes to treat peripheral vascular disease and enabling off-the-shelf medicine without the technical problems of cell therapies	– <u>Education, training and publications</u> – one publication for industry users, four formal education programs delivered, conducted industry-based student projects, around 25 undergraduate and graduate students were supported through projects, – <u>International collaboration</u> - VivaZome has established a global network of collaborators, research service providers and alliances with multinational technology providers, and is represented on the expert regulatory and clinical committee of ISEV.
A scalable detection tool for childhood inattention: TALI Detect™	Med-Tech/ pharmaceutical	Deliver TALI Detect™, an accurate, low-cost inattention detection tool for individuals that is scalable to national screening of all children entering school	– <u>Improved health and wellbeing</u> – social benefit from the early treatment and intervention of Australian children.
Project Vaccinate Driving Innovation in Dairy Goat Vaccines	Food and agriculture, Med-Tech/ pharma.	Develop standardised protocols and operating procedures for the development and delivery of targeted vaccines for endemic disease prevention in large Australian dairy goat milking operations	– <u>Business success / education contribution</u> – the vaccine protocols from this project have the potential to be applied broadly to other aligned industry sectors such as sheep and cows. The transferrable findings are due to be published into research papers for global access.

C Literature review

C.1 Methodology

The review uses academic literature (sourced from a variety of data bases) and grey literature sourced from the internet and other channels will be used to supplement the literature review.

Preliminary searches suggested the review needed to be constrained due to the very large volume of literature available on university industry collaboration and the very small volume of literature available on cooperative research centres. Following discussions with the Department it was agreed that this literature review would focus on:

- any recent evaluations of the CRC Program (from 2013-2021)
- a sub-set of literature³⁵ from 2013 onwards in the broader university industry collaboration space with a focus on best practice, novel approaches and views of how government can best:
 - facilitate collaboration
 - measure outcomes.

Thirty-three papers were sourced and reviewed as part of this literature review. Referenced papers are listed in the reference listC.1 Review of recent work on the CRC Program

Since Allen Consulting's evaluation of the CRC Program in 2012 there has been few reviews of the Program with the exception of the Miles Review in 2015. In the broader literature, a review by the Australian Council of Learned Academies (ACOLA) in 2015 focuses on international best practice and makes several findings that are relevant to the CRC Program.

C.1.1 The 2015 Miles Review

The Miles review, accepted by the Government, concluded that the CRC Program was valuable but needed more of an industry focus going forward. Miles made 18 recommendations which focused on the CRC Program's:

- Appropriateness
- Effectiveness
- Efficiency
- Integration
- Performance assessment
- Strategic policy alignment

The CRC Program was considered appropriate by Miles in terms of the program objectives and value which have largely been confirmed by multiple reviews conducted prior to 2013.

³⁵ Use of "university industry collaboration" title searches, with focus on highly cited literature (> 50 citations) and literature which takes a meta-analysis or systematic review approach. Research with a developing country or newly industrialised country focus is excluded.

The exception being the National Commission of Audit (2014) report which recommended CRCs be abolished due to duplication with other program objectives.

*Currently there is a range of programmes designed to encourage collaboration between universities and the private sector. Given that all of these programmes have the same objective, there would be efficiency benefits in consolidating them. **Cooperative Research Centres should be abolished**, with funding rolled into the Australian Research Council Linkages programme.*

National Commission of Audit (2014)

Miles disagreed with the National Commission of Audit's assessment as the ARC Linkage Program is "fundamentally different" to the CRC Program because there is no requirement for collaboration with industry and industry partnerships are not required for all grants. One of the key recommendations was the introduction of the CRC-P program element to support short term, industry led research. The review's findings and recommendations can be summarised under three banners: better alignment, improved efficiency and international benchmarking.

Better alignment with government and industry priorities to improve outcomes and performance

A shift towards achieving government priorities (including priorities of portfolios outside the then Department of Industry and Science) and better alignment with industry (including Industry Growth Centres) is Miles' central message throughout his report noting the need for:

- refocusing the Program objectives so as to orient them more on delivering growth sector outcomes including but also beyond science
- increasing the industry role in the CRC Program and process
- improving engagement with, and involvement of, small to medium enterprises (SMEs).

Improved efficiency through streamlined administration

Miles proposed revision of the CRC Program Guidelines to introduce a two-stage application process for CRCs and a single stage process for CRC-Ps with an online process open to applications three times a year.

A single (mandated) governance model (where CRCs are established as incorporated companies, limited by guarantee) reduces complexity and the time taken to set up new CRCs. CRC-Ps should be managed by agreement between an industry nominated entity and the Government.

Data collection and reporting arrangements should aim to minimise red tape and aligned with revised Program objectives and outcomes and intellectual property agreements should be designed with consideration of best practice and streamlined.

Miles notes the "priority public good funding mechanism", introduced in 2013 to extend the life of relevant CRC's, should be abolished as:

CRC Programme funding inherently delivers public good by enabling industry focused research on key issues.

Miles (2015).

Related to this, Miles recommends that CRCs should be funded for a maximum of ten years without extension (with CRC-Ps limited to three years of once off funding).

International benchmarking

With reference to international benchmarks, Miles set out to align the CRC Program with the then newly formed UK Catapult Centres (refer Box 1.1) and the long established German Fraunhofer Institutes (refer Box 1.2). Miles concluded that if the 18 recommendations resulting from his review were made – then the CRC Program would be well on the way to best practice in line with these two initiatives.

Box C.1 UK Catapult Centres

With the aim to accelerate business growth and stimulate markets the Catapult Network has nine technology and innovation centres across 40 locations in the UK.

Each centre has state of the art R&D infrastructure, knowledge, collaboration and technical expertise to assist in proving and adopting products, services and technologies across manufacturing, space, health, digital, energy, transport, telecoms, the urban environment and others.

Between 2013 and 2020 Catapult supported over 8,000 SMEs, was involved in 14,750 industry collaborations, 5,000 plus academic collaborations and managed more than £1.3 billion (\$A2.38 billion) in R&D facilities for a total of £744 million (\$A1.36 billion) of investment.

Source: <https://catapult.org.uk/> and <https://catapult.org.uk/wp-content/uploads/2020/12/Catapult-Network-Impact-Brochure-2020-FINAL.pdf>

Box C.2 German Fraunhofer Institutes

Established in 1949, the Fraunhofer-Gesellschaft is a not-for-profit organisation with a focus on excellence in research and is the leading applied research organisation in the EU with 74 institutes and research institutions across Germany.

Each Institute develops its own business field and core areas of expertise based on its market environment and its links with the wider scientific community. The institutes operate as separate profit centers but are not autonomous legal entities.

In 2019, the Fraunhofer-Gesellschaft administered more than €2.8 billion (\$A4.4 billion) of research business of which €2.3 billion (\$A3.6 billion) is contract research. The German Federal and State governments contribute about 30 per cent of funds. There are currently seven areas of strategic focus:

- Bioeconomy
- Digital Healthcare
- Artificial Intelligence (AI)
- Next Generation Computing
- Quantum Technologies
- Resource Efficiency and Climate Technologies
- Hydrogen Technologies

Source: <https://www.fraunhofer.de/en.html> and <https://www.fraunhofer.de/content/dam/zv/en/Publications/Annual-Report/2019/Fraunhofer-Annual-Report-2019.pdf>

C.1.2 The 2015 ACOLA Report

The aim of ACOLA's 2015 report was to examine best practice approaches to improving research translation and business-researcher collaboration around the world (with a focus on OECD countries)³⁶, and their applicability for Australia. Australia is assessed as having, relative to other OECD countries, reflected in a low level of innovative universities³⁷ (despite the high performance by Australian researchers) and a low level of engagement and translation of research in the public sector (despite higher-than-average public R&D expenditure).

ACOLA provides a series of key findings to improve translation and collaboration in research based on global best practice approaches. With a focus on relevance to the CRC Program, these include:

- increasing funding and stability of the funding for collaborative research and translation across the innovation system (Findings 1, 5 and 8)
- supporting SMEs and start-ups with high potential will lead to better translation of research to the public sector (Finding 2)
- incentivising universities is a proven method for increasing external engagement (Finding 9)
- using innovation intermediaries to facilitate collaboration and translation (Finding 11)
- adopting a national strategy for innovation and an agency to manage it (Finding 12)
- improving university policies, processes and procedures to facilitate collaboration (Finding 14)
- developing research translation and entrepreneurial skills in public sector research institutions (Finding 15).

The CRC-P program element goes part way to assisting with Finding 2, and potentially some work by universities on Findings 14 and 15. In November 2015, DISER released a National Innovation and Science Agenda (NISA) report titled *Welcome to the Ideas Boom* which went some way to articulate the government's role in collaborative innovation – specifically:

change funding incentives so that more university funding is allocated to research that is done in partnership with industry; and invest over the long term in critical, world-leading research infrastructure to ensure our researchers have access to the infrastructure they need.

Welcome to the Ideas Boom (2015).

Resulting from NISA was the introduction of the *Engagement and Impact Assessment (EIA) 2018-19* for assessing universities' contribution on a number of fronts: support for ongoing collaboration,³⁸ provision of infrastructure and support mechanisms for knowledge transfer.³⁹ The next EIA report is scheduled for 2024.

³⁶ With specific focus on: Finland, Denmark, Sweden, Germany and the UK, Israel, USA and Canada, South Korea, Japan, Singapore and China, Brazil and Chile.

³⁷ No Australian universities rank in the top 100.

³⁸ Refer: <https://dataportal.arc.gov.au/EI/NationalReport/2018/pages/section3/support-for-ongoing-collaboration/>

³⁹ Refer: <https://dataportal.arc.gov.au/EI/NationalReport/2018/pages/section3/support-mechanisms-for-knowledge-transfer/>

C.1.3 Academic literature related specifically to the CRC Program

Four academic articles (2013-21) were identified with specific and direct relevance to the CRC Program.⁴⁰ The relevant findings from these articles are summarised in Table C.1.

⁴⁰ A fifth article by Garrett-Jones *et al* in 2013 was identified, but this was based on a survey of 370 people involved in the CRC program in 2004-05 and was therefore excluded from this summary as the key findings are likely to be outdated.

Table C.1 Academic literature specific to the CRC Program (2013-2021)

Author	Year	Title	Method	Relevant findings
Sinnewe <i>et al</i>	2016	Australia's Cooperative Research Centre Program: A transaction cost theory perspective	Application of economic theory (Transaction Cost Theory) to explain the formation and survival of CRCs specifically the cost of lodging an application; the costs of negotiation and agenda setting and the cost of monitoring and enforcement.	– government funding appears to play an important role in reducing the governance costs of CRCs – there is limited theoretical evidence to suggest that cross-sectoral collaboration is incentivised beyond the life of the CRC (i.e. beyond government funding).
Noble <i>et al</i>	2018	The research collaboration paradox: A tale of two governance narratives in an Australian innovation setting	A discussion on the influence of government policy narrative on cooperative/collaborative research.	– Development of true and long-lasting relationships between industry and universities is difficult to achieve – There has been a shift in government funding principles to become more accountable and as a result, objectives for funding need to be specific, scrutinised frequently and be done over shorter time frames and projects which will be able to demonstrate immediate outcomes so as to reduce risks of 'poor' investment – this comes at the expense of R&D and at developing longer term collaborative relationships between universities and industry. – CRC-PS are considered to be less able to produce truly innovative solutions to problems and less likely to produce collaborative long-term relationships.
Noble <i>et al</i>	2019	Desperately seeking innovation nirvana: Australia's cooperative research centres	A review of theoretical approaches to developing innovation systems, innovation policy diffusion and innovation performance. CRCs as a case study.	Key findings: – CRC Program “exemplifies innovation policy” that is not clearly defined, and incremental changes mean innovation in Australia is just “business as usual” – A small, geographically disperse population and markets make it difficult for Australia relative to the “absorptive capacity of the USA and the EU. – Australia should build on the 2016 Global Innovation Strategy to capitalise on Australia’s national system of innovation.

Author	Year	Title	Method	Relevant findings
Noble <i>et al</i>	2020	Embedding SMEs in national systems of innovation: Participant perceptions of Australia's CRC-P program	A review of CRC-Ps and SME involvement in the National systems of innovation (NSI). Using semi-structured interviews based on a literature review. Specifically: (a) the degree to which the Program has facilitated the embedding of SMEs into the Australian NSI and (b) any barriers to successful university industry collaboration.	The results showed: – SMEs are more embedded in the NSI as a result of the CRC-P program element – SMEs learnt research skills and capability (including the ability to partner with researchers) from working with universities through the CRC-P – Compulsory quarterly reporting is burdensome and detracts from purpose and drives more time to compliance rather than innovation. Three barriers were identified to successful university SME collaboration these were: – Issues to do with SME leadership and relational difficulties with academic researchers. – Cultural differences in terms of researchers being less able to work to short timelines and be agile. University bureaucracy also created issues relating to working hours, holidays etc – a ‘public service mentality’ which caused delays. – Gaming of the system by multi-national corporations “using” SMEs to gain access to the program funding and direct research – Other adverse effects identified included researchers who were part of both the SME, the university and the CRC-P; SMEs forming purely to access funding; projects being funded because of their largely ‘political’ alignment with government requirements crowding out rather promising projects that did not directly align.

Source: see reference list

C.2. Review of best practice and novel approaches to university industry collaboration

A review of 25 articles published between 2013 and 2020 was conducted on the best practice approaches for university industry collaboration in terms of facilitating collaboration and measuring outcomes. The findings are summarised below.

C.2.1 Best practice approaches to facilitating collaboration

Collaboration between universities and industries assists in “higher capitalisation of returns from science and innovation” (Musico and Vallanti, 2014).

Barriers exist for both industry and universities. Recent literature identifies numerous barriers (some real and some perceived) which tend to decline with increased frequency of interaction (Musico and Vallanti, 2014), (refer Table C.2).

Table C.2 Barriers to university industry collaboration

Barrier	
Structural/transactional barriers	Cultural/cognitive barriers
Institutional issues	Objectives
Intellectual Property (IP) policy	Perception of time
Administrative processes	Motivation
Governance	Capability
Social capital barriers	Environmental/contextual barriers
Experience	Resource availability
Trust	Innovation policy
Capacity	Geographic distance

Source: various, see reference list)

Villani (2014) notes that although these barriers are common across university industry collaboration the key differences between universities and industry should also be understood as it helps to explain the complexity of collaboration in this space in terms of cultural, institutional and operational differences. The major differences can be summarised as follows:

- Objectives: academics focus on research for publication; industry focuses on economic outcomes.
- Motivation: academics focus on research results for the purposes of promotion and recognition; industry focus on protection of research for competitive advantage and financial gains.
- Incentives: academics are incentivised by peer recognition and reputation; industry focuses on financial reward.
- Organisation of work: academics have a higher level of autonomy; industry generally has less workplace autonomy.
- Language used: academics are considered “abstract, ambiguous and complex” (Villani, 2014) and industry more goal driven.

The majority of research in this space focuses on the institutional structure/governance of universities rather than industry. Atta-Owusu *et al* (2020) in a study focusing on the research output and participation in university industry collaboration in Scandinavia finds that industry

strategy and geographic proximity are more important drivers than the characteristics of university collaborators.

Collaboration can be encouraged through the removal of barriers. It is easier to work on improving structural/transactional and environmental/contextual barriers, especially in the short term but that cultural cognitive and social capital barriers, such as trust, may have a larger impact but are harder to remove in the short term (Sjoo and Hellstrom, 2019). Indeed, Musico and Vallanti (2014), Steinmo and Rasmussen (2018) and Sjoo and Helstrom (2019) find that the strongest predictor of collaborative success is prior experience (i.e. university and industry working together on repeat basis over time – building trust).

Opportunities for universities

For universities the importance of sustaining collaboration is well recognised and there are several areas that have been promoted as solutions to barriers university industry collaboration face, these include:

- long term development of industrially relevant academic R&D resources (Awasthy *et al*, 2019)
- better communication (de Wit-de Vries *et al*, 2019)
- reduced transactions costs (i.e. the cost of application, interaction and the financial costs) (Dollinger *et al*, 2018)
- improved administrative processes (including project management) and conflict resolution processes. (Villeux and Queenton, 2015).

Opportunities for industry

Industry contributors to collaborative arrangements need to focus on:

- commitment to and interest in (at senior levels in the firm) the project during the initial phases of project design and collaborative development (Rahm *et al*, 2013).
- internal capability to absorb the research fully and transform it into useable/marketable products (Rahm *et al*, 2013).
- confidence of the industrial partner in university participants (Awasthy *et al*, 2019).

Best practice framework

There is much consistency in recent findings with similar success/enabling factors identified by Mäkimattila *et al* (2015), Villeux and Queenton (2015) Dollinger *et al* (2018), Awasthy *et al* (2019), Rybníček and Königsguber (2019), Mahrino *et al* (2020), Nsanzumuhire and Groot (2020) and Pertuz *et al* (2021). These have been adapted into a set of 4 best practice concepts that should be considered when seeking to enable better university industry collaboration.

1. **There is no one size fits all:** Understanding differences and noting that each university industry collaboration is unique in terms of motivation, objective, degree of involvement and duration is important. Success appears to be largely built on a combination of trust and experience developed over time.
2. **Find the right people for the right job:** Consideration needs to be given to the set of stakeholders involved, their intent and purpose and how they propose to ‘use’ the collaboration. Leadership on both sides is needed to select people with collaboration inducing behaviours such as openness to change, willingness to cooperate and ability to span boundaries. It is also important that leaders have the ability to identify obstacles and

understand how to overcome them. Two suggestions on ensuring the right people include, either:

- a) consideration of the establishment and management intermediary people (liaison officers)⁴¹ either within both universities and industries., or
 - b) someone that is neutral and independent from the university and industrial systems.
3. **Address obvious structural/policy barriers** including administrative barriers and IP policies. Changes are generally needed to university incentive systems to recognise the efforts of the academics participating in partnerships with industry. Rewards and incentives are expected to influence the motivations and level of engagement of individuals, leading to more effective collaborations. There are two options for management, either:
- a) cross sectoral reform to better align policies and incentives to maximise collaboration, or
 - b) case by case basis where stakeholders work to develop a set of guidelines including conflict resolution mechanisms.
4. **Better communicate and disseminate** both the findings, lessons learned and benefits of both the project and the findings, lessons learnt and benefits of the collaboration over time are important for accountability, improving processes and also for encouraging future collaborations between universities and industry.

C.2.2 New approaches to measuring outcomes

Few articles focus on performance assessment of university-industry collaboration. Seres *et al* (2019) propose a framework based on previous work. This framework has a program logic focus from inputs to in-process, output and impact – with impact being defined as a “successful alliance” (new ideas, solution conception, innovations and development of human capital). Seres *et al* (2018) framework is generally aligned with the approach taken to evaluate the impact of the CRC Program:

The impact of the university-industry collaboration (UIC) can be considered as its’ long-term outcome and in general can be distinguished as economic or social impact. To measure the impact of university-industry collaboration outputs, the indicators should show if the collaboration achieved its aim and what have been the consequences of the collaboration for the partners.

Seres *et al*, 2018.

Alternative measures to the effectiveness of collaboration include:

- Lamberti *et al*’s (2017) framework of four objects: partners, forms, results and innovation funnel and value chain, and three indicators of effectiveness: collaboration costs share, collaboration revenues share, and joint patents share. These metrics are based on objective and available data and allow for the creation of benchmarks for comparison over time. This means decision makers can:
 - analyse the collaborative position of companies, monitoring the evolution of collaboration.
 - assess the collaboration productivity of a collaboration by examining process and output metrics.
- Manotungvorapun and Gerdri’s (2021) framework for the assessment of direct and indirect performance measures based on complementarity and compatibility. This results in an assessment of the degree of collaboration from orchestrated collaboration through to assistive collaboration, attentive collaboration and mismatched collaboration.

⁴¹ Also known as a technology transfer officer, moderator, mediator or facilitator or a boundary-spanner/agent.

Advantages of this framework is that it can be used:

- To inform decisions *ex ante* and *ex post* (i.e. determine the effectiveness of a partnership prior to collaboration) or assess the relative effectiveness of partnerships after collaboration).
- To develop partner profiles and assist with relationship management which has been identified as one of the biggest social cultural barriers to collaboration.

C.2.3 Considerations for the CRC Program

These best practice findings in the recent literature suggests consideration of the following ideas as a way to facilitate industry researcher collaboration under the CRC Program (see further discussion in section 7.2):

- A liaison officer within both the university and industry to take responsibility for inter university industry relationships and ‘span the boundaries’ of the difference in both structural and cultural alignment.
- Developing relationships over time leads to better trust and increased collaboration over time. One way to do this would be to take into account evidence of previous collaboration. One vehicle for enabling this could be through involvement in a successful CRC-P or prior CRCs.
- Consideration should be given of reviewing international perspectives such as the Singaporean IP system⁴², for example, to identify what might work best in Australia, although this is beyond the scope of the review.

Outcomes and performance measurement is generally operating at best practice standard relative to the literature reviewed, consideration could be given to developing an assessment of collaboration as opposed to evaluation of the CRC Program.

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⁴² “Singapore, unlike many countries, has a country-wide specific IP policy that is also accompanied by professional training to help stakeholders understand their rights. The policy further allows the inventor(s) to retain more of the profits early on, but distributes more of the overall royalties across the departments and universities involved if the innovation continues to be successful long term. This set-up is different from other IP policies in other global contexts, where such policies often morph depending on the initial research funding or the policies set by the institution.” (Dollinger *et al*, 2018).

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D Tasman Global

Tasman Global is a dynamic, global computable general equilibrium (CGE) model that has been developed by ACIL Allen for the purpose of undertaking economic impact analysis at the regional, state, national and global level. A CGE model captures the interlinkages between the markets of all commodities and factors, taking into account resource constraints, to find a simultaneous equilibrium in all markets. A global CGE model extends this interdependence of the markets across world regions and finds simultaneous equilibrium globally. A dynamic model adds onto this the interconnection of equilibrium economies across time periods. For example, investments made today are going to determine the capital stocks of tomorrow and hence future equilibrium outcomes depend on today's equilibrium outcome, and so on.

A dynamic global CGE model, such as *Tasman Global*, has the capability of addressing total, sectoral, spatial and temporal efficiency of resource allocation as it connects markets globally and over time. Being a recursively dynamic model, however, its ability to address temporal issues is limited. In particular, *Tasman Global* cannot typically address issues requiring partial or perfect foresight. However, as documented in Jakeman et al (2001), it is possible to introduce partial or perfect foresight in certain markets using algorithmic approaches. Notwithstanding this, the model does have the capability to project the economic impacts over time of given changes in policies, tastes and technologies in any region of the world economy on all sectors and agents of all regions of the world economy.

Tasman Global was developed from the 2001 version of the Global Trade and Environment Model (GTEM) developed by ABARE (Pant 2001) and has been evolving ever since. In turn, GTEM was developed out of the MEGABARE model (ABARE 1996), which contained significant advancements over the GTAP model of that time (Hertel 1997).

D.1 A Dynamic Model

Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before an economic disturbance and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues for which both the timing of and the adjustment path that economies follow are relevant in the analysis.

D.2 The Database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database is derived from the Global Trade Analysis Project (GTAP) database (Aguilar et al. 2019). This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities. It is the most detailed database of its type in the world.

Tasman Global builds on the GTAP database by adding the following important features:

- a detailed population and labour market database
- detailed technology representation within key industries (such as electricity generation and iron and steel production)
- disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG
- the ability to repatriate labour and capital income
- explicit representation of the states and territories of Australia
- the capacity to represent multiple regions within states and territories of Australia explicitly.

Nominally, version 10.1 of the *Tasman Global* database divides the world economy into 153 regions (145 international regions plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Allen regularly models Australian or international projects or policies at the regional level including at the or at the state/territory/provincial level for various countries.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 76 industries (Table D.1). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands.

Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input.

Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, transport and iron and steel sectors are modelled using a ‘technology bundle’ approach. With this approach, different known production methods are used to generate a homogeneous output for the ‘technology bundle’ industry.

For example, electricity can be generated using brown coal, black coal, petroleum, base load gas, peak load gas, nuclear, hydro, geothermal, biomass, wind, solar or other renewable based technologies – each of which has its own cost structure.

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

Table D.1 Standard sectors in Tasman Global Model

No.	Name	No	Name
1	Paddy rice	39	Diesel (incl. nonconventional diesel)
2	Wheat	40	Other petroleum, coal products
3	Cereal grains nec	41	Chemical, rubber, plastic products
4	Vegetables, fruit, nuts	42	Iron ore
5	Oil seeds	43	Bauxite
6	Sugar cane, sugar beet	44	Mineral products nec
7	Plant- based fibres	45	Ferrous metals
8	Crops nec	46	Alumina
9	Bovine cattle, sheep, goats, horses	47	Primary aluminium
10	Pigs	48	Metals nec
11	Animal products nec	49	Metal products
12	Raw milk	50	Motor vehicle and parts
13	Wool, silk worm cocoons	51	Transport equipment nec
14	Forestry	52	Electronic equipment
15	Fishing	53	Machinery and equipment nec
16	Brown coal	54	Manufactures nec
17	Black coal	55	Electricity generation
18	Oil	56	Electricity transmission and distribution
19	Liquefied natural gas (LNG)	57	Gas manufacture, distribution
20	Other natural gas	58	Water
21	Minerals nec	59	Construction
22	Bovine meat products	60	Trade
23	Pig meat products	61	Road transport
24	Meat products nec	62	Rail and pipeline transport
25	Vegetables oils and fats	63	Water transport
26	Dairy products	64	Air transport
27	Processed rice	65	Transport nec
28	Sugar	66	Warehousing and support activities
29	Food products nec	67	
30	Wine	68	Communication
31	Beer	69	Financial services nec
32	Spirits and RTDs	70	Insurance
33	Other beverages and tobacco products	71	Business services nec
34	Textiles	72	Recreational and other services
35	Wearing apparel	73	Public Administration and Defence
36	Leather products	74	Education
37	Wood products	75	Human health and social work activities
38	Paper products, publishing	76	Dwellings

Note: nec = not elsewhere classified

Source: ACIL Allen

D.3 Model Structure

Given its heritage, the structure of the *Tasman Global* model closely follows that of the GTAP and GTEM models and interested readers are encouraged to refer to the documentation of these models for more detail (namely Hertel 1997 and Pant 2001, respectively). In summary:

- The model divides the world into a variety of regions and international waters.
 - Each region is fully represented with its own ‘bottom-up’ social accounting matrix and could be a local community, an LGA, state, country or a group of countries. The number of regions in a given simulation depends on the database aggregation. Each region consists of households, a government with a tax system, production sectors, investors, traders and finance brokers.
 - ‘International waters’ are a hypothetical region in which global traders operate and use international shipping services to ship goods from one region to the other. It also houses an international finance ‘clearing house’ that pools global savings and allocates the fund to investors located in every region.
 - Each region has a ‘regional household’⁴³ that collects all factor payments, taxes, net foreign borrowings, net repatriation of factor incomes due to foreign ownership and any net income from trading of emission permits.
- The income of the regional household is allocated across private consumption, government consumption and savings according to a Cobb-Douglas utility function, which, in practice, means that the share of income going to each component is assumed to remain constant in nominal terms.
- Private consumption of each commodity is determined by maximising utility subject to a Constant Difference of Elasticities (CDE) function which includes both price and income elasticities.
- Government consumption of each commodity is determined by maximising utility subject to a Cobb-Douglas utility function.
- Each region has n production sectors, each producing single products using various production functions where they aim to maximise profits (or minimise costs) and take all prices as given. The nature of the production functions chosen in the model means that producers exhibit constant returns to scale.
 - In general, each producer supplies consumption goods by combining an aggregate energy-primary factor bundle with other intermediate inputs and according to a Leontief production function (which in practice means that the quantity shares remain in fixed proportions). Within the aggregate energy-primary factor bundle, the individual energy commodities and primary factors are combined using a nested-CES (Constant Elasticity of Substitution) production function, in which energy and primary factor aggregates substitute according to a CES function with the individual energy commodities and individual primary factors substituting with their respective aggregates according to further CES production functions.
 - Exceptions to the above include the electricity generation, iron and steel and road transport sectors. These sectors employ the ‘technology bundle’ approach developed by ABARE (1996) in which non-homogenous technologies are employed to produce a homogenous output with the choice of technology governed by minimising costs according to a modified-CRESH production function. For example, electricity may be generated from a variety of technologies (including brown coal, black coal, gas, nuclear, hydro, solar etc.), iron and steel may be produced from blast furnace or electric arc technologies while road transport

⁴³ The term “regional household” was devised for the GTAP model. In essence it is an agent that aggregates all incomes attributable to the residents of a given region before distributing the funds to the various types of regional consumption (including savings).

services may be supplied using a range of different vehicle technologies. The ‘modified-CRESH’ function differs from the traditional CRESH function by also imposing the condition that the quantity units are homogenous.

- There are four primary factors (land, labour, mobile capital and fixed capital). While labour and mobile capital are used by all production sectors, land is only used by agricultural sectors while fixed capital is typically employed in industries with natural resources (such as fishing, forestry and mining) or in selected industries built by ACIL Allen.
 - Land supply in each region is typically assumed to remain fixed through time with the allocation of land between sectors occurring to maximise returns subject to a Constant Elasticity of Transformation (CET) utility function.
 - Mobile capital accumulates as a result of net investment. It is implicitly assumed in *Tasman Global* that it takes one year for capital to be installed. Hence, supply of capital in the current period depends on the last year’s capital stock and investments made during the previous year.
 - Labour supply in each year is determined by endogenous changes in population, given participation rates and a given unemployment rate. In policy scenarios, the supply of labour is positively influenced by movements in the real wage rate governed by the elasticity of supply. For countries where sub-regions have been specified (such as Australia), migration between regions is induced by changes in relative real wages with the constraint that net interregional migration equals zero. For regions where the labour market has been disaggregated to include occupations, there is limited substitution allowed between occupations by individuals supplying labour (according to a CET utility function) and by firms demanding labour (according to a CES production function) based on movements in relative real wages.
 - The supply of fixed capital is given for each sector in each region.

The model has the option for these assumptions to be changed at the time of model application if alternative factor supply behaviours are considered more relevant.

- It is assumed that labour (by occupation) and mobile capital are fully mobile across production sectors implying that, in equilibrium, wage rates (by occupation) and rental rates on capital are equalised across all sectors within each region. To a lesser extent, labour and capital are mobile between regions through international financial investment and migration, but this sort of mobility is sluggish and does not equalise rates of return across regions.
- For most international regions, for each consumer (private, government, industries and the local investment sector), consumption goods can be sourced either from domestic or imported sources. In any country that has disaggregated regions (such as Australia), consumption goods can also be sourced from other intrastate or interstate regions. In all cases, the source of non-domestically produced consumption goods is determined by minimising costs subject to a Constant Ratios of Elasticities of Substitution, Homothetic (CRESH) utility function. Like most other CGE models, a CES demand function is used to model the relative demand for domestically-produced commodities versus non-domestically produced commodities. The elasticities chosen for the CES and CRESH demand functions mean that consumers in each region have a higher preference for domestically-produced commodities than non-domestic commodities and a higher preference for intrastate- or interstate-produced commodities than foreign commodities.
- The capital account in *Tasman Global* is open. Domestic savers in each region purchase ‘bonds’ in the global financial market through local ‘brokers’ while investors in each region sell bonds to the global financial market to raise investible funds. A flexible global interest rate clears the global financial market.

- It is assumed that regions may differ in their risk characteristics and policy configurations. As a result, rates of return on money invested in physical capital may differ between regions and therefore may be different from the global cost of funds. Any difference between the local rates of return on capital and the global cost of borrowing is treated as the result of the existence of a risk premium and policy imperfections in the international capital market. It is maintained that the equilibrium allocation of investment requires the equalisation of changes in (as opposed to the absolute levels of) rates of return over the base year rates of return.
- Any excess of investment over domestic savings in a given region causes an increase in the net debt of that region. It is assumed that debtors service the debt at the interest rate that clears the global financial market. Similarly, regions that are net savers give rise to interest receipts from the global financial market at the same interest rate.
- Investment in each region is used by the regional investor to purchase a suite of intermediate goods according to a Leontief production function to construct capital stock with the regional investor cost minimising by choosing between domestic, interstate and imported sources of each intermediate good via the CRESH production function. The regional cost of creating new capital stock versus the local rates of return on mobile capital is what determines the regional rate of return on new investment.
- In equilibrium, exports of a good from one region to the rest of world are equal to the import demand for that good in the remaining regions. Together with the merchandise trade balance, the net payments on foreign debt add up to the current account balance. *Tasman Global* does not require that the current account be in balance every year. It allows the capital account to move in a compensatory direction to maintain the balance of payments. The exchange rate provides the flexibility to keep the balance of payments in balance.
- Detailed bilateral transport margins for every commodity are specified in the starting database. By default, the bilateral transport mode shares are assumed to be constant, with the supply of international transportation services by each region solved by a cost-minimising international trader according to a Cobb-Douglas demand function.
- Emissions of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF₆) associated with economic activity are tracked in the model. Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled but can be accounted for externally. Prices can be applied to emissions which are converted to industry-specific production taxes or commodity-specific sales taxes that impact on demand. Abatement technologies similar to those adopted in a report released by the Australian Government (2008) are available and emission quotas can be set globally or by region along with allocation schemes that enable emissions to be traded between regions.

More details regarding specific elements of the model structure are discussed in the following sections.

D.4 Population Growth and Labour Supply

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for each region represented in the *Tasman Global* database is projected using ACIL Allen's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projected period.

For each of region, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc.). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and regional participation rates by age by gender. Over the projected period labour supply in most developed economies is projected to grow slower than total population because of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Allen's demographic module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

D.5 The Australian Labour Market

Tasman Global has a detailed representation of the Australian labour market which has been designed to capture:

- different occupations
- changes to participation rates (or average hours worked) due to changes in real wages
- changes to unemployment rates due to changes in labour demand
- limited substitution between occupations by the firms demanding labour and by the individuals supplying labour, and
- limited labour mobility between states and regions within each state.

Tasman Global recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms that hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit ANZSCO (Australian New Zealand Standard Classification of Occupations) level which are presented in Table D.2.

The labour market structure of *Tasman Global* is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.

Labour supply in *Tasman Global* is presented as a three-stage process:

1. labour makes itself available to the workforce based on movements in the real wage and the unemployment rate
2. labour chooses between occupations in a state based on relative real wages within the state, and
3. labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all CGE models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model).

Table D.2 Occupations in the Tasman Global database, ANZSCO 3-digit level (minor groups)

ANZSCO code, Description	ANZSCO code, Description	ANZSCO code, Description
1. MANAGERS	3. TECHNICIANS & TRADES WORKERS	5. CLERICAL & ADMINISTRATIVE
111 Chief Executives, General Managers and Legislators	311 Agricultural, Medical and Science Technicians	511 Contract, Program and Project Administrators
121 Farmers and Farm Managers	312 Building and Engineering Technicians	512 Office and Practice Managers
131 Advertising and Sales Managers	313 ICT and Telecommunications Technicians	521 Personal Assistants and Secretaries
132 Business Administration Managers	321 Automotive Electricians and Mechanics	531 General Clerks
133 Construction, Distribution and Production Managers	322 Fabrication Engineering Trades Workers	532 Keyboard Operators
134 Education, Health and Welfare Services Managers	323 Mechanical Engineering Trades Workers	541 Call or Contact Centre Information Clerks
135 ICT Managers	324 Panel beaters, and Vehicle Body Builders, Trimmers and Painters	542 Receptionists
139 Miscellaneous Specialist Managers	331 Bricklayers, and Carpenters and Joiners	551 Accounting Clerks and Bookkeepers
141 Accommodation and Hospitality Managers	332 Floor Finishers and Painting Trades Workers	552 Financial and Insurance Clerks
142 Retail Managers	333 Glaziers, Plasterers and Tilers	561 Clerical and Office Support Workers
149 Miscellaneous Hospitality, Retail and Service Managers	334 Plumbers	591 Logistics Clerks
2. PROFESSIONALS	341 Electricians	599 Miscellaneous Clerical and Administrative Workers
211 Arts Professionals	342 Electronics and Telecommunications Trades Workers	6. SALES WORKERS
212 Media Professionals	351 Food Trades Workers	611 Insurance Agents and Sales Representatives
221 Accountants, Auditors and Company Secretaries	361 Animal Attendants and Trainers, and Shearers	612 Real Estate Sales Agents
222 Financial Brokers and Dealers, and Investment Advisers	362 Horticultural Trades Workers	621 Sales Assistants and Salespersons
223 Human Resource and Training Professionals	391 Hairdressers	631 Checkout Operators and Office Cashiers
224 Information and Organisation Professionals	392 Printing Trades Workers	639 Miscellaneous Sales Support Workers
225 Sales, Marketing and Public Relations Professionals	393 Textile, Clothing and Footwear Trades Workers	7. MACHINERY OPERATORS & DRIVERS
231 Air and Marine Transport Professionals	394 Wood Trades Workers	711 Machine Operators
232 Architects, Designers, Planners and Surveyors		712 Stationary Plant Operators
		721 Mobile Plant Operators

ANZSCO code, Description	ANZSCO code, Description	ANZSCO code, Description
233 Engineering Professionals	399 Miscellaneous Technicians and Trades Workers	731 Automobile, Bus and Rail Drivers
234 Natural and Physical Science Professionals		732 Delivery Drivers
241 School Teachers	4. COMMUNITY & PERSONAL SERVICE	733 Truck Drivers
242 Tertiary Education Teachers	411 Health and Welfare Support Workers	741 Storepersons
249 Miscellaneous Education Professionals	421 Child Carers	8. LABOURERS
251 Health Diagnostic and Promotion Professionals	422 Education Aides	811 Cleaners and Laundry Workers
252 Health Therapy Professionals	423 Personal Carers and Assistants	821 Construction and Mining Labourers
253 Medical Practitioners	431 Hospitality Workers	831 Food Process Workers
254 Midwifery and Nursing Professionals	441 Defence Force Members, Fire Fighters and Police	832 Packers and Product Assemblers
261 Business and Systems Analysts, and Programmers	442 Prison and Security Officers	839 Miscellaneous Factory Process Workers
262 Database and Systems Administrators, and ICT Security Specialists	451 Personal Service and Travel Workers	841 Farm, Forestry and Garden Workers
263 ICT Network and Support Professionals	452 Sports and Fitness Workers	851 Food Preparation Assistants
271 Legal Professionals		891 Freight Handlers and Shelf Fillers
272 Social and Welfare Professionals		899 Miscellaneous Labourers

Source: ABS (2009), ANZSCO – Australian and New Zealand Standard Classifications of Occupations, First Edition, Revision 1, Abs Catalogue No. 1220.0

D.5.1 Labour Market Database

The *Tasman Global* database includes a detailed representation of the Australian labour market that has been designed to capture the supply and demand for different skills and occupations by industry. To achieve this, the Australian workforce is characterised by detailed supply and demand matrices.

On the supply side, the Australian population is characterised by a five-dimensional matrix consisting of:

- 7 post-school qualification levels
- 12 main qualification fields of highest educational attainment
- 97 occupations
- 101 age groups (namely 0 to 99 and 100+)
- 2 genders.

The data for this matrix is measured in persons and was sourced from the ABS 2011 Census. As the skills elements of the database and model structure have not been used for this project, it will be ignored in this discussion.

The 97 occupations are those specified at the 3-digit level (or Minor Groups) under the Australian New Zealand Standard Classification of Occupations (ANZSCO) (see Table D.2).

On the demand side, each industry demands a particular mix of occupations. This matrix is specified in units of full-time equivalent (FTE) jobs where an FTE employee works an average of 37.5 hours per week. Consistent with the labour supply matrix, the data for FTE jobs by occupation by industry was also sourced from the ABS 2011 Census and updated using the latest labour force statistics.

Matching the demand and supply side matrices means that there is the implicit assumption that the average hours per worker are constant, but it is noted that mathematically changes in participation rates have the same effect as changes in average hours worked.

D.5.2 Labour Market Model Structure

In the model, the underlying growth of each industry in the Australian economy results in a growth in demand for a particular set of skills and occupations. In contrast, the supply of each set of skills and occupations in a given year is primarily driven by the underlying demographics of the resident population. This creates a market for each skill by occupation that (unless specified otherwise) needs to clear at the start and end of each time period.⁴⁴ The labour markets clear by a combination of different prices (i.e. wages) for each labour type and by allowing a range of demand and supply substitution possibilities, including:

- changes in firms' demand for labour driven by changes in the underlying production technology
 - for technology bundle industries (electricity, iron and steel and road transportation) this occurs due to changes between explicitly identified alternative technologies
 - for non-technology bundle industries this includes substitution between factors (such as labour for capital) or energy for factors
- changes to participation rates (or average hours worked) due to changes in real wages
- changes in the occupations of a person due to changes in relative real wages
- substitution between occupations by the firms demanding labour due to changes in the relative costs
- changes to unemployment rates due to changes in labour demand, and
- limited labour mobility between states due to changes in relative real wages.

All of the labour supply substitution functions are modified-CET functions in which people supply their skills, occupation and rates of participation as a positive function of relative wages. However, unlike a standard CET (or CES) function, the functions are 'modified' to enforce an additional constraint that the number of people is maintained before and after substitution.⁴⁵

⁴⁴ For example, at the start and end of each week for this analysis. *Tasman Global* can be run with different steps in time, such as quarterly or bi-annually in which case the markets would clear at the start and end of these time points.

⁴⁵ As discussed in Dixon et al (1997), a standard CES/CET function is defined in terms of *effective units*. Quantitatively this means that, when substituting between, say, X_1 and X_2 to form a total quantity X using a CET function a simple summation generally does not actually equal X . Use of these functions is common practice in CGE models when substituting between substantially different units (such as labour versus capital or imported versus domestic services) but was not deemed appropriate when tracking the physical number of people. Such 'modified' functions have long been employed in the technology bundles of *Tasman Global* and GTEM. The Productivity Commission have proposed alternatives to the standard CES to overcome similar and other weaknesses when applied to internationally traded commodities.

Although technically solved simultaneously, the labour market in *Tasman Global* can be thought of as a five-stage process:

- labour makes itself available to the workforce based on movements in the real wage (that is, it actively participates with a certain number of average hours worked per week)
- the age, gender and occupations of the underlying population combined with the participation rate by gender by age implies a given supply of labour (the potentially available workforce)
- a portion of the potentially available workforce is unemployed, implying a given available labour force
- labour chooses to move between occupations based on relative real wages
- industries alter their demands for labour as a whole and for specific occupations based on the relative cost of labour to other inputs and the relative cost of each occupation.

By default, *Tasman Global*, like all CGE models, assumes that markets clear at the start and end of each period. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model). In principle, (subject to zero starting values) people of any age and gender can move between any of the 97 occupations while industries can produce their output with any mix of occupations. However, in practice the combination of the initial database, the functional forms, low elasticities and moderate changes in relative prices for skills, occupations etc. means that there is only low to moderate change induced by these functions. The changes are sufficient to clear the markets, but not enough to radically change the structure of the workforce in the timeframe of this analysis.

Factor-factor substitution elasticities in non-technology bundle industries are industry specific and are the same as those specified in the GTAP database⁴⁶, while the fuel-factor and technology bundle elasticities are the same as those specified in GTEM.⁴⁷ The detailed labour market elasticities are ACIL Allen assumptions, previously calibrated in the context of the model framework to replicate the historical change in the observed Australian labour market over a five-year period⁴⁸. The unemployment rate function in the policy scenarios is a non-linear function of the change in the labour demand relative to the reference case with the elasticity being a function of the unemployment rate (that is, the lower the unemployment rate the lower the elasticity and the higher the unemployment rate the higher the elasticity).

⁴⁶ Narayanan et al. (2012).

⁴⁷ Pant (2007).

⁴⁸ This method is a common way of calibrating the economic relationships assumed in CGE models to those observed in the economy. See for example Dixon and Rimmer (2002).

D.6 Detailed Energy Sector and Linkage to *PowerMark* and *GasMark*

Tasman Global contains a detailed representation of the energy sector, particularly in relation to the interstate (trade in electricity and gas) and international linkages across the regions represented. To allow for more detailed electricity sector analysis, and to aid in linkages to bottom-up models such as ACIL Allen's *GasMark* and *PowerMark* models electricity generation is separated from transmission and distribution in the model. In addition, the electricity sector in the model employs a 'technology bundle' approach that separately identifies up to twelve different electricity generation technologies:

- brown coal (with and without carbon capture and storage)
- black coal (with and without carbon capture and storage)
- petroleum
- base load gas (with and without carbon capture and storage)
- peak load gas
- hydro
- geothermal
- nuclear
- biomass
- wind
- solar
- other renewables.

To enable more accurate linking to *PowerMark* the generation cost of each technology is assumed to be equal to their long run marginal cost (LRMC) while the sales price in each region is matched to the average annual dispatch weighted prices projected by *PowerMark* – with any difference being returned as an economic rent to electricity generators. Fuel use and emissions factors by each technology are also matched to those projected in *PowerMark*. This representation enables the highly detailed market-based projections from *PowerMark* to be incorporated as accurately as possible into *Tasman Global*.

D.7 References

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