



Informing strategic development of a national climate services capability for Australia

A report by the National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub for the Department of Agriculture, Water and the Environment on behalf of the (former) National Climate Science Advisory Committee

April 2021

Earth Systems and Climate Change Hub Report No. 19

The Earth Systems and Climate Change Hub is supported by funding through the Australian Government's National Environmental Science Program. The Hub is hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and is a partnership between CSIRO, Bureau of Meteorology, Australian National University, Monash University, University of Melbourne, University of New South Wales and University of Tasmania. The role of the Hub is to ensure that Australia's policies and management decisions are effectively informed by Earth systems and climate change science, now and into the future. For more information visit www.nespclimate.com.au.

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Citation

NESP Earth Systems and Climate change Hub. 2021. *Informing strategic development of a national climate services capability for Australia*. Earth Systems and Climate Change Hub Report No. 19. Earth Systems and Climate Change Hub, Australia.

Contact

Enquiries regarding this report should be addressed to:

Geoff Gooley

CSIRO

Geoff.Gooley@csiro.au

Published April 2021

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Acknowledgements

Lead authors (Earth Systems and Climate Change Hub and affiliates): Geoff Gooley, Kevin Hennessy, Neil Plummer and Roger Street

Contributing authors (Earth Systems and Climate Change Hub): Rebecca Gregory and Sonia Bluhm

The authors would like to acknowledge the helpful insights and constructive feedback from various stakeholders and domain experts from across government, industry, academia and the community during the course of this project.

We would particularly like to acknowledge Professor David Karoly, CSIRO Climate Science Centre and Leader, National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub for reviewing the final draft report, and Anthony Swirepik, Paul Mattiazzi and Will Howard from the Department of Agriculture, Water and the Environment (DAWE) who provided helpful guidance and feedback throughout the project.

This project was delivered by the NESP ESCC Hub as part of the 2020 Annual Research Plan Version 6 and funded by DAWE.

Executive Summary

Climate variability and change pose risks to the Australian economy, environment and society. A properly coordinated and resourced national climate services capability delivering climate data and information to inform decision-making can help mitigate these risks.

What are climate services?

Climate services are the means by which climate knowledge, in the form of scientific data, information and analyses, is turned into ‘actionable knowledge’, in the form of tools and other information products and services, for end-users.

The European Union Roadmap for Climate Services defines climate services as:

“... the transformation of climate-related data – together with other relevant information – into customised products such as projections, forecasts, information, trends, economic analyses, assessments (including technological assessments), counselling on best practices, development and evaluation of solutions and any other services in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management.”

Climate services consist of the generation and provision of a wide range of data and information on past, present and future climate; development of decision support tools and other products that help improve the understanding of climate and its impacts on natural and human systems; and technical support for the application of these data, information, analytics and other products for decision-making in all walks of life and at all levels of society.

Depending on user needs, these data and information products may be combined with non-meteorological data, such as agricultural production, health trends, population distributions in high-risk areas, road and infrastructure maps for the delivery of goods, and other socioeconomic variables. In a number of areas, global cooperation and research on hydrometeorological and climate services is moving towards a seamless framework with advances in development and delivery of climate services relevant across multiple time scales; with potential for improving predictive accuracy and increased lead time, facilitating applications in a wide range of user sectors.

Why do we need climate services?

The primary purpose of national climate services capability is to help mitigate sovereign risk and thereby create value for all stakeholders in the form of sustainable environmental, economic and social outcomes; in particular through:

- increasing awareness and building capacity to better understand and inform climate action, and
- provision of relevant, usable, legitimate and credible, *science-based evidence for decision-making*.

Market demand for climate risk guidance is growing in the public and private sectors. This demand is driven by government, business and community awareness of the physical risks and impacts of climate change and variability, including weather and climate-related natural disasters. In the corporate world, regulators, finance providers and insurers increasingly seek disclosure and reporting of companies' climate risks; the latter of which are expected to be a mandatory, regulatory requirement in the near future. It is also the case that investment in climate services can provide tangible, macro-economic benefits at a national scale.

The *National Disaster Risk Reduction Framework* recognises the need for up-to-date climate information tailored to providing decision-makers with an accurate picture of current future natural hazards. Globally, the *G20 Task Force on Climate-related Financial Disclosures* (TCFD) is developing voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders.

The TCFD recommends organisations assess their climate-related risks, including vulnerabilities to the physical impacts of climate change. In Australia, the Australian Prudential Regulation Authority has provided similar guidance on climate risk disclosure.

User needs for climate services are context-specific and need to be met by tailored products and services beyond those available 'off-the-shelf' from platforms and applications usually provided by government scientific agencies. Users are looking for authoritative, credible, accessible and relevant climate products and services to meet their specific needs for climate risk management and adaptation planning.

The *Australian National Climate Science Advisory Committee* (DAWE, 2019) concluded that the value of climate science to Australia could be greatly enhanced by climate services. A national climate services capability would provide decision makers with tailored climate risk information. Broadly, climate services make climate information and analyses useful and useable as an evidence base for decision-making. Through climate information products tailored and differentiated for specific sectors and industries, climate services can provide the insight decision-makers need to manage interactions between climate risk and their sectors' or industries' activities. This understanding is crucial to building resilience through policy development, adaptation planning, risk assessment and investment.

What are the elements of climate services?

A national climate service capability for Australia would have the following elements:

- Guidance on building climate resilience, delivered through climate risk assessments, climate risk management frameworks or other formats.
- Data and information to support climate impact assessment and adaptation.
- Tools to support planning and decision-making in the context of climate risk.
- Enabling capabilities including knowledge brokering, capability development, case studies, training, communication activities and communities of practice.

What climate service resources does Australia have?

Australia has a strong base on which to build climate services, in the form of our already-substantive climate science and services capabilities. Our world-leading climate science enterprise places Australia at the forefront of understanding our changing climate. Our nascent climate service capabilities have this authoritative, underpinning science foundation. We have world-leading climate research infrastructure and institutions in science agencies and universities, including the CSIRO Climate Science Centre, the ARC Centre of Excellence for Climate Extremes, the Bureau of Meteorology, the Australian Community Climate and Earth System Simulator, the Integrated Marine Observing System, among other core capabilities.

Australia has a range of existing climate services in the form of platforms and guidance products available for users to help assess and manage climate risk, and to inform the development of adaptation strategies. These include Commonwealth-supported platforms and products such as *Climate Change in Australia*, *CoastAdapt*, and *Climate Compass*. State and Territory governments, in collaboration with universities and science agencies, have built climate information platforms delivering projections and analyses. These include Queensland's *Long Paddock*, *Climate Futures for Tasmania*, New South Wales's *NARCLIM*, and Victoria's *Climate Projections 2019*.

What would an enhanced climate services capability for Australia look like?

An enhanced, nationally coordinated climate services capability would provide a more effective and efficient link between providers and users of climate information through public and/or private sector 'purveyors' (intermediaries). It would elevate users into the governance arrangements for the national capability and prioritise user needs for decision-making. It would also link core products and services such as climate observations, model-based projections and related assessments with differentiated products and services such as decision support tools and climate risk assessments tailored for specific businesses, industries and sectors.

Providers of climate services have historically been agencies and institutions who generate climate information and analyses in the form of data, forecasts or outlooks, and projections. In Australia this role has been filled by agencies such as the Bureau of Meteorology, the CSIRO, university research groups, and research collaborations such as the Antarctic Climate & Ecosystems Cooperative Research Centre, along with various State and Territory governments. These providers mainly deliver core products and services for the most part publicly funded for the primary purpose of public good.

Purveyors of climate services add value to existing data, information, analytics, tools and other products with expertise including in knowledge brokering, translation and exchange to provide value-added services and products targeting specific users. This role may be played by the public sector (e.g. universities) or the private sector (e.g. consultants) or both in collaborative partnerships. Likewise, the delivery of climate services via States and Territories has the ability to prioritise end-user needs for communication and engagement activities given the key role they play in community engagement, social licence and behaviour change for resilience and adaptation

Differentiated products and services would be delivered by climate service providers primarily for end-users in non-profit and for-profit organisations and would serve users' sectoral needs and the time scales on which they need to make decisions.

An enhanced national climate services capability would strengthen existing capabilities of public and private sector providers and purveyors, by providing a strategic framework and operational business model as a means for better planning, coordination and resourcing across existing and new and emerging capabilities. It would provide a 'space' in which public and private provision of climate services interact to facilitate innovation, with the private sector purveyors expected to play a greater role as services become more specialised and differentiated by sector or industry.

What do we need to build an enhanced national climate services capability?

Australia would need:

- Governance mechanisms to facilitate coordination and alignment between providers and purveyors, and integrate existing climate products, services and platforms:
 - A new national centre could help facilitate coordinated development and delivery of climate services across multiple actors including core, differentiated and underpinning capabilities.
- A group to manage the boundary conditions between the fundamental science, the users and the national capability:
 - National Climate Science Advisory Committee (DAWE, 2019) recommended the establishment of a Climate Science Advisory Group to support such a role through provision of high-level advice on and coordination of Australia's climate science effort.

- User, purveyor and provider capacity for practical applications to address current and future climate risk.
- Standards for delivery, presentation, and analysis of climate data and projections.
- Availability of detailed scientific knowledge about potentially damaging and dangerous current and future extreme weather events.
- Agreed standards for suitable decision-support tools, and
- Knowledge-brokers, resources for capacity-building, guidance material and communities of practice.

1 Introduction

Climate variability and change present a range of risks for our society, economy and environment (Reisinger et al., 2014; BoM and CSIRO, 2018; IPCC, 2018; Climate Council, 2019). Australia and other parts of the world have seen the acute impacts of more heatwaves, droughts, fires, floods and storms against a background of chronic increases in temperature, sea level and ocean acidification. There is a compelling need to better understand these impacts and associated risks and thereby to inform 'climate action' in relation to both adaptation and mitigation. As demonstrated by the 2019-2020 fires in Australia, extreme weather events have compounding and cascading impacts that test our resilience and highlight the need for better risk management.

International policy frameworks driving the need for climate risk management and by association science-based services to inform decision-making include the UN Agenda 2030 Sustainable Development Goals, the Paris Agreement (UNFCCC, 2015), the Sendai Framework for Disaster Risk Reduction (UNDRR, 2018) and the Global Framework for Climate Services (2014). In relation to the present study, the most directly relevant national policy settings include various Federal, State and Territory climate resilience plans e.g. *National Climate Resilience and Adaptation Strategy* (Australian Government, 2015a), the *National Disaster Risk Reduction Framework* (Australian Government, 2018), and the report on *Climate Science for Australia's Future* (NCSAC, 2019). Although more broadly relevant at an international level, the *Taskforce on Climate-related Financial Disclosure* (TCFD, 2017) has also impacted directly as a nationally relevant market driver on Australia's private sector, and in particular for large, publicly listed corporations.

2 Present study

The National Climate Science Advisory Committee (NCSAC) prepared the report on Climate Science for Australia's Future (DAWE, 2019). The report provides strategic advice to the Australian Government on a nationally aligned and integrated approach to climate science, which will inform the direction and sustainability of Australia's climate science capability and research priorities. The purpose of the advice is to:

- Advise the Government on the development of a strategy for climate science in Australia, including:
 - Australia's climate science priorities, capabilities and resources, including a stock-take of existing capabilities and options for addressing any gaps.
 - Consolidation of commitments from key climate science delivery agents for current and future resourcing of the strategy.
 - Ongoing climate science community coordination arrangements.
- Provide an ongoing forum to coordinate and drive local and international collaboration across key climate science agencies, investors and users of science.
- Promote Australia's climate science research capability with both Australian and international stakeholders.

The NCSAC report describes ten strategic actions designed to build on current strengths and to realise the full benefits of the Australian climate research capability and knowledge. While all strategic actions in that report are relevant to the present study, in relation specifically to climate services, the report refers to:

Action 6) *The (proposed new) National Climate Science Advisory Group should consider the potential for the future integration of climate projections and data services, including:*

6a) *the costs, benefits and risks of combining seasonal and regional scale projections in a nationally consistent framework;*

6b) *exploring the potential for integration of climate data and projections with other Earth Systems information to enhance the relevance and utility of the climate information; and*

6c) *identifying opportunities for co-design with business and community end-users in the development of supporting tools and systems.*

Action 7) *The Earth Systems and Climate Change (ESCC) Hub of the National Environmental Science Program (NESP), in conjunction with key partners in the Bureau of Meteorology, CSIRO and the university sector, should prepare an initial report on options for building a national climate service capability that would provide decision-makers with climate risk information tailored to their organisations and sectors:*

7a) *The ESCC Hub and partners should report to the Advisory Group on their findings by June 2020; and*

7b) *The provision of comprehensive knowledge brokering and climate services needed by industry, government and the community to manage risks of a variable and changing climate should take account of the initiatives and ongoing work of key research agencies and institutions and state and territory governments.*

The NCSAC (DAWE 2019) concludes that the value of climate science to Australia can be greatly enhanced through climate services. To ensure public and business sectors can derive maximum value from the science, the entire pipeline needs to be supported.

The Terms of Reference for this study (see Appendix) require preparation of “..a report on the development and implementation approach for a national climate service capability that would provide decision makers with climate risk information tailored to their respective organisations and sectors..”. The remainder of this report describes:

- Climate services, platforms and knowledge value chain
- Value proposition and vision
- Methodology
- Current state of Australia’s national climate services capability
- Vision for the future state of Australia’s national climate services capability
- Next steps

This study is being complemented by a concurrent study on behalf of the NCSAC and under direction of DAWE designed to elucidate the requirements for ‘Next Generation Climate Projections for Australia’ (Box 1; DAWE 2019).

Box 1: NextGen projections for Australia (DAWE, 2019)

Climate projections data must provide an evidence base for Australian stakeholders to assess important existing and new questions such as—what if the world does (or does not) meet the Paris Agreement targets? What if climate engineering is employed? What if multiple climate extremes occur concurrently and stress-test our systems?

The next generation of Australian climate projections will need to assess and utilise the expanding range of inputs to get maximum benefit from the latest developments and meet growing needs. New data sources generated in Australia or from international programs include observed *in situ* and satellite datasets, new reanalyses and new climate model simulation ensembles from Global Climate Models and high-resolution model inputs from the current CMIP6 projects. Downscaling and high-resolution modelling is moving to greater coordination, and Australia should adopt this approach, including participating fully in the CORDEX and CORDEX2 programs for intermediate downscaling, and having a coordinated program for very high resolution modelling (grid size of 5 km to below 2 km) for specific applications, such as extreme events, rainfall and urban climate.

Australia needs to use the latest science, digital platforms, ‘big data’ management practices and delivery models to provide climate change data and information tailored to the growing range of stakeholders that now includes private industry and consultants. This delivery requires researchers to engage more deeply and earlier with end-users than they have previously. Data platforms must be compatible with other datasets and platforms needed to address climate change risks, such as socio-economic vulnerability, exposure, land use and physical infrastructure data. A crucial component is the provision of different levels of information, knowledge brokering expertise, guidance and protocols for applying climate information and data. There is an increasing demand for these services in response to an increased awareness of risk, legal liability and social-license-to-operate regarding climate change impacts.

3 Climate services, platforms and knowledge value chain

In simple terms, climate services are the means by which climate knowledge, in the form of science-based data, information and analyses, is turned into ‘actionable knowledge’, in the form of management tools and other derived information products and services. The latter are then applied by end-users to achieve tangible impacts (on-ground practice change). This latter step is usually facilitated through some form of knowledge brokering and/or exchange (outreach) between service providers and end-users (of the services); all of which makes up the so-called conceptual climate knowledge value chain (Figure. 1) complete with user engagement feedback loops.

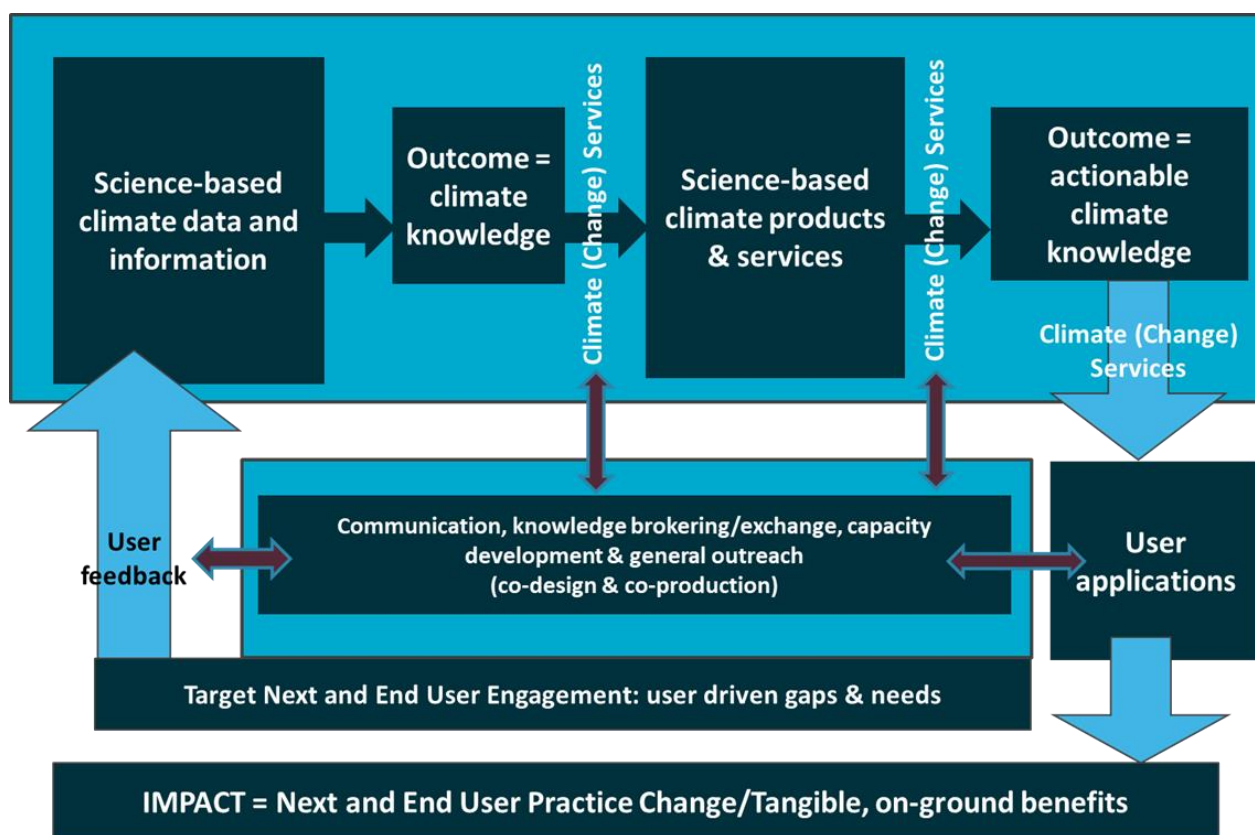


Figure 1: Conceptual characterisation of a climate services knowledge value chain.

There is no single and unambiguous, formal definition of climate services in the literature; mostly because the development, delivery and application of climate services is highly context specific.

The European Union Roadmap for Climate Services (European Commission 2015) defines climate services as:

“... the transformation of climate-related data – together with other relevant information – into customised products such as projections, forecasts, information, trends, economic analyses, assessments (including technological assessments), counselling on best practices, development and evaluation of solutions and any other services in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management.”

In a similar fashion, the World Meteorological Organization (WMO 2013) refers to climate services as:

“...a decision aide derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making. A climate service requires appropriate and iterative engagement to produce a timely advisory that end-users can comprehend, and which can aid their decision-making and enable early action and preparedness. Climate services need to be provided to users in a seamless manner and, most of all, need to respond to user requirements”

Depending on users' needs, these data and information products may be combined with non-meteorological data, such as agricultural production, health trends, population distributions in high-risk areas, road and infrastructure maps for the delivery of goods, and other socioeconomic variables. In a number of areas, global cooperation and research on hydrometeorological and climate services is moving towards a seamless framework with advances in development and delivery of climate services relevant across multiple time scales; with potential for improving predictive accuracy and increased lead time, facilitating applications in a wide range of user sectors (Figure 2).

face-to-face (such as a gathering of people across the country, supported by a web-based holder of information). Content may specifically include communication of knowledge for making decisions, and facilitation of capacity building through networking, training and mentoring; for example via face-to-face or online forums, peer-to-peer learning opportunities, workshops, case studies, guidance materials and decision support tools on impact, vulnerability and risk assessments, adaptation planning and implementation and a variety of other content. A platform can also be called a portal; the idea is it is a vehicle to transmit information.

- *Climate intelligence platform*: climate science (e.g. process studies, model development, predictions and projections) and associated infrastructure (e.g. observation networks, data repositories, computer resources, web portals). The climate intelligence platform underpins the climate intelligence.
- *Decision support tools*: methods and other knowledge resources that facilitate decision-making for adaptation to climate change. Examples include tools for costing adaptation options relative to the impacts avoided, such as cost-benefit analysis, guidance on identifying and assessing adaptation options, guidance on monitoring and evaluation, and tools for data visualisation, such as a GIS-based tool.
- *Risk management framework*: a structured process to assess risks, to develop and implement strategies to manage those risks, and to monitor and evaluate the outcomes. The process is generally circular, starting with 'Establish the context', followed by 'Identify/analyse risks', then 'Assess options to treat risk', 'Plan/implement risk treatment', and 'Monitor and review'.
- *Decision support framework*: a risk management framework together with the decision support tools necessary to implement the framework. The tools may include case studies demonstrating the application of the framework.

Climate services have shifted of recent times from being science-driven and decision-informed to being decision-driven and science-informed (Lourenco et al., 2016; Vincent et al., 2018). There is a strong emphasis on co-design and co-production across institutions and disciplines (Street, 2016; (Brasseur and Gallardo, 2016; Harjanne, 2017; Djenontin and Meadow, 2018; Bremer et al., 2019).

At the present time, climate services and associated platforms in Australia typically apply across multiple time scales, from weather (days to weeks) to climate (monthly/seasonal) to climate change (multi-decadal). In practice, the application of climate services and associated platforms variously includes (in no particular order) tools and resources that:

- Raise awareness of climate impacts and build capacity in 'communities of interest' (e.g. enhance climate science literacy, training in use of management/decision support tools etc.)

- Provide science-based evidence to inform decision-making related to:
 - climate hazard/impact analysis and related exposure/vulnerability/risk assessments at sectoral and/or portfolio level
 - policy development and planning for climate adaptation and climate-related disaster risk management, and
 - climate finance and associated investment needs and opportunities.
- Empower experts from different institutions and disciplines to co-design, co-produce and co-evaluate products and services to build climate resilience.

Box 2: Definitions of climate services

Organisation	Definition
European roadmap	Covers the transformation of climate-related data – together with other relevant information – into customised products such as projections, forecasts, information, trends, economic analyses, assessments (including technological assessments), counselling on best practices, development and evaluation of solutions and any other services in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and disaster risk management.
GFCS	A service providing climate information in a way that assists decision-making by individuals and organizations. It requires appropriate engagement along with an effective access mechanism and must respond to user needs.
JPI Climate	Considered as the user-driven development, translation and transfer of climate knowledge to researchers and decision makers in policy and business. This includes knowledge for understanding the climate, climate change and its impacts, as well as guidance in the use of climate knowledge.
Climate Services Partnership	Involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making and climate-smart policy and planning.

Sources:

- A European research and innovation roadmap for climate services (2015)
- The Global Framework for Climate Services (2018)
- Joint Programming Initiative “Connecting Climate Knowledge for Europe” (JPI, European Research Area for Climate Services, 2016)
- Climate Services Partnership (2011)

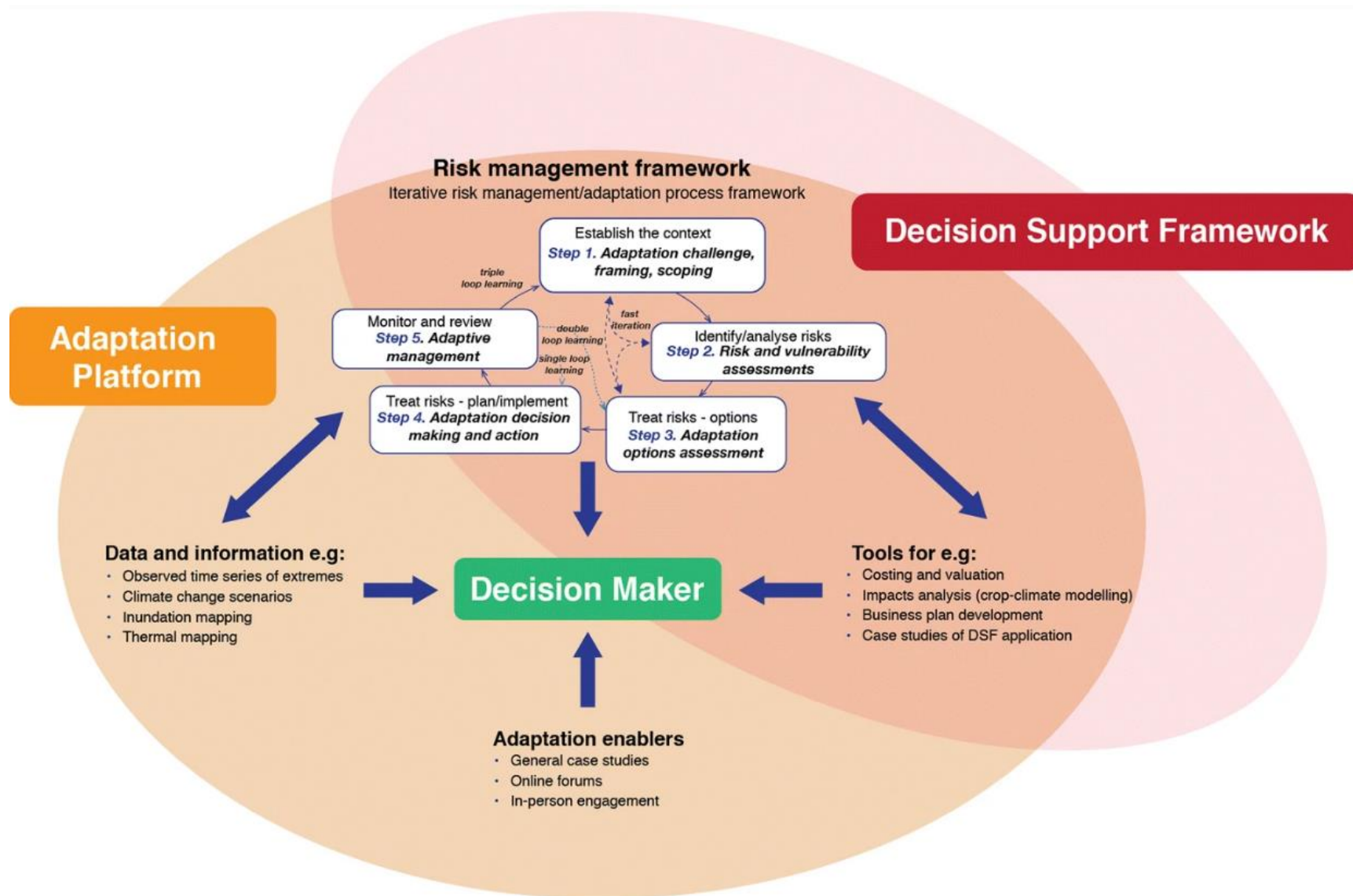


Figure 3: Typical structure of a climate adaptation platform (Palutikof et al, 2019)

4 Vision and value proposition

To achieve the vision of a **climate resilient Australia**, and consistent with the specified Terms of Reference for the present study (see appendix), the *a priori* value proposition for a national climate services capability for Australia, is tentatively framed as follows:

What? a national climate services capability which is:

- outcome focussed based on the needs of target users for addressing both risk and opportunity-based climate action, and
- incorporates principles of co-design, co-production and co-evaluation...decision-driven and science-informed, and
- supports governments, businesses and communities by delivering public and private value from better decision-making for disaster risk reduction and adaptation planning across all sectors.

Why? to mitigate sovereign risk and create value for all users and funding providers in the form of sustainable economic, social, and environmental outcomes, through:

- increasing awareness and building capacity to better understand and inform climate action, and
- provision of relevant, usable, legitimate and credible, science-based evidence for decision-making.

How? through development and delivery of a sustainable, nationally coordinated, climate services capability for Australia, featuring:

- Multi-disciplinary, ecosystem-based platform-based capability across the public and private sector
- Climate intelligence in the form of integrated, multi-disciplinary scientific data and information
- Core and differentiated products and services:
 - tailored to the needs of target users
 - based on quality assured/controlled standards, and
 - subject to continuous improvement (efficiency and effectiveness) and innovation reflecting ongoing changes in needs, knowledge and capabilities of providers, purveyors and users.
- Technical guidance and outreach support to build capacity and facilitate user applications, and

- Governance arrangements based on partnerships which:
 - elevate user engagement and facilitate equitable resourcing across public and private sectors
 - incorporate monitoring, evaluation and learning to facilitate adaptive management and path-to-impact for service delivery, and
 - measure triple bottom line outcomes to demonstrate tangible value and benefit to all stakeholders.

This value proposition and vision is further elucidated later in this report as part of the theory-of-action for the proposed future state of Australia's national climate services capability. The understanding that there is macro-economic benefit in climate services at a national scale, and the earlier investment starts the better, is also described in more detail later in this report.

5 Methodology

The methods, activities and work plan for the present study include the following key components:

- an initial review of published national and international literature, reports and other documentation
- an environmental scan of relevant climate service platforms, provider-user networks, projects, policies, plans and other initiatives, including internationally
- an assessment of strengths, weaknesses, opportunities and threats
- a stakeholder engagement and consultation process, including interviews with key stakeholders, an online survey of a broader set of stakeholders and a workshop
- a program logic and conceptual framework for a national climate services capability for Australia, and
- a synthesis and analysis of key findings and identification of future directions and next steps.

These components are intended to identify stakeholder expectations, existing capabilities, market gaps and needs, risks, challenges, opportunities and strategic options for developing a national climate services capability for Australia. The present study broadly follows the process described by Hubbard *et al.* (2014) related to developing a strategic direction document (Figure 4; white boxes, starting at the top).

It thereby provides input to the development of a strategy (Figure 4; yellow boxes) as a possible next phase of this study, on the understanding that the decision to develop a formal strategy is yet to be made. The next section of this report describes the current state of Australia's climate service capability, drawing upon the literature review, stakeholder interviews and environmental scan. The following section describes a vision for the future state of Australia's climate service capability (where we want to be). The final section describes the next steps in terms of strategic options and potential pathways for achieving the vision (how we transition from current to future state).

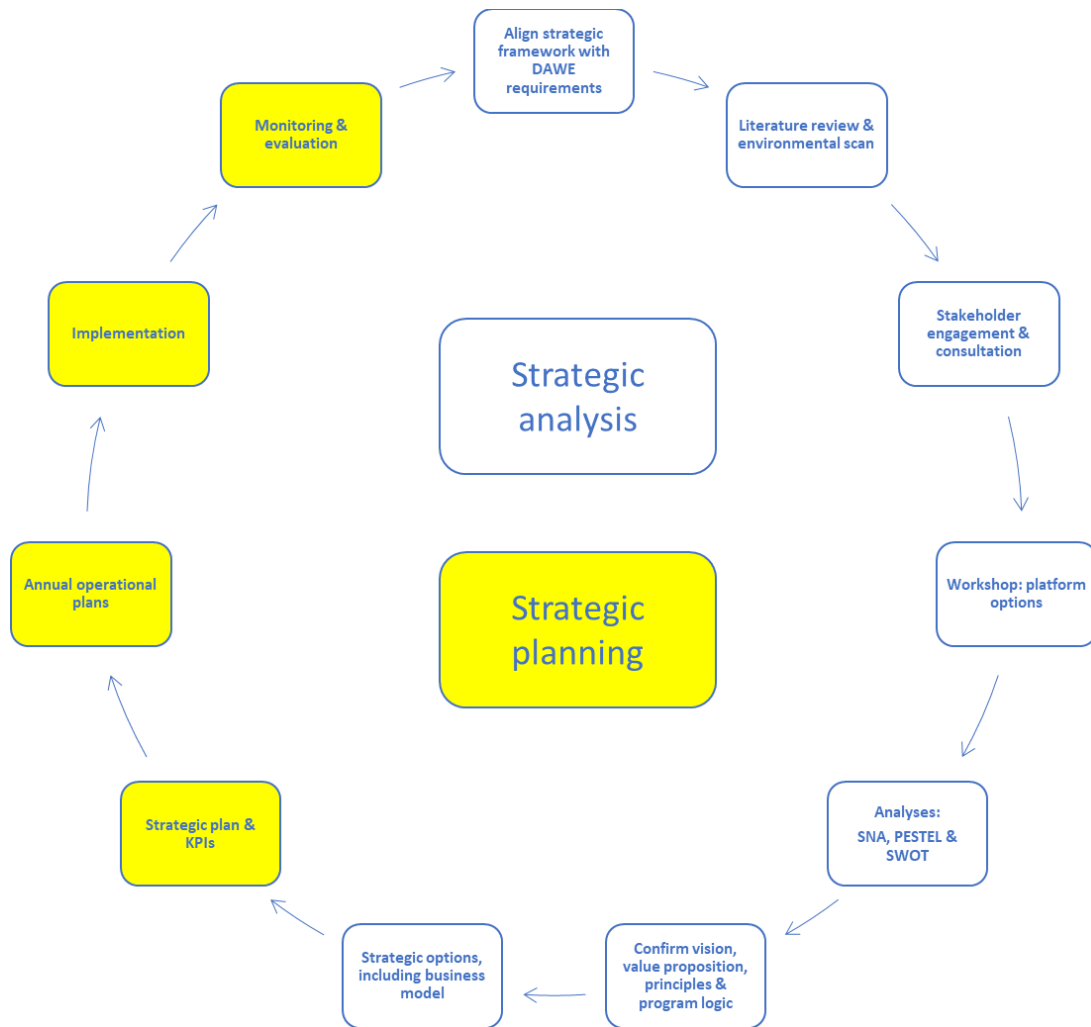


Figure 4: Strategic analysis and planning framework (adapted from Hubbard et al. 2014). White boxes: strategic analysis, starting at the top, are the stages undertaken in the present study. Yellow boxes: strategic planning, are possible next steps following completion of this study.

6 Current state of Australia's national climate services capability

Australia has a strong base on which to build climate services, in the form of our already- substantive climate science and services capabilities (Figure 5). Our world-leading climate science enterprise places Australia at the forefront of understanding our changing climate. Our nascent climate service capabilities have this authoritative, underpinning science foundation. We have world-leading climate research infrastructure and institutions in universities and science agencies, including the CSIRO Climate Science Centre, the ARC Centre of Excellence for Climate Extremes, the Bureau of Meteorology and Geoscience Australia. This national science effort has been developed over 30 years and has included the Australian Climate Change Science Program and more recently the National Environmental Science Program Earth Systems and Climate Change Hub, among other initiatives.

Central to this science effort has been development of and access to world-leading research infrastructure and associated networks, including the development of Australia's national climate model, ACCESS. Investment in ACCESS has delivered a world-class modelling capability that is rated highly in international comparisons, particularly for its capacity to simulate Australian climate. The contributions made via ACCESS to international engagement are recouped many times over through the wealth of tools, data and knowledge obtained for the national benefit.

Australia's role in the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project Phase 6 (CMIP6) is leveraged off our ACCESS capability. Likewise, Australia's role in the complementary Coordinated Regional Climate Downscaling Experiment (CORDEX) is leveraged of our existing capability across multiple national and state based GCM downscaling capabilities.

The Integrated Marine Observing System (IMOS) and the Terrestrial Ecosystem Research Network (TERN) provide critical underpinning infrastructure in the form of collaborative facilities for the collection of and access to key atmospheric and oceanic observational data. The National Computational Infrastructure (NCI) provides high performance computing capability which is critical to supporting climate model development, operations and capability across Australia's national science providers.

Australia has a range of existing climate services in the form of platforms and guidance products available for users to help assess and manage climate risk, and to inform the development of adaptation strategies. These include Commonwealth-supported platforms and products such as *Climate Change in Australia*, *CoastAdapt*, and *Climate Compass*. State and Territory governments, in collaboration with universities and science agencies, have built climate information platforms delivering projections and analyses. These include Queensland's *Long Paddock*, *Climate Futures for Tasmania*, New South Wales's *NARCLIM*, and Victoria's *Climate Projections 2019*.

AUSTRALIA'S CLIMATE SCIENCE & SERVICES 'MARKETPLACE' (CURRENT STATE)

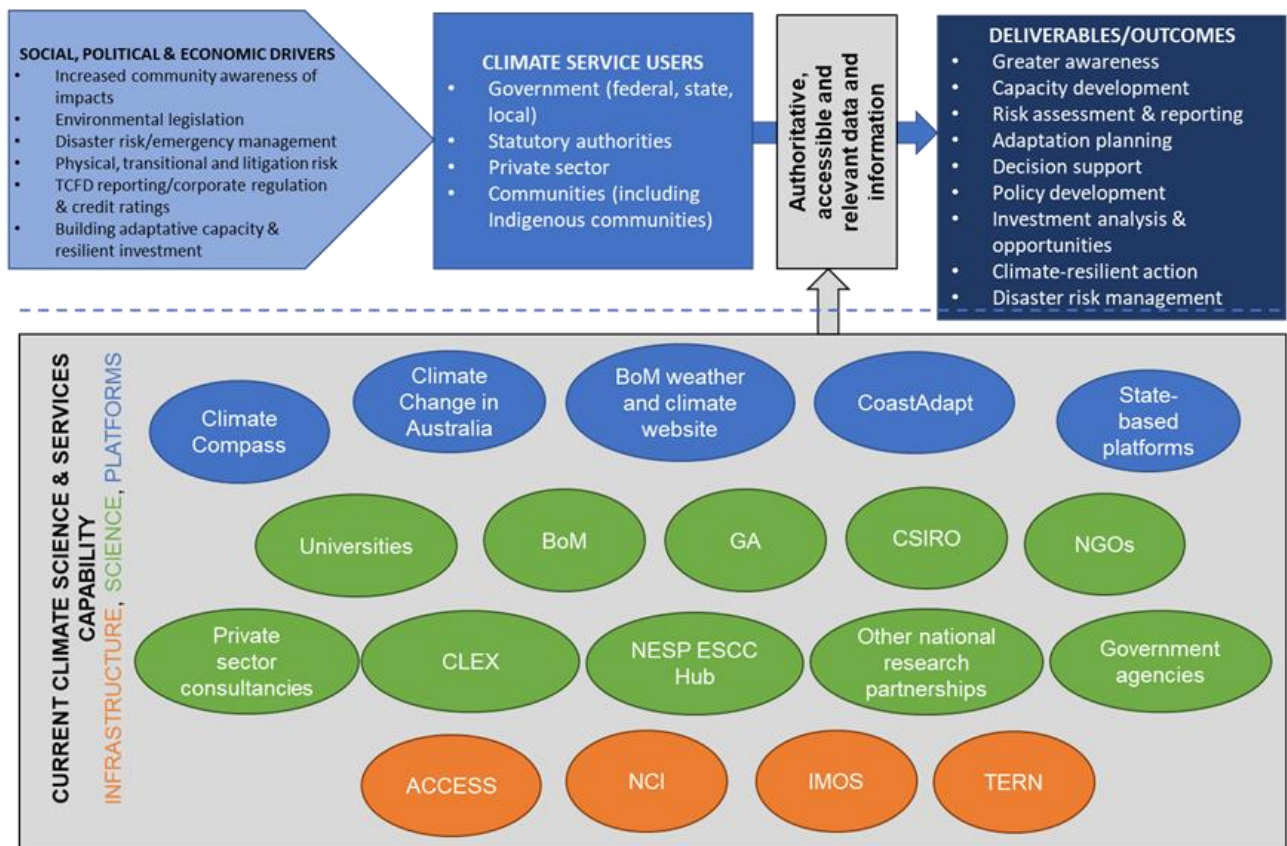


Figure 5: Schematic summary of existing climate services capabilities in context of Australia's national climate science 'landscape'.

The further assessment of the current state of Australia's climate services capability draws upon the literature review, environmental scan, stakeholder interviews, policy settings, online survey and workshop from the present study.

6.1 Literature review

The literature review covers national and international publications related to climate services and is focused on elucidating aspects of the environmental scan and key outcomes of the stakeholder consultations undertaken as part of this study.

The supply-side of the Australian market for climate services is well-established with many products and tools. However, efforts have been fragmented and poorly coordinated so there is a lack of efficiency and effectiveness.

There is little guidance about which products are most relevant to particular purposes, and a lack of perceived authority, quality control and assurance, accessibility, consistency, enabling support, ongoing resourcing and sustained learning and enhancement. In addition, what is available has not been clearly positioned in the broader process with few products being incorporated in leading adaptation practices.

This fragmentation has led to user confusion and lack of trust, but also to duplication of effort and limited product support (Webb et al, 2019).

The demand-side is rapidly emerging and evolving, driven by national and international policies and strategies described below. Meeting this growing demand efficiently and effectively is the challenge. There is a need for core and differentiated climate services, with appropriate business models (Webb et al., 2019).

6.2 Environmental scan

The environmental scan includes an assessment of policy settings, key climate service providers, purveyors (next-users who add value to products and services from providers and then provide these to end-users; also often referred to as intermediaries and/or next users) and users, business development/models, SWOT (Strengths, Weaknesses, Opportunities and Threats) and PESTEL (Political, Environmental, Social, Technological and Legal) analysis, illustrated by selected, nationally relevant case studies. Together with the literature review and stakeholder consultation, this provides insight into the scope and network of Australia's climate services capability and how it is distributed between providers, purveyors and users.

6.2.1 Policy settings

The National Climate Resilience and Adaptation Strategy (Australian Government, 2015a) has three elements: global action to reduce emissions; effective adaptation research, planning and action at the national and sub-national levels; and a program to limit or remove other human pressures on systems affected by climate change. The strategy looks at national action in priority policy areas or sectors that Australian governments collectively identified after considering the economic, social and environmental magnitude of potential climate change impacts, likely timing and relative importance of early action to manage the risks. The seven sectors and policy areas considered (Figure 6) are:

- Coasts, cities and the built environment
- Agriculture, fisheries and forestry
- Water resources
- Natural ecosystems
- Health and wellbeing
- Disaster risk management
- A secure and resilient region.

Of relevance to the needs for a national climate services capability, the strategy also notes:

- One of the most important roles of governments in adaptation is ensuring that others within society can make informed decisions about their behaviour in response to climate risks, by providing authoritative climate information. The Australian Government plays a major part in providing this climate science and information.
- As the effects of climate change vary across different parts of Australia, the information and actions required will also vary across the nation. State and territory governments have the leading role in adaptation actions, primarily through their planning laws and investments in public infrastructure.
- Beyond our borders, Australia helps developing countries, particularly in Asia and the Pacific, with effective disaster risk management, climate change science, adaptation planning and capacity building.

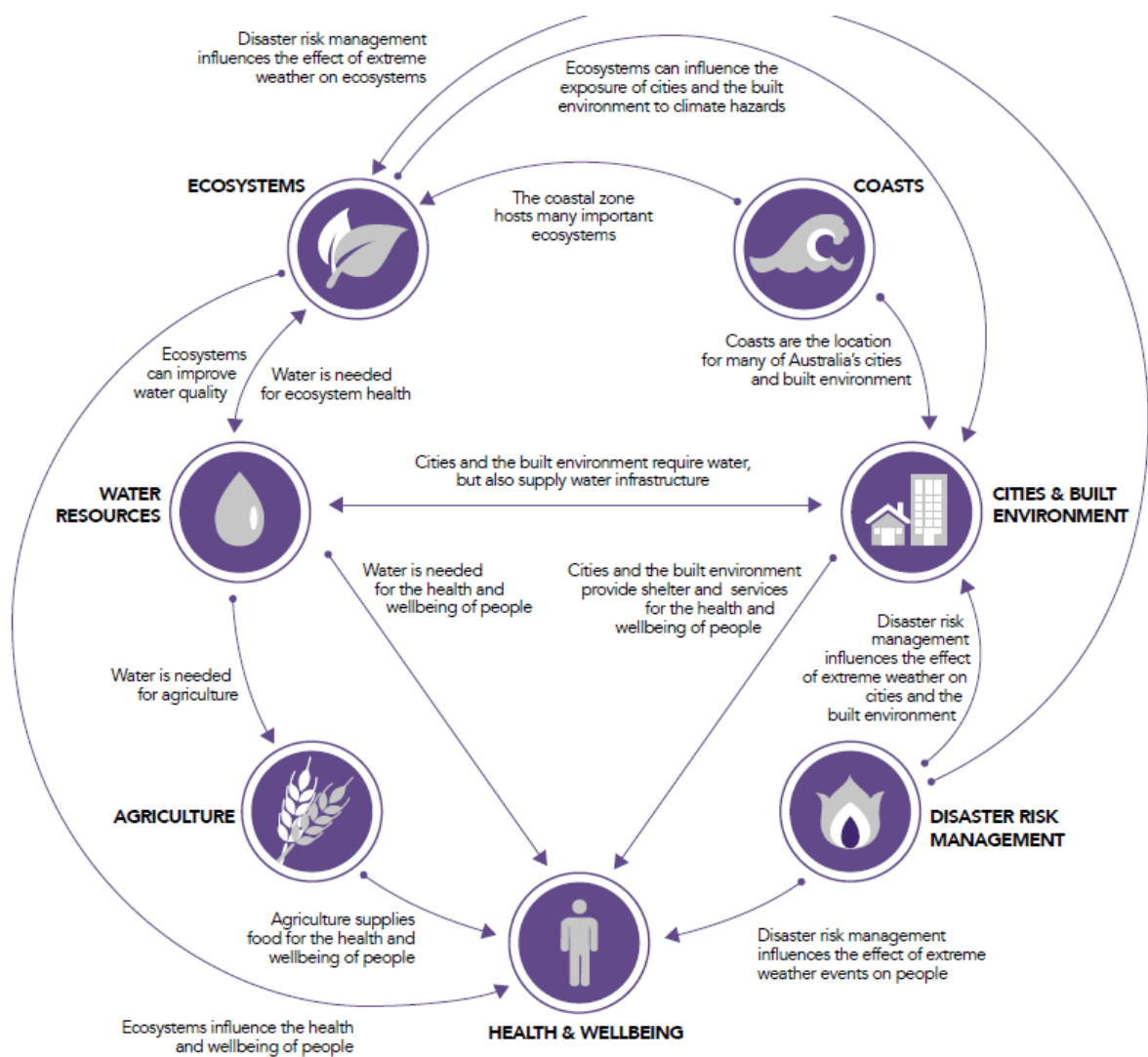


Figure 6: Key inter-dependencies between priority sectors. Source: Australian Government (2015a)

The *National Disaster Risk Reduction Framework* (DHA, 2019) guides national action to address existing disaster risks and minimise new risks for Australia, setting a five-year foundation from 2019-2023 to address systemic disaster risk in all sectors against four priority outcomes:

- understand disaster risk
- accountable decisions
- enhanced investment; and
- governance, ownership and responsibility.

A key feature of the Framework is the proposal for a *National Disaster Risk Information Services Capability* (NDRISC) to facilitate delivery of the requisite data and information which underpin achievement of outcomes in these four priority areas; noting also a capability such as NDRISC is foundational to a broader, integrated approach to disaster risk reduction and climate adaptation (Fig. 7). Climate services would provide the requisite climate data, information, analytics, tools and associated technical evidence to inform hazard, exposure, vulnerability and risk assessments, and associated decision-making relevant to management of climate related natural disasters.

Specifically, NDRISC (DHA 2020) or a similar capability would support decision makers across public and private sectors to:

- understand disaster risk, whereby consistent agreed hazard, exposure, vulnerability and risk information is accessible and fit for purpose; to make accountable decisions, whereby risks and vulnerabilities are assessed, understood and addressed in all types of decision-making
- make investments that are targeted to reduce risks and vulnerabilities, and to minimise the creation of new risks; and
- provide governance, ownership and responsibility, whereby partnerships and independent and ongoing accountability for disaster risk assessment and reduction is provided across sectors.

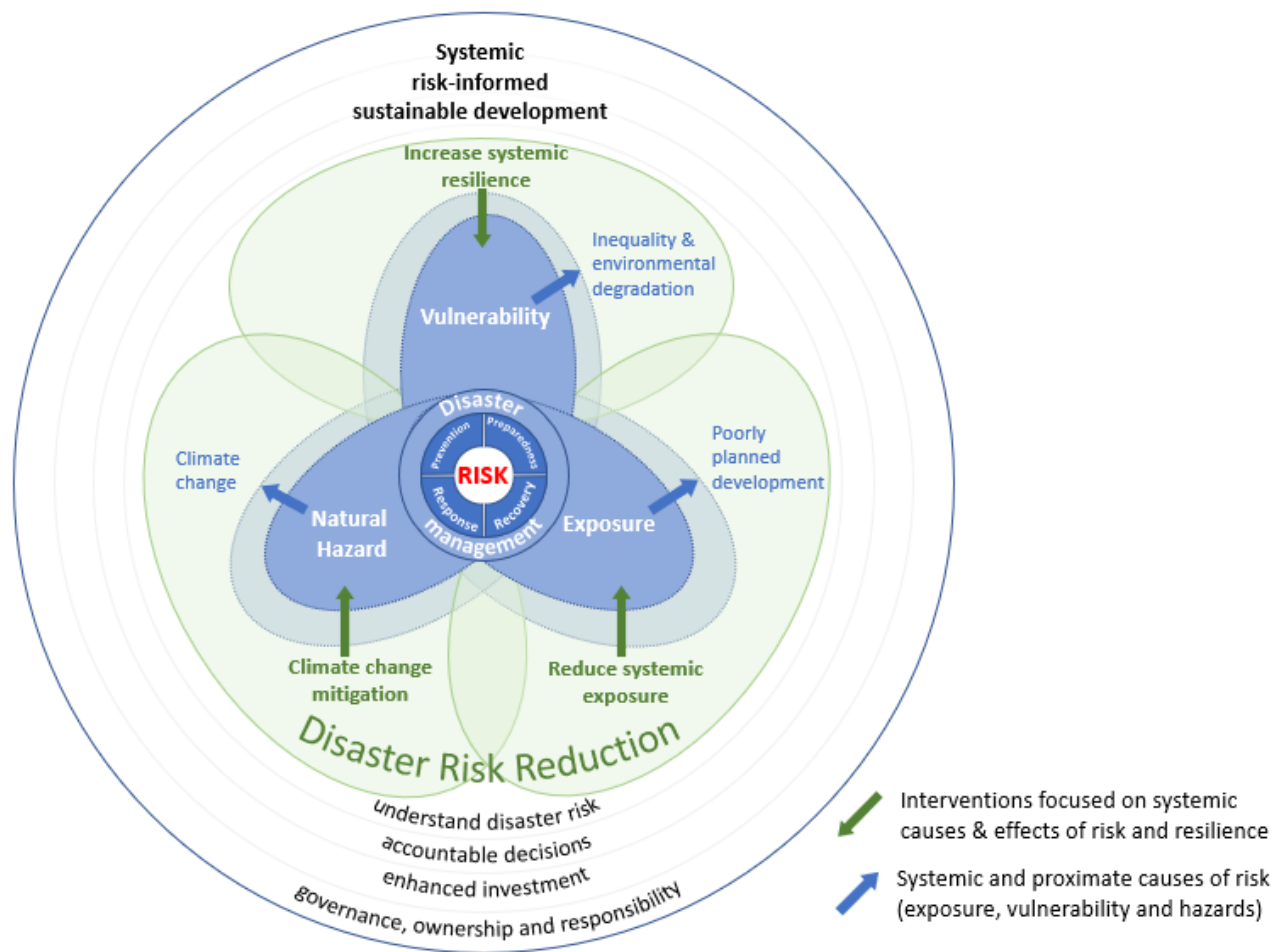


Figure 7: Extending the scope of disaster management to disaster risk reduction and climate adaptation (DHA 2020)

The *Climate Science for Australia’s future* (DAWE, 2019) report provides a strategic overview of six essential elements to Australia’s national climate science effort, all of which are needed for sectoral decision makers to have the scientifically robust information they need to understand climate change and to manage its risks and impacts. These are:

- Observations (climate data, analysis and infrastructure)
- Climate Process Studies
- Climate Modelling and Projections
- Climate Risk, Adaptation and Services
- International Engagement and Dependencies, and
- Research Coordination and Funding.

Priority areas for strategic action are identified across each of these elements, designed to build on current strengths, and to realise the full benefits of Australian climate research. DAWE (2019) suggests “...a sustained investment and integrated research effort utilising the full capabilities of Australian climate science can deliver the

climate services and products that businesses and the broader community will increasingly demand as the impacts of climate changes continue”.

The report on Climate Science for Australia’s Future (DAWE 2019) also refers to the ‘climate science pipeline’ in which the systematic interdependencies between the underpinning science capability and how the outputs of this capability inform science-based services are described. The features of this pipeline include:

- observational infrastructure which contributes to the global network of climate observations that span the temporal and spatial ranges necessary for climate researchers to understand the physical processes that drive the climate
- research informs climate modelling (and vice-versa), and the need for observational infrastructure
- these activities are supported by high- performance computing and eResearch infrastructure, which provide the processing capability for global climate models and the tools to share and use large quantities of data
- Climate science, data and modelling provides the basis for climate services, which is the information needed by citizens, businesses, and governments to make decisions over multiple climate/climate change timescales, from sub-seasonal/seasonal to decadal/multi-decadal and 100-year forecasts.

The Taskforce on Climate-Related Financial Disclosures (TCFD, 2017) was established as an industry-led initiative by the G20 Financial Stability Board to identify the information needed by investors, lenders, and insurance underwriters to appropriately assess, price and disclose climate-related financial risks and opportunities.

The recommendations of the TCFD provide a clear market signal to industry and also climate service providers and purveyors as to the climate data and information gaps and needs for reporting climate related financial risk to the satisfaction of prudential regulators.

Relevant excerpts from TCFD (2017) include:

...The Task Force was asked to develop voluntary, consistent climate-related financial disclosures that would be useful to investors, lenders, and insurance underwriters in understanding material risks. The Task Force structured its recommendations around four thematic areas that represent core elements of how organisations operate: governance, strategy, risk management, and metrics and targets.

...One of the Task Force’s key recommended disclosures focuses on the resilience of an organization’s strategy, taking into consideration different climate-related scenarios, including a 2° Celsius or lower scenario.

...The Task Force recognizes the use of scenarios in assessing climate-related issues and their potential financial implications is relatively recent and practices will evolve over time, but believes such analysis is important for improving the disclosure of decision-useful, climate-related financial information....

....The Task Force recognizes the challenges associated with measuring the impact of climate change, but believes that by moving climate-related issues into mainstream annual financial filings, practices and techniques will evolve more rapidly. Improved practices and techniques, including data analytics, should further improve the quality of climate-related financial disclosures and, ultimately, support more appropriate pricing of risks and allocation of capital in the global economy...

6.2.2 Existing platforms, products and services

A review of 300 climate products and services available in Australia and overseas, and they were categorized into three groups (Webb and Beh, 2013): 90 process support products that typically guide the user through steps in the adaptation cycle; 80 data products including climate, risk and adaptation options data; and 130 broader knowledge products, of which 30 were general adaptation portals. Two thirds of the products reviewed were Australian (Webb et al., 2019).

Some of the nationally relevant Australian climate platforms, products and services are briefly described in Box 3. There are also several internationally relevant climate platforms offering a range of globally and nationally relevant climate products and services (Box 4). It is noted however there is limited integration and alignment between existing web-based platforms in Australia for delivery of physical climate change data and information as well as climate adaptation data and information, with multiple national and state-based sources each meeting part but not all of the needs of many users without additional third-party technical support.

The release of the new archive of CMIP6 global climate models as part of the pending publication of the IPCC Sixth Assessment Report provides a significant new opportunity for the Australian climate science community to update existing projections and associated science-based services, including for purposes of developing globally consistent, standardised scenario analysis as framing for sectoral, hazard-based climate impact/sensitivity analysis (see Box 1).

Box 3: Nationally relevant climate (service) platforms

The **Climate Change in Australia (CCiA) website** is the principle platform used by CSIRO and the Bureau of Meteorology to disseminate national climate change projections data and related guidance material. It was released in 2015, with new content and functionality having been added since. The site annually records 300,000 unique user sessions: www.climatechangeinaustralia.gov.au/en/

The Bureau of Meteorology plays a key operational role as Australia's national meteorological service, including meeting the increasing demand for climate information. Its **Long-range weather and climate** site provides extensive access to data, reports and analyses covering climate monitoring, prediction as well as climate change: www.bom.gov.au/

The National Climate Change Adaptation Research Facility (NCCARF) developed **CoastAdapt** as a platform to support coastal decision-makers (especially local councils) to adapt to the risks and impacts of climate change by providing comprehensive and targeted information in appropriate language, linked to local policy initiatives. CoastAdapt is funded to the end of 2021: <https://coastadapt.com.au/>

CSIRO and (formerly) the Department of the Environment and Energy developed **Climate Compass** as a framework designed to help Australian public servants manage the risks from the changing climate to policies, programs and asset management. It includes step-by-step instructions, guidance and information to develop an understanding of climate change risks: www.environment.gov.au/climate-change/adaptation/publications/climate-compass-climate-risk-management-framework

Several State Governments supported by various universities and national institutions have developed state-based climate platforms and portals, featuring finer spatial-scale regional climate projections data, information, guidance and associated climate adaptation knowledge products, including:

- Queensland: *Long Paddock* www.longpaddock.qld.gov.au/
- New South Wales: *NARCLIM* <https://climatedata.environment.nsw.gov.au/>
- Victoria: *VCP19* www.climatechange.vic.gov.au/adapting-to-climate-change-impacts/victorian-climate-projections-2019
- Tasmania: *Climate Futures for Tasmania* <https://dpiwwe.tas.gov.au/conservation/climate-change/climate-futures-for-tasmania>

Box 4: Internationally relevant climate platforms

The **World Climate Research Programme (WCRP)**: facilitates analysis and predictions of Earth system change for use in a range of practical applications of direct relevance, benefit and value to society. The five WCRP core projects are:

- Climate and Cryosphere (CliC)
- Climate and Ocean Variability, Predictability and Change (CLIVAR)
- Global Energy and Water Exchanges (GEWEX)
- Stratosphere-troposphere Processes And their Role in Climate (SPARC)
- Coordinated Regional Climate Downscaling Experiment (CORDEX)

The four unifying themes are:

- *Observations and analysis*: including the Expert Team on Climate Change Detection and Indices (ETCCDI)
- *Modelling*: including the coupled model intercomparison project (CMIP), the Working Group on Subseasonal to Interdecadal Prediction (WGSIP), and Decadal Climate Prediction Project
- *Education and capacity development*: including fostering future leaders, meetings and activities
- *Regional climate*: including Climate Information for Regions, and the Working Group on Regional Climate

The Intergovernmental Panel on Climate Change (IPCC) assesses the science related to climate change. It is an organization of 195 governments that are members of the United Nations or World Meteorological Organisation (WMO). Scientists volunteer their time to assess the literature and provide a comprehensive summary of what is known about observed climate variability and change, drivers of climate change, observed and future impacts, and how adaptation and mitigation can reduce those impacts. Some key outputs include global and regional summaries of observed climate trends, global and regional climate projections for different greenhouse gas emission scenarios, impact assessments for various regions and sectors, adaptation enablers and barriers, and mitigation options. The IPCC's reports are comprehensive and provide balanced assessments based on a rigorous process of scoping, drafting and review to ensure the highest quality. These reports are highly regarded by governments, industry, non-government organizations and researchers. The IPCC also support the Data Distribution Centre which provides climate, socio-economic and environmental data, both from the past and also in scenarios projected into the future. Technical guidelines on the selection and use of different types of data and scenarios in research and assessment are also provided. www.ipcc.ch/; <http://www.ipcc-data.org/index.html>

Knowledge Exchange for Climate Adaptation Platforms (KE4CAP) is an EU funded project which provides a forum for platform developers and operators to come together to compare and learn from their individual approaches, to share knowledge and best practices, and to work together to address common and emerging challenges. The overall aims are to i) stimulate knowledge exchange in order to advance cooperation and learning, and ii) to inspire the evolution of national and regional adaptation platforms in terms of scope, governance, content coverage, functionality and management. KE4CAP facilitates international networking, collaboration and knowledge exchange between multiple platforms and initiatives which provide a range of relevant global, regional and national climate data, and adaptation and risk information services, including EU Copernicus, Joint Partnership Initiative (JPI) Climate, European Research Area for Climate Services (ERA4CS), Climate Services Partnership, Climate-Adapt, WeAdapt, Climate Ireland, KLIVO and the Asia-Pacific Climate Adaptation Platform (AP-Plat), amongst others.
www.weadapt.org/knowledge-base/climate-change-adaptation-knowledge-platforms/the-ke4cap-project

6.2.3 Providers, purveyors and users

The climate services landscape in Australia is complex and changing rapidly. Users of climate services include three tiers of government (federal, state/territory and local), statutory authorities, Indigenous communities, and the private sector. These users demand authoritative, accessible and relevant data and information to raise awareness, build capacity and more specifically to inform risk assessment, adaptation options, policy development, investment analysis, climate-resilient action and disaster risk management. Providers and purveyors of climate services in Australia include CSIRO, the Bureau of Meteorology, Geoscience Australia, Federal and State Government agencies and other statutory authorities, various universities and associated collaborative partnerships, NGOs and private sector consultancies. A visual representation of the current Australian climate services landscape in the context of users, providers and purveyors is provided in Figure 8 (see also Fig. 5).

Australia is not currently limited by availability of existing 'climate intelligence' for many existing needs, however we have limited alignment, coordination and integration of existing climate services and platforms. We are also limited to varying degrees by:

- Both user and provider capacity for practical applications to address current and future climate risk
- Availability of detailed scientific knowledge about current and future extreme weather events that cause significant damage
- Suitability of decision-support tools, and
- Resourcing of knowledge-brokers, capacity-building, guidance material and communities of practice.

These limitations are further constrained by lack of a unified view across relevant knowledge domains and the user/purveyor/provider landscape more broadly on strategic drivers, mechanisms, priorities and opportunities. There is much to learn and leverage from existing platforms, both in Australia and internationally, and we also have much to offer.

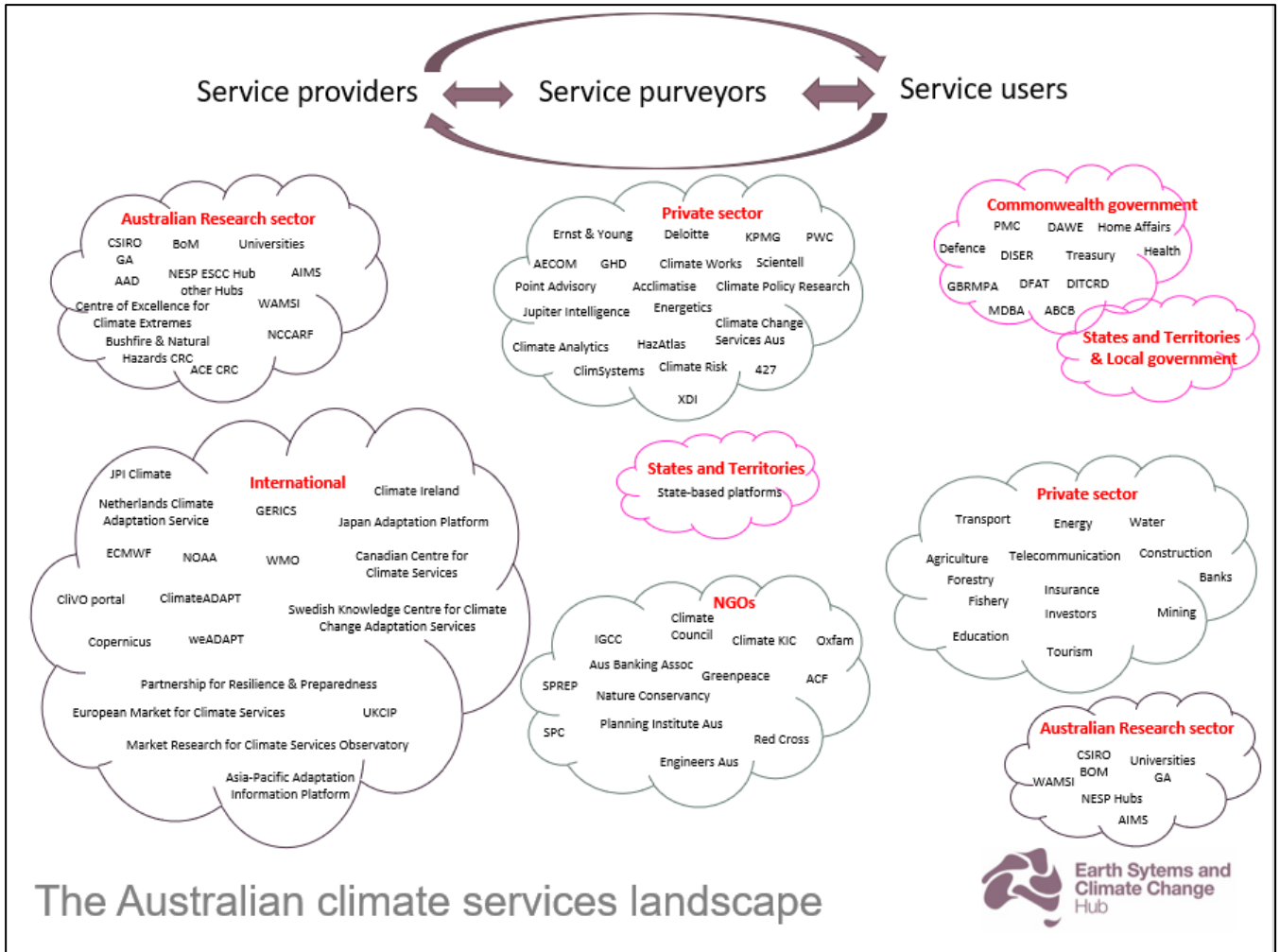


Figure 8: Different types of providers, purveyors and users within the current Australian climate services landscape (NESP ESCC Hub 2020)

6.3 Stakeholder consultation

Stakeholder consultation for the present study involved three primary components:

- General consultation with selected individuals and groups via face-to-face and/or vid-conference meetings during the period Nov 2019-Mar 2020, including from CSIRO, the Bureau, NESP ESCC Hub Leadership Team and Stakeholder Advisory Group, the Inter-Jurisdictional Climate Science Community of Practice, and a cross-section group of university, government and private consultancy sector representatives from WA.

- A national stakeholder workshop in March 2020 entitled *Platform-based science and services supporting climate action: an EU-Australia bilateral knowledge exchange workshop on developing and using web-based resources to enhance climate intelligence and support climate action* was co-sponsored by the European Commission (Knowledge Exchange for Climate Adaptation Platform/KE4CAP project), NESP ESCC Hub and the CSIRO Navigating Climate Change Mission, and included representatives from the Australian Government, States and Territories, CSIRO, BOM, universities, Traditional Owners, NGOs, the private sector and representatives from the EU public sector on behalf of the KE4CAP project (NESP ESCC Hub 2020).

The focus of the workshop was to i) ascertain current and preferred future state of Australia's national climate services landscape, and the options for transitioning to the future state, and in the process to ii) share and leverage experiences and learnings between Australia and the EU to facilitate collaborative climate platform development across international boundaries.

- A structured Social Network Analysis (SNA) undertaken on behalf of the project by the University of Technology Sydney during the period Jan-March 2020 was designed to map the national climate services landscape in Australia. The primary objective was to identify the transactional inter-dependencies between key providers, purveyors and users of climate services, including the scope and purpose of such transactions. The SNA was based on an on-line survey of multiple stakeholders with an interest in the development and delivery of climate services across the public and private sector in Australia (Cunningham, 2020).

6.3.1 General consultation

Key findings from the general stakeholder consultation, including paraphrased commentary from key stakeholders, are summarised as follows:

Policy and strategic drivers

- Legislation is very important in driving action – are there merits in working more actively in jurisdictions which have legislation more amenable to climate service provision?
- The innovation from the private sector is much needed but shouldn't prevent the accessibility of information to the most vulnerable because they can't afford it – there is a clear role for government in the provision of public-good climate services.
- In terms of value proposition, implementing the European Roadmap for Climate Services was also recognised as a major contributor to the knowledge economy and jobs creation. The potential for significant efficiency savings was also key.

- Funding of climate services as a national capability should be based on realistic funding options and business models to go forward, e.g. current level of investment plus some extra and, if funds do become available then we can shift to more ambitious options.
- Important to consider where we want to be in 10 years-time regarding the questions we need to answer.

Governance

- Authority, standardisation, quality-assurance/quality control and high-level coordination is essential, including:
 - Australian coordination/standardisation process should be user led and not a research body.
 - Some important government supported climate service platforms do currently exist in Australia (see Box 3 and Fig. 5), and
 - CMSI (*Climate Measurement Standards Initiative* for the finance sector) is a relevant industry-led example that can help further the standardisation imperative.
- Developing standards is potentially the best opportunity for improving coordination and comparability, and for strengthening collaboration and partnerships, and
- Need to continually share information and join up the conversations across the many current strategic efforts underway at both national and state-level (e.g. NDRISC, CSIRO Navigating Climate Change Mission, BOM Climate Services, NCSAC Climate Services and NextGen projections, and relevant state-level initiatives including NARCLIM, LongPaddock, Climate Futures Tasmania, VCP19 etc).

Customers and users

- The term 'climate services' remains problematic for some and a suggestion to make the choice of term as inclusive as possible.
- Evidence that demonstrates climate service value, i.e. meeting user demands and delivering economic benefits are very important.
- There is currently an inability to link customers, who have needs for climate services, with where capability exists and shortcomings with how long it takes to access and deliver the data and information.
- Integrating climate information into customer's decision-making processes is what we would like to do but sometimes customers' processes are sub-optimal, and they don't want to change their processes.

- Some stakeholders, who may have lower literacy in relation to climate services should be included, potentially engaging through peak bodies or umbrella groups. These stakeholders would benefit from an introductory briefing to build their awareness and capacity to identify and use climate services.

Partnerships and collaboration

- There is a need for both public good and private benefit climate services that can be delivered in a complementary and collaborative manner.
- There are considerable opportunities to partner, e.g. EU Copernicus for database development, application generation, etc. Public-private partnerships for risk assessments and supporting the evaluation and implementation of adaptation options.
- Need a strong Asia-Pacific representation and so engagement with DFAT is very important.
- Geoscience Australia important for risk analysis and data, including as a partner.

Observations, data, models, tools and related infrastructure

- The private sector needs assurance around data from authoritative and independent sources such as government or leading science agencies.
- As a key data provider, BoM's work in developing its new data infrastructure will be important.
- Models for climate reanalysis are weather models so they need to be considered as part of the underpinning infrastructure.
- We need harmonisation of data from different sectors, demographic data, etc. delivered as an open-source knowledge / data hub.
- The consistent development of data sets and tools which are seamless across multiple timescales will be important (see Figure 2).
- Need to move away from considering that climate data and information alone is the core and that other data and information is otherwise considered 'non-core'.
- A product/service needs to be able to track back to what specific inputs went into the product, i.e. data provenance.

Information, products and services

- National Resilience Taskforce <https://www.aidr.org.au/news/national-resilience-taskforce-on-the-knowledge-hub> is experimenting through doing demonstrated prototype to deliver benefits and, at the same time, informing design; this builds communication and linkages while developing the important system components.

- Important to include scenarios that are both multi-hazard and “worst case”, e.g. concurrent tropical cyclone, bushfires, and heatwaves.
- Knowledge brokering and education products are essential.
- The lack of coordination of climate services is creating a fragmented market with proliferation of portals and tools and with lots of players taking advantage of niche opportunities.

Research

- BoM developing 5-10 year research priorities that will take a customer view.
- CSIRO developing a strategic Mission called Navigating Climate Change focused on informing adaptation and mitigation solutions.
- Researchers will want to have a pathway to improving and impacting on the service.

Capacity building and education

- There is a lack of structured capacity building and education for providers and users of climate services and this will need to extend across the value chain and be multi-disciplinary.

6.3.2 Knowledge Exchange for Climate Adaptation Platforms

The workshop entitled *Knowledge Exchange: Science and Services Supporting Climate Action* was convened at CSIRO Aspendale (Melbourne, Australia) from 3-5 March 2020 under joint sponsorship of:

- The Stepping-Up *Knowledge Exchange between Climate Adaptation Knowledge Platforms* (KE4CAP) project funded by the European Commission.
- The National Environmental Science Program (NESP) Earth Systems and Climate Change (ESCC) Hub (specifically the Hub’s *National Climate Science Advisory Committee (NCSAC) National Climate Services Capability for Australia* project).
- The CSIRO Navigating Climate Change (NCC) Mission.

The objectives of the workshop were to:

- Share information between EU and Australia to inform best-practice approaches to developing a national climate intelligence capability for Australia, with development of a national (digital and domain) climate services capability as a core component.
- Identify the steps towards further bilateral and multilateral collaborative partnerships to facilitate ongoing engagement, knowledge exchange and longer-term learnings.

At the workshop it was agreed that the key climate services stakeholder ‘community of interest’ (those willing to be involved directly in next steps) for development of a national climate services capability needs to consider the following priority actions:

- Collate ideas and demonstrate the value of this approach, including practical examples, case studies, etc.
- Demonstrate to government the existing capability of platforms and providers and the demand (gaps/needs) from end-users.
- Review published national and international literature on climate services, identify ‘best practice’ as well as gaps and needs, and build a vision of the way forward.
- Demonstrate the costly risk of ‘doing nothing’ or ‘business as usual’ for government and industry, and the potential benefits of climate resilience.
- Review Australian climate service capabilities and existing platforms, assess strengths, weaknesses, opportunities and threats (SWOT), key environmental factors (e.g. political, technological, legal) and how the network of service providers and users is structured.
- Highlight how we might build on what we already have, mapped in a way that can be communicated to a particular region’s or sector’s needs and opportunities.
- Evaluate existing activities and identify what end users think of what is already out there and identify the gaps.
- Identify an initial cohort of key private sector users and providers for public sector counterparts to work with, to start framing ongoing future needs and find a way forward.
- Drive the value proposition for a national capability by drawing on input from all key stakeholder groups, including governments, the private sector, NGOs, Indigenous communities and research and associated science/technical expert networks.
- Be ready as a community to respond to opportunities (political and/or industry driven) that may arise in the near term including having proposals, ideas, planning ready to roll out at short notice.
- Continue to engage in a meaningful and culturally sensitive way with Indigenous communities as part of the co-design/co-production process to address needs and incorporate Traditional knowledge where appropriate.
- Consider the longer-term vision, creating ideas about how projects will build on each other to provide services for all Australians, with equity of access.
- Work with KE4CAP to identify priorities on which to focus, and to develop a national climate platform capability as part of international cooperation.

A report which summarises the proceedings from the workshop, including key issues, insights and outcomes is available at <http://nespclimate.com.au/knowledge-exchange-science-and-services-supporting-climate-action/>.

6.3.3 Social network analysis

This analysis was undertaken on behalf of the project by researchers at the University of Technology, Sydney (Cunningham 2020). The objective was to use an online survey to map the interactions of current providers, purveyors and users of climate services in Australia to show how they are linked within a market setting. More specifically Social Network Analysis (SNA) was used to analyse and visualise:

- the connections between organisations that source climate services information,
- the connections between organisations that supply climate services information,
- whole of network cohesion measures, and
- optimal channels for information diffusion through the network.

In addition to the SNA, the survey included questions regarding the type of climate services information being accessed, the rationale for selecting the specific sources, the capacity of organisations to access and utilise climate services information, how they develop climate services information products, and their reflections on the development of the sector. Purposive sampling was undertaken with the survey being sent to contacts within priority sectors including Agriculture, Research, Finance and Insurance, Government, Water and Disaster Management.

Although this was a national survey, respondents came primarily from large organisations within these sectors which may cause some level of bias in some of the results. Of the total respondents, 74 were climate service providers, 99 were users of climate services, and 60 were both users and providers (including purveyors) of climate services. The findings demonstrated that climate information and associated services are sourced primarily from national climate service providers (e.g. CSIRO, BOM), universities, the Climate Change in Australia website, Geoscience Australia and some international climate service providers (e.g. Intergovernmental Panel on Climate Change (IPPC)).

Several participants sourced information from state and federal agencies, with some looking to The Climate Council, media and events to garner climate information. Climate information was also supplied diffusely with some state level cliques. Most information was derived freely from open sources. Scientific validity, trust and accessibility were key reasons for selecting these sources. Information was mostly used for climate hazard analysis and impact assessments, followed by strategic planning and/or policy development, and to build new tools and products.

Over 80% of organisations felt they had the internal capacity to develop, use and share climate information and products such as decision support tools, dashboards, web applications, training and guidance material.

External product development examples included developing dashboards and web mapping applications (e.g. real time air temperature), and guidance materials, to inform industry and government stakeholders, develop asset-level risk analysis and synthesis for third parties, producing reports for government on greenhouse gas emissions, translating the information to third parties in the applied space (e.g. visualisations), incorporating climate change models into existing decision support tools, factsheets and guidance, and tailored data sets to match metrics stakeholders are currently using to understand climate risk, strategic development and decision support tools (e.g. crop suitability maps).

There are key actors working as knowledge hubs within the source network for climate services in Australia. These were identified to be BOM, CSIRO, IPCC and universities, with the majority of respondents accessing information from these entities. These organisations also hold key structural positions integral to information provision throughout the network. However, these connections, are highly relational, often held by individuals rather than through formal mechanisms. The network is highly fragmented (Figure 9).

Survey participants felt the Climate Change in Australia portal and the BoM seasonal forecasts were great resources, but there is duplication, poor coordination and poor governance. There are inadequate downscaled climate projections and extreme weather projections, and difficulty translating climate information into impacts. Participants called for a coordinated and centralised climate services platform, with improved governance, supported by more government investment, reinstating NCCARF, more tailored products for industry and more training materials.

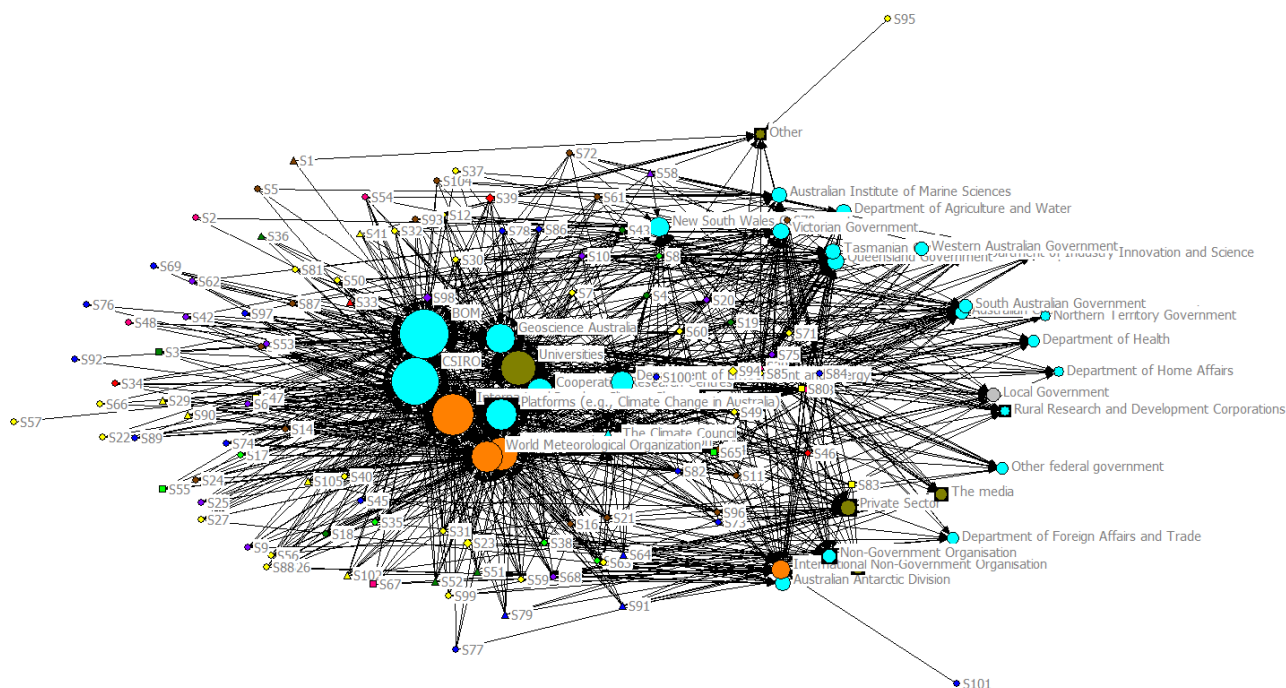


Figure 9: Visualisation of source climate services information network with nodes categorised by sector. Size of node denotes in-degree: larger the node, the greater the in-degree of that node. Shape of nodes represents Organisation type: Various = circle in square; Micro = Square; Small = diamond; Medium = Triangle; Large = Circle. Legend for node colour is provided in **Cunningham (2020)**.

6.4 PESTEL and SWOT Analysis

A structured PESTEL (Political, Economic, Social, Technology, Environmental and Legal) analysis was undertaken as part of the present study to inform a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the current state of Australia's national climate services capability. This activity effectively allows for the identification and analysis of strategic imperatives and critical success factors to meet the needs of an enhanced national capability, including those that must be addressed for the future success of a national climate service capability.

Key findings are as follows:

- Strengthening stakeholder engagement, including through strategic partnerships and communication through:
 - Strengthening stakeholder engagement within and across governments, businesses and communities and, supporting knowledge exchange and capacity building in disaster risk reduction, human health and well-being, agriculture, water management, energy, natural resource management, biodiversity and finance.
 - Ensuring services are prioritised for emergency services in partnership with the National Disaster Risk Information and Services Capability (NDRISC).
 - Supporting services development for policy makers and company directors and executives to strengthen their strategies and governance around mitigating climate risks and building adaptive capacity.
 - Developing methodologies and engagement practices to ensure traditional knowledge is part of climate services and from which Indigenous communities' benefit.
 - Working with developing and least developed countries in the Pacific and southeast Asia, and in partnership with donor agencies and NGOs, to build capability and resilience, on disaster risk reduction services and climate adaptation.
 - Strengthening linkages with international climate service providers to support mutual knowledge and technology exchange.
 - Developing and implementing communication plans that promulgate the value and impacts of climate services and how this can be extracted, explain uncertainties in products and services, engage with sector leaders, and actively counter misinformation.
- Sound governance drives credibility, impact and value in services through:
 - Ensuring users' integrated needs are satisfied through effective engagement within and between i) providers, purveyors and users, ii) public and private actors, and iii) Federal and state governments.

- Leadership in developing and implementing rules, relationships, structures, systems, procedures and practices to support strategy, coordination, manage risks and provide effective oversight within an interjurisdictional policy and legislative framework.
- Immediate co-development of standards and quality assurance/control for data, methodologies, products and services to improve coordination and comparability, building trust and strengthening partnerships.
- Ensuring effective engagement with international partners and, especially in the Pacific and southeast Asia, with user communities to build national and overseas capabilities and supporting Australia's aid obligations.
- Effective resource management, including an appropriate mix of public and private funding, to satisfy investor confidence and ensure capability and services are sustainable.
- Performance management, including monitoring, evaluation and review, to ensure continuous improvement and strategy alignment.
- Building capability to deliver sustainable services through:
 - A comprehensive capability and capacity audit covering activities and actors across the services value chain and identifying and addressing any gaps.
 - Clearly and strongly demonstrating the value and impact of climate services, including through return on investment approaches, case studies and tangible on-the-ground impact to support a knowledge economy, national sovereignty, jobs creation, innovation and capture investment.
 - Establishing and communicating evidence of the value of investment in infrastructure (e.g. supercomputing, climate models, observation systems, data systems) and R&D in supporting the quality of climate services and supporting a business model where investments support both infrastructure and R&D.
 - Strengthening areas which would benefit from interdisciplinary capability and systemic approaches and which would stimulate innovation across the value chain.
 - Investing in specific areas of capability such as knowledge brokering and exchange, communities of practice, workshops and conferences, education and training, mentoring and targeted work placements/exchanges.
- Innovation in products and services improves decision-making, risk management, adaptation and builds resilience through:
 - Co-designing and co-developing a 'Climate Solutions' platform as an online marketplace for providers, purveyors and users to ensure the accessibility of quality core public products and services and supporting the development of products and services both from and for the private sector.

- Reviewing all existing platforms, within Australia and overseas, as potential contributors to the national capability and recommending any further development for integration.
- Developing and designing a core set of climate products and services that are authoritative and quality-assured and deliver significant benefits to the Australian community and for the Pacific and southeast Asia, prioritising disaster risk reduction and human health in 2020-21.
- Developing seamless services that are relevant to the decision-making needs of sectors, including those derived from data analysis, reanalysis, seasonal forecasts, climate projections, impact and vulnerability analysis and those which can rapidly respond to needs before, during and after extreme weather or climate events.
- Product and service development is accompanied with comprehensive and discoverable metadata and user guidance that support users finding solutions to their needs.
- Auditing and reviewing all available datasets, including sector-based/impact/vulnerability related datasets, regarding the extent to which they can improve national capability and prioritising gaps for improvements.
- Developing best practices for product and service development, including supporting the principles of co-design and co-development, channel management, research to services transition, product lifecycle management, agile methodologies, and staged releases.

6.5 Synthesis of initial findings

Based on the above findings, the key issues identified from the present in relation to the current state of climate services in Australia are summarised as follows:

- Climate variability, extremes and change are threat multipliers which are collectively driving existential risks to the Australian economy, environment and society in general.
- A properly constituted, coordinated and well-resourced national climate services capability delivering effective and efficient technical support to users can help to substantively mitigate sovereign/sub-sovereign and private sector climate risk for Australia.
- There is a need to support development and delivery of public good climate services to ensure that relevant, usable and scientifically credible climate knowledge is discoverable, accessible and otherwise available to the general public, while still meeting the private benefit needs of a more limited sub-set of users with sufficient resources to pay.

- There is an existing cohort of peer-reviewed scientific data, information, analytics and associated knowledge informing our understanding of Australia's climate system. This includes the physical science incorporating historical climate, observations and trends and future climate modelling, and a much broader range of capabilities informing aspects of climate change adaptation, resilience and mitigation (i.e. climate action), including socio-economics, impact modelling and decision- support tools and resources.
- This cohort of knowledge is supported by critical underpinning infrastructure for collection and analysis of core observational data relevant to historical and current climate, and the modelling and analysis of future climate including systems, impacts and risks. However, there is not a similar critical underpinning infrastructure supporting the broader range of knowledge. Uncertainty around the future resourcing of this infrastructure on a sustainable, long-term basis is a risk to the development and long-term sustainability of national capability for climate services.
- This knowledge base is not comprehensive, and ongoing research is required to address gaps in our understanding of the climate system, and associated impacts and risks. It is however sufficient to inform existing climate services as an initial evidence base to inform climate awareness raising, climate action (adaptation, resilience and mitigation) policy development, adaptation and risk management planning, climate finance and associated decision-making, and capacity development as part of a longer-term endeavour to build climate resilience within Australia.
- At a national and state level, there are collectively multiple digital (web-based) and domain (people-based) platforms and associated climate services across the public sector, with varying degrees of governance, maturity, capability, scope, funding support/resourcing, viability and success (market impact). Lack of coordination across these platforms and associated climate services is confusing users and complicating applications, rather than providing complementary and differentiated products and services.
- This is mostly also the case across the private sector, noting however that:
 - Strategic drivers for service delivery in the private sector are primarily for private benefit (as opposed to the public sector in which activities/outputs are publicly funded and driven by a 'public good' imperative), and
 - Activities/outputs are often privately funded and therefore proprietary protected with limited transparency of core metadata, methods and analysis (as opposed to the public sector in which service delivery is mostly publicly funded and therefore open-source).
- The existing climate services knowledge value chain has incomplete coverage of user needs, and is highly fragmented with limited inter-operability and strategic alignment:

- Public and private sector market offerings are out-of-step, with ill-defined and poorly defined roles and responsibilities to avoid duplications/gaps and ensure effective and efficient use of existing science-based knowledge.
- There is limited integration and alignment between existing web-based platforms for delivery of physical climate change data and information as well as climate adaptation data and information, with multiple national and state-based sources each meeting part but not all the needs of many users without additional third-party technical support.
- Domain capability (core skills/functions) and/or political circumstances of key service providers for most part characterises or otherwise defines the perspective and focus as to the entry point for informing decision-making of users; likewise, the context and associated functionality and utility of related data and information platforms and services. This in turn perpetuates fragmentation of capability, resources and knowledge to the disadvantage of users (and sometimes creating confusion and mistrust) who for the most part are looking for a seamless and fully integrated, end-to-end climate services capability addressing all aspects of climate-related decision-making.
- There is limited effective and efficient uptake and application by users of existing knowledge through the mechanism of climate services:
 - There are data and modelling limitations and constraints, with incomplete coverage of all key variables, metrics and scenarios at requisite spatial and temporal scales for analysis.
 - Climate extremes, in particular for compound (or cascading) and coincident events resolved at explicit spatial and temporal scales relevant to user needs are not well understood or presented in a relevant, usable and credible manner.
 - Many users have limited and/or incomplete capacity and capability to understand their own needs and to apply existing services to their fullest potential utility and functionality; in particular for purposes of managing uncertainty when applying climate model outputs to inform future climate impacts and risks.
 - Many providers have a limited and/or incomplete understanding of user needs and capabilities leading to a mismatch between what is offered and what is relevant and usable. This mostly stems from a lack of understanding of the decision processes for which the services are being used.
 - Where such applications are occurring, there are examples of inappropriate and/or otherwise incorrect applications of services beyond the known, explicit limitations of the underpinning data and information. This situation is aggravated by users' limited understanding of how best to manage uncertainty in model projections. This situation is also aggravated by providers and purveyors' limited understanding of the role of uncertainty in decision processes and the ability to communicate uncertainties in a

relevant, usable and legitimate manner. Practical and legal implications of such outcomes are presently unclear but, at the very least, is the increased risk of maladaptation.

- Existing data and information underpinning climate services delivered through web-based platforms lack sufficient functionality and utility to meet the needs of users for highly visualised and geo-spatially referenced data and information with on-demand analytical capability.
- The need for enhanced data visualisation, geo-spatial referencing and on-demand analytics for climate model outputs is technically challenging in relation to model selection and communicating uncertainty at the spatial and temporal scaling required by users. This is particularly the case in the context of reconciling model outputs as quantitative inputs to future climate configured financial, natural catastrophe and other risk assessment models in the financial services sector (and thereby often resulting in so-called commercial 'black-box' metrics and analytics of uncertain scientific integrity).
- Existing climate services are delivered via multiple sources and platforms with in some case uncertain scientific integrity and market status, and mostly with limited integration and alignment, resulting in a confusing array of options and decisions to be made and an incomplete servicing of needs for users; particularly those users requiring 'end-to-end' support for awareness raising, to assessment of physical and transitional risk assessment and to planning and development and implementation of climate actions, including adaptive capacity and longer term climate resilience.
- Market demand for climate services is changing rapidly across the public and private sector, variously driven by the increased community awareness of the existential impacts/risk from climate change, consequent political drivers of change, threats of legal litigation and the expectations of corporate regulators for full disclosure and reporting of risks by corporate regulators.
- User needs are increasingly context specific, dictating the need for tailored products and services which are not otherwise readily available 'off the shelf' through existing web-based platforms.
- Recommendations of the TCFD for the enhanced disclosure and reporting of climate-related financial risks for the private sector is placing increasing demands on climate service providers in order to meet the expectations of industry regulators (e.g. APRA, ASIC), international ratings agencies, and the Federal Government/Reserve Bank. In this context it is also noted that there is a compelling need through this process to address issues of sovereign and sub-sovereign climate-related risk for Australia.
- In addition to risk, climate change presents opportunities for investment to take advantage of new technologies as part of the transition to a low Carbon economy (e.g. renewable energies, climate 'smart' agriculture, etc.), through 'green investment' climate finance market mechanisms such as

Green/Climate/Adaptation Bonds. Fund managers in the financial services sector have identified an increasing need for a climate science rationale in the form, of climate services to analyse, inform and validate such investments.

- Australian indigenous communities are a target user group for climate services, however specific needs are yet to be elucidated. The consultative process for identifying needs and opportunities for knowledge exchange with indigenous communities, particularly in terms of better understanding and applying traditional knowledge in a complementary manner with science-based knowledge is presently underway through various agencies and programs, including the NESP ESCC Hub in the form of an ongoing 'national dialogue'. The immediate priority is the establishment of trusted stakeholder relationships designed to facilitate meaningful engagement, before specific gaps and needs for climate services are identified.
- There is a compelling case for development of a 'best practice' platform approach to national climate service capability for Australia, with emphasis on 'seamless' integration of both digital (web-based) and domain (people-based) service delivery across multiple timescales, hazards and sectors; codesign/co-production.
- There are multiple providers in the private sector with varying levels of (digital and domain) capability delivering a range of value-added data, decision support tools and technical support) servicing public and private sector needs.

These providers are typically:

- Agile and responsive with relatively quick turn-around times (compared with the public sector), with the ability to deliver tailored products and services on a 'cost-effective' commercially viable basis.
- Products and services cover historical, current and future climate as well as a range of socio-economic analyses, risk assessment and adaptation products and services, and policy and planning support.
- Services delivered to the private sector often have limited transparency in terms of details around methods and analyses, and for the most part there is limited industry-wide coordination and governance in place to identify and leverage off key learnings and to drive broader industry-level 'best practice'.
- Interdependencies with public sector science institutions are fragmented and otherwise somewhat tenuous and opportunistic, again limiting scope for industry-wide learnings.
- The private sector includes larger (international) and SME (local) consultancies, including purpose-built consultancies. The bigger corporates have different business models for accessing climate 'intelligence' (market term for climate data and information to inform risk and investment, disclosures and reporting, etc.). Some firms have established and/or are developing in-house capability, others have entered strategic partnerships

with climate service providers and others have undertaken market acquisitions of third-party capability.

- The roles of public sector entities (e.g. CSIRO, Bureau, Geoscience Australia, universities) need to be more clearly defined in terms of:
 - Trusted (legitimate) and authoritative (credible) sources of science data/information.
 - Providers of scientifically validated (peer reviewed) and quality assured/controlled standards and guidance.
 - Service delivery focus which can reconcile public good v private benefit in a way that is transparent and agreed, particularly for purposes of addressing market failure in delivery of specific products and services.
 - Ensuring an appropriate balance between delivery of open source v proprietary protected IP, with appropriate costing models in place as part of both established agency roles and as part of creative new public-private partnership business models.
 - Ensuring key role in implementation of a science-based Innovation pipeline to inform and facilitate development of new and emerging technologies for 'next generation' climate services (e.g. 'NextGen'/CMIP6 projections, decadal predictions, detection and attribution capabilities, etc.).
 - Ensuring funding equitably shared across both public and private sector to maintain and further develop a national climate services capability to meet the needs of Australia's national interest.

7 Vision for future state of Australia's national climate service capability

7.1 Background

The literature review in the present study has identified various high-level design considerations relevant to the rationale, strategic planning and conceptual framing of an enhanced future state for Australia's national climate service capability. According to Jacob (2020), and primarily from an EU perspective:

- Developing relevant and effective climate services requires a variety of expertise along the value chain, from providing climate knowledge to the final climate service product.
- Collaboration and good networking are key success factors to develop relevant climate services.
- This includes public and private providers of climate services equally, which, to some extent, requires the development of new business models.

More effective collaboration and leadership across the public and private sectors is essential to understand and respond to climate risk and opportunity (CPD 2019). According to CPD (2019) a cross-sectoral climate risk assessment is required at a whole of economy scale, to be undertaken by a coalition of actors across the public and private sector, coordinated by the Commonwealth Government, working with senior officials from all jurisdictions, the Council of Financial Regulators, energy-market bodies, firms, investors and peak bodies. In the first instance, the focus could be placed on supporting national adaptation priorities and disaster preparedness (CPD, 2019).

Webb et al (2019) recommend five principles for a more coordinated national climate resilience and adaptation decision-support strategy:

- Consolidate national efforts into core authoritative adaptation platforms and products, with common and linked process guidance and data sources, and a commitment to ongoing support and continuous improvement.
- Meet differentiated needs by encouraging user demand-driven platforms and products that build on and extend the core national products.
- Ensure these platforms and products are quality assured (to an appropriate standard).
- Complement the platform and product development process with ongoing enablers, especially communities of practice and knowledge brokering.
- Catalyse the national strategy initially through government leadership and

coordination, but with progressively increasing cross-sector private and community stakeholder support, ownership and resourcing in a strategic coalition.

According to Webb et al. (2019) incorporating leading practices into the adaptation process and support products requires:

- An overall adaptation process that is cyclical, iterative and can be used in standard risk management approaches.
- Continuing learning throughout the process, including iteration between steps, formal monitoring and review and active learning from others.
- Strong and sustained leadership (both formal and informal) and effective stakeholder engagement are required through all adaptation stages, and their nature will also evolve.
- Explicit, agreed framing and scoping to be addressed up front, but are also likely to evolve:
 - Taking an integrated 'systems' approach to understand and manage climate risks and opportunities, and adaptation responses, including critical interdependencies.
 - Defining a practical boundary for the relevant socio-economic-environmental systems to be encompassed.
 - Addressing various spatial and temporal scales involving choice of the most appropriate scales for the issue at hand.
 - Considering to what extent the framing will require stakeholder values, institutional and related transformational change.
 - Considering when and how to integrate adaptation planning, decision-making and implementation into current organisational roles/structures and business/decision-making processes.
 - Articulating a clear statement of adaptation vision, intent, objectives and goals.
- Evaluating risks and responses using good practice approaches:
 - Selecting climate scenario and other impact and options data most relevant to the context and need; incorporating qualitative, quantitative, local, expert and cross-disciplinary inputs.
 - Assessing climate risk using 'bottom up' current and local climate knowledge as an entry point and for engagement, subsequently complemented by 'top down' projected climate change analysis.

- Focusing on evaluation of adaptation options most relevant to support decision-making moving relatively quickly to a first pass of response options identification to facilitate a ‘fast iteration’ process between steps.
- Carefully choosing methodologies and methods most appropriate to the issue, tailored where necessary to local need.
- Supporting decision-making under uncertainty, including the optimum sequence and timing of decisions, including flexible adaptation pathways.
- Adaptation product characteristics that support common and differentiated user needs (applies to entire product concept):
 - Products and processes must be authoritative and current, so that organisations can rely on their use to justify their decisions to external as well as internal bodies.
 - A range of products are needed to cover both common (generic) and differentiated (e.g. sector/location specific) needs. Common needs are best provided by national cross-sector products: differentiated needs by demand-driven sector or location-based groups
 - Products need to reflect that there are multiple possible ‘decision entry points’ to adaptation initiatives and decision types—typically sector specific reflecting their distinctive business processes.
 - Products should be layered to reflect different organisational stages of development and consequently different related decision ‘domains’ and complexity, different organisational capacities and flexible starting points and sequencing in the cycle.
 - Products need to provide integrated access to process, data and knowledge products and to complementary enablers (e.g. knowledge brokers, user/peer networks, learning processes, communication and engaging, etc.) – knowledge portal products, which encompass and link process guidance and data products, are important, but made even more valuable by links to a range of supporting enablers.

Palutikof *et al* (2019a) recommends ten guidelines for improved climate services as part of a typical adaptation platform:

- Practitioner involvement: Co-development and co-production are resource intensive activities but can deliver decision-support resources that are relevant, trusted and used by the target audience.
- Communities of practice: Web-based tools offer some strong advantages over professional societies and conference series—they are low cost, accessible to all and available at all times. If they capitalise on this advantage, they can complement other initiatives to create and maintain active and useful communities of practice.

- Matching decision-support to user needs: The needs of adaptation practitioners for decision-support resources are differentiated by the complexity of the task and the capability of the decision-maker.
- Time dependence: Ensuring relevance of adaptation decision-support resources from inception to release requires developers to be flexible, undertake meaningful and sustained stakeholder engagement and pay close attention to emerging adaptation policy and practice trends.
- Uptake: Innovative approaches are needed to achieve visibility and credibility, and hence uptake of decision-support resources. These might include using datasets and standard procedures (e.g. for risk assessment) that are familiar to target users and aligning with climate change information and guidance disseminated by professional societies/peak bodies.
- Capability matching: Developers should be mindful of potential users throughout the design and build of an adaptation decision-support tool or platform, especially the need to address potential barriers to take-up such as lack of user capability, time and resources.
- Translation: Decision-support resources may be successfully translated for use in different sectors and locations, especially where the primary aim is to take advantage of the existing credibility and experience embodied in the original resources. Past successes suggest effective translation requires close collaboration between users and experts in the targeted sector or location, along with scientific and technical support from the original developers.
- Evaluation: Independent medium- to long-term evaluation of adaptation platforms is required to understand whether they are effectively fulfilling their original purpose and, if not, why not.
- Comparison: In-depth comparative studies could help all adaptation decision-support resources by enhancing relevance, confidence and trust, improving user experience and bolstering decision-support outcomes.
- Renewal: Active updating and maintenance of an adaptation platform or decision-support tool, accompanied by clear and visible documentation, will ensure continued relevance and sustained viability, and hence user confidence in the long-term and ongoing usage.

To understand the costs and benefits of science-based climate services for Australia, Newth (2020) has undertaken a macro-economic (GDP scale) integrated assessment of standardised climate and investment scenarios. Comparison of these scenarios allows estimating the costs and benefits of climate services over time (see Box 5).

As an example, under the RCP8.5 world, investment in climate services returns a net benefit to the Australian economy in 2100 whereby the 'high investment' scenarios outperform the 'low investment' scenarios (Newth 2020).

These findings and insights from the literature have collectively informed the vision, logic and conceptual framework of a future state for a national climate services capability for Australia as part of the present study.

Box 5: Cost-benefit analysis of climate services

To understand the costs and benefits of science-based climate services for Australia, Newth (2020) has undertaken a macro-economic (GDP scale) integrated assessment of standardised climate and investment scenarios. This study used a combination of computable general equilibrium and plausible scenario analysis based on the Global Trade and Environment Model (GTEM) to measure desired indicators of changes in climate adaptation capacity and resilience.

Comparison of these scenarios allows estimating the costs and benefits of climate services over time. As an example, under the RCP8.5 world, investment in climate services returns a net benefit to the Australian economy in 2100 whereby the 'high investment' scenarios outperform the 'low investment' scenarios. The early high investment scenario results in just over US\$52Bn yr⁻¹ in 2100, after all costs and benefits are considered. The late action low investment policy setting is the poorest performing scenario, only increasing GDP by \$34Bn yr⁻¹ in 2100 (Newth 2020).

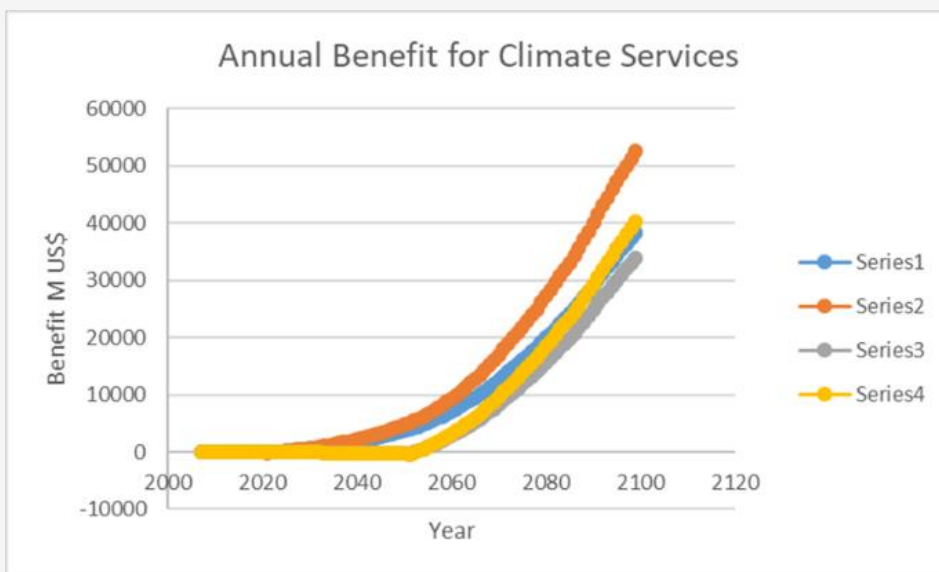


Figure B5.1: Annual benefit of four climate services investment scenarios (in \$US millions) in a high (RCP8.5) world. Investment scenarios are early-low (series 1; blue), early-high (series 2; orange), late-low (series 3; grey) and late-high (series 4; yellow).

Further gains are possible if the quality and quantity of services are increased through investment in infrastructure, the observational capability, interpretative and decision support tools, guidance materials, user training and other capacity development, and the basic underlying R&D to inform the development and facilitate the application of the services.

Normative or prescriptive models clearly indicate the wide range of sources of potential economic benefits of improved, and improved use of, climate and meteorological services. There is now also a growing number of examples of market transactions for climate (change) services, particularly for specialised value-adding services for specific sectoral users, in which market prices paid indicate significant economic benefits e.g. the financial services sector (Newth 2020).

7.2 Logic-based theory-of-action

Based on the outcomes of the present study, including in particular the specific outcomes of the March 2020 KE4CAP stakeholder workshop, a ‘theory-of-action’ has been developed to outline the logic-based, strategic rationale for the future vision of a national climate services capability for Australia. This theory-of-action (also variously referred to as a ‘program logic’) has been developed using a modified *Bennett’s Hierarchy* approach (DPI 2008) to what is otherwise considered conventional, logic-based, scientific program-level evaluation planning.

It follows that such a theory-of-action is intended as a top down planning tool for designing the strategic rationale and structure for an outcome focused, program level intervention to address specific objectives and thereby facilitate a tangible path-to-impact. This theory-of-action can also be used as a bottom up program management tool for routinely monitoring operational performance against the objectives of the intervention once implemented and evaluating impact against the related outcomes at various stages during and following implementation.

The major elements of a theory-of-action for the proposed national climate services capability for Australia are shown in Figure 10, with details of these elements schematically summarised in Figure 11.

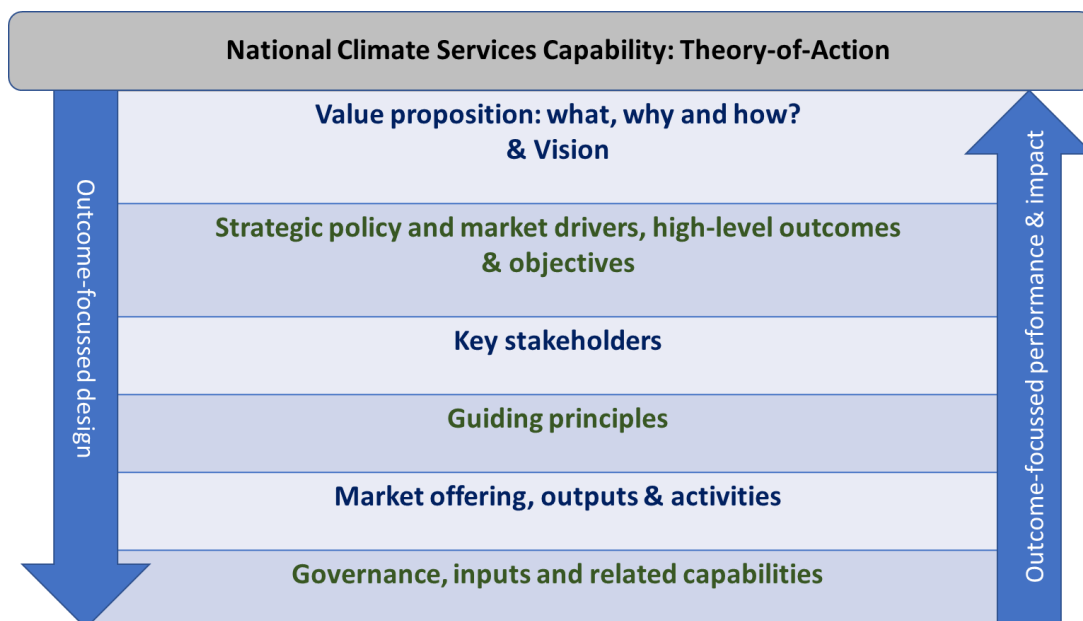


Figure 10: Major elements of the theory-of-action for the proposed national climate services capability.

7.2.1 Value proposition and vision

As previously described, the value proposition is intended to briefly articulate essential elements of *what, why and how* the proposed intervention of a national climate services capability would add value to Australia’s national interest, and in particular the efforts of providers, purveyors and users of climate services in realising the stated outcomes of the proposed theory-of-action. For the most part, the value proposition and vision is designed to succinctly describe in brief narrative form the overall logic for the national capability.

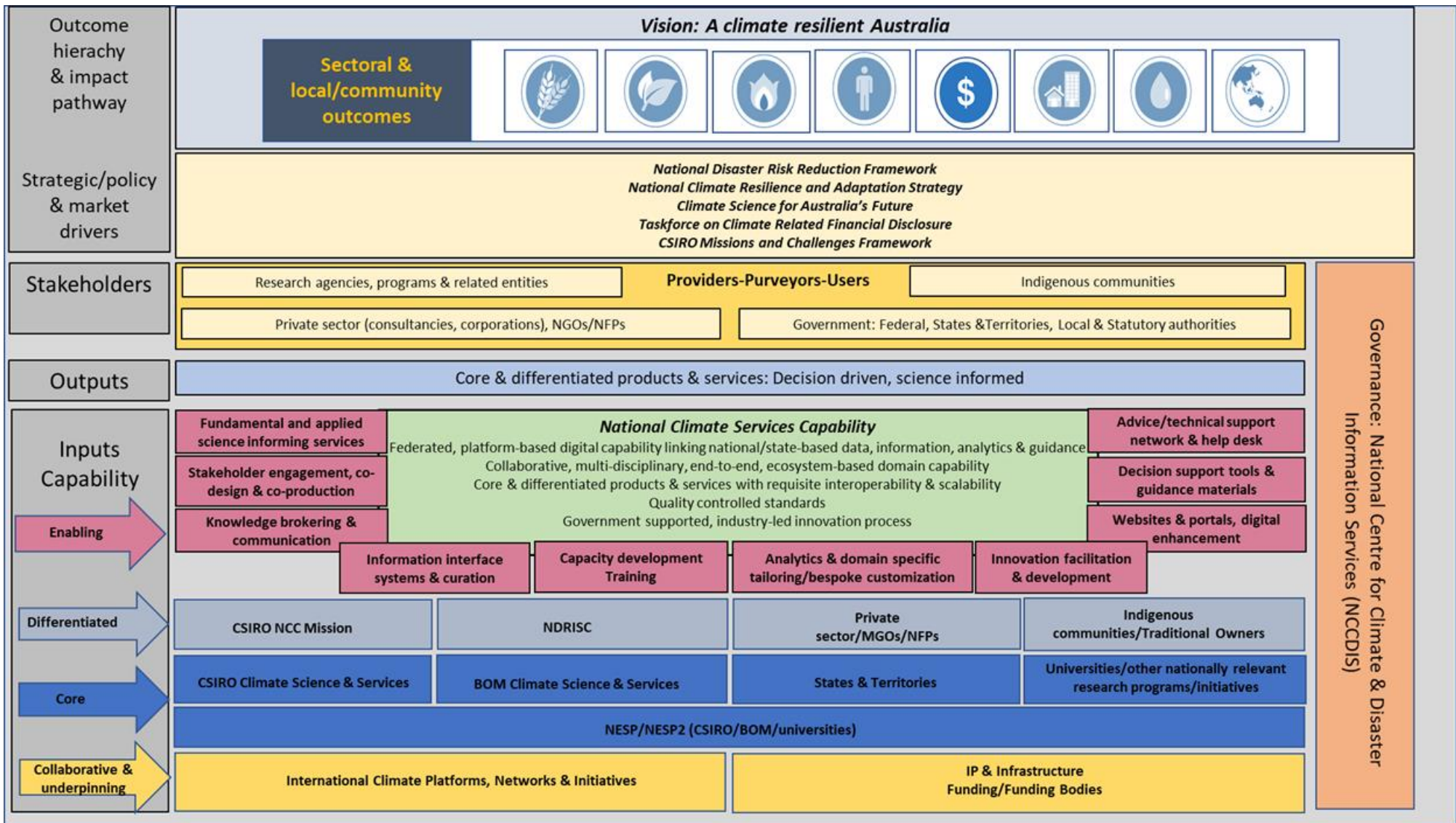


Figure 11: Conceptual, logic-based representation of an enhanced climate services capability for Australia. Featuring existing capability (including Bureau of Meteorology, CSIRO, states & territories, universities and the private sector) and associated programs and initiatives (e.g. NESP, CLEX etc), together with emerging and future capabilities (including CSIRO NCC Mission, NDRISC and Indigenous traditional knowledge).

7.2.2 Strategic policy/market drivers and high-level outcomes

The key drivers providing strategic policy and market settings for the proposed national climate services capability for Australia have been described previously in this report, and include the:

- National Disaster Risk Reduction Framework (2019)
- National Climate Resilience and Adaptation Strategy (2015)
- Taskforce on Climate Related Financial Disclosure (2017), and
- Climate Science for Australia's Future (2019)

These policy and market settings provide the context collectively for the hierarchy of high-level outcomes which are expected to be realised through the proposed national climate services capability. These outcomes are nationally relevant but are realised in terms of impact for the most part at a sectoral and/or local level:

- Providers, purveyors and users across the public and private sector actively support ongoing national coordination, development and delivery of a platform-based climate intelligence and services capability for Australia and the Asia-Pacific region = **a national climate services capability for Australia.**
- A national climate services capability in the form of a platform that effectively and efficiently provides data, information and analytics in the form of accessible, science-based products and services which meet appropriate quality standards, together with technical support, knowledge brokering and related outreach for users.
- These products and services are co-designed and co-produced through public/private partnerships, with mutual benefits tailored to address the needs of target users.
- Climate services are routinely accessed and applied by users from the national capability to enhance understanding of climate risk and inform climate action including climate sensitive decision-making, which delivers both public good and private benefits for users, mitigates sovereign risk and enhances adaptive capacity more generally.
- The combined benefits of applying this capability can be demonstrated to:
 - Enhance adaptive capacity and the resilience of Australian communities, the economy and environment to the impacts of climate variability, change and extreme events/climate-related natural disasters, and thereby
 - Mitigate sovereign/sub-sovereign risk and realise investment opportunities thereby helping maintain Australia's AAA credit rating.

- Engagement is strengthened within and across government, business and communities, in particular to support innovation, knowledge exchange and capacity building in relation to development and application of climate intelligence and services which enhance Australia's ability to adapt to a changing climate.

7.2.3 Objectives

The objectives of the proposed national climate services capability are to:

- Establish and implement a nationally coordinated climate services capability for Australia, including both digital and domain-based platforms, and based on robust governance arrangements, guiding principles and partnership-based business model(s).
- Develop and deliver a portfolio of core and differentiated, science-based products and services to consistent standards and tailored to the priority needs of target users.
- Provide technical support, knowledge brokering and related outreach to purveyors and users of climate products and services and build their capacity to facilitate enhanced understanding of needs and application of climate data and information for decision-making.
- Provide a stakeholder forum and business-based delivery mechanism to facilitate continuous improvement and an innovation process that is user driven and solutions-based.
- Monitor (operational) performance and evaluate (strategic) impact to inform adaptive management and to facilitate continuous improvement and innovation in service delivery and knowledge exchange over the life of the national capability.

7.2.4 Key stakeholders

The key stakeholders that these objectives have most relevance, and therefore roles and responsibilities for purposes of implementation of the national climate services capability include:

- **Providers** (of products and services to next and end-users) **and purveyors** (next-users who add value to products and services from other providers and then provide these to end-users), including:
 - Federal, State & Territory government departments
 - CSIRO (including NCC Mission), BOM, Geoscience Australia & universities
 - National consortia, incl. NESP ESCC Hub/NESP2 Climate Systems & Adaptation Hub, CLEX, NCCARF & NCDISC

- Private sector consultants, SMEs, consortia and intermediaries/industry bodies, NGOs/NFPs
- Traditional owners and Indigenous communities
- International providers and purveyors (public & private sectors)
- **End-Users** (many of whom are also providers and/or purveyors from time to time), including:
 - Private sector consultants/SMEs, large-scale corporations, industry consortia and industry bodies/intermediaries, NGOs/NFPs
 - All levels of Australian government: Federal, States/Territories and Local
 - Traditional owners and Indigenous communities
 - Statutory authorities
 - Asia-Pacific communities of interest at regional, national and sub-national/sectoral level, and
 - Other international users (private sector)
- **Other key stakeholders** (who are not otherwise providers, purveyors or users of climate products and services), including: both public and private sector sponsors/funders/donors who provide the underpinning investment in climate services at a national/sub-national level, industry regulators with oversight of relevant standards informed by climate services, and digital service and infrastructure providers etc.; the latter of whom provide (amongst other things) critical underpinning infrastructure for collection and curation of climate observations and data, and high performance computing infrastructure required for climate modelling and the storage, processing, analysis and curation of related data and information upon which for the most part science-based climate services are based.

7.2.5 Guiding principles

Based on the key findings of the present study, and to complement and align with the stated value proposition, high level outcomes and objectives, the following guiding principles have been developed to inform 'best practice' development of a national climate services capability for Australia (where appropriate and feasible), including strategic rationale, operational design features and implementation imperatives:

- Recognise there is a **fundamental market driven change** in the understanding and management of climate resilience, systemic risks and emerging opportunities for decision-makers, dictating the need for a forward-looking, nationally-coordinated, fit-for-purpose approach to providing data, information, analytical capability and associated knowledge in the form of climate services based on continuous improvement and learning.

- **Decision-driven and science-informed capability** that helps users navigate the **climate resilience** landscape and provide science-based evidence to inform decision-making for end-to-end **climate action**; from exploring the decision context to assessing risks and opportunities, assessing priorities, implementing actions, monitoring progress and evaluating impact.
- An **integrated and nationally coordinated digital and domain-based platform** approach, with appropriate functionality and utility which facilitates discoverability, accessibility and security of data, information, analytics and associated knowledge.
- **A governance** approach that is participatory, based where appropriate on a collaborative **public-private partnership business model** that facilitates consensus, ensures legal compliance, and quality-controlled standards, and is transparent with equitable cost sharing and mutually compatible roles, responsibility and resourcing for providers, purveyors and users across the public and private sector.
- Address **user needs** across:
 - Multiple climate/climate change timescales (seasonal to multi-decadal and beyond) and, where possible, in a manner which is operationally seamless to users.
 - The full spectrum of i) awareness raising, ii) decision support and iii) associated capacity development, to inform climate (adaptation and mitigation) policy development, risk management planning and implementation, investment planning and related reporting and disclosures.
 - Both science-based and traditional (indigenous) knowledge domains.
- Adopt an **open-source 'platform' approach** where possible, particularly where publicly funded, to facilitate accessibility and application by a broad cross-section of users, with emphasis on enhanced utility/usability and functionality of products and services
- **Products and Services** that are **co-designed, co-produced** and evaluated for **co-learning**, tailored to the priority needs of target users, with quality controlled standards and ranging from objective-setting to generating information and data, developing or modifying decision-support tools, and enabling uptake of information through knowledge-brokering and capacity-building; including:
 - **Core products and services** that are credible, relevant, standardized, quality-assured and freely available through a centralized government-led business model and which primarily deliver public good to a broader user or user group(s).
 - **Differentiated products and services** that are consistent with core products and services, but which primarily deliver private benefit to a specific user or user group(s).

- Strive to achieve **equitable and sustainable resource allocation and investment** in an appropriately proportional manner prioritised across relevant users and providers on both the supply and demand side, including through the use of purpose-built business and costing models for climate services which, in a balanced and transparent way, variously to:
 - Ensure equitable access to **publicly funded intellectual property for societal benefit**, particularly for agreed minority or otherwise disadvantaged communities of interest.
 - Support **development of public-private partnerships** which optimise the technical capability/capacity and other technical resources, data and information in a way that delivers mutually beneficial outcomes for both public and private sectors.
 - **Cost recover, publicly funded intellectual property used for private profit** for specific users on an appropriate fee-for-service or other commercial basis for re-investment back into the underpinning science.
 - Enable **development and delivery of privately funded intellectual property** for entirely private ‘commercial-in-confidence’ purposes, in particular where this provides a broader **capability dividend for the national interest**.
 - Where appropriate provide a **return-on-investment in the national interest to support ongoing R&D** and associated innovation pipelines for ‘next generation’ climate services.
- Place a premium on service delivery that optimises benefits to and otherwise adds value for users in that they are **relevant, usable, authoritative, scientifically credible/robust and quality controlled/assured** based on agreed ‘best practice’ standards where appropriate
- **Align variously with climate and other environment-related national and international strategic policy and regulatory drivers** across all tiers of Government (federal, state and local) and the private sector, with emphasis on:
 - Enhanced management of sovereign/sub-sovereign risk; and
 - Compliance with legislative and/or other regulatory requirements.
- Technical support and training that **builds capacity** in the national climate services capability to meet emerging and future needs on **both the supply and demand side** of the climate services knowledge value-chain to ensure requisite and complementary skills and continuous improvement across all aspects, including communication, knowledge brokering, translation and exchange for both science-based and traditional (indigenous) knowledge
- Be defined by core functions and terms of reference consistent with **international best practice**, but otherwise with sufficient flexibility for customisation to be **contextually specific to meet local user needs**

- A **continuous improvement imperative** and **innovation process** that draws on the best available national and international science, infrastructure, policy and business intelligence to enhance knowledge development, brokering and exchange as user needs and capacity inevitably change over time
- A strategic and operational business imperative designed to facilitate a **return on investment** for Australian communities, environment and the economy compared to the current arrangements, and in a way that can be quantitatively measured in terms of tangible metrics of **socio-economic benefit**
- Be underpinned by **fit-for-purpose observations, high performance computing and associated infrastructure** for securing, accessing and applying relevant data, information, analytics, tools and other products.

7.2.6 Market offering and outputs

Consistent with the guiding principles, the headline market offering for the proposed national climate services capability features the following elements:

- Federated, platform-based, digital capability connecting national and state-based data, information, analytics and guidance.
- Collaborative, multi-disciplinary, end-to-end (for the climate decision-making spectrum), ecosystem-based domain capability.
- Core and differentiated products & services with requisite interoperability and scalability.
- Science-based standards and quality control (including peer reviewed where appropriate).
- Government supported, industry-facilitated innovation process.

More specifically, the scope of core and differentiated products and services for a national climate services capability would include (but not otherwise be limited by) the summary examples listed in Table 1.

It is assumed that the core products and services would for the most part be publicly funded and delivered by the major government owned climate science and service providers and purveyors, for the primary purpose of generating public good. It is also assumed that the differentiated products and services would for some part be privately funded and delivered by the major privately-owned climate service providers, for the primary purpose of satisfying end-users and generating private profit.

In this context, the critical role and responsibility of the government-funded public sector in supporting the foundational scientific capability that effectively informs the core products and services is acknowledged. This investment of public resources is inevitably therefore the basis of how much of the development of differentiated products and services is able to be cost-effectively leveraged by the private sector, including through public: private partnerships. For this process to be optimised, there is also a need for high levels of inter-operability and scalability between the various

products and services, particularly where in addition to the private profit imperative there is also an overt or implicit national interest related to sovereign/sub-sovereign risk (e.g. where such products and services can be utilised by the financial services sector to de-risk Australia and mitigate the fiscal impacts of climate change in a way that contributes to maintaining Australia's AAA credit rating).

However, it is also the case that there already is and will be significant overlap between the interests and activities of both the public and private sector providers and purveyors in which both core and differentiated products and services are developed and delivered jointly for generating co-benefit as part of a structured public: private partnership-based business model.

Indeed, in the interests of facilitating innovation and cost effective and efficient development and delivery of climate services for users, the private sector is deemed to have a significant role going forward as part of the national landscape, both as a stand-alone capability and in partnership with the public sector.

The public sector for its part has an additional responsibility, in particular through delivery of core products and services and joint delivery of differentiated products and services, to ensure such outputs are appropriately quality assured/controlled, scientifically robust and legitimised by trusted and scientifically independent and credible sources. In Australia, there are presently a number of examples of public, private and joint public: private funded science and science-based services from which the proposed national climate services capability could leverage useful learnings. A schematic summary of the conceptual and relative inter-dependencies between the public and private sector funded core and differentiated climate services is provided in Figure 12. Likewise, a conceptual representation of the functional interdependencies between core and differentiated products and services delivered through public, private sector and joint funding (PPPs) is provided in Figure 13.

By comparison, the roles and responsibilities and associated funding arrangements for provision, operation, maintenance and use of the critical underpinning infrastructure needed to support the national capability, are considered to sit firmly in the public domain as a primary role of government. This includes the underpinning science capability and the collection, processing and curation of climate observations and modelling data and information.

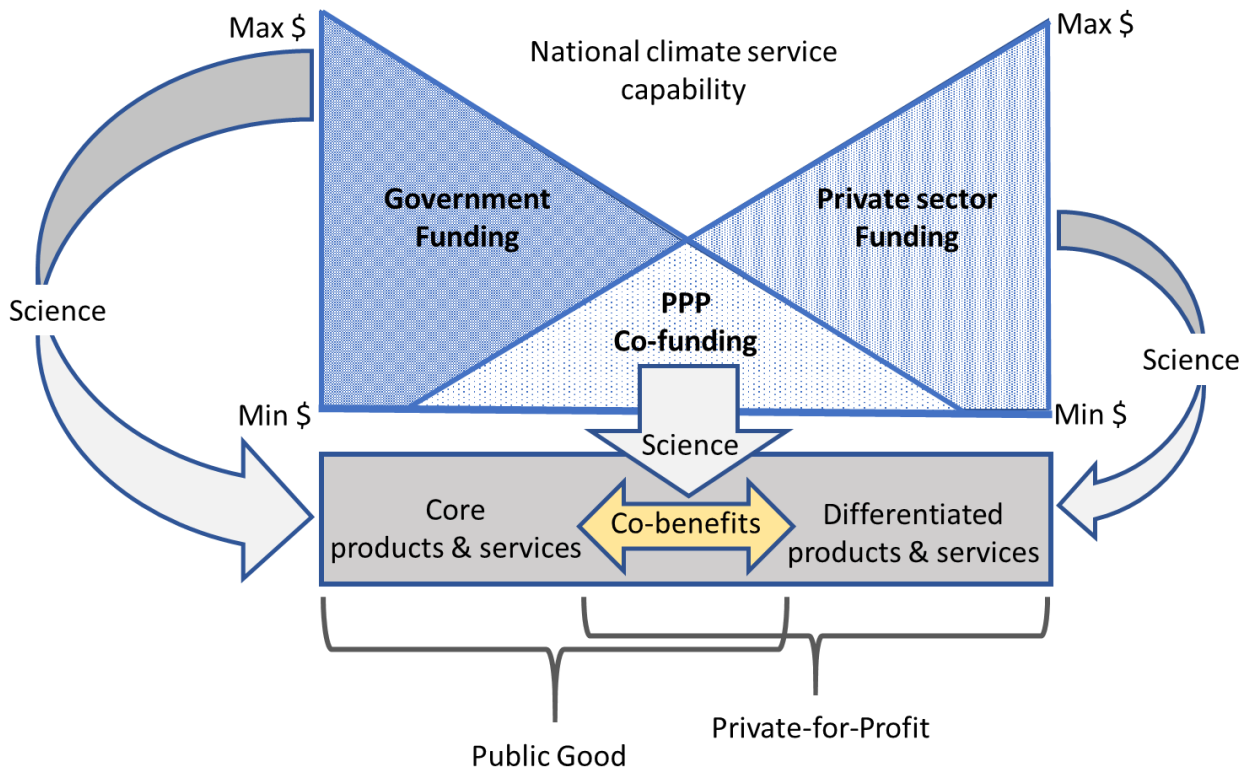


Figure 12: Conceptual representation of the interdependencies, indicative proportional funding for underpinning science and development and delivery of core and differentiated products and services across public and private sectors and PPPs, and flow of benefits and co-benefits between public good and private-for-profit; arrows represent nominal source, directional flow and relative scale, proportionality and interdependencies of financial investment in the science underpinning an enhanced national climate services capability.

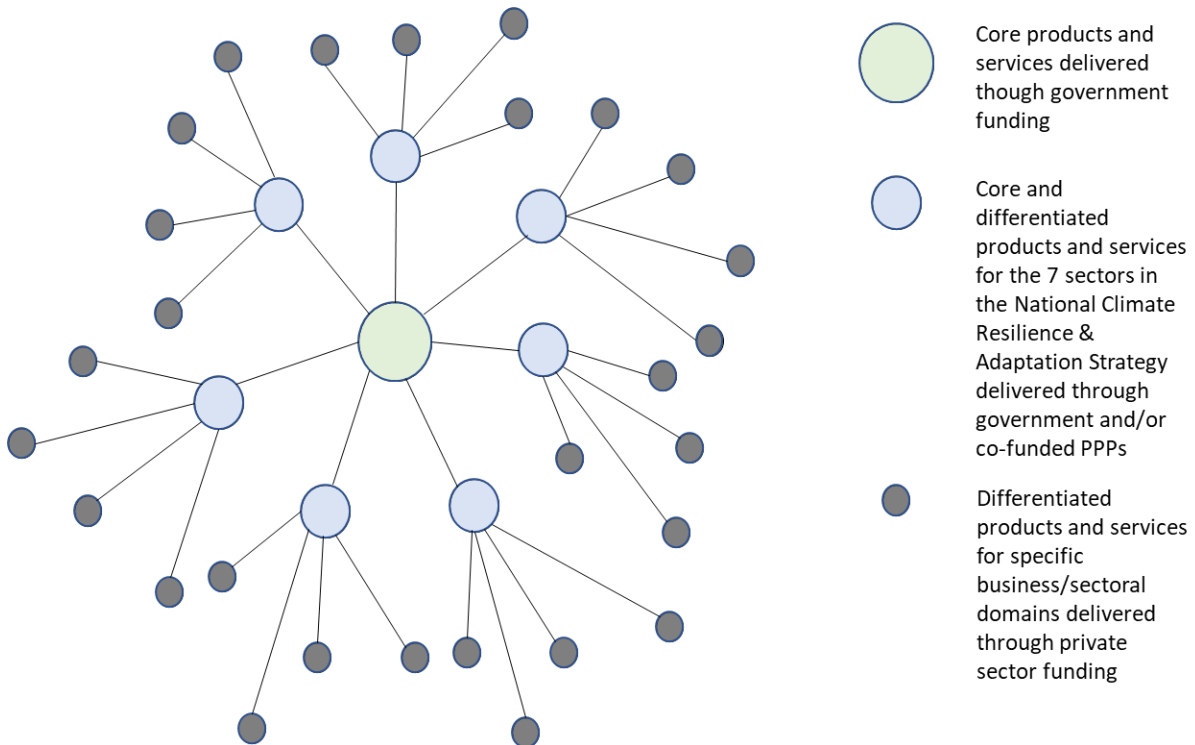


Figure 13: Conceptual representation of the functional interdependencies between core and differentiated products and services delivered through public, private sector and joint funding (PPPs).

Table 1: Examples of the scope of core and differentiated products and services as part of an enhanced national climate services capability for Australia

Core products and services	Differentiated products and services
Best practice climate-based risk management and resilience planning guidance/frameworks	Sector-specific applications including new and innovative, commercially sensitive (proprietary-protected) tools, products and services
Best practice guidance on establishing the context, e.g. stakeholder engagement, climate-sensitive decisions, governance, responsibilities, resources, knowledge	Adding additional user specified value to core products and services, including tailored data delivery, tools and customised CCiA/INDRA domain content for specific sectors/users
Undertaking climate impact assessments, preliminary analytics, and exploring preliminary adaptation options and decision pathways	Traditional knowledge co-designed and co-produced with Indigenous communities, including outreach and applications
Knowledge brokering and exchange to facilitate data discovery, access, understanding, analysis and application	Application-ready data streams, information, analytics, guidance and tools for sectoral/user specific exposure, vulnerability and risk assessment and investment analysis
Quality controlled standards, including standardised, globally consistent scenario analysis framework to inform hazard identification and sensitivity analysis/impact assessment	Exploring detailed decision pathways, adaptation options, and planning, disaster management and associated decision-support; including harmonised scenarios to underpin adaptation and resilience planning.
Climate change science literacy/101 training materials & awareness raising	Climate model output parameterisation for industry Nat-Ca, risk and financial models, analysis/assessment and outputs
Science-based evidence and guidance to inform climate resilience planning and decisions, managing uncertainty etc	Bespoke ensemble modelling and analysis of sector specific climate scenarios at fine spatial scale and/or for specific asset classes and associated stress-testing, including for analysis of compound/coincident/cascading extreme events
Federated, web-based digital climate intelligence platforms including BOM data portal, CCiA, INDRA, CoastAdapt, CRISP and state-based platforms	Integrated assessment modelling including bespoke, climate-configured macro-economic impact modelling for 1 st 2 nd 3 rd order physical climate risks and associated investment analysis
Climate data services, including monitoring, seasonal forecasts and multi-decadal projections	AI/machine learning based integrated knowledge management systems tailored to climate intelligence needs of private sector
Decision support tools and knowledge products, including guidance materials and case studies, and communication collateral including State-of-the-Climate reports, web content, fact sheets, brochures, webinars, seminars/conferences, media etc	Commercially oriented communication collateral, knowledge products and related resources including corporate Board and Executive Management presentations, other engagements etc
Monitoring and evaluation of publicly funded service delivery	Monitoring and evaluation of privately funded service delivery

7.2.7 Activities and governance

The activities to be undertaken in order to develop and deliver the suite of core and differentiated products and services in a staged process would need to be prioritised on the basis of an agreed long-term strategy (5-10yrs) and operational 3yr work plan for the national capability to be established. The work plan would prioritise the establishment of a new national centre for climate services as the formal governance mechanism for overseeing and coordinating the development, delivery and overall stewardship of the national capability, as well as development of the long-term strategic plan (Table 2).

Table 2: Three-year work plan for establishment of a national centre for climate services

<p>Year 1 priorities</p>	<ul style="list-style-type: none"> • Expression of Interest process to identify foundation partner membership and establishment of advisory body(ies) • Design/develop and commission the National Centre for Climate Services, incl: <ul style="list-style-type: none"> ○ Terms of Reference, guiding principles, operating protocols ○ Develop and implement business model ○ Governance arrangements (management structure/secretariat) • Develop and implement 3 year work plan and budget • Develop 5-10 year strategy for ongoing sustainability of national climate services capability, including national centre for climate services • Develop collaborative partnerships and identify infrastructure needs • Year 1 (Stage 1) core products and services and capacity development • Undertake domestic and international stakeholder engagement • Undertake monitoring and evaluation (M&E) and annual reporting
<p>Year 2 priorities</p>	<ul style="list-style-type: none"> • Implement Year 2 work plan incl: <ul style="list-style-type: none"> ○ Year 2 (Stage 2) core products and services and capacity development ○ Stage 1 differentiated products and services ○ Communication and knowledge brokering • Further develop governance arrangements, incl. business/costing models and establish PPP(s) • Undertake target user engagement and establish CoPs • Undertake domestic and international stakeholder engagement • Revise Year 3 work plan and undertake M&E and reporting
<p>Year 3 priorities</p>	<ul style="list-style-type: none"> • Implement Year3 work plan, incl: <ul style="list-style-type: none"> ○ Year 3 (Stage 3) core products and services and capacity development ○ Stage 2 differentiated products and services ○ Communication and knowledge brokering • Further develop governance arrangements, incl. management of PPP(s) • Undertake target user engagement and support CoPs • Undertake domestic and international stakeholder engagement, including host international event to facilitate long term planning • Undertake M&E and annual reporting • Review and update 5-10 year strategy for ongoing sustainability of national climate services capability, including national centre for climate services • Domestic and international stakeholder engagement

It is expected that the centre in the first instance could leverage off the activities, resources and strategic directions of key stakeholders within the existing national climate services landscape, including the Federal Government, States and Territories, CSIRO, BOM, GA and universities as partner agencies. Further partners including the private sector would be recruited thereafter. Priorities for establishment of a national centre and three-year work plan would include:

Who would be involved?

Foundational members, advisory bodies, secretariat etc:

- Foundational members could potentially include organisational representatives and/or representative bodies across the full spectrum of existing climate service capability in Australia: providers and purveyors (including existing national and state-based programs and initiatives)), users, infrastructure providers and funders. Identification of foundational membership could be through a formal expression-of-interest process, and subsequent membership would be facilitated as part of core business for the centre.
- Responsibility and substantive support for the foundational membership could be expected from relevant public sector organisations, including CSIRO and the Bureau in the first instance, but private sector partnerships and support through PPPs could also be an immediate priority
- A formal governance structure could be established to deliver core functions of the centre including a partnership-based steering committee, one or more technical and user-based reference and advisory bodies, and a program management/secretariat unit.

What would it do?

Terms of Reference, core functions, roles & responsibilities:

- Preliminary Terms of Reference (ToR) and associated 5-10 year strategic plan could be developed for the centre by an interim Steering Committee as part of the initial planning and proposed EoI process in Year 1. This would elucidate the core functions, roles and responsibilities, work plan and associated scope of work for the centre, in alignment with the agreed vision, high level outcomes, objectives and guiding principles of the national climate services capability outlined in this report.
- The program management role to be established as part of the commissioning of the centre itself would oversee and coordinate with and on behalf of the centre partnership the development of the ToR, and implementation of the core functions of the centre. This could include the day-to-day administration, coordination and oversight of the centre's core functions, strategic and operational work planning, as follows:
 - The role of internal focal point for the membership and external focal point ('concierge') for otherwise unaffiliated users and other external stakeholders

- Development and management of participant agreements aligned with the ToR and agreed scope of work for the centre, and management and oversight of new IP generated through the centre consistent with legal obligations and flow-through T&Cs of relevant partner agreements and the licencing conditions of existing, underpinning, third-party IP.
- Management and coordination of the development and implementation of the centre's standard operating systems and procedures and associated work plan including development and delivery of the suite of core products and services.
- Management of foundational partner relationships and development and management of new partnerships, including PPPs and international engagement, and the associated development of differentiated products and services.
- The ToR, strategic plan and related risk management for the centre could take into account the changing nature of relevant policy settings for climate adaptation, risk and resilience in Australia and thereby:
 - Leverage off the strengths and aim to realise the opportunities of the existing capability.
 - Address the weaknesses and threats to the existing capability, as outlined in this report.
- The centre could also undertake the additional core functions:
 - Advocacy to raise stakeholder awareness of the centre including its value proposition, capability and core functions.
 - Management and oversight of development, delivery and quality control/assurance for core products and services.
 - Network development, relationship management, communication, knowledge brokering and capacity development of and with providers, purveyors and users of climate services.
 - Performance monitoring, impact evaluation, knowledge exchange/learning and reporting to facilitate real-time adaptive management and continuous improvement in service delivery.

How would it operate?

Business model(s) and resourcing:

- The centre would operate under a fit-for-purpose business model to be developed and implemented as an immediate priority in Year1, and designed to accommodate the roles and responsibilities of both public sector foundational partners in the first instance, but with sufficient flexibility to accommodate the

roles and responsibilities of the private sector through agreed PPP arrangements

- Such a business model would need to take into account the specific requirements for ownership and management of both public (open-source) and privately owned (proprietary protected) IP as appropriate, including terms and conditions of use, as will apply to the available core and differentiated products and services. This would also need to extend to consideration of legal liability for production and use of the full suite of products and services as might apply to the centre's membership and broader network of users
- Costing models to be developed and implemented as part of the overarching business model would likewise need to account for the production of the centre's core and differentiated products and services to ensure equitable cost-recovery and sharing in an equitable manner, including to facilitate where appropriate a return-on-investment to offset the cost of the underpinning and foundational science capability informing core and differentiated products and services as appropriate.
- Business development for the centre would need to:
 - Foster private sector investment and collaboration through development of PPPs and associated business models for co-investment in development and delivery of differentiated products and services.
 - Undertake active market development and marketing to promote the core functions of the centre, including the uptake of core and differentiated products and services across the full spectrum of users.
 - Develop and implement a business plan to ensure the long-term strategic, operational and financial sustainability of the national centre with support from both the public and private sector.
 - Facilitate an innovation process underpinned by PPPs to support pipeline development and delivery of differentiated products and services, and where appropriate the spin-up of new and innovative PPP-based climate service business opportunities.

As part of the Year 1 work plan for the national centre it would be necessary to initially review a variety of different business models before adopting and implementing an appropriate 'fit-for-purpose' arrangement. Learnings from international platforms would be part of the review process, including to satisfy non-negotiable governance requirements as agreed by the partner agencies, and an evaluation of risks and alignment against the strategic outcomes and objectives of the national capability.

7.2.8 Capabilities and other inputs

The primary domain and digital capability inputs required to initially support delivery of a newly constituted national climate services capability for Australia, featuring a new national centre for climate services, for the most part already exist within the existing network of providers, purveyors, users and related programs, platforms and initiatives; albeit with limited coordination, integration, effectiveness and efficiency. They are schematically summarised in Figure 14 and include:

Enabling capabilities which are cross-cutting for multiple agencies and initiatives, in the form of domain knowledge, skills and capacity including:

- Stakeholder engagement, including co-design, co-production and co-evaluation.
- Fundamental and applied climate and adaptation science (informing services), including climate, climate impact and socio-economic modelling, analytics and interpretation covering relevant aspects of climate hazard, impact, exposure, vulnerability and risk.
- Data, information, analytics and associated management systems and digitally enhanced information interface systems and data curation, including web sites, portals and other databases and repositories.
- Decision support tools and guidance materials.
- Analytics, bespoke modelling and domain specific tailoring and content.
- Communication, knowledge management, exchange and brokering, general advocacy and outreach, and capacity development and skills-based training.
- Technical advice including help desk support and science quality control/peer review.
- Innovation facilitation, business, product development and program management.

Core capabilities specific to public sector agencies and nationally relevant initiatives, primarily (but not exclusively) aligned to the development and delivery of core products and services for the national capability, including:

- The existing NESP Earth Systems and Climate Change (ESCC) Hub, a collaborative national partnership between CSIRO, the Bureau and five universities ending in 2021, and the proposed NESP2 Climate Systems Hub to commence during the same period. The NESP hubs deliver the underpinning foundational and applied climate science and science-based services to target users in a way that is cross-cutting and representative across the broader capabilities of the Hub partners. The ESCC Hub is also presently responsible for supporting the management and further development of the Climate Change in Australia website, including in conjunction with other nationally relevant initiatives such as the ESCI project which is developing new climate risk data and risk assessment methods and services for the Australian electricity sector.

- CSIRO across its multi-disciplinary ecosystem of research capability has extensive experience in developing and delivering various aspects of climate and adaptation science, services and associated risk information services, including climate change information, projections and hazards, scenarios, adaptation and transition pathways for all sectors of the Australian economy, vulnerability and resilience assessments, climate risk assessment and management tools, and quantifying impacts of climate damage and assessment of interventions. These are delivered through several business domain-based business units, including Oceans and Atmosphere (Climate Science Centre), Land and Water, Agriculture and Food, Energy and Data61.
- The Bureau of Meteorology has extensive experience and capability in climate services, including data management and provision, climate analysis, monitoring and prediction, climate advice and international activities aligned with the WMO mandate, climate change analysis and projections, and are heavily reliant on robust information systems and research support. Services are delivered through a range of online products and tools as well as through briefings, training and social media platforms. The Bureau uses user-centric design, development and delivery, and engages strongly with its user communities. Its weather, climate and water services give priority to disaster risk reduction and the BoM is progressing the concept through its new research strategy of seamless data and information services across multiple timescales from weather to climate and climate change.
- States and Territories, including the Cross-Jurisdictional Climate Science Community of Practice and existing state-based regional climate platforms and portals in Queensland (Long Paddock), NSW (NARCLIM), Victoria (VCP19) and Climate Futures Tasmania. These platforms/portals feature a range of core products and services including finer spatial-scale regional climate projections data, information, guidance and associated climate adaptation information and knowledge products tailored for use across the public and private sectors.
- Universities and other nationally relevant research capabilities, including (but not otherwise limited to) the Centre of Excellence for Climate Extremes (CLEX), the National Climate Change Adaptation Research Facility (NCCARF), which presently supports the CoastAdapt portal, the Electricity Sector Climate Information (ESCI) project being delivered jointly by DAWE, CSIRO, BOM and AEMO, the Bushfire and Natural Hazards CRC, the new Australian Antarctic Partnership, and the proposed new Murray-Darling Water and Environment Research Program.

Differentiated capabilities specific to a combination of public sector agencies, private sector SMEs and Indigenous communities (in particular Traditional owners), aligned primarily to the development and delivery of differentiated products and services as part of the national capability; the latter of which would be through PPPs and/or other appropriate partnerships between partner organisations and third-party entities.

These may include, but not otherwise be limited by:

- **CSIRO NCC Mission:** The Navigating Climate Change Mission will provide the means to access trusted climate risk and hazard information and provide support to explore adaptation options. It will thereby help build a national climate risk capability, including:
 - A comprehensive platform, which will serve as the entry point to a variety of information, tools, capabilities and services, including INDRA: Australia's first comprehensive on-call analytics tool that would empower users to understand climate risk and hazards.
 - A 'Climate Exchange' collaboration hub, facilitating research partnerships that solve complex, large scale adaptation and transition challenges. The hub would also design and deliver sector-wide capability uplift exercises to empower large cohorts to understand and respond to their climate risk.
 - Both the platform and hub would be the catalyst for a new industry in climate services, capable of servicing national and regional markets.
- **Private sector SMEs and Non-Government/Not-for-Profit/social enterprise organisations and entities:** The industry-led Climate Measurement Standards Initiative (CMSI) is presently in the final stages of an initial 'sprint' to develop globally consistent, standardised scenario analysis to inform climate related financial risk for TCFD-based reporting. The industry consortium includes representatives from the financial services sector, including banking, insurance/re-insurance and fund managers, as well as observers from Government and corporate regulators. The CMSI is hosted by Climate-KIC, the Australian entity of a global NGO, and the science capability is supported by the NESP ESCC Hub. A second iteration of CMSI (2.0) is in planning and serves as a potential business model for other new collaborative SME and/or large corporation-based PPPs as part of the national climate services capability. Innovation in the development of other business models for collaborative PPP entities are also potentially in scope including new social enterprise-based consortia designed to develop new, non-traditional markets and associated users for differentiated climate services.
- **NDRISC:** The purpose of NDRISC is to provide access to reliable, authoritative, trusted, analysis ready information products, modelling capability, processes and tools via an information platform together with guidance, expertise, knowledge translation and brokerage through a service centre to enable climate and disaster risk understanding, assessment and action. This capability represents a foundational element for evidence based systemic climate and disaster risk reduction envisioned through the National Disaster Risk Reduction Framework. To support the concept of a NDRISC, the following components are proposed:

- A core pool of subject matter experts and knowledge brokering practitioners from the domains of science, disaster risk, policy, emergency management and climate science.
- An innovative technology platform to facilitate federated access to services, data and methods.
- Standards-based protocols, tools and resources.

Core functions of NDRISC include support for decision making, translation of science to policy, brokerage of information, shifting culture and attitudes, and identification of emerging risks.

- **Traditional Owners via Indigenous Land Councils and other Indigenous Prescribed Bodies Corporate:** The existing NESP ESCC Hub in partnership with an Indigenous-led Steering Committee comprising representatives from the Yorta Yorta Nation Aboriginal Corporation (YYNAC), Kimberley Land Council and SEED (Indigenous Youth Climate Network), and building on the [2012 National Workshop on Indigenous Knowledge for Climate Change Adaptation](#), convened the National Indigenous Climate Dialogue Workshop in November 2018. More than 50 traditional owners from across Australia met in Barmah, Victoria in November 2018 to share observations, talk about priorities and explore opportunities to improve knowledge of climate change and its risks for people and country. Importantly, the two-way dialogue between researchers and traditional owners working on climate change helped improve the understanding of mutual goals and potential benefits from working together to support the community's climate information needs. A second National Gathering is planned, and this capability is potentially a valuable input to the national climate services capability going forward. This engagement process is considered a significant step towards establishing a nationally relevant enabling capability for considering how science and traditional knowledge can potentially be linked in a way that can add significant value to Australia's national climate services capability more generally.

Collaborative capabilities that would be external to the formal governance arrangements for the national centre, but otherwise considered an adjunct capability for Australia as part of a broader network of collaborative partners, include various international climate science and services platforms, partnerships and research programs and initiatives (Box 3), including:

- The World Climate Research Programme (WCRP)
- The Intergovernmental Panel on Climate Change (IPCC)
- Knowledge Exchange for Climate Adaptation Platforms (KE4CAP)

Underpinning capabilities that are critical to the resourcing and infrastructure needs of the core and differentiated capabilities, include:

- Funding bodies within Federal and State government agencies which have an existing mandate to support the development and delivery of climate science and services, with scope for committing through appropriate strategic and operational alignment both existing (e.g. NESP/NESP2, NDRISC, NCC Mission, State and Territory platforms etc) and potential new (e.g. through NPPs) allocations of cash and in-kind resources towards an enhanced national climate services capability and the establishment of a national centre for climate services
- National Infrastructure programs and initiatives including: i) the National Computing Infrastructure (NCI) for provision of critical high-performance computing for storing, processing and analysing climate data and information as part of Australia's national climate modelling capability, and ii) Australian observation infrastructure as part of the various global observation networks, including the Integrated Marine Observing System (IMOS) and Australia's Land Ecosystem Observatory TERN, for which the core and differentiated capabilities are dependent for the collection and curation of critical climate related marine, atmospheric and terrestrial observations.

A national Climate Services Capability for Australia

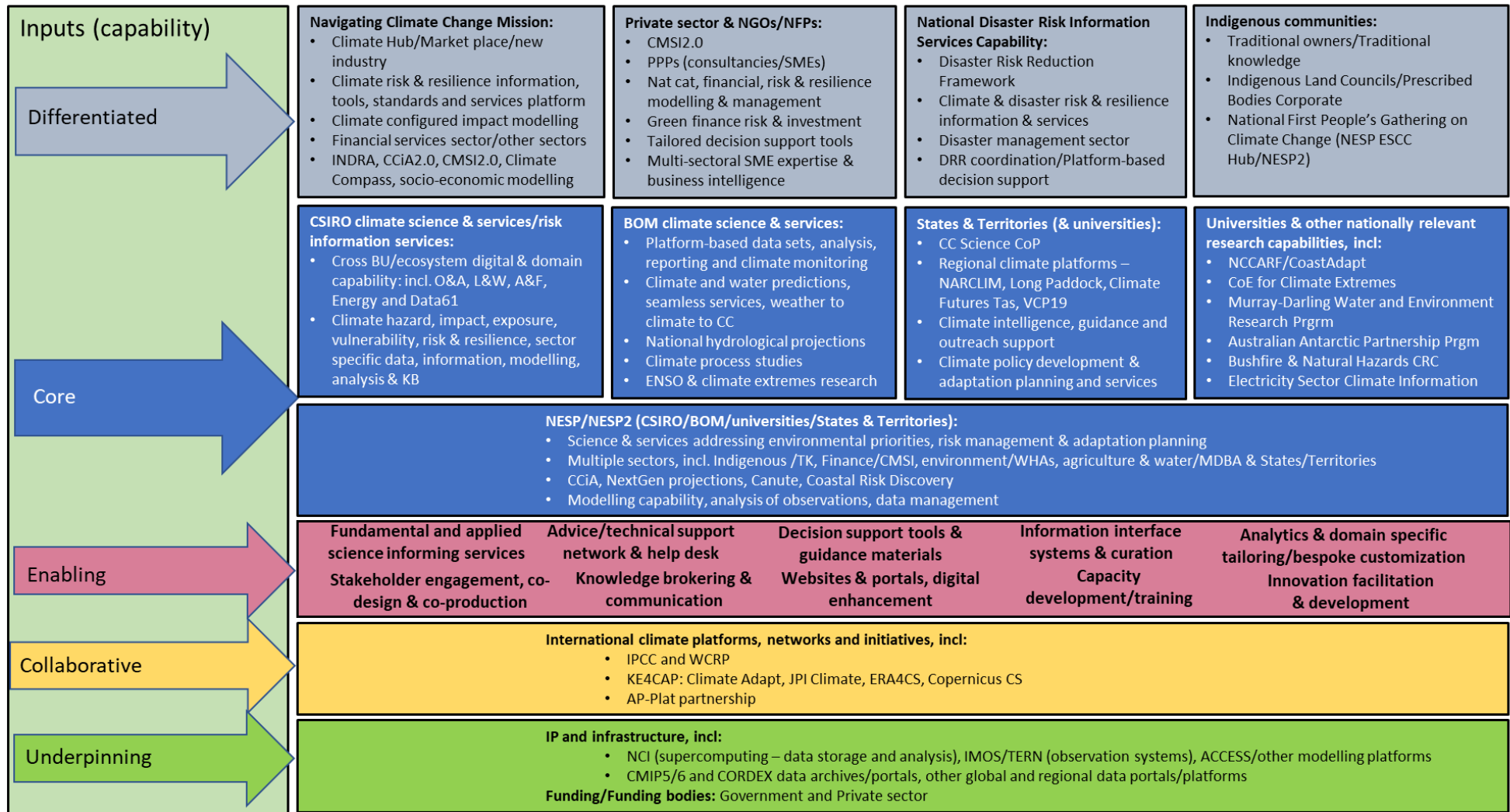


Figure 14: Schematic summary of the suite of digital and domain capabilities required for strategic development and delivery of a preferred (enhanced future state) national climate services capability for Australia

7.3 Functional interdependencies

The conceptual theory-of-action makes a number of assumptions and incorporates many implicit functional interdependencies in relation to the previously referred knowledge value chain, schematically summarized in Figure 15.

By way of further clarification, the suggested approach to an enhanced national climate services capability as outlined in the proposed theory-of-action introduces some potential new approaches and arrangements which could inform strategic development of the national capability over the longer term. It also introduces the concept of purveyors of climate services which refers to the important complementary role of those who add value to existing data, information, analytics, tools and other products with expertise including in knowledge brokering, translation and exchange to provide value-added services and products targeting specific users.

More specifically, Figure 15 provides a conceptual, overarching illustration of the nature and scope of what comprises a national climate services capability with reference to the functional interdependencies inherent within an Australian contextualised climate knowledge value chain. Each of the boxes and the arrows are illustrative only and require further fleshing out as to what comprises detail in each, and how they contribute to the required capability and its evolution. This need for greater detail is particularly the case for the arrows that are illustrative of the required two-way exchanges (e.g. co-learning and knowledge exchange). Additionally:

- The two boxes to the left side of the schematic are illustrative of the provider/purveyor capabilities. The upper box is comprised of the science capabilities that are fundamental to the provision of climate services. They and the supportive infrastructure (not reflected in this schematic) are critical to the effective provision and focus of those foundational capabilities – towards providing relevant, usable, legitimate and credible climate services. The second of the two boxes reflect the essential roles that partnerships with targeted purveyors play in the design, development and delivery of climate services. The bold two-head arrow between these two boxes is illustrative of the critical links between these partners' capabilities and the focused science capabilities.
- The central box is illustrative of that required to provide access and an integrated focus for interactions with the user communities. This includes an overarching interface working with other web-based platforms (reflected by the shadow boxes) operating at different levels within Australia that are also providing climate services. Identified within this central box are components that are the building blocks of such an interface, including consultancy-based services and partnerships involving users/clients and providers/purveyors, knowledge translation services/products and intermediaries, as well as a market-facing web-based portal providing and introduction capability and assisted service delivery. The nature of these building blocks and their linkages are critical to the success of this interface as are the two-way knowledge exchanges between the different elements of this interface.

Linked with the other web-based platforms and the science and partnership capabilities.

- The user communities' box is illustrative of the main grouping of what comprises those communities. This includes additional private and public sector climate service purveyors that are using that available through the national capability to provide added value services and products to targeted users. Once again, the two-way knowledge exchanges between users and the interface are critical to enhancing the relevance, usability and legitimacy of the services and products provided as are those linking to the science and purveyor partner capabilities (continuous learning and improving).
- The overarching blue box – National Centre for Climate Services – reflects the governance requirement for an effective and sustainable climate service capability. The exact nature and roles of this governance/forum require further development. The fact that it spans the science capabilities, interface and user communities is suggestive of the scope of engagement that is deemed essential for effective governance.

National Climate Services Capability

Governance: Australian Climate Service Community Collaborative Forum/Platform

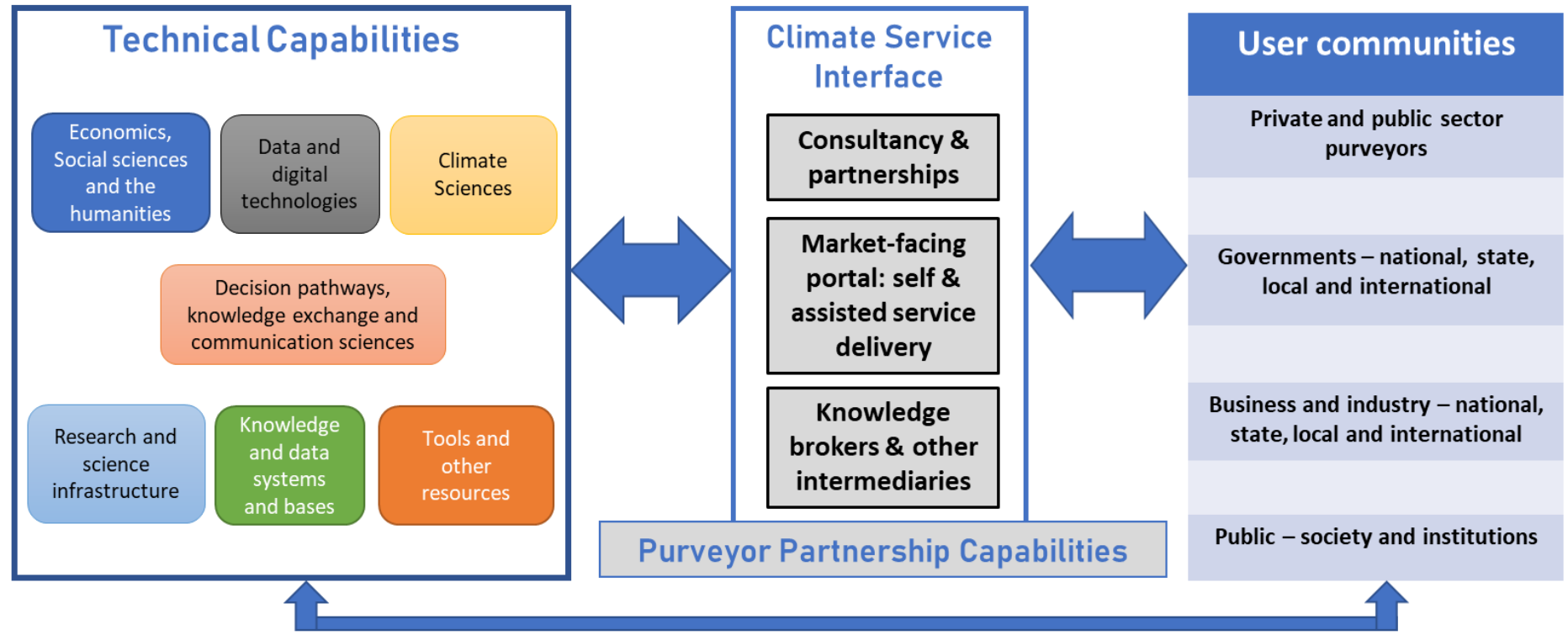


Figure 15: Schematic summary of the functional interdependencies inherent within the knowledge value chain of proposed national climate services capability

8 Next Steps

Subject to advice and directions of DAWE and the new (yet to be convened) national climate science committee, the next steps for enhancing Australia's national climate services capability may consider the following actions:

- Implement key findings of this report to facilitate implementation of the '*Vision for future state of Australia's national climate services capability*', in particular the establishment of a national centre for climate services as detailed in the section 7.2.7 Activities and governance.
- Give due consideration to the key issues, assumptions and design features of the theory-of-action to provide guidance for the development of the proposed 5-10 year strategic plan and associated 3yr work plan, recognising in the interim:
 - Compelling, real-time needs of users and ongoing activities of providers/purveyors, and
 - Expected increasing demands of user needs, evolving capabilities of providers, purveyors and users in the context of ongoing and likely increasing impacts of climate variability, extremes and change across the Australian environment, economy and communities in general.

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Appendix: Terms of Reference

The Terms of Reference for the present study as specified by the (then) Department of Environment and Energy in 2019 include that the scope of work and the final report for this study should:

- Include input from key stakeholders, particularly the Bureau of Meteorology, CSIRO and the university sector.
- Focus on the provision of comprehensive knowledge brokering and associated climate services needed by industry, government and the community to manage the risks of a variable and changing climate
- Take account of:
 - The extensive contributions and ongoing work of state and territory governments.
 - The National Resilience Taskforce and its work to establish a national disaster risk information capability to equip decision makers and Australians with the knowledge they need to prepare for and respond to natural disasters.
 - The Bureau of Meteorology's efforts to ensure users of climate information participate in development of climate resilience and risk management tools, models and systems that meet the needs of Australian businesses and communities.
 - The CSIRO's work with the Bureau of Meteorology, universities and the Australian Antarctic Division on current and future climate risks and climate projections, including the development of the next generation global climate projections and a national downscaling capability through ACCESS.
 - The CSIRO's work to integrate climate information into the agricultural digital revolution, improve near-term climate situational awareness, ensure greater resilience of farming systems and increase opportunities to enhance productivity through proven adaptation strategies.
 - The ESCC Hub's consultation and engagement processes with industry, business other end users of climate services and with climate product developers and service providers.



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