NZIER
NEW ZEALAND INSTITUTE OF ECONOMIC RESEARCH

Assessing the commercial and social value of the SfTI Challenge

NZIER report to the Science for Technological Innovation (SfTI) National Science Challenge

June 2024

About NZIER

New Zealand Institute of Economic Research (NZIER) is an independent, not-for-profit economic consultancy that has been informing and encouraging debate on issues affecting Aotearoa New Zealand, for more than 65 years.

Our core values of independence and promoting better outcomes for all New Zealanders are the driving force behind why we exist and how we work today. Our purpose is to help our clients and members make better business and policy decisions and to provide valuable insights and leadership on important public issues affecting our future.

We are unique in that we reinvest our returns into public good research for the betterment of Aotearoa New Zealand.

Our expert team are based in Auckland and Wellington and operates across all sectors in the New Zealand economy and combine their sector knowledge with the application of robust economic logic, models and data and understanding of the linkages between government and business to help our clients and tackle complex issues.

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The assistance of Sarah Spring is gratefully acknowledged.

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Key points

We reviewed a selection of projects from an economic perspective

The Science for Technological Innovation (SfTI) National Science Challenge was one of 11 Challenges created to address wicked problems facing Aotearoa New Zealand, by using mission-led research and innovation practices. SfTI has been a 10-year (2014–2024) science investment with a mission to enhance the capacity of Aotearoa New Zealand to use physical sciences and engineering for economic growth and prosperity.

SfTI selected a small set of projects that are farthest along the development and commercialisation process, and NZIER assessed them for economic impact. We used a framework we first developed over 10 years ago that guides our thinking about the multiple pathways to impact for science and innovation.

SfTI has invested $106 million into a high-tech research portfolio of over 100 projects, big and small, and the capacity of more than 700 researchers here in Aotearoa New Zealand. SfTI events have catalysed thousands of personal connections that bridge the gap between skilled scientists and the people they ultimately want to help.

The Challenge has gathered evidence of a step change in how high-tech science is done here in Aotearoa New Zealand. It has also seen growth in genuine collaboration with Māori, industry and potential users.

The SfTI Challenge has potentially created hundreds of millions of dollars of economic value

We reviewed a set of innovations supported by SfTI. They are at different stages of commercialisation, so their market values cannot be determined by sales volumes, prices and share values. However, by considering the markets and problems targeted and the business strategies employed, we can estimate a rough potential economic value for them.[1] Our approach is demand-centric – what is the value of the problem? – rather than just supply-focused – what product have we made?

Across the innovations we evaluated, we found:

- The markets targeted by these innovations are worth from a hundred million New Zealand dollars per year (crowns for dental caries) up to a hundred billion dollars per year (the market for lithium-ion batteries).
- Considering the products under development and the business strategies we heard, each project looks to have an annual potential revenue for the Aotearoa New Zealand economy in the millions to tens of millions of dollars, and some have significant upside potentially into the hundreds of millions of dollars.
- Specific approaches taken by firms will determine the value to the country. For example, where firms are located and who they sell to will generate different value

1 These estimates should in no way be considered economic or financial valuations, or predictions of the future performance of any products, companies or investments.

capture possibilities. Scale, distance to markets, competitor reaction, patentability and other specific business issues will be factors in the choices companies make.

It's hard to measure the economic impact of early-stage research. There is still so much we don't know about how the tech developed with SfTI support will impact our lives in the future.

There are some things we do know:

- The projected revenue of just one SfTI-funded technology close to commercialisation could pay off the initial $106 million investment in 10 years
- This is only one of over 100 SfTI projects, all with technological discoveries at different stages of development
- Tech funded by SfTI was recently in orbit on the International Space Station – so a demanding supply chain has validated it
- SfTI-nurtured start-ups developing innovations for the global aquaculture markets have their sights set on revenues in the millions
- Health sector start-ups built on SfTI-funded work are looking to improve access to healthcare with a potential impact in the hundreds of millions of dollars.

All this doesn't account for the value of the talent nurtured here in Aotearoa New Zealand's Innovation system. Calculating this accurately is impossible – but the benefits for Aotearoa New Zealand are potentially significant, because the ability to develop high-tech businesses successfully is built on its people.

NZIER has estimated that the SfTI Challenge's work examined in this paper could contribute a minimum economic value of over $300 million per annum within 10 years. This is currently half the size of the ICT sector in New Zealand. The table below provides some detail.

Table 1 Summary of potential impacts

Entity	Potential size (pa)	Market growth	Spillovers	Companies like this
Health sector focused entities				
Snow Cap Crowns	Tens of millions	5 percent (USA)	Potential benefits in oral health over the life-course	BBC Technologies, focus on new technologies in expanding markets
Toku Eyes	Tens of millions	4 percent (USA)	Very large health system benefits	Orion health, focused on improving efficiency and effectiveness of health outcomes
Tautoko Tech (MedTech)	Tens of millions	7 percent (USA)	Self-management reducing health system burden	Aroa Biosurgery, finding a niche in a fast-growing health market
Environmentally focused entities				
Armada Sensing (Nitrate Sensors)	Millions	Not known	Gain insights into nitrate leaching	Compac, measures the impact of activities of real interest to business and society
Tonalli Moana (Algal Bloom Biosensors)	Tens of millions	10 percent	Real time measurement	M-Com, the potential to be a highly successful niche player
Aquaculture focused entities				
Autonomous Underwater vehicles	Millions	15 percent	Enhancement of a growing aquaculture industry	Phitek Ltd, niche player enabling other companies improve their offering
Ocean Intelligence	Millions	15 percent	Enabling offshore farms	Starboard Maritime Intelligence, niche player enabling other companies to improve their offering
Manufacturing focused entities				
Tasmanion Ltd (Aluminium-ion Batteries)	Millions	10 percent	Generating research activity, more high paid science jobs	Nyriad, providing a new way of doing things with major advantages
Spherelose Ltd (Cellulose-based surfactants)	Hundreds of millions	5 percent	Developing environmentally friendly products	NZ Pharmaceuticals, providing high value intermediates and ingredients
Forestry Surveying Robots	Millions	Could quadruple in size within 10 years	Potential applications in other areas is high	WhereScape, working to improve productivity and reduce risk
Protein Nanosatellites	Millions	8 percent per annum	Expands the demand for high skilled labour	Aroa Biosurgery, produces high quality products meeting strictest standards

Source: NZIER, Callaghan Innovation 2019

SfTI is working in growth markets and solving big problems

The economic value of a technology is not due just to some clever bit of science. It also depends on the importance of the problem being solved. That is, we have to consider both supply and demand when assessing value.

By targeting markets with higher rates of growth and considering the importance of problems being addressed, SfTI ensured that its support would tend to have larger impacts. This important information is also provided in Table 1 and formed part of our judgment about the value of these innovations.

SfTI combined direction and flexibility in managing innovation

Mission-led innovation needs to balance two competing drivers. It needs to stay focused on the mission, which provides direction for research. It also needs to include flexibility to avoid being locked into research that isn't working. Our assessment found that SfTI provided researchers freedom to pursue their research but also worked to bring them to a focus on creating products and commercial innovations. SfTI worked to connect research and researchers into markets earlier than business-as-usual science and nurtured continued collaboration between researchers and users of technology.

This focus on impact is a feature of mission-led innovation systems, and SfTI implemented it well.

SfTI helped develop technology while creating a portfolio with spillovers

The mission-led research literature is clear about the uncertainty involved with achieving missions. There can be several competing approaches to solving a problem, but some of them may not work. It is important to remain somewhat agnostic about technologies and support several approaches until success is clear. In addition, deep-dives into innovation in Aotearoa New Zealand have shown the value of spill-ins and spillovers: the wider impacts of new knowledge beyond the specific application in a particular research programme.

We found that SfTI strategically supported a range of technologies, applications, and teams. This approach increases the probability that the portfolio will include successful technological innovations and raises the potential for spillover impacts from research.

The range of technologies supported by SfTI has been a strength of the Challenge

The following Table sets out the technologies looked at in this paper.

Table 2 The diversity of projects is a strength

Research entity	Area of research	Comment
Snow Cap Crowns: Drill-free plastic crowns	Dental health	Anticipate spin out and capital raise in 2024
Toku Eyes	Eye examinations	Company formed; Series A raised. Technology being rolled out in the United States
Armada Sensing Ltd: Nitrate Sensors	Measuring nitrate leaching in waterways	Company formed – pre-revenue
Autonomous Underwater Vehicles	Open ocean aquaculture farm management	In the Sprout Accelerator
TasmanIon: Aluminium-ion Batteries	Battery market	Company formed – pre-revenue
Tonalli Moana: Algal Bloom Biosensors	Food safety – initially an aquaculture emphasis	Considering KiwiNet Spin-out Programme. Anticipate spin out and capital raise in 2024
Spherelose: Cellulose-based surfactants	Emulsification and wetting agents – FMCG applications	In Ministry of Awesome Founder Catalyst cohort. Anticipate spin out and capital raise in 2024
Tautoko Tech: Disruptive MedTech Leaps	Personalised medicine – Insulin pump with wrap-around support	In Ministry of Awesome Founder Catalyst cohort. Anticipate spin out and capital raise in 2024
Forest Robots	Forestry clearing	Anticipating Joint Venture late 2024/2025 with licensing deals
Ocean Intelligence	Aquaculture – informed data driven farm management	Company formed – pre revenue. Anticipate capital raise in 2024.
Protein Nanosatellites	Manufacturing in space for health applications	Currently in WNT Tech-incubator; Anticipate spin out and capital raise in 2024

Source: NZIER

Caveats

We must stress that there are limitations in the analysis due to the information available on different aspects of each project. The robustness of the analysis is influenced by the potential bias in the information provided.

It should be recognised that there is nothing certain about innovation, even for those companies that are more advanced in their commercial ambitions. In fact, from the interviews, it is those companies that are more advanced in their commercial ambitions that have the most realistic understanding of the challenges they face. This is because they are aware of the fine details of the markets they are confronted with and the challenges they need to overcome.

Figure 1 Summary of SfTI Challenge projects examined by NZIER

Source: SfTI challenge

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1 Introduction and scope

The Science for Technological Innovation (SfTI) National Science Challenge was one of 11 Challenges created to address wicked problems facing Aotearoa New Zealand by using mission-led research and innovation practices (Ooi and Husted 2022; Gluckman 2015; Ministry of Business, Innovation & Employment 2013). SfTI has been a 10-year (2014-2024) science investment with a mission to enhance the capacity of Aotearoa New Zealand to use physical sciences and engineering for economic growth and prosperity (Ministry of Business, Innovation & Employment 2018).

SfTI has invested $106 million into a high-tech research portfolio of over 100 projects, big and small, and into the capacity of more than 700 researchers here in Aotearoa. SfTI events have catalysed thousands of personal connections that bridge the gap between skilled scientists and the people they ultimately want to help.

NZIER has estimated the potential social and economic benefit of 11 projects that are in varying stages of market development. SfTI selected this small set of projects that are farthest along the development and commercialisation process. To do the analysis, we used a framework we first developed over 10 years ago that guides our thinking about the multiple ways science and innovation have economic and social impact.

We have focused on describing the technologies, briefly reflecting on the market drivers, and giving tentative indications of the possible contribution of the research-focused entities being funded and the potential wider contributions of successful product launches.

Some are in the early commercial stages. These include Toku Eyes, Armada Sensing, and Tasmanion. Other projects are further back in the pipeline at a pre-incubation or pre-spinning out stage.

It should be recognised that there is nothing certain about innovation, even for those companies that are more advanced in their commercial ambitions. In fact, from the interviews, it is those companies that are more advanced in their commercial ambitions that have the most realistic understanding of the challenges they face. This is because they are aware of the fine details of the markets they are confronted with and the challenges they need to overcome.

While there are sometimes broad indications of the 'direction of travel' and ways of systematically going about R&D programmes (see Mazzucato 2018), the precise pathway of the advances is elusive.

It is the uncertainty of science and technology that drives the challenge of investment. Uncertainty can come in different forms:

- How the scientific endeavour is applied to a specific industry or other parts of an economy, e.g. the AI programme developed by Toku Eyes may have other applications. Also, the ability to predict lifestyle diseases could have major implications for health systems around the world.
- The components of a system and how they interact are well known, but outcomes cannot be known at the beginning of a programme of R&D work, e.g. the aquaculture research applications Ocean Intelligence and Autonomous Underwater Vehicles are

aimed at enabling aquaculture farms. What the shape of those farms will look like in the open ocean is unknown.

- Whether outcomes are practically achievable: can issues such as technological constraints, reliability and consistency, and response times be overcome? It is not yet clear whether Protein Nanosatellites can establish a consistent supply chain that allows regular access to the space environment. If this can be achieved, then producing a consistent high-quality product is possible.
- Technological opportunities across fields and eras have a major impact on the pathway of technological progress. And, of course, we do not know what technologies will pay off. The 11 projects examined are all in markets growing above 4 percent. There has been a deliberate strategy by researchers and the Challenge to focus on high-growth markets, maximising the chances of successful commercialisation.

It is for these reasons that support from the government is generally forthcoming. The government wants to encourage and nurture investment in a spread of uncertain activities since the payoffs do not just accrue to those involved in the work but spill over to society (Ministry of Business, Innovation & Employment 2013).

There is, however, a balance required. Researchers need time to invent and refine their innovation with no specific goal or product in mind. But there is a time when these innovations need to be 'hot housed' to further understand if commercialisation is possible. The aim of the Science for Technological Innovation Challenge was to intervene to assist and mentor 'the coalition of the willing' along the journey of commercialisation.[2]

From an individual business perspective, having the right business model is just as important as having a unique product offering that is being developed. From a national perspective, having a portfolio of science investments and providing the right incentives and skills at the right time increases the chances of a payoff from public money invested (Ministry of Business, Innovation & Employment 2018; 2013; Foray, Mowery, and Nelson 2012).

It could also be that these projects stimulate ideas in other sectors or spur competitors to provide better products that benefit New Zealand society. The idea that technology is dynamic and new products force a reaction in competitive markets is not always appreciated by economists, scientists and policy makers.

1.1 A mission-led approach

SfTI has nurtured teams of researchers connecting research to its market earlier and driven a continued collaboration with those who have commercialisation experience. The aim has been to create innovation geared to have impact. The portfolio (see the following figure) has been based on four themes:

- Vision Mātauranga guides researchers on how science and mātauranga Māori interface to develop research and development solutions for a prosperous, technology-driven economy.

[2] Rew Ake Is one of the workshops which assists early stage researchers and should be done early in the programme (see https://kiwinet.org.nz/Events/RewaAkeEndUserDiscovery)

- Sensors, robotics, and automation aim to develop robotics and automation for use in a range of products and applications. The focus is on cost reduction, improved efficiencies and safety.
- Data science and digital technologies aim to develop innovative algorithms, models, methods, tools and practices that could underpin new or enhanced business processes, hardware, systems, and software
- Materials, manufacturing technology and design aim to advance the sector's reputation as a leader in smart, green manufacturing processes and materials.

Figure 2 SfTI projects at a glance

Notes (1) EWIPS – ending with impact projects. Seven of these projects (EWIPS) came out of the Spearhead projects.

Source: Science for Technology Innovation Challenge

1.2 Mission-led work requires nurturing

SfTI recognises that bringing innovation to the market requires skills completely different from product/service innovation in the lab. Bringing an innovation to the market is a struggle. Rather than 'leaving them to it' or letting 'a thousand ideas bloom', budding entrepreneurs require a raft of interventions to navigate their way through potential pitfalls. This includes the pathway beyond SfTI into the various incubators.

New firms do not have one thing they need to do to succeed; there tends to be a whole range of complex problems they need to solve before they are initially successful. To navigate these issues requires a whole range of new skills which they need to learn.

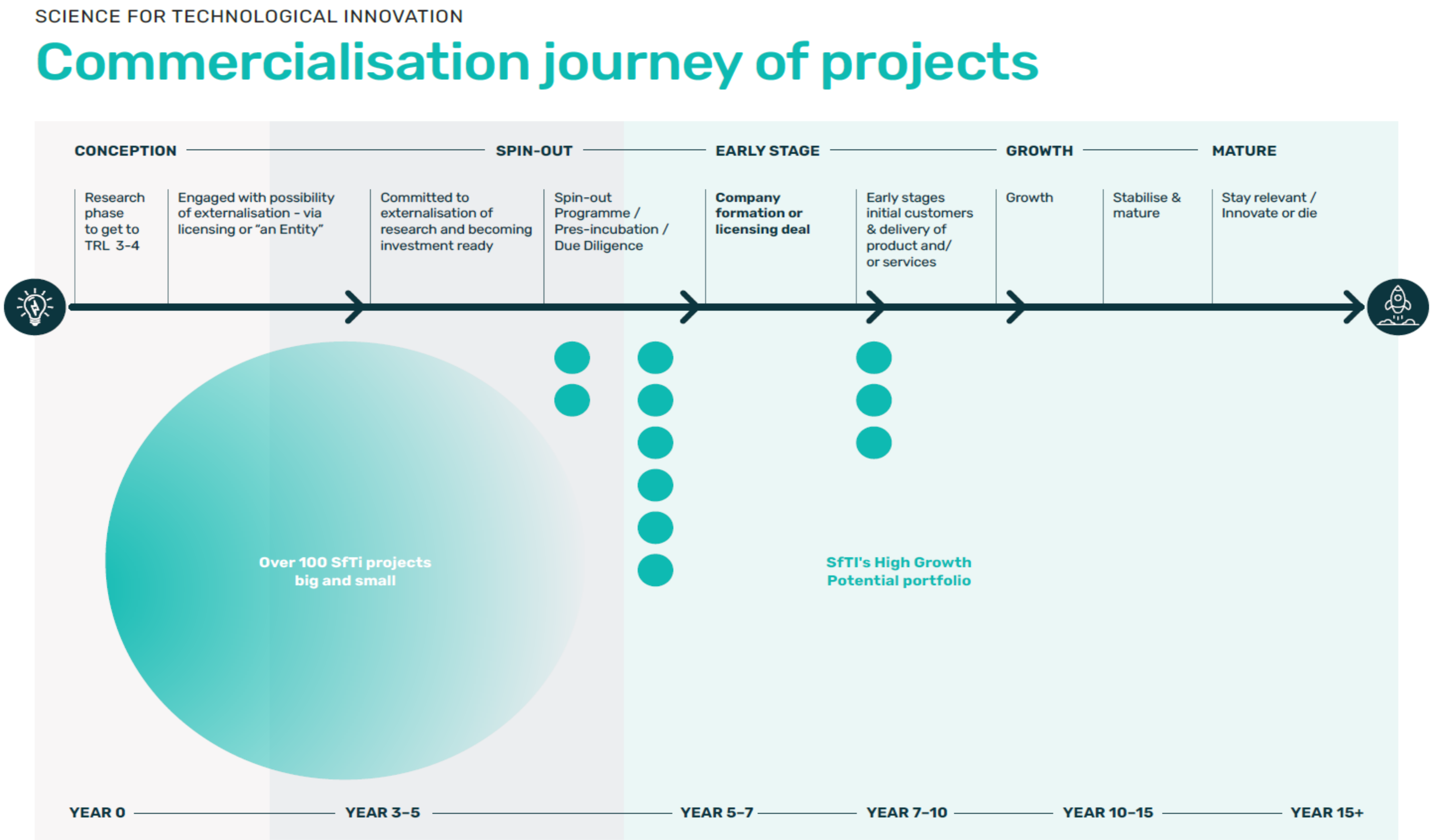
Nurturing a broad range of research projects (a portfolio approach) and intervening at a critical time in the product or service development stage may be the most important legacy of the SfTI Challenge. Important to this process is having the wrap-around services that encourage a sharper focus on commercialisation:

- General business coaching and mentoring:
  - Coaching tends to focus on the immediate issues in front of the entrepreneur. Coaches can provide specific tactics and strategies that maximise the chances of short-term success
  - A mentor's job in SfTI was to share their experience, knowledge, and wisdom with the entrepreneur to help them grow and advance in their career. This can be an enduring role, based on trust and guidance over time.
- Developing a workable business plan that examines the target market in depth. A mentor or coach can be invaluable to an entrepreneur since they can provide guidance that points to where information/market data can be obtained and what the entrepreneur should be looking for
- Providing the tools necessary to deal with the practical challenges that they will face. Having the right tools to meet the challenges can be difficult. An entrepreneur may not know where to start. By utilising SfTI resources and courses, making use of information provided by coaches and mentors, and learning from other innovators, SfTI have crafted a structured approach that pushes entrepreneurs out of their comfort zone to address the challenges they have to be commercially successful.

The following diagram sets out the progression of the whole SfTI programme in various stages from conception to maturity. Since success is not guaranteed at any stage, fledgling firms are offered by SfTI a Capacity Development (professional development) Programme to support them in taking their careers to the next level.

The focus is to support researchers in building their human (soft skills) and relational (networking) capacities. The goal is to improve connections between researchers, Māori and industry so that science is not left 'stranded in the lab'.

Figure 3 Commercialisation journey of projects



Source: SfTI Challenge

2 Approach taken

2.1 Framework development

To arrive at the expected value the NZIER used Figure 5 (see Appendix A) to assess the potential for the 11 projects examined. This included understanding:

- The change that will take place if the objectives reach full commercialisation
- What resources would be used to create a successful commercialisation
- The partners required to make the project successful (particularly in the supply chain)
- How adoption would take place. Would the market be receptive to the innovation.

Many of the innovations were in growth markets. If the potential is realised, then success is likely to be of significant value. Further the SfTI Challenge coached and mentored its entrepreneurs in a way to maximise the chances of success. When we made our calculations, we considered the following equation:

Probability of success (potential is high and maximised by SfTI) multiplied by value (in a high growth market) all multiplied by the new situation with the technology minus the situation without the technology.

Innovation operates in many different ways in the economy. It can reduce costs by changing inputs or process. It can increase revenues by reaching new markets or new consumer segments. It can create whole new products that solve 'pain points' – a customer's problems – in new ways. It can also create social or environmental value through non-market impacts (spillovers). Our framework reviews the 11 SfTI innovations as a package providing a full picture of their economic potential.

2.2 Evaluation process

The evaluation aims to understand further the progress that the Challenge has made and how the entities are progressing. We:

- Examined the business cases, proposals, and literature on the target markets
- Developed a semi-structured questionnaire to engage with selected interviewees
- Engaged with the initial set of participants and stakeholders where necessary.

The written material and briefs on the Business Cases yielded the most information, and interviews supplemented the approach. The approach was not designed with any statistical method in mind. Instead, the aim was to read the material submitted and to paint a picture of progress to date. We were interested in and focused on:

- The strategic intent, where they think they are going and how they will get there
- What was achieved and the challenges faced around the research, marketing, processing and any other issues
- The specific challenges and possible tensions. This included testing the awareness of the issues they may confront.

3 Discussion of economic impacts

Assessing the economic impacts of early-stage innovations is difficult. It can be challenging to understand the market or context for the innovation, and then the changes expected. An analysis could also consider the technological context of competitors and alternatives, as well as the business strategy. Before we move to a discussion of the economic value, we wanted to highlight a few of these issues.

3.1 The macro SfTI view

The SfTI Challenge has been a 10-year journey with a mission to enhance the capacity of Aotearoa-New Zealand to use physical sciences and engineering for economic growth and prosperity.

SfTI invested in two types of research projects - Seed and Spearhead projects. In the final two years of the Challenge, SfTI invested in high-impact spin-off projects from Spearhead projects (Ending with Impact Projects - EWIPS), plus Early Career Researchers from within projects with the potential to lead an extension to their existing work (Early Career Researcher 'Bolt-on' Projects).

The following Figure sets out the macro SfTI view at a glance.

3.2 The portfolio of projects gives the programme strength

Innovation, by its very nature, is uncertain. The question for the Challenge was what to invest in. This is not a trivial problem, and it is an issue that we have struggled with since New Zealand has been investing in science. We have thought about the issue in terms of a portfolio approach. Portfolio theory, pioneered by Markowitz (see Logue and Schepp 2023), describes how and why portfolio managers take on and reduce risk. Markowitz described the relationship between the expected return on investment portfolios and the risk of owning these portfolios and determined that investors hold a variety of assets within their portfolios with the aim of diversifying away as much risk as possible.

Applying this to an investment in scientific research that could be commercialised or create value in a cultural/social setting, we recognise the risks involved. Since we are uncertain about what will be successful, the aim is to spread the risks across a variety of research projects that meet certain criteria.

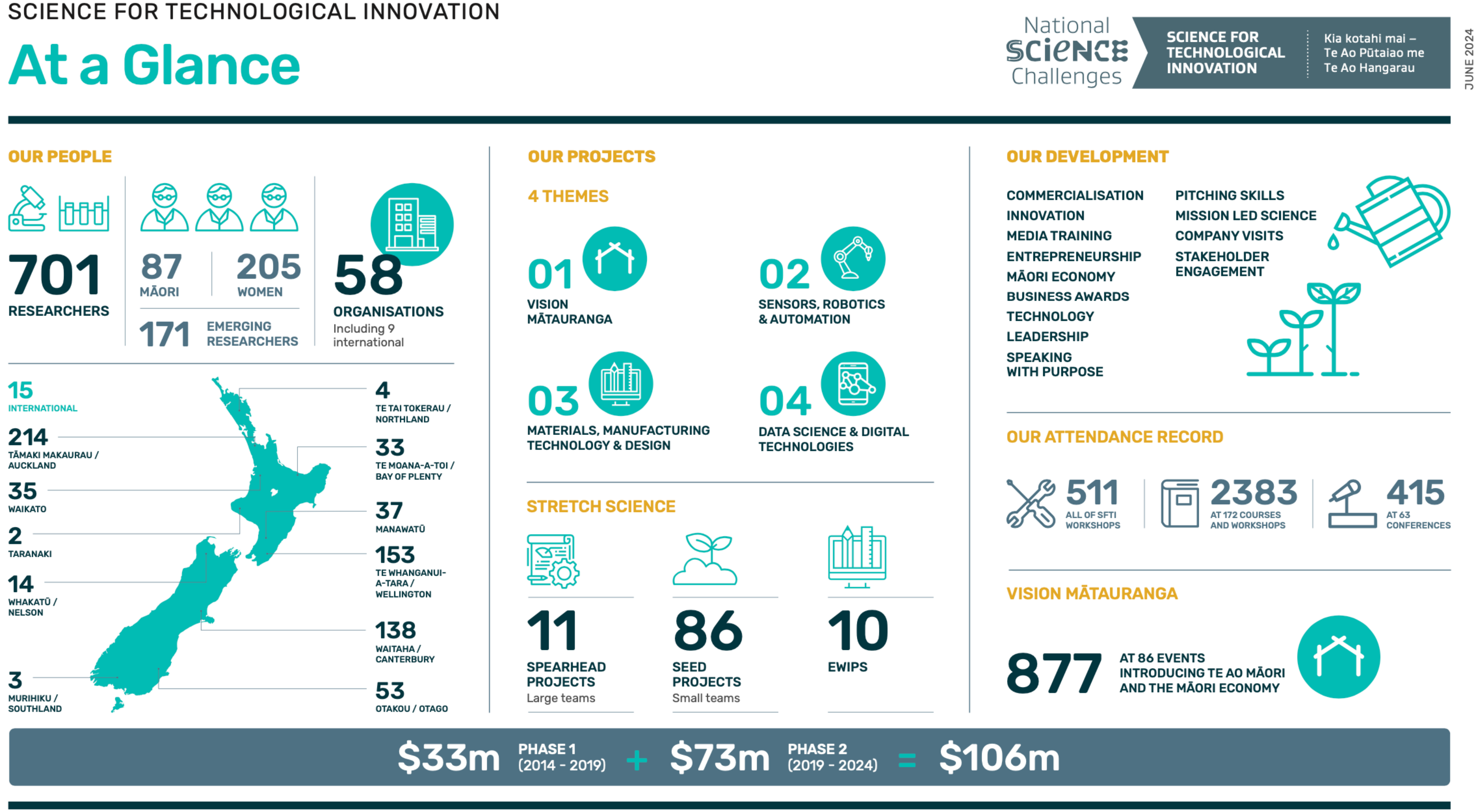
We would not pretend this was easy, but investing in different streams of work with different risk profiles, based on acknowledged areas of expertise, business relationships developed, and an understanding of where they could progress to commercialisation or create social/cultural value, will potentially maximise chances of success.

This is akin to the approach taken by Mazzucato (2018):

- going from picking winners to picking the willing
- attempting to co-shape markets
- welcoming experimentation
- a focus on quality science and the commercial/social offering.

The 11 projects examined all have some elements of these points.

Figure 4 Overview of SfTI activities



Source: SfTI Challenge *Does not include data from SfTI's final Capacity Development activities

3.3 Economic impacts versus financial benefits of innovation

As these innovations are commercialised, the owners and investors are looking at ways to create profitable businesses around them. They are looking for financial benefits. The prospectuses and investor slide decks explain how the innovations can be commercialised and turned into revenue, what the costs are, and how profitable they can be.

However, economic impact is different. Financial benefits – profits – are one type of economic benefit. Making products more accessible to a wider range of users, consumers, or patients is also a benefit. Reducing the burden of disease is a benefit. Improving environmental outcomes also provides benefits that can be valued economically. Even employment is an economic benefit, even though it is a cost from a financial perspective.

Where we have obtained figures for financial benefit, they should be considered an estimate of the minimum value of an innovation. Cost reductions or reduced harms can also be used to estimate economic impacts.

3.4 Impact of business models and strategies

In moving from an innovation to a commercialised product, a business has to decide on a business model and strategy. That is, the business is selling a product or service to a market and a consumer segment, possibly with the help of partners. For example, software can be sold as a product or as a service; software-as-a-service (SAAS) has made considerable advances as a business strategy in the past decade.

An innovation can be technically successful and beneficial but fail as a business. This is especially true if competitors are selling similar solutions to similar consumers. A different business model – a different package for consumers – might have more appeal.

Several innovations face risk due to the business model since one of the most difficult questions is how do I get paid for the service I have provided? When selling eye test services that detect life-threatening diseases and their precursors, it can be difficult, particularly since the customer/patient may not be aware that they need the (in some cases life-saving) service.

Failure also breeds resilience. To bridge the gap between science and creating a product that a customer will buy takes a lot of work. Ideas are one thing; creating value requires a whole set of skills that need to be worked at and developed. It requires being prepared to go down a 'large number of rabbit holes' that yield no value. This is true for the research process, the development of proof of concept, commercialisation, and the development of a business model plan. Coming through this process and succeeding is a triumph in itself.

3.5 Technology competition

People are buying solutions to their problems. They are technology-agnostic as long as the thing works, a feature of mission-oriented innovation stressed by Mazzucato (2022). It's important to look past the specific technology to the benefit being produced and consider how it might otherwise be delivered. For example, Autonomous Underwater Vehicles may be useful for aquaculture farms to view their farms and monitor performance. However, stationary sensors or sensors built into lines or structures might deliver the same benefits – knowledge and the ability to manage farms.

We have found, in our experience of studying innovation, that many innovations are competing with other technologies or approaches, which creates risks for them. We have even found that 'do nothing' might beat 'do something' if innovations are too expensive or problems are small or transitory.

3.6 Need for investment

Technology development requires investment money. More money can make investment easier and faster. Aotearoa New Zealand struggles with low levels of investment and consequently has low productivity growth and low uptake of technology. Innovations and companies outside of Aotearoa New Zealand may benefit from higher levels of investment and more interest in the commercialisation of innovations. Despite technical superiority, overseas innovations might succeed on the basis of better investment environments.

This is a particular problem when the economy is in recession.

3.7 Summary of impacts

In this section, we summarise our discussion of the innovations into a few elements that influence their economic value.

We have compiled some economic figures to create some understanding of the potential economic impacts of the innovations. These are not precise values, nor are they valuations. They are figures intended to give a sense of the scope or scale of the potential.

- ***Health sector focused entities***
  - **Snow Cap Crowns** – is a new way of providing dental care for one of the most chronic childhood diseases. It improves established technology without using injections or drilling. The initial market focus is on the United States, Australia and New Zealand. Projections are for revenues in the tens of millions in three years. This is an optimistic forecast sales projection for the United States, Australia and New Zealand. There is also some economic value attached to the potential to reach vulnerable populations.
  - **Toku Eyes** – with something around 100 million eye exams per year in the United States, the market there could be in the billions of dollars and Toku Eyes could capture tens or hundreds of millions of dollars in revenues. Alternatively, the value of avoided disease impacts is in the tens or hundreds of billions of dollars per year in the United States, so a diagnostic tool would have a value in the millions or tens of millions of dollars (Jordan et al. 2015). Likely revenues are thus in the tens of millions of dollars.
  - **Tautoko Tech (disruptive MedTech)**– the technology around personalising medicine is the future. The first intervention the researchers are focused on is a patch insulin pump with wrap-around support and education software. The researchers are in the early stages of commercialisation; however, the benefits go far beyond this company. More efficient and effective use of medicines will reduce visits to medical specialists, reduce the health spend, and improve the well-being of those around the patient.

- ***Environmentally focused entities***
  - Armada Sensing (nitrate sensors) – the biggest economic impact would be getting land uses and farming practices right for each location. Freshwater regulation in Aotearoa New Zealand may significantly constrain land use practices (Snelder et al. 2023). Therefore, the potential for use by farmers, regional government and other stakeholders is high. In this respect, the real-time sensors will provide a much greater understanding of the nitrate leaching problem.
  - Tonalli Moana –The business model for algal bloom biosensors is currently being developed. For aquaculture, the market could be in the hundreds of millions. The wider food safety market is in the billions. Once the test piloting is done this year, we will have a clearer understanding of the ability of the innovation to capture some of these markets. For scientific purposes or regulatory purposes, the potential gain is a more efficient food safety system since biosensors can react in real-time and are easy to use.
- ***Aquaculture focused entities***
  - **Autonomous underwater vehicles** – these will be an important management tool for New Zealand aquaculture. The sector has exports of hundreds of millions of dollars, and the government's strategy is to increase exports to $3 billion. Ocean farming has significant costs. These can be derisked by providing expected yields and quality/grades so the factories can be well prepared for processing what is to come off the farms, and farm harvests can be timed better to optimise factory throughput. This type of management tool could be worth millions to New Zealand.
  - **Ocean Intelligence** – the move from inshore farming to the open ocean will require data-driven solutions and on-farm sensors and provide dashboards that the industry can pick up and use to monitor farm conditions. The technology is still in its infancy and is still going through an iterative improvement process. Technology such as this will be required to drive open ocean farming, which is required to meet industry/government growth projections.
- ***Manufacturing focused entities***
  - **TasmanIon** – offers huge potential to play a significant role in the battery market. Aluminium-ion batteries can overcome significant issues seen in battery chemistries currently prevalent in the market. They are cheaper, more sustainable and safer. There is a market gap that AIBs can exploit as demand for batteries skyrockets. Commercialisation is in its early stages, but the signs are promising that this technology will be successful.
  - **Spherelose** – cellulose-based surfactants are a growth area because of their spreading and wetting properties. The market opportunity is built around replacing toxic surfactants with plant-based surfactants in many different industries (e.g. cosmetics, agricultural formulations and pharmaceutical formulations). While this is a highly competitive area, Spherelose Ltd – the company formed by the researchers – has developed a product with unique properties that have excited the market and put them ahead of the competition.
  - **Forestry Surveying Robots** – adds to the growing mechanisation of forestry production, making it safer and more efficient. Robotics in forestry is a huge challenge, given the unforgiving environment. Commercialisation is still some way

off, but the potential for use in New Zealand conditions is clear. The more autonomy a vehicle has, the less labour will be required. We are unclear what the value will be; the research team are working closely with the industry to overcome the challenges. From a national perspective, improving productivity by substituting capital for labour is a critical part of the puzzle that New Zealand needs to solve.

- **Protein Nanosatellites** – high-quality protein crystals grown in space are in high demand by pharmaceutical companies and government research institutes. This is an entirely new area for New Zealand researchers and has been driven by the reduction in the price of space payloads and the increased access to those payloads by paying customers. The market for crystals is in the billions and growing at a rapid 8 percent per annum. While the potential is uncertain, it does open up areas for research and commerce that previously did not exist outside government institutions in the United States.

Table 3 Summary of innovations and impacts I: Health sector focused entities

Based on information sources described in reports

	Snow Cap Crowns	Toku Eyes	Tautoko Tech
Change	White material for crowns	Disease detection with eye exams	Patient-based medicines
System impact	Minor	More disease diagnosed	Reduce costs with better use of medicines
Resource need	Minor	Minor (major for treatment)	Minor
Partners	Dental clinicians	Optometrists	Many
Dynamic considerations	Better acceptance of crowns	AI development – more uses	Competition in this area is growing
Market (annual)	Hundreds of millions	Billions	Unknown significant billions, 7% growth
Revenue	Tens of millions	Confidential – large potential	Unknown
Jobs	Under 20, Specialised jobs	20, Specialised jobs	Under 20, specialised jobs
Other benefits	Social – for disadvantaged children	Better disease management	Effective and efficient interventions
Risk	Business model – some risk	Business model -- some risk	Technology race
Cost impact	Lower cost for dentists, potentially lower cost to the economy if dental participation rates rise	Premium service, which is driving increased numbers of optometrists. Early detection will lead to lower costs for health systems in industrialised nations	New service that could potentially drive lower costs for the health system in terms of less contact time with health professionals and self-managed individual care

Notes (1) Risks can be associated with slow take-up of services/products, other competing business models taking different paths to market, and the chances of competing products either being first to market or with better performance. (2) Most entities are in their infancy, so it is difficult to forecast how many jobs they will create. However, most jobs are highly specialised. (3) Costs are examined in terms of service provision and overall impact on the economy.

Source: Multiple, NZIER

Table 4 Summary of innovations and impacts II: Environmentally focused entities

Based on information sources described in reports

	Armada Sensing (Nitrate Sensors)	Tonalli Moana (Algal Bloom Biosensors)
Change	Automated water sensors	Detect toxicity
System impact	More use of water monitoring	Unknown
Resource need	Need manufacturing	Minor
Partners	Possibly many	Unknown
Dynamic consideration	Regulations could increase use	Freshwater management implications?
Market (annual)	Hundreds of millions	Unknown
Revenue	Unknown	Unknown
Jobs	Under 20, Specialised	Under 20, Specialised
Other benefits	Improved environment	Improved environment
Risk	Technology race, lack of market	Business model, although no known competitor
Cost impact	Will drive lower cost of detection using sensor technology. Lower costs could increase numbers of users. Has a real-time impact which will have broad market appeal.	Use of biosensors to detect algal blooms for aquaculture reduces costs and time taken for results. A move into the much larger food safety market(s) could have a similar cost reduction

Notes (1) Risks can be associated with slow take-up of service/product, other competing business models taking different paths to market, and the chances of competing products either being first to market or with better performance. (2) Most entities are in their infancy, so it is difficult to forecast how many jobs they will create. However, most jobs are highly specialised. (3) Costs are examined in terms of service provision and overall impact on the economy.

Source: Multiple, NZIER

Table 5 Summary of innovations and impacts III: Aquaculture focused entities

Based on information sources described in reports

	Ocean Intelligence	Autonomous Underwater Vehicles
Change	Required to move the industry into the open ocean	Capital replacing labour in the open ocean
System impact	Enabling technology	Better information
Resource need	Minor	Need manufacturing
Partners	Aquaculture firms	Aquaculture firms
Dynamic consideration	Enables/supports open ocean objectives	Enables/supports adaptive management
Market (annual)	New Zealand-specific market size not known – aquaculture markets growing strongly (15% per annum)	Fraction of aquaculture exports, currently in the hundreds of millions
Revenue	Unknown	Unknown
Jobs	Under 20, specialised jobs	Specialised jobs. Unknown
Other benefits	More efficiency, greater workplace safety	Better environment, greater workplace safety
Risk	Technology race	Technology race
Cost impact	Increase investment in capital by farmers. Upfront costs will be mitigated by reduced costs over larger farming operations	Initial increase in costs for farmers. Allows them to substitute capital for labour over much bigger farms. Likely to drive down costs per unit sold overall

Notes (1) Risks can be associated with slow take-up of service/product, other competing business models taking different paths to market, and the chances of competing products either being first to market or with better performance. (2) Most entities are in their infancy, so it is difficult to forecast how many jobs they will create. However, most jobs are highly specialised. (3) Costs are examined in terms of service provision and overall impact on the economy.

Source: Multiple, NZIER

Table 6 Summary of innovations and impacts IV: Manufacturing-focused entities

Based on information sources described in reports

	Tasmanion (Aluminium-ion Batteries)	Protein Nanosatellites	Spherelose (Cellulose-based surfactants)	Forest Surveying Robot
Change	Alternative battery type	A consistently superior product	Plant-based emulsifier and wetting agent	Substituting capital for labour – increasing efficiency
System impact	Sustainability, significant benefits since it uses abundant natural resources	Higher-quality protein structures for biomedical application	Higher performance, environmentally friendly, not reliant on fossil fuels	More mechanisation in a difficult environment
Resource need	Reduced	Minor	Planned to manufacture for the Aotearoa New Zealand market – possibly licensed overseas	Minor
Partners	Many	Pharmaceutical companies	Focus on the New Zealand market before overseas markets	Forestry machinery Industry
Dynamic consideration	Continues the battery revolution	Earth-based competition	Strong market pull. Fierce competition, but no patents in this area	Very difficult area could result in further applications
Market (annual)	Worldwide is ~$125b	$1.5 b, 8% growth	Surfactants market (US in the billions)	Unknown, niche market
Revenue	Unknown	Unknown	Unknown	Unknown
Jobs	Under 10, highly specialised jobs	Under 20, highly specialised jobs	Under 20, highly specialised jobs	Under 20, highly specialised jobs
Other benefits	Sustainability, safety	Spillovers to other knowledge industries	Better environment, greater workplace safety	Lower costs, fewer "boots on the ground"
Risk	In a technology race where the winner is yet to be determined	In a technology race where the winner is yet to be determined	Stiff competition, but no other patents in this area	Too early to tell, but nobody else has done this
Cost impact	Potentially lower cost. The environmental "pull" is likely to make them very attractive to the consumer.	High cost, high quality, together with strong demand	Unknown. Potentially could be sold at a premium in the market given the demand for cellulose-based products	Premium product that substitutes capital for labour. Initial capital cost mitigated by lower costs per log.

Notes (1) Risks can be associated with slow take-up of service/product, other competing business models taking different paths to market, and the chances of competing products either being first to market or with better performance. (2) Most entities are in their infancy, so it is difficult to forecast how many jobs they will create. However, most jobs are highly specialised. (3) Costs are examined in terms of service provision and overall impact on the economy.

Source: Multiple, NZIER

4 Health sector focused entities

4.1 Snow Cap Crowns

4.1.1 Description and background

Dental caries[3] is a common chronic childhood disease. Standard treatments revolve around surgically removing infected dental tissues and the use of fillings.

Alternatives now exist. The Hall Technique, first introduced in the literature in 2006, provides a 'no-drill, no pain' technique that uses metal preformed crowns (PFCs) (Altoukhi and El-Housseiny 2020).

The Hall technique has the benefit of increasing a child's compliance and dental technician comfort since local anaesthesia is eliminated. Using the Hall technique means a child could have a less traumatic dental experience and may return for more difficult treatment in the future (Liddell and Locker 2000).

Metal PFCs are clinically effective, although they have aesthetic limitations – the crown is silver rather than tooth-coloured. Placement of the metal crown can be difficult.

Snow Cap Crowns has developed an innovative white shell crown system designed for use with the Hall technique. The approach improves aesthetics and reduces treatment costs by using a white flexible material with smart crown design; making the crown placement easier for clinicians (Choi et al. 2021; Rathee and Sapra 2023).

4.1.2 Applied research aims to make a change

As well as being aesthetically pleasing Snow Cap Crowns are easier to place than metal PFCs. Easier placement means a quicker placement, reducing costs and increasing productivity (i.e. more patients can be seen).

Snow Cap Crowns are targeting markets in Aotearoa New Zealand, Australia and the United States. Children between 3 and 12 years old are the initial market segment. Other markets potentially include special needs children and geriatric patients in palliative care.

The potential exists to extend their reach into the resin fillings market (drill and fill). The PFC market in the United States is small (20 percent), but a white PFC could help grow the market segment by capturing part of the drill and fill market. This gives the market proposition significant upside.

The manufacture of crowns requires injection moulding. The injection moulding process has been widely used for the mass production of complicated geometries with high dimensional precision. It is cheap and easily replicable.

Once the Snow Cap Crown is patent protected and the injection moulding process is fully optimised, the crowns can be readily manufactured at scale under license, locally and internationally.

[3] A chronic infectious disease that results "… from tooth-adherent cariogenic bacteria that metabolise sugars to produce acid, which over time demineralises tooth structure." In short tooth decay.

The well-established Hall Technique means that a marketing campaign can include a collaboration with influential clinicians in paediatric dentistry and universities for training.

Other reasons for confidence are:

- A survey done of 70 professionals in industrialised nations suggested overwhelming support for white crowns (between 80% and 100%)
- The Hall technique allows for more clinicians to provide a minimally invasive treatment. More children can receive the treatment, increasing the accessibility and improving the dental experience (Laske et al. 2019).

Human health treatments require a high standard of regulatory oversight; regulatory clearance in Aotearoa New Zealand, Australia, and the United States (Choi 2024) is critical and ongoing.

4.1.3 Expected value

Snow Cap Crowns has done some preliminary analysis of the market and its potential impact (Choi 2024). Raising money in today's market is much more difficult than it has been (relative to the last few years). This risk will be mitigated somewhat since the product is easily understandable by the market, easily scaled up, and is "near market" ready.

Global demand for dental products is growing (5 percent per annum), driven by rising dental diseases. Also, in the United States, nearly 17 percent of children have untreated dental caries (Straits Research 2023). Therefore, technological advances are anticipated to offer profitable prospects.

Government initiatives focused on dental health are contributing to market growth. For instance, the American Dental Association (ADA), in 2018, introduced Action for Dental Health: Dentists Making a Difference, a nationwide, community-based movement to end the current dental health crisis faced by the United States (American Dental Association, n.d.).

Policy impacts and spillovers

Snow Cap Crowns have the potential to reach populations that currently are not being seen by dentists (Choi 2024). This is because:

- Snow Cap Crowns are more economically viable in terms of cost and time taken to fit the crown compared with existing PFC products
- treatment of dental caries (in children aged between 3–12) results in a financial benefit to both the patient and the dentist.

Developing a cheaper product, Snow Cap Crown, will assist in exposing children and more vulnerable patients within society to dental care.

Marketing reach is critical. Snow Cap Crowns are targeting major United States distributors as partners.

Value

The economics is driven by:

- Less time at the dentist by the patient[4] (the Hall technique potentially is up to one-third less time) (Elamin et al. 2019). This reduces costs for all
- Providers can see more patients improving profit margins
- The market for crowns will be bigger since Snow Cap Crowns can fit all children's crowns (metal PFCs cannot). In preliminary work, it was estimated that a further 28 percent of children's crowns could be covered.
- There is potential to cover other parts of the total dental caries restoration market. The Resin fillings market is 66 percent of the United States market compared to 20 percent for metal and other crowns (Choi 2024).

There is potential to reach more children. How many more children is open to question. In Aotearoa New Zealand, preschool children do not get dental check-ups, so if sugar consumption is high or dental hygiene habits are poor (e.g. going to bed with a bottle of juice or inconsistent teeth brushing), tooth decay can get quite advanced before they hit school (and the school dental service). That means pain is the reason it's being picked up, and some teeth, at least, maybe too far gone to be saved by a crown.

This research was selected after an independent economic assessment. Snow Cap Crowns is expected to have revenues in the order of $10–$20 million within three years and $50 million in revenues within five years. Within 10 years, it could reach over $100 million, and the revenue from this one technology will surpass the total SfTI Challenge investment.

From the description of companies showcased by Callaghan Innovation (Callaghan Innovation 2019) the company most like Snow Cap Crowns is BBC Technologies. Snow Cap Crowns expects to reach similar market capitalisation investments in R&D and follow a similar growth pattern.

Table 7 Potential impact of Snow Cap Crowns

Economic characteristics	Potential	Comment
Potential entity size	Tens of millions	Potential to broaden market
Market growth	5 percent market growth (United States)	Continued growth expected
Potential market spillovers	Potential improvement in oral health over the life course	A good experience may mean going more often to the dentist
Companies like this[1]	BBC Technologies	Focused on new technology in expanding markets
Note (1) Callaghan Innovation 2019		

Source: NZIER

4 A critical issue is productivity particularly in the arts and health from a national perspective. How to increase productivity is a major issue since the cost of a clinician's time (or an orchestra's time) is increasing all the time. Therefore, ways of saving time (i.e. potentially through innovation) are critical to improve cost effectiveness.

4.2 Toku Eyes

The name Toku means 'virtue' in Japanese and 'self' in Māori.

4.2.1 Description and background

Toku Eyes connects optometry with the prevention of a range of health issues. In an eye examination a practitioner can find indications of other diseases using AI technology. This includes cardiovascular, renal, and liver diseases.

The size of the problem Toku Eyes are addressing includes:

- $1,000 billion is the annual cost of heart disease in the United States
- $300 billion savings from reductions in CVD events by implementing lifestyle changes.

(See for example, Ekinci 2023)

The initial focus was on 'eye diseases'. The research process focused on the development of AI software that could detect diabetes retinopathy, an eye disease that people with diabetes usually contract after a period with the disease.

In the clinical phase, it became clear that the AI programme had detected the underlying disease. The team were able to detect the precursor of the eye disease as well as diabetes retinopathy. This opened the way to looking at other diseases.

4.2.2 Applied research aims to make a change

Using this approach challenges the traditional business model of private practices where highly trained optometrists manually view the scans of every patient. AI meant that specialists could focus on the more complex cases, and staff with less training could operate the scanner. This is an allocative efficiency gain since scarce skilled resource use is improved, reducing the cost per patient (scale efficiency) and introducing new technology (innovation).

The diagnostic is opportunistic. Only 40 percent of patients in industrialised nations are on drugs (e.g. statins or hypertension pills) they should be on. The other 60 percent are unaware of their situation. These patients tend to be from lower socioeconomic communities.

The barriers to treatment are the inability to access medical services and the lack of patient knowledge. Currently, getting to the diagnosis stage requires blood tests, measuring blood pressure, etc. Potential patients don't realise the gravity of their condition(s) until they have chest pain or renal failure. Over 80 percent of high-risk patients are diagnosed too late.

Current products provide information on overall health risks and CVD risks. The supply chain involves the provision of AI software so optometrists can on-sell to patients. The challenge for optometrists is to convince patients that a full eye test is worth it.

Their current supply chain mix includes:

- A marketing and funding base in the United States.
- A 'production' base in Auckland. Auckland is where the company started and received research grants, skilled labour is cheaper, and there are R&D tax rebates.

AI companies are continuously having their standards updated in the United States (updates happen every 6 months to a year). AI markets are moving fast; therefore, cyber security, data management, etc. are being scrutinised carefully.

Other markets, such as the Middle East and the United Kingdom are also being explored. These require meeting international standards and domestic regulatory requirements.

4.2.3 Expected value

The commercialisation process is occurring mainly in the United States where the services have been rolled out through optometrists (equivalent to SpecSavers in the Aotearoa New Zealand market).

The main challenge to this roll-out is the lack of interoperability. Each optometrist has different medical reporting systems, image repositories, and other software systems. This increases the complexity of updating software.

We have no information on profitability, but we know Toku Eyes is growing and investing in that growth.

Capital-raising activities have been successful, with over $13 million raised in 2023, with a total of $16 million to date (Callaghan Innovation 2019).

The types of diseases that an eye examination can detect are exploding around the world. For example, 49,000 deaths per day are recorded globally from CVDs. Renal and diabetes diseases are also growing strongly.

The number of optometrists is growing (in the United States by over 4 percent per annum) because:

- They are the primary eye care specialists, and they are in good locations
- An increased awareness by the patients of their importance and increased use of technology that provides more services
- Increased diagnostic services driven by easy-to-use new technologies
- Receptive operators willing to invest in new technology.

Toku Eyes products may benefit from the predicted growth in these trends since the types of services they are providing fit into optometrist growth strategies (Transparency Market Research 2018).

Policy impacts and spillovers

The policy implications are significant since many of the diseases being accurately detected are major costs to health systems around the world. **It does not matter which service prevails; the predictive powers of eye tests will become an important part of an effective and efficient health system**.

Reaching a wider patient audience is a significant advantage. A visit to a more accessible optometrist is much more likely than a visit to a doctor.

Scaling up software does not require a physical production process. The products are generated by a group located in Auckland (a highly skilled staff of 20). Scaling up involves the marketing and distribution of software to the users (optometrists). It is the optometrists who then sell their services to patients.

Success may also be useful for other related applications. This is a dynamic market, and Toku Eyes' skills may be readily applied to other services. Even if success is not realised, the skilled resource would not remain redundant for long.

Value

The economics is driven by:

- Reduced costs to optometrists and increased market size. The use of AI and relatively easy-to-use software programmes expands the number of patients that can be reached
- Increased reach of the intervention. Patients have a greater and more immediate incentive to get their eyes checked, improving patient accessibility, less invasive approach, etc.
- The potential impact on the health system is that if better diagnostic capability is available, then there is a real possibility to:
  - Improve patient outcomes and quality of life
  - Reduce costs and increase efficiency and effectiveness of health systems in industrialised nations of diseases that are growing at significant rates.

Toku Eyes fits in with the SfTI Challenge’s themes around innovative algorithms, models and methods. Currently, it is investing in its rollout, and it is likely to be profitable in two years. Revenues could be substantial, along with the economic savings from preventing lifestyle diseases. The turnover within 10 years is expected to be in the tens of millions.

Toku Eyes is similar to Orion Health. Both companies are aimed at improving the efficiency and effectiveness of the services they offer (Callaghan Innovation 2019).

Table 8 Potential impact of Toku Eyes

Economic characteristics	Potential	Comment
Potential entity size	Tens of millions	The size of the population is large – over 100 million eye tests done in each year in the USA.
Market growth	4 percent per annum (USA market)	Growing on the back of services such as those offered by Toku Eyes
Potential market spillovers	Very large, predicting the precursors of rapidly growing diseases has the potential to shave billions off industrial nations health bills.	To be able to demonstrate the precursors to lifestyle diseases will have a major impact on health systems around the world
Companies like this[1]	Orion health	Changing the focus of healthcare by improving the efficiency and effectiveness of service delivery
Note (1) Callaghan Innovation 2019		

Source: NZIER

4.3 Tautoko Tech (Disruptive MedTech)

4.3.1 Description and background

Chronic disease management is undergoing a revolution as it moves from generic information given to patients infrequently to personalised approaches that are self-administered and driven by data and technology. This is a move to empower patients to understand their health and engage more directly with the management of their health. Diabetes is one area that will benefit from easy-to-use devices with personalised, wrap-around support empowering approaches since it will:

- Improve health literacy with personalised education, increasing opportunities for self-medicine management whilst reducing the workload burden of the frequency of continual management by medical professionals
- Enable earlier, more equitable access to an insulin pump, the gold standard in insulin management
- Eliminate the feedback that is not specific to the patient (i.e. doctors giving generic advice)
- Increase the amount of health information and data that is exclusive to the patient.

Diabetes is significant from a New Zealand health perspective. Over 250,000 people have the disease live with diabetes, with a further 100,000 undiagnosed. An improvement in health literacy and greater management access to insulin pumps is important since:

- Good control can reduce complications and cost
- Current treatment revolves around regular meetings with clinical staff, with limited clinical capacity to train additional patients to use insulin pumps.

4.3.2 Applied research aims to make a change

The goal is to:

- Provide access to improve health literacy around diabetes management
- Provide an insulin support pump earlier during diagnosis to improve greater health outcomes
- Reduce the cost of health complications from poor management

To do this requires:

- Development of new techniques to encourage continued engagement with health information
- Access that eases and improves the management of diabetes
- An insulin pump that is 10 times easier to use than existing pumps

The fundamental change is the continuation of moving from generic approaches to treating diseases and to empowering individuals to improve health literacy while making the best management tools available as early as possible in the patient's diabetes journey. This has huge advantages for patients who are able to make good decisions by modulating their medicine use.

This could be the first of many applications that are driven by the right patients, the right drug, at the right dose, at the right time, enabled by:

- Patient-specific models for personalised care
- Informatics that improves the delivery to patients or groups of patients (data specific)
- Advanced technology enables this to happen.

The resources in the research project are based on the technology that enables a more patient-centric approach, which also makes it easier for patients to be active in their health management. Technology being developed inside the Disruptive Medtech project includes:

- Development of novel insulin pumps with a low-power actuator, enabling lower build costs with an extended battery life. The pump will meet or exceed ISO standards and meet/exceed Medtronic pump delivery quality and variability
- Development of a Bluetooth app for talking to the chip used on the light-based Continuous Glucose Monitor (CGM)
- Development of needle-free delivery methods.

Tautoko Tech is commercialising the novel insulin pump with the wrap-around support, with the remaining technology requiring further research to prove commercial viability.

It is the change in technology that will drive patient and provider behaviour modification to improve outcomes for current and future diabetics.

Tautoko Tech and its insulin pump with wrap-around support software could be the first of many applications that are driven by the tailored support with the right drug, at the right dose, at the right time, enabled by:

- Patient-specific models for personalised care
- Informatics that improves the delivery to patients or groups of patients (data specific)
- Advanced technology enabling this to happen.

4.3.3 Expected value

Many of the diseases where personalised medicines can assist, are a huge burden on health systems around the world. Even small reductions in government spending on these diseases will have very large benefits.

The innovations in themselves are technologically incremental. However, when they are applied in a patient setting, they are likely to have far-reaching positive impacts. They represent a step change in the way medicine is used since the technology (with accompanying data collection) allows for individual approaches that have multiple benefits to patients, clinicians, and health systems.

The global personalised medicine market size was valued at $ 1,000 billion in 2022 and is projected to grow at a compound annual growth rate (CAGR) of 7.20% from 2023 to 2030 (Grand view research 2020).

The growth of the personalised medicine market is attributed to factors such as the growing demand for novel drug discovery to combat the growing incidence of cancers, chronic diseases, and other diseases across the globe.

Personalised medicine is increasingly used for applications in companion diagnostics that are precisely designed for a patient's specific treatment and to gauge the patient's response to a therapeutic regime (such as diabetes).

Companion diagnostics play an essential role in devising efficient precision medicine considering the micro-environment: patient's genome characteristics, ethnicity, and lifestyle choices.

Tautoko Tech is targeting insulin dependent users at first diagnosis, a market of $100 billion in the United States. The global potential for the insulin pump is $800 billion. The expected entity size of Tautoko Tech will be in the tens of millions once the insulin pump gains US FDA clearance.

Policy impacts and spillovers

Industrialised nations have growing health budgets, a shortage of skilled workers, and concerns over variable access to the public health system. Encouraging the development of personalised medicine/medical devices with personalised support that allows for patients to control their own medication will provide benefits to the patients, health care professionals and to the health system. Patients will use fewer resources (in terms of clinician's time) and have approaches tailored to their needs.

Value

This will create value for the firms that can develop their markets, but the main value will be gained by patients and the health system.

Any reduction in the costs of treating chronic diseases in New Zealand will have large, positive, society-wide benefits, given the size of the problem.

The SfTI Challenge saw the potential of self-managed health since it fits in with its mission-led approach associated with methods and tools that underpin new business practices and processes. Not only is it a growth area in medical markets, but it also can increase the efficiency and effectiveness of already stretched health professionals.

Health costs are increasing rapidly along with the needs and demands of patients. Aroa Biosurgery has been able to find its niche in the same way that Tautoko Tech aspires to.

Table 9 Potential impact of Disruptive MedTech

Economic characteristics	Potential	Comment
Potential entity size	Tens of millions	Technologies meeting the needs of those with life course diseases are increasing dramatically
Market growth	7.2 percent	Strong growth in this market
Potential market spillovers	Self-managed care	Reduced the burden on the health system, particularly on health professionals
Companies like this[1]	Aroa Biosurgery	Finding a niche in a high-growth health market

Note (1) Callaghan Innovation (2019)

Source: NZIER

5 Environmentally focused entities

5.1 Armada Sensing (Nitrate Sensors)

5.1.1 Description and background

Human development has altered freshwater systems in ways that have detrimentally affected the health of the water, as well as its flora and fauna. Since the 1980s, New Zealand's water quality monitoring regime has relied on manual methods, with little innovation since nationwide monitoring began.

As part of this project, a new water-quality sonde has been developed with specific focus on creating a low-cost in-situ nitrate sensor. The overarching goal is to comprehensively monitor freshwater systems with high-frequency, high resolution, and real-time data by using this new technology within frameworks based on indigenous knowledge and principles. This approach offers an autonomous and integrated method that will benefit water quality in New Zealand.

Characteristics of freshwater monitoring in New Zealand include:

- The establishment in 2012 of data provided by regional and national authorities, as well as CRIs
- The establishment in 1989 of the National River Water Quality Network (NRWQN) with 77 sites across 35 of Aotearoa's rivers. However, due to increasing financial strain, monitoring at some sites is slated for discontinuation
- A method of collection and measurement that has remained mostly unchanged over the past 30 years. It involves monthly manual sample collection and delivery to the lab for testing, with databases updated every three months.

There are shortcomings to this approach:

- Water quality and nutrient levels can vary significantly throughout the day, with rainfall, and flow variations; none of which are captured by monthly sampling
- Manual sampling and testing at a limited number of sites lacks spatial and temporal comprehensiveness. However, continuous and autonomous water quality testing technology is expensive and not considered an economically viable option to replace this regime
- Frameworks and protocols were developed at a time when water quality was not as poor, stakeholder input was undervalued, and the present environmental stressors did not exist.

5.1.2 Applied research aims to make a change

In-situ sensing technology for water has the potential to play a critical role in environmental monitoring, resource management, and scientific research by providing direct, real-time measurements of key water health indicators essential for understanding and managing water quality. The ambitious goal is to revolutionise freshwater monitoring in New Zealand, balancing economic, agricultural, environmental, and cultural objectives, ensuring an integrated and comprehensive approach that better serves all stakeholders.

The approach has been to:

- Develop low-cost, fit-for-purpose in-situ sensing technology (e.g. nitrate sensors) and intelligent datalogging and display systems (cloud-based data repositories and dashboards) to facilitate real-time water quality reporting
- Ensure appropriate monitoring of areas significant to Māori (mahinga kai, wai tapu, wai taonga, etc.) with protocols based on mātauranga pūtaiao and tiakitanga
- Create reporting templates that meet both scientific and Māori requirements
- Establish a network of kaitiaki equipped with innovative scientific technology, mātauranga pūtaiao and mātauranga tiakitanga o te taiao, along with feedback mechanisms to refine sensor technology.

Water quality sensors are common and widely used in various applications related to environmental monitoring, research, resource management, and industrial processes. They vary in type and complexity, ranging from handheld portable devices for field measurements to sophisticated multi-parameter probes and continuous monitoring systems installed in fixed locations or integrated into autonomous platforms (e.g., buoys). However, these sensors are often expensive and require frequent maintenance and re-calibration. This maintenance is crucial for ensuring their accuracy and proper function and is typically performed by skilled operators with a high level of scientific expertise. In in-situ monitoring systems, re-calibration is particularly critical because the sensors are continuously immersed in waterways and are susceptible to fouling and drift.

Armada Sensing takes a different approach by protecting the sensors to eliminate fouling altogether and incorporating autonomous on-board calibration. The technology has been configured into a buoy designed for continuous immersion, allowing for extended deployment periods. This enables sampling and reporting at hourly intervals.

Armada Sensing Ltd has been established to commercialise this product.

Advantages are:

- Low cost
- No fouling exposure
- On-board calibration
- Accuracy
- Fouling exposure
- Calibration
- Low maintenance
- Easy deployment
- Connectivity.

Armada Sensors are a step up from the technology that is currently in use. They offer a significant advancement over current technology, providing for easier use and continuous measurement capabilities. With prices potentially dropping – possibly one-third of the cost of the current sensors – this innovation is expected to expand the market size.

More effective measurement of nitrates can drive more effective improved management practices from among regulators, Māori, consultants, and farmers. This technology will give all stakeholders who are interested in a cost-effective and reliable option for measuring water quality an advantage; potentially broadening the user base and enabling better nitrate management.

5.1.3 Expected value

The innovation is based on an advance in technology in water quality measurement, particularly the measurement of nitrates.

Potentially, this market could expand, given the further development of cost-effective and user-friendly sensor solutions. Segmentation-wise, the nitrate sensor market will be highly dependent on industries using the sensors and geographical regions.

The market could also grow from the target industry, agriculture. Water treatment plants, environmental monitoring agencies and industrial processes are all potential users, each presenting distinct requirements and challenges. Geographically, the market may be segmented to address regional variations in regulatory frameworks, environmental concerns, and technological adoption rates.

Sensor use may also drive this market since they will be able to point to and provide data on areas of environmental concern where different management practices are required.

By making sensors easier to use and reducing the cost, the product is accessible to a wider audience. This is an incremental advance, but it could be a major step forward in our understanding of the dynamics of nitrate leaching at specific sites.

Further integration of the Internet of Things (IoT) and data analytics in nitrate sensing systems will facilitate remote monitoring and data-driven decision-making. Precision agriculture, in particular, benefits from these advancements, enabling farmers to optimise fertiliser use and reduce the environmental impact.

The United States market segment for nitrate and phosphate sensors is approximately $250 million and is potentially the largest initial market.

Policy impacts and spillovers

The improvement in sensors will drive a deeper understanding by all stakeholders of how nitrate is leaching from farms. This, in turn, will drive more effective and efficient management of nitrate. It also has other applications that can be explored, particularly in water treatment plants.

Some manufacturing will be required once the patents are in place. More importantly, the marketing infrastructure will be critical as a new generation of sensors is coming on the market.

Value

The cultural, social, and environmental values will be driven by:

- Employment and training of iwi and other stakeholders for the deployment and maintenance in local catchments
- Modification, over time, of farm and local body management practices
- Development of more effective and efficient remediation practices and strategies

- Improved data collection leads to a better understanding of the impacts of water catchment, which will inform policy.

The SfTI Challenge recognised that the benefits of the sensors could go beyond measuring nitrate leaching. Not only could this be used to inform regulators but also inform farmers to refine their farming practices further – widening the market as the cost of sensors is reduced.

Like Compac, Armada Sensing is geared towards further improving the effectiveness and efficiency of business activities (Callaghan Innovation 2019).

Table 10 Potential impact of Nitrate Sensors

Economic characteristics	Potential	Comment
Potential entity size	Millions	Market in the United States growing
Market growth	Not known	Market is approximately $150 million in the USA
Potential market spillovers	Meets a market need for all participants in the industry	Has the potential to better understand how and when nitrate leaching occurs
Companies like this[1]	Compac	Measures the impact of activities that are of real importance to business

Note (1) Callaghan Innovation (2019)

Source: NZIER

5.2 Tonalli Moana (Algal Bloom Biosensors)

5.2.1 Description and background

Algal blooms are nothing new. Japanese archives reported coastal 'red waters' ('akashiwo') as early as the year 731 (Hallegraeff, Anderson, and Belin 2021).

Algal blooms exhibit high impact variability and trends observed reflect the wide range of harmful event types caused by more than 200 different microalgae occurring in diverse coastal environments.

Biosensors are a useful tool in determining whether a harmful algal bloom is present around aquaculture farms. Current detection methods are cumbersome and slow, which creates cost.

The aim of Tonalli Moana is to develop an easy-to-use biosensor that could be used at the point of inspection and inform harvesting decisions to provide a result within minutes, aiding the aquaculture industry to reduce waste, increase harvesting and be open more days.

The development of Tonalli Moanawas focused on an aptamer-based point-of-care sensor[5] that can accurately assess the concentration of PSP toxins in seawater and shellfish tissue

5 Aptamers are short, single-stranded DNA, RNA, or synthetic XNA molecules that can be developed with high affinity and specificity to interact with any desired targets. They have been widely used in facilitating discoveries in basic research, ensuring food safety and monitoring the environment.

samples. The aptamers needed to perform under variable temperature and salinity levels to be implemented in variable environmental conditions.

5.2.2 Applied research aims to make a change

The research team have demonstrated that aptamers are a tangible solution for toxin detection and quantification. The critical applied research objective is how to make the technology portable so it can be implemented in the field.

The aim is to develop an aptamer-based point-of-care (POC) sensor that can accurately assess the concentration of STX, neoSTX and Gonyautoxins responsible for PSP:

- The resulting biosensor will address key criteria such as low cost and easy usability for end-users and it is expected to be used by aquaculture farmers and processors, Iwi, council personnel and even local communities to monitor their coastal waters
- To develop the final product, a biosensor is required to have stable aptamers across a range of temperature and salinity levels to increase its versatility and efficiency
- To date, the team has developed a functional prototype and run the first field trials with successful results in the lab and the field.

Current methods of detecting and monitoring harmful algal blooms are expensive, requiring specific equipment and highly trained individuals. They rely on the use of liquid chromatography-mass spectrometry methods and phytoplankton taxonomic methods using microscopy to identify harmful phytoplankton species. The results are available 3 to 7 days after the harvest. The wait time incurs losses of around $130 million/year for the whole shellfish aquaculture industry in New Zealand and above $3.5 billion worldwide.

Using aptamers that are easy to develop and have the monitoring advantage of having high affinity, specificity, and on-site real-time application without the need for expensive equipment or trained personnel is the goal. The aptamers are stable and tolerate variation in environmental conditions without losing any specificity or binding properties.

Compared to the conventional analytical methods to detect and quantify PSP toxins from environmental and tissue samples, aptamers provide a simple, more economic and more efficient method, even at low concentrations below the regulatory level.

The application for aquaculture is that they can obtain data within minutes of testing and there is certainty about whether to harvest, or not, at optimal times. This results in savings for aquaculture companies and less food waste.

Aptamers have been widely used in human health diagnostics and therapeutics. The application to environmental monitoring has the advantage of high affinity and specificity, which are independent of ligand’s size or type, allowing them to bind small molecules, large molecules and even whole cells at small concentration levels. This allows:

- The sensor to be portable for PSP-toxins detection in coastal waters. The aptamers are chemically stable, their thermal denaturation is reversible, and they have a long life, therefore providing durability in their use
- For easy handling of oligonucleotides that could be shipped at room temperature and stored on shelves for long periods of time without affecting their specificity and accuracy

- For minimal sample preparation in aptamer-based detection systems. The specificity of the aptamers allows production at a low cost, and the targeted end-users of this technology are Iwi, local communities, consumers and industry.

Tonalli Moana is in business formation. The initial business plan has been developed, and trials are planned for New Zealand and the United States. Once pilot trials have been completed, continuous monitoring systems/solutions will be developed, and food safety markets outside of aquaculture will be addressed.

Aptamers for four toxins have been developed. The aquaculture market requires the development of aptamers to detect 21 toxins. Development outside of the aquaculture market requires aptamers that detect eight different bacteria and three different species of fungi in the initial stage.

5.2.3 Expected value

The food safety market is around $25 billion, while the aquaculture biosensor market is approximately $650 million. Taking a small part of the food safety market would make Tonalli Moana highly successful.

The market opportunity is large and is based on addressing specific pains:

- Uncertainty, since product safety is critical for consistent market supply
- Timing, this is a real-time decision-making tool
- Waste, the more time taken to test, the greater the chance that the product will be unfit for consumption
- Illness can occur from eating untested product.

Further application of the technique to other food safety issues offers huge potential.

Policy impacts and spillovers

New biosensor technology benefits better (more efficient) policy decision-making by improving our information on aquaculture and our aquatic environment. Wider benefits will arise if it can be extended to more food safety areas. And there is a direct benefit to kaitiakitanga practices in Māori aquaculture businesses and communities.

Some manufacturing will be required once the patents are in place. Scaling up production is not a major issue since biosensors are not mass production consumer items.

Value

The research team continues to engage and interact with market players. Tonalli Moana believes the following sales projections are possible. The biosensors being developed can also be readily used in other food safety fields.

The potential wider use of biosensors is a major economic benefit. Food safety product markets are growing quickly, and the ability to apply this technology to those markets is promising. The ability to tap into a fast-growing $25 billion market will be key to its commercial success. This fits with the mission-led approach of the SfTI Challenge with the development of smart biosensors that underpin and enhance business processes through hardware applications.

Tonalli Moana has the potential to be a highly successful niche player akin to firms such as M-Com. By focusing on a high-growth market and bringing state-of-the-art technology to bear, Tonalli Moana can maximise its potential in aquaculture and the wider food safety market.

Table 11 Potential impact of Algal Bloom Biosensors

Economic characteristics	Potential	Comment
Potential entity size	Tens of millions	Aquaculture market $650 million – food safety much larger ($25 billion in the United States)
Market growth	10 percent per annum	Food safety markets growing strongly
Potential market spillovers	Real-time measurements	Potential to be significant when it is applied to food safety markets
Companies like this[1]	M-Com	A highly successful niche player

Note (1) Callaghan Innovation (2019)

Source: NZIER

6 Aquaculture-focused entities

Autonomous underwater vehicles

6.1.1 Description and background

Technology that supports precision farming has the potential to drive ongoing productivity gains and transform land and sea-based farming activities. In aquaculture, autonomous underwater vehicles (AUVs) could radically change the way aquaculture or sea farming is conducted. The use of this type of technology could pave the way for large offshore farms. For this to happen, aquaculture intelligence systems such as advanced sensors, communication and visualisation technologies that support farming activities are required.

The approach consisted of the development of on-farm sensors, data communication, and tools for farmers. This involves high technology with practical approaches to implementation. This includes:

- Connecting with and working with Māori-owned aquaculture companies to commercialise the technology. It is their investments that will drive the sector
- Imaging intelligence is the technical, geographic, and intelligence information derived through the interpretation or analysis of imagery and collateral materials. Smart underwater images capture and analysis, georeferenced, high frequency, time-series data will enable deeper analysis of the environmental conditions and trends, and farming techniques to provide useful insights to farmers and de-risk their business
- Exploring the use of acoustic modems and blue/UV light communication systems to support future full untethered operation
- Data engineering is the practice of designing and building systems for collecting, storing, and analysing data at scale.

The use of this technology is required to support and enhance production and improve the value proposition of aquaculture and de-risk aquaculture in the face of rapid climate change.

6.1.2 Applied research aims to make a change

The objective is to modernise and drive the aquaculture sector in a way that has not been possible in the past. By doing this, we can increase the primary production of sustainable seafood, build tech exports, and create deep-tech jobs in Aotearoa New Zealand.

Technology offers the possibility of increasing scale in the open sea. New technologies such as sensing devices, autonomous robotics, and data science will be essential.

Technology is the only way this will occur since there are not only logistical and farm engineering challenges but also health and safety challenges due to rougher environments and larger boats. By partnering with Māori and driving technology change, the industry can make significant changes to operational scale, productivity, and economic success.

To fully realise the potential, some protection in the form of novel trade secrets and non-disclosure agreements will be required. Specific areas of protection will include:

- AUV sensing and autonomous navigation

- Realistic AUV simulation for testing code
- Novel artificial intelligence and algorithms for counting, sizing, and detecting additional species
- Full pipeline for uploading and hosting data, and extracting metrics from images and recorded telemetry
- Novel hardware – cost-effective manoeuvrable AUV for visual scanning.

As part of this process, global patent searches have been undertaken to verify the novelty of design and implementation processes. IP is currently protected via copyright and trade secrets. This is being continually evaluated.

Commercialisation is in its infancy. Researchers are engaged with two of Aotearoa New Zealand's largest mussel farmers accounting for a third of the Aotearoa New Zealand mussel market: Sanford and MacLab. They are providing industry insights to ensure that the technology being developed can be incorporated into their operations and that the data provided is relevant and accurate.

The major challenge is ensuring that the technology works reliably in difficult conditions. The researchers are developing functioning prototypes of remotely operated vehicles ROVs/ AUVs with novel software that can autonomously scan and survey mussel farm dropper lines.

These systems require refinement so that:

- The sensors and software improve data capture. Data capture is cost-effective and sustainable - this is where autonomy is critical
- Further validation of the accuracy of image-based mussel counts and pipeline measurement can occur. Proving the accuracy of metrics to the farmers and exploring insurance to cover themselves if estimates are inaccurate will be required. Ways of building continual validation into scanning processes to ensure metrics are accurate for different environments and subspecies are critical
- Improvements can be made to robotic mussel sampling.

6.1.3 Expected value

The research team continues to engage with the industry on a consultancy basis. Researchers are examining the value chain for additional opportunities within aquaculture, and exploring other markets such as other seafood, and surveys and mapping for infrastructure, ecology, mining, and biosecurity.

The innovation is based on an advance in technology that will enable the industry to move from inshore waters to the open sea. This is a quantum leap that will encounter significant challenges and opportunities.

Work has been done to evaluate the market. AquacultureDirect LTD mapped out the Aotearoa New Zealand market extensively and the global opportunities, including outreach to potential global customers.

Their report shows strong potential for the technology being developed, a clear market within Aotearoa New Zealand and globally, and potential for strong industry growth.

Policy impacts and spillovers

The policy impacts are significant. Government and industry point to the billions that could be made from fish farming if off-shore at scale can be achieved. The aquaculture strategy has a goal of reaching $3 billion in annual sales by 2035.[6] It is highly dependent on strong research and commercialisation. However, regulatory constraints are onerous. Industry consistently points to the opposition to aquaculture despite its low environmental impact, particularly in the open sea.

The technology provides massively scalable and cost-effective information and insights into the underwater environment. Regulation could progress significantly where monitoring and reporting are currently cost-prohibitive.

Some manufacturing will be required once the patents are in place. The researchers are engaged with hardware partners to manufacture products at scale.

Companies offering complementary and adjacent services can potentially be combined to offer a powerful joint database and dashboard system to mussel farmers.

Value

The cultural, social, and environmental values will be driven by:

- Connection with iwi-based companies that own a substantial part of the aquaculture industry. What they invest in will partly determine the industry's future
- Modification of aquaculture farm location over time – moving from inshore and local body management practices
- Development of more effective and efficient operations that impact positively on scale, e.g. using electric boats reduces costs relative to diesel
- Mussels sequester carbon from the ocean. This means that mussel farming is already close to carbon neutral.
- Improved data collection that will lead to more understanding of what more services/technology can be developed
- Improving environmental outcomes to further assure regulators that they are good sea-based custodians.

The combination of software and hardware development operating in harsh environments meets the SfTI Challenge's requirements around mission-led growth. Specifically, the development of innovative algorithms, models, methods, tools, and practices that enable the aquaculture industry to expand into the open ocean.

There is potential for Autonomous Underwater Vehicles to mimic the success of Phitek Ltd in providing services that improve the ability of other entities to provide better services. Phitek Ltd has built a strong brand in a niche area. Autonomous Underwater Vehicles can potentially do the same for aquaculture farms both in Aotearoa New Zealand and overseas.

6 https://www.mpi.govt.nz/dmsdocument/15895-The-Governments-Aquaculture-Strategy-to-2025

Table 12 Potential impact of Autonomous underwater vehicles

Economic characteristics	Potential	Comment
Potential entity size	Millions	An enabling technology that will assist in increasing the size of farms
Market growth	15 percent	Aquaculture markets are growing strongly around the world
Potential market spillovers	Assist in meeting industry growth goals	Support government objectives for the industry
Companies like this[1]	Phitek Ltd	Niche players assisting other companies providing services

Note (1) Callaghan Innovation (2019)

Source: NZIER

6.2 Ocean Intelligence

6.2.1 Description and background

Global precision aquaculture is growing quickly around the world as demand for farmed fish increases. This drives investment, product innovation, advancement in new technologies, and the pressing need for real-time monitoring.

Open ocean farming presents a unique set of challenges and risks, and realising its potential depends on the capacity to use human management capabilities, physical sciences, and engineering. The opportunities are to:

- Develop and commercialise transferable technologies that can assist in rapidly accelerating a sustainable aquaculture industry
- Assist a data-driven open ocean farming technology sector that underpins a rapidly growing global blue economy.

At the heart of the current problem is that aquaculture farms often collect incomplete, inconsistent, or poorly formatted data. An investment in quality data collection, whether it's through better sensors, cameras or other technology, both saves employee time and minimises the risk of human error. Higher-quality data also means higher-quality insights down the line. This will be a critical issue when moving from in-shore to open ocean farming.

6.2.2 Applied research aims to make a change

Ocean Intelligence is combining customised sensors and data analytics to optimise existing farms and enable expansion into large-scale ocean farm management. It aims to maximise the impact in the form of greater access to data-driven knowledge by stakeholders.

Data engineering solutions enable compilation and integration of multiple data streams from on-farm sensors and other sources, such as forecasting models. An API that maximises access and has the ability to rapidly generate and customise dashboards for marine farmers will be developed.

The specific aims have been to:

- Improve the ability to provide real-time data with greatly improved certainty around the uninterrupted supply of data
- Build capacity and improve links with iwi
- Develop and utilise real-life data gathered from multiple databases to develop a prototype dashboard, which enables the team to receive and incorporate industry feedback.
- Develop on-ramps to take data from other sensors, such as the Autonomous Underwater Vehicle.

The changes are significant since they underpin and enable the aquaculture industry to address many of the challenges associated with farming in the open ocean. Farmers will be armed with the ability to monitor in real-time so that adjustments can be made around farm operations, harvest schedules, etc. These advances will enable, and be a critical part of, assisting the industry in its growth ambitions and its ability to develop farms thousands of hectares in size in open seas.

The physical resources are mainly used for the development of software.

Alongside the development of software and industry dashboards, researchers are seeking a much tighter relationship with stakeholders (iwi and other commercial entities) to pilot the software developments and iterate towards commercial solutions.

A company (Ocean Intelligence; OI) has been established as a way of communicating and commercialising the technology that has been developed. This process is in the pre-seed investment stage, with due diligence currently being carried out for potential investors.

The industry is receptive to the types of technologies being produced. They understand that the challenges of open ocean farming will require enabling technology as a means of optimising farm operations and, in some cases, substituting capital for labour. They are looking for specific approaches adapted to their particular circumstances.

6.2.3 Expected value

The research team have reported strong interest among domestic and overseas customers. A critical issue is how they will be paid for the services they could potentially provide. The team is engaging leading companies in a six-month trial as a way to test their business model, pricing, and user experience/product refinement as a lead-up to seed investment.

The technology focus has been on commercialising the key outputs. This includes:

- Sensor technologies for scaling up data collection on farms, with a current focus on IoT temperature strings and BlinkLink for automating navigational light surveillance. Funding has allowed the team to build up twenty additional floats and t-strings ready for deployment. BlinkLink has been modified to address some technology issues and is about to be deployed in Tasman Bay
- Data continues to come in from the equipment deployed on the Ngāti Rarua farm in Admiralty Bay and from the sensors deployed in Tasman Bay
- Cawthron's new API has been successfully completed, with real-time data observations being ingested into Oceanum's datamesh. Mock data in the mussel farm app has been

replaced with real-time data. An MVP version of the app has been deployed for the Top of the South and can be made available/visible to key stakeholders as required.

As expected, the technology has gone through an iterative improvement process that is still continuing.

This is a highly competitive market which is growing fast. Many nations are investing heavily in fish farming since it offers major potential. Growth in aquaculture technology is expected to be nearly 15 percent per annum over the next five years (Markets and Markets 2020).

Aotearoa New Zealand does have some unique challenges that require solving. What technology will be imported and what will need to be created locally is still unclear. Equally, the technology developed in Aotearoa New Zealand could find ready markets overseas.

There is a clear need for technology that can support large open ocean farms that will require significant on-shore monitoring. The type of software systems being developed are necessary to enable infrastructure and could be a critical part of the transition from in-shore aquaculture to open ocean farming.

Policy impacts and spillovers

The development of these types of systems will be required to meet Aotearoa New Zealand's aquaculture goals. Aotearoa New Zealand has its own ambitious goals to realise a strategy that returns $3 billion per annum in turnover. This requires a significant improvement in skills, capabilities and technology.

The challenge involves the development of systems that will likely reduce the reliance on labour on farms and developing systems that have not been used before in an Aotearoa New Zealand context.

Physical resources to complete the technology are minimal (mainly software development).

Value

It is not yet fully determined and will depend on market growth (which is strong) and the degree of competition.

Another important issue is the development of the business model, particularly how services will be paid for. The current model proposed is to generate base-load revenue via a tiered subscription service, with value-add from specialist analytical tools and apps, IP licensing of third-party solutions, and creation of digital pathways to leverage high-value consultancy.

Technology development operating in harsh environments meets the SfTI Challenge's requirements around mission-led growth. Specifically, the development of innovative software applications to enable the expansion of aquaculture into the open sea.

Ocean Intelligence could follow the path of Starboard Maritime Intelligence in providing services to assist in improving the efficiency of current farms and enabling the building of larger off-shore farms. Success for Ocean Intelligence would mean supporting farms not only in New Zealand but overseas.

Table 13 Potential impact of Ocean Intelligence

Economic characteristics	Potential	Comment
Potential entity size	Millions	Niche area, with strong growth
Market growth	15 percent	Very large growth expected in aquaculture
Potential market spillovers	Enabling bigger off-shore farms	Meet government objectives for the sector
Companies like this[1]	Starboard Maritime Intelligence	Niche players assisting other companies providing services

Note (1) Callaghan Innovation (2019)

Source: NZIER

7 Manufacturing focused entities

7.1 Tasmanion (aluminium-ion batteries)

7.1.1 Description and background

Battery technologies such as lithium-ion can fit easily into various industries, such as portable consumer electronics such as laptops, cellular phones, and electric cars. They are also used for grid-scale energy storage, military, and aerospace applications. While the industries that need instant energy output are working on cheaper LIBs, the sectors that cannot have flammability risk or a high battery cost are actively looking for alternative technologies which can take advantage of the market's gaps and have a significant impact. Rechargeable aluminium-ion batteries (AIBs) are a promising alternative to LIBs.

The advantages of AIBs are:

- They are non-flammable and avoid the risk of explosion due to the absence of flammable raw materials.
- Cost-effective: aluminium and the patented cathode material are commodities and do not require advanced manufacturing techniques. We can use the existing production techniques of lithium-ion battery manufacturers to assemble AIBs.
- More sustainable.

Improved and consistent performance and preliminary data validation are essential for market readiness. Patents have been filed to secure this IP.

7.1.2 Applied research aims to make a change

The research has focused on increasing the overall performance of rechargeable AIBs by using new cathode material.

The research was focused on eliminating the disintegration of the cathode material, improving cell voltage and removing high internal resistance that causes an uneven battery performance.

The research has addressed this problem to make AIBs universally acceptable and a commercial alternative to expensive battery technologies.

The aims were to:

- Improve the coating thicknesses on battery performance
- Eliminate moisture to improve the battery’s shelf life
- Establish the battery's mechanism to finetune the fabrication process and enhance performance.

The change has been to develop an alternative to LIBs:

- Sustainable AIB- Aluminium is abundant and avoids the need for the mining of critical and rare metals such as cobalt and lithium
- Safe technology not using flammable materials suits industries requiring high safety standards and rigorous design parameters

- Scalable product that uses production infrastructure similar to LIBs
- Low-cost products that could be used in various applications and are less susceptible to commodity price fluctuations.

Using aluminium in batteries is not a new idea. The problem has been that early prototypes had low capacity due to aluminium oxidation and were not good enough for long-term use. The change that made the difference was using a non-flammable ionic liquid electrolyte, which prevented the metallic anode from further oxidation.

The raw materials can be cheaply recycled, and they are easily sourced. The patented cathode material is a well-known material used in agricultural and other industries.

The commercialisation process has just started. Tasmanion has grown steadily over the last two years, now comprising five team members and three board members. The company is still actively identifying battery manufacturers and seeking input from industry partners to take their technology forward to prototype testing agreements and licensing partnerships.

The approach is to find licensing partners to mass-manufacture the AIBs. Tasmanion will hold the IP for the technology, and the in-house R&D will focus on expanding the IP family and establishing the first pilot soon.

7.1.3 Expected value

The management continues to engage with potential strategic and venture capital companies for investment opportunities and understand their requirements.

The innovation departs from the usual new battery technology pathway. As a result, the change is a relatively significant step and, if successful, will shake up the battery market. As signalled, the demand for batteries is growing strongly and will continue for many years.

The market opportunity is immense and has several appealing features around:

- Safety: using technology that has no flammability risk
- Sustainability: The battery incorporates materials used in other applications, has a well-known supply profile, and is abundant. They are less susceptible to metal price volatility
- No scale-up risk: cell fabrication is similar to LIB technology and does not need expensive advanced techniques.

Policy impacts and spillovers

The AIBs have significant sustainability benefits and require a reduced regulatory burden (relative to LIBs).

Companies such as TasmanIon can also attract and employ highly skilled individuals who support knowledge creation and spillovers.

Most manufacturing will be done under licenses and partnerships close to the Asian and US markets.

Value

The environmental and economic value will be driven by:

- Licensing fees from battery manufacturers and following a B2B model.

- The nature of the product. It could replace LIBs in relevant industries in Āotearoa, New Zealand and worldwide.
- The development of a centre of excellence around battery research in Aotearoa, New Zealand.

The development of new products with environmentally friendly characteristics could generate significant demand. It can be compared to a company such as Nyriad, which has developed a new way of storing multiple data types.

The battery market is growing quickly (10 percent per annum) and worth $125 billion worldwide. The product developed by Tasmanion Ltd, with its environmental benefits, maximises the chances of successful commercialisation. This fits with the SfTI Challenge's mission-led aim to create a smart green manufacturing process that underpins business and societal objectives. The potential impact is likely to be in the millions in revenue per annum.

Table 14 Potential impact of Tasmanion Ltd

Economic characteristics	Potential	Comments
Potential entity size	Millions	There are major advantages of producing this type of battery
Market growth	10 percent, provides a new type of battery, so not known	Demand could be very large
Potential market spillovers	A battery research institute for R&D of other battery technologies	Could attract other high paid jobs into the economy
Companies like this[1]	Nyriad	Providing a new way of doing things that will be in demand

Note (1) Callaghan Innovation (2019)

Source: NZIER

7.2 Spherelose Ltd (Cellulose-based surfactants)

7.2.1 Description and background

A surfactant is a substance that, when added to a liquid, reduces its surface tension, thereby increasing its spreading and wetting properties. It is used as an emulsifier to allow oil and water to mix and prevent their separation into two layers. This is hugely valuable for a whole raft of industries, including personal care, industrial cleaning, pesticides, textiles, oilfield chemicals, and more.

Surfactants are a growth market. There are a number of reasons for this:

- Increased demand as an intermediate good in many industries
- A rise in demand in the personal care industry
- Important for cleaning applications which are in high demand
- Mounting demand for green surfactants.

This research aims to deliver a new class of surfactants that are biodegradable, low-leaching and recoverable from industrial waste streams. These properties are achievable by designing surfactants based on cellulose particles.

The research team has focused on surfactants used in personal care and cosmetics and surfactants for the chemical industry. Currently, surfactants are used to aid the mixing of oil and water and to allow for efficient removal of dirt and stains. Conventional surfactants are molecules with one end water-soluble and one end oil-soluble. In cosmetics, this property allows the beneficial oils found in many cosmetic formulations to efficiently mix with water. In cleaning products, surfactants allow dirt and grime to be picked up from stained surfaces and washed away with water. However, conventional surfactants possess the following undesirable properties:

- Many surfactants in current use are toxic and made from unsustainable sources such as petroleum
- Surfactants currently on the market are not recoverable and are discharged into waterways at the end of their use
- Current research is directed towards the production of sustainable 'biosurfactants' but the production of these alternates is expensive, and they do not address the issue of recoverability.

7.2.2 Applied research aims to make a change

This research aims to deliver a new class of surfactants that are biodegradable, sustainably produced and recoverable from industrial waste streams. The objective of this project is to demonstrate the advantages of cellulose-based surfactants and showcase their performance in an emulsifier for personal care and cosmetic formulation.

The scientific stretch is the use of particles that are significantly larger than conventional surfactants. Larger particles have the potential to act as more efficient emulsifiers due to their greater affinity for the water/oil interface and offer the advantages of higher performance and recoverability. The cellulose surfactants will also be sustainably produced and will not be produced from petrochemicals.

The cellulose surfactant technology uses wood pulp from New Zealand's forestry industry and combines it with plant oils to form a range of cellulose surfactants with properties suitable for diverse applications. The technology has been demonstrated in the laboratory, and Spherelose Ltd are working with process engineers on how to scale up the process. This technology has the potential to turn a low-value commodity (wood pulp) into higher-value products and allow diversification of the pulp and paper industry.

Spherelose Ltd was formed in April 2024 to raise private funding and commercialise the cellulose surfactant technology. Spherelose Ltd has an exclusive licence covering the provisional patents on the cellulose-based surfactant technology, currently owned by AUT Ventures.

7.2.3 Expected value

The global surfactants market was valued at $60 billion in 2022 and is projected to reach $110 billion by 2032, growing at a CAGR of 4.7 percent from 2023 to 2032.

Growth is occurring, but competition is intense. The development of cellulose-based surfactants is a competitive business. The challenge will be to carve out a marketing niche with a distinctive edge while making incremental scientific gains.

A critical factor is the replicability of cellulose surfactant production. A patent strategy is vital for this approach. Two provisional patents have been filed.

The market for surfactants faces the following issues:

- Increasing demand from end-use industries, mainly for cleaning applications
- The desire/commitment of manufacturers to reduce their carbon footprint and produce more sustainable products
- There is increasing consumer demand for products that are ethically and sustainably produced
- It is constrained because of the competition from rival surfactant manufacturers. A cellulose-based approach could be a competitive market edge
- The opportunity revolves around the need for sustainably produced, biodegradable surfactants, providing a substantial chance for cellulose surfactant research
- The challenge is that some surfactants are harmful. This reinforces the need for inherently safer cellulose-based surfactants.

The market opportunity is built around replacing more toxic surfactants and surfactants derived from the petrochemical industry with cellulose surfactants in cosmetic and body care formulations. Other applications include the use of surfactants for industrial processing, food processing, and the formulation of pesticides, pharmaceuticals, paints, and coatings. The opportunity is large, but the competition in this area is intense, especially from well-funded research groups.

Third-party patentability searches and freedom-to-operate analyses have shown that no cellulose-based surfactant technologies are currently being developed. Cellulose particles are much larger than conventional surfactants and provide higher emulsification efficiency and recovery from waste streams. These are additional benefits not found in the rapidly growing biosurfactants market.

Policy impacts and spillovers

If successful, this approach will have positive environmental impacts and reduce the carbon footprint of surfactant producers and industries that use surfactants in their manufacturing process. These industries include food and beverage, agriculture, pharmaceuticals, paints & coatings and chemical manufacturing.

Spherelose Ltd is planning to manufacture cellulose surfactants in Aotearoa New Zealand, and sell them to product formulators for incorporation into products such as cosmetics, agricultural formulations and pharmaceutical preparations. As production scales and production volumes increase, it may be that production will move overseas to reach economies of scale to target lower-cost applications such as surfactants for industrial cleaning applications in the oil and gas industry.

Value

Extensive market engagement has resulted in interest from numerous global players in the surfactant industry, including Croda, Procter & Gamble, Evonik, Sassol, and Brenntag.

The move away from using chemicals derived from petrochemicals has led to a growing focus on biosurfactants – derived from biological sources and produced by fermentation.

The increasing uptake of this new class of surfactants indicates that there is an appetite in the industry for new and improved products to enter the market.

Whilst at an early stage, cellulose surfactant technology, with its additional advantages of having higher performance and being recoverable, has the potential to take a noteworthy fraction of a $100 billion industry.

Spherelose Ltd may be ahead of the competition. From third-party patentability and freedom-to-operate searches, Spherelose Ltd found no other patents or companies developing particle-based surfactant technology like cellulose surfactant technology.

The market for environmentally friendly surfactants is growing quickly. Providing inputs into products that are aimed at this market will maximise the chances of success for Spherelose Ltd. This fits in with the SfTI Challenge's mission-led outcome that seeks to advance smart, green manufacturing processes.

By providing environmentally friendly surfactants to companies requiring wetting properties, Spherelose Ltd could aspire to the role of a company such as NZ Pharmaceuticals, which, over many years, has developed valuable intermediate products for pharmaceutical companies.

Table 15 Potential impact of environmentally friendly surfactants

Economic characteristics	Potential	Comments
Potential entity size	Hundreds of millions	Markets for surfactants is approximately $100 billion
Market growth	5 percent	Solid growth, particularly for environmentally friendly surfactants
Potential market spillovers	Providing environmentally friendly products	Helping government, businesses, and individuals achieve environmental objectives
Companies like this[1]	NZ Pharmaceuticals	Providing pharmaceutical intermediates and ingredients

Note (1) Callaghan Innovation (2019)

Source: NZIER

7.3 Forest Surveying Robots

7.3.1 Description and background

The development of robotic systems to operate in forest environments is of great relevance for the public and private sectors. Robots operating in outdoor natural environments, including forest scenarios, have been the object of a substantial amount of research for decades.

Using robotics in forests has proven to be one of the most difficult research areas in robotics and has yet to be robustly solved. Difficulties in dealing with environmental conditions, the diversity of natural obstacles to be avoided, and the effect of vibrations or external forces, such as wind, are among some of the technical challenges faced.

The need identified in Aotearoa New Zealand forests is:

- The development of field robots that demonstrate Aotearoa New Zealand's capabilities and needs
- To more closely connect manufacturers of forestry equipment with Aotearoa New Zealand's academic R&D.

This approach intends to demonstrate the capabilities and potential of robotics that are being piloted and connect more tightly with industry in what is a difficult working environment.

The approach is based on end-user demand to develop a Forest Surveying Robot and the development of a 'Digital Twin' (DT) for this robot type, a computer model of the robot itself in its environment.

The motivation for the development of a Digital Twin is:

- To develop a communication tool between academic research and industry, allowing the research team to share and explore R&D outputs
- To assist with robot control when it requires information about the upcoming environmental situations and to assess the critical performance capabilities of the robot.

7.3.2 Applied research aims to make a change

The research team have collaborated closely with industry partners to make the most promising outputs available to the manufacturers and distributors by:

- Conducting trials of the selected Forest Robot Platform (FRP) with end users with a view to incrementally advancing the performance features
- Developing IP and taking the necessary steps to protect the IP with all partners
- Conducting in-forest tests with the end users and iteratively advancing towards fulfilling the criteria of the target performance levels and incrementally improving performance
- Developing a model to commercialise the forest robot platform (FRP) with stakeholders and other interested parties.

This project has taken an industry-led approach, uses computer simulations to inform the research, and focuses on the development of a surveying robot in a forest robot case study.

The change substitutes capital (in the form of a robot) for labour. If successful, it is likely to increase productivity and workplace safety, reducing costs and risks for forestry companies.

The resources used by the research team in building prototypes and developing software to produce a digital twin are relatively minor compared with the resources required for scaling disruptive technology shifts.

Working in collaboration with industry partners means that the technology (prototypes/software), if commercialised, will be licensed by those industry partners. This eliminates the need to spend on marketing or a marketing network.

The research team will form a joint venture, which will then, in turn, license commercialisation rights to industry partners based on sector and territorial reach. This provides a 'franchise' type model to enable scaling beyond just forestry into other sectors, and beyond just Aotearoa New Zealand into global territories.

The intellectual property rights and technology development skills to continue producing new robotic solutions for the industry remain in Aotearoa New Zealand.

The tight connection between the research team and industry partners means that the technology – if successful – will be absorbed in a way that those businesses will anticipate.

7.3.3 Expected value

Not yet determined, but improved productivity will assist the forestry industry in maintaining its viability while at the same time creating more intangible value by enabling safer working conditions.

Automation in the forest sector is an emerging and very new market:

- The Global Precision forestry market was $8.0 billion in 2023 and will grow to $50 billion by 2032
- The current market for precision hardware equipment is 15% of the total market
- Researchers are aiming at a sub-market of the hardware equipment market that is currently worth approximately $200 million.

The is expected to grow over time as there are still numerous forestry tasks that need to be mechanised, then once they are mechanised, they can move into robotics driving demand for automation.

The research team has identified that leveraging its strong existing relationships with industry bodies in New Zealand aids credibility in new jurisdictions, as well as strengthening international connections across those industry bodies.

Forestry is a niche area, but there is keen interest in robotic technology in such a difficult environment. Companies are interested since they have objectives to further substitute labour for capital. The more autonomy a vehicle has, the less labour is required.

The markets are pushing for such features. However, none of the current manufacturers have yet worked on implementing this type of technology for difficult operating environments such as forestry. Therefore, most of them are interested in the commercialisation models that are being proposed.

Policy impacts

Productivity is a major preoccupation of policymakers and economists. The more that can be done to foster innovation that leads to further productivity gains, the more likely that the economy will advance.

The resources used are minimal in the research and proof of concept stage. Scaling up will be done through existing forestry marketing channels.

Value

In the first instance, successful robotic technology will be demonstrated in use case-specific research trials and then licensed to businesses that specialise in servicing the forestry industry. Given the difficulties for robotics operating effectively in the forestry environment, there may also be other uses for this type of technology in the economy.

Export revenues into Aotearoa New Zealand, from conducting trials in other jurisdictions, is feasible in the near term, with over $500,000 of proposals pending in Australia that would incorporate the use of the field robot in Australian forestry conditions. These proposals have secured up to $150,000 in in-kind support from offshore plantation owners wanting to participate, demonstrating market pull.

New Zealand's Forest Growers Research industry levy body has supported engagement with the Forest & Wood Products Australia funding body, providing a valuable trans-Tasman linkage.

Research trials incorporating the field robot may provide the initial revenue stream in each jurisdiction to validate the technology for country-specific field challenges. Providing this level of validation will encourage distributors to take on a license matched to their sector and territory reach (franchise model).

From a national perspective, substituting capital for labour is a critical part of the productivity puzzle that New Zealand needs to solve. Incremental advances, such as successfully introducing robotics into forestry, assist with this.

Using robots in the testing forestry environment is something many companies are aspiring to do. Success in this area will attract worldwide interest and enhance Aotearoa New Zealand's reputation as a vibrant high-tech hub. It is likely to have other applications which could drive further success. In the first instance, this could be worth millions with markets in Aotearoa New Zealand and around the world.

Forest surveying robots fit into SfTI objectives for robotics and automation, specifically geared at reducing costs and improving efficiency. While the risks are different for WhereScape, improving productivity is critical for both entities. Mastering an environment such as forestry also means that applications for other industries are possible. WhereScape, data management systems work across a wide variety of industries.

Table 16 Potential impact of forest surveying robots

Economic Characteristics	Potential	Comments
Potential entity size	Millions	Not yet known
Market growth	Growing quickly could quadruple in size within 10 years	Success would mean strong demand and applied applications
Potential market spillovers	Application to other areas of the economy are possible	Mastering a difficult environment such as forestry means that other applications could well be developed
Companies like this[1]	WhereScape	Works on improving productivity and reduce risk.

Note (1) Callaghan Innovation (2019)

Source: NZIER

7.4 Protein Nanosatellites

7.4.1 Description and background

The COVID-19 pandemic has spotlighted the importance of structural biology in the development of new drugs to treat a range of diseases. One fruitful pathway for investigation has been to examine protein structures.

This has a range of biomedical applications:

- Accelerating the understanding of disease models
- Treatment of genetic disorders
- Development of new drugs to combat cancer and microbial infections.

There are other applications as well since it allows us to understand the structures of proteins in bacteria, fungi, plants, humans and other animals. This has led to high-value precision fermentation, the development of alternative food proteins, the engineering of superior crop strains, and the characterisation of agricultural diseases.

The dominant method for determining protein structure is through protein X-ray crystallography. Gravity impedes protein crystallisation. By reducing gravitational forces, the quality of the crystals improves, containing fewer impurities and imperfections, leading to higher-quality protein structures.

This is the reason for scientific interest in growing protein crystals and conducting a wide range of other biomedical and biological research in space. Many scientists from many different R&D entities have, for example, utilised the International Space Station for both fundamental and applied research.

Commercial applications from utilising a microgravity environment include new drug development, clinical biomedical applications, and sustainable solutions for the agriculture, health, and technology sectors.

7.4.2 Applied research aims to make a change

The goal of this research was to develop cost-effective, recoverable biological laboratories via nanosatellites, pushing the boundaries of fundamental science and commercial research and establishing a unique niche in the emerging space ecosystem for Aotearoa New Zealand researchers.

The objectives were to:

- Construct a protein crystallisation payload for nanosatellites
- Integrate the protein crystallisation payload into a CubeSat
- Test the protein crystallisation CubeSat on simulated space environments in anticipation of launch to orbit.

This is well beyond the scope of any research done in Aotearoa New Zealand. It has come about because of the continuing fall in the costs of launching payloads into space and the increased commercialisation of payloads.

Most of the resources used are focused on the development of the experiments in space and securing the payloads on space services.

Resources needed are minimal since this is the first attempt to bridge the gap between the development of a new knowledge-intensive industry and the aerospace and biotechnology/biomedical sectors.

The development of protein crystallisation modules is continuing but still in the research phase.

7.4.3 Expected value

The market for protein crystallisation modules is approximately $1.5 billion. Pharmaceutical and biotechnology companies are the biggest users and generate the most revenue from the protein crystallisation market. The expected demand growth for protein crystallisation is around 8 percent (Precedence Research 2021).

The approach has been enabled by the reduction in costs associated with production in space. This is a relatively new frontier for science where known techniques are applied in a completely new environment. The marketing chains that would be utilised are unlikely to change.

The market growth is driven by innovative product launches, mainly by pharmaceutical and biotechnology companies. Research is also a user with growing expenditure by various governments for proteomics research and technological advancements in crystallisation techniques.

The main growth is around:

- A growing demand for protein therapeutics to treat cancers
- The problem that high-quality protein crystals are required, and this is constraining growth
- Technological advancement is occurring, which potentially will have a major impact on the supply of quality crystals.

Pharmaceutical firms are the likeliest entities to pay for microgravity protein crystallisation services since crystallisation helps them develop drugs, and they have the biggest market share along with biotechnology companies.

Further strong demand is expected, approximately 8 percent.

Domestically, the Aotearoa New Zealand pharmaceutical and biotechnology market is valued at around $0.8 billion; therefore, there is some scope for market development. However, this will depend on the price and the willingness to pay for microgravity protein crystallisation.

Policy impacts and spillovers

It is too early to tell from a policy perspective what the outcome of this research programme will be. It does open up an area of research and potential economic activity that:

- Expands Aotearoa New Zealand's aerospace potential that could impact positively on capabilities, expertise, and revenue
- Creates a new, highly-skilled, high-paid, domestic workforce
- Delivers significant future export revenue via the platforms being developed and high-demand services provided to global pharmaceutical and biotechnology industries.

Value

Potential revenues are uncertain. This industry is just getting started, and it is difficult to figure out what revenues might be or whether competing technologies ‘on Earth’ will outperform microgravity crystals as demand drives more research.

Protein Nanosatellites fits with the SfTI Challenge's mission-led approach, opening up a new area of manufacturing that advances the sector's reputation as small, vibrant and high-tech. Potentially, it could service both customers in Aotearoa New Zealand and around the world, adding millions in turnover.

There are similarities between Arao Biosurgery and Protein Nanosatellites since both are focused on providing high-quality products for niche markets. These products are in high demand from clients.

Table 17 Potential impact of Protein Nanosatellites

Economic Characteristics	Potential	Comment
Potential entity size	Millions	High demand for quality. New approaches to producing microgravity crystals
Market growth	8 percent per annum	Market worth approximately $1.5 billion
Potential market spillovers	Expands variety of exports	Increases demand for high skilled labour
Companies like this[1]	Aroa Biosurgery	Niche market for high quality products meeting strictest standards

Note (1) Callaghan Innovation (2019)

Source: NZIER

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Appendix A Framework for analysis - innovation pathways

The framework we present is shown in Figure 5. It recognises the many ways that research leads to innovation and then creates value. The framework is intended to be universal – the pathway of every research project from discovery to deployment should be locatable on it.

Starting from the top, the Figure considers several features of innovation:

- Research interacts with the current state of the world
- Research aims to affect the economy, society, public policy, or other research
- Research uses resources
- Other actors are involved
- Innovation is a dynamic process
- Its outcomes are uncertain, and thus, research has an expected value.

The starting point is the interaction between research and someone or something who can use the research. The end point is greater value.

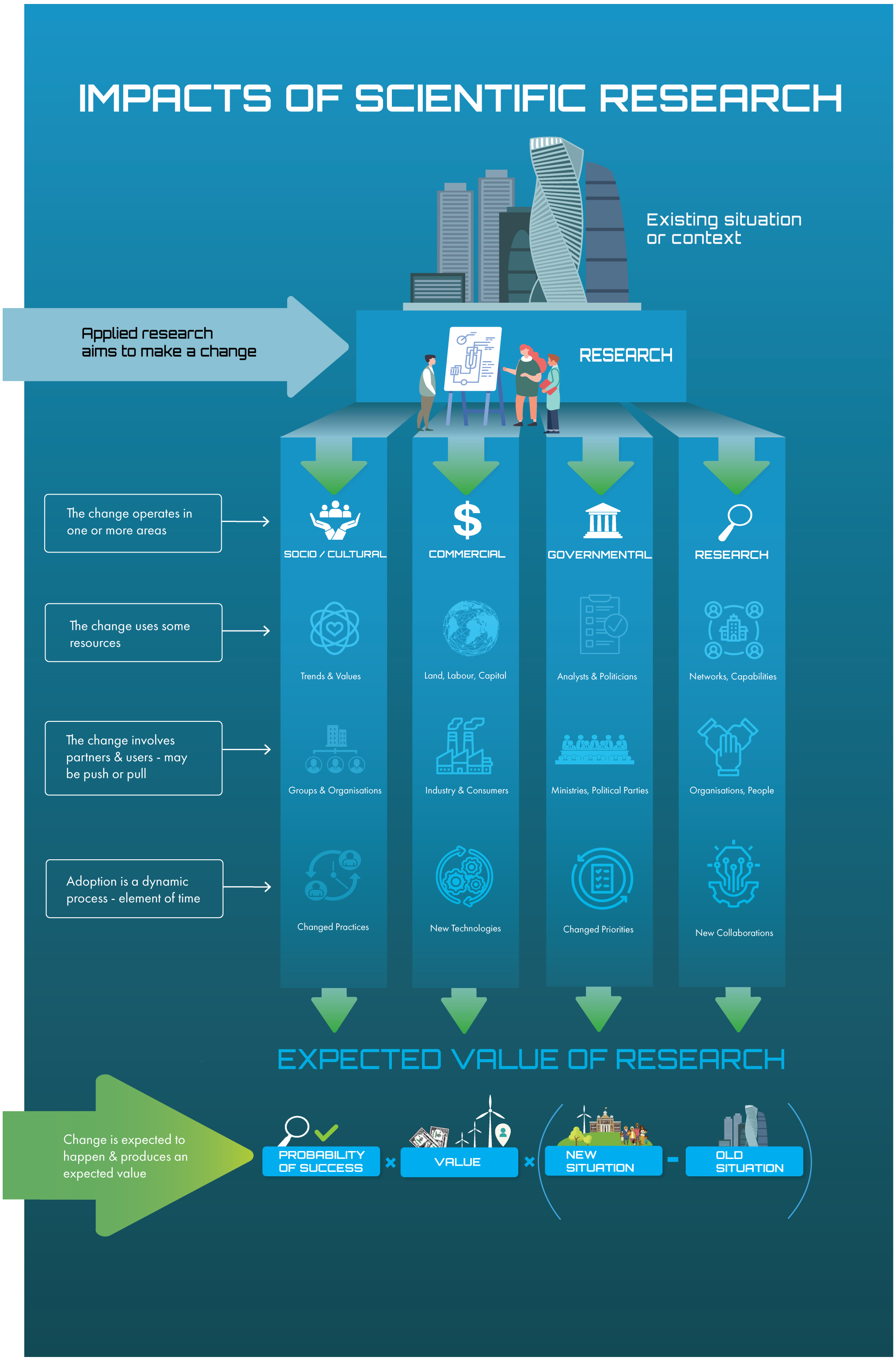
A.1 Links to prior frameworks

The link to the expected value concept should be immediately apparent. The process of change mapped out in the Figure leads to two assessments. The first is the probability that the required changes occur. The difficulty and complexity of the changes can be determined by following the required pathway. The second assessment is the value of the impacts. A common framework is the four wellbeings as dimensions of value. We use a similar idea here: research can create value across the four wellbeings. The wellbeings, from the Local Government Act of 2002, are social, cultural, economic, and environmental. Overall, this second assessment comprises:

- Some understanding of social, cultural, environmental, and economic value in New Zealand
- A description of the expected future, the new situation that will prevail in families, whanau, society, and economy
- A description of the counterfactual.

Together, these assessments can be summarised in a calculation of expected value.

Figure 5 Analysis framework



Source: NZIER

The framework has six main issues that it focuses on:

- The applied research makes a change

- The change operates in one or more areas
- The change uses resources, both physical and human. How these work in tandem impacts success
- The change involves partners and end users. What drives the research is likely to have push and pull factors
- Adoption is a dynamic process. This is tricky since we all tend to look at markets in a static sense. We can take a certain percent of the market without thinking about the competitor's response to a changing market
- Changes will happen as a result of technology, and there will be an expected value. Whether this can be estimated with any certainty depends on how far down the track the innovation is to commercialisation or social value.

A.2 Details of the pathways

A.2.1 Applied research aims to make a change

This framework is focused on the kind of research generally funded by the Challenge rather than more theoretical research funded by others. The approach captures the idea that research is interacting with its social, environmental, or economic context; it does not sit outside of that context. Applied research also seeks to make a change, to change the existing situation or context into something new. The change may be incremental or minor, or the research may target a step change.

A.2.2 The change operates in one or more areas

Funding may target one or more areas. We have identified four specific areas:

- Social/cultural
- Commercial
- Governmental
- Research.

The focus of the Challenge has been on:

- Social/cultural changes are those that affect society, families, whanau, and individual behaviours. These are often health-related but can also include changes such as choosing energy-efficient appliances.
- Commercial areas, research is intended to promote the economy or the performance of businesses or workers.

Governmental and (pure) research are not looked at in this report.

In this framework, the environment is not treated as a separate area.

A.2.3 The change uses some resources

Whatever change is envisioned it will use some resources. In a simple economic model, these resources might be land, labour, and capital. In an expanded description, resources include natural resources, financial resources, social capital, cultural capital, time, cognition, managerial ability, institutional capacity, and more.

Including resources as part of the pathways focuses the analysis on two important aspects:

- Resources are limited – we are accustomed to thinking of land, labour, capital, and natural resources as limited. In fact, all the resources we could use to conduct research and apply it to social/cultural, commercial, governmental, and research areas are limited. We will never have enough to do it all. With any specific research project or innovation, it is important to understand the limiting factor, the resource in the shortest supply. It creates the main limit on change
- Marginal contributions are important – given that each resource contributes to research and its application, it should be possible to understand the marginal contribution that each resource makes. Quantifying that contribution may be difficult, but understanding the marginal contribution conceptually may be sufficient.

A.2.4 The changes involve partners and users

People and groups will be involved in the change. They may have different roles and may be designated by several names: end users, stakeholders, partners, etc. Any specific project will involve such people or groups. We can describe the number of relationships, their strength, and their role in defining or evaluating the research. They may simply accept it when it is complete or contribute to shaping it.

The human and scientific resources used in innovation can be broken into two broad categories:

- demand-pull
- supply-push.

Demand-pull captures the idea that some end users will have an issue or problem that needs addressing, and they will find or conduct the research required. In the economic sphere, there is demand for a new product, such as healthier food alternatives, and then industry reacts to that demand.

Supply-push looks at innovation from the other end of the process. It focuses on producing more knowledge and more innovations, with the expectation that the good ones will be adopted. In New Zealand, the perceived low rates of adoption of university and CRI innovations are then analysed as an adoption problem. That is, the existence of the innovations is considered proof of their value; non-adoption is a failure in the pipeline, not the factory.

It is not clear what dominates. Some in New Zealand (e.g. Hendy 2012) have a more supply-push view of technology change, where the technology opportunities are a function of the state of the underlying science in any particular sector. While science has played a role in some areas (i.e., most recently in biotechnology), science has not driven innovation in other areas.

Mokyr (chapter 2 in Steil et al, 2002) shows that advances or breakthroughs in science and technology played no role in the development of steelmaking and steam power. These industries used already available technology to produce new products. In fact, causality ran the opposite way (demand pull) since the development of steam power assisted in the creation of the field of modern thermodynamics.

A.2.5 Adoption is a dynamic process

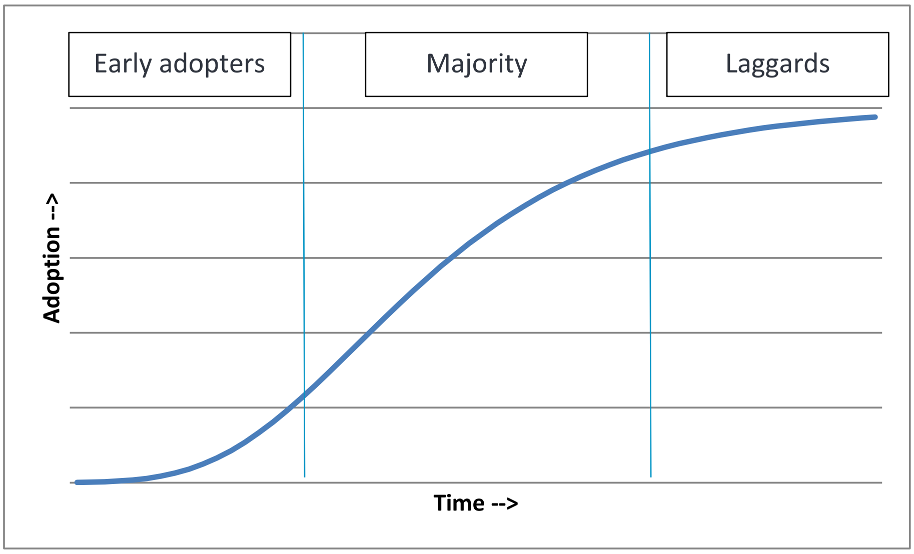
The framework explicitly includes time as a dimension to consider. Under each area of change, different elements might change. In the social area, beliefs or behaviours may change over time. In the commercial area, firms may adopt new processes. Governments may change their approaches to policy, or their key focuses, e.g. the focus on nitrate leaching as an important policy area. Research solves problems and then moves on to new areas. All of these changes will happen over time, both with and without the research or the innovation.

Less apparent but still included are feedback effects. When working with end users or stakeholders, researchers may find that their research priorities shift or become involved with new networks and collaborations. These effects are noted as possible impacts in the Research area as feedback from the adoption process.

One common approach to thinking about the timeframe of adoption is the adoption curve, shown in Figure 6. It shows a sigmoid curve in which adoption starts slowly and then builds momentum as it reaches the majority. At some point, the rate of adoption slows. In the last phase, adoption is a slow process.

Figure 6 divides adopters into three categories (some research uses more categories): early adopters, who are in the minority and keen to adopt; the majority, who are the bulk of adopters; and laggards, who adopt and innovation slowly and only after most people have already adopted. The adoption curve shows that adoption is a non-linear process and that it can take a while to build acceptance of an innovation.

Figure 6 Innovation adoption curve



Source: NZIER

Another approach to thinking about the time element of adoption comes from complexity theory. The twin forces of variation and selection create – over time – products, processes, organisations, and institutions that are well suited to their specific contexts. Variation is essential, because it creates a number of possible configurations that could be more successful than prior ones.

Selection pressures then eliminate poor performers and allow useful variations to thrive. Over time, better configurations arise and are selected. Complexity theory is essentially a Schumpeterian view of the economy, as described above. Failure or de-selection is inherent in the process – poor configurations must fail in order for better configurations to have access to those resources. Complexity theory also includes an element of time: successful innovations are those that have had time to arise but may be supplanted by later innovations.

Any assessment should take into account changes over time, the impacts on adoption, the feedback effects, and what they mean for the pathway that a piece of research takes.

A.2.6 Change is expected

The final part of the pathway framework is the calculation of expected value. As before, the expected value is based on the probability of an impact occurring, the size of the impact, and the counterfactual to which it is compared. The framework also reinforces the idea that research and innovation are directed towards change; the goal is to effect a change in society, culture, the environment, the economy, government, or research.

A.3 Use of the pathway framework

This framework is a kind of map. It lays out the possible geographic features in the innovation space. The next step is to examine different research projects and examples of innovation. We can map their paths through this terrain to determine which ones are easier, which ones are well-travelled, and which ones are perhaps underused. By categorising the paths through this space, we can create a taxonomy. With enough examples placed into this taxonomy, we could then determine which characteristics tend to be linked to successful research and innovation.