MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
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The Impact of Science

Discussion paper

New Zealand Government

This discussion document seeks to stimulate conversation and dialogue among stakeholders in the science system on the impact pillar of the National Statement of Science Investment 2015-2025.

The paper discusses the concept of impact as it relates to the science system. It sets out why impact is important, what impact is, what impact looks like, and how and where impact is generated. It also discusses the implications of the impact pillar for the science system.

The purpose of the paper is to stimulate conversation and dialogue among stakeholders. It does not present an impact measurement framework with indicators, but it does canvass measurement issues.

MBIE welcomes feedback on the document, in particular, responses to the points raised. Following receipt of feedback, MBIE will produce a policy paper on impact that will inform policies, investment processes and evaluation frameworks.

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Summary

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Identifying the impacts of public investment in science is important

Researchers, scientists, governments, industry and communities all have an interest in better understanding the impacts of science. Scientists wish to demonstrate the benefits of their work, while governments, industry and communities wish to gain value from new knowledge.

Governments around the world are increasingly demanding that public investments in science demonstrate tangible impacts. As major investors in science, governments must be able to show the value of science funding to the public. Science is expected to make contributions to the attainment of explicit societal goals and advance development. An inability to demonstrate impact can jeopardise support for public investments in science over the long term.

New Zealand is no exception to this international trend. The National Statement of Science Investment 2015-2025 (NSSI) sets impact as one of two pillars of the science system. The vision of the NSSI provides the clear expectation that the government's investments in science make measurable contributions to productivity and the wellbeing of New Zealanders. To enact the pillar of impact, the science system needs a collective understanding of impact and an appreciation of the issues involved in generating and demonstrating impact.

Impact is the final, long-term effect in a causal results chain

Impact is part of results-based management and is critical to demonstrating value for money. The 'pathway to impact' is a concept that maps out the causal sequences in a 'results chain', linking the inputs, factors and actors involved in generating outcomes. Impact is the end of the causal chain, representing the final and long-term effects.

Policymakers use the word impact broadly to refer to effects on individuals, groups and society. This is different from the academic use of the word, which refers to the use of knowledge by other academics. This paper suggests that academic impact be integrated into the results chain as a step before impact. Doing so would recognise that excellent science delivering academic impact is an important step along this pathway.

This paper sets out a generic results chain for science

The New Zealand public sector use of the terms outcomes and impacts differs from that widely used across the OECD and the standard results chain model. New Zealand uses outcomes to refer to the final results, ie, the final step in the chain. This can lead to some confusion in the science system, particularly given that many New Zealand scientists collaborate with scientists around the world who

are working in funding systems that use impacts to refer to the end result. A closer alignment with the OECD results chain model and associated definitions would provide needed clarity.

This paper puts forward a generic results chain model for science:

- *Inputs*: stock of knowledge, people, funding, infrastructure and facilities
- *Activities*: interactive process of generating knowledge and training others
- *Outputs*: publications, products and IP that codify knowledge; tacit knowledge exchanged between collaborators; students and postgraduate researchers trained
- *Outcomes*: filling of knowledge gaps; use of knowledge by other researchers, government, industry and organisations; increases in economic, natural, social and human capital
- *Impacts*: increases in productivity and wellbeing.

Properties of knowledge and science make impact assessment challenging

Science is by its nature about discovery, generating new knowledge and applying knowledge. Whole networks of scientists and collaborators generate knowledge, making it challenging to establish inputs and attribution. This is especially the case for a small country like New Zealand.

It is inherently difficult to identify the potential uses of science up front – history tells us we are poor at predicting the use of knowledge. It can take many years for new knowledge to be widely used and applied in various settings, and these uses are often difficult to monitor and track. Complementary inventions and technology are sometimes needed before the full benefits of particular knowledge can be put to use, creating lags in full impact generation. In other cases, society may not be ready to adopt the knowledge; financial, regulatory, social and other barriers may prevent uptake.

Science contributes to a wide range of impacts. Generating these impacts requires engagement of other actors and institutions. Untangling the effect of the science and research is often very challenging. Further, it is difficult to quantify many impacts, such as social and environmental impacts.

This paper discusses the implementation of the impact pillar across the science system

The concept of impact needs to be embedded fully across the New Zealand science system. This may require changes to policies, investment processes and evaluation. For the impact pillar envisioned by the NSSI to be implemented effectively, the following is required:

- Conceptual clarity on the generic results chain with clear distinction between outputs, outcomes and impact
- Focus on the mechanisms and processes to generate impacts (ie, pathways to impact) – such as knowledge exchange, collaboration with end users, and improvements in public policy and human capital – given the difficulties in identifying the contribution science has made to impacts
- Clearer understanding of the geographic, sectoral and social distribution of impacts, given its importance to the rationale for government investment
- Further information on the value New Zealanders place on various impacts

- Widespread use of credible pathways to impact in ex-ante and ex-post processes (assessment of funding applications is an ex-ante process; assessment of results following completion of the science is an ex-post process)
- A much greater emphasis on ex-post evaluation to demonstrate actual impacts, to better understand pathways to impact, and to inform ex-ante assessment
- Development of an ex-post evaluation framework that includes measurement principles and that is underpinned by robust data and information
- Creation of an evidence base drawing on data, information, analytics, and studies on science that show how science has contributed to various impacts.

1. Introduction

The New Zealand Government has identified that excellent, high-impact science is fundamental to New Zealand's ability to achieve economic, environmental, social and cultural benefits for New Zealand.

Impact is one of two pillars of the NSSI; the other is excellence

The National Statement of Science Investment (NSSI) 2015-2025 gives particular prominence to impact, placing impact as a pillar of the science system along with excellence. All New Zealand science is expected to have a measurable contribution to the eventual benefits for individuals, communities, businesses or society.

This paper discusses the concept of impact; it does not present an impact measurement framework

This paper discusses the concept of impact as it relates to the science system. It sets out why impact is important, what impact is, what impact looks like, and how and where impact is generated. It also discusses the implications of the impact pillar for the science system. The purpose of the paper is not to present an impact measurement framework with indicators, but it does canvass measurement issues.

The paper puts forward current thinking and perspectives on impact, drawing on the literature and internal discussion within MBIE. Known gaps in our knowledge are clearly stated.

The paper is designed to stimulate conversation

The intent of the document is to stimulate conversation and dialogue among stakeholders in the science system. A common and shared understanding of the concept of impact and its implications will enable the whole sector to move forward together and realise the vision of the NSSI. This will ultimately improve the impacts generated from science in New Zealand and maximise benefits from government investment.

As a discussion paper, MBIE is seeking feedback – by 29 September

The paper includes a series of discussion points. MBIE welcomes feedback on the document; in particular, responses to the specific points raised. Feedback is sought by September 29 and can be directed to clinton.watson@mbie.govt.nz. Following receipt of feedback, MBIE will produce a policy paper on impact that will inform policies, investment processes and evaluation frameworks.

2. Why impact?

The National Statement of Science Investment (NSSI) 2015–2025 sets out the Government's long-term vision for the science system, and a strategic direction to guide future investment.

> "A highly dynamic science system that enriches New Zealand, making a more visible, measurable contribution to our productivity and wellbeing through excellent science."
>
> **IN 2025, WE WANT TO SEE...**
>
> - a better-performing science system that is larger, more agile and more responsive, investing effectively for long-term impact on our health, economy, environment and society
> - growth in BERD to well above 1 per cent of GDP, driving a thriving independent research sector that is a major pillar of the New Zealand science system
> - reduced complexity and increased transparency in the public science system
> - continuous improvement in New Zealand's international standing as a high-quality R&D destination, resulting in the attraction, development and retention of talented scientists, and direct investment by multinational organisations.
> - comprehensive evaluation and monitoring of performance, underpinned by easily available, reliable data on the science system, to measure our progress towards these goals.

Government wants science to make a measurable contribution to productivity and excellence – this is clear in the vision of the NSSI

The vision is supported by two main pillars or areas of focus where Government will concentrate its activity. These are impact and excellence.

The impact and excellence pillars of the NSSI

- **Impact**: "All of our science should have a strong line of sight to the eventual benefits for individuals, businesses or society. This does not mean focusing purely on industry-led, close-to-market research. Science has an important role in challenging, as well as supporting, existing industries, products, practices, approaches and frameworks." [NSSI, page 7]
- **Excellence**: "the quality of the science system and of the people who work within it is the key determinant of impact. Investment should be subject to a rigorous test for the quality of the science undertaken." [NSSI, page 7]

The pillar of impact is important for several reasons.

Governments are large investors in science and expect science to support the attainment of explicit social goals

First, the New Zealand government, like others around the world, invests significant sums of public funds in the science system.[1] The nature of that funding and expectations associated with public investment have changed over time. Globally, the post-War 'social contract' between science and society left the research community to a high degree free to choose what it researched. It was funded on trust, with the expectation that something socially as well as intellectually useful would come of it in the end. Since the 1960s and 70s, it has been increasingly expected that publicly-funded research should support the attainment of explicit social goals, contribute to economic development and develop solutions for major societal challenges such as climate change. Governments have been increasingly identifying complex societal issues that research should help solve and shifting science investments accordingly.

Public investments in the science system must show value for money

In this context, public investment in the science system must show value for money. This is done by demonstrating and articulating the full range of benefits and impacts of the investments made, *relative* to the funds invested. Ex-post evaluation, which is underpinned by theory and monitoring data, should articulate these benefits.[2] Showing value for money brings about accountability and provides an evidence base for discussions about policy and funding settings. In New Zealand, linked data infrastructures are beginning to generate strong evidence for a wide range of sectors, including the social, justice and health sectors. The research and science systems are not yet able to demonstrate the same compelling evidence. This needs to change given the scale of government investment of around $1.5 billion per year.

> *As the scientific enterprise has expanded and the demand on the taxpayer's dollar also expanded, it is perhaps inevitable that the utilitarian purpose of public science is now expected to be transparently clear. (Gluckman 2012, p. 3).*

Funding agencies must decide how best to allocate money

Funders assess potential impact by looking at particular characteristics that indicate the likelihood of impact generation; these characteristics need to be better understood

Second, those responsible for distributing funding must decide how best to do so. Like any investor, science funders seek to maximise their return on investment. Funding agencies therefore must assess the *potential* impact of research proposals and understand the *actual* impacts of previous and current investments. In ex-ante assessment, funding agencies look for particular characteristics of the proposals that indicate the likelihood of impact generation. These characteristics typically include research quality, alignment to strategic objectives, the track record of applicants, team mix, scientific collaboration, end user engagement and a projected pathway to impact. Gathering data and evidence of successful uptake, translation and impact generation improves understanding of the factors required for impact. This greater understanding improves the assessment of potential impact.

Explicit focus on impact alters behaviours and expectations

Third, an explicit focus on impact alters behaviour and expectations for researchers and end users. There is the opportunity to improve the targets, quality and delivery of science, and increase translation through enhancing engagement between researchers and stakeholders

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[1] The economic case for government investment in science dates back to Nelson (1959) and Arrow (1962). The central idea is that entrepreneurs invest too little in research because the uncertainties are too great and it is difficult to monopolise the new knowledge that results and obtain a good return on the research investment. Empirical studies fairly consistently show that the private rates of return to R&D are high and that the social returns to R&D are consistently higher than the private returns (see, for instance, Wieser 2005). This difference adds further justification to government investment in R&D.

[2] Ex-post evaluation occurs once the investments have been made, ie, once the science has actually finished. Formative evaluation, which occurs while the science is still being performed, may also be needed. The OECD (2002) defines formative evaluation as "evaluation intended to improve performance, most often conducted during the implementation phase of projects or programs" (p. 23).

(Harland and O'Connor 2015). Requirements to show impact – whether potential impact at application stage, or actual impact at reporting and follow-up stages – can make researchers more aware and conscious of pathways to impact. Early engagement with potential users of the research can enable improved understanding of potential relevance and uses of the research. Research questions and methodologies can be more tailored to stated needs of users. An explicit focus on impact might also raise expectations of industry and other end users, which induces more demand for research and collaborations. All of these factors can maximise benefits and shorten the time taken to realise impacts.

An impact focus can foster collaboration and improve the relevance and usefulness of research

> *…the new impact element of the REF [Research Excellence Framework] has contributed to an evolving culture of wider engagement, thereby enhancing delivery of the benefits arising from research…(Stern 2016, p. 9)*

> *Impact…encourages researchers and investors to think about the broader implications of research from the outset, as priorities shift, or when research raises unexpected discoveries (NSSI, p. 11)*

The focus on impact is part of a global trend in public management

The emphasis in the NSSI on impact mirrors general public management principles and international trends in science funding. Over the last 20-30 years, governments around the world have been increasingly referring to impact as results-based management principles become more embedded into public sector management frameworks and operational processes. Impact analysis is now a standard component of the policy or programming cycle in public management. The research community and investment in science is not immune to this trend, as shown below.[3] Most of these settings and initiatives were put in place over the last 5-10 years.

New Zealand is not alone in its emphasis on impact in the science system: eg Australia, Canada, Ireland, the EU, the UK and the US all assess impact

- The United States has developed a repository of data and tools for assessing the impact of federal R&D investments – *Science and Technology for America's Reinvestment Measuring the Effects of Research on Innovation, Competitiveness and Science* (STAR METRICS).
- The US National Science Foundation uses the concept of "broader impacts", ie, "the potential to benefit society and contribute to the achievement of specific, desired societal outcomes"[4] along with intellectual merit (the potential to advance knowledge) to assess proposals.
- The UK Research Excellence Framework now includes an assessment of the impact of research outside of academia.
- Research Councils UK (RCUK) requires applicants to provide pathways to impact statements.
- Ireland's science strategy *Agenda 2020* places impact at its core and Science Foundation Ireland has developed an impact framework to help implement the strategy.
- The Canadian Academy of Health Sciences and the Canadian Institutes of Health Research (CIHR) have developed an impact framework for health research to evaluate the returns on investment in health research.

[3] See also Ruegg and Feller (2003).
[4] https://www.nsf.gov/od/oia/publications/Broader_Impacts.pdf.

- The UK National Institute for Health Research (NIHR) has produced an impact synthesis of 100 case studies showing how NIHR-supported research is improving the health of the public and improving the healthcare system.
- The Australian Research Council is introducing a national impact and engagement assessment, which will examine how universities are translating their research into economic, social and other benefits.
- The European Union has set up a High Level Group of Experts to advise on how to maximise the impact of the EU’s investment in research and innovation.

3. What does impact mean?

Theory of change and results chain

Impact is part of the results chain

Understanding impact requires establishing a theory of change or intervention logic

Impact is a component of results-based management. It is critical to demonstrating value for money. Understanding impact involves establishing a "theory of change", a "programme theory" or "intervention logic."[5] These describe the cascade of cause and effect leading from an intervention to its effects (OECD 2015b). The essence of impact analysis is therefore establishing a chain of causation (or a theory) from intervention to impact, and to measure or describe the changes induced along that chain (results chain).

Results Chain is the causal sequence for a development intervention that stipulates the necessary sequence to achieve desired objectives – beginning with inputs, moving through activities and outputs, and culminating in outcomes, impacts, and feedback (OECD, 2002, p.33)

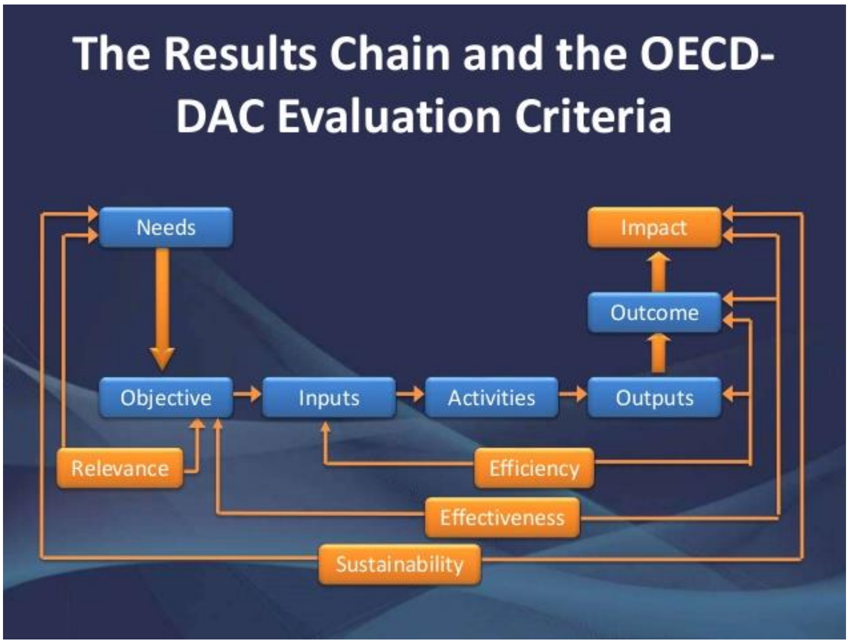
Results chains describe causes and effects, stepping through inputs, activities, outputs, outcomes and impacts

The results chain is a simplification of reality, intended to help reason through the main causal links between inputs, activities, outputs, outcomes and impacts. As one moves through the results chain, the degree of attribution to the original inputs weakens. For instance, many factors are usually required to generate an impact, whereas outputs are more closely tied to the original set of inputs and are under the more immediate control of those receiving funds.

Impact is the ultimate culmination in the results chain. Generating impact requires relevance, efficiency, effectiveness and sustainability. The diagram below from the OECD shows the results chain and the relationship to the five basic evaluation criteria: relevance, efficiency, effectiveness, sustainability and impact. Note that impact is both an element in the results chain and an evaluation criterion.

Impact is the final stage of the results chain and is one evaluation criterion

The blue boxes show the components of the results chain; the orange boxes show the evaluation criteria



[5] Other terms used include logical frameworks, logic models and outcome mapping.

The pathway to impact concept is based on the results chain

As impact is the final step in the causal chain, the phrase "pathway to impact" has emerged over the last 15–20 years to illustrate that previous parts of the results chain – in particular inputs and outputs – have line of sight to impacts. The impact pathway is a model based on the results chain. Pathways identify the different phases of impact generation, the actors involved, the flow of resources, and the progressive transformation of knowledge into outcomes and impacts. Pathways to impact tend to be used mostly in ex-ante assessment.

Impact versus evaluation

Evaluation is key to evidence-based policymaking

Evaluation has become a key component of evidence-based policymaking, providing information and evidence for priority-setting and strategies. Evaluation is expected to foster learning and improvement as well as to ensure accountability.

Evaluations are conducted at increasing levels of aggregation. In the past, research and innovation evaluations typically focused on the individual contract or project level, but they are now also being done at the level of fund, portfolio, research-performing organisation, research funder and national system. There is increasing interest not only in the quality of research outputs, but also in the resulting outcomes and impacts in society.

Impact evaluation is one form of evaluation

Evaluation is broader than impact assessment – it may account for all five criteria identified in figure above

Impact evaluation is one type of evaluation that focuses on the impact of an intervention. Other evaluations may consider the other evaluation criteria – relevance, efficiency, effectiveness and sustainability. Impact evaluation may therefore answer fewer questions than other types of evaluation; it may have little to say about many things that matter to policymaking, such as efficiency related questions or system design. Although impact evaluations can be narrower than other forms of evaluation, the majority can contribute to addressing broader evaluation questions. Collectively impact evaluations can provide insights into wider system-level constraints and opportunities.

The OECD definition of impact

The OECD definition of impact is the most commonly used definition around the world

The most widely used general definition for impact is contained in the OECD's glossary of key terms in evaluation and results based management (OECD 2002). International organisations[6] and evaluation societies, such as the European Evaluation Association, mostly use this definition. Others base a more tailored definition to a specific setting (such as impact in the social sector) on this definition.

The OECD definition says impacts are long-term effects

Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended. (OECD 2002, p. 24)

The OECD definition contains several key concepts:

1. Primary and secondary long-term effects
2. Effects caused directly or indirectly by an intervention
3. Positive and negative effects

[6] See, for instance, United Nations Evaluation Group (2013).

4. Intended or unintended effects.

The results chain distinguishes between short- and medium-term effects (called outcomes) and long-term effects (called impacts)

Impacts usually follow from outcomes with *some* degree of attribution back to the intervention

According to the definition, impacts are limited to *long-term* effects. In the results chain, short- and medium-term effects are considered outcomes.[7] The concept of a long-term effect highlights the duration of the effect, not when the effect occurs in the results chain. However, in line with the cause and effect sequence of the results chain, outcomes typically precede impacts and are frequently intermediate steps to the ultimate impact. In other words, the generation of impact typically relies on the previous elements in the results chain: inputs, outputs and outcomes.

Long-term effects may be either primary or secondary, direct or indirect. The inclusion of secondary and indirect effects in the definition of impact is very important. It signals that an impact may be partially attributable to the intervention. The impact does not need to be solely attributable to the intervention.

The primary effects are the main impacts of an intervention. These usually tie back to the stated purpose of the initiative, ie, the problem to be solved.[8] For instance, the expected primary long-term effects (ie the impact) of a particular science fund may be to stimulate economic diversification. A secondary effect could be that the diversification process contributes to better environmental outcomes as extraction of natural resources decreases. Conversely, an environmental research fund could generate a secondary effect of improving certain health outcomes.

The OECD definition also highlights that impacts may be positive or negative, and intended or unintended. Many interventions yield impacts that were expected in the initial concept and planning documents. It is not unusual, however, for interventions to generate unexpected or unforeseen impacts. This is particularly the case for science where expected uses of knowledge are difficult to foresee. Basic science by definition has no particular use or application in view.

The long-run effect of science and technology is that it improves development. However, negative effects can also occur. For instance, a new technology may lead to production efficiencies, which may then incite job losses. New health technologies can increase quality of life, but can place significant cost pressures on the health system diverting resources away from other uses. Distinguishing between negative and positive effects can be challenging, and may involve value judgments or, ideally, the aggregation of individuals' preferences.

New Zealand public sector definition of impact

The NZ public sector definition of impact is different from the OECD definition

Outcomes in NZ are the end result

In the New Zealand public sector, the use of the terms outcomes and impacts is opposite to that of the OECD. The Treasury defines outcomes as:

> *A condition or state of society, the economy or the environment, and include changes to that condition or state. In effect, outcomes are the end result we [want] to achieve for New Zealanders. Outcomes describe 'why' we are*

[7] The OECD definition of outcome is : "the likely or achieved short-term and medium-term effects of an intervention's outputs".
[8] Note that these problems are often identified following an open consultative process, which usually attempt to respond to the values and preferences of individuals and groups in society.

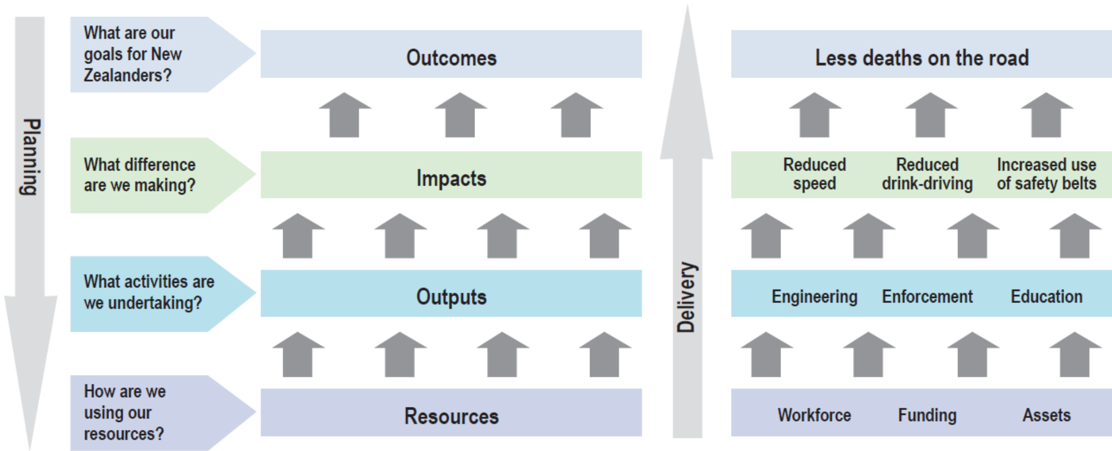
delivering certain interventions on behalf of New Zealanders. (quoted in State Services Commission and the Treasury 2008, p. 31)

Effectively outcomes and impacts are reversed in New Zealand, where impacts are "intermediate outcomes"

This definition of outcome roughly corresponds to the results chain concept of impact as the *final* result. It is fairly consistent with the OECD definition of *outcome* as the extent of attribution back to the intervention is stronger:

> *The contribution made to an outcome by a specified mix of interventions. It normally describes results that are directly attributable to the interventions of a particular agency. Measures of impact at the intermediate outcome level are the most compelling performance indicators for the State sector, as they demonstrate the change in outcome attributable to the specific interventions of the agency. Performance information around impacts enables Ministers and the public to determine the effectiveness of agency performance. (quoted in State Services Commission and the Treasury 2008, p. 31)*

The diagram below reproduces a worked example of the State Services Commission and Treasury concepts of outcomes and impacts. Note that an equivalent diagram using the OECD definitions would be similar, except that the terms outcomes and impacts would be switched. An OECD diagram would also clearly separate activities and outputs.



The NSSI definition of impact

The NSSI definition focuses on the end results – the effects on individuals, communities and society

The NSSI definition is similar to the OECD definition of impact in that it specifically references direct and indirect effects of research. It is similar to the New Zealand Treasury definition of outcome in that it focuses on the end result, ie, the societal effects of research.

> *The direct and indirect 'influence' of research or its effect on an individual, a community, or society as a whole, including benefits to our economic, social, human and natural capital.*

The main difference with the OECD definition of impact is that it does not explicitly refer to long-term effects.[9] However, the explicit references to effects on individuals, communities or society suggest that impact is limited to the long-term, final results – the focus of the OECD definition.

The NSSI definition includes human capital as an impact, but it is questionable whether this is a final or end result

The NSSI definition states that improvements to human capital are impacts. However, this is difficult to reconcile with the idea that impacts are final results. Higher human capital leads to more informed decision-making and to people more equipped with skills and tools for broad application.[10] This increased human capital is put to effective use across the economy and society, such as in the research process itself, in a firm, in a non-profit organisation, or in policy formulation. Rather than conceptualising improvements in human capital as an impact, it would be more consistent with the results chain model to view human capital as an intermediary effect. The *effects* of improvements in human capital are the impacts. An example of a final or long-term effect would be firms increasing their productivity as a result of better human capital.

Academic definition of impact

Academics use impact in a different sense, referring to the use of academic outputs by other researchers

Academics and policymakers often use the word impact in different ways. In the academic world, impact tends to be a more limited concept, referring to the use of academic outputs by other researchers. As a result, much of the scholarly literature on impact is focused on bibliometric proxies of research quality and use, rather than on the benefits society expects to gain from the research it funds. Bibliometrics tell us something about the use of outputs by other researchers, particularly academic researchers.[11] However, we do not know with any certainty the relationship between academic impact and broader socioeconomic impacts.

To avoid confusion between the two usages, RCUK clearly separates “academic impact” from “economic and societal impacts”. The two are defined in the following ways:

RCUK clearly distinguishes between academic impact and economic/social impacts

> *Academic Impact:* The demonstrable contribution that excellent research makes to academic advances, across and within disciplines, including significant advances in understanding, methods, theory and application.
>
> *Economic and societal impacts:* the demonstrable contribution that excellent research makes to society and the economy. Economic and societal impacts embrace all the extremely diverse ways in which research-related knowledge and skills benefit individuals, organisations and nations by:
>
> - Fostering global economic performance, and specifically the economic competitiveness of the United Kingdom
> - Increasing the effectiveness of public services and policy
> - Enhancing the quality of life, health and creative output.

[9] Intended or unintended is not mentioned, but could be taken as implicit, as could positive and negative effects. It should be noted that negative effects of research are unusual as research that leads to ‘dead-ends’ is still valuable. A negative effect could be if a new technology inducing technological change led to increased unemployment.
[10] As demonstrated in endogenous growth theory, human capital is a critical ingredient to economic growth.
[11] There are also limitations to bibliometrics which the vast literature on scientometrics and bibliometrics discusses.

The definition of impact used in the UK Research Excellence Framework (REF) explicitly excludes academic impact. Their definition of impact is "an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia".[12] This includes effects on activities, attitudes, awareness, behaviours, capacities, opportunities, performances, policies, practices, processes or understanding of an audience, beneficiary, community, constituency, organisation or individuals in any geographic location.[13] The Australian Research Council's definition of research impact is similar, as it specifically excludes contributions to academia.[14]

Academic impact should be integrated into the results chain, where it is part of the pathway to impact

Rather than separating academic impact and socioeconomic impact, it is more useful to integrate academic impact into the results chain construct. Academic impact typically forms *part* of the pathway to impact, albeit through indirect and complex channels. The use of knowledge by other researchers is an outcome, i.e. it is the next step after production and dissemination of a scientific output, such as a publication. This use may be critical to generation of further knowledge – in the short term or very long term. Many theories and findings developed decades – even centuries ago – are still being widely used and are even making profound contributions to many innovations today. The accessibility and visibility of research findings influences the use of knowledge.

Considering the definitions

It would be useful to distinguish between outcomes and impacts in a way that aligns with international practice, particularly given the international nature of science

This paper proposes that the New Zealand science system use definitions aligned with the OECD definitions of outcomes and impacts, rather than those used by the New Zealand public sector. The NSSI definition of impact already corresponds more closely to the OECD definition. Science is an international endeavour, and alignment with international definitions and concepts is important for comparability and cross-country dialogue, collaboration and the evaluation of impact generated by investments in different countries. Adopting the international concepts would not mean ignoring the New Zealand public sector definitions. The issue is more one of labelling, rather than an underlying difference in concept. In order to have clarity and a sound understanding of the 'pathway to impact' concept, the OECD-based definition is the most appropriate.

The NSSI does not make a clear distinction between outcomes and impacts. Moving forward, it may be useful to delineate between outcomes and impacts in the New Zealand science system, with the key distinction being intermediate versus final effects. The short-term versus long-term distinction of the OECD definition is also generally useful as impacts have a long-term duration and many follow intermediate outcomes. Distinguishing between the effects does not lessen the importance of short-term and intermediate outcomes. The distinction helps clarify the pathway to impact and the end points of the path.

[12] http://www.hefce.ac.uk/rsrch/REFimpact/.
[13] See REF 02.2011.
[14] The ARC defines research impact as "the demonstrable contribution that research makes to the economy, society, culture, national security, public policy or services, health, the environment, or quality of life, beyond contributions to academia" (Australian Research Council 2015).

Discussion points: While the focus needs to be on the pathway to impact, the definition of impact still matters. Should the NSSI definition of impact be made clearer to refer only to final results, long-term results or both? What are the reasons for your view? Note focusing only on final results would mean excluding improvements in human capital and academic impact as impacts, but these concepts would clearly form part of the results chain, ie, part of the pathway to impact.

4. What does impact look like?

Science generates many different types of impacts. The NSSI places productivity[15] and wellbeing as overarching impacts supported by economic growth, environment, health, mātauranga and society (refer to the diagram below).

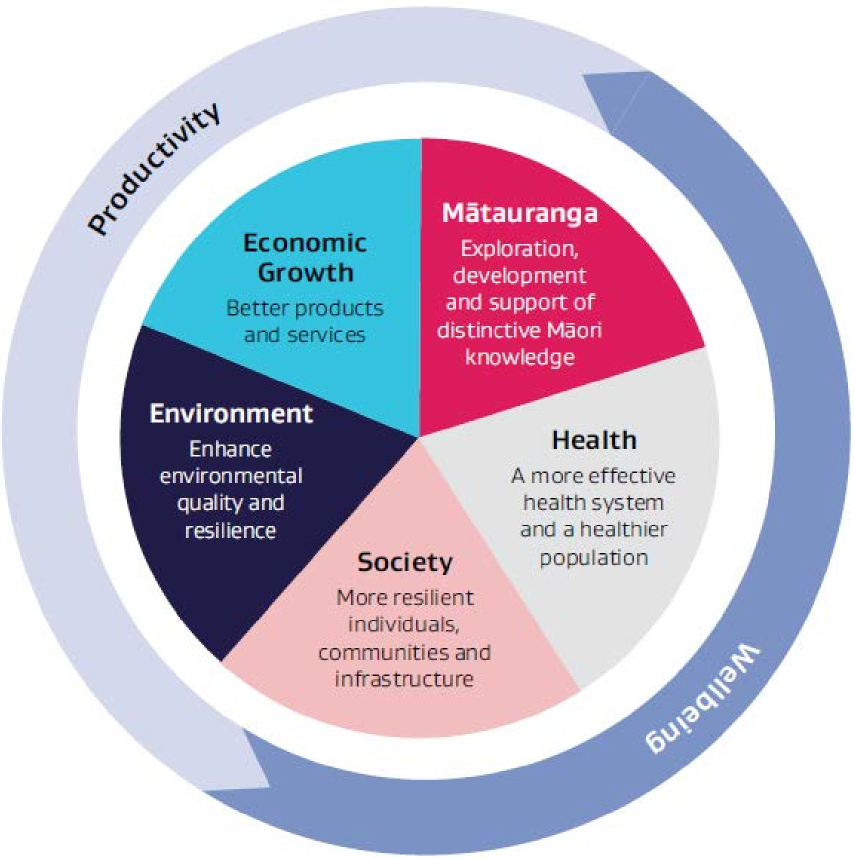
Science contributes to multiple impacts

Science and research can contribute to a wide range of impacts. For example, the impact of endangered species protection could be considered in terms of economic (growth in the tourism industry), environmental (role in the ecosystem), and cultural or social (as taonga or public amenity) values. A new medical treatment may improve health and reduce the days of work lost to a particular illness.

Science is a contributor to impacts – other actors and institutions are required to generate impacts

It is important to note that science is a *contributor* or *input* to achieving these impacts, rather than an end or objective in itself. Generating outcomes and realising the final impacts requires engagement of other actors and institutions beyond scientists and researchers. For instance, in the health area, realisation of health outcomes is dependent on the research system generating useful knowledge and the health system applying that knowledge into policies and practices.

The NSSI sets out productivity and wellbeing as the final impacts, with impacts separated into economic growth, environment, society, health and mātauranga



[15] Refer to pages 32 and 33 of the NSSI for a discussion on economic productivity.

Specifying all the impacts of science is not practical as they are so diverse and varied

Within these broad areas in the NSSI, the impacts of science are so many and diverse it would be a fruitless exercise to capture them all at planning stages. The US National Science Foundation purposely does not prescribe targets for its impacts, but leaves them "open to innovation from the field". However, we can identify the key *areas* of impact by drawing together government's various objectives across the economic, environmental, health and social domains.

The NSSI provides *examples* of the dimensions of impact to which science could be expected to contribute (refer following page). Many of the dimensions are interdependent. The NSSI list reflects key government priorities in the various areas. Note that the table does not clearly distinguish between outcomes and impacts with the result that the table contains a mix of both.

A wide range of government documents set out impacts in various areas – the science sector need not duplicate this effort

Some government documents contain more details on particular goals in specific areas. For instance, the *Conservation and Environment Science Roadmap* sets out expected long-term goals for New Zealand in the conservation and environment areas.[16] For health and disability, the New Zealand Health Strategy, the New Zealand Disability Strategy, *He Korowai Oranga* (the Māori health strategy) and *'Ala Mo'ui* (the Pacific health strategy) articulate various goals. These goals are reflected in New Zealand's health research strategy.

The following are some of the dimensions of impact that we consider

<table>
<tr><th>ECONOMIC</th><th>ENVIRONMENTAL</th><th>HEALTH & WELLBEING</th><th>SOCIAL</th></tr>
<tr><td>New/improved products and services</td><td>Reduced or mitigated environmental impact</td><td>Improved population health and health status for disadvantaged groups</td><td>Increased knowledge of and interest in science</td></tr>
<tr><td>Reduced operating costs or commercial risk</td><td>Reduced or mitigated environmental risk</td><td>Reduction in health maintenance costs</td><td>Understanding of and resilience to real or perceived communal risk</td></tr>
<tr><td>New job opportunities</td><td>Improved condition of an environmental asset</td><td>Early detection and mitigation of health risks</td><td>Stronger social and infrastructure systems and improved techniques for delivery of public services</td></tr>
<tr><td>Improved business and industrial processes</td><td>Better understanding of the environment, and characterisation and management of natural capital</td><td colspan="2">Improved wellbeing through development of human and social capital, and removal of institutional barriers</td></tr>
<tr><td colspan="4">Value extraction from existing science</td></tr>
<tr><td colspan="4">Improvements in public policy advice</td></tr>
<tr><th colspan="4">VISION MĀTAURANGA</th></tr>
<tr><td>Indigenous innovation: economic growth through distinctive R&D</td><td>Taiao: sustainability through iwi and hapū relationships with land and sea</td><td colspan="2">Hauora/Oranga: improved health and social wellbeing</td></tr>
<tr><td colspan="4">Mātauranga – explore indigenous knowledge for science and innovation</td></tr>
</table>

[16] See page 11.

The NSSI dimensions outlined are similar to those used by others.

- The Small Advanced Economies Initiative has proposed a six pillar impact framework: economic, health and wellbeing, natural capital and built environment, policy and public services, future capacity and skills, societal and international.
- Science Foundation Ireland groups impacts into economic, societal, international engagement, policy and public service, health and wellbeing, environmental, professional services and human capacity impacts.
- The UK Research Excellence Framework (REF) groups impacts into eight categories: political, health, technological, economic, legal, cultural, societal and environmental.
- A framework proposed by Motu Economic and Public Policy Research has five categories: economic, environmental, public policy, capability and social.

Treasury's Higher Living Standards Framework

The Treasury's *Higher Living Standards* Framework may provide a useful way for framing up impacts

A potential useful frame for organising the impacts of science is the Treasury's *Higher Living Standards* framework. Living standards refers to people having greater opportunities, capabilities and incentives to live a life that they value, and that people face fewer obstacles to achieving their goals. The Treasury notes that others have used terms like wellbeing and happiness to mean much the same thing as living standards (Treasury 2015).

The framework emphasises four types of capital: economic, natural, social and human

The framework is based around four types of capital:

- *Economic* – individual, community and financial assets
- *Natural* – extracted and renewal resources, environmental services such as climate, breathable air and soil
- *Social* – the cultural, philosophical and ethical norms of society, social and political institutions that organise society, the way people interact
- *Human* – stock of skills and qualifications that people have, level of health, systems used to organise people to create value.

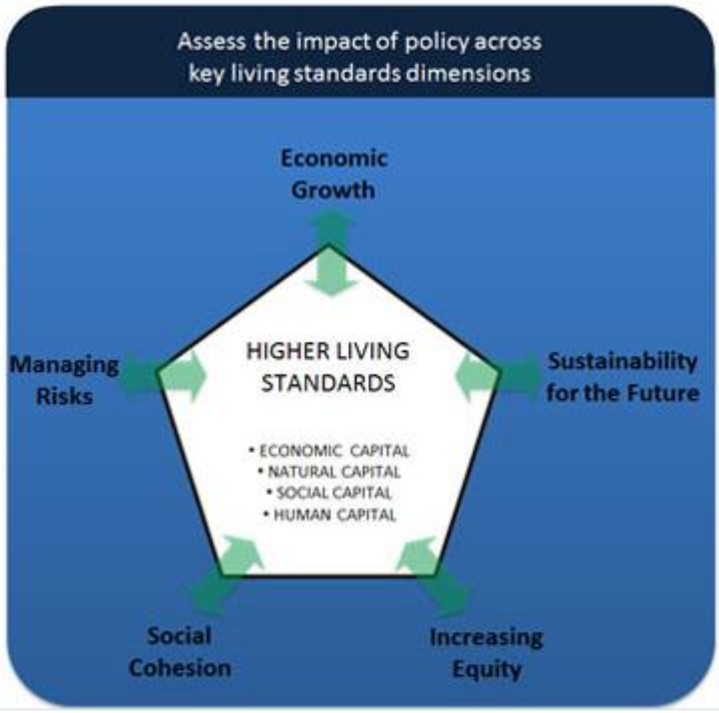
These capitals are intermediate steps to generating the final impacts

These different types of capital drive many of the things that are important for lifting living standards. They can therefore be seen as *intermediate steps* to generating the final impacts.

The living standards framework suggests policies indicate their effects on five aspects:

- *Economic growth* – lifting people's incomes and the resources available to spend on community assets, like schools, hospitals, welfare and roads
- *Sustainability for the future* – the future of human, social and physical/financial capital as well as natural capital
- *Increasing equity* – the distribution of everything of value, including income, and fair processes
- *Social cohesion* – core institutions and trust that underpin New Zealand society
- *Managing risks* – New Zealand's ability to withstand unexpected shocks, including economic and natural hazard risks.

We could view these five areas as the impacts of science with specific inclusion of Vision Mātauranga.



Discussion point: Should the science system adopt the Treasury's Higher Living Standards *Framework to assess and organise the impacts of science? What about the other impact categorisation frameworks, such as that proposed by the Small Advanced Economies? What are the reasons for your views?*

5. How and when is impact generated?

Many factors are required to generate impact, including scientific excellence and use of knowledge

The generation of excellent science underpins impact generation, but does not by itself lead to widespread adoption of new knowledge and thus impacts. Other actors, institutions and circumstances are required to ensure dissemination, adoption and use of knowledge. The science system must therefore produce new knowledge and diffuse knowledge effectively through various mechanisms in partnership with others. Those in the science system need to work with others to facilitate the adoption and use of knowledge. Other sectors and systems need effective mechanisms for applying knowledge, which often involve partnership with the research and scientific community.

Theories of change for the science system are not well developed

To understand how and when impact is generated requires a theory of change or a well-developed results chain. The results chain highlights that the generation of impact results from a chain of circumstances. We need to understand the reasons why the inputs and activities will lead to the outputs, and why those outputs lead to outcomes and impacts. As the science of science policy is a nascent area of research, we do not fully understand the results chain for science and the mechanisms by which all impacts are generated.

High-level results chains for science

The diagram on the following page sets out a generic results chain for science. It shows the range of inputs, activities, outputs, outcomes and impacts generated from the science system. Science push and demand pull factors can occur at any step in the chain. Knowledge dissemination and diffusion can occur at any stage, but in particular during the research process itself and following the production of outputs.

Pages 28–31 contain four examples of results chains using the generic model. The examples are designed to show the concepts and steps in the chain. Most are not drawn from actual examples and are not designed to show all the inputs and impacts of a particular grant. It is likely that there are many indirect effects of any one science intervention, given the properties of knowledge and the fact that innovations feed off one another.

All the examples take a specific funding award as the unit of analysis. They also do not show the many possible indirect effects of the award. Results chains could also take a fund or portfolio of projects as the unit of analysis. Theoretically a whole national science system could be the unit of analysis, but actually constructing the web of interactions would be very challenging. Tools from network analysis are providing ways of understanding the system, but network studies on the science system are sparse.

A further diagram on page 32 shows a more complex chain to show the reality of the science system as a complex web of interactions. The diagram is designed to show the interconnectedness of the science system and the multiple uses of knowledge.

The generic results chain for science includes:

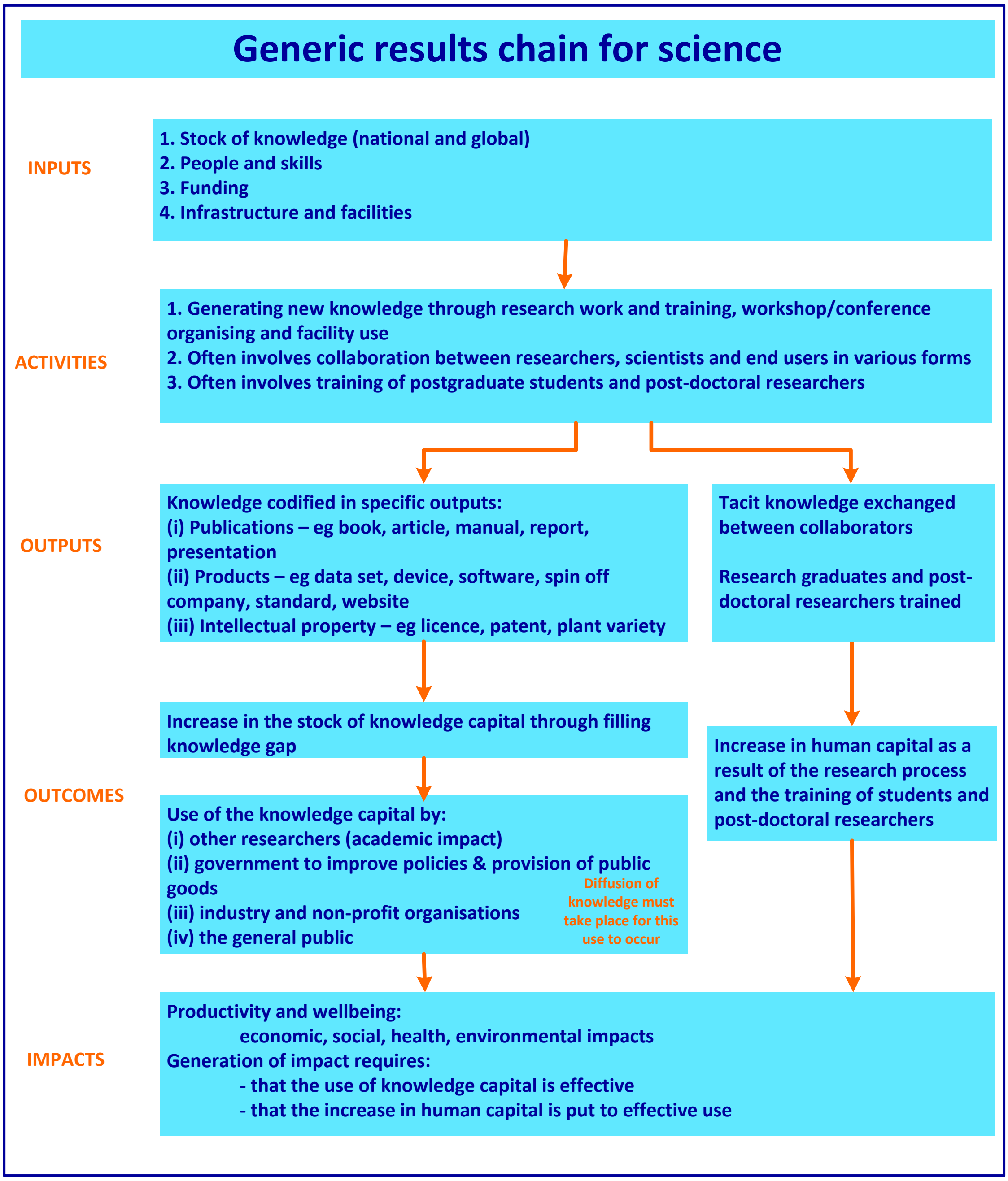
A wide range of inputs, including the existing stock of knowledge

A series of activities, involving generation of new knowledge, collaboration and training

Outputs that codify knowledge and other outputs indicating tacit knowledge transfer and trained people

Outcomes that indicate the stock of knowledge is increased and that the knowledge is being used; outcomes that lead to increased human capital

Impacts that show quality of life has improved



Discussion point: How well does the generic results chain capture the science system at a high-level?

Discussion point: How could the worked examples on pages 28–32 be improved?

Key mechanisms along the pathway to impact

Need to distinguish outcomes and impacts

This paper helps clarify the distinction between outcomes and impacts and the pathway to impact. Several of the examples provided in the NSSI would be better seen as outcomes, ie, steps along the pathway to impact. For instance, new products and processes are outputs of publicly funded science. The adoption of a new product is an outcome and the impact is the effect on productivity of the new product.

Key mechanisms for generating impacts are changes in policy, provision of improved public goods and human capital development. These sit in the outcomes part of the results chain. The OECD has called them "intermediate impact mechanisms".

The OECD has proposed a set of "intermediate impact mechanisms" (OECD 2015c). These mechanisms fall in the *outcomes space* of the generic framework on the previous page. The set includes the following:

- industrial innovation (including innovation in services as well as products and processes)
- research-influenced changes in policy, agenda-setting
- the provision of improved public goods (and potentially the provision of associated state services)
- the improved exercise of professional skill, for example in research-based improvements in medical practice
- human capital development.

Research and science have made significant contributions to public policy in the past and will continue to do so in the future. Public policy is, however, not an end in itself, as policies are designed with particular societal objectives in mind. Effects on public policy are better considered an intermediate step to generating an impact. For instance, social research may lead to changes in delivery of social services by government agencies and non-profit organisations. These changes are an outcome. The effects of these changes in delivery, such as a higher employment rate, are the impacts.

In a similar vein, improvements in human capital resulting from participation in the research process, may be better seen as intermediate outcomes. As identified in the Treasury's *Higher Living Standards* framework and the OECD's intermediate mechanisms, human capital is a critical underpinning factor to achieving many impacts, such as improved economic growth and greater levels of wellbeing.

We do not know the importance of each of these mechanisms to the generation of impact. Further investigation is needed to understand how these mechanisms operate and their importance. A key question is the role of science in triggering and shaping the mechanisms.

Discussion point: What are your views on the mechanisms or processes for generating impacts? What intermediate outcomes are especially important?

Uncertainties and complexities of science

Applying the results chain incurs many challenges:

Applying the generic results chain for science contains several challenges:

Inputs are hard to measure

- The inputs of a science project are often difficult to specify and measure, because a key input to almost any activity is the global stock of knowledge – either codified or tacit. This reflects the fact that research and innovation is cumulative, building on existing knowledge and findings.

Networks make attribution difficult

- Networks of people and institutions are often involved in the creation of research outputs and in their diffusion and adoption. Attributing effort, activities and results to individuals and institutions can therefore be difficult.

Impact often cannot be predicted

- In many cases impacts cannot be foreseen or predicted. Basic research by definition has no particular use in mind,[17] although some basic research is oriented or directed towards broad fields of general interest, with the explicit goal of a range of future applications.[18]

Impacts often occur years after the initial science

- The use and impacts of research, in particular basic research, is often generated years after the research has been undertaken.

It is hard to track the use of research outputs

- Knowledge is non-rival and non-excludable.[19] Because of these properties it can be very challenging to follow and track the use of research outputs.

Outputs can be used by thousands – if not millions of researchers

- A particular output can be used by multiple researchers, sometimes thousands – even millions. These researchers may then expand and apply the new knowledge, in conjunction with other knowledge. Attributing this new knowledge back to particular outputs can be very challenging, especially for basic research. The advent of bibliometrics in the 1960s has, however, shed much light on this, although much research is not cited or credited.

Many end users may use the knowledge and their use is hard to track

- Various end users may use the new knowledge embodied in the output, but this can be difficult to track. Where an end user is pre-identified and is providing funding, the monitoring and tracking is more straightforward. However, many other end users may also use the knowledge – sometimes years after the production of the knowledge. This can create difficulties in knowing where to look for evidence of impact. The commercialisation of science can also make obtaining evidence of impact challenging

[17] The Frascati Manual (OECD 2015a) defines basic research as “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”.

[18] Frascati Manual para 2.27. Pure basic research is carried out for the advancement of knowledge, without seeking economic or social benefits or making an active effort to apply the results to practical problems or to transfer the results to sectors responsible for their application. Oriented basic research is carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to recognised or expected current or future problems or possibilities.

[19] Non-rival means that others can use the knowledge without detracting from the knowledge of the producers. Non-excludable means that others cannot be stopped from using the information.

as those capturing the benefits of specific intellectual property may be reluctant to reveal the commercial advantages generated.

Not all knowledge is codified

- Not all knowledge can be codified and expressed in an output. Some have argued that scientific and technological knowledge often remains tacit.[20] Understanding how this information is transferred and the associated uses and effects of this can be challenging.

These challenges are caused essentially by uncertainty and lags

Many of the challenges for understanding the generation of impact arise from the uncertainties and complexities associated with knowledge generation, transmission and use. These uncertainties and lags also affect all impact assessments. These factors combined with the lack of research on the science system make it difficult to create comprehensive results chains for science, no matter the unit of analysis for the chain – eg, contract, portfolio or fund. Impact assessment is therefore challenging.

The sources and categories of uncertainty and lags include the following:

There are large uncertainties in identifying the uses of knowledge and technologies up front

1. Inherent difficulty of identifying uses for a new theory, finding or technology, for instance:
    a. Faraday first discovered electromagnetic induction, the principle behind the electric transformer and generator in 1831, but it took many decades for the uses of electricity to be identified.
    b. The laser was not first applied in industrial applications until 30 years after its scientific discovery and these applications were not originally envisaged.
    c. Theories in solid state physics laid the basis for the semiconductor decades later, but this was not foreseen.
    d. Wireless telecommunications drew on the 1940s information theory of Shannon, but this application was unable to be identified at the time.
2. The potential of a new breakthrough or technology can be realised only after a long period of improvement, involving ongoing research and development, for example:

Lags occur because potential applications can often only be realised after a long period of improvement

    a. The potential applications of *Aspirin* were only discovered almost a century after its invention. The origins of Aspirin trace back to 1897[21] when Bayer's Felix Hoffman developed and patented a process for synthesising acetyle salicylic acid or aspirin. Clinical trials in 1899 were successfully completed and aspirin was launched. But it was not until 1974 that the first evidence of aspirin's effects in preventing heart attacks emerged. In 1989 research suggested aspirin may delay the onset of senile dementia. Further uses were discovered in 1994 when researchers found that aspirin may help in treating pre-eclampsia in pregnant women. In 1995 aspirin was found to protect against bowel cancer (International Aspirin Foundation 2017).
    b. LCD display can be traced back to a series of theoretical and technological breakthroughs: 1888 in Austria with Friedrich Reinitzer's discovery of liquid

[20] See, for instance, Rosenberg (1990) and Pavitt (1991, 1998).
[21] Even this research drew on previous knowledge, including the 1853 French discovery that salicylic acid irritated the gut, and research by German scientists in 1893. In fact the story of aspirin goes back to around 400 BC when Hippocrates gave women willow leaf tea to relieve the pain of childbirth.

crystal properties, 1927 the electrically switched light valve of Vsevolod Frederiks, and the Marconi Wireless Telegraph Company British patent of 1936 for the liquid crystal light valve (Nesterov 2014).

Lags also occur because of the systemic features of innovation, eg, complementary technologies are often required before the knowledge can be put to effective use

3. The systemic features of complementary improvements or innovations, for instance:
   a. people are often limited in their thinking or limited by the existing system – eg, during the telegraph era, the telephone was almost inconceivable.
   b. improvements of complementary technologies are needed before a technology can be put to use, for example wind power needed a raft of technologies: turbine, generator, new materials, machine tools.
4. Inventors tend to aim new technology at narrow and specific domains of use, sometimes foreclosing other applications. For example, the transistor was designed for use only in hearing aids, but it then moved to use in consumer electronics, computers and semiconductors. Modern ICT systems would not be possible without the transistor, yet the transistor's initial targeted use was very narrow.

Financial, regulatory and other barriers can slow down adoption

5. Even if a product is a potential market success, it is possible that financial, social or other barriers might prevent it being developed.
6. New products may depend on policy or regulatory settings for their success, in which case their ultimate value will depend on policy decisions.

A key complicating factor of impact assessment is that the diffusion of new knowledge – and therefore the use of knowledge – takes many years. The longer the time takes, the more likely additional actors have had an influence on the process. This makes attribution analysis more complicated. Some highlights from research on this area:

Empirical studies show diffusion and use of knowledge takes many years, often 20-30 years

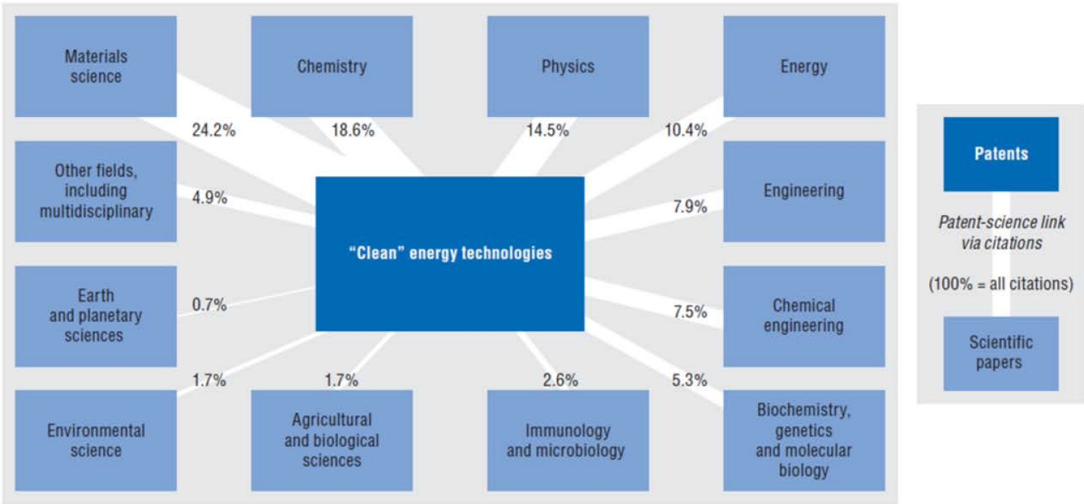
- Adams (1990) found a 20-30 year lag between scientific publication (the knowledge stock) and productivity growth.
- A ground-breaking research paper from 1990 found that the average lag between academic research findings and the commercialisation of the innovations based on those findings was seven years (Mansfield 1990).
- Work on agricultural research in the United States identified that lags in the range of 35-50 years are plausible, although most impacts were exhausted within 35 years (Alston *et al* 2010).
- One study found that the average time for translating research in the biomedical and health sciences into societal benefit is 17 years (Morris et al 2011).
- Citations for journal articles typically peak seven years after the article was published. Citations for books peak even later.
- On a more positive note, a review of the REF impact case studies estimated research has impacts on society after three to nine years (King's College London and Digital Science 2015).

Researchers use new knowledge in multiple ways, increasingly across institutions, disciplines and borders – this makes it hard to track use of knowledge

Science is becoming increasingly collaborative as interdisciplinary research is required to address complex problems. The research process is therefore becoming more complex. Researchers and innovators use new knowledge in multiple ways, increasingly across institutions, disciplines and borders. As an example, clean energy technologies used knowledge from a wide range of disciplines, including material sciences, chemistry, physics, energy, engineering and biochemistry (see diagram below). This illustrates that pathways to impact are complex and sometimes difficult to foresee. Basic research is particularly complex as the uses tend to have broad applicability, suggesting that impact from basic research is high when considering impact over a long time. The impact from more applied research is likely to be more immediate and predictable, particularly if end users are involved in the research process. However, as the potential uses of the knowledge is narrower, the final impacts may be lower.

For example, clean energy technologies drew on a whole range of scientific fields

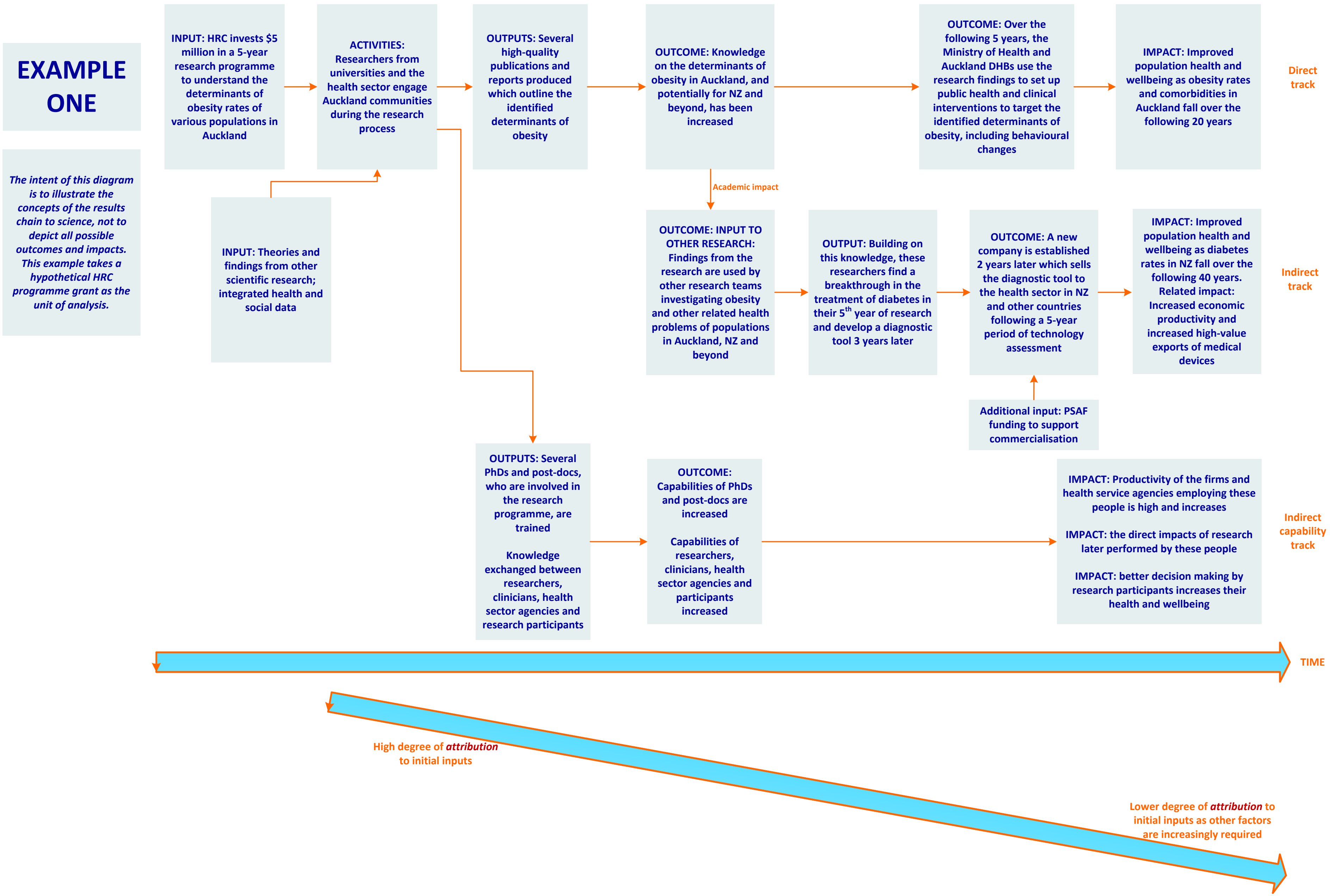
(Share of scientific fields cited in total non-patent literature cited in patents for clean energy technologies)

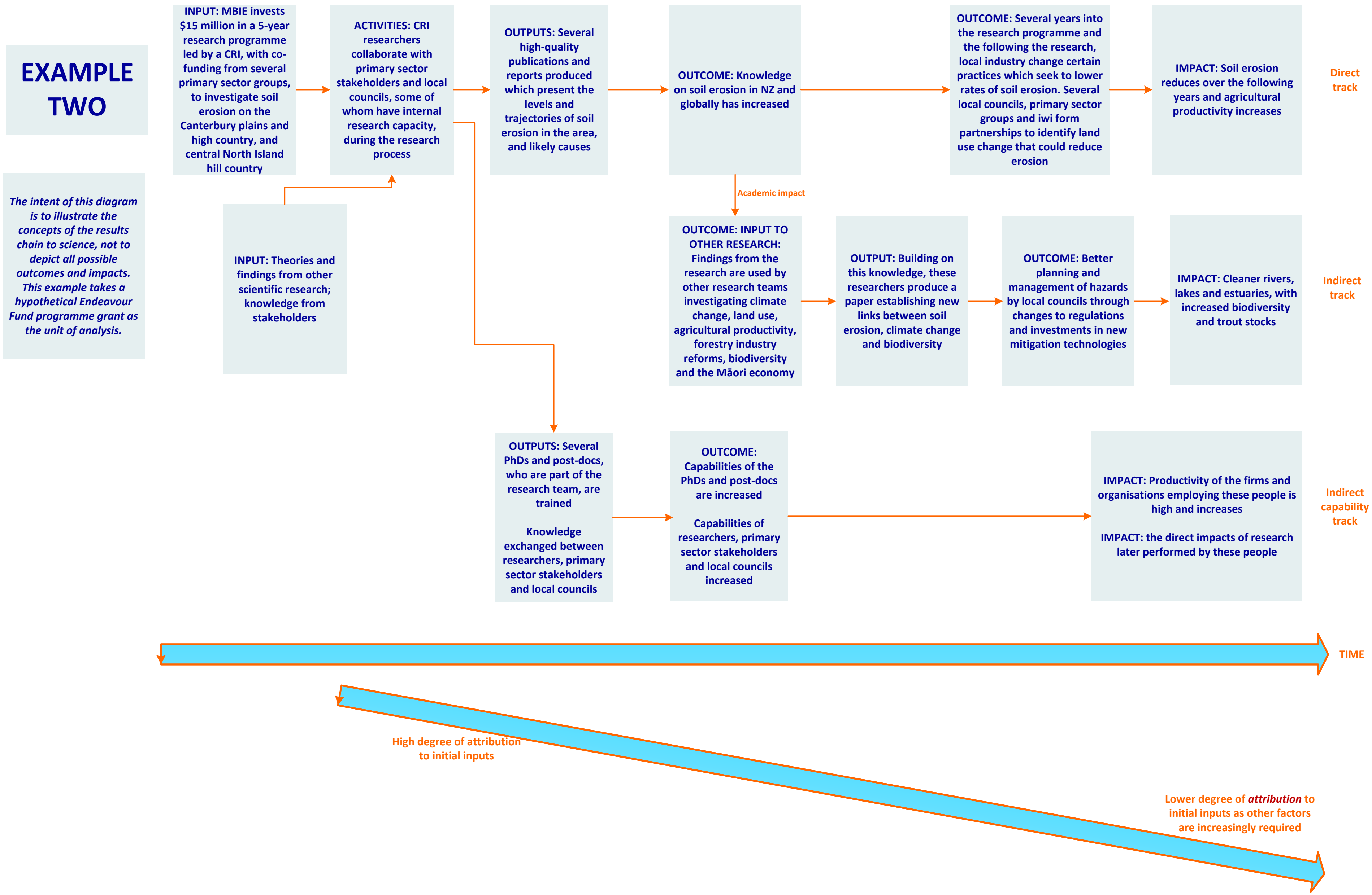


Source: OECD STI Scoreboard 2011, based on Scopus Custom Data, Elsevier, December 2010; and EPO, Worldwide Patent Statistical Database, April 2011.

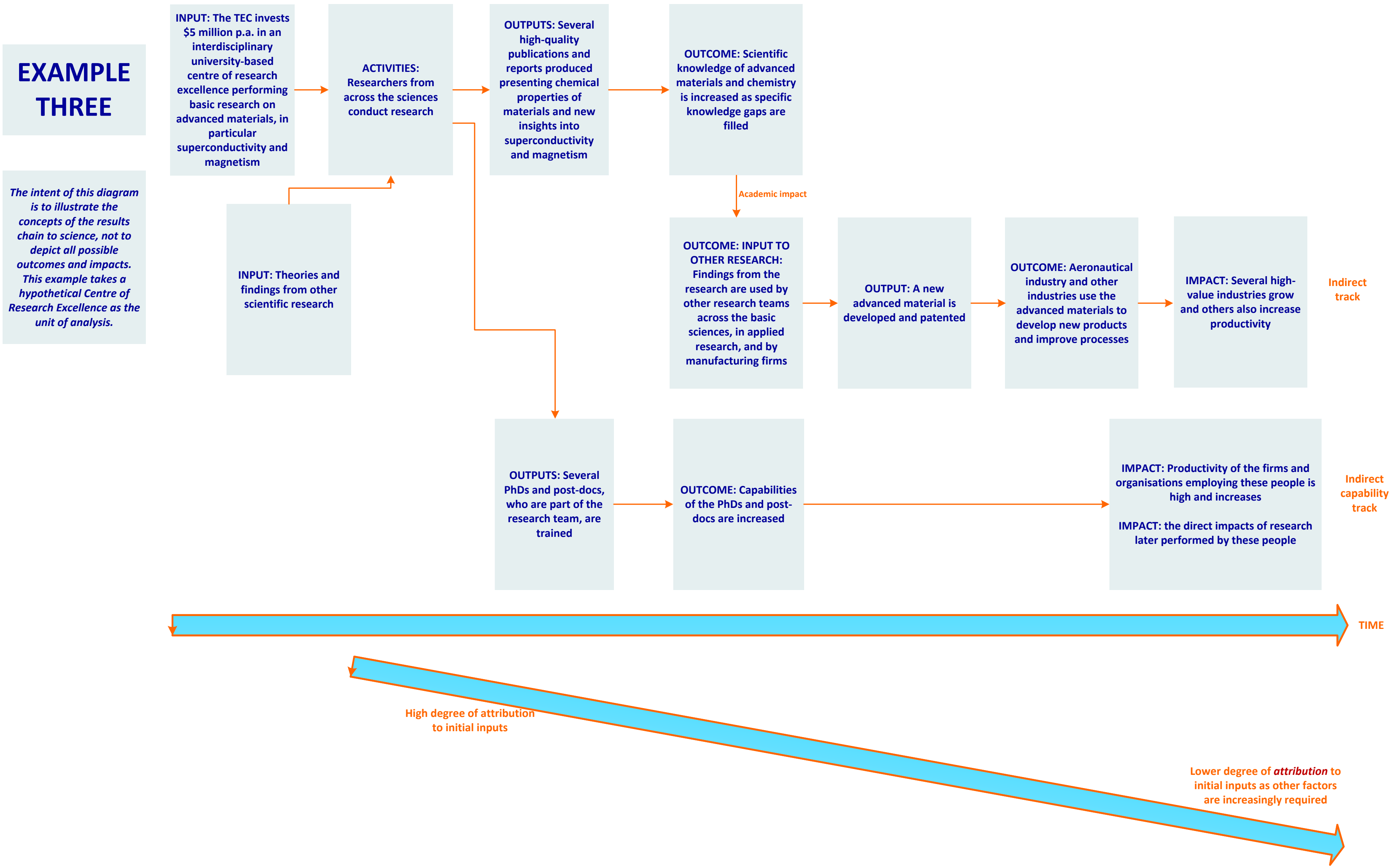
Source: OECD (2016).

This section has proposed a generic results chain for science. It has also discussed the challenges in applying that results chain, in particular, the uncertainties and complexities of science. Given the imperative on all public investments to demonstrate impacts and value for money, we need to find ways to deal with the difficulties and improve impact assessment. The next section discusses several possible approaches.

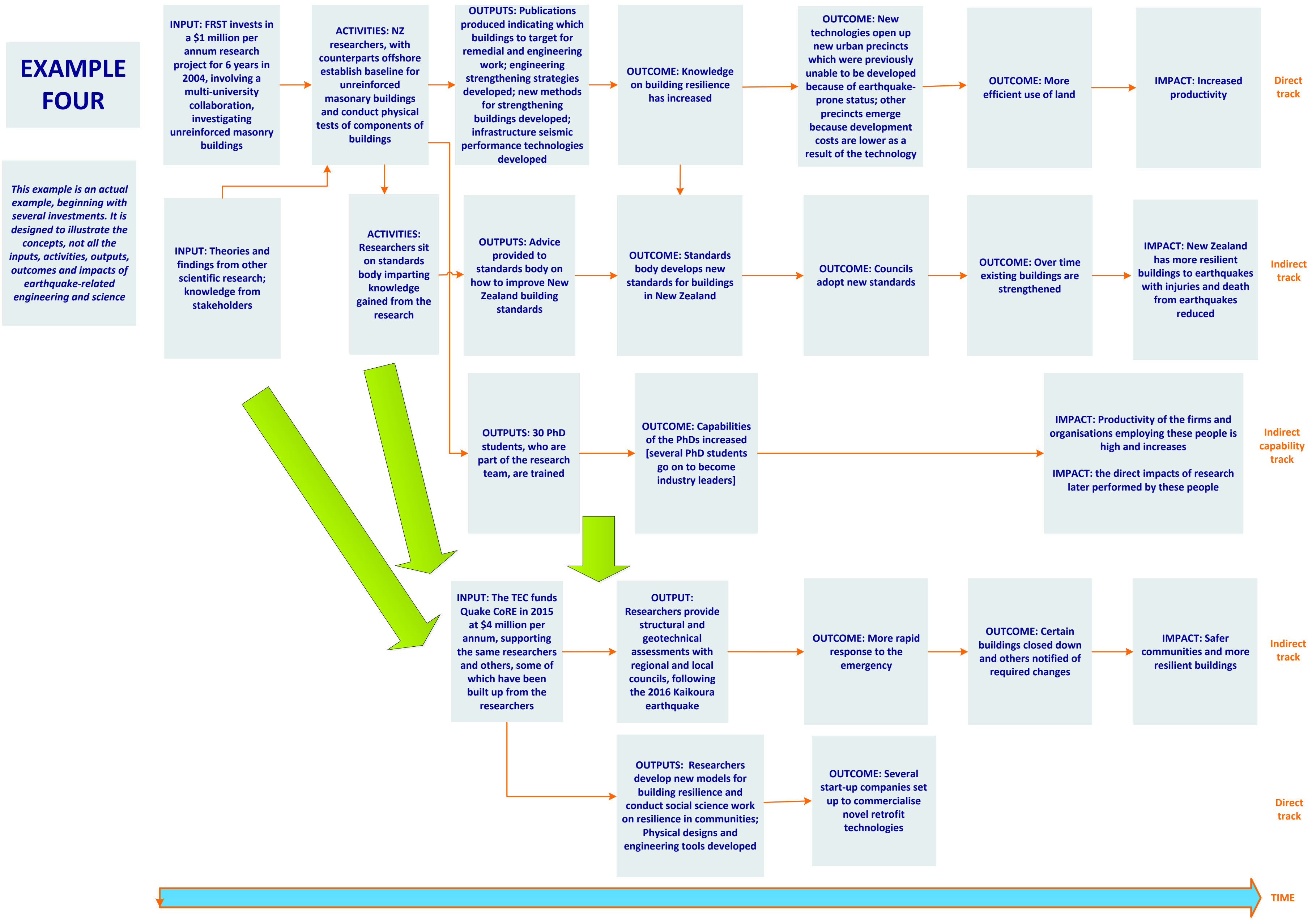

EXAMPLE ONE
The intent of this diagram is to illustrate the concepts of the results chain to science, not to depict all possible outcomes and impacts. This example takes a hypothetical HRC programme grant as the unit of analysis.
INPUT: HRC invests $5 million in a 5-year research programme to understand the determinants of obesity rates of various populations in Auckland
ACTIVITIES: Researchers from universities and the health sector engage Auckland communities during the research process
OUTPUTS: Several high-quality publications and reports produced which outline the identified determinants of obesity
OUTCOME: Knowledge on the determinants of obesity in Auckland, and potentially for NZ and beyond, has been increased
OUTCOME: Over the following 5 years, the Ministry of Health and Auckland DHBs use the research findings to set up public health and clinical interventions to target the identified determinants of obesity, including behavioural changes
IMPACT: Improved population health and wellbeing as obesity rates and comorbidities in Auckland fall over the following 20 years
Direct track
INPUT: Theories and findings from other scientific research; integrated health and social data
Academic impact
OUTCOME: INPUT TO OTHER RESEARCH: Findings from the research are used by other research teams investigating obesity and other related health problems of populations in Auckland, NZ and beyond
OUTPUT: Building on this knowledge, these researchers find a breakthrough in the treatment of diabetes in their 5th year of research and develop a diagnostic tool 3 years later
OUTCOME: A new company is established 2 years later which sells the diagnostic tool to the health sector in NZ and other countries following a 5-year period of technology assessment
IMPACT: Improved population health and wellbeing as diabetes rates in NZ fall over the following 40 years. Related impact: Increased economic productivity and increased high-value exports of medical devices
Indirect track
Additional input: PSAF funding to support commercialisation
OUTPUTS: Several PhDs and post-docs, who are involved in the research programme, are trained
Knowledge exchanged between researchers, clinicians, health sector agencies and research participants
OUTCOME: Capabilities of PhDs and post-docs are increased
Capabilities of researchers, clinicians, health sector agencies and participants increased
IMPACT: Productivity of the firms and health service agencies employing these people is high and increases
IMPACT: the direct impacts of research later performed by these people
IMPACT: better decision making by research participants increases their health and wellbeing
Indirect capability track
TIME
High degree of attribution to initial inputs
Lower degree of attribution to initial inputs as other factors are increasingly required



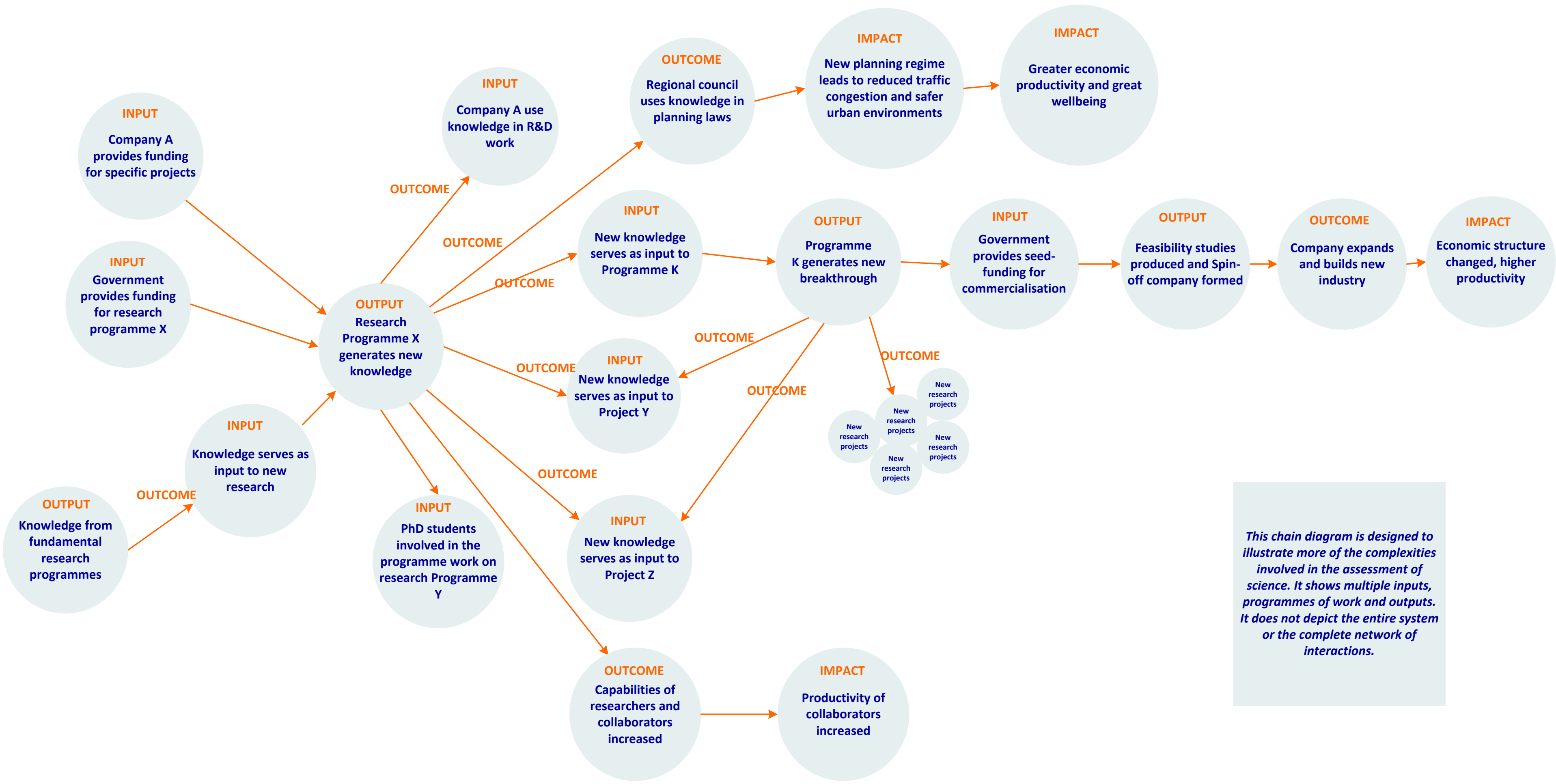
EXAMPLE TWO
The intent of this diagram is to illustrate the concepts of the results chain to science, not to depict all possible outcomes and impacts. This example takes a hypothetical Endeavour Fund programme grant as the unit of analysis.
INPUT: MBIE invests $15 million in a 5-year research programme led by a CRI, with co-funding from several primary sector groups, to investigate soil erosion on the Canterbury plains and high country, and central North Island hill country
ACTIVITIES: CRI researchers collaborate with primary sector stakeholders and local councils, some of whom have internal research capacity, during the research process
OUTPUTS: Several high-quality publications and reports produced which present the levels and trajectories of soil erosion in the area, and likely causes
OUTCOME: Knowledge on soil erosion in NZ and globally has increased
OUTCOME: Several years into the research programme and the following the research, local industry change certain practices which seek to lower rates of soil erosion. Several local councils, primary sector groups and iwi form partnerships to identify land use change that could reduce erosion
IMPACT: Soil erosion reduces over the following years and agricultural productivity increases
Direct track
INPUT: Theories and findings from other scientific research; knowledge from stakeholders
Academic impact
OUTCOME: INPUT TO OTHER RESEARCH: Findings from the research are used by other research teams investigating climate change, land use, agricultural productivity, forestry industry reforms, biodiversity and the Māori economy
OUTPUT: Building on this knowledge, these researchers produce a paper establishing new links between soil erosion, climate change and biodiversity
OUTCOME: Better planning and management of hazards by local councils through changes to regulations and investments in new mitigation technologies
IMPACT: Cleaner rivers, lakes and estuaries, with increased biodiversity and trout stocks
Indirect track
OUTPUTS: Several PhDs and post-docs, who are part of the research team, are trained
Knowledge exchanged between researchers, primary sector stakeholders and local councils
OUTCOME: Capabilities of the PhDs and post-docs are increased
Capabilities of researchers, primary sector stakeholders and local councils increased
IMPACT: Productivity of the firms and organisations employing these people is high and increases
IMPACT: the direct impacts of research later performed by these people
Indirect capability track
TIME
High degree of attribution to initial inputs
Lower degree of attribution to initial inputs as other factors are increasingly required



EXAMPLE THREE
The intent of this diagram is to illustrate the concepts of the results chain to science, not to depict all possible outcomes and impacts. This example takes a hypothetical Centre of Research Excellence as the unit of analysis.
INPUT: The TEC invests $5 million p.a. in an interdisciplinary university-based centre of research excellence performing basic research on advanced materials, in particular superconductivity and magnetism
ACTIVITIES: Researchers from across the sciences conduct research
OUTPUTS: Several high-quality publications and reports produced presenting chemical properties of materials and new insights into superconductivity and magnetism
OUTCOME: Scientific knowledge of advanced materials and chemistry is increased as specific knowledge gaps are filled
INPUT: Theories and findings from other scientific research
Academic impact
OUTCOME: INPUT TO OTHER RESEARCH: Findings from the research are used by other research teams across the basic sciences, in applied research, and by manufacturing firms
OUTPUT: A new advanced material is developed and patented
OUTCOME: Aeronautical industry and other industries use the advanced materials to develop new products and improve processes
IMPACT: Several high-value industries grow and others also increase productivity
Indirect track
OUTPUTS: Several PhDs and post-docs, who are part of the research team, are trained
OUTCOME: Capabilities of the PhDs and post-docs are increased
IMPACT: Productivity of the firms and organisations employing these people is high and increases
IMPACT: the direct impacts of research later performed by these people
Indirect capability track
TIME
High degree of attribution to initial inputs
Lower degree of attribution to initial inputs as other factors are increasingly required


EXAMPLE FOUR
This example is an actual example, beginning with several investments. It is designed to illustrate the concepts, not all the inputs, activities, outputs, outcomes and impacts of earthquake-related engineering and science
INPUT: FRST invests in a $1 million per annum research project for 6 years in 2004, involving a multi-university collaboration, investigating unreinforced masonry buildings
ACTIVITIES: NZ researchers, with counterparts offshore establish baseline for unreinforced masonary buildings and conduct physical tests of components of buildings
OUTPUTS: Publications produced indicating which buildings to target for remedial and engineering work; engineering strengthening strategies developed; new methods for strengthening buildings developed; infrastructure seismic performance technologies developed
OUTCOME: Knowledge on building resilience has increased
OUTCOME: New technologies open up new urban precincts which were previously unable to be developed because of earthquake-prone status; other precincts emerge because development costs are lower as a result of the technology
OUTCOME: More efficient use of land
IMPACT: Increased productivity
Direct track
INPUT: Theories and findings from other scientific research; knowledge from stakeholders
ACTIVITIES: Researchers sit on standards body imparting knowledge gained from the research
OUTPUTS: Advice provided to standards body on how to improve New Zealand building standards
OUTCOME: Standards body develops new standards for buildings in New Zealand
OUTCOME: Councils adopt new standards
OUTCOME: Over time existing buildings are strengthened
IMPACT: New Zealand has more resilient buildings to earthquakes with injuries and death from earthquakes reduced
Indirect track
OUTPUTS: 30 PhD students, who are part of the research team, are trained
OUTCOME: Capabilities of the PhDs increased [several PhD students go on to become industry leaders]
IMPACT: Productivity of the firms and organisations employing these people is high and increases
IMPACT: the direct impacts of research later performed by these people
Indirect capability track
INPUT: The TEC funds Quake CoRE in 2015 at $4 million per annum, supporting the same researchers and others, some of which have been built up from the researchers
OUTPUT: Researchers provide structural and geotechnical assessments with regional and local councils, following the 2016 Kaikoura earthquake
OUTCOME: More rapid response to the emergency
OUTCOME: Certain buildings closed down and others notified of required changes
IMPACT: Safer communities and more resilient buildings
Indirect track
OUTPUTS: Researchers develop new models for building resilience and conduct social science work on resilience in communities; Physical designs and engineering tools developed
OUTCOME: Several start-up companies set up to commercialise novel retrofit technologies
Direct track
TIME

More complex chain



This chain diagram is designed to illustrate more of the complexities involved in the assessment of science. It shows multiple inputs, programmes of work and outputs. It does not depict the entire system or the complete network of interactions.

6. Implementing the impact pillar of the NSSI

Previous sections have summarised the need for impact, explained the concept of impact and discussed the generation of impact. This section discusses the implementation of the impact pillar of the NSSI.

Embedding a shared concept of impact

The concept of impact needs to be embedded across the science system

Most importantly, a shared concept of impact needs to be embedded across the New Zealand science system. Strategies, investment plans, funding mechanisms, operational policies, evaluation frameworks and data systems all need to support impact. This does not mean that all research and science needs to generate immediate impact, but that at some point in time all investments should be able to demonstrate actual pathways to impact.[22]

What it does mean is that the science system needs to place weight on both the creation of knowledge and its diffusion. The science system needs to support collaboration between researchers, scientists and end users. This will improve knowledge generation, application and dissemination processes. But the science system cannot be solely responsible for the use of knowledge and impact generation. At the highest level, the national innovation system needs to support interactions between the science system, the economy and society.

Results chains and pathways to impact are needed for ex-ante and ex-post evaluation

More ex-post evaluation is needed, which can inform ex-ante assessment

The embedding of impact requires the mainstreaming of the concept of 'results chains' or 'pathways to impact.' This can happen in both ex-ante and ex-post evaluation. To date, the science system has focused almost exclusively on ex-ante assessment, with little ex-post evaluation. A better balance needs to be struck between the two forms of assessment, particularly given the major difficulties of identifying the *expected* uses and impacts of science. Improved ex-post assessment of impact also improves ex-ante assessment. Better understanding of real-life pathways and examples of science impact need to feed into ex-ante assessment criteria and processes.

Need to focus on the mechanisms and processes needed to achieve impact

It can be very difficult to step through the pathway to impact for particular science projects, funds or the activities of whole research institutions. Because of these challenges, the *mechanisms* and *processes* to achieve impact need to be embedded throughout the system. These mechanisms and intermediate outcomes are often easier to identify and measure than the effects of science on long-term impacts. Particular emphasis needs to be placed on diffusion, engagement with end users, and building of the four types of capital. All assessments and evaluations need to pay particular attention to these dimensions, while recognising that it is often not research and science organisations that are responsible for them. Concerns around time lags and reliance on conditions outside of a researcher's control can be minimised by explicitly identifying these factors in applications, reporting and evaluation.

[22] Scientific failure can be very important as it identifies that a particular approach or methodology does not yield results, thus filling a gap in knowledge.

Constructing and assessing chains and pathways ex-ante

All research proposals should contain pathways to impact, even if they are only partial

All research proposals should contain credible pathways to impact. The generic results chain for science provides a useful way to apply a pathway to impact for the particular scientific proposal and problem definition.

Pathways to impact should integrate the fact that the generation of new knowledge and impacts faces many uncertainties and lags. Multiple actors are required to generate impact. Because of these factors, ex-ante assessment of science proposals needs to look at characteristics along the pathway to impact that indicate the likelihood of impact generation. Our understanding of these characteristics is growing as better data becomes available. At present, the following considerations are thought to influence impact generation:

Pathways should address many considerations, such as research quality, end user engagement and scientific collaboration, as these are thought to influence impact

- At the *input* level:
  - Track record of applicants and institutions
  - Team mix
  - Investment from other sources, such as industry or non-private organisations
- At the *activity* level:
  - Relevance of the research to the funder
  - Relationships and engagement with end users, including users shaping the agenda[23]
  - Scientific collaboration
  - Training of postgraduate students and young researchers
  - Diffusion mechanisms for knowledge
- At the *output* level:
  - Alignment of research outputs to strategic objectives and identified societal challenges
  - Contribution to the national and global stocks of knowledge
  - Quality of research outputs
- At the *outcome* level:
  - The importance of the particular knowledge gap to be filled
  - Identification of possible users of the expected knowledge and those users' needs and capacities to make the best use of knowledge
  - Diffusion mechanisms for knowledge
  - Previous uses of similar research
- At all levels:
  - Use of evaluation throughout the project.[24]

[23] See, for instance, Sarewitz (2016) which argues that impact is increased when users drive the agenda.
[24] Developmental evaluation has recently emerged as a means for researchers and stakeholders to engage regularly, reflecting on the extent to which their activities are progressing towards the target outcomes and impacts. Developmental evaluation is particularly suited to innovation and complex environments given the rapid pace of change and multiple interactions occurring at any one time. See Patton (2011).

Pathways to impact for basic research proposals are likely to only be partial; they can address many of the considerations, but the use and application of the knowledge may be fairly uncertain

These aspects may not be able to be applied to all research proposals. Basic research by definition does not have a particular use or application in mind, hence end users cannot usually be identified with any certainty. However, proposals for oriented basic research[25] can identify expected contribution to a broad base of knowledge which is likely to form the basis of the solution to recognised or expected problems or possibilities. Basic research proposals can also identify potential impacts by showing how similar research in the past has been used. For instance, a quantum theoretical modelling research proposal could show how models have been used to develop industrial catalysts or new engineering alloys. Basic research proposals can indicate the quality of the research idea, the importance of the identified scientific problem to the advancement of knowledge, the quality of the researchers, and the extent of collaboration with leading researchers in New Zealand and around the world.

Engagement with end users is especially important

Applied science proposals, but also some basic research proposals, should be underpinned by effective engagement and collaboration with potential users of the knowledge. However, Government invests because of the spillovers generated from science. Mechanisms are therefore needed to ensure wide dissemination of the knowledge so that a broad range of people and institutions may apply the knowledge. Open access policies and practices – particularly of data and publications – play an important role in disseminating and transferring knowledge beyond pre-identified users. The use of outputs should not be locked into a narrow set of users for government funded science.

Constructing and assessing chains and pathways ex-post

Because of the nature of science more investment is needed into ex-post evaluation

Ex-post evaluation is an assessment conducted after a certain period has passed since the completion of an intervention. Given the nature of the science, ex-post evaluation is important for understanding pathways to impact and demonstrating actual impacts, whether expected or unexpected.

There has been very little ex-post evaluation of science in New Zealand and capacity needs to be built. No funding agency has systematic ex-post evaluation. On a more positive note, the CRIs and several universities have commissioned a limited number of case studies to show the actual impacts of their research.

Evaluation of science is more complicated than in most other areas. The central problem for ex-post evaluation is to connect an intervention or activity with its effects: that is, to establish what it caused. But interventions take place in a dynamic context. Many changes are afoot and it is not always evident what would have happened if the intervention had not taken place. That is, construction of the counterfactual is challenging.

Retrospective pathways can be reconstructed

However, retrospective pathways to impact for research investments can be reconstructed, even if the journey along the pathway takes many years. The pathways may be partial, but can still be extremely useful for demonstrating some of the impacts of investments over many years. The results chains can start with known uses and impacts, and work back to identify underpinning research. Other times, the analysis may begin with the investments and work forward to identify outputs, outcomes and impacts associated with the investments.

[25] Refer Frascati Manual 2.28.

Case studies can begin with an innovation and work backwards to construct a pathway

Case studies are widely used in science impact assessment. One of the most famous case studies was the retrospective tracing of key events that led to five major technological innovations, including the oral contraceptive “the Pill”. The study was conducted by the Illinois Institute of Technology Research Institute in the 1960s, and was entitled “Technology in Retrospect and Critical Events in Science” (TRACES). The study found that more than 340 significant R&D events were important to the five major innovations; that about 90% of the non-mission research relevant to the innovations had been accomplished 10 years prior to innovation; and the bulk of non-mission research was completed without sight into the innovation to which it will ultimately contribute (Mosaic 1970).

Distribution of impacts

We need to better understand the distribution of impacts as this affects investment decisions

Government primarily invests in R&D and science because of the spillovers generated. Empirical studies consistently show that the social rates of return are systematically higher than the private rates of return. Government effectively subsidises the science system to ensure more R&D is generated than would otherwise be the case. However, at present little is known about the nature of the returns from different funding mechanisms and different fields of research. We also know very little about the distribution of impacts of various investments.

An expected narrow distribution of impacts weakens the case for government investment, but broad benefit strengthens the case for government investment

In theory, a very narrow distribution of benefits significantly weakens the case for government investment. In the science system, if a particular firm or industry is expected to capture the benefits from the science, the case for government to support the R&D is weakened. In reality, one firm or industry is unlikely to capture all the benefits, but it is possible that they could be the primary captors of the benefit. Conversely, a wide distribution strengthens the case for government intervention as each benefiting entity is less likely to be able to capture the benefits of the science. It is because of this distribution that government support for basic science around the world has been greater than that for experimental development.

Geographic distribution is also an important consideration

Another aspect to consider is the distribution of benefits to New Zealand versus the rest of the world. The New Zealand government is primarily interested in benefits that accrue to the New Zealand economy and society. Some types of research may yield more benefit to New Zealand than other types of research because of the importance of the application to New Zealand and the lack of research carried out elsewhere. Examples might be research on specific population groups in New Zealand, geological and climate features of New Zealand and science for economic sectors which are larger in New Zealand than elsewhere.

Ex-post evaluation will increase understanding of the benefit distribution

Ex-ante assessment of science proposals should consider the distribution of impacts. This is certainly not straightforward, given the difficulties highlighted in the previous section. However, as ex-post evaluation is strengthened, we will begin to build the evidence for understanding the types and distributions of impacts. This can then inform policy design and ex-ante assessment of proposals. A better understanding of how knowledge is used (ie, the outcome level) will be critical to understanding the distribution of impacts and informing evidence-based policy.

Comparing impacts

Monetisation of different impacts would facilitate comparison and adding up of benefits, but monetisation is not always possible or appropriate

Science contributes to a wide range of impacts. Comparing the different impacts of the science system and adding them together requires a common unit of analysis. The most pervasive common unit of value in current society is money. Some economists argue that theoretically everything can be valued in monetary terms. Others, however, argue that monetisation is either inappropriate or not always possible. Jaffe (2015) argues that different types of science impacts are fundamentally non-commensurable so it is not possible to derive a single composite metric of all research impacts that would be useful for decision purposes. Jaffe also argues that some impact categories cannot be monetised. NZIER also reaches similar conclusions.

An advantage of expressing benefits in dollar values is that it allows a comparison across projects. It is not uncommon that there are no market transactions from which to take dollar values – this is particularly so in relation to social and environmental outcomes. There are a number of techniques to estimate dollar values, such as surveys and experiments to assess people's willingness to pay for, say, water quality improvements or for road features that avoid accidents that could result in harm. Sometimes it is not practical (or appropriate) to convert outcomes into dollar values. In such cases it is helpful to express the benefits of projects in a consistent as possible basis. This will then make it still possible to compare the relative effectiveness, if not utility, of projects per dollar spent. (NZIER water evaluation).

Even if monetisation cannot be done systematically, the science system can still state the nature and scale of its contribution to various impacts

In an ideal state, technical assessments would compare and weigh impacts – whether ex-ante or ex-post. In the absence of this, the political system provides a way of balancing impacts. Decision-makers in this system need information and evidence on the nature and scale of impacts in different areas. Information on the processes and mechanisms required for generating impact is also useful. It can help government Ministers, policymakers and the public understand and appreciate the benefits of science, including the distribution of those benefits. We need to improve our ability to demonstrate the wide types of impacts generated from science and the mechanisms involved.

People place different values on various impacts

Assessing committees need to be able to draw on studies showing the value New Zealanders place on different impacts – science proposals tend to contribute to multiple impacts

The assessment of science proposals is confronted directly with the difficulty of comparing and adding up expected impacts.[26] People place different values on various outcomes and impacts and determining these values for society as a whole across the range of benefits is not feasible. Assessors of various proposals also have their own values which will influence their assessment of proposals. In order to maximise the wellbeing of New Zealanders, assessing committees should draw on information showing the value New Zealanders place on various impacts. Even if this information is partial and does not compare all types of impact, the information would help ensure research proposals respond to the impacts New Zealanders value. One example of the type of information that could be useful is the survey results commissioned by New Zealanders for Health Research. The results show the importance New Zealanders attach to health research compared with other research areas and expenditure on other public goods.

[26] Ex-post evaluation is also confronted with this problem, but most ex-post evaluations do not attempt to compare and add up all impacts.

Developing an evaluation framework

An evaluation framework for assessing ex-post impacts of the science system is needed

Alongside improved understanding and embedding of pathways to impact, we need an evaluation framework for assessing ex-post impacts of the science system. This could expand on the generic results chain and include a set of standard measures that apply across funding mechanisms. Various approaches have been developed overseas that could be adopted for the New Zealand context, such as the Canadian payback model for health research.[27] A challenge with creating measures is that a narrow focus on limited measures can create perverse outcomes. For example, researchers may focus on boosting their reportable performance instead of pursuing genuine research engagement that translates into economic, social or other benefits.

A set of principles need to underpin the framework, which would be based on the generic framework on page 22. These could include:

- A foundation on the inputs, activities, outputs, outcomes and impacts of the generic framework on page 22
- Acknowledgement of the broad range of impacts to which science may contribute, including mātauranga Māori
- Acknowledgement of the timeframes involved in impact generation
- Acknowledgement that evaluation frameworks influence incentives and behaviour
- Measurement principles (discussed below).

Evaluation can take place at different levels: portfolios, funds, entities, projects, the individual

The evaluation framework needs to consider evaluation at *different levels*, such as portfolios, funds and entities. Several points are worth stating:

- It is likely that assessing impacts for smaller, especially one-time, research projects is not insightful. Aggregating various projects into any number of portfolios may be more meaningful given the nature of science and innovation and the interactions across various projects.
- Another potential unit of analysis is the individual researcher. It is ultimately people that generate new knowledge through collaborating, sharing ideas and using equipment. Understanding collaborations and how knowledge is transferred through people-to-people interactions may help demonstrate impacts of science and developing better results chains.
- Perhaps the most powerful evaluation would be impact at the level of the system. Typically, impact assessments of individual instruments (such as individual funding mechanisms) do not take into account the interactions of these instruments with other mechanisms, even with those seeking to attain identical goals. Yet these interactions can have powerful positive and negative effects on goal attainment.

A set of *impact measurement principles* could form a part of the framework. The Australian Research Council (2016) has developed the following principles:

[27] The 'payback' model seeks to capture knowledge production; research targeting and capacity building; informing policy; health and health sector benefits; economic benefits. See CIHR (2005).

Impact measurement principles are needed for the evaluation framework – the Australian Research Council (ARC) has developed a set

- Acknowledge that excellent research underpins impact
- Promote understanding through use of common language and terms associated with research impact
- Respect the diversity in research disciplines/sectors in demonstrating research impact
- Cooperate in developing a set of common, cost-effective and efficient parameters for data collection and reporting
- Adopt a consultative approach with stakeholders regarding implementing impact reporting in support of future research investments
- Encourage, recognise and reward positive behaviour in planning, monitoring and evaluating research impact.

Other principles could include: consideration of the counterfactual; and for evaluation to take place at various levels – eg, contract, portfolio, fund, institution.

The evaluation framework needs specific measures and ways to address attribution

A useful evaluation framework would set out *specific measures and ways to address attribution back to research and science*. New Zealand already has many measures for impact and the science system does not need to re-collect this data, such as statistics on GDP, unemployment, firm and industry productivity, life expectancies, burdens of disease, air quality, climate, land use, crime and social cohesion. There are perhaps very few impact measures that are solely attributable to science. The focus for the science system needs to be on developing models and methods to determine the effect science has had on those measures. For example, in the economic space, evaluation needs to show how science has contributed to:

- improving firm-level and industry-level productivity through developing new products, processes, methods and practices
- improving productivity through improved human capital as a result of participation in research (eg, research graduates)
- development of new high-value industries
- deepening integration into global value chains
- enabling access to new markets and state-of-the-art knowledge for businesses.

Measures that are more directly attributable to research activities and outputs could include:

- income from intellectual property, such as licensing arrangements
- income from industrial research
- revenue from spin-off companies.

Improving data and information

Evaluation framework needs to consider data and information requirements – the *Domain Plan* sets out the direction and vision for data improvement

Any evaluation framework needs to consider data and information requirements. Data is required along *all* steps of the results chain.[28] The *Research, Science and Innovation Domain Plan* sets out the strategic vision and direction for improving data on research, science and

[28] Note that input data is also important for answering questions related to value for money or return on investment. It is also needed for attribution.

innovation in New Zealand. One key driver for the domain plan is to provide data for monitoring and evaluation purposes.

Data in the National Research Information System will be an important resource for impact assessment

The National Research Information System, and its associated data model and standards, will generate data for various measures and uses. The data will be at a sufficient level of disaggregation that it can be grouped and cut in various ways for different analysis. The system is designed to capture unit record data, ie, metadata about particular inputs and outputs, as this enables data analytics and the linking of data. This kind of data forms the basis for evaluative work, such as a recent study on research outputs of the Marsden Fund (Gush et al 2015) and the Ministry of Education's *CoREs and effect* report (Smyth and Smart 2013).

> *Actors involved in the development of information for evaluation and interested in the use of its outcomes now span all levels of the research system, from policy makers to the researchers themselves. To satisfy this set of policy demands requires a much higher level of data availability and analysis across multiple domains. (Ruegg and Feller 2003)*

Data on the use of knowledge is difficult to track, but information technologies are opening up new avenues

A particular challenge for gathering data is the fact that the use of knowledge is often dispersed widely across many people and institutions. It is difficult and potentially costly to track this use beyond bibliometrics, although information technologies are opening up new avenues for monitoring the use of digital material. Funding agencies and research institutions need to know what outputs have been produced, and tacit knowledge transfer before the use of knowledge can be understood and measured. It is not clear what is the best way to track the use of knowledge and how. Critical questions include:

- Should the use of knowledge be collected systematically for each science project and/or output? Alternatively, should 'use data' be collected randomly or for certain bundles of projects in a portfolio approach?
- What kinds of information would be useful for demonstrating the use of knowledge?
- Who should provide the information – the research organisation that may have incentives to exaggerate use; pre-identified users; random selection of identified possible users who may not know the sources of knowledge?
- When should the information be collected – how far out from completion of a contract, a research project or output?
- Who should provide the resources to enable this information to be gathered?

Data on impacts is plentiful and improving

Attribution of impacts to science is much more than a data problem

Evidence requires data, information, analytics and research

Outcome data is essential. This primarily comprises data to understand the contribution science has made to the stock of knowledge, and secondly the use of that knowledge by other researchers, industry, government or other organisations. Data in itself is not enough to generate evidence. As stated above, data on impacts is already plentiful and there is significant work underway across multiple domains to improve data quality, such as on environmental data measures. Because impacts are caused by many factors, impact measures are mostly not useful in highlighting the contributions of science. Frameworks, theories and research on the science system are needed to understand science contribution to impacts. A combination of data, information, frameworks and research studies on science is needed to create the required evidence base.

Discussion Point: What are your views on the balance between ex-ante and ex-post evaluation? What principles should underpin an ex-post evaluation framework? What data should be collected on the use of knowledge and how might it be collected?

List of discussion points

1. While the focus needs to be on the pathway to impact, the definition of impact still matters. Should the NSSI definition of impact be made clearer to refer only to final results, long-term results or both? What are the reasons for your view? Note that focusing only on final results would mean excluding improvements in human capital and academic impact as impacts, but these concepts would clearly form part of the results chain, ie, part of the pathway to impact.

2. Should the science system adopt the Treasury's *Higher Living Standards framework* to assess and organise the impacts of science? What about the other impact categorisation frameworks, such as that proposed by the Small Advanced Economies? What are the reasons for your views?

3. What are your views on the mechanisms or processes for generating impacts? What intermediate outcomes are especially important?

4. How well does the generic results chain capture the science system at a high level?

5. How could the worked examples be improved?

6. What are your views on the balance between ex-ante and ex-post evaluation? What principles should underpin an ex-post evaluation framework? What data should be collected on the use of knowledge and how might it be collected?

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