Report prepared for the Ministry of Business, Innovation and Employment

New Zealand's high speed research network: at a critical juncture

David Moore, Linda Tran, Michael Uddstrom (NIWA) and Dean Yarrall

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Wellington Level 9, 1 Willeston St PO Box 587 Wellington 6140 Ph: +64 4 915 7590 Fax: +64 4 915 7596	**Auckland** Level 8, 203 Queen St PO Box 2475 Auckland 1140 Ph: +64 9 909 5810 Fax: +64 9 909 5828	
Sydney Suite 18.02, Level 18, 135 King St Sydney NSW 2000 GPO Box 220 Sydney NSW 2001 Ph: +61 2 9234 0200 Fax: +61 2 9234 0201	**Canberra** GPO Box 252 Canberra City ACT 2601 Ph: +61 2 6267 2700 Fax: +61 2 6267 2710	**Melbourne** Level 8, 90 Collins Street Melbourne VIC 3000 GPO Box 3179 Melbourne VIC 3001 Ph: +61 3 9005 1454 Fax: +61 2 9234 0201

For information on this report please contact:

Name:	David Moore
Telephone:	+64 4 915 5355
Mobile:	+64 21 518 002
Email:	dmoore@srgexpert.com

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New Zealand aspires to high impact research and data intensity and a high speed research network is instrumental in realising high impact research. This aspiration is documented in policy statements and is in line with e-research strategies internationally.

Likely, the imperative for agility in e-research is greater in New Zealand due to our need to mitigate geographic distance and to collaborate given the small size of our research sector. Many of the areas identified within our science challenges imply greater data intensity, some of which will be catered for by centralisation of supercomputing for data analysis, supplemented by access via our high speed network. Researchers indicate to us that data intensity will increase materially from changes in instrumentation in areas such as radio astronomy, medical imaging and genetics.

Research and Education Advanced Network New Zealand (REANNZ) has occupied much time over the years with a tumbling series of funding reviews and general discontent both on the part of the owner, science policy analysts and its client groups. This continued discontent has come to a head with eight universities now formally indicating a take it or leave it offer. This offer, combined with a precarious financial position places REANNZ at a critical juncture.

We have the means of supporting data intensive research but users are not realising its full potential

REANNZ has established the technology and assets but there is not sufficient membership to make that investment affordable. Our review identified the following categories of problem:

- Institutional - problems associated with particular features and characteristics of REANNZ.
- Organisational - problems associated with how REANNZ goes about its business.
- Market-specific - problems relating to how markets operate, including access and dynamic/timing issues.

Institutional problems centre on perceived value

We established that the value of REANNZ was neither straightforward to articulate, nor was it uniform in size and incidence. The problem is not a lack of value from REANNZ per se, but that for some university users, REANNZ membership is not cost-effective (i.e. not value-for-money). The problem is complicated by there being two separate components of value:

- Cost-saving from shared services/buying club features.
- Dynamic value as a result of research participation that is or could be enabled by REANNZ membership.

The link between the end users of the service (researchers) and the cost of the service to universities (applied to IT departments) is not direct, thereby resulting in a loss of the value that may be realised. Understandably, some users focus on the more cost-saving benefits of REANNZ and therefore find it beneficial. The costs of REANNZ membership are 'here and now' while the payoffs are:

- diffuse (research benefits accrue to others, including society at large);
- specific (benefits are large to single researchers or clusters of researchers); and/ or
- non-existent as many, (but not all), current user needs can be met by commercial providers.

CRIs provided a different and united perspective compared to the diversity of university opinion. They agreed REANNZ was forward looking and the network strategy aligned with research needs. It enables science productivity by making it easier to do research.

Obviously, where the perceived value to users is less than the cost of REANNZ membership, either the perceived value (benefits) needs to rise, and/or the costs faced by members need to fall.

Organisational problems relate to transparency, governance and business/funding model
REANNZ is seen by members to lack:

- transparency - some members have no visibility of key decisions
- alignment - member views and specific needs are not factored into REANNZ actions
- coherence - cost and pricing models are opaque, not fit for purpose and no more equitable solution has been identified.

In short, REANNZ (the organisation) is not seen as member-oriented. In the face of such issues some members become disillusioned and disengaged with REANNZ as an organisation, making it more difficult for them to see the value of REANNZ as an NREN.

Markets for connectivity and data intensive research are evolving at different rates
The government's Ultra-Fast Broadband (UFB) Initiative started in 2010 to provide UFB access to 80% of New Zealanders by 2022. $2 billion of Crown Funding has been used to get high speed internet (up to 1Gbps) to households. The UFB rollout has been a significant advance for the telecommunications industry and has made commodity internet cheaper, and access to capacity greater.

Former members have shared their current and former costs from commercial providers and REANNZ. Service provision is significantly cheaper from commercial suppliers; and those former REANNZ members indicate the quality of service is sufficient for their current needs while noting they no longer receive the full service of an NREN.

REANNZ provides a high quality NREN service with high transfer speeds, low latency and near zero packet loss. However, the market for data intensive research in New Zealand is yet to develop fully, meaning the network is underutilised. Growth in data intensive research is expected, but is yet to materialise.

There are options available, but there is no silver bullet
We develop a set of options ranging from cost cutting through to changes in institutional arrangements, through to market expansion. No one option exists to solve all the problems. Action in multiple areas is needed. Within all of this, the discussion focuses on how we go about running a National Research and Education Network (NREN) rather than whether we need an NREN. That case is well and truly proven here in NZ and internationally.

From here, our suggested next steps

The first step is to further clarify REANNZ's current fixed and variable cost structure, by activity. Following this, there needs to be a forecast of costs including close appraisal of material assumptions such as the renewal cost of the Vocus contract, or of alternatives to Vocus, and assessment of cost reductions. All REANNZ stakeholders should then work together to assess appropriate engagement models with a focus on ensuring we have a durable, dynamically efficient institutional response. These two inputs, understanding current and future connectivity costs, and an exploration of engagement models provide a basis for an options workshop. We would hope that options workshop throws up a short list of two to three options to pursue to the point of a preferred option. From that point, there may be sufficient information for MBIE to formulate advice to Ministers.

Table 1 Answer and response to primary questions

Primary questions	Findings
1. Effectiveness of specialist connectivity in supporting data-intensive research of value to New Zealand?	• The capability and support is there; however it is not being fully leveraged by the research community • Its utility is important in realizing our e-science aspirations
2. National science infrastructure elements/services critical to a high-performing research system?	• High speed domestic network with NREN characteristics is an imperative • Added services such as Tuakiri are useful • International connectivity through other NRENs is critical
3. Barriers to and incentives for, use of specialist network connectivity?	• Last mile is the issue for many but not all researchers • Low member engagement • Cost is a major barrier even for data intensive organisations • A research environment that is yet to fully mature
4. Alternative models for funding and delivering connectivity and network capability, including the role of government?	• Increase data intensity of research • Remove costs from REANNZ • Change organisation connections with members to make decision making more inclusive • Increase relevance to organisations and/or expand membership • Merge with other government networks

1. Introduction

REANNZ is the National Research and Education Network (NREN) in New Zealand. It is a crown-funded entity established in 2006 with the purpose of providing a high-speed network for researchers and scientists in New Zealand. Its members are predominantly universities and Crown Research Institutes. REANNZ has dedicated national and international links that allows high-speed data transfer between its members and other members of the national and international NREN community.

The Ministry of Business, Innovation and Employment (MBIE) is interested in the connectivity needs that would enable high impact research. As such, MBIE has commissioned a review of REANNZ's current role in enabling high impact research as a specialist connectivity service. The commissioning of this review would seem prescient with universities offering to leave REANNZ with a take it leave it offer of reduced payment and other proposed changes.

The review (the subject of this report) is structured around four key areas of interest, namely the:

- effectiveness of specialist connectivity in supporting data-intensive research of value to New Zealand
- national science infrastructure elements/services critical to a high-performing research system
- barriers to and incentives for, use of specialist network connectivity
- alternative models for funding and delivering connectivity and network capability, including the role of government

We then explore a problem definition and discuss options for solution. The material in the report was sourced from the following:

- A desk-based scan of information available about REANNZ and the services it provides to its members.
- A literature review of the case and benefits for having an NREN, and how they are funded and managed in other countries such as Canada, the UK and European countries.
- A half day information session with REANNZ staff members.
- Semi-structured interviews with thirty-two key stakeholders to identify how they used the network, pressure points and issues. This included discussions with chief information officers and researchers from all universities and Crown Research Institutes and others as identified and deemed relevant.
- Reports and information provided by various universities and institutes as an evidence base to supplement claims in discussion.
- A survey designed for researchers to inform the current use of the network and future changes in data intensive research.
- An options session with MBIE officials, REANNZ staff members, and representatives of the research community.

2. NRENs are essential to research data exchange

In existence since the 1960's, National Research and Education Networks (NRENs) are purpose-built networks engineered for the provision of large scale data-transfers between research and higher education organisations.

2.1 A long history of NRENs

The premise of a research and education network (REN) has existed since 1969 with the creation of Advanced Research Projects Agency Network (ARPANET) in the US[1]. It is within ARPANET that the mechanics of packet switching was invented in which data was broken down into individual packets where each packet was identified and addressed with its final destination[2]. Computers within the network read the addresses and sent them in the right direction where the destination computer would reassemble and process the data. This would be refined into the Transmission Control Protocol and Internet Protocol (TCP/IP). This allowed for almost any network to connect to ARPANET and is the technology at the base of today's Internet.

By the start of the 1980s, the National Science Foundation (NSF) in the United States had funded the Computer Science Network to provide networking services to computer science researchers that could not be connected to ARPANET. The success of the networks led to the creation of NSFNET, with the aim to link separate networks in the US, and would become the backbone of the Internet[3]. NSFNET eventually became the national high-speed backbone for R&E in the US[4]. By 1995, commercial ISPs had proliferated which lead to the growth of the Internet. NSFNET was decommissioned in 1995 leaving only commercial operated backbones to serve the research and education community. Internet2 was founded in 1996 when the NSF provided seed money to design and engineer a purpose-built network for research and education[5].

2.1.1 Established prior to adoption of TCP/IP

While some preliminary form of networking using different protocols had previously existed it was not until the wider adoption of TCP/IP by the rest of the world that TCP/IP

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1 J.F. Cassel, S.K. Little (1994) *"The national research and education network: The early evolution of nren"*, Reference Services Review, Vol. 22 Issue: 2, pp.63-96. Retrieved from https://doi.org/10.1108/eb049218

2 CA*net Institute, (2001) *"A Nation Goes Online"*, CANARIE Associates. Retrieved from https://www.canarie.ca/

3 Internet2 (2018) *"Internet2 Community Timeline"*. Retrieved from https://www.internet2.edu/about-us/internet2-community-timeline/

4 J. Dyer (2009) *"The Case for National Research and Education Networks (NRENs)"*, TERENA. Retrieved from https://www.casefornrens.org/Resources_and_Tools/Document_Library/Pages/All_documents.aspx

5 Internet2, "*Internet2 Community Timeline*".

networking began to gain traction[6]. Early networks had different techniques for data distribution and there was a need for a standardized procedure. The adoption of TCP/IP by NORDUnet, the REN for Nordic countries, pioneered the widespread use of it throughout Europe.

Similarly in Canada, its original NREN operated on a different set of protocols[7]. Using TCP/IP that had been created and employed in the US, they formed CA*net, Canada's predecessor NREN. CA*net engineers built campus networks, broadening into regional networks across Canada. Eventually, these would become the backbone for Canada's current NREN, CANARIE.

In Australia, the early stages of AARNet came about in an effort to link universities across different states that had been operating on different protocols[8]. AARNet provided routers for universities in different regions that could be configured to different protocols to act as a gateway between campuses and be linked to the network. In 1990, they had effectively built the Internet in Australia. In 2003, due to the collapse of the telecommunications market and NextGen going into receivership, AARNet was able to purchase a backbone infrastructure at below-market cost intended for research and education in Australia.

2.2 An NREN to reduce coordination and transaction costs

Each instance that a university or research institution wants to connect directly to an end user incurs a cost. It would require 28 individual links alone in New Zealand to directly connect our eight universities. In Figure 1, we can see that, in the absence of an aggregating entity, there is duplication in effort and cost. It is easy to see how on a local, regional and global scale, the costs of each entity individually making connections becomes inefficient.

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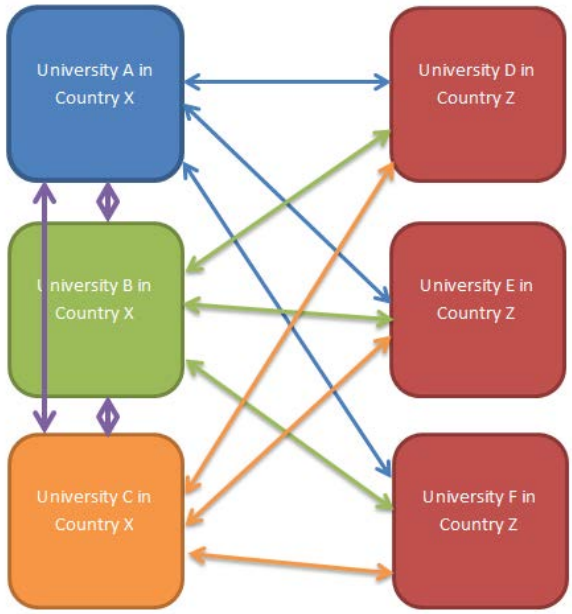
6 K. Lehtisalo (2005) "*The History of NORDUnet: Twenty-five years of networking cooperation in the Nordic Countries*". Retrieved from http://www.nordu.net/history/book.html

7 CA*net Institute, *"A Nation Goes Online"*.

8 G. Korporaal (2009) *"AARNET: 20 years of the internet"*. Retrieved from https://www.aarnet.edu.au/

Figure 1 Connecting universities in the absence of an NREN



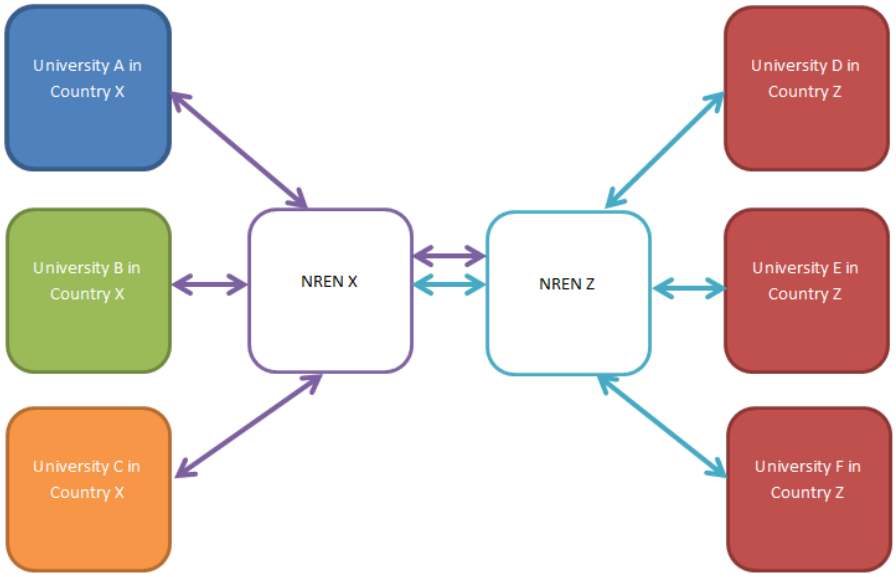
Source: Sapere analysis

As shown in Figure 2, by having a single entity, an NREN that aggregates and operates on behalf of users, coordination and transaction costs are reduced for not only users under that NREN, but the costs for users in other NRENs as well. For example, if University A was not part of an NREN and wished to connect with University D (that was only connected to NREN Z), it would need to either find an exchange point that would allow it to peer with NREN Z, or find a point-of-presence (PoP)[9]. If connecting via an exchange point through the NREN was not possible, University D would need to incur costs to set up a connection from its campus to that PoP.

In an NREN-connected scenario, each university or research institution connects to their respective NREN. The NREN provisions the connections to other members of the same NREN, and to other NRENs it has peering arrangements with and subsequently all members of that NREN. Each participating institution connects to their NREN which provides them with domestic and international connectivity to other institutions, reducing the cost of coordination and transaction. This eventuates in 120 networks working to connect to each other, rather than tens of thousands of universities, research institutions, scientific instruments and high performance computing hardware individually connecting. This connected scenario is the current arrangement globally.

[9] An interface point between two entities.

Figure 2 Connectivity arrangements with an NREN

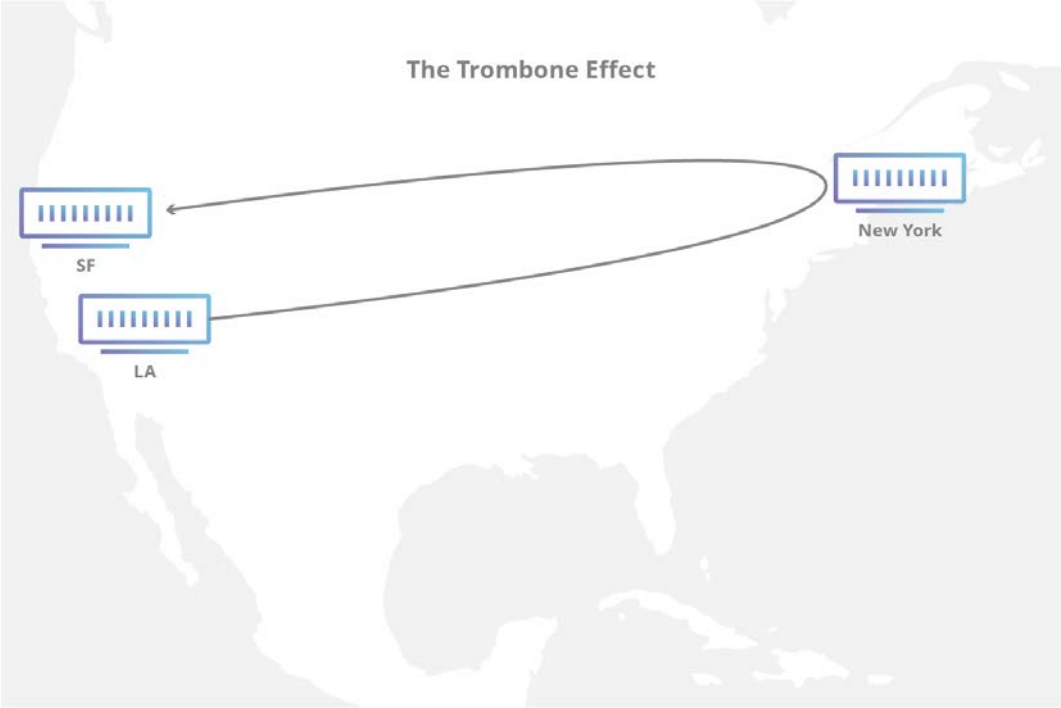


Source: Sapere analysis

Commodity internet provided by commercial ISPs transfer data. However, traffic going from the source to its destination may not travel in a straight line – it may travel an exhaustive path before it ends up at its destination. This is called the 'Trombone Effect'[10]. As seen in Figure 3, even if Los Angeles (LA) and San Francisco (SF) are geographically close to each other, the Internet traffic from Los Angeles routes to New York first before reaching its destination in San Francisco. This increases latency, or the time it takes for data to move between its source and destination. Not only that, the traffic pipe is shared with other users of the network. For universities or research institutions that send large datasets this situation is not ideal, as time waiting for data to be transferred results in loss of productivity. By connecting to these exchange points, the route which data is transferred may be shortened. Within the NREN network, data may be routed in the most efficient way possible, improving round-trip time between institutions and reducing latency.

9 Cloudflare (2018) *"What is an Internet Exchange Point?"*. Retrieved from https://www.cloudflare.com/learning/cdn/glossary/internet-exchange-point-ixp/

Figure 3 The Trombone Effect



Source: Cloudflare, "*What is an Internet Exchange Point?*"[11]

2.3 NREN services support data-intensive research and international collaboration

Each country typically has one 'representative NREN' that operates on behalf of the research and education institutions within that country due to minimisation of cost duplication mentioned in the previous section. They act in the interest of researchers by connecting institutions nationally and internationally using high speed links that have large bandwidth capacity at low latencies designed for research and education data[12].

- NRENs are highly specialised network service providers operating the national and international backbone that connects users to other NREN networks in a seamless global connection.
- Target clientele of users sending data from an NREN is typically a user from another NREN, such as researchers and data-generating scientific instruments, that require quick data transfer between users and/or research infrastructure.

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[10] Cloudflare (2018) *"What is an Internet Exchange Point?"*. Retrieved from https://www.cloudflare.com/learning/cdn/glossary/internet-exchange-point-ixp/

[12] Bandwidth refers to the amount of data that can be transferred from one point to another and latency is the time that it takes for that data to make it from point A to point B.

- There is a reciprocal nature to the international NREN network based on trust – NRENs trust that peering partners are sending research and education traffic on their backbone.[13]

This technology is not unique to NRENs; it can also be deployed by an ISP. However, the difference lies in its onus – NRENs are not-for-profit entities serving the research and education community that recovers costs from its members or shareholders. While ISPs may be able to resolve the cost of coordination and transaction, they stand to make a profit as well. The focus of NREN services is in providing high quality services that are capable of transferring low latency data streams with no packet loss. This contrasts with normal ISP service where the objective is high utilisation with lower quality of service parameters to ensure profitable return on network investment.

2.4 A deliberately informal club

The global architecture of NRENs has no official governing body. Instead, the common purpose of supporting research and education brings NRENs together, forming an international community or 'club'. NRENs don't operate in isolation – the operating model of NRENs is to provision connectivity to the mutual benefit of everyone in the research and education community. This goes as far as having research and education focussed ISPs, such as Netherlight[14], which is operated by the Netherlands NREN SurfNet and seeks to connect research networks worldwide, and the pan-European REN, GEANT[15], owned by the European members it connects, that serves as a backbone for European NRENs. In the Asia Pacific region APAN (the Asia Pacific Advanced Network) provides a collaboration framework for regional NRENs and engages in the facilitation of NREN development in that region.

An NREN CEO described the NRENs cooperating under handshake agreements, with a set of unwritten principles that guide the way NRENs work together. Since there is no governing body and no hardcoded rules to abide by, the community trusts each other thereby creating confidence that each NREN can commit to a way of working that benefits the community. Users of NRENs depend on the network to connect them to international peers or global infrastructure and incentivise collegial behaviour.

The end result is a seamless international architecture that supports data-intensive transfer and international collaboration by reducing the 'digital divide'[16] between countries.

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13 Retrieved from https://searchtelecom.techtarget.com/feature/BGP-essentials-The-protocol-that-makes-the-Internet-work. Peering is based on Border Gateway Protocol (BGP) and tells a collection of IP networks what other networks is willing to receive its traffic, called "announcing". When you peer as an NREN, you trust that the receiver/sender, a collection of IP networks, is receiving/sending R&E information or data that is not malicious.

14 SURF (2018) *"Netherlight"*. Retrieved from https://www.surf.nl/en/services-and-products/netherlight/index.html

15 GEANT (2018) *"GEANT IP"*. Retrieved from https://www.geant.org/Services/Connectivity_and_network/Pages/GEANT_IP.aspx

16 GEANT (2014) *"GEANT Strategy 2010: Over the horizon"*. Retrieved from GEANT.

3. REANNZ and e-Research in NZ

NRENs are idiosyncratic and each RENs evolution is different from the others. We set out the role and function of New Zealand's NREN. Both the topography and geography of New Zealand is challenging: our nearest neighbour of size, Australia, is 2,000 km away, and connection to the United States is 12,700 km. Infrastructure is needed to span the length of two islands.

3.1 An NREN to align with goals for science in New Zealand

Size and distance are key factors for New Zealand. In terms of economic performance, the rise of the weightless economy (i.e. intangible products and services) has lessened the burden of size and distance. A key part of the weightless economy is information technology and telecommunications.

From a research perspective, issues of size and distance are highly relevant. Our research community lacks the scale of countries such as the United States and the United Kingdom and opportunities to interact with other researchers is limited by proximity. An NREN provides an accessible and highly specialised link to the world's research and knowledge community.

An NREN lowers the natural barriers New Zealand faces in its dealings with the world and allows us membership to 'clubs' we might not otherwise enjoy. We summarise the value that has been estimated to accrue to New Zealand from REANNZ in particular, and international research collaboration specifically.

The club is informal and New Zealand plays a larger role than expected in this club. A total of 16 CEOs from various research networks meet to discuss policy issues related to science data. New Zealand is represented in this forum in recognition of the connection difficulties faced by a small and isolated country. New Zealand, through REANNZ, also participates in a Global Network Architecture group, an initiative to create a blueprint for a global NREN network[17]. More broadly, membership of the global NREN club allows New Zealand to remain at the forefront of networking technology.

An NREN also has benefits in respect of complementary investment in national research and science infrastructure, such as the New Zealand Science Infrastructure (NeSI). NeSI provides the New Zealand research community with access to a national high performance supercomputing environment. High performance supercomputing is supported by the network as its infrastructure is necessary for the supercomputer to be used effectively (at least for some projects). An NREN is necessary to ensure the full return to NeSI is achievable.

[17] GNA (2018) "*Global Network Architecture*". Retrieved from https://gna-re.net/

3.2 Levels of service are generous

REANNZ has built in advance of demand and there is considerable under-utilised capacity:

- **High bandwidth capacity beyond what is currently needed** – the main trunk of the network provided by REANNZ currently comprises 100Gbps links with resilience, albeit the resilience is provided at lower bandwidth (up to 20Gbps) than the main trunk. The network previously operated at 10Gbps for 10 years and then at 20Gbps for 18 months before moving to 100Gbps recently.
- **Low latency** – latency measures the time it takes to send a data packet from one designated point to another and affects the perceived responsiveness when using remote infrastructure services. Long latencies (or multiple retries of lost packets) make the connection seem sluggish and harder to use. Therefore, the lower the latency, the faster the data transmission, which is especially important when data has to travel far. On the REANNZ network the average time it takes to transmit data between Auckland and Wellington is 9 milliseconds and between Auckland and Los Angeles 120 milliseconds.
- **No packet loss** – packet loss is the estimated level of information parcels that get lost in data transfer. This occurs for a number of reasons, for example, high latency that increases the time it takes to transmit data or transmission points lacking the capability to handle data loads. If a packet is lost, the transfer of data must stop until the lost packet has been retransmitted and received. NRENs (including REANNZ), focus on delivering a lossless network so the likelihood that data is transmitted successfully on its first attempt is almost guaranteed. The impact of packet loss is significant due to data resubmission and therefore decreases in data transfer rates.
- **High burst ability** – the ability for the network to handle sporadic peak loads of data at any given time. Commodity internet is typically subject to traffic shapers which regulate the performance of a network by delaying the flow of packets according to their priority[18]. This is to reduce the impact of heavy data users slowing others on the network and can be achieved by reducing the bandwidth available to users or by dropping packets. Given its network capacity, REANNZ does not need traffic shapers as it is able to accommodate sporadic bursts in data transfers without impacting other users.

3.2.1 Added services such as Tuakiri essential

REANNZ also provides access to Tuakiri, which is a federated identity service allowing users a single sign-on to access a range of online services (e.g. academic journal subscriptions). Tuakiri services underpin the security of the log on process to the NeSI high-performance computer infrastructure. Tuakiri was previously provided outside of REANNZ, and there is not a requirement that REANNZ provide it.

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[18] A10 Networks (2018) *"What is traffic shapping?"* Retrieved from https://www.a10networks.com/resources/articles/traffic-shaping

3.2.2 Eduroam needs one node for NZ but that need not be REANNZ

Eduroam is also provided by REANNZ. Eduroam, developed by the global NREN community, allows global NREN end users wireless network access when visiting other countries and institutions without having to register or pay access fees. The CEO of AARNet (Australia) described the operation of eduroam function as follows:[19]

> **I was at a lunch recently with the Queensland Health minister and the vice chancellor of the University of Queensland where we've put eduroam into five or six hospitals. For University staff going into those hospitals all the time, and staff from the hospitals coming into universities, if they walk in with their device, they're eduroam-enabled. They can walk into the campus of the University of New South Wales, or MIT, or Oxford and don't need to put in a password! It simply authenticates your device.**

Eduroam requires a single organisation to provide it in a given country, which is conventionally the NREN. It may also be provided by a member of the NREN. In New Zealand, it is provided by REANNZ, but it is not required to be REANNZ.

3.3 Infrastructure is a mix of leased or bought

NRENs take various decisions about owning or leasing fibre as well as leasing or owning the network equipment on the end of the fibre. REANNZ does both and we set out the key network assets below.

3.3.1 Infrastructure built around a 'backbone'

REANNZ has a core domestic network running from Mangawai to Invercargill (see Figure 4 below).The majority of the backbone connects at 100Gbps while other connections, as shown in the graph, range from speeds of 1Gbps to 20Gbps. The high capacity is to cope for variable and sporadic data loads so that it is infrequently at saturation – if one researcher had to send 10 TB of data on the network, this would not affect other researchers network experiences.

The backbone connects metropolitan nodes such as Auckland, Hamilton, Rotorua, Palmerston North, Wellington, Christchurch and Dunedin – these nodes are called points of presence (PoP) serving as an access point for connections. Multiple links connect PoPs to provide resilience to the network. For example, if the direct connection between Wellington and Christchurch is interrupted, traffic can be rerouted through PoPs in Blenheim or Nelson.

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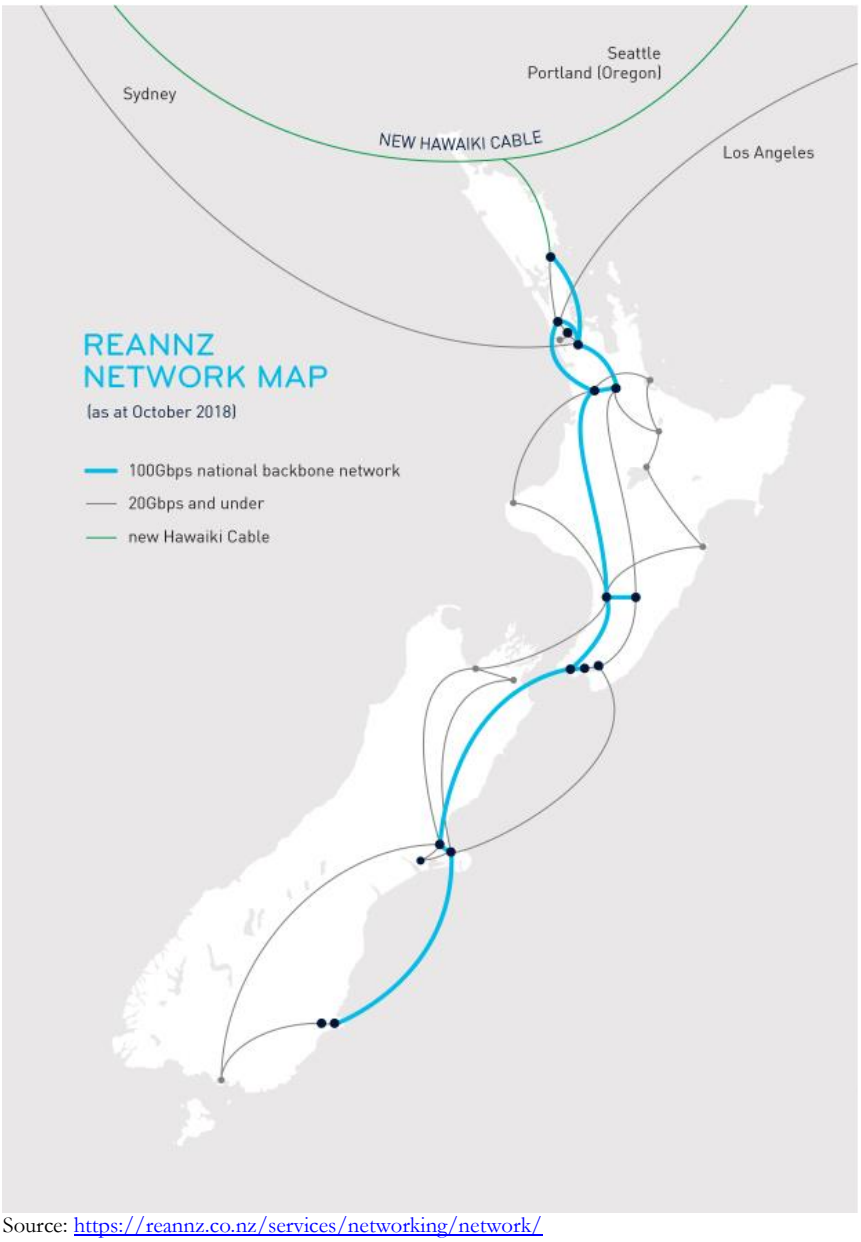
[19] Fell L (2012) *"Australia's National Research and Education Network. Innovation and Learning – An Interview with Chris Hancock."* Telecommunications Journal of Australia, v62(5).

Areas not located along the backbone connect to PoPs on the backbone. For example, Tauranga connects to Rotorua. Rotorua is a PoP on the backbone. Altogether there are 26 PoPs around the country.

Figure 4 REANNZ Network



Source: https://reannz.co.nz/services/networking/network/

3.3.2 A cornerstone investor in Hawaiki Cable

Recognising the importance of New Zealand's currently limited international connectivity, and the potential for greater connectivity need in future, REANNZ signed up to be an anchor tenant on the newly constructed Hawaiki Cable. The capacity is leased for 25 years.

3.3.3 Capacity within New Zealand is provided by Vocus

When the REANNZ network was launched in 2006, Telstra (now Vodafone) was selected to provide fixed capacity at a fixed price, on a fixed footprint. At the end of the period, REANNZ entered into a contract with Vocus (then FX Networks) to purchase fibre capacity in a shared network. The current contract allows REANNZ to access 25% of the system capacity of the shared network and gives the freedom to deploy network hardware and control for management of its own network logistics. In locations where Vocus does not have suitable coverage, REANNZ can work with selected local fibre providers to connect members to the Vocus backbone network

The shared network has 8Tbps[20] of capacity and with the contract REANNZ has access to 2Tbps of capacity. Thus there is potential to radically increase traffic if that is needed. REANNZ can increase this capacity, when it is needed, by adding additional cards to light more capacity without needing to go back to the market.

3.4 Unanimous support for an NREN

There is clear stakeholder support for an NREN. We examined the proposition of NZ not having an NREN as the fastest way to identify the value of an NREN. We look at this in a number of ways, the first being the benefits identified to us:

- Research collaboration will become more difficult. For some, with point to point connection needs, this may be resolvable. However for others, such as those working in international research programmes (e.g. The Square Kilometre Array project) or with a dispersed network (e.g. medical research requiring exchange of genetic data with peers), the issues will be much more difficult to resolve.
- Researchers will be lost to NZ or will not come to NZ. Data intensive researchers will expect there to be a high-speed network. They will not come and some might leave if this is not available.
- Research opportunities may be lost. For instance, it would not be possible to participate in many European, Asian or American research projects without NREN connectivity.
- Data intensive research under-pins a number of our science challenges and productivity may reduce as workarounds are found. Genetics research, climate change and earthquake research are given to us as examples.
- Transaction costs of moving large datasets will increase including the need to negotiate arrangements for the transfer of each dataset.
- Alternative connection costs will be incurred by international collaborators. One NREN does not charge another and research organisations subscribe to the local NREN. If NZ institutions used a commercial provider, transferring to another commercial provider overseas, the receiving research organisation may need to establish

[20] Note: 1 TeraByte per second (TBps) = 1000 GigaBytes per second (GBps).

its own connection to the commercial providers, at a cost. Some will just say 'no thanks'.

A further observation is about the nature and spread of these benefits. These benefits are large in magnitude but specific to researchers or clusters of research. In particular, we have identified clusters of researchers in genomics, astronomy, weather and climate modelling and medicine as gaining specific benefits. These marginal users receive benefit for their own research, however the benefit from high value research also accrues across New Zealand and internationally. The data intensive, high quality research is seen to be leading edge, and is moving beyond current boundaries.

3.4.1 International collaboration benefits seem real

We isolate international collaboration benefits as particularly important. An NREN is a key enabler of many aspects of that collaboration. International research collaboration has a value premium of almost 8% relative to domestic research[21].

International research collaboration does, however, have a good rate of return. A recent study assessing the return to New Zealand from international collaboration found that international research collaboration provides net benefits to the economy (measured by GDP). In particular, $1 invested in international research collaboration yields a GDP return of $2.46 in net present value terms after 15 years. This compares to a return of $2.28 for an 'average' domestic research project, a difference of 7.7%[22].

In general, around 10%[23] of that return accrues to the university (through increased student enrolments, patents and licenses) and 90% accrues to the general public (as business, government and industry apply, and benefit from, improved knowledge). The precise split of benefits is likely to vary depending on the type of research project.

The estimated benefits from international research collaboration increase over time, as the productivity payoff from research generally takes time to manifest. After 20 years the increase to GDP, in present value terms, reaches $7.46 (for a $1 investment).

To the extent that a specific international collaboration would not be possible without an NREN, then the entire benefit of international collaboration could be attributed to REANNZ. In most cases the attribution of benefit to REANNZ would be a percentage of the total estimated benefit, which given the predicted increase in data-intensive research and international collaboration, is generally likely to rise in future.

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21 DeloitteAccessEconomics (2017) *"Assessing Returns on International Collaboration."* Report to Universities New Zealand.

22 Note that the study also estimated returns to international collaboration arising from academic staff exchanges, student exchanges and work placements. These are not necessarily impacted by the presence or not of an NREN, so are not covered here.

23 Ibid.

Current assessments of value are out of date

The total economic benefit to New Zealand from the existence of REANNZ was estimated to be between $25 million and $50 million per annum[24]. This total comprised:

- Commercial benefits (i.e. avoided commercial costs for users to secure similar services if REANNZ did not exist) of $10 million-$25 million per annum[25].
- Wider benefits (i.e. increased research and education productivity through the network effects described above) of $25 million per annum.

When considered against the annual cost of $14 million for REANNZ, PWC assessed the net benefit is estimated to be between $21 million and $36 million per annum. These figures suggest that $1 invested in REANNZ results in benefits of $1.50-$2.57.

This analysis may have been correct at the time but is out of date now for the following reasons:

- For many universities, it appears there is a commercial cost rather than a commercial saving.
- The costs of providing the high speed network have increased from $14 million in 2015 to $16 million in 2018.
- Productivity gains for many researchers are more limited than expected possibly because of choke points in getting data to the network but also because the alternative service offerings of commercial ISPs is closer to REANNZ performance than it was before.
- Research density is low therefore cost per transmission is high and productivity effects are not as high as might be expected.

24 PriceWaterhouseCoopers (2016) *"Economic Analysis. Understanding the Value of REANNZ Services."* Report to Research and Advanced Network New Zealand.

25 The lower estimate assumes that only staff as users and a bandwidth of 30 Gb/s, while the upper estimate assumes both staff and students are users and bandwidth of 190 Gb/s.

4. REANNZ is in a precarious financial position

REANNZ is faced with rising costs and falling revenue. REANNZ projects operating losses of $6.2 and $5.1 million in financial years 2019 and 2020 respectively (years ended 30 June). While the current balance sheet is strong, with estimated cash reserves in excess of $20 million at the start of the 2019 financial year, continued operating losses will rapidly deplete the cash reserves. REANNZ projects **the depletion of reserves by the end of financial year 2022**. This is the best scenario for REANNZ. In a more extreme situation, if the remaining university members also choose to leave, **cash reserves would be depleted midway through financial year 2021** – a little over two years away.

4.1 Costs have risen and are forecast to continue to rise

Between 2014 and 2020, costs are forecast to increase from $11.1 million to $19.7 million, an increase of 77%, a compound annual growth rate (CAGR) of 10%. Table 2 shows the change in costs from 2014 to 2020 in each category, and its annual growth rate.

Table 2 REANNZ cost changes by category, 2014 (actual) to 2020 (forecast)

Cost Category	2014 ($million)	2020 forecast ($million)	% Change	CAGR
National Network	4.0	6.2	55%	**8%**
International Network	2.6	5.8	123%	**14%**
Network Maintenance & Development	0.9	0.4	-56%	**-13%**
Network Personnel	0.8	2.5	213%	**21%**
Corporate Personnel	1.3	2.3	77%	**10%**
Corporate Costs	1.5	2.5	67%	**9%**
Total Costs	11.1	19.7	77%	**10%**

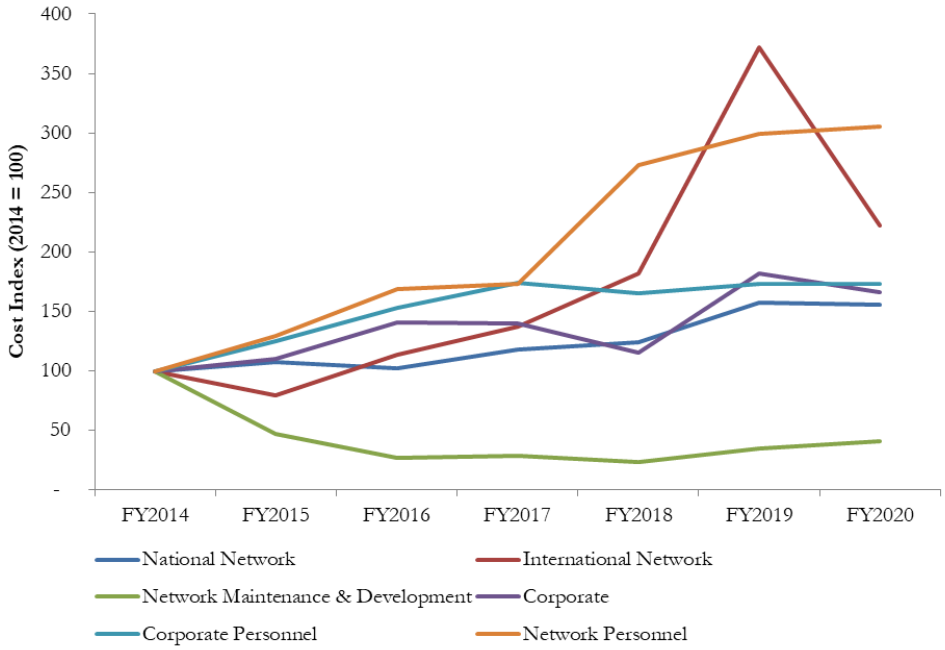
Source: REANNZ data, Sapere analysis

The cumulative 10% year-on-year increase in costs is concerning. While the cost of network provision could be understood, increases in corporate personnel and corporate costs do not appear to align with an organisation that has a strong focus on cost efficiency for its members.

National network provision efficiency needs to be tested. The Vocus contract expires soon and options for provision of national network services should be explored promptly.

Figure 5 shows the evolution of costs over time. In the six year period, excluding network maintenance and development, all other cost categories have increased by at least 55%.

Figure 5 REANNZ cost index, financial year 2014 to 2020



Source: REANNZ data, Sapere analysis

4.2 Revenue from the Crown and members is falling

Excluding the Hawaiki grant, revenue falls slightly over the period 2014 to 2020, from $14.7 million to $14.5 million. This is evidenced in:

- Membership income is the most significant reduction in income, driven by the non-renewal of membership from Canterbury, Lincoln and Victoria universities. This contributes a fall of $1.7million in FY 2019.
- Additionally Crown income falls $1million in FY 2018, following the reduction in the SSIF grant.

Services and other income nearly doubled over the period, from $2.2 million to $4.4 million. This is primarily due to increases in managed services and commodity internet. However, the

increase in other income does not offset the loss of income from the Crown and members, nor does it offset the increase in costs.

In this situation, REANNZ has a structural deficit and needs to rely on its reserves. Interest income is treated as revenue and is a substantial $751,000 in the last financial year. This income will disappear quickly with the calls on reserves.

Table 3 REANNZ revenue, financial years 2014 to 2020

Revenue ($m)	2014	2015	2016	2017	2018	2019 forecast	2020 forecast
Crown income	4.0	4.0	4.0	4.0	3.0	3.0	3.0
Hawaiki	0.0	0.0	1.5	5.3	5.3	3.0	0.0
Membership fee income	8.1	8.0	8.1	7.9	8.0	6.7	6.7
Services and other income	2.2	2.6	2.8	4.0	4.5	4.3	4.4
Interest income	0.4	0.6	0.7	0.8	0.8	0.5	0.4
Total	14.7	15.2	17.1	21.8	21.5	17.6	14.5

Source: REANNZ data, Sapere analysis

4.2.1 The possibility of a significant future liability

REANNZ has a long-term commitment to infrastructure contracts but short term revenue streams. In particular, if REANNZ were to deplete its cash reserves, the Hawaiki contract would become stranded. The Hawaiki contract runs to 2042 with large annual payments in excess of $1million per annum. We anticipate the future payments to be in the range of $40 to $70 million. The crown would inherit this significant future liability if REANNZ were to cease operation.

4.3 Member engagement is low

We identified a variety of client reactions to REANNZ and the following were identified to us by those feeling less aligned to REANNZ. Unfortunately, this is also the group of clients who pay the most for REANNZ services, the universities.

4.3.1 Transparency of costs and cost decisions lacking

Transparency, or lack thereof, of how REANNZ is organised and how it has calculated its costs and overheads served as a pressure point for all the members (universities and CRIs). The process of what made up membership fees was opaque and universities were not informed of how REANNZ priced their services. Members felt that long-term decisions and commitments such as the Hawaiki Cable[26] were made without consultation and that trade-offs, options, alternatives and such decisions are instead imposed upon members when it is the members that have to pay the on-going costs.

We note that REANNZ presents a contrasting view. REANNZ states it had made multiple attempts to seek member input in areas such as cost structures, pricing and network design and performance parameters, and options for change. Specifically REANNZ held member groups in 2016, 2017 and 2018 in the following areas:

- Strategic Advisory Group in 2016.
- Core Member Working Group in 2017.
- Member Services Advisory Group in 2018.

4.3.2 Members question focus

Sitting behind this discussion, is a concern that REANNZ is losing sight of its core focus (of being an NREN). Across members the feeling was that REANNZ was looking to expand into the area of commodity internet providers where they may not necessarily have the capability or scale to compete (even if they were permitted to).

4.3.3 Governance arrangements lead some to feel like captive customers rather than members

The opaque nature of decision-making led to another issue that served as a pressure point for universities – the governance structure of REANNZ. Though they were members of the 'club', universities felt more like customers in a monopoly situation and that in a membership there is more involvement with the direction and strategy than what is currently present with REANNZ.

4.3.4 Concerns of universities are ignored by REANNZ

During discussions with the stakeholders, when we asked if they had approached REANNZ about their grievances, the response from both remaining and departed universities was, 'For the last (however many) years, I have talked to REANNZ about this matter but they don't seem to listen.'

For those universities who withdrew from REANNZ in particular, it seemed that REANNZ had failed to communicate with their stakeholders and their needs. There seemed to be a sense of bitterness from members towards REANNZ and their lack of ability to effectively

[26] Noting the external drivers to participate in Hawaiki

convey or allay member concerns. For departed members, their withdrawal from the network seemed akin to a bad breakup. The departed universities had repeatedly conveyed their concerns about the rising costs of the network, while the price of commodity internet had fallen.

4.3.5 Bundling of products causes friction

Members receive access to the NREN and global (and New Zealand) community services such as Eduroam as part of the REANNZ membership. For Victoria, Canterbury and Lincoln, their withdrawal from the network also meant loss of access to global community services, which are not available elsewhere.

The departed universities recognise the global community services were important for their researchers and negotiated with REANNZ to purchase these services without being part of the network. REANNZ came back to the universities and negotiated a contract for the provision of Tuakiri which is a subsidised New Zealand community service albeit at an increased price to overcome the subsidy.

REANNZ was unable to provide Eduroam to the departed universities after consultation with the global community – attempts have been made by the universities to negotiate separately for the provision of Eduroam which has been a point of frustration.

4.4 Market evolution means the competition is cheaper and faster than 13 years ago

As we saw in the previous chapter, recent work suggests that the cost savings for internet services provided by REANNZ, relative to commercial ISPs, are not guaranteed. At the inception of REANNZ, commodity internet was not provisioned or offered as a service. Commodity internet was introduced as a service because it could be delivered more cost effectively than commercial provision. However, since that time the market for commodity internet has changed significantly and there have been several cycles of commercial demand expansion and several investment steps to both keep step with demand, and provide enhanced user experience. Now REANNZ commodity internet provision is not competitive on price because of changes in the market.

The roll out of fibre around most of New Zealand has led to very good internet connections, often at desk-top. This is in sharp comparison with, for instance, Australia, which suffers material internet quality issues. The government's Ultra-Fast Broadband (UFB) Initiative started in 2010 to provide UFB access to 80% of New Zealanders by 2022[27]. $2 billion of Crown Funding has been used and allocated to get speeds of up to 1Gbps to households. The UFB rollout has changed the game for the telecommunications industry – and has made commodity internet cheaper, and access to capacity, greater.

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[27] World Institute of Culture Discourse & Communication (2015), *"The Rollout of Ultra-Fast Broadband (UFB) in New Zealand, 2015"*. Retrieved from https://www.aut.ac.nz/

Departed universities report they have a reliable high speed network available from commercial suppliers, at a significantly reduced cost, with a 6Gbps speed. It is worth noting that commodity internet provision by ISPs will not provide the full range of services available from REANNZ, though many researchers find this acceptable. For instance, this view was presented in our survey by a member from a university that had left REANNZ.

We have not found any issues with shifting to a commodity ISP

5. Why we have not realised specialised connectivity benefits in New Zealand

The New Zealand Government in the National Statement of Science Investment (2015) has stated a vision for New Zealand's science system:

> **'A highly dynamic science system that enriches New Zealand, making a more visible, measurable contribution to our productivity and wellbeing through excellent science.'**

Underpinning the vision are two pillars, excellence and impact. Excellence is the quality of the science system and of the people who work within it, and is the key determinant of impact. Impact is the eventual benefit for individuals, businesses or society.

5.1 REANNZ supported through the Strategic Science Investment Fund

The Strategic Science Investment Fund (SSIF), which defines itself as supporting longer-term programmes of mission-led science and science infrastructure of enduring importance to New Zealand, provides investments critical to realising the 2025 vision for the New Zealand science system. SSIF is the Government's vehicle for funding REANNZ, and the Government recognises REANNZ provides specialist services and activities that enable data-intensive research and high-performance science applications.

It is also recognised that New Zealand is geographically isolated from many of its trading partners. For New Zealand to compete, we need to attract and partner with international R&D and talent to connect our research to the world.

Likely, the imperative for agility in e-research is greater in New Zealand due to the need for us to mitigate geographic distance and collaborate given the small size of our research sector. Many of the areas identified within our science challenges imply greater data intensity, some of which will be catered for by centralisation of supercomputer capacity and thereby taking analysis to the data, and some by attending to our high speed network. Our own view is that data intensity will increase with material increases in data from changes in instrumentation in areas such as radio astronomy, medical imaging and genetics.

Specifically, REANNZ is a critical part of New Zealand's research infrastructure, which enables excellence and impact across the science system, including improved productivity and operation at greater scale. International collaboration in data-intensive research is best undertaken through an NREN.

5.2 REANNZ needs to be used more

REANNZ's strategy has been to 'build ahead' of the market. This strategy is in the expectation of climbing data usage meaning increasing greater cost effectiveness of the platform. We set out why this is important and then consider why the expected growth has not happened universally.

High fixed costs mean scale is important. Networks are all about increasing returns to scale. We observe REANNZ cost base is dominated by fixed costs. Table 4 shows the breakdown of REANNZ 2018 costs into fixed and variable costs[28]. REANNZ costs are 81% fixed, as expected from an infrastructure organisation.

A high fixed cost organisation implies that marginal costs are much lower than average costs. Broadening of the member base or building usage of the network by the existing base is clearly an imperative. However, there is limited scope for increasing membership among the current member universe. Conversely, reductions in members will increase costs for remaining customers. The current situation of members not renewing may increase member fees beyond their reservation price[29], resulting in further membership losses. Subsequent membership loss may see an unfortunate spiral of increasing costs, and decreasing members. The result would be organisational failure.

Table 4 REANNZ fixed and variable costs, 2018

Category	Fixed/Variable	$m	Proportion of total
International and national network	Fixed	9.8	61%
Corporate	Fixed	5.8	6%
Personnel	Fixed	1.9	14%
Corporate	Variable	4.0	5%
Personnel	Variable	5.3	14%

Source: REANNZ data, Sapere analysis

[28]. We assume that network personnel are fixed to operate the network, and corporate personnel are variable.

[29] As noted in interviews with both University and Crown Research Institute CIOs.

5.3 Market-specific problems are timing and maturation based

The merits of REANNZ, in value terms, principally relate to the research-enabling properties of NRENs (i.e. international collaboration and participation in 'Big Science' projects). The value of 'Big Science' has been recognised the world over.

As a facilitator of research collaboration, the services provided by REANNZ are a derived demand; they are dependent on the rise of the research activity in New Zealand rather than being sought independently. Specifically, anticipated growth in demand for REANNZ services from areas such as growth in data producing instrumentation, use of high performance computing; and data intensive research at a national level and with international collaboration, is yet to be seen.

This may be a timing issue, in the sense that eventually the 'market' will develop, but both patience and trust is required. Neither of those factors is in great supply currently. While current reserves might provide REANNZ with some breathing space, there is limited ability to gear up for any major changes that might be in the pipeline (e.g. the SKA project).

5.4 Internal network connectivity is the main barrier to research use

We went through three cycles of survey analysis thereby increasing the number of responders from 23 to 73. The range of science endeavour increased and we received much more input from CRI versus university based researchers.

The primary message around barriers did not change. The last mile connecting the researcher to REANNZ remains the main barrier to use. The bandwidth capability of the last mile limits the bandwidth of data that is available to researchers due to the infrastructure of internal networks.[30] This means that the network performance of REANNZ is beyond what an average researcher is able to utilise. We expand on this in Appendix 2.

5.5 Asymmetry of use by members results in different value perceptions

Institutions being universities and Crown Research Institutes pay for REANNZ services. These stakeholders are unanimous that membership of REANNZ is desirable and beneficial. Membership of REANNZ means that everyone is effectively on the same network, nationally and internationally, and members of the club are collaborating together to achieve this.

[30] Note that this is the responsibility of the member institution, and will reflect their willingness to invest in their local network.

There is less unanimity in terms of stakeholders' willingness to pay for REANNZ membership. Several universities do not consider REANNZ membership provides 'value for money'. While there may be some benefit, it does not the match the (financial) costs. Those universities are using alternative commercial providers and, would return to REANNZ only if the price were approximately the same as the alternatives. One challenge of providing a network sufficient for all users is that the more data-intensive users set the requirements, which can result in a network that is over-providing for less data-intensive users - consequently increasing costs for less data-intensive researchers.

CRIs were more aligned in their value perception. They agreed the network strategy aligned with their research needs. Research data was a focus for REANNZ, whereas commercial vendors did not specialise in this area. CRIs felt REANNZ understood their objectives as research organisations. REANNZ enables science productivity by making it easier for researchers to do research.

Questions of cost and transparency become the main issue due to the inability of some members to perceive value (outside of cost savings to meet existing needs) and the inherent difficulty placing a tangible economic value on research. Tension arises when the research network cost is higher than the commercial alternative, where the commercial cost is equal to perceived value. Tension can be alleviated by:

- lowering the cost of the research network to members;
- reducing the member funding contribution (either through spreading the costs across more members or lowering contributions to the total cost); and/ or
- increasing perceived value.

6. How does New Zealand compare to international NRENs?

NRENs come in different shapes and sizes – there is no 'one size fits all' model that satisfies the geography, regulations, politics or education and research environment for all countries. Though each NREN may be different, there are common themes amongst the successful NRENs (comparative analysis is provided in Appendix 3). We draw out our conclusions for REANNZ from this comparison.

6.1 What makes a successful NREN?

Characteristics of a successful NREN overseas typically feature strong member engagement and a mix of government/member funding. This government/member funding mix is influenced by a number of factors, such as number of members or ownership. Figure 6 presents the spectrum of possible funding models, using axes relating member engagement and funding sources. The 'sweet spot' yields maximum response for a given amount of effort[31].

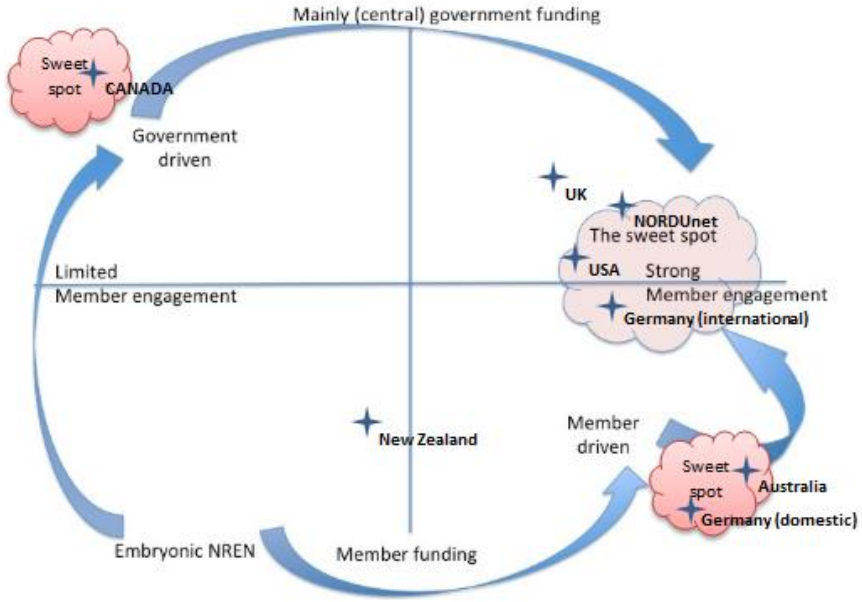
At this spot, there is strong member engagement with mixed government/member funding. Two other viable successful positions may be;

- where member engagement is low but there is strong government support with on-going relationship management with members
- where there is no government funding and membership revenue is sufficient to cover its cost.

We make a number of observations about NRENs as follows, recognising each has had its own idiosyncratic history.

[31] Case for NRENs (2018) *"What makes a successful NREN"*. Retrieved from https://www.caseforrens.org/Case_Examples/What_is_a_successful_NREN/Pages/Home.aspx

Figure 6 Quadrant diagram of a successful NREN



Source: Case for NRENs[32], Sapere analysis

6.1.1 DFN in Germany is self-funded due to economies of scale

DFN in Germany is self-funded - all users contribute to cover costs associated with X-WiN, the platform that serves as the research and education network[33]. This is made possible due to economies of scale – DFN has 348 organisations to split its cost between.

DFN is one of 41 member countries of GEANT, the pan-European REN that is owned by its members. GEANT connects the NRENs of its member countries to each other and to the rest of the world[34]. In the most recent upgrade, the European Commission funded 60%[35] while members funded the remainder 40%. For the entirety of DFN, its subscription fee to GEANT, and therefore its international connectivity, is EUR 2.2 million, which is the highest of any member country and requires only 20 km of fibre[36]. That means that on average, each organisation pays EUR 6,300 for its international connectivity.

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32 Case for NRENs (2018) *"What makes a successful NREN"*. Retrieved from https://www.casefornrens.org/Case_Examples/What_is_a_successful_NREN/Pages/Home.aspx

33 DFN (2018) *"Cost allocation"*. Retrieved from https://www.dfn.de/en/xwin/cost-allocation/

34 NORDUnet (2018) *"GEANT"*. Retrieved from https://www.nordu.net/content/g%C3%A9ant

35 GEANT, *"GEANT Strategy 2010"*.

36 GEANT Assembly Meeting (2017) "*Cost sharing resolution: GEANT subscription and membership fees 2018"*. Retrieved from GEANT.

Users of the network do not have ownership in the NREN due to regulations for institutions under public law. However, membership engagement is high – universities, research institutions and trade and industry entities make up the DFN membership and representatives of the members decide on the finances of the association and the split of costs[37]. The members elect three personnel to their Executive Board who conduct business on behalf of the association.

DFN is in two 'sweet spots' – the NREN itself is self-funded by its members without government support while at the same time it has strong member engagement with GEANT for its international connectivity, partly funded by the European Commission (the government funding in this case).

6.1.2 Internet2 in the US strongly supported by the government

The infrastructure for Internet2 in the US was funded by seed money from the National Science Foundation (US government agency), purposed for a research and education network, just after the creation of the Internet[38]. Major infrastructure upgrades have been provided funding by the federal government to upgrade the backbone network[39] with the fibre infrastructure being owned by Internet2. Users pay a small fee, the maximum being USD $95,000, to access and use the network which contributes just over 50% of revenue. Further funding from NSF is provided to build international connectivity through their International Research Network Connections programme[40].

Internet2 is owned by over 400 members comprising higher education institutions, R&E networks, corporations and federal members. Members pay dues amounting to $13 million and account for 17% of revenue. Representatives of the member organisations elect a Board of Trustees that oversees the direction and strategic direction of Internet2. These are further broken down into committees with functions such as finance, procedures regarding governance composition and recommendations and establishing Internet2 priorities. The Board is made up of university presidents, CIOs, researchers and industry partners[41].

Internet2 is in the 'sweet spot' – there is strong membership engagement with members having ownership in the NREN and the government providing funding for critical elements of the NREN such as infrastructure upgrades for domestic and international connections and users providing on-going costs.

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37 DFN (2018) *"Tour out site"*. Retrieved from https://www.dfn.de/en/association/tour-our-site/

38 Internet2, "*Internet2 Community Timeline"*.

39 D. Howell (2010) *"National R&E Partnership Awarded $62.5M Recovery Act Grant for 100 Gig Community Anchor Backbone Network"*, Internet2. Retrieved from https://www.internet2.edu/news/detail/2342/

40 National Science Foundation (2018) *"International Research Network Connections (IRNC)"*. Retrieved from https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503382

41 Internet2 (2018) "*Board of Trustees"*. Retrieved from https://www.internet2.edu/vision-initiatives/governance/board-trustees/

6.1.3 CANARIE in Canada is completely government-funded

In Canada, the CANARIE network infrastructure is fully funded by the government[42]. The government provides over CAD $100 million each year to support the Canadian NREN. It recognises that research and education benefits all Canadians and therefore removes financial barriers to promote the advancement of research and knowledge. Twelve regions and provinces in Canada connect research and education institutions to the CANARIE backbone to link all members to the NREN[43]. It has over 2,000 km of fibre for international connectivity, this is funded by the government.

CANARIE is owned by the government and members of the NREN are able to pay a membership fee of CAD $2,500 to cast one vote in the governance of CANARIE[44]. Board members are elected by member votes and are a mix of public (such as universities and RENs) and private (such as Microsoft and IBM) members that decide on the strategy and initiatives of CANARIE.

The 'sweet spot' for CANARIE's is where membership engagement is relatively low with strong government support.

6.1.4 JANET in the United Kingdom has both funding and engagement

JANET in the UK is funded by various higher education and further education bodies (all government related) which cover 88% (£77 million) of the costs required to deliver core NREN services[45]. The remaining 12% (£ 10.5 million) of funding is made up of subscription fees and is shared between almost 200 higher education providers, making the cost of access to JANET low[46]. Similarly to DFN, JANET pays a subscription fee of EUR 2.0 million to GEANT for its international connectivity.

JANET is owned by three representative members that represents further education colleges, universities and higher education institutions in the UK and hold 30% of voting rights each. The remaining 10% comprises of institutional members who are all eligible higher and further education institution across the UK[47]. The Board is made up of the three representative members, one representative institutional member, a funder representative and six additional trustees appointed by the Board to represent a mix of skills and expertise.

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42 CANARIE (2018) *"About us"*. Retrieved from https://www.canarie.ca/about-us/

43 CYBERA (2018) *"Canada's National Research and Education Network"*. Retrieved from http://www.cybera.ca/network/national-network/

44 CANARIE (2018) *"CANARIE Membership"*. Retrieved from https://www.canarie.ca/members/

45 Jisc (2018) *"Higher education subscription"*. Retrieved from https://www.jisc.ac.uk/membership/higher-education-subscription

46 Jisc (2018) *"Janet Network"*. Retrieved from https://www.jisc.ac.uk/janet

47 Jisc (2018) *"Representative and institutional members"*. Retrieved from https://www.jisc.ac.uk/membership/representative-and-institutional-members

JANET is between two 'sweet spots' –government support is strong while membership engagement is moderately strong. The funding bodies provide the bulk of the funding in the government-member funding mix but do not have ownership. Instead the majority of the ownership lies with representative members that represent the users with actual users collectively owning 10% of JANET.

6.1.5 NORDUnet in Nordic countries aggregate at many levels

The Nordic countries have RENs at a national, regional and pan-European level. The RHNet of Iceland[48], similar to New Zealand with an even smaller population density, is paid for by its members. Sunet for Sweden, who also has a backbone that is long but not quite as thin as New Zealand, is 75% funded by its institutions. Both have the advantage of being part of the NORDUnet REN, which provisions regional connectivity between the five Nordic countries and is owned, funded and operated by them as well[49]. Each NREN pays a proportion of base costs, allocated by a country's GDP. International connectivity is provisioned by GEANT, for which NORDUnet pays EUR 1.4 million between its five members. Therefore Nordic institutions that connect to their NREN will also be connected to NORDUnet and GEANT.

Each Nordic NREN has different governance structures but typically have representative members of the institutions they serve. NORDUnet is owned by the governments of the Nordic countries and board members are the head of their country's respective NREN and manage the body of NORDUnet, resolving political and strategic issues[50].

NORDUnet's 'sweet spot' is its strong member engagement, with members owning and funding the network. Its government support is implicit as the government is both a member and a funder.

6.1.6 AARNet in Australia and below-market fibre

In Australia, Nextgen began building an $850 million network in 2000 – a joint venture rolled out by a consortium of investors[51]. However, by 2003, the market for bandwidth had collapsed, Nextgen went into receivership and AARNet purchased the network for a fraction of the price it had cost to build. The government provided funding to AARNet to support the development of AARNet as a research and education network. AARNet was able to obtain a national backbone for a below market rate with further support and funding provided by the government. Members pay a subscription based on their student numbers and research income, with 260 members sharing the AUD $70 million cost.

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48 GEANT (2014) *"Compendium 2014 (for RHnet)"*. Retrieved from https://compendiumdatabase.geant.org

49 NORDUnet (2018) *"About NORDUnet"*. Retrieved from https://www.nordu.net/content/about-nordunet

50 NORDUnet (2018) *"The NORDUnet Board"*. Retrieved from https://www.nordu.net/content/nordunet-board

51 G. Korporaal *"AARNET: 20 years of the internet"*.

AARNet is owned by 36 Australian universities and the government agency for scientific research. The overall direction of AARNet is overseen by its Board, made up of vice-chancellors of universities and independents. The Advisory Committee provides technical and policy advice and highest-ranked IT members from each state sit on the committee.

AARNet is in a unique position – it managed to procure fibre at a below market rate. It allows for AARNET's 'sweet spot' to be member funded with no government support with on-going costs are paid for by users.

6.2 A number of implications for REANNZ

REANNZ is relatively new compared to other NRENs, having only been operational since 2006. For example, at the time REANNZ was connecting its research and education institutions, Europe was already six years into the development of its pan-European REN, GEANT.

Other than its relative youth, we make several observations of REANNZ in comparison with its peers.

- Not for profit motivation: As with the NRENs in our comparative analysis, REANNZ is a not-for-profit entity that provides specialist connectivity services to research and education institutions. Costs aside, it operates on a cost-recovery basis, recovering the costs of providing connectivity from its members and the government with no surplus.
- Connecting to the international NREN community: REANNZ currently has two major international connectivity points: Sydney, Australia and Hillsboro, USA[52]. These connections connect to PoPs or exchanges that subsequently connect New Zealand to international NRENs in Europe, Canada, Asia and South America[53].
- Ability to operate autonomously: NRENs require autonomy in deploying capability that matches user needs. They acquire this autonomy in different ways, by lease or purchase of cables depending on their own set of circumstance. The current contract between REANNZ and Vocus allows for the same operating model as other NRENs where they own or have IRUs for dark fibre while owning and operating the optical network. That means as data-intensive research increases and the network starts to become saturated, REANNZ can deploy optical equipment that would allow it to upgrade its backbone network up to potentially 2TBps of capacity.
- Promotes data transfer: We have a small number of users and institutions in comparison to the other NRENs therefore logically, the amount of data transfer is proportionately smaller. At 18,000 TB of international data transfer in 2017, on average, each member institution is transferring 620 TB of data compared to AARNet where each member institution on average transfers 765 TB of international data.

In Figure 6 we show a model for a successful NREN. Currently, REANNZ sits between the lower left and right quadrants – the members who remain part of the network engage in the

[52] REANNZ (2018) *"What we do"*. Retrieved from https://reannz.co.nz/about/what-we-do/

[53] Pacific Wave (2018) "*Pacific Wave 2017 map*". Retireved from https://pacificwave.net/files/map/Pacific_Wave_2018.pdf

network and make up the bulk of funding. We reiterate the three 'sweet spots' for a successful NREN:

- Strong member engagement with mixed government/member funding
- Low member engagement with strong government support
- No government support but membership revenue is sufficient to cover cost

In each of the 'sweet spots', the perception of value is significantly different. Where members are strongly engaged, their perceived value of an NREN is higher, which aligns with higher member funding. There is less appetite for member funding where perceived NREN value is lower, with the gap being filled by government support. In the New Zealand context, member value perception is diverse and government funding may be bridging the value perception gap.

New Zealand's opportunity to becoming a successful NREN lies in moving towards the first two options; is it evident that membership revenue when compared to the cost of alternative provision is not sufficient to cover cost even at the current level of government support, much less no government support. We do not have the numbers needed to exploit economies of scale to cover costs. There are simply not enough institutions in New Zealand to make this possible.

6.2.1 Poor representation of members and users

The Board of Directors are appointed by the shareholding Ministers of REANNZ and is intended to consist of representatives across compulsory education, tertiary education, research, innovation and commercial sectors[54]. The network users are predominately, research and education members, with a few exceptions. The board establishes strategic policy and monitors affairs of the company on behalf of the shareholders.

A recurring issue as conveyed by previous and current REANNZ users was the low engagement of members. Members are not well represented in the governance structure of REANNZ. Of the current Board, there is currently one Board member from a research organisation (and that organisation is no longer a member of REANNZ).

Typically with NRENs that have no government support such as DFN and AARNet, member engagement is high where members fund the NREN as well as elect representatives that make decisions for the NREN on behalf of the members. Even at the other end of the spectrum, in the case of CANARIE where the government funds the NREN and has the lowest member engagement in our comparison, members are still able to allocate a vote to elect members of the Board.

However, members of REANNZ make up a bulk of the funding without input to decision-making and it has been the case thus far that decisions have been made independently of them. In comparison of the international NRENs, user representation in REANNZ has been limited.

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54 REANNZ (2018), *"Governance"*. Retrieved from https://reannz.co.nz/about/governance/

The case for members' role in governance at board level is not proven. Members have diverse use cases, between universities, CRIs or comparing individual universities with each other. User representation at board level, considering the low number of board members may result in network design that is less appropriate for other non-represented members. Member representation may be better located by feeding into the operational level, such as providing input into the level of service provision, and in the trade-offs available in choosing the quality of service.

6.2.2 The cost of international connectivity

The landing of cables such as Southern Cross or Hawaiki provides us with the international capacity to connect to the rest of the world and allows New Zealand to overcome the 'digital divide'[55] and the barriers of our geography. However, this comes at a price and at a length of 15,000km.

We are as far from the rest of the world as our neighbour, Australia. While they also face the problem of geographical isolation, it can be mitigated by having economies of scale of institutions that can cover the cost of international connectivity. Moreover, Australia does not face the additional financial burden of procuring a national backbone on top of its international connectivity as AARNet acquired its fibre network at a fraction of market value. Therefore despite their geographical isolation, the international connectivity cost is offset by the economies of scale and owning their fibre network. New Zealand does not have the scale and must lease both national and international capacity.

As of 2017[56], only Australia and New Zealand have NRENs operating in the Oceania Pacific region. The geographical isolation from other NREN-operating countries makes it difficult to form entities that provision regional or international connectivity such as NORDUnet or the pan-European REN GEANT in order to further reduce transaction and coordination costs. DFN in Germany pays the highest amount out of all GEANT members for its international connectivity, while New Zealand pays 50% more for its international connectivity with only 10% of the institutions that Germany has. To further highlight this cost differential, the average cost of international connectivity per NZ institution is NZD $120,000 compared to NZD $9,900 per German institution[57]. Therefore compared to the European nation that pays the most for its international connectivity, on average, a New Zealand institution pays 12 times more than a German institution for international connectivity.

The physical divide between New Zealand and the rest of the world will always persist and the cost of getting connectivity to the bottom of the world will always be higher than a European country lighting 20 km of fibre to connect to a regional backbone that provisions international connectivity. When assessing the affordability (or lack thereof) of NREN

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55 GEANT, *"GEANT Strategy 2010: Over the horizon"*.

56 GEANT (2017) "*NREN Compendium Survey"*. Retrieved from https://compendiumdatabase.geant.org/reports/answers_per_nren

57 International connectivity figures taken from REANNZ(2018) and GEANT(section 6.1.1). Number of institutions as reported in our comparative analysis in Appendix 3, 39 and 348 respectively.

services, the cost of our international connectivity needs to be taken into account in the 'sweet spot' mix.

6.2.3 A limited user base

As previously stated, there are not enough institutions in New Zealand to allow REANNZ to be fully member-funded without government support as we do not have the numbers needed to exploit economies of scale to cover costs. However, by expanding its user base, the government may be able to reduce transaction and/or coordination costs.

REANNZ currently has two private secondary school members. It could further expand its user base by incorporating Network 4 Learning onto its network. N4L is a Crown Company connecting 98% of New Zealand schools to internet services, through a secure managed network. The government currently funds N4L to provide secure internet connections to over 2,400[58] schools. We understand the services include hardware in the schools, a content filtering service, local connectivity and national and international connectivity, amounting to a service cost of $20 million[59]. N4L may be able to utilise some of the existing backbone on the REANNZ national and international network, reducing the duplication of costs.

The benefits are twofold – if the government funding for N4L goes towards REANNZ while they also maintain existing levels of services for N4L, this would reduce the duplication of costs for the government where they may be paying for links where the REANNZ network already operates. Moreover, this fits within the mandate of REANNZ and serving the education arm of an NREN. Secondly, the increased government funding reduces the funding required of the small number of research institutions (8 universities and 7 CRIs) who currently pay the bulk of REANNZ through membership fees.

It is not uncommon to connect schools to an NREN. In Slovenia, their NREN ARNES connects nearly all 1000 schools (primary and secondary) to its NREN[60]. Slovenia has a population even smaller than New Zealand, at 2 million, and has five universities. As a small country, Slovenia makes use of economies of scale to make ARNES more affordable for schools, which make up the majority of their customer base, and other ARNES customers. NEN – the Education Network connects 15,000 schools in the UK using high-speed links from JANET, the NREN for the UK[61]. Schools are typically not members, but are users of the network, and use their NREN for connectivity services. We can see this in our comparative analysis with AARNET, CANARIE, Internet2 and SURF.

We note that increasing the user base with N4L and therefore government funding does not address the value perception of an NREN by differing institutions. The government funding may still be bridging the value perception gap. However, it does reduce costs for both the government and REANNZ and moves REANNZ from the lower left and right quadrants to

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58 Network 4 Learning (2018). *"Managed network overview"*. Retrieved from https://www.n4l.co.nz/managed-network-home/

59 Networking 4 Learning (2017) *"Annual Report 2017"*

60 TERENA (2005) *"NREN services for schools in Slovenia"*

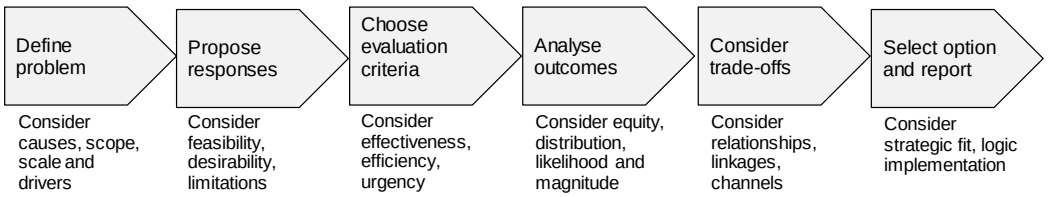
61 NEN (2018) *"About NEN"*. Retrieved from http://www.nen.gov.uk/about

the centre of the graph. Therefore by increasing member engagement, however that may be done, would place REANNZ in the 'sweet spot'.

7. An options assessment framework

Our review has surfaced a range of issues. In this section we summarise the issues and outline a framework for assessing possible options to address them. We first set out what we see as the most important criteria for assessing any options before we spell out the options that we have identified. The generic structure of an options framework is shown below**.** The framework draws on quality policymaking guidance, but is somewhat tailored to the situation at hand.[62] In essence, the framework maps potential options to identified problems. Thus we implicitly take the status quo as given. In this case, the starting premise is that REANNZ already exists and has sufficient funding to survive in the next few years. Problems and subsequent options are then assessed against each other, relative to the status quo.

Figure 7 Options framework structure



7.1 Assessment criteria must be strategic

Following are the criteria we identify as being critical to producing a strategic long-term solution to NREN provision:

7.1.1 Supports NZ's data science initiatives

An NREN is a strategic initiative and the first assessment criteria relates to the ability of the option to underpin and support our e-research aspirations. All of those we talked to agree an NREN is essential to this vision and the reasons for this unified view are the desire to make research collaboration easier and to enhance researcher productivity. The issue is how we implement that NREN rather than whether we have one. In that, the NREN needs to grow its relevance to its end customers (being researchers) and, likely, over time will see an increase in relevant, research related traffic.

[62] Department of Prime Minister and Cabinet (2017) *"Policy Quality Framework. The Policy Project."* Available at: https://www.dpmc.govt.nz/sites/default/files/2017-05/policy-quality-framework-development-insights-and-applications.pdf

7.1.2 A durable solution

The Crown also requires a durable solution, where the structure and funding of REANNZ is not continually revisited. All participants record their discontent at the amount of time the REANNZ contracting and cost issues cause them. Likewise, government officials raise concern at continual funding requests from REANNZ.

Durability is more than direct cost and needs to be 'dynamically efficient'. The REANNZ model must be able to react to changes in technologies, demand for data intensive research, and in members and their requirements of the network. A durable solution will also see all funders of REANNZ; CRIs, universities, and the government, committed to REANNZ's long term operation.

7.1.3 An affordable service to members

REANNZ's current financial situation has been triggered by a combination of a lack of affordability for members in the face of a changing, competitive offering and an increasing cost base. Now, commercial ISPs are able to provide a reliable service able to meet some members' research needs at lesser cost.

There is a complex game theoretic issue of what to offer customers to move away and then how that might play out over the years. At the moment, universities want to take advantage of lower pricing, lock that in for several years (thus shifting cost on to the network provider if data volumes increase) and still retain the benefits of an NREN. If at all possible, price should not be a debate; an NREN needs to be cost-effective for its members.

7.1.4 Enhanced member engagement

For members, the issue is not only a one-off price decrease but also a desired change in institutional incentives for REANNZ to remain consistently cost efficient.

The current institutional arrangements mean REANNZ decisions are seen as opaque and non-transparent. However, for REANNZ there is a catch-22. Some of its members are in active discussion with vendors who have high powered incentives to shift REANNZ members to their networks and therefore open conversations about network costs are difficult.

There are some mechanisms that might provide more transparency and enhance engagement without giving commercial ISPs an unfair advantage. For instance, in regulatory settings, industry working groups may meet to resolve issues of standards, measurement and pricing. Possibly, working groups focussed on levels of service, cost structure and pricing policy principles might enhance member engagement by increasing members input into decision making. At the same time, the costs of dealing with REANNZ might reduce as a more collaborative approach to decision making and cost sharing is identified.

7.1.5 The Crown is not worse off

The Crown currently funds $3 million per annum and faces a possible significant liability in excess of $40 million. The Crown does not want to continually find itself in the position of funding REANNZ. The Crown also requires a robust case for investment, with confidence that there are benefits for New Zealand and value for money from any investment.

7.2 The status quo is not an option

We do not recommend the status quo. Status quo is at best a weak option providing medium term security but a longer term lack of viability.

7.3 Options range from 'do minimum' to 'devolution'

We have developed a range of options based around possible management actions, changed organisational arrangements and changes in strategy.

Reduce cost options:

(a) Costs have grown rapidly and clearly one option is to **reduce operational costs**.

(b) **Reassess value of Vocus contract**. The imminent decision point for national connectivity provides an opportunity to test all options (including commercial) for provision of a national network.

(c) **Reduce network resilience**. The network is built for a data intensive environment that is not currently fully developed and does not require the full spectrum of resilience provided by REANNZ. Therefore do not invest further in the network and potentially reduce service offerings to selective nodes.

(d) A further cost reduction may be **outsourcing of management** of NREN services for instance to a member organisation or indeed to an ISP.

(e) Reduce service offerings, by ascertaining what members want REANNZ to provide. Service offerings could range from:

  (i) **Focussing only on core network services** only and stopping all other services such as managed services.

  (ii) **Or at the extreme, provide international connectivity only** and stop offering all other services including national connectivity including the identity service.

Increasing relevance and therefore grow network data intensity:

(f) Increase relevance to members by **building a Science DMZ architected network** to the researchers' desktop, instruments and data-stores. We have identified that this network may be cheaper and easier to build than we first thought (there may however be increased monitoring and management costs that would fall on member organisations) and, if developed progressively, may be a cost efficient one through enabling researcher productivity gains; and

(g) Increase **relevance to other science, education or innovation organisations**. We note there are organisations not making use of REANNZ that we would have considered possible members. For instance, Livestock Improvement Corporation updates over one billion data items a year, is obliged to transport data to Dairy NZ and is increasingly operating across a number of sites.

Merge with other organisations to grow demand:

(h) **Merge with member operations** such as the e-research group at Auckland University, or the High Performance Computing group at NIWA, where there both some existing capacity and a close relationship with researchers.

(i) Merge to **create unified big data infrastructure**- combine the some or all of existing government networks REANNZ and NeSI (with NIWA's consent) in a semi-autonomous business unit and task that unit with improving access to storage and other data intensive research capability.

Merge with other organisations to reduce overhead:

(j) **Merge with Network for Learning** (N4L). Membership of REANNZ does not currently include the school sector. N4L could be accommodated on the REANNZ network. At a total level, in the year to June 2017 REANNZ traffic was 42 PB[63], while N4L traffic was approximately 18 PB[64].

(k) **Merge with AARNET** thus creating an Australasian network solution.

Change the funding model:

(l) An easy and popular option for members would be to **increase Crown contributions**, though this would be more difficult for Government to approve.

(m) **Rebase the charging model** in some way felt to be more equitable. For instance, by charging on a volume basis.

(n) **Fund researcher costs directly** through payment in research grants thus taking the decision out of the hands of CIOs.

(o) **Make participation in REANNZ obligatory** and a requirement for data-intensive research granting.

Instruct changes in institutional arrangements:

(p) Sell all assets to members. The Crown could retreat from provision of the network and could **sell the existing network to network members**. They in turn would fix a price and run and govern the network. The Crown may choose to continue to subsidise the network as part of the sale agreement.

(q) Restructure the board and **allow membership governance and voting**. There have been a large number of REANNZ working groups and we suggest these working groups are symptomatic of issues rather than resolving issues. Likely there will be further collaborative working groups but clearly one option is to modify governance to allow directors to be appointed by members and to act in the interests of both members and researchers.

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[63] Annual Report, REANNZ, June 2017

[64] Annual Report, Network for Learning, June 2017

(r) Consider other ways of allowing member input, such as more effective **use of expert groups** in areas such as network capacity, network resiliency or service level offerings.

Build two domestic networks that have clear strategic alignment with member objectives:

(s) There is a lack of sense of common purpose in the stakeholders we interviewed and, although universities have come together, there was a clear difference between university alignments with REANNZ depending on data intensity, and further differences in alignment between universities and CRIs. An option is to **allow two domestic networks connecting to one NREN** in New Zealand; one for universities and the other for CRIs. Thus, each network would have a common sense of purpose.

(t) **Allow two NRENs** in New Zealand.

7.4 Our assessment

Table 5 below contains our high level assessment of each option against the criteria identified. This is our provisional view, based on our desktop assessment of the options. A much greater level of analysis would be required to fully assess the options as well as integration with the views of a much wider group of stakeholders.

Table 5 Options assessment and evaluation criteria

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Reduce operational costs	No impact	Partial, addresses some of the concerns of members	Partial, will not be a total solution. It assists crown and member contributions	No Impact, though dependent on exact area of cost reduction	Yes	This is a given under all options
Reassess value of Vocus contract To be effective tender for national connectivity will need to explore all options including commercial provision of national network	No impact, provided replacement delivers same quality of service	Partial, addresses some of the concerns of members	Partial – may deliver savings if tender comes out with a lower cost option	No Impact	Partial	Process should be started immediately to give indication of future costs and certainty for members

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Reduce network resilience, and reduce level of service	No immediate effect as current capacity is not fully used. However may become an impediment in the future. May limit future growth of membership.	Partial, requires service agreement to cover if main link goes down., may restrict future growth of data transfer	Partial, increases affordability, but significance may be limited	No, may adversely impact engagement if resilience reduces level of service	Partial, may improve overall position partially	Growth may not be impacted if sufficient headroom on main link
Outsourcing of management of NREN	No, harder to deal with user requirements	No, would depend on length of outsourced contracts	Partial, requires outsourced operator to be lower cost than existing model	Likely to increase separation between membership and management	Partial, requires outsourced operator to be lower cost than existing model	Cost of contracting and monitoring of contracts, and loss of technical knowledge within science sector. No incentive on outsource partner to share IP

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Reduce service offerings (e.g. do not offer commodity internet or managed services)	No impact	Reduces management load and clarifies purpose More financially durable?	Partial, the majority of cost is fixed, in national and international infrastructure.	No impact, provided members pay full cost of additional services	Limited impact, non-core services are paid for by members. REANNZ revenues significantly exceeded its costs prior to 2015	Requires a review of the cost of the network and the cost of services provided, and members requirements for those services
Provide international connectivity only	No, puts impediments in place for bringing together the best teams of top scientists. It would impede access to NeSI infrastructure.	Uncertain impact on national connectivity	Unknown, but possibly No. All members would have to gain extra technical capability to manage national connectivity and internal networks?	No, quality of service provision reduced. Would shift national connectivity costs to members.	Yes, lower cost	Undercuts the fundamental goal of collaboration in research

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Building a science Demilitarised Zone in each institution	Yes, improves access to the NREN.	Yes, it improves access to the NREN	Yes, though extra cost of DMZ would fall on members	No. Makes no difference.	Yes, provided members are responsible for infrastructure provision	A set of rules about transmitting data across an NREN. Increases trust (on a white list) and doesn't pass through a fire wall
Increase relevance to other science, education or innovation organisations	Yes, improves access to wider New Zealand science, education and innovation community	Yes, improves	Yes, spreads fixed costs over more members	No impact	Lowers average cost – but mix of government and member fees would need to be determined	May come down to whether data is research or commercial and if commercial, whether held in NZ. Need to meet acceptable use policies

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Merge with member operations[65] (could be a university or a CRI such as NIWA)	Partial, depending on the service agreement and who the member operation was – may threaten competency	No, less likely to be stable as dependent on member organisations' long term commitment to the provision of NREN.	No, costs are likely to remain the same	No. Could potentially aggravate the current discontent.	Unknown. But likely the Crown would remain the residual risk taker.	Would depend significantly on how members not running the NREN are engaged.

[65] Michael Uddstrom noted his clear conflict of interest, and abstained from any discussion of, or suggestion of a group such as NIWA running the NZ NREN

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Create unified big data infrastructure	Yes. Could reduce barriers to access data intensive research capability including connectivity, store and compute. May support sharing other significant investments (e.g. instruments)	Makes the REANNZ business more complex, but may simplify arrangements for managing connectivity, store and compute, and provide a platform for adding additional capability. More opportunity for members to realise joint value from data infrastructure and encourages further participation.	Would possibly increase costs if HPC costs were also charged through at some level. Dependent on the commercial arrangements (e.g. risk and funding) for delivering the capability	Makes member engagement more difficult especially for those that don't use other infrastructure. Possibly reduces transparency	Depends on commercial (e.g. risk and funding) arrangements	A big data infrastructure still needs to get data to and from it, so will always need a high speed link REANNZ would need to build member trust and confidence if it were the vehicle i.e. fix connectivity first, then may be trusted to expand capability

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Merge with Network for Learning	No impact, provided N4L traffic can be carried on network	Yes – would increase durability	Yes – good cost synergies	The Ministry of Education could be a pan-user	Yes – as long the apparent merger benefits are real.	Could work if REANNZ can deliver at commercial ISP rates. Would need to build out the network with connections to all schools
Merge with AARNET	No. New Zealand institutional needs may be lost in the wider organisation.	Uncertain, dependent upon international organisation. No guarantee New Zealand priorities would be supported in long term.	Uncertain	No. Governance would be dominated by Australia, we could become a minority party.	No. Would likely cost more	We would become a link in Australia's university system rather than managing our own. Australian investment in this area has been much less efficient.

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Increase Crown contributions	No change from status quo	No. Doesn't change incentives and could discourage efficiencies	Yes	No increase of engagement, though cost complaints would be reduced	No	REANNZ has been adept at attracting Crown funding
Rebase the charging model	Yes depending on the model choice. A model based on volumes used would create perverse incentives for data intensive research.	Possibly if there could be agreement about fairness, and if there is member commitment to longevity such as increasing member contract length	Only if accompanied by cost reduction	No. This has been talked through extensively with members.	No. Likely to be the residual risk holder.	Would want to link service contracts with any domestic supply contracts (e.g. the successor to Vocus)

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Fund researcher costs directly	No because the pressure will always be on reducing costs and therefore may impede collaboration and maintenance of a network for data-intensive research	Funding would be uncertain depending on success of data intensive researchers' success in funding rounds. Use of network for other purposes (e.g. WAN) would require a different model. REANNZ funding may vary significantly from year to year.	Yes, costs removed from member organisations	No impact	No. Likely the Crown will end up paying at researcher and network level.	Incentive would be to lower cost of network provision for each interaction, and would lead to incentive to lower service provision

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Make participation in REANNZ obligatory	Yes. Reduces the co-ordination issues.	No	No and may enhance monopolistic charging behaviours	No. Compulsion unlikely to be acceptable.	No. Would likely lead to outright dissention	
Sell the existing network to network members	No impact, if we assume the network retains its characteristics.	May end up having to set up another NREN. Could end up with members taking tactical cost reduction actions rather than maintaining strategic value and strategic science infrastructure	No. Members would need to find the capital.	No. Because there are such diverse needs from users.	Possibly.	Makes value of an NREN transparent to members

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
Allow members to nominate board members	Yes, creates more engagement in the solution	Partial, may create more commitment from members, may create perverse incentives	Partial, could provide better challenge to REANNZ cost growth. Different member representatives may drive different strategies seeking divestment of investment according to their own needs.	Yes. But may not increase member alignment	Partial – if members are able to better mitigate cost growth by participation in governance. Significant risk that member controlled board shifts costs out of members into REANNZ, and then expects the Crown to fund.	There have been researchers on the board before and that influence has not been successful. Needs further options analysis in tandem with other options (e.g. funding models, scope of operation)
Allow members input into decisions	Will improve network's relevance to members	Enhanced engagement will increase durability	No impact, though member input may encourage efficiency	Yes, critical to improve members sense of involvement	No impact	Any input must be meaningful for members

Option	Supports NZ data intensive research	Durable solution	Affordable for members	Enhance member engagement	Crown not worse off	Comments
To allow two domestic networks connecting to one NREN	No. Would need to connect two networks to ensure a full collaborate solution.	No	No. Would likely fragment buying power.	Yes. As they could choose which domestic network.	No. Likely to end up with stranded REANNZ costs.	
Allow two NRENs in New Zealand	Would still have to connect to one NREN for international traffic.	No	No. Would likely fragment buying power.	Yes. As they could choose which domestic NREN.	No. Likely to end up with stranded REANNZ costs.	

Source: Sapere analysis

7.4.1 Reinforce research collaboration in every way possible

We would reject any option that leads to increased barriers to researcher collaboration. For instance, if charging were to move to volume based charging then there would be an incentive of institutions to implement throttles moderating usage and therefore usage costs. The major economic benefit comes from data intensive research activity and research collaboration and any disincentive works against the wide ranging initiatives in data intensive research.

In contrast, initiatives such as a pragmatic, step wise introduction of a science network connecting through to researchers are relatively low cost and reinforce core purpose.

7.4.2 Transparency means integrity of decision making

REANNZ may have made the right decisions but it has not taken its members with it. If it had, it may have more understanding and buy-in to key decisions such as building or buying infrastructure ahead of demand. At this point, where the costs are running ahead of benefit, it could have had more member support.

7.4.3 Cost cutting is essential and synergies are worth exploring

Cost increases in excess of revenue do not make sense. Synergies attained through merger or by cost cutting may be found in at least three areas; governance, corporate overheads and network. As an example, N4L synergies could be achieved in the areas of:

- Corporate overheads; REANNZ corporate overheads in 2018 were approximately $2 million.[66] We base our savings estimates on REANNZ's accounts as further detail is not available from N4L. Given N4L is a larger organisation than REANNZ, 2017 revenue of $30.2 million (cf $16.6 million excluding Hawaiki) and corporate overheads of $9.2 million (cf $4.4 million), our estimates may be conservative.
- Networks; as an example, discussion with REANNZ suggests that traffic from N4L might be accommodated on the REANNZ network. At a total level, in the year to June 2017 REANNZ traffic was 42 PB[67], while N4L traffic approximately 18 PB[68]. Further analysis of N4L data patterns was not available; however, anecdotal evidence suggests peak requirements from N4L is lower than for REANNZ. Assuming REANNZ national network costs of $5 million in 2018 is replicated within N4L's direct network costs of ~$20 million, a further $5 million could be saved across both organisations.
- Governance; both organisations operate under a board structure. REANNZ spend approximately $0.2 million on their board, with N4L also spending $0.2 million. A combined operation would only require a single board.

[66] This includes Accounting & Finance, External Advice, ICT, Office Costs and 50% of Corporate Personnel.

[67] Annual Report, REANNZ, June 2017

[68] Annual Report, Network for Learning, June 2017

Our back of the envelope estimates of potential savings across the two organisations could be in the order of $7.2 million, of which half could be used to reduce REANNZ cost base – assuming that the Ministry of Education would wish to see the rest of the synergies. We recommend detailed investigation of what overheads could be eliminated by combining the two companies, and the technical feasibility of combining the two networks considering the user experiences of the two diverse sets of users.

7.4.4 Don't try to change university incentives through REANNZ

REANNZ is, in many ways, a collective action problem being dealt through a membership with differing objectives, thus making a sense of common purpose difficult to achieve. University incentives differ sharply from those of CRIs particularly where competitiveness does not depend on data intensive research. That difference of world view leading to differences in perceptions of value is something REANNZ has to work with rather than being able to change.

The incentives for universities to undertake data intensive research are implicit through the incentive to undertake high quality research. REANNZ is a vehicle that enables data intensive research. Incentives for data-intensive research are best not operated via REANNZ, but should be engaged through wider science and research policy settings.

7.4.5 Option short list

The assessment in Table 5 against the evaluation criteria leads to a short list of options to be considered:

- Reduce operational costs
- Reassess national connectivity options (Vocus contract)
- Allow member participation in decision making
- Increase relevance to other organisations
- Explore merger with N4L
- Build science DMZ

Additionally, there are a set of secondary options that have passed through the evaluation though are less clear cut with different member perceptions of value

- Reduce resiliency
- Focus on core network services
- Create a more unified big data infrastructure (over time)

Appendix 1
Researcher interviews and survey

Researchers are the end client but REANNZ and its services are largely invisible to them. We surveyed 67 researchers and interviewed a number to identify perceived value and barriers to use, in particular.

NZ researchers identify value but this value cannot be measured

Researcher views are critical as they are the end client. Here we summarise feedback received from interviews with researchers and a survey relating to value. There are a number of key findings as follow:

- Collaboration is key to researchers
- Research is data intensive
- Research will become more data intensive, and the use of enabling services such as the high speed network will also increase
- A high speed network is critical to the New Zealand science system
- REANNZ network characteristics and services are important to researchers

Collaboration is key to value

International collaboration is important to a number of researchers and particularly those involved in the areas identified above. Interviewees identified to us that collaboration is increasing in many areas of science as data-bases are shared, data underpinning research is published (as well as the results) and as research networks mature. Researchers identified that collaboration, nationally and internationally was important for the New Zealand science system.

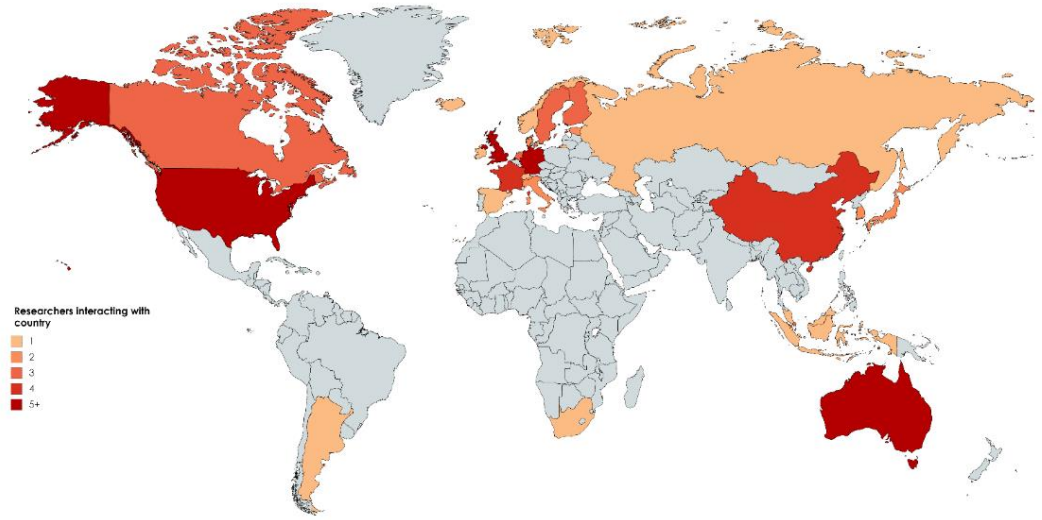
> **Without global linkages our research risks becoming insular, dated and irrelevant.**
>
> **We are so remote, we are likely to get left behind, and we do not have the population base to support all our own developments**
>
> **Without international collaboration we cannot compete globally**
>
> **We do not have the skills & infrastructure to go it alone in world class research.**

A researcher even questioned their future in the country. Further, researchers coming to New Zealand will anticipate we have an NREN.

> **I could not stay in the country.**

Researchers identified that collaboration, nationally and internationally was important for the New Zealand science system. Only 4 of the 67 researchers surveyed did not note international collaboration. Figure 8 below shows where researchers are transferring data to or from.

Figure 8 International data transfer



Research is considered to be data intensive

85% of researchers considered their research to be data intensive (based on a yes/no response). 93% of researchers in the previous year had transferred more than 10 GB of data, 67% of researchers had transferred more than 100 GB of data and 37% of researchers had transferred more than 1 TB of data in the previous year.

Data intensity is expected to increase

We asked researchers what changes in data related research they expected in the near term:

- In the next 2-5 years, how do you anticipate your data needs and research aspirations to change
- In the next 2-5 years, how do you anticipate your usage of the high-bandwidth network will change?

Table 6 Researchers views on changes in data needs and use of network

Question	Decrease significantly	Decrease somewhat	No Change	Increase somewhat	Increase significantly
Change in data needs	0%	0%	12%	32%	56%
Change in network use	0%	1%	14%	42%	12%

Source: Researcher survey

The majority anticipated increases in data requirements, increases in the use of the network. They attributed this to new data sources, greater amounts of data and use of other key science infrastructure.

> **Freely available high frequency satellite imagery**
>
> **Increased demand for, and downloading of, output from higher-resolution climate models.**
>
> **Data intensive remote sensing and need for data processing.**
>
> **Data generation is getting faster and cheaper. New data sources are getting added. There is still a need to transfer data rather than doing all analysis where data resides.**
>
> **With more climate simulations on NeSI HPCs we will need to transfer larger amounts of data.**
>
> **The increasing use of public data and metadata**

Data intensive research needs specific network characteristics

For university interviewees with data-intensive research activities, a high speed, high capacity network with rapid bursts and lack of packet loss is invaluable. A small group of university researchers (predominantly University of Auckland and Auckland University of Technology) identify to us that REANNZ is crucial; without it they would not be able to do some of the research it currently does and could do. This value relates to both domestic and international undertakings.

> **We will be a lot less efficient in our work without high-speed network. Certain types of work, e.g., operational processing of satellite images may not be possible**
>
> **The absence of high-speed network would severely decrease the pace of my research.**
>
> **Not sure how we would do our research if we couldn't move data files**
>
> **It would affect research badly. Mitigation is to send around hard drives. Dissemination of results and receiving input data from overseas is very important.**
>
> **Ability to collaborate and be considerate of collaborating centres needs would be impacted. Ability to bring down the necessary data for timely research collaboration would be impacted considerably, as would our ability to participate in joint centre work**
>
> **It would be a show stopper. The cost of shipping physical media would be prohibitive.**

The ability to do important research and to publish would be negatively impacted.

I will be unable to work with some collaborators and miss out on being including in high impact work

We would find it hard to reference our algorithms against publicly available reference datasets and thus prejudice publication

These researchers cluster in particular areas of undertaking. In particular, researchers in radio astronomy, genetics, climate change or human health (where medical images need to be exchanged), report the network is critical to their research.

We asked what the impact would be if there was no high speed network. The answers were clear. Efficiency and speed of research would be impacted.

- The ability to do important research and to publish would be negatively impacted.
- Use of other science infrastructure would be hampered.
- A researcher even questioned their future in the country.

REANNZ network characteristics and services are important

The service most valued by researchers was a reliable internet connection. Then international and national collaboration, as well as high bandwidth and low packet loss were valued next highly. Low latency and technical assistance were less value, though at a weighted score were still noted as somewhat important.

Table 7 Importance of REANNZ attributes

Service	Not at all important (1)	Not very important (2)	Somewhat important (3)	Very Important (4)	Critically important (5)	Weighted Average
Reliable internet connection	0	6	0	18	49	4.5
Collaboration with researchers outside of New Zealand	3	6	3	27	34	4.1
Collaboration with researchers within New Zealand	2	7	6	29	29	4.0
High bandwidth (ability to move large amounts of data in a timely manner)	1	15	3	24	30	3.9
Having access to off-site datasets and services	2	14	5	29	23	3.8
Low packet loss (no loss of quality or data in transmission - the ability to move your data reliably)	3	19	4	17	30	3.7
Security and privacy of data transmission	3	10	12	33	15	3.6
Low latency (responsiveness of interaction services when provided via an off-site system e.g. NeSI HPC or cloud service)	4	25	13	19	12	3.1

Service	Not at all important (1)	Not very important (2)	Somewhat important (3)	Very Important (4)	Critically important (5)	Weighted Average
Technical assistance and support for data transfers	6	24	17	20	6	2.9

Others services of lesser value

The array of bundled services that REANNZ offers in addition to network connectivity (e.g. eduroam, Tuakiri) is mentioned as a secondary source of value. While secondary in nature, almost all of the university researchers interviewed saw value from these services.

Interviewees did not see much value in commodity internet. Interviewees mentioned it as being part of REANNZ membership, but did not place much value on its availability through REANNZ.

The survey indicated REANNZ services were more diverse in perceived value. Eduroam was of most value (though perhaps not as critical to data intensive research), followed by the national and international connectivity. REANNZ support was of less importance to researchers, this may indicate REANNZ's primary engagement with IT departments, not the researcher, or the REANNZ network being fit for purpose. Of interest was the lack of knowledge of Tuakiri.

Table 8 Importance of REANNZ services

Service	Not at all important (1)	Not very important (2)	Somewhat important (3)	Very Important (4)	Critically important (5)	Don't know (Null)	Weighted Average
Eduroam	3	12	4	21	21	12	3.7
National Research and Education Connectivity	7	9	10	14	21	12	3.5
International Research and Network Connectivity	12	10	4	16	16	15	3.2
Tuakiri	8	9	5	8	5	38	2.8
Dedicated REANNZ Support	9	20	11	10	5	18	2.7

Value not always apparent, and may be expressed through complementary investments

For some researchers, the value of REANNZ (through an NREN) remains 'hidden.' Much like electricity or water, the ability to move data is almost taken as given. For these researchers, the National eScience Infrastructure (NeSI) has more visibility and hence user value. To the extent that REANNZ enables or augments the activities undertaken through NeSI, then REANNZ does add value. That is, if the functionality provided by REANNZ was not there, it would reduce the value of other, complementary infrastructure such as NeSI.

> **We will not be able to use NeSI as effectively. We may have to start reinvesting in local HPC and stop investing in the national facility.**
>
> **I will continue to process data on computers in the US as much as possible to reduce the amount of data transferred to NZ.**

The major barrier to use; internal network connectivity

The last mile refers to the portion of the network chain that physically reaches the end users – in this case, the researcher's desk. The bandwidth capability of the last mile limits the bandwidth of data that is available to researchers due to the infrastructure of internal networks. This means that the network performance of REANNZ is beyond what a researcher is able to utilise.

High speed data transfer on the optical fibre occurs from node to node on the REANNZ network. The optical fibre that underpin the network is capable of 10Gbps, and in some cases, 100Gbps. Data centres that sit at the end of the nodes are able to make use of the bandwidth that REANNZ has to offer. For researchers within the universities, they are part of the local university network and therefore the capacity available to researchers is dependent on whatever switches are controlling the local network.

In the last mile, local networking throttles the capacity of REANNZ – normal firewalls throttle speeds down to 1Gbps. From this point, there may be more switches that throttle speeds even further. By the time it gets to the researcher's desk, the speeds have been throttled down anywhere between 10Mbps to 100Mbps, a very small fraction of what the REANNZ network is capable of. This makes it difficult for researchers to be enthused about the capability of REANNZ as they aren't able to experience what the network is capable of.

The University of Otago has the Science DMZ, the only one of its kind in the country[69], a data transfer node that bypasses firewalls and allows users to realise the true capacity of the network. However, this capacity is not available to the average researcher from other

[69] NIWA are exploring building a DMZ for NeSI infrastructure at Greta Point.

universities where from the point where they send data via their desktop to other points in the world, it is still throttled.

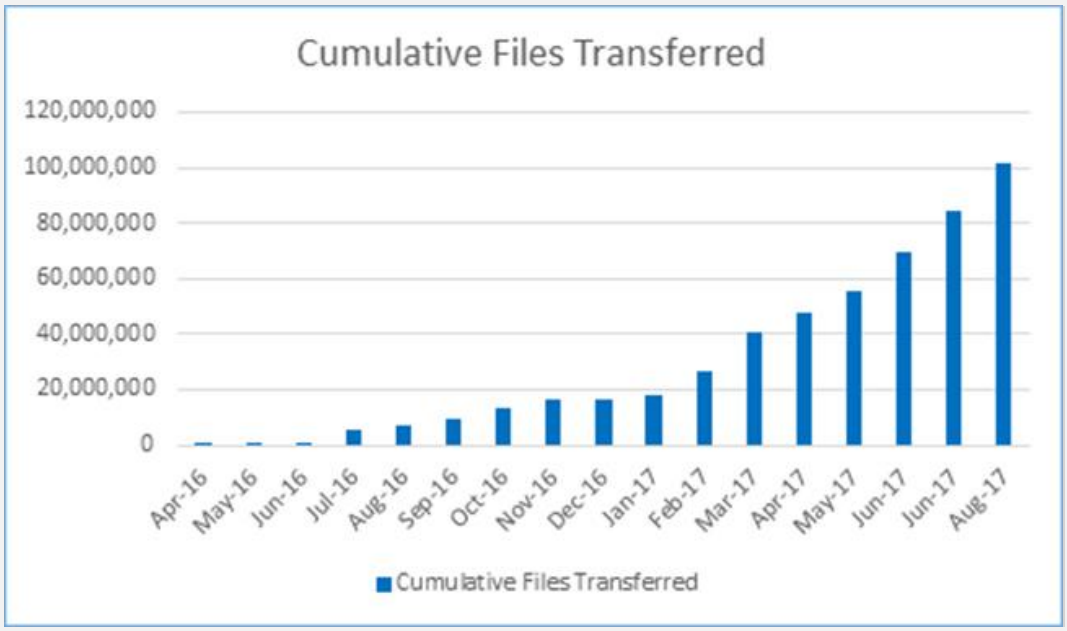
University of Otago has linked REANNZ to researchers

Prior to having the Science DMZ, UoO had commodity traffic shapers which delayed data transmissions in order to comply with a desired traffic shape and an old legacy network. The rate of data transmission was slow and not consistent so large data maneuverers were not possible – they had resorted to using hard drives. REANNZ helped the UoO set up its Science DMZ, a switch that allows all research data to go down a different, faster path that bypassed firewalls, packet savers to reach speeds previously not seen on their network.

The same protocols are shared at NeSI so that there is capability at either ends to accommodate the volume and scale of data transfers which serves as a benefit for their research. UoO works heavily with genomics data which has travel to sequencing facilities overseas and back. The Dunedin longitudinal study is now incorporating neuroimaging into its workload. Researchers sent an MRI scan to NeSI and it came back a few seconds later. A singular MRI scan contains a lot of data and these will be published eventually due to the global interest in the Dunedin Study.

The graph below shows an exponential growth in the amount of data being transferred since the inception of the Dunedin Study neuroimaging research. If the UoO had been on its previous network, they stated they would be sending hard drives every day to transfer the same amount of data they were currently sending on the network.

Figure 9 Graph of cumulative files transferred for University of Otago



Source: University of Otago

The internal network connectivity is not supplied by REANNZ, but overall the network is only as good as its slowest point. While the local network sits within the universities (as well as CRIs), without point to point connectivity, it diminishes the value of the REANNZ network as researchers working from their desk are essentially getting commodity speeds.

Not all researchers would require full unfettered high speed access to the REANNZ network. University and CRI members indicated that only a subset of researchers would need full speed access, and efficiency of provision should be considered if upgrading internal networks. They also noted that specialist research areas such as data labs would be areas to prioritise for improved network access.

University and CRI researchers noted internal network quality issues in response to the survey.

> **Speed seems slow but I don't know how much of this is antiquated buildings and cabling or how much is external connection.**
>
> **The quality of network to University DCs is excellent. The quality of connection to desktop / laptop is less good than my connection at home.**
>
> **Can be difficult for working on remote computers due to occasional sudden reductions in speed.**
>
> **We are bandwidth limited on the desktop 300Kb per connection and behind a proxy server/firewall which restricts many things we do**
>
> **Data transfer is very slow between my institution and the UK and requires manual time spent checking while transfers are on-going**
>
> **On occasion, current download speeds have limited our progress when bulk data downloads needed to be done.**

Appendix 2
Feedback from CIOs of member institutions

We interviewed and ran two focus groups to understand the institutional perspectives of clients as mediated through, largely, Chief Information Officers. We ran two focus groups, one of Crown Research Institutes, and the other of universities. We then interviewed a number of university Chief Information Officers to provide more detail around different perspectives of the value of REANNZ. Our discussions with institutions highlight a diversity of views and, also, highlight the cost of REANNZ is too steep for the current needs of many of its users.

Underlying value differs between universities and Crown Research Institutes

Stakeholder meetings made it clear that the value of REANNZ differed vastly amongst members. With three departed university members and one impending, it was important to understand the value proposition of REANNZ as perceived by its two main user groups – the universities and Crown Research Institutes (CRIs).

We look first at the value proposition for universities particularly as these institutions are allocated 70 percent of REANNZ cost recovery. There are several reasons why the value proposition for universities differs from CRIs:

- **Capability not needed as most of the traffic is commodity traffic:** Universities are both a research and education institution serving students and researchers. The majority of its users, students, don't require the capabilities offered by REANNZ; their current needs can be met at a cheaper price point by commercial providers. The REANNZ network is configured for researchers within the universities who require fast, large scale data transfer capabilities. Thus, universities essentially balance two different connectivity requirements and concomitant levels of service.
- **Universities operate in constrained fiscal environment:** The financial disposition of universities differs but all are stretched for money. There is close scrutiny of all contracts from cleaning through to hostel services, through to IT services. We are informed that, after staff, the REANNZ service charge is the second largest budget item and therefore given close scrutiny. The cost of research can be considerable and even prohibitive when those costs are allocated to a few researchers whereas the majority of need can be dealt with at considerably less cost. One university indicated it was five times as expensive.
- **Mixed incentives:** Universities are first and foremost education providers, but also serve a function as a research institution. Therefore, the survivability or longevity of the university depends more on their strategic goals for education than on strategic goals for research, which can be short-term given the driver is often PhD research lasting around three years. Though they might struggle to recruit and retain staff, a university

will not cease to exist if they are not producing research – they will still be operational as long as they are providing education services and these services can be provided without the need for collaboration with other universities.

Within-group differences drive perceptions of value for universities

We asked the universities how they used the network, what issues they faced and what their future demand for data-intensive research looked like. The universities agreed that there were no issues in the quality of service provided by REANNZ – it catered to the research needs of the community – with the only ramifications in this regard being perhaps overprovisioned for the current connectivity demand for research in New Zealand.

The value placed on REANNZ by the universities boiled down to the scale and magnitude of their data-intensive research and it was very apparent that, within the universities, there were two distinct views on the value proposition of these services.

More data-intensive universities and CRIs perceive greater value from REANNZ

The University of Auckland (UoA), AUT University and the University of Otago (UoO) relied on the existence of REANNZ to meet their research connectivity needs. In particular, the capacity and services it provides was critical to the success and continuation of their research. Reasons for this perspective are set out below.

- **The data intensity of research**: The universities undertake different research, all with need for transfer of very large data sets:
  - AUT, with its work in radio astronomy data and soon with the Square Kilometre Array, is the heaviest user of the network especially with regards to international capacity and burst ability – these aspects of service provision are described as being 'absolutely crucial for AUT'.
- **The depth of collaboration:** It is clear that some research such as gene research happens as part of international networks.
  - At UoO, a researcher involved in the diagnosis and treatment of rare disease in children identified the need to receive large genomic data-sets and to share them with colleagues in other parts of the world.
- **Supercomputer needs:** Some of the researchers need to access the supercomputer capacity of NESI. This supercomputer capability is connected via REANNZ and is unlikely ever to connect to commercial service providers due to concerns over quality of service provision.
  - UoA identified its brain research programme requires regular access to the NESI super computer sited in Wellington, at NIWA.
- **Large spread of locations:** CRIs observed their geographically diverse locations led to a need for Wide Area Networks. These were most efficiently provided by REANNZ in comparison to commercial providers.

The trends these universities are seeing indicate that data-intensive research is on the rise and more international collaboration will be taking place. These stakeholders identify research is being shaped by the community of researchers and research infrastructure such as NeSI that is changing the way in which data is used, promoting the need for the underlying connectivity to link users to services.

These stakeholders are experiencing a further surge in demand as research programmes and new instrumentation becomes available. For example, in the last 12 months, UoA had seen a significant shift in the amount of data transferred.

The pattern is volatile and unpredictable. These universities report it is difficult to estimate demand as research projects may bring a whole team that completely change the pattern of data usage. Demand is dependent on what research projects have been funded or commissioned so the traffic type that is generated and what different services they require reflect the needs of those projects. Though the research data intensity in New Zealand has been slower than predicted, these universities expect the demand for data transfer by its researchers is currently there and it will only increase in the future.

Options workshop confirmed the problem definition

At the options workshop with MBIE officials, REANNZ staff and research representatives; we gathered participants' opinions on the critical issues facing REANNZ. The issues confirmed the problem definition we proposed earlier in the report:

Cost of capability

Focus on cost over research capability (reduction in government funding)

Misunderstanding of potential lost opportunities in medium term

Clarity of purpose from government for strategy for NREN

On cusp of dissatisfaction

Cost pressures on institutions

Price is an issue, change in funding mix, perceived value, diversity of need

Budget setting process mandates members' costs

Opportunity is not seen

Commercial providers are unable to meet these users' needs

UoO tested commercial traffic and burst rates in a parallel test of REANNZ and commercial networks. Attempted transfers over commercial networks did not succeed. UoO identified that commercial provider interpreted the transfer of large research data-sets as a denial of

service attack.[70] On the other hand, REANNZ is able to observe the transfer of data from one point in a network to another and identified a node in Europe was slowing transfer down; it was able to contact that NREN and speed transfer.

This view is confirmed in testing undertaken by REANNZ, which showed that international data transfers using retail internet connections were unreliable or at times could not happen at all.[71] Specifically, REANNZ found data transfers from AUT and UoA were unsuccessful due to dropped data packets. We note there is considerable criticism of this testing as it did not permit the option of supervised data transfer.

Cost factors less important to these universities

Relating these observations back to the discussion above on the economic value of NRENs in the previous chapter, the focus of these users is less on the potential cost savings from REANNZ (relative to commercial provision) and more on the potential value associated with research, which REANNZ would help to 'unlock.'

That is not to say that costs are immaterial, but that for these universities value is more important and encompasses more than just financial outlay, even though the relevant universities are in the top bracket of fee-payers (see Figure 10). We note that Massey is an outlier as most of its traffic is nationally, between its sites.

Figure 10 2016 University membership fee comparison to data use

REDACTED – CONFIDENTIAL DATA

Source: REANNZ

Massey perceive value from cost-savings rather than research enablement

Figure 10 shows that Massey University is also among the top fee-payers for REANNZ connectivity. We understand that this relates to its geographically dispersed campuses. In their case, the REANNZ network is a cost-effective solution. Campuses linked to the high-speed network were able to connect to other campuses as a private Wide Area Network (WAN)[72] to run business operations, virtual reality centres in Auckland and daily data replication – they were the highest users on the domestic side of the network.

In the absence of REANNZ, Massey would need to set up these links between the campuses themselves using commercial providers. Connections would have to be set up at each campus, all geographically distant from each other, which connect to a circuit linking each of the campuses. While this is possible, it was more cost-effective for Massey to use REANNZ to provide connectivity between its campuses for which Massey derives its value from

[70] In simple terms, this is where a user floods the service with large volumes of data to effectively block other users from using the service.

[71] REANNZ Performance Testing 2017, REANNZ.

[72] A WAN is a network used to transmit data a large geographical distance, typically in excess of 1km or more

REANNZ. Being able to connect to other members, international NRENs and the use of eduroam are additional benefits.

Costs and research needs drove former university members from REANNZ

Previous members of REANNZ who have since departed (Victoria, Lincoln and Canterbury with Waikato impending) agreed that it was not value-for-money and found that their research connectivity needs were met by services provided by commercial vendors at a much cheaper price point. This research involved transfers of datasets to universities overseas.

Victoria University has tested speeds of up to 6Gbps to Australia. Victoria University is confident that the speeds it achieves with its commercial provider are not unique and can be achieved without packet loss. Both UC and Lincoln had found alternative commercial providers prior to cancelling their membership with REANNZ.

These universities consider that their research, though in data-intensive in nature, was not on the same scale as UoA, AUT and UoO. While no one could deny that the demand for data-intensive research was on the rise, for the departed universities, the capacity offered by REANNZ exceeded the capability they required.

When posited with the question of what they required from an ISP, it came down to a high speed network with high capacity bandwidth and burst ability where large datasets could be sent and received without being classified as a Distributed Denial of Service (DDoS) attack. When asked about the lossless nature of their packets, universities were firm that there was no issue with the quality of data or packet loss on their commercial network provider. This was in direct contradiction with the tests run by University of Otago, suggesting a disparity in the quality of service required by the different institutions.

For the departed universities, the decision to leave REANNZ came down to cost of provision. No universities disagree with having an NREN – it is important to New Zealand and its research as only a few developed countries in the world do not have an NREN. However, in its essence, REANNZ is still just an internet provider to these universities and the services they required such as bandwidth, low packet loss and latency were met by a commercial provider at a more attractive price point to the universities.

> ***'I spend way too much time on them. They are just a service. We are paying one fourth of the cost.'***
>
> ***'I absolutely support the need for an NREN in New Zealand as there is value to be gained, from the bundled services as well, but not as its current premium price point. I could send my academics out using hotspot and would still come out on top in terms of eduroam.'***
>
> ***'My data requirements are nowhere near the size of AUT with their radio astronomy data. I'm paying for a Falcon when I need a Swift.'***

If their needs are truly met by a commercial provider then for these universities, it would seem to be the case that the cost of REANNZ is the cost to be part of the 'club'. The cost of that premium is in the ballpark of two to three times the cost of their commodity internet connection.

Crown Research Institutes are heavily reliant on the network

We posed the same questions to Crown Research Institutes (CRIs) as we did to universities – what do the CRIs need most from REANNZ, what issues do they face and what does their future demand for data-intensive research look like?

CRIs are research institutions – the majority, if not all, of their users are researchers. Their direction is guided by the research purpose of their institution. CRIs are smaller than universities and shared a common purpose – advancing research in New Zealand. This purpose brought CRIs together to develop strategic plans as though researchers will come and go, the direction and purpose of their research would still remain the same. Being a part of the network had improved collaboration between institutions. Unlike universities, a research institution without a strategic purpose would cease to exist. Therefore, a collaborative approach to develop strategic plans for research in New Zealand benefits all CRIs.

CRIs agreed that REANNZ was forward looking and the network strategy aligned with research needs. It focussed on research data, whereas commercial vendors weren't, and understood what CRIs were trying to do as a research organisation. They were the only connectivity services that understood the types of science workloads. There were three benefits that answered the value proposition question for CRIs which underpin the value of the network to researchers – it enables science productivity by making it easier for researchers to do research.

The first being the ability transfer large datasets over the high speed network to national and international destinations with no packet loss, identical to the value proposition for researchers in universities. The examples of the network enabling data-intensive research are numerous – one member used to send genomic files to Rio de Janeiro, Brazil via commodity internet. The files were moderate in size and took 72 hours to send, processed and then sent back; all up a 5-day turnover for one iteration. Once the member was on the REANNZ network, they were able to access internet2, the US NREN, which was linked to redCLARA, the Latin-America REN, reducing the time from 72 hours to 55 minutes to complete an iteration. The second benefit was the ability for CRIs to outsource their IT capability to REANNZ and third benefit was that the services provided were cost savings.

A decentralised IT model provided by REANNZ membership allows CRIs to function

CRIs reported being heavily reliant on the technical expertise provided by REANNZ, effectively operating a decentralised IT model as a result. Each CRI has a small IT team – without the high speed network, each CRI would have to figure out how to set up similar capabilities on their own. They would struggle to provide such services in house –more staff would be needed to manage connections between sites, to set up connections with other institutions and configure the predicted capacity needed.

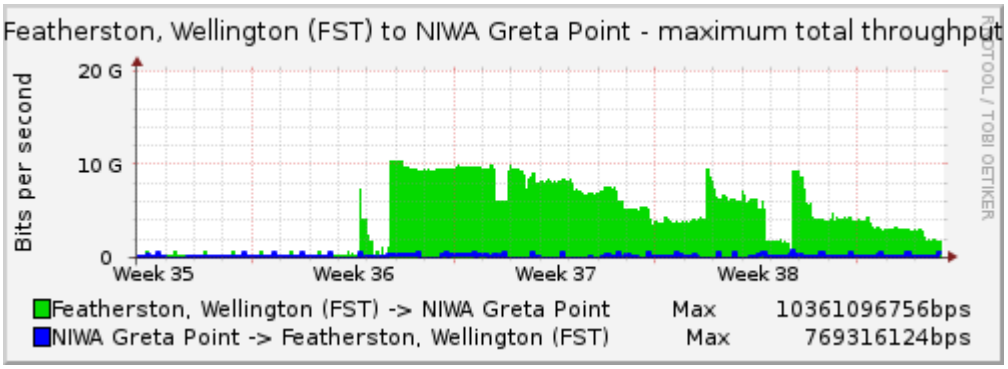
Having the high capacity connection influenced the architecture and changed how CRIs thought about conducting their research. There is no consideration of overloading and what costs are involved – they treat the network like a local area network (LAN). To put this in

perspective, a researcher within the Faculty of Science at the University of Auckland wanted to send a 300 GB file to a researcher in the Faculty of Engineering, also within the same university. This is an example of a LAN transfer as the internal configuration and wiring are all part of the same network and researchers wouldn't worry that this would overload the network. By being part of the REANNZ, members are connected across the country as if they were part of a LAN.

The network was so valuable to the CRIs that they said that without it, it would be unlikely they would be able to function. Their alternative would be to send hard drives via courier as they had done in the past or 'pay an arm and leg to be at the mercy of their costing model' with respect to commercial vendors providing the same functionality.

Specifically, in Figure 11, NIWA indicated they have used part of the REANNZ network to full capacity. Over a period of three weeks, NIWA transferred data consistently from their site in Auckland to Wellington. This allows them to operate data backups between their two operations, to provide disaster recovery backup.

Figure 11 Saturation of 10Gbps link, NIWA



Source: NIWA, REANNZ

A cost effective solution, with 'club' member privileges

In contrast to universities, CRIs reported that being a part of REANNZ was cost-effective.

Each CRI is slightly unique in their network needs – some have geographically distanced sites around New Zealand and require them to be connected as a private WAN - much like Massey, some need managed firewall solutions and some require high-speed connections with other members to collaborate. What all the CRIs have in common is that they all require the services provided by REANNZ.

> *'Primary benefit is that they are cheaper than commercial vendors for the range of services that we use them for.'*

The cost savings could be significant. When one institution tried to set a managed firewall service with commercial providers, it was 'easily twice what we are paying with REANNZ'. If each collaborator was on a different network, a single organisation would have to obtain the design specifications from each other collaborator to connect the two parties. These

costs would be duplicated across each CRI at a lower capability than what is currently offered. By offsetting all their telecommunication needs to REANNZ, bar their phone services, it was cheaper for CRIs to use REANNZ.

We heard an example of domestic collaboration opportunities falling through as a result of lack of connectivity through REANNZ. One CRI issued a Request for Information on shared data storage services. They received a reply from one of the universities who was no longer a member of REANNZ.

The transactions (and financial) costs to the CRI were such that it brought into question the viability of collaborating with the particular university. The CRI would have needed to set up a separate high-speed commercial network to facilitate the data storage network of non-REANNZ members, adding costs which would not otherwise have been incurred if the university was still a REANNZ member. While this instance was domestic in nature, it is conceivable that a similar outcome would be reached in terms of potential international collaboration.

Other parties show the value proposition can teeter either way

Here, we summarise feedback given from two other parties who interact with researchers and research institutes, but also have separate and distinct views – the Tertiary Education Commission (TEC) and Livestock Improvement Corporation (LIC). The former is part of REANNZ while the latter is not.

TEC has both education and research dimensions, sees value from REANNZ in both

The view of TEC in respect of research is quite simple. Without connectivity provided by REANNZ, it is difficult to conceive how effective research capability in New Zealand would exist. The key, in TEC's view, is that the nature of research traffic will increasingly involve transportation of large data bundles more frequently. As research capacity (and capability) improves through agglomeration/collaboration the need for massive connectivity increases, especially in areas such as health, agriculture and other primary production and genomics.

On the education front, New Zealand has some characteristics that are often overlooked, but raise the potential import of a relevant connectivity backbone. New Zealand is sparsely populated and the education institutions are geographically dispersed, meaning that education delivery can be challenging. In particular, the need for more high definition, richer and more complex visual options and more collaboration (i.e. communities of learning) suggest connectivity of the type provided by REANNZ is material now and is likely to be more so in the future.

REANNZ provides a cost-effective approach. When combined with an internal push to cut costs, the result was savings of about 15% compared to market offerings. Ultimately, the decision to go with REANNZ was based on value-for-money, not just price. REANNZ offered greater quality (especially in relation to video).

While highlighting the cost-effectiveness of REANNZ at present, there was mention of the possibility of commercial providers further developing their offerings and becoming far

more attractive (cheaper and better levels of service) in future, from both education and research perspectives.

In addition, it was not clear why there were separate network entities operating in what are similar spaces. In the view of this interviewee, if N4L (Network for Learning) and REANNZ were to merge, there would be reductions in corporate overheads and potentially other shared services that could be passed on to users.

LIC sees potential, but cannot yet justify investment

LIC has a specialist IT need in relation to biological research which often generates large scale data. With a 60 terabyte dataset and requirements to work out the genome sequence of all cows descended from bull sequence stage the task of sharing data is significant.

We heard at times that 500 GB of data can take three to four days to download and that successful download is not always guaranteed when transferring across sequencing centres. In that case, LIC indicated it would be cheaper to put the dataset on a hard drive and wait a week or so than trying to download. A high-speed network could do that within an hour.

Considerable planning is required in order for LIC to do anything involving large-scale data transfer, with a purchase order needing to be prepared for extra dedicated bandwidth. In addition, other measures such as creating holes in the firewall and negotiating security protocols for software are needed. The relatively low frequency of such needs means that a business case to invest in a high-speed network does not stack up, essentially trapping LIC in a low productivity environment.

The view was tendered that such investment could alter the deployment of resources, the benefits of which are not always factored into decisions (i.e. there is some degree of myopia in investment decisions). This may be because company communications and networking are configured for 'classical' IT operations involving steady streams and no outages, rather than the varied and capricious demands of researchers.

Appendix 3 International Comparison

Table 9 International Comparison of NRENs

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Country	Australia	Netherlands	Sweden	Canada	United States	New Zealand	United Kingdom	Germany	Pan European	Nordic countries	Kenya
Website	https://www.aarnet.edu.au/	https://www.surf.nl/en/	https://www.sunet.se/about-sunet/	https://www.canarie.ca	https://www.internet2.edu/	https://reanz.co.nz/	https://www.jisc.ac.uk/janet	https://www.dfn.de/en/	https://www.geant.org/	https://www.nordu.net	https://www.kenet.or.ke/
Established	1989	1986	1984	1993	1997	2005	1984	1984	2000 (predecessor DANTE was 1993)	1985	1999
Structure	Company	Co-operative: SURF has 3 branches which is an NREN, science e-infrastructure and HPC and ICT procurement for research and education	Government organisation - part of the Swedish Research Council	Corporation	Corporation	Crown owned entity	Charitable company limited	Registered association	Association	Company	Trust

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Structure	Company	Co-operative: SURF has 3 branches which is an NREN, science e-infrastructure and HPC and ICT procurement for research and education	Government organisation - part of the Swedish Research Council	Corporation	Corporation	Crown owned entity	Charitable company limited	Registered association	Association	Company	Trust
Type	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit	Not for profit
Business Model	Regional, national and international connectivity provider	National connectivity, connects to GEANT for international connectivity	National connectivity by SUNet, NorduNET provides regional connectivity which is connected to GEANT for international connectivity	Links 12 regional networks to form national backbone and provides international connectivity links	Provides regional, national and international connectivity	National and international connectivity	Regional and national connectivity, international provisioned by GEANT	National connectivity, international provisioned by GEANT	Connects NRENs across Europe to international NRENs	Connects Nordic countries, international connectivity through GEANT	National connectivity, regional connectivity provided by UbuntuNet which connects to AfricaConnect2 for international

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Shareholding /Ownership	38 Australian Universities and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) which is a government agency	69 members are co-owner of SURF: 14 research universities, 40 universities of applied sciences and 15 other institutions	SUNet is part of the Swedish Research Organisation which is a government agency within the Ministry of E&R and funds research and research infrastructure	I think its owned by the government	Owned by the 486 members and owns and operates the backbone infrastructure 318 Higher Education 43 Research & Education Networks (which connects to universities, schools, museums, libraries, non-profits) in those regions 65 corporations 60 affiliate and federal affiliate members	Owned by the Crown (Minister of Finance and Minister of Research, Science and Innovation	JANET (NREN) is owned by Jisc, a not-for-profit charitable company dedicated to research and education. It is owned by its members (representative members: Association of Colleges, GuildHE and Universities UK and institutional members which are all eligible higher and further education institutions)	DFN is owned by the registered association DFN-Verein, which sole mandate is to collect dues to cover the cost of running DFN. The members/users do not own the NREN as the acquisition of shares is restricted for institutions under public law	GEANT is owned by its core membership which are its 36 National NRENs and one representative member (NORDUnet)	Owned by the government of the 5 Nordic countries	Owned by the Trust, 5 "Founders" university and 5 individuals referred to as Trustees

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Pricing	AARNet is funded through member subscriptions determined by a formula based on an organisation's staff /student numbers, and research income. The annual fee is aligned to financial systems/budgeting of education institutions and includes only a very small component that is volume based. Subscription fees are paid by the institution but the benefits flow directly to individual researchers (unless an institution elects to undertake internal cost recovery).	Combination of flat fee and usage based fee but unsure of specific	The services of SUNET are government funded and connected organizations are charged for services.	Only pricing is if they want to be a member to cast a vote $2,500 per year otherwise government pays for it	R&E networks pay $13,415 each Affiliates pay from and corporations pay $2,555 to $60,910 depending on operating budget Higher Education pay between $11,800 and $97,500 based on their annual expenditure and their annual expenditure on R&D Pricing includes membership dues and network participation fees	Two main users: universities and CRIs. Universities pay the majority as largest users of data and CRI (and other parties) make up the rest of membership fees.	HE funding bodies contribute the majority of cost required to deliver core NREN services and HE institutions make up the rest. Pricing is based on the income, research income and student FTEs.	Not details on how costs are allocated as this is decided by the General Assembly but if we take the client institutions funding amount divided by the number of users, each institution on average pay ~115,000 euro	Most members pay both subscription and membership fees based on their GNI. Highest fee paid is DFN 2.05mil euro and the lowest being 36k euro. Eastern European countries have their subscription fees paid (95%) by the European Commission so only pay membership fees (highest fee being 33k euro)	Base costs are allocated based on country's GDP	Members pay a one-off fee to set up infrastructure and then pay an annual membership fee and then pay for the bandwidth they subscribe to

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Funding sources	Total: $86,393,075 AUD Service revenue (subscription, traffic, access): $70,398,902 (81%) Infrastructure revenue (as AARNet owns fibre): $11,988,367 (14$) Grants and contribution: $536,161 (>1%)	Total: 40.2 million euro Revenue from institutions: 28.14 million euro (70%) Governme nt: 10.854 million euro (27%) GEANT subsidy: 1.206 million euro (3%)	Total: 26 million euro Client institutions: 19.5 (75%) Government /public bodies (Swedish Research Council): 6.5 (25%)	100% funded by the government - ~$105 CAD million provided each year to support NREN	Total $78.1 million USD Network fees: $44.1 mil (56.5%) Member dues: $13.0 mil (16.6%) Trust and identity fees $6.1 mil (7.8%) Income from sponsored programs (government grants): $6.6 mil (8.5%) Other revenue: $8.3 mil (10.6%) Major infrastructure and international connectivity through NSF Grant is government grant for purchase and build of network for a total project cost of $96.8 mil	Client members Managed services Government	Total: 87.35 million pounds Higher education funding bodies: 76.88 m pounds (88%) Membership fees: 10.47 m pounds (12%) The higher education funding bodies are education funding councils across the UK. Membership /subscription fees paid for by Higher Education institutions (universities)	Total: 45 million euro Client institutions: 40.05m (89%) GEANT subsidy: 0.9m (2%) Other sources: 4.05 m (9%) Majority of funding is provided by the users	Current GEANT project is GN4-2. Duration of 32 months with a total budget of 96m euros with EC contribution of 59m euro. Subscription fees 24m euro Membership fees 1.6m euro	Revenue from members: 17m euro	

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Governance	Board of Directors - responsible for overall direction. Primarily made up of independent directors and VCs of stakeholder universities. AARNet Advisory Committee - provides technical and policy advice to the CEO. Representative of shareholders - there is a member from each state that work as the highest ranked IT position (such as Director, Information and Technology Management at the University of Canberra).	Members' Council: approves the financial statements, strategic and annual plans and appoints the Board. Consists of 33 members representatives Supervisory Board: supervises the 3 operating companies and ensure activities in line with cooperative 's objective Board: organisational policy and strategy	Committee for SUNet responsible for vision, strategy, operational planning and budget. Comprises 11 members nominated by Swedish Research Council, Association of Swedish HE Institutions, Swedish National Union of Students and National Library of Sweden. SUNet. institutions	Members $2,500 access fee and membership is made up of public and private participants and they get to cast one vote each in the governance of CANARIE (membership subject to approval by Board). Board members are elected by member votes. Mix of private (ie Google and IBM) and public (universities, regional LANs). Board decides on strategy and initiatives	Board of trustees elected by representatives from member organisations and include university presidents, CIOs, network researchers and industry partners. Provides strategic direction, leadership and oversight for Internet2.	Board/governance is appointed by shareholding ministers. Members do not provide insight into governance	Representative members hold 30% of the voting rights each, institutional member hold 10% of the voting rights. Each member appoints one person to the board and funders appoint one member to the board and the board appoints 6 further people with a mix of skills and experience	Representatives of the members decide on budget, share of cost, utilisation of services and elect three directors who conducts business of the association	Representatives of each country and also associates such as Cern or technology companies (Ciena) which is 36 countries, NORDUnet and 15 associates (52 altogether) elect members to the Board of Directors who manage and administer the organisation	Each country has one representative from their respective NRENs (CEOs) which manages the issues of NORDUnet	Board of trustees made up of five founding universities VCs, one private university VC , one public university VC, one CEO of research institutions, one Principal Secretary responsible for HE in Kenya, one head of ICT regulatory affairs, one from private sector. Management board: 5 from founding universities, two senior faculty from private and public university each, 1 research institutions, 2 by virtue of professional qualifications and develop policy and strategy and decisions

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Users	260	179	93	5929 (379 without K-12 schools)	93076 Community Anchor Institutions (from 2013)	39	616	348	37	5	131
User Composition	42 Universities 25 Further education 117 Secondary schools 1 Research institutes (note that CSIRO is Australia's national science organisation) 20 Libraries, museums, archives, cultural institutions 9 Non-university public hospitals 46 Government departments	54 Universities 47 Further education 37 Research institutes 7 Libraries, museums, archives, cultural institutions 19 Healthcare institutions 16 Other 250 schools provided with internet (secondary and high school but not part of core NREN per se)	39 Universities 2 Research institutes 33 Libraries, museums, archives, cultural institutions 19 Other	126 universities 144 Colleges 30 CEGEPS (pre university or technical colleges) 25 federal government research labs 46 teaching and research hospitals 10 business incubators/accelerators 48 government departments and agencies 5500 K-12 schools	Members 84146 K-12 Schools 4203 Public Libraries 1491 Colleges and Universities 799 community and vocational colleges 2237 Health Care Organizations 200 Museums, Science Centres, Zoos and Aquariums	4 universities 7 CRIs 13 polytechnics/ Wananga 15 other	188 Universities 358 FE 2 Secondary Schools 43 Research Institutes 4 libraries, museums, archives, cultural institutions 1 non university public hospital 11 government departments 4 international research organisation 5 for profit organisations	Universities, research institutions, trade and industry	36 European NRENs NORDUNet (which serves 5 Nordic countries) Connects over 10,000 institutions	Connects 5 Nordic NRENs (connects more than 400 R&E institutions)	88 Universities/Colleges 17 research institutions 14 government institutions 5 other (cultural, hospital etc)
FTE staff (permanent and contractors)	85	148	50	34	??	29	545	55	100	Unsure but small team	19

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Fibre arrangements	Purchased dark fibre from NextGen who was going into receivership at below market price	Leased dark fibre (doesn't say IRU) for 15 years (optical network owned by SURFNET)	IRU dar kfibre for 15 years (optical network owned by SURFNET)	Hybrid - both lease and purchase dark fibre	Internet2 established FibreCo, non-profit, that holds their dark fibre assets	25 IRU dark fibre, own 25% optical	Leased dark fibre (JANET owns optical)	Leases dark fibre long term, own and operate equipment	8+2 year dark fibre lease, unsure of optical network ownership	Long term lease on dark fibre	KENET owned fibre through government fibre (NOFBI) and other ISPs. Total lease capacity is 30858 mbps
Network fibre	9,600km in country 38,900km outside country	13,556 in county 100 km outside country	8,200 in country 20 km outside country	31,000 km in country 2043 km outside country	25294km in country ?? Out of country	~5000km in country ~ 15,000km out of country (Hawaiki)	9,000 in country 100 out of country	10500 km in country 20 km out of country	?	?	NA
Typical usable capacity in backbone (Gbit/s	100	40	100	100	100	10	100	100	100	100	Dependent on subscription. Highest capacity available is 10Gbps
Traffic volumes (TB)	Traffic to and from NREN customers: 12645 Traffic to and from external networks (commercial, exchanges, peering, other NRENs): 199015	Traffic to and from NREN customers: 202982 Traffic to and from external networks: 181814	Traffic to and from NREN customers: 105195 Traffic to and from external networks: 10083 (low as NREN customers are also NorduNET)	Traffic to and from NREN customers: 72986 Traffic to and from external networks: 81946	??	within NREN: 41200 (majority user is Massey) external: 18000		Traffic to and from NREN customers: 400195 Traffic to and from external networks: 421103	1752000 approx	?	

	AARNet	SURFNet	SUNet	CANARIE	Internet2	REANNZ	Janet/JISC	DFN	GEANT	Nordunet	KENET
Ratio of commodity vs R&E	6% vs 94%	78% v 22%	All R&E	Not available	??	34% v 66%	Unknown	No commercial 0%	Depends on what the NRENs are sending but only services R&E	?	?

All figures from 2016/2017 unless stated