SIEF Impact Review

An evaluation of the impact of SIEF

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ACKNOWLEDGMENT

This report was commissioned by the Science and Industry Endowment Fund (SIEF) (hereafter “SIEF”) for the purposes of assisting SIEF measure the impact and value of its innovation investments. Much of the data for the impact analysis was collected during the period September 2016 to December 2016 from a range of sources:

- publicly available documents;
- progress and other reports produced by the research teams in fulfilment of their obligations to SIEF;
- raw data provided by SIEF for independent and confidential analysis by CSIRO and ACIL Allen Consulting;
- correspondence and interviews with stakeholders, including research project leaders and others who had received SIEF funding over the period; and
- Seven facilitated workshops which were designed to explore and ultimately reach agreement with the project teams and collaborators on the precise nature of the impacts arising from the project.

The authors are grateful to those individuals who generously provided their input and feedback, which has been of enormous value in the development of the report.

SIEF's impact on Australian Innovation System

STRATEGIC RESEARCH INVESTMENT

To date SIEF has **invested $153.2 million** in support of strategic scientific research since 2009.

$500m research portfolio

SIEF investment has supported the creation of a portfolio of research activities with a total investment of **$500 million**.

Collaborating partners in this research have contributed almost three quarters of the total funding (73.5%), with SIEF contributing the remainder.

The Impact Assessment of SIEF's 7 case studies indicated current and future returns to the Australian community **of $4.3 billion**.

This equates to a benefit-cost ratio of 95:1, or $95 return for every dollar invested.

SCIENCE EXCELLENCE

Between 2010 and 2016, SIEF funded activities resulted in the publication of **417 articles** in various journals on a wide range of topics.

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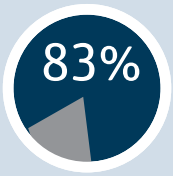
In the case of SIEF 22% of the published articles appear in the **top 5% of journals**.

This compares favourably with the 11% of NHMRC supported research which is published in the top 5% of journals.



Almost **83% of articles** reporting on the results of SIEF-funded activities are co-authored.

Almost 69% of these have Australian co-authors, while 46% have at least one or more international co-author.

CAPACITY BUILDING

Through the Promotion of Science program, SIEF has provided support to **47 PhD students and postdoctoral fellows**.

All of these were co-supervised by more than one organisation, while 32% were co-supervised by more than two organisations.

Over the period from 2010 to 2016, SIEF has supported **302 Earlier Career Researchers** through its Promotion of Science and Research Program.

Almost 40% of these ECRs were women.

SIEF's investment of $56 million has successfully leveraged an additional investment of $270 million from other organisations for the development of five leading-edge, strategic, cross-disciplinary **research facilities**.

Contents

APPENDICES

GLOSSARY OF TERMS

AAS	Australian Academy of Science
ANAO	Australian National Audit Office
ANSTO	Australian Nuclear Science and Technology Organisation
ARC	Australian Research Council
ARCF	Australian Resources Characterisation Facility
ASKAP	Australian Square Kilometre Array Pathfinder
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BMTF	Biomedical Materials Translational Facility
CCS	Carbon Capture and Storage
DIISTRE	Department of Industry, Innovation, Science, Research and Tertiary Education
ECRs	Early Career Researchers
EDP	Experimental Development Program
ICT	Information and Communications Technology
IHC	Immunohistochemistry
IPO	Initial Public Offering
KEQs	Key Evaluation Questions
KPIs	Key Performance Indicators
MOF	Metal-Organic Framework
MHTP	Monash Health Translation Precinct
MRO	Murchison Radio-Astronomy Observatory
NAESP	National Agricultural and Environmental Sciences Precinct
NHMRC	The National Health and Medical Research Council
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
PAF	Phased Array Feed
PFRAs	Publicly Funded Research Agencies
PoS	Promotion of Science Program
PV	Present Value
RAFT	Reversible Addition Fragmentation chain Transfer
RDC	Rural Research and Development Corporation
RI	Research Infrastructure Program
RP	Research Project Program
SIEF	Science and Industry Endowment Fund
SKA	International Square Kilometre Array
SMEs	Small and Medium-sized Enterprises
SRP	Special Research Program
STEM	Science, Technology, Engineering and Mathematics
VC	Venture Capital
WLAN	Wireless Local Area Network

Executive summary

SCIENCE AND INDUSTRY ENDOWMENT FUND

Background

The Science and Industry Endowment Fund (SIEF) has been in existence since 1926. The activity of the Fund increased significantly in 2009 when CSIRO gifted a total of $150 million to the Fund. SIEF's objective is to make strategic investments in scientific research that addresses national priorities and which contributes to Australia's sustainable future.

A recent audit by the Australian National Audit Office (ANAO) evaluated the internal processes and administration of the Fund and found that SIEF's funds were being transparently and efficiently managed. However, the ANAO report recommended that an impact and value evaluation of SIEF's activities should be conducted in the near future. This report implements that recommendation.

Approach

This report has examined the various programs that SIEF supports and has used the information gathered to develop insights into the impact created by SIEF and an estimate of the value delivered by it. The process for doing so was a multi-stage one:

- Eight of SIEF's activities were examined in detail in order to prepare a set of case studies. These case studies have enabled a robust and defensible lower bound for the estimated value of SIEF's investments to be established.
- This lower bound was subsequently tested by considering the nature of the assumptions used and by reviewing any of the dimensions of value from the case studies that were not quantified.
- The results of the performance review were then used to assess the extent to which other SIEF activities might realistically add further to the estimate of overall value delivered by SIEF.
- Finally, the value that is provided by the ability to use the skills, experience, and research infrastructure supported by SIEF funding to quickly respond to unexpected threats or opportunities was considered. While this value is difficult to quantify, it can provide greater confidence that the actual value delivered is likely to be above the lower bound developed through the case studies.

Findings

Five Research Projects (Energy Waste, Early Nutrition, Plant Breeding, RAFT for medical applications, and Distal Footprints) were selected for this report. The eReefs Research Project, which was examined as part of a previous analysis of the impact and value of CSIRO's research, was also considered[1]. Case studies were also developed on a Special Research Program (Synchrotron Science) and a Research Infrastructure Activity (Advanced Resources Characterisation Facility (ARCF)). The full case studies for the Research Projects and the Special Research Project are provided in Appendix 1.

Table ES 1 summarises the results of the benefit-cost analysis conducted for each activity. No results are provided for the ARCF as it is too early in the activity to estimate the value it might deliver[2].

Some benefits from SIEF supported research are clear and quantifiable. For example, there is certainty around the income from royalties and licence fees that have already been received. However, it is important to understand that many of the benefits from the SIEF research projects lie in the future and it is therefore necessary to make a series of assumptions in order to quantify these benefits. Our approach is to be fully transparent about all the assumptions used in this report. We also try to ensure that our assumptions are as conservative as is reasonable.

As a methodology for impact assessment, Cost Benefit Analysis (CBA) relies on the use of available data, assumptions, and judgments related to economic indicators for benefits, attribution, and the counterfactual position. These data, assumptions, and judgments should be carefully considered when interpreting the results of the analysis. While it would be ideal to include both the research costs, as well as any usage and adoption costs borne during the commercialisation of the technology, in this current evaluation this was not possible due to a lack of data and commercial confidentiality issues.

[1] For a detailed analysis of the eReefs Research project, please refer to http://www.csiro.au/en/About/Our-impact/Our-impact-in-action/Latest-impact-case-studies.

[2] The inclusion of the ARCF in this report was deemed appropriate given the importance of the research conducted at ARCF to SIEF: the ARCF was one of the original SIEF Research Infrastructure Programs.

This report presents an estimate of the prospective benefits of all the case studies. The CBA analysis provides a 'ball-park' estimate of the potential realisable net benefits. As the costs and benefits relating to the case studies are incurred and delivered at different points in time, they are expressed in Net Present Value (NPV) terms and are converted to a common metric by discounting (at 7 per cent per annum in real terms)[3]. The discount rate reflects the fact that money available now is worth more than the same amount in the future due to its potential earning capacity. This is illustrated in Figure ES.1, which shows (as an example) the discounted CSIRO costs as well as the discounted and undiscounted benefits in 5-year periods for the SIEF Energy Waste case study.

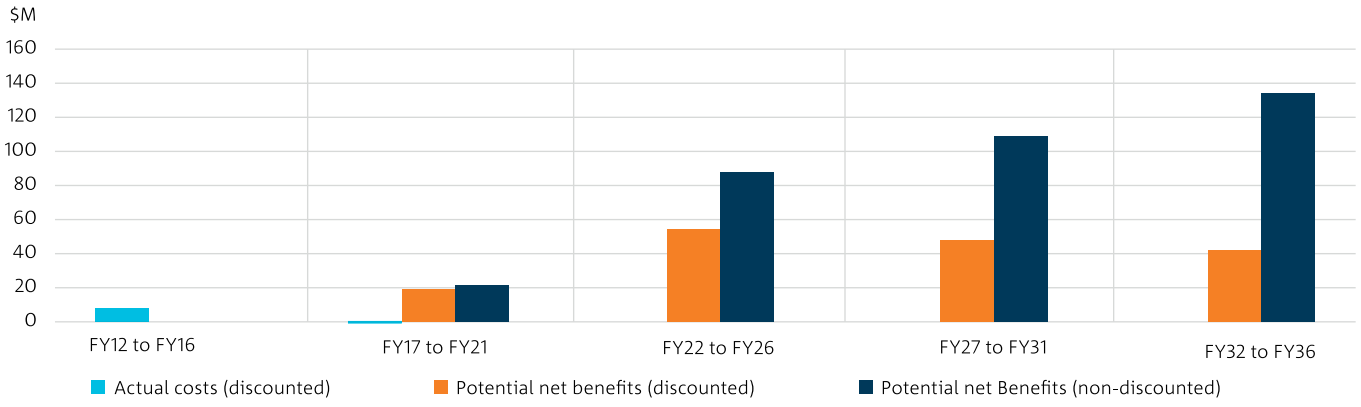
The figure illustrates the estimated benefits of the technology based on what is currently known together with our assumptions about the impact of the technology, uptake rates, potential market shares, attribution of benefits and the counterfactual. All assumptions have been developed in conjunction with the research team. Where possible any commercial partners involved in the projects have also been consulted. There would be merit in updating the CBA analysis as more information on each of the above factors becomes available.

TABLE ES.1 SUMMARY OF BENEFIT-COST ANALYSIS RESULTS

CASE STUDY	PV OF SIEF FUNDING ($m)	PV OF BENEFITS ($m)	NPV ($m)	BCR
Energy waste	$7.3	$151.6	$144.3	20.8
Early nutrition	$6.2	$428.2	$422.0	68.8
Plant breeding	$6.2	$2,825.3	$2,819.1	459.5
RAFT for medical applications	$4.8	$53.2	$48.4	11.1
Distal footprints	$4.3	$23.4	$19.2	5.5
eReefs[a]	$4.3	$11.9	$7.6	2.8
Synchrotron[b]	$11.9	$811.2	$799.3	68.3
Seven case studies	**$44.9**	**$4,304.9**	**$4,259.9**	**94.8**

[a] The data for the eReefs case study is based on the results of earlier work by ACIL Allen which examined the impact and value of CSIRO research. The eReefs project was funded in part by SIEF; and to arrive at the figures above we have allocated 10% of the estimated benefits of eReefs to SIEF.
SOURCE: ACIL ALLEN CONSULTING

[b] This estimate is conservative and based on only 3 of over 200 projects.



(NB: The discounted figures (cost and benefit) reflect the fact that money available now is worth more than the same amount in the future due to its potential earning capacity.)

Figure ES.1 SIEF Energy Waste case study – actual costs and potential net benefit

[3] As future economic benefits can be spread over many years, net benefits are expressed in Net Present Value (NPV) terms—this provides an aggregated value of benefits in excess of costs over time in today's dollars. NPVs allow comparison of the economic benefits from different case studies with different time lines and cost structures. NPVs are calculated by applying an annual discount factor to future benefits (in the CSIRO case it is 7 per cent) to reflect the time value of money.

RESEARCH PROJECTS

The estimated net present value (NPV) of the six Research Projects is $3.5 billion in 2016-17 dollars. These are very substantial benefits. In fact, any one of the first three projects listed in **Table ES 1** are estimated to have returned benefits that would largely or fully offset the full amount spent by SIEF on all of its various programs.

Furthermore, there were a number of potential benefits associated with the selected case studies which were unable to be quantified, either because it was still too early to do so, or because of commercial confidentiality. Hence, there are strong arguments that a number of the case studies could deliver substantially higher benefits than those identified above.

It is possible that some of the estimated benefits may not eventuate or may take longer to eventuate than previously thought. However, with so many paths towards delivering benefits being actively explored, coupled with the fact that only a subset of all the Research Projects supported by SIEF has been examined, ACIL Allen is confident that the eventual benefits of the Research Projects will easily exceed their costs and, most probably, also exceed the total cost of the SIEF program.

SPECIAL RESEARCH PROGRAM

From time to time SIEF funds activities which align with its purpose and strategic objectives, but which fall outside the scope of its other programs. These activities are covered under the Special Research Program. To date two such activities have been funded. One of these, Synchrotron Science, was selected as a case study for this review.

Over the period 2012 to 2016, SIEF's funding of the Synchrotron supported 243 projects. The majority of these projects related to the minerals, health, manufacturing, and energy sectors. The potential benefits of three of the projects were analysed in greater detail and the results are shown in **Table ES 1**. These three projects included the assessment of gold in eucalypt leaves, the discovery of a new pharmaceutical for treating blood disorders, and understanding the nanostructure of casein micelles. The estimated benefit-cost ratio for the Synchrotron Science activity was over 68.

While the other 240 projects conducted under the Synchrotron Science activity have not been examined in sufficient detail to estimate their benefits, it is highly likely that, over time, they too will deliver significant benefits. Given this, we can be relatively confident that the benefits described above are an underestimate of the total benefits likely to flow from the SIEF-funded science activity.

A value has not been assigned to the other Special Research activity supported by SIEF (the Australian Square Kilometre Array Pathfinder (ASKAP)). However, it is clear that it has already delivered a number of benefits in terms of employment opportunities and exports. This strengthens the confidence that this element of the SIEF portfolio of activities will deliver benefits that exceed the cost of the Special Research Program and most probably the total cost of SIEF.

RESEARCH INFRASTRUCTURE PROGRAM

SIEF provided a $12.4 million grant as part of its Research Infrastructure Program to establish an Advanced Resource Characterisation Facility (ARCF). The SIEF funding enabled the purchase and installation of three items of equipment at three sites in Perth. The equipment will be used primarily to conduct research to support minerals exploration and processing.

The SIEF-funded research infrastructure has only relatively recently begun to be used by researchers, and a number of interesting projects are already underway. The researchers using the equipment have identified that there appears to be a high likelihood that these projects will deliver economic, environmental, and social benefits. However, it is too early to be able to confidently quantify any benefits at this stage. Therefore, the extent to which the ARCF is delivering the objectives set for it by SIEF was examined.

The analysis suggests that the ARCF is satisfying all of the evaluation criteria specified for the Research Infrastructure Program. For example, the equipment purchased is leading-edge and significantly increases the research capacity of the National Resource Sciences Precinct in Perth. Further, the institutions collaborating on the ARCF have developed a 'one-stop shop' approach to meeting the resources sector's growing need for increasingly detailed information about mineralisation. This approach is leading the way in the creation of a more open environment for accessing research infrastructure.

While a value has not been assigned to this element of the SIEF Program, ACIL Allen is confident that the benefits that will ultimately result from SIEF's investment in Research Infrastructure will add to the estimated benefits of the SIEF portfolio of activities.

PROMOTION OF SCIENCE PROGRAM

SIEF's Promotion of Science (PoS) Program aims to support the creation of a nationally significant STEM workforce in Australia by helping researchers to develop their research career and the skills and experience that will enhance their career mobility.

Early career researchers (ECRs) were surveyed and interviewed to obtain their views on the PoS program. Based on the information obtained from this process, the PoS Program has successfully provided mentoring and general advice to ECRs; helped them to develop collaborative relationships; and improved their career mobility, and their research and non-research skills. This, in turn, has helped the majority of the ECRs to develop their research track record and further establish their research careers.

EXPERIMENTAL DEVELOPMENT PROGRAM

The Experimental Development Program (EDP) was launched in 2016. The Program is designed to improve the technology readiness level of the outputs of PFRA-funded research, with the aim of encouraging commercialisation and accelerating market uptake. The Program is intended to address a significant gap in the current funding options available to PFRAs for progressing the commercialisation of the technologies they have developed.

As the EDP has only recently been launched, it is too early to assess the performance and benefits of the program. However, it seems likely that the EDP will complement SIEF's other programs and activities.

Has SIEF delivered value?

The answer to this question is a resounding yes!

Based on the information in **Table ES 1** the benefits of the seven case studies alone easily exceed the full cost of SIEF's activities. There is a strong argument that these benefits merely provide a lower bound for the value delivered by SIEF. A number of factors are likely to add to that value, namely:

- The potential benefits from the elements of the selected case studies that were **not** able to be valued.
- The potential benefits of SIEF-supported research activities that were **not** examined in detail.
- The potential benefits of SIEF programs for which it is still too early to judge the impact that they will have.

Based on these factors, it is possible to have reasonable confidence that the value delivered by SIEF could easily be two orders of magnitude greater than the cost of the Portfolio.

SIEF has also shown that it is able to deliver a range of benefits that, while difficult to value, are nonetheless crucial to the ongoing robustness of the Australian Innovation System. These benefits include:

- Developing and fostering the next generation of Australian researchers.
- Encouraging and promoting increased research collaboration both within Australia and with researchers from overseas organisations.
- Increasing engagement between Australian research agencies and industry.
- Developing and maintaining leading-edge research infrastructure

These outcomes are all important prerequisites for ensuring that Australian researchers can continue to deliver high quality research output which enables businesses to innovate and grow, and which allows the nation to address the environmental and social challenges it faces.

1 Introduction

The Science and Industry Endowment Fund (SIEF or the Fund) was founded by statute in 1926 at the same time as the precursor to CSIRO was established. The Fund has been in existence since then; however, its level of activity has increased significantly since 2009 when CSIRO gifted a total of $150 million to the Fund.

The objective of the Fund is to make strategic investments in scientific research that addresses national priorities and which contributes to Australia's sustainable future. Since its revitalisation in 2009, SIEF has provided support for a range of different activities, including:

- Fundamental research into new paradigms for more sustainable use of resources, better protection of the environment, and improved health for the community.
- Tactical research that aims to fast-track solutions to national problems.
- Collaborative research that brings together organisations to work together to develop solutions to national problems.
- Support for high quality research infrastructure that will enable researchers to conduct leading-edge research in areas of national interest and expertise.
- Scholarships that create and sustain the next generation of young researchers capable of addressing national problems.

Many of the activities supported by the CSIRO Gift to SIEF are now completed or nearing completion. It is therefore timely for SIEF to commission this study to review the impact of the activities supported by the Fund and estimate the economic, environmental, and social value it has delivered (or is anticipated to deliver) to the nation as a whole.

The SIEF Advisory Council is also interested in the role that SIEF has played in encouraging innovation and what lessons might be drawn from SIEF's performance to date that could help inform the design and operation of similar funds in the future. This is an issue that is also likely to be of interest to the CSIRO Board and Governments more broadly.

Approach for measuring impact and value

This report summarises and presents key findings on the overall impact and value delivered by SIEF. The success of SIEF-funded research activities, and ultimately their impact in solving issues of national importance, can only be measured in the long term. However, in the interim, this report presents the results of the SIEF-funded research performance evaluation. Six Research Projects, one Research Infrastructure Program, and one Special Research Program were selected as case studies for this review. Appendix 1 provides the full case studies for the Research Projects and the Special Research Program. The full performance evaluation is provided in Appendix 2.

To date, SIEF has invested $153.2 million[4] in support of strategic scientific research since 2009. The Australian community reasonably expects that significant benefits will flow from this substantial investment. However, the diversity and nature of SIEF's investments, along with the manner in which it complements and encourages Australian businesses to innovate, suggests that any evaluation needs to look beyond simple 'return on investment' measures if justice is to be done to the full scale and scope of SIEF's impacts and their associated value.

Classical benefit-cost analysis tends to focus on monetary wealth as a simple indicator of well-being – investments that build monetary wealth, after accounting for investment costs, are viewed favourably. Modern benefit-cost analysis commonly extends the coverage beyond just financial wealth – allowing scope for including less tangible impacts, such as better social and environmental outcomes, provided that it is possible to approach these impacts in terms of how much wealth people might forgo in order to secure these benefits.

[4] This figure includes CSIRO's Gift of $150 million and interest earned.

All major investments have to deal with substantial uncertainty. The emphasis on the discovery of new knowledge, and the cultivation of new capabilities, does differentiate R&D and innovation from other forms of investment where the pathways to value are typically more clearly defined. SIEF's investments, although they have a strong focus on applied research that seeks to address issues of concern to Australians, are no different. This is particularly so given that many of the future applications of SIEF-supported research may not yet be well understood or even known.

Investment in the face of such uncertainty relies heavily on the proposition that better knowledge and skills, backed up by a system that allows that knowledge and skill to be applied, will fuel beneficial innovation that will ultimately translate into gains for industry (and, ideally, for society and the environment). The hope is that the value of the benefits delivered is sufficient to justify the funding provided.

Determining the value of SIEF is a complex matter – the Portfolio delivers multiple elements of value. These elements are delivered across time (both forwards and backwards); and involve the delivery of tangible outcomes in terms of better advice and new or improved technologies. They also deliver less tangible but still valuable outcomes in the form of the ability to better manage the risks to our society and the creation of new knowledge as a valued cultural asset, not just for its direct application.

Value is provided by the flow of delivered research outputs and research based advisory services, as well as by the creation and maintenance of valuable research capabilities (e.g. skilled researchers, important research infrastructure, strong collaborative networks, and valuable databases). In addition, the systems and internal culture that allow these capabilities to be managed add value to Australia's innovation efforts. Finally, there is additional value in the trust that has built up over time between researchers and industry which enables the translation of research outputs into innovative solutions that can be applied in the market place.

Individual SIEF-funded activities support several different elements of value. For example, SIEF support for the ARCF under the Research Infrastructure Program has created world class infrastructure which is attracting the interest of researchers from around the world; supports the training of a new generation of scientists; drives collaboration; and produces a mixture of ground-breaking knowledge and practical science with real world implications for business and society.

The elements of value delivered as a result of the SIEF Portfolio are highly dependent on a range of current and past research activities. In effect, past activities influence the direction of current activities, which, in turn, influence decisions on the direction of future activities. There are clearly synergies between undertaking targeted research to deliver high direct value, and the attraction and maintenance of skills and capabilities that provide option value. This option value enables the nation to draw on them in order to address emerging issues or needs.

The SIEF-funded Energy Waste Research Project provides an example of this. It was the ability to access researchers with skills in continuous flow processing that enabled the development of the Metal-Organic Framework (MOF) pilot plant that is now capable of reliably producing large quantities of many different MOFs that appear likely to have the best prospects for delivering value in the medium term. This has provided a benefit which is distinct from the initial intention of the project, which was to develop technologies to improve the economic viability of carbon capture and storage (CCS).

This example also demonstrates the importance of the systems and cultures that support the application of skills and capabilities in a multidisciplinary way. These are the same systems and cultures that allows SIEF-supported researchers within SIEF collaborators to develop the confidence and trust that can build and maintain their external relationships.

The challenge for the present study lies in communicating a balanced understanding of the value delivered by SIEF across its multiple dimensions. That value is supported by solid empirical evidence through case studies; but needs to go beyond that to capture the full range of value delivered.

The approach we have adopted is a multi-layered one:

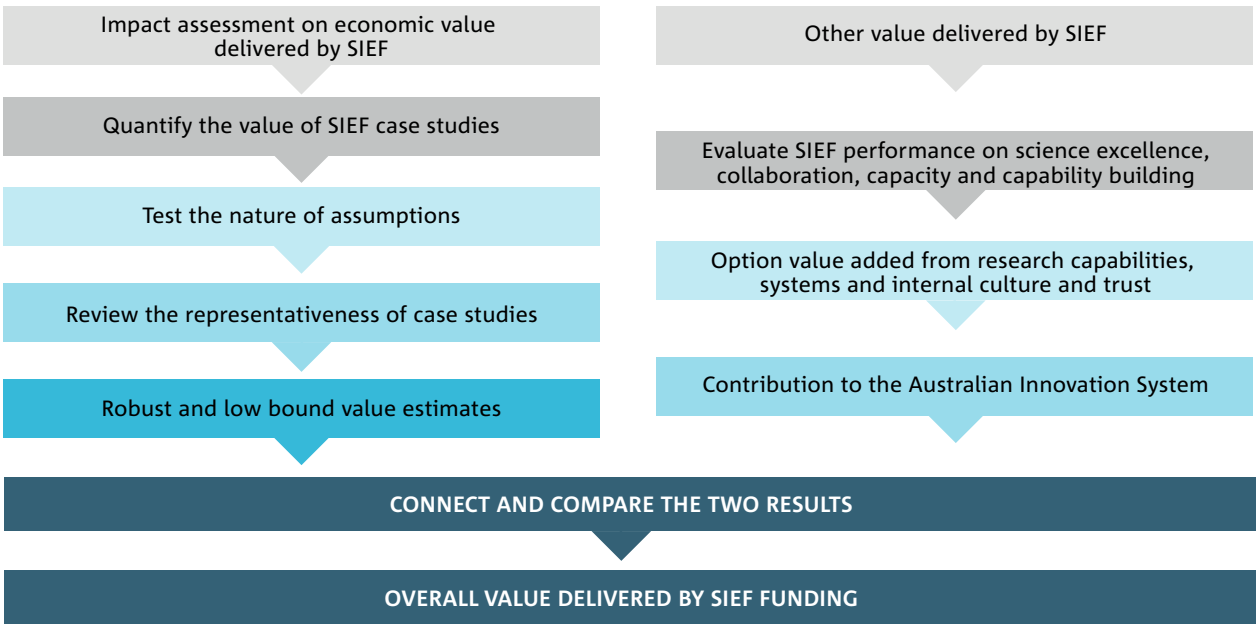
- First, a foundation for the estimate of the value delivered by SIEF is established by assessing the impact, and quantifying the value, of a series of case studies. In doing so, very conservative assumptions have been adopted with the aim of estimating a conservative, yet highly robust and defensible, lower bound for the value delivered by SIEF's investments.
- This lower bound is then tested by considering the nature of the assumptions used and also by reviewing any of the dimensions of value from the case studies that were not quantified. This may justify a lower bound for the value of SIEF that is above the initial estimate.
- The fact that only a relatively small sample of all the SIEF-funded activities was selected to develop the case studies presented is considered. The results of the performance review are used to assess the extent to which other SIEF activities might realistically add further to the estimate of overall value delivered by SIEF. For example, an analysis of the relative performance of the case study activities compared to the remainder of the SIEF activities against the indicators used to assess performance can inform thinking on the likelihood that the other SIEF activities might make a further increase in the lower bound value.
- Finally, the value that is provided by the ability to use the skills, experience, and research infrastructure supported by SIEF funding to quickly respond to new (and sometimes urgent) demands for scientific information in response to unexpected threats (or opportunities) is considered. Further, the value delivered by other elements of SIEF, such as the support provided by the Fund for training and developing the next generation of researchers and encouraging collaboration, is examined. Although this may be difficult to quantify, it can be used to provide greater confidence that the actual value delivered is likely to be above the lower bound estimated based on the case studies.

Report structure

The structure of the remainder of this report is as follows:

- **SECTION 2** provides an introduction to the Fund. It reviews the history of SIEF and explains its current objectives. The section also provides a brief description of the different categories of support that SIEF offers as a means of delivering its objectives.
- **SECTION 3** summarises and presents the conclusions on the overall impact and value delivered by SIEF.
- **SECTION 4** discusses the role that a fund like SIEF can play in enabling and encouraging innovation.
- **SECTION 5** presents the lessons learnt through the review and discusses the way forward, including measures that could aid future evaluations, and the role that funds like SIEF might play in supporting innovation.

Copies of each case study are provided in Appendix 1. The full performance review is also provided in Appendix 2.



2 Background

2.1 History of SIEF

In 1926, the Science and Industry Endowment Fund (the Fund) was established by the Science and Industry Endowment Act (1926) (the Act) at the same time as the predecessor organisation to CSIRO – the CSIR. It was seeded with an appropriation by Parliament of £100,000 from consolidated revenue. SIEF's investment priorities, as reflected in the Act, were to provide assistance to people engaged in scientific research, and for the training of students in scientific research.

In October 2007, the CSIRO Board decided that proceeds from the organisation's fast wireless local area network (WLAN) technology should be applied to the advancement of scientific research in Australia. In June 2009, the Board endorsed a recommendation from CSIRO's management that current proceeds from the fast WLAN project should be gifted to the Fund with the intention of supporting nationally important research.

On 20 October 2009 the then Minister for Innovation, Industry, Science and Research announced the rejuvenation of SIEF through an initial gift of $50 million to SIEF by CSIRO. CSIRO has subsequently made an additional two gifts of $50 million each, bringing the total to $150 million. At that time, the Minister observed that the Fund would support research activities "at Universities as well as at CSIRO" and expressed the hope that CSIRO's Gift would be "augmented by donations from industry and other benefactors".[5]

The injection of monies into SIEF, was made under a Deed of Gift dated 15 October 2009. The Deed outlines the arrangements to be adopted to administer CSIRO's Gift, including setting out the purposes for which the Gift can be used; and mechanisms for providing support and assistance to the Trustee in the exercise of his/her responsibilities.

The 2009 rejuvenation of SIEF provided the opportunity to extend the reach of SIEF and diversify its support for a range of research activities which fall outside the mainstream and address present and future major challenges.

2.2 Objective of the Fund

The objective of the Fund is to make strategic investments in scientific research that addresses issues of national priority for Australia. Specifically, the Fund invests in science that contributes to Australia's sustainable future, including:

- Fundamental research into new paradigms for sustainable resource use, environmental protection, and community health.
- Tactical research to fast-track solutions to national challenges.
- Collaborative research that brings together organisations capable of working together on solutions to national challenges.
- Scholarships that create and sustain young researchers capable of addressing national challenges.

The Deed provides that research funded from the Gift may be carried out "by or within one or more single institutions or within collaborative partnerships". To give effect to this feature of the Deed, two important design elements of the financial assistance provided from the Gift are:

- The promotion of collaborative research and related activities — within one or more single institutions and within collaborative partnerships between research organisations, tertiary institutes and industry.
- The leveraging of co-investment — either from the collaborators or from other parties, including industry.

[5] Senator the Hon Kim Carr, 2009, CSIRO Science and Industry Endowment Fund, Media Release, 20 October 2009, Canberra, ACT.

2.3 Operational roles and responsibilities

The Science and Industry Endowment Act (1926) provides that the Trustee of the Fund is CSIRO's Chief Executive (currently Dr Larry Marshall). As provided for under the Deed of Gift, the Trustee is supported by an independent Advisory Council chaired by Professor Alan Robson, retired Vice Chancellor of the University of Western Australia. The Council advises on research priorities. Also, as provided for under the Deed of Gift, CSIRO assists the Trustee in the administration and operation of the Fund under a Services Agreement.

2.4 SIEF support programs

SIEF's Primary Purpose requires that the grants it provides must:

- Be for activities in the fields of natural or applied science for the extension of knowledge, including the practical application of such knowledge.
- Provide national benefit that assists Australian industry, furthers the interests of the Australian community, or contributes to the achievement of Australian national objectives.

SIEF provides financial assistance through a Portfolio of measures. Table 2.1 provides details of the objectives and the application process for each of these programs.

TABLE 2.1 SIEF PROGRAMS

	OBJECTIVE	APPLICATION PROCESS
Special Research Program (SRP)	To support proposals identified by the Trustee and Advisory Council as aligning with the purpose and strategic objectives of the Fund and to expand research opportunities in the Australian Innovation System.	Application by invitation
Research Infrastructure Program (RI)	To support the creation or enhancement of nationally significant research infrastructure facilities or equipment.	Application by invitation
Research Project Program (RP)	To support projects in the areas of: emerging science issues or priorities; developing solutions to science challenges or opportunities; and support for the delivery of scientific advances.	Open and competitive funding rounds
Promotion of Science Program (PoS)	To support research undertaken by early career scientists, the appointment (or joint appointment) of scientists to university positions, and scholarships and fellowships.	Open and competitive funding rounds
Experimental Development Program(EDP)*	To address a significant gap in current funding options available for progressing technology development to a stage suitable for attracting commercial investment and market uptake.	Applications assessed on merit

*Note: The Experimental Development Program has only just commenced operation. SOURCE: ANAO REPORT 2015 and CSIRO

3 Has SIEF delivered value?

3.1 The estimated financial value delivered by SIEF

ACIL Allen has considered the potential benefits associated with eight activities selected as case studies for this review, including the results of the eReefs project, which was examined by ACIL Allen earlier in 2016. For one of these activities, namely the ARCF, it was clear that it was still too early to be able to confidently quantify what the potential benefits might be. However, **Table 3.1** summarises the results of the benefit-cost analysis conducted for the other case studies.

Each of the case studies is estimated to have a benefit cost ratio that is greater than one. In other words, the potential benefits of the activity outweigh its costs. In the case of three of the case studies, the estimated benefits from any one of them on its own easily exceed the total cost of the SIEF Portfolio.

Despite the conservative estimates of the potential benefits that might be delivered by the case studies, the total estimated benefits comfortably exceed the costs of the SIEF Portfolio by more than two orders of magnitude.

As with any estimate of a potential future benefit from a research activity, there is a non-zero chance that the anticipated benefit will ultimately prove to be unrealisable. However, ACIL Allen would judge the probability that none of the many identified potential benefits from the case studies will be realised as being near zero. Furthermore, for most of the case studies multiple pathways have been identified through which benefits could be delivered. A number of these paths could on their own deliver benefits that exceed the total cost of the SIEF Portfolio.

In addition, ACIL Allen has intentionally sought to use extremely conservative assumptions to arrive at the figures provided in **Table 3.1**. A conscious decision not to value a number of additional potential benefits associated with the case studies has also been made. These additional benefits could deliver significant additional value. Consequently, ACIL Allen regard the estimates of benefits as a relatively conservative lower bound on the potential value that SIEF may deliver.

This view is further supported by the fact that less than half the Research Projects supported by SIEF have been examined in detail for this report. It would be unusual if some proportion of the projects that were **not** examined did not also deliver benefits in the medium to long term.

TABLE 3.1 SUMMARY OF BENEFIT-COST ANALYSIS RESULTS

CASE STUDY	PV OF SIEF FUNDING ($m)	PV OF BENEFITS ($m)	NPV ($m)	BCR
Energy waste	$7.3	$151.6	$144.3	20.8
Early nutrition	$6.2	$428.2	$422.0	68.8
Plant breeding	$6.2	$2,825.3	$2,819.1	459.5
RAFT for medical applications	$4.8	$53.2	$48.4	11.1
Distal footprints	$4.3	$23.4	$19.2	5.5
eReefs[a]	$4.3	$11.9	$7.6	2.8
Synchrotron	$11.9	$811.2	$799.3	68.3
Seven case studies	**$44.9**	**$4,304.9**	**$4,259.9**	**94.8**

[a] The data for the eReefs case study is based on the results of earlier work by ACIL Allen that examined the impact and value of CSIRO research. The eReefs project was funded in part by SIEF and to arrive at the figures above we have allocated 10% of the estimated benefits of eReefs to SIEF.

SOURCE: ACIL ALLEN CONSULTING

The information in **Table 3.2** suggests that the SIEF Research Projects selected as case studies are broadly similar in nature to the 'other Research Projects' in terms of their performance against the indicators listed.

While this clearly provides no guarantees that the 'other Research Projects' will deliver benefits similar to those of the case studies, it does provide some degree of confidence that they might do so. The number of patents generated by the 'other Research Projects' particularly supports this view.

Given the uncertainty around the eventual outputs of the 'other Research Projects', the value that they might deliver has not been quantified. It is sufficient to note that the fact that they are highly likely to provide some (unspecified) level of benefit provides greater confidence that the value delivered by SIEF is likely to outweigh the program's costs.

3.1.1 WHAT IS A 'NORM' FOR BENEFIT-COST RATIO FOR R&D?

Some might argue that the estimated benefit-cost ratio of just under 95 for all the case studies listed in **Table 3.1** is high. **Box 3.1** provides some examples of benefit-cost ratios for various investments in R&D. From the examples listed we see benefit-cost ratios that range from 9 to 85. The range of benefit-cost ratios are broadly comparable to those which have been estimated for the majority of SIEF case studies.

There is of course an outlier among the SIEF case studies, namely the Plant Breeding project. The benefit-cost ratio for this project is just under 460; and this is certainly a very large ratio by most standards. As with all the other case studies, conservative assumptions have been made regarding the potential impact of this project.

TABLE 3.2 COMPARISON BETWEEN CASE STUDIES AND REMAINDER OF RESEARCH PROJECTS

INDICATOR*	CASE STUDY PROJECTS	OTHER RP ACTIVITIES
Number of publications	105	141
Number of patents	15 (this includes 14 patents reported by the RAFT project after the cut-off date for the original reporting period)	21
Proportion of financial contribution to project provided by collaborators	63%	60%
Percentage of RP activities involving more than one organisation	80%	92%
Number of RPs that have received additional funding to further develop the outputs of their SIEF project	4 (out of 5) (this includes the Gates Foundation funding for the Plant Breeding project which was reported after the cut-off date for the original reporting period)	5 (out of 12)

*Notes: 1. These were the only KPIs where performance of the Research Project case studies could be compared to the performance of the remainder of the Research Projects. 2. The information in the table is based on reporting from SIEF-supported Research Projects. SOURCE: CSIRO

BOX 3.1

Examples of benefit-cost ratios for R&D investments

It is instructive to compare the estimated benefit-cost ratio that flows from the analysis of SIEF-supported research to that achieved by other research projects funded by other research organisations. A review of past benefit-cost analyses of various research projects identified a range of different benefit-cost ratios. For example:

- Grape and Wine Research and Development Corporation (2001) (estimated a BCR of 9)
- Productivity Commission Inquiry Report (2007) (estimated a BCR of 40)
- The Australian Centre for International Agricultural Research (ACIAR) (2011) (estimated a BCR of 85)
- CSIRO Salmon Breeding Case Study (2015) (estimated a BCR of 27).

SOURCE: CSIRO

However, the scale of the market is such that even a very small impact can produce very significant benefits.

Note that if the Plant Breeding project is excluded from the calculations, then the estimated benefit-cost ratio drops to just over 37. This lies in the mid-range of the ratios listed in **Box 3.1**. ACIL Allen believes that there are a number of reasons why research supported by a fund such as SIEF might have an estimated benefit-cost ratio of this magnitude. This is discussed further in Section 3.3.

3.2 Other value delivered by SIEF

SIEF has also delivered benefits that are not easily quantified, but which nonetheless appear likely to provide substantial long term value. These additional (non-quantified) elements of value include:

- The benefits that flow from SIEF's investment in three Research Infrastructure activities. This investment has:
  - Mobilised more than four and a half times SIEF's investment from other organisations.
  - Delivered significant and valuable research capability to existing National Sciences Precincts in Perth, Clayton, and Canberra.
  - Supported the creation of common access arrangements that will help to ensure that the infrastructure is effectively managed and utilised by researchers.
  - Already attracted the attention of researchers and businesses both in Australia and overseas.

- The benefits that the Promotion of Science Program has delivered, including:
  - Fostering the skilled, experienced, and highly motivated early career researchers who will become the research and innovation leaders of tomorrow.
  - Encouraging the creation of linkages and collaborations, both among researchers and among researchers and businesses.
  - Helping to provide a career structure for early career researchers that encourages them to develop and grow as members of the research community.

3.3 A final observation

Finally, ACIL Allen notes that many would no doubt regard the potential 'success rate' of SIEF supported research activities to be quite high by comparison with publically funded research more generally. In ACIL Allen's view, there are a number of possible reasons for this. These include:

- The focus that SIEF has on supporting developmental technology or strategic research.
- The emphasis of SIEF on multidisciplinary activities that enable new thinking and approaches to be more easily introduced and applied by the research teams.
- The ability of the research teams to tap into a broad range of skills and expertise to address unanticipated challenges that arise from time to time.
- The fact that many of the research teams considered in this report are able to access world class, and in some cases world leading, research infrastructure.
- The long term track record of the majority of SIEF collaborators involved in delivering research outputs that meet the needs of its business partners. This has enabled SIEF collaborators to build and maintain long term relationships with businesses which are based on a culture of mutual trust and understanding.

The information presented in the SIEF Research Performance Evaluation supports this assertion. For example, SIEF-supported activities are reported as generating not only more publications, but more publications in high impact journals. Furthermore, SIEF publications are more highly cited than the national or global average. For example, 22% of the published articles supported by SIEF appear in the top 5% of journals. This compares with 11% of the National Health and Medical Research Council (NHMRC) supported research being published in the top 5% of journals. SIEF-supported journal articles are over twice as frequently cited as the global average of publication.

4 Has SIEF encouraged innovation?

Innovation is an important driver of productivity and economic growth. However, an innovation ecosystem itself is driven by four specific factors:

- capacity and capability;
- collaboration;
- funding for world class transformational science; and
- innovation and entrepreneurship culture.

To assess if SIEF has encouraged innovation, its contribution in each of the above areas was analysed.

Capacity and capability

Scientific capability and capacity underpin the ability to innovate. They provide the framework within which complex problems can be examined and solved. Building capacity is a long term process which requires a network of underpinning activities, such as the development of research infrastructure, scientific talent, and collaborative partnerships among different players in the innovation system.

Research Infrastructure development activities are challenging because of the cost, scale, and the number of stakeholders involved. SIEF has co-invested in three Research Infrastructure activities in Perth, Clayton, and the ACT. In addition, SIEF has also funded the Australian Square Kilometre Array Pathfinder (ASKAP) in Western Australia, and the Australian Synchrotron in Victoria. Across these five initiatives, SIEF's investment of $56 million has successfully leveraged an additional investment of $270 million from its partners for the development of leading edge, strategic, cross-disciplinary facilities. These are significant facilities for the Australian Innovation System as they address the rapidly emerging needs of the Australian research environment, provide capacity that will underpin our research in the decade ahead, and ensure that research outcomes are translated into tangible impacts for Australia in areas such as manufacturing, mining, and health.

SIEF has also contributed to the development of the next generation of researchers in Australia. Over the period from 2010 to 2016, SIEF has supported the skill and capability development of 302 ECRs. A survey of these ECRs demonstrates strong evidence that SIEF has helped them to address some of the structural barriers they faced in the early stages of their professional careers. SIEF support has assisted them to gain new skills, work experience, and opportunities for collaboration, thereby improving their long term career prospects. For example, 23% of respondents of the survey believe that the support they received through SIEF had an *extremely high* impact on their career progression, while a further 45% said that support from SIEF had a *high* impact on progressing their careers. This, in turn, has also created a pipeline of talented researchers for the Australian Innovation System which has contributed to Australia's aspirations of being a growing knowledge economy and an innovation-led nation.

Collaboration

Studies of innovation have shown that collaboration is critical for improving the effectiveness of translating research outputs into business innovation that delivers economic benefits. In the past 7 years, SIEF has successfully facilitated collaboration among 60 different organisations that have been formally involved in SIEF-supported research. These collaborators represent a mix of Australian universities, governments, industry, and overseas organisations. Almost a quarter of these collaborators have come from industry, with a further quarter from overseas entities. To date, through SIEF's support, these collaborators have created a portfolio of research activities with a total investment of $500 million. This level of collaboration is a significant achievement, as the ability and willingness to collaborate among Australian industry, SMEs, universities and PRFAs has been traditionally low owing to factors such as transaction costs, legal arrangements, and commercial and technical risks. A good example of SIEF's collaborative efforts is the STEM+Business Fellowship program which enables ECRs to work with Australian SMEs for two to three years. This placement helps to break down the cultural divide between researchers and SMEs which can be a barrier to innovation.

The successful completion of these collaborative initiatives has built trust and confidence among a network of Australian investors, researchers, and university faculty, while setting a precedence for other collaboration efforts.

This network will only grow with time; and will assist to promote a culture of collaboration in the Australian Innovation System, thereby improving the odds of future effective collaboration at the national level.

Funding world class transformational science

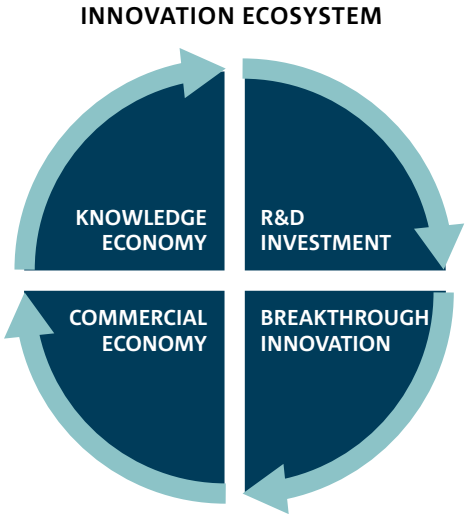
98% of SIEF's investment has been channelled into research which addresses Australia's National Science and Research Priorities. Across diverse areas, SIEF funding has supported world class researchers working on emerging, strategic, and supporting research projects. These projects have produced 37 patents and 417 journal articles on various topics in the 2010-2016 period, almost a quarter of which have appeared in the top 5% of journals. The quality of the outcomes of these Research Projects is also evident from the fact that collaborators in 8 out of the 17 Research Project activities have already obtained further funding, support, or partners with the intention of further progressing or commercialising their research. Further, 6 of the 17 Research Project activities have obtained funding to use the outputs of the project as inputs for new research. These outcomes provide a significant flow-on effect for future research in Australia.

ACIL Allen has estimated that the net present value (NPV) of the impact of six of the Research Projects is in the vicinity of $3.5 billion in 2016-17 dollars. Therefore, there are strong arguments that SIEF's funding has not only significantly progressed Australian research efforts, but that it will also deliver substantial economic benefits for Australia in the future.

Innovation and entrepreneurship

Australia performs strongly on research excellence, but poorly by international standards in translating publicly-funded research into commercial outcomes. This is evident from the Global Innovation Index Innovation Efficiency Ratio, which ranks Australia 81st out of 143 countries. Noting that access to financial support in commercialisation is a significant challenge for Australian innovation-active firms, SIEF has recently started the ED Program that will support technologies to develop to a stage where they are suitable for attracting commercial investment and market uptake. This early stage financing will assist such technologies progress to proof of concept and prototyping stages, which will play an important role in avoiding the 'valley of death' in innovation that lies between research activities and positive cash flow from commercialisation. Through this program, SIEF will catalyse the translation of research into commercial outcomes, boost commercial returns from research, and improve the research productivity of the Australian Innovation System.

Conclusion



Source: Jackson, 2011

An innovation ecosystem is said to be thriving and healthy when the resources invested in the knowledge economy are subsequently replenished by innovation-induced profit increases in the commercial economy[6]. SIEF, through its range of programs, has supported activities across the Innovation Ecosystem. Its investment in research projects, capability, and infrastructure development has been a milestone contribution to the Australian Innovation System. Evidence suggests that the outcomes of these initiatives have contributed strongly to the Australian research field and the national knowledge economy and has also helped attract further research funding. In addition, the breakthrough innovation achieved through some of the SIEF-funded projects is expected to deliver economic, social, and environmental impacts worth billions of dollars to the Australian economy. Overall, these factors strongly indicate that SIEF has encouraged innovation in Australia, and has contributed to the overall health and sustainability of its Innovation Ecosystem.

[6] Jackson, D., 2011. "What is an Innovation Ecosystem?" Arlington, VA: National Science Foundation. http://www.erc-assoc.org/docs/innovation_ecosystem.pdf

5 The way forward – lessons learned

This section discusses some of the lessons learnt over the course of the review.

The role of funds like SIEF

The analysis of the SIEF case studies has established that the value of the benefits delivered by the activities supported by SIEF are highly likely to be significantly greater than the total value of the fund. The Fund has also delivered a range of benefits that, while difficult to monetise, are clearly making an important contribution to the future health of the Australian Innovation System.

The results of the SIEF Impact Review confirm that SIEF is facilitating the delivery of impact and value across the Australian Innovation System. Much of this effect can be attributed to the manner in which SIEF has implemented its strategic objectives by:

- supporting a diverse set of research activities;
- implementing transparent, efficient, and validated processes for managing its innovation investments; and
- prioritising research activities that assemble multidisciplinary, cross-system, and collaborative teams, and actively supporting these teams to achieve their objectives.

SIEF activities are very attractive for researchers, resulting in highly competitive application rounds that lead to only the very best research opportunities being funded. SIEF actively manages investments from start to finish including having independent experts monitor and provide advice on progress toward targets at a relatively low administrative cost due (in part) to its streamlined processes.

SIEF performs well against measures such as numbers of citations, the quality of the journals in which research results are published, the number of patents granted, the level of co-investment by research partners, and the extent of collaboration (see the full performance report in Appendix 2).

SIEF also provides important support that is helping to develop and foster the next generation of Australian researchers, and to build and maintain world class research infrastructure with Australia.

Finally, it is important to note that the ANAO found that SIEF's funds were being transparently and efficiently managed with strong alignment with the Commonwealth Grant Guidelines (July 2007) document. This point, along with the significant value of the benefits delivered through SIEF as detailed in this report, supports an argument for providing SIEF with additional funding to enable it to continue its support for research.

Improving research evaluation

There are a number of ways that the task of evaluating the benefits of programs, such as SIEF, could be facilitated, including:

- collecting data and other information at the beginning of a project, particularly information that can be used to establish a 'baseline' against which changes can be measured. Planning, monitoring and gathering evidence along a project's defined impact pathway is essential. To improve the best practice of attribution, it is also important to collect data to understand what had already been invested in the project before commencing SIEF funding.
- a 'light-handed' and targeted follow up of the outcomes from activities in the medium term. For example, testing whether any of the case studies are continuing to pursue research in the same area and/or whether commercialisation is being pursued and/or been successful, and whether any projected benefits had begun to be realised.

SIEF Impact Review

An evaluation of the impact of SIEF

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