Designing the building blocks for an advanced manufacturing nation

The economic impact of the ARC Research Hub for Energy-Efficient Separation

12 April 2023

Building a better working world

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Contents

Executive summary

At a glance: The economic impact of the ARC Research Hub for Energy-Efficient Separation

Key activities

$12 million
co-invested

25
research projects

33
investment partners

Key outcomes

$700 million
economic output

8:1
return on investment

Cultivates key international research and industry linkages

EY

Supporting innovation in critical sciences

Australia's knowledge and innovation system is crucial for driving long term prosperity and building Australia's ability to tackle major national challenges.

In 2017 the Australian Research Council (ARC) established a dedicated research centre for energy-efficient separation technologies.

- The Hub targets critical areas of the Australian economy, providing new and improved technologies for pharmaceuticals, manufacturing and the circular economy.
- It partners with industry and universities to drive innovation and support Australian industry to become more energy-efficient and globally competitive.
- To date, the Hub has partnered with 33 organisations including domestic and international universities, government, and industry. It has supported 25 applied research projects and secured funding of more than $12 million, with $4 million from the ARC.

Assessing the economic and innovation payoffs from the Hub

This report evaluates the Hub's economic impact, encompassing its performance to date and its role in driving innovation and deployment of separation technologies over the longer term.

The analysis takes a whole-of-economy perspective. It examines how the Hub's research program, technology innovations and commercialisation initiatives have, and continue to, deliver wider economic spillovers. The analysis draws on discussions with the Hub's management team, discussions with its industry and university partners, and further research on the benefits from R&D.

The Hub's priority areas of applied research

The Hub supports applied research in membranes and other separation technologies. These technologies, which underpin a range of critical industrial functions, involve separating mixtures into their constituent elements to purify, recover and isolate valuable materials. In effect they can be considered some of the essential (but largely unseen) building blocks of a modern, sustainable and knowledge based economy.

The Hub focuses on four research areas:

Bioseparation

- Virus filtration and plasma purification
- Purifying bioactive nanoparticles from fruit for medicine

Water desalination and wastewater treatment

- Cleaning and recycling wastewater
- Water desalination in remote communities

Resource recovery

- Extracting minerals from salt water and waste water
- Extracting lithium from brine rock

Industrial processing separation

- Improving the structural integrity of pre-cut cement structures through reducing air bubbles
- Gas separation and removal in industrial processes

Helping build a modern Australian economy

Commercialisation and development pathways

Projects undertaken by the Hub were assessed by EY on a range of scientific and economic factors, including industry productivity, commercial prospects, timing of realisation, and role in furthering research.

Applied scientific research is, by its very nature, uncertain. The analysis examined two scenarios reflecting different prospects for commercialisation, industry uptake and market penetration, as well as the potential impact of applying new technologies on specific industries.

Core economic impact pathway

A relatively conservative 10-year pathway for the translation and commercialisation of Hub research activities.

Maximum commercialisation

An 'outer envelope' scenario reflecting the upper range of potential commercial and economic payoffs from research activities.

The Hub's economic impact

- Based on this assessment, the economic payoff of the Hub's activities could be over $700 million over the next decade under conditions in which research activities reach their maximum commercial potential.
- The Hub has the potential to deliver a range of positive spillovers for industry as new technologies are developed and deployed. Key industry gains are likely to occur in construction ($183 million), manufacturing ($168 million) and water and waste industries ($112 million).
- Funding for the Hub represents an investment in Australia's science and innovation system. The evaluation indicates that the Hub's activities could generate an economy-wide return on investment in the range of 4.5:1 - 8:1. Under the core economic pathway, this estimate closely aligns with analysis undertaken by Universities Australia.*

Projected 10-year economic payoff of the Hub

Economic indicator	Core economic impact pathway	Maximum commercialisation
Economic output (GDP)	$540 million	$700 million
Additional employment in 2032	94 FTE	120 FTE
Additional investment	$230 million	$280 million
Additional national income	$510 million	$670 million
Indicative return on investment	4.5 : 1	8 : 1

Tackling Australia's long term challenges and key economic priorities

Beyond its direct economic impact, the Hub also plays an important role in uplifting Australia's scientific capacity to address some key policy challenges:

- Improving pharmaceutical manufacturing and processing to uplift capacity and help manage future health challenges such as pandemic preparedness and population ageing.
- Developing better resource extraction techniques and processes to increase the yield of critical minerals, reduce the carbon intensity of mining and support Australia's net-zero emissions target.
- Strengthening Australia's R&D capacity by deepening linkages with industry and leading international universities.
- Advancing domestic manufacturing capability, especially in novel membrane production, to build Australia's sovereign manufacturing base.

**Source: Universities Australia 2020*

1 Introduction

Introduction

The ARC Research Hub for Energy-Efficient Separation (the Hub) was established in 2017 to support research outcomes in critical separation technologies including water recycling, resource recovery, biochemistry and industrial processing. In advancing these technologies, the Hub seeks to support Australian industry become more energy-efficient and globally competitive.

- Over the past five years, the Hub has supported 25 research projects and numerous collaborations with national and international academic organisations, and industry partnerships.*
- The Hub is based at Monash University and forms part of the Australian Research Council's broader research and partnership agenda.

At the forefront of the knowledge economy in a transitioning energy market, the Hub has the potential to have a significant impact on Australia's economy and its global strategic position

- In light of rising energy prices and the transition to renewables, energy efficiency in industrial processes is central for lowering costs and future-proofing advanced manufacturing in Australia.
- Efficient use of scarce resources is crucial for supporting advancements to net-zero industrial processes and supporting growing demand for critical minerals such as aluminium, copper, and nickel.
- Expanding Australia's skills in critical manufacturing can grow its competitive advantage, unlock economic and strategic value, and build sovereign manufacturing capabilities.
- Implementing practical solutions to build a circular economy can unlock value in waste, streamline production lines and reduce material wastage.

The Hub connects industry with specialised researchers to solve real-world problems. Through the Hub, industry has access to leading researchers, academic networks, and resources to collaborate, leverage, and build industry-leading solutions.

Purpose of engagement

EY is supporting Monash University to evaluate the Hub's economic impact, encompassing its performance to date and its role in driving innovation and deployment of separation technologies over the longer term. The analysis examines the Hub's research program, its technology innovations, commercialisation outcomes, and wider economic spillovers.

As part of the Hub's evaluation to government, this report showcases how the Hub's applied research has directly benefited Australian industry as well as the broader economy.

The report is structured in the following chapters:

1. Outlines the structure and activities of the ARC Energy-Efficient Separation research Hub
2. Highlights the technologies developed by the Hub including targeted case studies across its portfolio of projects
3. Showcases the potential economic benefits of applied scientific research hubs
4. Assesses the potential economic impact of the Hub on key industries, based on its research priorities and innovation mandate

**Information provided by the Hub*

2 The ARC Research Hub for Energy-Efficient Separation

Accelerating Australia's manufacturing capabilities in separation technologies

A research Hub for developing energy-efficient separation techniques

The Hub specialises in developing innovative energy-efficient separation technologies for industrial processes. The Hub supports industry to connect with PhD students and postdoctoral researchers to solve practical scientific issues. Over its 5 years, the Hub aimed to:

- Develop smart processes of material separation that underpin Australian industry including advanced materials membranes, resins and absorbents that are more energy-efficient and cost-effective.
- Create a highly-trained, industry-ready workforce of engineers and researchers specialised in manufacturing advanced separation materials and equipment.
- Advance Australia's manufacturing capability and reputation to build sovereign manufacturing and scientific capabilities.

The Hub initially partnered with 33 industry and university institutions to develop energy-efficient, cost-competitive and environmentally sustainable separation technologies for industrial processes.

The ARC Industrial Transformation Research Program

The Hub forms part of the Australian Research Council's Industrial Transformation Research Program supporting university researchers to partner with industry in high priority areas. The Industrial Transformation Research Program fosters collaborative research activity between the Australian higher education sector and industry. It is designed to focus on strategic outcomes that are not independently realisable.

ARC RESEARCH HUB
ENERGY-EFFICIENT SEPARATION

The Hub's stakeholders and their engagement

Government

The Australian Research Council provided a platform to connect industry with researchers, and funding for the Hub.

Industry

Industry provided ongoing support, real-world challenges, and funding for the Hub.

Universities

Domestic and international universities provided support to the Hub through both funding and providing specialised chemical engineering researchers to collaborate with other researchers and solve industry challenges.

The Hub: By the numbers

Over its 5 year period, the Hub has been supported with $12 million through a mix of direct funding and in-kind contributions (usually in the form of researcher hours) from government, industry and university partners. This funding supported 25 Hub research projects across four research priorities:

- Bioseparation
- Resource recovery
- Water desalination and wastewater treatment
- Industrial processing separation

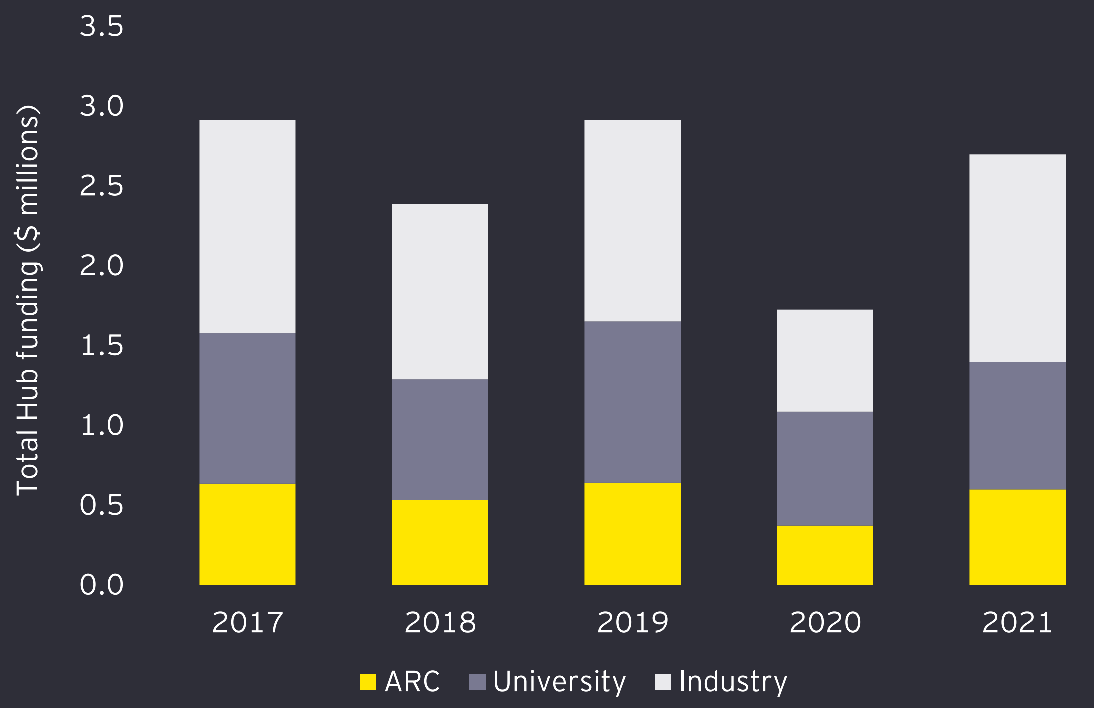
A list of research projects can be found in the appendix.

Collaboration between industry and academia continues to be an important factor in the Hub's success. Even through COVID-19, the Hub hosted academic forums through community briefings, talks, conferences, workshops and, when possible, international visits.

- More than 150 delegates attended a conference run by the Hub in 2018 and about 200 delegates from seven countries (including Australia, China, Singapore, United States, Saudi Arabia, Qatar and England) attended a conference in 2019.
- Research outputs from the Hub (including journal articles, books, book chapters, conference publications, prizes and awards) and media commentaries also increased over time, reaching 175 in 2021.

Snapshot: The Hub's outputs in 2021

18	39	45	21
employees	students	research outputs	partners



Information on this slide was provided by the Hub

EY

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Understanding the technologies

The Hub provides a platform to link industry and researchers

Research hubs are a focal point of technological innovation and skill development that leverage technical expertise towards industry applications. Research hubs partner real-world problems with the people who have the knowledge and capability to solve them. ARC research hubs work to maintain and develop Australia's capabilities in critical research areas of national priority.

A key role of research hubs is to understand industry problems, research, then return results to industry through technological expertise and skills diffusion. This is done through close collaboration of industry partners and researchers.

A Universities Australia study completed in 2020 found the direct benefit of research collaboration to businesses was $12.8 billion in 2019.* This report evaluated the benefits from business-industry collaboration:

$4.50	return on every dollar companies invest in research with universities
25.6%	of Australian innovating businesses cited lack of skilled staff as the main barrier to innovation
$26.5b	contributed by university and business collaboration to the Australian economy
38,500	full-time jobs supported by university and business collaboration in Australia

The Hub's focus on four research areas has benefited industry through:

- **Novel technology –** Research hubs work with industry to create technology with commercial applications. Industry can utilise the expertise of the research hub in technology development, especially where their own internal R&D capabilities may be lacking or at capacity.
- **Industry profitability –** Industry partners can significantly reduce their R&D costs by investing in research hubs that provide access to leading researchers and made-for-purpose laboratories. Industry can gain cost-effective scientific and research services to develop commercial-ready technologies.
- **Access to specialised and limited skill sets –** Complex scientific issues can arise, requiring industry to be agile in the face of challenges. Oftentimes, these challenges require specialised and niche skillsets. Working with a research hub allows companies to access specialised researchers to provide high-skill problem solving.
- **Innovation diffusion across industry –** Breakthroughs from research hubs are shared with industry partners. Industry partners can spread innovation throughout the value chain through leveraging research hub outputs.

This section outlines the technology areas researched through the Hub, what they do, why they matter and what their applications are. A case study of how the Hub is driving practical innovations in these areas is also provided.

***Source: Universities Australia 2020**

Bioseparation

The Hub has conducted a range of multi year research initiatives in the field of bioseparation. Advancements have been delivered through key industry and higher education partnerships with CSL Behring and Monash University.

What is bioseparation?

Bioseparation involves separating products in a biochemical reaction without damaging organisms or biological substances. High performance membranes are typically used to refine molecules, cells and parts of cells into purified products.

Why is it important?

The process of bioseparation is critical for a range of extraction and purification applications, especially in medicine. Novel applications include:

- Separating and reusing bioproducts from plasma
- Removing virus cells from proteins
- Purifying bioactive nanoparticles from naturally occurring plants to be used for medical purposes.

What are the major challenges? And what is the hub doing?

Bioseparation processes can be inefficient, costly and complicated. They often require two separate separation processes to be effective and, as many biological substances are unstable when heated, they often need to be handled in sub-ambient temperatures which adds to the costs of transport and handling.

The Hub's applied research in bioseparation has focused on developing new technologies to reduce the energy needs and costs of separating biological substances.

Project spotlight: Protein separation membrane

CSL Behring, the world's largest collector of human plasma, manufactures plasma-derived products to develop medicines for patients with rare diseases. CSL Behring supports six projects within the Hub to develop high performance membranes for the separation and purification of therapeutic proteins.

The challenge

Once a rarely used subset of medical treatment, protein therapeutics have increased dramatically in their scale and scope, and are now extensively used to treat cancer, HIV, and other diseases.

Rapid growth in demand is a major manufacturing challenge, particularly in downstream protein separation and purification which is labour and capital intensive and can be difficult to scale.

New membrane technologies

Researchers at the Hub have developed new nanofibre membranes for therapeutic proteins which can be operated continuously at a much higher flow rate. This means the membranes can provide higher processing capacity and productivity.

- The membranes currently have a readiness level of around 4-5, meaning they are undergoing laboratory testing before a prototype is made. Testing has been successful, and further funding has been secured to scale up the membranes.
- Two patents covering the technologies will be filed shortly and two research papers have been published.
- Commercialisation could involve creating a spin-off company or licencing the technologies to a membrane manufacturing company.

Water desalination and wastewater treatment

99.5% of the water on Earth is undrinkable, either because it is salty, has been contaminated from industrial, commercial, agricultural or domestic activities, or is too difficult to retrieve.

Water desalination makes undrinkable water drinkable by removing salt and impurities from sea water or cleaning wastewater. The processes can get water to a quality suitable for drinking, or just clean enough for industrial uses, such as for power generation and construction industries.

Water treatment projects aim to improve water security in regional communities, build climate resilience and reduce water use across industrial processes.

What is the problem with current desalination processes?

With a large demand for fresh water, whether for drinking or other purposes, the search to desalinate sea water and treat wastewater has become increasingly important.

- Desalinating seawater is, however, extremely energy intensive.
- Seawater desalination is four times more energy intensive than groundwater collection, and over 40 times more energy intensive than water sourced from dams.*

How is the Hub solving these problems?

Discovering new, more efficient ways of treating water has been a high priority for the Hub. The Hub has developed technologies to desalinate water more cost-effectively, requiring less equipment and space, and using less emissions. Additionally, the Hub has developed ways for industrial processors to treat their own wastewater and reuse it in their operations.

Project spotlight: Water desalination machines for remote communities

Water scarcity remains one of the world's most pressing development issues, with more than 2.8 billion people still lacking access to safe water. As a result, more countries are turning to alternative water sources to produce potable water, with the majority of these systems utilising reverse osmosis to transform saline water to potable water.

What's the problem with current processes?

Conventional centralised desalination approaches require specialised maintenance procedures and are capital and energy-intensive. This makes them difficult for remote, small, off-grid and low-income settings. Innovative, tailored and cost-effective desalination solutions are needed to meet the growing demand for reliable and affordable safe water globally.

Providing the solution

This project has developed a compact, portable, low-cost, solar-driven, low maintenance water filtration device which can produce safe drinking water from contaminated water sources.

- The device is low-cost, energy-efficient, sustainable and designed for rural areas. It can also be tailored to be used for other applications, including farms, ships, hotels and schools.
- The developed micro-desalination device is a potential game-changer for people who live in resource-poor, remote or conflict-affected areas.
- The micro-desalination prototype water purifier improves access to clean, potable water for resource-poor communities in remote off-grid locations.

No patents have been filed for this project as the knowledge and technology will benefit more people as open source information.

***Source: WA Water Corporation**

Resource recovery

Resource recovery is the process of extracting valuable resources from generally invaluable products, and repurposing them for productive uses. Materials are separated from waste and other usually unproductive materials and recycled into new products or used as an alternative to fossil fuels.

Resource recovery may involve recovering high value products (minerals, water and resources) from less valuable resources (salt lakes, wastewater, rocks).

Why is resource recovery important?

The recovered resources can be repurposed as renewable fuels to replace non-renewable natural resources. Resource recovery also repurposes, recycles and reuses waste products from landfill to create valuable products, such as energy.

How is the Hub recovering resources from waste?

The Hub has six dedicated projects to discovering energy-efficient, cost-effective ways to recover resources. It has looked at new places these resources can be recovered from, and discovered new ways the previously 'useless' material can be used in our everyday lives.

Project spotlight: Extracting lithium from brine rock at a higher rate

ElectraLith is a start-up company spun out of Monash University developing technology for sustainable lithium extraction and production. ElectraLith aimed to develop a technology which improves the complex process of extracting lithium from hard rock: spodumene (prevalent in Western Australia) and mineral-rich brine (most common in South America).

The technology involves electro-dialysis (using electricity to separate salt) and uses a membrane to separate lithium from other ions such as sodium and magnesium.

What's the problem with current processes?

Currently, lithium extraction and production processes require large evaporation ponds. These are not only costly, but also inefficient and extremely slow. The process also has a pretty significant environmental footprint due to using large quantities of fresh water and damaging the ecosystem.

Providing the solution

Through the Hub and its researchers, ElectraLith was able to evolve, therefore enabling the research and development of the lithium production technology.

- ElectraLith's membrane recovers a higher selectivity of lithium in the separation process than current approaches, producing higher purity lithium.
- It significantly speeds up lithium brine projects (at roughly 1000 times faster).
- It reduces costs, uses less fresh water, creates fewer carbon emissions, creates less wastage, and can use renewable energy as the energy feedstock.

Having secured funding from the global mining company Rio Tinto and innovation investor IP Group, the technology is currently under commercial development and is expected to be commercially available in the coming 2-3 years.

Industrial processing separation

Industrial processes are necessary for the way we live. They form a critical component of Australia's manufacturing base and provide high paying regional employment for relatively low skilled jobs.

However large industrial facilities are highly emissions intensive with the largest 215 industrial facilities contributing to 28% of Australia's emissions in 2021.*

Why are energy-efficient processes important?

As the world moves to lower its emissions, energy efficiency in industrial processes is becoming increasingly important. Finding new ways to use less energy and increase efficiency through manufacturing processes is crucial for Australia's future.

- New technologies using energy-efficient techniques will be critical if government is to meet its industrial emissions targets.
- The Safeguard Mechanism, for example, requires emissions intensive industries to lower their Scope 1 emissions. Many of these industries have already maximised ways to reduce their emissions and now require new technologies to further lower their emissions and hit their targets.

How is the Hub lowering emissions in industry?

The Hub has researched into new ways to reduce the energy required for gas and water separation in coal seam gas processing and developed a lubricant for cement production.

Project spotlight: Developing a lubricant to decrease the size of air bubbles in cement manufacturing

Shijiazhuang Chang'an Yucai Building Materials Company (SCY Building Materials) is a large Chinese construction company which builds dams, highways and channels, as well as other forms of civil infrastructure. The company was seeking ways to reduce the size of air bubbles in pre-cut concrete structures which can cause major structural problems. Initially trying to solve the air bubble issue using its own engineers, SCY Building Materials soon realised the problem was a chemical engineering issue, and required specialists. This led to its partnership with the Hub and Monash University to develop an energy-efficient admixture technology to decrease the size of air bubbles.

Providing the solution

In developing the admixtures, the researchers provided understanding of some important interaction effects, and the presence of each polymer, and how to separate them. In fact, the two polymers react negatively with each other, and using both in the same mixture resulted in poorer performance than using them individually.

- Decreasing the size of air bubbles in concrete improves the concrete's performance including its flowability, the pumping efficiency of concrete slurries, and its strength at an early stage of setting.
- It can also reduce the amount of water used in concrete manufacturing.
- It significantly reduces the number of voids caused by the air bubble issue.
- The low cost chemical additives has widespread potential applications, and can be used for construction, coating and other industries which use concrete.

SCY Building Materials is already applying the new technology, however it is not yet publicly commercialised. SCY Building Materials has applied for a several patents covering the polymer technologies which are now being assessed. The project research has also resulted in publishing five academic papers. SCY Building Materials is in the process of making scaled production of the new admixtures for commercialization.

*Source: Department of Climate Change, Energy, the Environment and Water

4

The economic impact of the Hub

The economics of applied scientific research

Australia's scientific research network plays a vital role in creating and disseminating new knowledge, enhancing Australia's productivity and capability, and building practical and intellectual capacity to meet current and future challenges.

A key part of this is direct research breakthroughs, along with stimulating industry innovation, commercial translation of research, and broader productivity increases in physical and human capital.

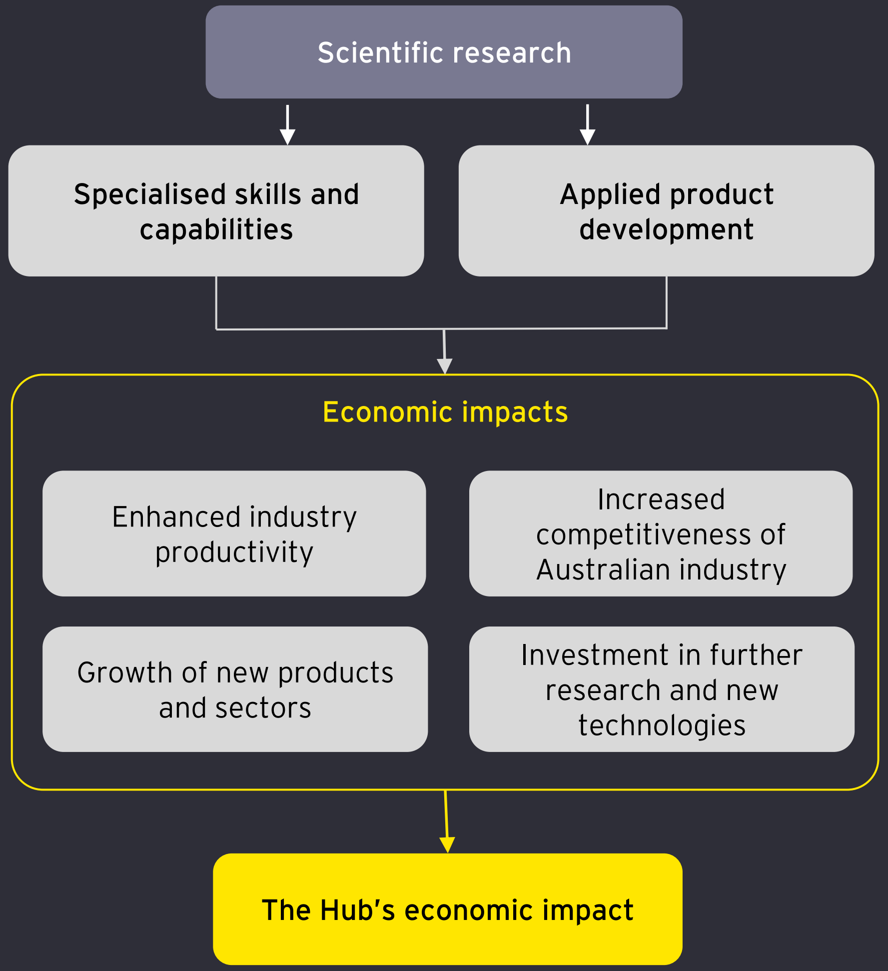
Harnessing the benefits of Australia's research sector, and supporting deeper community and industry engagement with world-class academic journals can support the economy through three major channels:

- Encouraging greater collaboration with industry to stimulate more R&D, innovation, and commercial translation activities across the economy.
- Promoting broad-based productivity increases through supporting Australia's ongoing transition to a more knowledge intensive economy.
- Supporting the Australian research sector to produce high-quality and impactful research.

Beyond the social and developmental value of scientific research, it generates valuable economic and environmental benefits for Australia

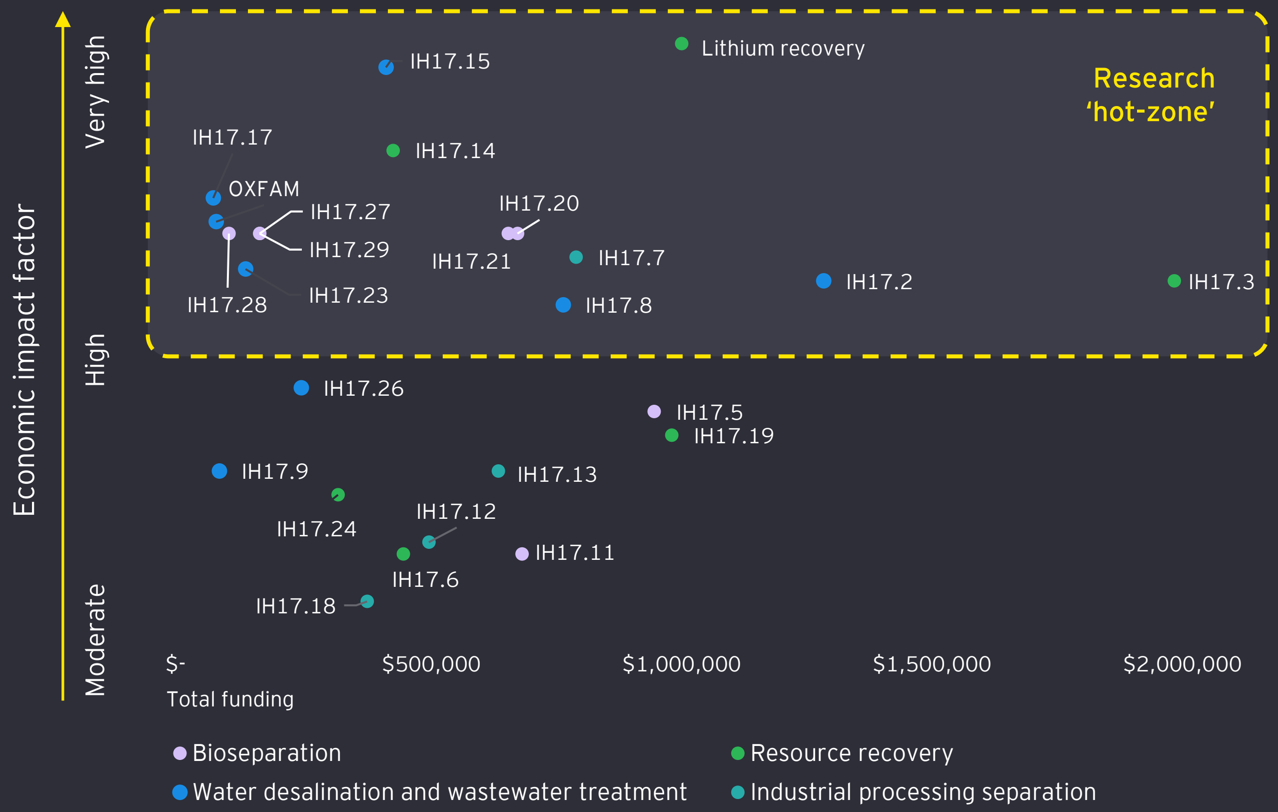
As Australia strives to grow the advanced manufacturing sector in a highly competitive global environment, it is important to understand the role that applied scientific research plays for the sector and quantify its economic benefits.

Framework for evaluating the economic impact of applied science



The potential economic impact of each project determined a research 'hot-zone'

The economic impact factor comprises a combination of implications for industry productivity, commercial prospects and timing of realisation, and the project's catalytic role in furthering research. The projects in the 'hot-zone' represent projects where the technology would be manufactured in Australia, have direct industry applications and show substantial future potential for the Australian economy. These projects demonstrate the greatest potential impacts on the Australian economy with respect to the technology's commercial viability, expected market penetration and magnitude of impact on industry.



Scenario development

The economic analysis examined two scenarios reflecting different prospects for commercialisation, industry uptake and market penetration.

The potential impact on each industry also differs by scenario, reflecting the technologies adoption potential across industries.

Core economic impact pathway

A relatively conservative 10-year pathway for the translation and commercialisation of Hub research activities. This scenario represents the most likely or expected outcome. It assumes that conditions will remain relatively stable and predictable over the next 10 years.

Maximum commercialisation

A 'outer envelope' scenario reflecting the upper range of potential commercial and economic payoffs from research activities. This scenario represents the most optimistic outcome that could occur under ideal conditions. This scenario assumes that all relevant factors are optimized impacted to the fullest extent possible. The scenario is more aspirational and can help planners identify possible opportunities for growth.

Note: See Appendix for a table of all Hub projects

Technologies for the future drive economic dividends

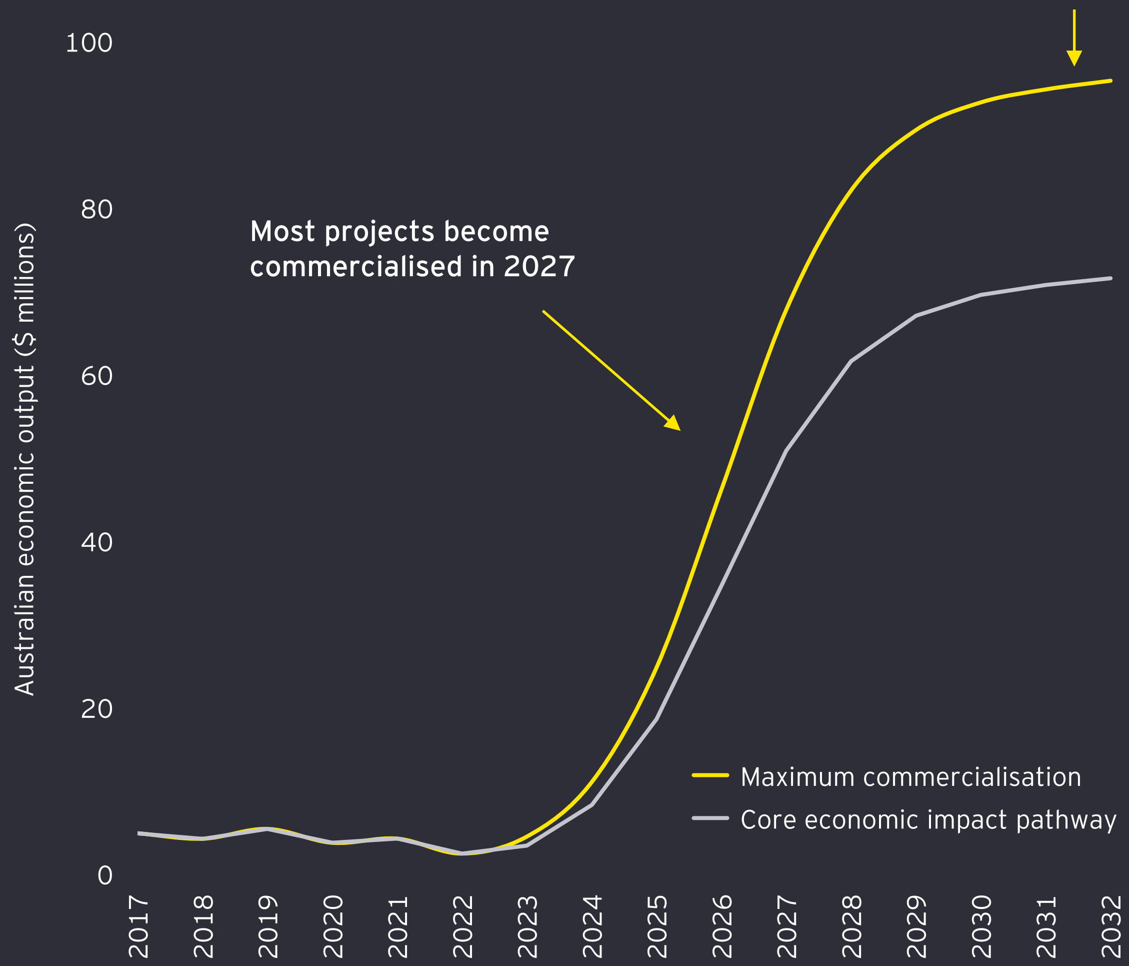
As a result of targeted funding and research, the Hub has significant potential to stimulate economic activity over the next 10 years. Although most projects will not be commercialised for at least another 5 years, economic contributions are felt through the development of the technology, such as through significant contributions to Australia's research agenda and upskilled PhD students.

- The economic payoff from the Hub's activities in Australia could be over **$700 million** over the next decade.
- There will likely be the greatest increase in economic payoff in 2027 when a significant proportion of projects are set to be commercialised and publicly available.
- The benefits to Australia's economy will continue over time as the developed technologies become more widely available and distributed amongst industry.

The technologies providing the greatest benefit to the Australian economy are due to their ability to increase industry productivity

- Reducing costs and operation time for industry increases its productive capabilities, and ability to complete more tasks in the same amount of time.
- This increases direct value added by industry, and increases demand for the given industry.
- Technologies with the greatest commercial prospects, and the greatest potential impact on a variety of industries, provide the greatest economic benefits to Australia.

The Hub's projects have the potential to increase Australia's GDP by $95 million in 2032



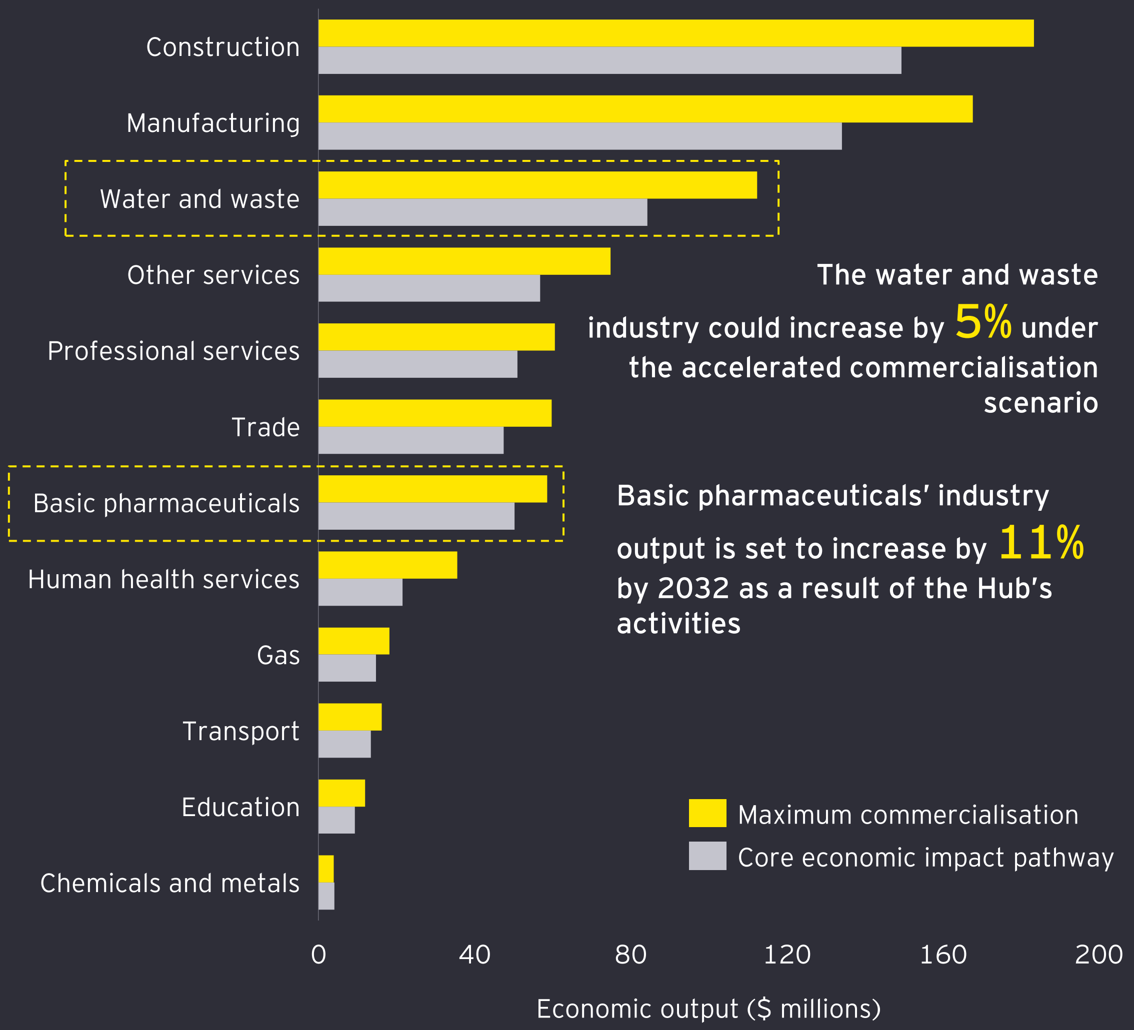
Economic gains flow throughout a variety of industries

The Hub's activity is dispersed across the economy, and as such, has large potential to provide economic benefits to a broad range of industries. Industries which have had, and will have, the greatest impact as a result of the Hub are those with direct benefits from the developed technologies.

There will also be spillover benefits to a broader range of industries where the industry is not directly impacted by the Hub.

- The **construction** industry is expected to grow by the largest margin of $183 million over the next decade as a result of the Hub, closely followed by **manufacturing** which is set to increase by $168 million under the accelerated commercialisation scenario. This shows the effects of the technologies being developed and constructed in Australia.
- **Water and waste** is also expected to see considerable gains from the Hub's activities through increased productivity and recycling of wastewater, with water desalination being a significant proportion of Hub projects.
- **Basic pharmaceuticals** will see direct benefits of almost $60 million, however much of these benefits will be delayed due to the lengthy measures the pharmaceuticals industry must take to get medicines approved through Australian standards.
- **Human health services** also benefit from the Hub's projects in developing new and improved techniques of bioseparation.
- **Gas, transport** and **other industrial industries** will also see benefits from the technologies developed at the Hub, mostly driving by reduced waste water processing costs and more streamlined operational tasks.

Output by industry as a result of the Hub's activities



Economic activity comes as a result of all Hub projects

New economic activity as a result of the Hub has the potential to increase Australia's national income, investment and jobs

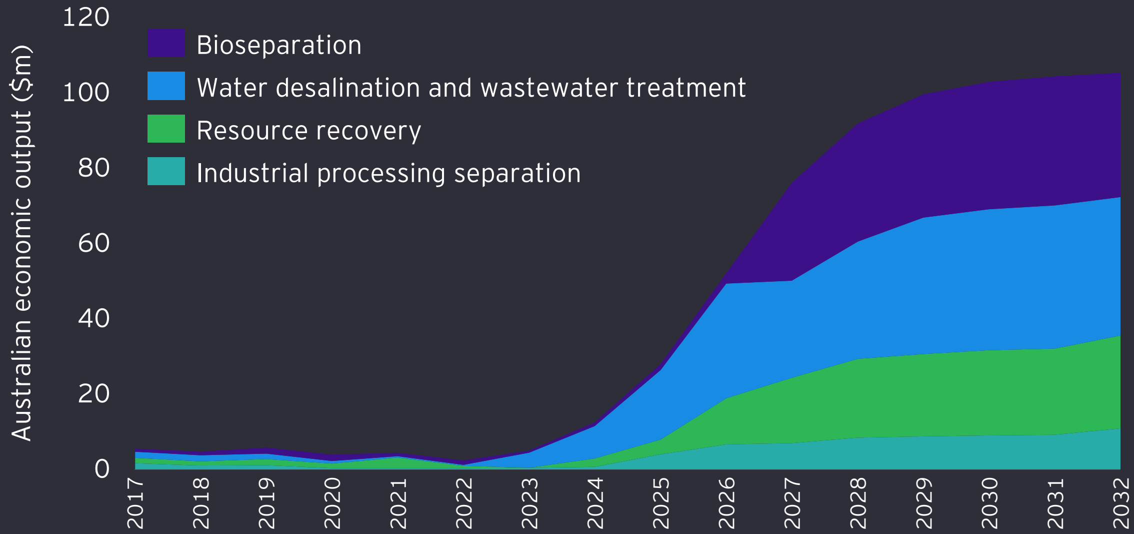
- The Hub's activities are expected to create 120 jobs by 2032. The developed technologies focus on making already existing tasks more efficient and productive – therefore not requiring a large workforce.
- Creating more effective, energy-efficient systems may not create a lot of jobs, however the jobs in these fields will see significant pay rises as a result of this productivity increase. This is seen through Australia's national income increasing by around $670 million over the decade.
- The Hub's projects are also expected to generate an additional $280 million in investment from industry, government and universities by 2032.
- The indicative return on investment under the core scenario of 4.5 : 1 closely aligns with research from Universities Australia on the gains from collaboration between universities and industry.*

The Hub's impact by 2032

120	$280m	$670m	8:1
additional employees	additional investment	additional income	return on investment

Breaking down the economic benefits from the Hub shows which research area is likely to make the greatest contribution to the Australian economy, and when this is likely to happen.

Water and waste projects will provide the greatest economic benefits of all research areas the earliest, with bioseparation projects coming in with force in five years time



The 10-year economic payoffs could be...

Bioseparation	$200 million
Water desalination and wastewater treatment	$160 million
Resource recovery	$275 million
Industrial processing separation	$70 million

**Source: Universities Australia 2020*

EY

The Hub has targeted Australia’s economic priorities

The Hub’s innovation agenda aligns with some major national priorities.

Supporting Australia’s energy transformation

Australia’s energy market is undergoing major change, and improving energy efficiency and lowering emissions intensity is now an urgent priority. Technologies developed through the Hub focus on reducing energy used in manufacturing and emissions intensive industrial activities.

Building sovereign manufacturing capabilities

The Hub has developed technologies which are made locally. This is also significant potential for future growth in making advanced materials. This aligns with Australia’s strategy to develop and build up local manufacturing, especially in critical technologies like pharmaceuticals and resource extraction.

- Manufacturing the membranes developed as part of the Hub will be an important step to furthering Australia’s domestic manufacturing base.
- This will also see exports increase as Australia increases manufacturing in high-end niche technologies.

Embedding the circular economy

Australia continues to look into discovering better ways to recycle and retrieve resources from renewable sources. Innovations made through the Hub have unlocked value in waste materials, streamlined industry production lines and prevented unnecessary wastage.

In a climate where energy-efficiency is at the forefront of government initiatives, the Hub has unlocked energy-efficient processes in emissions intensive industries

The impact of changing government priorities and COVID-19 was unprecedented. It caused a change in industry behaviour, as industry was forced to find local ways to undertake their everyday operations, as well as lower their emissions.

As industry emerges from the impacts of COVID-19, the Hub has responded to innovate new technologies focussing on some important development drivers:

- **Technology and advanced manufacturing** – Embracing new technologies and innovations to accelerate growth, maximise local content and manufacturing capabilities and enhance operational resilience to future market disruptions.
- **Reskilling talent** – Upskilling workers secures future opportunities and helps businesses to adapt to new business models.
- **Responsible business** – Circular business models coupled with sustainable sourcing to adapt to government requirements and progressive standards.
- **Market expansion** – Competing effectively against other leading exporting nations for a greater ‘share of wallet’ globally and locally.

Appendices

Technology readiness levels

TRL1
Basic research
Initial research and discovery

TRL2
Applied research
Initial practical applications identified

TRL3
Critical function
Early development stage, proof of concept

TRL4
Isolated laboratory testing
Design, development and lab testing of components

TRL5
Laboratory system testing
Process validation in relevant environment

TRL6
Prototype system verified
Prototype demonstration in relevant environment

TRL7
Integrated pilot system demonstrated
Process demonstrated in an operational environment

TRL8
System incorporated in commercial design
Pre-commercial demonstration

TRL9
System proven/ready for commercial development
System is ready for full commercial deployment

The development of the technology readiness level (TRL)

- The technology readiness level (TRL) is an assessment matrix developed by NASA in the 1970s to measure the process of technology development, from initial research to final viable product.
- Assessing technology maturity is central to judging project progress and success, and accurately estimating project timeframes.
- Each TRL stage is a concrete milestone in technology development that indicates research value and output.

Applying the TRL to the Hub

The TRL matrix can be effectively used in assessing Hub projects as the Hub focuses on developing separation technology for commercial application.

The Hub's research projects

Project	Research area	Description
IH17.5	Bioseparation	Purifying bioactive nanoparticles from fruit to be used in medicine
IH17.11	Bioseparation	Modifying nanobodies for medical applications
IH17.20	Bioseparation	Efficient virus filtration from plasma-based protein solutions using membranes
IH17.21	Bioseparation	Reusable and recyclable membranes for protein purification
IH17.27	Bioseparation	Membrane absorbers for virus filtration
IH17.28	Bioseparation	Separating and reusing bioproducts from plasma
IH17.29	Bioseparation	Purification of plasma using membranes
IH17.2	Water desalination and wastewater treatment	Chemical resistant membrane for water desalination and purification to increase fresh water supplies
IH17.8	Water desalination and wastewater treatment	Recycling and reusing wastewater in the steel industry
IH17.9	Water desalination and wastewater treatment	Floating device for water purification in river ecosystems
IH17.15	Water desalination and wastewater treatment	Deployable water treatment plants for remote communities
IH17.17	Water desalination and wastewater treatment	Identifying effective stormwater treatment processes
IH17.23	Water desalination and wastewater treatment	Higher quality water reuse using energy-efficient membranes
IH17.26	Water desalination and wastewater treatment	Energy-efficient management of high water quality for recycling wastewater
OXFAM	Water desalination and wastewater treatment	Small water desalination machines for remote communities
IH17.3	Resource recovery	Extracting minerals from salt lakes
IH17.6	Resource recovery	Extracting uranium from seawater used for nuclear medicine
IH17.14	Resource recovery	Developing and reconstructing natural zeolites for various industrial applications
IH17.19	Resource recovery	Recycling scrap tyres to turn bio-oil into transport fuel
IH17.24	Resource recovery	Resource recovery from wastewater
Lithium recovery	Resource recovery	Extracting lithium from brine rock at a higher rate
IH17.7	Industrial processing separation	Dehumidifying natural coal seam gas using membranes
IH17.12	Industrial processing separation	Reducing metal poisoning caused during gasoline production and extracting valuable materials from fly-ash waste
IH17.13	Industrial processing separation	Developing low cost lubricant admixture to decrease the size of air bubbles in cement manufacturing
IH17.18	Industrial processing separation	Gas separation with novel molecular sieving membranes

Modelling the economic impact of the Hub

Modelling inputs

- Evaluating the economic impact of the Hub was based on information provided by the Hub, including:
  - funding from the ARC, industry and university partners
  - numbers of employees, students (and students who completed their PhDs) and visitors
  - community briefings, talks, conferences, workshops and international visits
  - research outputs including journal publications, number of citations, media commentary, IP patents and licences.
- To inform analysis of potential future impacts, consultations were undertaken with the Hub's partners and key stakeholders. Consultations focused on identifying where research and collaboration has been successful, the key barriers to commercialising energy-efficient separation technologies, the major applications for these technologies, and how the Hub has advanced important areas of research.
- Industry partners and research partners discussed their views on the Hub, how it benefited their research, how their technology works, who it will benefit, and when they expect the technology to be commercialised.
- Research on the potential applications and productivity uplifts from the various technologies was also conducted.

Developing the scenarios

- Two scenarios were developed to assess the Hub's economic impact. Both scenarios captured key elements of the potential future impact of the cost savings, commercial gains, productivity diffusion, and the extent to which respective industries will be impacted by the Hub's developed technologies.
- The potential economic impacts were examined on a project-by-project basis, applying a multi-criteria analytical framework to determine an 'economic impact factor' for each project. The evaluation considered each project's commercial prospects, potential productivity benefits, capability of furthering research and spillover benefits to other industries.
  - The analysis evaluated independent economic impact factors for each project across the two scenarios.
  - The potential industries benefiting from the Hub were also examined on a project-by-project basis.
- The **core economic impact pathway** demonstrates a relatively conservative and practical 10-year pathway for the translation and commercialisation of Hub's research activities.
- The **maximum commercialisation scenario** reflects an upper range of potential commercial and economic payoffs from research activities. It represents an optimistic outcome that could occur under ideal conditions.
- The expected time to commercialise the technologies and the funding received for each project is consistent across the scenarios.

Economic impact assessment

- Applying the TRL for each project, the time to commercialisation, scaled up productivity benefits and a commercial output uplift were evaluated. This applied an S-shaped uptake curve which reflects the gradual diffusion and adoption of new technologies. The uplift factors for each project are based on:
  - The economic impact factor.
  - The scale of funding for the Hub, by industry, as a percentage of the entire industry. This value has determined how much of each industry adopts the technology and is consistent across both the scenarios.
  - Estimated direct productivity benefits and commercial prospects from each project. These were based on direct consultations and project information, and progress updates provided by the Hub.
- These uplift factors were used as inputs into a whole-of-economy model to estimate the potential impact on the Australian economy. More information about EY's CGE model is on page 31.

Our analytical framework

Economic levers

Completed individually for each research area

Research agenda

Purpose and objectives of each research area

- Bioseparation
- Water and wastewater treatment
- Resource recovery
- Industrial processing separation

Research investment and activities

Scale, timing and composition of research activities over the five years of the Hub

- Investments/funding
- People involved / researchers / staff / project partners
- Size of the Hub
- Expenditure
- Conferences / talks / briefings
- Research outputs (journal publications, media, patents, citations, conferences)

Obtained from the Hub

Industry impact

Research prioritisation
The economic impact factor

- Commercial translation and market penetration (opportunity)
- Timing
- Scalability
- Novel products
- Technology readiness level (TRL)

Spillovers

Cost and energy savings and competitiveness in flow on applications

- Research ecosystem
- Industry / university collaboration
- International linkages
- Flow on applications:
  - Commercial / industrial
  - Basic science

Obtained during consultations

Modelling the impacts

Stratified and aggregated by research area

Scenarios

- **Prospectively:** Map the ‘possibility space’, including likely and upside outcomes
- **Uncertainty:** Alternative roadmap and investment scenarios

The CGE model

- EY’s whole of economy model
- Isolate sectors of focus
- Consistent assumptions, tested with DISER

More detail on our CGE model is on the next slide

The impacts

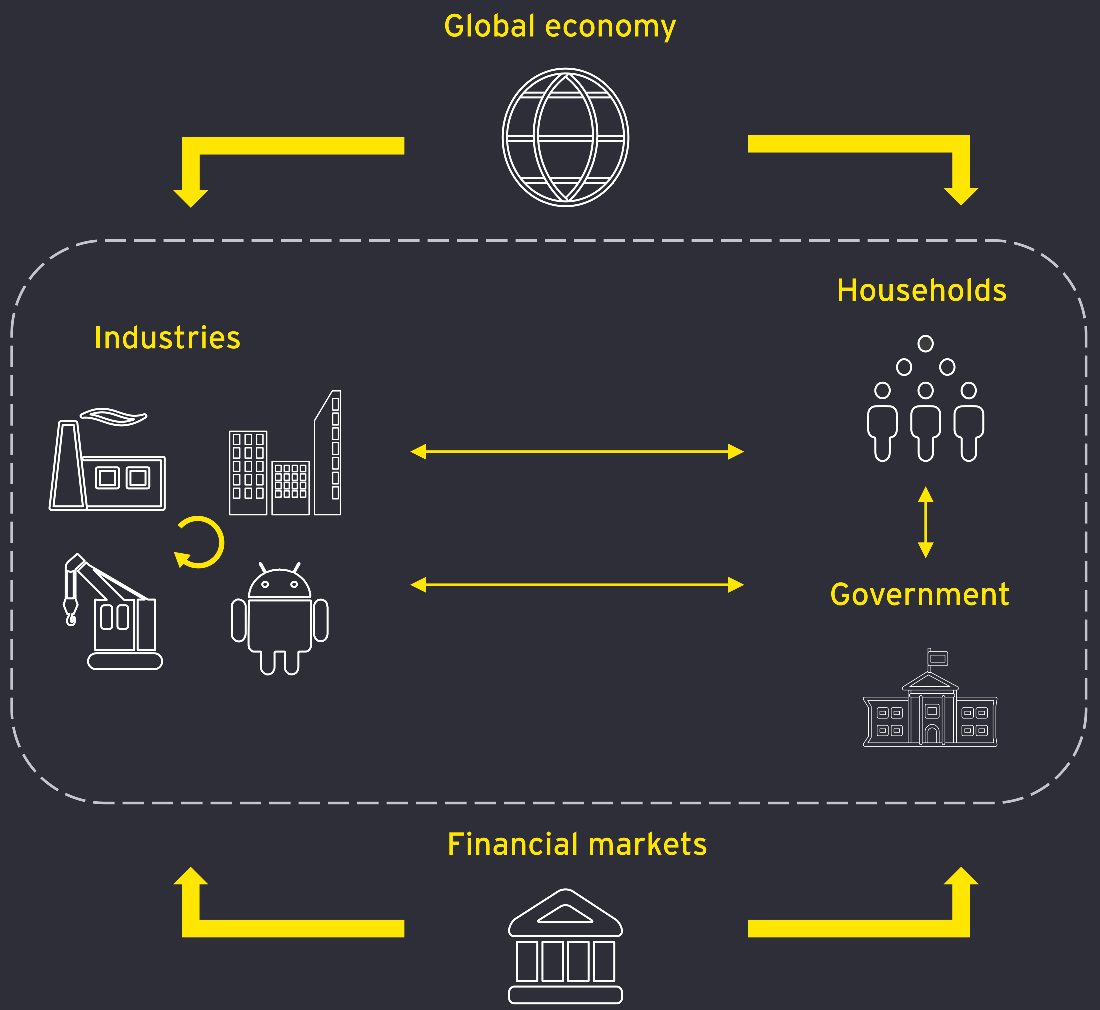
- Decomposed picture of the economy
- Impacts reported by research area, sectors and whole Australian economy

Our CGE model

EYGEM is EY's in-house, state of the art Computable General Equilibrium (CGE) model. It is a large scale, dynamic, multi-region, multi-commodity model of the world economy.

The model provides a rich and realistic representation of how changes in one part of the economy flow through to other parts.

- **Comprehensive regional analysis** – The model contains 141 distinct regions, with the ability to disaggregate these into sub-national regions for highly granular economic analysis.
- **Rich sectoral detail** – All sectors of the economy are integrated into the model, with 65 discrete sectors. These can be further refined for specific industries.
- **Time dynamics** – Solving year-on-year over a flexible periods, the model can assess short term policy initiatives and decades-long reforms or investments.
- **Market tested and strong academic foundations** - A model has a lineage that has been applied globally across the public and private sector.



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