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SCIENCE SYSTEM ADVISORY GROUP

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TITLE	Overview of the technology research landscape in New Zealand		
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PURPOSE	To provide an overview of different components of New Zealand's tech research landscape, including missing elements		

Contents

Preamble

The Science System Advisory Group (SSAG) has been asked to develop a set of recommendations to strengthen New Zealand's science, innovation and technology system and ensure its future success.

To support the SSAG in its role, the secretariat has prepared this background document on an Advanced Technology Initiative. It outlines initial thinking on the nature and role of critical functions for technological advancement in national innovation systems, and the enabling role such functions play in taking advantage of innovation as a driver of economic competitiveness. It also contains information on international comparisons of functions and a gap analysis of said functions in New Zealand's national innovation system.

This document is intended to be introductory rather than comprehensive. Different criteria for analysis of options could be considered going forward as well as other international case studies, including different options for how to embed critical functions for technological advancement in New Zealand's national innovation system.

The secretariat will be happy to provide more information and detail on these topics on request.

MBIE's policy thinking on the Advanced Technology Initiative is being provided in three distinct documents to align with the SSAG discussions:

1. Document 1: Overview of the technology research ecosystem in New Zealand
2. Document 2: International models for technology research ecosystems
3. Document 3: Potential options for an Advanced Technology Initiative

This is Document 1: Overview of the technology research ecosystem in New Zealand

Section 1: The Economic Imperative for an Advanced Technology Initiative

Our economy is relatively small and unproductive

1. New Zealand's economy is small relative to other developed countries, especially compared to our major trading partners and other small, advanced economies. Our Global Domestic Product (GDP) was $US263 billion in 2022,[1] making us the 52nd largest economy in the world.

2. Per Capita, New Zealand was ranked number 19 in the OECD group of developed economies, in 2022. This is much lower than comparator countries like Australia, UK, USA, Denmark and Finland.[2]

3. New Zealand's economic productivity has declined relative to other countries since 1970. Moving us from one of the most productive economies in the OECD, to one of the least.[3] Collectively, New Zealanders are becoming poorer than people in other countries, and less able to afford the high and increasing costs of social services, education, and infrastructure.

We rely heavily on the primary sector

4. Like other developed countries, service-producing industries make the largest contribution to GDP (66 per cent), by far. This is followed by 20 per cent from goods-producing industries such as manufacturing and seven per cent from primary industries such as agriculture, fisheries, forestry, and mining.

5. Another large share of New Zealand's economic activity occurs in the goods and service producing industries within the primary sector. Food and beverage manufacturing make the largest contribution to GDP among goods-producing industries. Alongside this, a substantial proportion of activity in the largest service-producing industries, including professional services and wholesale trade, is directed towards businesses in the primary sector.

Our narrowly focused economy that exports technologically simple products reduces resilience

6. For a developed economy, New Zealand 's international trade is focussed on a narrow range of products (see Figure 1). The lack of diversity in things we sell to other countries means that changes in global conditions could significantly impact the prosperity of New Zealanders. This includes things such as changing climate, changing consumer sentiment, geopolitical upheaval, or technological change.

7. Many of New Zealand's products are technologically simple.[5] To compete internationally, we rely on achieving lower costs of production for exports, creating downward pressure on wage rates. However, this increases our vulnerability to technological changes that reduce costs in other countries, such as robotics in fruit production, or genetic modifications that increase the efficiency of food production.

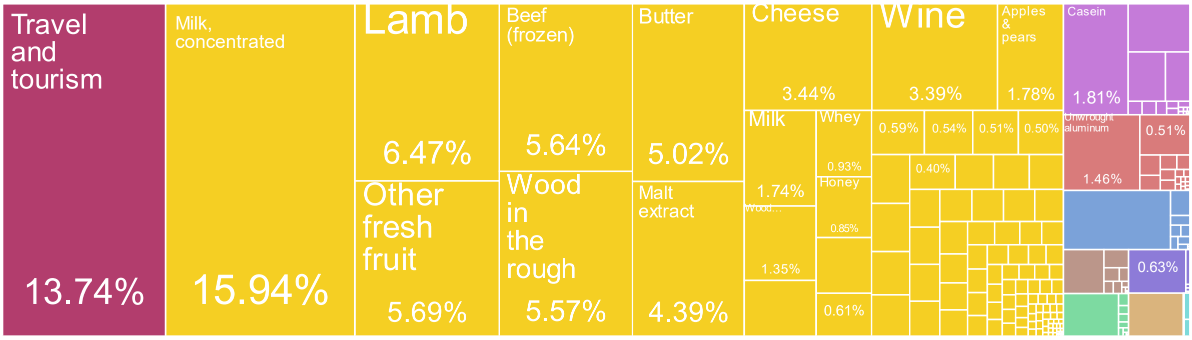
[1] https://data.oecd.org/gdp/gross-domestic-product-gdp.htm

[2] New Zealand's GDP per capita is 73% of Australia's, 95% of the UK's, 67% of the USA's, 69% of Denmark's, and 87 % of Finland's.

[3] https://www.productivity.govt.nz/assets/PBTN-2023-digital-final-3-July.pdf

[5] The Economic Complexity Index (ECI) is a proxy measure of the relative knowledge intensity of an economy or a product. It can be broken down by trade data (ECI trade), patent data (ECI technology), and research publication data (ECI research). New Zealand ranks 46th on the economic complexity of trade (based on products exported), 16th on the economic complexity of research (based on publications), and 33rd on the economic complexity of technology (based on patents): https://oec.world/en/profile/country/nzl. During the last 20 years New Zealand's economy has become relatively less complex in terms of this Index, moving from the 20th to the 46th position in the ECI rank.

Figure 1. *Profile of Aotearoa New Zealand exports by product type (2021)*



Source: *https://oec.world/en/profile/country/nzl*

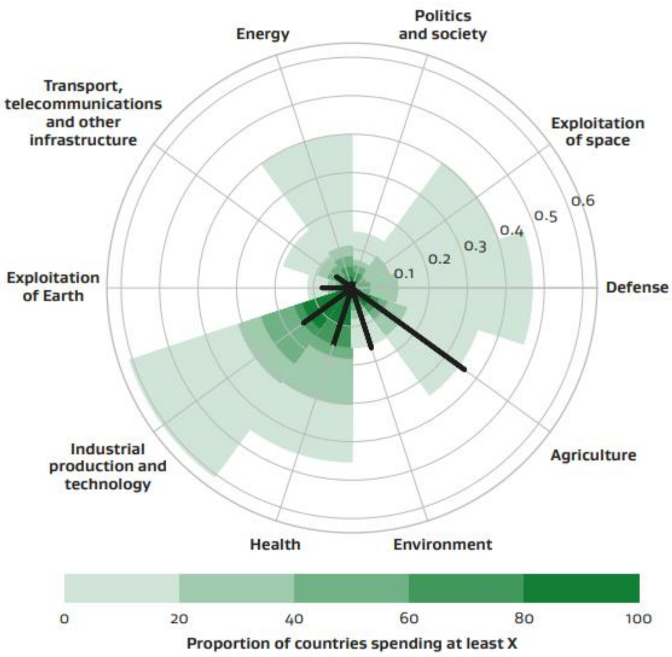
New Zealand's investment in research, science and innovation is largely focused on maintaining existing (and historical) sources of competitive advantage

8. New Zealand's economy lacks diversity, being overly dependent on less productive sectors. Our economic history is grounded in our institutional landscape, which has had a high focus on the environment and primary industries. It has also shaped how we invest, what sectors we directly support, and the research outputs our science, innovation and technology system delivers.

9. At present, the bulk of New Zealand's research investment is focused on maintaining its current sources of advantage in existing areas of strength. Government spends a much higher proportion of its research budget on research and development for the benefit of primary production, and the environment, than any other country in the OECD.

10. Figure 2 reveals that, as a developed economy, New Zealand's public funding of R&D by socio-economic objective is overly focussed on a few less productive sectors.

Figure 2. *Fractional government budgeted appropriations on R&D by socio-economic objective 2012-2016 (OECD). Black lines represent New Zealand's proportion of expenditure; green shading shows the proportion of other countries which reach particular proportions of expenditure*



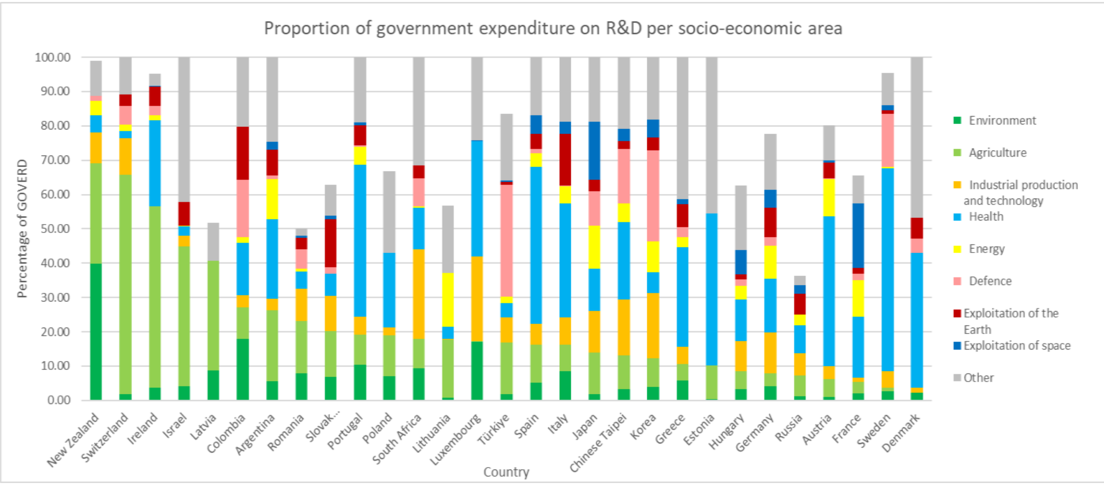
11. In contrast, comparator countries focus their spending on production and technology. Even for those that focus on health – like Denmark and Australia – a large proportion is on health with economic benefits (e.g., drug discovery, MedTech, etc.).

Our institutional landscape supports current sources of advantage, largely in the primary industries

12. Our institutions facilitate research activities and innovation, and for a long time, our institutional landscape has shaped New Zealand's economic and investment strategy. An important factor is the enduring and direction-setting powers of our public institutions, which attract and direct investment into the system.

13. Even though industrial production and technology dominate general government project allocation on R&D (GBARD), activity undertaken by our public research organisations (PROs) is more focused on environment, health, energy, geology, defence, as shown in Figure 3.

Figure 3. *Environment and agriculture represent 70% of New Zealand's PRO R&D. Source OECD Main Science and Technology Indicators*



Economic renewal through technological advancement

Technological advancement is critically important to New Zealand's future

14. New Zealand's economy needs to transform over the next 25 years, underpinned by uplifting the nation's broader technological capabilities, to sustainably deliver prosperity for current and future generations. To meet the multiple challenges, New Zealand needs to export a more diverse set of products and services to a wider range of countries, producing them with lower emissions and higher rates of productivity. This cannot be achieved without a clear commitment to facilitating technological advancement.

15. Failure to keep up will result in a New Zealand economy that is poorer, less integrated with the world, and less resilient to future shocks. Due to investment and institutional gaps in our knowledge economy, we are already falling behind in critical General Purpose Technologies (GPTs) that will underpin future global economic competitiveness, such as artificial intelligence, quantum technologies, robotics and synthetic biology.

16. We are currently not investing enough to make good the investment and institutional gaps in our knowledge economy during a time of significant technological change. Closing these gaps is necessary to keep up with other developed countries. We currently have no credible institutional or funding pathway to make good this gap.

To compete internationally we must leverage existing and emerging areas of strength

17. We need to develop new areas of advantage in global product markets if our economy is to become more productive, sustainable, inclusive, and resilient. New areas of advantage can be grown off existing areas of strength, such as primary industries, or in emerging areas, such as aerospace and cleantech.

    a. Creating sustainable returns in existing areas of strength requires producers to move up the value chain into market segments where customers are willing to pay a premium for a product. Effective marketing and product differentiation is key to success.

    b. New areas require both substantial global demand and the potential for businesses to obtain a competitive advantage with technology developed in New Zealand. They also require us to diversify into new or emerging areas where New Zealand companies have the potential to obtain a competitive advantage. Developing new economic activities will provide choices, meaning we can concentrate our resources and investments in areas where we are competing successfully in global markets.

18. To build a sustainable competitive advantage in new and emerging areas, New Zealand will need to make a substantial research investment and create the necessary institutions to technologically advance in those areas over a long period of time.

Section 2: Technology research ecosystems

Technological capability underpins economic competitiveness

19. The government has signaled the intent to rebuild New Zealand's economy and ensure future economic competitiveness through sustainable economic growth over the long run.

20. Typically, pushing out the national productivity frontier under optimal conditions requires exploiting new or heretofore untapped resources, or introducing new technologies. Consequently, we have considered the supporting role of technological advancement and innovation in the government's economic agenda. We conclude New Zealand has a substantial gap in critical functions for technological advancement, which underpin innovation as a driver of economic growth.

Box A: Framing & background context

Annex 1 considers the historical development of national innovation systems more generally. Competitive economies overseas rely on innovation as a driver of economic growth and focus on global economic competitiveness. But they do so on the back of already taking advanced technologies seriously and having strong technological capabilities in place.

21. We conceive of 'technological capability' through the lens of 'critical functions' that facilitate the technological advancement of a nation.

22. In what follows, we discuss these functions and consider the extent to which such functions are present in New Zealand's national innovation system. Our initial thinking is that New Zealand has significant gaps. A proposed 'advanced technology initiative' covers anything we may undertake to address these gaps. We discuss high-level options for initial consideration.

Advanced technologies need to be facilitated by fit for purpose institutions

23. Advanced technology for the purposes of this document are technologies that sit at the cutting edge of knowledge, but are already becoming centrally important for economies and societies. They include fields such as quantum, biotechnology, advanced energy, medical technology, and aerospace. All advanced economies are investing seriously in such technologies for a variety of related reasons. These include having unique high value products to offer to trading partners, maintaining sovereignty over technological development, and a basic desire not to be left behind in, or left out of, global efforts to raise productivity, solve big problems, protect citizens, and secure a prosperous future.

24. Competitive nations intentionally put in place institutions that facilitate technological advancement. They know the disruptive power of new and emerging – potentially even revolutionary – technologies depends on how compatible they are with existing institutions. Critical technologies are more disruptive when institutions are not fit for purpose and cannot facilitate entry or promote distribution and adaption of critical technologies throughout the economy and society. Finally, our ability to take economic advantage of them depends on the readiness of our institutions and their ability to adapt.

Promoting technological advancement requires a broad yet cohesive focus

25. Our institutions are critical to facilitating the development and diffusion (adoption and adaptation) of advanced technologies in society and the economy.

26. However, our public institutions, which are – by and large – vertically integrated with specific value chains of a narrow range of sectors (e.g. our CRIs) are not well placed to support the

development and adoption of advanced technologies of the general purpose and broadly enabling kind. Rather, such technologies stand to benefit more from operating with a broad yet strategically cohesive focus on 'advanced technology platforms' that support firms at all levels of innovation potential and maturity, and which promote innovation and development across a broad range of high-value sectors and value chains.

27. A sufficiently broad science and technology focus enables:

    a. dedicated institutions to command an effective quantum of funding. This does not mean 'system-wide' funding distribution, but a significant enough amount of funding to impact the overall balance of the nation's investment portfolio in R&D.

    b. the allocation of resources for research across a cohesive range of sciences and technologies, which are needed to meet the diverse and deep external knowledge requirements of high tech/competitive firms and anticipate future industrial opportunities.

Section 3: Functions

Innovation depends on technological capability to drive economic growth

28. While innovation is a key driver of economic growth, it depends on technological advancement to 'lead the wave' (develop firms at the global frontier) and 'follow fast' (improve the performance of middle firms to come closer to the frontier):

    a. To 'lead the wave' we develop new areas of global competitive advantage through focused innovation, enabling firms to create new and unique products and services that can command a premium on the global market and/or in global value chains,[6] and

    b. To 'follow fast' we lift the productivity of New Zealand's domestic economy, particularly by raising firms that are not on the global frontier up towards the frontier, through targeted supports and improving our ability to absorb, adapt, and adopt new technologies.[7]

29. Small Advanced Economies have in common that they support their government's economic aims by taking a deliberate, joined-up, and selective approach to developing innovation systems to 'lead the wave' and 'follow fast', involving time-consuming strategic research to create new advanced technologies and intensive R&D and other efforts – including investment and cost – to achieve the valuable novelty firms need to become world-leading.

30. At the core of their growth-generating innovation systems is high-end basic and applied technology research capability that generates unique expertise (see Annex 2). This capability attracts the formation of globally significant hubs of expertise and the necessary international engagement, talent, and linkages at sufficient scale. Creating a critical mass of high-level technological capability in a country is the key objective of technology policy.

> **Box C: Growth-generating innovation systems and critical facilitating functions**
>
> Annex 2 describes how sustainable and growth generation ecosystems develop.
>
> Annex 3 captures the continuum of functions present in national innovation systems worldwide, most of which are performed by technology institutes and innovation agencies with some degree of overlap.

Building technological research capability requires dedicated functions and structures

31. A review of technology research institutes and innovation agencies worldwide reveals that they serve distinct purposes in national innovation systems:

    a. Tech-research institutes: Generate a critical mass of high-level technological research capability in a country to advance the development and use of new technologies.

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[6] Competitive firms succeed by undertaking strategic research that combines different sources of knowledge, some which they develop internally and some of which they draw from outside, be they domestic or international. Consequently, successful firms develop novel and unique products, services and processes through absorbing new technologies and creating novel innovations with the help of high-end research capability available in-house or through the wider innovation ecosystem.

[7] The productivity of our non-frontier firms depends significantly on our own frontier firms, which are globally competitive firms uniquely able to overcome the challenge of diffusing knowledge and technology over distance, from the global frontier to the national frontier. As a result, 'following fast' depends on building globally competitive firms. This makes their development in New Zealand critical and a necessary precondition to taking full advantage of innovation as a driver of economic growth.

b. Innovation agencies: Achieve a critical mass of connectivity and collaboration between research and industry to drive the creation, adaptation and adoption of new products, services and processes in markets, businesses, and wider society.

32. Although functions for tech and innovation can co-exist and may overlap in specific institutions (i.e. some functions are simultaneously present in a single institution/entity), it is not necessary. Institutional arrangements differ between national innovation systems and reflect bespoke responses to unique conditions considering existing capability, current institutions, maturity of science system, and scale and sophistication of industry.

33. Functions for both tech and innovation are necessary. Historically, science systems typically evolved by first putting in place foundations for technological advancement, to then pivot to innovation as the driver of economic growth. However, successfully shifting to innovation for the purpose of economic competition, especially in global markets, commonly depends on the nation already having foundations in place to promote technological advancement (Annex 1).

34. We have observed in our work exploring what works internationally that growth generating innovation systems typically have institutions focused on technology research that provide a unique set of functions for technological advancement over and above the functions fulfilled by innovation agencies globally (Annex 3 for more detail).

35. Tech-focused functions supply the cores (e.g. high-end technological research capability) around which innovation ecosystems dynamically arise. Table 1 below outlines these functions:

Table 1. *High-level critical functions that facilitate technological advancement*

Function	Type	Description
Strategic tech leadership	Strategy/ Policy	
System-wide direction setting		Identification of tech priorities, focus areas, economic opportunities for New Zealand, and areas of collaboration with industry.
Tech advice to government		Sensing, scanning, foresighting, and the identification of domestic and international demand, including critical technologies for New Zealand that need protecting or provide unique opportunities.
Funding for tech research	Funding	
System-wide distribution of tech funding		Decision making around distribution of significant ($300m+) tech-related research funding, potentially including, managing tech research organisations/institutes (e.g. Tech CoREs)
Devolved tech funding		Independent decision making around allocation of significant funding negotiating national strategy and

		priorities with market signals, industry conditions, local demand, and emerging opportunities.
Research and 'fee for service' R&D	Research	Precompetitive and precommercial research in strategic fields that address needs and markets that shape the future. Also provides direct R&D services (e.g. testing helps get smaller/younger businesses access to expertise and equipment) to reduce barriers to entry for industry R&D (high fixed costs to get into R&D).
Provision of research and scale-up infrastructure	Structure	Access to state-of-the-art infrastructure (TRL 1-3), including physical space and kit, to undertake research, as well as scale-up facilities to bridge gap to commercial viability (TRL 4-6), and the capability to use such infrastructure effectively.
Tech anchor and first mover	Anchor / First Mover	Provide stable and enduring vehicles with sufficient scale and draw to be strategic anchors and ecosystem first movers that attract talent, international collaboration, investment and firm clustering. They also function as launch pads that build spin-off companies from science and technologies developed through strategic research.

36. Critical functions can play a strategic role in national innovation systems and they are realised by dedicated technology research organisations or other dedicated structures with sufficient scale. They operate as anchors and first movers with significant drawing power to shape government investment, attract international engagement, crowd-in private sector investment, and firm clustering. This strategic aspect of tech-focused functions is particularly important for New Zealand and it has implications on the form of possible solutions.

Section 4: The Gap and Possible Objectives

We are an outlier among competitive OECD countries in not having critical functions for technological advancement embedded in our national innovation system

37. We have undertaken a high-level gap analysis of functions for technological advancement in New Zealand compared to what is available overseas, based on selected examples that have for all intents and purposes strong, dynamic and growth generating innovation systems.

38. Our gap analysis reveals that New Zealand lacks dedicated functions, as well as suitable structures/vehicles to house these functions.

> **Box D: Gap Analysis of Tech-Functions in New Zealand's National Innovation System**
>
> Annex 4 provides a high-level assessment of functions against New Zealand's national innovation system compared to other competitive OECD economies, including the EU.

39. Table 2 outlines how our national innovation system either

    a. completely lacks certain functions altogether (e.g. systemwide strategic technology leadership and system-significant technology resource allocation), or

    b. sporadically provides various functions in a partial or ineffectual manner, such as limited scope or with subtherapeutic doses (e.g. strategic anchoring, ecosystem first mover capacity, structures (e.g. kit and innovation facilities), and strategic research).

40. Table 2 also offers potential policy objectives that could be considered for addressing the identified gaps against which possible options can be assessed. The SSAG may want to consider these objectives, reflect on their comparative importance, and whether any objectives should be omitted or added.

Table 2. *Current and future states of functions in our national innovation system*

Type of Function	Current State	Future State (Policy Objectives)
Policy	**This function is completely absent in our national innovation system.** Neither government nor Callaghan Innovation provide leadership on advanced technology.[8] MBIE's Innovative Partnerships unit does undertake some of the activities of this function, but with limited scope and on an opportunistic basis. This function also lacks much needed support from expertise to identify critical technology trends and market opportunities.	**<u>Focus</u> – our national innovation system responds to credible signals on critical technologies and promising economies of the future** We need to concentrate resources in our national innovation system to go beyond 'sub-therapeutic' doses of investment to achieve impact. This requires identifying our most critical technology needs and opportunities. We are generally challenged to achieve scale and New Zealand's SI&T system is already smaller than it needs to be

[8] Callaghan Innovation (2024) Board Paper – Strategic Direction: 'Where to from here'. *Callaghan Innovation's future state options*, p.3.

	Universities are not able to be system leaders and policy stewards for our national innovation system. By virtue of universities being outside and specifically independent from government, they cannot fulfil critical systemwide strategic leadership and stewardship functions in relation to new and emerging advanced technologies.	in absolute and relative terms, so focusing what limited resources we have is paramount.
Funding	**Existing funding models orient universities and public research institutions away from industry.** The funding mechanisms that govern CRIs and the university sector, in particular the performance-based research fund (PBRF) in the case of universities, create incentives that orient academics away from seeking contact and collaboration opportunities with industry, and this has also had negative impacts on business access to innovation infrastructures. CRIs are reliant on government as their primary source of revenue in the form of government research contracts. This orients CRIs towards government rather than industry.	**<u>Incentives</u> – methods for funding technological capability and research orient scientists towards industry.** We need to direct technological capability towards creating economic value by: i) novel competitive advantages for future industries; and ii) solving industry problems as NZ's industry scales up and matures. We need to shift incentives in favour of research-industry collaboration to generate value from research. This means enhancing connectivity between research and industry to increase uptake of R&D initiatives.
Structure	**We have a distinct lack of, and issues with accessing, innovation infrastructures and scale up facilities**. We are missing out on innovation potential because firms have difficulty accessing innovation facilities. Most innovation facilities (including research expertise) relevant to high tech and competitive firms sit within universities or are associated with universities. Stakeholders (both providers and users of innovation facilities) signal multiple issues with access to public pilot and scale up facilities.[9] Callaghan Innovation was also unable to properly build and scale up	**<u>Kit</u> – tech & innovation infrastructures are housed in ways that make them easy for businesses to access.** We need to ensure physical facilities and equipment are adequately funded and housed in institutions with incentives to collaborate with industry. Tech platforms, especially for deep tech, need to be linked with specialist capability to enable effective use. Provision affords access to state-of-the-art infrastructure (TRL 1-3), scale-up facilities to bridge gap to commercial viability (TRL 4-6), and

[9] Sapere (2021) *Analysis of Access to Innovation Facilities*, pp.3-4.

	technology platforms as originally intended by policy.	the capability to use such infrastructure effectively.
Anchor/ First Mover	**Our current institutional landscape lacks anchors for advanced tech that can crowed-in resources (govt funds, private investment, talent, firms, etc).** Our existing institutional landscape determines our broader SI&T strategy and investment portfolio. Public research institutions (in particular, CRIs) are strategic anchors and have to date had a strong and lasting influence on how public funding is channelled through the SI&T system.	**Pull – institutions create significant draw and are enduring.** We need to counterbalance the strategic impact of our existing institutional landscape on resource allocation. Reorienting our investment landscape is critical to economic transformation and requires: i) vehicles that pull significant resources and generate revenue ii) increased investment in new areas; and iii) sustained effort over a long enough time horizon to build towards a 'tipping point' that makes our innovation system growth-generating.
Research	**No critical mass of broad technology capability.** While some centres of research excellence (CoREs) housed in universities have a good reputation and create some draw, they are too dispersed, bespoke and too small scale to achieve a critical mass of broad capability (basic and applied). Existing CoREs are not oriented towards industry or future economies. They do not have dedicated funding mechanisms that create 'centripetal force' between research and industry.	**Scale – form attracts and retains a critical mass of world-leading expertise.** We need to build and maintain talent. New Zealand's economic geography and size of business sectors at all levels (small, medium and large) make this difficult. We have first mover challenges in breaking out of a vicious cycle created by a perfect storm of factors perpetually reinforced by our limited scale. We need to favour forms that create sufficient scale to attract a critical mass of tech research capability.

Annex 1: NZ implications of historical development of innovation systems

International history indicates that facilitating structures for technology were built before focusing on innovation policy to drive economic growth

Internationally science policy has evolved in phases throughout history in line with growing clarity on how science, technology and innovation create value for society and drive economic growth

1. Science policy has historically evolved from a singular focus on 'science'10 to a more expanded endeavour that added to science a strong technology focus (i.e., 'science and technology'11 (S&T) policy). It then further expanded to integrate S&T policies with other policy areas emphasising 'innovation'12 and its role in driving economic growth.13

2. The evolution of science policy reflects a growing understanding of how technology and innovation ecosystems work as a whole (like the 'funnel model') and that these pass a critical tipping point early on, to then become healthy at every stage, leading to the creation of strong, dynamic and antifragile ecosystems that can generate new areas of competitive advantage and rejuvenate economies. Table 3 provides a succinct overview of this historical development alongside a specific international example of how the research, science and innovation system evolved in Finland:

[10] 'Science policy' affects the conduct of scientific research, including sciences, social sciences and humanities, and the instruments comprise: funding of universities and research organisations as well as research projects and posts, researcher training, and centre of excellence policy.

[11] 'Science and technology policy' affects the development and use of new technologies, such as instruments and the knowledge of how to produce and use them. R&D across science and technology are closely integrated (e.g., biotech and ICT). The main instruments are: Long-term stable funding for dedicated tech-research institutions, lower R&D costs through grants for public and private organisations and programs, and R&D subsidies.

[12] 'Innovation policy' is "a set of policy actions to raise quantity and efficiency of innovative activities (where 'innovative activities' refers to the creation, adaptation and adoption of new or improved products, processes or services." It combines elements of science, technology and industrial policy that collectively aim at promoting the development and use of new products, services and processes in markets or inside organizations, and may comprise technical innovation (to not only invention of new products and processes but also their successful commercial use) and social innovation (new ideas and way of doing things that meet social needs of all kinds). Some policy instruments cover: supply side innovation (support of research and development activities in public and private organisations) and demand side innovation (establishment of information and communication networks, regulation (and standardisation), and innovative public purchases. Cowan & van de Paal (2000) *Innovation Policy in a Knowledge-based Economy* [A merit study commissioned by the European Commission Enterprise Directorate General]. https://edz.bib.uni-mannheim.de/www-edz/pdf/innopap/ip-02-2000.pdf

[13] Ruivo (1994) 'Phases' or 'paradigms' of science policy?, in *Science and Public Policy*, 21(3), pp.157-164. https://doi.org/10.1093/spp/21.3.157

Table 3. *Historical evolution of science, technology and innovation policy (with a Finnish case study)*

Global			Finland		
Period	**Science Paradigm**	**Description**	**Period**	**Finnish Evolution**	**Description**
1945-1960	Science as a motor of progress	• the linear model of 'science push' • mainly national science projects • scientists govern the science, government supports • emphasis on basic research, little demand for exploitation of research results	**1950-1970s**	Science & Higher Education Policies	• Beginning of the science and higher education (HE) policies • Building of basic structures of the research system • Establishment of Science Research Council and Council of HE and funding councils • Academic career professionalised • Central role of the state • Expanded role of the Ministry of Education • Nationalisation of private universities
1960-1980	Science as problem solver	• main concern is the demand from society: research problems come from different sectors of society • priority for government is applied research: money allocated for these objectives	**1980s**	Science and Technology (S&T) Policy	• Shift from science policy to science and technology (S&T) policy with a strong orientation towards tech • Knowledge becomes core of national strategy à competitiveness through high-quality products and upgrading the nation's technological capability • New and multiple organisations dedicated specifically to technology

					• R&D funding & post-graduate education emphasise fields critical to economic growth (ICT, biotech, and material technology)
1990s-	Science as a source of strategic opportunity	• research becomes strategic and is more interdisciplinary and collaborative in nature • a complex policy model with a diversity of actors and processes that integrate 'science push' and 'demand pull'	**1990-2000s**	Innovation Policy	• Innovation and competitiveness become core goals of state policy • Integration of S&T policies with other policy areas with an emphasis on innovation (commercialisation of inventions and social innovations) • National innovation system (NIS) reformulated S&T policy to shift from a linear to an interactive model of innovation (which explains differences in economic growth rates between countries)

Focus on innovation without first building a nation's technological capability can lead to ineffective and fragile innovation ecosystems that cannot pass the 'tipping point'

3. A recent review of the Scottish technology ecosystem concluded that its ecosystem currently operates in the 'pre-tipping point' state. Key network effects that are characteristic of dynamic and antifragile ecosystems are not operative (i.e., sustaining experiential learning environments, attracting talent, and attracting large scale investors).14

4. The reason the Scottish technology ecosystem is in its current state is that, during the 1980s, at a critical developmental stage of global science policy as well as its own RSI system, Scotland failed to put in place the necessary facilitating structures to support the early funnel stages of its technology ecosystem and in so doing, did not sufficiently upgrade its technological capabilities as a nation. Instead, it 'skipped the early stages of the funnel and imported large-scale companies from abroad'.15

The overarching strategy should be to put in place facilitating structures that accelerate the ecosystem towards the tipping point emphasising the early stages with the greatest impact

5. Scotland's example does not show that focussing on supporting specific domains and building up critical expertise and scale in several industries is not a valuable part of a wider industrial strategy. The point is that the underlying core strategy must be an additive one:

   a. Select domains of interest and ensure these can be executed at a world-class level,

      AND

   b. level-up the general capability to produce world-class scalable tech companies, regardless of domain membership.

6. Upgrading our general capability relies on broader technological capabilities that can develop and take advantage of cross-board technologies which apply to many, if not all, sectors.

7. What exact interventions are required depends on a holistic view of how the overall ecosystem funnel is operating and what facilitating structures are already in place, since it must be healthy at all stages. Generally, a portfolio approach to interventions that speaks to the specific context is desirable alongside an emphasis on the earlier stages of the innovation ecosystem funnel. While interventions that target the later stages yield smaller returns sooner, interventions in the early stages have a much greater impact, for two main reasons:16

   a. 'Interventions made in the very early stages of the ecosystem funnel and its dependent areas have greater eventual impact overall than interventions made later in the funnel. This is because interventions made at the start of the funnel affect all later stages too.

   b. 'The effectiveness of later-stage interventions, while easier to make, is permanently reduced if not made in conjunction with earlier-stage interventions. This is because earlier-stage interventions effectively create more 'fuel' to power the beneficial effects of later stage interventions.'

[14] Logan (2020) *Scottish Technology Ecosystem Review* [An independent review commissioned by the Scottish Government], p.16. https://www.gov.scot/binaries/content/documents/govscot/publications/independent-report/2020/08/scottish-technology-ecosystem-review/documents/scottish-technology-ecosystem-review/scottish-technology-ecosystem-review/govscot%3Adocument/scottish-technology-ecosystem-review.pdf
[15] Logan (2020) *Scottish Technology Ecosystem Review*, p.12.
[16] Logan (2020) *Scottish Technology Ecosystem Review*, p.18.

Annex 2: The creation of sustainable and growth-generating innovation systems

Innovation Ecosystems focused on developing new areas of advantage depend on critical facilitating structures and a proactive government

Innovations arise dynamically, in close cooperation between many diverse actors: intentionally developing innovation ecosystems requires a systems approach alongside joined-up government

1. The traditional account of how innovations are developed describes a linear process or pipeline that begins with basic research, progresses to applied research and then commercialisation. This emphasises 'science push' where the translation of ideas appears a black box (i.e., 'it just happens') in the middle of an input-output type model.

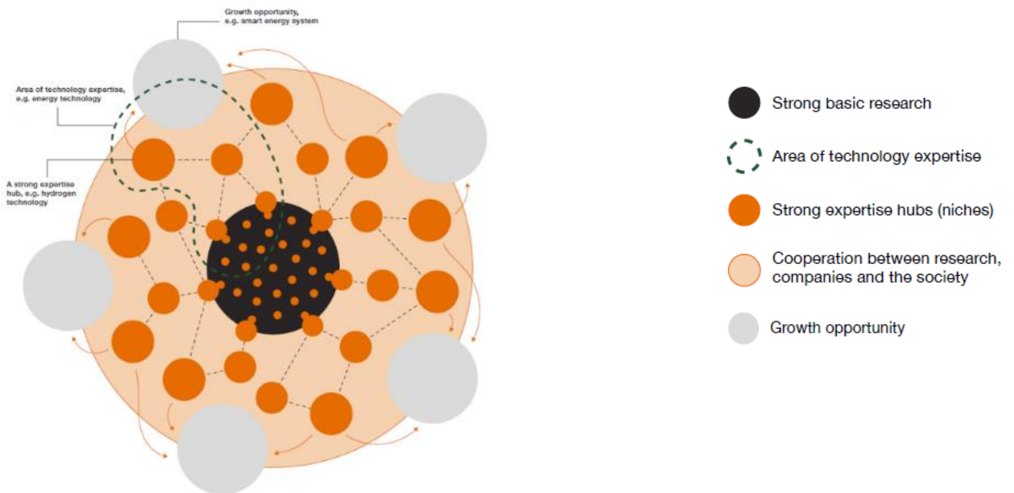
2. However, this model does not correspond to reality. Rather, the process of developing innovations is nonlinear. Innovations arise dynamically, in close cooperation between many diverse actors in which 'demand pull' elements also play an important role.[17]

3. MBIE's (2016) *Research, Science and Innovation Domain Plan* anticipated that the linear model of innovation needed to be framed within a broader nonlinear systems approach, which emphasises the connections and feedback loops in the system as well as wider dependencies on system features and policy settings in which broader government plays a key role, such as: regulation, competition, enabling innovation infrastructure, access to capital, and the maturity of industries, including supporting industry policies.18

Innovation ecosystems arise dynamically through close cooperation between many players who form networks around core facilitating structures that provide high technological research capability

4. Within the context of a systems approach to innovation ecosystems, Figure 11 below illustrates how sustainable and growth generating innovation systems are born. At their core exists high-level basic technology research capability that generates unique expertise.***19*** Creating a critical mass of high-level technological capability in a country is the foundational objective of technology policy.

Figure 4. Anatomy of sustainable growth-generating ecosystems



[17] Finish Technical Research Institute (VTT) (2022) The *most promising technologies: Perspective on sustainable growth and effective innovation policy in Finland*, p.5. https://www.vttresearch.com/en/explore/vtts-vision-paper-most-promising-technologies
[18] MBIE (2016) Research, *Science, and Innovation Domain Plan*, pp.9-11. https://www.mbie.govt.nz/dmsdocument/1448-research-science-and-innovation-domain-plan-pdf
[19] Figure 6 has been reproduced from VTT's vision paper. See VTT (2022) *The most promising technologies*, p.5.

5. With the help of a proactive government, globally significant hubs of expertise are then constructed around this foundational technology research capability. This requires choices, long-term and predictable funding, and multi-disciplinary international cooperation.20 For example, the leaders of the Australian Quantum Strategy have observed that centres of expertise were critical for Australia to develop its quantum ecosystem. They were built around critical high-level basic tech-research capability and consequently attracted the necessary international engagement, talent, and linkages at sufficient scale to construct the foundations of world class ecosystems.

6. The innovation ecosystem proper is born as companies in different roles join this network. Partners in this network then initiate research and development genuinely together in close collaboration. Plenty of interaction, cooperation, and collaboration is needed between researchers, companies and other actors and entities in society across every stage of the funnel of the technology and innovation system to solve problems and make innovative solutions accessible to society. Achieving a critical mass of connectivity and collaboration between research and industry is a foundational objective of innovation policy.

International examples of antifragile and growth generating innovation ecosystems have critical facilitating structures in place that build their nation's broader technology research capability

7. When we examine dynamic, antifragile and growth generating innovation ecosystems overseas (e.g., Germany, Finland, and the wider European Union), we observe that at the heart of their ecosystems are large scale institutions and centres of expertise focused on technology research that fuel those ecosystems with new advanced technologies of which their eventual applications create new areas of competitive advantage.

8. The facilitating structures for technology (specifically focused on advancing the development and use of new technologies) provide a set of unique functions over and above the functions fulfilled by innovation agencies globally. These generally comprise strategic and research functions, and they can act as strategic anchors and first movers that attract international engagement and firm clustering at scale, which is a critical contribution to the early funnel stages and making innovation ecosystems antifragile.

9. Annex 3 provides a more detailed breakdown of these functions fulfilled by facilitating structures for technology (technology policy levers in blue). It also provides information on the range of functions fulfilled by innovation agencies (innovation policy levers in yellow).

[20] VTT (2022) *The most promising technologies*, p.5

Annex 3: Critical Tech-Facilitating Functions

Technology	**Strategic Leadership**	• **Strategic foresight** (sensing/scanning, viability assessments, feasibility assessments of emerging new technologies) • **Determines focus areas and priorities** (e.g., identification of critical technologies for society/the country) à Examples: Australia's 'Critical Technology Statement'[21], Germany's 'High Tech Strategy 2025'[22] and Fraunhofer's 'Strategic Research Areas'[23], VTT's 'Most Promising Technologies'[24]
	System-significant Tech Resource Allocation	• **The entity independently distributes a system-level significant amount funds** according to its own policies, strategy and plans for growth à Example: Fraunhofer's 'executive board'[25] • **Determines the creation, transformation and dissolution of research entities** through its own governance body, depending on the type of entity it is à Example: Fraunhofer's 'senate'
	Strategic Anchor	• **Provides a stable and enduring vehicle with significant draw** that can shape the strategic RSI funding and activity landscape à Example: NZ CRIs (sector specific) • **Has financial capacity, scientific freedom and scope** necessary to develop a significant research portfolio for new areas of socially relevant technological research that are not yet fully on the radar screens of industry partners (e.g., it receives sufficient base funding and maintains strong links with academia) • **Generates competitive advantage** to partners and fosters new business opportunities by providing access to latest technologies developed through strategic research and by cultivating protected technology (intellectual property rights) portfolio à Example: VTT's 'IPR Portfolio'[26]
	Ecosystem First Mover	• **Provides the core of innovation ecosystems**, catalyses their generation & sustains them e.g., by providing unique expertise generated from high-level basic research capability and it attracts international critical capability) à Example: NZ CRIs (specific sectors only)

[21] Australia Critical Technology Statement, https://www.industry.gov.au/publications/critical-technologies-statement#:~:text=This%20statement%20sets%20out%20the,environmental%20sustainability%20and%20social%20cohesion
[22] The new High-Tech Strategy Innovation for Germany, https://knowledge4policy.ec.europa.eu/sites/default/files/hts_broschuere_engl_bf.pdf
[23] Fraunhofer's Strategic Research Fields, https://www.fraunhofer.de/en/research/fraunhofer-strategic-research-fields.html
[24] How Finland develops its national plan for investment in innovation, https://www.computerweekly.com/feature/How-Finland-develops-its-national-plan-for-investment-in-innovation; and VTT's most promising technologies, https://www.vttresearch.com/en/vtts-vision-paper-most-promising-technologies
[25] Fraunhofer Annual Report (see 'Structure of the Fraunhofer-Gesellshaft'), https://www.fraunhofer.de/en/media-center/publications/fraunhofer-annual-report.html
[26] The VTT IPR portfolio creates competitive advantage, https://www.vttresearch.com/en/vtt-ipr-portfolio-creates-competitive-advantage

		• **Renews industries and society** (delivers on strategy) by being a launch pad that builds spin-off companies from the science and technologies developed through strategic research à Example: VTT's 'Launch Pad'[27] and NZ CRIs (limited to dedicated sectors) • **Potential to break 'causality dilemma'** through scale and ability to attract firm clustering
	Strategic Research	• **Determination of strategic research fields** that address needs and markets that will shape the future of society and a country, and, within these fields undertake pre-competitive and pre-commercial research specifically targeted towards projects that have high commercial potential à Fraunhofer 'Strategic Research Fields'[28] and VTT's 'Systemic and Technological Challenges'[29] • **Create conditions for new futures** that enable the development of new products, services and business (e.g., test the technological feasibility of new product and process concepts, adapt technological opportunities to local conditions and minimise economic risk by experimenting in a safe environment) • **Strategic and technological research and business services** that support companies create competitive advantage by developing future-proof business strategies which anticipate future trends, identify new upcoming business opportunities and prepare for risks. à Example: VTT's 'Strategic Foresight Service'[30] that comprises 'Future Radar' (identifies tech-based growth opportunities), 'Future Customer' (creates insights of future customers and consumer behaviour), and 'Futures Design' (combines business and service design methods with foresight work to develop new products and services)
Tech-Innovation Overlap	**Quality Technology Infrastructures**	• **Provides access to state-of-the-art infrastructures**, innovation facilities and breakthrough technologies. Innovation facilities help de-risk the innovation process by limiting the capital expenditure required to get a product up and running since innovators do not need to invest in their own facilities • **Provides scale up facilities** for partners to enable them to fast-track R&D and trial commercial runs, as well as expand their operations and enter new markets • **Houses human capability and expertise** required to make best use of kit ('physical equipment').
	Absorptive Capacity	• **Firm-level instruments** that aim at building the necessary capabilities of firms to increase competitiveness, exports, and productivity, etc. (e.g., by strengthening companies' dynamic capability, performance, and efficiency; and by offering R&D support services that promote the production, diffusion, and transfer of technological innovations, with a particular focus on product development for business)

[27] VTT LaunchPad, https://www.vttresearch.com/en/vtt-launchpad
[28] Fraunhofer's Strategic Research Fields, https://www.fraunhofer.de/en/research/fraunhofer-strategic-research-fields.html
[29] VTT 'Our Strategy', https://www.vttresearch.com/en/about-us/our-strategy-lead-path-exponential-hope-science-based-innovation
[30] VTT Strategic Foresight, https://www.vttresearch.com/en/ourservices/strategic-foresight

		• **Promote acceptance** of new technologies within society • **Train the needed future generation** of scientists and engineers for the economy
Innovation	**Non-monetary Business Support**	• **Business advisory services** that provide coaching and mentoring (e.g., proposal developments, etc.) • **Intangible asset advisory services** that help firms identify and maximise intangible assets (beyond innovations that are patented or trademarked) to unlock competitive advantage (e.g., staff expertise, brand recognition, unique processes, proprietary data, customer and network relationships) à Example: Callaghan's 'Beyond IP'[31] for businesses with products in the market
	Networking, Collaboration & Coordination	• **Link up dispersed capability** throughout the system across government (central and local) and private sector (e.g., through the creation of clusters and networks for innovation) • **Enhance research-industry collaboration** (e.g., linking up innovators with technology adoption and generation instruments, or by a of referrals of early-stage innovative ventures to technology extension services, technology centres, science and technology parks and technology transfer offices, etc.) • **Foster international collaboration** with outstanding research partners and companies, possibly supporting export • **Coordinate and implement** system-relevant research projects
	Innovation-inducing Programs	• **Vertical programs** focused on inducing innovation among firms operating in a particular sector, such as a through prizes (sector examples: textiles, manufacturing, tourism, etc.) • **Horizontal programs** aimed at inducing innovation among firms, regardless of the sector in which they operate (non-sector-specific funds, general digitalisation program, etc.)
	Supply and Demand Measures for Innovation	• **Supply-side measures** aimed at creating incentives among firms by reducing costs and risks of innovation (technology extension services, R&D support for education and training, etc.) • **Demand-pull instruments** aimed at increasing demand for innovations by improving conditions for their uptake (e.g., pre-commercial and/or public procurement, and information and advocacy measures)
	Funding and Finance Support	• **Direct support** that involves a direct influence from the agency on the firm-level innovation activity (e.g., by choosing which projects to support in a competitive grant scheme or matching grants) • **Indirect support** provided to any innovation activity eligible under the rules of the program (e.g., R&D tax incentives, loan guarantees or innovation vouchers in the form of small credit lines for service purchase), without the agency being involved in the choice of which project to support

[31] Beyond IP: Intangible Asset Management Programme, https://www.callaghaninnovation.govt.nz/learning/beyond-ip

Annex 4: Gap Analysis of New Zealand's Landscape of Technology and Innovation

Functional Landscape of Technology & Innovation

◆ Present

◇ Partial, indirectly or only narrowly available

Facilitating Structures for Technology
(Advancing the development and use of new technologies and the nation's broader technological capability)

Facilitating Structures for Innovation
(Promoting creation, adaptation & adoption of new products, services and processes in markets, inside organisations or society)

	Systemwide Strategic Tech Leadership	*System-significant Tech Resource Allocation*	*Strategic Anchor*	*Ecosystem First Mover*	*Strategic Research*	*Quality Tech Infrastructures*	*Absorptive Capacity*	*Non-monetary Business Support*	*Networking, Collaboration & Coordination*	*Innovation-inducing Programs*	*Supply and Demand Measures for Innovation*	*Funding and Finance Support*
Technology												
Finland *VTT*	◆	◆	◆	◆	◆	◆	◆	◆	◆			
Germany *Fraunhofer*	◆	◆	◆	◆	◆	◆	◆	◆	◆			
EU *EIT & KICs*	◆	◆	◆	◇	◇	◇	◆	◆	◆	◆	◇	◆
Australia *Critical Tech*	◆	◆		◇	◇							
Innovation												
International *Inn. Agencies*						◆	◆	◆	◆	◆	◆	◆
Tech & Innovation												
New Zealand *Callaghan*						◇	◇	◆	◆	◆	◆	◆
New Zealand *NZTE*								◆	◆			
New Zealand *KiwiNet*							◇		◆	◇		◇
New Zealand *Sect-only CRIs*			◇	◇	◇	?	?	?	?	?	?	?
New Zealand *CoREs*			◇	◇	◇	◇	◇	?	?	?	?	?
New Zealand *Universities*			◇	◇	◇	◇	◇	?	?	?	?	?