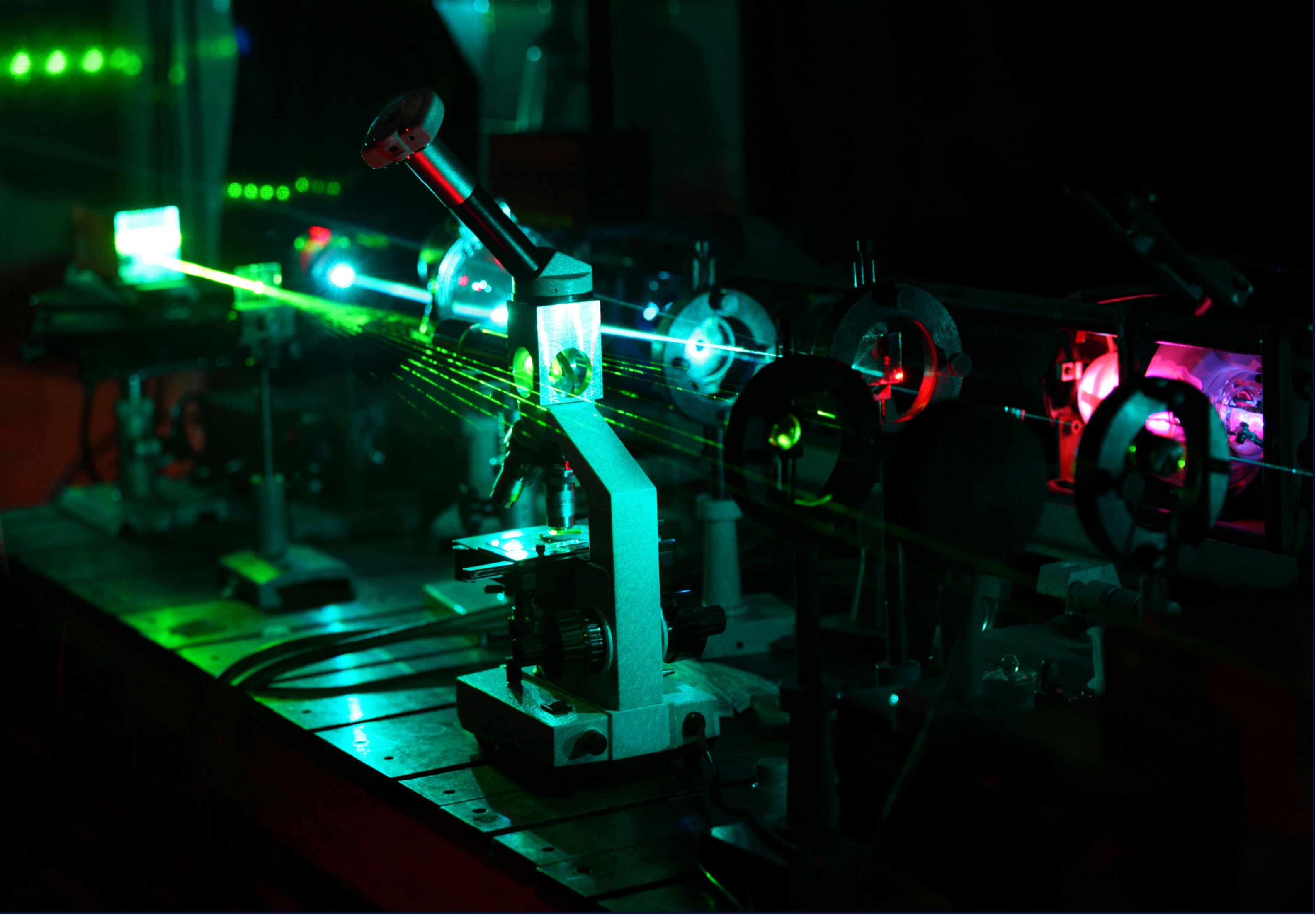

Kitmap — he tirohanga whānui o ngā tūāhanga rangahau i roto i ngā whakahaere rangahau a te Kāwanatanga o Aotearoa

Kitmap - A Stocktake of Research Infrastructure in Aotearoa New Zealand's Government Research Organisations

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Te Kāwanatanga o Aotearoa
New Zealand Government

Ministry of Business, Innovation and Employment (MBIE)

Hīkina Whakatutuki – Lifting to make successful

MBIE develops and delivers policy, services, advice and regulation to support economic growth and the prosperity and wellbeing of New Zealanders. MBIE combines the former Ministries of Economic Development, Science and Innovation, and the Departments of Labour, and Building and Housing.

MORE INFORMATION

Information, examples and answers to your questions about the topics covered here can be found on our website: www.mbie.govt.nz or by calling us free on: 0800 20 90 20.

DISCLAIMER

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Te reo Māori translations by Taumatua Māori Language Services Ltd

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October 2022

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WHAKARĀPOPOTOTANGA MATUA

I whakahaeretia e te kaupapa Kitmap he rangahau o ngā tūāhanga rangahau puta noa i tētahi huinga o ngā whakahaere rangahau e utua ana e te kāwanatanga, kei roto ko ngā Pūtahi Rangahau Karauna (CRI), te Tūāhanga īPūtaiao ā-Motu (NeSI), me Callaghan Innovation. Ko te pūtake o te rangahau nei he mārama haere ki te hanga o te kōpaki tūāhanga, te āhua e urua ai, e whakaruruhautia ai, e utua ai, me ngā momo rangahau ka whakamanahia. Ka whai mōhio te hoahoa anamata o te pūnaha rangahau, pūtaiao me te auahatanga i aua mōhiohio.

Ka taea e ngā kaipūtaiao o Aotearoa te whakamahi te whānuitanga o ngā rawapuni. Ko te āhua o te kōpaki tūāhanga puta noa i ngā whakanōhanga ko te nunui o ngā taiwhanga pūtaiao me te huhua noa o ngā momo taputapu me ngā rauemi kei roto. Ko te nuinga o ngā mea kei te toenga o te kōpaki tūāhanga ko ngā pae ā-rohe, ngā kohinga ōkiko me te matihiko, ngā rauemi rorohiko, me te whatunga o ngā paerongo hei aroturuki i te taiao tūturu. He wāhanga iti ngā waka rangahau o te kōpaki tūāhanga rangahau, engari he kaha te tono mō ēnei, ka mutu ka whakahohe i te matahuhua o ngā papa rangahau. Ko ngā papa rangahau tino nui rawa kua whakahohea i ngā tūāhanga rangahau ko ērā e tautoko ana i ngā rāngai ahuwhenua, ahumatua hoki, ā, puta noa i ngā pūtaiao ā-nuku, ā-taiao hoki, ā, e hāngai ana ērā ki ngā pūtake matua o ngā whakanōhanga i rangahautia.

Ka taea te nuinga, engari kāore te katoa, o ngā tūāhanga rangahau te uru e ngā kaiwhakamahi o waho. I kite te rangahau i te rerekētanga nunui i waenga i ngā kaupapahere mō te whai urunga ki te tūāhanga puta noa i ngā whakanōhanga i rangahautia. E tuku ana ngā whakanōhanga katoa i ngā taumata rerekē o te urunga e ngā kaiwhakamahi o waho, ka mutu ka taea ngā tūāhanga neke atu i te haurua nō te nuinga o ngā whakanōhanga te uru e ngā kaiwhakamahi o waho. I te nuinga o ngā wā me utu te urunga e ngā kaiwhakamahi o waho, engari ka whakawātea ētahi whakanōhanga i te wāhanga nui o te tūāhanga ki ngā kaiwhakamahi mō te koreutu. Whakamahi ai tata te katoa o ngā whakanōhanga i ngā tūāhanga o tāwāhi ki te whakawhānui i ō rātou āheinga ki tua i ērā ka wātea i tēnei whenua.

Ko ngā umanga kāwanatanga me ētahi atu CRI ngā kaiwhakamahi matua o waho. Ko tētahi wāhanga nui o ngā kaiwhakamahi o waho o te tūāhanga rangahau puta noa i ngā whakanōhanga ko ngā whakahaere kāwanatanga. O ērā, ko te rōpūtanga tino nui rawa, ko ngā CRI, tērā e tohu ana i te kaha mahi tahi i waenga i aua whakahaere. Ko te nuinga o ērā atu kaiwhakamahi ko ngā kaunihera ā-rohe, ā-takiwā hoki me ngā tari kāwanatanga, tērā e whakaata ana i ngā tūnga aroturuki pūmate me ngā rawa, me ētahi atu ratonga pūtaiao e tukuna ana e ngā whakanōhanga.

E utua ana te nuinga o te tūāhanga e ngā whakanōhanga anō. Ko te tikanga whakatauria ai ngā haumitanga tūāhanga mā te whakanōhanga ake, me te aha ka whakaatu whānui i nga whakaarotau o te whakanōhanga anō. Puta noa i ngā whakanōhanga, e whiwhi pūtea ana te nuinga o ngā tūāhanga mai i ngā rauemi o roto, me tētahi wāhanga iti iho e whiwhi ana i te pūtea tika mai i te kāwanatanga, te pūtea rānei mai i ngā takuhe rangahau. Ka kitea ētahi momo haumitanga tautokorua ki ngā tūāhanga i waenga whakanōhanga, me ngā whare wānanga, ngā kamupene tūmataiti rānei, engari he rōpū iti ēnei o ngā tūāhanga.

EXECUTIVE SUMMARY

The Kitmap project undertook a survey of research infrastructures across a set of Aotearoa New Zealand's government-funded research organisations, comprising the Crown Research Institutes (CRIs), the National eScience Infrastructure (NeSI), and Callaghan Innovation. The purpose of this study was to understand the composition of the infrastructure portfolio, how it is accessed, governed, and funded, and the types of research it enables. This information will inform future design of the research, science and innovation system.

New Zealand scientists can access a wide range of infrastructures. The infrastructure portfolio across the institutions is characterised by large numbers of laboratories, each housing a variety of equipment and resources. The remainder of the infrastructure portfolio is composed mainly of field sites, physical and digital collections, computational resources, and networks of sensors for monitoring the natural environment. Research vessels make up only a small proportion of the research infrastructure portfolio, though these are in high demand and enable a variety of fields of research. The largest fields of research enabled by research infrastructures are those supporting the agricultural and primary sectors and across the earth and environmental sciences, which is in line with the core purposes of the institutions surveyed.

Many but not all research infrastructures can be accessed by external users. The survey found that policies for access to infrastructure vary significantly across the institutions surveyed. All institutions enable some level of access to external users, with well over half of the infrastructures from most institutions being accessible to external users. In most cases institutions charge fees for access to external users, though some institutions make substantial infrastructure available at no cost to users. Almost all of the institutions make use of international infrastructure to broaden their capabilities beyond what is available domestically.

Government agencies and other CRIs are key external users. Government organisations make up a significant portion of external users of research infrastructure across the institutions. Of those, the CRIs themselves make up the largest grouping, revealing a significant degree of cooperation between these organisations. Local and regional councils and government departments make up the majority of other users, reflecting the hazard and resource monitoring roles and other science services offered by the institutions.

Most infrastructure is self-funded by institutions. Decisions on infrastructure investments are generally made at the institutional level, and largely reflect the priorities of the individual institutions. Across the institutions, most infrastructures are primarily funded through internal resources, with a lesser amount receiving direct government funding or funding from research grants. There are instances of co-investment in infrastructures between institutions or with universities or private companies, although these make up a small minority of the infrastructures.

NIWA - Research Vessel (RV) Tangaroa

At 70 m in length, RV *Tangaroa* is Aotearoa's largest single piece of research infrastructure, and our only ice strengthened deep-water research vessel. Equipped for ocean science, exploration, and marine engineering, Tangaroa is a critical environmental survey and research platform for use throughout the South Pacific, Southern Ocean, and Antarctica. It supports Aotearoa's effective stewardship over 5.7 million km² of ocean (20 times our land area).

The research supported by Tangaroa covers a very wide range of disciplines, from marine geology to fisheries stock assessments to atmospheric dynamics. It underpins ocean resource development and management, natural hazard management, and important international research. Examples of the recent use of Tangaroa include establishing a network of buoys (the DART network), to improve the accuracy and detection of tsunami risk to Aotearoa, and a voyage to the Hunga Tonga-Hunga Ha'apai volcano that erupted in January 2022.

AgResearch - Portable Accumulation Chambers Trailer

Portable Accumulation Chambers (PAC) are a transformative technology that enables measurement of sheep methane emissions on farm, helping farmers to reduce on-farm emissions. The trailer has 12 chambers and gets transported to sheep breeders all over the country. Sheep are individually placed into the chambers for one hour while concentrations of CH4 (methane), CO2 (carbon dioxide) and O2 (oxygen) are measured. So far over 15,000 sheep have been measured for their methane emissions. The technology is used to give sheep breeders information used for genetic selection purposes. It is anticipated that breeders selecting for lower methane (alongside other traits) can lower their flocks' emissions by up to 1 per cent per annum.

1. KUPU WHAKATAKI | INTRODUCTION

Research infrastructure is an area of the Research, Science and Innovation (RSI) system where there has historically been little visibility. The need for information in this space has been repeatedly identified in previous MBIE publications, and flagged as making it difficult to identify gaps, prioritise investments, and address the general needs of the sector. The 2016 RSI Domain Plan[1] highlighted key gaps in data relating to identifying nationally significant assets, their use, accessibility, and costs involved for research. Previous MBIE publications have referenced the three pillars of the RSI system as excellence, impact, and connections[2]. Infrastructure is an enabler across all three pillars. The Kitmap project aims to fill this gap in our understanding of the RSI system by undertaking a stocktake of science facilities and equipment available across Crown Research Institutes (CRIs), Callaghan Innovation, and the National eScience Infrastructure (NeSI).

One of the issues highlighted in the 2016 RSI Domain Plan is the lack of a coordinated system for research infrastructure. The lack of awareness of available research infrastructure can affect decision making around infrastructure investments and potentially limits the sharing of resources between institutions, which is one way of maximising the value of large infrastructure investments. By bringing together this information on research infrastructure held by the institutions, the Kitmap project is a first attempt at centralising this information. The information will support MBIE and the institutions in collective planning for resilience and meeting critical equipment needs across the country, to ensure sustainable, efficient, and enabling infrastructure. We use a fairly broad definition of research infrastructure that includes physical equipment and facilities, scientific collections and databases, and, to some extent, the technical and support staff that underpin them (see more on definitions later in this section).

The Strategic Science Investment Fund (SSIF) investment plan[3] reflects the current policy on investment in national infrastructure. In recent years, several challenges around funding and governance for national infrastructures have emerged. MBIE has endeavoured to explore these further through the RSI system reform programme Te Ara Paerangi – Future Pathways. The insights provided by this report will serve as one of the inputs for future work on research infrastructure as part of Te Ara Paerangi. Through that process, we seek to understand how to increase the value from infrastructure investment, improve outcomes for the system, and better invest in enabling infrastructure to create opportunities for researchers in Aotearoa New Zealand (Aotearoa).

Through Kitmap, we aim to fill gaps in this missing information so that future policy work can begin to address the key questions raised through these reports and consultations, such as:

- How should government design its investments in research and science?
- What value is generated from investment in physical infrastructure in research and science?
- Which investment mechanisms are the most effective?
- What is the best use of research infrastructure?
- How could research infrastructure be shared or co-owned?
- What is Aotearoa’s physical infrastructure for research?
- What is the demand for research infrastructure from different sectors?

The Kitmap project has two major outputs: this Kitmap report, and the Kitmap online tool.

This report shares analysis of our current research infrastructure holdings, the types of research and capabilities they enable, and the ways they are accessed and used. It also aims to increase understanding of our broader research infrastructure portfolio and begin to answer some of the key questions outlined above.

The Kitmap online tool will be a continuing product of the Kitmap project, supporting connection and collaboration across the RSI sector. It is intended to serve three important uses:

- As a platform for research institutions to showcase their available research infrastructure.
- As a tool for research offices and policy makers to identify gaps and opportunities in our research infrastructure holdings.

[1] 2016 Research, Science and Innoation Domain Plan (mbie.govt.nz)

[2] New Zealand's Research, Science and Innovation Strategy: Draft for consultation (mbie.govt.nz)

[3] Strategic Science Investment Fund: Investment Plan 2017 - 2024 (mbie.govt.nz)

- As a portal for researchers, domestic and international, to connect with the infrastructure they need to carry out their research.

The Kitmap tool is expected to be available from early 2023. It will initially contain the data collected through this survey, but built with the intention of maintaining the current data set and new data being incorporated from other sources, such as universities and independent research organisations. A Kitmap survey is unlikely to be repeated in this form, with the Kitmap tool serving as the basis for any future reports of this nature.

Report outline

The information for Kitmap was collected from the seven CRIs, plus Callaghan Innovation and NeSI, hereafter referred to collectively as *the institutions*. The information was gathered through a survey consisting of a spreadsheet with over 100 fields to be completed. The Kitmap team gratefully acknowledges the significant effort from the institutions in compiling detailed information about their infrastructure for this project.

In addition to basic data about the institutions' research infrastructures, the survey requested information on usage and access arrangements, funding sources, and the capabilities and fields of research which the infrastructures enable.

This report is divided into three main sections, structured around the three key themes of the survey (Figure 1).

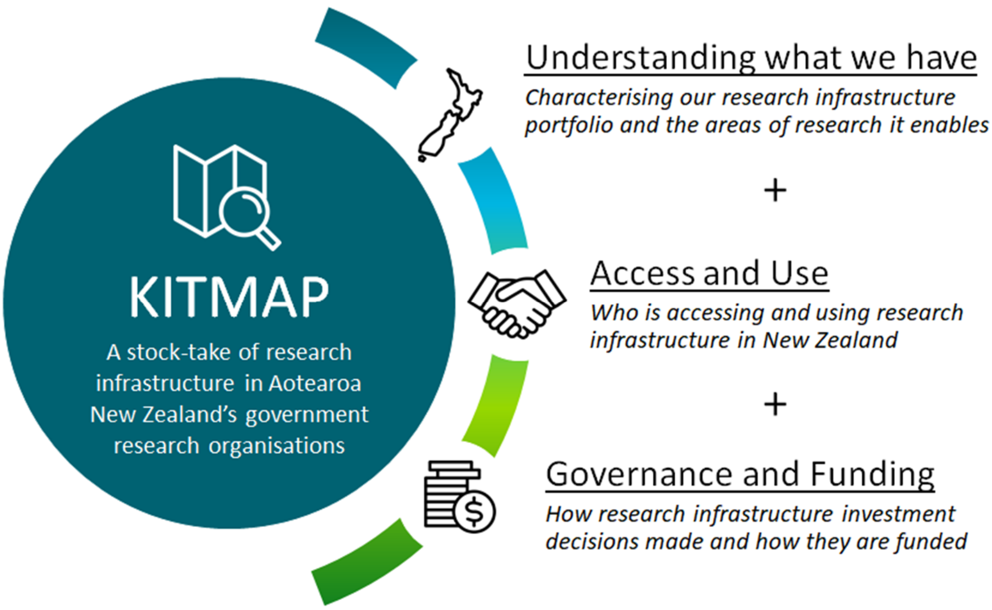


Figure 1: High-level overview of the Kitmap project approach and themes.

Survey details

The nine institutions included in the Kitmap survey are unified by being primarily Crown-funded institutions, with all except NeSI being defined as *Crown Entities*.

The institutions included all seven of Aotearoa's CRIs: AgResearch, ESR, GNS, Manaaki Whenua, NIWA, Plant and Food Research, and Scion. The CRIs were established in 1992 by the New Zealand government under the Crown Research Institutes Act 1992, with the purpose of undertaking research of benefit to Aotearoa. Each of the seven CRIs is aligned with a productive sector of the economy or a grouping of natural resources. The CRIs operate on a commercial model as stand-alone companies (Crown entity companies under the Crown Entities Act 2004) with their own boards and executives, and subject to the Companies Act 1993. As crown entity companies, CRIs are not expected to maximise profit, but are required to operate in a way that maintains their financial viability. MBIE provides core funding for CRIs through the SSIF fund.

Callaghan Innovation is another form of statutory entity, a *Crown agent,* that "must give effect to government policy when directed by the responsible Minister". Callaghan Innovation was established under the Callaghan Innovation Act 2012 and receives Crown funding through an annual appropriation.

NeSI is a SSIF Research Infrastructure that operates as an unincorporated entity, hosted by the University of Auckland, and in collaboration with NIWA, Manaaki Whenua, and the University of Otago.

THE INSTITUTIONS

agresearch
āta mātai, mātai whetū

AgResearch

AgResearch leads agri-based science innovation in Aotearoa. It delivers new knowledge and technologies to support the agriculture sector. AgResearch states its purpose as "to use science to enhance the value, productivity and profitability of Aotearoa's pastoral, agri-food and agri-technology sector value chains to contribute to economic growth and beneficial environmental and social outcomes for New Zealand". AgResearch has broad specialities including seeds, pest control, high value foods and farming systems. It undertakes research ranging from small rural projects up to large international research projects, all with the intention of benefitting Aotearoa's agricultural sector.

AgResearch employs approximately 700 staff. It has four locations which include two research centres located in Lincoln and Palmerston North, and two agricultural centres located in Hamilton and Mosgiel, with their head office also in Lincoln.

CallaghanInnovation
New Zealand's Innovation Agency

Callaghan Innovation

Callaghan Innovation is Aotearoa's innovation agency that provides services to support research and development (R&D) by Aotearoa businesses. It also works closely with government and research organisation partners to enhance Aotearoa's innovation ecosystem. Within its services, Callaghan Innovation offers access to experts, technology and product development, and R&D funding. Callaghan Innovation's mission is to activate innovation, accelerate commercialisation and help businesses grow faster for a better Aotearoa.

Callaghan Innovation employs around 450 staff. Callaghan Innovation has sites in four urban offices: Auckland, Wellington and Christchurch with the largest being the Gracefield Innovation Quarter in Lower Hutt, Wellington. It also has a regional partner network across a further 14 locations.

Institute of Environmental Science and Research (ESR)

ESR specialises in science that protects and improves the health and wellbeing of communities. ESR's core purpose is to "deliver enhanced scientific research services to the public health, food safety, security, and justice systems". Over the last two years ESR's public health capabilities have been highlighted through wastewater testing and whole-genome sequencing as part of the country's COVID-19 response. ESR is the sole provider of forensic services to the New Zealand Police supporting our justice systems, alongside this ESR researchers undertake R&D projects helping to deliver advancements that improve justice outcomes.

ESR employs over 400 people. ESR has four sites located around the country: Auckland, Christchurch, and two sites in Wellington - one at Kenepuru, and the other within the National Centre for Biosecurity and Infectious Disease complex in Wallaceville.

Institute of Geological and Nuclear Sciences Limited (GNS)

GNS is Aotearoa's lead agency in earth, geoscience and isotope research and consultancy services. The work of GNS centres around four science themes: natural hazards and risks, environment and climate, energy futures, and land and marine geoscience. Additionally, GNS undertakes investment in data science and social science. GNS provides key capabilities for Aotearoa, including around-the-clock monitoring of natural geohazards (earthquakes, tsunami, volcanoes, landslides) through the National Geohazards Monitoring Centre/ Te Puna Mōrearea I te Rū (NGMC). GNS, in collaboration with Toka Tū Ake Earthquake Commission (EQC), also manages the GeoNet platform which operates the geological hazard monitoring system in Aotearoa. GeoNet is comprised of geophysical instruments, automated software and staff to provide the data for the monitoring capability.

GNS employs over 390 staff. GNS has sites across Wellington, Taupō and Dunedin, with monitoring infrastructure spread across the country.

Manaaki Whenua Landcare Research (Manaaki Whenua)

Manaaki Whenua is the lead research organisation in Aotearoa for land environment and biodiversity. Its multidisciplinary teams work across the following priority areas: biota, characterising land resources, climate change adaption and mitigation, managing land and water, plant biodiversity and biosecurity, society culture and policy, and wildlife management and conservation ecology. Manaaki Whenua curates almost a third of Aotearoa's Nationally Significant Databases and Collections (including reference collections of biological material, cultural knowledge, online databases and tools), which is a key capability that provides resources for Aotearoa's scientists and others around the world.

Manaaki Whenua employs over 400 staff. Manaaki Whenua has a head office in Lincoln, with further sites in Alexandra, Auckland, Dunedin, Hamilton, Palmerston North and Wellington.

New Zealand eScience Infrastructure (NeSI)

NeSI is a virtual platform but has physical collaborator institutions (Universities of Auckland and Otago, and CRIs NIWA and Manaaki Whenua). NeSI is Aotearoa's national platform for eScience, supporting our High-Performance Computing (HPC) and eResearch capabilities. It supports national science priorities by providing access to HPC and data infrastructure for researchers to pursue research in the modern science environment. NeSI is funded through SSIF Infrastructure funding, works with collaborator institutions who contribute to the platform through investment, employment of NeSI team, and enabling wider connections for the platform.

The NeSI team consists of around 38 people, who are employed across the collaborator institutions.

National Institute of Water and Atmospheric Research (NIWA)

NIWA's core purpose is stated as "to enhance the economic value and sustainable management of New Zealand's aquatic resources and environments, to provide understanding of climate and the atmosphere, and increase resilience to weather and climate hazards to improve safety and wellbeing of New Zealanders." NIWA is the lead agency in the areas of aquatic resources and environments (with a focus on surface freshwaters and coastal environments), oceans, freshwater and marine fisheries, aquaculture, climate and atmosphere, climate and weather hazards, aquatic and atmospheric-based energy resources, aquatic biodiversity (including biosystematics) and biosecurity.

NIWA has more than 670 staff. NIWA's staff are located throughout Aotearoa and overseas, and it has a head office located in Auckland.

Plant and Food Research (PFR)

PFR has the role of looking at the whole food system "from field or sea to plate", focusing on creating healthy and nutritious foods. The broad research areas of PFR include future plants, fish and food, sustainable, resilient food supply, and blue-sky research. PFR's sectors are arable crops (grains and cereals etc.), berryfruit, food & ingredients, seafood, technologies, tree crops, vegetables and vine crops. PFR was created in 2008 following the merger of two former CRIs (HortResearch and Crop & Food Research).

PFR employs over 900 staff across its sites. PFR has 14 sites across Aotearoa (Clyde, Dunedin, Gore, Hawkes Bay, Kerikeri, Lincoln, Marlborough, Motueka, Nelson, Palmerston North, Pukekohe, Ruakura, Te Puke and Wellington) and its head office in Auckland. It also has two Australian locations (Queensland and South Australia) and one in the United States (Oregon).

New Zealand Forest Research Institute Limited (Scion)

Scion specialises in research, science and technology development for the forestry, wood product, wood-derived materials, and other biomaterial sectors. Scion works across the whole forestry value chain from forest genetics to manufactured products from trees. It is the leading CRI in sustainable forest management and tree improvement, forestry biosecurity, risk management and mitigation, wood processing, wood-related bioenergy, waste streams and other biomaterials, and forestry and forestry-based ecosystem services to inform land-use decision making.

Scion employs around 370 staff. Most of its staff are based at the head office in Rotorua, with around 40 in the Riccarton, Christchurch offices.

DEFINING RESEARCH INFRASTRUCTURE

The Kitmap project survey was developed under the three themes of 'understanding what we have', 'access and use' and 'governance and funding'. The survey was structured to produce data that would help to address the gaps in knowledge that existed around these themes — a difficult task given the magnitude of the questions and the existing lack of data.

One of the difficulties with this project is the lack of internationally recognised standards for classification or taxonomy of research infrastructure. The OECD has highlighted that there is no consensus definition of the term 'research infrastructure'. The European project Mapping the European Research Infrastructure Landscape (MERIL[4]) used the definition -

> "a facility or (virtual) platform that provides the scientific community with resources and services to conduct research in their respective fields. These research infrastructures can be single-sited or distributed or an e-infrastructure, and can be part of a national or international network of facilities, or of interconnected scientific instrument networks".

Definitions of research infrastructure can be broadened to include the technical support staff that operate and manage the equipment and are essential to maximise the value from investments in infrastructure.

The Kitmap data dictionary considered information from the Common European Research Information Format (CERIF[5]) and classifications of research infrastructure from the MERIL and Catalogue of Research Infrastructure Services (CatRIS[6]) projects. The Kitmap survey used a three-layer data model to categorise holdings within each institution, comprising platforms, infrastructures and resources (Figure 2). These are defined as follows:

1. **Platform** – A collection of one or more infrastructures, with a shared strategic purpose or shared governance, co-location or another unifying feature (refers to groups of infrastructures and not SSIF platforms).
2. **Infrastructure** – An individual laboratory/facility, eg a field site, specialised laboratory or set of equipment.
3. **Resource** – A significant scientific instrument, collection, or a piece of equipment used or maintained as a single entity. The survey set a threshold value for significant equipment of $150k by agreement with the institutions.
    a. We note that due to the nonstandard nature of resources, these have been further subdivided in the report into two categories — large groupings and small groupings. These categories were used to distinguish between resources with significantly larger unit counts, such as specimens in a collection, sensors in a monitoring network, or computers in a cluster, compared with what would more typically be considered as individual pieces of equipment. An arbitrary threshold of 75 units was applied as it suitably delineated these different categories within the dataset such that most fall in the small groupings category (1,722 items across 475 infrastructures), with a small subset of the types described above falling under large groupings (408,686 items across 18 infrastructures). Unless otherwise specified, references to resources throughout the report refer to those in the small groupings category.

[4] https://portal.meril.eu/meril/
[5] https://eurocris.org/services/main-features-cerif
[6] https://www.portal.catris.eu/

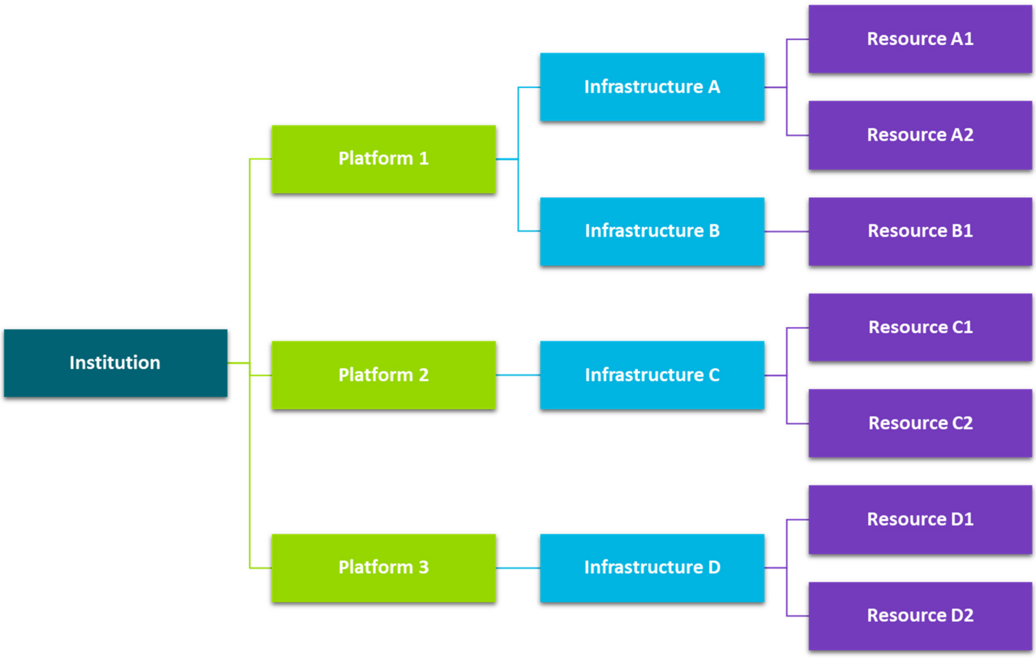
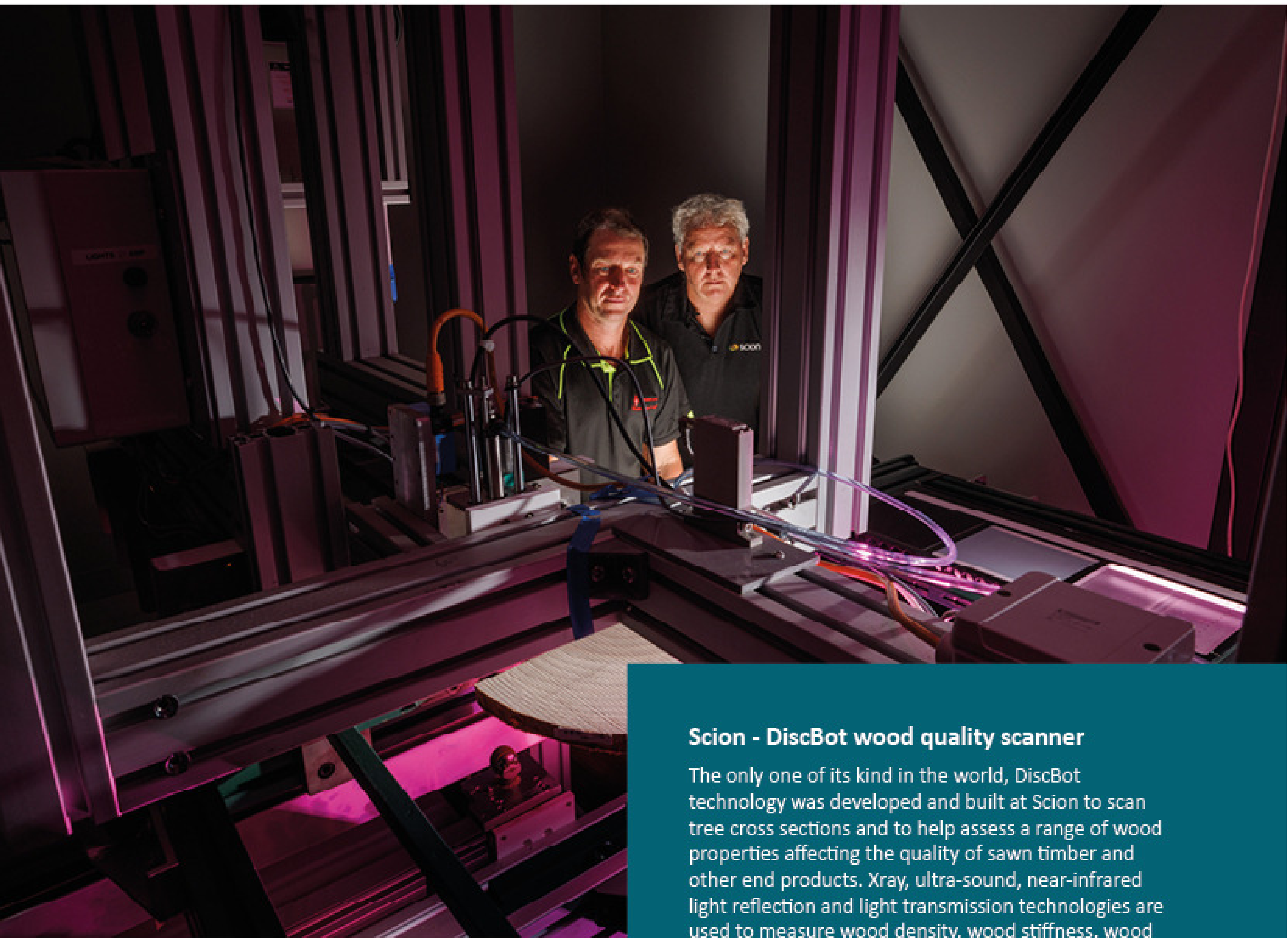


Figure 2: Overview of the hierarchy of research infrastructures in the Kitmap data model. See definitions in the text

Most of the information gathered in the survey was collected at the infrastructure level. Platforms were included as an organising concept to help standardise very different kinds of information, although these were found to be of limited value for the analyses in this report, and only summary information is presented at the platform level.

LIMITATIONS OF THE SURVEY DATA

Given the volume of information requested and competing pressures for those providing responses from the institutions, some were able to provide more data than others, and there are parts of the dataset that, as a result, are relatively incomplete. The data are self-reported and, to some extent, self-organised by the institutions. In some cases, data from the institutions include best estimates available at the time of their response. Similarly, different institutions have interpreted some of the questions in different ways or have provided a greater level of granularity than others, which has led to inconsistencies in the data. To ensure transparency and appropriate context to the data presented in this report, figures and text relating to variables with limited data are qualified by a measure of the data quality or accompanied by metrics on response rates, such as the metadata tables that accompany many figures. Certain topics of interest to the Kitmap project were not able to be fully explored through the data, and some analytics in the report do not cover all of the institutions. These include information about the lifecycle of infrastructures and replacement timeframes, more detailed information on funding and capital values of infrastructures, and users of infrastructures from Iwi organisations.

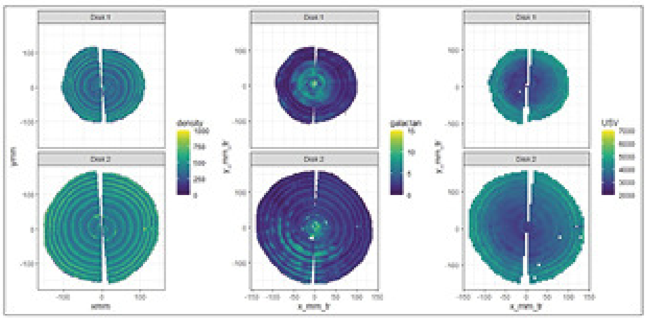


Scion - DiscBot wood quality scanner

The only one of its kind in the world, DiscBot technology was developed and built at Scion to scan tree cross sections and to help assess a range of wood properties affecting the quality of sawn timber and other end products. Xray, ultra-sound, near-infrared light reflection and light transmission technologies are used to measure wood density, wood stiffness, wood chemical composition and wood grain angles. These measures all impact on wood quality.

The DiscBot has been used in both research and commercial activities and allows properties of a tree to be measured (including non-destructively) well before harvest age. This enables confidence that the wood from that tree will meet the needs of the market and gives the grower the option to harvest earlier and start another growth cycle. These insights allow Scion to assess how the environment, silviculture (forest management), tree genetics and the effects of climate variation all affect wood.

Scanned disc images Density, Galactan and USV



ESR - Wastewater-based Epidemiology extraction laboratory

These automated machines are used to both extract and concentrate chemicals and metabolites from wastewater for sensitive testing by liquid chromatography-mass spectrometry (LC-MS). This technique can detect concentrations of less than 1 part-per-trillion in the original samples (the equivalent of finding one pebble on the whole of state highway 1).

This infrastructure enables estimates of community exposure to or consumption of specific chemicals, such as illicit drugs, alcohol, pesticides, and other markers of human health. This provides an unintrusive, unbiased measure of community health, and when sampled over time can provide useful data on trends in consumption and exposure. For example, these sensitive analyses can quantify the difference between weekday and weekend alcohol consumption, and, by comparing different towns and cities, help dispel inaccurate stereotypes of the residents of certain areas.

2. TE WHAKATAU I TE ĀHUA O TĀ MĀTOU KŌPAKI TŪĀHANGA RANGAHAU | CHARACTERISING OUR RESEARCH INFRASTRUCTURE PORTFOLIO

Research infrastructure is a key aspect of research capability — it *enables* research. In order to understand the capabilities of research and science in Aotearoa, we need to understand the infrastructure that underlies and enables it. This section characterises the research infrastructure portfolio across the institutions. We note that this is a summary of infrastructure reported through the Kitmap survey, and reflects those held by the institutions at a given point in time. They do not reflect the future strategy or direction of infrastructure holdings or utilisation requirements of the institutions.

Institutions identified 493 different research infrastructures

In characterising the infrastructure, we look to the type of infrastructure and the trends across the institutions to see which types are most heavily invested in. This section also provides an indication of the scale of this infrastructure portfolio through counts of infrastructure and collections, broken down by institution. From this characterisation we can build a picture of the capabilities these institutions provide, enabled by their infrastructure investments.

Table 1: Number of platforms, infrastructures, and resources at each institution.

		AgResearch	Callaghan Innovation	ESR	GNS	Manaaki Whenua	NeSI	NIWA	PFR	Scion	Total
Platforms[8]		15	4 [7]	5	9	7	3	12	28	9	**98**
Infrastructures[8]		62	124	47	53	49	16	31	46	65	**493**
Resources[8]	Small groupings	146	87	131	155	11	12	304	380	218	**1,444**
	Large groupings	0	0	0	125,000	0	0	4,702	0	285,824	**415,526**

Table 1 shows the number of platforms, infrastructures, and resources at each institution. Note that some of the variation across the data can be attributed to the decision-making process of each institution in fitting their portfolio to the Kitmap data definitions, as well as the different scales of infrastructure required by different fields of research.

Platforms were self-identified by the institutions and represent groupings of infrastructures. Thus, the number of platforms is somewhat arbitrary and less meaningful for understanding the total amount of infrastructure available. Where an institution has a high platform count, this could indicate that the institution has more infrastructures with standalone purposes or on a significantly larger scale, whereas a low platform count may indicate that the institution already has a different way of grouping their infrastructures, either physically (co-location) or by shared strategic purpose. Thus, the platform count is not especially informative for the purposes of this report, although the data are included for completeness.

[7] This value reflects the core platforms at Callaghan Innovation; this value would be higher if expanded to included co-located companies that are tenants of Callaghan Innovation.

[8] See definitions in Section 1

Table 2: Breakdown of research infrastructures at each institution by type.

	AgResearch	Callaghan Innovation	ESR	GNS	Manaaki Whenua	NeSI	NIWA	PFR	Scion	Total
Laboratory	36	112	47	19	30	-	5	33	45	**327**
Digital Collection	-	-	-	26	9	-	2	2	5	**44**
Field Site	12	-	-	-	-	-	7	5	5	**29**
Computing	-	2	-	1	-	16	1	1	1	**22**
Samples Collection	2	-	-	3	8	-	2	-	6	**21**
Monitoring	3	-	-	3	-	-	6	1	-	**13**
Livestock Research	4	1	-	-	2	-	-	4	1	**12**
Workshop	-	7	-	1	-	-	1	-	-	**9**
Pilot Plant	5	2	-	-	-	-	-	-	1	**8**
Vessel	-	-	-	-	-	-	4	-	-	**4**
Other	-	-	-	-	-	-	3	-	1	**4**

The infrastructure counts are more informative in terms of how much research infrastructure is held by an institution. These are made up of a variety of types (defined on the following page), as indicated in Table 2. However, infrastructure counts are more nuanced than might be taken at first glance. High infrastructure counts reflect where an institution has reported large numbers of individual physical spaces, collections, or networks with different purposes, or where an institution has listed many individual physical spaces as a separate infrastructure. In contrast, low infrastructure counts reflect institutions' grouping of physical spaces/collections/network with a shared purpose as a single "facility" at the infrastructure level. Therefore, comparison of the total number of infrastructures at each institution does not necessarily reflect the scale of operation of each institution.

The individual resources reflect significant pieces of equipment, although the scale of each is not apparent from the counts, ie some may be much larger than others. The individual resource types are not presented here, however these will be an important component of the forthcoming Kitmap online tool.

These counts and breakdown of infrastructure across categories are explored in more detail below.

The majority of science facilities are laboratories

Figure 3 illustrates the proportion of infrastructure types held by each institution, based on the data in Table 2. Each infrastructure was tagged to one category through a standardisation process —many of the infrastructures have broad capabilities that may overlap across multiple categories but are here simplified to reflect the main category for each infrastructure. The infrastructure types used here are:

- **laboratory**: conventional laboratory rooms/buildings
- **digital collection**: online databases and digital archives
- **sample collection**: collections of physical specimens
- **field site**: physical spaces used for research activities which are not conventional scientific laboratories (not only sites at which field work is carried out)
- **computing**: physical computing hardware and/or virtual spaces and networks
- **monitoring**: sets or networks of monitoring equipment
- **livestock facilities**: physical spaces for rearing, containing, or conducting research with livestock (including farm animals, fish, and insects)
- **workshop**: physical spaces which support research activities through fabrication/maintenance of research equipment

- **pilot plant**: production facilities which enable trials of new production technologies or products on a pre-commercial scale
- **vessel**: ships or boats which are equipped to enable research to be conducted at sea
- **other**: infrastructures whose main designation/purpose does not match the previous categories

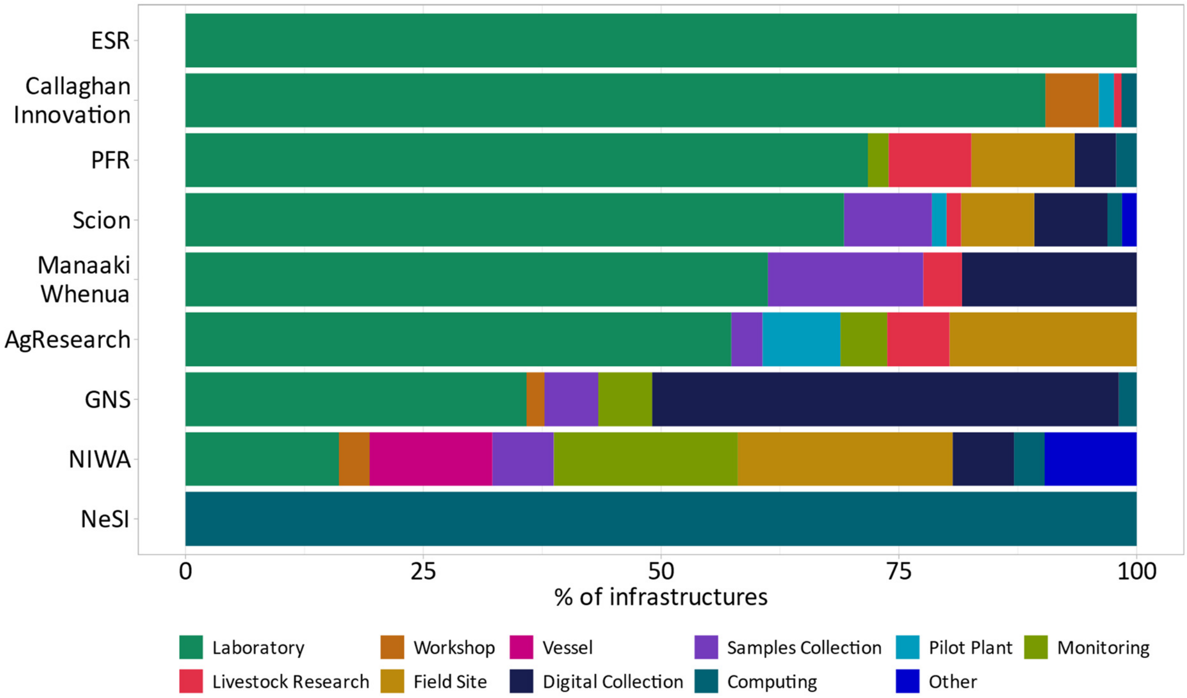


Figure 3: Types of infrastructures at each institution, sorted by proportion of laboratories in infrastructures reported.

Most infrastructure reported across the institutions are laboratories. These laboratories host a wide range of resources and represent the backbone of the scientific research infrastructure that supports research across the institutions. The large fraction of laboratories in the infrastructure from ESR and Callaghan Innovation reflects the research focus of these institutions. PFR, Scion, Manaaki Whenua and AgResearch have more diverse infrastructure holdings to support their research priorities, which encompass a broader range of scientific approaches. Similarly, GNS and NIWA have the most diverse holdings, reflecting the environmental and monitoring focuses of these institutions requiring the widest range of supporting infrastructure types. The primary exception to these points is NeSI, as its significant infrastructures all fall in a single category, computing (Figure 3), which reflects NeSI's role as Aotearoa's eScience infrastructure.

The breakdown of users across these infrastructure types is explored further in Section 3.

Facilities have varying numbers of resources

As described in Section 1, resources here comprise the tools and equipment that researchers use, often customised to allow particular activities. Resources are often key attractions for a facility and reflect the differences in capabilities of the institutions.

Figure 4 shows the total number of resources reported by each institution. Per the definitions in Section 1, resources data in Figure 4 show a subdivision of the resources data to exclude those with numerous individual parts (eg individual specimens in a collection, sensors in a monitoring network, or computers in a cluster) to focus on small groups of resources.

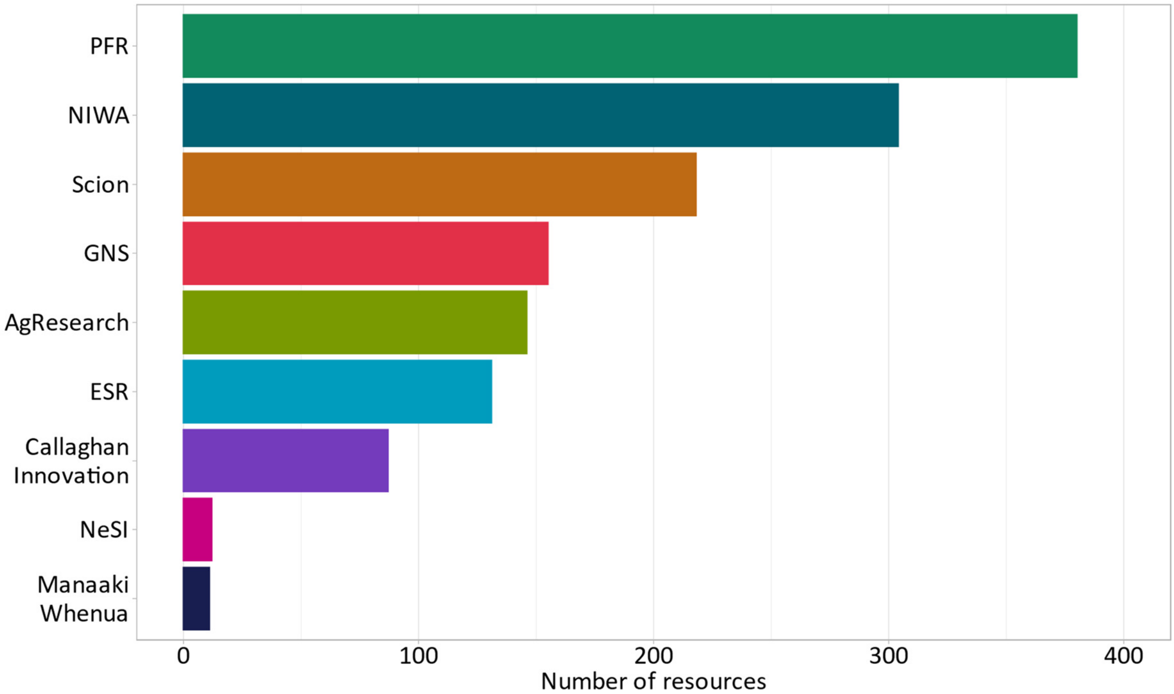


Figure 4: Number of resources reported by each institution.[9]

Figure 4 metadata:

Institution	Infrastructures with at least 1 resource assigned
AgResearch	61/62 (98%)
Callaghan Innovation	22/124 (18%)
ESR	22/47 (47%)
GNS	17/53 (32%)
Manaaki Whenua	5/49 (10%)
NeSI	8/16 (50%)
NIWA	25/31 (81%)
PFR	40/46 (87%)
Scion	41/65 (63%)
Total	248/493 (50%)

[9] Data notes: Includes only small groupings (see definitions in Section 1). Low resource counts from some institutions likely reflect the complexities of categorising research infrastructure. For example, much of NeSI's equipment could be equally categorised at infrastructure and resource levels. The low resource count from Manaaki Whenua arises from only specialised pieces of laboratory equipment being reported in this category, rather than a full inventory of general laboratory equipment, and not all infrastructures being complete at the resources level, eg it is unlikely that this accurately reflects Manaaki Whenua having the smallest amount of research infrastructure across the institutions. Other institutions may have also under-reported.

The counts of resources at the institutions ranged from 11 to 380. This large variation may partly be a result of differences in reporting from the institutions [8], which means some relative differences between institutions are not accurately reflected. However, some reflect the true number of resources (noting that these do not reflect the scale of each resource). For example, NeSI's lower resource counts likely reflect that supporting eResearch requires a narrower variety of equipment compared with organisations than carrying out experimentally based research, though each resource may be of high value.

Facilities support research across all fields, but reflect the focus of the organisations surveyed

Here we address the core Kitmap question of what infrastructure is used for and what areas of research are enabled by infrastructure in Aotearoa. These categories were self-identified by each institution according to Australian and New Zealand Standard Research Classification (ANZSRC) codes for Fields of Research (FoR) and Socio-Economic Objective (SEO) [10]. We note that it can be difficult to apply these codes, as the objectives or types of research enabled by some types of infrastructure can be extremely broad.

Figure 5 and Figure 6 show the numbers of research infrastructures supporting each of the ANZSRC FoR and SEO codes, respectively, across the infrastructures reported in the Kitmap survey. The available data clearly reveal the focus of Aotearoa's research efforts, at least as supported through infrastructure. Unsurprisingly, these show that a significant fraction of the research infrastructure held across the CRIs is used to support the primary industries (particularly agriculture) or for researching and/or monitoring the natural environment and natural hazards, which align with the core purposes of the respective institutions and the overarching goals of the funding they receive. This is addressed in further detail in Section 3.

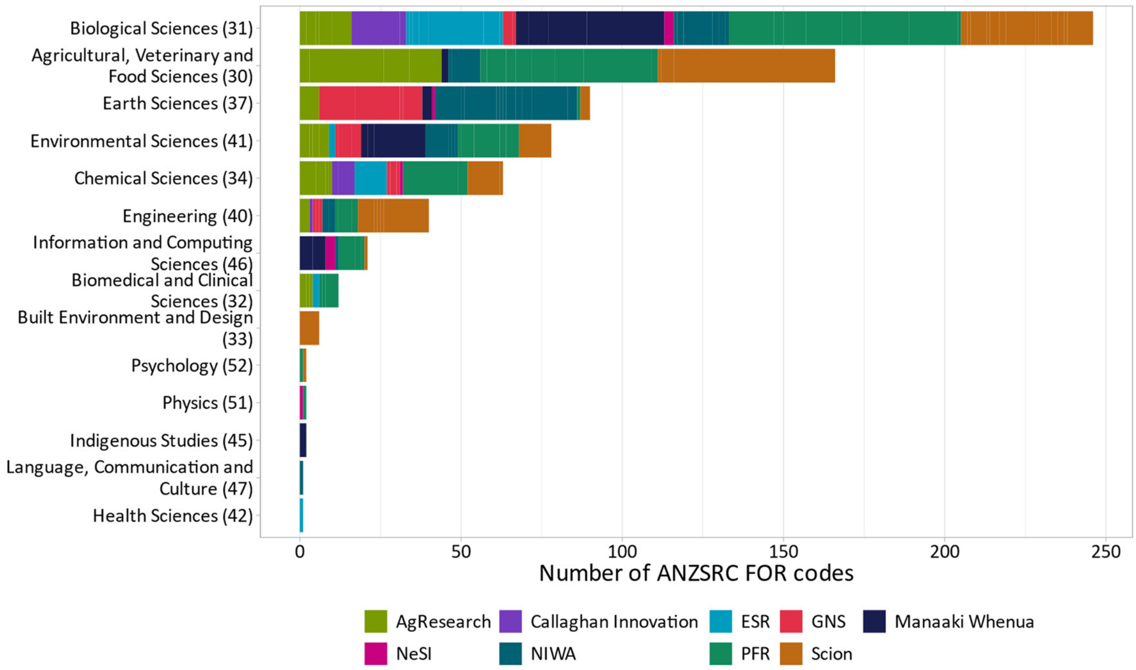


Figure 5: ANZSRC Field of Research (FoR) divisions supported by research infrastructure at each institution. [10]

[10] ANZSRC is a statistical classification used for the measurement and analysis of R&D across the two countries, classifying R&D projects by Type of Activity (ToA), Fields of Research (FoR) and Socio-Economic Objectives (SEO). The FoR and SEO categories are divided into a hierarchy of levels comprising division (2-digit codes), group (4-digit codes), and field (6-digit codes), becoming more specific at each level. Here the ANZSRC 2020 iteration is used. We note that there are cases where it is a valid approach to not apply an ANSZRC code, such as where the research infrastructure is science services only and not performing research, or if the research infrastructure serves many different research areas making it misleading to apply only a few.
Data notes: Institutions could apply up to five classifications for each infrastructure. Institutions missing from these figures did not provide FoR or SEO data. While the survey collected data at the group (4-digit) level, the data have been simplified in this figure into their respective divisions in order to give a high-level overview of what our research infrastructure is used for.
For the FoR classifications (Figure 5), 331 out of 493 infrastructures in the survey had at least one FoR code attached, representing 67 per cent of the research infrastructures at the nine institutions. Slightly fewer infrastructures were tagged with SEO codes (Figure 6), 286 out of the 493 infrastructures having at least one SEO code attached (ie 58 per cent coverage). We note that the simplification to division level codes results in some infrastructures being counted more than once in these figures. However, the proportion of each field of research or socio-economic objective supported by research infrastructure remain valid.

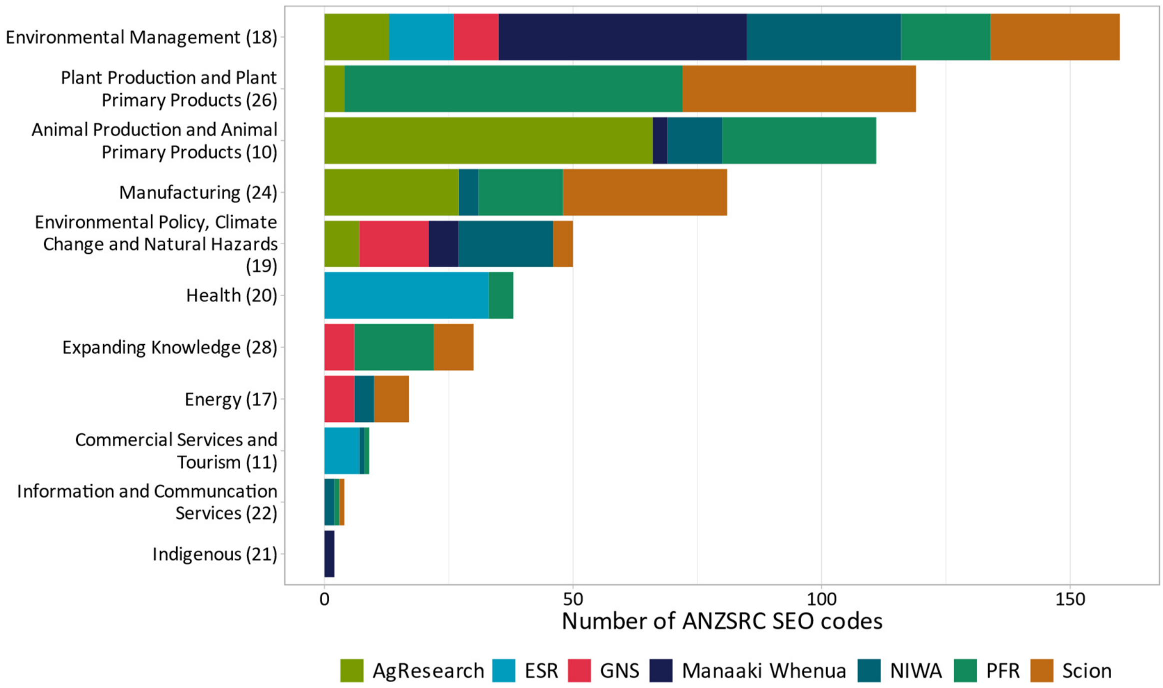


Figure 6: ANZSRC Socio-Economic Objectives (SEO) supported by infrastructure at each institution. [10]

Figure 5 and 6 metadata:

Institution	Infrastructures with at least 1 FoR code	Infrastructures with at least 1 SEO code
AgResearch	62/62 (100%)	58/62 (94%)
Callaghan Innovation	17/124 (14%)	-
ESR	34/47 (72%)	28/47 (60%)
GNS	21/53 (40%)	8/53 (15%)
Manaaki Whenua	49/49 (100%)	49/49 (100%)
NeSI	6/16 (38%)	-
NIWA	31/31 (100%)	31/31 (100%)
PFR	46/46 (100%)	46/46 (100%)
Scion	65/65 (100%)	65/65 (100%)
Total	331/493 (67%)	285/493 (58%)

As would be expected, GNS and NIWA have the most infrastructure used for earth science. Notably, every institution features infrastructure under the biological sciences FoR division, revealing this as a connecting area across a wide range of disciplines. Manaaki Whenua was the only institution reporting infrastructures with SEO codes for indigenous outcomes. The majority of research infrastructures reported are generic technologies which could as easily apply to indigenous as non-indigenous SEOs. The small number of infrastructures with this SEO applied reflects those with a more defined focus, such as collections containing taonga species with specific links to indigenous outcomes. Several institutions reported infrastructures supporting the Expanding Knowledge SEO, which is interesting given that this SEO is suggestive of basic research, whereas these organisations are more typically thought of as carrying out applied research.

Most institutions access international infrastructures

While the primary focus of the Kitmap survey was to characterise our domestic research infrastructure portfolio, understanding how the institutions utilise research infrastructure outside of Aotearoa provides further insights into our infrastructure needs and how they are resourced. International agreements provide opportunities for accessing infrastructure that could otherwise be unattainable, particularly for Aotearoa as a smaller country. Such arrangements are integral to our research remaining competitive and at the forefront of research on a global scale.

The institutions were asked to describe access to international research infrastructure or facilities. Most institutions reported the use of at least one piece of international research infrastructure, which are accessed through various access arrangements. These agreements for access included fee-paying memberships, service delivery contracts, access fees, collaborative research, including collaborative arrangements between individual scientists (both contracted and non-contracted), pan-CRI agreements (agreements between groups of CRIs and an international facility), use of research infrastructure purchased in exchange for maintenance, and fee-for-service arrangements.

Several of the institutions (AgResearch, GNS, Callaghan Innovation and PFR) are fee-paying members of the New Zealand Synchrotron Group (NZSG) which coordinates Aotearoa's investment in and access to the Australian Synchrotron, one of Aotearoa's largest nationally funded research infrastructures, with substantial funding from the SSIF[11]. The Australian Synchrotron is a large facility with many experimental stations and a wide variety of research applications, including health, environment, food production, nuclear science, and development within space and quantum technologies. Through this bilateral agreement, our researchers gain access to this infrastructure that would otherwise be beyond the reach of Aotearoa institutions, and this is a good example of how our needs can be met through international arrangements.

[11] NZ Synchrotron Group Ltd (royalsociety.org.nz)

GNS - XCAMS

XCAMS is an eXtended Compact Accelerator Mass Spectrometer (AMS), used primarily for radiocarbon dating. XCAMS is the only AMS in Aotearoa and was installed in 2010, manufactured to GNS's design specifications by National Electrostatic Corporation, one of three manufacturers worldwide.

XCAMS supports many of the research activities in GNS, where it is an integral part in the development of chronologies for past natural hazard events and environmental changes and improving our understanding of the carbon cycle and climate change. Working with the Rafter Radiocarbon Lab, it also provides commercial AMS measurement services.

PFR - Compac™ produce grading equipment

The Compac™ fruit handling and category sizing equipment is used to quickly and reliably measure attributes of fruit. Using optical and/or near-infrared vision and specialised sorting software, it can check for internal defects, check the ripeness of fruit, and sort fruits by shape, size, or colour. PFR use this technology at four field locations to assess different production and storage systems, optimise crop management, and select the best fruit breeding lines for further development and evaluation. The picture shows grading equipment in use with the PiqaBoo™ pear developed by PFR, renowned for its intense red coloration which brightens during fruit storage when picked at the correct fruit maturity.

3. TE URU ME TE WHAKAMAHI I TE TŪĀHANGA RANGAHAU | ACCESS AND USE OF RESEARCH INFRASTRUCTURE

An important aspect of the Kitmap project was not only to understand what infrastructure we have, but also how it is accessed and used. This includes who uses the infrastructure, how they get access to it, and how it is maintained. Information about access to infrastructures is also a key input for the Kitmap online tool.

The Kitmap survey asked a range of questions about access policies for external users of the infrastructure, including whether access was granted by academic merit, commercial agreements, or was open/unrestricted, and in each of these cases, whether there are costs involved for the user. Institutions were also asked whether external users could utilise the infrastructures/resources in-person (ie on-site use with supervision/training), however, those data were ultimately not included in this report due to ambiguity of the responses.

The survey results indicated that each institution has a different approach to access and use of their infrastructure, and that access policies for research infrastructures vary significantly both within and across institutions.

More than half of research infrastructures are accessible to external users

In Figure 7, survey data were reframed to the binary question: can the infrastructure be accessed by external users? This shows the proportion of each institution's infrastructures with at least one mode of access that is available to external users. Of the 493 total infrastructures, 53 per cent (264) were reported as being accessible to external users, with 13 per cent (63) being inaccessible, and no data available for the remaining 34 per cent (166) infrastructures. We note that there a range of reasons why some infrastructure is not available for wider use, including health and safety concerns, compliance/regulatory approvals, calibration requirements, current capacity limitations, or where security requirements restrict physical access.

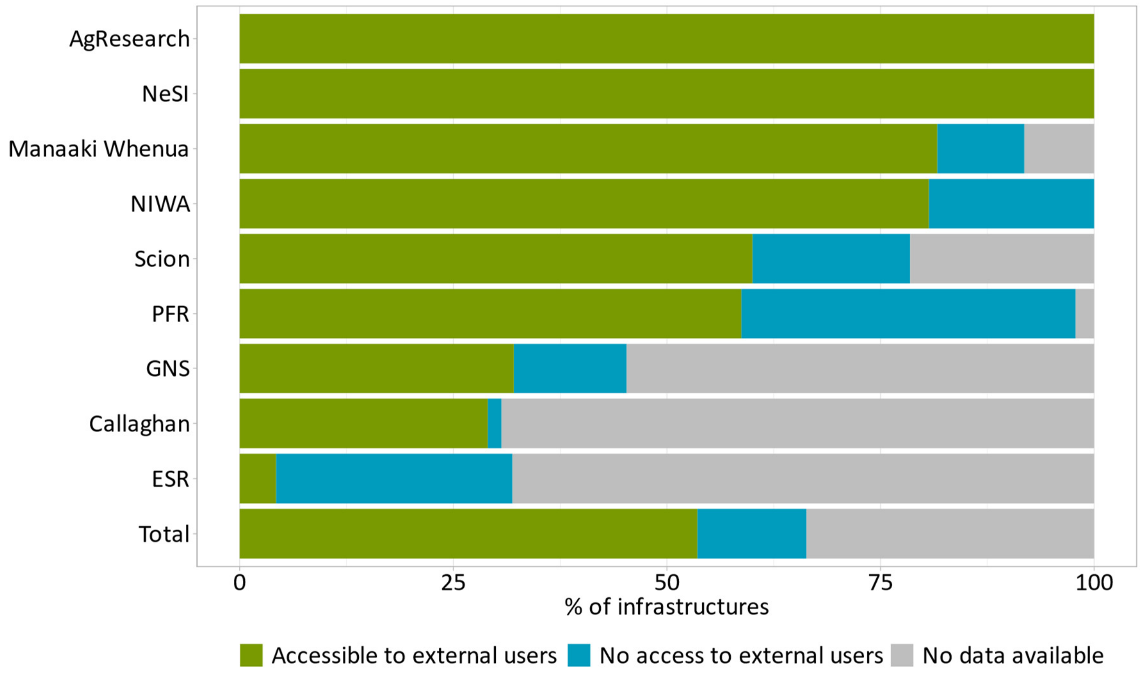


Figure 7: Accessibility of research infrastructure to external users. More than half of research infrastructures are accessible to external users at most institutions. [12]

Figure 7 metadata:

Institution	Accessible to external users	Inaccessible to external users	No data available
AgResearch	62/62 (100%)	-	0/62 (0%)
Callaghan Innovation	36/124 (29%)	2/124 (2%)	86/124 (69%)
ESR	2/47 (4%)	13/47 (28%)	32/47 (68%)
GNS	17/53 (31%)	7/53 (13%)	29/53 (55%)
Manaaki Whenua	40/49 (82%)	5/49 (10%)	4/49 (8%)
NeSI	16/16 (100%)	-	0/16 (0%)
NIWA	25/31 (81%)	6/31 (19%)	0/31 (0%)
PFR	27/46 (59%)	18/46 (39%)	1/46 (2%)
Scion	39/65 (60%)	12/65 (18%)	14/65 (22%)
Total	264/493 (53%)	63/493 (13%)	166/493 (34%)

[12] Data notes: Due to variation in the survey responses, the data on access were subject to a standardisation process whereby survey responses were simplified according to some parameters. In this case, all infrastructures with some mode of access were classified as 'Accessible to external users'. The modes of access are explored in the subsequent section.

The proportion of research infrastructures made available by the institutions to external researchers is highly dependent on the type of research it supports. For example, NeSI, as an eScience platform, develops its infrastructure entirely for the use of external users, which is reflected in 100 per cent of its research infrastructure being accessible to external users. By contrast, ESR provides a significant number of services that are enabled by its infrastructures, including restricted services for government that precludes access by external users. This is reflected in ESRs low rate of accessible research infrastructure. PFR reported the highest fraction of infrastructures that are fully utilised internally and are inaccessible to external users, although the majority of its infrastructures (primarily laboratories and field sites) are externally accessible.

Modes of granting access to research infrastructure vary

Of the 264 infrastructures identified as accessible to external users in Figure 7, these can be further categorised in terms of the means by which access is granted to external users.

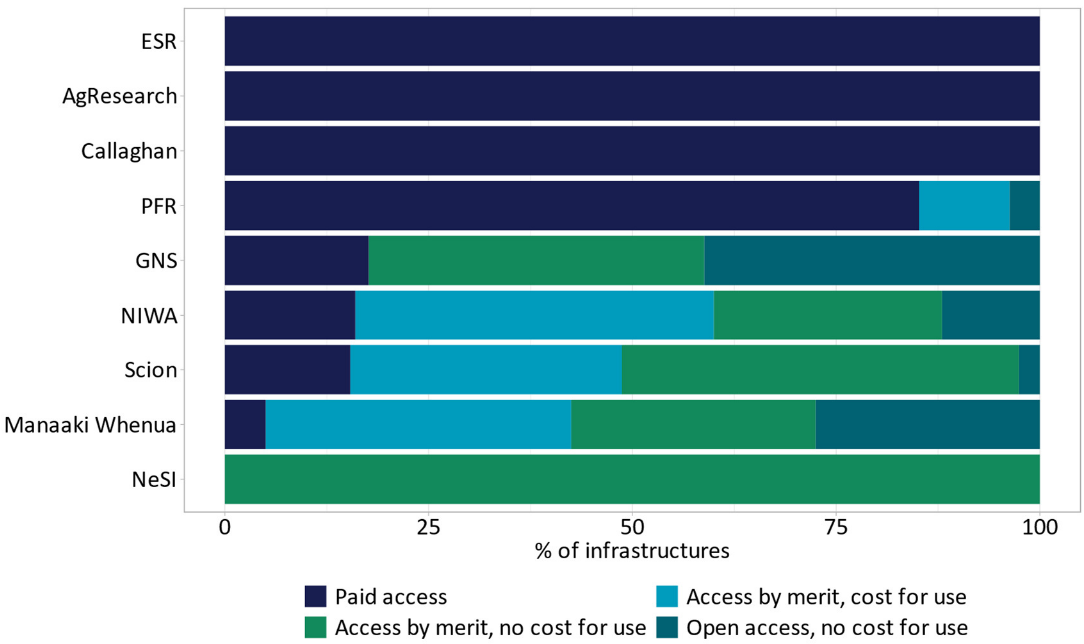


Figure 8: Primary means by which external users can access infrastructure at each institution. [13]

In Figure 8, survey data have again been simplified from more complex responses for clarity. Access is divided into four categories: fully paid access, access by merit for a cost, access by merit with no cost, and open access at no cost (Figure 8). We note that these describe costs to the external users – those infrastructures provided at no cost to external users may be at considerable costs to their host institutions.

Paid access is where an external user must pay a fee to access the infrastructure. This includes, but is not limited to, infrastructures accessed through commercial arrangements, those which require a fee, and those that are available as a service. Access by merit is where access is granted based on the specific research to be undertaken by the external user, and is further split based on whether there is a cost to the external user once access is approved. Access by merit for a cost can apply in situations, for example, where an assessment process is required before access to the infrastructure is approved. Access granted by merit for no cost is typically applied where there is limited capacity available or the specific

[13] Survey data have been simplified into four categories for clarity: fully paid access, access by merit for a cost, access by merit with no cost, and open access at no cost. The details of these categories are given in the text.

resource requires approval to gain access, but there is no cost to users (eg NeSI). Finally, ‘open access, no cost for use’ is where any external user can access this infrastructure for no cost. In the Kitmap data this often includes, though is not limited to, digital resources such as databases and digital collections, which are available online.

Policies for access to infrastructures can be complex, and no uniform approach for connecting to and granting access to them exists across the institutions. In some cases, different access policies can apply for different resources within the same infrastructure, eg external users can only use machine A, while machine B is for internal use only. Another complicating factor is that in these data, external users include those accessing the outputs of the infrastructures, and not just the physical equipment. An example is how access to the outputs of GeoNet are available to all, but the sensor network itself is not. Furthermore, in some cases it is not the physical infrastructure that is limited, but the time of the support staff whose expertise is required to operate it.

Seven of the nine institutions have a significant percentage (between 40 – 100 per cent) of reported infrastructures that are available at a cost to users (ie paid access or merit access with cost; Figure 8). We note that cost recovery through access charges for external users can be entirely appropriate, and that this does not necessarily imply that the infrastructure costs are fully met through these fees.

The highest percentages of open access infrastructures are at GNS and Manaaki Whenua (Figure 8), which reflects their significant number of online databases (Figure 3), a number of which are funded by MBIE to provide open access. GNS, Scion, Manaaki Whenua, NIWA, and NeSI each have a significant proportion of infrastructures (25 – 100 per cent) that can be accessed by merit for no cost (Figure 8). For NeSI, this represents the entirety of its infrastructure, and reflects the nature of the organisation.

Data on the criteria for merit basis for access was not collected in the survey, although some of the institutions outline their access policies online (eg NeSI [14]). The mechanisms for assessing merit-based access likely vary significantly across the institutions, but include review processes through online portals, specific institutional committees, or infrastructure managers. Internationally, access assessment approaches often include consideration of academic merit, expertise in the field, and, where necessary, competency to operate the specified infrastructure.

Organisations reported almost 5000 users across their research infrastructure

Understanding who is using research infrastructure and how they are using it is a key part of characterising our research infrastructure portfolio and whether/how it is meeting the needs of researchers. In Figure 9 we analyse the total annual users of research infrastructures reported by the institutions, categorised by type of infrastructure. We note that here users are not limited to those who are physically interacting with infrastructures (ie researchers), but also include the direct users of the outputs from those (eg government departments).

[14] Access Policy | New Zealand eScience Infrastructure (nesi.org.nz)

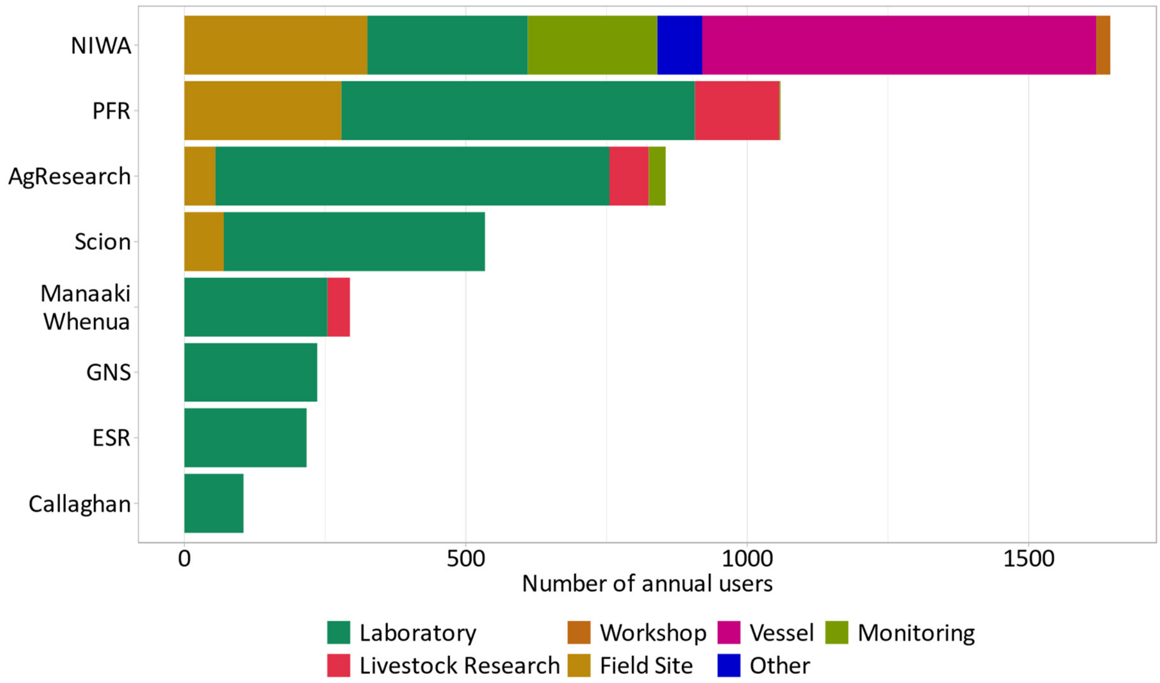


Figure 9: Annual users of research infrastructure Those infrastructures with (comparatively) unlimited capacity (i.e., computing, sample and digital collections) are excluded.[15]

Figure 9 metadata:

Institution	Infrastructures with annual user data
NIWA	23/31 (74%)
PFR	42/46 (91%)
AgResearch	50/62 (81%)
Scion	41/65 (63%)
Manaaki Whenua	32/49 (65%)
GNS	11/53 (21%)
ESR	16/47 (34%)
Callaghan Innovation	6/124 (5%)
Total	221/493 (45%)

[15] Data notes: The response rates for Figure 9 provide important context for interpretation of the data. NIWA, PFR, AgResearch had the highest response rate (over 70 per cent), which means their values are most representative of the annual users. User counts from Callaghan Innovation, ESR, GNS are lower due to the user counts being available for only a small percentage of their total infrastructures, which likely underrepresents their total users. Manaaki Whenua and Scion may also be underrepresented due to sample and digital collections being excluded from this figure.

Here, annual users includes both internal and external users. Nine individual infrastructures with significantly higher user counts were excluded from Figure 9, which comprised sample collections, digital collections, and computing infrastructure that have different capacity limits from other infrastructures. For example, whereas a laboratory or instrument can only have a certain number of users at one time, a website or database has essentially unlimited capacity. For that reason, those high-capacity infrastructures (including all NeSI infrastructures) were excluded. This approach is most useful for understanding the usage, capacity, and availability of research infrastructures in Aotearoa.

Across the institutions, the main infrastructure usage is for laboratories (Figure 9). This is perhaps unsurprising, as laboratories are a fundamental part of many areas of scientific research, and for the same reason, laboratories are the most abundant type of infrastructure across the institutions (Figure 3). The relative abundance of laboratory users for some institutions is also partly due to laboratories being their only infrastructures with user statistics. While the users within these reflect access to a wide variety of different types of resources, the data do not readily allow further comparison at that level.

The greatest diversity of research infrastructure types accessed by users occurs at NIWA, with users across six types of infrastructure. A significant fraction of NIWA's users are across its research vessels, reflecting the high demand for those infrastructures, as well as their large-scale and uniqueness in the Aotearoa infrastructure portfolio.

Government agencies and other CRIs are primary external users of research infrastructure

Figure 10 and Figure 11 represent where the external users of infrastructure are from, with Figure 10 showing these by sector, and Figure 11 giving the details of government organisations as users of research infrastructure. Note that in both cases, these reflect the number of times an organisation was listed amongst the users, not the actual count of individuals directly using the infrastructure (which is shown in Figure 9).

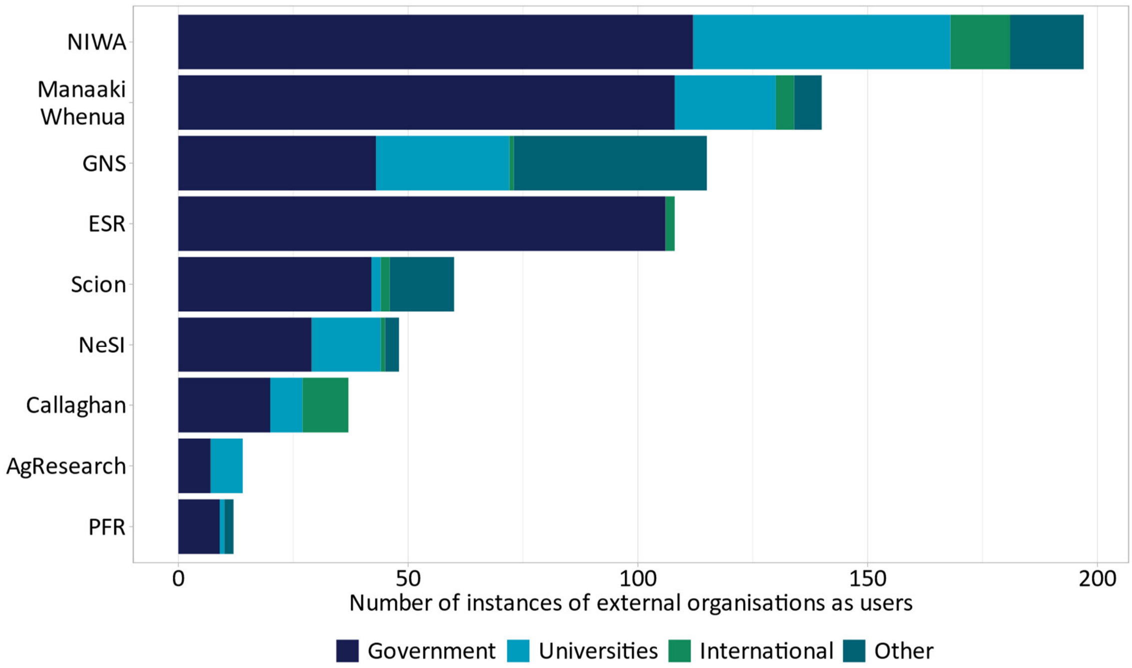


Figure 10: Number of instances of external organisations listed as infrastructure users at each institution, grouped (broadly) by sector. Government organisations (including CRIs) make up a large proportion of external users of research infrastructure. [16]

[16] Data notes: The categories used to define users in Figure 10 are broad. 'Government' includes all government organisations depicted in Figure 11. 'Universities' includes all New Zealand universities and tertiary institutions. 'Other' refers to commercial, museum, and education users. 'International' encapsulates all research, government, and commercial users from outside of New Zealand. The survey allowed for multiple users to be listed for each individual infrastructure. For example, the same universities will have been listed against multiple infrastructures, so the number listed against each institution reflects the total times they were listed, not the number of universities appearing in the data.

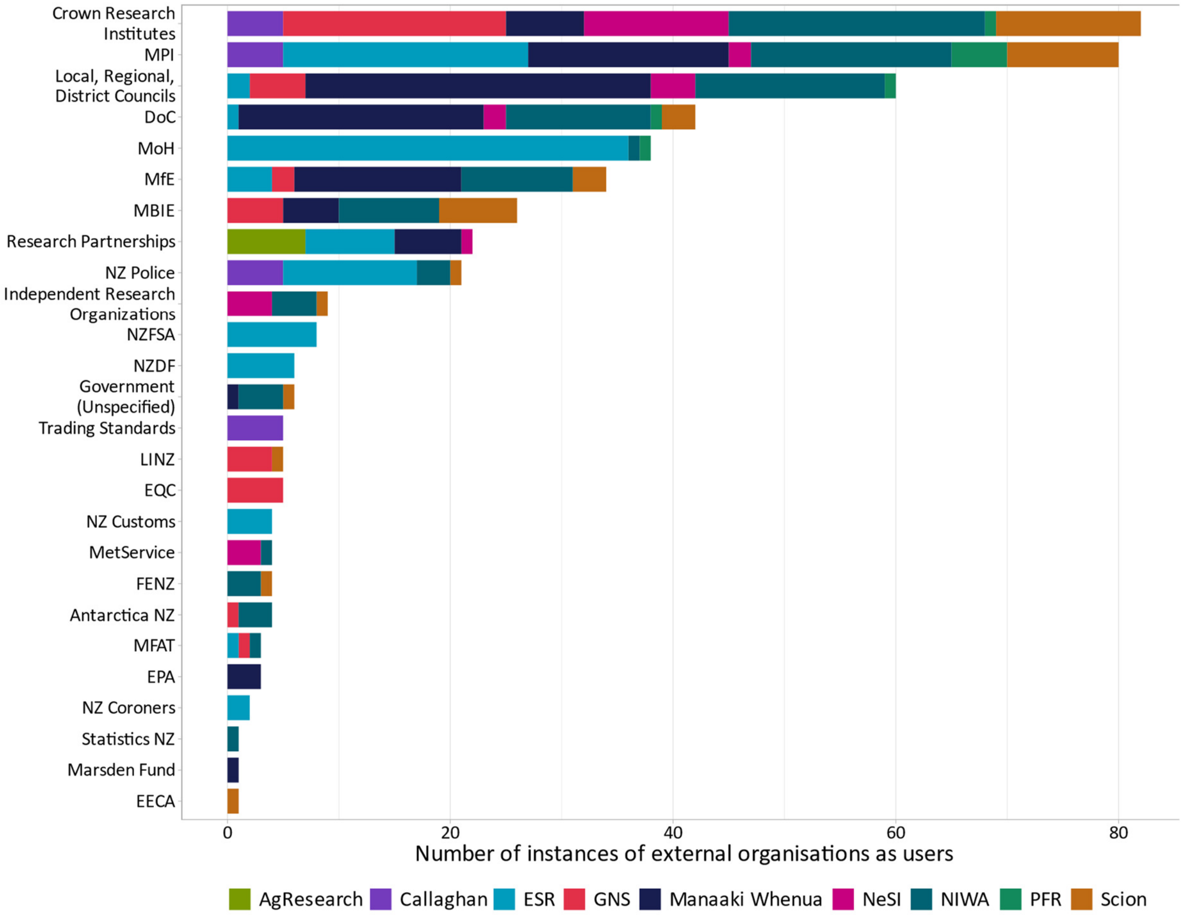


Figure 11: Number of times government organisations were listed amongst the users of research infrastructure. This shows who are the major external users of research infrastructure across government organisations. [17]

Figure 10 and 11 metadata:

Institution	Infrastructures with at least 1 external organisation listed	Infrastructures with at least 1 government organisation listed
AgResearch	7/62 (11%)	7/62 (11%)
Callaghan Innovation	7/124 (6%)	5/124 (4%)
ESR	44/47 (94%)	44/47 (94%)
GNS	22/53 (42%)	19/53 (36%)
Manaaki Whenua	40/49 (82%)	36/49 (73%)
NeSI	4/16 (25%)	4/16 (25%)
NIWA	27/31 (87%)	27/31 (87%)
PFR	9/46 (20%)	7/46 (15%)
Scion	20/65 (31%)	18/65 (28%)
Total	180/493 (37%)	167/493 (34%)

[17] Data notes: Organisations counted reflect both direct and indirect use, i.e., users of the infrastructure outputs as well as physical access to the infrastructures. The survey allowed for multiple users to be listed against each infrastructure. Some infrastructures may have diverse external users that were not captured in the survey responses. For context, the data in this figure represent 37% of total infrastructures reported in the survey. The low numbers for some institutions are reflective of their response rates in the Kitmap survey. The data do not let us distinguish between infrastructure with only internal users and infrastructure with missing data for users.

Together, Figure 10 and Figure 11 demonstrate that the majority of the institutions have a diverse range of external users of their infrastructure, and that all carry out a variety of functions that support both the government and research sectors.

Figure 10 highlights that the government sector represents significant use of research infrastructure across the institutions. These government users are spread across several different organisations, as shown in Figure 11.

Figure 11 shows that across the institutions, the most common grouping of external users of research infrastructures are from other CRIs. This reveals a high level of cooperation between the institutions, even if this is not coordinated centrally. Other significant government users include local and regional councils, government ministries, and range of government departments. These reflect the large number of government services and critical functions that are enabled by research infrastructure held by the institutions, and the strong demand for the scientific research they enable.

Staff support for research infrastructure

Part of the gap in our knowledge of the RSI system that the Kitmap project aimed to address is how well our research infrastructure is supported. Technical staff are an integral part of the operation of research infrastructure, without whom the value of infrastructure investments cannot be fully realised. The Kitmap survey collected some basic information about the total specialist staff, in terms of fulltime equivalents (FTE), that are allocated for the operation and maintenance of the infrastructures.

Across the 149 infrastructures where staffing information was provided, institutions identified 529.24 FTE of supporting staff. Table 3 looks at the statistics of the FTE data reported in the survey, and how the FTE values relate to the number of infrastructures and resources across the institutions.

Table 3: Average FTE per infrastructure and resource at each institution. [18]

	AgResearch	**GNS**	**Manaaki Whenua**	**NIWA**	**PFR**	**Scion**	**Total**
FTE per infrastructure							
Infrastructures with FTE data	17/62 (27%)	16/53 (30%)	30/49 (61%)	22/31 (71%)	40/46 (87%)	24/65 (37%)	149/493 (30%)
Average FTE per infrastructure with data	2.11 ± 1.17	2.63 ± 3.37	1.51 ± 2.25	7.81 ± 9.71	4.83 ± 5.65	1.70 ± 2.72	3.55 ± 5.49
FTE per resource							
Infrastructures with resource and FTE data	17/62 (27%)	10/53 (19%)	5/49 (10%)	14/31 (45%)	33/46 (72%)	17/65 (26%)	96/493 (19%)
Average FTE per resource with data	1.34 ± 1.18	1.02 ± 2.12	0.56 ± 0.59	0.70 ± 0.41	1.70 ± 1.98	0.47 ± 0.33	0.97 ± 1.10

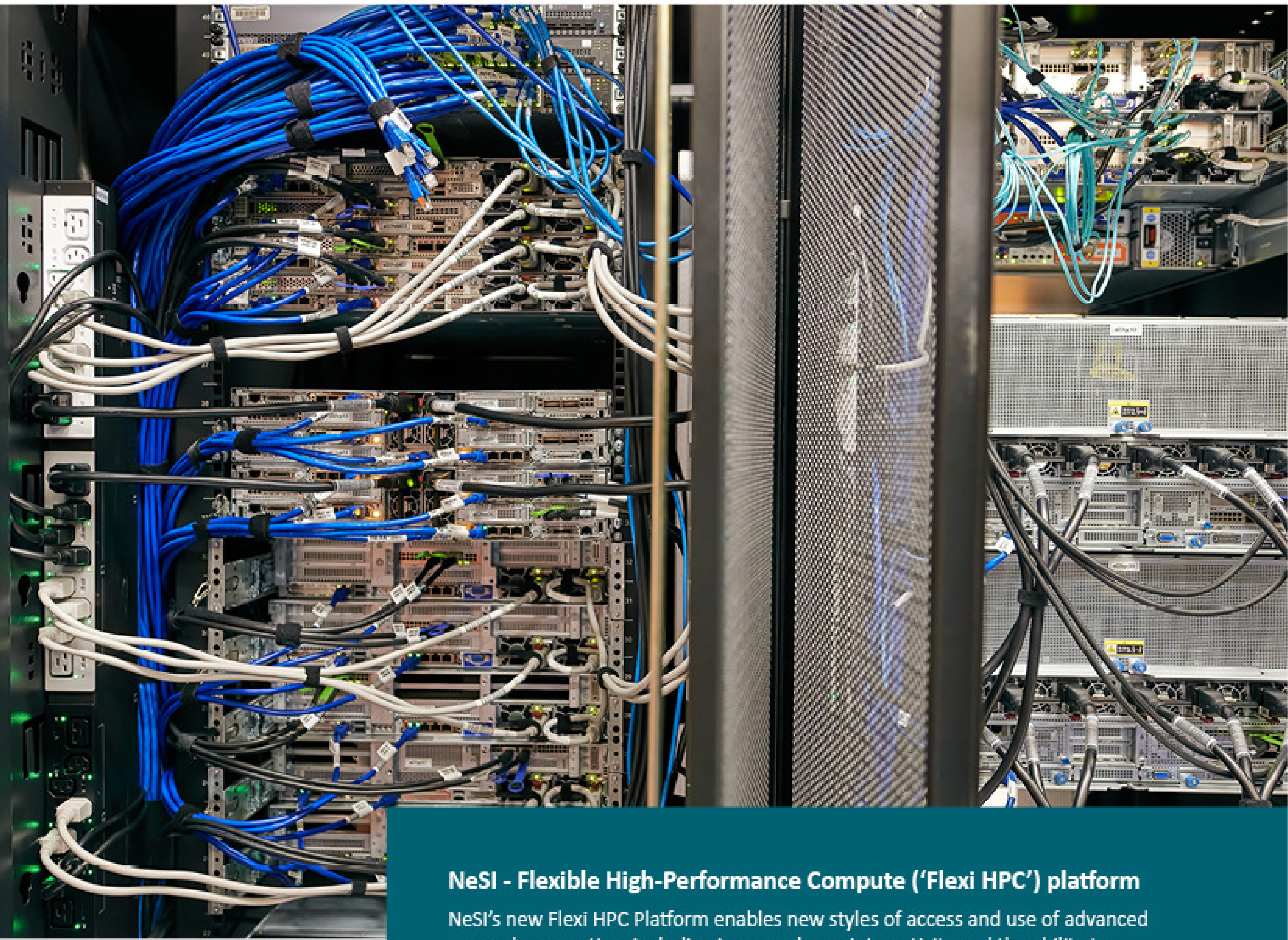
The FTE per infrastructure in Table 3 represents the average number of staff support assigned per infrastructure (excluding those for which no FTE data were provided), which could be, for example, a laboratory or facility. The FTE per resource represents the number of staff support per significant piece of equipment, such as large scientific instruments. We note

[18] Data notes: Average values reflect only those infrastructures/resources with FTE data; those with no FTE data were excluded. There was difficulty across most of the institutions in collecting and reporting this information. As a result, these data represent only around 20 per cent of total infrastructures reported in the survey, with large variations in coverage between the institutions. The data do not account for differences in the scale of infrastructure, eg 0.1 FTE may be ample support for a small instrument but not sufficient for a large instrument.

that these averages do not account for the different scales of the infrastructures and resources they encapsulate. For example, larger scale infrastructures or resources with greater numbers of staff support could significantly raise the average value, while large numbers of smaller infrastructures or resources will lower the average Table 3.

The large variations in per infrastructure values at both the institutional level and overall indicates that research and technical staff are not evenly distributed between infrastructures.

The variability in FTE on a per resource basis is much smaller than per infrastructure, which suggests that number of staff scales with the sizes of the infrastructures. Across the institutions, there is typically around 0.5 to 1 FTE allocated per significant piece of equipment.



NeSI - Flexible High-Performance Compute ('Flexi HPC') platform

NeSI's new Flexi HPC Platform enables new styles of access and use of advanced research computing, including increased user interactivity and the ability to provide complete data and compute isolation (to meet security needs or support a multi-tenant infrastructure). This more flexible design than traditional high-performance computing enables a more inclusive and equitable approach to eResearch and HPC infrastructure for researchers across Aotearoa. Current usage includes an all-in-one eResearch environment with AgResearch, advanced graphics processing unit (GPU) capabilities for the Strong AI Lab at the University of Auckland, and hosting of the Aotearoa Genomic Data Repository and eventually the Rakeiora Pathfinder interactive data analysis environment, both of which have Māori Data Sovereignty requirements at their core.

Callaghan Innovation - Measurement Standards Laboratory of New Zealand

The Measurement Standards Laboratory of New Zealand (MSL) is Aotearoa's national metrology institute. MSL has primary responsibility to provide measurement standards in accordance with the International System of Units (SI). Our scientists realise and maintain the most accurate mass, length, time, electrical, temperature, photometric and radiometric measurements for our nation.

MSL's activity ranges from the fundamental — for example contributing to the determination of the value of Boltzmann's constant — to the industrially applied — for example supporting the electricity industry to quantify energy delivered during charging of electric vehicles. MSL offers calibration services to over 600 commercial testing and calibration laboratories around Aotearoa, supporting them to gain access to overseas markets, meet standards, monitor and control quality, enforce regulations, innovate, and demonstrate performance.

4. PŪTEA ME TE WHAKARURUHAU | FUNDING AND GOVERNANCE

Funding and governance are important aspects to building the picture of research infrastructure in Aotearoa. The insights gained from the data in this section provides a key input to address the enduring questions around how research infrastructure investments should be coordinated and what constitutes effective investment mechanisms. This section covers the way in which decisions about research infrastructure are made and how it is managed across its lifetime, and the sources of funding for investments in infrastructure.

Most research infrastructures are funded by the institutions

The Kitmap survey asked institutions about how their research infrastructures are funded. Specifically, institutions were asked whether their infrastructures received external funding from grants or other sources, or if they were funded internally through overheads, commercial income, or payments for access to the infrastructures.

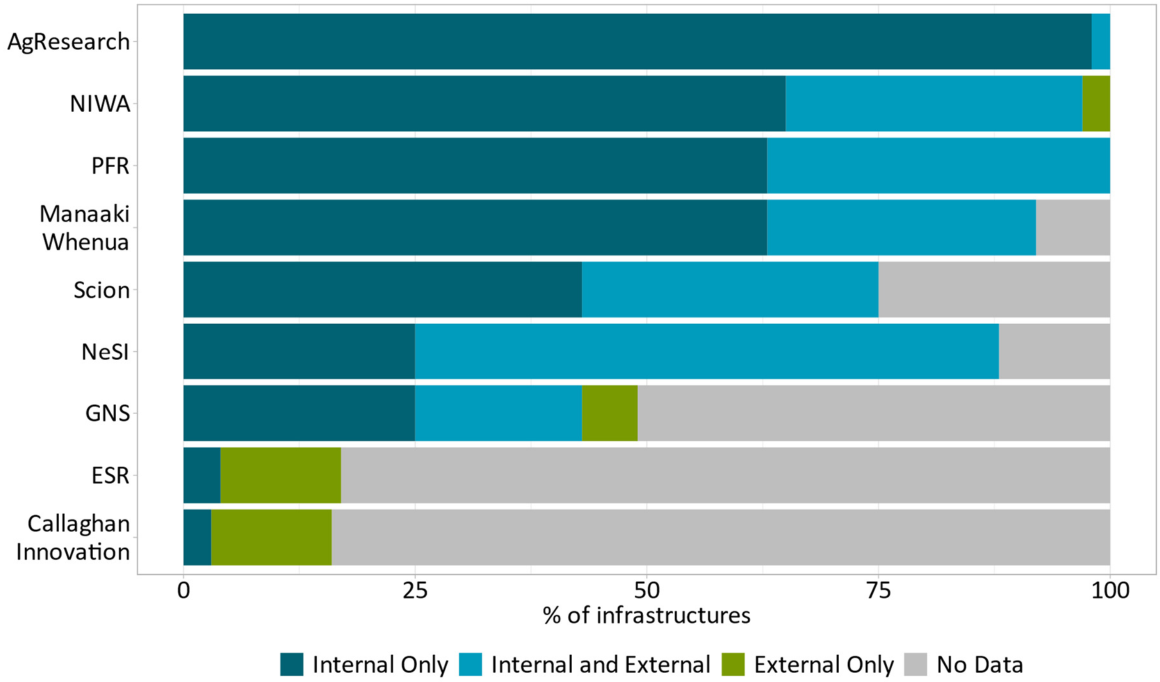


Figure 12: Funding sources for infrastructures at each institution. [19]

Figure 12 metadata:

Institution	Infrastructures with funding data
AgResearch	62/62 (100%)
Callaghan innovation	20/124 (16%)
ESR	8/47 (17%)
GNS	26/53 (49%)
Manaaki Whenua	45/49 (92%)
NeSI	14/16 (88%)
NIWA	31/31 (100%)
PFR	46/46 (100%)
Scion	49/65 (75%)
Total	301/493 (61%)

[19] Data notes: Data on funding sources have been simplified into categorical groupings. Some infrastructures are funded from a combination of sources, and the *Internal and External* category was employed so that the fractions of each category add up to a whole. Funding data were available for 301 (ie 61 per cent) of the 493 infrastructures reported in the Kitmap survey. Total fraction of externally funded infrastructures may be higher or lower than shown, due to missing data.

The number of infrastructures supported by each funding source are shown in Figure 12, along with an indication of the fraction of infrastructures for which funding information was provided. We note that the responses to these questions are not mutually exclusive, as each infrastructure can receive funding from more than one source. The proportions in Figure 12 reflect only the number of infrastructures with each funding source, and not the amount of funding from each source.

As shown in Figure 12, the majority of research infrastructures from most institutions are funded internally from the institutions, with some receiving both internal and external funding. All institutions reported some level of external funding for research infrastructure, with external (direct) funding being the dominant source for ESR and Callaghan Innovation. NeSI also reported a high proportion of external funding for its research infrastructure, which is consistent with its funding as a SSIF infrastructure.

As discussed above, the institutions have different, independent approaches to infrastructure investment, which is consistent with the large proportion of funding that comes from the institution's own sources. As institutions are the primary funders of their own infrastructure, they have chief responsibility for the governance and investment decisions around it. While there are instances in the data of infrastructures being co-funded between institutions or with private companies or universities, these were rare and do not make up a significant portion of the infrastructures.

The Strategic Science Investment Fund is an important means of supporting research infrastructure

For those infrastructures where external funding was reported, the sources of that funding are broken down in Figure 13. This figure represents the 22 per cent of total infrastructures in the survey that were designated as receiving external funding.[20]

[20] The data here do not distinguish between different categories of SSIF funding (such as SSIF Programmes or SSIF Infrastructure). We note that while SSIF Infrastructure provides the highest amount of funding, relatively few infrastructures are directly supported through that instrument.

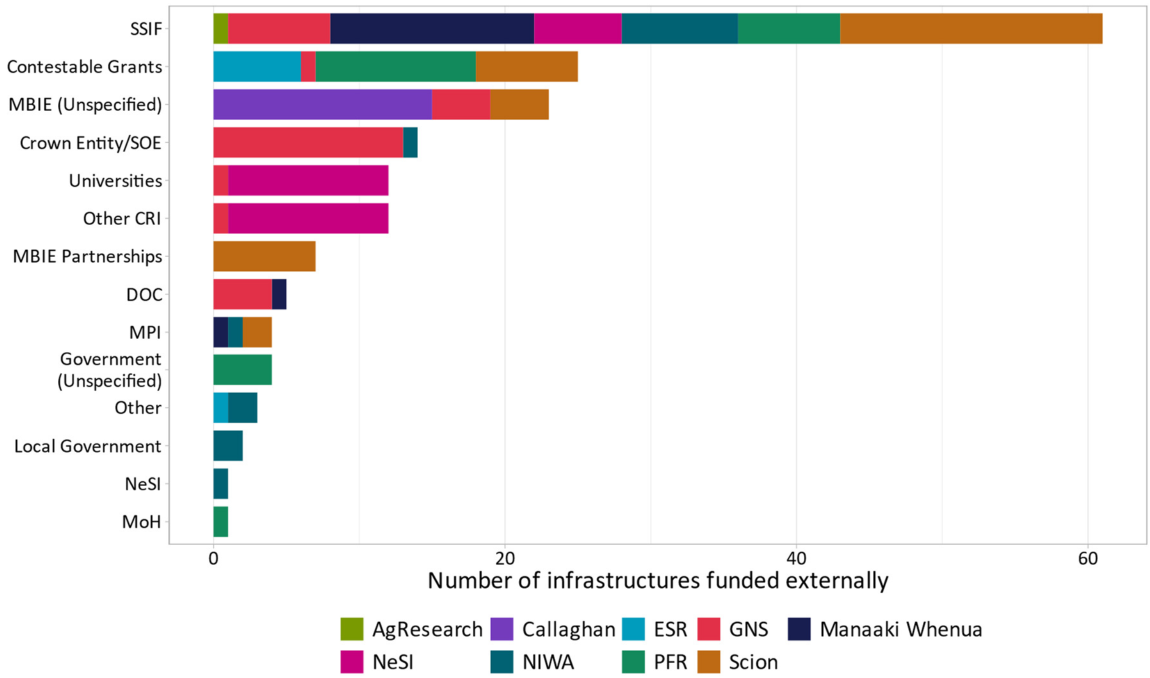


Figure 13: Number of infrastructures linked to each external funding sources in the Kitmap data. [21]

Figure 13 metadata:

Institution	Infrastructures with details of external funding sources
AgResearch	1/62 (2%)
Callaghan Innovation	16/124 (13%)
ESR	6/47 (13%)
GNS	13/53 (25%)
Manaaki Whenua	14/49 (29%)
NeSI	10/16 (63%)
NIWA	11/31 (35%)
PFR	17/46 (37%)
Scion	21/65 (32%)
Total	109/493 (22%)

[21] Data notes: The data show the number of times each external funding source was linked to an infrastructure in the data. This does not reflect the amount of funding for each infrastructure from each source.

SSIF funding was the primary source of external funding by a significant margin (Figure 13). This is consistent with the CRIs and NeSI receiving funding as SSIF programmes and SSIF infrastructures respectively (we note that these two instruments are not distinguished in the data). As a Crown agent, Callaghan Innovation is predominantly funded through its own appropriations, which are (partially) represented in the '*MBIE (unspecified)*' bar on Figure 13. ESR did not report SSIF funding, which may reflect incomplete data, although it may be the case that ESR's SSIF funding does not directly fund any of its infrastructure.

Contestable grants feature prominently in the data as a source of external funding for infrastructure reported by the institutions, with four institutions reporting significant proportions from this source. However, information on the specific funding instruments was not provided.

A number of Crown Entities or State-Owned Enterprises (SOE) were represented in the external funding sources. These organisations included Antarctica NZ, the Earthquake Commission, Land Information New Zealand (LINZ), and MetService. Several institutions reported direct funding from government Ministries beyond MBIE, including Ministry for Primary Industries (MPI), Department of Conservation (DOC) and Ministry of Health (MOH), which relates to the proportion in which these Ministries featured as users of research infrastructure from the institutions (Figure 11). MBIE is the largest funder of research infrastructure (through the SSIF fund and grants; Figure 13), although a number of other government ministries feature more prominently in the data on users (Figure 10).

Institutions lead decisions around infrastructure

The institutions reported on their respective approaches to governance and funding of research infrastructures through a free text field in the Kitmap survey. The CRIs all described similar governance processes to approach decisions pertaining to research infrastructure investments. These processes appear to exist in relation to not only initial investment in research infrastructures, but renewal, upgrade, and replacement.

Broadly, the size of each prospective investment determines the approach taken by institutions. That is, large research infrastructure investments over a certain dollar amount will be subject to a different process than smaller investments under that amount. Aspects of the decision-making process reported by the institutions included businesses cases (always for high value infrastructures), asset management planning, lifecycle evaluation, justification of investment to meet current and future science needs, consideration of duplication of infrastructure elsewhere in Aotearoa, and opportunities to consider partnerships as opposed to investing themselves. Final approval occurs at different governance levels depending on size of investment, with large investment decisions being made at the board level, while some investment decisions are made at lower organisational levels when below a defined dollar amount. There may also be differences in processes for considering investment in, for example, equipment versus a building or land, linked to requirements from Treasury for the institutions in preparing their business cases for these investments.

This approach of the institutions both initiating, investing in, and governing their own research infrastructures is established by the SSIF framework, which is a major source of funding for all of the institutions except Callaghan Innovation. The role of SSIF is to fund strategic investment in research programmes and scientific infrastructure that have long-term beneficial impacts on New Zealand's health, economy, environment, and society[22]. The SSIF Investment Plan outlines that

> "the bulk of infrastructure investments are made by research organisations, paid for as part of the regular costs of conducting research. The SSIF supports the few infrastructure projects that have high national benefits that will not emerge in the course of usual business because of the public nature of the benefits, and the scale, complexity, long duration and multi-user nature of the investment."[23]

Some of the institutions reported that they undertake internal CAPEX processes on an annual basis, through which all proposals for research infrastructure purchases are considered for approval through a common governance process.

[22] Strategic Science Investment Fund | Ministry of Business, Innovation & Employment (mbie.govt.nz)

[23] Strategic Science Investment Fund: Investment Plan 2017 - 2024 (mbie.govt.nz)

NeSI has a different institutional structure to the CRIs, and thus a more unique approach to governance and funding of research infrastructure. It operates on a governance model of investment based on co-design and joint investment across the contributing institutions. NeSI reported that its approach builds a common view of user needs across institutions and research communities nationally, which is informed by capacity management and demand. Through this framework, review of current and future infrastructure is supported every two years for major investments, and annually for incremental management of capacity.

While these examples share similarities with international approaches to governance and funding of research infrastructure, there are also important differences. Internationally, research infrastructure road-mapping exercises are a common approach for national coordination, providing planning and strategic priorities for research infrastructure investment, typically for 5–10 years in the future. As Aotearoa does not have such a national planning mechanism or other central coordination for research infrastructure investment, our institutions make investment decisions on an individual basis, with large national infrastructures decisions occurring at a government level on a case-by-case, ad hoc, basis.

Manaaki Whenua - New Zealand Arthropod Collection (NZAC) - Ko te Aitanga Pepeke o Aotearoa

The NZAC is the largest and geographically most comprehensive invertebrate collection in Aotearoa. It contains 1.6 million "objects", and an estimated 7 million individual specimens (e.g., one jar or "object" may contain many hundreds or thousands of specimens), primarily from Aotearoa, but also from Pacific Island nations.

The NZAC is used by the primary production sector, researchers in universities, CRIs, and international organisations, as well as through identification services available to the general public. The collection helps guide conservation priorities that lead to outcomes of importance to iwi and the public. Manaaki Whenua works in partnership with the Department of Conservation to periodically update the New Zealand Threat Classification System to enable more accurate estimation of species distribution, rarity, and conservation status.

The NZAC supports biosecurity responses by the Ministry for Primary Industries and provides data to the Environmental Protection Authority for making decisions on the introduction of new organisms, particularly insect biocontrol agents.

5. NGĀ MĀRAMATANGA KITMAP KI TE PŪNAHA RANGAHAU PŪTAIAO ME TE AUAHATANGA (RSI) | KITMAP INSIGHTS INTO THE RSI SYSTEM

The data in this report will provide insights into aspects of the infrastructure portfolio that serving the system well, and areas where future system design should look to address gaps.

We found that the infrastructure portfolio across the institutions is characterised by large numbers of laboratories (Section 2). Given that laboratories of different kinds are the fundamental venue of many types of research, this abundance seems entirely fitting as the basis for our research system. Similarly, the proportions of other types of infrastructures, such as field sites, physical and digital collections, computational resources, research vessels, and networks of monitoring sensors, are entirely in line with the fields of research prioritised by and demanded of the institutions. The main subject areas of research enabled by infrastructures are those supporting the agriculture and primary sectors, and the earth and environmental sciences, which aligns with the core purposes of the CRIs and the current system priorities they represent.

The Kitmap data show that there is significant demand for and use of these various infrastructures, both from within and outside the institutions. We found that policies for access to infrastructure vary significantly across the institutions surveyed, though all enable some level of access to external users, and over half of the infrastructures from most institutions are accessible to external users. While some infrastructures remain inaccessible, most of these are either fully utilised internally or access is restricted due to the type of research activities they support. In most cases institutions charge fees for access to external users, though significant fractions of infrastructures at some institutions are available at no cost to users. Almost all of the institutions make some use of international infrastructure that broadens their capabilities beyond what is available domestically, as well as likely spurring international collaborations.

Across the institutions, government organisations make up a significant portion of external users of research infrastructure. This reflects the delivery of science services to government, which makes up a core part of the business of the CRIs. These users include many local and regional councils and government departments, reflecting the role of the institutions in supporting government functions such as hazard and resource monitoring.

Decisions on infrastructure investments are devolved to the institutions, in line with the SSIF investment plan. As a result, decisions on infrastructure largely reflect the priorities of the individual institutions, with no clear mechanism for central coordination of investments to focus on the needs of the system as a whole. The data show that across the institutions, most infrastructures are primarily funded by the institutions through internal resources (including overheads and commercial revenue), with a lesser amount receiving direct government funding or funding from research grants. There are occasional instances of co-investment in infrastructures between institutions or with universities or private companies, though these appear to be the exception rather than the rule.