The Value of CSIRO
The Broader Impact of CSIRO's Portfolio of Activities

2022 Update

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Prepared for

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Executive Summary

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's national science agency. It solves the greatest challenges through innovative science and technology. These challenges are: food security and quality; sustainable energy and resources; health and wellbeing; resilient and valuable environments; future industries; and a secure Australia and region.

Every two years CSIRO assesses the value it delivers to the nation by analysing its impact via an increasing annual portfolio of externally validated impact case studies. The 2022 *Value of CSIRO* report, prepared by the non-profit research institute RTI International, compares the monetised impacts resulting from CSIRO's work with the costs of those projects and programs. This report also provides qualitative and quantitative descriptions of non-monetised elements of CSIRO's impact.

ES.1 ECONOMIC IMPACT RESULTS

We reviewed 112 case studies of CSIRO research and infrastructure outcomes published between 2010 and 2022. Impact estimates were quantified using 68 case studies that analysed reach initiated in the last 25 years. We also removed benefit and cost projections beyond 10 years for each case study to reduce the uncertainty inherent in estimating future benefits and costs.

We aggregated values across all case studies and years to generate the present value (PV) of benefits and costs of CSIRO research activities and programs. We calculated the net present value (NPV) by subtracting the PV of costs from the PV of benefits and calculated the benefit-cost ratio (BCR) by dividing the PV of benefits by the PV of costs.

We estimated a benefit-cost ratio (BCR) of 8.4 to 1, meaning that every $1 invested in CSIRO results in about $8.40 in economic, social, and environmental value.

ES.2 AREAS OF IMPACT

The economic impact results are substantial, but the use of dollar terms as a common denominator can underappreciate the nuanced impact CSIRO is having. As such, we explore CSIRO's economic, social, and environmental impact across six challenge areas (see Table E.2). For each challenge area, we present excerpts from case studies completed in the last two years.

ES.3 ADDITIONAL IMPACT METRICS

CSIRO's stated purpose is to solve the greatest challenges through innovative science and technology, with an ultimate vision to create a better future for Australia. CSIRO's primary objectives[1] are to:

1. Conduct and encourage the translation of Australia's world-class scientific research into impact;

2. Enable the use of science infrastructure and collections; and

3. Stimulate innovation for Australian industry, academia, and government.

While some of CSIRO's impacts from meeting these objectives are captured in the portfolio of impact case studies, others are not readily monetised. As such, we provide additional metrics of success (see Figure E.1).

ES.4 CONCLUDING REMARKS

The impact case studies along with the additional areas and metrics of impact reviewed in this report suggest that CSIRO continues to deliver on its purpose to solve the greatest challenges through innovative science and technology, with an ultimate vision to create a better future for Australia. Applying the case study portfolio BCR of 8.4 to CSIRO's operating expenses of $1.4 billion for the 2021-2022 financial year suggests that CSIRO generated $11.7 billion in benefits for a NPV of $10.2 billion.

Table E.1. Benefit-Cost Analysis Summary Results

COUNT OF CASE STUDIES (Number)	ANALYSIS TIME PERIOD (Years)	PV BENEFITS (2022$m)	PV COSTS (2022$m)	NPV (Benefits – Costs) (2022$m)	BCR (Benefits/Costs)
68	1998–2031	$22,531.5	$2,671.7	$19,859.9	8.4

Sample includes Case Studies Starting in 1997 or Later with Each Study Capped at 10 Years of Projected Benefits or Costs

1 As stated in CSIRO's Annual Report for the 2020-2021 financial year.

Table E.2. Highlighted CSIRO Case Studies Addressing Six Challenge Areas

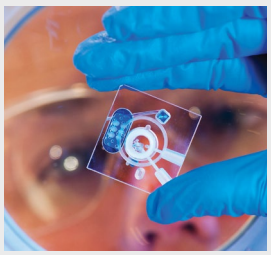
CHALLENGE AREA	CHALLENGE	CSIRO SOLUTION	BENEFITS
Health and Wellbeing	Difficulty assessing pain symptoms in non-communicative people	App to assess pain in non-communicative people	Decreased morbidity in vulnerable populations
	Difficulty reaching vulnerable populations with brick-and-mortar health services	Integrated telehealth platform	Increased health services access during the pandemic and for needful populations Decreased patient transit time
Food Security and Quality	Unmet desire for plant-based protein alternatives	v2food venture	New jobs, export revenues, and agricultural markets Decreased emissions and land and water use
	Root and leaf diseases from uninterrupted adoption of dual-purpose wheat in high rainfall zones	Dual-purpose canola as break option in mixed farming systems	Increased farming profitability, flexibility, and risk mitigation Increased weed and disease control and resource efficiency Increased financial and social resilience
Secure Australia and Region	Lack of consistent bushfire modelling and prediction technology to support frontline fire crews	Software to produce statistics, visualisations, and predictions of bushfire spread	Reduced damage to habitats and biodiversity Reduced stress and trauma for persons in vulnerable locations Reduced economic damages and increased cost-effectiveness of firefighting strategies
	Cyber vulnerabilities can be highly costly to modern economies	Initiatives to boost cybersecurity research, commercialisation, and connectivity outcomes	Deterred threats, prevented downtime, and reduced losses of valuable information Increased national security from cyberattacks and improved economic resilience
Resilient and Valuable Environments	Crown-of-Thorns Starfish (CoTS) causes coral mortality, threatening the Great Barrier Reef	Integrated pest management solution incorporating spatial and temporal dynamics	Protected biodiverse reef environments Retained Great Barrier Reef tourism
	Barriers to adoption of carbon farming	App to determine carbon farming benefits and coordinate with government	Reduced CO_2e emissions and protected or restored native habitats Enabled broader distribution of economic benefits and risk reduction via diversification
Sustainable Energy and Resources	Hydrogen's renewable energy potential limited by difficult storage and transport	Proof-of-concept plant to produce ammonia as a hydrogen carrier	Improved hydrogen distribution catalyses electric vehicle development Created an emerging export market for hydrogen
	Existing wind turbines are capital intensive and require frequent maintenance	Commercialisation support for small turbine with increased energy extraction	Decreased noise pollution and environmental damage Optimised power extraction and prevented damage from high wind speeds
Future Industries	Room for increased efficiency in factories and warehouses	Situational awareness software using security cameras	Workflow efficiency benefits and real-time solutions to prevent build-ups and delays
	Renewable hydrogen fuel has failed to develop at scale from prior initiatives	*National Hydrogen Roadmap* addressing industrial development	Addressed key questions about hydrogen viability and catalysed the industry formation Expedited achievement of economic gains from future hydrogen fuel use

Figure E.1. CSIRO Objectives and Metrics of Impact*

5,200+ employees across every state and territory of Australia and globally

86% research positions

Objective 1 Conduct and encourage the translation of Australia's world-class scientific research into impact



650+ families of patents
540+ active technology licenses

210+ companies started
20+ active spinouts or start-ups

3,412 publications with average normalised citation impact of **1.5**

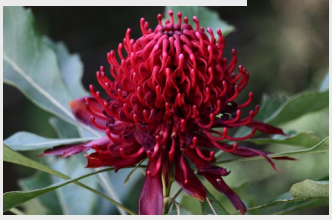
Objective 2
Enable the use of science infrastructure and collections

Marine National Facility

Pawsey Supercomputing Centre

Australian Synchrotron

Atlas of Living Australia



National Research Collections Australia

Australian Centre for Disease Preparedness

Australia Telescope National Facility

Objective 3 Stimulate innovation for Australian industry, academia, and government

Direct Industry Investments

- ON Program: **60+** companies
- Innovation Fund : **35+** ventures
- **1,350+** jobs supported

Tertiary Student Engagement

2020-2021 programs reached:

- **1,500** undergraduate and postgraduate students
- **218** postdoctoral students

Research collaborations: About 91% of CSIRO's research published with external collaborators

* As stated in CSIRO's Annual Report for the 2020-2021 financial year.

Icons made by FreePik and Becris from www.flaticon.co

1. Introduction

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's national science agency. It solves the greatest challenges through innovative science and technology. These challenges are: food security and quality; sustainable energy and resources; health and wellbeing; resilient and valuable environments; future industries; and a secure Australia and region.

Every two years CSIRO assesses the value it delivers to the nation by analysing its impact. This is done with an increasing annual portfolio of externally performed and/or validated impact case studies. These case studies account for the resources entrusted to CSIRO and measure the impact that its various programs and initiatives deliver to the nation and its partners.

The 2022 *Value of CSIRO* report provides the most up-to-date information about CSIRO's collective impact. Prepared by the non-profit research institute RTI International (RTI), this year's report compares the monetised impacts resulting from CSIRO's work with the costs of those projects and programs. This report also provides qualitative and quantitative descriptions of non-monetised elements of CSIRO's impact.

We estimated a benefit-cost ratio (BCR) of 8.4 to 1, meaning that every $1 invested in CSIRO results in about $8.40 in economic, social, and environmental value. This result is an underestimate because many advances in knowledge, contributions to Australia's human capital, and contributions to conservation and culture are not readily expressed in dollar terms. The additional qualitative and quantitative impacts described in this report offer some insight into the scale of CSIRO's impact beyond the monetised estimates.

1.1 BACKGROUND

For more than 100 years, CSIRO has been Australia's national science agency, collaborating across the innovation ecosystem to help future-proof the quality of life for all Australians. It is an Australian Government statutory authority within the Industry, Science, Energy, and Resources portfolio, operating under the provisions of the Science and Industry Research Act 1949.

CSIRO's stated purpose is to solve the greatest challenges through innovative science and technology, with an ultimate vision to create a better future for Australia (CSIRO, 2021a). CSIRO's primary objectives2 towards achieving this purpose and vision are to:

1. Conduct and encourage the translation of Australia's world-class scientific research into impact;
2. Enable the use of science infrastructure and collections; and
3. Stimulate innovation for Australian industry, academia, and government.

CSIRO acts intentionally to achieve these aims, especially in six challenge areas that it believes are of the greatest importance to Australians:

- Health and wellbeing
- Food security and quality
- Secure Australia and region
- Resilient and valuable environments
- Sustainable energy and resources
- Future industries

CSIRO acts as a bridge for Australian innovation, providing the essential research, technology platforms, and best practices needed by innovators, and collaborating with those innovators to convert their discoveries and ideas into technologies and services that benefit the nation (see Figure 1.1).

1.2 REPORT OBJECTIVES

The primary purpose of this report is to provide an estimate of the return on Australia's investment in CSIRO. CSIRO commissioned economists in RTI's Centre for Applied Economics and Strategy[3] who are experts in the analysis and evaluation of innovation programs, research infrastructure, and related services, to:

1. Review case studies describing the impacts of CSIRO's technology development and innovation programs,
2. Synthesise the monetised economic impacts described therein,
3. Compare monetised benefits with costs to estimate Australia's return on investment in CSIRO's technology development and innovation portfolio, and
4. Compile qualitative and quantitative metrics of non-monetised elements of CSIRO's impact.

2 As stated in CSIRO's Annual Report for the 2020-2021 financial year.
3 RTI's Centre for Applied Economics and Strategy specialises in the domains of innovation and new technology, environmental and natural resources, food and agriculture, and energy and economic development.

Impact case studies were either completed by CSIRO's internal impact evaluation team or were commissioned by CSIRO and completed by ACIL Allen, ACIL Tasman, the Centre for International Economics (CIE), Deloitte Access Economics (DAE), RTI, or Tractuum. In addition, this report includes innovation performance metrics that are tracked longitudinally by CSIRO's performance team.

1.3 REPORT ORGANISATION

This report is organised as follows:

- **Section 2** describes our methods and results for quantifying the value of CSIRO using its increasing annual portfolio of externally validated impact case studies, and suggests lessons learned from those case studies.
- **Section 3** contextualises CSIRO's portfolio of impact case studies along economic, social, and environmental dimensions and across CSIRO's six key challenge areas.
- **Section 4** provides additional metrics of impact that further address CSIRO's objectives as Australia's national science agency.
- **Section 5** offers concluding remarks.

Figure 1.1. CSIRO's Role in Australia's Innovation System

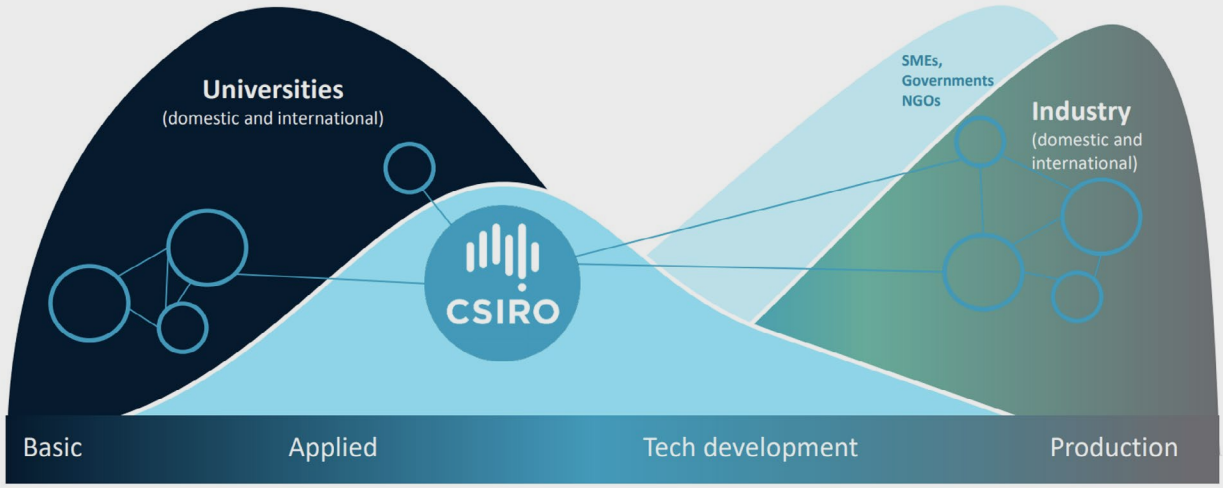
RESILIENT AND VALUABLE ENVIRONMENTS	Enhancing the resilience, sustainable use, and value of our natural and built environments, including by mitigating and adapting to the impacts of climate and global change.
FOOD SECURITY AND QUALITY	Achieve sustainable security through new AgriFood products, technology and innovation for Australia.
HEALTH AND WELLBEING	Enhance the health of Australians through preventative, personalised, biomedical, and digital health services.
FUTURE INDUSTRIES	Help create Australia's future industries and jobs by collaborating to boost innovation performance and promote Science, Technology, Engineering and Math (STEM) skills.
SUSTAINABLE ENERGY AND RESOURCES	Build competitiveness, sustainability and security, nationally and regionally, of our energy and minerals systems and resources while lowering emissions to Net Zero.
SECURE AUSTRALIA AND REGION	Help safeguard Australia from threats (terrorism, regional instability, pandemics, biosecurity, disasters, and cyber-attacks).

CSIRO drives ambition, national coherence, scale
Manages Innovation Fund as national steward, bridging gap between science and industry

CSIRO catalyses network
Manages Challenge Fund to frame, co-create, and deliver solutions

CSIRO delivers critical orchestration skills
Acts as trusted advisor and solution architect, creates transdisciplinary teams and deep collaborations, and maintains mega-sites in capital cities

CSIRO accelerates innovation for national benefit
Solves big challenges, acts as national commercialiser, creates new ecosystems and utilities, and seeds new industries



2. Quantifying the Value of CSIRO

We quantified the value of CSIRO by comparing the present value of benefits with the present value of costs for technologies and programs delivered by the organisation. As in the 2020 *Value of CSIRO* report, we compared a time series of benefits and costs covering research initiated within the last 25 years and capped at 10 years of projected values. Continuing to shift this time series forward with each new *Value of CSIRO* report will produce estimates that reflect a moving average of the value CSIRO delivers.

2.1 PORTFOLIO OF IMPACT CASE STUDIES

CSIRO's primary evaluation approach is to prepare case studies of research outcomes. We reviewed 112 case studies published between 2010 and 2022. These case studies assessed the benefits and costs of research initiated between 1965 and 2022, with most of the studies covering research initiated after the year 2000. Each study was completed by one of seven institutions: ACIL Allen, ACIL Tasman, CIE, DAE, RTI, Tractuum, or CSIRO's internal impact evaluation team.

Of the 112 case studies, 63 were included in the 2020 *Value of CSIRO* report (RTI, 2021a), and 49 were delivered to CSIRO since the publication of that report. Of the total 112 studies, 39 had insufficient benefit or cost data. We filtered the studies to only those with benefits and costs beginning in 1997 or later, which removed four additional studies. One further case study was refreshed, causing the original study on that subject to be removed from the pool. This meant there was a maximum of 68 studies available to inform our synthesis (see Table 2.1).

Table A.1 in the appendix provides a complete list of the case studies reviewed, including title, author, date range covered, and whether each was included in the 2020 and/or 2022 Value of CSIRO reports. These 68 case studies present a broad range in years of benefits and costs covered in the studies (see Table A.2 for calculation results of each study). The annual benefits (in 2022$) among the case studies ranged from about $0 to about $274 million, with an average of $21 million. The total project costs among the case studies ranged from $100,000 to about $765 million, with an average of $39 million.

2.2 ANALYSIS OF IMPACT CASE STUDIES

As an initial step in our synthesis, we reviewed the available data and benefit-cost analysis calculation methods for each case study. We verified the accuracy of the data and methods for each, and standardised methods or made other corrections or adjustments as needed.

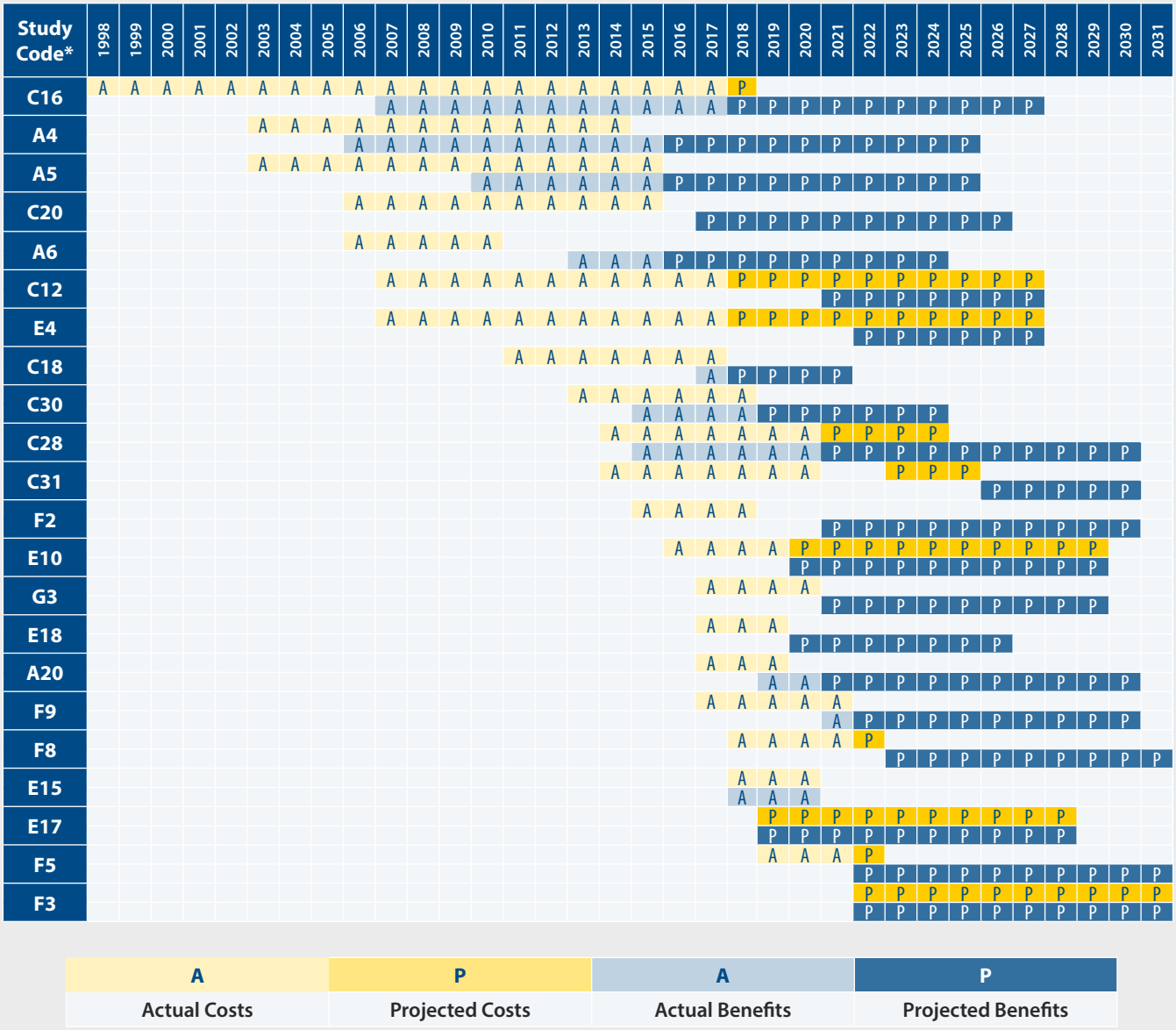
We focused on the reported research costs funded directly by CSIRO and on the estimated benefits attributable to CSIRO. We did not review the underlying assumptions for each case study's valuation approach. The 2017 *Value of CSIRO* report did so for three selected case studies and found those assumptions to have been robust and conservative (ACIL Allen, 2017a).

When sufficient time series data for benefits and costs were available for a study, we standardised the study's benefit-cost analysis methods by performing inflation and discounting adjustments for each year of data. We adjusted for inflation (i.e., converted from nominal to real values) using the Australian Consumer Price Index (CPI), estimating the 2022 CPI value based on observations from previous years. We discounted benefit and cost time series to 2022 values using the benchmark 7% real social discount rate specified by the CSIRO Impact Evaluation Guide (2020a). We used 2022 as the base year for both inflation and discounting adjustments, as recommended in the guide.

Table 2.1. Number of CSIRO Impact Analysis Case Studies Reviewed and Included in the Analysis

	FROM 2020 VALUE REPORT	NEW STUDIES	TOTAL STUDIES IN CURRENT REPORT
Total studies reviewed	63	49	112
Studies with sufficient benefit and cost data for inclusion in our analysis	41	31	72
Studies with data beginning within the last 25 years (i.e., starting in 1997 or later)	38	30	68

Figure 2.1. Benefit and Cost Data for a Sample of Studies by Year and Type (Actual vs. Projected)



*See Table A.1 in the appendix for code translation.

2.3 AGGREGATED TIME SERIES OF BENEFITS AND COSTS

After reviewing, standardising, and updating the case study data, we built a dataset comprising the time series of benefits and costs for all case studies with time series data. We also identified which values were realised versus projected at the time of publication for each study. The resulting dataset provided a portfolio of benefits and costs from CSIRO activities that can be used to estimate the return on investment over time.

Next, we limited the set of case studies included to those covering research initiated within 25 years (i.e., between 1997 and 2022). We removed benefit and cost projections beyond 10 years for each case study to reduce the uncertainty inherent in estimating future benefits and costs. This shortened the benefit and/or cost projections for 32 of the case studies that included projected values for anywhere from 11 to 52 years into the future.

As an illustration, Figure 2.1 shows the years and type (actual versus projected) of benefit and cost data for a selection of case studies. Figure A.1 in the appendix provides the same information for each case study in the portfolio. Figure 2.1 shows that projected values of either benefits or costs are limited to no more than 10 years, while there is no limit to the number of years of actual (realised) benefit or cost data included.

The resulting dataset includes 68 case studies of CSIRO-funded research projects and covers benefits and costs spanning 1998 through 2031.[4] Figure 2.2 shows the annual aggregate benefits and costs across all case studies in the portfolio. Going forward, as new studies are added to each bi-annual review, both the benefits and costs of the portfolio will be updated appropriately.

We aggregated benefits across all case studies and years to generate the present value (PV) of benefits of CSIRO research. We used the same method to generate the PV of costs. We calculated the net present value (NPV) of CSIRO research activities and programs by subtracting the PV of costs from the PV of benefits and calculated the benefit-cost ratio (BCR) by dividing the PV of benefits by the PV of costs.

2.4 ECONOMIC IMPACT ANALYSIS RESULTS

Table 2.2 presents the aggregate 2022 PV of benefits, PV of costs, NPV and BCR across all 68 case studies with time series data starting within the last 25 years and including up to 10 years of projected values. Table A.2 in the appendix provides a detailed account of the benefit-cost analysis results for each case study in the portfolio.

We found an aggregate PV of benefits of $22.5 billion and PV of costs of $2.7 billion for all case studies in the portfolio.

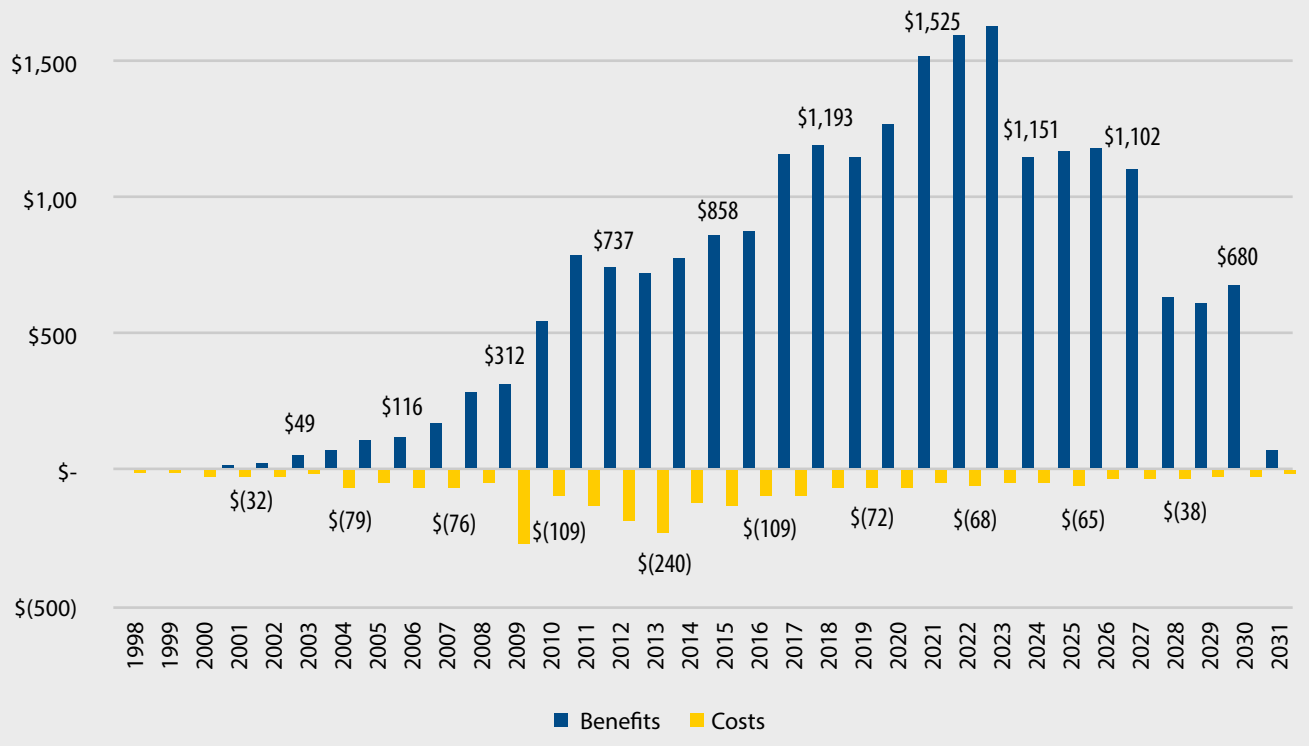
We found an NPV of $19.9 billion and a BCR of 8.4-to-1, indicating strong returns. The BCR indicates that for every $1 invested in CSIRO at least $8.40 in value is returned to the Australian people.

Table 2.2. Benefit-Cost Analysis Summary Results

COUNT OF CASE STUDIES (Number)	68
ANALYSIS TIME PERIOD (Years)	1998–2031
PV BENEFITS (2022$m)	$22,531.5
PV COSTS (2022$m)	$2,671.7
NPV (Benefits-Costs 2022$m)	$19,859.9
BCR (Benefits/Costs)	8.4

Sample includes Case Studies Starting in 1997 or Later with Each Study Capped at 10 Years of Projected Benefits or Costs

Figure 2.2. Total Annual Discounted Benefits and Costs (2022$m) across all Included Case Studies



4 There were no case studies with data beginning in 1997 or with 10-year projections extending out to 2032, so the data start in 1998 and end in 2031 for the current portfolio of studies.

2.5 CASE STUDY LESSONS LEARNED

Overall, the impact case studies in CSIRO's portfolio show strong positive returns. Six case studies had a BCR near or above 100 to 1, while seven showed negative returns after 10 years of projected benefits and/or costs. About half of the remaining studies had BCRs between 1.5 and 9.9 to 1, while the other half had BCRs between 10 and 75 to 1. Average returns were strong for case studies across CSIRO's six challenge areas, indicating the importance of addressing all of these challenge areas.

Unsurprisingly, the six case studies with the highest returns assessed programs and initiatives with relatively low costs—with PV costs below $5 million—and relatively high benefits—with PV of benefits above $100 million. The case study on CSIRO's investment in the PainCheck app, described in Section 3.2 above, showed far and away the highest returns and had the fourth highest PV of benefits and the third lowest PV of costs among all case studies in the portfolio (ACIL Allen, 2020a).

Four of the six case studies with the highest returns covered CSIRO's development of or investment in high-impact software or apps, which tend to be inexpensive to develop (ACIL Allen, 2014; CIE, 2020b; RTI, 2021b; ACIL Allen, 2020a). The other two case studies assessed small research initiatives or collaborations that resulted in the identification or deployment of industry-shifting technologies: a more accessible and less invasive method for ageing fish to monitor and manage fish populations in commercial fisheries and wild habitats (RTI, 2021d), and a site-based pain treatment to replace the use of narcotics (ACIL Allen, 2016).

As Australia's national science agency, CSIRO is well positioned to invest in ambitious research initiatives that have potentially high impact but may be too risky for private industry to take on. While it is important that CSIRO maintain public trust and accountability by ensuring that Australian investments yield positive returns, it should not be expected that every CSIRO research initiative will do so. In fact, exclusively positive returns on research initiatives would indicate a lack of innovation on CSIRO's part. Furthermore, CSIRO is well positioned to invest in highly advanced infrastructure and technology that may not yield positive returns for some time. Such investments help ensure that Australia is a global technological and economic leader.

Some of the results of case studies with negative returns after 10 years of projections reflect the long-term investment required to develop next-generation technologies that may take longer to deploy (ACIL Allen, 2017b; CSIRO, 2021e) or advanced infrastructure with high start-up costs (CIE, 2019). Others are indicative of the high risks associated with conducting innovative research as projected benefits may not always outweigh program costs in the near term (CSIRO, 2021f; CIE, 2020c).

Continuing to conduct impact case studies to add to CSIRO's increasing annual portfolio will add increased confidence in estimates of the value of CSIRO. It is also possible that gathering data on anticipated impacts of high-risk or costly projects before investing in the work could help inform future investment decisions.

2.6 KEY TAKEAWAYS

The benefits and costs of this research were originally estimated in 68 case studies published since 2010, with included studies restricted to those with data starting within the last 25 years and with each study restricted to projecting values forward no more than 10 years into the future. Even these conservative estimates suggest strong positive returns to CSIRO-funded research for Australia.

Additional case studies assessing the benefits and costs of CSIRO-funded research provide an even deeper understanding of the public value of CSIRO. The studies new to this value report add $7.9 billion in NPV over the $12.0 billion NPV (adjusted to 2022 values) of case studies that had been reviewed in the 2020 report. The aggregate NPV naturally increases as more studies are added to the portfolio, because most studies contribute a positive NPV. Hence, the increase in aggregate NPV is not necessarily a reflection of increased value. However, the 2022 portfolio BCR of 8.4 is also higher than the 7.6 BCR of the more limited portfolio of case studies in the 2020 value report. The increased BCR indicates that the newly added case studies reflect higher returns to the Australian people from CSIRO's research activities and programs.

The estimates for the sample covering research initiated within the last 25 years and capped at 10 years of projected values provide a moving average of the value of CSIRO research. These estimates are a lower bound because many impacts are not reflected in the portfolio of case studies, such as those from contributions to the knowledge base, greater awareness of science and innovation across Australian society, education programs, and the role CSIRO plays in conservation and culture. Some additional metrics of impact are provided in Section 4.

3. Areas of Impact

The 8.4-to-1 return on investment presented in the preceding chapter aggregates results across a wide portfolio of CSIRO activities, using monetised benefits and costs as a common unit of measure. The results are substantial, but the use of dollar terms as a common denominator can underappreciate the nuanced impact CSIRO is having. As such, this chapter explores CSIRO's impact across CSIRO's six challenge areas:

- Health and wellbeing
- Food security and quality
- Secure Australia and region
- Resilient and valuable environments
- Sustainable energy and resources
- Future industries

The focus herein is on value delivered in terms of economic, social, and environmental dimensions. For each challenge area, we present excerpts from case studies completed in the last 2 years by CSIRO's Performance, Planning and Impact team, ACIL Allen, CIE, RTI, and Tractuum. These case studies are briefly described in Table 3.1. One-page vignettes on the case studies for each challenge area follow.

Table 3.1. Highlighted CSIRO Case Studies Addressing Six CSIRO Challenge Areas

CHALLENGE AREA	CHALLENGE	CSIRO SOLUTION	BENEFITS
Health and Wellbeing	Difficulty assessing pain symptoms in non-communicative people	App to assess pain in non-communicative people (ACIL Allen, 2020a)	Decreased morbidity in vulnerable populations
	Difficulty reaching vulnerable populations with brick-and-mortar health services	Integrated telehealth platform (Tractuum, 2021a)	Increased health services access during the pandemic and for needful populations Decreased patient transit time
Food Security and Quality	Unmet desire for plant-based protein alternatives	v2food venture (Tractuum, 2021b)	New jobs, export revenues, and agricultural markets Decreased emissions and land and water use
	Root and leaf diseases from uninterrupted adoption of dual-purpose wheat in high rainfall zones	Dual-purpose canola as break option in mixed farming systems (CSIRO, 2021b)	Increased farming profitability, flexibility, and risk mitigation Increased weed and disease control and resource efficiency Increased financial and social resilience
Secure Australia and Region	Lack of consistent bushfire modelling and prediction technology to support frontline fire crews	Software to produce statistics, visualisations, and predictions of bushfire spread (Tractuum, 2021c)	Reduced damage to habitats and biodiversity Reduced stress and trauma for persons in vulnerable locations Reduced economic damages and increased cost-effectiveness of firefighting strategies
	Cyber vulnerabilities can be highly costly to modern economies	Initiatives to boost cybersecurity research, commercialisation, and connectivity outcomes (CIE, 2020a)	Deterred threats, prevented downtime, and reduced losses of valuable information Increased national security from cyberattacks and improved economic resilience
Resilient and Valuable Environments	Crown-of-Thorns Starfish (CoTS) causes coral mortality, threatening the Great Barrier Reef	Integrated pest management solution incorporating spatial and temporal dynamics (CSIRO, 2021c)	Protected biodiverse reef environments Retained Great Barrier Reef tourism
	Barriers to adoption of carbon farming	App to determine carbon farming benefits and coordinate with government (RTI, 2021b)	Reduced CO_2e emissions and protected or restored native habitats Enabled broader distribution of economic benefits and risk reduction via diversification
Sustainable Energy and Resources	Hydrogen's renewable energy potential limited by difficult storage and transport	Proof-of-concept plant to produce ammonia as a hydrogen carrier (CSIRO, 2020b)	Improved hydrogen distribution catalyses electric vehicle development Created an emerging export market for hydrogen
	Existing wind turbines are capital intensive and require frequent maintenance	Commercialisation support for small turbine with increased energy extraction (ACIL Allen, 2020b)	Decreased noise pollution and environmental damage Optimised power extraction and prevented damage from high wind speeds
Future Industries	Room for increased efficiency in factories and warehouses	Situational awareness software using security cameras (CIE, 2020b)	Workflow efficiency benefits and real-time solutions to prevent build-ups and delays
	Renewable hydrogen fuel has failed to develop at scale from prior initiatives	*National Hydrogen Roadmap* addressing industrial development (RTI, 2021c)	Addressed key questions about hydrogen viability and catalysed the industry formation Expedited achievement of economic gains from future hydrogen fuel use

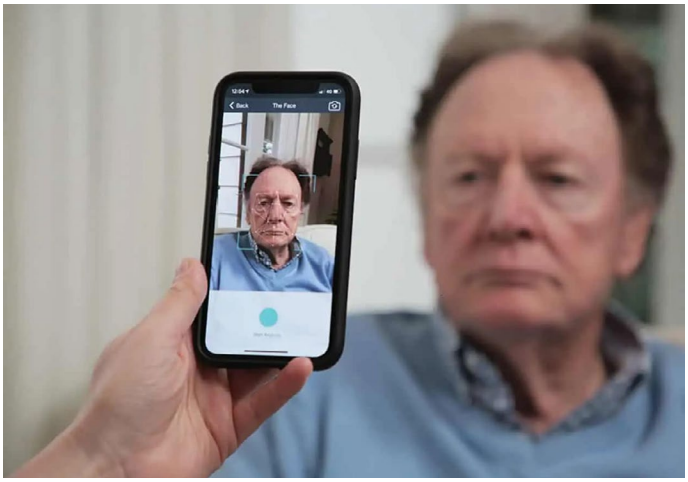
3.1 HEALTH AND WELLBEING

The health and wellbeing area covers CSIRO's work to enhance health for all Australians through preventative, personalised, biomedical, and digital health services. Many of the case studies of CSIRO's research and technologies over the last three years addressed the organisation's efforts to improve health outcomes.

3.1.1 App Development for Tracking of Pain Symptoms

Chronic pain affects 20% of Australians, and one in three people over age 65. The reduced quality of life and productivity losses from chronic pain symptoms were estimated to cost Australians $139 billion in 2018 (Australian Institute of Health and Welfare, 2020). Those who cannot effectively communicate their pain symptoms, including young children and persons with dementia, can suffer from chronic pain symptoms without adequate support.

Out of this need, a team of researchers from Curtin University developed The PainChek® app, which is designed to assess pain accurately in non-communicative people. The resulting company participated in CSIRO's science and technology accelerator, the ON Program. After participation in the ON Program, the Australian Government decided to invest $5 million to facilitate the implementation of the PainChek app in Australian residential care centres.



The PainChek app is currently used in more than 1,600 healthcare facilities. It has been validated against the Abbey Pain Scale and provides healthcare professionals with better information to diagnose and treat pain in non-communicative persons, including persons with dementia and infants. In addition to relieving pain symptoms, PainChek's pain management capabilities can reduce complications from poor pain management in persons with dementia, such as delirium, which worsen health outcomes (ACIL Allen, 2020a).

3.1.2 Advancing Telehealth to Meet Growing Demand

Australia's low population density has historically forced Australia to overinvest in medical services to provide adequate care for all Australians. Population density, along with other common issues such as limited access to transport, disability, and age, has been a consistent factor pushing the importance of telehealth solutions to reduce the cost that it takes Australia to provide medical care.

Supported by CSIRO's ON Program, with investment from CSIRO's Innovation Fund, managed by Main Sequence, and other follow-on support, Coviu has become Australia's premier telehealth platform. Coviu's artificial intelligence (AI)-backed clinical capabilities remove the need for physical presence during practitioner-patient consultations. Coviu's platform is designed to provide a complete medical care experience to improve continuity of care, provide greater flexibility, reduce costs, and facilitate a more efficient use of resources. To do this, Coviu's platform includes access to in-call clinical tools, online appointment bookings, integration with practice management systems, and in-house payments, all within a simple, email-based, user interface. In 2020, the COVID-19 public health emergency caused significant changes to routine healthcare and required practitioners and patients to adopt a safe and secure method of delivering and receiving medical care without physical contact while supporting those in isolation.

Coviu responded with agility to scale its team, technology, and cash management for a 10,000 per cent growth in daily business within two weeks, going from delivering 400 to 25,000 consultations a day. In addition to providing a solution for many people to be able to receive otherwise unobtainable health services, Coviu offers many additional benefits as a platform. During non-pandemic environments, Coviu saves people transit time and offers people a complete medical care experience through the integration of payment systems and scheduling systems, for instance, in the platform. Coviu was designed to be easy for practitioners to adopt and can be used across most platforms, allowing Coviu to be easy to adopt so that it can reach needful populations (Tractuum, 2021a).

3.2 FOOD SECURITY AND QUALITY

The food security and quality area focuses on CSIRO's work to achieve sustainable food security and grow Australia's share of premium agrifood markets.

3.2.1 Developing Plant-Based Protein Alternatives

CSIRO pursued a venture science model for the creation of plant-based protein options for the global market. The initiative involved industry partnerships, investment from Main Sequence, and the development of a new plant-based protein venture, v2food. Within 10 months, v2food produced the Rebel Whopper®, which was released in more than 400 Hungry Jacks stores across Australia. v2food now supplies the key supermarkets, including Coles, Aldi and Drakes, as well as Hungry Jacks, Soul Burger, Burger Urge, Marley Spoon and Mr Muscle Chef. The start-up has continued to expand its offerings, serving millions of Australians since 2019 and expanding into New Zealand, the Philippines, Japan, South Korea, and Thailand.

The benefits of the v2food venture have been extensive. It has delivered economic benefits through domestic and export sales. The budding industry has also created new high-skilled Australian jobs and led to the development of sovereign capabilities novel to CSIRO and Australia in the domain of meat flavours, textures and colours (Tractuum, 2021b). Environmental and resource savings may include lower emissions, improved land use, reduced water, eutrophication, and pesticide use.

3.2.2 Using Canola to Combat Root and Leaf Diseases

Dual-purpose cereals (cereal crops grown for both grain and grazing) have been a fundamental component of mixed farming operations in southern Australia in recent decades. In particular, dual-purpose wheat has been widely adopted. However, the wide adoption of dual-purpose wheat in high rainfall zones increased root and leaf diseases because the strategy did not allow for a break in the continuous system of cereal and grassy pastures.

In the early 2000s, CSIRO researchers theorised that canola could be sown early and grazed during winter with no cost to subsequent grain production, providing a profitable break option in mixed farming systems. Within five years, CSIRO researchers developed and translated the concept of dual-purpose canola into southern Australian mixed farming enterprises, and today the practice is an integral part of the farming system.

Adoption of dual-purpose canola helps farms economically by mitigating risk and increasing flexibility. Environmental benefits include control of weeds and diseases in subsequent pastures and crops, increased groundcover, and improved nutrient and water use efficiency. Improved financial resilience in farming enterprises likely improved social resilience in rural and regional communities where farming is a significant economic driver. Anecdotal evidence also suggests mental health benefits for farm managers associated with the improved flexibility and risk mitigation offered by dual-purpose canola (CSIRO, 2021b).

3.3 SECURE AUSTRALIA AND REGION

The secure Australia and region area refers to CSIRO's efforts to meet the challenges of safeguarding Australia from risks such as war, terrorism, pandemics, disasters, and cyberattacks.

3.3.1 Predicting and Reducing Damage from Bushfires

Australia is frequently affected by bushfires, which cause extensive harm to people, infrastructure, and the environment. Annually, hundreds of lives are lost because of bushfires, and the destruction costs the economy billions of dollars in infrastructure replacement and environmental restoration. Australia lacks a nationally consistent bushfire modelling and prediction technology to support frontline fire crews across state borders. Consequently, emergency response remains restricted by capabilities of varying approaches to bushfire modelling in different states and over different types of landscapes.

In response to this gap, CSIRO developed 'Spark', to produce statistics, visualisations, and predictions of bushfire spread for effective disaster planning, coordination, and management. Spark uses over 60 years of bushfire research knowledge developed at CSIRO. Spark's improved spatial and temporal prediction is expected to enhance firefighting efforts and disaster response to reduce bushfire damage to Australia's people, environment, and economy. The open model can also be adjusted for other potential applications such as agriculture or mineral resources.

Spark provides a plethora of environmental and economic benefits to Australians. Environmentally, Spark aims to prevent damage from forest fires, minimising damages to habitats and allowing Australia to retain greater biodiversity. As a result of better modelling and predictive strategies, bushfire response will be timelier and more efficient, reducing economic damages and increasing the cost-effectiveness of firefighting strategies. Spark technology may also yield export benefits, and the open-source nature of the model could also yield follow-on benefits due to flexibility of the modelling for other predictive purposes. Bushfires also yield a high social cost in the form of stress and trauma on persons who live in bushfire-vulnerable locations, which will be reduced by Spark's mitigation strategies (Tractuum, 2021c).

3.3.2 Enhancing National Cybersecurity Infrastructure

The proliferation of the internet has come with increased vulnerabilities because data leaks and impairments to internet infrastructure can be highly costly to modern economies. Cybersecurity incidents are estimated to cost the Australian economy up to $1 billion per year (Australian Criminal Intelligence Commission, 2019).

Since 2016, CSIRO has undertaken a range of initiatives to boost research, commercialisation, and connectivity outcomes across Australia's cyber industry and drive the development of new cybersecurity architectures. Over 60 cybersecurity researchers and engineers have been funded to support projects to improve cyber research and technology commercialisation over the past three years. These researchers have delivered new platform technologies and associated products that are actively being trialled and adopted by academia, industry, and all levels of government, both in Australia and internationally.

The impact pathway for CSIRO cybersecurity is multidimensional, including impacts associated with discrete technology partnerships, training opportunities, and changes in the cybersecurity system and capacity in Australia. Short-term benefits include benefits to individual organisations from threat deterrence, resulting in prevention of downtime from responding to cybersecurity threats; reduced losses of valuable information from attacks; and more efficient spending on prevention measures. In the long term, CSIRO aims to make Australia less vulnerable to cybersecurity risks, furthering benefits to individual organisations, providing national security benefits, and increasing overall economic resilience (CIE, 2020a).

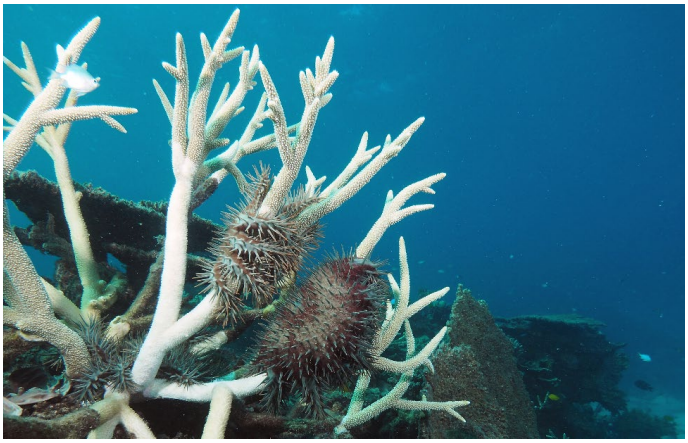
3.4 RESILIENT AND VALUABLE ENVIRONMENTS

The resilient and valuable environments area refers to CSIRO's work to enhance the resilience, sustainable use, and value of Australia's environments.

3.4.1 Managing Threats to Australia's Coral Reefs

The Crown of Thorns Starfish (CoTS) is carnivorous and preys on coral. CoTS are a major cause of coral mortality and reef degradation across the Indo-Pacific region, including the Great Barrier Reef.

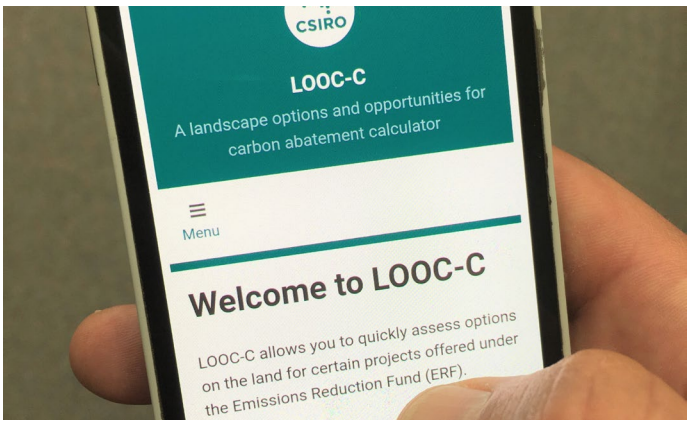
The Australian Government's National Environmental Science Program engaged CSIRO to lead research into integrated pest management (IPM) for CoTS control. CSIRO designed an ecologically informed IPM program that integrates knowledge of the spatial and temporal dynamics of CoTS outbreaks and the operations of on-water control. As of November 2018, the entire national CoTS control program has adopted the IPM principals developed through this research investment.



While no target reefs had their entire perimeter controlled to desired thresholds before the change to the CSIRO-developed IPM strategy, 89% of reefs met desired control standards after IPM strategy deployment (Westcott et al., 2021). Anticipated benefits accrue from the cost savings of more efficient CoTS management strategies, the preservation of biodiverse habitats that rely on health reefs, and the improvement in long-term health of Great Barrier Reef tourism, which is expected to decline as the condition of the reef worsens (CSIRO, 2021c).

3.4.2 Reducing Barriers to Carbon Farming

As part of the mission to reduce climate change, the Australian Government has committed to reducing greenhouse gas emissions by 26% to 28% below 2005 levels by 2030. To incentivise these activities, the Australian Government created the Emissions Reduction Fund (ERF), which incentivises landowners and farmers to adopt mitigation actions that generate abatement (known as carbon farming). However, launching a carbon farming project often means spending thousands of dollars in consulting fees, collecting and monitoring data, and working with carbon service providers, which serve as barriers preventing small-scale farmers from participating in carbon farming.



In response to these barriers, CSIRO created the Landscape Options and Opportunities for Carbon Abatement Calculator (LOOC-C). After the user enters basic information about location and farm characteristics, LOOC-C provides estimates of carbon abatement potential. The tool establishes a common basis of understanding and trust among user groups, including farmers, landowners, carbon service providers, and emissions reduction fund managers, it makes the process of designing, funding, and executing emissions reduction projects more efficient.

LOOC-C's chief monetisable benefit is the catalysation of an additional 11 to 36 million tonnes (Mt) CO2e of emissions reductions through 2030, worth an estimated $1.3 billion. Additional environmental benefits include the protection, improved management, or restoration of native vegetation and habitats, which underpin a wide array of provisioning and regulating services including protecting water and air quality, safeguarding biodiversity, and providing recreational opportunities. Another value that the LOOC-C tool provides is in the democratisation of carbon farming, which makes it possible for a broader and more diverse spectrum of landowners and farmers to participate in and benefit from the market. Wider spread of the carbon market yields even further social benefits, including broader distribution of benefits for rural communities and risk reduction via diversification (RTI, 2021b).

3.5 SUSTAINABLE ENERGY AND RESOURCES

The sustainable energy and resources area refers to CSIRO's work to build regional energy and resource security and competitiveness while lowering emissions.

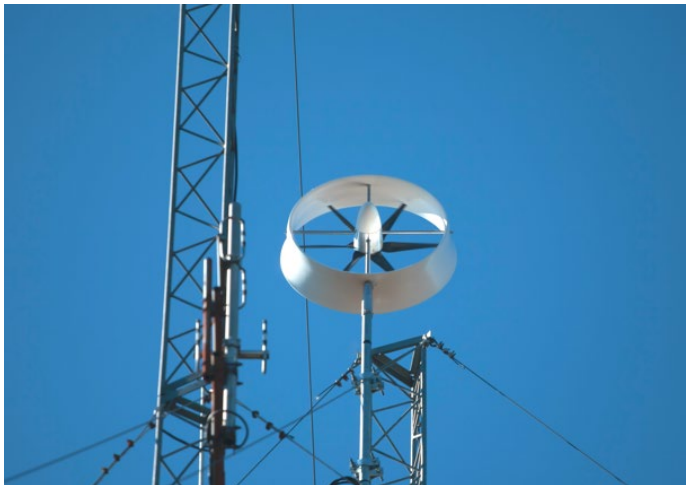
3.5.1 Developing Transportation Solutions for Clean Hydrogen Fuel

Hydrogen has the potential to power vehicles and industry around the world while decarbonising the environment; however, because of its low density, it is notoriously difficult to store and transport. CSIRO's solution for the transportation of hydrogen involves using ammonia as a carrier, so renewable hydrogen produced in Australia can be readily distributed at large scale using existing infrastructure for ammonia transport. Ammonia stores almost twice as much hydrogen than liquid hydrogen and is easier to ship and distribute, opening possibilities for a renewable energy export market.

CSIRO's two-year Science and Industry Endowment Fund (SIEF) project completed the final development of the CSIRO's metal membrane technology and incorporated it into a proof-of-concept plant for the refuelling of Australia's first hydrogen-powered fuel-cell electric vehicles. This project integrated all sub-systems into a single demonstration system, producing high-purity hydrogen from ammonia that is used to refuel commercial fuel-cell vehicles from Toyota (Mirai) and Hyundai (Nexo). This proof-of-concept demonstrates a technique that would allow hydrogen to become more stable for export, which may catalyse the development of the market for fuel-cell electric vehicles, and positions Australia to benefit from the export of hydrogen should that market become robust (CSIRO, 2020b).

3.5.2 Promoting Small-Scale Renewable Energy

Diffuse Energy is a company that produces small wind turbines. Founded by three colleagues from the University of Newcastle. Diffuse Energy's Hyland 920 consists of



a diffuser (an aerodynamically shaped cylinder) that, together with specially designed blades, increases the mass flow of air passing across the blades, allowing more energy to be extracted from the wind. The Hyland 920 has technology improvements to optimise the amount of power extracted for a given wind speed, prevent damage to electrical systems from high wind speed, minimise damage to the environment from safe blade design, and lessen noise pollution.

The Diffuse founders participated in CSIRO's science and technology accelerator, the ON Program, over the course of 2017 and 2018. The ON Program assisted the team with the transition from being academics to entrepreneurs and business owners. Without this, the team believes that poor decisions would have been made and investments lost, and the team would have remained at the university. The ON Program also helped the team improve their pitching skills and gave them a better understanding of their target markets and clientele.

Diffuse Energy has identified the potential for the Hyland 920 turbine to be supplied to three markets: off-grid telecommunications systems as a complement to existing small-scale energy systems; remote locations with power supply difficulties, such as the mining and agriculture sectors; and remote living (tiny homes, caravans, and yachts) looking for a sustainable energy supply. They have participated in two trials and have already demonstrated that the technology can reduce diesel costs for remote communications towers (ACIL Allen, 2020b).

3.6 FUTURE INDUSTRIES

The future industries area refers to CSIRO's work to create Australia's future industries and jobs by collaborating to boost innovation performance and STEM (science, technology, engineering, and mathematics) skills.

3.6.1 Providing Affordable Situational Awareness Technology

Modern economies, now more than ever, are beholden to extensive and complex supply chains for the provision of consumer goods. The efficiency of the workflow operations within factories and warehouses has thus had increasing importance within modern economies, and improvements in workflow can provide important benefits to the financial sustainability and productivity performance of businesses and the economy.

CSIRO's Robotics and Autonomous Systems Group responded to this opportunity with the creation of 3DSA. 3DSA utilises existing security cameras to recreate a 3D reconstruction of facilities, providing full awareness of all moving parts of a facility and providing potential for real-time alerts, analysis, and continual optimisation of workflow operations. Thus far, 3DSA has been used in trials and has demonstrated the capacity to identify locations of tools and objects for easier retrieval, real-time information and feedback for Industry 4.0 applications, and advanced analytics to enable analysis on maximising the efficiency and value of material flows and workflows.

3DSA is the first system to offer security camera-based situational awareness technology and, thus, provides strong opportunities for workflow efficiency benefits. Foremost, companies can use 3DSA to plan workflow to gain efficiency benefits and to react in real time to prevent build-ups and part delay. 3DSA can also work in coordination with pedestrians and vehicles and can provide real-time alerts to ensure safe coexistence and operation. Finally, 3DSA only requires off-the-shelf security cameras for operation, creating an affordable option for businesses wanting to reap the benefits of a situational awareness system (CIE, 2020b).

3.6.2 Leading Australia Towards Hydrogen Capitalisation

Renewable hydrogen fuel offers a source of energy that is clean, flexible, storable, and safe. Hydrogen initiatives launched in Australia in earlier years had varying degrees of success and were narrow in focus.

In 2018, CSIRO convened stakeholders from industry, academia, and government to test the hypothesis that hydrogen could be a broad-based market opportunity for Australia. They compiled evidence from existing state government investments and CSIRO research and showed the need for a guiding document addressing next steps. CSIRO proposed a market-oriented roadmap that would be sponsored by a mix of stakeholders, guided by a steering committee, and supported by working groups. The resulting National Hydrogen Roadmap was oriented towards the market potential of hydrogen, developing an understanding of assumptions and cost drivers required for hydrogen to be competitive for different applications in the market.

The roadmap revealed that Australia was in a prime position to lead as an exporter of renewable energy through hydrogen. The work of the roadmap has led Australia towards future economic gains by reducing asymmetries in information between market participants and accelerating hydrogen investment, initiatives, and policies to address market opportunity. The process of making the roadmap involved bringing together diverse stakeholders from industry, government, and academia. In its role as lead collaborator, Futures generated social value by recognising the need for a market-focused roadmap; establishing a neutral, precompetitive forum for the exchange of ideas and information; and avoiding duplication of effort by stakeholders who may have acted individually or in smaller groups (RTI, 2021c).

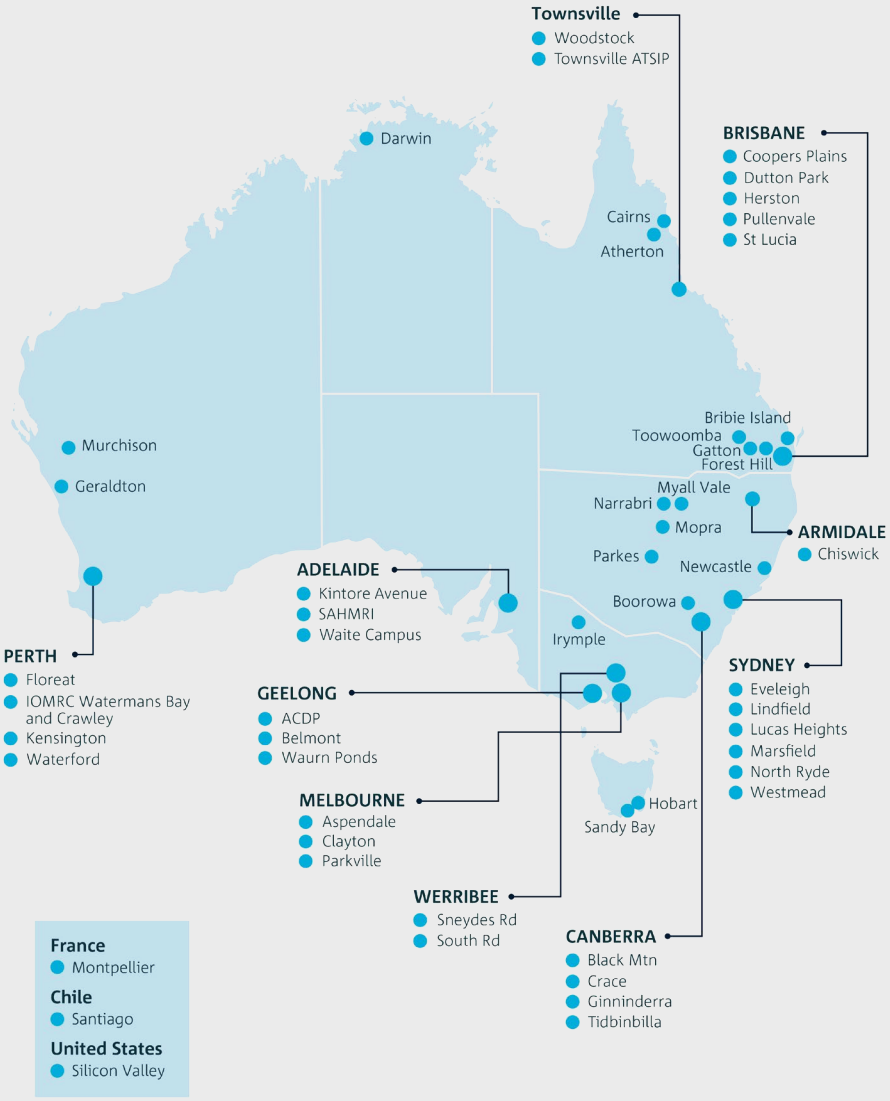
4. Additional Impact Metrics

CSIRO's positive impact on Australia extends beyond the monetised values captured in the portfolio of impact case studies. CSIRO's main objectives[5] are to:

1. Conduct and encourage the translation of Australia's world-class scientific research into impact;
2. Enable the use of science infrastructure and collections; and
3. Stimulate innovation for Australian industry, academia, and government.

While some of CSIRO's impacts from meeting these objectives are captured in the portfolio of impact case studies, others are not readily monetised. As such, we provide additional metrics of success below. It should also be noted that CSIRO directly supports the people of Australia by providing high-paying jobs and striving to ensure a vibrant, safe, and positive work culture to nurture and attract world-class talent. CSIRO employs over 5,200 people in Australia and globally, with about 86% of full-time equivalents coming from research positions. CSIRO operates sites in every state and territory of Australia (see Figure 4.1).

Figure 4.1. Current CSIRO Office Locations



Source: CSIRO. 2021. Corporate plan 2021-22. Canberra, Australia: CSIRO.

5 As stated in CSIRO's Annual Report for the 2020-2021 financial year.

4.1 RESEARCH TRANSLATION

CSIRO aims to conduct and encourage the translation of Australia's world-class scientific research into impact. The impact assessment results of this report provide a key metric of CSIRO's success in meeting this objective. CSIRO also advances research translation through its extensive research dissemination efforts. As of 2021, CSIRO had 3,412 publications with an average normalised citation impact of 1.5, indicating the strong contributions of CSIRO's trusted research results to the scientific knowledge base.

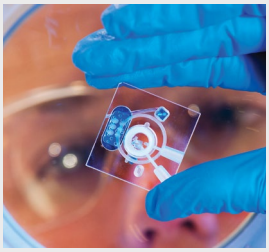
Importantly, CSIRO's research translation efforts extend beyond scientific knowledge dissemination. CSIRO works to ensure that its science and technology are adopted and create value for industry. As of 2021, CSIRO held over 650 families of patents and more than 540 active technology licenses. More than 210 companies have been started from CSIRO technology, with over 20 active spinouts or start-ups as of 2021. Industry is also a direct customer of CSIRO's research services, and CSIRO's consumer surveys have indicated continuous increases in ratings of positivity and trustworthiness.

4.2 SCIENCE INFRASTRUCTURE AND COLLECTIONS

As Australia's national science agency, CSIRO maintains science infrastructure and collections for public use. These include the Australian Centre for Disease Preparedness, Australian Telescope National Facility, National Research Collections Australia, and Atlas of Living Australia, among others. Impact case studies provide monetised estimates of the impacts of three such elements: the Marine National Facility (MNF), Pawsey Supercomputing Centre, and the Australian Synchrotron. Each of these case studies is summarised below.

4.2.1 Marine National Facility

The MNF supports research and education about oceanography, seafloor geology, marine life, weather, and climate that further Australian science on a global scale. Launched in 2014, CSIRO's new premier research vessel, the RV Investigator, has overhauled Australian ocean observation capabilities. The RV Investigator is a 94-metre research vessel outfitted with world-class instrumentation and gear that is capable of spending up to 300 days per year at sea.



650+ families of patents
540+ active technology licenses

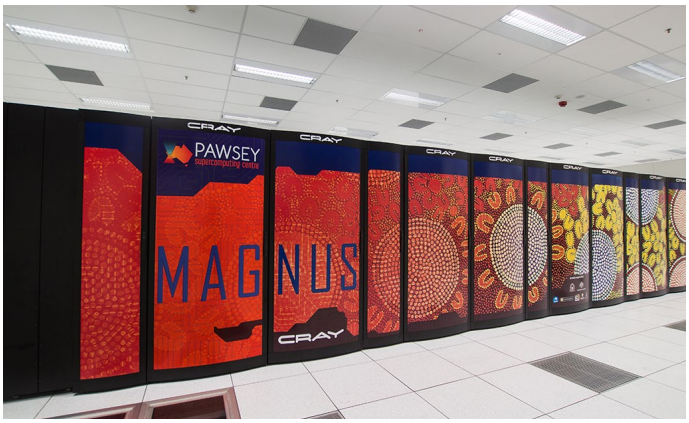
210+ companies started
20+ active spinouts or start-ups

3,412 publications with average normalised citation index of 1.5

The RV Investigator generates value by collecting robust data about oceans, marine life, the seafloor, and the atmosphere. These data are made available at no cost for use by the public and play a critical role in evidence-based decision making, resource and risk management strategies, and offshore activities. Users from all segments of Australian society leverage these data to deepen and expand their collective understanding of ocean ecosystems, climate and weather changes, and fisheries.

RTI's (2020) economic impact analysis of the MNF reviewed four of its main value streams: Seabed Mapping, Ecosystem Health, Weather Forecasting, and Shipwreck Discovery. Cumulatively, these impacts are projected to yield $3.8 billion in 2022 dollars to Australia's economy through 2031. These benefits greatly surpass the $765 million cost of MNF improvements and operations, yielding a BCR of 5.0 to 1.

4.2.2 Pawsey Supercomputing Centre



The Pawsey Supercomputing Centre (Pawsey) is a world-class petascale facility. It supports a range of cutting-edge research, including radio astronomy, engineering, physics, chemistry, earth sciences, and life sciences. Pawsey helps

researchers interpret complex data and demonstrates how to adopt scalable computational approaches to advance the biggest scientific questions. In a single year, Pawsey has the capacity to support over 1,500 researchers and 194 projects and to upskill over 600 Australians in high-performance computing and data activities.

The benefits of Pawsey are far reaching and include accelerating scientific progress and offering a proving ground for commercial ventures that require supercomputing access. There are also scientific discoveries that could not take place but for supercomputing capabilities, such as those relying on large genetic datasets. Pawsey also provides expertise and attracts talent in the fields of data engineering, warehousing, data mining, statistical analysis, cloud and system architecture, data management, machine learning, and visualisation. Finally, Pawsey yields social benefits by forging international relationships in supercomputing and large-scale data processing and analysis.

Pawsey presents a long-term investment in advanced infrastructure for public use. While positive returns are expected over the next 30 years, short-term returns over 10 years are negative (CIE, 2019). This displays the important role of a national agency like CSIRO in maintaining science infrastructure because private industry would not be able to make a long-term investment of this nature.

4.2.3 Australian Synchrotron

Synchrotrons are highly intense sources of light that range from infrared to hard X-rays supplied at the end-stations of beamlines. Synchrotron operations serve the needs of a wide array of researchers, including in the fields of advanced materials, agriculture, biomedics, defence, environmental sustainability, food technology, forensics, oil and gas, mining, and nanotechnology.

Previously, Australian researchers used overseas synchrotrons and were often faced with limited beam time availability and high travel costs. The SIEF Special Research Program filled a gap in the national innovation system by providing merit-based beam time access to the Australian Synchrotron for Australian publicly funded research agencies (PFRAs).

The ability to access synchrotron facilities in Australia is invaluable to Australian researchers. Synchrotrons are far superior to traditional laboratory tools in terms of accuracy, quality, robustness, speed of collection, and the level of detail that can be seen. Most SIEF-funded synchrotron projects with PFRAs have involved research collaboration partners from universities, medical research institutes, and other research organisations. PFRA researchers have also participated in many other synchrotron projects, led by other collaboration partners. ACIL Allen's (2017b) impact assessment estimated that by 2026 increased public access to the synchrotron through the SIEF program would result in a BCR of 12.9 to 1.

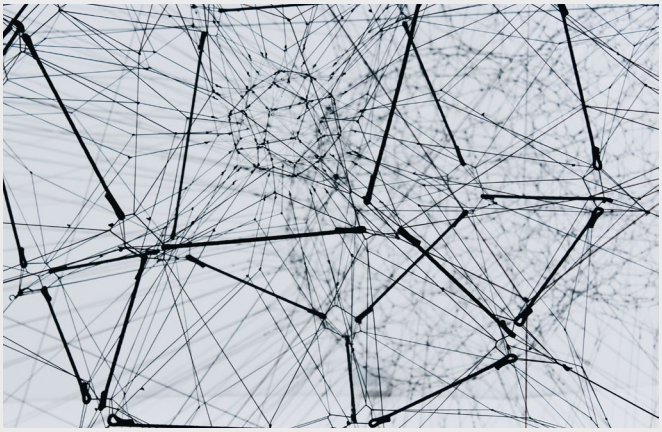
4.3 STIMULATING INNOVATION

CSIRO's third objective to stimulate innovation for Australian industry, academia, and government entails research collaborations, direct investments in industry, and talent development through education and outreach programs. CSIRO's extensive collaboration is displayed through its publication record. About 91% of CSIRO's research publications are published jointly with external collaborators.

CSIRO also invests directly in industry by supporting deep-tech startups through the ON Program and the Innovation Fund managed by Main Sequence. The ON Program supports Australian scientists to create startups to commercialise their research with activities including business planning, development of presentation skills, raising of capital, and recruiting of a Board. Since its initiation in 2015, the ON Program has supported more than 60 companies. The Innovation Fund invests in companies borne out of Australia's research sector and supports the transition to commercialisation. Since its inception in 2017, the Innovation Fund has supported over 35 ventures. Together, CSIRO's portfolio companies employ over 1,350 people.

CSIRO helps meet Australia's growing demand for STEM skills by nurturing and developing the next generation of STEM researchers through its education and outreach programs. CSIRO engaged about 1,500 undergraduate and postgraduate students in the 2020–2021 fiscal year, reflecting a decrease compared with previous years because of COVID-19-related restrictions (CSIRO, 2021a).

CSIRO's undergraduate education programs include the Undergraduate Vacation Scholarship, which engages students in STEM workshops and career development opportunities, and the Undergraduate Research Opportunities Program, which facilitates traineeships for students in research laboratories. CSIRO supports postgraduate students through either sponsored studentships via a full or top-up stipend, supervised-only studentships, CSIRO's Industry PhD program, or postgraduate internships. The CSIRO Early Research Career Postdoctoral Fellowship supported 218 postdoctoral students in the 2020–2021 fiscal year. Again, the number of students engaged decreased compared with previous years because of COVID-19-related restrictions.



About **91%** of CSIRO's research publications are published jointly with external collaborators

The Innovation Fund has supported over **35** ventures, employing over **1,350** people

Since its initiation in 2015, the ON Program has supported more than **60** companies

The CSIRO Early Research Career Postdoctoral Fellowship supported **218** postdoctoral students

5. Concluding Remarks

This report provides multiple measures of the value that CSIRO brings to Australia. We estimated a BCR of 8.4 to 1 for CSIRO's increasing portfolio of externally validated impact case studies of its various programs and initiatives. This means that every $1 invested in CSIRO projects and programs results in about $8.40 in economic, social, and environmental value. This result represents an increase from earlier estimates of the value of CSIRO and is still an underestimate as many elements of CSIRO's impact are not readily expressed in dollar terms.

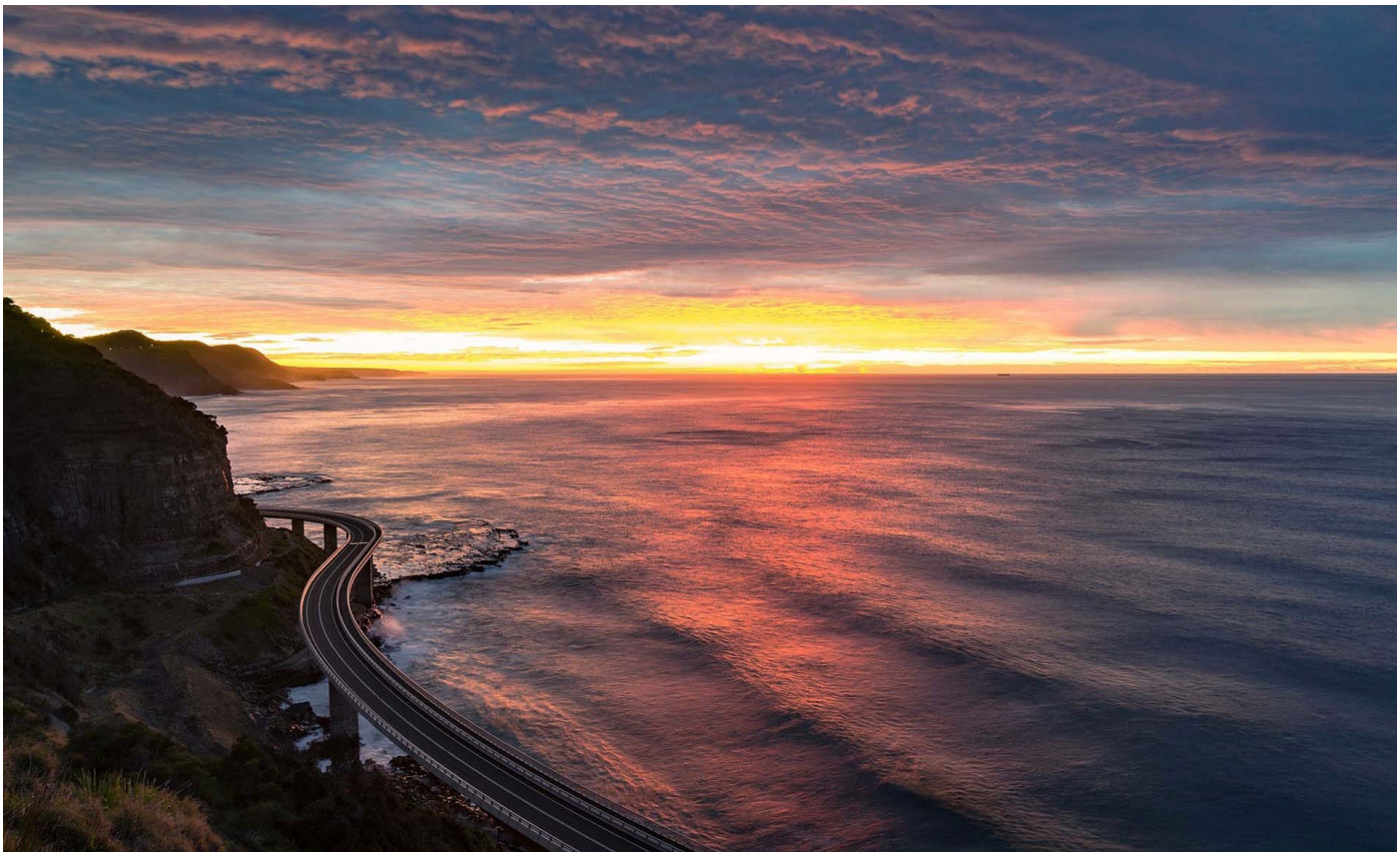
We can apply the BCR of 8.4 generated by the case study portfolio analysis to CSIRO's operating expenses of $1.4 billion for the 2021-2022 financial year to impute the total impact of CSIRO. This process suggests that CSIRO generated $11.7 billion in benefits for a NPV of $10.2 billion.

CSIRO is a mission-driven organisation focussed on addressing national challenges by investing broadly and holistically across the spectrum of innovation to deliver impact to current and future generations of Australians. CSIRO acts as a bridge for Australian innovation, providing the essential research, technology platforms, and best practices needed by innovators, and collaborating with those innovators to convert their discoveries and ideas into technologies and services that benefit the nation.

For example, CSIRO maintains science infrastructure and collections for public use. CSIRO also ensures that its science and technology are adopted and create value through patents, technology licenses, and the formation of start-ups and spinouts. Additionally, CSIRO invests directly in industry by providing SMEs with guidance and funding through its dedicated SME programs.

CSIRO also develops the pool of scientific talent within Australia by providing jobs in a vibrant, safe, and positive work culture to nurture and attract world-class talent. CSIRO further develops the next generation of talent in Australia by engaging undergraduate, postgraduate, and postdoctoral students in STEM education and career outreach programs.

The impact case studies and additional areas and metrics of impact reviewed in this report suggest that CSIRO continues to deliver on its purpose to solve the greatest challenges through innovative science and technology, with an ultimate vision to create a better future for Australia.



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Appendix: Case Study Details

Table A.1. High-Level Summary of CSIRO Impact Case Studies

CASE STUDY	STUDY CODE	PUBLICATION YEAR	AUTHOR	IN 2022 ESTIMATES	IN 2020 ESTIMATES
Diffuse Energy	A23	2020	ACIL Allen	✓	✗
Genics	A20	2020	ACIL Allen	✓	✗
Grover Scientific (E-DNA Sampler)	A24	2020	ACIL Allen	✓	✗
PainChek LTD	A19	2020	ACIL Allen	✓	✗
Voconiq	A21	2020	ACIL Allen	✓	✗
3D Situational Awareness research	E14	2020	CIE	✓	✗
CSIRO Cybersecurity Research (Data 61)*	E15	2020	CIE	✓	✗
CSIRO's Collaboration with CBG Systems	E18	2020	CIE	✓	✗
CSIRO's Development of Synthetic Biomedical Polymers	E19	2020	CIE	✓	✗
Microencapsulation Technology	E25	2020	CIE	✓	✗
NAME REDACTED	E24	2020	CIE	✓	✗
Wildcat SLAM	E17	2020	CIE	✓	✗
Crown-of-Thorns Starfish Integrated Pest Management	C25	2021	CSIRO	✓	✗
Early and Dry Sowing of Wheat	C30	2020	CSIRO	✓	✗
Early Sowing of Canola in Eastern Australia	C32	2020	CSIRO	✓	✗
From Boat to Plate*	C24	2020	CSIRO	✓	✗
Megasonics Olive Oil Recovery*	C31	2021	CSIRO	✓	✗
Saltbush Forage Improvement (Anameka™)	C28	2021	CSIRO	✓	✗
1622 Water Quality Apps	F7	2021	RTI	✓	✗
Coral Reef Monitoring and Response Technologies	F8	2021	RTI	✓	✗
CSIRO Eveleigh AI Centre of Excellence	F4	2021	RTI	✓	✗

Table A.1. High-Level Summary of CSIRO Impact Case Studies (continued)

CASE STUDY	STUDY CODE	PUBLICATION YEAR	AUTHOR	IN 2022 ESTIMATES	IN 2020 ESTIMATES
DNA Ageing Technology Emerging	F5	2021	RTI	✓	✗
Graincast	F2	2020	RTI	✓	✗
LOOC-C Carbon App	F9	2021	RTI	✓	✗
Marine National Facility	F1	2020	RTI	✓	✗
WaterWise	F10	2021	RTI	✓	✗
Westmead Lab of the Future	F3	2021	RTI	✓	✗
Coviu Refresh V3	G3	2021	Tractuum	✓	✗
MS3	G5	2020	Tractuum	✓	✗
Agricultural Flagship: Cotton Varieties	A3	2014	ACIL Allen	✓	✓
Aquaculture Feed (Novacq) & Prawn Breeding	A10	2016	ACIL Allen	✓	✓
Bluelink	A4	2016	ACIL Allen	✓	✓
Botanical Resources Australia	A5	2016	ACIL Allen	✓	✓
BuildingIQ: Opticool	A6	2016	ACIL Allen	✓	✓
Distal Footprints*	A15	2017	ACIL Allen	✓	✓
Early Nutrition*	A12	2017	ACIL Allen	✓	✓
Energy Waste*	A11	2017	ACIL Allen	✓	✓
eReefs	A7	2016	ACIL Allen	✓	✓
Longwall Automation Steering Committee: Longwall Automation	A8	2014	ACIL Allen	✓	✓
Medical Developments International: Penthrox	A9	2016	ACIL Allen	✓	✓
Plant Yield*	A13	2017	ACIL Allen	✓	✓
RAFT for Medical Applications*	A14	2017	ACIL Allen	✓	✓
Synchrotron*	A16	2017	ACIL Allen	✓	✓
Care Assessment Platform/ MoTER Cardiac Rehabilitation Program	E7	2017	CIE	✓	✓

Table A.1. High-Level Summary of CSIRO Impact Case Studies (continued)

CASE STUDY	STUDY CODE	PUBLICATION YEAR	AUTHOR	IN 2022 ESTIMATES	IN 2020 ESTIMATES
CSIRO's CAMP – Oventus	E9.2	2019	CIE	✓	✓
Kick-Start Program	E10	2019	CIE	✓	✓
NAME REDACTED	E2	2017	CIE	✓	✓
Pawsey Supercomputing & CETO	E3.3	2019	CIE	✓	✓
Pawsey Supercomputing & Efficient Gas Turbines	E3.1	2019	CIE	✓	✓
Pawsey Supercomputing & the Murchison Widefield Array	E3.2	2019	CIE	✓	✓
Remote-I Digital Eye Health System	E8	2018	CIE	✓	✓
STEM+Business: Aquarius	E11.2	2019	CIE	✓	✓
STEM+Business: Optotech	E11.1	2019	CIE	✓	✓
TerriaJS	E1	2019	CIE	✓	✓
Vaximiser	E4	2017	CIE	✓	✓
Atlantic Salmon Breeding	C4	2016	CSIRO	✓	✓
Biomarkers for Detection of Colorectal Cancer	C20	2017	CSIRO	✓	✓
Biosensors for Health & Food: CYBERTONGUE®/ CYBERNOSE®	C22	2017	CSIRO	✓	✓
Dry Slag Granulation	C12	2018	CSIRO	✓	✓
Future Grid Forum & Electricity Network Transformation Roadmap	C11	2017	CSIRO	✓	✓
High Pressure Processing	C16	2018	CSIRO	✓	✓
Improving Iron Ore Sintering Process Performance	C14	2018	CSIRO	✓	✓
Maintaining Access to EU Markets for Australian Canola	C18	2019	CSIRO	✓	✓
Magnetic Resonance Ore Sorter	C13	2018	CSIRO	✓	✓
Medical Image Communication Exchange (MICE)	C17	2018	CSIRO	✓	✓
Natural Hazards & Infrastructure Initiative	C5	2019	CSIRO	✓	✓
Rabbit Biocontrol	C8	2017	CSIRO	✓	✓

Table A.1. High-Level Summary of CSIRO Impact Case Studies (continued)

CASE STUDY	STUDY CODE	PUBLICATION YEAR	AUTHOR	IN 2022 ESTIMATES	IN 2020 ESTIMATES
Reservoir Rejuvenation Technology	C7	2017	CSIRO	✓	✓
Coviu	A22	2020	ACIL Allen	✗	✓
Cereal Rust	C1	2016	CSIRO	✗	✓
Yield Prophet	C3	2016	CSIRO	✗	✓
Cement Substitutes & Novel Products	B3	2010	ACIL Tasman	✗	✗
Climate Adaptation Flagship: Climate Ready Crops	B2	2010	ACIL Tasman	✗	✗
Climate Adaptation Flagship: Coastal Communities	B1	2010	ACIL Tasman	✗	✗
Radio-Astronomy: Square Kilometre Array	B5	2010	ACIL Tasman	✗	✗
The UltraBattery	B4	2011	ACIL Tasman	✗	✗
Australian Animal Health Laboratory: Foot and Mouth Disease	A1	2014	ACIL Allen	✗	✗
Integrated Water Resource Assessments	A2	2014	ACIL Allen	✗	✗
Silentium Defence	A18	2018	ACIL Allen	✗	✗
AuScope	D4	ND	DAE	✗	✗
BARLEYmax™	D1	2014	DAE	✗	✗
Clinical Terminology Tools	D3	2017	DAE	✗	✗
Sustainable Commercial Fisheries	D2	2014	DAE	✗	✗
Air Quality Forecasting System (AQFx)	E26	2021	CIE	✗	✗
Applied Research and Innovation System in Agriculture (ARISA) Program	E20	2020	CIE	✗	✗
Centre for Australian National Biodiversity Research	E21	2020	CIE	✗	✗
CSIRO's Clayton Advanced Manufacturing Precinct (CAMP)	E9.1	2019	CIE	✗	✗
CSIRO's Collaboration with the Five-Hundred-Metre Aperture Spherical Telescope (FAST)	E23	2020	CIE	✗	✗
CSIRO Investment in Proficiency Testing	E22	2021	CIE	✗	✗
CSIRO's RNAi Investments	E16	2020	CIE	✗	✗

Table A.1. High-Level Summary of CSIRO Impact Case Studies (continued)

CASE STUDY	STUDY CODE	PUBLICATION YEAR	AUTHOR	IN 2022 ESTIMATES	IN 2020 ESTIMATES
CSIRO-Viet Uc Shrimp Breeding Program	E27	2020	CIE	✗	✗
IA Quantified Risk Assessment of Complex Systems	E12	2019	CIE	✗	✗
Impromy	E5	2017	CIE	✗	✗
NAME REDACTED	E6	2017	CIE	✗	✗
TAGV NeWheel	E13	2020	CIE	✗	✗
Automated Farm Provenance: Animal Welfare Compliance*	C23	2021	CSIRO	✗	✗
Clinical Terminology Tools	C21	2017	CSIRO	✗	✗
Direct Injection Carbon Engine (DICE)	C15	2017	CSIRO	✗	✗
Dual Purpose Canola	C26	2021	CSIRO	✗	✗
Grapevine Breeding	C2	2016	CSIRO	✗	✗
Hydrogen Generator for Refuelling Fuel-Cell Electric Vehicles (FCEV)*	C33	2020	CSIRO	✗	✗
M♡Ther: Gestational Diabetes e-Health Platform	C27	2021	CSIRO	✗	✗
Patient Administration Prediction Tool	C6	2017	CSIRO	✗	✗
Phalaris Breeding Program	C29	2021	CSIRO	✗	✗
The Scientists and Mathematicians in Schools Program	C19	2015	CSIRO	✗	✗
Trustworthy Systems Group's Research & Technology	C10	2019	CSIRO	✗	✗
Weed Biocontrol	C9	2017	CSIRO	✗	✗
CSIRO Futures: A Case Study of the National Hydrogen Roadmap	F6	2021	RTI	✗	✗
RV Investigator SE Ecosystem Survey	G2	2021	Tractuum	✗	✗
SPARK	G4	2021	Tractuum	✗	✗
Virtual Power Station	G1	2021	Tractuum	✗	✗
v2food	G6	ND	Tractuum	✗	✗

* The Science and Industry Endowment Fund Projects

Table A.2. Benefit-Cost Analysis Results from Impact Case Studies with Values Starting in 1997 or Later and with Each Study Capped at 10 Years of Projected Benefits or Costs

CASE STUDY	STUDY CODE	ANALYSIS PERIOD	PV BENEFITS (A)	PV COSTS (B)	NPV (C)	BCR (D)
		YEARS	2022$m	2022$m	(A)-(B) 2022$m	(A)/(B) RATIO
High Pressure Processing	C16	1998-2028	$412.6	$183.0	$229.6	2.3
Magnetic Resonance Ore Sorter	C13	1999-2028	$258.9	$17.0	$241.9	15.2
Improving Iron Ore Sintering Process Performance	C14	1999-2028	$3,689.7	$99.6	$3,590.1	37.0
Microencapsulation Technology	E25	2000-2027	$92.8	$34.0	$58.7	2.7
Longwall Automation Steering Committee: Longwall Automation	A8	2001-2024	$2,980.8	$75.1	$2,905.7	39.7
Bluelink	A4	2003-2025	$96.5	$50.4	$46.0	1.9
Botanical Resources Australia	A5	2003-2029	$15.1	$2.6	$12.5	5.9
Atlantic Salmon Breeding	C4	2004-2024	$150.4	$6.0	$144.3	24.9
Aquaculture Feed (Novacq) & Prawn Breeding	A10	2004-2024	$1,029.9	$70.9	$959.0	14.5
CSIRO's Development of Synthetic Biomedical Polymers	E19	2004-2029	$22.0	$31.0	($9.0)	0.7
Biosensors for Health & Food: CYBER-TONGUE®/CYBERNOSE®	C22	2005-2027	$79.7	$16.8	$63.0	4.8
Saltbush Forage Improvement (Anameka™)	C28	2005-2030	$0.8	$1.7	($0.9)	0.5
BuildingIQ: Opticool	A6	2006-2024	$130.4	$1.4	$129.0	95.3
Agricultural Flagship: Cotton Varieties	A3	2006-2024	$1,166.4	$161.5	$1,005.0	7.2
Biomarkers for Detection of Colorectal Cancer	C20	2006-2026	$282.4	$22.8	$259.6	12.4
Dry Slag Granulation	C12	2006-2027	$91.6	$16.3	$75.3	5.6
Vaximiser	E4	2007-2027	$56.2	$20.9	$35.3	2.7
Care Assessment Platform/ MoTER Cardiac Rehabilitation Program	E7	2008-2017	$533.8	$139.6	$394.2	3.8
Reservoir Rejuvenation Technology	C7	2008-2026	$4.4	$2.6	$1.8	1.7
Rabbit Biocontrol	C8	2008-2026	$184.3	$11.6	$172.6	15.9
eReefs	A7	2009-2025	$175.8	$17.7	$158.1	9.9
Natural Hazards & Infrastructure Initiative	C5	2009-2027	$11.9	$0.9	$11.1	13.6
Pawsey Supercomputing & CETO	E3.3	2009-2028	$0.0	$556.5	($556.5)	0.0

Table A.2. Benefit-Cost Analysis Results from Impact Case Studies with Values Starting in 1997 or Later and with Each Study Capped at 10 Years of Projected Benefits or Costs (continued)

CASE STUDY	STUDY CODE	ANALYSIS PERIOD	PV BENEFITS (A)	PV COSTS (B)	NPV (C)	BCR (D)
		YEARS	2022$m	2022$m	(A)-(B) 2022$m	(A)/(B) RATIO
Plant Yield	A13	2010-2023	$872.3	$12.2	$860.1	71.4
NAME REDACTED	E24	2010-2029	$12.5	$4.1	$8.4	3.0
Maintaining Access to EU Markets for Australian Canola	C18	2011-2021	$122.0	$5.9	$116.1	20.7
Early Nutrition	A12	2011-2026	$126.3	$12.0	$114.3	10.5
Energy Waste	A11	2011-2026	$449.5	$14.0	$435.6	32.2
Marine National Facility	F1	2011-2030	$3,834.3	$764.7	$3,069.6	5.0
RAFT for Medical Applications	A14	2011-2026	$0.0	$9.2	($9.2)	0.0
CSIRO's CAMP – Oventus	E9.2	2012-2016	$7.1	$0.4	$6.7	16.4
STEM+Business: Optotech	E11.1	2012-2016	$9.2	$0.3	$8.9	27.6
Future Grid Forum & Electricity Network Transformation Roadmap	C11	2012-2026	$55.6	$5.9	$49.7	9.5
Synchrotron	A16	2012-2026	$291.3	$22.5	$268.8	12.9
Distal Footprints	A15	2012-2027	$23.5	$8.4	$15.2	2.8
Kick-Start Program	E10	2012-2029	$1.4	$0.1	$1.3	12.4
Early and Dry Sowing of Wheat	C30	2013-2024	$47.7	$1.6	$46.1	30.4
Pawsey Supercomputing & the Murchison Widefield Array	E3.2	2013-2028	$6.4	$66.0	($59.6)	0.1
Remote-I Digital Eye Health System	E8	2013-2028	$9.4	$6.0	$3.5	1.6
NAME REDACTED	E2	2013-2028	$70.7	$4.8	$66.0	14.8
Megasonics Olive Oil Recovery	C31	2013-2030	($0.3)	$4.8	($5.1)	0.0
From Boat to Plate	C24	2014-2024	$42.6	$3.9	$38.7	10.8
Pawsey Supercomputing & Efficient Gas Turbines	E3.1	2014-2028	$3.4	$3.8	($0.5)	0.9
Early Sowing of Canola in Eastern Australia	C32	2014-2028	$21.7	$2.4	$19.3	9.1
TerriaJS	E1	2014-2028	$81.7	$12.2	$69.5	6.7
Medical Developments International: Penthrox	A9	2014-2029	$215.1	$1.3	$213.8	170.5

Table A.2. Benefit-Cost Analysis Results from Impact Case Studies with Values Starting in 1997 or Later and with Each Study Capped at 10 Years of Projected Benefits or Costs (continued)

CASE STUDY	STUDY CODE	ANALYSIS PERIOD	PV BENEFITS (A)	PV COSTS (B)	NPV (C)	BCR (D)
		YEARS	2022$m	2022$m	(A)-(B) 2022$m	(A)/(B) RATIO
Crown-of-Thorns Starfish Integrated Pest Management	C25	2014-2030	$8.8	$1.5	$7.2	5.8
Graincast	F2	2015-2030	$228.9	$5.6	$223.3	41.1
Medical Image Communication Exchange (MICE)	C17	2016-2028	$1.1	$0.6	$0.5	1.9
Voconiq	A21	2016-2028	$19.7	$0.8	$18.9	25.5
PainChek LTD	A19	2016-2028	$2,060.3	$0.4	$2,059.9	5939.8
1622 Water Quality Apps	F7	2016-2030	$47.9	$2.2	$45.7	21.6
Coviu Refresh V3	G3	2016-2030	$64.1	$1.8	$62.4	36.2
CSIRO's Collaboration with CBG Systems	E18	2017-2026	$1.1	$0.5	$0.6	2.1
Diffuse Energy	A23	2017-2028	$4.3	$0.5	$3.8	9.0
MS3	G5	2017-2029	$4.2	$0.6	$3.6	6.6
Genics	A20	2017-2030	$29.4	$0.7	$28.7	42.7
3D Situational Awareness Research	E14	2017-2030	$302.3	$2.6	$299.7	114.8
WaterWise	F10	2017-2030	$347.3	$20.1	$327.2	17.3
LOOC-C Carbon App	F9	2017-2030	$733.8	$4.4	$729.4	165.4
CSIRO Cybersecurity Research (Data 61)	E15	2018-2020	$61.2	$31.9	$29.3	1.9
Grover Scientific (E-DNA Sampler)	A24	2018-2030	$4.5	$0.4	$4.0	10.3
Coral Reef Monitoring and Response Technologies	F8	2018-2031	$156.9	$6.0	$150.9	26.1
Wildcat SLAM	E17	2019-2028	$313.5	$5.3	$308.2	59.2
STEM+Business: Aquarius	E11.2	2019-2029	$3.3	$0.4	$2.9	8.1
DNA Ageing Technology Emerging	F5	2019-2029	$130.5	$1.1	$129.4	118.1
Westmead Lab of the Future	F3	2022-2031	$54.4	$27.2	$27.2	2.0
CSIRO Eveleigh AI Centre of Excellence	F4	2022-2031	$184.5	$50.7	$133.8	3.6
Totals		**1998-2031**	**$22,531.5**	**$2,671.7**	**$19,859.9**	**8.4**

Table A.3. Benefit-Cost Data from Impact Case Studies Excluded from Analysis due to Date Restrictions or Insufficient Time Series of Benefits or Costs

CASE STUDY	STUDY CODE	ANALYSIS	PV BENEFITS	PV COSTS
		YEARS	2022$m	2022$m
Grapevine Breeding	C2	1965-2024	$572.90	$67.90
Weed Biocontrol	C9	1972-2006	$3,027.80	$10.10
Cereal Rust	C1	1994-2024	$755.00	$276.00
Yield Prophet	C3	1994-2031	$16.60	$5.70
Cement Substitutes & Novel Products	B3	2000-????	$198.10	$63.40
The UltraBattery	B4	2004-2020	$112.10	$15.80
Integrated Water Resource Assessments	A2	2005-????	$2,188.30	$291.70
Climate Adaptation Flagship: Coastal Communities	B1	2006-2070	$591.40	$28.60
The Scientists and Mathematicians in Schools Program	C19	2007-2015	$48.40	$13.00
Direct Injection Carbon Engine (DICE)	C15	2007-2050	$61.00	$18.80
Australian Animal Health Laboratory: Foot and Mouth Disease	A1	2008-????	$9,689.40	$558.70
Patient Administration Prediction Tool	C6	2008-2017	$95.30	$0.50
Climate Adaptation Flagship: Climate Ready Crops	B2	2008-2049	$1,478.60	$13.70
Trustworthy Systems Group's Research & Technology	C10	2009-2028	$98.20	$5.40
Clinical Terminology Tools	C21	2010-2016	$266.00	$8.80
Coviu*	A22	2016-2031	$159.40	$0.50
Dual Purpose Canola	C26	2010-2028	NA	$5.10
M♡Ther: Gestational Diabetes e-Health Platform	C27	2018-2022	NA	$0.50
Automated Farm Provenance: Animal Welfare Compliance	C23	2019-2020	NA	$2.80
Phalaris Breeding Program	C29	1973-2040	NA	NA
CSIRO Investment in Proficiency Testing	E22	2007-2027	NA	NA
CSIRO's RNAi Investments	E16	2012-2020	NA	NA
CSIRO-Viet Uc Shrimp Breeding Program	E27	2012-2024	NA	NA

Table A.3. Benefit-Cost Data from Impact Case Studies Excluded from Analysis due to Date Restrictions or Insufficient Time Series of Benefits or Costs (continued)

CASE STUDY	STUDY CODE	ANALYSIS PERIOD	PV BENEFITS	PV COSTS
		YEARS	2022$m	2022$m
CSIRO's Clayton Advanced Manufacturing Precinct (CAMP)	E9.1	2012-2032	NA	NA
Air Quality Forecasting System (AQFx)	E26	2013-2040	NA	NA
Impromy	E5	2014-2017	NA	NA
Applied Research and Innovation System in Agriculture (ARISA) program	E20	2014-2019	NA	NA
CSIRO's Collaboration with the Five-Hundred-Metre Aperture Spherical Telescope (FAST)	E23	2014-2034	NA	NA
Virtual Power Station	G1	2015-2019	NA	NA
Centre for Australian National Biodiversity Research	E21	2016-2020	NA	NA
IA Quantified Risk Assessment of Complex Systems	E12	2016-2029	NA	NA
TAGV NeWheel	E13	2016-2030	NA	NA
NAME REDACTED	E6	2016-2035	NA	NA
Silentium Defence	A18	2017-2017	NA	NA
Hydrogen Generator for Refuelling Fuel-Cell Electric Vehicles (FCEV)	C33	2017-2031	NA	NA
CSIRO Futures: A Case Study of the *National Hydrogen Roadmap*	F6	2018-2030	NA	NA
v2food	G6	2019-2030	NA	NA
SPARK	G4	2021-2024	NA	NA
RV Investigator SE Ecosystem Survey	G2	2021-2040	NA	NA
Radio-Astronomy: Square Kilometre Array	B5	?-?	NA	NA
BARLEYmax™	D1	?-?	NA	NA
Sustainable Commercial Fisheries	D2	?-?	NA	NA
Clinical Terminology Tools	D3	?-?	NA	NA
AuScope	D4	?-?	NA	NA
Totals		**1972-2070**	**$19,364.90**	**$1,387.40**

*This study was excluded from the analysis because it was refreshed in 2021.

Figure A.1. **Benefit and Cost Data for Each Study by Year and Type (Actual vs. Projected)**

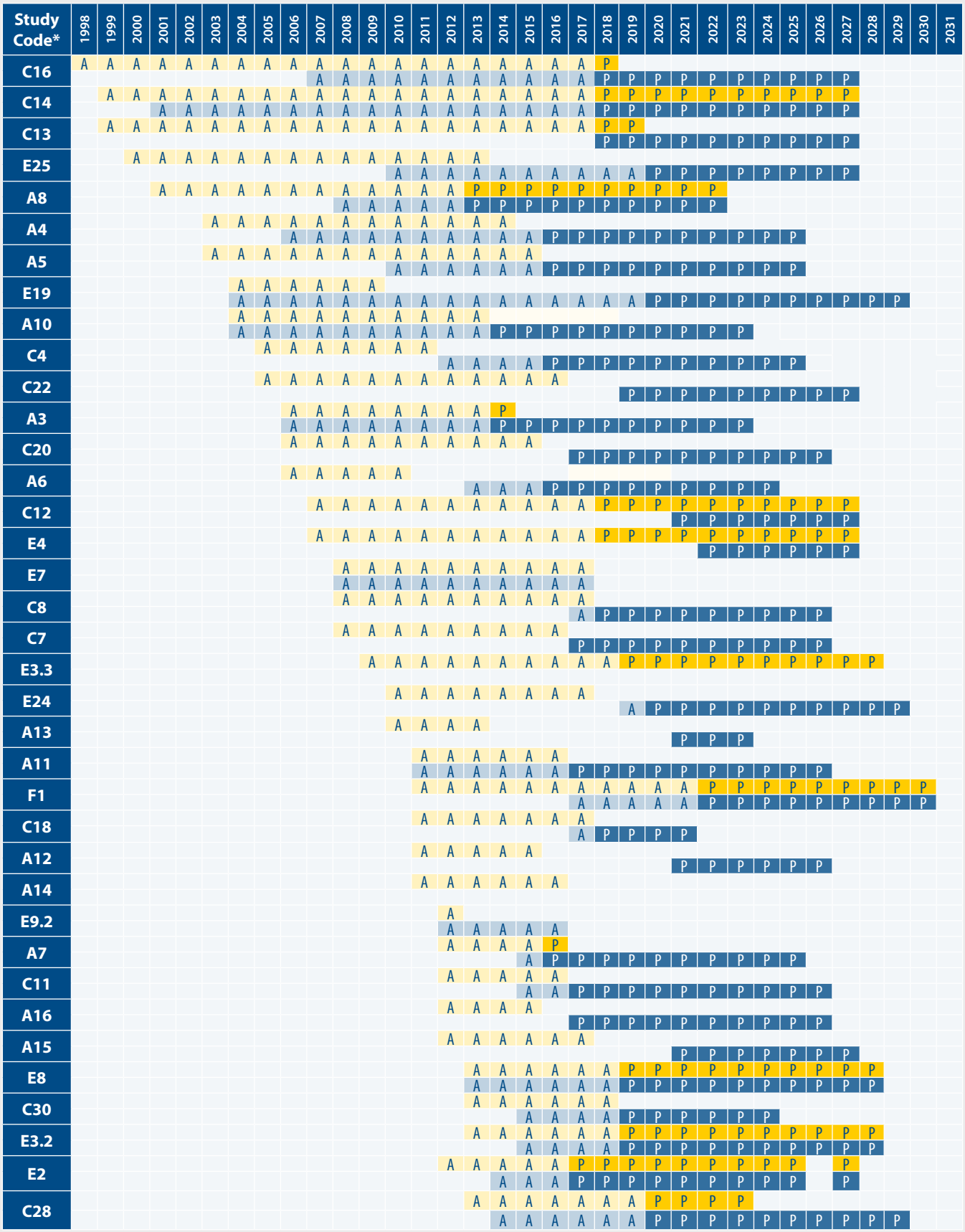
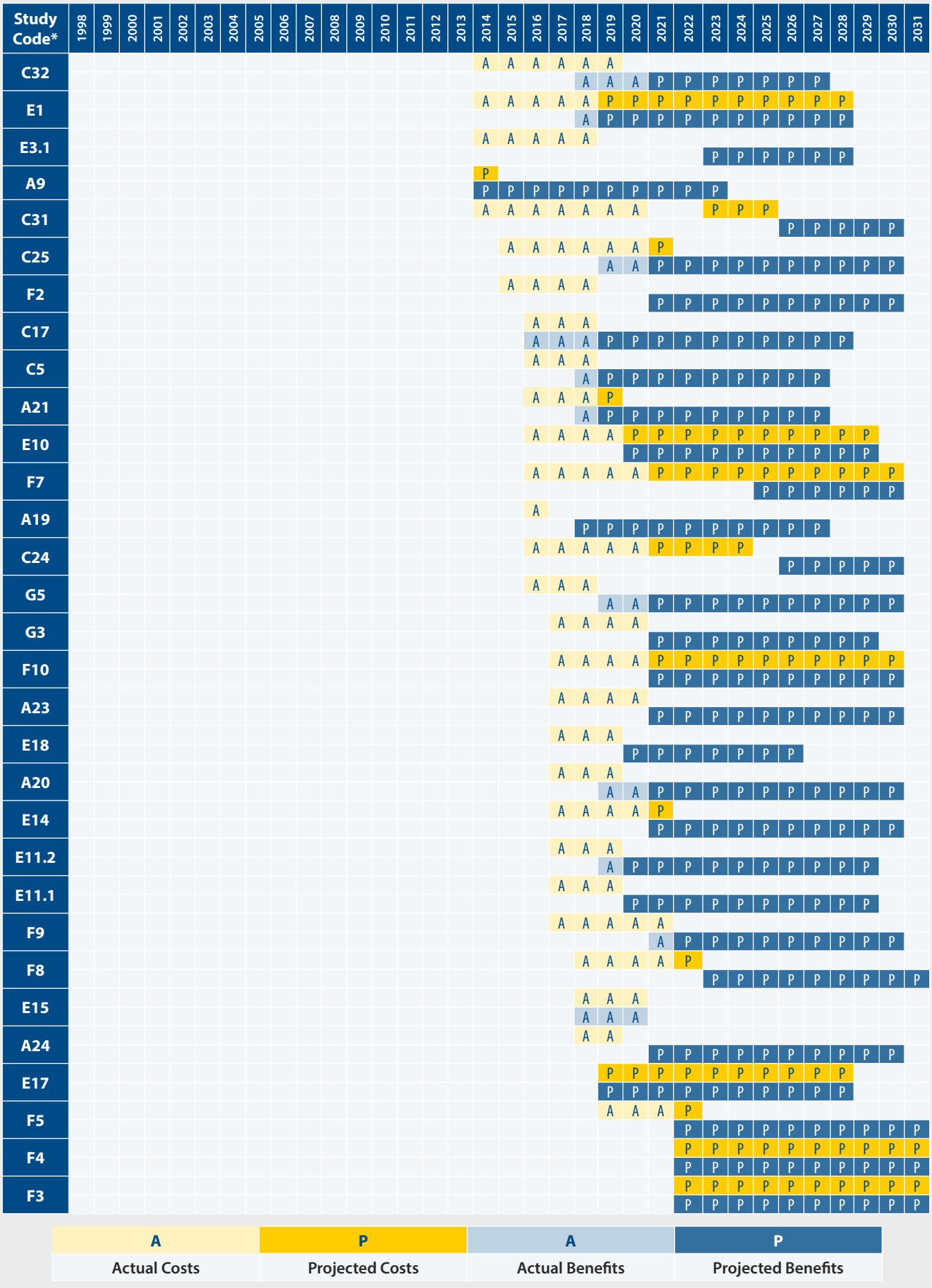


Figure A.1. **Benefit and Cost Data for Each Study by Year and Type (Actual vs. Projected) (continued)**



The Value of CSIRO
The Broader Impact of CSIRO's Portfolio of Activities

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2022 Update

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