Stimulating the Science and Research Ecosystem Creates Jobs and Investment

The research presented in this paper was commissioned by Victoria's Lead Scientist, Dr Amanda Caples and the Department of Jobs, Precincts and Regions (DJPR) Victoria

VICTORIA State Government | Jobs, Precincts and Regions

ACOLA AUSTRALIAN COUNCIL OF LEARNED ACADEMIES

ACKNOWLEDGEMENTS
Our thanks to the ACOLA reference group, DJPR-Victorian Universities Deputy Vice Chancellors' Forum, Dr Amanda Caples (Victoria's Lead Scientist), Dr Andrew Woolnough (DJPR) and case study participants who put a great deal of time, effort, and insight into reviewing the report and providing excellent advice, comments and resources. Also, thanks to the ACOLA team, in particular Mr Ryan Winn, Dr Lauren Palmer, Dr Michelle Low and Ms Ella Relf who made significant contributions in undertaking analysis, drafting of the report and managing the project.

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ISBN 978-0-6483303-7-0 (print)
ISBN 978-0-6483303-6-3 (digital)

DATE OF PUBLICATION
August 2020

SUGGESTED CITATION
Australian Council of Learned Academies (2020) *Stimulating the Science and Research Ecosystem Creates Jobs and Investment*. acola.org

PUBLISHER
Australian Council of Learned Academies
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ACKNOWLEDGEMENT OF COUNTRY
ACOLA acknowledges the Traditional Owners and custodians of the lands on which our company is located and where we conduct our business. We pay our respects to Elders past, present and emerging.

Foreword

Professor Joy Damousi

ACOLA welcomes the opportunity to collaborate with the Victorian Government and Victorian Universities to better understand the value of the research ecosystem and how it can stimulate economic activity in the short and long term. Research and innovation has and will continue to be key drivers of economic growth and improved quality of life.

2020 will be a year that we will never forget. However, it has shown the capability and capacity of Australia's science, research and innovation sectors to respond quickly and decisively to emerging issues, most recently with the unprecedented 2019-20 bushfires and the COVID-19 pandemic. This has been made possible through past investments in research (both basic and applied), universities, industry partnerships and research infrastructure across all levels of government.

We are currently in uncharted waters for modern society, with no part of our society immune to the impacts of COVID-19. As we emerge from this crisis, there will be economic and societal challenges, many of which will be long-lasting. Recovery will be challenging, and planning for it is critical, bringing together all aspects of the research community. However, there may also be opportunities to build a more sustainable and efficient society that drives and strengthens our knowledge economy.

Domestic and international evidence highlights that sustained investment in the research ecosystem provides researchers, organisations, states and territories and the nation as a whole a competitive edge. This leads to the attraction of competitive grant funding, talent (domestic and international researchers and students) and industry partnerships. There are significant benefits to the wider economy through new products, development of a job-ready workforce, activity in service sectors (accommodation, construction, tourism etc.) and new industries.

ACOLA encourages all governments, not just the Victorian Government, to consider the evidence outlined in our report to understand the value universities and the research sector can provide to safeguarding our future, to tackle both the known and unknown issues Australia will face.

Professor Joy Damousi
ACOLA Board Chair

Foreword

Dr Amanda Caples

Victoria has built a globally competitive innovation ecosystem, catalysed by a substantial program of investment in science and research capability initiated over twenty years ago.

The last significant systematic state government investment in science and research capability in Victoria was in 2010. Since then, the state's economy and the opportunities and challenges it faces regionally, nationally and globally, have all undergone a step change.

Changes to the state's economic growth have been underpinned by long term developments, such as transformation of local manufacturing industries, and service industries, including the growth of the education export sector. These are now all impacted by shocks such as the recent coronavirus pandemic and geopolitical instability, making further step change in the economy inevitable.

Australia faced declining productivity, even prior to the COVID-19 pandemic. Our scientific and technological research and research infrastructure have a crucial, indeed essential role, to play in economic transformation, especially for our education sector, the transformation of existing industries and the development of emerging industries. State, territory and national governments have a key catalytic role to invest in the success of our science and research ecosystem directly and indirectly by optimising the incentives for other sectors to also invest.

Advances in manufacturing and digital technologies provide new approaches to address long-standing challenges in health services and population health, energy security and the environment. In particular, adoption of Industry 4.0 will need continuing investment in new technologies and interdisciplinary and human-centric skills.

Recent events have crystallised the need for Victoria and Australia to be more self-sufficient, better prepared for unexpected events and changes, and able to seize opportunities to improve government service delivery and business resilience. This means that our capacity to innovate and find solutions must grow to match the big challenges of today and the future.

In this context, a key question is how best to stimulate and evolve Victoria's world-class science and research ecosystem to meet the needs of a changing world and secure Victoria's position as a knowledge economy supporting future jobs?

This paper answers that question, by providing broad evidence of the economic value of Victoria's systematic investment in research infrastructure, skills, talent attraction and of the benefits of using contestable funding to stimulate industry-led technology improvements.[i]

Australian research and innovation are at a critical inflection point. Government has an opportunity to build on this evidence base to co-design with industry, universities and the research sector a set of initiatives that respond to the pressing challenges and emerging opportunities to support economic activity in the short and long term.

Dr Amanda Caples
Victoria's Lead Scientist

i The impacts of Victoria's investments in health and medical research is not specifically explored in this report.

Executive summary

Victoria's world-class science, technology and innovation ecosystem has been stimulated by systematic investment in research infrastructure, skills, talent attraction and the use of contestable funding to catalyse industry-led innovation. This has helped secure Victoria's position as a knowledge economy, and as a result, supported jobs and prosperity in the long term.

Impacts of these investments are noticed in several areas:

Victoria's *Science, Technology and Innovation (STI) Initiative* (2000 to 2008) delivered substantial economic impact and jobs

A 2009 evaluation of $470 million *STI Initiative* funded projects found that even with many projects at an early stage, investments increased gross state product by up to an additional $1.7 billion (2008 prices) and created up to an additional 7,600 one-year fulltime equivalent (FTE) jobs. It led to an increase in research-industry collaborations and export contracts; and cumulative real investment of up to an additional $1.2 billion (2008 prices). The Deloitte evaluation found that "while many of the projects are likely to generate benefits in the future which cannot yet be captured, even at this early stage the economically modelled elements of the Initiative have generated an increase in GSP equivalent to between $2.40 and $3.56 for every dollar of Victorian Government funding provided."

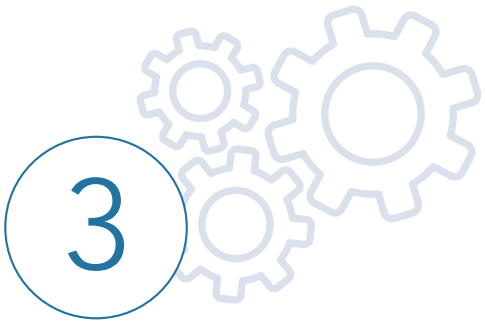
The overall vibrancy of Victorian universities has increased since 2000

Victoria's share of HERD[ii] funding has risen from 22.6% in 2000 to 29% in 2012. Non-government funding for HERD has steadily grown from $82 million in 2000 to $419 million per annum in 2018.

In 2018-2019, Victoria's international education sector generated $12.6 billion in export revenue[iii] for the state; supported almost 79,000 FTE Victorian jobs; contributed expertise to Victoria's research outputs, assisted with international research partnerships, and facilitated an alumni network supporting global research, trade and business collaborations.

ii Higher education expenditure on R&D

iii Captures fee revenue (around 40% of total) and goods and services spend (around 60% of total)



Investments have created lasting capability supporting future industries and enabled an environment that has rapidly responded to the coronavirus crisis

Investments in science and research infrastructure and people have led to the establishment of new industries and capability:

- in light-weight manufacturing through a dedicated pilot-scale manufacturing facility (Carbon Nexus) producing aerospace-grade carbon fibre, which has catalysed an employment precinct that supports around 1,400 jobs in the Geelong region.
- in renewable energy by combining next-generation organic solar cell chemistry with polymer technology to attain a leadership position in printable technologies (VICOSC). CSIRO's Flexible Electronics Laboratory in Clayton is recognised world-wide for its ability to translate laboratory research to large scale, industry-relevant outcomes.
- in characterisation capabilities supporting advanced manufacturing and medical research. The Australian Synchrotron has enabled more than 100 international patents and has supported industry to improve manufacturing processes and undertake clinical trials for new medicines. The Melbourne Centre for Nanofabrication (MCN) has assisted in the attraction of over $300 million in research investment and has supported industry to develop a range of commercial products.
- for an advanced biomedical imaging network (VBIC), which has attracted $235 million in competitive grants including US$106 million from the National Institutes of Health.
- a fellowship program to support globally competitive researchers and attract them to relocate their research to Victoria (veski). The 27 veski innovation fellows have delivered an 18.4 to 1 economic return on investment through attraction of research funds from national and international sources.

Victorian public research institutions have all contributed to the national COVID-19 response, improving the understanding of the immunology and epidemiology of the virus, developing vaccines and treatments and leading research into the social impact of the pandemic.

As we rebuild the economy, this report provides the evidence base to support further investment in science and research infrastructure, skills, talent attraction and the use of contestable funding to catalyse industry-led innovation as part of stimulus measures for future jobs and economic prosperity.

Introduction

Knowledge-based economies enable society to be flexible to new needs.[1] This includes agility amidst global competitiveness and challenges, especially as other countries adopt ideas and technologies that increase their productivity and quality of their services and products.[2,3] Australia's capacity and success in innovation is reflected in the Global Innovation Index – remaining in the top 25 out of 130 countries over the past decade.[4] Notably, Australia ranks in the top 15 for research and development (R&D), with an improvement in score of 4% since 2011.[5] Knowledge economies require persistence, but as this report demonstrates, the benefits from research arise in both the short and long term and extend to industries beyond science and technology to strengthen the broader Australian economy.[6]

In the coming months, decisions made by leaders and policymakers will determine the direction of Australian innovation for many years to come. This report outlines how Victoria's science and research landscape has and can continue to support economic activity, and why it should be considered a critical component of future funding commitments.

Victoria's sustained investment in science and research

The impacts of investment in science and research capability usually take seven to ten years to materialise fully and continue to build over subsequent years. This timeline has been demonstrated in both Australian and overseas contexts.[7–10]

Initial investments are often enhanced by other activities in the system. Significant co-investors in science and research, in addition to the Victorian Government, include universities, the Commonwealth Government, government research agencies, research institutes, philanthropy and industry.[11,12] This range of actors can make it difficult to precisely quantify the investment impact and make it challenging to attribute causality from specific components of funding.[7,8,13]

For these reasons, it is important to understand Victoria's strong recent history of investment in science and technology which foreshadow and underpin our advanced science and research ecosystem today.[14] Starting in 2000, the $620 million *Science, Technology and Innovation (STI) Initiative* was the centrepiece of the Victorian Government's innovation strategy (Figure 1). It aimed to support Victoria's ideas and skills through investment in science, technology and innovation projects across the state, and represented one of the largest investment programs in science and research capability by an Australian state government.[15]

Delivered through two investment rounds, the program focused on developing major research infrastructure, building capability in priority sectors, and fostering the skills and environment for commercialisation. The *STI Initiative* was successful in leveraging significant Commonwealth and industry investments into the state.

From 2008-2010, the state government launched the *Innovation: Victoria's Future* funding program, which carried forward the policy intent of the *STI Initiative* but focused on industry-led collaborations.[15] This funding aligned outcomes with state government priorities and challenges of an ageing population, climate change and international competition (to make Victoria more healthy, more sustainable

and more productive); allocating funds towards environment and climate change, health and wellness, and business innovation. To support these areas directly, the program included investment in R&D infrastructure, skills formation and commercialisation of new technology, as well as the means for facilities, organisations, and networks to generate and commercialise knowledge.

During this period, and reflecting Victoria's long history of excellence in medical research, the Victorian Government also provided $230 million through *Healthy Futures* for capital initiatives to facilitate consolidation of research capability.[16,iv]

This figure leveraged $1 billion of investment from the Commonwealth Government and philanthropy.[17]

Since then, the Victorian Government has continued to invest in a broad range of other science and research facilities, from AgriBio at La Trobe University through to the Victorian Comprehensive Cancer Centre and the Peter Doherty Institute for Infection and Immunity in the Parkville Precinct.[16,18–21]

The scale of these investments and the impact they are having in supporting economic and social outcomes deserve separate consideration by ACOLA or other stakeholders.

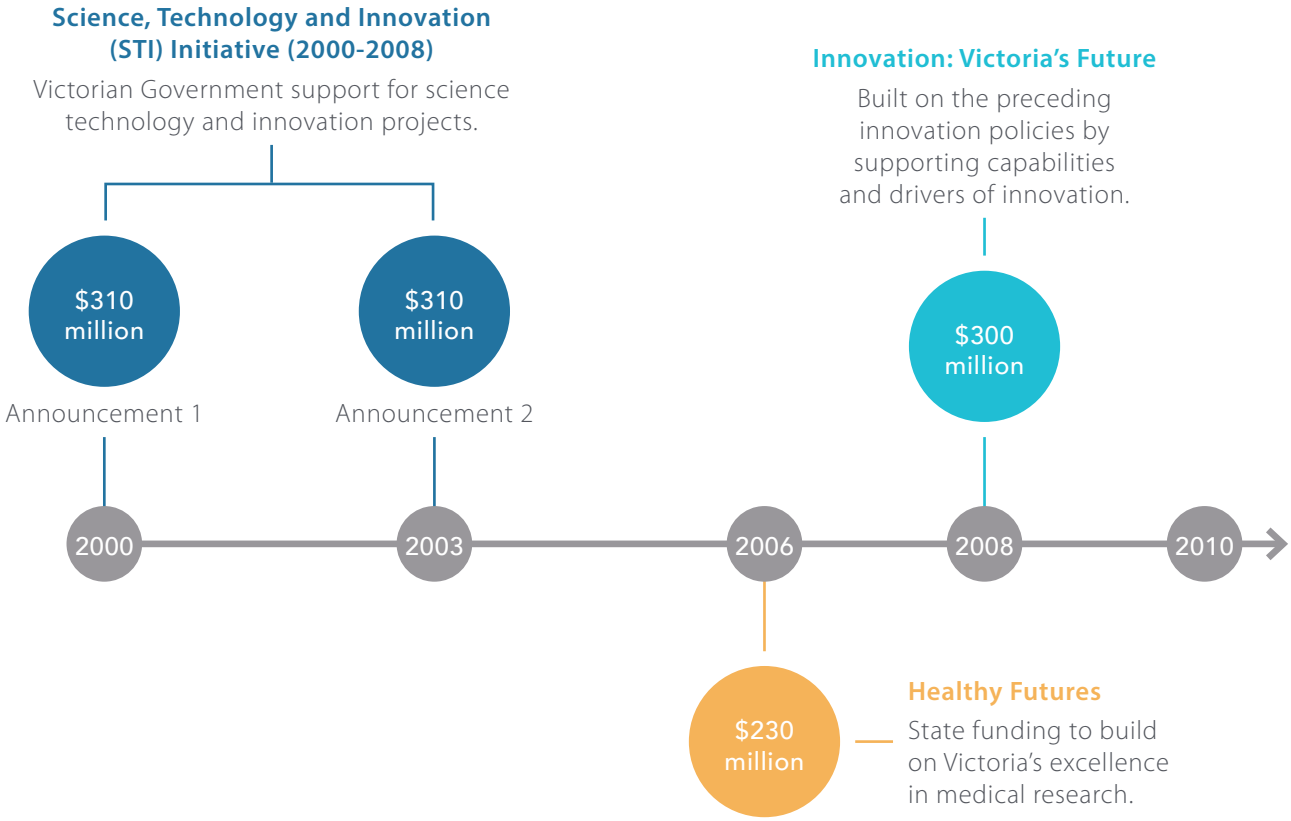


Figure 1. Timeline for Victorian Government investment in science and research

iv Projects include the expansion of the Walter and Eliza Hall Institute; the merger of neuroscience research institutes to create the Florey Institute of Neuroscience and Mental Health and the Melbourne Brain Centre; the merger of the Austin Research Institute with the Burnet Institute and the establishment of the Alfred Centre; and the creation of the Australian Regenerative Medicine Institute at Monash University and Victorian Cancer Agency.

Economic evaluation finds that Victoria's *STI Initiative* has delivered substantial economic impact and jobs

The *STI Initiative* is a useful program to examine the benefits of research investment in the Victorian context. A key aspect of the *STI Initiative*'s design was that all funded projects were required to report against five core outcome areas as indicators of performance: collaboration, science awareness, skills base, commercial and scientific research.[22,23] This reporting requirement enabled an independent evaluation of the initiative in 2009, involving economic impact modelling by reviewing the 135 projects funded by the initiative.[23]

Noting that some projects had only recently commenced at the time of the review, key findings from the economic impact modelling for the Victorian economy were presented based on what was observed at the early stage in the benefits realisation lifecycle. The key findings included: [23,v,vi]

- From $470 million funded projects included in the economic modelling, STI was estimated to increase gross state product by an additional $1.1-$1.7 billion and create between 6,200 and 7,600 additional one-year fulltime equivalent (FTE) jobs over the period 2000-2014.
- Cumulative real investment of an estimated additional $1,045 million to $1,232 million over the period 2000-2014.
- Increase in exports: an additional 1,750 export contracts valued at $173 million.
- Increase in research-industry collaborations: an additional 1,915 researchers in industry and an additional 2,414 researchers working for industry.
- Creation of new intellectual property: 115 US patents and 260 Patent Cooperation Treaty patents, 97 exclusive and 604 non-exclusive (or multiple) licensing agreements.
- Generation of productivity gains for government and industry, including skills development.

The independent evaluation also noted that many projects provided significant social, health and environmental benefits to the state. These impacts are likely to continue into the future and address the overarching goal to increase the living standards for all Victorians.[11,24,25]

Victoria's research ecosystem provides the economy with a flow of talent, knowledge, tools and global relationships

Universities are a key part of Australia's public science and research capability ecosystem. They provide businesses – and other employing organisations – with a flow of talent, knowledge, tools and global relationships that support the overall economy.

Universities were the main beneficiary of Victoria's stimulus spending from 2000 to 2010 and, along with the Australian Government, were also significant co-investors.[11]

v In 2008 prices.

vi Using an Outcome Monitoring Tool Survey on *STI Initiative* investments, forecast modelling for 2014 was based on a conservative social rate of return for two scenarios 25% and 37.5%. Full details on the methodology used are available in the 2009 Deloitte Report.[23,67–71]

The research ecosystem (Figure 2) is important because our research institutions provide broad functions to employing organisations, including:

People

including leaders in business, government, social enterprise, education, science and research leaders who attract collaborators and students to their work, as well as people in the services sector who play an important role in supporting facilities and providing services in the surrounding areas.

Knowledge

flowing from research activities and through the university education system to equip students and business with new ideas, critical thinking and skills.

Tools

ranging from access to major national research facilities, specialist equipment and technical services.

Technology

such as computational and digital support for data analysis and improved advanced manufacturing processes.

Relationships

formed between research institutions, business, industry and community stakeholders, students, teachers and alumni, building reputations and sustained learning.

Employing organisations access these functions from universities to drive science, research and innovation and thus economic and social value to the economy.

Figure 2. Universities enable key components of an effective science and research ecosystem which support employing organisations and lead to positive economic impacts

The overall vibrancy of Victoria's science and research ecosystem has improved since 2000, creating jobs, attracting students and sustained benefit

University performance is assessed in a variety of ways, which can provide an understanding of their impact in the science and research ecosystem. Global rankings and Higher Education R&D (HERD) funding have long been considered two traditional measures of success, and in recent years, international education enrolments has risen in importance. Understanding university performance in relation to these three indicators provides insight into the impact of funding and the success of investment in Victoria's science and research ecosystem.

Rise in university rankings

Australian universities are strongly represented in global rankings, both in terms of academic and societal impacts.[26,27] While different ranking systems weight different performance metrics – such as quality of research, teaching and employability – the status and prestige of a university on the international stage significantly impacts their enrolments, funding, research collaborations and contribution to the economy.[28]

Rankings can play an important role in attracting staff and students.[29] In 2018, over 90% of international students in Australian universities considered the reputation of the education provider and its research quality when choosing where to study.[30]

Victoria's universities are successful across a wide range of disciplines, with around 70% of fields of research assessed as "well above world standard" in the 2018 Excellence in Research Australia ratings (managed by the Australian Research Council).[31]

In 2019, over half of Australian universities (23 out of 33, including 6 in Victoria), were ranked in the Academic Ranking of World Universities (ARWU) top 500, and Australia's world class university system was in the top 5% of the world in 2017-18.[32,33]

The 2020 Times Higher Education (THE) World University Rankings placed eight Victorian universities in the top 400, and two universities (University of Melbourne and Monash University) in the top 75 (Figure 3).[34]

Victoria hosts two of the top 75 universities in the world

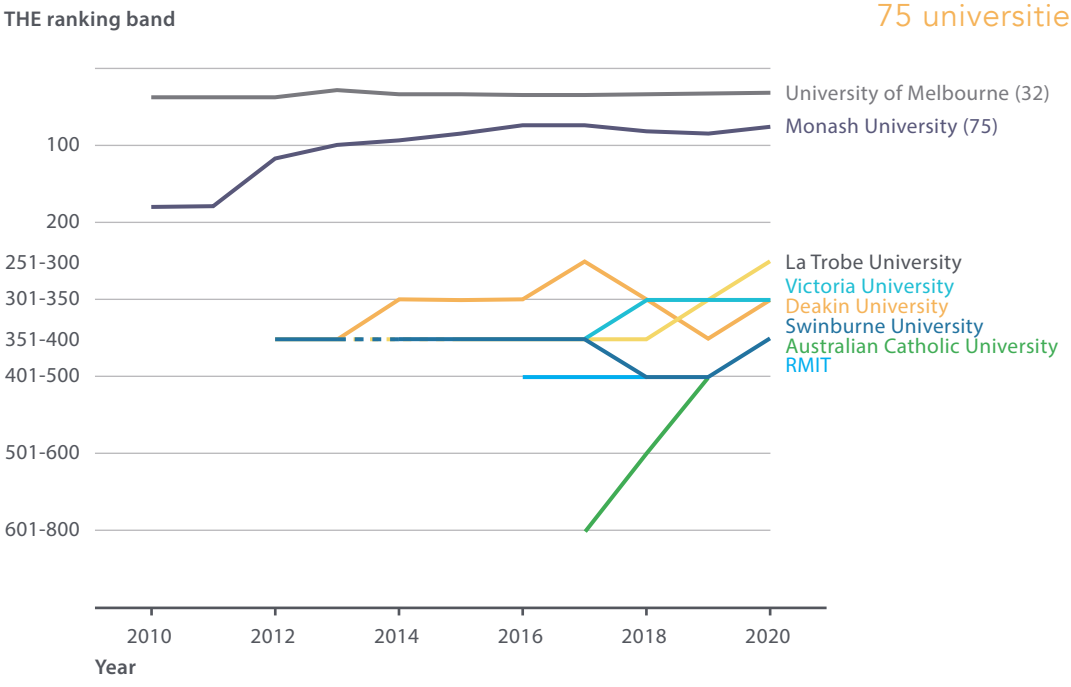


Figure 3. THE World University Rankings of Victorian Universities

Dashed line represents no data

Increase in Victoria's R&D competitiveness

Victoria's science and research ecosystem has increasingly become attractive and competitive, domestically and internationally. HERD funding is seen as a national measure of R&D efforts in universities. In 2000, Victoria's share of HERD funding was 22.6%, well below the national average of 25% on a per capita basis. By 2005, Victoria's share of HERD funding had increased to 26%. It continued to rise to 29% in 2012 where it has now plateaued (Figure 4).[35] This represents a rise from $600 million per annum in 2000 to over $3 billion in 2018.[vii]

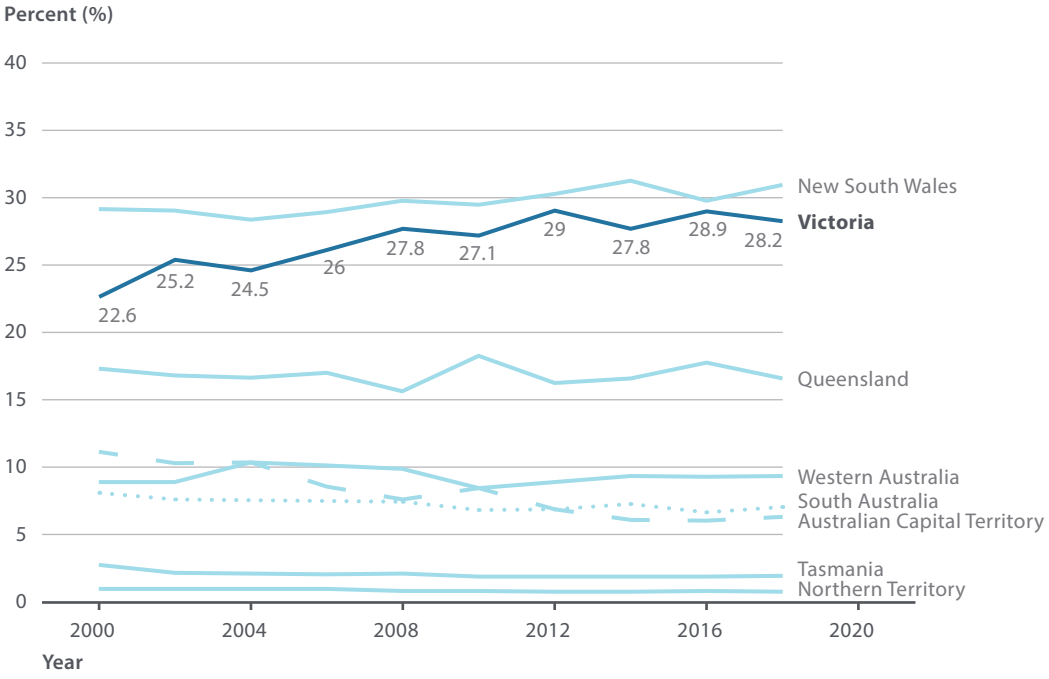


Figure 4. Percentage value of HERD funding according to states

Source: abs.gov.au

vii Dollar amounts unadjusted for inflation.

Stimulating the Victorian science and research ecosystem improves revenue impact.[21] The growth in market share of HERD funding occurred during the period of Victorian Government stimulus for the science and research ecosystem. Victoria's HERD share, most of which comes through attracting a greater share of competitive grant funding from the Commonwealth Government, has grown five-fold in value because of Victoria's research strengths. These strengths were supported by increased investments in initiatives (like the stimulus), research infrastructure and non-government sources such as industry and philanthropy – some of which relate to or enhance Victorian Government investments.[12,36]

In terms of non-government funding, over the past 20 years Victoria's strong science and research ecosystem has steadily grown and provided a base to attract further revenue from industry contracts and philanthropy, from $82 million in 2000 to $419 million in 2018 (Figure 5).[viii,37]

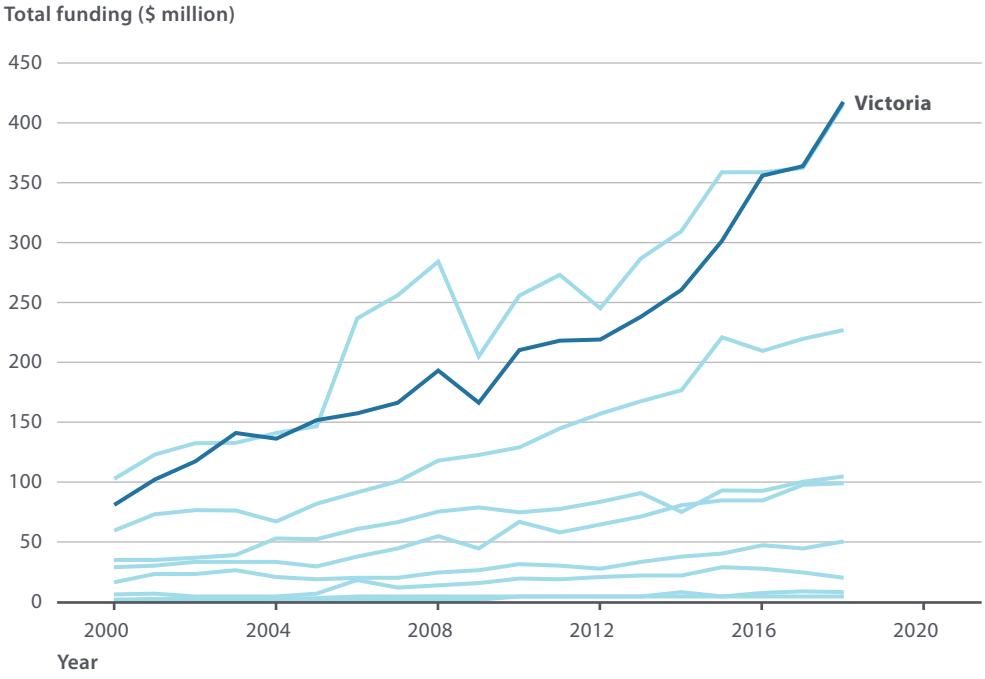


Figure 5. Dollar amount of non-government (Category 3) funding according to states
Source: education.gov.au

viii Dollar amounts unadjusted for inflation.

Growth in international students

Victoria is the second largest international student destination in Australia, after New South Wales, accounting for around one third of the market and performing at a growth rate of 8% since 2002 (Figure 6).[38]

In 2018-2019, Victoria's international education sector generated $12.6 billion in export revenue[ix] for the state, and supported almost 79,000 FTE Victorian jobs.[39,40]

International students provide spill-over benefits to the local economy and community, including through contributing international expertise to Victoria's research outputs, assisting with the establishment of international research partnerships, and facilitating an alumni network that enables strong and meaningful connections between Victoria and the world, subsequently supporting global research, trade and business collaborations.[8,41–44]

International students also make a significant contribution to the local economy through tourism, hospitality and retail.[42,45,46]

Many factors have contributed to Victoria's success in growing the international educational market. Significant Victorian Government investment in international education commenced in 2011 and includes the Victoria International Research Scholarships, the Victoria India Doctoral Scholarships and the Study Melbourne Student Centre.[47–49] These investments focused on delivering and promoting a world-class student experience, in parallel with the State's high-quality education offering. Since 2011, international student numbers have increased by 66%.[50] Melbourne is ranked as the world's third best student city, based on a diverse range of indicators, including university rankings that have increased over the years due to past investments in science and research.[51,52]

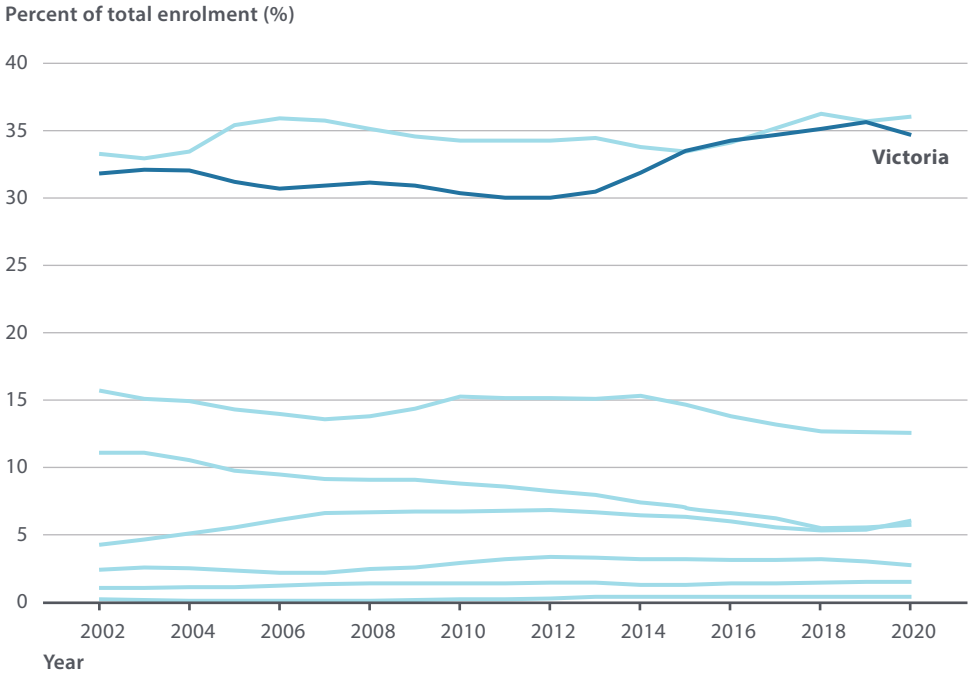


Figure 6. Percentage of onshore higher education international students in Australia

Source: internationaleducation.gov.au

ix Note this figure is for all sectors (higher education, vocational education, English language and foundation courses) and all educational domains. It captures fee revenue (around 40% of total) and goods and services spend (around 60% of total).[72]

Investments have created lasting capability

Governments have a role in supporting a modern and world-class science and research ecosystem to drive advances in technology and knowledge that boost productivity, create jobs, and deliver economic growth. Governments have the capacity to invest over the long-term time frame needed for research and to establish research infrastructure.[53]

Science and research infrastructure provides a technology and skills platform to initiate and grow collaborations and partnerships with industry and support the risk taking behaviour that drives innovation and technological breakthroughs.

Over the last two decades, Victoria has focused on building a vibrant and productive science and research ecosystem by investing in research infrastructure (including skills), talent attraction and industry-led strategic capabilities.

Major initiatives include facilities that provide access to shared high-technology equipment, such as the Australian Synchrotron and the Melbourne Centre for Nanofabrication (MCN) and attract global talent through veski.[54]

Industry-led collaborative projects with universities were also key drivers of investment decisions. In 2010, three consortia were successful in competing for funding through the $25 million Victoria's Science Agenda Strategic Project Fund (under *Innovation: Victoria's Future*):

- *Carbon Nexus* – to stimulate a light-weight manufacturing industry cluster in Geelong (and throughout Victoria). This has opened a new market in light-weight materials, export materials and contributed to the growth of a precinct.
- *Victorian Organic Solar Cell Consortium (VICOSC)* – to advance the development of next-generation printed solar technology and attain a leadership position in renewable energy technologies. VICOSC capabilities have enabled further partnership with industry partners and establishment of centres of excellence.
- *Victorian Biomedical Imaging Capability (VBIC)* – to make Victoria a leader in biomedical imaging, a research translational capability supporting health and medical research.

Profiles of these three consortia together with profiles of the Australian Synchrotron, MCN and veski (respectively representing major research infrastructure, shared technology equipment and talent) are presented in detail as case studies in Appendix A.

Victoria's Science Agenda Strategic Projects were selected through a contestable process. Investments were supported by a formal business plan, had substantial co-investment from universities, the Australian Government and industry and aligned with a government policy outcome (health, environment, productivity).

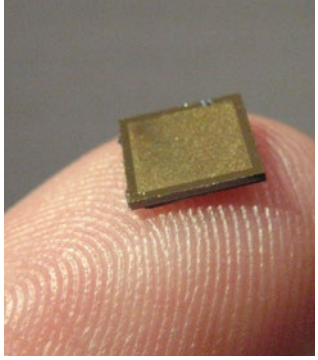
Although these investments differ in type, their key economic outcomes were felt across many levels benefitting many stakeholders. The establishment of these facilities, consortia and associated infrastructure have employed skilled workers[x], attracted and retained world-leading research expertise, created jobs, generated innovative ideas, identified business solutions, enabled new discoveries, led to the commercialisation of products, supported industry and SMEs, attracted subsequent R&D investment, facilitated collaborations and contributed to positive health, environmental and social outcomes.

Improvements to realise the full potential of future investments include:

- a greater focus on translational outcomes embedded into the business case
- new approaches to increase access to existing and future infrastructure including vouchers and supporting collaborations
- engagement with critical thinking and creative skills from the humanities and social science sector.

x A large component of Australia's R&D workforce are domestic and international university PhD students and postdoctoral fellows.[73] Also, TAFEs provide appropriate workforce skills to support current and emerging industry priorities.[74]



Case study highlights

Investments in science and research infrastructure and people have led to the establishment of new industries and capability:

- in **light-weight manufacturing** through a dedicated pilot-scale manufacturing facility (Carbon Nexus) producing aerospace-grade carbon fibre. Carbon Nexus has acted as a catalyst for other companies to consider manufacturing investment in the Geelong region resulting in an employment precinct that supports around 1,400 jobs
  - the facility has led significant domestic and international industry partnerships, including with Boeing, LeMond and Vestas
  - additionally, Carbon Nexus directly supports 60 FTE jobs and has supported 16 PhD students
- in **characterisation capabilities** supporting advanced manufacturing and medical research. The Australian Synchrotron has enabled more than 100 international patents and has supported industry to improve manufacturing processes and undertake more than 250 clinical trials for new medicines. MCN has assisted in the attraction of well over $300 million (over a horizon of 5-7 years) in science and technology investment
  - together, the Australian Synchrotron and MCN support over 190 FTE jobs, who support more than 5,400 domestic and international academic and industry users per year, including the Walter and Eliza Hall Institute of Medical Research (WEHI) and NASA
  - MCN has played a vital role in a range of significant commercial successes, including supporting the work of MuPharma, Trajan and Calumino
- in **renewable energy** by combining next-generation organic solar cell chemistry with polymer technology to attain a leadership position in printable technologies (VICOSC). CSIRO's Flexible Electronics Laboratory in Clayton is recognised world-wide for its ability to translate laboratory research to large scale, industry-relevant outcomes
- in an **advanced biomedical imaging network** (VBIC) who support 500 users. It has secured $235 million in competitive grants, including US$106 million from the National Institutes of Health (NIH) – the largest biomedical research agency in the world, based in the USA, into Victoria
- through a **fellowship program** to support globally competitive researchers and attract them to relocate their research to Victoria, supporting 37 Fellows across its three streams (veski). Notably, the 27 veski innovation fellows have delivered 18.4 to 1 economic return on investment (ROI) through attraction of research funds from national and international sources
  - the six inspiring women fellows have delivered 14.5 times ROI, which includes securing $13.1 million in research income. The fellowship has provided up to 4,800 hours of child care support to enable these inspirational women to engage in their research.

Adaptability in a time of crisis

During the COVID-19 pandemic, the Australian research sector has provided critical support to numerous facets of the response effort.[55–57] This has drawn on multidisciplinary capabilities to understand and address technical, social, cultural and economic issues. Drawing on all research domains will continue to be important moving forward.

In Victoria, universities, research institutions and research infrastructure have contributed substantially to the search for the best prevention and treatment, gathering knowledge, sharing data and supporting an effective response.[58] Past investments in science and research has created opportunities and enhanced underpinning research capabilities, infrastructure and partnerships within and between universities, research institutes and industry.[59] This has supported an environment that has enabled the science and research ecosystem to pivot and respond to large-scale crises, including COVID-19 as well as the 2019-20 bushfires.[60]

At the same time, universities in particular have been hit hard by the reduction in revenue from international students. The resulting budget pressures are putting at-risk the vibrancy of Victoria's science and research ecosystem which puts at risk the economic and social benefits of the sector and capacity to respond to crisis. Specific examples of the COVID-19 research-led response effort by Victorian universities are presented in Appendix B.

Pillars of Public Research Response to COVID-19 in Victoria

Increase medical knowledge and response capacity

- Mobilise research efforts, and utilise pre-existing research infrastructure, towards understanding the spread, control, management and treatment of COVID-19, including producing vaccine candidates.
- Foster global and national collaboration to share knowledge, databases and methods.
- Provide protective gear and medical equipment to those on the front line.
- Collate expertise, health workers, volunteers and education tools to bolster the skills and labour-force of the response.

Understand socio-economic impacts and plan for recovery

- Explore impacts on vulnerable populations and care industries.
- Trace public responses of fear, anxiety, racism and discrimination.
- Research the impact of isolation and shut-down on emotional wellbeing, intimacy, exercise and mental health.
- Research economic impact and recovery pathways for industries, such as tourism.
- Forecast developments and recovery efforts using modelling techniques.

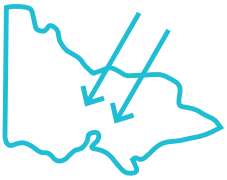
Launch projects and external collaborations

- Work with government, industry, and hospitals to provide up-to-date research, modelling and advice.
- Support businesses overcome challenges and adapt to new markets.
- Strengthen the capacity for collaboration with industry stakeholders and global partners.
- Learn from international research, impacts, responses and recovery measures to reapply.

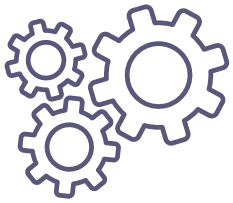
Building on success

Stimulation of Victoria's science and research ecosystem in the period 2000-2010 has contributed to the Victorian economy through:

the direct and indirect
creation of jobs



attraction of further
investments



support of local SMEs and startups
through technology and knowledge transfer

and creation of
new linkages
with the services sectors that support them.

This investment has produced and strengthened a world-class science and research ecosystem from advanced manufacturing to health and medical research.

Victoria's science and research ecosystem has, and will continue to have, a vital role in Australia's economic, social and cultural response and recovery from the COVID-19 pandemic.

While this report has explored the research ecosystem, there has been an emphasis on science and technology fields because this has been the focus of Victoria's past strategic investments. Specific engagement and investment in critical thinking and creative skills from the humanities and social science sector will be important into the future, including but not limited to supporting the multidisciplinary approaches to the design and adoption of new technologies. For example design students and researchers played an important role in the work of VICOSC in exploring the potential real world applications of flexible solar cells in clothing accessories (e.g. bags), electronic devices (e.g. mobile phones) and buildings (e.g. shade sails and blinds).[61]

As we rebuild the economy, this report provides the evidence base to support further investment in science and research infrastructure, skills, talent attraction and the use of contestable funding to catalyse industry-led innovation aligned with government priorities as part of stimulus measures for future jobs and economic prosperity.

APPENDIX

A

CASE STUDY 1

Australian Synchrotron

Identified problem / gap

Australia lacks a world-class, high-brilliance light source capable of meeting domestic research needs, requiring Australian scientists to use in-demand overseas synchrotron facilities at high cost.

Overview of the investment

The Australian Synchrotron is one of the nation's most significant pieces of scientific infrastructure. Using the largest particle accelerator in the Southern Hemisphere, the Synchrotron produces powerful beams of light allowing individual experimental beamlines to examine materials with applications in health and medical, food, environment, biotechnology, nanotechnology, energy, mining, agriculture, advanced materials and cultural heritage. Synchrotron facilities enable researchers to gather information faster and in a more accurate and detailed manner than conventional techniques – for instance allowing thousands of images to be collected in the time it would take for one using a laboratory source undertaking non-destructive testing.

Initial funding came from the Victorian Government ($157 million[62]) with more than $100 million capital additionally contributed in the first ten years of operation by Australian organisations and the Commonwealth Government as well as funding from New Zealand Government agencies, crown research institutes and universities.

In 2016, ownership of the facility was transferred to ANSTO, accompanied by Commonwealth funding of $520 million, providing ten years of operational funding. The facility continues to attract significant ongoing investment from a range of domestic and international organisations, including $94 million in capital for additional beamlines.

Like all similar facilities around the world, the Synchrotron is predominately publicly funded. ANSTO employs 170 FTE staff at the Synchrotron, over 90% in science and technical roles.

Success – Benefits and impact

Since opening in 2007, the Synchrotron has enabled more than: 7,200 peer-reviewed publications, 1,300 student theses, 100 international patents and 250 clinical trials for new medicines. Annually, use is made by all research active universities in Australia, research agencies, such as DST and CSIRO, government departments, and companies in the manufacturing, mining, health and energy sectors. This has resulted in over 5,000 researcher visits, carrying out up to 1,000 experiments

The Synchrotron enables significant industry outcomes improving: R&D – by providing data that helps get new pharmaceuticals to market; sales – by validation of electronics technology; and company publicity – with ASX announcements of improved technology in manufacturing.

The Synchrotron is a globally competitive national research facility. In 2019 alone the Synchrotron produced over 600 peer-reviewed publications; at 60 per beamline this is more than double the global average.

The Synchrotron continues to deliver real-life benefits, strengthening the application of research that underpins new products and processes. Notable examples include:

- development of an award-winning x-ray imaging detector with CSIRO, which has been used in National Gallery of Victoria restoration projects
- development of new medicines, including WEHI work on Venetoclax, that is used for the treatment of a range of blood cancers including chronic lymphocytic leukemia, and which has been approved for use in more than 50 countries including in the European Union, the United States, and Australia, and
- recent support of COVID-19 research activities with pharmaceutical companies and Australian researchers.

CASE STUDY 2

ANFF-VIC Node Central Facility – Melbourne Centre for Nanofabrication

Identified problem / gap

SMEs and individual research teams lack the financial capacity (initial capital investment) or capability (necessary skills) to set up, outfit and maintain leading edge fabrication cleanrooms needed to develop next generation products or offer bespoke fabrication services to similarly positioned clients.

Overview of the investment

Melbourne Centre for Nanofabrication (MCN) is the flagship facility and headquarters of the Australian National Fabrication Facility (ANFF), a critical national research infrastructure set up as part of the Commonwealth-funded NCRIS program that supports seven nodes in other states.

ANFF's Victorian Node (ANFF-VIC) was founded in 2007 through a joint venture partnership between six Victorian Universities (Monash University, University of Melbourne, La Trobe University, Swinburne University, RMIT and Deakin University), and CSIRO. Having opened in 2011, MCN (a strategic consolidation of leading-edge capabilities) provides a broad spectrum of fabrication and characterisation resources to Victorian researchers and SMEs. Initial funding was from the Victorian Government ($15 million), the Commonwealth Government ($13.5 million – NCRIS/CRIS) and joint venture partners ($15 million). EIF funding ($15.5 million in 2010-13) facilitated further expansion of MCN infrastructure and the establishment of satellite capabilities hubs within a number of ANFF-VIC partner institutions. To date, NCRIS has invested a further $16.5 million in MCN's operational expenses. In 2020 Victoria University joined the Joint Venture as the eighth member.

MCN's 20 FTE staff support more than 400 domestic and international academic and industry users each year – logging more than 30,000 contact hours on the instruments – with research activities ranging from renewable energy technology to novel medical devices.

Success – Benefits and impact

The MCN is the largest facility of its kind in the Southern Hemisphere, with most users (around 80%) based at Victorian Universities or CSIRO. 10-15% of users are SMEs and the remainder are a mix of international (e.g. NASA), non-Victorian universities and Victorian publicly funded research institutes, such as Peter Mac and WEHI.

The ANFF-VIC Node Central facility has assisted in the attraction of well over $300 million (over a horizon of 5-7 years) in science and technology investment. MCN also provides the critical infrastructure needed for Victorian researchers needed to attract millions in research grant revenue every year, with 13 projects attracting $44 million in external funding in 2019 alone. The facility also underpins significant scientific output, including approximately 300 peer-reviewed publications per year, patents and commercial spin-offs.

MCN has played a vital role in a range of significant commercial successes, including:

- *Vaxxas* – an innovative needle-free nanopatch™ for non-invasive delivery of vaccines.
- *Calumino* – a micro temperature sensor for use in a range of applications, including elevated face temperatures, smart buildings, transport, fire safety and security.
- *Trajan* – an innovative portable device for collecting and safely storing blood samples by anyone, anywhere, anytime.

In 2018, MCN formalised a long-term international partnership with a Japanese manufacturing firm ULVAC Inc for cooperative research, staff development and supply of infrastructure to enable ground-breaking nanotechnology research. Future benefits could include, creating ten high-skilled jobs and increased international linkages to Japan.

Recently, the ANFF-VIC Node and ANSTO have set up a joint program of work to develop x-ray lithography at the adjoining Australia Synchrotron. There is only one other place in the world that can partner in this way (Switzerland). This capability will enable scale up of nanofabricated devices for commercialisation and industry.

CASE STUDY 3

The Victorian Organic Solar Cell Consortium (VICOSC)

Identified problem / gap

Despite Victoria's status as a manufacturing powerhouse, by the early 2000s Victoria was yet to capitalise on the opportunities afforded by printed solar cells.[63] VICOSC was funded to use industry to kickstart the development of solar technologies (organic photovoltaic), translating next generation laboratory work into commercially manufactured accessible and affordable products.

Overview of the investment

VICOSC was a collaboration between CSIRO, The University of Melbourne, Monash University and industry partners – to print solar technologies on a large scale. The program was designed to reduce barriers for entry for Australian manufacturers to use solar-power, and utilise research infrastructure and expertise. Organic photovoltaics are a new technology that harvest light which can be printed cheaply on plastic, creating flexible and semi-transparent solar cells.

Founded in 2008 with Commonwealth Government funding ($6 million), VICOSC continued to thrive with key grants and co-investments from 2010-2012 from the Victorian Government and matched consortium investment ($5 million), and joint funding by the Australian Solar Institute Applied Research Grant and Victorian Government funding programs ($7.2 million). The project concluded in 2014.

During the investment, key components and activities included solar ink development, printing, testing, and scale-up. VICOSC established two complementary activities to accelerate organic solar cell R&D and significantly reduce the cost of solar energy generated from organic photovoltaics. Over this time, the technology developed to a level suitable for near term applications, such as providing portable power for short term applications.

Success – Benefits and impact

Victoria is Australia's go-to location for next generation printed solar research. VICOSC's reputation has led to many on-going collaborations nationally and across the globe – from Asia, Europe and America. VICOSC partners have attracted further funding, cumulatively more than $60 million into Victoria from funding organisations such as ARENA and the ARC.

Since the initial VICOSC investment, all activities and key components have continued to flourish through the original research partners with around 21 FTE staff across CSIRO, Monash and University of Melbourne. Key achievements include:

- produced a highly skilled workforce both in Australia and abroad, training more than 100 students, PhDs and postdoctoral fellows, including international students
- actively managed a portfolio of more than 100 patents
- senior researchers went on to establish the ARC Centre of Excellence in Exciton Science, which was funded for seven years with an initial grant of $31.85 million, enabled by key partnerships with CSIRO and the Reserve Bank of Australia
- attracted funded projects with industry partners GreatCell Solar, RayGen, CSR Viridian and Norwoord on the development of next-generation solar cells worth over $2 million.

CSIRO Flexible Electronics Laboratory is recognised world-wide for its ability to translate world-leading laboratory research to large scale, industry-relevant outcomes. Additionally, they are attracting more than 50 local businesses to address their energy needs.

CSIRO is focusing on producing real-world printed demonstrators. While future investments are needed, the facilities for small scale device fabrication and characterisation across Monash University and the University of Melbourne provide the essential fundamental underpinnings to realise this translation. A local printed photovoltaic industry could support hundreds of jobs directly and thousands indirectly. It would also mitigate an estimated $60 billion of imported solar panels required to reach Australia's target for solar renewables.[xi]

xi Estimate of $60 billion based on 2019 values: calculated using $1/W and scaling the current 5% market share of 13.9 GW to 25%.[75,76]

CASE STUDY 4

Victorian Biomedical Imaging Capability (VBIC)

Identified problem / gap

Rapid advancements in high-quality imaging technology and the high-cost of purchase of equipment poses challenges in maintaining competitiveness in the healthcare sector.

Overview of the investment

Biomedical imaging instruments (e.g. X-ray and MRI machines) generate scans of the human body and are crucial to many areas of medical understanding such as cancer treatment, neuroscience, cardiovascular systems, respiratory systems and infectious disease.

VBIC aims to pair valuable medical imaging equipment with networks of expertise and research. VBIC helps the Victorian biomedical imaging research community and industry partners to maximise the state's existing equipment assets, providing them with access to state of the art equipment and skills.

VBIC was launched in 2010 with a $25 million investment, comprising $8.5 million from the Victorian Government and the remaining provided by collaborating organisations.

Over the past decade, VBIC has become part of NCRIS National Imaging Facility (NIF) and has supported over 500 active users of the biomedical research imaging infrastructure across research, education and industry. Across the five VBIC nodes (Monash University, The University of Melbourne, The Florey Institute, Swinburne University, and at the Austin Hospital) they currently employ over 150 FTE staff per year, with more than 100 of those representing imaging research support scientists who have been recruited and trained in advanced biomedical imaging research techniques.

Success – Benefits and impact

Biomedical imaging investment strengthens Victoria's $12.7 billion Medical Technologies and Pharmaceuticals Sector. In this context, VBIC has, for example, collaborated with local and international companies such as Siemens, Cyclotek, GE, Bruker and Telix.

Since its establishment in 2010, VBIC has expanded its partnerships well beyond the initial scope to generate outstanding collaboration and research opportunities. It has partnered with more than 90 national and international organisations. In 2018 commercial collaborations were valued at over $35 million.

Across the nodes, VBIC provides scope for local SME's and startups to bolster their businesses with the transfer of technology and knowledge, improving commercial viability and success. Significant commercial successes and partner innovations include:

- *Avipep* – a Victorian company positioned to capture the US$40 billion per annum market for cancer therapeutics with its engineered antibodies for cancer imaging and therapy.
- *Florey Magnetic Resonance Imaging Facility* – has expanded Victoria's equipment and staffing capacity at the Magnetic Resonance Imaging Facility at the Brain Research Institute (now part of The Florey Institute in the Austin LifeSciences Precinct), which has facilitated over 200 research projects.

VBIC researchers have received multiple awards and are leaders on a global stage, leading to over 1,000 peer-reviewed scientific publications, attracting $37 million of additional funding committed to major capital investments and $235 million in competitive research grant incomes, including from the ARC ($20 million), NHMRC ($31 million), NIDR ($18 million) and international funding from the NIH (US$106 million). The NIH project, at the Monash University Node, is called ASPREE. It is an international, multicentre clinical trial 10-year study that is looking at aspirin in a healthy elderly patient cohort.

Since its inception, VBIC estimates they have delivered over $350 million in economic activity to Victoria.

CASE STUDY 5

Carbon Nexus

Identified problem / gap

Without a production-scale manufacturing and development site, Australia risks falling behind new manufacturing opportunities as industry increasingly explores lightweight, low-cost and energy efficient carbon fibre and advanced composite production technologies.

Overview of the investment

Deakin's Carbon Nexus at the Waurn Ponds Geelong Future Economy Precinct is an open-access research facility, incorporating world-first infrastructure designed to manufacture carbon fibres, textile pre-forms and composites. Carbon Nexus meets the needs of a wide range of industries looking to replace aluminium and steel in their products, and develop new processes – including the aerospace, automotive, sporting goods, transportation and renewable energy industries. It is the only such site in the Southern Hemisphere.

In 2006, efforts began to position Victoria, and in particular the Geelong region, as the international hub for research in advanced fibrous material.[64] The original project partners were Deakin University, CSIRO and the Victorian Centre for Advanced Materials Manufacturing.

The project commenced in June 2010 as part of the Australian Future Fibres Research and Innovation Centre (AFFRIC) project, with investments from the Victorian Government ($10 million grant for the carbon fibre processing lines) and Commonwealth Government ($10 million for infrastructure), plus cash and in-kind contributions from Deakin University.

The facility opened in 2014 with 30 FTE employees. By 2020, they had doubled their employment numbers and produced significant commercial outcomes for Victoria.

Success – Benefits and impact

Carbon Nexus has provided access to high quality and flexible equipment as well as highly experienced technical and research teams.

This has attracted researchers, universities, and national and international industry partners across China, Middle East and the United States to Victoria. Notable international partners include Quickstep, Dow Chemical, Boeing, Ford, Vestas, Daimler, SABIC, LeMond and Bluestar Fibres.

Since the initial investment, Deakin University with the support of key partners, including LeMond and CSIRO, have been investing in new laboratory and process equipment to enhance their capabilities to the value of over $3 million.

Since opening, Carbon Nexus has attracted $14.3 million in collaborative research grants and $5.24 million of overseas research contracts and exported $0.45 million of advanced material. Additionally, the facility has enabled over 16 PhD students, 210 peer-reviewed papers and attracts over 120 attendees to their bi-annual conference (25% from overseas).

Carbon Nexus has been the catalyst for over 1,400 FTE jobs in the Geelong region, many of those have been skilled workers displaced by the closure of local manufacturing in 2014-16:

- catalysing the growth of the Future Economy Precinct and its around 1,400 jobs, including within Carbon Nexus, Carbon Revolution, Quickstep and tenants at Manufutures.
- leading to the formation of the Advanced Fibre Cluster Geelong, a member-based collaboration platform comprising of 17 companies in the Geelong and Melbourne region

Since it was established, Carbon Nexus has commercialised new technologies, including:

- an award-winning, world-first carbon fibre composite production process, which has been commercialised by Mulitmatic, producing parts for the Mercedes AMG S-Class
- a new process for manufacturing carbon fibre with significantly lower cost and energy, commercialised via a 20-year licence with LeMond Composites (USA) worth $58 million.

CASE STUDY 6

veski – inspiring innovation

Identified problem / gap

To ensure a vibrant and effective research ecosystem Victoria required a pipeline of intellectual capital, innovation and creativity. Victoria lacks a cohesive system to support globally competitive researchers and attract them back from overseas.

Overview of the investment

In 2003 the Victorian Endowment for Science, Knowledge and Innovation (veski) was established with a Victorian Government endowment of $10 million. veski uses the annual interest earned to fund its principal objective of enhancing Victoria's intellectual capital in science, knowledge and innovation for the benefit of the Victorian public. In 2010, the Victorian Government provided an additional $1.5 million to veski to increase the number of available fellowships. veski has three FTE employees.

Since 2004, the veski innovation fellowships provide around $150,000 over three years, to repatriate and/or attract leading Australian and international researchers to work in Victoria. Fellows are placed in a host organisation who provide matched cash and in-kind support over and above the fellow's salary.

Following the success of the fellowships program, in 2015 veski introduced two additional programs – veski inspiring women and veski sustainable agriculture. The inspiring women fellowships support female leaders to remain competitive in their field, enhancing the current talent pool and affecting cultural change. The inspiring women fellowships fund the cost of childcare, enabling 4,800 hours of the fellows' time to be dedicated to research.

Success – Benefits and impact

Over 15 years, 37 fellowships have been funded across its three fellow streams: innovation, sustainable agriculture and inspiring women.

To date, 27 fellows have secured $68.2 million in science research income into Victoria from Commonwealth and international bodies – such as Wellcome Trust, US Air Force Office for Scientific Research, Unilever R&D and GE Aviation. Also veski has attracted $500,000 in philanthropic dollars to support key activities.

As of 2019, the veski fellows have enabled the creation of over 70 FTE research jobs, educated over 94 STEM students (including 90 postgraduates), and attracted over $23 million investment by hosts.

- The four sustainable agriculture fellows are carrying out community identified projects based in regional Victoria. Collectively, the fellows have secured $3.4 million in research income, delivering a 5.7 times ROI (return on investment).
- The six inspiring women fellows have delivered a 14.5 times ROI, which includes securing $13.1 million in research income.
- The 27 veski innovation fellows have delivered a 18.4 to 1 economic ROI on the initial investment to Victoria, through attraction of research funds from Commonwealth and international sources.[65]

A predictive 10-year impact analysis of five veski innovation fellows in the healthcare sector identified impact in excess of $257.7 million, including reduction in cost of care, cost savings for industry partners, income through partnership and collaboration and licensing revenues.[66]

The veski inspiring women fellows have obtained several awards, leadership positions, and attended national and international conferences. The impact of the program continues around the world through a series of highly engaged collaborations with individuals and organisations such as the Bill & Melinda Gates Foundation, Waterloo Foundation, Imperial College-London, Delft University and Kyoto University.

APPENDIX

B

3 Pillars of Public Research Response to COVID-19: Notable examples and activities in Victorian Universities

Increase medical knowledge and response capacity

- Grew the COVID-19 virus and undertook all the early Australian testing.
- Produced Australia's first mRNA COVID-19 vaccine candidates using an advanced technological approach capable of generating vaccines ready for human testing in record time.
- Established a COVID-19 External Community Response Team that enabled a strategic and coordinated response for industry, government and hospital partners.
- Developed a #beatcovid19now symptom tracker and website. Enabling health officials to identify potential emerging clusters and allowing informed decision-making for resource deployment.
- Advising the Commonwealth Government and Chief Medical Officer on Australia's COVID-19 response through a team of pandemic modellers, infectious disease and public health experts.
- Continually delivering updated guidelines from global evidence on the clinical management of patients with suspected or confirmed COVID-19 infection across primary, acute and critical care settings via the National COVID-19 Clinical Evidence Taskforce.

Understand socio-economic impacts and plan for recovery

- Launched a COVID-19 Industry Response Program to support small businesses, including those in regional Victoria, to adapt to new markets and new ways of working.
- Established an Infohub to help international democracy analysts collate information on state responses to the pandemic, exploring the impact on modes of governance and democracy.
- Involved in the planning and development of several major initiatives that are relevant to Victoria's and Australia's post-COVID recovery and regrowth pathways. For example developing a program focused on mental health and productivity of the workforce, and attracting international investment to build a local supply chain in Victoria.
- Modelling the economic effects of COVID-19 on the Victorian economy, to help develop region-based recovery strategies for Victoria.
- Investigating the impacts of COVID-19 and home schooling on educational outcomes, mental health and wellbeing.

Launch projects and external collaborations

- Manufactured and trialling ACTIVAT3D copper push plates, in partnership with SPEE3D, for opening doors on campus that have wider industry application. An initial study in the New England Journal of Medicine indicates that COVID-19 was less stable on copper than other surfaces.
- Design of novel PPE from low cost locally sourced materials and working with manufacturers producing PPE and ventilators, including adapting CPAP (continuous positive airway pressure) machines to work as ventilators.
- Leading the Australian Chapter of Survey of COVID-19 Responses to Understand Behaviour (SCRUB) to give policymakers actionable insights into public attitudes and behaviours relating to the pandemic. More than 120 international collaborators are involved in the project.
- Working in collaboration with clinicians and a Melbourne industry partner, designing and manufacturing diagnostics for Rapid COVID-19 Point of Care Tests and tests for identifying patients at high risk of poor outcomes.
- Participating in a global study to assess health and wellbeing in collaboration with researchers from across Australia, USA and the UK, the Survey of Health and Wellbeing: Monitoring the impact of COVID-19.

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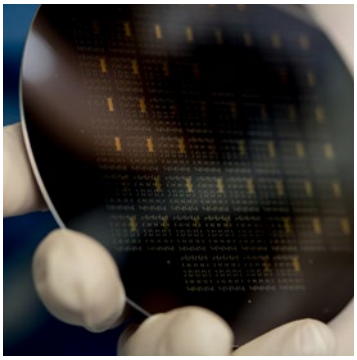

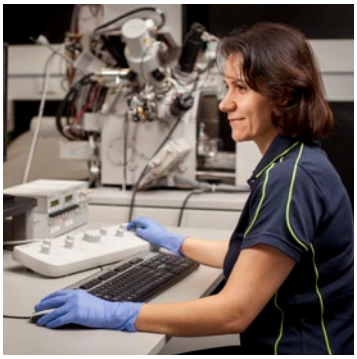

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