**Please note:** the substantive content of the 2026 NRI Roadmap Survey begins at Question 20 (with prior questions dealing with administrative and other information).

As such all submissions that are published include the responses submitted from Question 20 onwards only.

*Q20.*

## Part 2: Research themes

2.1 NRI comprises the assets, facilities and associated expertise to support leading-edge research and innovation in Australia and is accessible to publicly and privately funded users across Australia and internationally.  We are seeking your input on possible directions for future national-level investment - i.e., where the requirements are of such scale and importance that national-level collaboration and coordination are essential.

The 2021 Roadmap used a challenge framework to support NRI planning and investment. With this in mind, consider likely future research trends in the next 5 - 10 years, and with respect to one or more of the 8 challenge areas identified in the 2021 Roadmap as listed below:

- describe emerging research directions and the associated critical research infrastructure requirements that are either not currently available at all, or not at sufficient scale and
- describe current national infrastructure requirements that you anticipate will no longer fit the definition of NRI in 5-10 years.

Do not limit your commentary to NCRIS funded capabilities.

*Q21.*

### Resources Technology and Critical Minerals Processing

*Q22.*

## Food and Beverage

Environmental variables play a natural and critical role in agriculture and agribusiness. Variables such as temperature and rainfall affect crops, livestock and water availability; forest cover affects temperature and carbon sequestration; groundwater levels affect salinity; climate change affects land use and land suitability; bushfires affect water quality which in turn affect seafood businesses. Despite the widespread and year-round impact of environment on food and beverage, data from TERN monitoring for this sector is largely restricted to Qld due to that state being the sole co-investor in ag monitoring.

*Q23.*

## Medical Products

*Q24.*

## Defence

*Q25.*

## Recycling and Clean Energy

*Q26.*

## Space

TERN has multiple links to international scientists and agencies involved in cal/val networks as well as for specific satellite missions. These collaborations have primarily focused around TERN SuperSites. The TERN SuperSites are also linked to the broader Australian Ozflux network, and the international FluxNet, which is also recognised as a reference network by the international Committee on Earth Observation Satellites Working Group on Calibration and Validation (CEOS WGCV). The TERN SuperSites have achieved international recognition because they strongly meet these criteria: the sites include flux and meteorological measurements and measurements of ecological variables including vegetation structure and composition, measurements are consistent, following national or international protocols, and the operations and infrastructure have now been supported for many years. The Australian sites are also important in global networks because they represent unique ecosystems including evergreen Eucalyptus forests and woodlands and arid and semi-arid woodlands and shrublands. Ideally, TERN seeks to extend the sites in its network that meet international best practice standards to be used for cal/val, which would necessitate more regular vegetation inventory updates accompanied at the same time by terrestrial and Aerial lidar scans (TLS and ALS).

*Q27.*

## Environment and Climate

Environment and climate challenges have seen the emergence of continental and global scale ecosystem research, otherwise known as macrosystem ecology. This new field of environmental and climate science has been made possible by the advent of national ecosystem research infrastructures such as TERN Australia with its multi-scale, multi-disciplinary ECRI datasets. The combination of long-term datasets and field-based infrastructure are the key to working at regional and continental scale, effectively incorporating observational data into multi-scale modelling and artificial intelligence (AI) frameworks. Integration and harmonisation of cross domain data are leading to changes in ecological science itself, and in turn, it is driving further changes to infrastructure, culture, and training. The ultimate and shared goal of macrosystem ecologists is a need to understand the resilience and predict the outlook for Australian ecosystems. The ability to develop hypotheses and forecast trends even just for the coming 5-10 years would inform countless studies that explore the uniqueness of Australia's biocomplexity. As a multi-decadal observatory of environment and climate change, TERN has no redundant infrastructure - every environment-climate researcher in Australia wants more data and from more contexts for multi-scale modelling and artificial intelligence (AI) frameworks. The diversity of end users and their different domains of research mean that TERN datasets are used in a multitude of different contexts over very long time periods, reinforcing the cost-effectiveness of the national ecosystem observatory. However, NRI investment to date has left gaps in ecosystems monitored, inhibiting researchers' capacity to build a more complete understanding of biocomplexity for modelling and prediction. For example, integration of catchment processes and associated freshwater biodiversity into TERN's monitoring framework is missing. Small headwater streams, which often fall within the footprint of TERN flux towers, are incredibly important components of terrestrial environments – yet they are under-monitored in Australia. These systems play a key role in both carbon and water cycles and integrating them into TERN's infrastructure would provide a more complete picture of both carbon cycling and hydrological connectivity. Doing this would also align with international best practices as is done in networks such as NEON and ICOS, which all incorporate a riverine component. Other gaps are to use TERN monitoring for climate data capture related to agricultural, urban and groundwater dependent ecosystems. Some of this infrastructure gap could be cost-effectively provided by UAVs and an array of specialised sensors, which are rapidly developing as an important part of Earth Observation cal/val programs, alongside the gold standard mentioned in other Roadmaps, but not yet funded, expansion of the TERN flux network.

*Q28.*

## Frontier Technologies and Modern Manufacturing

*Q29.*

2.2 The 2024 statement of National Science and Research Priorities (NSRPs) includes outcomes linked to each priority to assist in identifying critical research needed in the next 5 to 10 years.
Consider the priority statements and, with respect to one or more of the 5 priority areas as listed below:

- describe emerging research directions and the associated critical research infrastructure requirements that are either not currently available at all, or
- not at sufficient scale and describe current national infrastructure requirements that you anticipate will no longer fit the definition of NRI in 5-10 years.

Do not limit your commentary to NCRIS funded capabilities, and where relevant, refer to the underpinning outcomes and research identified in the NSRPs document.

*Q30.*

## Transitioning to a net zero future

Net zero requires baseline data and standardised monitoring protocols so that performance against targets can be evaluated. Australia does not have any credible monitoring in urban environments to match international best practice initiatives (e.g., ICOS Cities and Ameriflux Cities) and it does not have all agricultural landscapes covered. TERN has 25 years of expertise of systematically monitoring fluxes but its infrastructure is not at sufficient scale yet to provide the necessary monitoring for industry and govt. It also has well established training and standard operating protocols in place which could be scaled to new industries. TERN's blue carbon monitoring network along Australian coastlines is also not yet at the scale needed for all coastal wetlands. The agriculture sector is our second highest greenhouse gas emitter when measured on a carbon dioxide equivalent basis. Agricultural soils are a major source of carbon dioxide, which is not a problem providing output balances input i.e., from plant uptake or addition of carbon. Instruments on flux towers operated by TERN measure the real-time exchange of gases (especially CO2), water and energy between plants, soil and air. The TERN flux network, already of world-class capability, could potentially be expanded, Tower measurements are more efficient, more accurate, and more reliable than traditional soil sampling, also fairly low cost by comparison. They are very low maintenance too. The TERN flux towers integrate data from a wide area (10-50 hectares), negating the inherent problem of local soil variability. Flux towers also measure albedo (reflectance), which indicates pasture palatability, and evapotranspiration, which indicates the efficiency of water usage. The data these instruments gather help refine soil carbon-cycle models as well as provide basic information to landholders to inform management decisions both now and into the future. We would need to scale up the current investment into TERN so it could routinely cover agricultural sites.

*Q31.*

## Supporting healthy and thriving communities

The environment has a huge impact on the health of the Australian population. The World Health Organization (WHO) puts a changing climate as one of the most important health risks of the future (WHO, 2020). However, national environmental datasets are required in order to quantify the true magnitude of these health effects, predict future health impacts in Australia, and target geographic areas at greater risk in order to provide more targeted, cost-effective mitigation and management. Research groups across Australia are investigating the impact of extreme weather events such as heatwaves, droughts and forest fires on chronic and acute respiratory illnesses, hospitalisations and deaths. Air pollution is one of the most important environmental risk factors associated with human health, killing about 3000 people (28,000 years of life lost) per year and costing around $11-24 billion per year from mortality alone (SOE Report, 2016). Air quality is an environmental variable in its own right and is strongly linked to other environmental variables: vehicle pollution is directly impacted by temperature, humidity and rainfall; air quality is directly influenced by environmental imposts such as bushfires; pollen is associated with vegetation and is spatially and seasonally variable. Climate, vegetation and other environmental factors are also strongly associated with the increased spread of vector-borne diseases. With the changes in climate that are conducive to expansion of vectors such as mosquitoes, the imperative to monitor is even greater. Environmental factors like temperature and rainfall and their interaction have been highlighted as drivers of the spatial and temporal spread of pandemics. Without a nationally distributed monitoring facility such as TERN, there will always be a large blind spot in Australia's ability to effectively monitor and predict environmentally-oriented health issues. This severely limits the identification of regionally-targeted mitigation strategies and impacts. The investment in research infrastructure for health purposes is not overwhelming - it is just a matter of deploying specific sensors such as Microsoft's Premonition sensors to complement TERN's existing site-based infrastructure across the nation.

*Q32.*

## Elevating Aboriginal and Torres Strait Islanders knowledge systems

With respect to providing data from national ecosystem monitoring, a first step is to recognise not only the urgent need to provide the data, evidence and tools to manage and adapt to dynamic change into the future, but also, that Aboriginal and Torres Strait Islander people have legally recognised rights in over 3,000,000 km2, or 40% of Australia’s landmass, in addition to extensive sea rights. Indigenous people own and manage Indigenous Protected Areas comprising 44% of the entire National Reserve System, or 8% of the Australian landmass. Tenure regimes such as Native Title furnish Traditional Owners and custodians with explicit bundles of rights that include responsibilities for land and resource management. What happens on these lands and waters determines Australia’s ability to maintain ecosystem function and biodiversity as well as national cultural and linguistic diversity and plays a crucial role in delivering on international and national efforts to mitigate anthropogenic climate change. NRI must make Indigenous Australian practices, knowledges and science central to its national ecosystem observatory (TERN), either directly (through appropriate funding) or through partnerships with initiatives that are already working successfully on Country. These include the NESP Resilient Landscapes Hub and the ARC Centre of Excellence for Indigenous Environmental Histories and Futures.

*Q33.*

## Protecting and restoring Australia’s environment

Australia is endowed with diverse terrestrial, aquatic and marine ecosystems that deliver immense public benefits when managed appropriately, and huge costs when impaired. Unfortunately, much of Australia’s natural capital has already been degraded and is subject to on-going stressors such as continuing development, invasive plants and pests and climate change-driven weather extremes such as drought and fire. It is widely accepted that we will lose more of our precious ecosystems unless we manage them more sensitively and improve their resilience. Thus, contemporary management of these ecosystems involves assessment, regulation, conservation and restoration, guided by State and Commonwealth legislation and agency functions and considerable investments. Government agencies responsible for these ecosystem management functions are required to assess how the cumulative effects of proposed developments, other disturbances and specific management interventions will affect these ecosystems. Many of these agencies advise that they lack the knowledge and tools to adequately forecast such impacts, resulting in assessment processes that are far more costly, lengthy, risky and opaque than they should be. Accordingly, they have called for major improvements in environmental data and prediction technologies. Redressing these shortfalls in national capability will not happen without targeted planning, collaboration and investment. Amongst the many groups that are needed to rise to the challenge is the Australian research community. Their role is to advance our scientific understanding of ecosystem function and response to stress, to instantiate that knowledge into predictive models and to assist end users to translate research outputs into decision support tools. A close working relationship with end users is necessary to ensure that the research focuses on the highest priority geographies, the ecosystems most at risk, the disturbances that are most problematic and the management interventions that are most effective. Continues NRI funding for TERN with additional investment in ecosystem gaps would produce the necessary transformation in transdisciplinary environmental research by enabling ecologists, computer scientists, environmental modellers and statisticians to co-develop the next generation data sets and models required that will underpin improved management of Australia’s terrestrial ecosystems, and ultimately, other environmental domains.

*Q34.*

## Building a secure and resilient nation

Almost all plant and animal pest incursions are driven by environmental factors. Surveillance systems are crucial to monitor and predict the risk of arrival and spread of these diseases. These systems rely on the availability of relevant environmental data at appropriate scales. Since they often need to be developed urgently, these data and attendant information need to be immediately available. Unfortunately, this is not often the case. With its national footprint, TERN has potential to provide appropriate surveillance. It already has the capability to provide the Threatened Species Index to Australia and could complement this with surveillance necessary to develop and maintain the national Invasive Species Index.

*Q35.*

2.3 The case for a new NRI capability, or enhancements to existing capabilities, typically emerges through advocacy from research communities clustering around rigorously identified needs and goals. Such a concept could respond to a requirement for novel or expanded capacity within a domain, or across domains, and must be such that it could only be made available with national-level investment.
If you have identified such a requirement, briefly describe the need, the proposed infrastructure capability, the medium-term goals, impacted research communities, and the timeframe over which you advocate its establishment. Your response can include links to relevant existing reports.

Despite the achievements and reputation of our environmental science researchers, our abilities to simulate ecosystem functions and predict how they might respond to future disturbances remain quite immature. This is an area of environmental science where all countries are struggling, mainly because it lies at the intersection of the biological, physical, chemical and data sciences, and few programs of sufficient scale exist to support such collaboration. To advance this area of science, Australia must find a way to engage scientists of diverse abilities using innovative digital approaches. The Environmental Futures Lab (EF-lab) is proposed as the catalyst for realising this ambition. It is anticipated EF-lab could receive project governance oversight from NEESFF - the National Earth and Environment Scientific Facilities Forum, providing incubation, training and translation services. In the ECRI space, EF-lab would sit alongside and complement ACCESS-NRI, which provides climate scenarios based on use of research infrastructure comprising coupled models. The community serviced by and contributing to EF-lab would be - model developers working on best-practice multi-domain model development and integration to minimise uncertainties - field ecologists and theoreticians playing key roles in conceptualisation and validation activities to build and extend prediction capabilities - environmental planners and regulators guiding the work toward critical information gaps and prediction needs and thereby contributing to focused research questions - policy makers and researchers defining prediction parameters - policy and decision-makers seeking and developing solutions to complex questions - technical experts working on system-of-systems interoperability. Examples of forecasting innovation outcomes are: 1. Predicting impacts of future fire regimes. 2. Predicting effects of interventions for preventing extinction of endangered species. 3. Predicting changes in vital soil nutrients and plant carbon in response to climate change. 4. Analysing interactions among climate change and the threatening processes of invasive species, fire regimes and habitat loss. 5. Predicting ecosystem change under cumulative impacts of development. Transformation of forecasts into a rigorous, scientific endeavour has only recently been made possible through: - observing capacity of operational satellites from which Australia acquires data streams - the long term national observing projects covering land, bedrock to atmosphere, coasts and oceans - ubiquitous and cost-efficient cloud computing and data storage - high-performance computing for modelling of complex, dynamic systems - machine learning and AI for mining of large quantities of data. Data and a range of analytic tools from existing NCRIS-enabled research infrastructure projects provide a low-risk foundation for building and operating the EF-lab. EF-lab is nevertheless a new capability because existing capabilities lack environmental prediction expertise, in either their own domain areas or synthesised across domains. They also lack delivery into new scales (the very large and very small) and incorporation of new processes, such as dynamic evolution, for addressing national challenges. The build stage for EF-lab would be 12 months during which time, governance, business processes, partner agreements, employment, data sharing agreements, licences, QA/QC systems, engagement plan, working groups and similar would be established alongside completion of arrangements for: a. Data access b. Data as a Service (DaaS) c. Modelling frameworks d. Client applications e. Community consultation

*Q36.*

# Part 3: Industry perspectives

**This section is seeking input specifically from industry-based respondents. Other respondents can skip this section.**

Recommendation 6 of the [2021 Roadmap] related to improvements in industry engagement with NRI. To complement work on this topic that has occurred since then, we are seeking additional advice on NRI requirements as perceived by current or potential industry-based users.

*Q37.*

3.1 Have you (or your organisation) interreacted with or used Australia's NRI?

- ◯ Yes
- ◯ No

*Q38.*

3.2 If so, please briefly outline the NRI capabilities you (or your organisation) have interacted with or used. Do not limit your response to NCRIS capabilities.

*This question was not displayed to the respondent.*

*Q39.*

3.3 Please indicate your (one or more) primary reasons for interacting with NRI:

*This question was not displayed to the respondent.*

*Q40.*

3.4 If you answered no, please indicate your (one or more) primary reasons:

*This question was not displayed to the respondent.*

*Q41.*

## Part 4: Other comments

4.1 Please elaborate on any of your above responses or add any other comments relevant to the development of the 2026 Roadmap. Your response can include reference or links to existing reports that you recommend be considered during the 2026 Roadmap development process.

In an analysis of all previous NRI Roadmaps, TERN found recurring themes that are still NRI gaps. These, interestingly, coincide with gaps identified during TERN's community consultation with researchers and so, unsurprisingly, align with and reinforce the answers TERN has given in this survey. These are: Freshwater – Observation/monitoring, experiments, characterisation, links to ocean and agriculture Satellite – Continental-scale observation, higher temporal resolution, and Cal/Val Managed landscapes – Observation and monitoring Biocomplexity – Cross-domain interoperability, modelling, critical ecosystem observation/condition monitoring, characterisation Climate-integrated data and analytics (e.g., ClimateRI) Biosecurity-integrated data and analytics Predictive environmental analytics (e.g., NEPS) Analytics for translation – Standardised/shared methods, user-ready data, national reporting Linking physical collections to characterisation NRI Some RI needs identified in the ecosystem community consultations that have not previously been included in Roadmaps are: Biodiversity markets AI/ML characterisation – Remote-sensed and ground-sensor observations Indigenous capability building – On-country monitoring. Furthermore, looking across past Roadmaps, it’s clear that expectations for environmental NRI have been ambitious from the outset. Goals like integrated and harmonised data or predictive analytics have been on the NRI table since 2008. Since the systematically collected ecosystem data did not previously exist and has required establishment of a physical monitoring network and data infrastructure, and an identifiable community as first steps, the target for environment NRI has been far more ambitious than the ‘next step’ approach seen in areas like characterisation. The perception therefore is that environmental NRI may appear to have made less progress / had little impact in nearly two decades, even though the real challenge has been one of scale and complexity rather than a failure to deliver.

*Q49.*

4.2 Optional Document Attachment.
Note: Our strong preference is that answers are provided against the relevant questions in the survey. However, this file upload option is available for submissions in file format, where needed. Please ensure the document includes your name or organisation.