February 2012

Report 9

2058

Science Embraced

Government-funded Science under the Microscope

MCGUINNESS INSTITUTE

Project 2058: Report 9

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Report name *Science Embraced: Government-funded Science under the Microscope*

Citation Please cite this publication as:

McGuinness Institute (2012). *Project 2058 Report 9 – Science Embraced: Government-funded Science under the Microscope.* [online] Available at: www.mcguinnessinstitute.org/publications/project-2058-reports [Accessed date].

Published

ISBN 978-1-877473-22-7 (paperback)
ISBN 978-1-877473-23-4 (PDF)

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About the Institute The McGuinness Institute is an independently funded non-partisan think tank. The main work programme of the Institute is *Project 2058.* The strategic aim of this project is to promote integrated long-term thinking, leadership and capacity-building so that New Zealand can effectively seek and create opportunities and explore and manage risks over the next 50 years. It is hoped that *Project 2058* will help develop dialogue among government ministers, policy analysts and members of the public about alternative strategies for the future of New Zealand.

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Acknowledgements

We would like to extend a special thank you to Sir Paul Callaghan, who has been a constant source of support and encouragement. Sir Paul was a keynote speaker at the Institute's *StrategyNZ: Mapping our Future* event in March 2011, and has since assisted in our other work programmes. His work as a leader of science in New Zealand has provided inspiration to both the Institute and the wider community and we thank him for his outstanding contribution to New Zealand's science sector.

This report could not have been written without the considerable assistance of the Institute's research team, my co-authors, and the advice of our external reviewers (for a full list of bios see Appendix 1 and 2). The Institute was fortunate to have a dedicated research team focused on producing a thorough and evidence-based review of government-funded science in New Zealand. The guidance and assistance of external reviewers over the past two years has proved invaluable. Combined with the skills of our editor Susan Brierley, this has resulted in a report that we envisage will contribute to the national conversation on how best to spend our scarce public research dollar.

It was also a great privilege to attend the International Conference on Strategic Foresight in National Government at the invitation of the South Korean government in December 2011. Many of my discussions in Korea with fellow presenters, Steffen Christensen and Katherine Antal from Policy Horizons Canada, and Chor Pharn Lee from the Ministry of Trade and Industry Future Group, Singapore, were woven into the final conclusions of this report.

The McGuinness Institute team, external reviewers, policy analysts, and Ministry staff who assisted with the analysis, reviewed sections and answered our questions were critical to getting the report to this standard. In particular, we would like to thank Liz Prendergast and Philippa Yasbek from the Ministry of Science and Innovation for their input and feedback. Naturally any errors or matters of opinion expressed within the report are my own.

Finally, a special thank you to all those who have committed themselves over the past century to improving science in New Zealand. Without their considerable contributions, our science system would not be of the high standard that it is today.

Wendy McGuinness BCom FCA MBA
Chief Executive

Foreword

If we can embrace its potential, science could be a major game-changer for New Zealand. For too long we have thought of ourselves as a small farming nation making an honest, but simple living; we have believed that our strengths lie in agriculture and tourism and that these areas should be the focus of our economic future. Playing to traditional strengths has merit, but at the same time we must ask ourselves, what is the long-term economic carrying capacity of these sectors? Are these sustainable ways to create long-term wealth for New Zealand?

If we are serious about holding on to our unique culture and way of life, preserving our beautiful country and creating sustainable wealth then we need to raise our eyes above the horizon. I have no doubt that New Zealand has the potential to transform itself into a thriving knowledge economy, taking advantage of the sheer scale of foreign markets to sell high-end technological and creative products, without exhausting the land. That future requires us to aspire. But it is a future that we can create. We are rich in water and energy resources, we have a great education system, world-class science and engineering, a vibrant artistic and creative sector, quality urban environments and a civil society. When we combine all this with our unique landscapes, and our pristine mountains and seas, we have the chance to be 'The place where talent wants to live'.

The gulf between vision and strategy is no small obstacle to navigate. We cannot expect to simply invest more money into scientific endeavour and think that industry will flourish on this alone. What is needed is a national strategy and the resolve to move consciously towards its vision. This is not just a challenge for the science sector; the New Zealand public need to be engaged and inspired, to be involved as stakeholders and investors, and to be willing to take up this challenge alongside the science community. The challenge for the scientists is to articulate and act upon the values that will inspire their fellow citizens.

This report addresses the issue of values and the role of science in contributing to New Zealand as a sustainable nation. It addresses the relationship between science and ethics, the concept of frugal science and the idea of science driving policy. It is not just a review of science; it is an exploration of the conceptual thinking and strategy that drives government investment in science in New Zealand. It addresses the inherent challenge of ensuring top performance by exploring the role of science in New Zealand and questioning how its systems and institutions can be better directed toward a sustainable national strategy. This document provides the basis for a conversation that needs to be happening across New Zealand.

Paul Callaghan

Sir Paul Callaghan GNZM FRS FRSNZ

Executive Summary

[I]f we look to what should be the grand object of all study, the formation, namely, of the mind and the character, it will be found that there is scarcely any mental or moral facility which Science cannot develope and discipline.

Governor Sir George Ferguson Bowen.
First President of the New Zealand Institute
Inaugural Address, 1868

In 1868, in the inaugural address of what was to become the Royal Society of New Zealand, Governor Bowen noted the significance of science to what he termed 'the grand object of all study' – the formation of the mind and character. This report looks not at the specifics of science but at society's investment in science. The proper role of this investment is to foster science that serves the public interest. Government-funded science has a vital role to play in shaping New Zealand's future, but the successful fulfilment of that role depends on the will of its citizens to embrace science, and the will of its scientists to embrace the needs and wants of society.

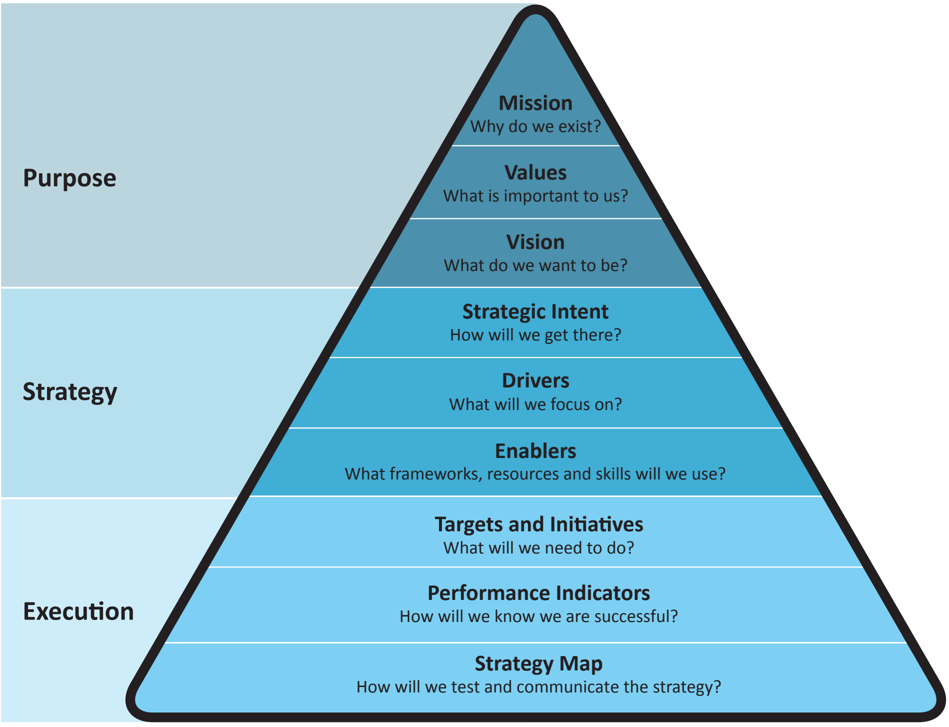
Assessing and strengthening the relationship between this process of investment and the broader context in which it occurs is critical if we wish to pursue science as a powerful tool for leveraging social action and improving well-being. A compelling vision, well-defined strategic intent, and a comprehensive strategy are all necessary to ensure this investment delivers on its potential. Essential to all these things is a broader discussion about what sort of future we want, and how we should work to achieve that future. This report aims to contribute to this important conversation by exploring the system of government-funded science in New Zealand. The report finds that there needs to be greater compatibility between government-funded science and the public interest, and that the responsible minister, policy analysts and science administrators will need to be very disciplined and committed if we are truly going to embrace science in this country.

The Approach

This report aims to contribute to the limited dialogue concerning the government-funded science system, in the hope that New Zealand invests its research dollar well, and delivers sustainable outcomes for current and future generations. The report is divided into four parts:

- **Part one** explains the purpose of the report and provides a brief overview of the methodology (Sections 1 and 2).
- **Part two** consists of three sections, which explore the historical context (where government-funded science in New Zealand has been; Section 3), the global context (the weak signals and wild cards that currently exist; Section 4) and the policy context (how science policy has responded to the global context; Section 5).
- **Part three** analyses the current government-funded science system. This is divided into three sections that address purpose, strategy and execution (Sections 6, 7 and 8). More detail on these sections can be seen in Figure 1.
- **Part four** identifies a number of key themes that become apparent in the earlier sections. Section 9 looks at policy knots – the questions that remain at the forefront of the debate yet are not often confronted. Section 10 suggests ways to optimise society's investment in government-funded science. In particular, it looks at the beliefs that are getting in the way and recommends nine key areas to recalibrate the system. Where possible, our approach has been to separate fact from opinion; allowing readers to make their own judgements about questions that remain outstanding, myths that act as constraints on the current system, and the actions necessary to optimise the government-funded science system.

Figure 1: The Strategy Pyramid
Source: Adapted from Kaplan & Norton, 2004: 33; 2008: 37



The report is built on an assumption that society needs good science. However, it finds that the government-funded science system has a long way to go before it delivers value to society through the provision of a vibrant and dynamic science community that is committed to working hard to achieve a shared vision for the future. What then is the formula for unlocking the science system so that it fosters significant improvements in the well-being of New Zealanders?

The Nine Pillars of an Optimal Science System

The formula for improving well-being through science consists of nine strategic pillars that together build a space where science and society meet. The pillars build sequentially on one another, creating an integrated and transparent framework in what could loosely be called a social contract. The pillars, in order, are: an agreed mission, a clear set of values, a compelling vision, a clear strategic intent (i.e. a preferred strategic direction), a set of overarching drivers, a set of enablers that meet the strategic intent, a comprehensive set of targets and initiatives, a set of indicators to benchmark progress over time and between countries, and finally a strategy map that communicates on one page how the strategy will deliver improvements to the well-being of New Zealanders.

The first pillar, the mission, is about ensuring there is clarity as to why the government should invest public funds in science and what would happen if this did not happen. Little exploration of this question is apparent in the literature; instead, there seems to be an assumption that this is what developed countries do. Why should this system be regarded as the best way to improve well-being, rather than, for example, purchasing expensive overseas-developed drugs to make New Zealanders well or creating generous research and development tax credits for businesses and allocating funds directly to central government to purchase the policy they require? Understanding why a system exists is an important starting point for designing an optimal system.

The second pillar is a set of shared values. The Ministry of Science and Innovation (MSI) indicates that a set of values is 'work in progress', but this is not good enough. A clear set of values should be driving change, not treated as an add-on after the main event. From our research, six values are paramount:

Value 1: To be honest.
Value 2: To discover.
Value 3: To serve.
Value 4: To sustain.
Value 5: To educate.
Value 6: To be accountable.

When rules and regulations fail, values are all we have. The right values enable those within the system to know right from wrong, know good science from bad, improve communication, collaboration and teamwork, and allow the system to respond consistently to ideas and issues, risks and opportunities, and emerging challenges.

The third pillar demands a compelling vision, one where short-term compromises and hard work are acceptable because of the long-term benefits they will deliver. MSI has put forward the vision of a 'high-performing science and innovation system improving New Zealanders' wealth and wellbeing'. This vision is about performance, and is as much focused on innovation as on science, as much on wealth as on well-being. This sets in place a research and development agenda that tends to focus on how the innovation process might create economic wealth. In contrast, a more compelling platform to attract and commit scientists is likely to be one that focuses on how the science process might best deliver improvements in the well-being of New Zealanders. For example: Science contributes to making New Zealand a sustainable nation.

The fourth pillar is strategic intent. Without transparent processes in regard to the identification and selection of strategic options, an optimal strategic direction will not be developed. New Zealand cannot afford sloppy thinking; it needs to put in place a clear strategy that says as much about what it will not focus on, as what it intends to focus on. The current system lacks a clear strategic intent, one that clearly sets out how well-being will be improved. After a great deal of discussion and deliberation, we suggest the strategic intent for the government-funded science system should be to focus on the following four objectives:

Strategic Intent 1: To inform public policy.
Strategic Intent 2: To improve the physical and mental health of New Zealanders.
Strategic Intent 3: To improve the financial security of New Zealanders.
Strategic Intent 4: To contribute to solving global problems.

Science must inform public policy, but as evidenced in this report, there is little proof that science – whether it is social, environmental, health-related or some other form of science – is shaping public policy. This aligns with the findings of the 2010 *Policy Expenditure Review*, which inquired into the cost, alignment, efficiency and quality of spending under the appropriations for policy advice and found that inconsistencies and gaps exist. It is also reinforced in a recent discussion paper by the Chief Science Advisor to the Prime Minister, who puts forward a case for the need to provide better use of evidence in policy formation.

Health, both physical and mental, is a key contributor to the well-being of New Zealanders, yet in the current system it fails to gain the level of financial support and focus one would have expected. For example, although there is a Health Research Council, it does not report to MSI, nor is there a Crown Research Institute (CRI) that focuses on health, meaning research and development in health is at best on the periphery of the system.

In terms of financial objectives, rather than referring only to wealth creation, the ability to preserve and grow other forms of capital such as intellectual capital, human capital, resource capital and natural capital should also be included.

Lastly, the current system does not focus on global problems, or indeed the opportunity to contribute to solving global problems. There appears to be a growing number of areas where New Zealand could join or lead global research partnerships aimed at resolving global problems. Synergies from such partnerships are likely to include opportunities to build capacity and recognition while at the same time contributing to the well-being of New Zealanders.

All four of the strategic objectives discussed above provide a clear intent, which can be further built upon to strengthen the system and ensure optimal outcomes.

The fifth pillar is clarity over the drivers that support the strategic intent. The current drivers of the science system tend to be broad ranging and nondescript. Drivers denote action and answer the question: if we decided to focus on three or four things to improve the system, what would they be? From our research, potential drivers that would deliver significant outcomes in the long term include a focus on foresight, education, and sustainable energy and food. For example, foresight can be used to test whether the current strategy has external cohesion with what we know or suspect about the future. Education is key as it is not only necessary to create good scientists, but also to create an informed society that is able to embrace science because its citizens know, use and receive the benefits. This means the public need to appreciate the nature of scientific inquiry, understand the processes that exist to test and peer review science, know the benefits of applying science discovery to business enterprise, and value the general knowledge that enables us all to observe and reflect on our current state of progress. Like science, education is a long-term investment, but it should also be assessed frequently to ensure any emerging young Ernest Rutherford or Beatrice Hill Tinsley is identified early and is supported to rise to the top, much in the same way potential sports stars are identified and supported early.

Universities also have an important role in transferring science to the private sector, as in the often-cited example of Stanford University's 700-acre industrial park, which was created in the 1950s specifically for private companies to commercialise the ideas of students. Education is currently undergoing significant change, which in turn provides a huge opportunity to utilise the learnings from scientific research, create science summer schools for budding scientists and integrate science inquiry into the curriculum.

The sixth pillar is a set of enablers to achieve the strategic intent. Our research identified five key enablers that need to be recalibrated: the institutional framework; scientists; research infrastructure; funding, and the regulatory framework. All five enablers need to work together to deliver on the strategic intent. Past experience would indicate that decision-makers tend to focus on changes to the institutional framework, rather than considering the other four enablers. This is unfortunate as institutional changes tend to be expensive and time consuming, therefore benefits take time to eventuate. Contrary to past practice, we consider there are real benefits to be gained from fine-tuning the other four enablers so that internal cohesion exists and synergies are gained.

Enabler 1: Institutional framework.
Enabler 2: Scientists.
Enabler 3: Research Infrastructure.
Enabler 4: Funding.
Enabler 5: Regulatory framework.

Enabler 1: Institutional framework
The current system is designed on the basis that more New Zealand research leads to more New Zealand development. We do not believe this is true (see Myth 1 below); we argue that they are two separate activities and require two different forms of management. This means that although we generally find the current institutional framework workable, there are two exceptions. Firstly, we suggest that development funds (those currently administered by the Innovation Board) should be appropriated to a sector better correlated with development, such as the Health Sector or the Economic Development Sector. The Education and Science Sector should retain the Science Board funding, appropriated to MSI, and focus specifically on education and scientific inquiry.

Secondly, the purpose of the eight CRIs does not align with the six priority investment areas. Ideally, they should be merged to form three entities: a biological development arm (a combination of AgResearch, Plant and Food, and Scion); a high-value manufacturing and services sector (HVMSS) development arm (IRL), and an environment research arm including energy and minerals research, hazards and infrastructure research and environmental research (a combination of ESR, Landcare, NIWA and GNS Science). Further, the current Health Research Council would become a CRI, creating a fourth arm focused on health and society. In addition to reporting to the Minister of Science and Innovation and the Minister of Finance, we believe CRIs should be required to report to the minister most closely related to the area in which they operate. For example, the Minister of Agriculture and Forestry for the biological CRI; the Minister of Economic Development for the HVMSS CRI; the Minister for the Environment (or Minister of Conservation) for the environment research arm, and the Minister of Health for the health and society CRI. The role of MSI would then be one of coordination, administration of the funding, and reporting on the input, process, output and outcomes of these four CRIs.

Enabler 2: Scientists
The 2010 *Policy Expenditure Review* recommended that central agencies should investigate a model of appointing Heads of Profession. This led to a Central Agency Policy Steering Group being asked to enter into discussions with the Chief Science Advisor to the Prime Minister with a view to looking at options on how to progress a Head of Science Policy. One of the findings of this report is that those who operate in the science community do not administer themselves as a profession; there is no qualification or organisational body that sets standards as to when and how the term 'scientist' may be used after someone's name. Providing more clarity over how this term is used would promote the science community and enable it to develop a better long-term relationship with society.

We believe the issue of who is a 'scientist' could easily be resolved by adding a professional body within the Royal Society, in much the same way the New Zealand Institute of Chartered Accountants (NZICA) administers use of the term 'Chartered Accountant'. For example, the term 'Professional Scientist' could be used to identify individuals who have a Bachelor of Science degree, have four years' work experience and now spend more than 50% of their working hours on science-related research or development.

Enabler 3: Research Infrastructure
The 2007 report prepared by the Research Infrastructure Advisory Group assessed the research infrastructure needs from 2007–2012, and was to be followed by the preparation of a government strategy for the sector. This project has been put on hold while the recent structural changes are finalised. Research infrastructure provides a strong platform from which the science sector can deliver globally competitive science, and it is timely for a deeper and broader public discussion on the optimal investment strategy. This should include the establishment of a register of current research infrastructure to ensure that assets are well utilised and properly maintained, and allow for an assessment of what should be outsourced or financed through public/private partnerships.

Enabler 4: Funding

Funding for the research agenda is the primary vehicle for change; as such it must be robustly debated, signed off by Cabinet, transparent, and reported against annually. Further, we consider the research agenda should be reassessed annually; this does not necessarily mean work programmes need to change, but they could be modified or fine-tuned to meet new and emerging needs and opportunities. There is a feeling in the literature that once a research investment is approved, it is a sunk cost. In business, it is about squeezing the best outcome out of an investment; hence an annual review of the research investment portfolio should be a matter of good practice, particularly in these challenging and changing times.

It is important to be able to assess whether the establishment of the ten CRIs in 1992 met investment expectations. Have they greatly enhanced the transfer of technology, and are there better ways to meet that goal? The funding of CRIs has long been a vexatious issue in the science system. The 2010 Crown Research Institute Taskforce resulted in a major change to the way in which CRIs are funded, with the introduction of core funding. The changes to date are improvements, but do not necessarily go far enough. We suggest that there needs to be a set of criteria to determine the optimal percentage of non-contestable funding (i.e. core funding) to total funding for CRIs, and that further inquiry should be undertaken to understand the risks, costs and benefits of these percentages. Given the suggested merger proposal above, our thinking would be that primarily commercial CRIs should receive a lower percentage of core funding, e.g. 45%. This is in contrast to CRIs with a less commercial focus, which should receive significantly more, e.g. 75%. The percentage of health and society funding would need to be considered more closely if a CRI were to be created in this area.

Enabler 5: Regulatory framework

The implementation of necessary regulations on public and private activity is critically important, yet it is often subject to criticism from many in the science community, frequently without supporting evidence. Safeguards against financial failure and environmental pollution, as well as regulations that support research and development, encourage investment, and the lodging of patents and intellectual property, inspire the private sector to grow. Scientists should embrace regulation as a means of creating a stable and robust market for development to flourish. This is not to say tweaking is not necessary, particularly as new research informs best practice, but the assumption that regulation negatively impacts on growth appears grossly overemphasised in the science community. Instead we found that risk management practice and ethical standards appear significantly behind public expectations, as indicated in examples relating to genetic modification, the Dairying and Clean Streams Accord and National Water Standards.

The seventh pillar relates to the need for execution of the strategy, in particular the need for clear targets and initiatives. Not only must each target be clear and concise, but the linkages between the target and the initiatives must be logical and achievable. Fundamental to this pillar is the need for the research agenda to be a publicly available document. It must not only list the agenda, but also explain how it was formulated, what evidence it was based on, and who was involved in its development. In other words, the same process of peer review that is common practice in science should also be applied to the research agenda. Ideally, the agenda must set out the high-level problems and mysteries it is trying to solve, and clarify how the research results will create value and how such findings might lead to further research or development. This could be explained using influence diagrams, a useful method for showing how one level of research can feed into another, making it clear that there is an order in which the research should be conducted to best solve the high-level problem.

The eighth pillar relates to the need for a comprehensive set of indicators to benchmark progress over time. One of the key assumptions underlying this paper is that citizens are key stakeholders in government-funded science, a point that is not always apparent in the current system. MSI, as the lead agency, must endeavour to report on the research agenda (input), the administration (process), the output (investment report) and outcomes (improvements in well-being) in a clear and transparent manner. Indicators of interest include the administration costs of the investment dollar for each method of allocating investment funds. For example, if the high-level problem was to reduce phosphate run-off, initiatives could be to research alternative forms of fertiliser, placing a tax on phosphates, looking at how to maximise the value from phosphates (e.g. application methods and timing of application), and reviewing ways to protect freshwater streams. A key indicator would then be a reduction in the imports of phosphates in to New Zealand.

The ninth pillar is testing and communicating the strategy to stakeholders through a strategy map. Strategy mapping is a concept that was developed by Professor Robert S. Kaplan of Harvard Business School and Dr David Norton, founder and director of the Palladium Group. Mapping a one page strategy has proven a very useful instrument for bringing about change. Since MSI's strategy is still a work in progress, this report provides an opportunity to showcase this tool in action (see example in Figure 36, page 126).

Together all nine pillars set out a way to develop a culture that embraces science, but this will not be enough. It is clear from reviewing the system that much of the debate on strategy is centred on the pillars in the middle of the strategy pyramid, and in particular on certain aspects of the enablers. The lack of focus on the remaining pillars is a key concern. Clarity over purpose and execution is fundamental to improving well-being; hence refocusing the debate on these pillars is the only way for real progress to be made.

The Way Forward

Put plainly, we need to research the research. Section 9 puts forward 30 policy knots, all of which must be addressed if we wish to develop an optimal government-funded science system in New Zealand (see Appendix 6). From this work it has become increasingly apparent that a number of dominant beliefs are not supported by evidence and are likely to be untrue. Dominant beliefs that are untrue are myths, and are extremely dangerous in that they can lead to poor decision-making based on false assumptions. If we want an optimal system, we need to ensure that the system design is based on beliefs that are true. Section 10 discusses each of the following four myths, addresses the implications if these myths were busted and, lastly, suggests how each of the nine pillars would be redesigned.

Myth 1: More New Zealand research leads to more New Zealand development.
Myth 2: New Zealand research informs New Zealand public policy.
Myth 3: Science ethics are embedded in science practice.
Myth 4: 'Innovation' is a useful term to drive the government-funded science system.

One of the key findings from this report is the idea that research and development are different activities, requiring two very different management styles. Research should be undertaken to inform policy and inform investment in science, hence it is about the research agenda and infrastructure; who sets the agenda, who implements it and who reviews the results. In contrast development is about new products and services; who creates them, what markets and niches will be targeted, who are the investors and who delivers them to the market. Both research and development intersect with society, but the first is about shaping society through policy, while the latter is about shaping society through products and services, and the wealth they create.

If government wishes to invest in science to preserve and improve our wealth, it must do so by applying the same rules as business. This means government must set the investment criteria including the level of business risk acceptable, the boundaries of the investment (and require approval to go outside these boundaries), the level of due diligence, and the frequency of independent and comprehensive reviews of individual investments and the overall investment portfolio. In this way value can be assessed, and if it is not performing or the government wishes to change the direction of the public's investment, it can do so by changing the investment criteria, the level of investment, the membership of the boards, and the boundaries so that outcomes can be optimised.

Critical to understanding why such a high-level of governance is needed, is appreciating why it is important. It is not the size of the investment that is crucial (just under 1% of government expenditure) but the fact that it is one of the few areas where government invests solely in our future. Much of government expenditure responds to past problems and current issues, the urgent issues that drive day-to-day activity. The opportunity for the science sector is to focus on the important issues that deliver leaps in progress. In addition, science is a long term investment, it takes many years to undertake research or develop new products and services, and therefore it takes even longer to acquire the benefits. However, although it is a long-term investment, when done correctly the returns can be greatly disproportionate to the level of investment.

Another idea from our research is that over the last twenty years government has wrongly put its effort into creating a dynamic and creative government-funded science system, in particular through the establishment of CRIs. In contrast, we believe the role of government should be two-fold: to create a stable and evidence-based government-funded science system while at the same time working with the private sector to help make it more dynamic and creative.

To conclude, greater compatibility between government-funded science and the public interest requires progress in three areas. Firstly, it requires ministers and policy analysts to be clear about what research they need, to have in place systems that assess and quantify the quality and independence of the research that is provided, and to report back to researchers on what was useful and why.

Secondly, it requires the science community not to distance itself from the public interest, but to seek out better practices that enhance the profession, such as ethical standards, public accountability, comprehensive reporting, and a high level of transparency. In particular, we suggest that science needs to be treated as a profession. Experience indicates this is best created through a membership organisation; one that is supported by individuals rather than entities, so that it creates a society of scientists, not science organisations. This way, scientists can strengthen their collective voice.

Lastly, it requires MSI to be disciplined and committed to providing an example of how science can be embraced to improve well-being. The ministry needs to be an example to the science community – brilliant, agile, forward-engaging, demanding, tactical, flexible, highly focused, ethical and disciplined – but most of all, it needs to create a strategy that compels the minister, scientists, industry and the public to join in a work programme that will deliver New Zealand to new levels of performance.

If New Zealand wishes to pursue science as a powerful tool for leveraging social action and improving well-being it is clear that there is significant work to do. It is our hope that the insights, issues and ideas put forward in this report provoke discussion and provide some light as to the best way forward.

[W]e all learn what are useful ideas or otherwise as we go.

Beatrice Hill Tinsley, 1941 – 1981

We don't have the money so we have to think.

Ernest Rutherford, 1871 – 1937

1. Purpose

This report forms part of the Institute's *Project 2058* and aims to assess the extent to which the current government-funded science system is capable of delivering value for New Zealand. In addition, and where appropriate, it suggests how the current system might be improved to achieve better long-term outcomes. To support this report, the Institute has undertaken an analysis of New Zealand's government-funded science system, science institutions and comparative international systems. This analysis is documented in two background reports and six working papers (see Section 2 for the full list of reports and working papers).

This provides background information about the Institute and *Project 2058*, and then answers three questions: what is government-funded science, what is a National Sustainable Development Strategy (NSDS) and what is the relationship between an NSDS and government-funded science?

1.1 The McGuinness Institute and Project 2058

The McGuinness Institute (previously the Sustainable Future Institute) is a privately funded, non-partisan think tank working for the public good, contributing strategic foresight through evidence-based research and policy analysis. The Institute's flagship project is *Project 2058*. The research program began by exploring the landscape through discussions with experts in the area then establishing our key objectives. The Institute then employed a research team and identified and invited external reviewers to guide the team through the process. Appendices 1 and 2 list the research team and the external reviewers involved in this report.

Earlier work by the Institute found that New Zealand is well behind on its international obligations to develop and implement a National Sustainable Development Strategy (NSDS) (SFI, 2007). The strategic aim of *Project 2058* is therefore to promote integrated long-term thinking, leadership and capacity-building through the development of an NSDS that effectively seeks and creates opportunities while simultaneously exploring and managing risks over the next 50 years. It is hoped that *Project 2058* will help develop dialogue among government ministers, policy analysts and members of the public about alternative strategies for New Zealand's future.

In order to achieve this aim, the *Project 2058* team is working to:

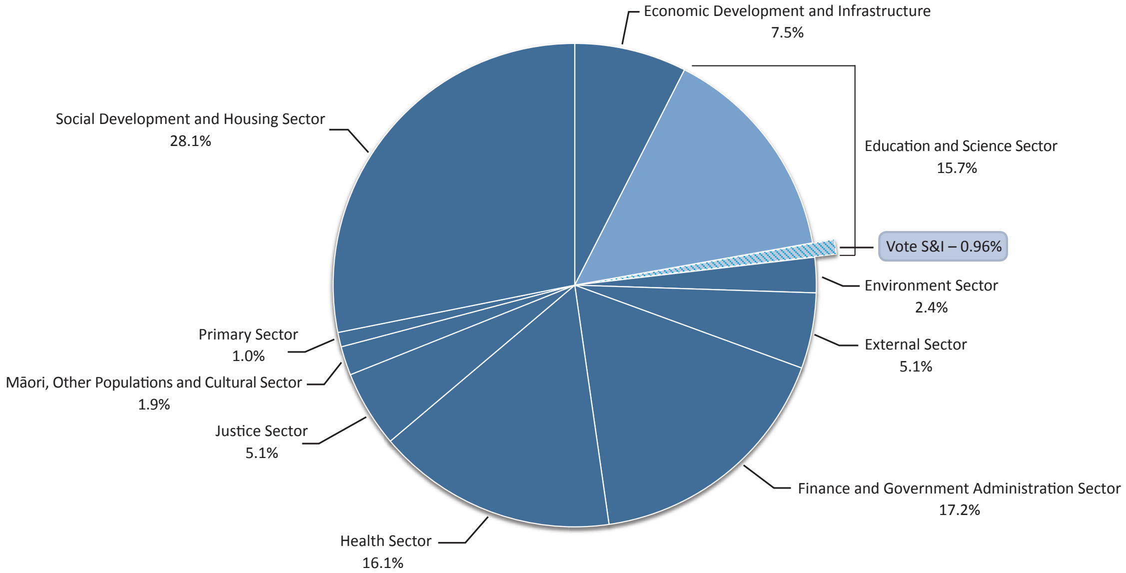
1. Develop a detailed understanding of the current national planning landscape, and in particular the government's ability to deliver long-term strategic thinking;
2. Develop a good working relationship with all parties working for and thinking about the long-term view;
3. Recognise the goals of iwi and hapū, and acknowledge te Tiriti o Waitangi;
4. Assess key aspects of New Zealand's society, asset base and economy in order to understand how they may shape the country's long-term future, such as government-funded science, natural and human-generated resources, the state sector and infrastructure;
5. Develop a set of scenarios to explore and map possible futures;
6. Identify and analyse New Zealand's future strengths and weaknesses, and global opportunities and threats;
7. Develop and describe a desirable sustainable future in detail, and
8. Prepare a *Project 2058* National Sustainable Development Strategy. (SFI, 2012a)

Earlier reports by the Institute have addressed, in particular, points 1, 3, 5 and 6 above. This report, along with the supporting background reports and working papers, is designed to help progress the fourth point, by providing an assessment of government-funded science. The final output of *Project 2058* will be point 8, the creation of the Institute's NSDS for New Zealand.

1.2 What is Government-funded Science?

As part of government spending, government-funded science sits within the Education and Science Sector, which is one of the 10 sectors that group government appropriations. See Figure 2 below and Appendix 3.

Figure 2: Vote S&I – Sector Appropriations, 2010/11 (Estimated Actual)
Source: Adapted from Treasury 2011a: xv–xvi; 2011b: xxviii–xxix



Science sits beside education, rather than in other related sectors such as economic development and infrastructure, health or the environment. This implies its high-level purpose is to inform (educate) these other sectors. In this report government-funded science includes all funds allocated through Vote Science & Innovation (Vote S&I).[1]

In 2011/12 these budgeted funds amounted to $773.7 million, which accounted for 0.94% (compared with 0.96% in 2010/11 [estimated actual]) of total government expenditure for this period (Treasury, 2011c: 273; 2011b: xxviii–xxix).[2] See Figure 11 for a detailed breakdown of Vote S&I appropriations budgeted for the year 2011/12.

A number of research funds exist outside of Vote S&I, such as the Performance Based Research Fund (PBRF),[3] and are managed via Vote Education, Vote Agriculture and Forestry, and Vote Health. The administrators of those funds are the Tertiary Education Commission (TEC), Ministry of Agriculture and Forestry (MAF) and the Health Research Council (HRC), respectively.[4] However, these funds are not the primary focus of this report. Details of other purchase institutions are outlined in Appendix 2, Report 9b (SFI, 2011a: 12) and the MSI infographic (MSI, 2011a).

Much of the literature also refers to public science interchangeably with government-funded science; however, the term public science is not used within this report as there also exist privately funded public research and publicly funded private research. For example, the New Zealand Institute, the Morgan Foundation and this Institute are all privately funded to benefit the public good.

1 Prior to 1 July 2011 Vote Science and Innovation (Vote S&I) was known as Vote Research, Science & Technology (Vote RS&T) (Treasury, 2011c: 270). Also the appropriations that were in Vote Crown Research Institutes in 2010/11 are now in Vote Finance 2011/12 (Treasury, 2011d: iv).

2 Vote S&I 2011/12 was $773,700,000 (Budgeted) (Treasury, 2011c: 273); total government expenditure 2011/12 was $82,050,480,000 (Budgeted) (Treasury, 2011b: xxvii–xxix)). Vote S&I 2011/12 = 0.94% of total budgeted government expenditure in 2011/12.

3 See report on the Performance Based Research Fund (PBRF), Bakker et al. (2006).

4 For information on specific funds and the administrators' investment strategies see MoE, 2010; MAF, n.d.; and HRC, 2010.

1.3 What Is a National Sustainable Development Strategy?

In 2001, the New Zealand Cabinet agreed to produce an National Sustainable Development Strategy (NSDS), but to date this decision and the resulting commitment to the United Nations to produce an NSDS remains unfulfilled; the New Zealand government has not produced an NSDS.[5] New Zealand's commitments to the United Nations included an agreement to reach two international targets: (i) the 'introduction' of an NSDS by 2002, a target set at a Special Session of the UN General Assembly (UN, 1997: para 24), and (ii) the 'implementation' of an NSDS by 2005, which was set under the Johannesburg Plan of Implementation (UNDESA, 2002a: para 162 [b]). At Johannesburg it was agreed that member states would take immediate steps to make progress on the formulation and elaboration of national strategies for sustainable development.

The McGuinness Institute advocates an NSDS as a key policy initiative for New Zealand's future prosperity and well-being. This concept is promoted internationally to improve the alignment and integration of diverse but interconnected national sectors, in order to achieve more sustainable outcomes over both the short and the long term (UNDESA, 2002b: 1).

Two internationally recognised definitions of an NSDS are given below. The Organisation for Economic Cooperation and Development (OECD) recognises an NSDS as:

> … strategic and participatory processes encompassing analysis, democratic debate, capacity development, planning and action towards sustainable development. (OECD/DAC, 1999: 2)

Similarly, the United Nations Department of Economic and Social Affairs (UNDESA) defines an NSDS as:

> … a coordinated, participatory and iterative process of thoughts and actions to achieve economic, environmental and social objectives in a balanced and integrated manner. (UNDESA, 2002a: 1)

An NSDS is an opportunity to construct a strategic pathway into the future by conceptualising what that future could look like (what is probable and what is possible) and balancing this against what is desirable (what is preferable). The cyclical, iterative nature of an NSDS means a strategy document is not the end product, but rather a stage in an on-going process (UNDESA, 2002b: 1).

In 2008, the Institute identified the NSDSs of Finland, Sweden and the United Kingdom as examples of 'best practice', and analysed them in order to understand the elements they held in common (SFI, 2008a). From this research seven elements were identified (see Table 1).

Table 1: The Seven Common Elements of an NSDS
Source: SFI, 2008a: 2[6]

Seven Common Elements of an NSDS	Seven Strategic Questions
1. Background (to the strategy)	Where have we been and where are we now?
2. Vision (including desired outcomes)	Where do we want to be in the long term?
3. Principles (and values)	What do we believe in?
4. Priorities	What do we need to focus on?
5. Method of implementation	What do we decide to do and not to do?
6. Governance	Who is going to do what?
7. Monitoring progress	How well are we going?

5 To learn more about New Zealand's international commitments, see Report 1: *A National Sustainable Development Strategy: How New Zealand measures up against international commitments* (SFI, 2007).

6 For further information on the seven common elements of an NSDS see the Institute's Report 5: *The Common Elements of a National Sustainable Development Strategy: Learning from international experience* (SFI, 2008a).

There are a number of benefits to developing an NSDS that go beyond simply meeting our international commitments or reinforcing a 'clean and green' brand globally. At its core, an NSDS is about thinking and acting in a way that does not sacrifice our long-term best interests for short-term rewards. Economist Michael Lewis discusses this dilemma in his recent book *Boomerang*, in which he asks what happens when a society loses its ability to self-regulate. One outcome may be that we hit rock bottom, in which case, the environment will 'administer the necessary level of pain' to change the way society operates, because we will have no other choice (Lewis, 2011: 206). An NSDS is a way to ensure we do not get to this stage.

1.4 What is the Relationship Between Government-funded Science and an NSDS?

An NSDS will help ensure that a coordinated approach is adopted across the public sector so that investment decisions relating to employees, services, resources, risk, public-private partnerships and much more are considered, integrated and reported upon, in ways that develop consensus, gain public support and deliver the best outcome for current and future generations. Ensuring that New Zealand has an optimal government-funded science system is an important part of any strategy that aims to deliver New Zealanders a robust future.

Many of the issues that New Zealand will face in the future have significant implications for our science sector. The long-term well-being of New Zealanders will depend in part on innovative science and technologies, more effective use of existing science and technologies, and changes in behaviour. Government-funded science has the potential to be a game-changer, provided the system is designed both to find new solutions to pressing problems within New Zealand (and the solutions are implemented) and create new strategic knowledge that drives positive change.

Decisions around investment in the science sector are not the sole domain of scientists and need to be considered in the public arena. Good public policy should engage with all sectors of the community through all stages of the process. An NSDS would require government institutions to: seek public engagement on how best to achieve the country's objectives throughout the whole science system; integrate policy objectives and strategy across the whole system; and report results back to the public. A transparent process creates trust and supports further investment in the science sector.

An NSDS also requires robust measures and benchmarking for monitoring and reporting progress. Statistics New Zealand's *Monitoring Progress Towards a Sustainable New Zealand* (2002) provides a selection of indicators related to sustainable development in New Zealand. These indicators show how science should inform public policy by helping to; (i) set the context for a discussing the research agenda, (ii) assess how changes in policy might impact on the environment and society in general and (iii) provide insights concerning New Zealand's progressing towards achieving it strategic goals. For example, the 2010 report on 16 key indicators tells us that; the unemployment rate is increasing, nitrogen in rivers is increasing, greenhouse gas emissions are increasing, distribution of all seven selected native species are down, and that energy intensity has decreased (Statistics New Zealand, 2010: 6, 14, 16–18). This is useful scientific data for informing our research agenda, assessing the impacts of current policies and shows where we are making progress or losing ground. Hence, the quality and timeliness of scientific data is a key factor in creating effective public policy.

It is not the size of the public investment that makes it relevant, but the fact that it is one of the few investments the government makes that may significantly change our future. Much of government expenditure responds to past problems and current issues, the urgent issues that drive day-to-day activity. The opportunity for the science sector is to focus on work that enables leaps in progress to occur, with an eye to the long-term future.

This report aims to contribute to improving the quality of public engagement on this important investment. It is hoped that the ideas, issues and challenges identified during this research will add to the debate as to why, when, where, what and how the New Zealand government should be investing in science.

2. Methodology

The methodology the Institute has adopted is set out in Version 4 of *Project 2058*'s methodology (SFI, 2012a). The work programme underlying this report was designed to assess the extent to which the current government-funded science system is capable of delivering long-term value, and where appropriate to make suggestions as to how the current system might be improved to achieve better long-term outcomes for New Zealanders.

2.1 Background

Scoping for this report began in 2007, with the Institute completing a number of interviews with New Zealand scientists and science administrators. At this time, neither the Institute nor those interviewed realised the full extent of the reforms being proposed by government. When this became apparent, much of our initial analysis was placed on hold and instead the Institute focused on completing a report on the history of government-funded science in New Zealand (i.e. Report 9a). It was only recently, as the system became more settled, that we reopened this area of study with a view to completing and publishing this final report.

2.2 Method

In order to achieve its purpose the Institute first undertook a scoping exercise. This led to the creation of three work streams: (i) the historical context (Background Reports 9a and 9b); (ii) the international perspective (Working Papers 2009/5 and 2010/01), and (iii) an analysis of the current system (Working Papers 2011/14, 15, 17 and 18). The full titles of these reports and papers are listed below:

Report 9a	*A History of Government-funded Science from 1865–2009* Authors: Wendy McGuinness, Chris Aitken, Joe McCarter, Mark Newton
Report 9b	*A History of Government-funded Science from 2009–2011* Author: Wendy McGuinness
Working Paper 2009/05	*Exploring New Zealand and International Government-funded Science Goals* Author: Chris Aitken
Working Paper 2010/01	*Exploring Long-term Policy Drivers in Science: A scan of international think tanks* Author: Lucy Foster
Working Paper 2011/14	*MSI Innovation Investment Board: Legislation, operations and board membership* Author: Wendy McGuinness
Working Paper 2011/15	*MSI Science Investment Board: Legislation, operations and board membership* Author: Wendy McGuinness
Working Paper 2011/17	*New Zealand Universities: Research activities, commercialisation and international benchmarking* Authors: Wendy McGuinness and Lucy Foster
Working Paper 2011/18	*New Zealand's Crown Research Institutes: Legislation, operation and governance* Author: Diane White

This report builds on the reports and papers listed above, with the view of meeting seven key objectives:

Objective 1:	Define what is meant by government-funded science (Section 1.2)
Objective 2:	Review the history of government-funded science in New Zealand (Section 3)
Objective 3:	Describe the changes to the government-funded science system between 2009 and 2011 (Section 3)
Objective 4:	Consider international developments and recent changes in science policy (Sections 4–5)
Objective 5:	Analyse the current government-funded science system in terms of purpose, strategy and execution (Sections 6–8)
Objective 6:	Identify outstanding issues (Section 9)
Objective 7:	Suggest how the current system can be improved to create a more effective and efficient science system for New Zealand (Section 10).

2.2.1 Approach

The structure and approach taken in this report has been strongly influenced by the strategy mapping methodology developed by Harvard Business School. Although the strategy map is just one tool used to develop and polish a strategy, it is a powerful tool that not only provides clarity, but also enables strategy to be discussed and debated. Strategy mapping was a core conceptual component of the Institute's *StrategyNZ: Mapping our Future* event, and the Institute regards the strategy mapping process as an important tool in the creation of a National Sustainable Development Strategy.

In adopting this approach we have drawn heavily on the work of Robert S. Kaplan, a professor at Harvard Business School and Dr. Norton, founder and director of the Palladium Group. Although strategy maps were developed with businesses in mind, their usefulness as a way of demonstrating a strategic outline clearly and communicating visions and strategies effectively means they are increasingly being used by communities and even countries.

Strategy mapping is a process whereby horizontal and vertical linkages between the different strategic components can be identified and integrated into the overall strategy. Each stage builds into the next through an integrated approach that vertically aligns the purpose, strategy and execution through cause and effect relationships. This approach ensures a strategy has both internal cohesion (within the elements of the strategy) and external cohesion (with the wider landscape). The strategy process can be divided into nine stages, all of which are necessary in order to implement an optimal strategy, see Figure 1 in the Executive Summary. Together these nine stages act as pillars, creating a sound platform for building New Zealand's future. Further information on this approach and how it relates to the development of an NSDS can be seen in Version 4 of *Project 2058*'s methodology.

2.2.2 Terminology

Key terms used throughout the report are defined below. In addition, a glossary and list of abbreviations are provided at the end of the report.

Government-funded science

Government-funded science is defined in Section 1.2. In Section 9 we also raise the concept of an optimal government-funded science system. In using this term we are not arguing for optimal science, but for a system that operates in such a way as to achieve the desired vision as effectively and efficiently as possible.

Commercialisation

The recurring theme of commercialisation is described in the Ministry of Research, Science and Technology's (MoRST) 2010 strategy document *Igniting Potential* as:

> [The] transfer [of] research outputs to end-users, either through existing businesses or where necessary through the creation of new commercial entities. (MoRST, 2010a: 19)

Invention and innovation

Briefly, an invention is a product or service that is completely new, while an innovation is an iteration of an invention or a significant improvement to a product or service. Later in the report we discuss the appropriateness of the term 'innovation' with respect to the ministry overseeing the science system. Definitions include:

> An invention discloses an operational method of creating something new. (Maclaurin, 1953: 102)
>
> Innovation is the process that translates knowledge into economic growth and social well-being. It encompasses a series of scientific, technological, organisational, financial and commercial activities. Research is only one of these activities and may be carried out at different phases of the innovative process. (Australian Research Council, n.d.)
>
> An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. (OECD, n.d.)

Research, Science and Technology

These terms are frequently used together, as a way of providing broad coverage of the subject. An example is the 'Research, Science, and Technology Act 2010'. Although it is implied that the individual terms have separate meanings, they are not defined in the Act. Instead, a general explanation is provided with regard to the purpose of RS&T funding:

> Purposes for which specified RS&T funding may be allocated
>
> 1. Specified RS&T funding may be allocated for research, science, or technology, or related activities, for the benefit of New Zealand.
> 2. The activities referred to in subsection (1) include (but are not limited to) any activity that—
>   a. is likely to increase knowledge or understanding of the physical, biological, or social environment; or
>   b. is likely to contribute to New Zealand's economic growth; or
>   c. is likely to develop, maintain, or increase skills or scientific or technological expertise that is of particular importance to New Zealand; or
>   d. is unlikely to be funded, or adequately funded, from non-governmental sources; or
>   e. facilitates research, science, or technology, or related activities; or
>   f. promotes or facilitates the application of research, science, or technology, or related activities. (Research, Science, and Technology Act 2010, s 7)

Definitions found in other legislation that have proved useful in this report include:

> Research means scientific research; and includes scientific development and related services. (Crown Research Institutes Act 1992, s 2) [Bold removed]
>
> Science includes the physical sciences, the biological sciences, and the social sciences; and also includes technology; and scientific has a corresponding meaning. (Crown Research Institutes Act 1992, s 2)[Bold removed]
>
> [T]echnology means the practical application of scientific principles and knowledge. (Income Tax Act 2007, LH7, s 5) [Bold removed]
>
> Research and development activities
>
> 1. In this subpart, research and development activities of a person are—
>   a. systematic, investigative, and experimental activities that are performed for the purposes of acquiring new knowledge or creating new or improved materials, products, devices, processes, or services and that—
>   i. are intended to achieve an advance in science or technology by resolving scientific or technological uncertainty:
>   ii. involve an appreciable element of novelty:
>   b. other activities that are wholly or mainly for the purpose of, required for, and integral to, the performing of the activities referred to in paragraph (a). (Income Tax Act 2007, LH7, s 1) [Bold removed]

The terminology used to discuss science is at best confusing. This is not specific to New Zealand, but is a global issue; if we cannot define and discuss problems in a clear, concise manner, there is little hope of gaining agreement on solutions. In this report we use the term science broadly, in the sense in which it was used by Sir George Bowen, as quoted in the Executive Summary; this includes invention, innovation, research, technology and the range of scientific activity. Our preference for a definition is that provided by J. P. Siepmann in the Journal of Theoretics. It is a simple definition that clarifies our interest in this area; this report considers science with a small ‘s’.

> Science: the field of study which tries to describe and understand the nature of the universe in whole or part. The field of study or discipline that we call Science is spelled with a capital “S” as it is a proper noun in this use while science with a small "s" is the application of this discipline. (Siepmann, 1999)

There are also a number of types of science discussed in the surveyed literature and referred to in this paper. These include such contrasting types as soft versus hard science, sound versus junk science and good versus bad science. These terms are subjective, but they are so frequently used in the literature that we have used them despite their inherent limitations.

Well-being

Well-being can mean many things to many people, hence a broad definition is necessary. The following definition is from Human Resources and Skills Development Canada (HRSDC):

> Well-being is made up of ten areas or domains: learning, work, housing, family life, social participation, leisure, health, security, environment and financial security. (Policy Horizons Canada, in press: 5)

2.2.3 Authorship

The continuous evolution in the structure of New Zealand’s government-funded science system was one of a number of challenges in completing this report. The long duration of this project meant that many researchers contributed to, or were involved in, the production of the final report. The contribution of the Institute’s staff is noted earlier in the report, while the authorship is retained under the authors who finalised its contents. Information about the authors and researchers can be found in Appendix 1.

2.2.4 External reviewers

Policy and strategy information is held across numerous government agencies, and in some cases it is not publicly available or easily discoverable. For this reason, the Institute was dependent on the external reviewers to provide key information, insights and guidance.[7] It would not have been possible to obtain this background information without expert knowledge. Although the report does not reflect every idea or view raised by the external reviewers, it is hoped that the final report honours their feedback.

2.3 Limitations and Boundaries

The boundary of this report is determined by the definition of government-funded science (Section 1.2) and limited by the experiences of the authors and contributors.

The report has benefited significantly from the breadth of wisdom of those interviewed during the scoping of the research programme and of the external reviewers who contributed to the content of the final report. Additional insights could have been gained through more extensive and in-depth interviews, for example with staff from the former Crown Company Monitoring Advisory Unit (CCMAU), the former Ministry of Research, Science and Technology (MoRST), the former Foundation for Research, Science and Technology (FRST), and the newly established Ministry of Science and Innovation (MSI). At the time this research was being undertaken these institutions and their staff were undergoing major changes, so instead we opted to clarify points of uncertainty. We thank the staff at CCMAU and MSI for their assistance at these times.

7 Brief biographies of the report’s external reviewers can be found in Appendix 2.

Valuable information could also have been gained by approaching individuals within each scientific area of study, each institution and each region, but this was beyond the Institute's resources. Instead, we relied on a broad range of external reviewers and completed an extensive review of recent reports by central government and non-government bodies (all of which are referenced in the text).

Although we go to significant lengths to indicate from where our data and information has been derived, it was not always possible to reference the opinions of experts who work within the system. Therefore, it was decided to reference all facts but not the personal opinions of experts or external reviewers (unless approval was obtained or opinions were published in the public arena). This approach enabled free and open discussions with external reviewers without any potential repercussions.

Lastly, the major challenge in completing this report was the continuous changes that occurred in the government-funded science system in recent years. Twice this report has been halted due to uncertainty over changes being proposed or implemented. As this report goes to press, we have discovered a further alteration to the goals and purpose of MSI (MSI, 2011b) and learnt of a new strategy document that will be developed this year (Philippa Yasbek, MSI, personal communication, 15 December 2011). This makes it difficult to see a comprehensive picture of all key documents and their linkages; therefore, the platform upon which this research has been based may not be complete. However, we have endevoured to keep abreast of recent changes and feel confident that a solid research platform has been secured at this point in time. This is clearly a changing landscape and our objective is to contribute to a national conversation on how government-funded science can best be calibrated to deliver significant improvements to the well-being of current and future New Zealanders.

3. Historical Context: The Four Eras of Government-funded Science in New Zealand

The following section divides the history of government-funded science into four different institutional eras so as to provide a context for the discussion that follows in later sections of this report. A more detailed discussion of the four eras is available in Report 9a: *A History of Government-funded Science 1865–2009* (SFI, 2009a) and Report 9b: *Government-funded Science 2009–2011* (SFI, 2011a).[8]

While government-funded science in New Zealand developed along Western lines of thought, significant discovery and knowledge creation took place in te ao Māori both before and after the arrival of Europeans. Early European settlers also conducted their own independent research without government support. It was against this backdrop of traditional Māori knowledge and independent European research that the concept of government-funded science first emerged.

3.1 The First Era: 1865 to 1926 – Gradual Organisation

The first government-funded scientific institution, the New Zealand Geological Survey, was established in 1865 to explore mineral wealth within New Zealand. By 1868, the New Zealand Institute (the forerunner of the Royal Society of New Zealand) had been established as a centralised body to draw together the growing number of independent philosophical and scientific organisations around the country. The earlier volumes of the New Zealand Institute's *Transactions and Proceedings* evidence a strong scientific focus on resources such as minerals, and how they might benefit the country's economy.[9] However, over time the focus shifted from exporting raw material and minerals to exporting agricultural products, meaning government-funded scientists began focusing on ways to improve productivity from land use.

3.2 The Second Era: 1926 to 1989 – One Dominant Institution

The government's involvement in science funding changed significantly in 1926 with the creation of the Department of Scientific and Industrial Research (DSIR). Based on the British department of the same name, the DSIR was initially responsible for increasing links between industry and science, overseeing research in New Zealand and subsidising industrial research. The DSIR soon began to undertake its own research, an activity that gradually increased over time. This research often concerned agricultural issues, such as increasing the productivity of soils or a particular strain of wheat. By the 1970s the DSIR had grown into a large organisation that acted mostly as a science provider, rather than maintaining the role of administrator as was initially envisaged (Galbreath, 1998; Palmer, 1994).

The 1980s saw the implementation of concepts such as 'New Public Management'[10] and 'Public Choice Theory',[11] both of which resulted in a move away from sole reliance on government-funded research, towards the commercialisation of research by the private sector and so-called 'user pays' policy. On this basis, the DSIR was disestablished in favour of a new tri-institutional structure.

8 Secondary sources have largely been relied upon (aside from examining the *Transactions and Proceedings of the Royal Society of New Zealand 1868-1961* [National Library of New Zealand, n.d.]), and the innate limitations of the conclusions drawn are recognised. We would especially like to acknowledge the work of C. M. Palmer (1994), R. Galbreath (1998) and F. L. Reid (2005), on which this section of the report draws significantly.

9 For example, an 1880 paper was presented to the New Zealand Institute on the country's forests, suggesting their potential value as exports or as raw material in the manufacturing industry. Shortly afterwards, an 1883 paper on clay deposits in Auckland was presented, suggesting such deposits could be used to increase pottery exports and decrease pottery imports. A further example is an 1887 paper on mineral deposits in the Nelson region that discusses mining possibilities (Kirk, 1880; Pond, 1883; Washbourne, 1888).

10 New Public Management was a movement that became popular throughout the Western world towards the end of the 1970s, and was crucial in the implementation of reforms across the OECD. Its main components were 'hands-on professional management … explicit standards of performance, greater emphasis on output control, increased competition, contracts, devolution, disaggregation of units and private sector management techniques' (Christensen & Laegreid, 2001: 78).

11 'Public Choice Theory suggests that if public service officials monopolise service delivery, the resulting system will suffer from oversupply and inefficiency. In contrast, it holds that if services are contracted out then the pressures of a competitive market will lead to efficiency gains and improved performance.' (Boyne, 1998: 474)

3.3 The Third Era: 1989 to 2010 – The Tri-institutional Framework

The 1980s reforms of the DSIR saw the separation of the department into a tri-institutional model based on policy, purchase and provision, and the stricter application of a commercial imperative to science.[12] This framework led to the creation of the Ministry of Research, Science and Technology (MoRST) to oversee the science strategy (policy), the Foundation of Research, Science and Technology (FRST) to allocate funding to individual projects (purchase),[13] and a number of science providers such as Crown Research Institutes (CRIs) and universities (provision).[14] The Ministerial Science Task Group behind the creation of the CRIs hoped that establishing research institutes with full commercial powers would 'greatly enhance' the ability to transfer technology to users (Davenport & Bibby, 2007: 181). This reflects the fact that the commercialisation of research by the private sector continues to remain the primary goal of the government-funded science system.

Two events put the tri-institutional framework under the microscope and eventually led to the fourth era. The first was the release of the *OECD Reviews of Innovation Policy: New Zealand* (OECD, 2007a), which provided an overview of the major strengths and weaknesses of New Zealand's science and innovation system. These are summarised in Table 2. The review also identified the following set of strategic tasks:

- Make the business environment more supportive of R&D and innovation, through improved key frame conditions and appropriate specific incentives.
- Reinforce the public research system's capacity to contribute to innovation and to human resource development, notably via improved steering and financing mechanisms. One should recognise that the CRIs and tertiary education institutions need to play a more important role in applied research and in ensuring the international connectivity of the innovation system than they do in many other advanced countries, since New Zealand lacks large firms in R&D-incentive sectors and must find other ways of sustaining an adequate stock of knowledge.
- Strengthen the domestic and international networks and other institutional frameworks that ensure that the flows of knowledge among key actors of the innovation system contribute effectively to increasing value added in resource-based sectors, and to developing new industries and services. (OECD, 2007a: 15)

Secondly, the National Science Panel released its *Science Manifesto* (NSP, 2008), which set out a 10-point programme as a 'plan for the recovery of New Zealand science'.[15]

3.4 The Fourth Era: From 2010 – The Bi-institutional Framework

The most substantial changes to the New Zealand science system in 20 years were made in 2010/11. The science policy (MoRST) and investment (FRST) arms were merged into one institution, the Ministry of Science and Innovation (MSI). The government also commissioned a CRI Taskforce to consider how to enhance the value of New Zealand's investment in CRIs (Mapp, 2010). The Taskforce reported back to government in February 2010 with 27 recommendations covering the roles and purposes of the CRIs, funding, monitoring, governance, and a range of other issues (CRIT, 2010: 11–13). These changes signalled a shift to an even greater focus on deriving economic value from investments in science through improving collaboration across the science system, reducing bureaucracy and building stronger linkages between government priorities and investment decisions.[16] Cabinet set out its expectations of this new bi-institutional framework as follows:

12 See Report 9b, *A History of Government-funded Science from 2009–2011* (SFI, 2011a) for more detail on these policy, purchase and provision institutions.

13 Other research purchasers that are funded by government include the Royal Society of New Zealand, the Health Research Council, other government agencies (such as the Ministry of Agriculture and Forestry, Ministry for the Environment, and Ministry of Health), the Tertiary Education Commission and Fulbright New Zealand.

14 Research is also undertaken by polytechnics, wānanga, private businesses and independent research organisations. For information on CRIs, see the Institute's Working Paper 2011/18: *New Zealand Crown Research Institutes: Legislation, operation, and governance* (SFI, 2011e).

15 For a discussion on the 10-point programme, see Report 9a, *A History of Government-funded Science 1865–2009* (SFI, 2009a).

16 For a more detailed discussion of these changes, see Report 9b, *A History of Government-funded Science from 2009–2011* (SFI, 2011a).

- Establishing a single entity that can act as the Government's lead agency on the science system and contribute to the oversight of New Zealand's innovation system
- Ensuring that consistent and aligned strategy drives the allocation of resources to New Zealand's science and innovation systems
- A single entity that could make public funding for science and innovation more responsive to sector needs, and closer to government
- Reducing complexity and transaction costs across the science and innovation systems
- Delivering efficiency gains in the delivery of science and innovation funding
- Improving policy development through more direct links to the science, business and research communities
- Increasing critical mass and building capability within a small but viable platform. (MSI, 2011c: 6)

Table 3 (overleaf) provides an overview of the four eras of government-funded science in New Zealand since 1865. Applying the approach identified in Figure 1, the table explores each era in terms of purpose, strategy and execution

Table 2: Strengths and Weaknesses of New Zealand's Innovation System Identified by the OECD, 2007
Source: Adapted from OECD, 2007a: 11–14

Strengths	Weaknesses
Good conditions for entrepreneurship and innovation including an open society which engenders trust, and a resourceful and entrepreneurial population.	**Shortcomings in physical and virtual infrastructure** such as impediments in internal land transport, vulnerability in energy delivery and relatively limited availability and speed of broadband internet access.
Most aspects of framework conditions are conducive to innovation; this includes a sound macroeconomic framework and a predictable and good business environment.	**Low level of private sector investment in R&D** as well as a lack of management resources and appropriate personnel.
Government is aware of the importance of RS&T to escape low productivity.	**Barriers to business growth**, including high costs and difficulties in accessing international markets and a common preference for 'lifestyle businesses'.
Predictable policy environment and a competent public administration, which reduces risk of government failures and is favourable for public-private partnerships.	**Lack of management, marketing and distribution skills which impedes innovation.**
Accumulated skills and institutional capabilities in public research organisations with world class competencies in many areas, especially agricultural and health research.	**Inadequacies in the process of technology diffusion and adoption**, including disparities between supply and demand for complementary technical services and training and advice for SMEs.
Competitive natural resource-based sectors with opportunities for high-technology/value added businesses.	**Insufficient policy coordination for foreign direct investment**, due to factors such as the absence of policy coordination between innovation and tax policy.
Pockets of excellence in new industries including software and creative fields.	**A fragmented system of government support to R&D and innovation combined with a lack of coherence across the full range of innovation-related policies;** this makes it difficult to allocate resources in a strategic manner.
	Inadequate incentives for public research organisations with competitive funding creating difficulties in building long-term capabilities, financing research infrastructure, transference of research results to business and the availability of internationally competitive wages.
	Excessive reliance on a few policy principles often at the cost of practicality in ensuring effective implementation and weakening the role of evaluation in monitoring.

Table 3: Four Eras of Government-funded Science in New Zealand, 1865–2012

Note: The stated purpose, strategy and execution of government-funded science for Eras 1–4 is largely a summary of the findings contained within the Institute's Report 9a: *A History of Government-funded Science 1865–2009* (SFI, 2009a) and Report 9b: *A History of Government-funded Science 2009–2011* (SFI, 2011a).

		Era 1: 1865 – 1926	Era 2: 1926 – 1989	Era 3: 1989 – 2010	Era 4: 2010 – 2012
Purpose	**Mission, Values and Vision**	**Mission:** Early government-funded science focused on understanding and taking resources from a new land mass.[17] A system was developed to respond to problems and commercial imperatives in the primary industries (such as agriculture) (SFI, 2009a: 14).	**Mission:** Government-funded science aimed to support scientific research through one dominant institution: the Department of Scientific Industrial Research (DSIR) (SFI, 2009a: 20).	**Mission:** Government-funded science aimed to create a market for scientific research. Science and technology were linked to economic growth. **Values:** Science was seen as a commercial enterprise. There was debate over the degree to which government should influence the shape of research (SFI, 2009a: 20–25).	**Mission:** Government-funded science aims to create 'benefit for New Zealand' (MSI, 2011a: 6). **Values:** The MSI's *Statement of Intent: 2011–2014* notes that in 2011 'there will be a focus on actively shaping a culture that supports MSI to be a high-performing agency' and that 'there will be a project defining the values for MSI and the integration of these across the organisation. These will form the baseline of our expectations of behaviour and standards and will be rolled out across the organisation' (MSI, 2011a: 27). **Vision**: 'High-performing science and innovation systems improving New Zealanders' wealth and wellbeing' (MSI, 2011a: 6).
Strategy	**Strategic Intent**	Organised research capability had not been a priority in a new, developing nation but attitudes started to change as successive governments realised the importance of research and science to the economic and social growth of the colony (SFI, 2009a: 15).	Transforming DSIR from administrator to provider, with increased investment in scientific research and an emerging commercial imperative for science.[18]	RS&T to 'grow an inclusive, innovative economy for the benefit of all'. (MoRST, 2000: 5)	'Establishing a single entity that can act as the Government's lead agency on the science system and contribute to the oversight of New Zealand's innovation system.' Further, one of the initiatives for 2011 was the 'development of a clear organisational strategy for MSI' (MSI, 2011a 16, 26).

17 The New Zealand Geological Survey was formed in a move to identify and control mineral assets such as gold and coal (Nathan, 2007). The Survey also took control of the Colonial Laboratory and Museum, which worked until 1892 to identify and describe New Zealand's natural assets (Galbreath, 1998).

18 The primary function of the DSIR changed significantly during this period. In 1926, the Scientific and Industrial Research Act 1926 stated that the functions of the DSIR were maintenance, administration and the provision of advice. The Scientific and Industrial Research Act 1974 repealed the 1926 Act and stated that the primary function of the DSIR was to 'initiate, plan and implement research calculated to promote the national interest of New Zealand' (SFI, 2009a: 19).

		Era 1: 1865 – 1926	Era 2: 1926 – 1989	Era 3: 1989 – 2010	Era 4: 2010 – 2012
	Drivers	*Government-funded science focused on:* • Problem-solving for commercial gains. • Steady coalescing and gradual organisation. • A gradual increase in research capability (SFI, 2009a: 15).	*Government-funded science focused on:* • Forming New Zealand's own institutions and conducting its own research, as Britain was requiring of the Dominions (SFI, 2009a: 16). • The war effort (in the early stages of the era). World War II acted as a significant driver of technical expansion (SFI, 2009a: 18). • The wider economic environment (in the later stages of the era). The economic downturn of the 1970s forced some commercialisation of science (SFI, 2009a: 20).	*The 2007 MoRST strategy had four main areas of focus:* • Providing greater clarity and coherence about the overall direction and development of RS&T in New Zealand; • Engaging New Zealanders with science and technology; • Improving business performance through research and development; and • Creating a world-class science system for New Zealand (MoRST, 2007a).[19]	*Government-funded science will focus on:* • Improving international linkages • Improving the innovation system • Ensuring processes are cost-effective, and • Developing partnerships (MSI, 2011c: 8, 10, 25).
	Enablers	**The institutional framework** Gradual organisation of an institutional framework: • In 1865, the New Zealand Geological Survey and Colonial Museum were established. • In 1867, the New Zealand Institute was established (the forerunner of the Royal Society of New Zealand). Creation of the first university: • In 1870, the University of New Zealand was created. **Funding** Ad hoc and sporadic funding (SFI, 2009a: 14).	**The institutional framework** One dominant institution developed: • The British Department of Scientific and Industrial Research (DSIR) model was imported and over time the DSIR transformed from the role of administrator to also taking on the role of research provider (SFI, 2009a: 16–19). The University of New Zealand split into six separate institutions: • The University of New Zealand, the sole tertiary institution up until 1962, was split and was replaced by six separate universities (SFI, 2011d: 3). **Funding** User-pays policy. However, as the DSIR grew, the need for an increase in funding became apparent (SFI, 2009a: 19). **Infrastructure** A lack of physical and technical infrastructure to back up scientific enterprise became apparent (SFI, 2009a: 20).	**The institutional framework** The tri-institutional framework: • In 1989, the DSIR was split so that policy, purchase and provision were overseen by independent bodies – MoRST, FRST and CRIs, respectively. • In 1992, ten CRIs were established. Creation of two new universities: • Lincoln University (1990) and Auckland University of Technology (2000) were established. **Funding** A shift in the funding ideology, from following Britain to using more global economic concepts, resulting in a competitive funding model (SFI, 2009a: 25). **Regulatory frameworks** The 'Arbuckle Report' of 1988, for the Science and Technology Advisory Committee (STAC), was instrumental in creating a new regulatory framework. This new framework focused on three key pieces of legislation: the State Owned Enterprises Act 1986, the State Sector Act 1988, and the Public Finance Act 1989 (SFI, 2009a: 21–22).	**The institutional framework** The bi-institutional framework: • Merger of MoRST and FRST into MSI, with two funding boards, one for science and one for innovation, recombining policy and purchase functionality. Review of CRIs: • The CRI Taskforce recommended a number of changes to the governance and funding of CRIs; however, no change to the number of CRIs was recommended. **Key enablers** • People • Infrastructure • International connections (MoRST, 2010a: 39). **Funding** A combination of competitive and core funding.

19 MoRST's 2007–2010 strategy (MoRST, 2007a) has been used as an example of government-funded science's main priorities within this era.

		Era 1: 1865 – 1926	Era 2: 1926 – 1989	Era 3: 1989 – 2010	Era 4: 2010 – 2012
Execution	**Targets, Initiatives and Performance Indicators**	*Specific initiatives:* • The export of minerals and raw materials (e.g. mining, forestry and wheat). Performance indicators: • The financial support of Britain. • The creation of the first national journal of scientific writing, *The Transactions and Proceedings of the Royal Society of New Zealand* (SFI, 2009a: 13–14).	*Specific initiatives:* • Continuation of agricultural research. • Increasing amounts of technical research, especially inspired by the war and post-war boom period. • Emerging focus on manufacturing and industry-focused research (SFI, 2009a: 20).	*Specific initiatives*: • In 1995, the Marsden Fund was established to support excellence in research (SFI, 2009a: 50). • In 2002, Centres of Research Excellence (CoREs) were established to encourage the development of collaborative, strategically focused research (SFI, 2011d: 5). • In 2003, the Performance Based Research Fund for universities was established to ensure that excellent research in the tertiary education sector was encouraged and rewarded (SFI, 2011d: 6). • Continuing focus on agriculture but also biotechnology, industrial and technical research (SFI, 2009a: 20).	*Specific initiatives for government include a number of new initiatives:* 1. Providing the CRIs with a greater level of secure funding to support their strategic role in the system ($40 million over four years) (MoRST, 2010a: 20). 2. Boosting the Marsden Fund by $36 million over four years to increase the level of investigator-led research that expands knowledge across all disciplines (ibid.). 3. Increasing investment in health research by $32 million over four years (ibid.). 4. The Prime Minister's Science Prizes (ibid.: 24). 5. The appointment of the Prime Minister's Chief Science Advisor (ibid.). 6. Supporting the people and infrastructure at the heart of science and innovation (ibid.: 39). 7. Improving the international connections that are increasingly important for researchers and firms (ibid.). 8. E-Science services for researchers (ibid.: 47). 9. Establishing stronger relationships with carefully selected bilateral partners (ibid.: 51). *Performance Indicators* Government will know it is successful because of increases in: 1. Number of publications; 2. Number of patents; 3. The commercialisation of science outputs; 4. Outcome monitoring; 5. Business expenditure on research and development, 6. Benchmarking with other countries (MSI, 2011c: 12–17). See also *Performance Information for Appropriations* (Treasury, 2011e).

3.5 Implications for the Future

A successful science system is dependent on how well it is designed to achieve the following: (i) science that supports the needs of society and industry; (ii) a system that puts the right drivers in place to facilitate this; (iii) education that supports the needs of the science system, and (iv) a public that understands the logic of the alignment and is informed of the outcomes.[20] All four success factors need to be measured and reported on over time to indicate whether or not performance is improving and goals are being achieved.

Changes in the system have been driven by a variety of factors. In the early days personalities such as James Hector and Ernest Marsden dominated the science scene. However, science in recent times has been redesigned according to pervasive international theories such as 'User Pays', 'New Public Management' and 'Public Choice Theory', and debates over the role of government and the extent to which it should influence who provides what science. These changes have been evident throughout all levels of policy, purchase and provision. In the past these changes have been gradual, but the most recent changes have been abrupt, such as the reforms of the late 1980s, and those implemented since 2010.

Changes with short lead-in times tend to be expensive in terms of social costs (e.g. redundancies),[21] restructuring costs associated with disbanding and establishing new institutions, and the creation of inherent uncertainty as new funding, investment, governance and reporting systems are put in place. This underscores the importance of having a significant independent review to assess whether the structural change has delivered what was promised, whether the benefits have exceeded the costs, and what lessons can be learnt. This point was also discussed in a recent briefing to the Education and Science Committee from the Office of the Auditor General. In its report the OAG suggests a number of questions to be considered, and in particular the following:

Office of the Auditor General Briefing to the Education and Science Committee

Please outline the gains and benefits expected from the amalgamation of MoRST and FRST, including:

- where the efficiency gains of $3 million in 2011/12, and $4 million a year from 2012/13, will come from;
- the expected benefits to the science and innovation sector and system; and
- how progress against these benefits will be measured and evaluated.

Will the amalgamation of MoRST and FRST be reviewed?

- If so; when and how? (OAG, 2011: 8)

Further, we would add that smaller regular reviews are critically important in the first few years in order to resolve any teething issues and enable management to address emerging problems before they become significant.

One would expect a profession that applies transparency and peer review in its day-to-day operations would require an independent review of the very system that shapes not only its future, but the future of the country. It is clear that MSI and other science-based government institutions are working hard to develop effective assessment tools so that they can report to their minister on the significant costs and benefits of the redesign of the science system. However, without a defined process in place, or a commitment to undertake a significant independent review, a thorough assessment of the net benefits is unlikely to take place in the near future, leaving the science community and the general public in the dark.

20 This observation was provided by an external reviewer, and summarises much of the feedback on this section.

21 Of note, MoRST had 78 full time equivalent (FTE) staff and FRST had 89.36 FTE staff as at June 30 2010 (MoRST, 2010b: 59; FRST, 2010: 21), a combined FTE total of 167.36. The merger into the single entity of MSI resulted in a reduction of staff numbers to 140 (MSI, 2011c: 8).

4. Global Context: Weak Signals and Wild Cards

A former Member of Parliament, Patrick Joseph O'Regan, writing in the *New Zealand Illustrated Magazine* in 1900, provided a revealing perspective on trends and progress at the beginning of the 20th century:

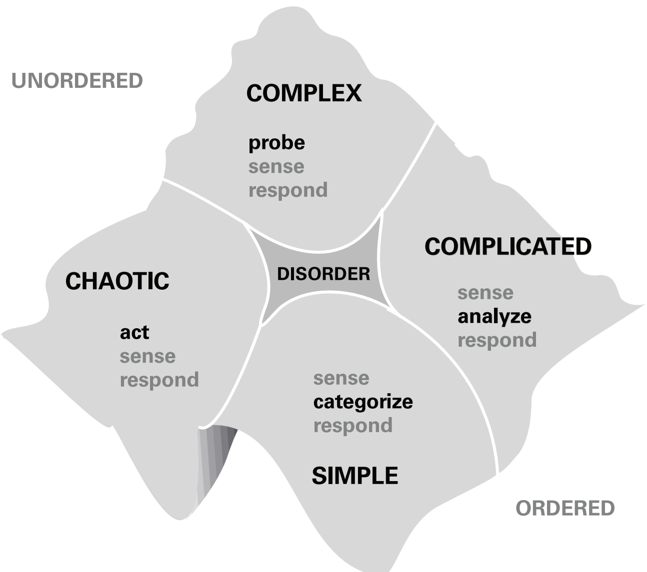
> Although the public is wont to regard predictions with an amount of scepticism, which is natural under the circumstances, there is absolutely no reason to doubt the accuracy of that foreknowledge which comes from reading the past and the trend of current events aright. Progress cannot be denied, and there is no difficulty in predicting what will happen in the next century if we consider the logical issue of many movements, now going on quietly, almost imperceptibly, but none the less surely. (O'Regan, 1900, cited in SFI, 2011f: 12)

A little over a hundred years later, society has moved on from the linear situation O'Regan describes, in which the pace of change is slow and 'reading the past' can be used to predict the future. In our increasingly complicated and chaotic world, decision-makers must find new ways of responding to the challenges and opportunities that face them. Science sits at the forefront of this changing environment as the best proactive and reactive response to emerging challenges. It is vital that science systems are instilled with the necessary capabilities to operate effectively in this increasingly complex environment.

Dave Snowden and Mary Boone, who are experts in complexity theory, suggest that decision-makers and policy analysts need to take into account their unique environment when making decisions.[22]

> The Cynefin framework [see Figure 3] helps leaders determine the prevailing operative context so that they can make appropriate choices. Each domain requires different actions. *Simple* and *complicated* contexts assume an ordered universe, where cause-and-effect relationships are perceptible, and right answers can be determined based on the facts. *Complex* and *chaotic* contexts are unordered — there is no immediately apparent relationship between cause and effect, and the way forward is determined based on emerging patterns. The ordered world is the world of fact-based management; the unordered world represents pattern based management. The very nature of the fifth context — *disorder* — makes it particularly difficult to recognize when one is in it. Here, multiple perspectives jostle for prominence, factional leaders argue with one another, and cacophony rules. The way out of this realm is to break down the situation into constituent parts and assign each to one of the other four realms. Leaders can then make decisions and intervene in contextually appropriate ways. (Snowden & Boone, 2007: 4)

Figure 3: The Cynefin Framework
Source: Snowden & Boone, 2007: 4



22 'In the complex environment of the current business world, leaders often will be called upon to act against their instincts. They will need to know when to share power and when to wield it alone, when to look to the wisdom of the group and when to take their own counsel. A deep understanding of context, the ability to embrace complexity and paradox, and a willingness to flexibly change leadership style will be required for leaders who want to make things happen in a time of increasing uncertainty.' (Snowden & Boone, 2007: 8)

Governments tend to operate in the 'simple' quadrant in Figure 3, where events and cause–effect relationships are predictable. However, the Centre for Strategic Futures, Singapore, believes 'governance has been increasingly taking place in an environment that is best represented by the unordered realms, on the left side of the diagram' (CFSF, 2011: 14). This is certainly true of New Zealand, where over the past few years earthquakes, a mining disaster and financial unrest, among other events, have created a chaotic environment in which to govern. Given this increasingly complex and possibly chaotic global environment, it is important that governments explore new ways of shaping public policy and developing decision-making systems to ensure policy advice is both robust and sufficiently flexible to suit a range of environments.

4.1 Addressing Weak Signals and Wild Cards

Given the increasing complexity of the issues that science is addressing (be they technological, environmental, or societal), much attention is now being paid to emerging issues, weak signals and wild cards. Sound science systems must support foresight research, which is necessary to investigate potential weak signals and wild cards before they become pressing and immediate concerns.[23] This research is especially important to identify issues that are evolving slowly and are not yet pressing, but may have significant consequences in the future.

iKnow is one of six foresight research projects funded by the European Commission's Seventh Framework Programme for Research and Technology Development. The project is primarily concerned with identifying possible weak signals and wild cards. Weak signals are defined as:

> … ambiguous events, often referred to as seeds of change, providing advance intelligence or hints about potentially important futures, including Wild Cards, challenges and opportunities. (iKnow, n.d.)

Weak signals can be seen as signs of emerging issues or changes that have not reached the critical mass required to be seen as immediate concerns and remain ambiguous in their implications. The capacity to identify and understand weak signals is a vital component of foresight work. Some examples of emerging issues have been put forward by NASA Chief Scientist Dennis M. Bushnell, who talks of 'seven simultaneous existential societal issues'.[24] He believes that any one of these will change society as we know it. However, Bushnell has identified that the impact of all seven, including potential synergisms, is 'approaching the unfathomable' (Bushnell, 2011).[25] The issues he identifies are:

- Climate change and energy
- Massive debt
- Water and food shortages/environmental issues
- Five simultaneous game-changing tech revolutions, tele-everything[26]
- Luddites/individual destructive power
- Robotics/machine intelligence/employment
- Humans merging with the machines. (ibid.)

At the *International Conference on Strategic Foresight in National Government,* held in Seoul, South Korea in December 2011, three weak signals that are currently driving foresight work were highlighted. One is the possibility of a drastic shrinking in job markets. This could come about because of the limited lifespan of 'green jobs', and redundancies caused by computers and robots carrying out automated tasks (reflecting Bushnell's point above). This could occur across a wide range of fields, for example in the legal profession, where the increasing sophistication of case law software may significantly reduce the requirement for legal staff. Another weak signal is the creation of major hubs dominating the economy, reducing the

23 Foresight research can be defined as the disciplined analysis of identifying emerging trends and their underlying causes. For examples of international government foresight initiatives see Tait et al. (2002).

24 Adapted from a presentation given via teleconference by Dennis M. Bushnell at the *StrategyNZ: Mapping our Future* workshop held by the Institute in Wellington on 30 March 2011.

25 This observation is supported by Silberglitt et al. (2006).

26 Tele-everything refers to many human activities being increasingly virtual through the use of the internet.

ability of medium-sized businesses to survive long-term in the global economy (Chor Pharn Lee, personal communication, December 6, 2011). An example could be aggressive marketing of smart and android phones that results in one brand dominating and effectively closing this market. Lastly, in a paper (in press) by Steffen Christensen and Katherine Antal, both from the government agency Policy Horizons Canada, the authors identify seven forces that could move well-being onto the Canadian Policy Agenda. Underlying their thinking is a need for a new set of metrics and a new set of policy tools to support and evaluate a well-being agenda.

Weak signals can be understood as having varying degrees of effect. A large number of effects develop as a result of a particular weak signal or wild card and can form a complex system of interactions. These effects can individually be small, but the overall effect can be dramatic. Policy Horizons Canada uses influence diagrams to explore the first-, second- and third-order impacts from a weak signal, change driver, or wild card (Steffen Christensen, personal communication, December 6, 2011).

In addition to weak signals, wild cards – low-probability, high-impact events (such as the 2010/2011 Canterbury earthquakes) – have the potential to challenge local communities, nations, or the planet. Writer Nassim Taleb, a scientific advisor at the International Monetary Fund, calls such events 'Black Swans' (Taleb, 2007). While the timing of these events, by definition, cannot be predicted, they can generally be planned for (for example, by having high building standards and detailed emergency procedures).

The science system has a role to play in preparing for and responding to wild cards, both those that relate directly to science and those that take place in a wider context. It is beyond the scope of this report to scan the global landscape for all significant weak signals and wild cards, but Table 4 shows some major emerging issues that would have been weak signals 10 years ago, and related wild cards. These are issues that science can play an important role in addressing, more so as they transition from emerging into immediate issues that demand public attention.

The need to forward engage with weak signals before they become difficult to manage is a concept explored by Leon Fuerth, the former National Security Advisor to Vice President Al Gore. Fuerth believes that it is possible to create intelligent countries through forward engagement (SFI, 2011g: 62), which aligns with the New Zealand government's pledge to create a smart nation.

4.2 Using Foresight to Create Intelligent Countries

Promoting foresight and long-term thinking contributes directly to creating an intelligent country. The Institute's Report 12: *StrategyNZ: Mapping our Future Workbook* describes this notion:

> Creating intelligent countries is not about raising the Intelligence Quotient (IQ) of the population, but raising the National Intelligence (NI) of a country by equipping its institutions with the necessary capacity to build foresight in order that a country can survive uncertainties and respond effectively to opportunities.
> (SFI, 2011g: 62)

Leon Fuerth, former National Security Advisor to Vice President Al Gore, has developed the concept of 'forward engagement' as a way for countries to become more 'intelligent' through the application of a formal foresight system. At the 2010 World Futures Conference he suggested that three components are necessary to create an intelligent system:

> 'First, there needs to be a formal foresight system for the whole of government; national security can no longer be seen in isolation. Second, there must be a networked approach to the formulation and execution of the policy; in other words, a flatter and faster response by delegating decision making further down the ranks. Lastly, and most importantly, countries need formal feedback loops, so that decision makers can learn from both their successes and their failures.' (McGuinness, 2010: 49).

This report does not endeavour to describe how foresight has been developed in intelligent countries, other than in the case study on Singapore (see Appendix 4). Reflecting on recent research and discussions, it becomes increasingly apparent that successful countries use foresight to determine their investment strategy, and define their research agenda. For example, it could be argued that Brazil tends to focuses on energy and agricultural innovation, Singapore on medical research, South Korea on the process underlying product development, Italy on the design underlying product development, China on innovative business models that respond quickly to changes in scale or technology, India on software and service innovation and so forth (see Rother, 2010: 6 and SFI, 2011g; 2–4 for example relating to Brazil; and Singapore, China and Appendix 4 and Saini, 2011: 10–13 for examples relating to Singapore, China and India).

New Zealand does not have any one institution specifically tasked with developing foresight but we do have six foresight initiatives of which the most important is the *Statement of Long-term Fiscal Position*. The Treasury is required under the Public Finance Act 1989 (as amended in 2004) to publish at least every four years a statement on the country's long-term fiscal position, looking forward at least 40 years (Treasury, n.d.[a]). These reports form the most comprehensive instruments to date for assessing New Zealand's long-term future. The first statement was produced in 2006, with a second following in 2009. This latest statement looks at what drives government spending and revenue, and the major issues that will need to be addressed if the country wants to maintain or improve its living standards and public services. In 2012 the Treasury aims to draw on a wider range of experts and materials, and develop more innovative ways of exploring and communicating strategic drivers in order to publish a more useful statement in 2013 (Paul Rodway, Treasury, personal communication, 1 December 2011).

The other five foresight initiatives identified in the Institute's Working Paper 2011/20 *Foresight in New Zealand* are: the New Zealand Productivity Commission, Welfare Working Group, Futures Forum, Government-funded Research, and Local Government and Long-term Plans. The government should regularly assess whether it has enough foresight capability to not only identify data, but collate and create information on weak signals and wild cards in such a way that develops strategic knowledge about the future and therefore better informs ministers and policy analysts in a cost-effective and timely manner.

4.3 Implications for the Future

MSI has a critical role in shaping the science system so that it is better able to address the complex emerging and immediate issues that New Zealand and the world are facing. A list of 'wicked problems' specific to New Zealand is included in Appendix 5. However, MSI by itself cannot solve these problems. Given the cross-cutting nature of many such problems, a coordinated government approach that includes scientific solutions and increased foresight capacity will be required. This is why an NSDS is considered a critical instrument to avoid costly repetition and drive progress.

The science community has responded to these weak signals, wild cards and wicked problems through improvements in science policy, which is discussed in the next section.

Table 4: Emerging Global Issues and Related Wild Cards

Source: Adapted from Ministry of Defence (UK), 2010; Royal Society (UK), 2011; Shell, 2011; World Economic Forum, 2011

Emerging Issues	Related Wild Cards
Food and water shortages – significant challenges exist in the production and distribution of healthy food to a growing world population. Access to adequate supplies of safe drinking water is being threatened in both developing and developed countries.	• New sources of protein – laboratory-raised meat, manufactured milk and greater consumption of insect protein could reduce the need for farmed livestock. • Marine farming – significant sustainable ways to farm fin fish would provide significant supplies of protein for the world.
Energy challenges – increased demand and reducing fossil supplies signal the need to transition to alternative, more sustainable, forms of energy.	• Solar power for all – significant advances in solar technologies and energy storage and distribution systems.
Environmental problems – overpopulation, growing resource exploitation and impacts of climate change threaten natural environments as well as quality of life for many societies.	• Extreme weather • Extreme earthquakes • New flora or fauna
Economic recession – globalisation coupled with financial instability and uncertainty puts the economies and well-being of many societies at risk.	• Intelligent robots – fundamentally changing how we live and work. • Extreme longevity – advances in healthcare that enable longer, healthier lives. • Brain regeneration – enabling neurological diseases and the effects of ageing to be reversed or stabilised. • Breaking up of EU and/or the United States
Inequality – inability to reduce social inequalities raises the risk not only of poor economic performance but also social unrest.	• Global unrest
Infectious disease.	• Pandemics • Cures for infectious diseases such as the common cold, influenza, HIV or malaria.

5. Policy Context: An Analysis of Science Policy

In this section we identify 12 emerging global trends in science policy in response to the weak signals and wild cards outlined in Section 4. This work builds on earlier research on science goals and policy drivers documented in Working Paper 2009/05: *Exploring New Zealand and International Government-funded Science Goals* (SFI, 2009b) and Working Paper 2010/01: *Exploring Long-term Policy Drivers in Science: A scan of international think tanks* (SFI, 2010a).

5.1 Twelve Trends in Science Policy

Attentiveness to trends is imperative for making sound long-term strategic decisions. We briefly describe how these 12 trends might drive public investment in New Zealand's science system so as to provide a useful platform for the discussion in the remainder of the report.

5.1.1 Scouting: Increased scanning and foresight

Internationally, decision-makers are looking toward new ways of responding to complexity and a number of governments regularly undertake foresight activities (European Commission, 2011). Recognising the importance of scanning and foresight in government, or 'scouting', Singapore established the Centre for Strategic Futures.[27] The organisation explores Singapore's future through scenario planning. The Centre uses this method to gain an understanding of drivers of change and to question assumptions about the world in order to identify where capacity is needed. Singapore has recently decentralised foresight into government agencies in order to ensure weak signals and wild cards are identified and fed back to the Centre. Further, effort has been put into creating micro scenarios which are expressed through short narratives (Chor Pharn Lee, personal communication, December 6, 2011).[28]

In New Zealand, MoRST established the Futurewatch programme in response to a recommendation from the Royal Commission on Genetic Modification that the government develop a capability for 'biotechnology futurewatch' (RCGM, 2001: 360). This technology scanning activity has not been continued under MSI, leading to a lack of on-going foresight activities among government agencies. Embedding foresight activities within New Zealand government agencies would not necessarily mean greater financial investment, but it would require a commitment from Cabinet to build capacity to identify and engage with emerging policy issues.

5.1.2 Using design to communicate science

Within the scientific community there is a shared language with which scientists communicate their findings. However, if scientific findings are to be communicated to policy-makers, businesses, and members of the public, the way in which those findings are communicated becomes paramount to their dispersion and understanding.

> One of the most important skills for almost everyone to have in the next decade and beyond will be those that allow us to create valuable, compelling, and empowering information and experiences for others. (Shedroff, 1994: 1)

There are many disciplines that organise and communicate information: Information Interaction Design, Information Design, Information Architecture, Interaction Design, Communication Design and Data Visualisation. These disciplines share fundamental goals of organising and presenting data and information in clear and engaging ways. Furthermore, they recognise that data is not the same as information, and

27 In addition to Singapore, countries such as the UK, Canada and Finland have incorporated foresight activities into government agencies to assist them to proactively address challenges and identify opportunities.

28 Examples include: The New Silk Road (2010), www.youtube.com/watch?v=CLrmUTDJan8; Peoples Republic of Change (2009), www.youtube.com/watch?v=YKJ5x68N5jw; The Great Reset Video (2008), www.youtube.com/watch?v=80JRHoOcPHU; Live Singapore! Exhibition (2011), http://senseable.mit.edu/livesingapore.

information is not the same as strategic knowledge. Thus, the interface between science and design is becoming increasingly important so that complex ideas can be quickly and clearly communicated to a wide range of stakeholders.

> Just as data can be transformed into meaningful information, so can information be transformed into knowledge and, further, into wisdom. Knowledge is a phenomenon that we can build for others just as we can build information for others from data. (Shedroff, 1994: 3).

A New Zealand example is the recent Land & Water New Zealand (n.d.) website where design is used to communicate scientific data and information in a clear, engaging, and interactive manner which fosters knowledge and understanding. There is clearly a significant opportunity to use design to communicate science challenges and opportunities.

5.1.3 Enabling citizen scientists through technology

The term 'citizen scientists' refers to volunteers who participate in science projects, working 'in partnership with scientists to answer interesting and relevant questions' (Science Learning Hub, 2011). While the involvement of non-scientists in such endeavours is not new, modern technologies have enabled citizen scientists to contribute to scientific research at a global level with increased ease. Internationally, there is a trend for networks of organisations to work together; an example is the Genetic Alliance, whose members undertake research, retrieve information and analyse data relating to genetics (Genetic Alliance, n.d.). Chief Executive Sharon Terry notes that the Alliance seeks to facilitate the exchange of genetic data between researchers and those who contribute DNA samples in return for open access to results for contributors (Marcus, 2011). Collaborations such as this are not without potential conflicts for scientists, who may have a vested interest in protecting their findings and preventing the early use and publication of their data by others.

In New Zealand, CRIs and the Department of Conservation have a number of projects with which citizen scientists can engage (Science Learning Hub, 2011). Members of voluntary organisations such as Forest and Bird collect data and monitor the trapping of pests to assist government conservation projects. The group Citizen Science New Zealand has its own blog, where projects can be publicised and people are able to comment and become involved (CSNZ, n.d.). As technology continues to develop, New Zealand citizens are increasingly likely to facilitate, participate and respond to science research.

5.1.4 Early engagement with the public over significant issues

Encouraging and facilitating public engagement has proven fundamental to ensuring the science system is trusted by the public, as well as creating a synthesis between science and the end user. In looking at global trends, leading independent Swedish organisation Vetenskap & Allmānhet ('Public & Science') identified the drivers of this trend as two-fold: an increasing demand for democratic participation as science increasingly affects people's lives, and the increasing focus of science on social issues and the needs of the public (Vetenskap & Allmānhet, 2011: 7). Many governments are leading the way. For example, the Parliamentary Commissioner for the Environment's (PCE) (2002) *Creating our Future: Sustainable development for New Zealand* cited the approach of the Dutch government as a potential way forward for developing policy.[29]

In New Zealand, the Prime Minister's Chief Science Advisor, Professor Sir Peter Gluckman, has spoken of what he sees as the two biggest challenges for New Zealand science in terms of public perception: gaining the trust of the public through true dialogue, and seamless interaction between business, government, academia and society (Gluckman, 2011: 51). There are many areas in which New Zealand stands to gain from public engagement in science, including mining of the conservation estate (PCE, 2010a), aquaculture development (Stringleman, 2011), and areas of cultural and ethical uncertainty.

29 Success in developing national environmental polices has been attributed to the following four criteria: the government provides a credible argument for change based on solid scientific consensus; government recognises that industry involvement in both the creation of policies and solutions encourages industry participation in the success of the strategy; the success of the process rests on continuity; and each sector needs to secure benefits and recognise concessions of the other parties (OECD, cited in PCE, 2002: 114).

5.1.5 Open data

The international trend towards open data at a government level is part of a wider movement around open democracy. The United States, United Kingdom, Canada and Australia all have websites to facilitate the retrieval of government information. The UK has over 5400 datasets available, from all central government departments, as well as other public sector bodies and local authorities (UK Govt, 2011) and an open government data project (HM Government, n.d.). The Canadian government is pursuing open government along three streams: open data, open information and open dialogue, and 'aims to drive innovation and economic opportunities for all Canadians' (Govt of Canada, 2011).

The New Zealand *Declaration on Open and Transparent Government,* released in August 2011, demonstrates a commitment on the part of the government to improving access to data held by its agencies (English et al., 2011).[30] Not only does the availability of such information increase accountability, but Finance Minister Bill English hopes that '[a]llowing research communities to reuse existing data for new purposes will also increase the value gained from state-funded research' (ibid.). While New Zealand is recognised internationally as demonstrating open government practices, the *Declaration* has been described as representing a 'cultural shift within government' (Goh, 2011). The proactive release of data by government agencies, free of charge, to research communities and the wider public will offer considerable benefit to the public as well as the economy.[31]

5.1.6 Commitment to open innovation

There is a global trend toward open innovation processes, in which collaboration with external partners such as suppliers, customers and universities is encouraged and fostered. For example, in a recent speech Dr Charles Vest, President of the US National Academy of Engineering, discussed six basic lessons for universities in the 21st century. These lessons, taken from his experiences of research universities in the 20th century, are: (i) teaching and research must be intimately intertwined; (ii) the quality of a research university is determined by the quality of its faculty; (iii) science can flourish only in an open environment; (iv) young [members of] faculty must be free to study and teach what they believe is important; (v) competition engenders excellence in higher education, and (vi) fundamental scholarship and research must exist on an equal plane with applied research and innovation (OIST, n.d.[a]).

However, while open innovation creates a larger base of ideas and technologies, it is not without risks. Open innovation is not a panacea; it has worked in some cases, but not in others. Challenges associated with open innovation are that it can be difficult to filter ideas generated through such processes, and getting external ideas may not always be useful (Birkinshaw et al., 2011: 46). The 2008 OECD report *Open Innovation in Global Networks* highlights the possible theft of intellectual property rights and difficulties associated with ownership of knowledge produced through collaboration (OECD, 2008a: 11). This is seen as a bigger challenge for small and medium enterprises because of their limited resources and expertise in intellectual property issues. Another potential limitation of open innovation is its transactional nature. It has been noted that developing longer-term relationships, rather than just undertaking transactions of services, is a critical factor in innovation (Davison et al., 2010).

30 For example, the Government Datasets Online is a directory of publicly available, non-personal New Zealand government-held datasets. This site does not host data, instead it links to datasets held on other government websites (NZ Govt, n.d.). Another example is the Government Electronic Tenders Service, a free service designed to promote open, fair competition in the New Zealand government market and meet international trade agreement commitments to provide information about New Zealand government business opportunities. Currently, interested parties need to log in and provide detailed information in order to gain access. (GETS, n.d.)

31 The government has also updated principles for managing government-held data and information, including:

- Government data should be released proactively in accessible formats and licensed for re-use unless there are good reasons not to.
- Information should be well managed, trusted and authoritative.
- Data should be free, or where fees are necessary, reasonably priced.
- Personal and classified data or information will remain protected (English et al., 2011).

Increasing use of open innovation models by businesses around the world is making it easier for New Zealand research teams to contribute to international research and development (R&D) programmes and gain access to the best scientific knowledge and infrastructure. However, risks such as protecting intellectual property rights need to be managed. The adoption of open innovation in New Zealand is directed toward optimising relationships while managing risks, and determining what and when it is in New Zealand's best interests to share data, information and/or strategic knowledge.[32]

5.1.7 Disclosure of conflicts of interest

Increasing the level of transparency around conflicts of interest in the area of scientific publications is another trend. Contributing authors whose interests may be in conflict with their research are being required to make full disclosures. The global science publisher Nature Publishing Group is at the forefront of this trend with its competing financial interest policy, which was implemented in 2001. The policy requires that all contributing authors declare any competing financial interests that are related to the work they have submitted.[33] The publishers recognise the potential for research to be undermined by commercial influences and believe that a policy of transparency will enable readers to trust the integrity of the publication and take any declarations into account when considering an author's work.

Research emerging from New Zealand is expected to meet a high level of transparency in order to maintain its value and integrity at both national and international levels. There has also been recent work to educate journalists on the reporting of science, and this includes advice to 'examine the affiliations of the authors of a published paper, to check for possible conflicts of interest' (SMC, 2010: 13). The development of journalism standards for science reporting, alongside a growing commitment in science publications to disclose possible conflicts of interest, reflects an effort to develop trust and provide accountability to the public.

5.1.8 Reporting on national science assets

A well-performing science system has robust processes that enable its performance to be continually measured against pre-defined objectives. The Argonne National Laboratory, the United States' first national laboratory and one that services both the public and private sectors, demonstrates best practice in monitoring performance of a national science asset. The performance of the laboratory, which is one of 10 nationally, is evaluated and graded annually using eight measures of success.[34] This appraisal scheme recognises the importance of ensuring the country gains benefits through maximising the performance and capacity of significant national science assets. It assesses the performance of the National Laboratory based on how it operates, not on the progress of its specific research programmes.[35] This means it has

32 This report makes an important distinction between these three terms. Data refers to only one piece of information; patterns of data (collated, connected or benchmarked over time or between comparable domains) become information, whereas only when the information is put in the context of decisions is it considered strategic knowledge.

33 The definition of 'competing financial interests' includes funding, employment and any personal financial interests. The declaration must appear at the end of each article, making clear whether or not the authors have identified a competing financial interest, and if so giving full details (Nature Publishing Group, n.d.). Nature's policy recognises that '[t]here are circumstances where selection of evidence, interpretation of results or emphasis of presentation might be inadvertently or even deliberately biased by a researcher's other interests' (ibid.).

34 The Laboratory has over 3000 employees, an operating budget of US$630 million, and is managed by the University of Chicago for the Department of Energy's Office of Science (United States Department of Energy, n.d.). In 2006 the US Office of Science introduced an appraisal scheme to 'evaluate the scientific, technological, managerial, and operational performance' of each national laboratory and its contracted operators (United States Department of Energy, 2011). The scheme's eight measurements are listed here along with Argonne's grades for the year ended September 2010:

1. (A-) Mission Accomplishment (Quality and Productivity of R&D)
2. (A-) Construction and Operation of Research Facilities
3. (A-) S&T Project/Program Management
4. (B+) Contractor Leadership/Stewardship
5. (B) Environment Safety and Health
6. (B+) Business Systems
7. (B) Facilities Maintenance and Infrastructure
8. (B+) Security and Emergency Management. (United States Department of Energy, 2010)

35 External reviewers suggested that two important indicators should be added to those reported on by the Argonne National Laboratory: maintenance of research capabilities, and growth of research capabilities.

put in place a system where a portion of the asset is used by not-for-profit organisations so that they can undertake research for the public good. This is overseen by a group of experts in a range of fields.

In New Zealand, a similar scheme might be applied to CRIs and other significant science assets.[36] Until recently, CRIs have tended to be monitored largely in terms of financial performance. With MSI taking over the role of monitoring CRIs from Treasury, it is anticipated that a range of non-financial factors will also be used to assess performance. This is to be welcomed. The idea of measuring performance in a report card format has been implemented successfully outside government by the New Zealand Institute.[37]

5.1.9 Use of competitions to achieve specific science outputs

Competitions are used increasingly to incentivise individuals or teams to solve complex problems or achieve specific outcomes. International examples include prizes aimed at encouraging technological breakthroughs (such as the Ansari X PRIZE[38] and the Defence Advanced Research Projects Agency [DARPA][39] competitions), addressing global food security (Royal Society [UK], 2009),[40] and enhancing national defence (NSF, 2011).[41] Internationally, prizes have been identified as being more effective when dealing with 'puzzles', where they are aimed at achieving a specific breakthrough, or 'finding the missing puzzle piece', than with 'mysteries', which require a wider assessment to attain a deeper understanding of the problem. Steffen Christensen (of Policy Horizons Canada) supported this view and added that it was important not to have too many prizes, they should be specific (based on achievement), and they should be relevant and small in number; otherwise prizes lose their value as an incentive to drive progress (Steffen Christensen, personal communication, December 6, 2011).

In New Zealand, the Prime Minister's Science Prizes, established in 2009, annually represent $1 million in prize money, and were introduced to raise the profile and prestige of scientific endeavour (MoRST, 2010a: 40). The top award, valued at $500,000, recognises a transformational science discovery or achievement that has had a significant impact on New Zealand or internationally. The prizes are aimed at celebrating scientific achievement, highlighting the impact science has on New Zealanders' lives, and attracting more young people into science careers (PMSP, 2011). Perhaps prizes for those who resolve problems that are specific to New Zealand, such as pest management, may be a useful way forward. Care must be taken to make prizes relevant to New Zealand, well administered, significant and easily discoverable to potential recipients.

36 Examples of other significant science assets include New Zealand's investment in the Australian Synchrotron, New Zealand Genomics Ltd and the National e-Science Infrastructure. Other large science infrastructure initiatives may also be funded by the government in the future. In all cases, large investments in infrastructure should be evaluated to ensure they are maintained and utilised to provide value for the public over the long term.

37 The New Zealand Institute's *NZ Ahead* report card project tracks 16 indicators over time, grading them in the same way, to give New Zealanders an idea of overall long-term social, environmental and economic performance (NZI, n.d.). The New Zealand Institute set targets for each indicator, looking to the year 2015. Its report discusses whether indicators are being addressed so that improvements can be made and targets met. Such performance reporting makes it clear whether policy change is resulting in actual change.

38 The 1996 Ansari X PRIZE aimed to prompt the development of low-cost spaceflight, and offered US$10 million to the first non-government organisation to launch a reusable manned spacecraft into space twice within two weeks (X PRIZE Foundation, 2011a). A recent deal between the company formed by the 2004 award winners, Mojave Aerospace Ventures, and Virgin Galactic is aimed at delivering scheduled space tourism in the near future. The Ansari X PRIZE is the largest and most high-profile competition to date from the X PRIZE Foundation. The Foundation is a not-for-profit organisation that aims to facilitate 'radical breakthroughs for the benefit of humanity'. These competitions are open to individuals and organisations across all disciplines (X PRIZE Foundation, 2011b).

39 DARPA aims to enhance United States national security by funding research and technology development in order to improve military capabilities, while also aiding technological breakthroughs that change the way we live (DARPA, n.d.). With Congress approving the awarding of cash prizes by DARPA, the US government has shown its support for such competitions.

40 The Royal Society, the UK's national academy of science, has publicly supported prize competitions. This has included appealing for a £2 billion 'Grand Challenge' research programme on global food security, stating that 'there's a very clear need for policy action and publicly-funded science to make sure this happens' (Royal Society [UK], 2009).

41 The National Science Foundation (NSF), an independent federal agency created by US Congress in 1950, provides grand challenge prizes across all fields of fundamental science and engineering, except in medical sciences. The NSF has an annual budget of around $6.9 billion (2010 financial year), and is the funding source for approximately 20% of all federally supported basic research conducted by America's colleges and universities in fields such as mathematics, computer science and the social sciences. Its aim of promoting 'the progress of science; to advance the national health, prosperity, and welfare; to secure the national defence …' is supported by awarding funding research in traditional academic areas as well as 'high-risk, high pay-off' ideas (NSF, 2011).

5.1.10 Pursuit of interdisciplinary research

Interdisciplinary research, which enables researchers from a range of disciplines to collaborate on a common work programme, is on the increase. Such research often leads to rich, creative solutions to complex problems, and individual disciplines can benefit greatly from the new approaches and expertise that come with collaborating with the wider science system. Globally there is a risk that current funding portfolios and allocation systems will not be able to properly assess interdisciplinary research proposals (NSF, 2009: 2; Royal Society [UK], 2010: 40). It is also a challenge to train emerging researchers to become more involved in interdisciplinary research when it was discouraged by past structures.

New Zealand is responding to this trend by fostering projects that utilise the interdisciplinary approach. One example is the taskforce that produced *Improving the Transition: Reducing social and psychological morbidity during adolescence*. In October 2009 the Prime Minister requested a report focused on how New Zealand may improve the outcomes for young people in their transition from childhood to adulthood. A taskforce was established with a number of distinguished academics and clinical practitioners from a variety of relevant disciplines (OPMSAC, 2011a: vii). Professor Gluckman stated in the report, 'Despite the broad range of backgrounds and disciplines on the Taskforce, the conclusions were reached with strong consensus and the Synthesis Report is endorsed by all members of the group' (ibid.). Key institutions within the science system should increasingly take the opportunity to consider how best to encourage interdisciplinary research, especially in light of the current changes to funding models and attempts to change elements of the science system's culture.

5.1.11 Focus on talent

Global competition for talent has increased markedly in the wake of the 2008 global recession. In a PricewaterhouseCoopers survey of global CEOs, 97% stated that having the right talent is the most critical factor for their business growth (PwC, 2010: 4). The increased focus on talent means that the traditional value placed on developing, attracting and retaining talent has become even more important as global competition increases in response to a more globally mobile workforce. Currently there is a lack of specific data flow on the migration of talented scientists and diaspora networks (Royal Society [UK], 2011: 6), and obtaining such data will be central to benchmarking change over time.

There has also been an increasing focus on the nature of talent. Matthew Syed, in his book *Bounce: The myth of talent and the power of practice*, discusses the work of Anne Roe, a psychologist at the University of Arizona, who concluded that scientific creativity is 'a function of how hard you work at it' (Syed, 2010: 92). Roe's study suggests that it is practice, rather than intelligence, that holds the key to success, a challenge to the common concept of innate talent and a strong case for focusing on talent development.

One of the key themes that emanated from the Institute's StrategyNZ: Mapping our Future event in March 2011 was expressed by Sir Paul Callaghan, an eminent scientist and 2011 Kiwibank New Zealander of the Year.[42] Callaghan described how New Zealand could become 'a place where talent wants to live', and emphasised the potential benefits if New Zealand created an environment that both attracts foreign talent and retains local talent. In July 2011 the Institute hosted a group of business leaders and entrepreneurs to discuss ways in which this idea could be better realised.

42 Text from this presentation has been reproduced in *New Zealand Science Review, 68*(3), 2011: 103-104.

Prior to the meeting Sam Morgan, the founder of TradeMe, made a number of observations concerning talent that were further developed by the group.[43] These included:

- Talent likes talent
- Talent wants to be the best in the world
- Talent enjoys being recognised
- Talent thinks and acts globally
- Talent hates completing forms
- Talent gets frustrated with delays
- Talent needs human capital
- Talent grows through investment
- Talent follows talent
- Talent is key

Following the meeting Sir Paul made the observation, 'So my take is this, we simply push on, ignore the pessimism, and lead by example. Then suddenly we find ourselves surrounded by success and telling ourselves that it was always meant to be this way' (Sir Paul Callaghan, personal communication, July 2011).

5.1.12 Global science to address global challenges

A recent report by the Royal Society (UK) (2011), *Knowledge, Networks and Nations: Global scientific collaboration in the 21st century,* found that the science industry is becoming increasingly global; that traditional and emerging superpowers (e.g. the US, Western Europe, China, Japan, Brazil and India) still lead the field, but the distribution of scientific activity is trending towards being concentrated in dispersed hubs (e.g. the Middle East, South-East Asia and North Africa), and science is flourishing beyond these hubs in order to drive economic activity and address local and global sustainability issues.[44] The international landscape has also changed as scientists are increasingly involved in intergovernmental collaborative efforts (e.g. the Intergovernmental Panel on Climate Change). The UK report recognises that global challenges are often interdependent and interrelated (such as climate change, water, food, energy security, population changes and loss of diversity) but responses to these challenges are often operating in isolation within national rather than global frameworks.[45]

New Zealand is engaging with scientists around the world in addressing global challenges. Participation in international research projects such as the Australian Synchrotron facility, the bid for the Square Kilometre Array, the Global Biodiversity Information Facility and the Global Research Alliance for Agricultural Greenhouse Gases are among recent examples. It has been noted that greater involvement in international collaborative projects means New Zealand scientists are able to 'learn from how other large-scale collaborations have built new partnerships, capability, infrastructure and cultures' (Penman et al., 2011: 45).

43 Participants included Paul Callaghan, Alan MacDiarmid Professor of Physical Sciences at Victoria University of Wellington and 2010 KiwiBank New Zealander of the Year; Miang Lim, Senior Food Scientist at Food Standards Australia New Zealand; Hamish Edwards, co-founder of Xero; Alex Fala of Trade Me; Gerald Fitzgerald of Kensington Swan; Kate Frykberg from the Todd Foundation; Lindis Jones of Z Energy; Mark McGuinness and Murray Gribben of Willis Bond; Jeremy Moon from Ice Breaker; Lloyd Morrison of HRL Morrison; James Palmer from MAF; Grant Patterson, finance and investment banker based in New York; Fran Wilde of the Greater Wellington Regional Council; and Wendy McGuinness and Jessica Prendergast from the McGuinness Institute.

44 The report further notes: 'Collaboration enhances the quality of scientific research, improves the efficiency and effectiveness of that research, and is increasingly necessary, as the scale of both budgets and research challenges grow … Collaboration brings significant benefits, both measurable (such as citation impact and access to new markets) and less easily quantifiable outputs, such as broadening research horizons' (Royal Society [UK], 2011: 6).

45 The report suggests all countries have a role in tackling global challenges and in developing global infrastructure that is resilient to existing and new challenges. It also recommends that governments work harder at robust and evidence-based policy making (bringing excellent scientists into the policy advisory process); at committing to building scientific capability in less developed countries and at maintaining flexible and adaptive policies to optimise the flow of talented people so that international collaboration is not stifled by bureaucracy (Royal Society [UK], 2011: 104–107).

5.2 Implications for the Future

Science policy will continue to evolve in response to changes in weak signals and wild cards. Fundamental to progress is whether ministries, policy analysts and general public are well equipped to make rational decisions about the important scientific choices New Zealand needs to make. As director-general of the European Organization for Nuclear Research (CERN) states:

> Thanks to the increasing globalisation of science ... scientific news travels faster, allowing scientists wherever they may be to pick up a topic and run with it. This is great for science, because no country or region has a monopoly on intellect. Scientific globalisation allows us to tap into genius wherever it may be ... [but] we as a global society are increasingly dependent on science, yet increasingly ignorant of it. This is not a healthy state of affairs, and it is one that science must address, both by engaging more with the wider world and by pursuing the globalisation of science more vigorously than ever. (Heuer, 2011)

Science policy and designing tools to progress effective policy will continue to be a challenge in the future. The next three sections of the report analyse the current government-funded science system. In doing so a number of policy knots became apparent. These are discussed in detail in Section 9 and linkages between these policy knots and strategies are listed in Appendix 6.

6. The Purpose of Government-funded Science

The following statement from the New Zealand Association of Scientists' submission to the Crown Research Institute Taskforce highlights the importance of developing a sound understanding of purpose before robust strategic planning can take place:

> A comprehensive review of the way the whole science system is operating and the assumptions that underpin it, is required before particular issues are addressed. In particular a robust analysis is needed of what the science endeavour is, what is required of it, and hence what its institutional needs are. We recommend that such a review be carried out before any attempts are made to reform CRIs. Otherwise there is a risk of superficial patch-up solutions that do not address the underlying problems and that simply create new malaises in the science system. (NZAS, 2009)

It is particularly important that there is a clear and compelling vision that describes a desired future destination. A wide-ranging and inclusive strategic planning process can also provide an invaluable opportunity for dialogue and collaboration within the scientific community, among policy-makers and with the wider public and stakeholders. Defining a shared vision, then working out how to achieve that desired outcome, is the essence of strategic planning.

This section explores and analyses the purpose of the current government-funded science system in terms of its mission, values and vision. While Table 3 in Section 3 provides an overview of the purpose of government-funded science over time, this section describes the current purpose in more detail. Sections 6–8 follow the strategy pyramid introduced in Figure 1.

6.1 Mission

A mission statement for the government-funded science system should answer the question 'Why does the system exist?' The MSI website currently answers this question by stating the following under the heading 'Purpose and Goals':

> New Zealand is a smart nation with unrealised potential, and key to our future prosperity and wellbeing is a high performing science and innovation sector.[46]
>
> MSI has an ambitious mandate to transform New Zealand by driving science and innovation to increase our economic, environmental and social performance.
>
> We will do this through our strategic leadership and by partnering with the science and innovation sector and through the networks we build across government, research organisations, business and industry.
>
> [The purpose of MSI is] Leading the science and innovation ecosystem to deliver a step change to New Zealanders' prosperity and wellbeing. (MSI, 2011b).

This builds on the May 2011 statement which articulated the mission as:

> Science and innovation creating benefit for New Zealand. (MSI, 2011c: 6)

46 The Minister 'asked MSI to focus its effort on giving effect to the "smart nation" concept through the following priority work programmes:

- Establish the "advanced technology institute" and respond to the high-tech sector review: Complete the budget process and high-level conceptual design to advance the Institute initiative, and provide advice on any systems or policy settings that will need modification in light of the review of R&D support to the high-tech sector.
- CRI Taskforce phase 2: Policy advice on the potential consolidation of CRIs to achieve scale, competitive advantage, cost efficiencies and improved strategic alignment.
- Internationalisation: Strategic engagement to maximise NZInc's impact offshore and derive greater benefit from MSI's international science and innovation efforts.
- Visible momentum on business support: Enhancing business linkages with the science system, including through the establishment of the National Network of Commercialisation Centres and as a result of the review of R&D support to the high-tech sector.
- Contributing to the future success of Christchurch: This includes supporting Canterbury businesses in close liaison with other agencies, and ensuring that science needs are adequately met for both earthquake hazards and the rebuilding work needed to achieve a viable, vibrant Christchurch city.' (MSI, 2011d: 24)

This mission is also evident in the legislature relating to the purpose of the Ministry, as set out at s 7(1) of the Research, Science, and Technology Act 2010 (the Act):

> Specified RS&T funding may be allocated for research, science, or technology, or related activities, **for the benefit of New Zealand**. [Bold added]

Thus, the mission according to the Act and MSI's *Statement of Intent* focuses on the benefit to New Zealand. Section 7(2) of the Act provides further insight into the science-specific nature of the benefits to be derived from government-funded science, stating that activity includes (but is not limited to) activity that:

a. is likely to increase knowledge or understanding of the physical, biological, or social environment; or
b. is likely to contribute to New Zealand's economic growth; or
c. is likely to develop, maintain, or increase skills or scientific or technological expertise that is of particular importance to New Zealand; or
d. is unlikely to be funded, or adequately funded, from non-governmental sources; or
e. facilitates research, science, or technology, or related activities; or
f. promotes or facilitates the application of research, science, or technology, or related activities.

The funding direction for the Science and Innovation Boards, as set out in the *New Zealand Gazette* (the *Gazette*), also provides an insight into a more science-specific mission. Instead of having a single board approve all funding, as was the case with FRST, the new system delegates investment decisions to either a Science Investment Board or an Innovation Investment Board.[47] The Act sets out the function of the two boards:[48]

> Under Section 10(3) of the Act, I specify that the Science Board will be responsible for making decisions for funding used predominantly by research organisations. Funding decisions made by the Science Board will enable New Zealand research organisations to conduct high-quality research that **creates economic, social and environmental benefits** for New Zealand. [Bold added]
>
> Under Section 10(3) of the Act, I specify that the Innovation Board will be responsible for making decisions for funding that supports business-led research and development and technology transfer. Funding decisions made by the Innovation Board will **support New Zealand businesses to grow** by becoming more innovative and internationally competitive; and to increase the benefit New Zealand derives from publicly funded RS&T. [Bold added] (DIA, 2011: 179)

This thinking is reflected in MSI's Performance Framework, which shows 'growing the economy' and 'building a healthier environment and society' as the two priorities underpinning the government-funded science system, see Figure 4. This diagram is effectively a strategy map,[49] in that it aims to describe how MSI will achieve the two high-level government priorities.

6.2 Values

Values are the set of common beliefs and standards held by stakeholders that drive the priorities and culture of the system. A set of core values empowers individuals to establish operational goals, make timely decisions and monitor progress, and to work together or individually to achieve shared goals. Such an approach leads to a more efficient and effective system and a more consistent set of deliverables.

47 Further to these two boards, some Vote S&I funding (formerly Vote RS&T funding) follows decision-making processes that do not require referral to a board established under Section 10(1)(a) of the Act. This includes: the Marsden Fund, Fellowships for Excellence (including Rutherford Discovery Fellowships and Fulbright), International Relationships, Health & Society research investments made by the Health Research Council, Vision Mātauranga Capability Fund, Business-Led Research and Development funding allocated via Regional Business Partners, and Commercialisation and Technology Transfer Support, Objective 1 (including National Networks of Commercialisation Centre funding and what was historically invested as pre-seed funding) (DIA, 2011: 209).

48 The Act also establishes the criteria for each board (as set out in the *Gazette*). For further discussion of the new boards and the criteria for funding under this new framework, see Working Papers 2011/14: *MSI Innovation Board: Legislation, operation and board membership* (SFI, 2011b) and 2011/15: *MSI Science Board: Legislation, operation and board membership* (SFI, 2011c)

49 Strategy maps provide the visual framework for integrating objectives and illustrate the cause and effect relationships that link internal processes to preferred outcomes (Kaplan et al., 2004: 55) (see Section 8).

There is a wider discussion to be had around how the cultures of the previous institutions, MoRST and FRST, will be unified under MSI. In addition, the culture within each CRI, and other science providers, will need to change in the new funding environment. MoRST's strategy document *Igniting Potential* did not explicitly define core values for the science system. However, MSI's *Statement of Intent 2011–2014* notes that a set of values remains a work in progress.

> [In 2011] there will be a focus on actively shaping a culture that supports MSI to be a high-performing agency. There will be a project defining the values for MSI and the integration of these across the organisation. These will form the baseline of our expectations of behaviour and standards and will be rolled out across the organisation (MSI, 2011c: 27).

Figure 4: Ministry of Science and Innovation Performance Framework (Outcomes, Impacts, Outputs), 2011
Source: MSI, 2011c: 11

GOVERNMENT PRIORITIES

Growing the economy

Building a healthier environment and society

EXTERNAL IMPACTS

- More businesses engage earlier with research organisations
- More companies invest more in R&D
- Decision markers are guided by relevant and up-to-date information, technology and tools
- Central and local government use research to identify and plan for over-the-horizon risks and opportunities

VISION

High-performing science and innovation systems improving New Zealanders' wealth and wellbeing

SUPPORTING OUTCOMES

Building high-performing science and innovation systems

Building improved international science and innovation linkages

SYSTEM IMPACTS

- Excellent people with relevant and high-value science and innovation skills
- Accessible, fit-for-purpose infrastrucutre
- Effective, well-connected and collaborative research organisations
- Research organisations engage early with companies and end users
- Increasing the number of scientists and engineers moving between research organisations and businesses
- Better translation of international science for domestic benefit
- Access to offshore knowledge, technology, infrastrucutre and expertise

MSI OUTPUTS

Strategy and priority setting
In partnership:

- Agree science and innovation priorities
- Agree sector investment strategies
- Contribute to key government initiatives

Facilitate, broker and invest

- Advice on, and strategic management of, investment processes
- Agree core funding agreements with CRIs
- Agree funding agreements with funding and investment agents

Monitor, measure and evaluate

- Monitor contracts and agreements
- Monitor statistics and other data
- Contract and institutional reviews
- Strategy and policy evaluations
- Funding and investment agent reporting
- Ownership advice to CRI shareholders

6.3 Vision

A vision statement should describe a state or position that stakeholders wish to move to; a place different from where they are currently situated. On 1 December 2011, MSI published its latest vision statement, which provides a much clearer context as to what this new state would look like, and the timeframe in which this change is expected to take place.

> [The MSI challenge is to] double the value from science and innovation for New Zealand [in the next five years]. (MSI, 2011b)

MSI's *Statement of Intent 2011–2014* refers to its vision as:

> High-performing science and innovation systems improving New Zealanders' wealth and wellbeing. (MSI, 2011c: 6)

This implies that the country currently has a low-performing science and innovation system.[50] The distinction between a high- and a low-performing science system is not defined. Only by providing such clarity can New Zealand be sure it is moving in the right direction and able to measure progress. The boxed text expands on Treasury's vision for government-funded science and sets out how MSI is likely to contribute to the concept of a 'smart nation'.

High-Level Objectives of Vote Science and Innovation

The Government is committed to lifting New Zealand's economic performance through science and innovation so that New Zealand becomes a smart nation. Key components to achieve this are to incentivise firms to invest more in Research and Development, focus investment in key areas, transfer knowledge and technology to firms and industry to accelerate business growth, and to increase the number of entrepreneurs and researchers doing high impact science - all of whom are needed to turn good ideas into export successes.

Science and innovation improves New Zealanders' wealth and wellbeing. Government's investment in research produces ideas and knowledge that drive innovation. Those ideas are taken up and applied in commercial products that fuel economic growth throughout society by enhancing New Zealanders' health and lifestyle, and in understanding how to make the most of our natural resources and protect our environment.

Science and innovation are considered central to New Zealand's future economic prosperity. Science plays a vital role in providing evidence for quality decision making, creating new knowledge to drive economic growth, while enriching our society. Government has a central role in ensuring that science delivers greater impact for New Zealand. The Government is the largest investor in science and innovation within New Zealand and also owns key research capability in the form of the Crown research institutes (CRIs).

MSI will focus on giving effect to the 'smart nation' concept through the following priorities:

- Explore the 'advanced technology institute' and respond to the high tech sector review
- Implement CRI Reforms
- Internationalisation
- Visible momentum on business support
- Contributing to the future success of Christchurch
- Top Talent
- Infrastructure. (Treasury, 2011e: 103)

50 In 2010, MoRST identified the desired outcome of its operations as 'science and technology improving New Zealanders' wealth and wellbeing' (MoRST, 2010c: 4). Prior to the release of the Ministry's 2010/11 *Statement of Intent*, MoRST had identified the ultimate goal of government-funded science in New Zealand as producing 'value for New Zealand' (MoRST, 2009a). Earlier, more specific high-level goals were stated to be: evidence for decision-making; new knowledge to drive economic growth, and enrichment of society (MoRST, 2009b: 5).

6.4 Discussion

The current mission is high-level and does not provide a detailed rationale as to why the public should support government-funded science. Without clarity over why it exists, stakeholders are unlikely to support the continued appropriation of public funds, and it is unclear how judgements can be made as to whether or not the investment has delivered the benefits promised. Further, investment in government-funded science is long term and as such the intra-generational aspect is an important element in understanding why government-funded science is central to sustainable development.

While it is encouraging to see that MSI established a project in 2011 to create a set of values, it is surprising that these values are still in progress. Ideally values should be identified early and then used to determine the optimal strategy and structure. Agreeing upon a set of core values for MSI and the wider government-funded science system remains critical to developing a more adaptive, creative, productive and resilient system.

The vision must be able to create a description of a future place and time that is compelling and succinct so that it is easy to navigate to and stakeholders know that they have arrived. Although the latest MSI vision is clear and is an improvement, it is also difficult to see how progress can be benchmarked over time. Agreeing a vision is not easy and requires an understanding of what is desired and what is achievable. Section 10 continues this discussion.

7. The Strategy Driving Government-funded Science

Having considered the purpose underlying government-funded science, the next step is to explore how this vision could be pursued through an effective strategy. This involves looking at how the current government is planning to spend its investment (strategic intent); what themes it will focus on to deliver the strategy (drivers); and what resources will be used to achieve its strategic intent (enablers). An effective strategy should state how it will achieve a particular purpose in sufficient detail so that the cause and effect can be understood and therefore executed, and its performance measured. A discussion on the importance of monitoring progress to be used for the purpose and strategy can be found in Section 8.

In order to determine the quality of a strategy, it must be assessed in terms of the extent to which integrity and alignment exist within it (internal cohesion) and whether it is appropriate within the current and future landscape (external cohesion). These questions are discussed at the end of this section.

7.1 Strategic Intent

The dialogue around how best to design the government-funded science system is continually evolving and is supported by a substantial background of discussion documents, as discussed below.

In late 2005, work was undertaken by MoRST to look at how to make a more stable funding environment (MoRST, 2005). In 2006, MoRST then undertook an overview of the Research, Science and Technology system (MoRST, 2006a). By 2007 the strategy was to focus primarily, but not exclusively, on the scientific part of research, science and technology; in particular the creation of new scientific knowledge (MoRST, 2007a: 2). The strategic framework was: (i) sharpening the agenda for science; (ii) engaging New Zealanders with science and technology; (iii) improving business performance through research and development, and (iv) creating a world-class science system for New Zealand. The core business included cross-government and international collaboration (ibid.: 5–6). The timeframe expected to achieve the strategic framework was 3–5 years.

In 2008 MoRST evaluated the Crown Research Capability Fund (MoRST, 2008a) and the R&D tax credit (MoRST, 2008b). Evaluations of research and development (MoRST, 2009c), Vision Mātauranga (MoRST, 2009d), priority research outcome areas (which were agreed by Cabinet in December 2009) (MoRST, 2009e) and foresight (MoRST, 2009f) followed and this process is ongoing.[51] The new priority investment areas came into effect on 1 July 2010 and continue today. They are:

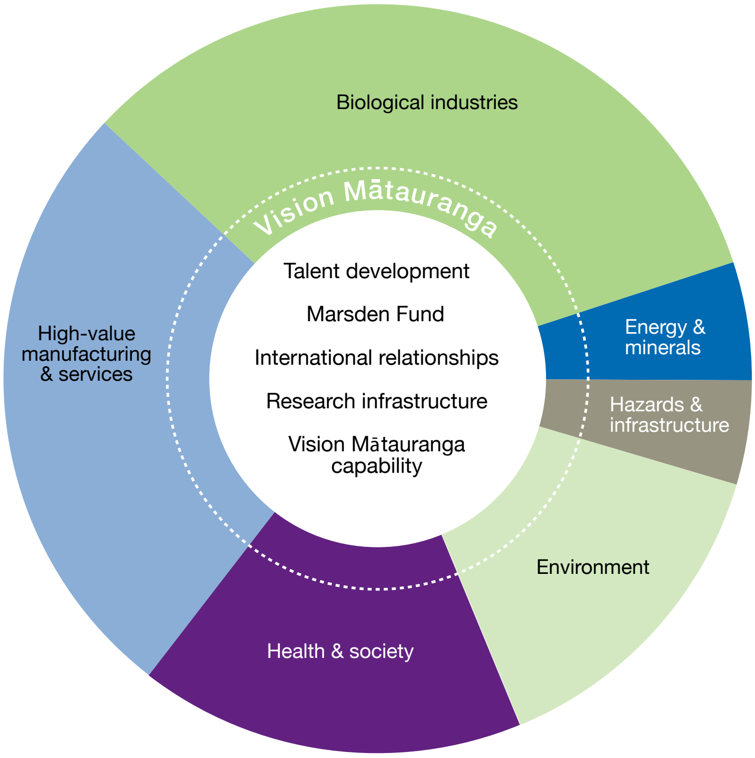
1. High-value manufacturing and services
2. Biological industries
3. Energy and minerals
4. Hazards and infrastructure
5. Environment
6. Health and society. (MoRST, 2009e)

Figure 5 shows the current priority investment areas in the outer circle and the supporting priorities at the centre of the circle.[52] The proportions are based on Budget 2010 investment.

51 Also see the discussion of the *Reviews of Innovation Policy: New Zealand* (OECD, 2007a) and the National Science Panel's *Science Manifesto* (NSP, 2008) in Section 3.3 of this report.

52 See 'priority investment areas' in glossary. We have used this term throughout the report, although it is not consistently applied across government documents. It is important that terminology of this nature is used consistently in government documents for monitoring and reporting purposes. Further, the use of the word 'priority' is arguably misleading in that the intent seems to be to divide science research into subsets rather than prioritise one area of science over another.

Figure 5: Priority Investment Areas, 2010 (Budget)
Source: MoRST, 2010a: 16[53]



MoRST's *Igniting Potential: New Zealand's science and innovation pathway* (2010a) sets out what is expected from a science system in New Zealand based on these priorities. It describes, in broad terms, how to achieve its goals, and the three sets of principles necessary to guide investment in science: (i) general principles; (ii) priority-setting principles, and (iii) operational principles.[54] The strategic intent of the current strategy is to unlock the potential within the system by a number of means, the most significant of which is the establishment of a single policy and investment agency. Many of the same themes such as collaboration and international relationships continue to be key aspects of the strategy today. *Igniting Potential* closes by describing the recent structural changes as 'steps being taken at the beginning of an exciting pathway' in which the report is 'the first stage of an ongoing process' (MoRST, 2010a: 59). The rationale for the recent reform is discussed in Section 3.4 of this report.

MSI's Statement of Intent *2011–2014* sets out the short-term intent and new responsibilities of the Ministry. The Statement of Intent includes discussion of MSI having primary responsibility for financial and non-financial monitoring of CRIs (MSI, 2011c: 3) and as the provider of strategic leadership in the science and innovation system.

MSI has recently published information on seven Sector Advisory Groups, which in effect represent all six priority investment areas outlined in Figure 5.[55] One of the priority investment areas (biological industries) was further broken up into 'biological resources' and 'food' (MSI, 2011e), resulting in seven

53 Vision Mātauranga is a MoRST policy framework with the mission statement: to unlock the innovation potential of Māori knowledge, resources and people to assist New Zealanders to create a better future. The purpose of the framework is to provide strategic direction for Vote RS&T funding for research of relevance to four themes: (i) Indigenous Innovation: Contributing to Economic Growth through Distinctive R&D; (ii) Taiao: Achieving Environmental Sustainability through Iwi and Hapū relationships with land and sea; (iii) Hauora/Oranga: Improving Māori Health and Social Well-being; and (iv) Mātauranga: Exploring Indigenous Knowledge and RS&T (MoRST, 2009d).

54 In addition to the general guidance provided by *Igniting Potential*, there are several central government documents specific to particular areas of scientific research in New Zealand. According to MoRST (2007c), public investment in certain areas of science had been guided, where relevant, by the following MoRST strategies, which form the *Roadmaps for Science* series of documents: the *Energy Research Roadmap*; *Nanoscience and Nanotechnologies Roadmap*; *Biotechnology Research Roadmap*, and *Environment Research Roadmap*. Under the 2011 merger of MoRST and FRST these responsibilities were transferred to MSI and information is not yet available as to their degree of continuity under the new scheme.

55 For the purposes of this report priority investment areas are considered to mean research areas; there is no implication that one area of research has priority over another.

groups. Shortly before this publication went to press MSI had just updated its stated purpose, set of goals and list of roles and functions. The newly articulated roles and functions indicate another change in the Ministry's strategic intent:

- Advising the Government on New Zealand's science and innovation system
- Overseeing science and innovation investment and supporting infrastructure
- Fostering commercialisation, enhancing productivity and achieving wider benefits for New Zealand through the application of research results
- Monitoring the financial and non-financial performance of New Zealand's eight CRIs. (MSI, 2011b)

7.2 Strategic Drivers

Strategic drivers identify the key focus areas that the strategy uses to drive activity. Key focus areas driving activity in the New Zealand science sector include:[56]

- Improving linkages;
- Improving the innovation system;
- Ensuring processes are cost-effective, and
- Developing partnerships both internally and externally.

The *Statement of Intent 2011–2014* includes the following statements that reflect the above drivers:

> MSI will focus on our vision, 'High-performing science and innovation systems improving New Zealanders' wealth and wellbeing.' This will be achieved by focusing on our supporting outcomes, 'Building high-performing science and innovation systems', and, 'Building improved international science and innovation linkages'. (MSI, 2011c: 10)
>
> MSI is a small agency with approximately 140 staff. To achieve our strategic intent we will have to work with and through others. An important role is therefore to facilitate, broker and connect key players in the science and innovation systems. (ibid.: 8)
>
> During 2011/12 the key areas of focus will be our people; leadership; culture; relationships; processes, policies and systems; our technology and property; measuring our health and capability; sound departmental capital and asset management practices and equal employment opportunities. (ibid.: 25)

7.3 Strategic Enablers

While strategic drivers outline the means used to achieve the strategic purpose, enablers drive change. Enablers generally change in response to changes in purpose. Through our examination of the key players in the MSI institutional framework, we have identified five key enablers: the institutional framework; scientists; infrastructure; the funding system, and the regulatory framework. However, we first consider barriers, or 'disablers', within the system, as perceived by the scientific community.

In 2005, the New Zealand Association of Scientists (NZAS) recommended eight initiatives in order to enhance both the productivity of New Zealand's science system and the morale of the research community.[57]

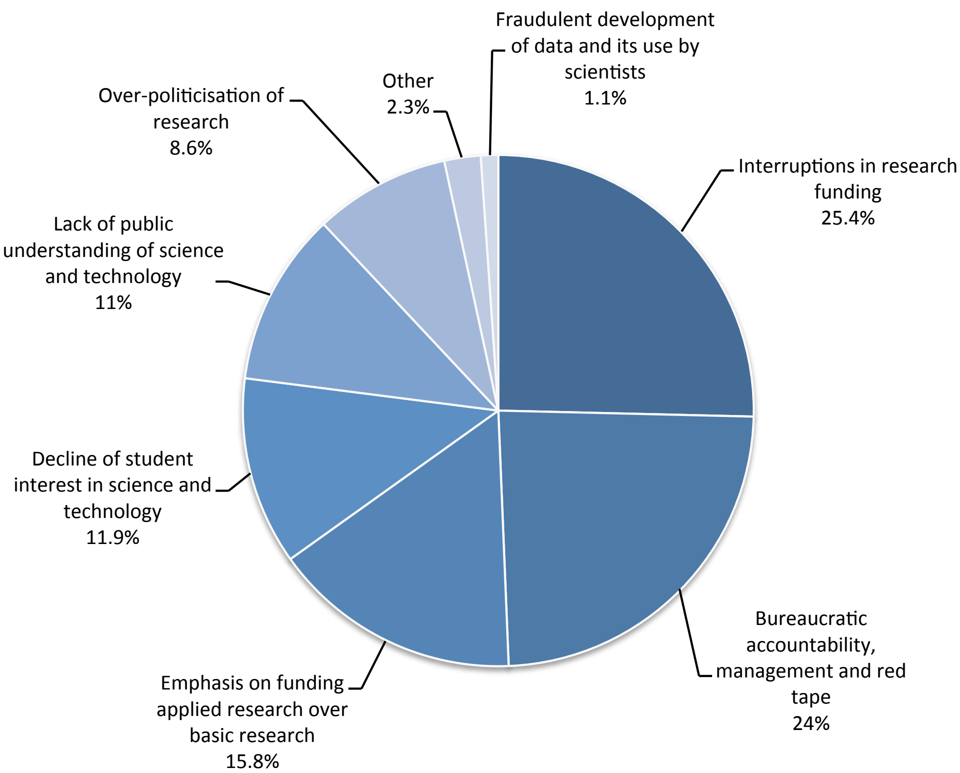
56 The key drivers behind New Zealand's science system are summarised in Table 3 of this report.

57 Briefly the eight initiatives were to: (i) increase RS&T public funding by at least 25%; (ii) reduce the current proliferation of funding instruments; (iii) develop clear guidelines concerning the expectations of managers of public-funded institutions in the RS&T system because conflicting objectives and incentives exert a negative impact on the functioning and effectiveness of the whole system; (iv) examine the continuing relevance of the roles of various RS&T institutions; (v) develop funding policy in a more transparent manner and signal future funding scenarios more clearly than at present; (vi) reconsider how CRIs should be funded; (vii) increase resources to excellence-based research, such as is presently funded within the Marsden Fund, by as much as 200%; and (viii) reinstate research excellence as an important funding criterion in the PGS&T and similar funds (NZAS, 2005: 2-3).

In 1996, 2000 and 2008, Professor Jack Sommer, a Senior Fulbright Scholar and science policy research scientist at the University of North Carolina at Charlotte, surveyed New Zealand scientists in an attempt to give the scientific community a voice on matters of interest to it. The three surveys explored the attitudes, opinions and concerns of the scientists. The findings of the 2008 survey were based on 361 valid responses, with 75.6% of respondents holding New Zealand citizenship. The survey questions were divided into four sections: concerns of scientists; science, values, and government; scientific inquiry and education; and performance of the science and technology system (Sommer, 2010: 4).

In 2008, Sommer took seven important issues that had been identified in the 1996 survey, and asked respondents to choose the two issues they considered to be most important at that time. The seven issues had been chosen based on focus group discussions with members of the New Zealand science community. Figure 6 shows Sommer's summary of the major issues facing science.

Figure 6: Major Issues Facing Science, 2008
Source: Sommer, 2010: 15



As Figure 6 shows, interruptions in research funding combined with bureaucratic accountability, management and red tape account for nearly half the responses (49.4%) (Sommer, 2010: 15). Sommer also looked at the connections between particular fields of science and individual issues. Those most concerned with interruptions in research funding were working in the fields of agriculture and soil sciences (58.1%), physical sciences (42.9%) and biological sciences (40.9%). Those most concerned with bureaucracy and red tape were working in agriculture and soil science (29.0%) and health science (28.6%) (ibid.). Interestingly, the responses from university and CRI scientists were similar, with one major exception: 49.3% of CRI scientists cited interruptions in funding as the most important issue, compared with only 24.2% of university scientists (ibid.). In questions such as this, what is interesting is not only what is most significant, but also what is not considered to be significant. In this case, scientists were not significantly concerned with a lack of public understanding of science, over-politicisation of research or fraudulent developments.

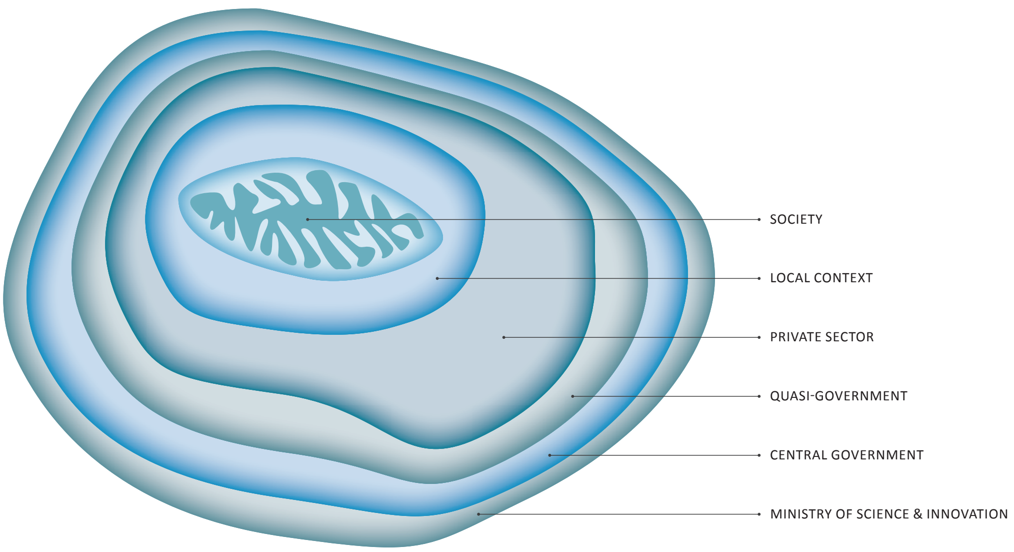
Together Sommer's three surveys provide an interesting insight into the barriers and issues facing the New Zealand scientific community as perceived by those working within the system.

7.3.1 Enabler 1: Institutional Framework

Section 3 provides the background history to the current structure. Appendix 7 describes the significant players as they exist today, and Appendix 8 describes the purpose, agenda and funding sources of CRIs. Many others provide checks and balances, such as the Office of the Auditor-General and the Parliamentary Commissioner for the Environment, or work with research providers, such as local councils. The most recent articulation of MSI's purpose and goals refers to the science and innovation system as an 'ecosystem' (MSI, 2011b). This alludes to the wide and varied nature of players in the government-funded science system. Reflecting the interdependent relationship between institutions, Figure 7 depicts the government-funded science system as one large cell, of which the nucleus represents the public at the centre and the membrane acts as a filter that allows information to be shared between institutions rather than creating definitive boundaries. This diagram assumes that the primary function of the government-funded science system is to increase the well-being of society.

Section 9 presents a number of outstanding policy and strategy questions that aim to either test the assumptions underlying the current institutional framework or examine the system linkages that are purported to deliver the desired outcomes.

Figure 7: The Government-funded Science Ecosystem

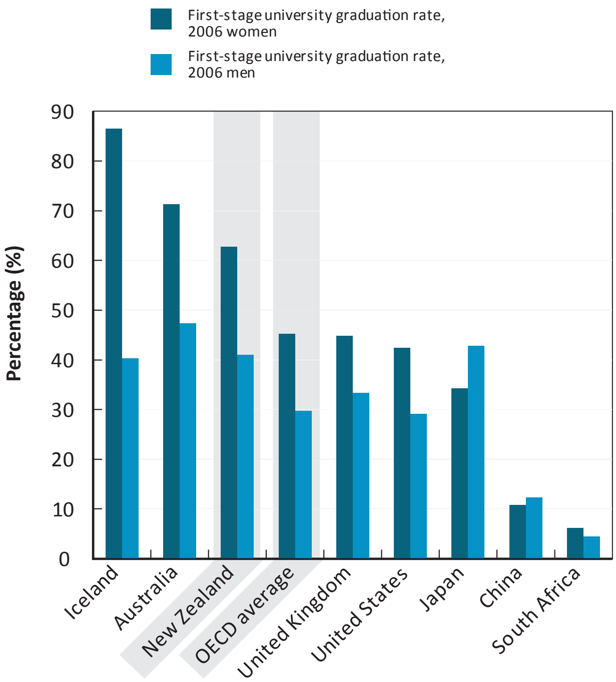


7.3.2 Enabler 2: Scientists

Science is about testing ideas. Those ideas are either supported or rejected based on evidence. The evidence can be either experimental or observational, but both the idea and the evidence must be judged by a jury of one's scientific peers. It is through this peer review process that ideas are either generally accepted and become knowledge or are rejected. Scientists therefore can have many roles in the government-funded science system; they may be the person with the idea or the evidence, or they may be the peer.

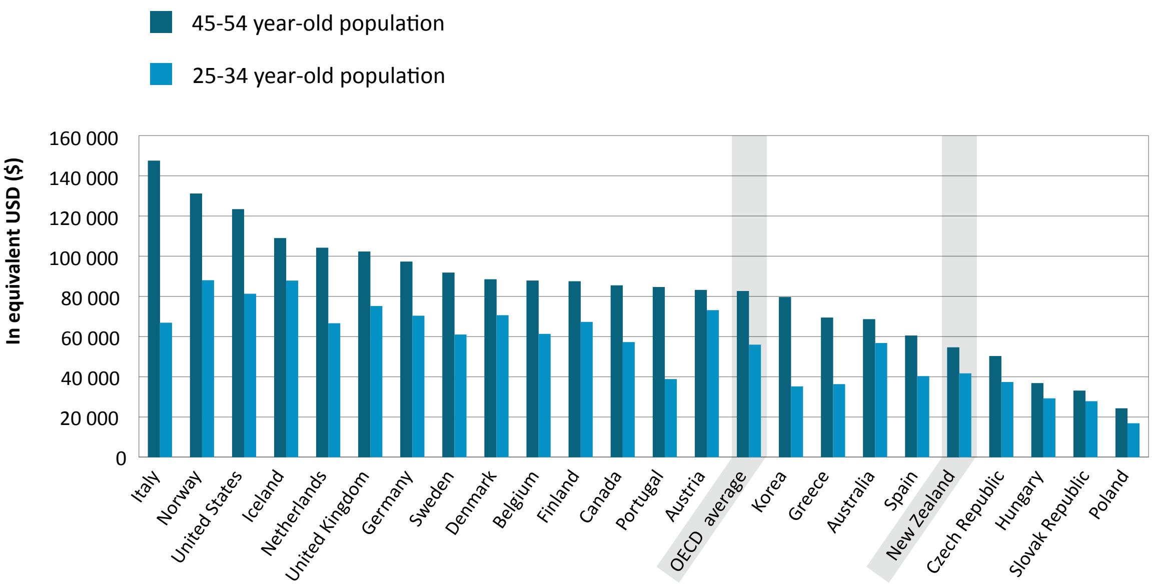
The wide-ranging nature of the functions undertaken by scientists in the government-funded system can present challenges. Scientists may be in a place to suggest investment priorities, make investment decisions on specific proposals aimed to build new knowledge, and provide public policy advice to government. This range of roles can result in a number of different conflicts of interest, in situations where personal interests, business interests, political interests and public good interests converge. These situations require careful management through well-governed and transparent processes, particularly as MSI brings on board a number of private sector interests though board membership and Sector Advisory Groups.

Figure 8: Graduation Rates at First-stage University Level as a Percentage of the Relevant Age Cohort, 2006
Source: Adapted from OECD, 2010a: 207



Note: Figures are taken from varying years. For Australia (2008), Canada (2008), Chile (2008), France (2008), Greece (2007), Iceland (2008), Korea (2008), Mexico (2007), New Zealand (2007), South Africa (2008), Switzerland (2008) and the United States (2007).

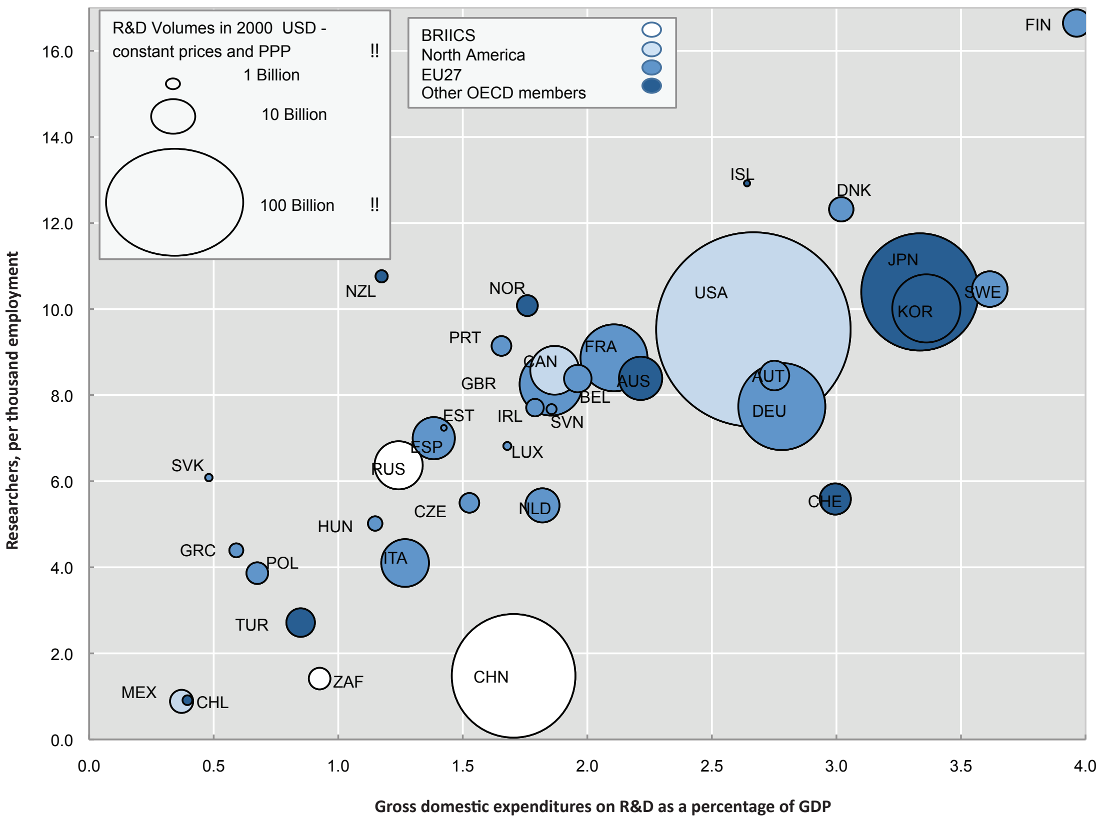
Figure 9: Annual Labour Costs Employing a Recent Versus Experienced Male Tertiary Graduate
Source: Adapted from OECD, 2010b



Note: Countries are ranked in descending order of annual labour costs of employing an experienced tertiary graduate. Figures are taken from varying years: Australia refers to 2005; Austria, Belgium, Denmark, Greece, Iceland, Italy, the Netherlands, Poland, Portugal and Sweden refer to 2006; Canada, Finland, Korea, and Spain refer to 2007. All other countries refer to 2008.

Figures 8 and 9 do not relate solely to science, but the statistics do provide a number of insights worthy of further investigation. Figure 8 indicates that of the students who graduate in New Zealand, more tend to be women than men. Figure 9 indicates that once students do graduate, significant disparity exists between recent New Zealand graduates who stay in New Zealand versus their overseas peers. Not only does that disparity begin immediately on graduation, but the gap widens considerably with experience. This suggests that in order to retain talent in New Zealand it will be necessary to increase salaries, promote existing benefits and/or provide further incentives. Further research in this area would be useful.

Figure 10: R&D In OECD and Non-OECD Countries, 2009
Source: OECD, 2011a



Note: Figures are taken from varying years. For Australia (2008), Canada (2008), Chile (2008), France (2008), Greece (2007), Iceland (2008), Korea (2008), Mexico (2007), New Zealand (2007), South Africa (2008), Switzerland (2008) and the United States (2007).

Looking more closely at the global arena, New Zealand has a small research and development budget in comparison with the number of scientists, which means that although we do not spend as much on research and development as other leading countries, such as Japan, Korea and the USA, we have a similar number of scientists per population (see Figure 10). This may mean we pay a lower rate on average per researcher and/or we employ the researchers without the same level of infrastructural support. Further research is necessary to understand the implications of this, and whether these statistics are positive or negative.

Recent research highlights a number of other issues relating to the science workforce: an ageing workforce, a global shortfall of scientists, dissatisfaction within the profession, a lack of women in some areas of science, and reluctance to produce commercial outcomes. Producing a strong science workforce is a long-term investment, given the time it takes to train and educate scientists to perform at the highest level. It is an investment that requires collaboration with universities and industry, as well as the scientific community itself (see discussion in Section 9.5).

Question 28 in Section 9 explores the make-up of the science profession and the expertise New Zealand needs in order to become a smart nation in the future.

7.3.3 Enabler 3: Research Infrastructure

Research infrastructure provides a strong platform from which the science sector can deliver globally competitive science, and is recognised as being a key enabler in many of the recent policy documents. The rationale underpinning the Crown's investment in 'large scale research infrastructure'[58] is as follows:

- Optimal utilisation of assets by making sector collaboration a prerequisite for participation in government-supported infrastructure;
- Increased productivity effectiveness and/or scale of activities;
- Assured access to international facilities through co-investment or agreements;
- Retention and attraction of top class researchers by creating an internationally connected and competitive research environment;
- Certainty in relation to access to advanced research infrastructure;
- More coordination of buyer power to get better value procurement and maintenance arrangements. (MoRST, 2010d: 17)

There is currently no central publicly available register of research infrastructure or resource assets for the science industry, which means it is not possible to debate a strategy for this significant public investment in science. One result of this is that scientists may not know what other assets exist in the public domain, meaning assets are not necessarily well-utilised and maintained. The development of a central register would encourage key players in the industry to work together to create a more valuable and utilised resource base for the future.

This section explores the current situation regarding a strategy underpinning the government's large-scale infrastructure projects and recent infrastructure investments.

(i) Strategic planning

In 2004, a large scale infrastructure policy was developed in an attempt to 'alleviate the market conditions that inhibited investment in modern research infrastructure' (MoRST, 2010d). This enabled the Crown to co-invest in large-scale or complex facilities on a case-by-case basis. The Research Infrastructure Advisory Group (RIAG) was established in 2005 to provide advice on each case put before the government under this model.

In August 2007, RIAG published its *Scan of New Zealand's Large Scale Research Infrastructure Needs 2007–2012*. The purpose of this report was to assess whether the current infrastructure enabled the science sector to achieve the government's goals. RIAG's report contains a list of New Zealand's research facilities and identifies the needs of some of these as 'urgent and key to a functioning and productive science sector, able to fully contribute to the health, wealth and well-being of New Zealanders' (RIAG, 2007:3). Further, it stated that the existing case-by-case method of funding was not conducive to the development and maintenance of large-scale infrastructure (ibid.:3). Existing facilities were assessed as not being effectively utilised and maintained, indicating cause for concern around their sustainability and the capacity to manage new infrastructure investments.

In response to the report, the Minister of Research, Science and Technology asked for a more comprehensive look at the large-scale research infrastructure required to enable the science sector to achieve the government's goals (MoRST, 2010e). In July 2010, MoRST developed the 'Large Scale Research Infrastructure Plan (2011–15 Investment Scenario)', which explored the strategic rationale for investing in large-scale research infrastructure, looked at the amount of investment required, and proposed policy settings to support this (MoRST, 2010d). This policy was developed by RIAG, and it appears there was limited consultation outside of this group with the wider research infrastructure community.

58 See glossary for a definition of 'large scale research infrastructure'.

Although MoRST's report was submitted to the Minister of Research, Science and Technology, Wayne Mapp, in July 2010, it was not endorsed and therefore did not become government policy. Instead, the work programme for RIAG and the development of a strategic investment plan for research infrastructure was effectively put on hold until the recent structural changes to the system had been completed.

In 2012, under MSI, a work stream has been created to develop a Large Scale Research, Infrastructure and Investment Plan covering the area of research infrastructure (Murray Bain, personal communication, 24 January 2012). This plan will take a strategic view of the sector and take into account the earlier work undertaken by RIAG and other work in this area under MoRST (Andrew Watson, personal communication, 26 January 2012). This process is likely to involve wider engagement with the sector. MSI will consider the wider landscape of New Zealand's national priorities in shaping research infrastructure priorities and seeks to ensure the two are well integrated, with the latter supporting and underpinning the former. MSI is hoping this new work stream will be completed during 2012 (ibid.). MSI also hopes to put in place a suitable process for assessing investment proposals for large-scale infrastructure, one that will align with government priorities so that there is a strong relationship between research infrastructure and research priorities.

Wide consultation will be essential if New Zealand's research infrastructure is to underpin and support science. There needs to be strong dialogue to ascertain research infrastructure needs. Ideally the strategy can build on the work done by RIAG and MoRST, ensuring earlier lessons are not lost in the restructuring process. Given the need for extensive stakeholder consultation, it may be that a phased investment plan is more appropriate than releasing one final document. The strategy needs to identify how New Zealand can best spend this limited pool of funds, and in particular, identify where public/private sector collaboration or outsourcing research to other countries is a more prudent investment.

(ii) Recent infrastructure investments

New Zealand is a small nation with a limited pool of resources, therefore it is essential that it looks to where it can most effectively develop large-scale infrastructure. The need for a centralised national infrastructure programme is recognised within the industry. For example, in welcoming the newly established New Zealand eScience Infrastructure (NeSI) project, Professor David Skegg, a former Vice-Chancellor of the University of Otago, stated:

> It is especially important this is a coordinated and consistent approach between Government and science institutions, leading to greater cost efficiencies, less duplication and one entry point for computational-based research which can be accessed from anywhere in the country. (NeSI, 2011)

Access to large-scale research infrastructure, such as high-performance computing and high-speed broadband, is vital for data-driven science. The NeSI project aims to help scientists gain access to superior computing power and coordinate research more efficiently across the sector. NeSI follows on from the establishment in 2010 of New Zealand Genomics Ltd, which provided genomics technology and bioinformatics to New Zealand scientists (NeSI, n.d.). At the launch of NeSI, the Minister of Science and Innovation, Wayne Mapp, stated:

> This will enable more accurate and higher-quality research, leading to discoveries and insights that will benefit our economy, environment and society. (Mapp, 2011a)

Two other significant projects initiated by MoRST in 2005/2006 and managed by the Crown-owned company Research and Education Advanced Network (REANNZ) are KAREN[59] and the Australian Synchrotron.[60] With the establishment of projects such as these, it is clear that coordination and support for key science assets will increasingly be required as expensive science tools continue to develop rapidly.

59 The Kiwi Advanced Research and Education Network (KAREN) is an ultra-high speed optical fibre internet connecting New Zealand research and education sectors. This project aims to link New Zealand researchers with collaborators both nationally and internationally (MoRST, 2010f).

60 The Australian Synchrotron produces high-energy electron beams to study the structures of materials.

7.3.4 Enabler 4: Funding

Through its investment in science the government seeks to distribute a limited pool of taxpayer funds among key players in the science community so that they can contribute to the greater public good. Funding mechanisms need to ensure that scientists are working within optimal conditions, with the support necessary to enable the best science, and also, where possible, that any benefits from the investment are returned to the public. Ideally, funding decisions should be undertaken in the most cost-effective, risk-managed, transparent and timely manner possible. This means the government, as the administrator of funds, must make decisions about the research agenda (the right science), the inputs (the right scientists and infrastructure), the process (the best funding mechanism), the desired outputs and outcomes (whose well-being is improved, and how), and the level and quality of feedback (what lessons can be learnt). Evaluating the funds over time is difficult due to the number of changes to the funding allocation system.

The change in the size of the Vote Science and Innovation (budgeted) between 2010/2011 ($787.680 million) and 2011/2012 ($773.7 million) appears insignificant when reviewing the total expenditure allocated for the year (Treasury, 2011c: 273). However, recent changes to the way in which the Vote is allocated amount to a significant alteration in how government-funded science operates. This subsection explores the size of the funds (the inputs) and the way the funds are distributed within the science system (the process).

(i) The size of the funds

Under the 2011/2012 Budget (see Figure 11), 92% of the Vote is allocated to Non-Departmental Output Expenses.[61] Under this allocation, the main six science and innovation research priorities (numbered 1–6 in Figure 11) account for 53% of the overall Vote.

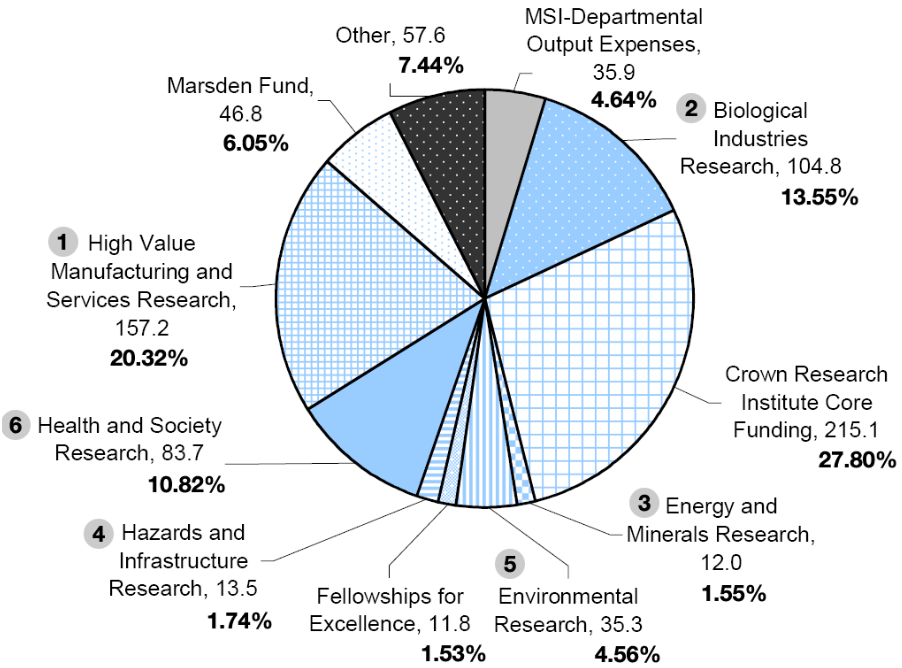
Treasury information on appropriations shows that of the remaining 8% of the overall Vote, 5% ($35.922 million) is allocated to Departmental Output Expenses,[62] and 3% ($28.171 million) is allocated to Non-Departmental Other Expenses, or 'priority investment that underpins a successful science system' (ibid.: 270). This 3% includes providing access to modern national research facilities, international relationships, the Vision Mātauranga Capability Fund, the Marsden Fund and fellowships (ibid.).[63]

61 The Budgeted Non-Departmental Output Expenses, which accounts for $707.490 million of the overall Vote in 2011/2012, is comprised of spending in the following areas: Biological Industries Research ($104.819 million); Crown Research Institute Core Funding ($215.145 million); Energy and Minerals Research ($11.997 million); Engaging New Zealanders with Science and Technology ($9.189 million); Environmental Research ($35.315 million); Fellowships for Excellence ($11.770 million); Hazards and Infrastructure Research ($13.459 million); Health and Society Research ($83.694 million); High Value Manufacturing and Services Research ($157.204 million); Marsden Fund ($46.755 million); National Measurement Standards ($5.764 million); Research Contract Management ($6.412 million); and Vision Mātauranga Capability Fund ($5.967 million) (Treasury, 2011c: 271–272).

62 The Budgeted Departmental Output Expenses, which accounts for $22.418 million (3%) of the overall Vote in 2010/2011, is comprised of spending in the following areas: Advice on Shaping the Science and Innovation System (Contract Management and Policy Advice) ($21.691 million) and Cross Agency Research ($727,000) (Treasury, 2010a: 279). In 2011/2012, the Departmental Output Expenses of Contract Management and Policy Advice were replaced with two new output expenses: Strategic Leadership in the Science and Innovation Sector ($14.930 million) and Science and Innovation Contract Management ($20.092 million) (Treasury, 2011c: 271; 2011e: 111). These changes are designed to reflect the new role and work of MSI.

63 'Priority investment that underpins a successful science system', which accounts for $28.171 million of the overall Vote in 2011/12, is comprised of spending in the following areas: Advanced Network Capability Building; Payment for New Zealand's annual subscription to Convention du Metre; Genomics Research Infrastructure; Grants for International Relationships; National eScience Infrastructure; an annual grant to the Royal Society of New Zealand; and Science Collections and Infrastructure (Treasury, 2011c: 272–273). It should be noted that under the allocation for Non-Departmental Other Expenses, funding for the Australian Synchrotron and CRI Capability Fund both ceased to exist in the 2011/2012 Budget (ibid.: 273).

Figure 11: Vote S&I – Total Appropriations, 2011/12 (Budget) ($million)
Source: Adapted from OAG, 2011: 7



Note: This figure shows the distribution of Vote S&I appropriations over $10 million for 2011/12. In particular it shows the size of the six priority investment areas in contrast to the significant investment in CRI Core Funding. Unfortunately the CRI Core Funding is not further broken down into priority areas, which gives rise to some doubt over the nature of CRI investment.

Under the 2010/2011 Budget, 74% (nearly $566 million) of what was then called Vote Research, Science and Technology (Vote RS&T) was allocated to Non-Departmental Output expenses, or 'priority investment within science research outcomes' (Treasury, 2010a: 278). This included funding for the same six research priorities referred to above, although funding for these six areas accounted for 68% ($522.249 million) of the overall Vote (ibid.: 279–282), compared with 53% in 2011/2012 (OAG, 2011: 7). Of the remaining 26% of the Vote, 3% was for Departmental Output Expenses,[64] 21% (nearly $164 million) was allocated to Non-Departmental Other Expenses, or 'priorities that underpin a successful science system',[65] and 2% was allocated to KAREN (Kiwi Advanced Research and Education Network)[66] (Treasury, 2010a: 278, 282).

Figure 12 looks more closely at the cost per capita of the investment which appears relatively consistent through to 2014/15. However, capital expenditure in Figure 13 is estimated to decline, indicating there is unlikely to be significant investment in funds in the short term. The challenge is therefore to live within ones means.

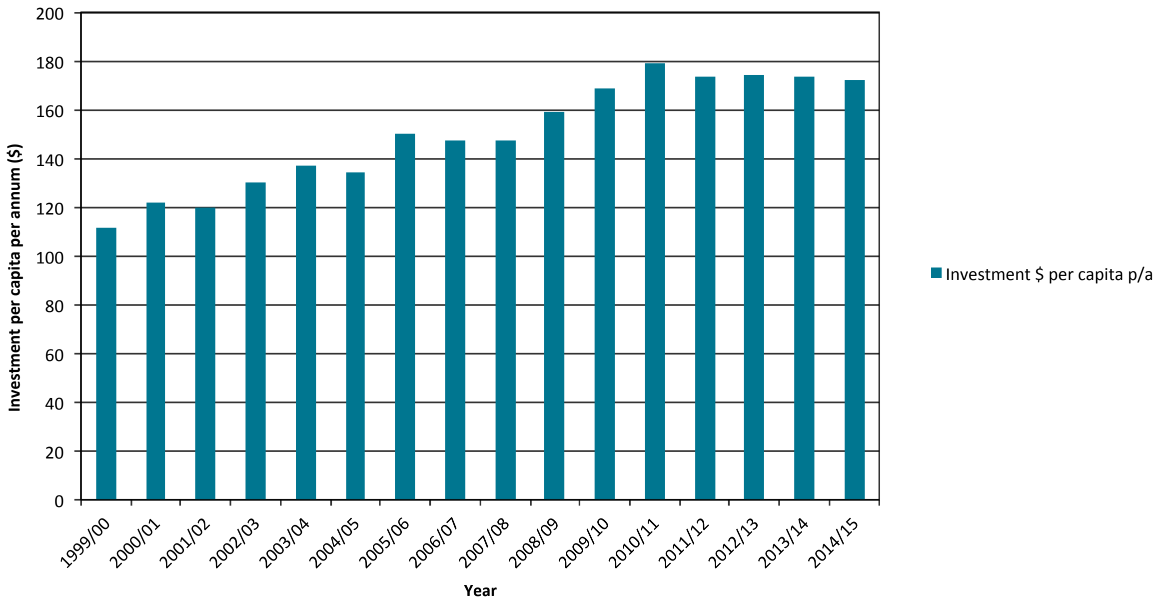
64 The Budgeted Departmental Output Expenses, which account for $22.418 million (3%) of the overall Vote in 2010/2011, comprised spending in the following areas: Advice on Shaping the Science and Innovation System (Contract Management and Policy Advice) ($21.691 million); and Cross Agency Research ($727,000) (Treasury, 2010a: 279).

65 This included funding to provide access to modern national research facilities, international relationships, the Vision Mātauranga Capability Fund, the Marsden Fund and fellowships (Treasury, 2010a: 278).

66 A total of $16 million (2% of the Vote) was allocated for capital investment through a Budget 2009 decision. The investment was for the continued operation of KAREN, which is managed by the Research Education Advanced Network New Zealand Limited (REANNZ) (Treasury, 2010a: 278).

Figure 12: Vote RS&T and Vote S&I – Total Appropriations Per Capita, 1999/00–2014/15

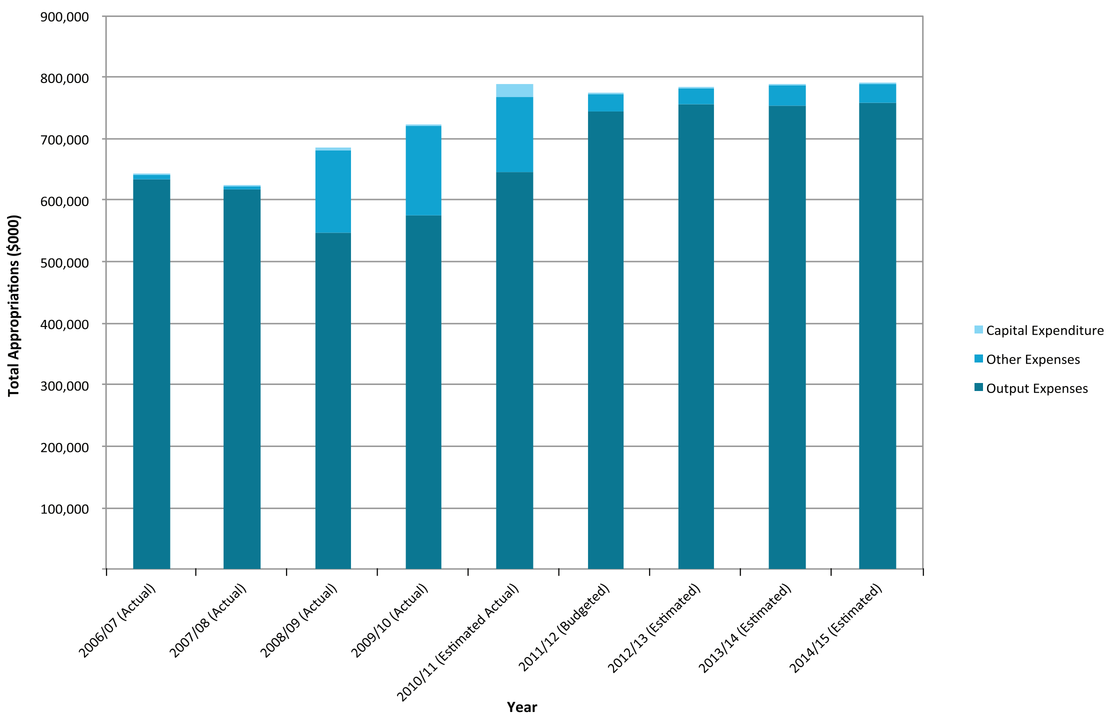
Source: Treasury, 2000: 328; 2001: 15; 2002: 16; 2003: 1081; 2004: 1109; 2005: 1126; 2006: 1008; 2007: 1014; 2008: 262; 2009b: 285; 2010a: 282; 2011c: 273; 2011e: 105; Statistics New Zealand, 2011a; n.d.



Note: Per capita investment was calculated using actual estimated total appropriation figures for Vote Science and Innovation (named Vote Research, Science and Technology until 2011/12) and national population estimates provided by Statistics New Zealand. Projected per capita investment (2012/13 – 2014/15) is based on estimated total appropriations in Vote Science and Innovation and national population projections provided by Statistics New Zealand, as per series 5.

Figure 13: Vote RS&T and Vote S&I – Total Appropriations, 2006/07–2014/15

Source: Treasury, 2011e: 105



(ii) The funding process

A stable funding environment enables the science community to build on past knowledge, maintain infrastructure capacity, and provide long-term career paths for scientists. Strong governance and monitoring will help maximise the benefit derived from the public's investment in science, and secure a continued level of investment. To enable the system to achieve its strategic goals, it is necessary to have both an adequate level of investment, and effective and efficient mechanisms for distributing funding.

Notable differences to the way in which funding was allocated in the 2011/12 Budget (compared to 2010/11 Estimated Actual figures) include:

- An increase in departmental output expenses, up 27.7% from $28.123 million to $35.922 million.
- A decrease in contestable funding for Biological Industries Research, down 37.6% from $167.962 million to $104.819 million.
- A decrease in contestable funding for Energy and Minerals Research, down 54.5% from $26.351 million to $11.997 million.
- A decrease in contestable funding for Environmental Research, down 52.3 % from $73.967 million to $35.315 million.
- A decrease in contestable funding for Hazards and Infrastructure Research, down 48.8% from $26.307 million to $13.459 million.
- The creation of Crown Research Institute Core Funding, for which a total of $215.145 million has been allocated (Treasury 2011c: 271-272).

In 2010/11 Vote S&I was restructured to provide simplicity and transparency with a focus on economic drivers and research investment to achieve science priorities (Treasury, 2011e: 125). Below we discuss three of the more significant changes. These differences do not reflect a significant change in the amount of funding, but instead a major shift in the way in which funding is allocated.[67] The implications of these are discussed below.

(a) Changes to the size of Departmental Output Expenses

An increase in Vote S&I budgeted departmental output expenses, up 27.7% from $28.123 million in 2010/2011 to $35.922 million in 2011/2012 (Treasury 2011c: 271), is significant. These expenses fall under three output classes: Strategic Leadership in the Science and Innovation Sector ($14.930 million), Science and Innovation Contract Management ($20.092 million) and Cross Agency Research ($900 thousand). These have been created to reflect the new role and scope of the work that MSI will complete (Treasury, 2011e: 111). Of particular interest is the Strategic Leadership in the Science and Innovation Sector output expense, which is limited to policy advice, ministerial services and leadership of the science and innovation sector (Treasury, 2011c: 271). This investment in the future of science is important for all key stakeholders, and therefore demands the highest-level of transparency across the whole science system. For example, in terms of process (i.e. how strategic leadership and policy is developed and ministerial services are provided), outputs (i.e. what policy advice is delivered, to whom it is delivered and what level of assurance is provided) and outcomes (i.e. how this investment has led to improvements in well-being).

67 As an example, while the funding for Environmental Research appears to have decreased by 52.3% between 2010/2011 and 2011/2012, it has instead largely been recategorised and remained the same overall. From 2009/2010, the Vote was restructured and some Environmental Research funds were recategorised into Science Collections and Infrastructure (databases and collections) and Hazards and Infrastructure Research. From 20010/11, some Environmental Research funds were moved into CRI core funding, primarily for Landcare Research and NIWA. This was limited to existing research contracts held at the time by those organisations (Liz Prendergast, MSI, personal correspondence, 16 January 2012).

(b) Changes to the Crown Research Institutes funding process

A significant change to the model of allocating funding has been the move from funding specific research areas to the creation of Crown Research Institute Core Funding. Greater stability of funding through core purpose funding was a key recommendation of the 2010 CRI Taskforce. In making this recommendation, the Taskforce aimed to lower the level of contestable and 'at risk' funding, which it felt rendered CRIs vulnerable as businesses, created uncertainty and undermined their ability to act strategically (CRIT, 2010: 8).[68]

FRST led the process whereby contestable funds were moved into core funding, and CRIs were allocated differing levels of funding. The allocations were decided after mapping existing long-term committed funds allocated to CRIs to support or develop critical national research capabilities (CEGIC, 2010). Further, there was a reallocation of a proportion of contestable contracts in Vote RS&T that were awarded to CRIs on an ongoing basis (ibid.). It was recommended to Cabinet that $215 million of the existing Vote RS&T be reallocated to CRI core funding (ibid.), and this was adopted in the 2011/2012 Budget (Treasury, 2011c: 271). This figure equates to 27.8% of the overall Vote, and it was proposed that around 60% ($447 million) of the Vote remain invested through open contest (CEGIC, 2010). The reallocation necessary to create core funding saw $164 million moved from committed long-term contracts already awarded to CRIs and an additional $51 million from the contestable, open-access funding pool from contracts awarded to CRIs on an ongoing basis (ibid.).

In reallocating funds, Cabinet was to consider research programmes that were: (i) aligned with areas of significant national importance; (ii) creating and maintaining capability that was critical to a CRI's core purpose and strategy; (iii) enduring (i.e. not with a short-term focus) (ibid.). The mapping process was also to take into consideration the nature of the research required by particular sectors and the CRIs' part in providing this research. As a result, CRIs primarily concerned with environmental research (namely Landcare Research, NIWA and GNS Science) were allocated a higher proportion of their funding in the form of core funding. The logic underpinning this was that the outcomes of environmental research are often long-term in nature and for the public good, with little or no commercial imperative (Liz Prendergast, MSI, personal correspondence, 17 January 2012). Consistent government support was seen as necessary to achieve outcomes and maintain research capability. Conversely, sectors that required shorter-term solutions (for example, high-value manufacturing) were allocated less CRI core funding (CEGIC, 2010).

Consideration was also given to the diversity of research organisations serving different sectors. More core funding was allocated to CRIs where the critical mass of capability resides primarily in one CRI, and less core funding was allocated where that capability is spread across several organisations and other research providers. For example, ESR and IRL received the least core funding proportionate to their overall funding due to the fact that they are not the dominant research providers in their fields; instead, there are many other research organisations and universities that contest contracts in these fields (Liz Prendergast, MSI, personal correspondence, 17 January 2012).

Figure 14 shows the overall amount of Vote RS&T funding allocated to each CRI in 2010/2011. Figure 15 shows the proposed amount of Vote RS&T CRI core funding to be allocated to each CRI.[69] Figure 16 shows the percentage of CRI core funding to CRI total funding for each CRI (2010-2011).

68 Recommendation 5 of the CRI Taskforce was that: 'The Government directly fund CRIs to deliver their core purpose in accordance with their strategy, as outlined in a Statement of Corporate Intent. The direct funding for delivering the core purpose should form a significant proportion of the CRIs' total Vote RS&T funding' (CRIT, 2010: 11).

69 The final totals for CRI core funding were to be confirmed in the 2011/2012 Budget process.

Figure 14: Vote RS&T – CRI Total Funding: Percentage of allocation to each CRI, 2010/11 (Indicative)
Source: Adapted from CEGIC, 2010

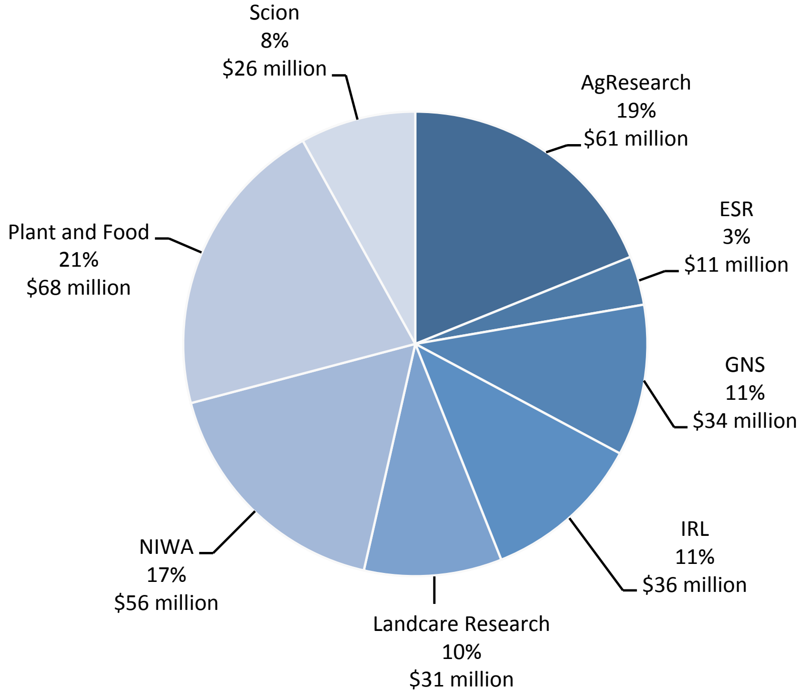


Figure 15: Vote RS&T – CRI Core Funding: Percentage of allocation to each CRI, 2010/11 (Indicative Proposed)
Source: Adapted from CEGIC, 2010

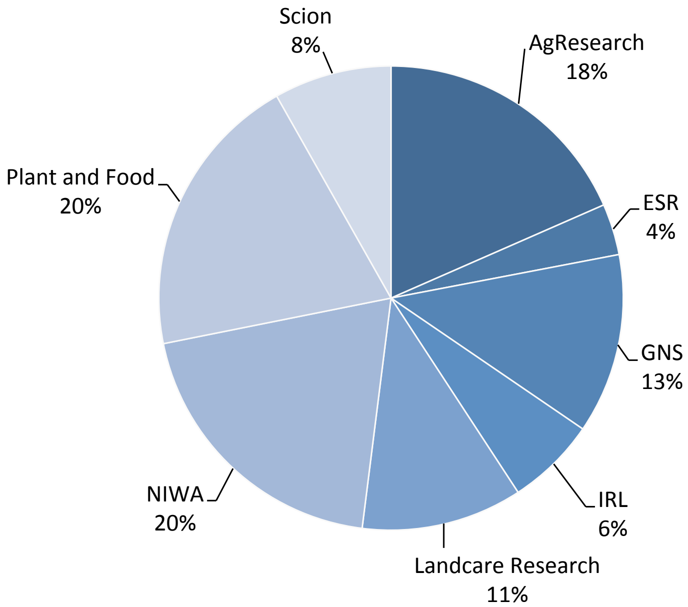


Figure 16: Vote RS&T – CRI Total Funding: Percentage of CRI Core Funding to CRI Total Funding for each CRI, 2010/11 (Indicative)
Source: Adapted from CEGIC, 2010

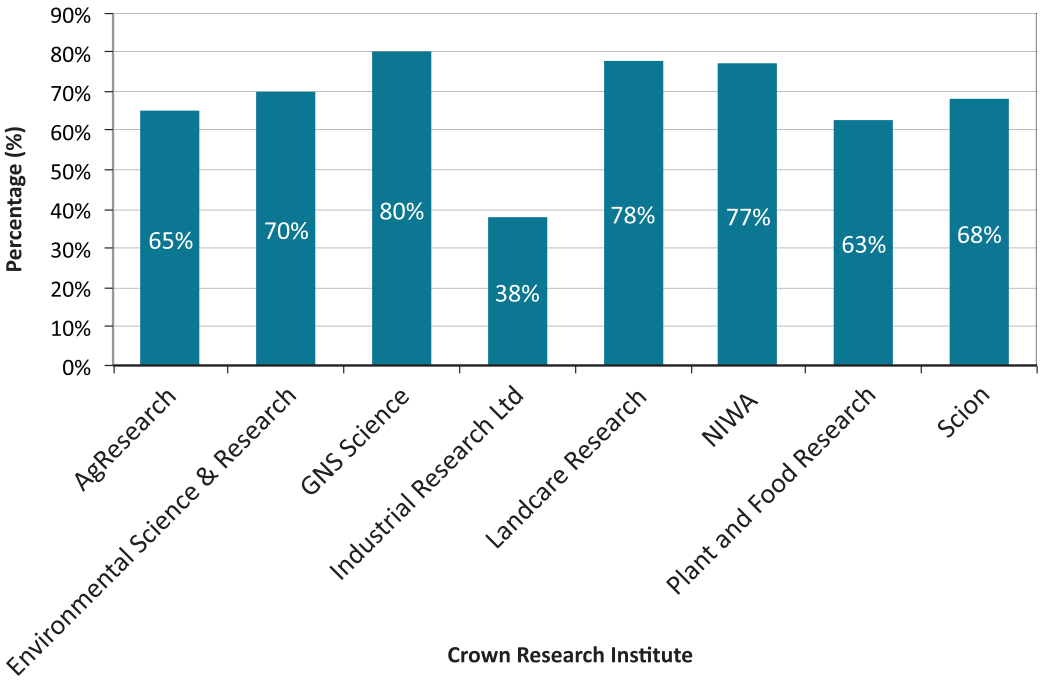


Figure 14 shows the relatively high level of core funding for CRIs, with the exception of Industrial Research Limited (38%). Given the commercial nature of four of the CRIs: AgResearch, Industrial Research Ltd, Plant and Food Research and Scion, we would expect the percentage of core to total funding to reflect a desire to create a commercial market for research; one that would invite business to move into the research area to solve specific commercial problems. For this reason a target percentage of below 45% seems more useful for commercially orientated CRIs in the short term. The current high percentages in effect create a monopoly of research for commercial purposes, preventing other research entries or public/private partnerships forming, other than through these four CRIs. This cannot be good for our agricultural based economy.

In contrast, the four CRIs that provide core capability for New Zealand to inform public policy; Environmental Science and Research, GNS Science, Landcare Research and NIWA, could reasonably be expected to receive about 75% of their funding from core funding. Because less of their research will lead to commercial outcomes they are not as well placed to attract parties incentivised by potential profits should research prove lucrative. Given this background, and the fact New Zealand needs this in-house capability, these non-commercial CRIs need more stability to build the capacity in terms of data, infrastructure and experience.

Given the different nature of the CRIs mentioned above, it seems likely that these will increasingly be seen as two separate types of CRIs. Further, over time we may see this evolve to two commercial CRIs (one being a biological industry CRI – a combination of AgResearch, Plant and Food Research and Scion, and another being a HVMSS CRI – Industrial Research Ltd) and one non-commercial CRI (that deals with New Zealand's unique oceans, air, water, soil and geology – as these capabilities are likely to become more integrated overtime). There clearly exists real opportunities to work with the emerging model, but also to take it further so that funds are allocated to suit the goals and the characteristics underlying those goals, so that New Zealand has a dynamic and productive research environment. See further discussion in Section 10.2.

These percentages are only intended as examples, and determining the appropriate level of non-contestable funding may benefit from a deeper understanding of successful overseas models. In our research we were interested to find that Singapore's A*Star Biomedical Research Council (BMRC) has recently established a contestable Industry Alignment Fund (IAF) of S$600 million, resulting in 30% of the Council's funds now being contestable. Prior to this, all funding went directly to individual institutes as non-contestable funding (see Appendix 4). An understanding of what drove the changes towards contestable funding in the context of Singapore, a country that has many parallels with New Zealand, is an area that could be explored in determining the appropriate level of contestable to non-contestable funding. However, the final percentage should be determined by a set of agreed upon criteria with primary consideration given to the purpose of the investment and what form of funding is most conducive to achieving that purpose.

If the investment seeks to generate commercial benefits, there may be advantages in opening up this research to other research providers and lowering the level of core funding for CRIs. Other obstacles may also need to be addressed if new players are unable or unwilling to enter the market, and other initiatives such as R&D tax incentives or grants may need to sit alongside changes to the level of non-contestable funding. It is necessary to foster an environment conducive to commercial development to ensure wider buy-in, ensuring clear linkages between investment and long-term profitability are highlighted to ensure a range of players are active in the system and working towards optimal outcomes. Conversely, if the investment is to encourage 'public good science', there may not be sufficient incentives for organisations outside the government-funded system to invest given the lack of commercial opportunities, and the nature of this research may mean it is best conducted within a government-funded environment such as a CRI. The need for stability of funding so to ensure the research is undertaken is likely to be more important than attempts to drive competition, and indeed contestability may not be desirable. In these situations, a higher level of non-contestable funding is desirable.

The move away from contestable funding towards core funding, announced in 2010, will make it increasingly difficult to gain a high-level view of how the government investment in science is spent. Further, reporting on each of the six priority areas is a useful metric for benchmarking the level of funding and the process by which contracts are allocated over time, and for measuring outcomes. Given that CRI core funding is not divided into the six priority investment areas, this important metric has been lost.[70] The difficulties of benchmarking output expenses over time is apparent in Figures 17 to 20, see pages 65–69.

Currently CRIs are not under any obligation to disclose the amount of funding they receive from private contracts; which includes contracts with individual government agencies and departments. Reporting and accountability for these other government agencies is a matter of contractual agreement under the CRIs' agreement with the department/agency (Peter Scott, personal communication, 25 January 2012). The main line of accountability and reporting is to the Minister of S&I and Minister of Finance. With less clarity over how funds are spent, tracking progress and outcomes over time has the potential to become increasingly difficult. MSI will need to work hard to provide quality reporting on changes to the level of funding and the funding process to ensure any changes are transparent and easily accessible to interested stakeholders.

While the amount of funding is subject to change each year, and indeed is likely to change, it is critical that the mechanism by which funding is allocated remains stable. The method for allocating funding has changed numerous times in New Zealand, with shifts between highly contestable funding models and stable core funding. It would seem that the recent change to how funding is allocated, and the move away from funding specific areas in favour of the creation of the CRI Core Capability Fund[71] is a move back towards the 'black bucket' model of funding, in which large amounts of funding are allocated with

70 While the areas in which some CRIs will use their core funding are clear, there is a crossover for some of the Institutes. For example, research conducted by GNS Science may fall under the Environment, Hazards and Infrastructure, or Energy research areas.

71 'The Crown Research Institute Core Funding output expense was created as a result of transfers from Biological Industries Research, Energy and Minerals Research, Environmental Research, Hazards and Infrastructure Research, Health and Society Research, High Value Manufacturing and Service Research, CRI Capability Fund, and Science Collections and Infrastructure. This new output ensures there are critical national research capabilities within CRIs to provide benefit to New Zealand in line with Government priorities' (Treasury, 2011e: 118).

limited direction. However, with the CRI Taskforce strongly recommending this move and the fact that it has been largely welcomed by the science community, it is hoped that this model of funding will prove successful and will be implemented as a long-term funding mechanism.

With CRIs returning back to core funding, and boards being required to improve reporting to the Minister of Science and Innovation,[72] there needs to be a new reporting framework to manage the risks and opportunities created from recent changes. The reporting framework must be comprehensive, timely, relevant and transparent so that the linkages between (i) MSI's core purpose, (ii) the CRI's core purposes, (iii) the CRI's Research Agenda, and (iv) the funding sources show clear cause and effect. Appendix 8 outlines the interlinking relationship between these four, as it is these key relationships that should drive reporting. Transparency is vital to developing public trust in science, hence it is critical that New Zealanders know what government-funded science funds are being allocated and how those funds are being spent. A reporting framework must therefore enable MSI to report on these linkages and make them apparent to ministers, managers, policy analysts and the general public.

Critical success factors for an optimal model to allocate government investment in science should include the following:

- The funding process is transparent;
- The application process is constant;
- The research agenda is clear and concise;
- The reporting framework is comprehensive, timely, relevant and transparent;
- A register of funds is easily discoverable;
- Funding applications are straightforward and not overly onerous or complex;
- Allocation decisions are transparent, non-partisan, and complaint mechanisms are in place; While the areas in which some CRIs will use their core funding are clear, there is a crossover for some of the Institutes. For example, research conducted by GNS Science may fall under the Environment, Hazards and Infrastructure, or Energy research areas.
- Members of the science community understand the application process
- Members of the science community recognise the constrained and limited nature of funding and readily invest in 'frugal science'.[73]

Ensuring the science system is based on a clear vision of what a successful mechanism for allocating funding looks like, and that there are critical success factors and performance indicators against which the model can be measured, will be essential if New Zealand is to maximise its investment in science.

(c) 2010/11 Changes to the Appropriation Structure

In the attempt to provide more simplicity and transparency within the system a number of new appropriations were created in 2010/11. Table 5 overleaf builds on Figure 11, which shows the total breakdown of funding within the Vote in 2011/12. The following table shows the new appropriations created within Vote RS&T in 2010/11 and highlights where funds were moved between 2009/10 and 2010/11. In cases where the name of an appropriation did not change it is not listed in the table. For example, the Environmental Research appropriation is not included in the table as it continues under the same name, even though it experienced significant changes as a result of the establishment of the new appropriations (see Column 2 in Table 5, and Figure 19). Please note that new appropriations created in 2011/12, such as CRI Core Funding, are not listed in the table.

72 In 2010, the CRI Taskforce noted that multiple lines of accountability 'dilute the CRIs' sense of purpose and direction. 'Each CRI is accountable to the shareholding Ministers, directly and through the Foundation for Research, Science and Technology (the Foundation), the Crown Ownership Monitoring Unit in Treasury (COMU), and the Ministry of Research, Science and Technology (MoRST). Each agency has its own perspective and requirements'. Furthermore, '[r]elevant legislation and documents such as the Owner's Expectation Manual for CRIs (CCMAU) define the board's roles and responsibilities. The Treasury's Crown Ownership Monitoring Unit (COMU), formerly CCMAU, assesses board performance on behalf of the shareholding Ministers. We believe that these arrangements should be changed to strengthen the link between the board of a CRI and overall CRI performance.' (CRIT, 2010: 7, 38).

73 Professor George Whitesides of Harvard University writes of the emergence of cost-conscious science – 'frugal science, designed to generate knowledge (and technology based on knowledge) with cost as an integral part of the subject' (Whitesides, 2011; see also Section 9.3, Question 18).

Table 5: Vote S&I: Changes to the Appropriation Structure, 2010/11
Source: Treasury, 2010b: 152–184, 2011c: 271–273

New: Appropriations Established in 2010/11	**Previous:** Appropriations from which expenses were *transferred*	**Purpose:** The new appropriation will focus on the following activities:	2009/10 (Restated) $000	2010/11 (Estimated Actual) $000	2011/12 (Budgeted) $000
High Value Manufacturing and Services Research (Priority Investment Area 1)	• New Economy Research Fund • Research for Industry • Pre-Seed Accelerator Fund • Technology New Zealand	• Develop new technologies, novel materials, and new products, processes and services for the manufacturing and technology sectors	111,857	141,011	157,204
Biological Industries Research (Priority Investment Area 2)	• Environmental Research • Pre-Seed Accelerator Fund • Technology New Zealand • Research for industry • New economy research fund	• Improve productivity, sustainability and competitiveness of New Zealand's agriculture, horticulture, forestry and fisheries industries • Develop new technologies for economic diversification based on the strengths of New Zealand's primary industries and increased export revenue from food and biological based products	178,212	167,962	104,819
Energy and Minerals Research (Priority Investment Area 3)	• Research for Industry • Sustainable Energy Research development	• Develop potential new sustainable low carbon energy technologies • Improve energy management and the understanding of current energy resources, and future energy needs • Increase wealth from mineral resources • Improve the identification and extraction of mineral resources	25,202	26,351	11,997
Hazards and Infrastructure Research (Priority Investment Area 4)	• Environmental Research • Research for Industry	• Get an effective understanding and management of risks and hazards with the potential to have a significant economic, social and environmental impacts to New Zealand • Improve the quality of New Zealand's urban, peri-urban and rural settlements	23,709	26,307	13,459
Health and Society Research (Priority Investment Area 6)	• Environmental Research • Health Research • Research for Industry • Social Research • Support for Primary Health Research • Supporting promising individuals	• Improve the health status of New Zealanders • Target health research and the Partnership Programme response to specific health sector issues • Improve health services • Support research in social, economic, and primary health	90,535	86,948	83,694

New: Appropriations Established in 2010/11	**Previous:** Appropriations from which expenses were *transferred*	**Purpose:** The new appropriation will focus on the following activities:	2009/10 (Restated) $000	2010/11 (Estimated Actual) $000	2011/12 (Budgeted) $000
International Relationships Fund	• International Science and Technology linkages • New Economy Research Fund • International Investment Opportunities Fund	• Influencing regional or international research • Science and technology-linked activities that advance New Zealand's national interests • Promoting international recognition for New Zealand as a centre for innovation • Co-invest with international partners in research programmes of joint interest that will involve researchers based in New Zealand • Increase the level of funding/ scientific skills/ and technological capabilities that New Zealand is able to source from other countries • Enable New Zealand researchers to respond to opportunities for international collaboration that arise out-of-cycle • Assist world-leading researchers to establish research programmes in New Zealand in key areas of strategic interest to New Zealand	13,764	13, 978	9,821
Fellowship for Excellence	• Rutherford Foundation • Supporting Promising Individuals	• Early-career researcher grants to support post graduate research • Fellowship and scholarships are awarded to top talent and to build capability in the research, science and technology workforce • Scholarships are awarded for United States of America based post graduate research • Supporting the development of human resources in research, science and technology	7,454	9,147	11,770
The Science Collections and Infrastructure	• Environmental Research • Research for Industries	• The national seed, plant, and other science collections research databases • Significant infrastructure being held in stasis that is to be retained and maintained • Management of the availability and suitability for access and use when required	22,379	22, 426	4,760
Vision Mātauranga Capability Fund	• Māori Knowledge and Development Fund • Supporting Promising Individuals	• Supporting development of researchers to undertake work that relates to the four themes of Vision Mātauranga; indigenous innovation, environmental sustainability, health and social well being, and exploring indigenous knowledge	5,967	5,555	5,967

This restructure has led to a number of large funding buckets, such of the Health and Society Research Fund (Priority Investment Area 6), which covers a wide range of areas and initiatives. Therefore, a tight reporting framework is necessary to ensures the right science (research agenda) – and the right scientists and infrastructure (inputs) – are funded through the most effective mechanisms (processes), benefiting and improving the well-being of the right people (desired outputs and outcomes) and resulting in lessons being learnt and improvements made where necessary.

(iii) Four research areas related to sustainable development

The following sections consider four research areas that are likely to be critically important in terms of informing public policy on sustainable development in the medium-to-long-term: (i) Social research; (ii) Māori knowledge and development research; (iii) Environmental research, and (iv) Health research. Failure to invest sufficient resources in these areas may restrict our science system from solving long-term issues. Therefore, benchmarking within these areas is critical to ensuring funding is sufficient and accurately depicted; constant reshuffles should not obscure the real level of funding in these core areas.

(a) Social research

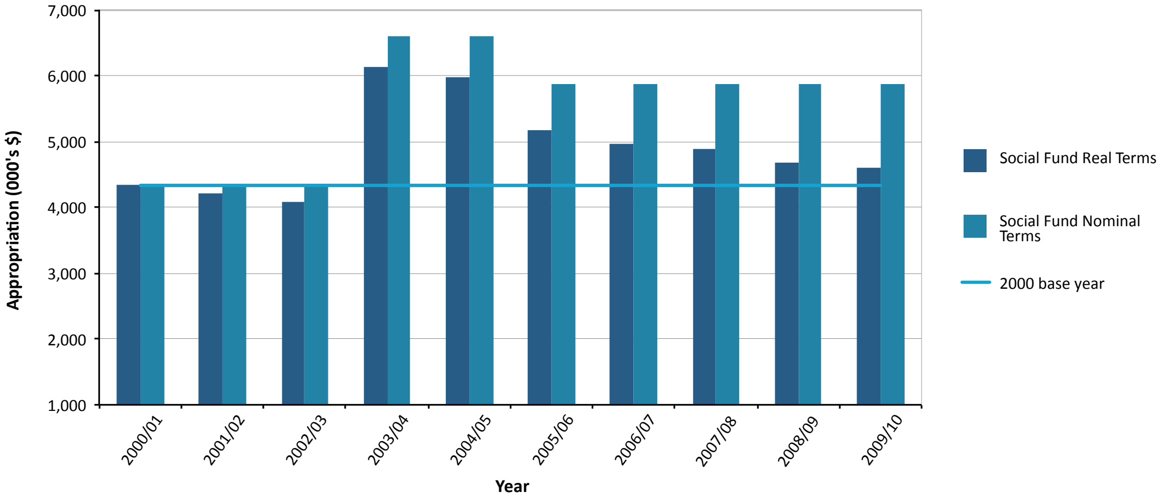
Social research is a large and complex area, but one that is critically important and an area in which New Zealand has great strength. For example, New Zealand is well-known internationally for its expertise in longitudinal studies (see Question 7, Section 9). Universities undertake the majority of social research in New Zealand,[74] using funding from the Performance Based Research Fund. Social research funding is also available through the Health and Society Research Fund. Figure 17 outlines the level of government investment since 2000/01.[75]

Much of the social research that is carried out under contract is purchased by the government, and this compounds the issues regarding social science capability. In these instances, social research is often funded on a marginal cost basis (SSRG, 2005: 31), i.e. only covering the cost of producing the research in question. This produces a faulty market signal and provides little incentive for institutions to invest in increasing their capability for social research by means such as strengthened career opportunities (ibid.). Within the last five years, two reviews of the sector have recommended that such marginal funding be increased to full-cost funding when government ministries and agencies are contracting social research (ibid.).

74 To learn more see Working Paper 2011/17: *New Zealand Universities: Research activities, commercialisation and international benchmarking* (SFI, 2011d).

75 The Health and Society Research Fund amounted to $86.948 million in 2010/11 (see Section 7.3.4: iv) and included monies for 'research and research applications to improve the health and social well-being of New Zealanders' (Treasury, 2011c: 272). Prior to 2010/11 appropriations for social research were made through the Vote RS&T Social Research Fund ($5.860 million in 2009/10) (Treasury, 2010a: 280).

Figure 17: Vote RS&T and Vote S&I – Social Research Output Class: Total Appropriations, 2000/01–2009/10
Source: Reserve Bank of New Zealand, n.d.;[76] Treasury, 2000: 327; 2001: 15; 2002: 16; 2003: 1079; 2004: 1107; 2005: 1125; 2006: 1007; 2007: 1033–34; 2008: 260; 2009b: 284



Note: In 2010/11 the Social Research Fund was transferred into the newly created Health and Society Research Fund. The change to the fund resulted in an expansion of investment in health research to include monies for the 'social well-being of New Zealanders'. Therefore, data for 2010/11 is not directly comparable with that of previous years (Treasury, 2010a: 280; 2011a: 272).

(b) Māori research

The Māori concept of research, science and technology, or Mātauranga Māori, represents an alternative paradigm to the Western model. Mātauranga Māori can be defined as follows:

> In a traditional context [it] means the knowledge, comprehension or understanding of everything visible or invisible that exists across the universe (ie: Aorangi, sometimes referred to as Rangi and Papa). This meaning is related to the modern context as Māori research, science and technology. (Mohi, 1993 in Williams, 1997: 15)

The Kaumatua Committee, charged with advising the Minister for Crown Research Institutes in 1991, defined three core principles underpinning the concept of Mātauranga Māori: (i) Māori research, science and technology exists and is a national treasure; (ii) Mātauranga Māori contributes in a vital way to the status of Māori as a culture; and (iii) Mātauranga Māori should be organised so that Māori, as tribally based social, economic and scientific entities, can participate as partners in the science system. In addition, the Institute has identified several guiding principles underpinning the three broad areas of Māori research: decolonising research, cross-cultural research and kaupapa Māori research.[77] These principles are linked to the principles of the Treaty of Waitangi and it can be argued that Mātauranga Māori has taonga status, imparting an obligation on both Māori and the Crown to protect, develop and capitalise Mātauranga Māori (Williams, 1997: 15).

76 Inflation-adjusted values calculated using the Reserve Bank of New Zealand formula (see Reserve Bank of New Zealand, n.d.). Comparison dates are second-quarter 2000 with the second quarter of each relevant budget year.

77 The Institute identified a number of guiding principles for Māori-focused research, which are grouped under the following headings below:

a. Decolonising research that 1) redistributes power to those who are marginalised; 2) privileges Māori knowledge; 3) is varied in its approach; and 4) is performative;

b. Cross-cultural research that 5) serves the communities in which the research is conducted; 6) respects the struggles of the past, the tensions in the present and the potential challenges of the future; 7) involves learning about difference; and 8) redistributes power to make space for those who are marginalised; and

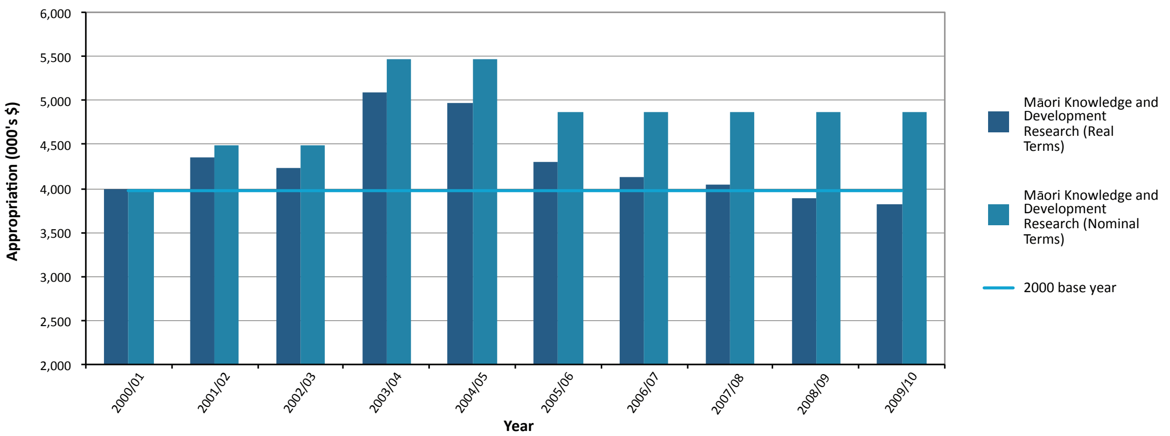
c. Kaupapa Māori research reflecting: 9) rangatiratanga (deeply respects the knowledge and authority of Māori scholars); 10) whakapapa (utilises Māori epistemology); 11) pukengatanga (contributes to the revitalisation of Māori scholarship); and 12) kotahitanga (creates a safe space).

For more information, see the Institute's Report 7: *Exploring the Shared Goals of Māori: Working towards a National Sustainable Development Strategy* (SFI, 2010b: 61).

Māori research funding[78] is available through the Vision Mātauranga Capability Fund, which totalled $5.555 million, or 0.71% of Vote S&I, in 2010/11 (Treasury, 2011c: 272).[79] The Vision Mātauranga Capability Fund includes monies for 'the development of skilled people and organisations undertaking research that supports the four themes of Vision Mātauranga, indigenous innovation, environmental sustainability, health and social well being, and exploring indigenous knowledge' (ibid.: 272). Prior to 2010/11, appropriations for Māori research were made through the Vote RS&T Māori Knowledge and Development Output Class. In 2009/10 these totalled $4.867 million, or 0.65% of Vote RS&T[80] (Treasury, 2009a: 145, 168). Figure 18 outlines the level of investment since 2000/01.

Figure 18: Vote RS&T and Vote S&I – Māori Knowledge and Development Research Output Class: Total Appropriations, 2000/01–2009/10

Source: Reserve Bank of New Zealand, n.d.; Treasury, 2000: 327; 2001: 14; 2002: 15; 2003: 1079; 2004: 1107; 2005: 1125; 2006: 1006; 2007: 1026–27; 2008: 259; 2009b: 283



Note: In 2010/11 the Māori Knowledge and Development Research Fund was renamed Vision Mātauranga Capability Fund. This resulted in a change in funding aimed at 'obtaining public good science and technology that unlocks the innovation potential of Māori knowledge' to include monies for the 'development of skilled people and organisations undertaking research that supports the four themes of Vision Mātauranga; indigenous innovation, environmental sustainability, health and social well being, and exploring indigenous knowledge'. Therefore, data for 2010/11 is not directly comparable with that of previous years (Treasury, 2010a: 280; 2011c: 272).

Māori research has the ability to facilitate self-determination for its participants by drawing its epistemological framework from the cultural aspirations, understandings and practices of Māori people (Bishop, 1998: 199). This provides the potential to create very different outcomes for New Zealand's science system, which in recent times has been heavily weighted toward a utilitarian point of view (Cartner & Bollinger, 1997: 787). Te Puni Kōkiri published *The Māori Economy, Science and Innovation* in May 2011, highlighting where benefits might lie if better engagement and alignment between Māori and the nation's science and innovation sector was to be achieved. It provides evidence that 'growth opportunities' for both the Māori and New Zealand economies are available through 'investment and effort in science and innovation' (TPK, 2011: 4). Then Minister of Research, Science, and Technology, Wayne Mapp, welcomed the publication, stating:

> [T]his report is a timely economic forecast of New Zealand's future over the next 50 years if investment in science and innovation is better aligned to the needs of the Māori economy …
>
> … work under way across the Ministry of Science and Innovation (MSI) and the Ministry's predecessor agencies over the past three years has started to unlock the innovation potential of Māori knowledge, resources and people. (Mapp, 2011b)

78 For the purposes of this report, Māori research focuses on issues, questions and challenges determined by Māori to be important (MoRST, 2006b).

79 Vote S&I 2010/11 was $787,680,000 (budgeted); Vision Mātauranga Capability Fund was $5,555,000 (budgeted) (Treasury 2011c: 272–273). Vision Mātauranga Capability Fund comprised 0.71% of Vote S&I 2011.

80 Vote RS&T 2009/10 was $745,063,000 (budgeted) (Treasury 2009a: 145); Māori Knowledge and Development Output Class was $4,867,000 (budgeted) (Treasury 2009a: 168).

Mapp also stated that the reform of the science and innovation system has resulted in increased responsiveness from CRIs to the needs of Māori, and that MSI has worked with iwi to deliver ‘robust iwi-led R&D strategies’ (MSI, 2011f). While Te Puni Kōkiri’s report quantifies the value of the Māori economy at $36 billion, Federation of Māori Authorities chair Traci Houpapa has commented that the research highlights issues of greater significance such as the role of science and innovation in allowing the Māori economy to capitalise on the ‘gigantic strides it is making’ (FoMA, 2011). It seems an opportunity exists here for the Māori economy to help set the research agenda, given its large size and significant growth rate.

(c) Environmental research

Broadly, environmental research studies should provide new knowledge needed to understand environmental problems and to solve them (Sandhu, 1997). Environmental research involving robust data collection and processing, alongside expertise and infrastructure capacity, is critical to ensuring national resources are managed in the long-term for New Zealand. Impact assessments, using this data, are becoming an increasingly important instrument within environmental legislation, as evidenced in the recent Exclusive Economic Zone and Continental Shelf (Environmental Effects) Bill and the existing Resource Management Act 1991.

Two important emerging areas of significant importance to New Zealand that demonstrate the importance of maintaining strong environmental research capacity, concern Antarctica and New Zealand’s Continental Shelf (including the Exclusive Economic Zone[81] (EEZ) and Antarctica Treaty 1959.[82] A combination of globalization, climate change and geopolitics will significantly impact the nature of governance concerning these resources. In 2007, with piecemeal legislation in place and no overarching environmental management regime for New Zealand's Exclusive Economic Zone and continental shelf, the Organisation for Economic Cooperation and Development (OECD) recommended New Zealand ‘finalise and implement ocean policy and pursue the further expansion of marine reserves’ (OECD, 2007b: 10).

The growing importance of this issue was further highlighted by the visit of Lawson W. Brigham, professor of Geography and Arctic Policy at the University of Alaska, to Australia to share his expertise on the changing Maritime environment in the Arctic (Brigham, University of Alaska, personal communication, 9 July 2010). This suggests the seabed and subsoil in the Continental Shelf and the Antarctica Treaty demands far more attention than it has in the past in order to shape New Zealand public policy. Furthermore, as outlined in our submission[83] to the Local Government and Environment Committee, it is critical that high-level principles are embedded in legislation, such as a sustainable development approach, precautionary approach, risk management and strategic policy development.

The amount of money allocated to the Environment Fund dropped by over $27.3 million between Vote RS&T 2009/10 and Vote S&I 2010/11 (Treasury, 2010a: 279; 2011c: 271). The Budget appropriation for 2011/12 shows a further decrease of over $38.6 million in money allocated to the Environment Fund (Treasury, 2011c: 271). Figure 19 outlines the level of investment from 2000/01 to 2010/11.

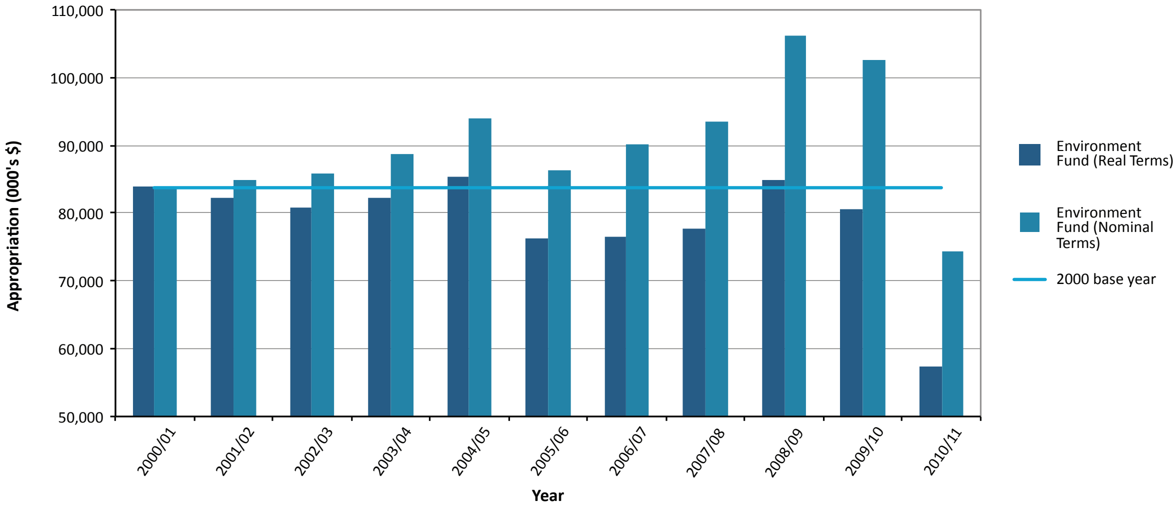
81 In 2011, the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Bill proposed an environmental management regime for New Zealand's EEZ and continental shelf. Activities covered by the Bill include seabed mining, some aspects of petroleum activities, energy generation, carbon capture and storage, and marine farming. The purpose of the Bill as stated in clause 10 is ‘to achieve a balance between the protection of the environment and economic development in relation to activities in the exclusive economic zone and on the continental shelf.’

82 The Antarctic Treaty came into existence in 1959. The Protocol on Environmental Protection to the Antarctic Treaty (Environmental Protocol or Madrid Protocol) was agreed in 1991 and came into force in 1998, once it had been ratified by all 26 (now 28) Antarctic Treaty Consultative Parties (ATCPs). The Environmental Protocol: (i) commits the Parties to the "comprehensive protection of the Antarctic environment"; (ii) designates Antarctica as a "natural reserve, devoted to peace and science"; (iii) sets out principles for environmental protection; (iv) bans all commercial mineral resource activity; and (v) requires the Environmental Impact Assessment (EIA) of all activities before they are allowed to go ahead. Further, A strategy for New Zealand Science in Antarctica and the Southern Ocean was published in 2004 (Antarctica New Zealand, n.d.).

83 More information on this Bill and issues regarding New Zealand’s EEZ can be found in the Institute’s written submission (SFI, 2012b)

Figure 19: Vote RS&T and Vote S&I – Environmental Research Output Class: Total Appropriations, 2000/01–2010/11

Source: Reserve Bank of New Zealand, n.d.; Treasury, 2000: 327; 2001: 15; 2002: 16; 2003: 1079; 2004: 1107; 2005: 1125; 2006: 1006; 2007: 1013; 2008: 259; 2009b: 283; 2010a: 279; 2011c: 271



Note: The major drop in funding to the Environment Fund from 2010/2011 is a result of transfers out to the newly established CRI Core Funding pool, to which funds from Biological Industries Research, Hazards and Infrastructure Research, Hazards and Society Research, and Science Collections and Infrastructure were also transferred (Treasury, 2011e: 118). Further explanation for the drop can be found in Section 7.3.4 where the introduction of core funding for CRIs is discussed. CRIs receiving funding from the Environment Fund were identified as those requiring the highest level of core funding, hence the large change.

MoRST's 2010 report, *Igniting Potential*, highlights the environment as a priority for science and innovation investment. It states:

> … the Government recognises that funding is necessary to support other areas and that improvement in areas such as environmental management can provide significant economic benefit, even if they do not always produce direct commercial returns. Firms can be affected by problems relating to health, social services, environmental degradation and hazards management. Much of New Zealand's wealth is built on natural resources and it is important to perform the research needed to maintain them. (MoRST, 2010a: 15)

The report further notes that 'The Environment outcome area will provide knowledge that helps New Zealand's economy develop within environmental limits' and environmental science investment will encompass 'work on land and freshwater resources, terrestrial ecosystems, climate and atmosphere, marine ecosystems and Antarctic' (MoRST, 2010a: 17).

In 2004 the Parliamentary Commissioner for the Environment, Dr J. Morgan Williams, released the report *Missing Links: Connecting science with environmental policy*. The report examines 'how the links between science, policy-making and the public interest can be strengthened to engender confidence in the way policies are developed and what they will achieve' (PCE, 2004: 8). Particular focus is placed on the need for greater interaction across disciplines to address complicated environmental issues effectively, and it is noted that a combination of specific scientific disciplines, worldviews and stakeholder interests often leads to only partial solutions (ibid.). The report makes four recommendations aimed at improving integration and processes where environmental policy is concerned,[84] the first of which is the publication of a regular report on changes in the state of New Zealand's environment. This issue has recently attracted renewed interest, and was taken up by the current Parliamentary Commissioner for the Environment, Dr Jan Wright. In April

84 The four recommendations are: (I) the Minister for the Environment establishes a process whereby changes in the state of New Zealand's environment are identifies and reported on at regular intervals (at least every five years); (ii) the Minister of Research, Science and Technology establishes a process to undertake regular and systematic reviews of central government environmental agencies and regional councils to assess the effectiveness of their scientific and technology capabilities for environmental policy-making; (iii) environmental policy makers consider developing strategic, long-term, formal alliances with science providers to encourage scientists input through the policy-cycle, and (iv) environmental policy makers explore options for improving accountability and communication links between scientists, policy makers, and the public (PCE, 2004: 85-86).

2010 Dr Wright published the report *How Clean is New Zealand? Measuring and reporting on the health of our environment*, and in her overview she stated:

> I was surprised to learn that we have no legislated process for regular national reporting on our environment and that we are the only country in the OECD who does not. In order to improve state of the environment reporting in New Zealand I have made three recommendations to the Minister for the Environment. These are that he should:
>
> - draft legislation that assigns roles and responsibilities for regular reporting on the state of the environment to different public entities;
> - ensure that indicators for assessing the state of the environment are reviewed, the underlying environmental statistics are significantly improved, and primary data is made publicly available on the internet;
> - assign the responsibility for state of the environment reporting to an agency or agencies that can provide the required independence and technical capacity. (PCE, n.d.)

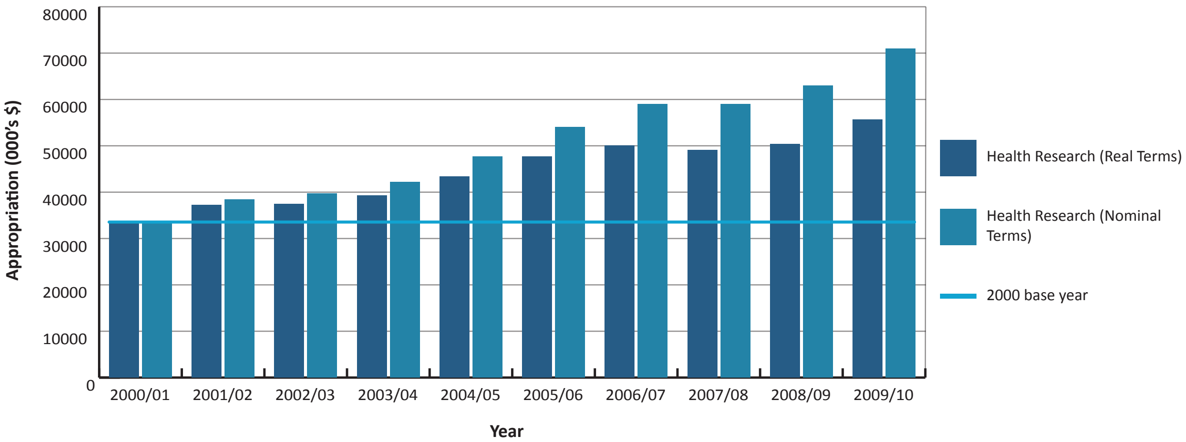
Four months after the publication of *How Clean is New Zealand*? the Environmental Reporting Bill was introduced into the parliamentary ballot. The Bill recommends the publication of a five-yearly state of the environment report using information gathered by local authorities and sequestered through changes to the Resource Management Act (RMA). In August 2011 the Ministry for the Environment released *Measuring Up: Environmental reporting*, a discussion document outlining the proposed system and asking for submissions. The document argues:

> Quality environmental information is as important to New Zealand's success as financial or economic information. Environmental information enables good decision-making and builds a reliable picture of how we are managing our natural capital. New Zealand's trade advantage lies in its worldwide reputation for quality products from a quality environment. (MfE, 2011a: 2).

(d) Health research

The Health Research Fund was designed to support public good science and technology that improves the health status of New Zealanders (Treasury, 2009a: 165). This fund places investment in health research at an important crossroads in the 'science for policy' and 'policy for science' interaction. As can be seen in Figure 20, investment in health research has been increasing since 2000. There are a number of reasons for this, but it is generally considered to be due to an increase in contestable funding. In its 2009 Budget the incoming National government announced that it would increase investment in Vote RS&T Health Research by $32 million over four years (MoRST, 2010a: 20). This was initiated by an $8 million increase to the Health Research Fund (from $62.955 million in 2008/09 to $70.955 million in 2009/10) (Treasury, 2009b: 283).

Figure 20: Vote RS&T and Vote S&I – Health Research Output Class: Total Appropriations, 2000/01–2009/10
Source: Reserve Bank of New Zealand, n.d.; Treasury, 2000: 327; 2001: 14; 2002: 15; 2003: 1079; 2004: 1107; 2005: 1125; 2006: 1006; 2007: 1013; 2008: 259; 2009b: 283.



Note: In 2009/10, the Health Research Fund was transferred into the Health Research and Society Research Fund, therefore, data from 2009/10 and beyond is not directly comparable with that of previous years.

Following restructuring of the Vote in 2010, appropriations previously allocated to the Health Research Fund were transferred to the Health and Society Research Fund. The Health and Society Research output class was created as a result of transfers from Environmental Research, Health Research, Research for Industry, Social Research, Support for Primary Health Research and from Supporting Promising Individuals (Treasury, 2011e: 128). The Health and Society Research Fund is therefore of even greater importance as a driver of policy as it has the potential to affect policy in a wide range of areas.

In the 2011/12 Vote, $83.694 million was allocated to the Health and Society Research Fund, a decrease from the $86.948 million budgeted for 2010/11 (Treasury, 2011c: 272). The government therefore still has a $20 million increase in funding to deliver if it is to fulfil its pledge of increasing investment in health research by $32 million by 2013.

MSI has appointed the Health Research Council (HRC) as the funding and investment agent for health aspects of the Health and Society Research Fund (MSI, 2011g). To add value the Council must manage its agenda carefully to produce genuine public good outcomes for New Zealanders by informing policy directions with sound research outputs.

There is a range of organisation types involved in health research alongside government institutions and funds; Independent Research Organisations (IROs), universities, private research institutions and commercial operations can all contribute, particularly if managed and aligned effectively, to advance the health and well-being of New Zealanders.

There is an important interaction between universities and IROs that generally operates under the radar but has the potential to deliver significant benefits to New Zealand. For example, Simon Robinson, a Wellington ear, nose and throat surgeon, together with emeritus Otago University professor Brian Robinson and University of Adelaide professor Peter-John Wormald, designed a sinus healing gel, that was sold in 2011 to the United States medical technology company Medtronic for several million dollars. MSI has invested more than $1 million in funding over five years into Otago University's research and development of the gel. The gel reduces post-surgery sinus scarring and could save the New Zealand health industry an estimated $10 million per year (Woodfield, 2011).

Research should be conducted that examines the effectiveness of IROs and how government could facilitate the interrelationships between fund managers, university researchers and IROs. Optimising these relationships will come from a greater understanding of how this interaction could be improved; what obstacles exist; whether research funds come too early or too late in the process; the extent to which private sector research infrastructure is underutilised; where there exists a role for government to provide a home for research infrastructure that could be managed centrally for the use of private independent institutes; how infrastructure could be better shared across organisations, and how best to support linkages between universities and businesses.

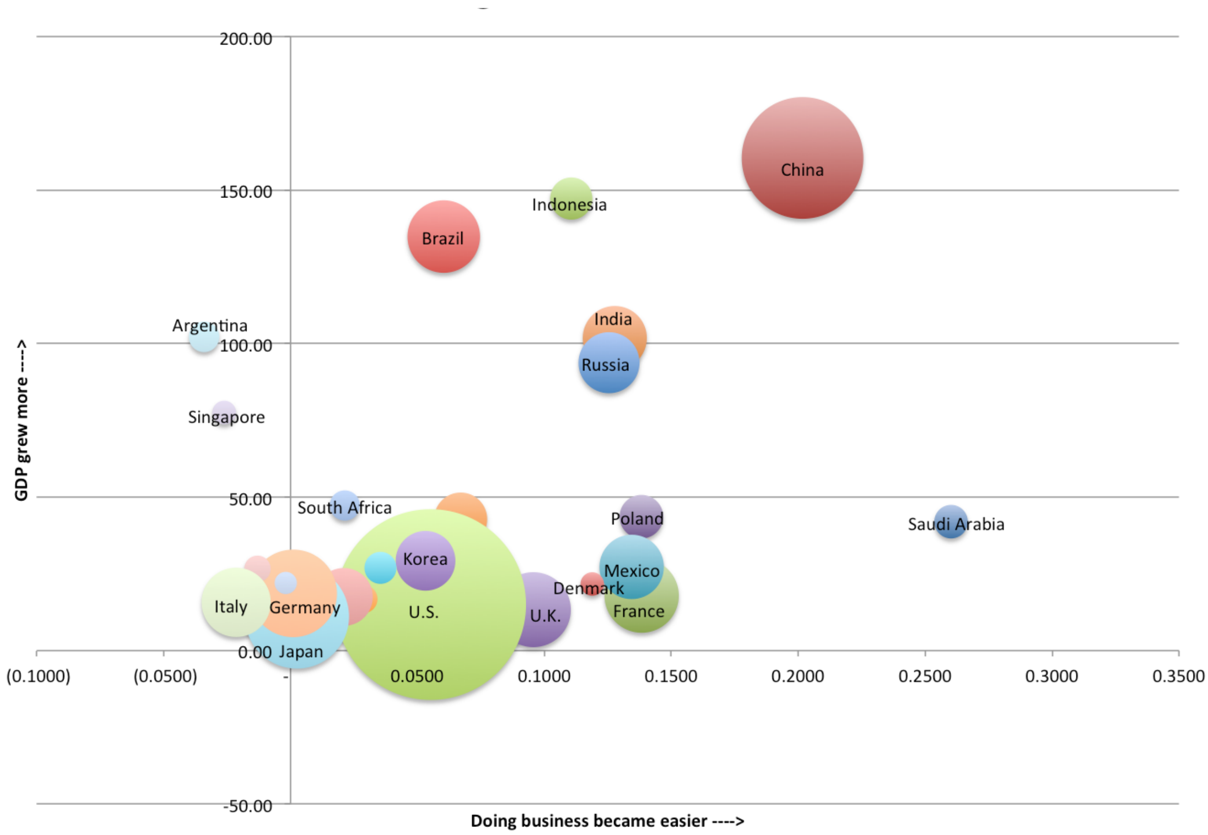
All four research areas discussed above indicate the need to develop better and more transparent processes for ensuring science informs policy. The importance of scientific research to inform policy is discussed in Question 6 in Section 9. See also Section 10.1, which explores the findings of Dr William Smith's research on science for policy.

7.3.5 Enabler 5: Regulatory Framework

There are a number of regulatory frameworks that operate within the science system. Most regulations are concerned with processes that must be followed or controls over what cannot be pursued. However, other forms of regulation can deliver financial benefits, such as taxation credits. Often regulation in itself is seen as an obstacle to economic growth, although this view looks increasingly flawed. It is the quality of regulation that is critical. Neil Gregory, a deputy director for indicators at the World Bank, has said he does not see a direct or indirect correlation between regulations and jobs (Gandel, 2011). While some regulations do make it harder for companies to grow, Gregory contends that others, such as those that support small business lending, are essential to creating jobs. In a recent *Time* article, Stephen Gandel analysed World Bank figures over a five-year period and found that some countries, for example Argentina and Singapore, had increased both regulation and gross domestic product (GDP) – see Figure 21.

> [Figure 21] maps major economies around the world by their five-year change in ease of doing business and their five-year growth rate. The countries to the right of the vertical line, which is most of them, reduced regulations during the past five years. The countries to the left of the vertical line made it more costly for local companies to operate in the past five years. The size of the circle corresponds to the size of each country's economy. (Gandel, 2011)

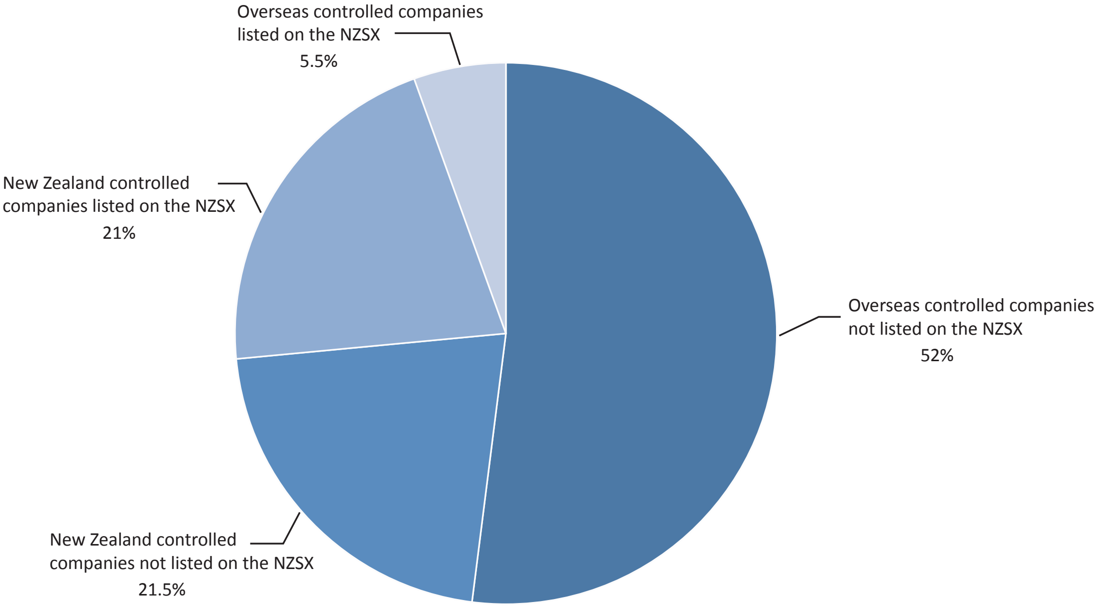
Figure 21: Mapping the Relationship Between Regulation and Growth
Source: Gandel, 2011



These fundings show that there is no straight forward correlation between regulation and economic performance, implying that regulatory frameworks, like any framework, need well-designed regulations to deliver on the system's overarching goals. Furthermore, small countries share characteristics in regard to the level of controlling interest held by overseas companies.

In New Zealand, 57.5% of the Top 200 companies are 50% or more controlled by overseas interests and are not trading publicly on the local stock exchange (see Figure 22). This level of foreign control leaves New Zealand vulnerable, as noted in the Institute's recent *One Integrated Annual Report Survey of New Zealand's Top 200 Companies*, which commented that 'it is in our interests to ensure that the more invisible companies – those that are owned and traded elsewhere – treat our citizens and country well' (SFI, 2011h: 9). Furthermore, this means New Zealand may be further disadvantaged if large companies prefer to undertake R&D closer to home and/or in countries where better incentives exist, or equally decide to out-source risky developments in New Zealand rather than at home. To address this, New Zealand needs to work harder to retain small and growing companies so that we are less vulnerable and less affected by foreign decision-making with regard to Business Expenditure on Research and Development (BERD).

Figure 22: Top 200 Companies by NZSX and by Overseas Control, 2009
Source: Adapted from New Zealand Management, 2009: 70–83



In the remainder of this section we explore four examples of regulatory frameworks that act as enablers in the system: intellectual property frameworks; research and development incentives; risk management, and ethics. Unlike the four previous enablers, the regulatory framework is not obvious, but it remains a major player in determining the nature and type of science the system delivers.

(i) Intellectual property

Intellectual property (IP) rights serve to protect creations of the human mind while encouraging the spread or use of an invention. The World Trade Organization (WTO) defines IP rights as 'rights given to persons over the creations of their minds' and divides them into rights related to copyright and industrial property. The main social purpose of protection of copyright is stated as being 'to encourage and reward creative work', whereas the purpose relating to industrial property is 'to stimulate innovation, design and the creation of technology'; it includes inventions (protected by patents), industrial designs, and trade secrets (WTO, n.d.).

The economic rationale behind the IP system is that developments in science and technology are fundamental to long-term productivity growth and economic success. Further, facilitating these developments involves both the creation of new technology and the dispersal of existing technology. IP rights exist to allow innovators to recover costs and gain on their R&D investments through the ability to both charge higher prices and prevent others copying their technology. While some evidence exists showing that the protection provided by the patent system acts as an incentive to innovation and therefore increases productivity, the *Review of the New Zealand Intellectual Property System* was unable to find evidence that IP, on its own, is a driver of productivity (Auckland Uniservices, 2010: 7).

At the time of writing, the Patents Bill, introduced to Parliament in 2008 and designed to update the New Zealand patent regime and replace the Patents Act 1953, is before a Select Committee. The Bill's objective is to 'ensure that it continues to provide an appropriate balance between providing adequate incentives for innovation and technology transfer while ensuring that the interests of the public and the interests of Māori in their traditional knowledge are protected'. While patents can encourage innovation there is still room for improvement. The 2004 OECD report *Patents and Innovation: Trends and policy challenges* recommends that governments should explore ways to encourage alternatives to patents to disseminate knowledge, such as greater use of the public domain and the publication of licensing guidelines (OECD, 2004: 5).

The conclusion of the aforementioned *Review* is that the New Zealand IP system is not working optimally. It is apparent that the key goal is to integrate inventions into economic growth. Secondary to this is ensuring there are sufficient incentives in the system to guarantee a good inflow of inventions, which in turn means that there are incentives for inventors. These incentives could take many forms; public acknowledgement, financial profits and branding rights are all likely to be part of the mix.

There needs to be further research into the potential to stimulate innovation, design and the creation of technology for the public good in a way that works alongside the IP system. Creating better forms of co-creation based on collaborative practices between institutions, and new initiatives that allow inventions to be put into the public domain more quickly, seem part of the solution. For example, New Zealand could consider becoming a leader in Common Patents, patents that register the creator and are fully transparent, but allow free use with acknowledgement (along the lines of the approach used by the Creative Commons,[85, 86] but through specific 'New Zealand Invention Commons'). There are obviously a number of different ways to explore this landscape, but it is clear that such a system, which puts vast numbers of inventions into an open marketplace where entrepreneurs have access to them, can help economic growth, health and well-being. The challenge is therefore to create a system where new knowledge and technological advances are created and then traded in an open marketplace, which recognises the creator but also enables the entrepreneur to bring benefits to society.

(ii) Research and development tax incentives

In the 2007 Budget, the Labour-led government announced a business tax reform package that included a 15% tax credit that was available for a number of research and development (R&D) activities. The credit was intended to encourage firms to invest more in R&D and address New Zealand's low levels of investment relative to other OECD members (MoRST, 2008b).[87] See Figure 23 below. In New Zealand R&D expenditure is measured across business, government and higher education (university) sectors, with government playing a very important role in R&D activities. In 2006, 43% of all R&D expenditure was funded by the government, which spent a total of $784.7 million in this area, or 0.5% of GDP (NZMEA, 2009: 7). The government sector includes government departments, ministries, Crown entities, Crown-owned companies, government funding agencies, and the local government sector.

Further, the government plays an important role in encouraging the development of R&D, and a supportive, competitive and stable tax policy can be an effective tool for encouraging an innovation-friendly commercial environment. Most OECD countries have specific tax incentives in place for R&D investments, and these are considered to have proven successful (NZMEA, 2009: 7).[88] Evidence of the success of this policy instrument can be seen in the 20% increase in the number of OECD countries with tax incentives for R&D (to 70%) between 1996 and 2006 (NZMEA, 2009: 8).

85 'Copyright grants to creators a bundle of exclusive rights over their creative works, which generally include the right to reproduce, distribute, display, make adaptations, perform, sell and so on. The phrase All Rights Reserved is often used by owners to indicate that they reserve all of the rights granted to them under the law. When copyright expires, the work enters the public domain, and the rightsholder can no longer stop others from engaging in those activities under copyright, with the exception of moral rights reserved to creators in some jurisdictions. Creative Commons licenses offer creators a spectrum of choices between retaining all rights and relinquishing all rights (public domain), an approach we call Some Rights Reserved.' (Creative Commons, n.d.)

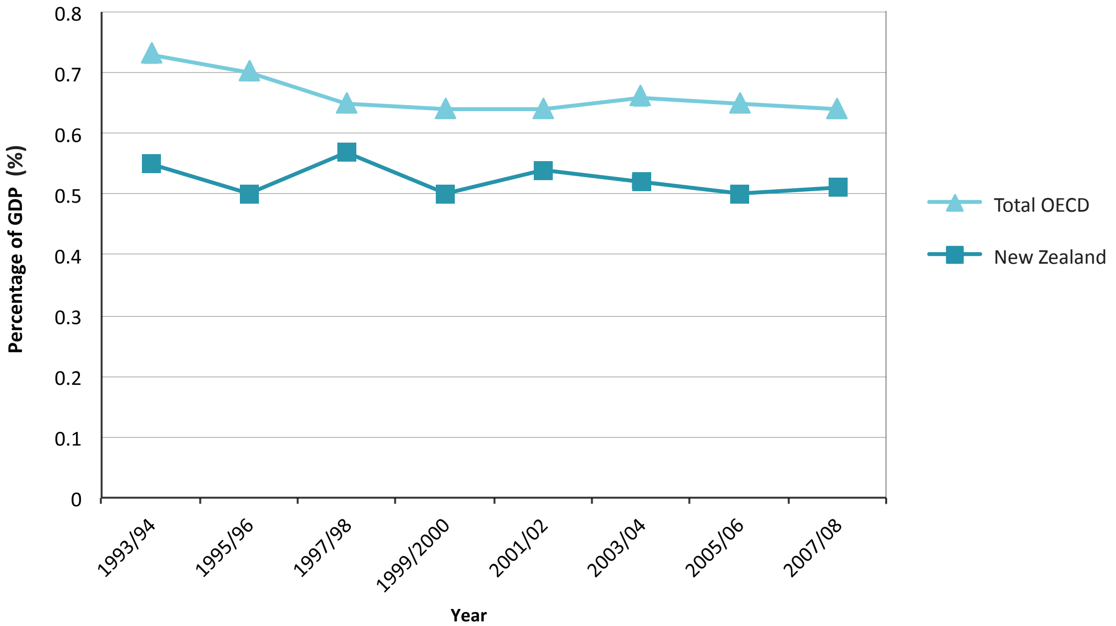
86 'One of our goals is to encourage creators and rightsholders to experiment with new ways to promote and market their work. CC's NonCommercial (NC) licenses allow rightsholders to maximise distribution while maintaining control of the commercialisation of their copyrighted works. Choose a license with the NC condition if you want to reserve the right to commercialise your work. The NC license condition only applies to users, not the owner of the work. As the rightsholder, you may still commercially exploit your work. If someone else wants to use your work commercially and you have applied an NC license to your work, they must first get your permission.' (Creative Commons, n.d.)

87 In 2006 New Zealand spent approximately 1.17% of GDP on R&D, which was well below the OECD average of 2.25% (NZMEA, 2009: 2).

88 The two main forms of R&D tax incentives are R&D tax credits and tax allowances. 'Tax credits are a specified percentage of R&D expenditures that allows a deduction from tax liability. Tax allowances represent additional deductions from the gross income, which indirectly lower the taxable income.' (NZMEA, 2009: 8)

Figure 23: Government-funded Gross Expenditure on R&D as a Percentage of GDP, 1993/94–2007/08

Source: Adapted from MoRST, 2009g; OECD, 2009



Note: At the time of publication the latest OECD data available on government-financed gross expenditure on R&D (GERD) as a percentage of GDP for New Zealand is for the 2007/08 year (OECD, 2011b: 35). The 2007/08 OECD figure is an estimate based on the 2006/07 figure (MoRST, 2009g: 1).

However, effective from the 2009/10 income year, New Zealand's R&D tax credit was repealed by the incoming National-led government. An explanatory note on the Taxation (Urgent Measures and Annual Rates) Bill states:

> The Government's objective in repealing the tax credit is to move towards a broad-based, low-rate tax system, which will improve the quality of investment and reduce distortions. Removing the R&D tax credit will also partially fund the reduction in personal tax rates. The Government considers the benefits of reducing tax rates are certain, whereas the benefits of the R&D tax credit are less certain. The Government is concerned that much of the credit will fund R&D that would have occurred in any case, the compliance costs associated with claiming the credit are high and that the credit will be paid out on standard operating expenditure re-characterised as R&D-related expenditure. (IRD, 2010)

The repeal of the R&D tax credit has been described as 'a huge disappointment for those in the productive economy' (NZMEA, 2009: 12). In view of the fact that some firms had invested significantly to maximise the advantage and implement systems to support the tax credit claims, and that the Labour-led government had spent considerable effort on policy design, the New Zealand Manufacturers and Exporters Association commented that '[s]ince the tax credit will not apply for the 2009/2010 income year, all these efforts have been wasted, and many innovative firms are likely to review their R&D activity' (ibid.).

The government recently replaced the R&D tax credit with Technology Transfer Vouchers and Technology Development Grants that are intended to encourage both research-active organisations and other firms to undertake more R&D, either by themselves or in collaboration with New Zealand research organisations.

(iii) Risk management

Strong, flexible and effective risk management and controls are necessary to both protect against serious and unanticipated harm and to instil confidence in the science system. Without such controls government, organisations and society as a whole are vulnerable to adverse material impacts (including systemic, operational and legal) and reputational risk. Key criteria underlying discussion on risk management include probability of occurrence, magnitude if the risk occurs, and timeliness concerning the length of time negative impacts may exist.

Public discourse on risk management includes debate around acceptable levels of uncertainty; who bears the risk in light of who gains the benefits; who is liable to remove the hazard; whether the risk can be reversed (irreversibility), and an appropriate risk appetite for New Zealand. Beyond this, there are issues around education, and the need to draw a distinction between influencing public opinion through the selective release of information and addressing concerns through an informed public. There is also the need to create greater clarity between perceived risks and rewards, and actual risks and rewards. Professor Gluckman noted the increasing role of society in policy development, commenting:

> [S]cientific advice and policy formation now increasingly act in a more iterative way – what has been termed the 'co-production' model of policy making, in which policy-makers, expert advisors and society negotiate to set policy goals and regulatory decisions that are agreed to be scientifically justifiable (in terms, say, of the information available and the levels of future risk that are tolerable) as well as socially and politically acceptable. (OPMSAC, 2011b: 8)

What follows is a brief discussion that looks more deeply at three examples where expert advisors and society negotiate policy and make regulatory decisions.

Example 1: Genetically Modified Organisms

A recent example of the way regulation is reviewed provides an insight into the current approach to risk management in the science system. In November 2011 the Ministry for the Environment called for proposals to 'determine the factors influencing New Zealand businesses' decisions to innovate using new organisms'. This is intended to inform the government's decision over whether regulatory changes with respect to new organisms are required. An extract from Appendix 1 of the *Request for Proposals* states:

> The Treasury and some research and industry stakeholders have raised concerns that the current regulatory environment associated with the deliberate introduction of new organisms impedes the introduction and uptake of biotechnological innovation. These stakeholders believe that New Zealand's economic performance may be increasingly affected over time, and our competitive position in relation to more permissive economies will be eroded. Others challenge this view with concerns over potential risks arising from the introduction of new organisms. (MfE, 2011b: 8)

However, if the evaluation focuses on the extent to which government regulation impedes innovation, at the expense of examining other factors that might also influence business decisions, it may fail to account for further risks that might arise from reducing controls. This issue was recently raised in the press, showing how sensitive this proposal was when aired in the public arena (Fisher, 2011).

Risks associated with using new organisms would have been an area considered by the former Bioethics Council or Office of the Parliamentary Commissioner on Biotechnology. However, the Bioethics Council was abolished in 2009 and the recommendation to establish the Office recommended by the 2001 Royal Commission on Genetic Modification (RCGM) was not implemented.[89]

Professor Jack Sommer's 2008 survey of New Zealand scientists and technologists provided an interesting insight into what scientists think (Sommer, 2010). For example, in contrast to the impression given in the majority of press reports, the survey showed that there was a range of differing positions on this topic within the science community. Question 25 asked respondents to provide their level of agreement with the following statement:

The 2008 Survey of New Zealand Scientists: Question 25
My understanding of the science of genetic modification of organisms leads me to believe they pose sufficient threat to the ecosystem to warrant suspension of research endeavours.
(Sommer, 2010: 25)

The survey found that 1.9% of respondents agreed emphatically with the above statement; 10.8% agreed in substance; 21.9% neither agreed nor disagreed; 39.9% disagreed in substance, and 20.2% disagreed

89 Recommendation 14.3: 'that Government establish the office of the Parliamentary Commissioner on Biotechnology to undertake futurewatch, audit and educational functions with regard to the development and use of biotechnology in New Zealand.' (RCGM, 2001: 360)

emphatically.[90] Overall, 12.7% agreed with the statement, while 60.1% disagreed to some extent. It is interesting to note that earth and environmental scientists, and mathematics and computer scientists, agreed the most (20.0% and 26.9% respectively), while agricultural and soil scientists (3.2%), medical and health scientists (8.6%), and biologists (9.1%) agreed the least (Sommer, 2010: 25).

It is notable that outdoor GM experiments were largely undertaken by CRIs (SFI, 2008b: 72–73), and surprising that genetic modification outdoors continues today with funding from the government when 20% of Earth and Environmental scientists agreed with the above statement in the blue box.

Example 2: Dairying and Clean Streams Accord

The *Dairying and Clean Streams Accord* is an example where the voluntary mechanisms have not delivered the desired outputs and outcomes. Signed in 2003, the Accord seeks to minimise the impact of dairying on New Zealand's streams, rivers, lakes and wetlands so that they are suitable, where appropriate, for fish, drinking by stock and swimming (MfE, 2011c). The Accord specifies targets to keep dairy cattle out of streams, lakes and wetlands; to treat farm effluent; and to manage the use of fertilisers and other nutrients (ibid.). However, the Accord is not legally binding on the parties nor on Fonterra's shareholders and in no way restricts any person in the exercise of any power or discretion under any statute (Fonterra et al., 2003: 1).

The Accord expires in 2012 and a recent report, *The Dairying Clean Streams Accord Snapshot of Progress,* notes that a nationwide survey to assess stock exclusion from Accord-type waterways found only 42% of farms had achieved complete stock exclusion, showing why regulation is often the only way to ensure risks are managed (MAF, 2011: 13). However, the report also notes that dairy cattle are excluded from accord-type waterways on 84% of farms supplying Fonterra (ibid.: 2), raising questions over the quality of reporting as both figures cannot be right, a point not missed in the press (Scoop, 2011). This explains why public reporting standards must also be included in future regulatory frameworks.

Example 3: National Water Standards

New Zealand's government environmental agency, the Ministry for the Environment, compiles data collected by local government and Crown Research Institutes on water quality from across 16 regions. Regional and district councils self-report against national water quality measures and have inherent differences in technical expertise, resources and needs. Section 69 of the Resource Management Act 1993 (RMA) allows standards to be set regionally, and provides direction for councils wishing to do this. Setting water quality standards in regional plans establishes a benchmark against which cumulative effects can be measured, as well as providing clear guidance for processing resource consents. Although regional and district councils can select whether to incorporate water quality standards within regional plans, it is not obligatory to do so. Voluntary regulation, such as that set out in s 69 of the RMA, goes some way in encouraging organisations to set priorities and long-term strategies for a benefit to the public good; however, information of this nature would benefit from being both mandatory and transparent to ensure the public can monitor progress against desirable outcomes and benchmark one council against another.

The view that regulation is a major barrier to innovation fails to take seriously the management of potentially costly risks. New Zealand's unique ecosystem needs strict biosecurity controls in order to ensure the preservation and continued health of our environment. Proactive planning approaches, in which risk is identified and assessed, and management strategies are developed and implemented, are necessary to ensure the continued and future success of our government-funded science system. Professor Gluckman's suggestion of a risk report framework across the public sector (including CRIs) may go some way to solving this problem. It would create a shared risk management framework that enables a deeper conversation about the country's risk appetite and how to balance risk, when those that bear the risk (the public) are different from those that benefit from the risk (CRIs and their international business partners).

90 There was no distinction in viewpoints with respect to age and gender, but university scientists (14.6%) agreed more than CRI scientists (9.9%) (Sommer, 2010: 25).

> [A]ll forms of science have challenges in terms of the certainty they can provide, and their interpretation. Departments should develop protocols on how to present probabilities, risks, uncertainties and magnitude of likely impact when offering policy advice. (OPMCSA, 2011b: 10)

(iv) Ethics

In order for an organisation or profession to engender trust from the public, it must demonstrate high ethical standards and a strong sense of integrity. Professions such as accounting and law work to achieve this trust by strongly policing their own ethical standards and codes of conduct.[91] Similarly, ethical standards and codes of conduct are rigorously upheld in all medical professions including, for example, nursing, physiotherapy, dentistry and radiation therapy. These standards continue to develop over time, with many major changes coming as reactions to serious events that have called into question the integrity of the profession.[92] Science as a discipline also needs to demonstrate that it is working hard to maintain the trust of the public and to pursue high ethical standards. In contrast to the above professions, scientific professional bodies do not tend to have mandatory memberships or disciplinary bodies. Cases of scientific misconduct are usually investigated by journals, research institutions, and/or the funding agencies (for example, see Miller, 2010).

The role of scientists in producing public good science and open scientific debate can be complicated by issues of 'professional ethics'. This can be a potential impediment to transparency and open debate on areas of public interest science. For example, a notice issued by the DSIR in the mid-1970s addressed the issue of scientists openly discussing controversial environmental issues, in this case indigenous forest utilisation. The notice begins:

> As an employee, the modem [*sic*] scientist has very real responsibilities to his employer. Such a man might well regard the scientific institution that employs him in the light that a lawyer regards a group of which he is partner, namely, that the professional relationship lies between the scientific institution and the client, and that it is the employee scientist's task to use this relationship to further the best interests of the client. What many scientists fail to realise is that they then have a duty to safeguard the client's interests, even if this may involve some conflict with their own interests. (Mark, 1993: 3)

This creates a dilemma for scientists as knowledgeable parties to public debate, who are not entirely free to operate as public good advocates. Scientists are caught between professional and ethical obligations on the one hand and their independent ability to contribute relevant public good information on the other.

There are a wide range of organisations that prepare codes or guidance on best practice, from Health and Disability Ethics Committees (NZHDEC, 2011) to those that set codes of conduct for those undertaking research on animals (as mandatory under the Animal Welfare Act 1999 [MAF, 2006]).

In November 2010, the Royal Society issued its revised *Code of Professional Standards and Ethics in Science, Technology, and the Humanities* (RSNZ, 2010a), which outlines the professional standards members of the Society are expected to uphold. However, membership is not compulsory and standards are not policed by any regulatory body able to hear complaints. Instead, under the *Rules for Hearing and Determining Complaints of Breaches of the Code*, individuals are relied on to bring complaints to the attention of the Society. A board then conducts an inquiry, giving the subject of the complaint an opportunity to respond before undertaking disciplinary measures where appropriate (RSNZ, 2010a). Education about the standards takes a number of forms, but there is no extensive programme in place to educate members on ethics and rules as they are updated. Members are notified when the standards have been updated and they are free to look at these at their leisure. New members of the Royal Society are required to read the

91 The Institute of Chartered Accountants is the membership body that works to ensure high standards in accounting practices, while the Law Society has a role in regulating the legal profession. Robust education systems are also in place to keep members of the profession up-to-date with the latest ethical developments in their field.

92 One of the most infamous examples in New Zealand was the treatment of women at the National Women's Hospital in Auckland in the 1960s. Dr Herbert Green, from the hospital's cervical cancer clinic, chose not to treat or inform women with abnormal cells in the cervix, in the belief that these cells did not always lead to invasive cancer. A number of women developed cervical cancer, and some died. When Green's practices were exposed, a Committee of Inquiry was established, led by then District Court Judge, Silvia Cartwright. This Inquiry proposed radical new measures to ensure patients' rights, including the establishment of the National Cervical Screening Programme, the Office of the Health and Disability Commissioner, the Code of Health and Disability Services Consumers' Rights, and nationwide patient advocacy services (MCH, 2011).

standards, and any application for funding asks that the applicant familiarise themselves with the standards and abide by them as a condition of funding.

The opportunity to achieve a more formalised professional body, whose members are considered professional scientists and required to reflect high standards of ethical behaviour in all aspects of their work, seems worth pursuing. Recent surveys indicate that scientists generally have high levels of trust, however there is strong support from the public for tight controls over what scientists are allowed to do (MoRST, 2010g: 18, 23). A framework to regulate and promote expertise within the science profession should be considered a priority if there is a strong demand for such from within the public.

7.4 Discussion

The purpose and strategy underpinning New Zealand's significant investment in science and innovation is continually changing, and although these changes are resulting in more clarity over the strategy, it remains a concern that so many iterative changes are necessary. In order for stakeholders to use the system to generate benefits for New Zealand, the strategy needs to be settled and demonstrate longevity. MSI's most recent strategic document, its *Statement of Intent 2011–2014*, outlines a three-year strategy and therefore does not set out the long-term strategic intent of the science and innovation system, meaning another document is necessary. Further, stakeholders need to be assured that the structures and frameworks in place will be long-lasting. Structural change is an expensive solution. There are costs in terms of morale, redundancies, administration and accounting systems, and moving premises. The most expensive cost is often that the problems that drove the change are not clearly identified and therefore continue to remain unresolved. Real opportunities lie in the detail, the linkages between strategic intent, drivers and enablers – what Kaplan et al. call 'the cause and effect' (2004: 30–32). The recent structural changes may continue to hide strategic problems and obstacles within the system; hence frequent monitoring of the system will be critical.

The public is a strategic partner in the science system, yet this partnership is not apparent in the *Statement of Intent* or the most recent articulation of purpose and goals. If MSI is going to be '[s]etting priorities for investments in business-led research and development, and public good science' (MSI, 2011c: 7), it needs to have a clear view of what the public wants and needs, to ensure the public good is served. Examples of where scientific and community views on research can differ include such varied subjects as genetic modification in the outdoors,[93] pre-birth genetic screening,[94] and the management of possums.[95] MSI, therefore, needs to be aware of public attitudes to potentially contentious areas of research and take account of this in preparing its plans and making decisions. Sector Advisory Groups could be expanded to include community representatives and/or Sector Research Investment Plans could be required to explore public attitudes and expectations with regard to contentious issues. In particular, all Sector Research Investment Plans should be required to identify, explore and explain how risks will be managed when one group of New Zealanders may gain a significant advantage or benefit from the public investment, to the detriment or at the expense of another group of New Zealanders. Further, these plans should be made public and comment invited so that the plan is thoroughly understood and the public, as a key strategic partner, is fully consulted. Similarly, scientists and research organisations receiving public funds have a duty to communicate their research. There may be exceptions where research cannot be released, but as Professor Gluckman notes, this should be on an opt-out basis (OPMSAC, 2011b: 15).

93 See *The History of Genetic Modification in New Zealand* (SFI, 2008b) and *Review of the Forty-nine Recommendations of the Royal Commission* (SFI, 2008c).

94 See *Bioethics Council of New Zealand* (2008).

95 See *Caught in the headlights: New Zealanders' reflections on possums, control options and genetic engineering*, PCE (2000).

8. The Execution of the Strategy

Professor Robert S. Kaplan and David P. Norton, authors of *The Execution Premium*, and Jim Collins and Morten T. Hansen, who recently published *Great by Choice*, provide useful frameworks for analysing the execution of a strategy. Kaplan and Norton conducted surveys in 1996 and 2006 focusing on the state of strategy execution. They concluded that companies were increasingly implementing a formal strategy execution system. This is a system that translates the strategy, manages strategic initiatives, aligns organisational units, communicates the strategy, and reviews and updates the strategy. The existence of a formal strategy execution system made success two to three times more likely than for a company without such a system (Kaplan & Norton, 2008: 3–5).

Collins and Hansen conducted a study of 10 extraordinary companies and benchmarked them against 10 similar companies that did not perform as well. The study posed the research question 'What did the great companies share in common that distinguished them from the direct comparisons?' (Collins & Hansen, 2011: 6–7). Collins and Hansen found three core behaviours that, when combined, distinguished the successful companies from the comparative companies: fanatic discipline (consistency and focus); empirical creativity (when faced with uncertainty they looked at the evidence), and productive paranoia (they were pessimistic and channelled fear into action) (ibid.: 36–37). These core behaviours are useful when looking at ways to successfully execute a strategy in the government-funded science sector.

8.1 Targets and Initiatives

Sections 6 and 7 describe the purpose and strategy of the current New Zealand science system, and in doing so discuss a number of initiatives that are being progressed by government. Immediately prior to and following the release of *Igniting Potential*, a number of government-led initiatives to support the science system were put in place. These key government initiatives can be broadly categorised into three major areas for change:

2009: Setting strategic priorities and boosting science;

2010: Supporting business, reforming CRIs and simplifying government structures;

Next steps: People, infrastructure and international connections. (MoRST, 2010a: 1)

While a number of initiatives from the old system have been continued, there are a number of new initiatives that have already been implemented. These include:

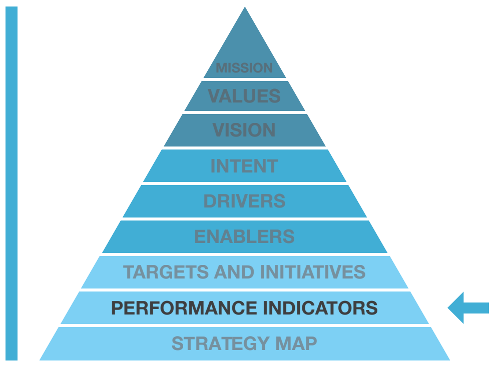
- Providing the CRIs with a greater level of secure funding to support their strategic role in the system ($40 million over four years) (MoRST, 2010a: 20);
- Boosting the Marsden Fund by $36 million over four years to increase the level of investigator-led research that expands knowledge across all disciplines (ibid.);
- Increasing investment in health research by $32 million over four years (ibid.);
- Supporting the people and infrastructure that are at the heart of science and innovation (ibid.: 39);
- Improving the international connections that are increasingly important for researchers and firms (ibid.);
- The Prime Minister's Science Prizes (ibid.: 45);
- e-Sciences services for researchers (ibid.: 47);
- Establishing stronger relationships with carefully selected bilateral partners (ibid.: 51).

At the time of writing, information explaining how these initiatives are being and will be implemented and what targets and timeframes have been agreed upon is not publicly available. This has made it difficult to discern how these new initiatives may relate to the overarching strategy for MSI and how we can measure success.

The implementation plan for the reform of CRIs provides a promising example of MSI providing clear targets and initiatives. MSI has been charged with implementing the recommendations of the CRI Taskforce and has established a clear and comprehensive implementation pathway with a detailed timeline.[96] These work streams form part of *Pathway to 2012*, a plan to create a science and innovation system that is integrated, responsive and collaborative, and supported by a simple and transparent funding system (MoRST, 2010h). The most recent version of this implementation plan was released in December 2010 and takes into account the merging of MoRST and FRST into MSI; the completion of three work streams; the reconfiguration of the remaining work streams into an integrated work programme, and the establishment of a dedicated project team to undertake the work programme (MoRST, 2010i: 1).

It is promising to see MSI's *Statement of Intent 2011–2014* set out how the Ministry plans to contribute to the delivery of the government's priorities for science and innovation. It outlines in detail the specific initiatives or targets needed to achieve the high-level strategy. The *Ministry of Science and Innovation Annual Report: 2010/2011* (MSI, 2011d) measures a number of specific targets and initiatives as 'annual components' carried over from MoRST, but no outcome reporting took place for 2010/2011 as required under s 40 of the Public Finance Act (ibid.: 8).[97] MSI will report against its desired outcomes in its 2011/2012 annual report, as detailed in the *Statement of Intent,* in accordance with the requirements of the Act (ibid.). The effectiveness of output reporting is contingent on the presence of strong initiatives and targets, hence the importance of linking targets and initiatives with performance indicators.

8.2 Performance Indicators



A growing number of metrics to measure science quality and productivity are being developed and applied by various governments and international agencies, such as the OECD.[98] However, there are concerns from researchers that they can be used inappropriately and inconsistently to assess individual scientists (Abbott et al., 2010). Sophisticated assessment schemes, for example the OECD's Assessment of Higher Education Learning Outcomes (AHELO) scheme for assessing universities' teaching and research, are being formulated (OECD, 2011c). While there is a general view that metrics for science performance can be helpful for both researchers and organisations, there is no ideal set of indicators and careful thought is required to determine which are appropriate for specific circumstances (Van Noorden, 2010).

The practices of a number of other countries represent a good starting framework for New Zealand to consider when monitoring the outcomes of its investment in the science sector. Individual countries periodically review the performance of their science achievements (or particular fields of science) based on a range of indicators. For example, in April 2011 the US Board on Science, Technology, and Economic Policy (STEP) held a workshop to address the question 'Can the impacts and practical benefits of research to society be measured either quantitatively or qualitatively?' The workshop discussion focused on a wide range of issues associated with assessing the return on federal investment, including broad social effects of public research investments such as economic growth, productivity, employment, social values, public good, and the actions of decision-makers and the public. An overview of the workshop is provided in

96 An example of MSI's implementation plan can be seen in *Progress of the Implementation of the Crown Research Institute Taskforce Report* (MoRST, 2010h).

97 MSI gave a number of reasons for failing to undertake outcome reporting in the 2010/2011 financial year: (i) strategic alterations made to MSI's focus in a number of areas; (ii) the reprioritisation or halting of work due to its new functions and changing strategic focus, and (iii) responding to the upheaval caused by the Canterbury earthquakes (MSI, 2011d: 8).

98 OECD *Reviews of Innovation Policy* provide an assessment of the innovation systems of individual OECD member and non-member countries. The reviews have a specific focus on the role of government. They provide country-specific recommendations aimed at improving policies relating to innovation performance, which include R&D policies, while also highlighting positive practices that are beneficial to a country (OECD, 2011d).

Measuring the Impacts of Federal Investments in Research: A workshop summary (Olson & Merrill, 2011). The workshop highlighted different approaches to measuring impact, and the risks as well as benefits of such assessments. The OECD has also reviewed and improved the indicators that it uses to measure innovation. The 2010 publication *Measuring Innovation: A new perspective* draws on 50 years of indicator development while describing broader contexts in which innovation occurs (OECD, 2010c). It presents new indicators as measures of innovation, such as investment in tangible assets and trademarks, and focuses on measurement gaps to propose ways for advancing measurement capabilities (ibid.).

The following is a brief discussion on a number of key measures of performance that the Institute's research has identified, divided into input, process, output and outcomes.

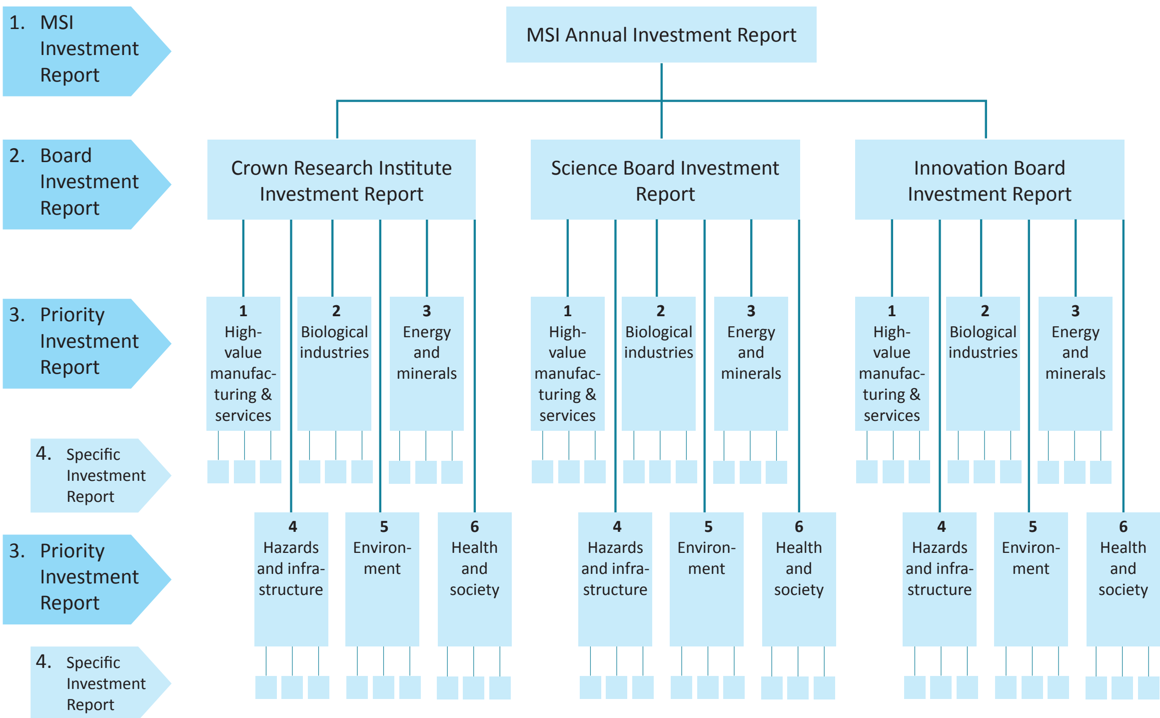
(i) Input monitoring: Reporting on the government investment dollar

Regular reports on investments not only provide transparency but also serve as a catalyst for public feedback. Monitoring investments is essential for structural evolution of the system, as well as for on-going system maintenance. There are four reporting levels that should be reported on and made available to the public as stakeholders in the outcomes of the science system:

1. MSI investment report
2. Board investment report
3. Priority investment report (the six priority investment areas)
4. Specific investment report (each investment)

The four levels of reporting are all linked to provide a meaningful picture of government-funded science at both macro and micro levels. Figure 24 shows how the six priority investment initiatives are distributed across the different investment boards. This distribution raises some important questions concerning how possible synergies across boards are considered and who is responsible for ensuring that all research agendas are aligned.

Figure 24: Recommended Reporting Framework



(ii) Input monitoring: Assessing the utilisation and life of science infrastructure

The development and maintenance of effective infrastructure is essential to producing optimal science outcomes. The importance of regularly monitoring the performance and quality of our asset base cannot be overstated. An asset management register is a fundamental part of long-term strategy and planning around equipment, laboratories and other scientific resources. Evaluation of asset-utilisation is also a necessary part of ensuring maximum benefit from infrastructure investment. The Institute has identified that, until recently, Crown Research Institutes have been monitored largely for their financial performance. MSI now has the opportunity to put in place measures around how an asset operates, alongside research outcomes. There are a number of ways this can be presented, for example applying the scorecard approach adopted by the Argonne National Laboratory (see discussion in Section 5.1.8).

In a country with a comparatively small population like New Zealand, planning around infrastructure also involves considering what research capability exists in other countries in the region (e.g. Australia). Forming partnerships with international facilities in some cases represents the best means of supporting scientific endeavour. Effective monitoring of performance and reporting against defined targets will enable good decisions to be made around New Zealand's science infrastructure.

(iii) Input monitoring: Assessing the quality and quantity of scientists

In an increasingly competitive global marketplace, organisations recognise that working to attract and retain the right talent is critical for business growth. Sir Paul Callaghan suggests New Zealand becomes 'the place where talent wants to live'; New Zealand's science sector strategy should encompass this vision. The ability to draw the world's best scientists to New Zealand to undertake research would represent one significant measure of a successful science system.

Building on the discussion in Section 7.3.5 (iv) on ethics, high ethical standards are critically important for science, as scientists provide an important service to society. As mentioned, organisations such as the New Zealand Institute of Chartered Accountants and the New Zealand Law Society police ethical standards and codes of conduct in their industries. Professional bodies in the science sector do not tend to have mandatory membership or bodies responsible for disciplining members involved in misconduct and there is no national forum where the ethical and moral implications of emerging technologies can be considered. The Bioethics Council was previously tasked with public engagement on ethical issues in New Zealand's science system. Following the Report of the *Royal Commission on Genetic Modification* (RCGM, 2001), the government of the day established the Council with the aim to 'enhance New Zealand's understanding of the cultural, ethical and spiritual aspects of biotechnology and ensure that the use of biotechnology has regard for the values held by New Zealanders' (NDHA, 2009). The Bioethics Council was a Ministerial Advisory Committee with the ability to establish its own work programme. The Council looked at ethical issues associated with human-assisted reproduction, use of human genes in other organisms, xenotransplantation and Māori responses to biotechnologies. The Bioethics Council was disestablished in March 2009. The level of engagement that the Bioethics Council received on some of its research projects indicates that the general public is willing and able to participate in discussion of ethical considerations, and the advice or comments they provided were valuable.

One reason behind its disestablishment may have been that the science community was not required to engage with the Council, and it was therefore easy to ignore. There may be value in requiring scientists to study ethics and in science institutions establishing a strong core set of values and mandatory ethical guidelines. The science system would benefit from recognising the opportunity to pursue a formalised professional body, whose members are required to reflect high standards of ethical behaviour in all aspects of their work or risk losing membership status. If the problem is that the public want tighter controls over what scientists do, a framework to regulate and promote expertise within the science profession should be considered a priority.

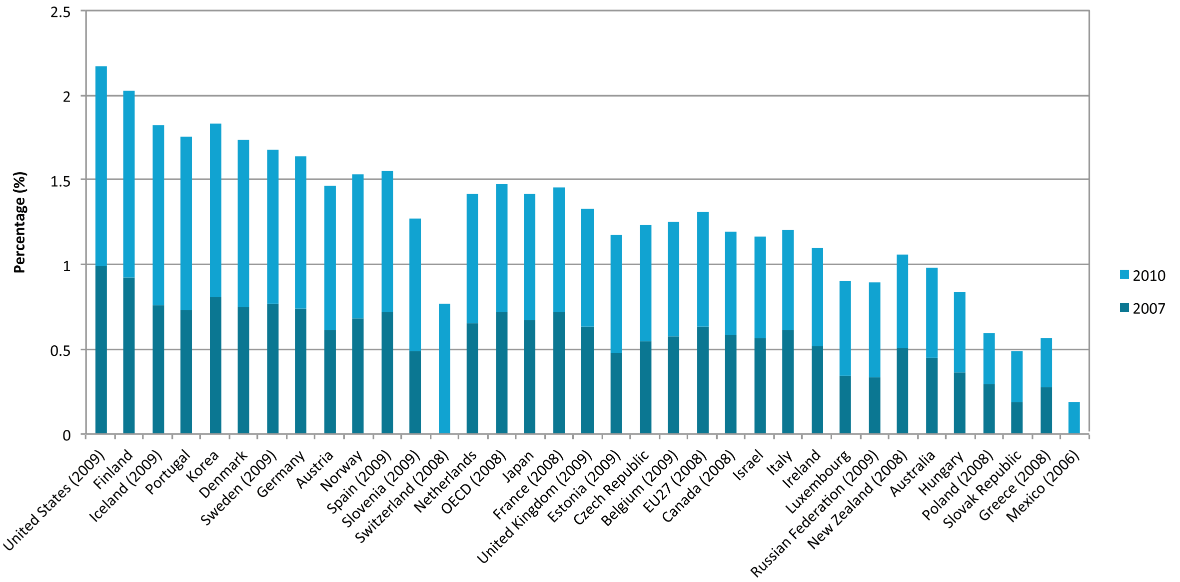
(iv) Input monitoring: Following business research and development

New Zealand's unique economy demands a unique approach to encouraging BERD. Our economy is based on a large number of small to medium-sized enterprises (SMEs), which may not be in a position to take advantage of public research and turn it into wealth-generating innovations.

There are several reasons to provide incentives for businesses to invest in R&D, which would deliver value to New Zealand as a whole. Incentives can be provided through national investment programmes, policy incentives, and encouraging overseas-controlled companies to invest their profits back into New Zealand. This may require developing radical new models, as suggested by the Prime Minister's Chief Science Advisor, who asked, 'Do we really think that lots of small start-ups working in isolation will create 20 new Fisher and Paykel Healthcare's or do we need to aggregate expertise in areas where special knowledge is needed, such as in the biotech space?' (Gluckman, 2010: 2). New Zealanders have proven that they can generate novel and innovative ideas, but other countries have shown us that sustained private and public sector investment is absolutely crucial to lifting productivity through innovation and commercialising science outputs to ensure that such ideas contribute to economic and social well-being. R&D incentives can also help to increase export income, taking pressure off primary industries for export-led growth. The technology grants introduced in 2010 are a step in the right direction by the government, but low public and private sector investment in R&D remains a critical weakness.

OECD data shows that in comparison to other OECD countries New Zealand's GERD as a percentage of GDP is low. Further, New Zealand ranked as the 25th lowest out of 34 comparative countries in 2007, dropping to 28th in ranking in 2010 (see Figure 25 below).

Figure 25: Government Budget Appropriations for R&D, Percentage of GDP, 2007 and 2010
Source: Adapted from OECD, 2011e

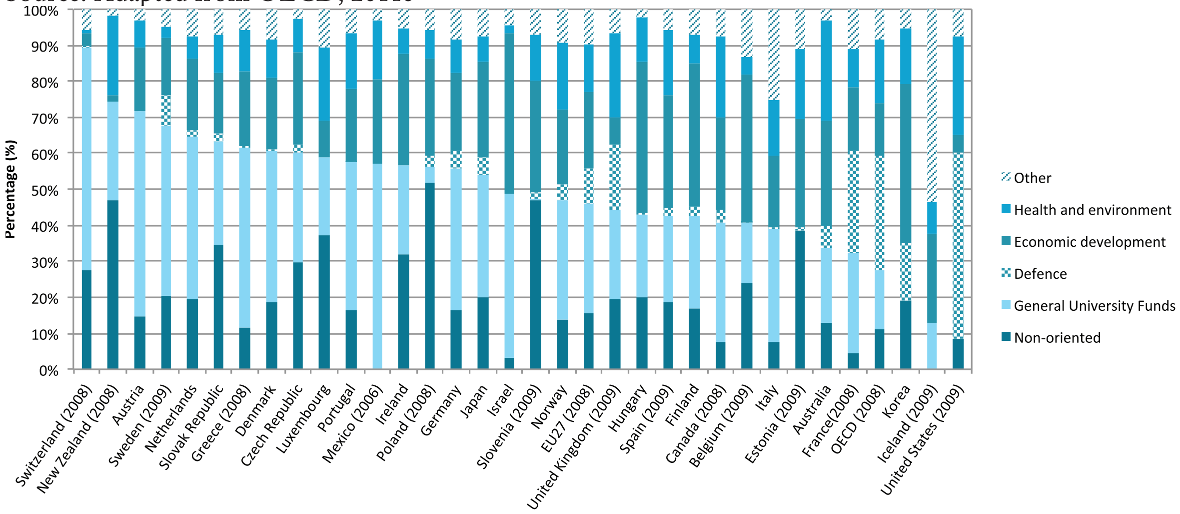


Note: For Israel, defence is excluded. In the United States, general support for universities is the responsibility of state governments, therefore general university funds (GUF) are not included in total Government Budget Appropriations or Outlays for R&D (GBAORD).

Of interest, GERD by selected socio-economic objectives places New Zealand at the highest in the OECD for Health and Environment appropriations; in comparison, New Zealand scores particularly low in appropriations to General University Funds (see Figure 26 overleaf).

Figure 26 Government Budget Appropriations for R&D, by Selected Socio-economic Objectives, 2010

Source: Adapted from OECD, 2011e



Note: For Israel, defence is excluded. For Japan, military procurement contracts are excluded from defence in Government Budget Appropriations or Outlays for R&D (GBAORD). In the United States, general support for universities is the responsibility of state governments, therefore general university funds (GUF) are not included in total GBAORD.

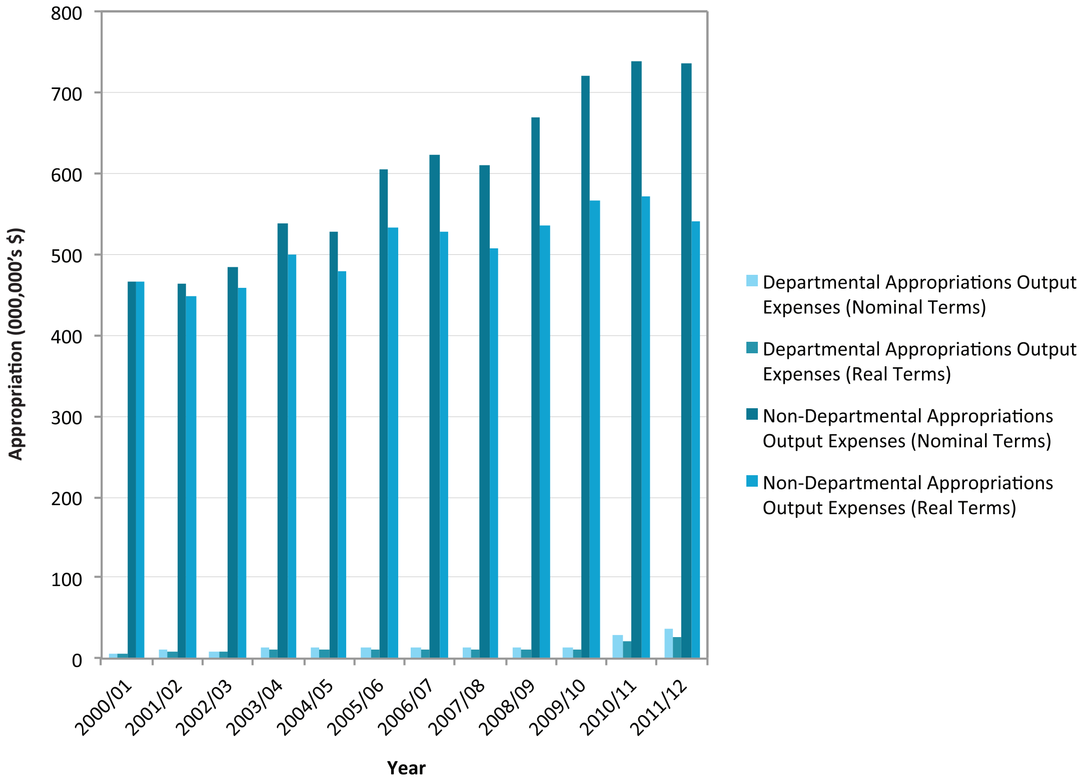
However, counting R&D is no way to measure a country's ability to deliver on science. Research spending is an input, not an output, and does not provide a great deal of insight concerning the value created. The challenge is to find measures that indicate the value gained from spending the research dollar well.

(v) Process monitoring: The cost of the research dollar

Included in the cost of the research dollar are administration costs (departmental appropriations) which support services such as advice and contract management. As a simple measure, the administration cost associated with each fund is a useful starting point for exploring costs versus benefits. Furthermore, benchmarking the cost of operating a range of funding systems, such as comparing administrative costs as a percentage of core funding versus contestable funding, may prove useful. The benefits of the research can only be determined by careful monitoring and comprehensively reporting upon long-term outcomes that can be attributed to the specific research undertaken, even if a positive outcome is just a small by-product of the original research aim. Figure 27 shows the Vote S&I appropriations by departmental and non-departmental dollars.

Figure 27: Vote RS&T and Vote S&I – Departmental and Non-departmental Appropriations, 2000/01–2011/12[99]

Source: Reserve Bank of New Zealand, n.d.; Treasury, 2001: 13, 15; 2002: 14, 16; 2003: 1078, 1080; 2004: 1105, 1108; 2005: 1123, 1125; 2006: 1005, 1007; 2007: 1013, 1014; 2008: 259, 261; 2009b: 283, 284, 285; 2010: 279, 281, 282; 2011a: 271, 272, 273



Note: Inflation-adjusted values are calculated using the Reserve Bank of New Zealand formula (Reserve Bank of New Zealand, n.d.). Comparison dates are second-quarter 2000 with the second-quarter of each relevant budget year. Figures from 2007 onwards include output expenses and other expenses. Figures do not include capital expenditure. 2011/12 figures are Budgeted, all other figures are Estimated Actual.

Given that one of the key reasons for the merger of MoRST and FRST was to reduce administration costs, data showing the administration cost of the research dollar over time should be a key indicator for measuring progress. Taking a view that departmental costs are comparable over time, this data indicates that departmental costs have been increasing in relation to the total Vote, and are forecast to increase in the 2011/12 financial year.[100]

(vi) Output monitoring: The quality and quantity of publications

As Sir Paul Callaghan noted in the Victoria University Inaugural Chancellor's Lecture in September 2011, the output of New Zealand scientists as measured by scientific publications per capita is well above the OECD average (OECD, 2010a: 206). There was continued improvement in this measure over the period between 1995 and 2006.

Many of the tools developed to assess the performance of science systems and scientists draw on quantitative data sources and statistics. MoRST has published an annual *Research, Science & Technology Scorecard* (MoRST, 2009g; 2010j), and commissioned national bibliometric reports every few years

99 Nominal Value is expressed in terms of a certain amount, without making allowance for changes in real value over time. Real Value is a measurement of an economic amount corrected for change in price over time (inflation), thus expressing a value in terms of constant prices (*The Economist*, 2011).

100 In 2000/01, 1.46% of Vote RS&T was allocated to Departmental costs (Treasury, 2001: 13, 15). In 2010/11, 3.57% of the Vote S&I was allocated to Departmental Ouput Expenses (Treasury, 2011c: 271, 273). In 2011/12, 4.64% of the Vote S&I is forecast to be allocated to Departmental Output Expenses (Treasury, 2011c: 271, 273).

(MoRST, 2007b).[101] However, controversy surrounds the value of bibliometric studies when they are used to rank individual scientists or organisations that are competing for funding (see, for example, Weingart, 2005).

In order to assess changes in the number of scientific papers and dollars spent per researcher over time, it is necessary to look at employment and education statistics. The Ministry of Education published a bibliometric analysis in 2007, *Quality vs Impact: A comparison of Performance-Based Research Fund quality scores with citations.* This compared the academic impact of research produced by New Zealand universities, in the form of citations per FTE researcher, with the quality of research at the universities, as measured by the Performance Based Research Fund (PBRF) (Smart, 2007). The Ministry of Education also tracks education statistics with *Education Counts,* a resource aimed at increasing the availability and accessibility of information about education statistics and research in New Zealand (MoE, 2011). Statistics New Zealand publishes *Research and Development in New Zealand* every two years; this collects information on business, government and university spending on R&D while also detailing the number of scientists and researchers in the country (Statistics New Zealand, 2011b).

Internationally, the Spanish research group SCImago has developed a bibliometric analysis site, SCImago Journal and Country Rank (SCImago, 2011a). This uses the *Scopus Bibliometric Database,* which is the largest abstract and citation database of research literature and web sources, covering nearly 18,000 titles from more than 5000 publishers, and contains country and journal summary information (Elsevier, 2011). Scopus can be used to compare scientific outputs internationally as well as provide comprehensive country-specific data. New Zealand statistics show a large increase in publications since 2003 (SCImago, 2011b), the year the Performance Based Research Fund was introduced. However, when the quantity of publications is measured against *Research and Development in New Zealand* (Statistics New Zealand, 2011b: 26), which shows similarly large increases in the number of FTE researchers, the productivity in terms of papers per FTE researcher remains relatively unchanged since 2003.

(vii) Output monitoring: The quality and quantity of patents

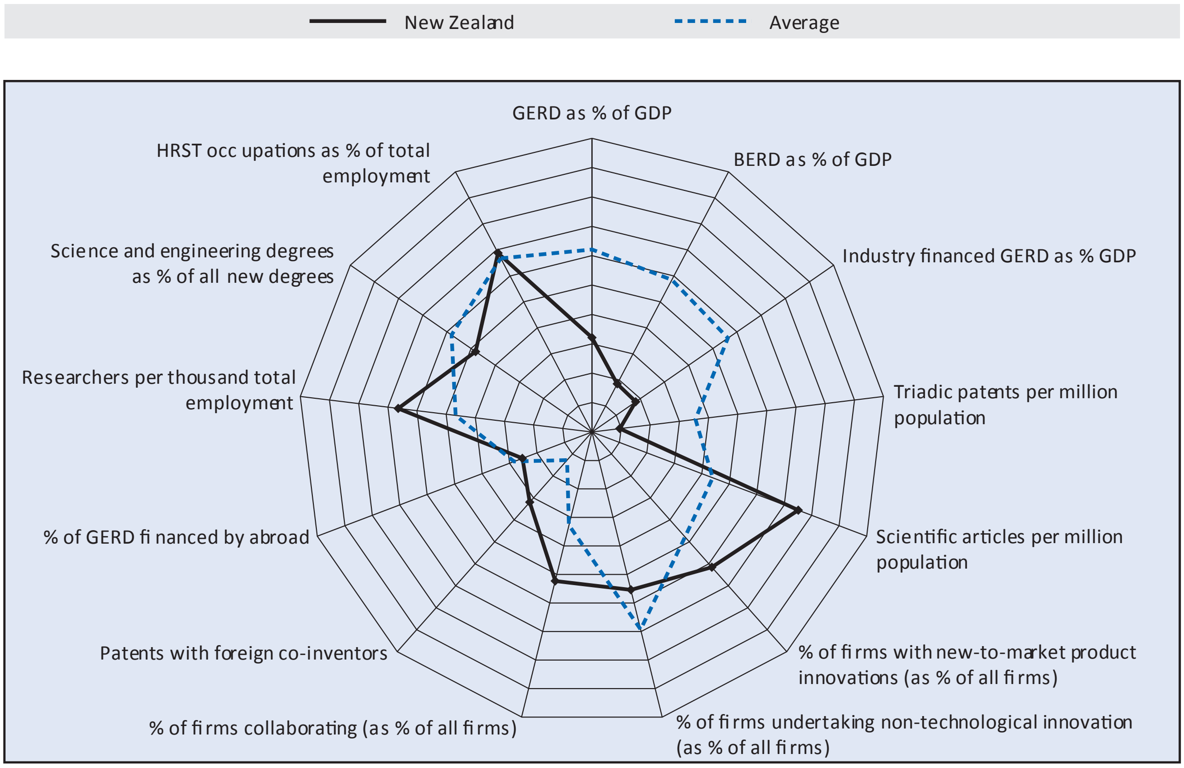
One way in which invention in New Zealand can be measured is by the number of patents lodged with the Intellectual Property Office New Zealand (IPONZ). Patents are exclusive monopoly rights awarded by the government agency for new inventions, allowing patent owners to exclude others from commercialising the patented invention for up to 20 years (IPONZ, 2009). A further initiative to encourage invention by streamlining the patenting process is the Australia New Zealand Integrated Patent system, which forms part of the Single Economic Market (SEM) initiative. Under this new system, there will be one patent examination process for both countries. This means that applications for patents in either country will be assessed by a single examiner and then accepted or denied according to the laws of each country (IPONZ, 2011).

Although analysis of the number of patents filed is one measure for evaluating science performance, these numbers are usually greater for private companies than for public institutions. Private companies are under less pressure to publish, and can choose not to release their findings until they have made a decision on whether or not to patent them. In contrast, public research organisations are encouraged to publish their research findings through conference presentations or journal articles. Once a research finding has entered the public domain it generally can no longer be patented, although provisional patents can be filed prior to publication. For a variety of reasons, care must be taken when counting or assessing the value of patent statistics. Patents do not always result in the release of commercial products, and companies can protect IP using alternative means, such as copyrighting or trademarks, undermining the results from the statistics.

101 A bibliometric study analyses the journal articles published by scientists, and it can provide an assessment of the impact scientists are making in their field through the quantity and quality of citations.

Figure 28 below indicates that our level of invention, in contrast to publications, is poor in comparison with other OECD countries, and is arguably an area that deserves more attention. The level of invention of a country is often measured by the number of triadic patents (i.e. corresponding patents taken out in a number of jurisdictions) and patents with foreign co-inventors. Interestingly, New Zealand is below the OECD average for the first, but significantly higher than the average for the latter. Figure 28 indicates New Zealand firms are very good at creating new to market product innovations, but below average in undertaking non-technological innovation. This indicates that our strength may be in inventing technological solutions, rather than creating and adopting non-technological innovations. More research is needed to draw useful conclusions, but the graph indicates this may be worth undertaking.

Figure 28: Science and Innovation Profile of New Zealand, 2007
Source: OECD, 2010a: 207



(viii). Output monitoring: The commercialisation of science outputs

Within the private sector, some high-tech firms such as Fisher & Paykel Healthcare, Rakon and Navman have succeeded in conducting and commercialising research in New Zealand. However, the list remains small compared with other countries. The University Commercialisation Offices of New Zealand (UCONZ) analysed the performance of university commercialisation between 2003 and 2006, and found: 736 new invention disclosures were received by university commercialisation offices; 303 new patents were applied for; 97 patents were granted, and 156 licences were issued. Between 2003 and 2006, over $155 million of capital was raised for start-ups. In the same period, 29 new start-ups were formed, bringing the number operating as of 2006 to 44. The number of full-time staff employed by these start-ups has grown from 198 to 363, and by 2006 market capitalisation of these companies was $1.1 billion (UCONZ, 2008: 2–3). Further, per dollar invested, New Zealand universities produced more than twice as many new companies as the United States average, and more than 50% more than Canada. In addition, New Zealand universities produced patent applications at a similar rate to US performance, and 30% more efficiently than Canada (UCONZ, 2008: 3).

In 2010, MoRST identified the need to increase the commercialisation of science outputs as a priority (CRIT, 2010: 12; MoRST, 2010a: 12). This goal has been transferred to MSI, which will now be facilitating the Research, Science and Technology sector's contribution to economic growth. Of significant importance is the government's commitment to this goal. In Budget 2010 some of the most detailed changes to the New Zealand science system were announced. They were:

- $189.5 million over four years for technology development grants to support R&D in businesses that already do significant amounts of R&D;
- $20 million over four years to trial technology transfer vouchers, which will encourage links between companies and publicly-funded research organisations;
- $11 million over four years to support technology transfer from research organisations to businesses and commercialisation of new products and processes;
- $13.7 million over four years in contingency funding for initiatives to improve the transfer of technology from research organisations to the private sector. (Key, 2010)

A further systemic change would be to improve the PBRF assessment scheme for universities (through Vote Education) so that recognition is given to more applied research and commercialisation. The previous assessments placed less emphasis on applied or commercial work than on published papers (MacFie, 2009). If greater recognition is given to patenting and commercial activities in the next assessment round it would legitimise university researchers' work on industrial problem-solving and applying real world solutions. Individual researchers could opt into the PBRF stream that most fairly recognises their contribution to academia or society.

Related indirectly to the commercialisation of science outputs is the need to ensure progress aligns with New Zealand's national brand. In August 2011, the New Zealand Business Council for Sustainable Development (NZBCSD)[102] released the results of a poll in response to negative international press that showed only 2% of New Zealanders think New Zealand completely lives up to its '100 per cent Pure' brand.[103] The majority of those polled thought New Zealand is 'nearly there' in terms of living up to this image. The poll also showed that 86% of respondents felt sustainability and the 'Pure' brand are important in giving New Zealand a competitive edge (NZBCSD, 2011).

(ix) Outcome reporting: Improvements in trust

New Zealand has sat among the top five countries in the Corruption Perceptions Index since the index was launched by Transparency International in 1995,[104] reflecting the fact that New Zealand is perceived as a 'high-trust society' (Snively, 2011). Further, three scientists led the *Readers Digest* 2011 most-trusted New Zealanders survey and scientists were 13th on the list of the most trusted professions (Readers Digest, 2011).[105] However, these types of benchmarks are dependent on any unethical and dishonest behaviour being discoverable.

The real test is developing and communicating metrics that relate specifically to the science community in the public arena, ideally in the annual reports of the Royal Society and MSI. For example, in the case of the Royal Society, metrics should include statistics such as how many members have not acted according to the code, what code has been broken, and what implications, penalties and punishments were placed on the scientists for breaking the code. Further, as indicated in the code, it is not mandatory for scientists, in particular government-funded scientists, to be members of the Royal Society. Uncertainty therefore exists over who polices the activities of these scientists and whether any discrepancies are discoverable. The code states:

102 The New Zealand Business Council for Sustainable Development (NZBCSD) seeks to 'provide business leadership as a catalyst for change toward sustainable development, and to promote eco-efficiency, innovation and responsible entrepreneurship' (NZBCSD, n.d.[a]). More than 50 New Zealand businesses are listed as members of the Council and each has made a commitment to sustainable development (NZBCSD, n.d.[b]).

103 For example see *BBC Hardtalk*, 9 May 2011 (BBC, 2011)

104 The Transparency International Secretariat is responsible for producing the Corruption Perception Index, which uses expert assessments and opinion surveys to rank almost 200 countries by their perceived levels of corruption (Transparency International, n.d.). The New Zealand chapter of the organisation seeks to promote transparency, good governance and ethical practices in New Zealand public and private sectors, the South Pacific and internationally as part of the global Transparency International movement (TINZ, 2009).

105 The most trusted New Zealanders were Sir Ray Avery, scientist, inventor, New Zealander of the Year 2010; Sir Peter Gluckman, Chief Science Advisor to the Prime Minister, and Sir Paul Callaghan, physicist, New Zealander of the Year 2011 (Readers Digest, 2011).

1. All members of the Royal Society of New Zealand must comply with this Code. Members whose conduct is considered to be in breach of the provisions of the Code will be asked to account to the Society for their actions.
2. Breaches of the Code, and complaints about such breaches, may be dealt with by the Society under the Rules for Hearing and Determining Complaints of Breaches of the Royal Society's Code of Professional Standards And Ethics.
3. This is a voluntary Code for all other persons involved in science, technology, and the humanities in New Zealand. The Society recommends the provisions to them. (RSNZ, 2010a).

(x) Outcome monitoring: Improvements in well-being

Outcome monitoring is advancing in many countries and is a useful performance indicator. The United States, for example, launched the Science of Science and Innovation Policy (SciSIP) in 2006 to 'develop the foundations of an evidence-based platform, from which policy-makers and researchers may assess the country's [RS&T] system, improve their understanding of its dynamics and predict its outcomes' (OECD, 2008b: 99). Examples of research to be funded under SciSIP include:

- examinations of the ways in which the contexts, structures and processes of science and engineering research are affected by policy decision,
- the evaluation of the tangible and intangible returns from investments in science and from investments in research and development,
- the study of structures and processes that facilitate the development of usable knowledge, theories of creative processes and their transformation into social and economic outcomes,
- the collection, analysis and visualisation of new data describing the scientific and engineering enterprise. (NSF, 2010)

The Australian system, which could be usefully applied to New Zealand, requires government agencies that receive appropriations from Parliament to deliver outcome statements and report to Parliament on their progress (Australian Government, 2010). Annual reports summarising and synthesising the scientific outputs and outcomes of all research produced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) are an example of this.

As another example of outcome monitoring, the European Union's 7th Framework Programme combines a broad range of qualitative and quantitative measures to monitor the impacts of RS&T (OECD, 2008b: 99). Portugal practises a three-pronged approach:

1. The first is the 2006 public governmental evaluation framework, based on internationally comparable indicators …
2. The second provides policy-makers, analysts and programme managers with a continual flow of statistical indicators and administrative data through the centralisation in one planning office of the collection process of all data related to the S&T, innovation and higher education systems …
3. The third is based on the government's decision to introduce foreign and/or independent evaluators … (ibid.: 100)

A third example of outcome reporting at a global level is the PricewaterhouseCoopers (PwC) recent report, *Counting the cost of carbon: Low carbon economy index 2011.* This report shows that carbon intensity has increased in 2011, following two years of minor reduction. The report states that these results 'call into question the current likelihood of our global decarbonisation ever happening rapidly enough to avoid 2 degrees of global warming' (PwC, 2011: 2).

System-wide monitoring of RS&T investments is essential if the government-funded science system is to evolve into one that is dynamic, productive, and meets the needs of New Zealanders and global citizens now and in the future. The New Zealand Association of Scientists has called for more robust monitoring processes so that the 'socially optimal levels of knowledge creation and diffusion' can be ascertained at any stage in the evolution of the science system, and thus guide further change (Open Letter Group of Scientists, 2006: 3, 7). This approach aligns with best practice, and the existence of a formal strategy execution system is clearly something that many stakeholders will be looking to see develop, once the strategy is finalised.

8.3 Strategy Map

The creation of strategy maps is a methodology developed by Harvard Business School. Although the strategy map is just one tool used in the development and polishing of strategies, it is a powerful one that not only provides clarity, but also enables strategy to be discussed and debated. It has been found that a one-page diagram that illustrates all the key elements of a strategy and how they interlink is the most effective tool for translating strategy to stakeholders. Most importantly, this has proven to be a valuable process of empowering the very people with the resources and energy to execute the strategy – for example, the employees. The ability of strategy maps to demonstrate a strategic outline clearly and to communicate visions and strategies effectively is finding value beyond the corporate world as they are increasingly being used by communities and even countries.

The *StrategyNZ: Mapping our Future* event, hosted by the Institute in March 2011, aimed to explore how New Zealanders might develop a strategy map for our nation. The results of the two-day workshop were published in Report 13 (SFI, 2011i) and an e-book of participants' reflections (SFI, 2011j). Key themes that resonated with the participants were the importance of attracting talent to New Zealand and retaining it; the desire to move to a much more entrepreneurial, high-income society; the constitutional review; the appetite from young people to engage in national dialogues; and the desire to have a robust, bicultural and multicultural society. Particularly relevant to this discussion was the theme that participants wanted New Zealand to be 'a place where talent wants to live'. This theme has implications for the optimal science system, which is discussed in Section 9.

Below we assess whether the strategy behind the government-funded science system (as explored in this section) has the two key characteristics of an effective strategy map: internal cohesion and external cohesion.

(i) Does the strategy have internal cohesion?

A strategy map has internal cohesion if it has been assessed both vertically and horizontally and found to be well aligned. There must be an integrated approach that vertically aligns the purpose, strategy and execution by cause and effect relationships. There should also be clear horizontal alignment that demonstrates the linkages between different drivers and enablers and shows how these can reinforce outcomes. A strategy map for New Zealand's science system should provide a clear sense of what MSI is going to do differently, or not do at all, compared with the past strategy, other strategic options and other countries' experience.

There are in effect two strategy documents currently driving this public investment: MoRST's *Igniting Potential* and MSI's *Statement of Inten*t. MSI's *Statement of Intent* takes a very short-term strategic position in line with the three-year planning cycle. In contrast, MoRST's *Igniting Potential* takes a long-term view and is clearly a far more strategic document. Both illustrate that there has been consideration of the cause and effect relationship between very broad goals and how they might be achieved (vertical integration), but the drivers, the recurring ideas that link the purpose with the enablers, are diverse and fragmented. It seems that although there is broad agreement on the sector groups, there is no consistent list of themes driving the strategic intent discussed in *Igniting Potential* or MSI's *Statement of Intent*.

MSI's *Statement of Intent* seems to draw very little from the content of *Igniting Potential*. This means it does not show how the enablers will work together to meet the strategic intent. A more focused and tightly structured strategy would mean the Ministry would focus on fewer initiatives, in order to have a higher likelihood of delivering more specific and useful outcomes. This is perhaps best understood in terms of Professor Michael E. Porter's well-known paper *What is Strategy?*

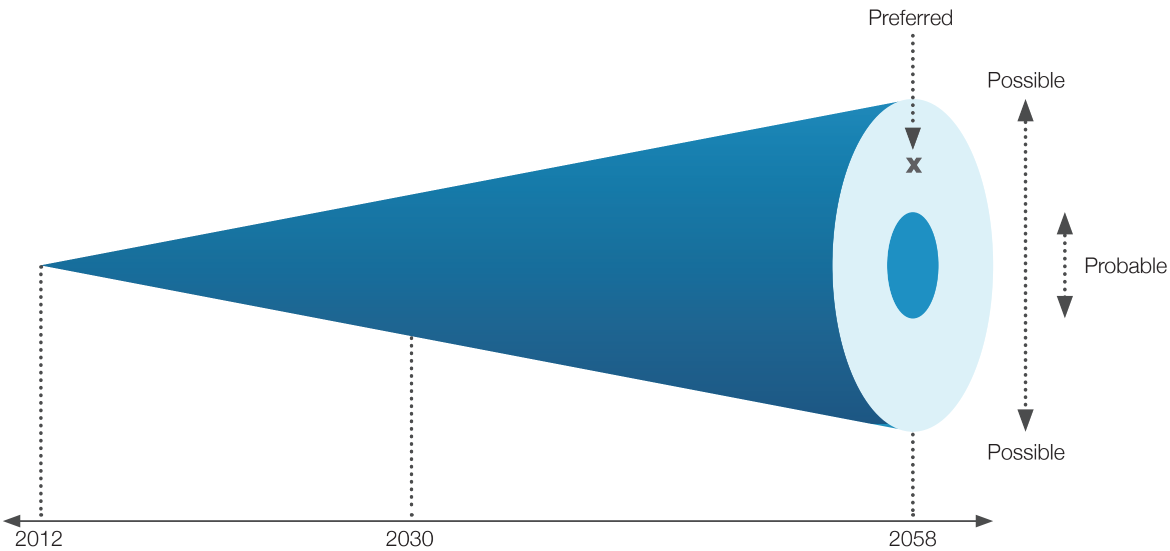
> The essence of strategy is choosing what not to do … Companies that try to be all things to all customers … risk confusion in the trenches as employees attempt to make day-to-day operating decisions without a clear framework … Trade-offs are … essential to strategy. They create the need for choice and purposefully limit what a company offers. (Porter, 1996: 69–70)

Further, there is little evidence that the strategy in *Igniting Potential* had been tested horizontally. We had hoped to see situations where initiatives were able to link across a number of drivers and hard decisions had been made over what it was not going to do, hence the strategy is likely to be in a preliminary stage of development. MSI has indicated that one of its initiatives for 2011 is the development of a clear organisational strategy (MSI, 2011b: 26), however, at the time of publication the final strategy remains a work in progress.

(ii) Does the strategy have external cohesion?

A strategy has external cohesion if it can be seen to fit within an understanding of the probable and possible futures and is able to deliver the preferred future. Figure 29 shows the well known cone that is frequently used in future studies to illustrate the concept of what is probable (the status quo) and what is possible. The challenge is to identify a preferred position in the future and then develop a strategy that will deliver New Zealand to that place at some time in the future.

Figure 29: The Cone: Exploring the Future, 2012–2058
Source: Adapted from SFI, 2012a: 9



A strategy should not be fixed in the present , 'particularly if we consider strategy as the transition of an organization from its current position to a desirable but uncertain future state' (Kaplan & Norton, 2000, cited in Buytendijk, n.d.: 1). Long-term thinking and contingency should always be built into a strategy map:

> Strategy maps are useful tools for strategy execution, but they are often built on unclear cause-and-effect relationships derived from the extrapolation of past performance data and insufficiently linked to possible future states. If too static, strategy maps could actually lead organizations on a risky path which assumes that present conditions will simply perpetuate. (Buytendijk, n.d.: 14)

There are a number of aspects involved in integrating long-term foresight thinking into a strategy map. The current government strategy already goes some way to anticipating the changing dynamics of the world's commercial scientific industry, with a focus on innovation and private industry buy-in. However, such a strategic position is not uncommon, as indicated by the current focus on innovation by the OECD. There is also large scope for consideration of changing policy drivers in New Zealand – for example, anticipated demographic changes – particularly given the central role of science in helping society anticipate, react to and recover from any number of potentially significant wicked problems and wild cards.

Appendix 5 provides an overview of these wicked problems as they relate to New Zealand and illustrates that flexibility must be built into a national science strategy map. While the current science strategy is clearly adapting to wider trends in the global science system, there is little evidence that the strategy incorporates enough long-term thinking to mitigate against major future events and challenges.

8.4 Discussion

Al Gore, the former vice president of the United States, recently published *A Manifesto for Sustainable Capitalism*, in which he quotes General Omar Bradley speaking in the aftermath of World War II. General Bradley said, 'It is time to steer by the stars, and not by the lights of each passing ship' (Gore et al., 2011: 11).

So often in the management literature, we are told that it is the focus on the execution of a strategy that makes the difference between success and failure. Professor Robert S. Kaplan and David P. Norton are world leaders in establishing a comprehensive framework for developing and executing strategy. In their book *The Execution Premium*, Kaplan and Norton note that a lack of strategy execution is a significant problem shared by many executives. They quote a 2006 survey of 143 performance management professionals in which 46% of respondents stated they did not have a strategy execution system in place, and conclude that 'strategy development and the links between strategy and operations remain ad hoc, varied, and fragmented'. Kaplan and Norton suggest managers should 'take a systems approach to link strategy with operations', particularly when attempting to implement transformational strategies (Kaplan & Norton, 2008: 7).

Consistency of performance measures is also a critical success factor, as found by Collins and Hansen (2011) in their survey of 10 extraordinary companies. New Zealand's government-funded science system has been beset by inconsistent policies, changes in strategic direction and structural reshuffles. In view of this variability, analysis of which policies are successful and which need improvement can only be made through having vigorous monitoring standards. Without rigid monitoring systems, improvements cannot be made to the performance of government-funded science.

In bringing these three sections of the report to a close, it is clear from reviewing the system that much of the debate on strategy is centred on the pillars in the middle of the strategy pyramid; in particular four of the five enablers. These four enablers; namely structure, scientists, funding and regulatory frameworks tend to, in colloquial terms, represent the tail that wags the dog. The exception is research infrastructure that was put on hold while the recent structural changes were implemented, but deserves significant research and debate. This lack of focus in the other remaining pillars is a key concern. Clarity over purpose and execution are so fundamental to improving wellbeing, hence refocusing the debate on the first and last pillars is the only way real progress happen.

9: Policy Knots: Strategic Questions that Exist in Government-funded Science

As governments increasingly recognise the potential benefits to society from a robust and flexible science system, governments have had to address a growing number of policy knots concerning decisions over where to invest, how much, and who should drive the research agenda. These policy knots have become increasingly challenging as the role of science has become more complex. Science is no longer defined by biology, chemistry and physics but increasingly by a range of new challenges (e.g. climate change, water scarcity, energy), new tools (e.g. robotics, genomics, nanotechnology, artificial intelligence and neuroscience), and a variety of synergies as we consider how best to respond to the range of challenges ahead of us. This emerging complexity poses a real and urgent challenge for policy analysts and others to untangle.

This represents the transition to a new era in science; we are leaving what Ravetz, author of several books on the philosophy of science,[106] has called 'normal science' and entering a new paradigm called 'post-normal science', characterised by an 'extended peer community' and the recognition of a multiplicity of legitimate perspectives on every issue (Ravetz, 2005: 10). Success in this new environment will depend on a country's ability to transverse this difficult terrain through actively creating a government-funded science system that seeks out a space where society and science intersect; where science delivers on real improvements in well-being.

In early 2011 Professor Sir Peter Gluckman, the Prime Minister's Chief Science Advisor, produced a discussion paper titled *Towards Better Use of Evidence in Policy Formation.* His paper provides a context for considering what Gluckman describes as a collection of 'low cost measures and an attitudinal shift that could, over time, advance the quality of policy advice and thus assist the capacity of Government to improve our national condition' (OPMSAC, 2011b: 17). It highlights a number of initiatives that could contribute to this goal in the short term and suggests there exist a number of other policy areas that require further examination.

Sections 9 and 10 aim to contribute to this discussion through explaining issues and ideas worthy of further examination. This section identifies 30 policy knots – issues that must be addressed but require further research. We have framed these as a series of questions for on-going consideration. These are divided into high-level questions that aim to clarify the overall purpose of the government-funded science system, and policy questions that aim to address the system from a number of different perspectives; the Minister of Science and Innovation, the Ministry of Science and Innovation, universities, and the science community as a whole. For those interested in maintaining the structure of the nine pillars identified in Figure 1, and apparent in the three earlier sections, we have also identified how each question relates to each pillar, see Appendix 6.

9.1 High-level Strategic Questions Related to Purpose

Seven high-level questions have been formulated as a way of clarifying the purpose of government investment in science. While not all of these questions are able to be answered, they provide a useful tool for highlighting the key areas of tension within the science system. Our intention is to identify and emphasise a number of alternative ways of conceptualising the system.

106 In 1962 , Thomas Kuhn, science philosopher and author of *The Structure of Scientific Revolutions*, introduced the concept of normal and post-normal science as part of his theory that scientific knowledge progresses through socially constructed paradigm shifts. Jerome Ravetz, author of *Scientific knowledge and its Social Problems* (1992, 1996), describes post-normal science 'as the sort of inquiry, usually issue-driven, where the facts are uncertain, values are in dispute, stakes are high and decisions are urgent' (Ravetz, 2005: 10).

Question 1: Should New Zealand have a greater focus on commercial research or non-commercial research?
Question 2: Should New Zealand have a greater focus on addressing New Zealand-specific issues or global issues?
Question 3: Should New Zealand have a greater focus on inventions or innovations?
Question 4: Should New Zealand have a high-risk appetite or a low-risk appetite?
Question 5: Should New Zealand have a greater focus on long- or short-term research?
Question 6: Should New Zealand have a greater focus on 'policy for science' or 'science for policy'?
Question 7: Should New Zealand have a greater focus on solving problems or mysteries?

Question 1: Should New Zealand have a greater focus on commercial research or non-commercial research?

The commercialisation of science is a major driver of the current model. While there is an obvious and understandable focus on commercialisation, if MSI intends to deliver on its vision to improve New Zealanders' wealth and well-being, both commercial and non-commercial research must be undertaken. New Zealand does not have a track--record of effectively generating commercial outputs from research. The OECD science and innovation profile of New Zealand shown in Section 8.2 (Figure 28) supports this view; the number of scientific articles per million of population is far in excess of the OECD average, whereas our ability to translate that research into new-to-market products is less apparent (Herringa, 2010).

The establishment of a scientific platform for economic development was the underlying purpose of CRIs. Professor Brian Robinson, Emeritus Research Professor, University of Otago (personal communication, 21 February 2012) noted that 'there is no evidence that economic or scientific 'health' comes from having more government control of scientific practice or operations' and that we tend to place too much effort in to CRI's. This perspective was supported by at least one of the external reviewers who had come to the same conclusion. Over the last twenty years government has got it the wrong way around by trying to create a dynamic and creative government-funded science system through the creation of CRIs. In contrast, the role of government should be two-fold: to create a stable and evidence-based government-funded science system while at the same time working with the private sector to help make it more dynamic and creative. The 2010 review of CRIs noted that these organisations were not adequately engaging with the private sector to facilitate commercialisation of their research findings (MoRST, 2010a: 33–34). The establishment by MSI of the National Network of Centres for Commercialisation (NNCC), may be a step towards improving these connections and facilitating cross-sectoral engagement in the public domain. However there are risks involved with this approach such as scientific knowledge being co-opted by special interests (Mirowski & Van Horn, 2005: 521). See also the Singapore case study in Appendix 4. Similar issues have been raised concerning commercialisation in a university setting.[107]

There is a lack of clarity surrounding the respective roles of MSI and the Ministry of Economic Development (MED) regarding economic development. MED clearly has a role in fostering economic development and prosperity for all New Zealanders, and many of its portfolios are aligned to the six areas

107 There is evidence that large-scale commercial involvement in university-based science, engineering and technology has impacts that can be detrimental. At the level of setting the priorities and direction of R&D, Langley and Parkinson, in their report *Science and the Corporate Agenda,* identified the following problems:

a. Economic criteria are increasingly used by government to decide the overarching priorities for public funding of science and technology, in close consultation with business.

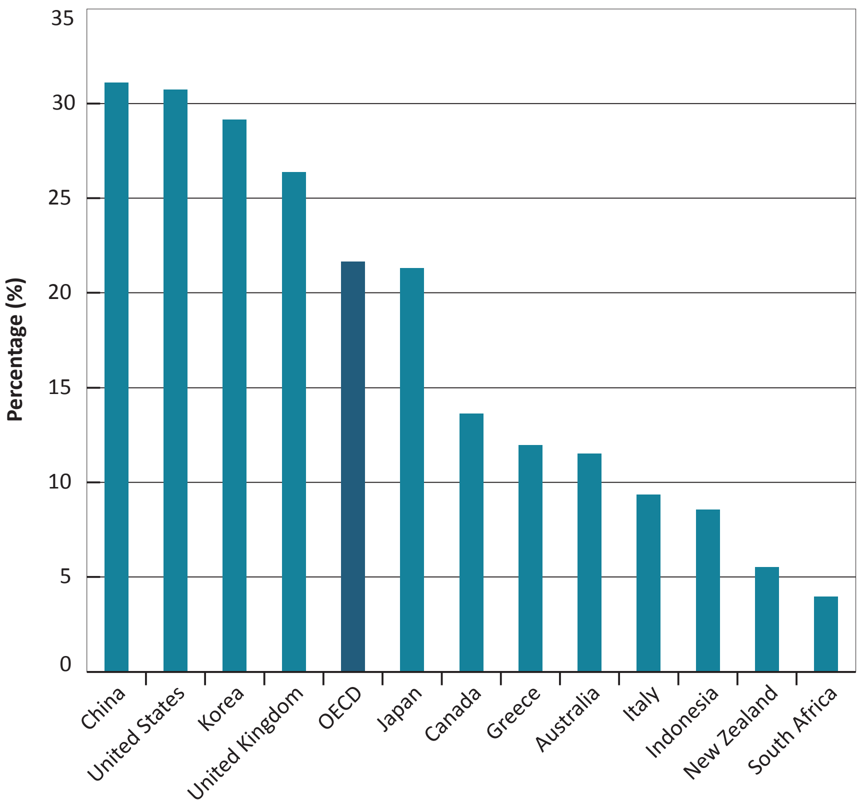
b. Universities are being internally reorganised so that they behave more like businesses, while key attributes of the academic ethos such as openness, objectivity and independence are being seriously eroded.

c. Companies have expanded the number and range of partnerships with universities, focusing on business research priorities and goals. The power and influence of some corporations, and the increased pressure on researchers to bring in funding from business, means that academic departments are increasingly orientating themselves to commercial needs rather than to broader public interest or curiosity-driven goals. This is a trend especially evident in biotechnology, pharmaceutical, oil and gas, and military partnerships.

d. The growing business influence on universities is resulting in a greater focus on intellectual property rights (including patents) in academic work. Hence knowledge is increasingly being 'commodified' for short-term economic benefit. This can undermine its application for wider public benefit, and produces a narrow approach to scientific curiosity.

e. A high degree of business interest in emerging technologies, such as synthetic biology and nanotechnology, leads to decisions about these powerful technologies being taken with little public consultation. This is of particular concern because of the major uncertainties regarding these technologies, including the possibility of detrimental health and environmental impacts which they may produce. (Langley & Parkinson, 2009: 7) of investment determined by MSI: high-value manufacturing and services sector (HVMSS); biological industries; energy and minerals; hazards and infrastructure; environment, and health and society (MED, n.d.; MoRST, 2010a: 3). It is not clear how the two ministries coordinate their strategies in these areas given that the difficulty in distinguishing the stated aims of these two ministries has been noted in the science-policy community.[108] Figure 30 shows that in terms of high-technology exports as a percentage of total manufacturing exports, New Zealand has considerable work to do if it wishes to create economic development through technology. If MSI's strategy is to focus on the commercial aspects of innovation (as indicated), we believe the solution is to bring the research agenda (and possibly the funding) under the control of the business community. Notably, in the 1960's at least 25% of private sector CEO's had science or engineering degrees, but today this percentage would be a lot lower (Professor Brian Robinson, University of Otago, personal communication, 21 February 2012). If we are serious about transferring science technology to users, government will need to focus more closely on the private sector; economic success comes from individuals, and a more realistic commercial strategy may be to identify entrepreneurs and supporting them to find new products and services, and to develop market and niche opportunities.

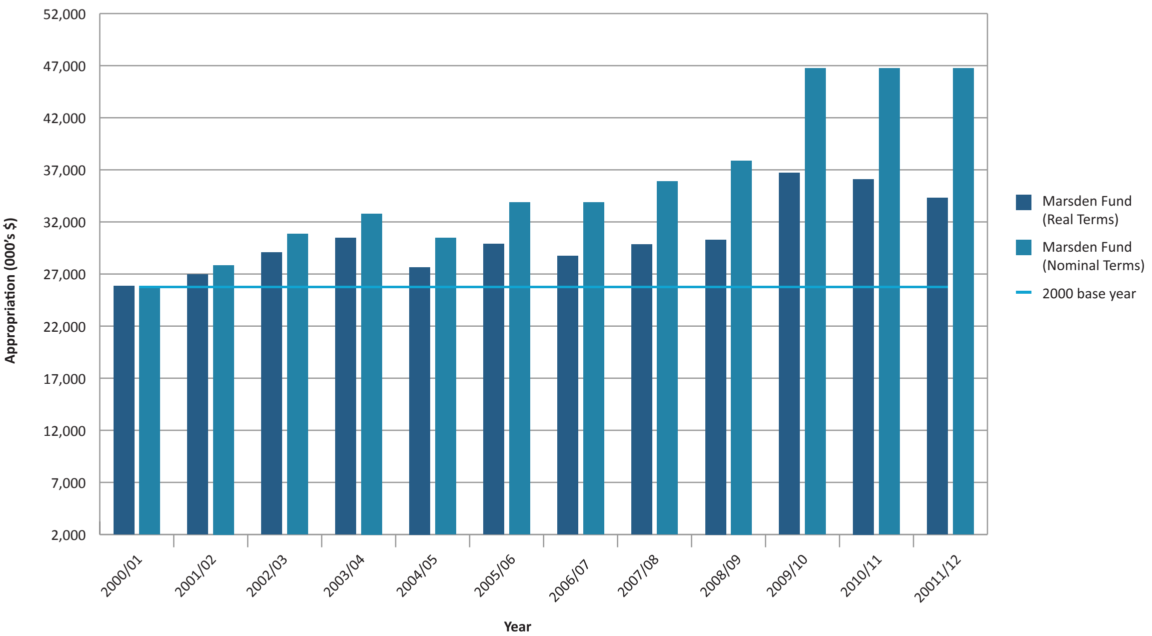
Figure 30: High-technology Exports as a Percentage of Total Manufacturing Exports, 2008
Source: Adapted from OECD, 2010a: 207



Non-commercial funding that exists to support research excellence in areas such as science, engineering and maths, social science and the humanities is available through a very limited number of funds, and is primarily financed through the Marsden Fund. This fund, managed by the Royal Society of New Zealand on behalf of the government, provides contestable research funding for investigator initiated 'blue skies' research which is not subject to government's socio-economic priorities (RSNZ, n.d.[a]). In 2010/11 the Marsden Fund Council invested $60.4 million on research projects, this includes the $9 million budget increase from the government in 2009 and a one-year spending of accumulated funds (ibid.). Total appropriations to the Marsden Fund has increased over the last decade and competition for grants is intense (see Figure 31). It represents the only major non-commercial science fund, and the high level of competition demonstrates how limited funding options are for such research.

108 This lack of distinction was discussed at the inaugural Asia-Pacific Science Policy Conference, 2012.

Figure 31: Vote RS&T and Vote S&I – Marsden Fund Output Class: Total Appropriation, 2000/01–2011/12
Sources: Reserve Bank of New Zealand, n.d.; Treasury, 2001: 13; 2002: 15; 2003: 15078; 2004: 1106; 2005: 1124; 2006: 1006; 2007: 1014; 2008: 259; 2009b: 283; 2010a: 280; 2011c: 272



There needs to be a balance between commercial and non-commercial science funding that generates the necessary capacity for blue skies research and the expansion of scientific domains that contribute to the well-being of New Zealanders. With commercial research the focus is on economic gain at minimal public risk, in contrast to non-commercial research, which aims to ensure the research delivers improvements to health and well-being. Both need a clear strategy to guide investment and assess results, they need to be recognised as separate systems with separate goals. Arguably, the investment strategy for the former should be shaped and assessed by MED, NZ Trade and Enterprise, industry groups, and business. It needs to operate as it would in any commercial setting, guided by those with appropriate commercial acumen and the ability to pick investments that are profitable while minimising risk, as well as providing transparency so that stakeholders are able to assess these investments retrospectively. Non-commercial research science also needs to be an apparent and relevant part of the government-funded science system.

Question 2: Should New Zealand have a greater focus on addressing New Zealand-specific issues or global issues?

New Zealand science reflects a mixture of research into local issues and opportunities, and participation in broader scientific questions. *Igniting Potential* noted that the publicly funded science system should produce better benefits for New Zealand (MoRST, 2010a: 10). In the Institute's view domestic issues should be the primary driver, and our international science relationships should focus particularly on areas where we have both expertise and a real desire to solve issues that matter to us. A comprehensive list of specific issues New Zealand needs to resolve is not apparent in the recent government-funded science documents discussed within this report. We would have expected to find specific issues 'significant to the national well-being of New Zealanders', such as obesity, diabetes, skin cancers, social inequality, earthquakes (prediction, management and building standards), pests (possums, rabbits, stoats and rats), nitrogen and urea, phosphates, damage caused by hooved animals, and ocean management. Without a deep understanding of the issues facing New Zealanders it is questionable whether the science system can deliver on its vision of 'improving New Zealanders' wealth and well-being'.

As science becomes increasingly globalised, there is greater opportunity for New Zealand scientists to tap into the best research teams in the world operating with critical infrastructure that New Zealand does not have. International science connections and collaborations are an excellent avenue through which some issues specific to New Zealand can be progressed beyond the means available at a domestic level. This is particularly true in fields where New Zealand has leading expertise, such as aquatic biodiversity and biosecurity.

Question 3: Should New Zealand have a greater focus on inventions or innovations?

The choice of name of the new science ministry suggests that innovation will be a major driver behind the government-funded science system. In order to discuss this question it is first important to have a clear understanding of the distinction between the terms invention (something that is created by an inventor and is new)[109] and innovation (which is an iteration of an invention and improves an existing product, process, marketing method, organisation or external relationship).

Professor Gary Hawke, in his case study *Technology in the New Zealand Economy* (Hawke, 2011), notes that the relationship between innovation and research and development (R&D) is complex.[110] This complexity is discussed further in Section 10.1, where the causal relationship between New Zealand research and New Zealand development is identified as a myth.

Question 4: Should New Zealand have a high-risk appetite or a low-risk appetite?

Investments by the public sector require a deep analysis and assessment of the net effect on the health and well-being of New Zealanders as a whole. Fundamental to this type of assessment is an in-depth understanding of the level of risk the public are willing to accept.

Following from a commercial imperative, there has been public concern about higher-risk science initiatives in New Zealand, particularly surrounding genetic modification. It is interesting to note that a large majority of genetic modification (GM) outdoor experiments have been undertaken by CRIs with international partners, resulting in public money being used to co-invest in private good science, for which the benefits go overseas but the risks to the public stay in New Zealand. Gluckman has commented on this conflict between public and private interests:

> In some cases, however, CRIs have entered into contracts with the private sector that limit their capacity to give such [*sic*] advice (e.g. around land use), and indeed they can find themselves being contracted to give advice contrary to the Crown's wider interests. In general entry into such contracts is often unwise and academia has shown them to be unnecessary. Academia enters into many private sector contracts and yet essentially none limit institutional ability to publish, subject to IP protection. On the basis of the now altered expectation of the CRIs, they must now take greater care in future arrangements to avoid compromising their ability to serve the Crown as important and independent advisors. (OPMSAC, 2011b: 14)

New Zealand society could be considered to have a relatively low technology risk appetite (as indicated by our response to nuclear power and genetic modification); this is perhaps best understood in terms of our dependency and attachment to the land. As a biological based economy, New Zealand needs to be prudent in regard to ecological risks, and take on board the lessons learnt from gorse, rabbits, opossums, didymo and the Varroa bee mite.

Question 5: Should New Zealand undertake research focused on the long-term or short-term?

A commercial research focus is likely to favour short-term research, however, public policy often benefits from long-term research. Examples of such research are the Dunedin Multidisciplinary Health and Development Study (University of Otago, n.d.), the Christchurch Health and Development Study (University of Christchurch, n.d.), and the more recently established Growing Up in New Zealand study (University of Auckland, n.d.).

109 A prime example is the work of the National Institute of Water and Atmospheric Research (NIWA) who have been experimenting with paua polyculture, which is the cultivation of multiple marine species in a closed-loop system to integrate wastes and improve efficiency of production. This was one of the first systems of its type in the world (NIWA, n.d.), with the potential to provide jobs in rural coastal areas, increase the value of seafood exports, and reduce the ecological impact of traditional harvesting.

110 Hawke states, 'Nearly all economies import most of the technological development and adapt it to the local circumstances. This is simply an implication of most countries having a small share of the world's population and a small share of new ideas that inform the process of innovation. It has certainly been true of New Zealand. The archetypal New Zealand innovation is employment of overseas engineering to achieve refrigeration and major local effort in adapting breeds of livestock, husbandry methods, and institutional arrangements for finance and managing processing. We can expect the future to be similar. One of the challenges for New Zealand is to focus on innovation and stop thinking about subsidies for research. "Commercialisation of technology" is part of the outmoded thinking. Innovation usually begins from generating human satisfaction and working out how to do it – at the very least there is genuine interaction between final satisfaction and perceived opportunities.' (Hawke, 2011: 149–150)

Long-term non-contestable funding ‘supports large-scale, long-term programmes of research and can support and maintain essential research infrastructure’ (MoRST, 2010a: 19), but whether it be through contestable or core funding, long-term research requires constant management and review to ensure that over the length of the research, the purpose remains relevant and the process is delivering the desired outputs along the way. Rather like a company reviews its investment portfolio annually, so too should research institutions. Long-term research that is no longer relevant (i.e. has no external value) or is not being well-managed, should either be redesigned or dropped in favour of more useful research.

Question 6: Should New Zealand focus on ‘policy for science’ or ‘science for policy’?

The Prime Minister’s Chief Science Advisor, Professor Gluckman, has recently suggested that ‘science for policy’, at least for his office, will become a ‘major theme in coming years’ (OPMSAC, 2011c: 2).[111] While pursuing this goal, it is equally important to encourage better ‘policy for science’ as a driver for the government-funded science system.

Science and policy should work together, in what Professor Gluckman calls the ‘co-production model of policy making’, where the public, experts and policy-makers negotiate policy goals. This model demands not just transparency about assumptions and evidence, but also the need to seek out the views of the public and engage with interested parties over time. Gluckman suggests a number of relatively cost-effective ways of making improvements in the short term:

- Rotation of staff [foster a scientific community and consider the purchase of academic/scientist time by government agencies]
- Internal departmental science advice [create a Departmental Science Advisor]
- Use of experimental science advice [create a set of generic protocols]
- Scientific advice from the Crown Research Institutes [clarity over conflicts of interest and contracts]
- Direct purchase of agency research [create a register of research reports]
- Social science research [a social sciences research purchasing and monitoring unit]
- A joined-up approach across government [create guidelines on use of scientific advice in policy-making]. (OPMSAC, 2011b: 11–17) [square brackets inserted]

In 2010, Cabinet, as part of the Confidence and Supply Agreement between the National Party and the Act Party, appointed a committee to enquire into the cost, alignment, efficiency and quality of spending under the appropriations for policy advice. The resulting report, *Policy Expenditure Review*, found that inconsistencies and gaps exist and makes recommendations to improve policy functions by focussing on three broad areas of action:

1. Treasury reviews policy advice expenditure with a view to seeking savings through targeted baseline reviews of policy advice expenditure;
2. Formal process of commissioning, for each agency, a multi-year policy work programme between ministers and chief executives,
3. To professionalise policy advice (Treasury, 2010c: iv).

As a result of the review Cabinet directed central agencies to investigate a model of appointing Heads of Profession (Treasury 2011f: 1). This resulted in the Heads of Profession trial project, which aims to test the concept of professionalising policy advice across the state sector (Treasury 2011g: 3). In 2011, the Central Agency Policy Steering Group in charge of this project agreed on a number of actions, one of which was that the trial project enter into discussions with Professor Sir Peter Gluckman on options on how to progress a Head of the Science profession (Treasury 2011g: 3). Concerns about how foster the development of professional body within the science community is further discussed in terms of a Code of Ethics in Question 27 and in Section 10.4.

111 ‘Science for policy’ could thus be set to become a key driver for science in New Zealand. ‘Policy for science’ is the input into the system to calibrate it to produce the desired outputs and outcomes. In contrast, ‘science for policy’ aims to use science to inform public policy across government. See also the definition in the Glossary.

Question 7: Should New Zealand focus on solving problems or mysteries?

The concept of whether good government-funded science is a problem-solver or a mystery-resolver is open to debate. The distinction between 'puzzles' and 'mysteries' was examined by Gregory Treverton in the context of National Intelligence (Treverton, 2003). The merit of this distinction was further expanded and publicised by Malcolm Gladwell in his 2009 novel *What the Dog Saw.* As defined by Treverton, a puzzle is a situation where the task is to find the missing piece of data that will deliver the solution (it is dependent on knowing what you are looking for), whereas the challenge for those trying to solve a mystery is to make sense of an overabundance of information (it is dependent on judgement and the assessment of uncertainty) (Gladwell, 2009: 151–176).

This idea is not new to science. Kuhn (1962) proposed that the traditional scientific approach, or 'normal science', is well-suited to solving puzzle-like problems with definite answers, but that when contradictory theories arise that cannot be explained a new approach must eventually follow. In such circumstances, a new way of conceptualising and solving problems is needed. Further, Funtowicz and Ravets (1993) proposed that hard science in the laboratory is not appropriate for designing and implementing solutions to complex environmental problems, problems which inherently have high degrees of uncertainty and costs associated with both action and inaction. These authors suggest that using a post-normal science[112] framework can provide the approach necessary to tackle these issues.

Commercial science is often directly related to a problem that scientists have been engaged to solve, such as creating a new drug for a specific illness or replacing a current product with a more sustainable one (hence the term applied research). For example, Sean Simpson, head of the scientific team at Lanzatech, believes the most effective scientists are passionate about solving problems.[113] When asked what makes a great scientist, he stated:

> We stand around obsessing about the problem and can think of nothing else until it is solved, then we are completely bored with it and move onto the next problem. (Coughlan, 2011: 104)

In contrast, public good science, by its nature, is likely to be a mystery, rather than problem-specific. Mysteries are often called 'blue skies' or 'basic research'; they tend to demand more deductive research which works from the general to the specific and is knowledge-driven, rather than inductive research which works from specific observations to broader generalisations or theories (Massey University, n.d.). Longitudinal studies can again be used here as an example, where researchers know it is important to study an area, but are unsure what they will find and how they will use the results.

9.2 Strategic Questions for the Minister of Science and Innovation

Question 8: Who will review the recent restructure, when will it be done, and against what criteria?
Question 9: What policies and initiatives will MSI not carry over from MoRST?

Question 8: Who will review the recent restructure, when will it be done, and against what criteria?

Significant investments in structural changes should be assessed in order to ensure the information that led to the change was correct, the process of change was effective, and the benefits and risks were anticipated. This ensures lessons are learnt and the system adjusted (where necessary) to optimise benefits. All significant structural changes should be required to include an assessment within two to five years of their introduction, to ensure policy analysts and other interested parties have the opportunity to learn from the process undertaken. At this stage, there is no evidence that such a review has been planned even though the OAG recently suggested to the Education and Science Committee that a review be undertaken of the recent amalgamation of MoRST and FRST (see discussion in Section 3.5). The Institute recommends that the Minister of Science and Innovation mandate a full, independent review to be completed within five years

112 See footnote 105.

113 Lanzatech is an Auckland-based company that uses microbial fermentation to convert industrial waste gases into biofuels and valuable chemicals.

of the restructure, and that the results of this review are made publicly available. Smaller, specific reviews should be done at regular intervals focusing on structural changes as they are implemented.

Question 9: What policies and initiatives will MSI not carry over from MoRST?

With a change in strategy and structure, one would expect there to be some programme areas that are not carried over or pursued. In researching this topic we found it difficult to determine what policy initiatives under MoRST are no longer relevant to the new institutional structure. We consider that a comprehensive list of disestablished initiatives would give a greater level of insight concerning the strategic focus of the changes and would enable the science community and the public to better understand what programmes have been disestablished in order to pursue new policy and research opportunities.

9.3 Strategic Questions for the Ministry of Science and Innovation

Question 10: How will MSI address the needs and wants of the public?
Question 11: How can MSI drive long-term outcomes for the government-funded science system?
Question 12: What research infrastructure is necessary to meet our long-term needs?
Question 13: How can Mātauranga Māori be progressed in a modern, funded research context?
Question 14: How can society have faith that decisions by the two MSI investment boards are independent, based on evidence and in the public interest?
Question 15: What are MSI's reporting obligations to stakeholders?
Question 16: Has the Crown Research Institute experiment worked?
Question 17: How can investment decisions by Crown Research Institutes be made more transparent?
Question 18: What level of funding is best for science in New Zealand?
Question 19: What method of funding is best for science, contestable or core funding?

Question 10: How will MSI address the needs and wants of the public?

Neither MoRST's *Igniting Potential* nor MSI's *Statement of Intent* place sufficient emphasis on defining the needs of New Zealanders. To achieve the vision of 'high-performing science and innovation systems improving New Zealanders' wealth and well-being' (see Section 6.3), a better understanding of the many diverse needs and wants of New Zealand's population is critical, meaning there is a need for greater dialogue between MSI and the public. Ensuring information about changes in structures or the development of new initiatives is publicly accessible, and ensuring information is clear and readily available are both critical to establish a relationship between MSI and the public.[114]

Question 11: How can MSI drive long-term outcomes for the government-funded science system?

While changes in structures and systems over time are usual, the Institute believes that the inability to find a management structure that has longevity is a long-standing weakness in New Zealand's science system. With continual changes to the science structure, there is the risk of institutional capabilities and knowledge being lost. Ways in which MSI can be sufficiently flexible to respond to the changing landscape, yet disciplined enough to stay focused on its strategy and apply best practice, are likely to be a significant challenge. MSI must seek out ways to identify and meet the needs of New Zealanders in a cost-effective and transparent manner, so that New Zealanders continue to trust and support this investment in science.

114 An example of a recent initiative that achieves this goal is the CRI Toolkit, accessible through the MSI website (see MSI, 2011h). This tool provides a comprehensive description of the relevant legislation, governance, planning and reporting mechanisms, monitoring and indicators and wider operation at CRIs.

Question 12: What research infrastructure is necessary to meet our long-term needs?

As discussed in Section 7.3.3, research infrastructure is a key enabler as it provides a strong platform from which the science sector can deliver long-term benefits to society. New Zealand is a small nation with a limited pool of resources; therefore it must think carefully as to how best to invest its infrastructure dollar. The government is tasked with a number of difficult questions: deciding when investment in large-scale research is necessary, and then establishing where best to make that investment. The government is currently refocusing on this area, but any investment plan must take a long-term view and include a set of criteria for judging investments, a comprehensive assessment of all options (e.g. outsourcing to other countries and/or developing public/private partnerships) and clear linkages to the six priority investment areas.

Question 13: How can Mātauranga Māori be progressed in a modern, funded research context?

As discussed in Section 7.3.4(ii) Mātauranga Māori refers to the knowledge that was brought to Aotearoa by tūpuna Māori (MoRST, 2006c) and further developed during their period of isolation on these islands and in response to the arrival of European settlers. The various theories of European science are a product of the application of what is generally referred to as disciplinary-based 'scientific method'. Mātauranga Māori is also the result of the application of methods that are generally considered to be very different to those employed by European scientists. Our report on the shared goals of Māori (SFI, 2010b) highlighted the importance of preserving and progressing this alternative epistemology. Given this research we believe that New Zealanders, now and in the future, will benefit from both protecting, understanding and building on this knowledge base. Given these long term goals, a further question is how science management and funding policies might be advanced to produce future outcomes of this kind?

There seems to be two key priorities. First, science administrators need to create space for Mātauranga Māori to grow and develop in its own way – not in a way that is dictated or shaped by Pākehā epistemologies. Second, there is the question of just how Māori and Pākehā researchers are empowered to work together in a manner that honours and protects their respective knowledge traditions while producing outcomes and outputs of mutual benefit to all New Zealanders.

Concerning the first priority outlined above, the creation of a separate space to retain and build Mātauranga Māori is different from the goal of integration (i.e. priority number 2) that is currently being pursued by the government. Vision Mātauranga has recently been integrated across MSI's investment priority areas (2010); a Vision Mātauranga Capability Fund has been established (2010), and Vision Mātauranga has been incorporated into the CRIs' Statements of Core Purpose (2011).[115] Effectively integrating Mātauranga Māori across the science sector, beyond assuming a merely symbolic status, requires a clear set of guiding principles to empower and protect knowledge. The Institute developed a set of guidelines for undertaking and understanding Māori-focused research in *A Methodological Approach to Māori-focused Research* and identified twelve guiding principles (SFI, 2009c). The second goal, which is arguably the most urgent, requires the creation of a space for the Māori world view to be protected and built upon. For example, Mason Durie, Professor of Māori Research and Development & Assistant Vice-Chancellor (Māori) at Massey University, states:

> Indigenous world-views, indigenous values and indigenous system of philosophy, technology and healing have become part of the indigenous legacy. Although it is often positioned in the past, and is sometimes valued because of its antiquity, indigenous knowledge has applications to modern times as it provides framework for understanding and exploring current and future worlds. (Durie, 2003: 277)

Question 14: How can society have faith that decisions by the two MSI investment boards are independent, based on evidence and in the public interest?

Section 10 of the Research, Science, and Technology Act 2010 sets out the functions and duties of the boards of innovation and science. These relate to '… funding decisions on proposals for specified RS&T funding referred to it' (s 10(4)(a)). Without mention in the Act of advisory functions, it remains to be seen

115 'CRIs are now required to enable the innovation potential of Māori knowledge, resources and people as part of their operating principles' (MSI, 2012a).

what this role entails. There needs to be more clarity concerning the scope of any advisory role and how it fits in with the Ministry's obligations to government. Further, the new structure places a great deal of power and responsibility in the hands of a few, with little clarity concerning checks and balances over the decisions made or the policy advice provided. Vote Science and Innovation states:

> Two boards, a science board and an innovation board-comprising leaders from these sectors have been established. The boards will make **independent funding decisions** and will advise MSI and Government **on the shape and direction of the science and innovation sector.** (Treasury, 2011c: 270) [Bold added]

The approach outlined above is an abdication by the government of its responsibility to ensure funds are invested effectively. The government should give the boards a clear investment mandate and investment criteria including guidance on its appetite for risk. The boards should invest within this criteria and need to ask permission to go outside it. This approach is similar to the criteria and balance factors previously applied by FRST.[116] The total funds available to the two boards in 2011/2012 amounted to $329,863,000 (SFI, 2011c: 4).[117] If the boards are going to be allowed to make independent funding decisions and provide policy advice to MSI and the government, New Zealanders need to have confidence that they are operating in an open and transparent manner. Each board must be continually assessed in terms of its overall composition as well as the quality of the individuals around the boardroom table and the decisions they make. In particular, board members need to disclose all potential conflicts of interest (e.g. ownership of patents, shares, licenses, board memberships) in a public register, past business dealings should reflect best practice, expertise should be relevant and useful, and ethical codes of conduct should be agreed and applied (see Working Paper 2011/15: SFI, 2011c).

The boards would benefit from the inclusion of one or more members who are outside the science industry but who have proven expertise in board governance and portfolio management. It is critical that experienced investment management expertise is on both boards, but in particular the Innovation Board. This is to assist, debate and deliver a perspective of risk versus return that would otherwise be lacking. The boards should also be comprised of people with a track record of proven success. This would have the advantage of mitigating the potential for group-think through the presence of 'independent' members, while also encouraging best practice. Although the MSI investment boards are not considered to be boards under the Companies Act 1993, we believe members should consider accreditation under the New Zealand Institute of Directors as a way of raising corporate governance standards (IoD, n.d.). Furthermore, we note that one person is both chair of one board and a member the other. We believe the position of chair is too important for that person to also be a member of the other board. If a joint membership is desired, this should be maintained through two shared board members, in order to ensure the power of one individual does not dominate decisions.

In addition, each funding investment must be transparent and easy to track over long periods of time. Under FRST, investment decisions were difficult to track, and linkages between the investment dollar (inputs) and research reports (outputs) have been, at best, problematic to define. The need for research reports to be published has been raised by the Prime Minister's Chief Science Advisor. Professor Gluckman believes that a level of quality assurance and peer review should be required of all internally purchased research; that research must conclude with the publication of formal reports, and that results should be accessible to the public in a government-wide register of datasets and research report summaries. Most importantly, Gluckman considers there should be a default position whereby all research reports are in the public domain unless there are security issues or other overriding concerns (OPMSAC, 2011b: 15). Increased accessibility to science publications would increase public trust in the government-funded science system and enable the public to understand and support future investments in science.

116 Under FRST, external advisory groups assessed proposals against assessment criteria and then FRST considered all proposals against a range of balance factors to select those in which to invest. These were: cover all the important research topics and priorities in a research area; do not duplicate research; support teams that are important for New Zealand's research capability; include a range of short and longer-term research; support a wide range of industries; address critical questions for New Zealand, and support research that will benefit Māori (FRST, n.d. [a]).

117 There is a crossover in the funds available to each board; therefore, separate figures as to the available funds for each board are not available.

Question 15: What are MSI's reporting obligations to stakeholders?

Under New Zealand's previous science systems, external advisory boards have been used to provide independent advice on investment decisions to the board (FRST, n.d.[a]). The extent to which the two new MSI investment boards are accountable to stakeholders, whether they be government, industry, the science community or the wider public, remains unclear. Unlike private sector boards or CRIs, neither board is subject to the obligation under s 208 of the Companies Act 1993 to prepare annual reports within five months of balance date. In particular we note that the latest MSI annual report does not provide any insights into the investment strategy of either of the two investment boards, nor any information on how their performance will be measured or reported upon (MSI, 2011d). This information is of significant interest to the public and we find the lack of disclosure concerning. Uncertainty around the current level and frequency of reporting exists and this must be resolved before the government-funded science system can convey trust and lead change.

MSI should be a leader in government reporting. Science is a key economic growth platform of the current government and therefore should report information that is accurate, comprehensive and meaningful, so as to inform and support changes in public policy. Further, benchmarking and indicators need to be reported in a timely manner to provide the earliest possible warnings should a situation arise to which the Minister, ministry, sector and society must react. Further, as science becomes increasingly integrated, so will reporting.

In pursuit of an integrated science system, the Institute suggests that MSI adopt the emerging reporting standard known as integrated reporting. The International Integrated Reporting Council (IIRC) is leading the development of a global framework for Integrated Reporting. The IIRC defines integrated reporting as the following:

> Integrated Reporting is a new approach to corporate reporting that demonstrates the linkages between an organization's strategy, governance and financial performance and the social, environmental and economic context within which it operates. By reinforcing these connections, Integrated Reporting can help business to take more sustainable decisions and enable investors and other stakeholders to understand how an organization is really performing. (IIRC, 2011)

Integrated reporting focuses on the linkages in an entity's behaviour and therefore supports the case for MSI reporting against its Statement of Intent. The link between MSI's Statement of Intent, MSI's annual report and the Ministry's strategies should be strongly emphasised and reported on. The annual report should also include a list of all strategies (large and small) that have been signed off by the Minister, in order for stakeholders to understand not only what MSI has done in the past, but what it plans to pursue in the future.

Question 16: Has the Crown Research Institute experiment worked?

In terms of investment, it is important to be able to assess whether the establishment of the ten CRIs in 1992 met expectations. Have they greatly enhanced the ability of transfer technology to users (see discussion in Section 3.3)? Many clearly do not think so. There is a concern that the CRIs do not generally interface well with business, and that scientists and technologists working in those institutes believe what they do is more important; their passion is to create knowledge not profits. The cultures do not naturally align. Arguably, a successful entrepreneurs[118] tend to focus on creating great products and services and the profits follow, which is perhaps a more palatable way to view the interface.

The funding of CRIs has long been a vexatious issue in the science system. The 2010 Crown Research Institute Taskforce resulted in a major change to the way in which CRIs are funded, with the introduction of core funding. The Taskforce recommended that less emphasis be placed on contestable processes as a way to drive improved performance, as recommended by the 2007 OECD review of New Zealand's

118 Steve Jobs, former CEO of Apple, goes to great lengths to make this point: 'My passion has been to build an enduring company where people were motivated to make great products. Everything is secondary...products not profits was the motivation ... It's a subtle difference, but it ends up meaning everything: the people you hire, who gets promoted, what you discuss at meetings' (Isaacson, 2011: 567). New Zealand examples of this approach include Peter Jackson and Sam Morgan.

innovation system (OECD, 2007a). The Taskforce accepted that contestable, open access to funding needs to remain an important element of Vote S&I funding, but that this should be on a smaller scale and the proportion of contestable funding should be reduced. Moves toward greater core funding for CRIs, and the resulting increased security of funding, may begin to address scientists' concerns about interruptions to funding noted in the *2008 Survey of New Zealand scientists and technologists* (Sommer, 2010).

The other major concern raised by CRI scientists and technologists in the 2008 Survey was that 'bureaucratic accountability, management and red tape' was a problem. These opinions were collected before the merging of MoRST and FRST, but raise issues about the culture of science in New Zealand and whether bureaucracy is necessary in order to make optimal decisions. It is important to understand whether those who identified this as one of the two most important issues at the time were more concerned with overly onerous bureaucratic accountability, management and red tape, rather than its existence at all. Indeed, it is essential that there are strong accountability and management structures in place, especially where inputs and outputs need to be closely monitored. For example, the ability for corporates to calculate risks, undertake due diligence and assess the risks against the benefits is fundamental to success. Concerns were raised about the lack of good investment practices by CRIs over genetic modification, raising questions over whether some CRIs had the necessary expertise to undertake effective due diligence before undertaking investments. AgResearch funding of genetically modified cattle research is a case in point (SFI, 2008d). Poor investments are not only an inefficient use of money, but they have the potential to create additional risks to the environment, our national brand, and therefore our economy. There is also the cost of the lost opportunity. For example, what if AgResearch had invested those funds in pest management, what environmental and economic benefits could we now be reaping?

The tension between what scientists think is important versus what business think is important may explain why CRI scientists are generally dissatisfied. They sit between central government, who are perceived as wasting their time through bureaucratic red tape, and businesses who are seen as not actively pursuing their services. This may also explain why, in the *2008 Survey of New Zealand*, CRI scientists believed that:

- New Zealand science is not heading in the right direction (53.5%)
- Government should not set the research agenda (37.3%)
- Interruptions to research funding is their most important concern (49.3%)
- They would not recommend research as a career to New Zealand youth (73.3%). (Sommer, 2010: 3)

When the 2008 Survey was undertaken, it appears the CRI model was not working for anyone. Arguably the original reason why CRIs were established, to transfer technology to users, has been lost over time and there is a risk that the recent changes in the method of funding CRIs is driven to provide job stability for the CRI community rather than to transfer technology to users. Designing a system to meet the needs of those engaged in the process, rather than end users, creates a form of moral hazard; not unlike what was experienced in the recent Global Banking Crisis that began in late 2007.

We believe that the changes to date are improvements, but do not go far enough. Further work is necessary to provide CRIs the right platform to deliver on outcomes that improve wellbeing. In particular, we believe the purpose of the eight CRIs does not align with the six priority investment areas. Ideally, they should be merged to form three entities: a biological development arm (a combination of AgResearch, Plant and Food, and Scion); a high-value manufacturing and services sector (HVMSS) development arm (IRL), and an environment research arm including energy and minerals research, hazards and infrastucture research and environmental research (a combination of ESR, Landcare, NIWA and GNS Science). Further, the current Health Research Council could become a CRI, creating a fourth arm focused on health and society.

Internationally there is some support for merging research providers. The Japanese government has recently approved a merger of prominent research organisations in order to enable world-leading science and technology research, while at the same time minimising administrative costs. The aim is to consolidate the RIKEN network of basic-research laboratories with the National Institute for Materials Science (NIMS), the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the National Research Institute for Earth Science and Disaster Prevention (NIED), and the national funding body Japan Science and Technology Agency (JST). The government also intends to set up a third-party audit system to evaluate administration and performance more strictly (Fuyuno, 2012).

The CRI Taskforce was asked to assess 'any alternative or additional initiatives that could be taken to strengthen the CRI model, including the merits of reconfiguring the number and scope of CRIs' (CRIT, 2010: 59). The report does not go into any detail as to how they made this assessment, but the Taskforce did state that it rejected any moves to change the numbers at this stage:

> 8.7 In our view, and in the view of the CRIs we interviewed, **the cost savings that might result from mergers would be unlikely in themselves to justify the costs associated with the change.** The Taskforce was unable to find evidence that cost savings in overheads would in themselves justify merging one or more CRIs and we do not recommend any such action.
>
> 8.8 We anticipate that there will be a continuing need to rebalance the capability held within the CRIs and across the whole science system, as new opportunities, threats and problems arise. The system needs to be more dynamic and responsive to national needs**. The question is not how many CRIs New Zealand should have, but what structures will best provide research services that address the problems New Zealand faces.**
>
> 8.9 Rather than make a one-off decision about number and scope, we recommend an incremental approach, as Government reviews the purpose and role of each CRI. **Strategic need should drive any rebalancing, not cost-saving.** Decisions to rebalance or merge CRIs should reflect both 'top-down' direction from the Government about its requirements and 'bottom-up' information from the CRIs and their stakeholders about ways to deliver. (CRIT, 2010: 51)[Bold added]

There is little apparent evidence in the report to support these recommendations. It does not explain what alternative models were identified, nor what criteria and information was used to make such an assessment. Developing an optimal system requires a wider and broader conversation; hence it is difficult to feel satisfied with the CRIT recommendation when the alterative merger models, time frames, potential costs savings and the cost of implementing any changes are not transparent. We believe a strategic review deserves more in-depth consideration, especially in light of the need to align science research with the six priority investment areas to improve funding and accountability mechanisms and foster better relationships with central government and industry.

Another way in which CRI performance could be better monitored would be to add another reporting Minister to the governance structure of each CRI. In addition to reporting to the Minister of Science and Innovation and the Minister of Finance, CRIs could be required to report to the minister most closely aligned with the area in which they operate: for example, the Minister of Agriculture and Forestry for the biological development CRIs; the Minister of Economic Development for the HVMSS CRI; the Minister for the Environment or the Minister of Conservation for the environment research arm, and the Minister of Health for the health and society CRI. Direct consultation with the relevant ministry could lead to sector research plans or high-level research agendas that are far more insightful and useful than the MSI Advisory Sector Plans, as they would be driven by what ministers and policy analysts want, and allow them to engage early in the process so that science does indeed shape policy.

Lastly, we suggest the percentage of core versus contestable funding be assessed in terms of the market for each CRI. In Section 7.3.4 we discuss changes to the CRI funding process, and suggest that the CRIs in the biological development arm and the HVMSS development arm, both described above, receive a target percentage of core to total funding from government of about 45%. This is in contrast to the environmental and social development arm, which we believe should receiving around 75% of their funding as core funding. Such a distinction is important because there is little direct correlation between investment and profit in social and environmental research, meaning it is not often an attractive proposition to profit orientated entrepreneurs to undertake environmental and social research. Such research takes many years of hard work to deliver outcomes that are useful, as indicated by the 12 years required to extend New Zealand's continental shelf,[119] hence the higher percentage is recommended to ensure stable funding matches long-term research projects, ensuring long-term knowledge and expertise is retained for the length of the project. The percentage of health and society funding would need to be considered more closely if a CRI were to be created in this area, as recommended above.

Question 17: How can investment decisions by Crown Research Institutes be made more transparent?
Increases to core funding will allow CRIs greater decision-making power over which of their projects receive funding. Essentially, greater trust is being put in individual CRIs to determine the best use of funding in the long term. However, this new model of funding could lead to a lack of accountability in decision-making around research. This creates a risk that CRIs could become the 'gatekeepers' for research funding in core areas (Kilkenny, 2010).

While core funding provides CRIs with greater scope for long-term thinking and enables them to determine where funding can be best spent, there needs to be mechanisms to ensure potential conflicts of interest are addressed. This needs to be built into the reporting requirements, and the new set of accountability measures currently in development.

It will also be critical that the CRI monitoring unit within MSI is empowered to scrutinise the performance and collaboration of CRIs as a whole and not just individually, so that system-level issues are identified and understood. MSI will also need to be active in encouraging a sense of national leadership across all CRIs.

Question 18: What level of funding is best for science in New Zealand?
The real challenge is to accept that government-funding for science is a scarce resource, and therefore to be funded to undertake science research on behalf of the country is a privilege. George Whitesides, a professor of chemistry, wrote in the *Economist* that we are seeing the emergence of cost-conscious science, what he calls frugal science. Frugal science is designed to 'generate knowledge (and technology based on knowledge) with costs as an integral part of the subject' (Whitesides, 2011). Filters are necessary to ensure New Zealand invests its scarce resources well.

Funding has been identified as a key enabler in the science system. However, the issue of science funding presents a complex problem split between two core concerns: the amount per capita (see Figure 12) and the amount of appropriation (see Figure 13). Total funding levels provide a useful indication of government investment priorities and broader science capacity building. However, funding levels alone do not paint an adequate picture of how funding relates to the system-wide strategic framework. The current investment priorities have shifted towards areas with a stronger economic focus. This is understandable in today's constrained financial environment, but it does not address what many consider to be a significant limitation in New Zealand's science and innovation system – an underfunding of research in comparison with international levels. This applies to both publicly funded and private sector R&D; 'In New Zealand, a better balance needs to be struck between the two types of funding to encourage the long-term efforts which its funders wish to support' (OECD, 2007a: 19). See also Figure 23.

Disaggregated and complex funding arrangements remain a major weakness in our country's science funding system. This situation results from the continual evolution of the wider system, which has led to the creation of a labyrinth of output classes, initiatives and funds. Determining a single figure for the number of funds to which scientists can apply was difficult. In 2010 the Institute estimated that there were 42 different funding sources to which applications could be made.[120] For small research providers, keeping track of the relevant output classes and bidding avenues is a difficult job that requires a level of

119 New Zealand's submission to the United Nations Commission on the Limits of the Continental Shelf to extend New Zealand's seabed was a result of a ten year project costing an estimated $44m. The submission was followed by a two year period of consultation and stakeholder engagement , meaning that twelve years had passed before achieving a successful outcome. Much of the scientific evidence that supported the project came from NIWA and GNS Science, indicating the extent to which a twelve year project needs stable, long-term financial support to ensure knowledge and expertise is developed and retained over the length of such projects (MFAT, 2012).

120 The 42 funds were identified from MoRST output expenses, FRST portfolios, the Royal Society-administered Marsden Fund, Fulbright research scholarships and Health Research Council of New Zealand research categories.

human resources that is not often available. The New Zealand Association of Scientists identified the complex FRST funding system as a key weakness of the former government-funded science system, describing it as a ‘fragmented, complicated, changeable, and jargon-ridden bureaucracy’ (NZAS, 2008). In order to improve the system there needs to be a high level of clarity from government concerning how the funds are delivered and the results measured.

Question 19: What method of funding is best for science, contestable or core funding?

Universities and CRIs, which have similar research capabilities and should collaborate as much as possible, have found themselves pitted against one another, competing for scarce funds through Vote RS&T and conducting research in isolation (MoRST & CCMAU, 2002: 30). The result has been a competitive race for funding in which all CRIs have noted feeling underfunded (ibid.: 29). Some analysts have gone as far as to speak of a new ‘cold war’ between CRIs and universities (Gorman, 2007).

The government has recognised that the proportion of contestable funding in New Zealand’s science-funding system is too high and that CRIs have been too focused on commercial returns rather than the economic benefit of their activities to New Zealand (MoRST, 2010a: 7–8). MoRST identified a range of funding tools to alleviate the problems of contestability and competition, which included support for investigator-initiated excellent research, science-led contestable funding, long-term non-contestable funding, and partnerships between research providers and research users involving co-funding (for further details on these initiatives see MoRST, 2010a).

9.4 Strategic Questions for Universities

Question 20: How can New Zealand’s decline in international university rankings be addressed?
Question 21: How can New Zealand ensure the best university researchers are collaborating effectively?
Question 22: Do adequate incentives exist to encourage excellence in teaching within universities, polytechnics and wānanga?
Question 23: Are there adequate incentives for post-doctoral researchers to stay and build their careers in New Zealand?

Question 20: How can New Zealand’s decline in international university rankings be addressed?

The declining ranking of New Zealand’s universities (see SFI, 2011d: 13) has widespread implications for individual universities, the broader science system and New Zealand’s economy. If New Zealand hopes to encourage the best research talent and the best local and international students to study here, the decline in our universities’ international rankings needs to be addressed. While international benchmarking is subject to some criticism, rankings have become important considerations for prospective staff and students. The general decline across disciplines by almost all New Zealand universities may affect their ability to recruit and retain the best students, researchers and teachers. It should be noted that in addressing declining rankings, universities need to be careful not to over-emphasise research activity to the detriment of teaching quality. In a university where resources are already stretched, there may be a temptation to focus heavily on research to remedy poor international rankings. If this leads to a reallocation of resources from teaching to research, it may be detrimental to the future of our university sector, science system, and wider society.

The government needs to recognise the central role universities play in New Zealand’s science system and their significance to New Zealand’s wider economy, and acknowledge this through the provision of adequate funding. Without sufficient investment, New Zealand universities are likely to remain stretched, quality and output will continue to decrease, and declining international rankings will continue.

Question 21: How can New Zealand ensure the best university researchers are collaborating effectively?

With New Zealand universities experiencing persistent downward trends in global rankings and concerns about levels of investment, questions arise as to their future role and structure. As each university diversifies and attempts to expand into new fields, resources and talent become less concentrated. Until 1962, all New

Zealand universities came under the umbrella of the University of New Zealand. However, as of 2011, there are now eight universities teaching similar courses across a relatively small geographical space and competing for students, staff and funding. There could be merit in specialisation within the wider university system to allow for greater concentration of skill and expertise at particular universities and to reduce contestability. Further, costs could be decreased by mergers, reducing the number of universities and campuses in favour of more on-line education facilities.

Question 22: Do adequate incentives exist to encourage excellence in teaching within universities, polytechnics and wānanga?

The Performance Based Research Fund (PBRF) aims to ensure that excellent research in the tertiary education sector is encouraged and rewarded. This reflects a global trend of governments using performance based funding to allocate resources for research within higher education institutions (Smart, 2009).

There are significant financial gains for a university in having high-performing researchers on its staff, meaning this funding model can result in a 'reallocation of academics' time between teaching and research' (Smart, 2005: 12). It is questionable whether, in light of the pressures on staff to produce a high level of research output for both the purpose of the PBRF and international rankings, there are sufficient incentives for excellence in teaching.

New Zealand currently has a number of National Centre for Tertiary Teaching Excellence awards that aim to recognise and encourage excellence in tertiary teaching and reward teaching practices that are student-focused and committed to promoting effective learning (Ako Aotearoa, 2011). However, these may not be sufficiently recognised or sought after in the same way as high PBRF rankings. Excellence in teaching is therefore at risk of remaining inadequately incentivised. Further incentives in this area are essential if New Zealand wants to inspire learning and produce future talent within the tertiary education system. New Zealand may benefit by learning from successful initiatives overseas which have improved the quality of teaching in universities.

Question 23: Are there adequate incentives for post-doctoral researchers to stay and build their careers in New Zealand?

Providing adequate support for researchers early in their careers, and incentivising researchers to stay in New Zealand, is essential to maintaining a strong and stable scientific workforce. The availability of scholarships for postdoctoral research in New Zealand has recently attracted criticism. In 2010, FRST's New Zealand Science and Technology postdoctoral scheme was disestablished and replaced by the Rutherford Discovery Fellowships. The former scheme provided a bridge for scientists who had recently completed a doctorate and were moving into permanent employment. In an open letter to key members of the science community,[121] 560 scientists expressed their concern about the discontinuation of the FRST-funded Postdoctoral Fellowships and the establishment of the Rutherford Discovery Fellowships. They stated that 'the lack of postdoctoral opportunities for the vast majority of New Zealand early career researchers adds to the "brain drain"' (Massaro, 2011). Further, they argued that instead of creating new opportunities for early to mid-career researchers, currently on fixed-term contracts and in need of employment to exercise their research skills, the Rutherford Discovery Fellowships simply provide an 'additional boost [to] a select few researchers, most of whom already have permanent positions in New Zealand research institutes' (ibid.). The result is that the new scheme fails to incentivise early to mid-career researchers to stay in New Zealand and thus fails to achieve its stated objective.

Shaun Hendy, a former FRST Postdoctoral Fellow who is currently Deputy Director of the MacDiarmid Institute for Advanced Materials and Nanotechnology, voiced a similar objection, describing the change as counterproductive and failing to support new, up-and-coming talent in New Zealand. Hendy states:

121 The letter was addressed to the Minister of Science and Innovation, the Prime Minister's Chief Science Advisor, the Chief Executive of the Royal Society of New Zealand, the Chief Executive of MSI, the Royal Society of New Zealand, the Tertiary Education Commission, the Selections Committee of the Rutherford Discovery Fellowships and Science New Zealand.

> [Along] with the axing last year of the Bright Futures Top Achievers Scholarships, New Zealand has backed away considerably from the support of our best and our brightest during their early development as scientists. I struggle to see the justification for this in a country where we are increasingly going to have to rely on developing and retaining talented individuals … While I strongly acknowledge the need for the Discovery Fellowships, I am very disappointed at the loss of the NZ S&T Post-Doctoral Fellowships. New Zealand needs both. (Hendy, 2010)

To remain globally competitive and retain top talent, New Zealand needs to provide adequate support for scientists early in their careers, or risk losing them to countries where lucrative scholarships are readily available. In its 2011 *Statement of Intent*, MSI sets out its intention to undertake a full review of the Rutherford Discovery Fellowship scheme before December 2012; however, in response to these concerns from within the research sector, the Ministry announced it would be bringing the review forward (MSI, 2011i).

9.5 Strategic Questions for the Science Community

Question 24: What impact will a reduction in contestable funding have on independent research organisations?
Question 25: How can we increase collaboration between research institutions?
Question 26: How can we improve linkages between businesses and research institutions?
Question 27: How can the public be confident that a Code of Ethics is being applied?
Question 28: What is the optimal composition of the science workforce?
Question 29: How can we promote science as an appealing career path for students?
Question 30: How can foresight be embedded in central government?

Question 24: What impact will a reduction in contestable funding have on independent research organisations?

A large amount of funding for CRIs has moved from short-term contestable funding to long-term core funding. However, reducing the pool of contestable funding may detrimentally affect the funds available to independent research organisations. Gillian Wratt, chair of the Independent Research Association of New Zealand (IRANZ), expressed the organisation's concern to the CRI Taskforce (CRIT), stating: 'Long-term capability needs are an issue across the whole science sector. The present administration of the Capability Fund benefits the CRIs at the expense of other research organisations. This is particularly so when investment is diverted from contestable funding portfolios to the Capability Fund' (IRANZ, 2009). IRANZ suggested that the Capability Fund be 'open to a broader range of "accredited" providers of public good science. In addition to building and supporting capability, the fund should be designed to promote collaboration and stakeholder involvement' (ibid.). However, this was not a recommendation of the Taskforce, and core funding has not been expanded to a broader range of providers. The Institute believes that independent research organisations have a key role to play in New Zealand's science system and could be supported through greater levels of collaboration and alternative means of funding.

Question 25: How can we increase collaboration between research institutions?

A key focus of the 2009 CRI Taskforce report was improving collaboration between CRIs and the wider science system, i.e. universities and business. Core funding was established for CRIs in 2011, consolidating CRI capability funding and some contracts held by CRIs in areas such as the biological industries, environment and hazards, and infrastructure (SMC, 2011). This should result in more time and flexibility for work on nationally important programmes and reduced contestability within the system, which aligns with another key recommendation of the CRI Taskforce.

However, with the establishment of core funding, there is a risk that CRIs will not be held accountable for their actions (see Question 17). Collaboration needs to be incentivised and encouraged, and the Institute has concerns around how the new system will achieve this. Kate Kilkenny, Executive Advisor at the Independent Research Association of New Zealand, expressed similar concerns, stating: 'If the funding systems are to be less contestable in favour of more core funding to CRIs, then it is essential that CRIs have clear consistent direction for collaboration behaviours and the use of core funding to support it' (Kilkenny, 2010).

Question 26: How can we improve linkages between businesses and research institutions?

Statistics New Zealand and MSI, through the 2010 survey on *Research and Development in New Zealand* have consulted with businesses on the type of engagement they have with universities and CRIs. The survey asked businesses for the first time about their engagement with universities and CRIs concerning their R&D needs. They found that of the businesses that documented expenditure in the area of R&D, '29% reported that they had engaged with CRIs or universities in New Zealand about their R&D needs over the past two years'. This was most commonly in the form of professional contact between staff (Statistics New Zealand, 2011b: 39).

The survey found 65% of respondents had not engaged with CRIs or universities. Asked why this was, the common response was that CRI or university staff expertise was not needed. Other reasons included: not being aware of how to make contact with CRIs or universities; CRIs' or universities' costs being too high; CRIs or universities not having the expertise required, and contractual difficulties (ibid.: 39–40). This kind of reporting is useful in assessing the reality of engagement and collaboration, and in learning more about what works and what does not.[122] Future surveys and reporting will be critical in determining whether the recent changes to the science system have improved linkages with business.

Question 27: How can the public be confident that a Code of Ethics is being applied?

Creating an effective professional standards and accountability framework that ensures transparency and maximum disclosure of interests, within a science community that is relatively small and highly interconnected, is a major challenge for New Zealand. There is scope for the Royal Society of New Zealand to take a stronger role in upholding professional standards and ensuring international best practice in the science sector. The Royal Society's code of ethics aims to facilitate best practice but questions remain around how standards and ethics are currently policed and can be assured throughout the science system. One option could be to make Royal Society membership compulsory for all scientists either employed by the government or receiving investment funds. Alternatively, the government could develop a separate code of ethics for all scientists operating within the government-funded system. MSI and the Royal Society should be actively encouraging a culture within the profession that recognises the rights and responsibilities inherent in the pursuit of government-funded science, and how these responsibilities are framed, actioned and policed is an important consideration. This issue is further discussed in Section 10.2(4).

Question 28: What is the optimal composition of the science workforce?

A strong workforce of scientists was identified as a key enabler in Section 7.3.2. The scientific community faces a number of challenges, five of which are outlined briefly below.

(a) An ageing workforce

A performance audit report on workforce planning in CRIs found that the ageing workforce, along with related issues regarding recruitment, retention and capacity-building of staff, will continue to be a significant strategic issue in the future (OAG, 2009: 3). While these issues were recognised by all CRIs, few had comprehensive workforce planning in place or included this within their strategic direction.

(b) Increasing international demand

International demand for scientists is increasing. Professor Jacqueline Rowarth explains the implications for New Zealand's economy as a result of the low recruitment of scientists as follows:

> … a global shortfall in scientists and engineers in the next decade has been predicted. The data suggest that New Zealand will not have the human capital it needs to drive the economic development desired. (Rowarth et al., 2006: 5)

122 The Technology Transfer Vouchers and Technology Development Grants (MSI, 2011j) are the latest attempts to improve business R&D performance. Industrial Research Ltd's (IRL) competition in 2009, 'What's your problem New Zealand?' also aimed to help businesses consider how they can be assisted by research organisations (IRL, 2009).

(c) Low satisfaction

In the 2009 paper, *Doing Science in a Culture of Accountability* (Hunt, 2009), Dr Lesley Hunt addresses the attitudes of scientists working at CRIs in New Zealand. Hunt's study found that there was a high level of cynicism, a distrust of management, and an 'us vs them' attitude (Renwick, 2011). The study suggests that 'while the CRI Taskforce made some progress, there are more fundamental issues that still need to be dealt with if New Zealand is going to get the most out of the science workforce (the CRI sector, at least)' (ibid.).

(d) Low number of women in science

The report *Women in Science: A 2011 snapshot,* prepared by the Association for Women in the Sciences, produced the following key findings:

- When science is compulsory at school, female students do well across the board but routinely choose the biological sciences above physics or chemistry when given the option.
- Women with a BSc or PhD earn $30,000 less on average than men with the same qualification level, due to an over-representation in lower paid jobs.
- Women are still under-represented at higher levels of University employment (Professor/Associate Professor/Senior Lecturer) although they are gaining ground at lower levels.
- Women are also under-represented at the level of decision making and funding allocation.
- Women scientists are not gaining the same degree of recognition as males with few awarded the top prizes in New Zealand science (AWIS, 2011).[123]

(e) Reluctance to commercialise innovation

A 2009 study by the University of Canterbury's Department of Economics titled *Innovation in New Zealand: Issues of firm size, local market size and economic geography* found that while New Zealand has strong institutional characteristics that enable entrepreneurship, this is not translated into high performance in terms of innovation. Three key attributes were found to be impeding this transition: small firm size, small market size, and our degree of geographical isolation (Shangqin et al., 2009: 21).

The optimal composition of the workforce must take into account emerging trends and what we want the system to deliver New Zealand.

Question 29: How can we promote science as an appealing career path for students?

There seems little doubt that there needs to be a clear and exciting career path if we wish to improve the quality of science generated in New Zealand. However, there is little agreement as to how to make this happen. When reading the literature and then reflecting on how other industries develop conceptual thinking and reward best practice, it became apparent that there are no milestones when a person moves from being a PhD graduate to being recognised as a scientist. It is as though ten or so years after completing your PhD you wake up one day and you are a scientist. Although understandable, this approach is not likely to motivate our goal-oriented youth, promote science as a career or create a sense of community.

Other sectors create industry standards through membership of professional bodies, which often includes a contract to apply standards of best practice. Once an individual has gained their academic qualifications they need to undertake a time to learn best practice and only then, apply for the right to be called a professional, e.g. charted accountant or a patent attorney.[124] Further, the role of purposeful practice is gaining traction in literature. As noted in Section 5.1.11, studies of talent have shown that it is practice, not intelligence, that holds the key to success and we need to not only create milestones for students, so they know what traits it takes to be a good scientist, but a system that demands that they gain purposeful practice towards these milestones.

In his book *Bounce: How champions are made*, Matthew Syed discusses the myth of talent and the power of practice. Syed discusses the work of Anne Roe, a psychologist at the University of Arizona, who

123 In 2011 Professor Christine Winterbourn was awarded the Royal Society of New Zealand's top science honour – the Rutherford Medal. She is the first woman to win the medal in its 20-year history (RSNZ, 2011a).

124 For example, the New Zealand Institute of Patent Attorneys (NZIPA) is an incorporated body that represents most patent attorneys who are registered under the Patents Act 1953, and who are resident and practising in New Zealand. The Institute is governed by its own set of rules and a Code of Professional Conduct to ensure its members maintain a consistently high standard of professionalism at all times (NZIPA, n.d.).

concluded that ‘scientific creativity is a function of how hard you work at it’ (Syed, 2010: 92). If this is correct, then it is practice, not intelligence, that is the key to success. Therefore we need to create not only milestones for students, so they know what traits it takes to be a good scientist, but a system that demands that they gain purposeful practice towards those milestones. It would not be difficult for the Royal Society of New Zealand to create a professional body within its current structure that managed this process, defined milestones and established ways for purposeful practice to be achieved. Such an approach would not only benefit those at the beginning of their careers, but would ensure that experienced scientists had a vehicle for passing on their expertise, as such building on past knowledge for future generations.

Question 30: How can foresight be embedded in central government?

One would expect that the thinking underlying New Zealand’s critical government-funded science strategy is built on a sound understanding of a range of possible future worlds within which New Zealand may find itself existing. A good strategy should provide a clear pathway; it should set out a point in time today and a point in time in the future, and set out the steps that will be necessary to get us there. This means the vision should not be framed in today’s world, but for the world we will find ourselves living and working in, at a specific time in the future. This is important because we know from experience that science capability takes a long time to shape and build, therefore our strategy should aim to build the capacity New Zealand will need in a time in the future, say 2030, not what we think we need today.

Foresight must be embedded in the intersection between the Prime Minister and the Public Service, namely the DPMC. The case study on Singapore in Appendix 4 provides a useful example of how this can be done. Singapore embedded foresight by focusing on three core components; scenario work (the Strategic Policy Office), the identification and application of a number of futures tools (Risk Assessment and Horizon Planning) and the integration of those tools and information between the Prime Minister’s Office and the Public Service (the Centre for Strategic Futures). The Strategic Policy Office (SPO), which includes the Centre for Strategic Futures (CSF), aims to create a forward-looking Public Service by developing strategic planning capabilities across the Public Service in order to shape whole-of-government policy to manage challenges in an increasingly complex environment. We consider this to be a highly compelling model.

New Zealand needs to become an intelligent country (see Section 4.2), one able to identify and respond quickly to emerging challenges and opportunities. Foresight is the mechanism that will bring science policy to the fore, both in terms of informing policy and informing science.

9.6 Implications for the Future

The questions above range from addressing broad areas of tension within the science in New Zealand to specific incentive models for teaching and research. Not all these questions are able to be answered, and certainly all are beyond the scope of this report to address fully. However, they represent gaps in a science strategy that policy-makers must address and resolve to develop a robust science system. These questions aim to test the assumptions underlying the current institutional framework and examine the system linkages that are purported to deliver the desired outcomes in the future.

The policy knots listed above are not exclusive to New Zealand. Many countries are reassessing the way that government invests in science and are looking at ways to embrace science through creating a government-funded science system that delivers genuine value. Appendix 4 provides a brief overview of the experience of the Singapore government. This discussion is not intended to be a comprehensive description or assessment of Singapore’s policy initiatives; rather it aims to show that there exist common policy knots and a range of diverse approaches to these policy knots. More detailed research should be undertaken so that evidence-based conclusions can be drawn concerning which approach works best for New Zealand. In order to compare countries, future research should focus on questions such as who decides on the research agenda, who decides on the ethics, who defines well-being and who assesses the consequences?

10. The Optimal Government-funded Science System for New Zealand

The consolidation of the two organisations responsible for science policy and purchase, MoRST and FRST, into the Ministry of Science and Innovation, resulted in significant structural change. However, the government-funded science strategy remained relatively unchanged (see Table 3 in Section 3.4). The amalgamation of the two agencies constituted an internal restructure that was designed to reduce complexity and transaction costs, but evidence of a comprehensive strategic plan for maximising public investment in science is yet to emerge. While institutional change is capable of delivering increased efficiency and effectiveness, strategic change is needed if the aim is to produce different outcomes.

Further, in undertaking this report it was initially difficult to find a pathway forward. This was due to a number of normative assumptions about government-funded science that have been built into the system, many of which were found to be wrong or had been incorrectly applied in the current system. These inaccuracies were often not apparent when we began our research, and have only become clear as a result of examining the system closely. We begin this section by identifying the incorrect beliefs underlying the current system, what are often referred to in future studies as the 'unconscious myths that support the entire framework' (Inayatullah, 2000).[125] These myths lead to a number of implications that need to be considered before a new improved system can be designed. The section then revisits the nine pillars and closes with 10 recommendations for science policy.

10.1 Myths Underlying Current Government-funded Science

Like any area of research, a number of beliefs underpin the government-funded science system. Beliefs are essentially the underlying assumptions we hold to be true about the world in which we live. They inform the way we think and the way we act, therefore it is important to regularly test our assumptions against the evidence and ensure we are justified in our beliefs. Incorrect assumptions and misinformed beliefs are important not only because they lead to wrong decisions, but also as our beliefs inform our values and those values drive our actions. Therefore, in order to strengthen or change a system, it is critically important to identify, test and assess existing beliefs to ensure that no unjustified beliefs are embedded in and underpin the science system. These dangerous beliefs are often referred to in the literature as myths. Much of science theory is based on scrutinising the dominant beliefs to assess whether dominant myths exist.

In preparing this report, it became apparent that at least four myths exist (see Table 6, column one), each one problematic in that they are likely to incorrectly inform decisions about public policy, and science and innovation investment. Table 6 also lists myths identified in Australia and Sweden as points of comparison.

125 Dr Sohail Inayatullah, a Professor of Political Science at the Tamkang University in Taipei, refers to this methodology as causal layered analysis. 'In this approach there are four overlapping levels of reality – the day to day visible and objective; the systemic i.e. the parts that comprise the issue; the worldview or the interests and perspectives of stakeholders and finally the underlying often unconscious myths that support the entire framework.' (Inayatullah, 2000)

Table 6: Potential Myths: New Zealand, Australia and Sweden

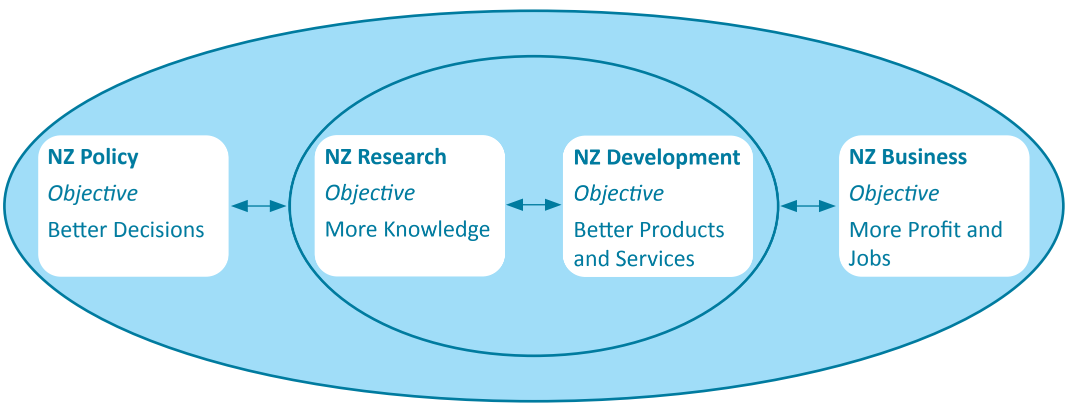
	New Zealand	Australia (Harris et al, 2011: 9-14)	Sweden (Granberg et al, 2006: 322)
Myth 1	More New Zealand research leads to more New Zealand development.	More science and technology will necessarily lead to more public good. Any new knowledge is helpful.	Sweden is an outstanding nation in terms of its (relative) volume of academic research.
Myth 2	New Zealand research informs New Zealand public policy.	Because the benefits of science are unpredictable, we should not attempt to steer science in a particular direction.	The direction of academic research is predominantly, and increasingly, controlled by researchers rather than by potential users.
Myth 3	Science ethics are embedded in science practice.	Scientific information provides an objective basis for resolving political disputes.	There is a conflict between the support of research controlled by researchers and the promotion of innovation and economic growth; to make policy more consistent, a larger share of academic research needs to be directed by potential users.
Myth 4	'Innovation' is a useful term to drive the government-funded science system.	Metrics of scientific quality (for example, peer review, journal citations) are sufficient indication of worthwhile investments.	There is a distance, or gap, between academic researchers and industry/ society at large, in part due to a poor attitude towards commercialisation.

Note: The four New Zealand myths discussed in Table 6 were identified by the authors as a result of preparing this report; hence they came directly from researching the New Zealand system. It was only in retrospect that it was decided to extend this section and include potential myths from other countries. The myths are cited in the order they appear in their respective papers, there is no relevance to reading this table horizontally. That in all three cases there are four myths is simply a matter of coincidence. Further research and analysis would be beneficial, both in terms of testing these four myths, examining other myths and then comparing these with potential myths in other countries.

Myth 1: More New Zealand research leads to more New Zealand development

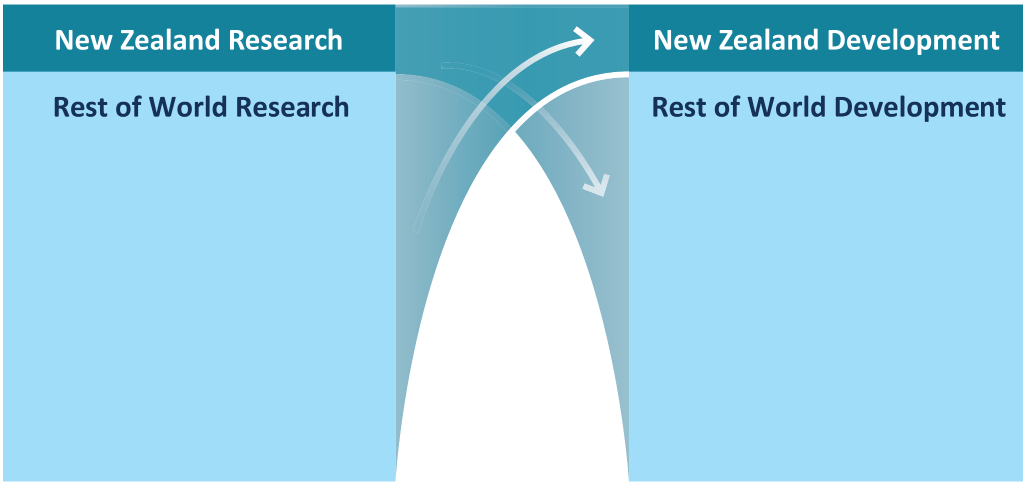
There is an assumed causal relationship between the research undertaken in New Zealand and new products and services developed in New Zealand. On this basis there is a belief that these two types of activities need to be managed by the same people. Figure 32 assumes this model.

Figure 32: The Assumed Relationship Between Policy, Research, Development and Business



Instead, research undertaken in New Zealand feeds into a global pool of research and New Zealand draws on that global pool to develop new products and services, as depicted in Figure 33. See also Figure 35, where the implications are fully explored.

Figure 33: The Actual Relationship Between New Zealand Research and New Zealand Development



Myth 2: New Zealand research informs New Zealand public policy

The second myth is that government-funded research informs public policy. Gluckman, in his paper *Towards Better Use of Evidence in Policy Formations*, draws a distinction between 'policy that informs science' and 'science that informs policy'. Gluckman believes there needs to be a stronger link between policy and research so that those who provide information to decision-makers do so based on evidence. He sees 'advice on science for policy' as a major theme of his office in coming years (OPMSAC, 2011c: 2).

In the literature we found little evidence that a strong causal link currently exists for 'science for policy' in New Zealand. For example, Dr William Smith from the University of Auckland undertook a study to analyse and discuss the extent to which decision-making by government in key areas of policy is supported by effective research, and scientific and technical input. The study examined 306 papers submitted in 1997 to either the Cabinet Committee on Education and Employment Policy (EEP) or the Cabinet Committee on Industry and Environment (CIE). Smith found that approximately 50% of the papers could reasonably have been expected to have included some research, but only 28% had some evidence of this research. MoRST had only been consulted on 7% of the papers (Smith, 1998: 1).

In recent years, examples of where research has significantly informed policy have tended to be situations where the research was sought directly by Cabinet,[126] rather than through the normal channels in the government-funded science system. So although we tend to believe that science does contribute to policy, the evidence is that this is more myth than reality.

Myth 3: Science ethics are embedded in science practice

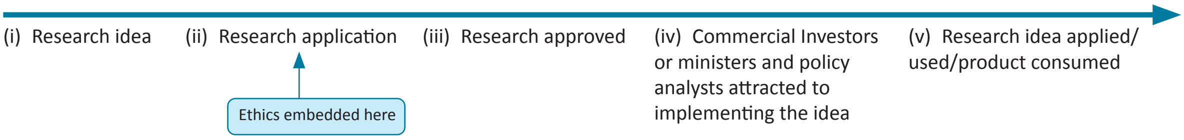
The third myth is that ethical frameworks are built into science practice as it is developed rather than as it is commercialised. As a profession, the science community is generally responsive to changes after the fact.

Ethical policies should be designed with the future in mind; too often in the past ethics have been developed after the practice has been developed, when many stakeholders have a vested interest. Examples where ethics and business practices have collided include tobacco, automobile safety rules, food safety, genetic testing, GM food and body-enhancing drugs. Future areas of ethics that we should

126 Examples include Cabinet's establishment of the Office of the Prime Minister's Science Advisory Committee and the Welfare Working Group. Recent reports include *Improving the transition: reducing social and psychological morbidity during adolescence* (OPMSAC, 2011a) and *Reducing Long-Term Benefit Dependency* (Welfare Working Group, 2011). The working group was established to undertake an expansive and fundamental review of New Zealand's welfare system. Its primary task was to identify how to reduce long-term welfare dependency, and it presented its recommendations to the government on 22 February 2011 (ibid.).

be considering now include potential new products and services such as brain-enhancing drugs and chips, nanotechnology,[127] robots, climate engineering and cloning. Science ethics tend to follow science practice, and as such the reflective thinking is done after the discovery and after commercial interests have engaged in the process. Ideally ethics need to inform commercialisation, which means ethics need to be considered alongside the creative process and be embedded early, for example in the funding application process for emerging issues, as indicated in Figure 34 below.

Figure 34 Continuum that Explores Where Ethics are Embedded



Myth 4: 'Innovation' is a useful term to drive the government-funded science system

Sir Charles Fleming, New Zealand ornithologist, avian palaeontologist and environmentalist, once stated that 'language is primary, and science would be inarticulate without the tool of language' (Fleming, cited in Catley, 2006: 54). Section 2.2.2 discussed the challenges of the language around science, and highlighted concerns over the distinction between invention and innovation. Globally, the term 'innovation' is frequently used in regard to science (for example by the OECD), however the reality is that innovation means far too many things to too many people; it is not easy to define, highly fashionable, and is frequently used outside of science. For example, the national airline, Air New Zealand, has consistently won international awards for its innovative approach – the airline's innovations to date are both numerous and varied, including technical engineering, seating arrangements, ticketing deals, chef-designed menus, customer service and marketing.[128] These are clearly all innovations, but are they all science? Weta Workshop is another example of a company known for its innovations, in this case in computer generated imagery and film production – but are all these innovations science?[129] Science is too important to be confused with other aspects of enterprise. The terms used to drive and debate science must be articulate and able to be understood by all.

10.2 Recalibrating the System

Identifying the myths that underlie the current system clears the way to think more deeply about what we now know about the current science environment. Below we briefly discuss what we know in terms of observations and suggestions worth exploring to improve the system.

1. Tensions exist, so trade-offs necessary

The international literature provides little evidence of an optimal model for a science system, but it is clear that a wide range of tensions exist. Moreover, to some degree these tensions have always existed, and they are likely to continue to exist into the future. Hence designing an optimal government-funded science system for New Zealand recognises that it will be impossible for all stakeholders' needs and wants to be met. Table 7 below lists a number of tensions that have been identified through reviewing the literature and as a result of discussions with external reviewers.

127 For example the National Nanotechnology Institute sets out in its strategic plan four objectives, of which the fourth is to support the responsible development of nanotechnology (NNI, n.d.).

128 '[Air Transport World's Airline of the Year] award means that in the eyes of the judges, Air New Zealand was the best airline in the world in the past twelve months. They praised Air New Zealand's "industry-leading innovation and motivation of its staff", which they said resulted in exceptional performance across the airline in market position, customer service, fiscal management and operational safety. They described Air New Zealand as an industry trendsetter in a number of areas including product innovation and social media. Judges were also impressed with the airline's environmental initiatives including its commitment to operating a very young and highly fuel efficient fleet.' (NBR, 2012).

129 Weta Workshop uses a combination of traditional model-making techniques and the latest in model-making technology and equipment (including digital 3D scanning and milling, laser cutting, 3D printing and rapid-prototyping) and continues to be nominated for and win top awards; for example, *The Adventures Of Tintin* leads the Visual Effects Society Award Nominees (Cinema Blend, 2012).

Table 7: Tensions in the Government-funded Science System

Source: Adapted from United States Congress, Office of Technology Assessment, 1991

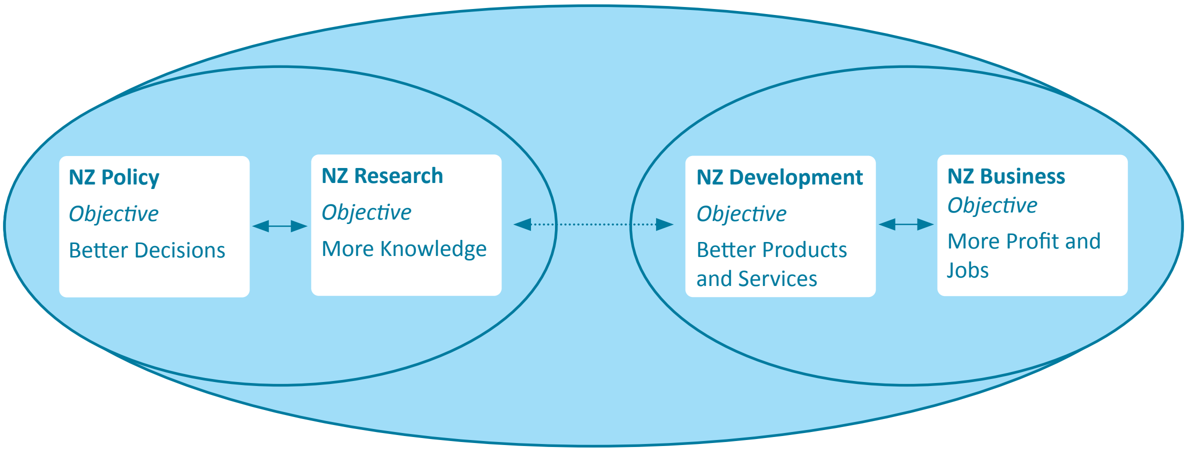
Central research planning and decision-making	⟷	Decentralised research planning and decision-making
Centralised infrastructure	⟷	Decentralised infrastructure
Political intervention (to shape the system, e.g. targeted by goal, programme, etc.)	⟷	Market forces (to shape the system)
Welfare model (government assisted)	⟷	Market model (user pays)
Focus on senior researchers	⟷	Focus on emerging researchers
Solving New Zealand-specific issues	⟷	Solving global issues
Dollars for inputs (research projects)	⟷	Dollars for outputs (facilities and medicine)
Needs of the public	⟷	Needs of scientists
Large-scale research teams	⟷	Many small research teams
Inventions (creation of new products and services)	⟷	Innovations (building on old products and services)
Short-term research	⟷	Long-term research
Training fewer researchers and reducing competition for funds	⟷	Training more researchers and increasing competition for funds
Problem-solving (applied science)	⟷	Mystery-solving (basic science)
Building solid career paths	⟷	Buying international expertise as and when needed
Non-commercial science	⟷	Commercial science
Outcome measures: wellness and profit	⟷	Output measures: patents and publications

Note: These tensions are listed in no specific order; the table simply recognises that a range of combinations and permutations exist. The role of good governance is to try first to align the model to the purpose, then to make all trade-offs transparent to all key stakeholders (in this case, this includes the public), with a view to inviting feedback and setting expectations.

2. Research and development are two separate activities

This discussion relates directly to Myth 1. New Zealand development is dependent on many factors, and is more a function of global research than New Zealand research. As noted above, research undertaken in New Zealand feeds into a global pool, and New Zealand draws on that global pool to develop new products and services. In addition, not all research is designed to inform development. Therefore the actual relationship between New Zealand research and New Zealand development is more accurately represented as two separate but interacting sub-systems, as shown in Figure 35. The dotted lines between the two sub-systems show that a relationship exists, but it is not a strong relationship.

Figure 35: The Actual Relationship Between Policy, Research, Development and Business



The implications of this reconceptualised model are significant. Rather than having one institution to manage both research and development, the model would be redesigned so that:

- **NZ Policy and NZ Research:** Ministers and policy analysts should set the research agenda by defining the information they need to drive policy, then create a system that helps researchers provide that information.[130]
- **NZ Development and NZ Business:** The business sector should scout the globe for interesting new products, services and research, and assesses how best to apply these new inventions or science innovations to create benefits such as profits, market share, and other improvements. There should also be a focus on developing a market in which independent research organisations are able to intersect effectively with businesses, universities and government.

Furthermore, this insight could lead to changes in the way government appropriates public funds to the science community. As noted in Section 1.2 and Appendix 3, the government currently groups appropriations into 10 high-level sector groups, and both research and development appropriations fall within the same sector, the Education and Science sector. Under this reconceptualised model, a more appropriate alignment would be to separate Vote S&I into two parts, retaining research under the current appropriation (Education and Science) as the pursuit of scientific knowledge aligns well with education, and moving development to the Economic Development or the Health sector.

The separation of funds between research (via the Science Board) and development (via the Innovation Board) is a step in the right direction. However, the two decision-making boards are unlikely to be as productive as would be the case if the development funds were allocated directly to entities such as MED, MoH, health boards, industry groups, and TradeNZ. This would allow a more market-led approach to research; if commercial organisations want research, it will purchase it from CRIs and other research providers, allowing the market to rule.

3. Research undertaken in New Zealand must inform public policy

This discussion relates directly to Myth 2. At the highest level, more investigation into government-funded research is needed. In other words, New Zealand needs to research the research: how is policy shaped in New Zealand; what research informed policy in the past (and what did not); was past research 'sound' (and if not why not); what research is needed to develop policy now; what research will be needed in the future and, most importantly, in what order should future research be undertaken? The model proposed in Figure 35 is designed to build a stronger relationship between sound research and effective policy so that government ministers and policy analysts would have access to research that meets their needs and enables them to make timely, accurate and relevant policy.

130 An Australian initiative working in this area is the Science Meets Policymakers conference held in February 2012. The conference was supported by government and encouraged participants to take a closer look at the intersection between the evidence base and policy processes and to work towards shaping a forward agenda between the research community and government (Australian National University, 2012).

Other initiatives also exist to help this process. Smith discusses a range of initiatives in his paper *Science into Policy: An evaluation of the use of science in policy formation.* He concludes that 'effective incorporation of research, science and technology into policy is conditional on who defines the policy problem and how the problem is defined' (Smith, 1998: 16). Smith suggests that there is a lack of an audit trail through to Cabinet paper level, and that improvements may be made by departments focusing on better ways to improve the policy advice process, so that they 'get ahead of the game'. He is not saying an audit trail does not exist, but that there is a lack of evidence that it exists, which aligns with Gluckman's comments quoted earlier. Smith also found that linkages tended to be informal, meaning services were provided by CRIs and others without being paid for and as such were not transparent. He suggests departments prepare their own strategy for policy research with assistance from the lead science body, in this case MSI. Some scientists also indicated a preference for a specific science and research tick-off to all Cabinet papers, and that there is scope to extend the current list beyond departments to include CRIs and other science bodies to explicitly acknowledge their role (ibid.: 14–16). It would be useful to repeat Smith's research today, to understand if the same weaknesses still exist.

A further observation is that 'science for policy' could be the focus of an eighth Sector Advisory Group, made up of 10–15 policy analysts from throughout the public sector. Together they would create a sector research investment plan, and define and explore the policy problem (for example, through a strategy mapping process as set out in Section 8.3). Smith notes, 'the success of any of the suggestions ultimately will rest on the promotion of a stronger research-science culture within the public service as a whole, and that in turn will be promoted or hindered by the creation of such a culture among the population at large' (ibid.: 16).

4. Ethics must be embedded early

This discussion relates directly to Myth 3. The Institute's research uncovered few examples of ethics being embedded early in the process; rather, there has been a tendency for ethics to follow commercial investments, delivering a situation where debate occurs after a financial stake in the outcome has been taken. When an ethical framework is created following a discovery and after commercial interests have engaged in the process, there is a risk that those with vested interests will lobby for the quickest pathway to commercialisation. Ethical frameworks and values must be developed before commercialisation occurs. This suggests that ethics should be considered and developed either before or during the research application process. Further, institutional bodies set up to consider and develop ethics must be more than simply an advisory body established by Cabinet Minute;[131] they must either have the right to make decisions or be required to report to a body that has both the right and the responsibility to make decisions over scientific and business practices. Otherwise the danger is that organisations such as ethics committees are simply seen as short-term mechanisms to allay public concern rather than contributing to best scientific practice and the long-term public good.

There are myriad ways in which ethics could be embedded in the government-funded science system. Options include:

i. Ensuring ethics are taught as part of a package of essential scientific skills at tertiary level.

ii. Requiring members to police ethics and requiring those scientists funded by government to join a society with a code of ethics (e.g. Royal Society of New Zealand).

iii. Requiring a multidisciplinary approach to education and government-funded research.[132]

iv. Establishing an independent Ethics Council with effective powers of oversight.

v. Requiring ethics to be built into funding applications.

131 For example, the Bioethics Council. The Council was an advisory body established as a Cabinet Minute in an ad hoc manner and therefore was not embraced by the profession or the industry. It is an example of how not to set up an ethics committee (see SFI, 2008c: 83-84). It was disestablished in 2009 (MfE, n.d.).

132 For example, the multidisciplinary approach applied by the Okinawa Institute of Science and Technology (OIST). This is an interdisciplinary graduate school offering a five-year PhD programme in science, in which researchers conduct multidisciplinary research in five major areas: Neuroscience, Molecular Sciences, Environmental and Ecological Sciences, and Physical Sciences (OIST, n.d.[b]). This kind of multidisciplinary approach could include ethics research and lead to a more holistic approach to scientific inquiry.

Global Science Community

Embedding ethics into science best practice will require both national and international co-operation as we increasingly come across challenges that have the ability to significantly disrupt and shape the world we live in. For example, the recent situation where the Chairman of the US National Science Advisory Board for Biosecurity recommended that research teams from Japan and the Netherlands be stopped from publishing the precise mutations needed to transform the H5N1 strain of birdflu virus into a human transmissible version is a case in point. As science becomes increasingly global, so must ethics. In this case, the researchers concerned have submitted their articles to the journals *Science* and *Nature*, although a 60-day moratorium on the publication of the research was declared to allay security fears (Connor, 2012; Meares, 2012). The only safeguard we have is creating robust and sound science communities that develop values and beliefs about the way they go about their business.

New Zealand Science Community

One way to embed ethics into the New Zealand science community is to review the membership organisation/s that support scientists to assess how they are servicing the community and if obstacles exist. Critical to creating a thriving and ethical community is scale. The membership community must represent a significant portion of the scientific community in order to be able to set and create a culture that polices professional standards. We do not have a final figure but the number of scientists and researchers working in New Zealand are likely to be between 20,000 and 30,000. Many other organisational membership societies already exist, for example, eight CRI organisations that have together established Science New Zealand. See Appendix 7 for a more detailed discussion on the membership organisations discussed below.

The oldest and best-known organisation relevant to this discussion is the Royal Society of New Zealand. It was set up by an Act in 1867, and in the current Act, the Royal Society of New Zealand Act 1997, s 6 states one of its key functions is 'to establish and administer for members a code of professional standards and ethics in science and technology'. The latest code was issued on 25 November 2010. Only members of the Royal Society of New Zealand must comply with the Code and members whose conduct is considered to be in breach of the Code will be asked to account to the society for their actions (RSNZ, 2010a: 3).

To this end, it was disappointing to find the Royal Society of New Zealand has about 1200 ordinary members and 374 elected Fellows.[133] The Royal Society of New Zealand believes it represents almost 20,000 scientists overall through organisational members. 1200 ordinary members out of a possible 20,000 to 30,000 does not reflect a significant portion. Therefore there is a potential 28,400 scientists not accountable to the RSNZ Code of Ethics. The Royal Society of New Zealand receives a significant amount of government funding, and efforts should be made to ensure that it effectively represents the interests of scientists in New Zealand. In addition, the large number of elected Fellows (374) in comparison to ordinary members (1200) may indicate some degree of institutional nepotism. This may explain why the more recently established New Zealand Association of Scientists already has 246 members. Based on the above, we make three suggestions below. By doing all three, not only will ethics be embedded early, but a science community will be developed, the voice of scientists will emerge and a strategy to embrace science can be unleashed.

a. The New Zealand science community should look more closely at its membership model with a view to removing organisational membership and establishing a society of only ordinary members with a mandatory Code of Ethics.

b. Every scientist or researcher that (i) receives government funds; (ii) is a public servant; or (iii) is employed by a Crown Research Institute must become a member of this society and therefore be accountable under its mandatory Code of Ethics.

133 The membership of the Royal Society is defined in s 9 of the Royal Society of New Zealand Act 1997, and states members consist of the following: (a) Fellows [374 members who are Fellows], (b) Ordinary Members [1163, including Professional, Honorary and Student members], (c) Companions [34], (d) Constituent Organisations [46], (e) Regional Constituent Organisations [9], (f) Affiliate Organisations that are members in accordance with section 15(2) [12], (g) Honorary Members [included in (b) above] and (h) Honorary Fellows [included in (a) above]. Figures in brackets were retrieved from the RSNZ website as at February 20, 2012.

c. An annual survey of ordinary members should be conducted in order to assess the current government-funded science system, gain a detailed understanding of the needs and wants of the science community and identify emerging issues. It is timely to research the researchers so that obstacles are removed; emerging issues identified and engaged with early, so that we can truly embrace science in the 21st century.

5. Public trust in science is fundamental to success

A social contract exists between the public and the science community, and the stronger the relationship between the two, the more likely it is to result in public good science that increases the well-being of New Zealanders now and in the long term. It is vital that the public have the space and opportunity to engage with scientists on areas of interest and that scientists are aware of their responsibilities to communicate effectively with the public.

6. Not all science is good science

Effective filters must be put in place to ensure the system delivers science that is robust and contributes to the well-being of New Zealanders. Underlying this is the need for a clear understanding of what 'well-being' means in this context.

7. A new language to drive science is necessary

As discussed in Section 2.2.2, 'science' is a broad term that can be used to cover everything. On its own it is not an action word that is able to be assessed or measured. In contrast, terms such as economic development and scientific inquiry refer to specific activity that has the ability to pull communities together to work on common goals. Stakeholders may therefore like to reconsider the primary language that is used to describe the overarching system, to ensure it resonates with the purpose of government-funded science.

It could be argued that the ministry overseeing the science system should not be named the Ministry of Science and Innovation, but instead the Ministry of Scientific Inquiry. The term 'scientific inquiry' immediately suggests a range of questions, such as what scientific inquiry, to solve what problem or issue, to be completed by whom, and for whose benefit? Scientific inquiry is something that can be measured, and therefore used to drive the system.

The use of the term 'innovation' in both the name of MSI and its vision ('to create a high-performing science and innovation system') is problematic. The observation has been made that the word innovation has 'become almost totally meaningless and the true "challenge of our time"' (Ries, 2011). Innovation is currently a fashionable word, rather as productivity was in the 1970s. Whereas the latter was about improving throughput, innovation is about anything that improves on an old idea (see Section 2.2.2). Innovation should not drive science unless it can be defined, because if we cannot define it we cannot measure it, and if we cannot measure it we cannot manage it.

8. Global demand for talent is on the rise

This assumption is generally accepted. New Zealand will need to undertake strong measures to attract, develop and retain world-class talent. The extent to which the New Zealand science system focuses on talent will be a major factor in its long-term success.

9. A culture of leadership is crucial

Critical to designing the optimal strategy is the necessity to create a culture of leadership that will sustain the strategy. This is particularly important given that the institutions within the science community are numerous, varied and not well-connected. This assumption builds on the stated purpose of MSI as the institution responsible for developing this culture (see Section 6). In the words of John P. Kotter, writing in the December 2001 edition of the *Harvard Business Review*:

> Just as we need more people to provide leadership in the complex organizations that dominate our world today, we also need more people to develop the cultures that would create that leadership. Institutionalizing a leadership-centered culture is the ultimate act of leadership. (Kotter, 2001: 33)

10.3 Revisiting the Nine Pillars

The previous section outlined misconceptions about the beliefs underpinning the current system and the implications of those in terms of recalibrating the system. This section reconsiders the nine pillars in terms of suggesting a way forward, and the findings are presented in a strategy map, see Figure 36.

Pillar 1. Mission: Why do we exist?

One way to answer the question of why government-funded science exists is to consider what would happen if public investment in science did not exist. Historically, much of the debate over investment in science has been about who gets what portion of the investment, rather than focusing on the problems New Zealanders need resolved and the benefits that science can deliver. Section 6 discusses the current mission and notes that it fails to acknowledge the nature of the investment, that it is long term, and as such calls for an intergenerational approach. We suggest that the mission – the reason for government-funded science – should be to improve the well-being of current and future generations of New Zealanders.

Pillar 2. Values: What is important to us?

A set of shared values is critical, particularly in times of restructuring. The shared values that drive relationships in MSI are a ‘work in progress’, with the Ministry undertaking to provide a set of values in the near future (MSI, 2011c: 27). This is an excellent initiative, and one that may have proved even more beneficial before the structural changes were instigated in 2010 and 2011. We suggest six values: to be honest (including reporting conflicts of interest);[134] to discover;[135] to serve; to sustain (current and future generations); to educate, and to be accountable (to be trustworthy, transparent, and provide assurance). These values are intended to set the context upon which high level principles can be agreed and actioned such as the precautionary principle.

Pillar 3. Vision: What do we want to be?

The current vision (to create a high-performing science and innovation system) is not a comprehensive or compelling vision for the future. It fails to describe a desirable ‘state’ that scientists will be prepared to work towards and the public will be prepared to support because of the benefits it will produce. There is also a concern over the terminology used in the vision. It assumes that all innovation is beneficial and that innovation is a goal in itself rather than simply a means to achieving the vision. We suggest the vision should be that science contributes to making New Zealand a sustainable nation; ensuring socially responsible economic development while protecting the resource base and the environment for the benefit of future generations.

Table 8: The Proposed Purpose of the Government-funded Science System

Mission	To improve the well-being of current and future generations of New Zealanders
Values	To be honest (including reporting conflicts of interest) To discover To serve To sustain (current and future generations) To educate To be accountable (to be trustworthy, transparent, and provide assurance)
Vision in the Year 2058	Science contributes to making New Zealand a sustainable nation

134 As New Zealand’s science system is small and integrated, individuals frequently find themselves in dual positions, hence the acknowledgement and the reporting of such conflicts is critical in order to ensure not only optimal decisions are made but are seen to be made.

135 One external reviewer considered this value was not useful and suggested in contrast ‘to be collaborative’, while another suggested this value should be more rigorous and suggested ‘to be seen to be free of conflicts of interest’.

Pillar 4. Strategic intent: How will we get there?

Since the proposed mission is to improve the well-being of current and future generations of New Zealanders, it is important to understand exactly what well-being means. Human Resources and Skills Development Canada (HRSDC) analyses well-being in terms of 10 different domains: learning, work, housing, family life, social participation, leisure, health, security, environment, and financial security (Policy Horizons Canada, in press: 5). While government-funded science has the potential to impact on all of these domains, some show a clear cause-and-effect relationship with scientific investment. Of the 10 domains listed above, four will deliver significant improvements as a result of science investment; learning, health, environment and financial security. This led us to the belief that the focus of the government-funded science system should be to deliver on four key areas. These key areas are discussed in turn below, drawing on some of the tensions shown in Table 7 (Section 10.2).

(i) To inform public policy

The government must have a clear view of what information is needed to make better decisions. There is little insight into how the current system might inform public policy or how the government might gain clarity over what the public needs from science. The exception is the paper by the Prime Minister's Chief Science Advisor, where advice on science for policy is seen 'as a major theme in coming years' (OPMSAC, 2011c: 2). Gluckman's paper invites a wide discussion as to how this might happen.

(ii) To improve the physical and mental health of New Zealanders

The system must be clear about the nature of the specific problems and then establish how best they might be addressed. Should the research dollar be spent on specific research, medicine, facilities or training? To what extent will the market model deliver the outcomes that are wanted and needed by society? To whom, when and where should the welfare model (welfare assistance) be adopted versus the market model where the user pays? In what order should the research take place? Hence, the resulting strategy should provide guidance to decision-makers and the public alike as to not only the nature of the research problems being investigated, but when research results can be expected. We believe the current system fails to gain the level of financial support and focus one would have expected. For example, although there is a Health Research Council, it does not report to MSI, nor is there a Crown Research Institute (CRI) that focuses on health, meaning research and development in health is at best on the periphery of the system.

(iii) To create more financial security for New Zealanders

Is the goal to create more jobs or to create more wealth? If the goal is to create more wealth, further tension is created if it is easier to create more extreme wealth in the hands of a few (inequality) versus more equal wealth in the hands of many (equality). Will the goal be achieved through exports by companies in the Top 200 or the work of SMEs? In each case the strategic objective needs to be clear at the outset in order to drive behaviour and for progress to be measured. Rather than referring directly to wealth creation, we believe the strategic intent should focus on making New Zealanders financially secure, with well-being assessed in terms of indicators such as savings, secure jobs, distribution of wealth, training, career paths, financial stability and sustainable growth over the long term.

(iv) To contribute to solving global problems

A recent trend has been the need and desire for countries to work together to contribute to solving global problems (see Sections 4 and 5). The tension in the optimal strategy arises where New Zealand-specific and global problems are not well aligned. New Zealand should ideally contribute expertise in areas where it has developed a high level of expertise, such as food production.

Pillar 5. Drivers: What will we focus on?

In 2009 MoRST identified six priority investment areas to drive the system (see Table 9 below). All six priority investment areas are very broad, arguably too broad to be useful. For example, it is very difficult to think of areas that would not be included under one of the six priority areas, raising the question of whether they are in fact priority areas at all, or simply divisions (see discussion in Section 8.3, in particular Porter's paper: *What is Strategy?*). Notably, only one of the six priority areas focuses on health.

Table 9 lists the four key areas the Institute believes might deliver more robust benefits, although in reality this exercise demands much more detailed research than has been undertaken here. The objective of Table 9 is to show a way to link the strategic intent to potential drivers. The aim is to guide policy analysts, researchers, investors and decision-makers and inform the general public as to what the system will focus on.

Table 9: Strategic Intent and the Six Priority Investment Areas

Six Priority Areas (as per the current system) / Four areas of Strategic Intent (as proposed by the Institute)	1. High-value manufacturing and services sector (HVMSS)	2. Biological Industries	3. Energy and minerals	4. Hazards and infrastructure	5. Environment	6. Health and society
i. To inform public policy	✓	✓	✓	✓	✓	✓
ii. To improve the physical and mental health of New Zealanders				✓	✓	✓
iii. To increase the financial security of New Zealanders	✓	✓	✓			
iv. To contribute to solving global problems				✓	✓	✓

Pillar 6. Enablers: What frameworks, resources and skills will we use?

Enablers implement the strategy, hence once the strategic intent and drivers are agreed, the next step is to clarify how each enabler will support the overall strategy. For more discussion on what this could look like, see the detailed discussion on each of the enablers in Section 7.3.

Pillar 7. Targets and initiatives: What will we need to do?

This report does not explore targets and initiatives in any detail, as this would not be useful until the strategic intent and drivers of the system have been agreed. However, Section 8.1 provides a brief outline of current initiatives that are likely to be further expanded when the strategy is developed by MSI. What we would strongly argue is that there needs to be a clear link between the purpose, the strategy and the targets and initiatives that are finally agreed.

Pillar 8. Performance indicators: How will we know we are successful?

Again, this report cannot explore the necessary performance indicators in any detail, as the earlier aspects of the strategy have not been confirmed. However, an extensive discussion of possible performance indicators is contained in Section 8.2, and these indicators are noted in Table 11 below.

Pillar 9. Strategy map: How will we test and communicate the strategy?

A strategy map aims to test and communicate the strategy. In testing the strategy the aim is to ensure that internal and external cohesion exists (see discussion in Section 8.3) while in communicating the strategy the aim is to ensure that all stakeholders understand how their actions contribute to its achievement.

Figure 36 shows the linkages that need to exist within a strategy to make it effective and efficient. It does not aim to be a full and final strategy, as this would require agreement over the strategic intent and drivers. Only after this agreement has been reached is it possible to add detail over how the enablers will make the strategy happen and how the targets and initiatives will act as instruments to drive change and measure performance. However, it does indicate why a strategy map is useful to both test and communicate strategy.

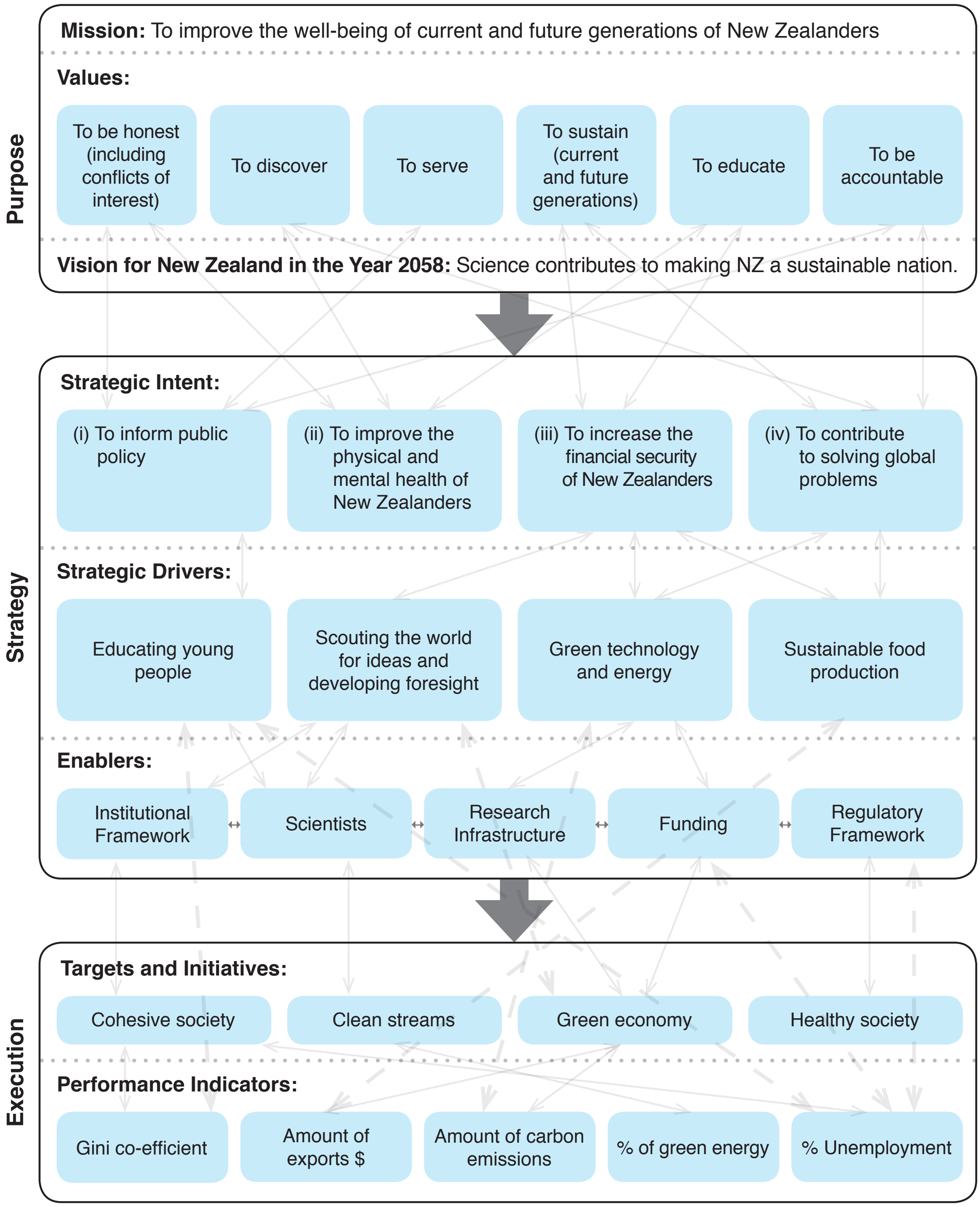
Table 10: The Proposed Strategy of the Government-funded Science System

Strategic Intent	(i) To inform public policy (ii) To improve the physical and mental health of New Zealanders (iii) To increase the financial security of New Zealanders (iv) To contribute to solving global problems
Strategic Drivers	(i) To inform **public policy** Focus on public policy that matters to New Zealanders; examples include health, wellbeing, education, welfare, social equity and diversity; water irrigation and fertiliser management; pest eradication; earthquakes (before, during and after); green energy; marine management, and science infrastructure. (ii) To improve the **physical and mental health** of New Zealanders Focus on managing and resolving child obesity, diabetes, rates of suicide, alcohol abuse and child abuse, which require specific research strategies to inform public investment and measure performance. (iii) To increase the **financial security** of New Zealanders Focus on providing a diverse range of niches that create long-term jobs and secure exports. (iv) To contribute to solving **global problems** Focus on support for Pacific neighbours, including climate science, food and water management, medical care and research. New Zealand could also be a repository for information on climate change, such as sea change and its impact in this part of the world, including Antarctica. Collaboration with Australia and others could lead to significant science infrastructure investments in areas such as telescopes, seed banks, and pandemic research.
Enablers	Institutional framework, scientists, research infrastructure, funding, and regulatory framework

Table 11: The Proposed Strategy Execution of the Government-funded Science System

Targets and Initiatives	Servicing the needs of the public, training scientists in scientific inquiry and ethics, reinforcing sound science, policing junk science, providing open data, open innovation, and foresight.
Performance Indicators	**Input monitoring:** Reporting on the government investment dollar, assessing the utilisation and life of science infrastructure, assessing the quality and quantity of scientists, following business research and development. **Process monitoring:** The cost of the research dollar. **Output monitoring:** The quality and quantity of publications, the quality and quantity of patents, and the commercialisation of science outputs. **Outcome monitoring:** Improvements in trust and improvements in well-being.
Strategy Map	Figure 36 is an example of a strategy map, bringing together the nine pillars mentioned above.

Figure 36: An Example of a Strategy Map for Government-funded Science



Note: This strategy map aims to show the internal cohesion within the strategy. The horizontal dotted lines show the horizontal integration between ideas, while the vertical lines indicate the linkages between the purpose and the execution. The dashed lines represent the high-level linkages between strategy and performance indicators. This map is provided for discussion and to show what a useful tool a strategy map can be. However it must also be assessed in terms of external cohesion and how it fits within the probable, possible and preferred futures. See discussion in Section 8.3.

10.4 Recommendations for Science Policy

This report seeks to contribute to a deeper discussion on science in society and the role of government in science. Countries that have significantly improved well-being through science have done so, not simply because of the level of funds invested, but because their governments' chose to think strategically. They used their investment as a lever to drive change, precisely and meticulously responding to the events around them. Developing a sound strategy for a dynamic and complex system is not easy, but intelligent countries do so through seeking engagement across government, policy analysts, scientists and researchers, and society. Their pathway to success is to identify feasible strategic options, select the best strategy, communicate that strategy and then implement and monitor progress – all with a view to optimising the public's investment in science. Critical to embracing science is to put sound and robust science at the intersection where scientists and society meet. This final section recommends ten actions that we believe together would propel the current system into action.

Foresight

Embedding foresight into central government has proven to be a critically important tool for shaping the government-funded science research agenda in Singapore. New Zealand would benefit from the establishment of a unit within the DPMC to increase the government's awareness and preparedness for the future. Such foresight will not only indicate where opportunities exist, but will dictate the type of research infrastructure New Zealand should be developing, the type of expertise required to drive this investment and the necessary regulatory frameworks required to manage risks and intellectual property.

Values and ethics

A set of shared values that are easily discoverable, understandable, and encourage engagement with the general public, are critical to ensure that trust is built on a stable and unifying framework. For this to happen there must be a 'will' by the profession and its employers to uphold and champion these values and to embed these shared values and ethics into their everyday practice. Figure 36 identifies the six values we believe are important. Ethical policies should be designed with the future in mind; too often in the past ethics have been developed after the practice has been developed, when many stakeholders have a vested interest. For example with increasing demands on resources, the Continental Shelf and Antarctica are areas where values and ethical practices need to be developed now for future exploration.

Well-being

MSI has stated its intention to contribute to the well-being of New Zealanders. Developing a shared understanding of what improvements to well-being might look like is a critical component to realising this objective. Well-being is an evolutionary concept, one that must be developed by each successive generation in terms of the political, social, economic, environmental and cultural climate at the time. We believe a well-being project is necessary along the lines of the Canadian study that aims to redefine progress in terms of well-being (Policy Horizons Canada, in press). Such a project is necessary to drive all policy and to make it clear what improvements we are working hard to achieve.

Governance over the research agenda

Strategic intent acts as the key link between the mission, values and vision, and the initiatives that will drive change in the government-funded science system. However, our current focus in the current strategic intent appears to focus on New Zealanders' financial security. While this is a critical factor in achieving the vision of delivering well-being to current and future generations, there are three other areas that are equally important: informing public policy, improving health and solving global problems. We recommend that each of the four areas should have a high-level research agenda that describes what the public investment will deliver. This description should make clear how each of the six 'priority investment areas' can be directed to achieve the four areas of strategic intent. This agenda should be signed off by Cabinet annually so that it aligns the public investment with existing and emerging issues. MSI should be required to report annually against the research agenda in detail.

The profession

The science community, at a national level, should consider how best to represent the profession. There are at least 20,000 researchers and scientists in New Zealand, but only a small number are represented directly by a scientific membership organisation. The majority are instead represented through the organisations that employ them. Science, more than most professions, needs a safe place to discuss, debate, peer review, advocate and integrate science. Experts will not always agree, and it is the science community that creates the place for best practice to be agreed, complaints managed, problems defined and resolved, and mysteries explored.

Enablers

The current government-funded science system tends to focus on the middle of the strategy pyramid in Figure 1, rather than aligning the whole pyramid. Further, there seems to be a tendency to respond to problems by changing the institutional framework rather than dealing with the less obvious enablers, such as the profession and the regulatory framework.

Terminology

The current language around the government-funded science system, and science generally, is inconsistent. MSI should undertake a project to develop a comprehensive glossary of the language that supports the government-funded science system and place it on their website. This would enhance the ability to effectively discuss, debate and drive science. Such language needs to be precise, articulate and particular so that it can be used to develop a strong mission and vision statement. We consider MSI would benefit from becoming the Ministry of Scientific Inquiry rather than of Science and Innovation.

Outstanding questions

Scientific inquiry is at the heart of sound science, yet the sector is not always good at applying this inquiry to the funding that is the life-blood of science, nor to the research agenda and the research outputs and outcomes. A number of outstanding questions exist, meaning that we need to research the research. Section 9 identifies 30 questions that address gaps in the science strategy, test the assumptions underlying the current institutional framework and examine the system linkages that are purported to deliver the desired outcomes in the future. Policy makers must address and answer these questions in order to develop a robust and flexible government-funded science system capable of engaging with emerging issues.

Execution

Delegation of funds and responsibility for how those funds are used will only work if a clear strategic intent is established and a clear measurement framework is put in place to monitor and benchmark progress over time. This would reveal whether performance is improving, goals are being achieved, and further changes are necessary. CRIs in particular need such a framework, as the method by which they are now funded requires greater clarity over the strategic intent and the metrics to assess progress. The metrics also need to be made public so that all stakeholders are able to assess the quality of the investment.

Review

As a matter of good practice, any significant change should require a robust one-off review to assess whether the promised benefits have been delivered and what lessons are to be learned. The Minister of Science and Innovation should require a full, independent review within five years of the recent restructure, ideally in 2015. The results of this review should be made publicly available. This point was discussed in a recent briefing by the Office of the Auditor General to the Education and Science Committee. Without setting such a milestone, the opportunity to assess and recalibrate the system will be lost.

Moving towards a science policy system that rejects myths, embraces values and pursues strategy will require both the engagement of the public and the 'will' of the science community. Now that the recent changes to the institutional framework are largely complete, we hope to see a persuasive strategy developed and communicated. One of the key findings of this report is the need for greater engagement between scientists and the New Zealand public. This research represents our commitment to a wider debate on the contribution that science can make to the well-being of New Zealanders, now and in the future.

Glossary

Term	Definition
applied research	Original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective. (University of Oxford, 2011)
basic research	Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. (University of Oxford, 2011)
basic untargeted research	Experimental or theoretical research to acquire new knowledge with no particular application in mind. (FRST, n.d.[b])
Centres of Research Excellence (CoREs)	Inter-institutional research networks, with researchers working together on commonly agreed work programmes (TEC, 2009a). The role of the seven current CoREs is to support leading edge innovative research of an international standard that fosters excellence and contributes both to New Zealand's national goals and to knowledge transfer (MoRST, n.d.[a]). CoREs focus on the development of human capital, so they undertake outreach activities (for example, within the wider education system). CoREs make a contribution to national development and focus on the impact of their research. (TEC, 2009a)
commercialisation	[The] transfer [of] research outputs to end-users, either through existing businesses or where necessary through the creation of new commercial entities. (MoRST, 2010a: 19)
contestable market	A contestable market is one in which the following conditions are satisfied: a) there are no barriers to entry or exit; b) all firms, both incumbent and potential entrants, have access to the same production technology; c) there is perfect information on prices, available to all consumers and firms; d) entrants can enter and exit before incumbents can adjust prices. In contrast to perfect competition, a contestable market may have any number of firms (including only one or a few) and these firms need not be price-takers. The analysis of contestable markets is designed for cases in which the existence of scale economies precludes a large number of competitors. (OECD, n.d.)
contestable funding	Funding science 'through contest-based investment processes'. (FRST, n.d.[a])
CRI capability funding	This funding was transferred into CRI core funding in 2011/12. (Treasury, 2011e: 118)
CRI core funding	Core funding refers to direct funding by the government to enable CRIs to deliver their stated core purpose (see Appendix 8) in accordance with their strategy, as outlined in a *Statement of Corporate Intent*. (CRIT, 2010: 11)
departmental output expense	Departmental output expenses are payments for the cost of producing the goods and services that a department is to supply to the government to contribute to outcomes that the government wishes to realise (Office of the Clerk of the House of Representatives, 2010: 459). These goods and services consist of policy advice, regulatory functions, inspection and administrative services and generally the 'core' activities of government (ibid.). Within Vote S&I, Budgeted Departmental Output Expenses comprise spending in the following areas: Advice and Support on Shaping the Science and Innovation System (Science and Innovation Contract Management, and Strategic Leadership in the Science and Innovation Sector) and Cross Agency Research. (Treasury, 2011c: 271)
enabling technologies	Research into technologies that might be used in multiple ways across different industries or other sectors. Enabling technologies are designed to accelerate the development of technology platforms. These are technologies that a wide range of sectors can use. The platforms are built on a core of expertise, knowledge and infrastructure (such as equipment) that can help research users, such as industry. (MSI, 2011k)
experimental development	Systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. (University of Oxford, 2011)
government-funded science	Government-funded science refers to all New Zealand science research undertaken with financial support from government. (See Section 1.2)

Term	Definition
innovation	Innovation is the process that translates knowledge into economic growth and social well-being. It encompasses a series of scientific, technological, organisational, financial and commercial activities. Research is only one of these activities and may be carried out at different phases of the innovative process. (Australian Research Council, n.d.) An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. (OECD, n.d.)
invention	An invention discloses an operational method of creating something new. (Maclaurin, 1953: 102)
kaitiakitanga	Guardianship, trusteeship, resource management. (Kawharu, 2002: 399)
large scale research infrastructure	Scientific equipment (and services to deploy the equipment) that is defined by its large size and extent, its ability to enable complex experimentation, and its capability to service research demands at national or even international level, rather than only at institutional level. Such infrastructure is technically advanced and typically expensive to buy and operate. (MoRST, 2010d: 17)
mauri	Life force. (Kawharu, 2002: 399)
non-departmental outputs	Refer to goods and services purchased by a Minister from a provider that is not a government department. For example the Minister of Social Welfare purchases services for the public from community-based providers and voluntary groups. Crown entities are often providers of these nondepartmental outputs. (Treasury n.d.[b])
organisational innovation	An organisational innovation is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations. (OECD, n.d.)
outcome	Impacts on, or consequences for the community of the outputs or activities of the Government. (Treasury n.d.[b])
output expense	A group of outputs that deliver a common set of goods or services; for example, the Environmental Research output expense. (MoRST, 2010k)
outputs	Outputs are goods and services purchased by the Crown from departments and other entities. Outputs range from policy advice to the administration of contracts and grants through to the provision of specific services. (Treasury n.d.[b])
patent	A patent is a right granted by a government to an inventor in exchange for the publication of the invention; it entitles the inventor to prevent any third party from using the invention in any way, for an agreed period. (OECD, n.d.)
policy for science	The role of government in decision-making that affects the conduct of science. (Harris et al., 2011: 2)
precautionary principles	Principles according to which: • Renewable resources should not be used in excess of their natural regeneration. • Non-renewable resources should be used prudently and efficiently with care that the same function is available to future generations, say by technological development or shift to use of renewable resources. • Sink functions should not be used beyond their assimilative capacities. • Activities which cause deterioration in service functions should be avoided or at least minimised. (OECD, n.d.)
priority investment areas	In December 2009 Cabinet set out what it referred to as the new science priorities for government-funded science, and these came into effect on 1 July 2010 (MoRST, 2010l). They included six priority investment areas for research outcomes: high value manufacturing and services; biological industries; energy and minerals; hazards and infrastructure; environment, and health and society. Note 1: These areas are also referred to in various government documents as 'priority research areas' (Landcare Research, n.d.: 8, 10, 12), 'priority research outcome areas' (MoRST, 2010l), and 'research areas' (MSI, 2012b). For the purposes of this report we have used the term 'priority investment areas'. Note 2: The use of the word 'priority' is arguably misleading in that the intent seems to be to divide science research into subsets rather than prioritise one area of science over another.

Term	Definition
process innovation	A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. (OECD, n.d.)
product innovation	A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. (OECD, n.d.)
regulation	Broadly defined as imposition of rules by government, backed by the use of penalties that are intended specifically to modify the economic behaviour of individuals and firms in the private sector. Various regulatory instruments or targets exist. Prices, output, rate of return (in the form of profits, margins or commissions), disclosure of information, standards and ownership ceilings are among those frequently used … Regulations may also be enacted to prevent excessive competition and protect suppliers from unstable output and low price conditions, to promote employment and more equitable distribution of income. (OECD, n.d.)
research	Research means scientific research; and includes scientific development and related services. (CRI Act 1992, s 2)
research and development and scientific and technological innovation	Scientific and technological innovation may be considered as the transformation of an idea into a new or improved product introduced on the market, into a new or improved operational process used in industry and commerce, or into a new approach to a social service. (OECD, n.d.)
research and experimental development (R&D)	Creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. (University of Oxford, 2011)
research infrastructure	Includes high-cost facilities or equipment needed to support New Zealand's research and science capability. (MoRST, 2010e)
science	Science: the field of study which tries to describe and understand the nature of the universe in whole or part. The field of study or discipline that we call Science is spelled with a capital "S" as it is a proper noun in this use while science with a small "s" is the application of this discipline. (Siepmann, 1999)
science for policy	The role of science in informing a wider range of policy decisions. (Harris et al., 2011: 2)
science policy	Decisions or processes that affect science. (Harris et al., 2011: 2)
smart ideas	Smart Ideas is a contest of ideas, designed to drive innovation and an entrepreneurial culture in the national research portfolio. Supporting novel ideas and emerging research capability is intended to continually challenge and refresh the national science portfolio. Smart Ideas does not apply to the Health and Society RfPs. (MSI, 2011k)
targeted research	Targeted research supports research programmes that meet a specific objective. These objectives are aligned with national research priorities in the six sectors MSI is investing in. (MSI, 2011k)
technology	[T]echnology means the practical application of scientific principles and knowledge. (Income Tax Act 2007, LH7, s 5)
triadic patent	A triadic patent family share common priorities and are consolidated into a single patent family. (Trilateral, n.d.)
wānanga	A tertiary institution that caters for Māori learning needs – established under the Education Act 1990. (Moorfield, 2010)
well-being	Well-being in made up of 10 areas or domains: learning, working, housing, family life, social participation, leisure, health, security, environment and financial security. (Policy Horizons Canada, in press: 5)
whakapapa	Genealogy. (Mead, 2003: 370) The essential expression of whānaungatanga between a wider cosmology, peoples, environmental properties and lands, where all entities are therefore interrelated and interdependent. (H. Smith, personal communication, November 18, 2009)

Abbreviations

Abbreviation	
AHELO	Assessment of Higher Education Learning Outcomes
AWIS	Association for Women in the Sciences
BERD	Business Expenditure on Research and Development
CC	Creative Commons
CCMAU	Crown Company Monitoring Advisory Unit (now COMU)
COMU	Crown Ownership Monitoring Unit
CoRE	Centres of Research Excellence
CRI	Crown Research Institute
CRIT	Crown Research Institute Taskforce
CSIRO	Commonwealth Science and Industrial Research Organisation (Australia)
CSNZ	Citizen Science New Zealand
DAC	Development Assistance Committee
DARPA	Defense Advanced Research Projects Agency
DIA	Department of Internal Affairs
DoC	Department of Conservation
DPMC	Department of Prime Minister and Cabinet
DSIR	Department of Scientific and Industrial Research
EPA	Environmental Protection Agency
ERMA	Environmental Risk Management Authority
ESR	Institute of Environmental Science and Research
FRST	Foundation for Research, Science and Technology
FTE	Full Time equivalent
GBAORD	Government Budget Appropriations or Outlays for R&D
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GETS	Government Electronic Tenders Service
GM	Genetic Modification
GNS Science	Institute of Geological and Nuclear Sciences Ltd
GUF	General University Fund
HBR	Harvard Business Review
HM	Her Majesty's
HRC	Health Research Council
HRSDC	Human Resources and Skills Development Canada
HRST	Human Resources in Science and Technology
HVMSS	High Value Manufacturing and Services Sector
IP	Intellectual property

Abbreviation	
IPONZ	Intellectual Property Office of New Zealand
IRANZ	Independent Research Association of NZ
IRL	Industrial Research Limited
IRO	Independent Research Organisation
KAREN	Kiwi Advanced Research and Education Network
MAF	Ministry of Agriculture and Forestry
MED	Ministry of Economic Development
MFAT	Ministry of Foreign Affairs and Trade
MfE	Ministry for the Environment
MoE	Ministry of Education
MoRST	Ministry of Research, Science and Technology
MSD	Ministry of Social Development
MSI	Ministry of Science and Innovation
NASA	National Aeronautics and Space Administration
NBR	National Business Review
NC	NonCommercial [licence]
NDHA	National Digital Heritage Archive
NeSI	New Zealand eScience Infrastructure
NIWA	National Institute of Water and Atmospheric Research
NNCC	National Network of Centres for Commercialisation
NSDS	National Sustainable Development Strategy
NSF	National Science Foundation
NSP	National Science Panel
NZAS	New Zealand Association of Scientists
NZHDEC	New Zealand Health and Disability Ethics Committee
NZI	New Zealand Institute
NZMEA	New Zealand Manufacturers and Exporters Association
NZSX	NZX Stock Exchange
NZTE	New Zealand Trade and Enterprise
OAG	Office of the Auditor General
OECD	Organisation for Economic Co-operation and Development
OIST	Okinawa Institute of Science and Technology
OPMSAC	Office of the Prime Minister's Science Advisory Committee
PBRF	Performance Based Research Fund
PCE	Parliamentary Commissioner for the Environment
PMSP	Prime Minister's Science Prizes
PwC	PricewaterhouseCoopers

Abbreviation	
R&D	Research and Development
RCGM	Royal Commission on Genetic Modification
REANNZ	Research and Education Advanced Network New Zealand
RIAG	Research Infrastructure Advisory Group
RS&T	Research, Science and Technology (as in Vote RS&T)
RSNZ	The Royal Society of New Zealand
SciSIP	Science of Science and Innovation Policy
SEM	Single Economic Market
SFI	Sustainable Future Institute
SMC	Science Media Centre
SME	Small and Medium Enterprise
SPEaR	Social Policy Evaluation and Research
SSC	State Services Commission
SSRG	Social Sciences’ Reference Group
STAC	Science and Technology Advisory Committee
STEP	Science, Technology, and Economic Policy
TEC	Tertiary Education Commission
TEO	Tertiary Education Organisations
TPK	Te Puni Kōkiri
UCONZ	University Commercialisation Offices of New Zealand
UNDESA	United Nations Department of Economic and Social Affairs
Vote RS&T	Vote Research, Science and Technology
Vote S&I	Vote Science and Innovation
WTO	World Trade Organization

Appendix 1 Authors and Research Team

Wendy McGuinness – Author

Wendy McGuinness is the founder and Chief Executive of the McGuinness Institute. Originally from the King Country, Wendy completed her secondary schooling at Hamilton Girls' High School and Edgewater College. She then went on to study at Manukau Technical Institute (MIT) (gaining an NZCC), Auckland University (BCom) and Otago University (MBA), as well as completing additional environmental papers at Massey University. As a Fellow Chartered Accountant (FCA) specialising in risk management, Wendy has worked in both the public and private sectors. In 1988 she prepared a major report for Treasury aimed at moving the public service from cash to accrual accounting. She is a member of the Royal Society of New Zealand and has twice been on a reference panel at the Foundation for Research Science and Technology, assessing applications. In 2001 she was a party in the Bleakley v Environmental Risk Management Authority court case. In 2010 Wendy completed Professor Robert S. Kaplan's Harvard Business School Executive Education Program 'Driving Corporate Performance:'.

Dr Robert Hickson – Author

Robert Hickson has a PhD in Genetics from Massey University. After six years post doctoral research in evolutionary biology he joined New Zealand's Environmental Risk Management Authority as a science advisor on genetically modified organisms. He then moved to the emerging technologies team at the Ministry of Research, Science and Technology, where he worked on biotechnology and nanotechnology policy. Robert also led the Ministry's Futurewatch programme from 2009 until early 2011, when his position was disestablished. He is now a consultant on science and strategic foresight issues. Robert initially engaged with the Institute as an external reviewer, before becoming the co-author of this report.

Diane White – Author

Diane White started working for the McGuinness Institute in July 2011, having recently completed a Bachelor of Laws at Victoria University of Wellington. She also holds a Bachelor of Arts majoring in English Literature and International Relations, which she completed at Uppsala University, Sweden in 2009. Diane also worked on Working Paper 2011/17 and authored Working Paper 2011/18.

The research team in alphabetical order are as follows:

Chris Aitken – Research Team

Chris Aitken grew up in Levin, moving to Wellington to study at Victoria University where he completed a BSc in Geography and Environmental Studies. He then undertook postgraduate research, completing a Master of Environmental Studies in 2009 by writing a thesis examining behaviour and attitudes towards climate change. While at the McGuinness Institute Chris worked on Report 9a and Working Paper 2009/5.

Lisa Bazalo – Research Team

Lisa Bazalo is studying towards a Bachelor of Laws and a Bachelor of Science majoring in Land Planning and Development at the University of Otago. Lisa has worked for the Institute for the past six years on a part-time basis. In 2011/12 Lisa worked solely on this report.

Meghan Collins – Research Team

Meghan Collins has a Bachelor of Arts and Science from McGill University in Montreal, majoring in Environment. She is currently working towards her Masters degree at Victoria University of Wellington, looking at the way science is used in New Zealand's aquaculture policy. Meghan has interdisciplinary research and writing experience in marine ecology, economics and the social sciences. This research draws on her experience in fisheries and the non-profit sector. Meghan was initially an external reviewer before joining the research team.

Lucy Foster – Research Team

Lucy Foster has a Bachelor of Commerce (Economics) at the University of Otago, and in 2011 completed a Bachelor of Arts (Art History), while on exchange at the University of Glasgow. She has worked at the McGuinness Institute on a part-time basis for the past five years. Lucy worked on Working Papers 2010/01 and 2011/17 and managed the external review process for this report.

Louise Grace-Pickering – Research Team

Louise has worked for the McGuinness Institute as a research analyst since early 2010. In that time her main project has been managing the Institute's Report 11: *A History of Future-thinking Initiatives in New Zealand 1936–2010: Learning from the past to build a better future*. She has an honours degree in Political Science from Canterbury University and a Masters in Information Studies from Victoria University. Prior to working for the Institute Louise held business analyst and research positions in the private sector. Louise researched specific areas of this report.

Joe McCarter – Research Team

Joe McCarter was born in England and emigrated to New Zealand in 1984. He has lived in several towns and cities in New Zealand, but did most of his growing up in the central North Island and now has his deepest roots in Wellington. He completed a BSc/BA in Biology, Classics and Religious Studies at Victoria University in 2005, and returned to complete a Post-Graduate Diploma in Environmental Studies in 2007. Since 2008 he has been working between Vanuatu and Wellington researching change in traditional environmental knowledge and resource management on Malekula Island, and facilitating the establishment of locally based 'custom schools' as a means of increasing intergenerational transmission of knowledge. This research forms the bulk of his PhD thesis, which was submitted in March 2011. Joe worked on Report 9a and helped scope this report.

Mark Newton – Research Team

Mark Newton worked as a research analyst at the McGuinness Institute after completing a Master of Environmental Studies at Victoria University of Wellington in early 2009. Mark completed a BSc in Geography and Environmental Studies in 2005, and in 2006 he studied Environmental Management at the Christian Albrechts University of Kiel, Germany. Mark's work experience includes tutoring students in Environmental Studies at Victoria University in 2007, and field technician work for Wildland Consultants the same year; the latter involved gathering scientific data on the damage deer are doing to New Zealand's native forest. Mark worked on Report 9a and helped scope this report.

Jessica Prendergast – Research Team

Jess Prendergast has worked at the Institute since 2009 and was promoted to Director of *Project 2058* in late 2010. She holds a BA in Psychology and Criminology from Victoria University. Previously Jess worked as an advisor in the Emissions Trading Group and Climate Change Implementation team at the Ministry for the Environment. Jess worked on this report, contributing to specific research areas.

Rory Sarten – Research Team

Rory Sarten has worked for the McGuinness Institute since early 2010 and is interested in strategy and future studies, research analysis and information management. He is currently the Project Manager of *Project One Integrated Report*, and managed the survey design and data processing for the project's first report *Integrated Annual Report Survey of New Zealand's Top 200 Companies: Exploring responses from Chief Financial Officers on emerging reporting issues*. Rory also manages the Institute's website and technology infrastructure as well as providing advice and support across a range of other projects. Rory holds a first class honours degree in Sociology. He completed Dr Peter Bishop's course in Future Studies and presented the results of the 2011 *StrategyNZ: Mapping our Future* workshop with a panel at the 2011 World Futures Conference in Vancouver. Rory provided editorial and research support for this report

Appendix 2 External Reviewers

Dr Sharon Adamson BA (Rutgers University, USA), PhD (Cambridge, UK) is Strategy Manager in the Policy Branch of the Ministry of Agriculture and Forestry.

Dr Janet Bradford-Grieve ONZM, FRSNZ, BSc (Hons) (University of Canterbury), PhD (University of Canterbury) is a retired emeritus researcher at the National Institute of Water and Atmospheric Research (NIWA) in Wellington.

Dr Anthony Cole Dr Anthony Cole BA (Hons) 1st class, PhD (Massey University) is a transdisciplinary researcher, educator and director of Pansophy Limited.

Roger Dennis is a foresight and innovation consultant based in New Zealand. He is part of the core team for Future Agenda, the world's largest open source foresight programme. Dennis co-led the 2007 Shell Technology Futures programme for the GameChanger team.

Professor Harlene Hayne ONZM, BA, MS (Rutgers, New Jersey, USA) and PhD (Rutgers, New Jersey, USA) is Vice-Chancellor of Otago University and a researcher and lecturer in psychology.

Professor Jack Heinemann BSc (Hons), PhD (University of Oregon, USA) is a Lecturer in Genetics at the University of Canterbury. He is an Adjunct Professor at the Norwegian Institute of Gene Ecology (GENØK), Tromso, Norway.

Sophie Howard is Senior Commercialisation Manager at VicLink, Victoria University's commercialisation limb. She has worked at both the Tertiary Education Commission and Pharmac.

John Lancashire QSM, BSc (Reading University, UK), MAgSc (Massey University) is a member of the Royal Society of New Zealand Council, and an independent science strategist. He is Immediate Past President of the NZ Institute of Agricultural and Horticultural Science.

James Palmer is Director of Strategy at MAF, where he is responsible for thought leadership in issues confronting New Zealand's land-based industries.

Professor Jacqueline Rowarth PhD (Massey University) holds the Foundation Chair in Pastoral Agriculture at Massey University, is Director of Massey Agriculture, an AGMARDT Trustee and Vice-President of the New Zealand Grassland Association. She was made a Companion of the New Zealand Order of Merit for services to agricultural science.

Professor Caroline Saunders ONZM, BSc (Hons) (Wales), PhD (Newcastle, UK) is Professor of Trade and Environmental Economics at Lincoln University and Director of Lincoln University's Agribusiness and Economics Research Unit.

Professor Phil A. Silva OBE, MA (Hons), PhD, DipTchg, is Founding Director of the Dunedin Multidisciplinary Health and Development Study and, until his retirement from the position in 1999, was Director of the Dunedin Multidisciplinary Health & Development Research Unit. In 1994, he was made an Officer of the British Empire (OBE) for services to health and education.

Professor Jeff Tallon is a senior research scientist with the CRI Industrial Research Ltd (IRL). In 2009 he was named a Companion of the New Zealand Order of Merit.

Dr Steve Thompson is current Chair of the Board at NZ MacDiarmid Institute for Advanced Materials and Nanotechnology and Researcher at British High Commission. He is past CEO at the Royal Society of New Zealand and past CEO at the Foundation for Research, Science & Technology.

Dr Morgan Williams MSc (University of Canterbury), PhD (Bath) is an ecologist and agricultural scientist who served as the Parliamentary Commissioner for the Environment from 1997 to 2007.

Appendix 3 Sector Appropriations

Table 12: Linkages Between Sector Appropriations, Institutions and Ministers, 2012

Source: Adapted from DPMC, 2011; Treasury, 2011a: xv–xvi, 2011b: xxviii–xxix, 1-343.

Sector	Votes By Sector	Departments by Sector	Cabinet Ministers and their Corresponding Portfolios	Ministers outside Cabinet and other responsibilities
Economic Development and Infrastructure Sector	Vote Commerce Vote Communications Vote Consumer Affairs Vote Economic Development Vote Energy Vote Tourism	Ministry of Economic Development	Minister for Economic Development Hon Steven Joyce Minister of Commerce Hon Craig Foss Minister for Communications and Information Technology Hon Amy Adams Minister of Energy and Resources Hon Phil Heatley Minister for Climate Change Issues Hon Dr Nick Smith Minister of Tourism Rt Hon John Key	Minister of Consumer Affairs Hon Chris Tremain Minister for Small Business and Minister for Regulatory Reform Hon John Banks
	Vote Canterbury Earthquake Recovery	Canterbury Earthquake Recovery Authority	Minister for Canterbury Earthquake Recovery Hon Gerry Brownlee	Minister Responsible for the Earthquake Commission Hon Gerry Brownlee
	Vote Transport	Ministry of Transport	Minister of Transport Hon Gerry Brownlee	
	Vote ACC Vote Employment Vote Immigration Vote Labour	Department of Labour	Minister of Labour Kate Wilkinson Minister for ACC Hon Judith Collins Minister of Immigration Hon Nathan Guy	Associate Minister for Tertiary Education, Skills and Employment[136] Hon Tariana Turia

[136] The delegated responsibilities in this portfolio will specifically relate to the Employment area (DPMC, 2011).

Sector	Votes By Sector	Departments by Sector	Cabinet Ministers and their Corresponding Portfolios	Ministers outside Cabinet and their Corresponding Portfolios
Education and Science Sector	Vote Education Vote Tertiary Education	Ministry of Education	Minister of Education Hon Hekia Parata Minister for Tertiary Education, Skills and Employment Hon Steven Joyce	
	Vote Education Review Office	Education Review Office		Minister Responsible for the Education Review Office Hon Hekia Parata
	Vote Science and Innovation	Ministry of Science and Innovation	Minister of Science and Innovation Hon Steven Joyce	
Environment Sector	Vote Environment Vote Climate Change	Ministry for the Environment	Minister for the Environment and Minister for Climate Change Issues Hon Dr Nick Smith	Minister Responsible for International Climate Change Negotiations Hon Tim Groser
	Vote Conservation	Department of Conservation	Minister of Conservation Hon Kate Wilkinson	
	Vote Local Government	This Vote is administered by the Department of Internal Affairs, which is in the Māori, Other Populations and Cultural Sector	Minister of Local Government Hon Dr Nick Smith	
	Vote Parliamentary Commissioner for the Environment	Parliamentary Commissioner for the Environment		Speaker of the House of Representatives The Rt Hon Dr Lockwood Smith
External Sector	Vote Foreign Affairs and Trade Vote Official Development Assistance	Ministry of Foreign Affairs and Trade	Minister of Foreign Affairs Hon Murray McCully Minister for Trade Hon Tim Groser	
	Vote Defence	Ministry of Defence	Minister of Defence Hon Dr Jonathan Coleman	
	Vote Defence Force Vote Veterans' Affairs – Defence Force	New Zealand Defence Force	Minister of Defence Hon Dr Jonathan Coleman Minister of Veterans' Affairs Hon Nathan Guy	
	Vote Customs	New Zealand Customs Service		Minister of Customs Hon Maurice Williamson

Sector	Votes By Sector	Departments by Sector	Cabinet Ministers and their Corresponding Portfolios	Ministers outside Cabinet and their Corresponding Portfolios
Finance and Government Administration Sector	Vote Prime Minister and Cabinet	Department of the Prime Minister and Cabinet	Prime Minister Rt Hon John Key	
	Vote Communications Security and Intelligence	Government Communications Security Bureau		Minister Responsible for the Government Communications Security Bureau Rt Hon John Key
	Vote Security Intelligence	New Zealand Security Intelligence Service		Minister in Charge of the New Zealand Security Intelligence Service Rt Hon John Key
	Vote State Services	State Services Commission	Minister of State Services Hon Dr Jonathan Coleman	
	Vote Finance	The Treasury	Minister of Finance[137] Hon Bill English Minister for State Owned Enterprises Hon Tony Ryall Minister of Science and Innovation Hon Steven Joyce	
	Vote Revenue	Inland Revenue Department		Minister of Revenue Hon Peter Dunne
	Vote Office of the Clerk	Office of the Clerk of the House of Representatives		Speaker of the House of Representatives The Rt Hon Dr Lockwood Smith
	Vote Parliamentary Service	Parliamentary Service		Speaker of the House of Representatives The Rt Hon Dr Lockwood Smith
	Vote Audit	Controller and Auditor-General		Speaker of the House of Representatives The Rt Hon Dr Lockwood Smith
	Vote Ombudsmen	Office of the Ombudsmen		Speaker of the House of Representatives The Rt Hon Dr Lockwood Smith
	Vote State Owned Enterprises	The Treasury	Minister for State Owned Enterprises Hon Tony Ryall	
Health Sector	Vote Health	Ministry of Health	Minister of Health Hon Tony Ryall	

137 The Finance portfolio incorporates the responsibilities formerly included in the Infrastructure portfolio (DPMC, 2011).

Sector	Votes By Sector	Departments by Sector	Cabinet Ministers and their Corresponding Portfolios	Ministers outside Cabinet and their Corresponding Portfolios
Justice Sector	Vote Justice Vote Courts	Ministry of Justice	Minister of Justice Hon Judith Collins	Minister for Courts Hon Chester Borrows
	Vote Corrections	Department of Corrections	Minister of Corrections Hon Anne Tolley	
	Vote Police	New Zealand Police	Minister of Police Hon Anne Tolley	
	Vote Serious Fraud	Serious Fraud Office	Minister of Police Hon Anne Tolley	
	Vote Attorney-General	Crown Law Office	Attorney-General Hon Christopher Finlayson	
	Vote Parliamentary Counsel	Parliamentary Counsel Office	Attorney-General Hon Christopher Finlayson	

Sector	Votes By Sector	Departments by Sector	Cabinet Ministers and their Corresponding Portfolios	Ministers outside Cabinet and their Corresponding Portfolios
Māori, Other Populations and Cultural Sector	Vote Arts, Culture and Heritage Vote Sport and Recreation	Ministry for Culture and Heritage	Minister for Arts, Culture and Heritage Hon Christopher Finlayson Minister of Broadcasting Hon Craig Foss Minister for Sport and Recreation Hon Murray McCully	
	Vote Statistics	Statistics New Zealand		Minister of Statistics Hon Maurice Williamson
	Vote Māori Affairs	Te Puni Kōkiri		Minister of Māori Affairs Hon Dr Pita Sharples Minister Responsible for Whanau Ora Hon Tariana Turia
	Vote Treaty Negotiations	This vote is administered by the Ministry of Justice, which is in the Justice Sector	Minister for Treaty of Waitangi Negotiations Hon Christoper Finlayson	
	Vote Pacific Island Affairs	Ministry of Pacific Island Affairs	Minister of Pacific Island Affairs Hon Hekia Parata	
	Vote Women's Affairs	Ministry of Women's Affairs		Minister of Women's Affairs Hon Jo Goodhew
	Vote Internal Affairs Vote Community and Voluntary Sector Vote Emergency Management Vote National Archives Vote National Library Vote Racing	Department of Internal Affairs	Attorney-General Hon Christopher Finlayson Minister of Internal Affairs[138] Hon Amy Adams Minister for Ethnic Affairs Hon Judith Collins Minister for Racing Hon Nathan Guy	Minister for the Community and Voluntary Sector Hon Jo Goodhew Minister of Civil Defence Hon Chris Tremain
Primary Sector	Vote Agriculture and Forestry Vote Biosecurity Vote Fisheries Vote Food Safety	Ministry of Agriculture and Forestry	Minister for Primary Industries[139] Hon David Carter Minister for Food Safety Hon Kate Wilkinson	
	Vote Lands	Land Information New Zealand		Minister for Land Information Hon Maurice Williamson

138 The Internal Affairs portfolio includes responsibility for Archives New Zealand and the National Library of New Zealand (DPMC, 2011).

139 The new Primary Industries portfolio incorporates the responsibilities formerly included in the Agriculture, Biosecurity, Fisheries and Aquaculture, and Forestry portfolios (DPMC, 2011).

Sector	Votes By Sector	Departments by Sector	Cabinet Ministers and their Corresponding Portfolios	Ministers outside Cabinet and their Corresponding Portfolios
Social Development and Housing Sector	Vote Social Development Vote Senior Citizens Vote Veterans' Affairs – Social Development Vote Youth Development	Ministry of Social Development	Minister for Social Development Hon Paula Bennett Minister of Veterans' Affairs Hon Nathan Guy Minister of Youth Affairs Hon Paula Bennett Minister of Health Hon Tony Ryall Minister of State Services Hon Dr Jonathan Coleman	Minister for Senior Citizens Hon Jo Goodhew Minister for Disability Issues Hon Tariana Turia Minister of Revenue Hon Peter Dunne
	Vote Housing	Department of Building and Housing	Minister of Housing Hon Phil Heatley	Minister for Building and Construction Hon Maurice Williamson

Appendix 4 Case Study: Singapore

Peter Ong, Head of the Civil Service in Singapore, notes that 'Singapore has never enjoyed the luxury of not planning for the future'. This is because it cannot 'absorb the consequences of multiple large policy errors', and as such must work hard to develop strategic depth and capacity (CSFS, 2011: 2). Singapore aims to develop this depth and capacity in a number of ways. Below we discuss three: building futures capacity, developing research hubs and thinking strategically.

Building Futures Capacity

Conversations for the Future, published by the Centre for Strategic Futures (CFSF) in 2011, outlines the history and progress of Singapore's governmental futures capacity.

Singapore began strategic planning in 1988 as an experiment in the Ministry of Defense (MINDEF) and started scenario planning in 1991 as a tool for long-term strategic and policy development. In 1995, these functions were transferred to the Prime Minister's Office where the Scenario Planning Office was established (ibid.: 10). The aim was to develop national scenarios, disseminate scenarios, coordinate policy implications and update expertise in scenario planning and methodology. In 2003, the Scenario Planning Office was renamed the Strategic Policy Office (SPO) and one of its first tasks was to form cross-agency teams to coordinate strategy formation at whole of government (WOG) level. In 2004 the WOG Integrated Risk Management (WOG-IRM) framework was developed to identify risks which could have an impact on strategic outcomes and was in turn integrated into the WOG planning process (ibid.: 16–17).

Also in 2004 the Risk Assessment and Horizon Planning (RAHS) programme was launched as part of the National Security Coordination Secretariat (NSCS) to explore methods and tools that could complement scenario planning in anticipating strategic issues. With WOG–IRM and RAHS in operation, a key remaining issue was how 'to build a strategically agile Public Service ready to manage a complex and fast-changing environment' (ibid.: 19). In 2009, this issue led to the establishment of the Centre for Strategic Futures (CFS) within the Prime Minister's office. The centre is the 'focal point' for futures work conducted by Singapore's government (Ho, 2010). Its primary function is to develop the capacity for futures thinking across all aspects of government and increase government awareness and preparedness for the future (Goh, 2010). *Conversations for the Future* outlines five lessons learnt over the course of this development:

- futures as a way to better appreciate the complexity of the present; it is not about prediction;
- futures work is never complete;
- it is more effective to show, rather than tell. Visual media has often proved more successful than prose;
- diversity is valuable, consulting inside and outside of the public sector and in and out of Singapore has proven to be extremely useful; and
- the future is an exogenous result of a combination of trends, to which we must adjust and adapt. (CFSF, 2011: 46-48)

Developing Research Hubs

In 1990 the Ministry of Finance in Singapore approved a plan for the development of an advanced engineering institute to assist the uptake of research developments into the economy. This became known as the National Science and Technology Board (NSTB). Its primary task was to transform Singapore into a research hub. Due the high cost of cutting edge research, Singapore focused on niche research areas that were predicted to have higher payoffs at the start of the 21st Century, such as biomedical sciences.

At the start of the new century the NSTB was renamed A*Star to reflect the focus on human talent. The goal was to have one agency develop the R&D agenda for all of Singapore. The agenda included an A*Star Graduate Academy to implement A*Star scholarship programmes, manage intellectual property and facilitate technology transfer: '[t]he goal was to form a multi-disciplinary, integrated approach to research, bringing different fields and capabilities together' (Singapore Press Holdings, 2011a). The Prime Minister recently announced the Research, Innovation and Enterprise 2015 Plan (RIE2015) to achieve the vision of Singapore becoming one of the most research-intensive, innovative and entrepreneurial countries in the world. Singapore aims to have science innovation equate to 3.5 per cent of GDP by 2015 (in 2010 it was 2.14 per cent). The most research intensive countries, as a ratio of GDP, include Israel (4.3 per cent), Finland (3.8 per cent), Sweden (3.6 per cent), and Korea (3.4 per cent). Others of note include Japan (3.3 per cent), the United States (2.8 per cent) and China (1.7 per cent). To achieve this goal, Singapore undertakes an annual survey of the science sector in order to understand the needs and wants of its pool of 28,296 scientists and researchers (Singapore Press Holdings Limited, 2011a; Ho, 2011). This figure has almost doubled since 2000 (Ong, 2010).

Singapore continues to emphasise the achievement of meaningful economic outcomes through public-private collaborations, given that there are limited financial resources in the country. For example, A*Star Biomedical Research Council (BMRC) recently established an Industry Alignment Fund (IAF) of S$600 million. Prior to this, all funding went directly to individual institutes, but under the new system 30% of funds are now contestable, meaning institutes must now compete for a share. Three categories of funding exist. To fall within any one of these categories applicants must: have a signed research agreement with industry as evidence of direct industry collaboration (Category 1); work with a medical doctor who is also a scientist (Category 2); or create technology platforms for companies to use (Category 3) (Singapore Press Holdings Limited, 2011b; Ai-Lien et al., 2011a). Early indications suggest that the funding system is working (Poh, 2011), although some scientists have raised concerns about the ethics of partnering with industry, as it could lead to potential conflicts of interest. One researcher is quoted as saying:

> Going to bed with industry makes us all very uneasy. Often they come, we waste a lot of time and money on them, and at the last minute there can be a change of plans and everything is called off. Plus scientists don't make the best negotiators with savvy businessmen. (Ai-Lien et al., 2011a)

This issue has been discussed in the press, not only in terms of being unnecessary red tape, but also in terms of red tape triggering a 'whale migration'; the migration of top foreign scientists to more attractive destinations. This raises the issue of whether there is sufficient home-grown talent to take their place when migration occurs (Ai-Lien et al., 2011a).

It is clear that the 1990 strategy to focus on niche areas of research, in particular biomedical research, has paid off. The biomedical sciences manufacturing output last year was $21 billion, about 8 per cent of Singapore's gross domestic product, from virtually nothing a decade ago [and] the sector employed 13,000 workers, and is charging towards its goal of 15,000-strong workforce and output of $25 billion by 2015 (Ai-Lien et al., 2011b). The scientific journal *Nature Medicine* has reviewed Singapore's track record and noted that much of this success was due to:

i. Focus - In 2001 the focus was about building up basic science capabilities, but five years later the focus changed to encouraging 'bench to bedside' research.
ii. A small and nimble administrative structure - Singapore's small size and short history means that it has been protected from large administrative structures, minimising obstacles to timely decision making, and
iii. Strategic engagement - a requirement for all stakeholders (including universities, ministries and other organisations) to agree on a strategic plan which took only days to develop. (Ai-Lien et al., 2011b)

Thinking Strategically

Mr Yinglan Tan, author and head of projects at the National Research Foundation is a well-known strategic thinker based in Singapore. Tan notes that 'entrepreneurs who do not innovate after copying usually do not survive' (Tham, 2012). Tan suggests that China has an excellent strategy for growth. It firstly 'copies' a rival's business model, then hones in on the rival's weaknesses so as to identify and create niche opportunities. The company then uses these niche markets to build client relationships, discover new markets and new products. He also notes that, as China excels in 'business model innovation' and India excels in 'software innovation', an opportunity exists for Singapore, with its pool of English and Mandarin speakers, to act as broker between India and China (ibid.). Singapore is therefore thinking strategically about its place in the world.

Appendix 5 Wicked Problems

Wicked problems are those that arise due to a range of factors, are too big or complex for any one agency to handle, and often have no clear solution. While diverse, they have a range of common characteristics:

- They are difficult to clearly define
- Have many interdependencies
- Attempts to address wicked problems often lead to unforeseen consequences
- Are often not stable
- Usually have no clear solution
- Are socially complex
- Rarely fall within the responsibility of any one organisation
- Involve changing behaviour
- Are characterised by chronic policy failure. (Australian Public Service Commission, 2007: 3–4)

Below we highlight several complex issues and wicked problems that are likely to be of concern (and may provide potential opportunities) over the next 50 years, and discuss how they could impact on investment of public monies in RS&T. This is not meant as an extensive list, but as a broad overview of potential challenges. Although these are extremely important issues that will severely impact on the future of science, an in-depth analysis of these challenges is outside the scope of this report.

These issues have been identified through a literature review and discussions with leading researchers. As new knowledge is gained, new technologies emerge, and society evolves, the details associated with each issue or challenge may change. However, we believe that the underlying challenges will remain, and so we require a science system that is adaptable to the changing environment. The issues noted below should be considered as a set of intrinsically linked and interrelated issues that are very difficult to separate. In many cases funding and research, with the aim of addressing one problem, is likely to have beneficial outcomes for another (for example, growing a high technology sector could relieve pressure on our natural resources).

1. Climate change

Climate change, possibly the biggest 'wicked problem', is a significant economic and sustainability issue for the whole world. It has a range of causal factors, and there is no agreement on the scale or nature of the problem or effective ways of solving it (Australian Public Service Commission, 2007: 1). While forecasts predict that New Zealand's climate will change relatively little (and there may even be positive impacts) compared with many other countries,[140] the global economic and societal changes that are anticipated to eventuate from significant changes in climate will greatly affect New Zealand.[141]

A changing climate will place increasing emphasis on sustainability measures. What we produce, how we produce it, and how we transport it are already coming under increasing scrutiny from many of our trading partners,[142] who are looking for sustainable production systems. New Zealand firms will need not only to use sustainable practices but document the environmental impact of their businesses. Our towns and communities also need to be prepared for the potential challenges (e.g., transport and energy systems, urban planning) brought by changing climate and climate forced migration. These challenges require research to understand our natural and built environments and our social structures, so that informed policy decisions can be implemented.

Technological approaches to mitigating and adapting to a changing climate will become increasingly important, be they reducing greenhouse gas emissions, transitioning to renewable energy sources,

140 See Nottage et.al. (2010).

141 See, for example, *Environment and Climate: Implications, reaction and response* (NZI, 2011).

142 See, for example, MFAT & NZTE's quarterly *Sustainability Market Intelligence* reports (MFAT & NZTE, 2011).

redesigning transport and production systems, etc. Policy initiatives also need to go hand in hand with technological developments (OECD, 2008c: 10).

2. Agricultural challenges

New Zealand has long been an agricultural nation, and is likely to be for the foreseeable future. However, as Richardson et al. (2004: 25) note, 'If natural capital is degraded, the ongoing viability of farming may also be threatened.' In a paper presented at the Partners in Progress Dairy Summit 2009, Rowarth argues that with increasing subsidies for agriculture in other countries, New Zealand needs to differentiate its agricultural products from those of the rest of the world if it is to maintain a 'first world living [standard based on] a third world economy' (Rowarth, 2009: 82). She contends that an integral part of achieving differentiation is to minimise New Zealand agriculture's environmental impact. Enhancing life cycle analysis to include water use, and to incorporate research on soil (in particular soil from erosion due to hooved livestock), plant, animal, pest management, water (quality, quantity and waste water) and atmosphere, is the way to achieve truly sustainable production systems (ibid.: 86).[143]

To remain a leading agricultural nation it is not simply a matter of focusing on agriculture, but having a clear view as to the type of agriculture and agricultural products that New Zealand can create and retain a competitive advantage in. Competitive advantage will be more about the quality of our food and our values than about how much we produce.

3. Diversifying New Zealand's economy

As Sir Paul Callaghan has emphasised in his book *From Wool to Weta: Transforming New Zealand's culture and economy* (2009), a sustainable and prosperous New Zealand will need to diversify its economy away from land-intensive industries such as agriculture and tourism. This will require cultural as well as technological and economic changes (for example, small business owners showing greater ambition and ability to grow and export their products and services). Knowledge-intensive manufacturing and related services have the potential to provide high economic returns and, if developed properly, low environmental impacts. Diversifying New Zealand's economy will require a responsive science system, innovative forward-looking policies and the right people to build new industries and sectors.[144]

4. Social challenges

Looking ahead 50 years, we are compelled to ask 'What form might New Zealand society take?' Population projections suggest our social demographics will alter significantly over the next 50 years. Perhaps most significantly, by 2031 one in five New Zealanders will be in the 65+ age bracket (more than one million in total), compared to one in eight in 2009 (Statistics New Zealand, 2009). Ethnic composition is also changing,[145] which can produce changes in economic structures, labour markets, and social and cultural attitudes and norms. The Institute's Report 7: *Exploring the Shared Goals of Māori: Working towards a National Sustainable Development Strategy* noted that:

> The 2010 national ethnic population projections for the period 2006–2026 indicate that New Zealand's population will exhibit greater ethnic diversity in the future... resulting in a more youthful and diverse Māori population that is projected to make up 16% of the total New Zealand population by 2026. Interestingly, the Asian and Pacific Island populations are expected to grow at a much faster rate, with the Asian population equal to that of Māori by 2026. In contrast, the 'European or other' population is both ageing and proportionately in decline. (SFI, 2010b: 28)

The outcomes of changing ethnic composition on the economic, social, and cultural framework of New Zealand are unknown, and are dependent on how government policy, institutions, communities and individuals respond to the changes in our population. Research can add a useful contribution to

143 Life cycle analysis is the process of calculating the environmental footprint of every component of a product (Rowarth, 2009).

144 See Procter (2011), *Enhancing Productivity: Towards an updated action agenda*.

145 For example, the Asian ethnic group grew the fastest between 2001 and 2006, increasing from 238,176 people in 2001 to 354,552 in 2006 (an increase of almost 50%) (Statistics New Zealand, 2006).

understanding potential outcomes and can provide valuable opinion on how they can be effectively managed under different scenarios. High-quality qualitative and quantitative social research will be necessary to inform individuals and institutions working hard to tackle complex social problems such as poverty, inequality, education, employment, and justice. Countries such as the Netherlands are adopting innovative action learning programmes to understand and solve such challenges (Aalbers, 2011).

5. Public health and medical challenges

A healthy population is a prerequisite for a strong society and economy.[146] Our lifestyles have health implications that need to be understood in order to be addressed. Diabetes, heart disease, nutrition and obesity; smoking, alcohol and drug abuse; cancers; mental health; violence; and the impacts of environmental factors such as housing, ethnic composition, poverty and social inequality are all complex problems which impact on the well-being of any population. The Health Research Council uses the New Zealand Health Strategy's 'Priority Investment Areas' for research to inform the research-funding decision-making process. Such explicit linkages between national strategies and research funding are necessary to achieve optimal outcomes.

6. Energy transformation challenges

Energy transformation will play a crucial role in defining New Zealand's future. The economic need to decarbonise the economy in response to the combined influences of increasing oil prices and the rising price of emission-intensive activities due to climate change regulation will demand innovative solutions. While much of the R&D component of this transformation will require being a fast follower of international research, New Zealand's unique urban and rural layouts, electricity-generation profile and poorly insulated housing necessitate specifically New Zealand-focused R&D to smooth the transition. Not only will this transition require technical solutions, but it will also require social research to encourage a change of behaviour to superior modes of urban living and transport that are both comfortable and sustainable. New Zealand's latest energy strategy (MED, 2011) notes the aspiration of increasing the supply of renewable energy in New Zealand, but provides little guidance on the transition away from fossil fuels.

7. Managing our marine resources

New Zealand has a considerable marine ecosystem to manage, with sovereign rights over more than 5.7 million square kilometres of ocean floor. This is an area 22 times that of the country's land area (MoRST, 2010a: 36). Put another way, for every New Zealander there is approximately 1.3 square kilometres of seabed and 0.06 square kilometres of land, over which we all have rights and responsibilities.[147]

This marine environment is rich in resources, such as fish, minerals, and gas, as well as having important marine life and landscapes that need protection. Balancing exploitation and protection can be complex, particularly when knowledge of what the resources are and how they could be sustainably managed is very limited. Policy needs to be informed by evidence-based research, to prevent further collapses in fish stocks such as occurred in the hoki fishery over the last decade. According to Forest and Bird's *Best Fish Guide 2009–2010*, not one of the New Zealand fisheries examined had a management plan (Forest and Bird, 2009: 6).

8. Freshwater and land use management challenges

Managing our freshwater resources is a recognised problem; the PCE, which has statutory functions under the Environment Act to investigate environmental issues, processes and public agencies, identified water management as a priority investment area of focus in its 2010 *Statement of Intent*:

> Water management is one of New Zealand's greatest environmental challenges. Freshwater has become scarce in parts of the country, and climate change is expected to exacerbate this… A major driver of deteriorating water quality in much of the country is the increasing intensification of agriculture. (PCE, 2010b: 7)

146 See Bell et al. (2010), *Challenges and Choices: Modelling New Zealand's long term fiscal position*.

147 In 2011 the total estimated resident population was 4,405,200 (Statistics New Zealand, n.d.). 5,700,000/4,405,200 = 1.29 square kilometres of land per person and 1.29/22 = 0.059 square kilometres of land.

The Land and Water Forum, comprised of a range of stakeholders outside of the government with a major interest in freshwater and land management, has begun to address some of the issues associated with water use. In 2009, the Forum was asked by the Minister for the Environment and the Minister of Agriculture and Forestry to advise on how water should be managed in New Zealand.[148]

As our population continues to grow, demands for new energy generation increase, and farming and other activities compete for the same land. Effective processes to prioritise and manage land use and address freshwater challenges, which also ensure New Zealand remains economically productive, are necessary for New Zealand's long-term security and well-being.

9. Earthquakes and other natural disasters

New Zealand's reputation as the 'shaky isles' was reinforced following the Christchurch earthquakes in 2010 and 2011. These reminded the country of the enormous social, economic and personal costs of a major earthquake. Geological sciences in New Zealand play a major role in enabling the understanding of fault lines and monitoring volcanic activity. 'Understanding what causes earthquakes, where and why they happen, is crucial to being best prepared. Although it is so far impossible to predict the exact timing of the next big quake, scientists can work out a lot about the statistical risk and potential size of future earthquakes' (GNS Science, n.d.). Scientists also advise and work with standard setters on the integrity of infrastructure and building projects across New Zealand and engage in a range of activities that seek to minimise the damage and disruption communities suffer when hit by an earthquake. Social science is essential to improving preparation and response to natural disasters.

10. Embedded institutional challenges

A final overarching problem is the embedded nature of the government institutional arrangements which strongly influence how we manage and respond to wicked problems. The design of institutional structures and processes has far-reaching implications and impacts upon how the governance model works, our legal system, and our educational system. Solving wicked problems starts, in many cases, by considering how our institutional set-up can be made more operationally flexible and therefore ensuring its capacity to evolve alongside science and society.

To gain a greater understanding of New Zealand's current government structure and its capability to evolve successfully, the Institute's *Project Constitutional Review* aims to provide research in this area and to engage with the advisory panel undertaking New Zealand's constitutional review.[149]

148 The Forum, using a collaborative governance process, produced a report for ministers which recommends shared outcomes, goals and long-term strategies for freshwater in New Zealand. For more information see Land and Water Forum (2010).

149 Further information on *Project Constitutional Review* is available on the Institute's website, and the EmpowerNZ website (EmpowerNZ, 2011).

Appendix 6 Policy Knots: Links to the Nine Pillars

Table 13: Policy Knots - Links to the Nine Pillars

Note: The following table lists all 30 questions from Section 9 of the report and shows how these questions, what we call policy knots, link to the nine pillars that shape strategy. This method of analysis indicates where, very generally, links exist between policy knots and strategy.

Pillars / Policy Questions	Pillar 1	Pillar 2	Pillar 3	Pillar 4	Pillar 5	Pillar 6					Pillar 7	Pillar 8	Pillar 9
						Enablers							
	Mission	Values	Vision	Strategic Intent	Drivers	Institutional Framework	Scientists	Research Infrastructure	Funding	Regulatory Framework	Targets and Initiatives	Performance Indicators	Strategy Map
	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3.4	7.3.5	8.1	8.2	8.3
Question 1: Should New Zealand have a greater focus on commercial research or non-commercial research?	✓	✓	✓										
Question 2: Should New Zealand have a greater focus on addressing New Zealand-specific issues or global issues?	✓	✓	✓										
Question 3: Should New Zealand have a greater focus on inventions or innovations?	✓	✓	✓										
Question 4: Should New Zealand have a high-risk appetite or a low-risk appetite?	✓	✓	✓										
Question 5: Should New Zealand have a greater focus on long- or short-term research?	✓	✓	✓										
Question 6: Should New Zealand have a greater focus on 'policy for science' or 'science for policy'?	✓	✓	✓										
Question 7: Should New Zealand have a greater focus on solving problems or mysteries?	✓	✓	✓										
Question 8: Who will review the recent restructure, when will it be done, and against what criteria?				✓	✓	✓							
Question 9: What policies and initiatives will MSI not carry over from MoRST?						✓					✓	✓	

Pillars / Policy Questions	Pillar 1	Pillar 2	Pillar 3	Pillar 4	Pillar 5	Pillar 6					Pillar 7	Pillar 8	Pillar 9
	Mission	Values	Vision	Strategic Intent	Drivers	Enablers					Targets and Initiatives	Performance Indicators	Strategy Map
						Institutional Framework	Scientists	Research Infrastructure	Funding	Regulatory Framework			
	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3.4	7.3.5	8.1	8.2	8.3
Question 10: How will MSI address the needs and wants of the public?	✓	✓	✓	✓							✓	✓	✓
Question 11: How can MSI drive long-term outcomes for the government-funded science system?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Question 12: What research infrastructure is necessary to meet our long-term needs?				✓	✓			✓			✓		
Question 13: How can Mātauranga Māori be progressed in a modern, funded research context?		✓							✓			✓	
Question 14: How can society have faith that decisions by the two MSI investment boards are independent, based on evidence and in the public interest?												✓	
Question 15: What are MSI's reporting obligations to stakeholders?		✓										✓	
Question 16: Has the Crown Research Institute experiment worked?				✓	✓	✓							
Question 17: How can investment decisions by Crown Research Institutes be made more transparent?									✓		✓	✓	✓
Question 18: What level of funding is best for science in New Zealand?	✓	✓	✓						✓				
Question 19: What method of funding is best for science; contestable or core funding?						✓	✓	✓	✓	✓			
Question 20: How can New Zealand's decline in international university rankings be addressed?							✓					✓	

Policy Questions / Pillars	Pillar 1	Pillar 2	Pillar 3	Pillar 4	Pillar 5	Pillar 6					Pillar 7	Pillar 8	Pillar 9
						Enablers							
	Mission	Values	Vision	Strategic Intent	Drivers	Institutional Framework	Scientists	Research Infrastructure	Funding	Regulatory Framework	Targets and Initiatives	Performance Indicators	Strategy Map
	6.1	6.2	6.3	7.1	7.2	7.3.1	7.3.2	7.3.3	7.3.4	7.3.5	8.1	8.2	8.3
Question 21: How can New Zealand ensure the best university researchers are collaborating effectively?						✓	✓				✓	✓	
Question 22: Do adequate incentives exist to encourage excellence in teaching within universities, polytechnics and wānanga?		✓					✓				✓		
Question 23: Are there adequate incentives for post-doctoral researchers to stay and build their careers in New Zealand?		✓					✓				✓		
Question 24: What impact will a reduction in contestable funding have on independent research organisations?		✓					✓					✓	
Question 25: How can we increase collaboration between research institutions?		✓					✓						✓
Question 26: How can we improve linkages between businesses and research institutions?		✓			✓						✓		
Question 27: How can the public be confident that a Code of Ethics is being applied?		✓					✓					✓	✓
Question 28: What is the optimal composition of the science workforce?				✓			✓					✓	
Question 29: How can we promote science as an appealing career path for students?		✓	✓		✓		✓						✓
Question 30: How can foresight be embedded in central government?		✓			✓					✓			

Appendix 7 The Institutional Framework

The science system in addition to the public, consists of a range of public and private sector actors, some of which are described briefly below.

1. Ministry of Science and Innovation (MSI) and other government departments

MSI is the government's lead agency with responsibility for stewardship of the New Zealand science system and its interactions with the wider New Zealand innovation system (MSI, n.d.). It both formulates and implements science and innovation policy, as well as funding research and development activities. MSI was established on 20 December 2010 with the passing of the Research, Science, and Technology Act 2010. The purpose of the Act is:

a. to establish boards to make independent funding decisions in respect of the allocation of specified expenses appropriated for the purposes of research, science, or technology, or related activities:

b. to repeal the Foundation for Research, Science and Technology Act 1990:

c. to provide for the transfer of employees, assets, and liabilities from the Foundation for Research, Science and Technology to a new department of State:

d. to provide for the transfer of employees from the former department to a new department of State:

e. to provide for savings in relation to contracts with the Foundation for Research, Science, and Technology, consequential amendments, and other savings and transitional matters.
(s 3, Research, Science and Technology Act 2010)

Departments such as the Ministry of Agriculture and Forestry (MAF), the Department of Conservation (DoC), and the Ministry of Social Development (MSD) often undertake or commission their own research using their own funds. For example, MAF administers the Primary Growth Partnership and Sustainable Farming funds; DoC has its own science and research group. Until recently MSD allocated funding for social research through the Social Policy Evaluation and Research (SPEaR) Committee. SPEaR is currently undergoing a review and its funding programmes are on hold. Other government departments and agencies also commission research.

2. Crown Research Institutes

As of 2011, there were eight CRIs charged with undertaking research for the benefit of New Zealand, and promoting the application of the results of research and technological developments.

CRIs are legislated for and governed by the Crown Research Institutes Act 1992, the Crown Entities Act 2004, and certain provisions of the Companies Act 1993. The current CRIs are:

1. AgResearch (formerly New Zealand Pastoral Agriculture Research Institute)
2. Environmental Science and Research (ESR)
3. GNS Science (Institute of Geological and Nuclear Sciences Limited)
4. Industrial Research Limited (IRL)
5. Landcare Research
6. NIWA (National Institute of Water and Atmospheric Research)
7. Plant & Food Research
8. Scion (formerly New Zealand Forest Research Institute Limited)

CRIs have a mandate to maintain financial viability while carrying out their research, but are not expected to maximise profits. CRIs have two shareholding ministers – the Minister of Finance and the Minister of Science and Innovation. These ministers are responsible for appointing the board of directors of each CRI in accordance with the Companies Act and the constitutions of the individual CRIs (MSI, 2011h). Further analysis of the governance structure, accountability and reporting mechanisms, and monitoring of CRIs can be found in the Institute's Working Paper 2011/18: *New Zealand Crown Research Institutes: Legislation, operation and governance* (SFI, 2011e).

In February 2010, the government released the results of a review into how to enhance the value of investment in the CRIs (CRIT, 2010). Based on this review, it announced changes to the funding of CRIs and, in combination with findings by the State Services Commission, announced the amalgamation of FRST and MoRST into a single agency (Mapp, 2011c; Ryall, 2010; SSC, 2010).

The findings of the CRI review were well considered. Particularly important recommendations from the Taskforce include: clear goals for CRIs; CRI success measured in terms of positive impact on New Zealand; reduced contestable funding for CRIs, and improved annual monitoring (CRIT, 2010: 11–13). MSI is now in the process of implementing these recommendations. The CRIs released 'statements of core purpose' in November 2010 (MoRST, n.d.[b]) with the intention of clarifying what each should return to New Zealand for the public investment given to it. A further analysis of the Taskforce's recommendations and their subsequent implementation can be found in the Institute's Report 9b: *Government-funded Science 2009–2011*.

The eight Crown Research Institutes foster a national constituency through Science New Zealand, which acts and speaks on behalf of its members on agreed matters (SNZ, n.d.).

3. Universities, polytechnics and wānanga

New Zealand currently has eight universities which are responsible for the provision of advanced learning and act as repositories of knowledge and expertise. Within these universities, there is an emphasis on obtaining high international standards in both research and teaching. Research takes place within individual faculties and colleges, and within university research centres. Each university also has a commercialisation entity, which is the body responsible for actively commercialising the intellectual property developed within the university. In addition to each university's research centres, there are currently eight Centres of Research Excellence (CoREs) funded by the Tertiary Education Commission. CoREs are inter-institutional research networks, which bring together researchers in particular fields from different organisations and institutions to work on shared work programmes.

There are 20 polytechnics and three government-funded wānanga in New Zealand. Their primary focus is on teaching and training. Polytechnics have a focus on applied, practical learning. The main role of wānanga is to help Māori move into tertiary education by providing education services and curriculum tailored toward Māori aspirations and needs. Research activity varies across polytechnics and wānanga. Unitec is an example of a polytechnic that undertakes a range of research. Otago Polytechnic and the Wellington Institute of Technology have been nominated as R&D partners by MSI, meaning that they are accredited to provide R&D services and expertise to businesses awarded Technology Transfer Vouchers.

The Performance Based Research Fund (PBRF) was established in 2003 as a way to ensure that excellent research in the tertiary education sector is encouraged and rewarded. This involves assessing the research performance of the participating Tertiary Education Organisations (TEOs) (universities and polytechnics) and then funding them on the basis of their performance. Funding is allocated on the basis of an established formula centred on three elements: Quality Evaluation, Research Degree Completions, and External Research Income (TEC, 2009b). In 2010 the fund was set at $250 million a year (TEC, 2011: 5). The increased scrutiny the PBRF has placed on the research activities of New Zealand's eight universities has been associated with a significant increase in research productivity at most universities (Smart, 2009). Further, high ratings under the PBRF also often result in reputational benefits for the top-ranked universities (Curtis et al., 2005: 9).

Global rankings enable universities to be judged on the basis of where they stand in international terms: prospective students use the rankings when choosing where to study, and universities themselves use the rankings in setting targets and determining advertising and branding strategies (Hazelkorn, 2009: 1). Further, given the role of higher education and academic research as drivers of economic growth and innovation in the wider national science system, rankings are used by politicians and governments as indicators of international competitiveness and strength (ibid.:1).

The overall as well as the individual discipline rankings of New Zealand universities have all generally fallen in recent years, indicating that our universities are not in line with international universities (SFI, 2011d: 10–12). In 2011 the University of Otago was the only New Zealand university not to fall in the QS World University Overall Rankings (SFI, 2011d: 13). Further, the University of Auckland consistently ranks the highest of all New Zealand universities across the five disciplines assessed by the QS System.

While these rankings are subject to varied criticism, as discussed in Working Paper 2011/17: *New Zealand Universities: Research activities, commercialisation and international benchmarking*, universities are increasingly recognising the need to succeed within the terms set by global ranking systems in order to build their international reputations, attract international students and researchers, and maintain national credibility.

4. The Health Research Council of New Zealand

The Health Research Council of New Zealand (HRC) is a Crown Entity that was established in 1990 under the Health Research Council Act 1990. The functions of the HRC, as provided in section 5 of the Act, include initiating and supporting health research and advising the Minister of Health on national health research policy (MoH, n.d.: 3). A portion of the government's investment in health research is administered by the HRC, primarily through the Health and Society Research Crown Fund in Vote Science and Innovation (HRC, 2010: 6). Health research is one of the priority research outcome areas for the government's investment in Science and Innovation (HRC, 2011a: 4). The HRC is responsible to the Minister of Health and the Minister of Science and Innovation (formerly to the Minister of Research, Science and Technology) and produces annual reports as required under clause 38 of the Health Research Council Act 1990 and clause 150 of the Crown Entities Act 2004 (HRC, 2008: 4; n.d.[a]). The HRC's mission and vision are:

> Mission: benefiting New Zealand through health research
> Vision: improved health and quality of life for all. (HRC, 2010)

In its Strategic Plan 2008–2013 the HRC identified four key goals that were designed to align with MoRST's strategy as well as with other relevant funding and investment agencies in the health sector (HRC, 2008: 4). The four goals are to:

1. Invest in research that meets New Zealand health needs and research that has international impact
2. Maximise the benefits of health research
3. Champion the integrity of the health research environment
4. Enhance the value of the organisation. (HRC, 2008: 4)

The funding invested by the HRC supports 'fundamental, strategic or applied research activities in biomedical, clinical, health services, public health, Māori health and Pacific health' (HRC, 2010: 4). The HRC also supports the development of research careers, a safe and ethical environment for health research, and administers a number of committees which 'provide advice on gene technology, accredit health and disability ethics committees and institutional ethics committees, monitor the safety of large clinical trials and review applications to use new medicines in trials' (HRC, n.d.[b]).

As at 1 April 2011 the HRC was managing 337 active research contracts, and at 1 July 2011 the Council had forward commitments to health research contracts to the value of approximately $195 million. These contracts involved 30 different research organisations and supported a research workforce of 2300 positions, the equivalent of 570 full-time posts. For the year ended 30 June 2011 the HRC's revenue was $84.98 million. This included $83.54 million from Vote Science & Innovation, $0.29 million from Vote Health, and $0.71 million from other sources (HRC, 2011a: 2).

In the 2011/12 year the HRC planned to invest $74.54 million in four priority areas:

- New Zealand Health Delivery
- Improving Outcomes for Acute and Chronic Conditions in New Zealand
- Rangahau Hauora Māori
- Health and Wellbeing in New Zealand. (HRC, 2011b: 3–4)

5. Independent Research Organisations

Independent Research Organisations (IROs) are non-government-owned research organisations that complement universities and CRIs in New Zealand's broader research landscape. These organisations typically receive research funding from government, as well as from other sources. They tend to be small in size and concerned with carrying out high quality scientific research, development and technology transfer in particular areas and specialities. IROs work collaboratively with universities, CRIs and the research departments of industrial organisations. IROs claim that their smaller size and greater flexibility are particularly conducive to innovation and complement university-based and CRI research (IRANZ, 2011).

The umbrella organisation for IROs is the Independent Research Association of New Zealand (IRANZ), which ensures that the collective interests of members are represented. IRANZ states that its IROs provide over $57 million of research for New Zealand and employ over 400 FTE staff. Further, they provide research training for 30 postgraduate students (IRANZ, n.d.).

Well-known IROs include the Cawthron Institute, Building Research Association of New Zealand (BRANZ), the Malaghan Institute of Medical Research, Heavy Engineering Research Association (HERA), Leather & Shoe Research (LASRA), CRL Energy, Lincoln Ventures Ltd, Opus Central Laboratories and Transport Engineering Research NZ Ltd (TERNZ).

6. The Royal Society of New Zealand

The Royal Society of New Zealand (RSNZ) was originally established under the New Zealand Institute Act 1867. It is tasked with the advancement and promotion of science and technology in New Zealand. Before 1933, it was known as the New Zealand Institute; subsequent Acts, the Royal Society of New Zealand Act 1933, 1965 and 1997, have modernised the structure of the organisation. It was originally established to support regional research societies including the Otago Institute, the Philosophical Institute of Canterbury, the Wellington Philosophical Society and the Auckland Institute, in publishing papers and maintaining records of their undertakings. The New Zealand Institute published a single volume of transactions and proceedings on behalf of these regional societies (McLintock, 1966).

Under the above Acts the stated objective of the RSNZ is 'the advancement and promotion of Science and Technology in New Zealand' (RSNZ, 2009). The following is the function of the RSNZ as set out in the Royal Society of New Zealand Act 1997.

> For the purpose of advancing and promoting science and technology in New Zealand, the functions of the Society are—
>
> a. to foster in the New Zealand community a culture that supports science and technology, including (without limitation)—
>   i. the promotion of public awareness, knowledge, and understanding of science and technology; and
>   ii. the advancement of science and technology education:
>
> b. to encourage, promote, and recognise excellence in science and technology:
>
> c. to provide an infrastructure and other support for the professional needs and development of scientists and technologists:
>
> d. to establish and administer for members a code of professional standards and ethics in science and technology:
>
> e. to provide expert advice on important public issues to the Government and the community:
>
> f. to do all other lawful things which the Council considers conducive to the advancement and promotion of science and technology in New Zealand. (RSNZ Act, 1997: s 6)

The RSNZ is an independent statutory body whose membership is comprised of ordinary members and honorary members, fellows and honorary fellows, companions, constituent organisations, regional constituent organisations and affiliate organisations. The RSNZ is governed by the Society Council; council positions are not salaried (RSNZ, 2011b: 9). Its membership covers science, engineering, social science and the humanities. The RSNZ currently has about 1200 ordinary members and 374 elected Fellows. Its membership also includes a number of regional branches and scientific and technological societies, bringing the number of scientists, technologists and technicians, argubaly representing nearly 20,000 scientists overall (RSNZ, n.d.[b]).

RSNZ is appropriated an annual grant from the Vote Science and Innovation fund. In 2011 this was $500,000 (Treasury, 2011c: 273). The society administered 20 contestable funds on behalf of the government in the year ended 30 June 2011, which was an increase from the 13 contestable funds it administered in 2009 and 2010. The RSNZ received $3.5 million in the 2010 financial year from MoRST in administration fees, a slight increase from the $3.4 million received in 2010 and $2.9 million in 2009 (RSNZ, 2010b: 16; 2011b: 16). The RSNZ also has a number of designated purpose funds, such as the Development Fund and the Charles Fleming Fund, which it distributes as it deems appropriate.

Further, in the 2011 financial year the RSNZ received $60,000 in journal income (an increase from $52,000 in 2010), $78,000 in membership subscriptions (a decrease from $90,000 in 2010) and $303,000 through other sources (a decrease from $436,000 in 2010) (RSNZ, 2011b: 16); (other sources may include fees for running events and venue hire).

Of particular relevance to this report is that the RSNZ manages the Marsden Fund on behalf of the government. The Marsden Fund provides contestable research funding for what is often called 'blue skies' research. A total of $53.8 million has been awarded to researchers to fund 88 projects for the 2011/2012 financial year (RSNZ, 2011c). In 2010/2011 it invested $60.4 million in research projects (RSNZ, n.d.[a]).

7. The New Zealand Association of Scientists

The New Zealand Association of Scientists (NZAS) is a professional body for scientists in New Zealand. The NZAS has a membership of 246 scientists. Unlike the Royal Society of New Zealand it is an independent non-profit incorporated society and registered charity. It exists to promote science in terms of increasing public awareness of science, represent views of New Zealand scientisis, and encourage scientific excellence (NZAS, n.d.[a]). The NZAS states that it works and lobbies to:

- promote science in New Zealand,
- increase public awareness of science and expose pseudo-science,
- debate and influence government science policy,
- improve working conditions for scientists, including gender and ethnic equality,
- promote free exchange of knowledge and international co-operation,
- and encourage excellence in science. (NZAS, n.d.[b])

To this end they are looking at better ways to improve the science system in New Zealand, for example their eigth recommendations in *There is a Better Way: Eight Recommendations on the Science System in New Zealand* (NZAS, 2005).

The NZAS also publishes a peer reviewed quarterly journal *New Zealand Science Review*.

8. Research and Education Avanced Network New Zealand Ltd (REANNZ)

Formed in 2005, REANNZ is the Crown-owned company that owns and operates New Zealand's high capacity, high performance advanced network – KAREN (REANNZ, n.d.).

9. Private sector

This ranges from large companies (such as Fonterra and Fisher & Paykel) through to small firms and consultancies. Many of these companies apply to and receive funding from the government for research. The booklet *Idea to Impact: Making R&D work for your business* (MoRST, 2009c) describes some of the smaller firms that are engaged in research and development.

Appendix 8 Crown Research Institutes: Background

Table 14: Linkages Between MSI's Purpose and the Purpose, Agenda and Funding of CRIs, 2012

Source: See references in Table

(i) MSI's Purpose	(ii) CRI Statement's of Core Purpose	(iii) Research Agenda	(iv) Funding Sources
Leading the science and innovation ecosystem to deliver a step change to New Zealanders' prosperity and wellbeing (MSI, 2011b).	**Industrial Research Limited (IRL):** To increase the contribution of the industrial manufacturing and associated sectors to the New Zealand economy by empowering industry to drive innovation in manufacturing and services. (IRL, 2010: 1)	• increase economic growth by improving the performance and productivity of New Zealand's industrial manufacturing and services sector firms in developing market-led products • increase diversity in New Zealand's manufacturing base by transforming products, processes and services through the development of disruptive technologies and by acting as an intermediary of technology from domestic and international sources for industry • increase human capital and research management expertise in the industrial manufacturing and associated sectors that will lead to a rise in business R&D investment and R&D performed by firms. (IRL, 2010: 1)	Capability Funding (2010/11): $5.67 million Other Funding Sources include: • US Department of Energy • The Pre-Seed accelerator Fund (set up by the government in 2003 to help transform results from publicly funded R&D into viable commercial prospects) • MLA Funding (Mark Loeffen & Associates Ltd) (IRL, 2011: 7, 42, 46, 48)
	Institute of Environmental Science and Research (ESR): To deliver enhanced scientific and research services to the public health, food safety, security and justice systems and the environmental sector to improve the safety and contribute to the economic, environmental and social well-being of people and communities in New Zealand. (ESR, 2010: 1)	• safeguard the health of New Zealanders through improvements in the management of human biosecurity and threats to public health • increase effectiveness of forensic science services applied to safety, security and justice investigations and processes • enhance protection of New Zealand's food-based economy through the management of food safety risks associated with traded goods • improve the safety of freshwater and groundwater resources for human use and the safer use of biowastes. (ESR, 2010: 1)	Capability Funding (2010/11): $5.8 million Other Research investors include: • Ministry of Science and Innovation (MSI) • Health Research Council • The Royal Society of New Zealand • Marsden Fund (ESR, 2011: 3)
	Institute of Geological and Nuclear Sciences (GNS): To undertake research that drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries, that develops industrial and environmental applications of nuclear science, that increases New Zealand's resilience to natural hazards and that enhances understanding of geological and earth-system processes. (GNS, 2010: 1)	• increase resource security and economic benefit from the development and diversification of New Zealand's oil, gas, geothermal energy and minerals industries • increase New Zealand's resilience to natural hazards and reduce risk from earthquakes, volcanoes, landslides and tsunamis • improve the sustainable management of and increase economic returns from groundwater resources • create value for New Zealand industry through the use of isotope and ion beam technologies • increase understanding of the geology and past climates of New Zealand, the Ross Dependency and Antarctica • enhance the geotechnical engineering that underpins New Zealand's transport and energy infrastructure. (GNS Science, 2010: 1)	Capability Funding (2010/11): $5.549 million Other Research investors include: • Technology Transfer New Zealand: 22% • Technology Transfer Overseas: 9% • Marsden Funding: 2% • GeoNet: 12% • Capability Funding: 8% • FRST Funding: 47% (GNS Science, 2011: 6, 48)

(i) MSI's Purpose	(ii) CRI Statement's of Core Purpose	(iii) Research Agenda	(iv) Funding Sources
Leading the science and innovation ecosystem to deliver a step change to New Zealanders' prosperity and wellbeing (MSI, 2011b).	**Landcare Research New Zealand (Landcare Research):** To drive innovation in New Zealand's management of terrestrial biodiversity and land resources in order to both protect and enhance the terrestrial environment and grow New Zealand's prosperity. (Landcare Research, 2010: 1)	• improve measurement, management and protection of New Zealand's terrestrial ecosystems and biodiversity, including in the conservation estate • achieve the sustainable use of land resources and their ecosystem services across catchments and sectors • improve measurement and mitigation of greenhouse gases from the terrestrial biosphere • increase the ability of New Zealand industries and organisations to develop within environmental limits and meet market and community requirements. (Landcare Research, 2010: 1)	Revenue Sources: • MSI: 44% • MW Press & Sundry: 2% • Business Sector: 10% • NZ Universities: 1% • Local Government: 3% • Central Government: 15% • Sirtrack: 7% • CRI: 6% • International: 2% • Capability Fund (MSI): 10% (Landcare Research, 2011: 41)
	National Institute of Water and Atmospheric (NIWA): To enhance the economic value and sustainable management of New Zealand's aquatic resources and environments, to provide understanding of climate and the atmosphere and increase resilience to weather and climate hazards to improve the safety and well being of New Zealanders. (NIWA, 2010: 1)	• increase economic growth through the sustainable management and use of aquatic resources • grow renewable energy production through developing a greater understanding of renewable aquatic and atmospheric energy resources • increase the resilience of New Zealand and South-West Pacific islands to tsunami and weather and climate hazards, including drought, floods and sea level change • enable New Zealand to adapt to the impacts and exploit the opportunities of climate variability and change and mitigate changes in atmospheric composition from greenhouse gases and air pollutants • enhance the stewardship of New Zealand's freshwater and marine ecosystems and biodiversity • increase understanding of the Antarctic and Southern Ocean climate, cryosphere, oceans and ecosystems and their longer-term impact on New Zealand. (NIWA, 2010: 1)	Capability Funding (2010/11): $12.06 million In 2010-2011, NIWA's total revenue, including interest income, was $117.9 million. The main revenue sources were: • Ministry of Science & Innovation: 45% • Other sales: 13% • Central government: 12% • Ministry of Fisheries: 11% • Capability funding: 10% • Private sector: 4% • Local government: 4% (NIWA, 2011: 8, 12)

(i) MSI's Purpose	(ii) CRI Statement's of Core Purpose	(iii) Research Agenda	(iv) Funding Sources
Leading the science and innovation ecosystem to deliver a step change to New Zealanders' prosperity and wellbeing (MSI, 2011b).	**New Zealand Institute of Plant and Food Research (Plant & Food Research):** To enhance the value and productivity of New Zealand's horticultural, arable, seafood and food and beverage industries to contribute to economic growth and the environmental and social prosperity of New Zealand. (Plant & Food Research, 2010: 1)	• increase the value of these industry sectors to the New Zealand economy through the development of high-value products and processes that meet current and future global market needs • protect and enhance market access in New Zealand's horticultural and arable sectors • sustain growth in these industry sectors driving ongoing efficiency gains with the development of environmentally resilient production systems. (Plant & Food Research, 2010: 1)	Capability Funding (2010/11): $10.03 million (Plant & Food Research, 2011: 8) Plant & Food Research receives funding from four major sources: • commercial contracts • contestable government funding, • Core Funding from the New Zealand government • commercialisation activities such as royalties. The most significant sources of contestable funding are: • The Ministry of Science and Innovation • The Ministry of Agriculture and Forestry's Sustainable Farming Fund • The International Science & Technology Linkages Fund and the European Seventh Framework Programme (FP7). Through this funding, a number of co-funded research projects arise with commercial partners, Universities and other Crown Research Institutes. (Plant & Food Research, n.d.)
	New Zealand Pastoral Agricultural Research Institute (AgResearch): To enhance the value, productivity and profitability of New Zealand's pastoral, agri-food and agri-technology sector value chains to contribute to economic growth and beneficial environmental and social outcomes for New Zealand. (AgResearch, 2010: 1)	• increase the value of these industry sectors to the New Zealand economy through the development of high-value pastoral-based products and production systems that meet current and future global market needs • position New Zealand as a global leader in the development of environmentally sustainable, safe and ethical pastoral production systems and products • ensure that New Zealand's pastoral sector is able to protect, maintain and grow its global market access • increase the capacity of rural communities and enterprises to adapt to changing farming conditions in ways that balance economic, environment, social and cultural imperatives. (AgResearch, 2010: 1)	Capability Funding (2010/11): $11.7 million (AgResearch, 2011: 50)

(i) MSI's Purpose	(ii) CRI Statement's of Core Purpose	(iii) Research Agenda	(iv) Funding Sources
Leading the science and innovation ecosystem to deliver a step change to New Zealanders' prosperity and wellbeing (MSI, 2011b).	**New Zealand Forest Research Institute Limited (Scion):** To drive innovation and growth from New Zealand's forestry, wood product and wood-derived materials and other biomaterial sectors, to create economic value and contribute to beneficial environmental and social outcomes for New Zealand. (Scion, 2010: 1)	• increase the value and productivity of these industry sectors to the New Zealand economy through improved forestry practices and production systems and increased diversification of New Zealand's biological industry base to meet current and future global market needs • protect and enhance market access and improve risk management in the forestry industry • increase renewable energy production and energy security by growing New Zealand's ability to produce sustainable bioenergy and liquid biofuel products • enhance New Zealand's opportunity to benefit from forestry-based ecosystem services to improve both the global market position of industry and the environmental sustainability of forestry production in New Zealand. (Scion, 2010: 1)	Capability Funding: $4.26 million (Scion, 2011: 17)

Note:

1. Column (iii) Research Agenda: Where a clear research agenda is not provided in the CRI's annual reports, the outcome has been listed instead. The outcomes identified follow that each CRI agrees to fulfil its purpose through the provision of research and transfer of technology and knowledge in partnership with key shareholders, including industry, government and Māori.
2. Column (iv) Finding Sources: The data listed may not be directly comparable with other CRIs as inconsistencies exist across what information they decied to disclose and what they decide not to disclose.

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