South Africa's Water Research, Development, and Innovation (RDI) Roadmap: 2015-2025

Water Research Commission

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EXECUTIVE SUMMARY

The National Water Research, Development, and Innovation (RDI) Roadmap provides a structured framework to focus the contribution of RDI activity to the implementation of national policy, strategy and planning in water resources management in South Africa. The vision of the roadmap is that South Africa is a leader among middle income countries in the development and deployment of water management practices and technologies. It competes with leading countries in providing sustainable solutions.

This has been achieved by means of a National Water Research, Development, and Deployment[1] (RDD) Programme focused on: delivery of at least one breakthrough technology every five years; increasing the number of small and medium sized enterprises operating in the water sector; increasing access to water for rural communities, including provision of sanitation for all in a sustainable manner. Together, this creates significant economic, health, social and environmental benefit.

The contribution of RDD to achieving the vision results from a focus on four key objectives: Increase the availability of water; improve the governance, planning and management of supply and delivery; enable water and sanitation services to operate as a sustainable "business" and increase the efficiency and productivity of water use.

The roadmap was developed through an exhaustive, structured process of eliciting staged responses from the professional community, reviewing the inputs, and assessing their implications.

The roadmapping process included participation, input, review, and revision from key stakeholders in industry, government and organisations within the National System of Innovation. The roadmap provides strategic direction, a set of action plans and an implementation framework to guide, plan, coordinate and manage South Africa's portfolio investment for the next ten years in seven identified clusters of RDD activity. The investment aspiration and potential return on investment is also mapped out.

The result of this process is a set of seven plans which over the period 2015-2025 develop out pathways to progress from the 2015 situation to a much improved future state, by implementing interventions in research, development, testing, demonstration, and deployment of new technologies and know-how, and demonstration and deployment of emerging technologies.

The seven plans provide itemised, actionable tasks under the following headings:

1. Water supply
    1.1. Increase ability to make use of more sources of water, including alternatives
    1.2. Improve governance, planning and management of supply and delivery
    1.3. Improve adequacy and performance of supply infrastructure
    1.4. Run water as a financially sustainable "business" by improving operational performance
2. Water demand
    2.1. Improve governance, planning, and management of demand and use
    2.2. Reduce losses and increase efficiency of productive use
    2.3. Improve performance of pricing, monitoring, billing, metering and collection

Developing, strengthening and embedding South Africa's water RDD capability and capacity within and between research institutions, academic institutions, industry and government, will enable faster and more effective deployment of context-appropriate technologies and create opportunities for the export of know-how and technology into the African continent and beyond.

This Water RDI Roadmap thus provides a set of Research, Development, and Deployment clusters (focal areas) and associated high level action plans to guide investments over a ten year period, and it also lays out an investment ambition to achieve these plans. This Roadmap is a high level planning tool that facilitates and guides refocusing of research, reprioritization of funds, synergising of existing initiatives and ring-fencing of new resources in order to facilitate a more optimal water innovation system.

[1] i.e. Deployment of innovative technologies and new know-how.

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South African National Biodiversity Institute
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Water Research Commission (WRC)
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Wildlife and Environment Society of South Africa
Worldwide Fund for Nature SA

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ACRONYMS & ABBREVIATIONS

ARC	Agricultural Research Council
ASSAf	Academy of Science of South Africa
CoC	Centre of Competence
CoE	Centre of Excellence
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DHS	Department of Human Settlements
DoH	Department of Health
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
HCD	Human Capacity Development, or Human Capital Development
HEI	Higher Education Institute
KG	Knowledge generation
M&E	Monitoring and evaluation
NBI	National Business Initiative
NEPAD	The New Partnership for Africa's Development
NGO	Non-government organisation
NIPMO	National Intellectual Property Management Office
NPC	National Planning Commission
NRF	National Research Foundation
NSI	National System of Innovation
NWRS2	National Water Resources Strategy 2
PSP	Professional service centre
R&D	Research and development
RDD	Research, development, and deployment
RDI	Research, development, and innovation
RFA	Research focus area
RP	Research programme
SALGA	South African Local Government Association
SANBI	South African National Biodiversity Institute
SAWS	South African Weather Services
SET	Science, engineering, and technology
SOE	State-owned enterprise
SWPN	Strategic Water Partners Network
TAC	Technical assistance centre
TCTA	Trans Caledon Tunnel Authority
TIA	Technology Innovation Agency
TRP	Targeted research programme
WADER	Water Technologies Demonstration Programme
WCDM	Water conservation and demand management
WDCS	Waste discharge charge system
WESSA	Wildlife and Environment Society of South Africa
WHO	World Health Organization
WRC	Water Research Commission
WUA	Water Users' Association
WUE	Water use efficiency
WWF-SA	Worldwide Fund for Nature South Africa

GLOSSARY

Centre of Competence	Pre-commercialisation instrument positioned downstream in the NSI of a CoE, and immediately before commercialisation.
Centre of Excellence	CoEs are physical or virtual centres of research that concentrate existing research excellence and capacity and resources to enable researchers to collaborate across disciplines and institutions on long-term projects that are locally relevant and internationally competitive in order to enhance the pursuit of research excellence and capacity development.
Cluster definition	A definition of the Cluster with its constituent Research Initiatives, together with the associated water sector objective and RDD Outcome for 2025, in support of the Cluster objective.
Customer and Partner Relationship Management	Recognises that the need to engage with customers, partner and investors – to engage, understand needs, secure buy-in, participation and commitment to collaborate, invest or commercialise requires explicit resource that is other, or incremental to those that are principally involved in conducting research itself. This may require a dedicated function, such as a desk
Customer needs	Statements of need expressed by 'Customers', who in this context were members of the water community of professionals, which were divided into four sectors: Agriculture, Industry, The public sector, and Environmental protection.
HCD Outline Plan	A summary of the research capacity required for each Cluster – at the level of Research Initiative – as well as the current level of competence in the associated Research Focus Areas (RFAs). This indicates the potential for realisation of the intended RDD Programme. It also provides a basis for more detailed investigation of requirements for HCD interventions.
Human Capacity Development, or Human Capital Development (HCD)	Honours and graduate students (not Masters or PhDs) supported as part of building a pipeline of RDI Capacity. In the investment model, masters and doctoral studies are catered for under Research Capacity because these students contribute to research activity as part of Research Groups. Investment is also required in the Bachelors and Honours part of the pipeline. This is provided for in the HCD component of the Investment Model.
Impact Assessment Framework	The Impact Assessment Framework used required assessment of anticipated impacts in a set of nine sub-areas in five broad areas: *Water Scarcity*, *Economic*, *Health*, *Society*, and *Environment*.
Interventions	Actions required or corrective measures that can be taken to satisfy a need, without prescribing a solution in terms of how, or when, such action could be taken.
Knowledge Diffusion	The extent to which knowledge about a specified topic has diffused from research into practice. The degree of KD is estimated on a scale of 0 (initial research, no implementation), through field testing and pockets of implementation, to 5 (research translated into full adoption).
Professional Service Centre (PSC)	A PSC is a market-facing unit that delivers services or technical offerings to a defined set of customers, on a commercial basis (though not necessarily as a for-profit enterprise).
RDD Impact	A high level summary of the potential impact anticipated, based on successful performance of the RDD Programme, in relation to five areas defined in the Impact Assessment Framework.
RDD Opportunity	An identified set of actions which would allow RDD activity to provide for interventions to satisfy needs.

RDD Outcome	Describes our ambition, i.e. what – ideally – will have been achieved at the successful conclusion of the Programme.
RDD Potential	The potential that resides in South Africa to undertake RDI and RDD activity, as a product of current research capability and strength, and existence of opportunities.
RDD Programme	Defined in immediate, short-, medium-, and long-term timeframes. The immediate phase is typically time-limited to one year in which to explore and further clarify the RDD Opportunity and plan an appropriate research response.
RDD Response	A high level summary of the planned RDD Programme planned for each Cluster based on identified Customer Needs and the opportunity to develop and deploy solutions in satisfaction of such needs through R&D.
RDI / RDD Objective	RDD Objectives distil and summarise the Needs and Interventions documented. Sets out at a high level the ambition and focus of the RDI Programmes that underpin the contribution of RDI to achievement of the vision.
RDI Infrastructure	Facilities and equipment required to perform RDI activity
RDI Success Factor	Success Factors are things that are required to enable achievement of the RDD Objectives.
Research Capacity	Research Groups, whether at a particular location or in the form of a distributed network, including masters and doctoral students that are associated with, and supervised by this Research Capacity. Capacity Outline Plan: forward needs summarised.
Research Chair	Research Chairs may be publicly or privately funded. They are held by a university in partnership with a private partner or a public research institution. The main goal of Research Chairs is to strengthen and improve research and innovation capacity of public universities for producing high quality postgraduate students and research and innovation outputs. The South African Research Chairs Initiative (SARChI) is designed to attract and retain excellence in research and innovation at South African public universities through the establishment of Research Chairs at public universities in South Africa with a long-term investment trajectory of up to fifteen years.
Research Focus Area	Areas of research expertise were defined both by the underlying academic discipline (e.g. microbiology) and the research focus area (RFA), or area of interest (e.g. potable water quality). The full list of RFAs is shown in Appendix C.
Research Strength	The number of people active in an RFA, with recognition of their length experience and depth and breadth of their capabilities. Research Strength is gauged on a scale of 1 to 8. The ideal situation is one in which 20% of research groups in a certain focus area are below level, 50% at levels 5-6, and 30% at level 7 or 8.
Sector Objective	The Target Objective for a sector.
Seeding	Covers investments made at the Exploratory Phase, as well as investment to enable a change in state in the course of the overall timeframe
Target Objective	The Target Objective sets out an intended end-state, in terms of a capabilities, products, and state of commercialisation for these key areas or contribution.
Targeted Research Programme (TRP)	A Research Programme (RP) designed specifically to satisfy a particular Need or Cluster of Needs.
Technology Development	Human resource investments associated with the development of technology (and service) components, platforms, systems, process improvements

REPORT ARCHITECTURE

This report does not present the roadmap in chronological order.

It contains the ten year roadmap for water research, development, and innovation (RDI) itself, in Chapter 2, and additionally contains the rationale (Chapter 1), the level of investment in water RDI required to carry out the plans set out in Chapter 2 (Chapter 3), and finally an explanation of the methodology used to create the roadmap (Chapter 4).

The diagram below depicts the architecture of the document.

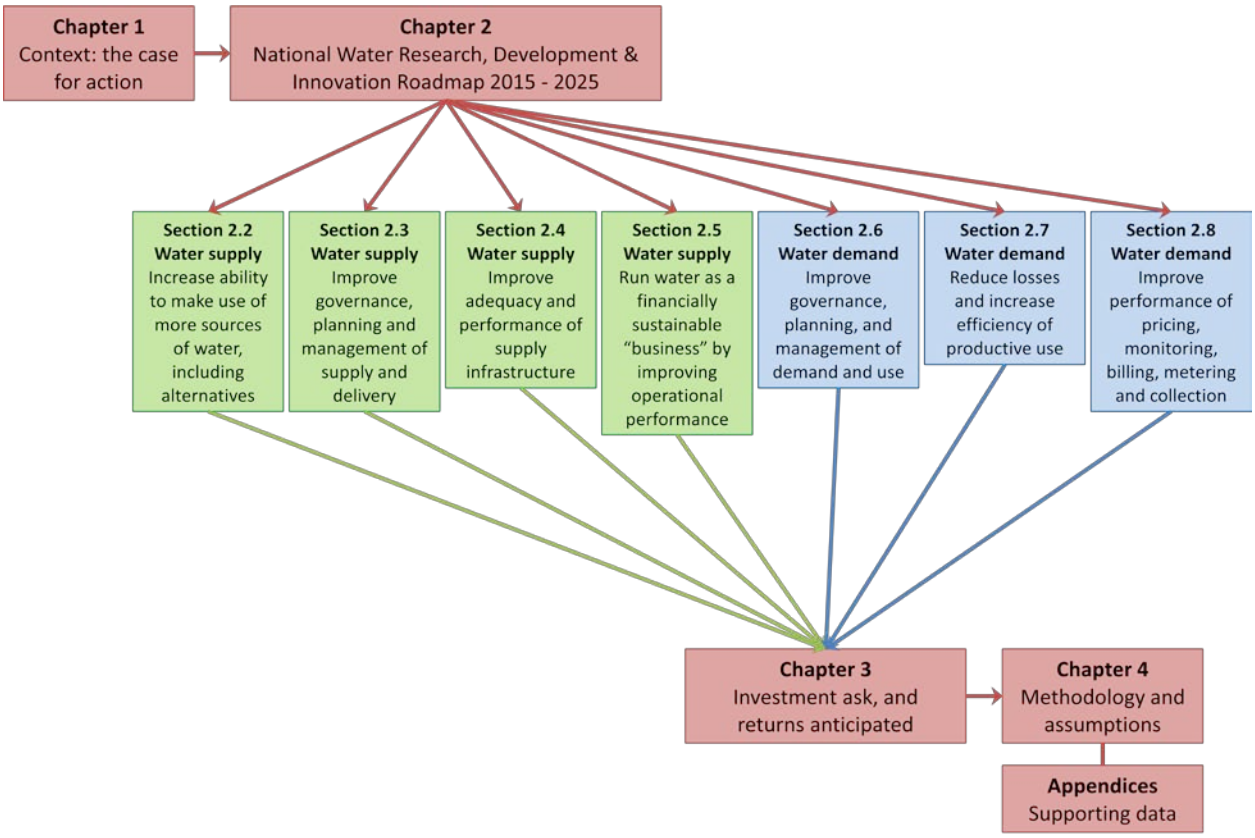


Figure 1: Organogram of this report

CHAPTER 1: CONTEXT

1.1 CONTEXT

The context within which the RDI roadmap was created is one of increasing water scarcity. Numerous international bodies, including the Water Resources Group 2030 (WRG2030), and the World Economic Forum (WEF) have identified water as a priority concern.

For four years, WEF Global Risk Reports have identified water as one of the three most important challenges worldwide; in 2015, for the first time, it has moved to the top, as the biggest societal and economic risk for the next ten years (WEF, 2015)[2]. The report assesses risks that are global in nature and have the potential to cause significant negative impact across entire countries and industries.

Risks from water overuse and shortage, poor water infrastructure and management came out on top – not as future problems outlined by models and simulations, but as facts today which are rapidly worsening.

Water is key for life, central to societal development. Water risks affect industrialised and developing economies alike; repercussions of its overuse and increasing shortage are multiple and complex, widespread and severe.

Water for people: according to the World Health Organization (WHO) there are still more than 700 million people without access to so-called 'improved' water – here the trend is positive: the proportion of the world's population with access to improved drinking water sources increased from 76% to 89% globally between 1990 and 2012. But 'improved' is by no means 'safe'. An article by Gérard Payen, former chairman of Aquafed and Member of the United Nations Secretary General's Advisory Board on Water and Sanitation, states that close to 2 billion people use water that is unsafe and dangerous for their health, while 3.4 billion people use water of doubtful quality, at least from time to time. And these problems are getting worse, due to insufficient investment in water infrastructure, in low income, middle income, and high income economies.

Water for food: WEF (2015) reported seeing the first problems in regions where natural buffers have been exhausted in times of normal rainfall. The public and the media tend to see natural drought as the problem, but droughts come and go. The real problem is that we destroyed the 'natural' safety nets by overusing groundwater. So without a change in the way we use water, the global growth in population and prosperity are rapidly leading us into massive shortfalls in global cereal production.

In the past water was mostly abundant – at least up until the 1990s – so we have forgotten how important it is for **socioeconomic growth**. Some occasions in India, South Africa, and the USA when power generation in thermal plants had to be slowed down because of lack of cooling water may be interpreted as early signs for more widespread problems ahead.

There is a **transboundary**, and increasingly geopolitical dimension, e.g., in the Crocodile and Orange, to mention but two cross-border basins.

Water for the environment: this is about urgently needed wetlands, about biodiversity. But drying rivers also destroy human livelihoods, and sinking groundwater tables threaten human settlements.

Based on rising population, economic growth projections, scarcity of resources as well as current use and efficiency levels, South Africa will demand 17% more water than exists by 2030. The net deficit between supply and demand could grow to between 2.7 and 3.8 billion m^3. In addition, it is crucial to recognise that South Africa's water supplies are already almost fully allocated. This means that new businesses and industries will find it increasingly difficult to access water licenses, particularly in more overdrawn catchments. Also, where licenses are allocated, increasing strain will be placed on the natural systems to produce a good quality and quantities of water.

This reality places renewed emphasis on the need for innovative solutions, technologies and processes as well as highly skilled individuals that will be able to rise to the challenge of navigating these complexities going into the future. It is this area of innovation and associated skills needs that the Water RDD Roadmap responds to.

[2] WEF (2015) *Global Risks 2015*. http://reports.weforum.org/global-risks-2015/ (Accessed 12 February 2015)

1.2 ALIGNMENT WITH NATIONAL AND INTERNATIONAL STRATEGIC OBJECTIVES

The list below was developed in collaboration by all three of the WRC, DST, and DWS. The DWS paid particular attention to the alignment of the Roadmap with their strategies, especially with the National Water Resources Strategy 2. The Water RDI Roadmap will serve as the basis for the implementation of the NWRS2, especially Chapter 14 (Research and Innovation) and Chapter 15 (Water Sector Skills and Capacity).

The list provides, from left to right, the name of the national initiatives with which the RDD Programmes presented in Chapter 2 of the Roadmap align, the objectives which are shared by the named national initiatives and the RDI Roadmap, and finally the sections of the Roadmap which are aligned with the named national initiatives.

National initiative(s)	Strategic objectives of national initiatives and RDI Roadmap	Roadmap contribution to national initiatives
Outcome 2 (Job creation) Outcome 4 (Employment) Outcome 12 (Public service) New Growth Path National Water Resources Strategy (NWRS2) Chapter 14, Chapter 9 (9.4.3), and Chapter 6 (6.4.3) DST Grand Challenges: Adapting the Way We Live and Innovation for Sustainability NWRS2 Chapter 4: 4.1.4 – reconciliation strategy, 4.1.2 – urban development, 4.1.6 job creation Provision of equitable and sustainable water services of acceptable quantity and quality Constitutional right to Free Basic Water	• Improve and increase the skills pool and build competencies in the DWS and within the sector • To articulate the need for aligned qualifications development with DHET and EWSETA and build into RDD programmes	• To maintain a minimum number of students supported in water research • To enhance human capital development by supporting SMMEs in Water R&D domain • Knowledge dissemination and training will form part of the functions of the PSPs and TACs within the RDD programmes
	• Implement programmes that create job opportunities	• To facilitate positive relationships with communities through active community participation in RDI • To maintain the minimum number of students supported in water R&D
	• Improve water resources and water services information	• To increase water knowledge by initiating new R&D • To provide the country with supportive knowledge via completed projects • To improve knowledge • To promote the uptake and communication of research in the form of manuals, guidelines, and other supporting materials • To engage the sector in knowledge-sharing events
	• Ensure effective performance of water management and services institutions	• Provision of PSCs and TAC will support performance of WSAs and WSPs
	• Ensure the availability of/access to water supply for environmental and socio-economic use	• To increase water knowledge by initiating new R&D that addresses the identified knowledge gaps • To provide the country with supportive knowledge via completed RDI • To improve knowledge dissemination • To promote the uptake and communication of R&D in the form of manuals, guidelines, and other supporting materials • To engage the sector in D&I via knowledge-sharing events through public dialogues and workshops
NWRS2 Chapter 7: 7.4.3, Chapter 8: 8.6, and Chapter 9: 9.4.8	• Appropriate tariffs and effective economic regulation	• The Price. Monitor. Bill. cluster provides for determination and review of pricing and tariffing best practices.
NWRS Chapter 8: 8.5.2 NWRS2 Chapter 9: 9.4.9	• Regulatory coordination • Coordinate regional and global water research cooperation • Correct planning and management of resources and revenues	• Through the Governance, Planning, and Demand clusters, enhance the relevance of South African water research locally and globally by coordinating strategic local and international partnerships, knowledge-sharing agreements or partnership agreements with knowledge-sharing institutions

National initiative(s)	Strategic objectives of national initiatives and RDI Roadmap	Roadmap contribution to national initiatives
Equitable and sustainable provisioning of raw water Outcome 2 (Job creation) Outcome 6 (Infrastructure) NWRS Chapter 7 New Growth Path National Development Plan (NDP)	• Improve equity and efficiency in water allocation • Strengthen and implement strategies for water management • Improve water use efficiency • Achieve an efficient, competitive and responsive economic infrastructure network	• TRPs leading to RDI successes in the governance, planning and management of water allocation, and in productive use of water • TRP to support water availability by finding solutions to problems related to bulk water supply and assisting the development of appropriate regulations regarding water quantity, quality, and usage
Outcome 9 (Local government) DST Grand Challenge: Water Security for South Africa (Adapting the Way We Live)	• Support the water sector	• To improve the dissemination of water R&D products
Protection of freshwater ecosystems (5.4.5 and 5.4.9) NWRS2 Chapter 5 (5.4.1) Outcome 10 (Environment) DST Grand Challenge: Conserving Biodiversity and Ecosystem Services (Reducing the Human Footprint)	• Improve the protection of water resources and ensure their sustainability • Achieve protection and enhancement of the country's environmental assets and natural resources	• The Water RDI roadmap supports this outcome through research aiming to improve basic services, with special emphasis on delivery of water and sanitation services
NWRS2 Chapter 15 National Skills Development Strategy NWRS2 Chapter 7: 7.4.8 and 7.4.9	• Stakeholder mapping • Strengthen linkages between research organisations • Increase water services-relevant offerings at HEIs, including undergraduate pipeline	• Research focus area capability mapping • To increase water knowledge by initiating new research • To provide the country with supportive knowledge via completed R&D, from fundamental research, through applied research, to demonstration via WADER, to implementation • To improve knowledge dissemination
National Desalination Strategy National Strategy for Water Re-use National Groundwater Strategy NWRS2 Chapter 4: 4.4.10, 4.4.11, 4.4.12, 4.4.13 and 4.4.14, Chapter 7: 7.4.1 and 7.4.2, and Chapter 9: 9.4.5) DST Grand Challenge: Doing More With Less (Reducing the Human Footprint)	• Increase the use of desalinated water sources, including wastewater, mine water, brackish water, and seawater • Increase the volume of wastewater being reused and / or recycled • Maximise use of rain water harvesting, groundwater and the artificial recharge of groundwater/ aquifers	• Through the Sources cluster, to diversify the mix of water resources in use
DST Grand Challenge: Earth observation and monitoring (Understanding a Changing Planet)	• Improving resource management	• Increased expertise in techniques such as GIS, remote sensing, to be utilised in the Supply Governance, Planning and Management cluster. • Such information underpins virtually all public policy decisions, from public health to water resource management, to protection of the ecosystem

National initiative(s)	Strategic objectives of national initiatives and RDI Roadmap	Roadmap contribution to national initiatives
NWRS2 Chapter 9 and Chapter 8: 8.5.12	• Research into amendment of legislation (9.4.1)	• Through the governance clusters, research into policy amendments to provide for evidence-based policy and regulation • Increase capacity and capability related to water law and public administration
Outcome 7 (vibrant, equitable and sustainable rural communities) DST Grand Challenge: Food and Fibre Security for South Africa (Adapting the Way We Live) Department of Rural Development and Land Reform: Vibrant, Equitable and Sustainable Rural Communities and Food Security for all	• Achieve vibrant, equitable and sustainable rural communities and food security for all	• TRP addressing water utilisation in agriculture, as well as in informal settlements and peri-urban communities. • The use of water by small-scale farmers (smallholders) and water allocation reform will be addressed in the clusters, Sources, Supply Governance, and Productive Use. • The RDI roadmap will continue to support the wise use of water for agriculture, specifically to reduce water demand from irrigation.
International and Regional Initiatives	**Strategic objectives of International and Regional initiatives and the RDI Roadmap**	**Roadmap contribution to international and regional initiatives**
Convention on the Law of the Non-navigational Uses of International Watercourses: equitable and reasonable use of shared water resources	• Use, development and protection of international watercourses shall be undertaken in an equitable and reasonable way. • Water course states shall employ their best efforts to process, develop and collect data and information in a manner that facilitates equitable and reasonable use.	• Two roadmap clusters focus on governance, planning and management that address the hydropolitical, transboundary, regional and international aspects of water innovation. • The cluster focused on pricing, monitoring, billing and metering is essential to responding to the data and information sharing requirements of international legislation.
Revised Protocol on Shared Watercourse in the Southern African Development Community: Research and appropriate technology development (Article 2E)	• Research and technology development, information exchange, capacity building, and the application of appropriate technologies to shared watercourses management.	• The SADC protocol emphasises aligning national legislation and policy to the regional treaty. The Water RDI Roadmap responds to this by putting a clear RDI investment and HCD strategy in place for the next 10 years. This clear plan also facilitates regional partnership as needs are clearly articulated.
SADC Regional Indicative Strategic Development Plan (RISDP): Environment and Sustainable development, Science and Technology	• Science and technology and Environment and Sustainable Development (to which water is linked) are highlighted as priority intervention areas for SADC.	• This roadmap responds to the regional call for targeted and strategic investment into science and technology and water-related environmental challenges.
Science, Technology and Innovation Strategy for Africa 2024: sustainable management of natural resources and environments to secure the interest of future generations	• Eradicate hunger and achieve food security. • Protect our space – knowledge of the water cycle, river systems and basin management. • Live together and build society – urban hydrology and urban waste management.	• The Cluster on reducing losses and increasing efficiency of productive use has important synergies with the agricultural sector. • The cluster focusing on water infrastructure (including ecological infrastructure) is essential to knowledge on river systems. • The clusters on running water as a business, improving operational performance and infrastructure directly support urban hydrology and waste water management innovation.

CHAPTER 2: SOUTH AFRICA'S WATER RDI ROADMAP: 2015-2025

2.1 STRUCTURE OF THE ROADMAP

This chapter presents the end results of the roadmapping process – i.e. the roadmap itself. Explanations of how the information in this chapter was derived are provided in Chapter 4. Definitions of the specialised terms used may be found in the glossary and list of abbreviations on pages vi-vii.

The reader should be aware that in order to fully understand the methodology and assumptions that underpin the conclusions of the roadmapping process presented in Chapter 2, s/he will need to read, or at least refer to, Chapter 4.

In brief, a comprehensive workshopping and reiterative review and rebuild process was adopted to create a list of the needs of the water community. The water community as a whole was divided into four sectors: Agriculture, Industry, Public Sector, and Environmental Protection.

Each sector then identified Interventions in order to provide lists of recommended actions that would satisfy each need. The needs and interventions could be categorised into seven Clusters, around each of which a ten year programme of action and investment was created. The process is described in full in sections 4.1 to 4.3.

The seven Clusters are divided into supply and demand side needs and interventions, as follows:

Water supply

1. Increase ability to make use of more **sources** of water, including alternatives
2. Improve **governance, planning and management of supply** and delivery
3. Improve adequacy and performance of supply **infrastructure**
4. Run water as a financially sustainable "**business**" by improving **operational performance**

Water demand

5. Improve **governance, planning, and management of demand** and use
6. Reduce losses and increase efficiency of **productive use**
7. Improve performance of **pricing**, **monitoring**, **billing**, metering and collection

Sections 2.2 to 2.8 present the programmes of RDD Responses designed for each Cluster. Figure 2 illustrates the way in which sections 2.2 to 2.8 have been structured.

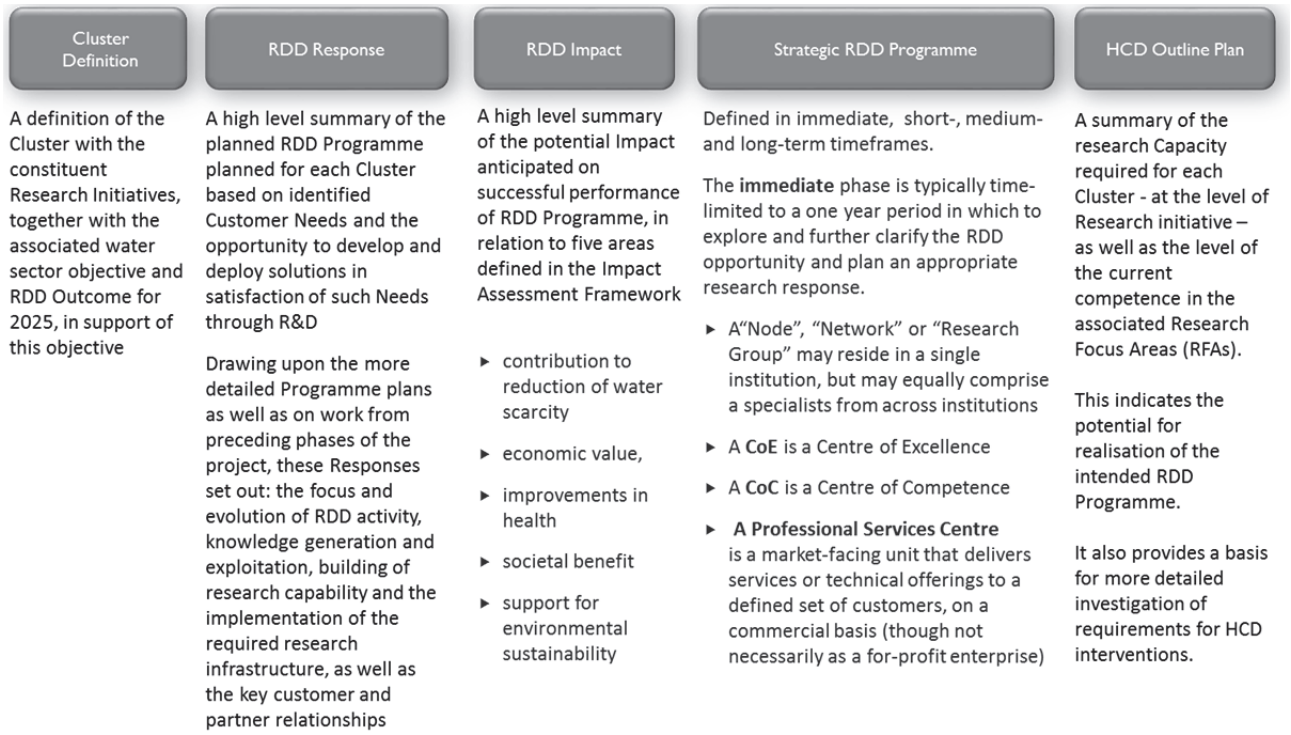


Figure 2: Structure and overview of the response for each Cluster

Each section begins by defining the Cluster, then provides the RDD Response, the anticipated impact of responding, an RDD programme which sets out actions over a ten year period, and finally an HCD plan for each research initiative within the RDD Programme.

The RDD Response plans each provide identification of national and international partners to be engaged, for each Cluster (for example, the Sources Cluster RDD Response is shown on page 7). This is important, as it informs decisions around co-funding, such as which donors may have overlapping priorities, and around internationalisation of the research outputs. Water is a major research and innovation theme that is central to Africa's development, and an area in which international co-operation is essential.

The impacts that would be made by implementing each ten year plan were assessed using the methodology set out in section 4.2.4. The appropriate instruments to implement each ten year plan were identified, and the costs estimated, based on sets of assumptions which are explained in detail in sections 4.2 and 4.3.

2.2 SUPPLY CLUSTER 1: INCREASE ABILITY TO MAKE USE OF MORE SOURCES OF WATER, INCLUDING ALTERNATIVES

2.2.1 Cluster definition, scope, and research initiatives

2.2.1.1 Sector Objective

Increase ability to make use of more **sources** of water, including alternatives.

2.2.1.2 Target RDD Outcome for 2025

Technology development for utilisation of diverse water sources at catchment level, with source localisation and exploitation driven by fitness for use is a key point of excellence in South African practices.

Focus on local resources and appropriate technologies, with strategic consideration of leverage potential and location opportunity from the adaption of inbound technology; explicit emphasis on deployment and uptake.

2.2.1.3 Research Initiatives

The Sources Cluster contains three research initiatives, which are:

Need	Define requirement to identify and make use of alternative sources of water supply; create basis for evaluation of localised source potential; monitor ongoing viability and changes in sources of supply
Potential	Evaluate potential value and feasibility of alternative approaches, including fitness for purpose and requirements on treatment. Improve systemic ability to make use of alternative supplies – technology management systems, capability
Enablers	Initiate and drive dialogue, research and programmes involving producers, users and consumers to increase social acceptance of recycled water

2.2.2 RDD Response: Sources

RDD Activity	
RDD Focus and Progression	Identification of opportunities to improve mix of water sources in use. Development of technologies, capacity, information and management methods to increase the use of treated effluent, decrease levels of salinity through desalination, increase rainwater harvesting and the use of groundwater. Explore the country's potential to increase floodwater and stormwater harvesting and management.
Underlying Science	Multiple disciplines within natural sciences, engineering, humanities, and law
Know-How	
Intellectual Property	Potential for patentable treatment technologies for direct and indirect water reuse and recycling
Knowledge Diffusion	Agriculture: not many products making the market to address needs. Public sector, Industry, and Environment: invest in commercialisation vehicles, product development centres, technology development, seed funding, etc. to shift balance more towards research being translated into full adoption.
Readiness to do Research™	
Capacity	The research groups are distributed between several universities, science councils, and private organisations. Most groups are emerging or building. Investment focus should be on strengthening the existing research groups.
Strength [1]	Too many at mid-level (4-6). Funding may be insufficient to grow the strength of institutions. Alignment and refocus of research may be required to increase strength and bring resources together. TRP needed, leading to CoE.
RDI Infrastructure	
Install, Maintain	Mapping and modelling infrastructure, laboratory ability to do LCA analyses, computing, water quality testing, materials testing. Pilot / demonstration plant facilities.
Customers and Partners	
Government and Stakeholders	DWS, NPC, DST, DoH, DAFF, DHS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies
Research	
Agencies	NRF, WRC, TIA – agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms
Science Councils and Universities	Broad range of partnerships at HEIs, ARC, Mintek, CSIR, CGS, with specific partners depending on RFA, discipline, and scale of technology. These organisations have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes.
Other Partnerships	SWPN, NBI, NEPAD. These 'other' partners will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks.

[1] Research Strength is gauged on a scale of 1 to 8. The ideal situation is one in which
- 20% of research groups in a certain focus area are below level 4 – this shows that there is growth, meaning new institutions starting to work in the focus area.
- 50% in levels 5-6, meaning that the majority of institutions are at a building level
- 30% at level 7 or 8, showing that there is enough research at a mature enough level to address market needs.

2.2.3 RDD Impact: Sources

Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Extremely high. Reduced withdrawal of raw water resources. Reduced consumption of raw and treated water. Improved water quality. Improved productivity of use.
Economic	
Wealth	Impact
Productivity	Moderate to high impact on increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	Impact due to beneficial effects increasing average revenues per unit product and per m^3 delivered, and increasing average revenue per producer (e.g. farmer, ecosystem, environment).
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	No impact
Wellness and Mortality	No impact
Society	
Food and livestock	Effects will include: improved availability and quality of environmental goods and services, increased food security – livestock, crops, and reduced loss of animals.
Education	No impact
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water.
Awareness and Behaviour	No impact
Environment	
Emissions, contaminants, pollution	Reduction in the following: carbon emissions, area of salinised land, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Reduced or reversed decline in biodiversity, reduced environmental debt, preservation and improved health of riverine and terrestrial habitats.

2.2.4 Strategic RDD Programme: Sources

		Immediate 2015	Short Term 2016-2018	Medium Term 2019-2021	Long term 2022 – 2024
Research Initiatives	Focus	**Explore:** Develop RP – defined research streams, objectives, plan. Aligned with NWRS2 and desalination strategy	**Research Programme**	**Centre of Excellence** for technologies associated with water recycling	Two **Professional Service Centres**
	Objective	Scope the whole opportunity with customers and stakeholders ▸ Customers: Users ▸ Mix and target mix over time – sources that are not waste	▸ Target particular sources that have higher potential ▸ Accelerate process of making operational impact ▸ Change the mix towards the ideal		▸ Provide effective technical assistance for regional water boards, WSAs and WSPs in decision-making about water sources and resource planning, technology selection, etc. ▸ Support strategic supply-side decision-making (link to Supply GPM)
	Need	**Quantify Need** ▸ From the Reconciliation Strategy, frame requirement to identify and make use of alternative supplies for agriculture and public supply: management, technology ▸ Define objective and requirement to increase use of treated effluent: management, technology ▸ Define objective and requirement to increase and sustain levels of rainwater harvesting and efficiency of conservation methods.	**Need** ▸ Produce up to date maps of rainfall and allocations - 2016 ▸ Develop Opportunities Map for each alternative source – precipitation, ground, waste and link to Planning and Management in Supply GPM ▸ Assess industrial ecology of (7) industrial urban centres	**Need** ▸ Continue monitoring for emerging pollutants and changes in sources of supply	▸ **Professional Service Centre** provides technical assistance to municipalities (specifications, technical and professional advice, support with tender evaluation)
	Potential	**Assess Potential** ▸ Identify suitable sites ▸ Conduct scientific-economic evaluation of alternative approaches eg potential and value of improving yields from enhanced rainfall, fog harvesting for strategic uses	**Realise Potential** ▸ Complete feasibility studies for sites with identified potential – including fitness for purpose. Identify requirements on treatment (alternate sources that are not waste) ▸ Implement efficient treatment management system for wastewater ▸ Increase the capability to identify and make use of alternative supplies ▸ Increase systemic ability to make use of treated effluent	**Realise Potential** ▸ **Centre of Excellence** for technologies associated with water recycling for different downstream uses. ▸ Continue to improve efficiency of treatment management system for wastewater ▸ Channel promising technologies to WADER (link to minimising Deliberate Demand in Productive Use	▸ **Professional Service Centre** supports functional resources planning and allocation processes, including reconciliation remapping, transfer schemes, macro decisions on water supply
	Enablers	**Enablers (link to Supply Gov., Plan, Manage)** ▸ Catalyse linkages between producers and users - e.g. mines and farms (non-food uses) ▸ Define programmes directed at increasing social acceptance of recycled water; behaviour change for alternative options	**Enablers** ▸ Implement research and programmes to address public perception issue around direct potable reuse	**Enablers** ▸ Improve industrial regulatory frameworks ▸ Improve the quality of decision-making information and also the uptake – resources planning and allocation	

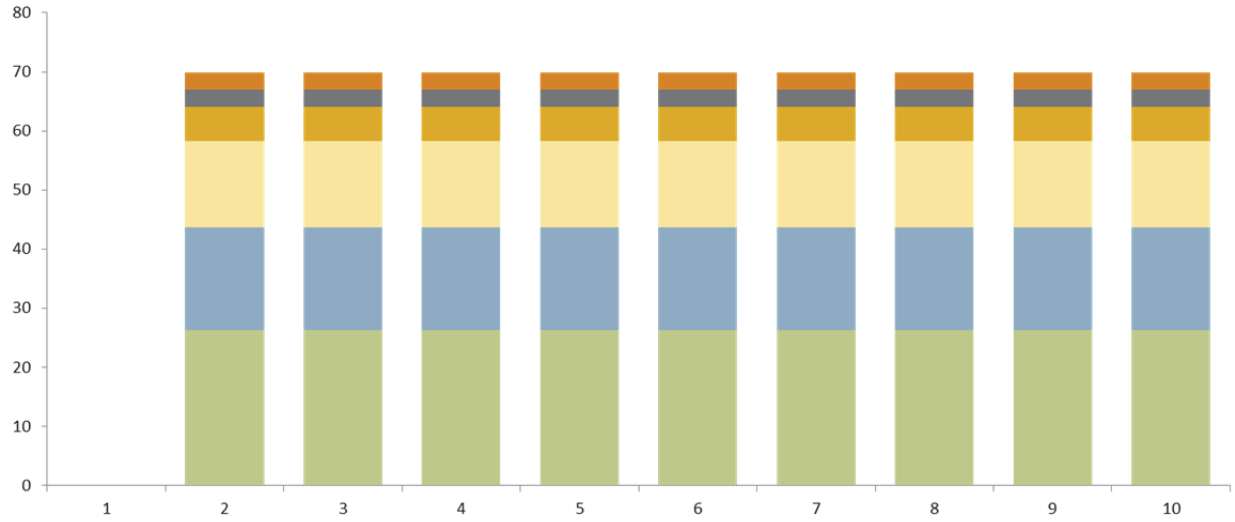
2.2.5 HCD Outline Plans per research initiative (Cluster: Sources)

The Research Capacity required to carry out RDD Programme, per year (i.e. number of people in each year, not a cumulative number) is presented graphically for each of the research initiatives.

The RDD Capacity by Research Initiative is also presented as a table indicating which research focus areas (RFAs) are relevant to the Research Initiative, and mapping the existing capacity in each RFA required to conduct research within the RDD programme set out in the preceding section.

Capacity has been identified at four levels using a scoring system for each research group (Emerging 0, Building 4, Established 7, Mature 10) based on composite score on a scale of 0-10 based on number and seniority of people, budget, publications and products, and technical services.

2.2.5.1 Needs Research Initiative (Sources)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	3	3	3	3	3	3	3	3	3
Principal researchers	0	3	3	3	3	3	3	3	3	3
Senior researchers	0	6	6	6	6	6	6	6	6	6
Researchers	0	15	15	15	15	15	15	15	15	15
Doctoral students	0	17	17	17	17	17	17	17	17	17
Masters students	0	26	26	26	26	26	26	26	26	26

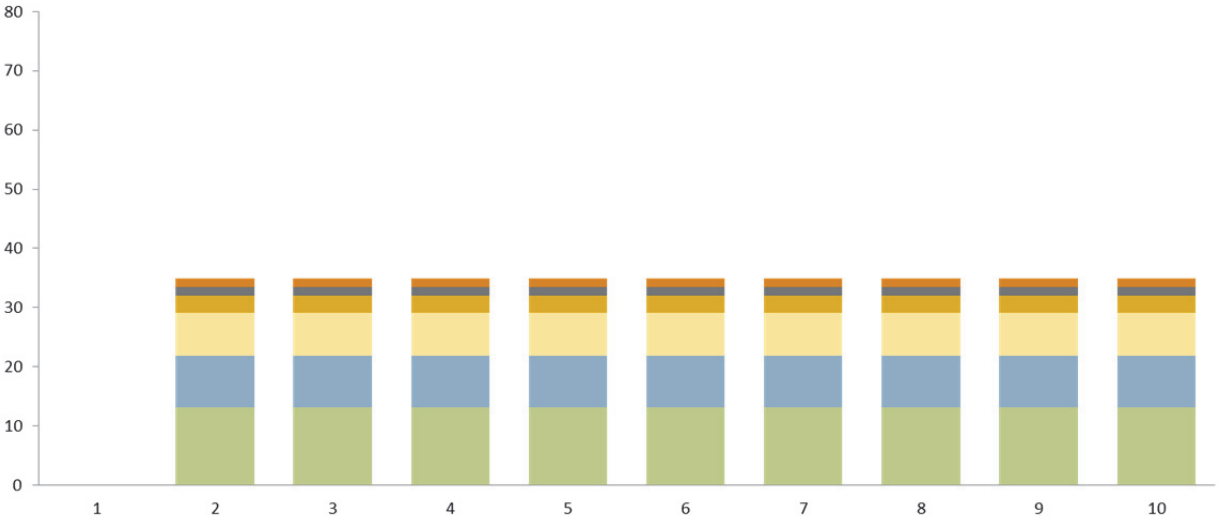
Figure 3: Research Capacity required each year to carry out RDD Programme, for the Research Initiative "Needs" within the Sources Cluster

Table 1: Mapping of capacity in underlying science (RFA) required to conduct research into "Needs"

Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

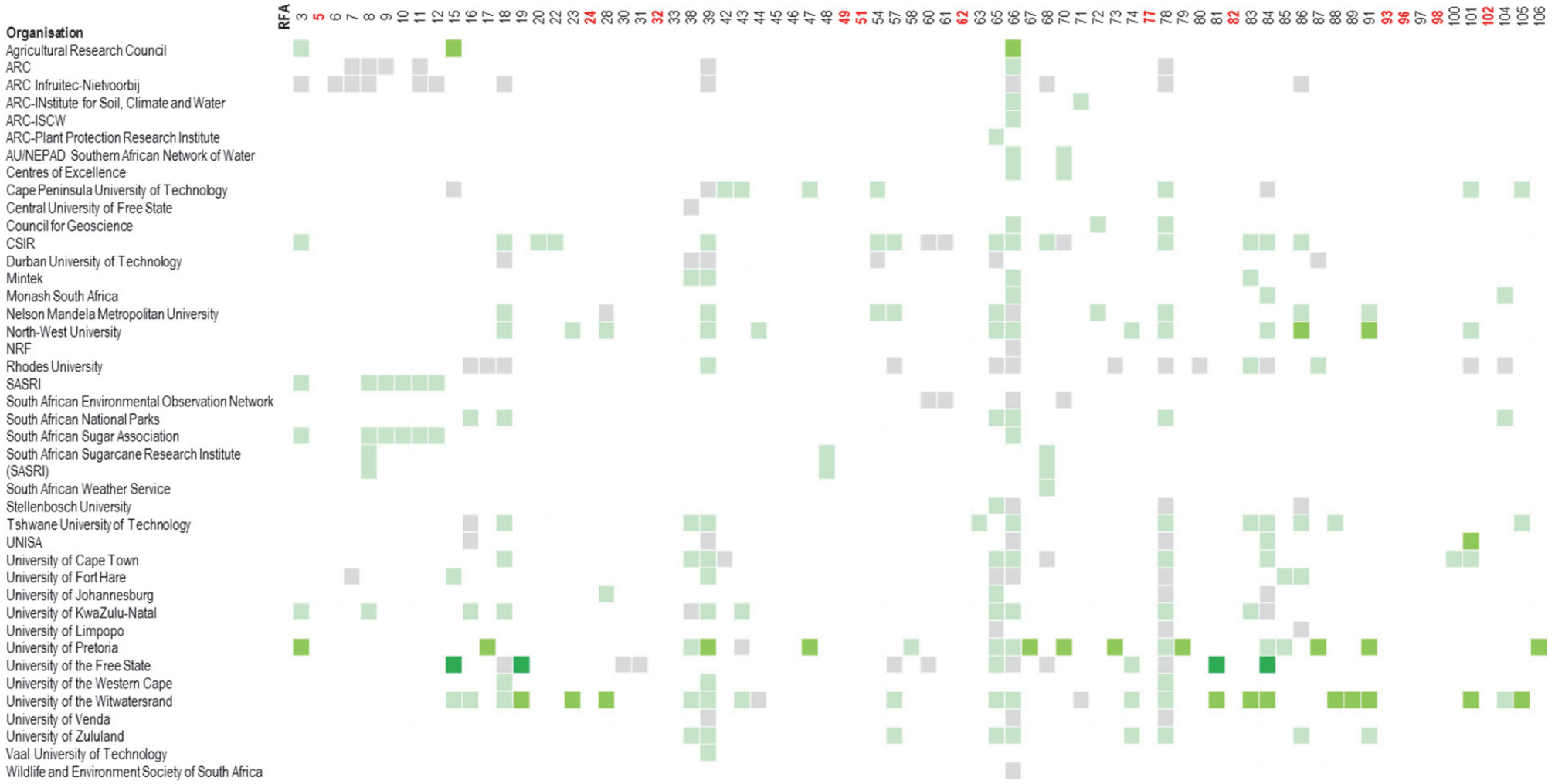
2.2.5.2 Potential Research Initiative (Sources)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	9	9	9	9	9	9	9	9	9
Principal researchers	0	9	9	9	9	9	9	9	9	9
Senior researchers	0	17	17	17	17	17	17	17	17	17
Researchers	0	44	44	44	44	44	44	44	44	44
Doctoral students	0	52	52	52	52	52	52	52	52	52
Masters students	0	79	79	79	79	79	79	79	79	79

Figure 4: Research Capacity required each year to carry out RDD Programme, for the Research Initiative "Potential" within the Sources Cluster

Table 2: Mapping of capacity in underlying science (RFA) required to conduct research into "Potential"

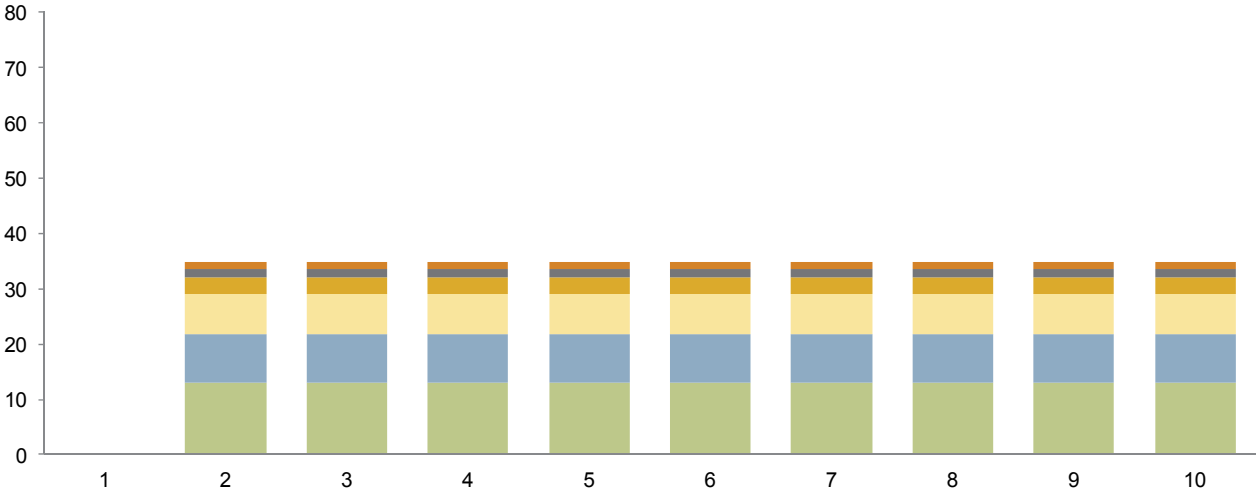


Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units

Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

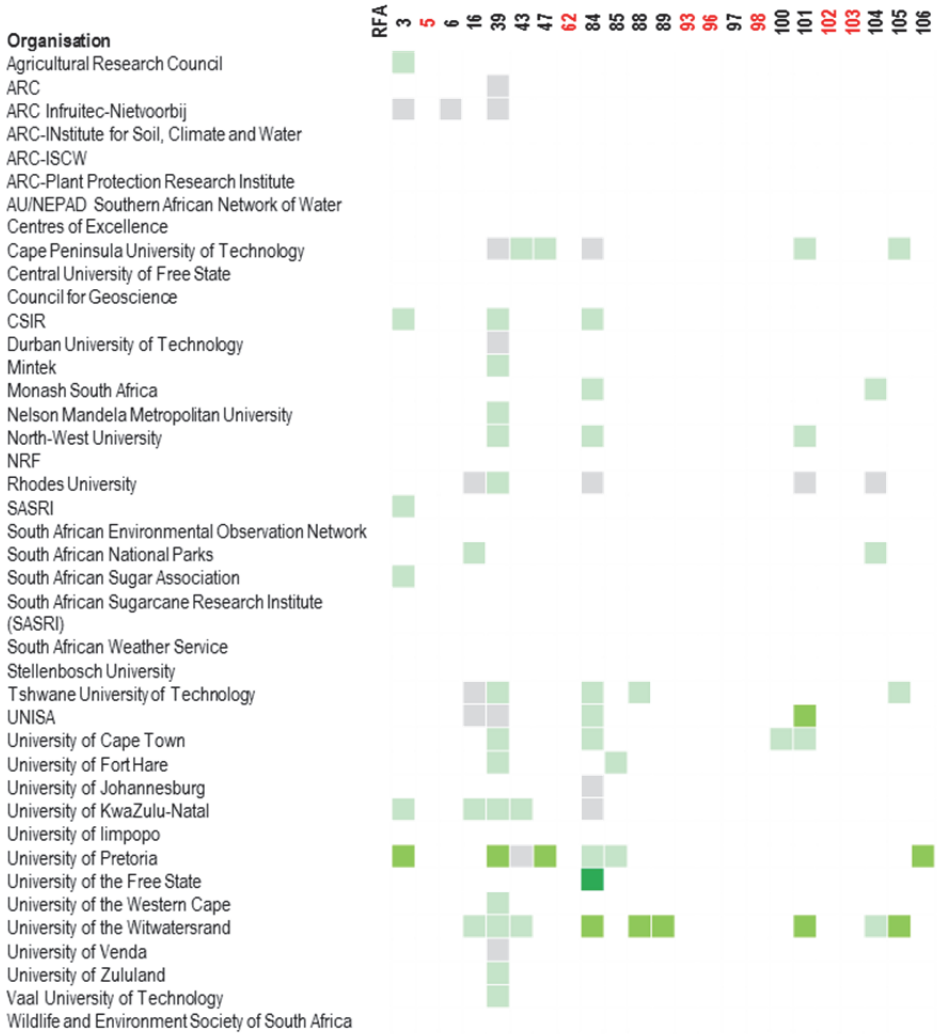
2.2.5.3 Enablers Research Initiative (Sources)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	1	1	1	1	1	1	1	1	1
Principal researchers	0	1	1	1	1	1	1	1	1	1
Senior researchers	0	3	3	3	3	3	3	3	3	3
Researchers	0	7	7	7	7	7	7	7	7	7
Doctoral students	0	9	9	9	9	9	9	9	9	9
Masters students	0	13	13	13	13	13	13	13	13	13

Figure 5: Research Capacity required each year to carry out RDD Programme, for the Research Initiative "Enablers" within the Sources Cluster

Table 3: Mapping of capacity in underlying science (RFA) required to conduct research into "Enablers"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units

Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.3 SUPPLY CLUSTER 2: IMPROVE GOVERNANCE, PLANNING AND MANAGEMENT OF SUPPLY AND DELIVERY

2.3.1 Cluster definition, scope, and research initiatives

2.3.1.1 Sector Objective

Improve **governance, planning and management of supply** and delivery.

2.3.1.2 Target RDD Outcome for 2025

The new DWS water allocations map (2016) is implemented by nine functional Catchment Management Agencies. The map includes groundwater, seawater, and wastewater.

This enables optimised reallocation and distribution of supplies and an improved ability to manage water flows. Focus on improved quality and resilience of planning for the future – ability to respond to changes, including climate change.

2.3.1.3 Research Initiatives

This cluster contains two research initiatives, which are Governance, and Planning and Management:

Governance	Design, implement, drive uptake and support in an integrated manner: ▸ effective governance models and mechanisms ▸ context-specific and transparent planning processes ▸ more efficient management of allocation and distribution all as the means to enable effective functioning of Catchment Management Agencies
Planning and management	

2.3.2 RDD Response: Governance, planning and management of supply

RDD Activity	
RDD Focus and Progression	Development of human capacity, information and management methods and deployment of technologies to improve governance, planning and management of supply and delivery. Creation of Research Programme, research chair, and finally CoE in water policy, governance and administration.
Underlying Science	Multiple disciplines within natural sciences, engineering, humanities, social sciences, economics, and law
Know-How	
Intellectual Property	None envisaged
Knowledge Diffusion	Not many products making the market to address needs. Investment required into technology development and deployment, commercialisation vehicles, product development centres, seed funding, etc. to shift balance more towards research being translated into full adoption.
Readiness to do Research™	
Capacity	The research group members are distributed between several universities, science councils, and private organisations. Most groups are emerging or building. Too high a proportion of research groups at mid level. Investment focus should be on strengthening the existing research groups.
Strength	Too many at mid level (4-6). Funding may be insufficient to grow the strength of institutions. Alignment and refocus of research may be required to increase strength and bring resources together. RP needed.
RDI Infrastructure	
Install, Maintain	Investment required into technology development and deployment.
Customers and Partners	
Government and Stakeholders	DWS, NPC, DST, DoH, DAFF, DHS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies
Research	
Agencies	NRF, WRC, TIA
Science Councils and Universities	Broad range of partnerships at HEIs, ARC, Mintek, CSIR, CGS, with specific partners depending on RFA ,discipline, and scale of technology
Other Partnerships	SWPN, NBI, NEPAD

Agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms. **Science Councils and Universities** have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes. '**Other' partners** will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks

2.3.3 RDD Impact: Governance, planning and management of supply

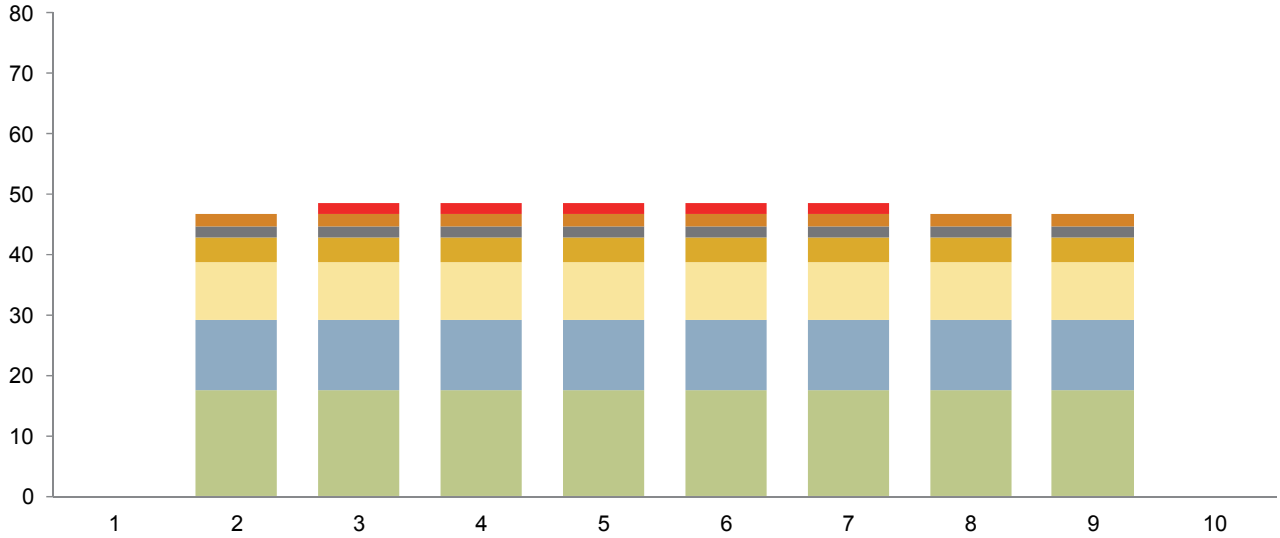
Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Moderate. Reduced withdrawal of raw water resources and improved productivity of use, which has been measured and benchmarked.
Economic	
Wealth	Impact
Productivity	Moderate to high impact on increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	No impact
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	Impact will be made through the reduction of the incidence of waterborne sickness and disease
Wellness and Mortality	Some impact will result from reduced absenteeism and early retirement - through increased wellness - and a reduced mortality rate.
Society	
Food and livestock	Effects will include: increased food security - livestock, crops, and reduced loss of animals.
Education	Increased school attendance (driven by access and quality) and improved educational outcomes will exert moderate impacts on education.
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water.
Awareness and Behaviour	Raised awareness of the value of water, driving increased willingness to pay, will be derived.
Environment	
Emissions, contaminants, pollution	Reduction in the following: area of salinised land, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Low to moderate, related to improved health of terrestrial habitats.

2.3.4 Strategic RDD Programme: Governance, planning and management of supply

	Immediate 2015	Short Term 2016 - 2017	Medium Term 2018 - 2020	Long term 2021 – 2023
Focus	**Explore:** ▶ Develop a RP – objectives, research streams, plan (aligned with NWRS2 and reconciliation strategy) ▶ Develop business case for Research Chairs	**Research Programme** Two Research Chairs for water supply policy and governance (rural and urban)	**Centre of Excellence** focused on governance policy and implementation	**Professional Service Centre** focused on implementation, uptake and support and specifically, provides strategic and management information to enable effective functioning of Catchment Management agencies
Supply – Governance, Planning and Management	▶ **Governance:** Confirm impediments (institutional, organisational, actors) to implementation of effective governance: relating to issues of mandates, responsibility and accountability around decision-making and compliance ▶ **Planning:** Identify requirements to Improve decision-making processes for water use authorisation ▶ **Management:** Determine required improvements to enable more efficient water ordering, improve management of distribution (link to Sources)	Refine, align and implement current legislation and strategy - W Service Act, WRN, NWA, NEMA, NWRS2 ▶ **Governance:** Develop and agree new model of co-operative governance, with clear accountability along the value chain ▶ **Planning**: Design and implement key aspects of context-specific and transparent planning ▶ **Management**: Design and implement key aspects of distribution of water allocation. With reference to: increased availability and uptake of alternative sources; enabling controlled transfers between end users: client-client, community Increase capacity and capability for decision-making and regulation	Further development of Governance, Planning and Management aspects of Supply Periodic performance reviews: ▶ Improve industrial regulatory frameworks ▶ Improve the quality of decision-making ▶ Better balancing growth with water security ▶ Verify and/or update water resource maps, NWRS, and reconciliation strategy (link to Sources)	Further development and Periodic performance reviews

2.3.5 HCD Outline Plans: Governance, planning and management of supply

2.3.5.1 Required research capacity: Governance, planning and management of supply

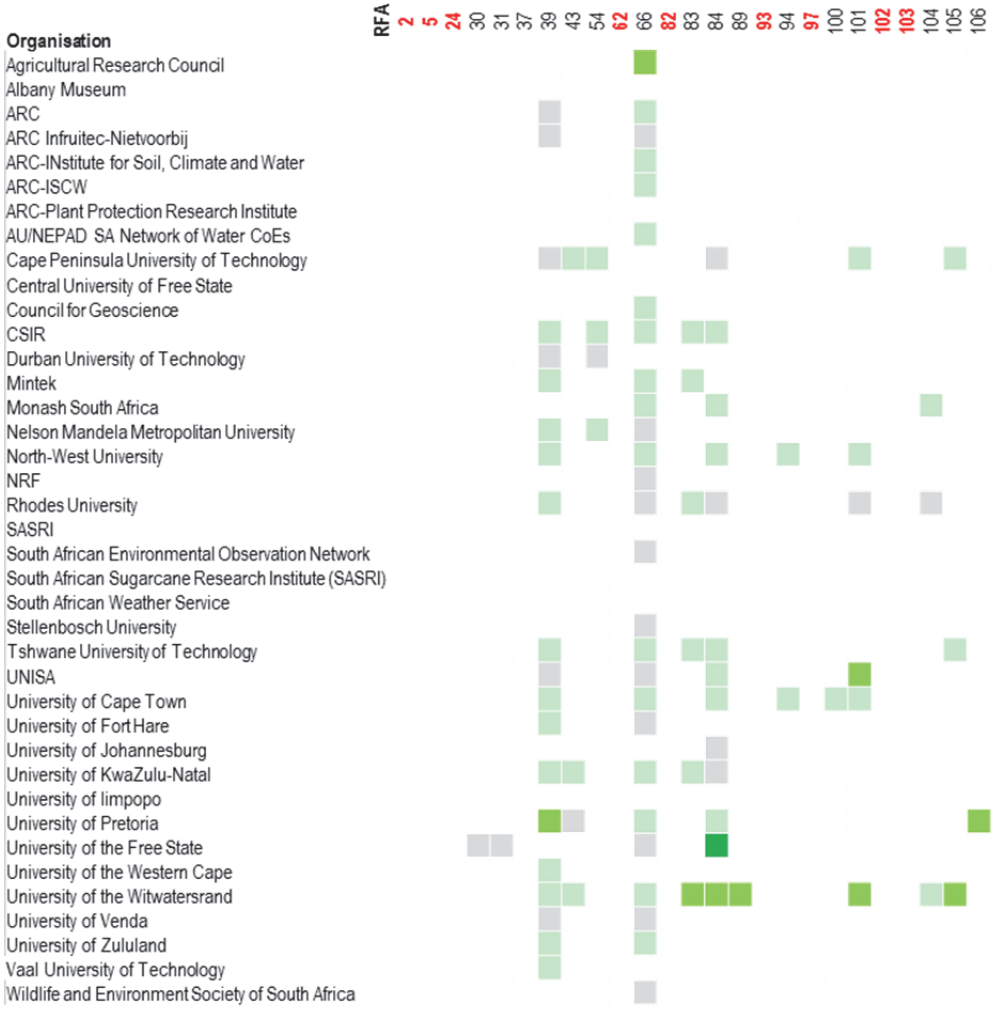


Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	2	2	2	2	2	0	0	0
Project leaders	0	2	2	2	2	2	2	2	2	0
Principal researchers	0	2	2	2	2	2	2	2	2	0
Senior researchers	0	4	4	4	4	4	4	4	4	0
Researchers	0	10	10	10	10	10	10	10	10	0
Doctoral students	0	12	12	12	12	12	12	12	12	0
Masters students	0	17	17	17	17	17	17	17	17	0

Figure 6: Research Capacity required each year to carry out RDD Programme, for the two Research Initiatives "Governance" and "Planning and Management" within the Governance, Planning and Management of Supply Cluster

2.3.5.2 *Current research capacity per research initiative within Cluster: Governance, planning and management of supply*

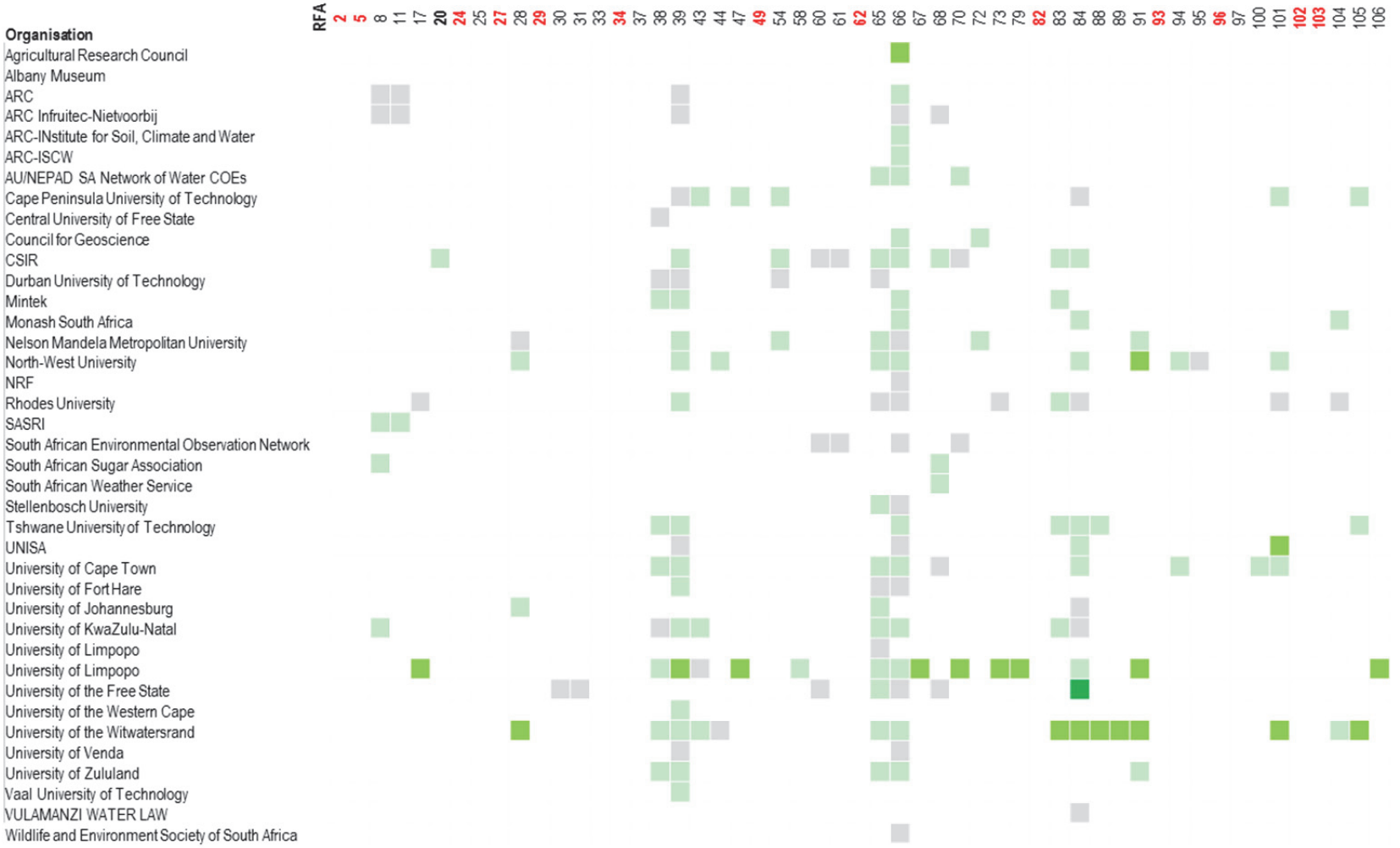
Table 4: Mapping of capacity in underlying science (RFA) required to conduct research into "Governance" (Supply)



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

Table 5: Mapping of capacity in underlying science (RFA) required to conduct research into "Planning and Management (Supply)"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units

Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.4 SUPPLY CLUSTER 3: IMPROVE ADEQUACY AND PERFORMANCE OF SUPPLY INFRASTRUCTURE

2.4.1 Cluster definition, scope, and research initiatives

2.4.1.1 Sector Objective

Improve adequacy and performance of supply **infrastructure**.

2.4.1.2 Target RDD Outcome for 2025

Increased volume and adaptability of storage capacity for raw water and treated effluent is available.

This has increased the levels of protection and reliability of ecological infrastructure, and the ecological reserve is sufficient.

2.4.1.3 Research Initiatives

This cluster contains two research initiatives, which are:

Ecological Infrastructure	Increase the ability and practice of making and implementing informed choices related to improvements in the performance of ecological infrastructure, including through rehabilitation and mitigation measures. The decision basis is sound socio-economic evaluation of the benefits and impacts of introduction or changes to environmental goods and services
Built Infrastructure	Evaluate performance of built infrastructure in respect of suitability, availability, capacity, flexibility. Support development and implementation of plans to optimise investment in supply infrastructure, including with tools for investment decision-making and integrated approaches to asset management

2.4.2 RDD Response: Infrastructure

RDD Activity	
RDD Focus and Progression	Develop human capacity, information and management methods; deploy existing technologies. Creation of Research Programme, two Research Chairs then two CoEs. Finally, embed capability and capacity in the community of practice.
Underlying Science	Multiple disciplines within natural sciences, engineering, management, and law / policy.
Know-How	
Intellectual Property	Some potential for more adaptive responses to water storage.
Knowledge Diffusion	Few products reaching market to address needs, therefore shift in balance needed towards translation of research into full adoption Investment into technology development and deployment, commercialisation vehicles, product development centres, seed funding
Readiness to do Research™	
Capacity	Research groups are multidisciplinary and members are distributed between several universities, science councils, and private organisations. Most groups emerging or building, with only two mature. Investment focus on strengthening existing capacity
Strength	Too high a proportion of research groups at mid level. Research chairs required. Funding may be insufficient to grow the strength of institutions. Alignment and refocus of research required to increase strength and bring resources together
RDI Infrastructure	
Install, Maintain	Investment required into laboratory capacity, technology development and deployment, information dissemination and utilisation.
Customers and Partners	
Government and Stakeholders	DWS, NPC, DST, DoH, DAFF, DHS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies
Research	
Agencies	NRF, WRC, TIA
Science Councils and Universities	Broad range of partnerships at HEIs, ARC, CSIR, with specific partners depending on RFA ,discipline, and scale of technology
Other Partnerships	SWPN, NBI, NEPAD

Agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms. **Science Councils and Universities** have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes. '**Other' partners** will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks

2.4.3 RDD Impact: Infrastructure

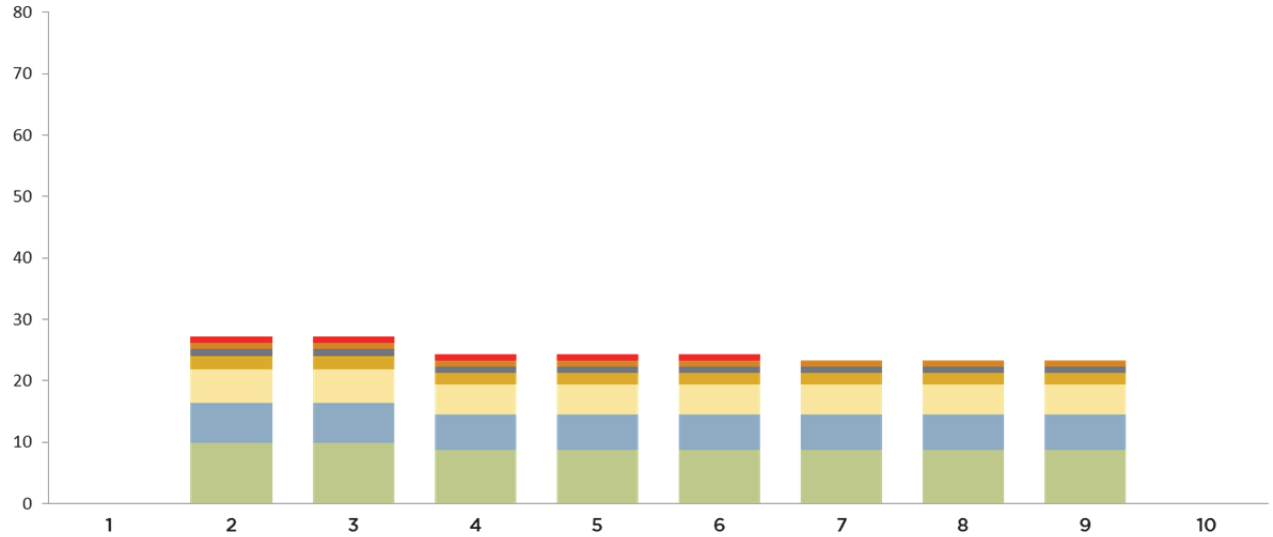
Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Moderate. Reduced withdrawal of raw water resources and improved productivity of use, which has been measured and benchmarked.
Economic	
Wealth	Impact
Productivity	Moderate to high impact on increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	No impact
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	Impact will be made through the reduction of the incidence of waterborne sickness and disease
Wellness and Mortality	Some impact will result from reduced absenteeism and early retirement - through increased wellness - and a reduced mortality rate.
Society	
Food and livestock	Effects will include: increased food security - livestock, crops, and reduced loss of animals.
Education	Increased school attendance (driven by access and quality) and improved educational outcomes will exert moderate impacts on education.
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water.
Awareness and Behaviour	Raised awareness of the value of water, driving increased willingness to pay, will be derived.
Environment	
Emissions, contaminants, pollution	Reduction in the following: area of salinised land, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Low to moderate, related to improved health of terrestrial habitats.

2.4.4 Strategic RDD Programme: Infrastructure

	Immediate 2015	Short Term 2016 - 2017	Medium Term 2018 - 2020	Long term 2021 – 2023
Focus	**Explore:** ▶ Develop RPs – objectives, research streams, plan (aligned with NWRS2 and reconciliation strategy) ▶ Develop case for establishment of Research Chairs	Two **Research Programme** Two Research Chairs for i) Urban Systems ii) Environmental Economics	Two **Centres of Excellence**	Two **Professional Service Centres**
Objective	▶ Define scope and objectives for planning and integration practices relating to new and existing infrastructure	▶ Increase ability to make informed choices on rehabilitation and mitigation (ecological) refurbishment and maintenance (built - incentives for O&M)	▶ Build out services and Know-How to address identified and targeted export potential	
Ecological Infrastructure	**Ecological Infrastructure** ▶ Assess value and evaluate reliability – both for storage and distribution. ▶ Identify opportunity to protect and improve performance	**Ecological Infrastructure** ▶ Develop capability to model and simulate actual and potential ecological infrastructure to highlight and evaluate choices, decisions (including trade-offs vs built infrastructure), benefits and impact ▶ Guide measures to improve control of alien invasive plants and wetland rehabilitation	**Ecological Infrastructure** ▶ Strengthen models and service capability	**PSC: Ecological Systems Services** – delivers models to enable socio-economic evaluation of the benefits and impacts of introduction or changes to environmental goods and services
Built Infrastructure	**Built Infrastructure** ▶ Evaluate performance (flexibility and responsiveness) including adaptability of storage capacity. ▶ Identify opportunities to optimise investment in built infrastructure – to increase suitability, availability, capacity, flexibility ▶ Identify requirements to improve visibility and management of asset base	**Built Infrastructure** ▶ Enhance artificial recharge - aquifers, rainwater tanks, existing capacity - small dams ▶ Develop and implement plans to optimise investment in supply infrastructure – to increase flexibility and responsiveness (link to Blue, Green, and No Drop certification and clusters around Productive Use and Ops Performance) ▶ Uprate competence and introduce adaptive practices to increase flexibility to plan and respond to the water effects of climate change	**Built Infrastructure** ▶ Continue to implement plans to optimise investment in maintenance of supply infrastructure ▶ Maintain competence in adaptive practices	▶ **PSC: Urban Systems Services** – provides and supports tools to public sector and industry for integrated asset management and optimising investment choices

2.4.5 HCD Outline Plans per research initiative: Infrastructure

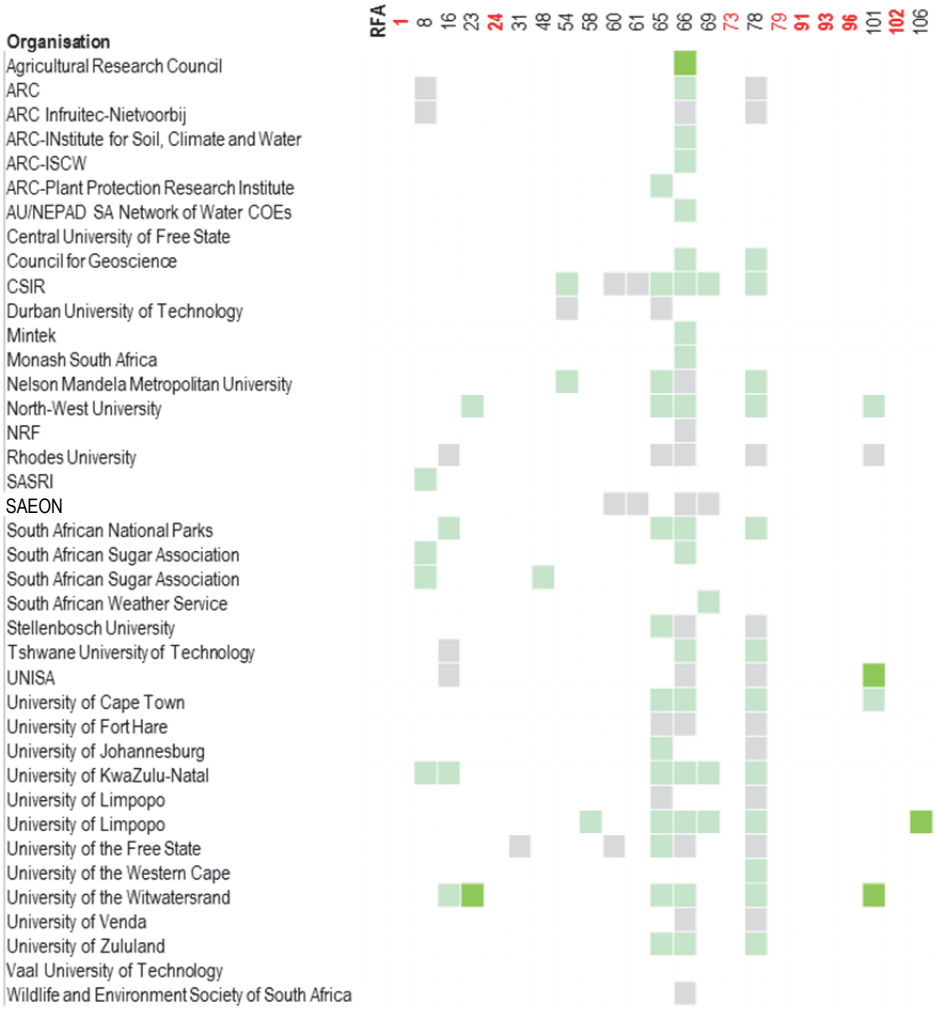
2.4.5.1 Ecological Infrastructure (Infrastructure)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	1	1	1	1	1	0	0	0	0
Project leaders	0	1	1	1	1	1	1	1	1	0
Principal researchers	0	1	1	1	1	1	1	1	1	0
Senior researchers	0	2	2	2	2	2	2	2	2	0
Researchers	0	5	5	5	5	5	5	5	5	0
Doctoral students	0	7	7	6	6	6	6	6	6	0
Masters students	0	10	10	9	9	9	9	9	9	0

Figure 7: Research Capacity required each year to carry out RDD Programme, for the Research Initiative "Ecological Infrastructure" within the Infrastructure Cluster

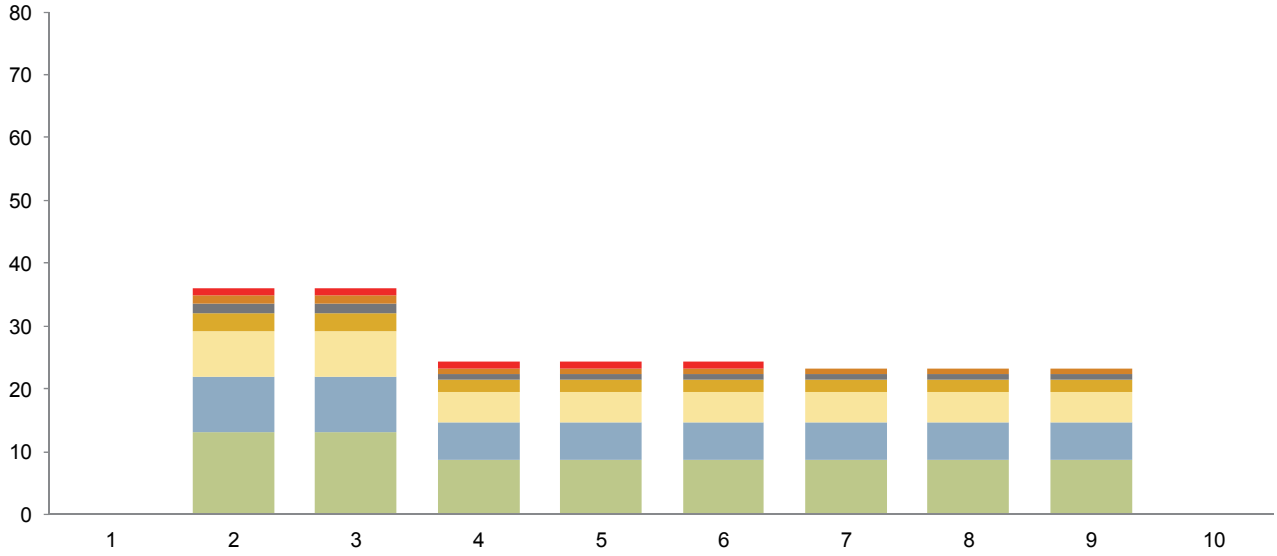
Table 6: Mapping of capacity in underlying science (RFA) required to conduct research into "Ecological Infrastructure"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research[IM] 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

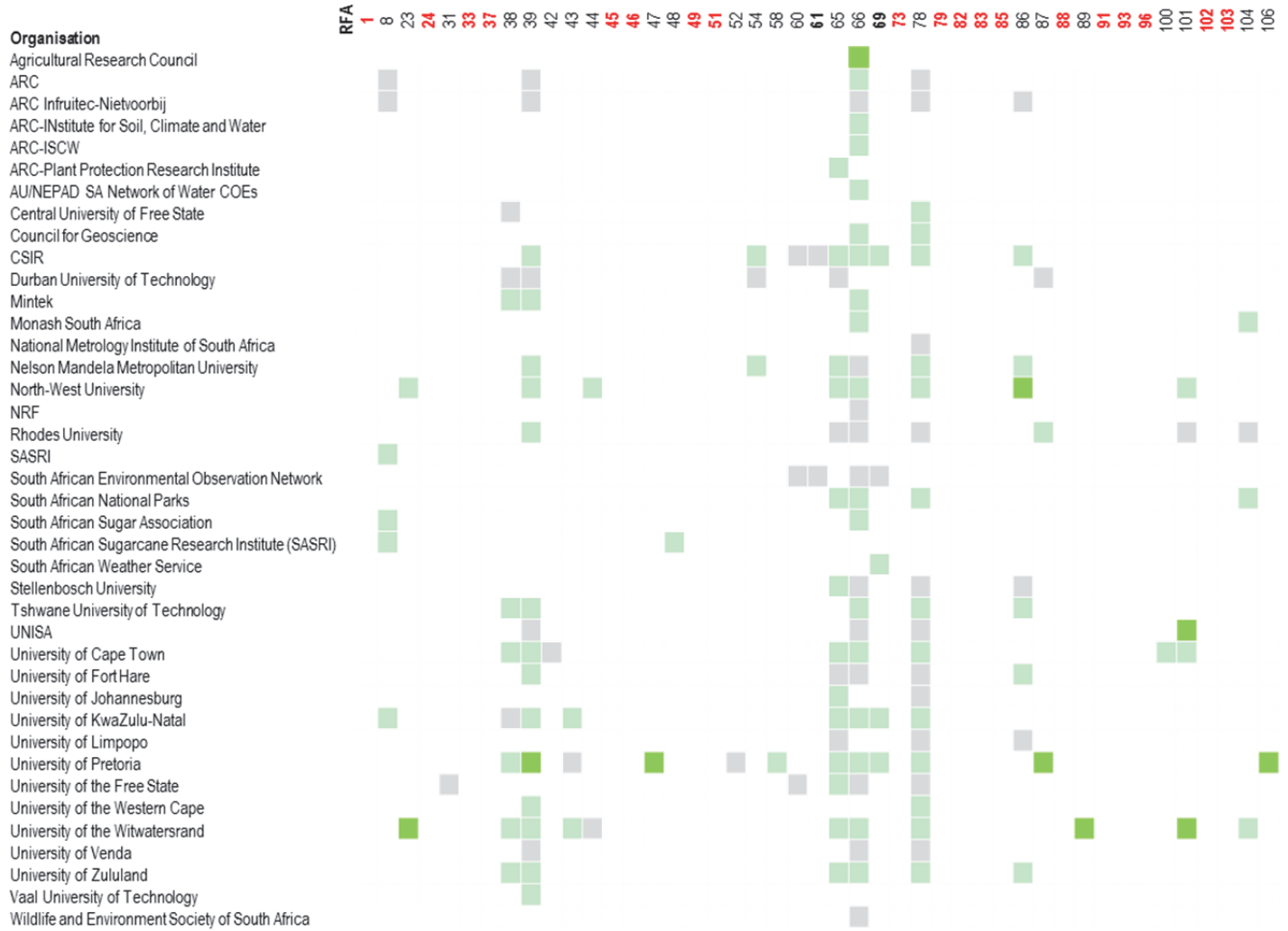
2.4.5.2 Built Infrastructure (Infrastructure)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	1	1	1	1	1	0	0	0	0
Project leaders	0	1	1	1	1	1	1	1	1	0
Principal researchers	0	1	1	1	1	1	1	1	1	0
Senior researchers	0	3	3	2	2	2	2	2	2	0
Researchers	0	7	7	5	5	5	5	5	5	0
Doctoral students	0	9	9	6	6	6	6	6	6	0
Masters students	0	13	13	9	9	9	9	9	9	0

Figure 8: Research Capacity required each year to carry out RDD Programme, for the Research Initiative "Built Infrastructure" and "Planning and Management" within the Infrastructure Cluster

Table 7: Mapping of capacity in underlying science (RFA) required to conduct research into "Built Infrastructure"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.5 SUPPLY CLUSTER 4: RUN WATER AS A FINANCIALLY SUSTAINABLE "BUSINESS" BY IMPROVING OPERATIONAL PERFORMANCE

2.5.1 Cluster definition, scope, and research initiatives

2.5.1.1 Sector Objective

Improve **operational performance** and run Water as a sustainable "business",

2.5.1.2 Target RDD Outcome for 2025

The financial sustainability of the water services system is secured.

Pricing is equitable and the attribution of water use is accurate. Non-revenue water is below 15% and revenues are collected punctually. Operational efficiency has been gained and >90% of water and wastewater treatment works have Blue Drop / Green Drop status.

2.5.1.3 Research Initiatives

This cluster contains three research initiatives combined into one:

Policy, Technology and Capacity	Improve the ability to monitor and evaluate the public sector system and its performance, including through technology insertion, service responsiveness and uprating of capacity Increase the financial sustainability of the public water supply system through support for evidence-based policy revisions relating to the requirement to pay

2.5.2 RDD Response: Operational performance

RDD Activity	
RDD Focus and Progression	Explore new tools for management and information dissemination. Demonstrate and deploy technologies and build capacity.
Underlying Science	Multiple disciplines within economics, management, political science, and social science.
Know-How	
Intellectual Property	No / little potential for commercial IP envisaged.
Knowledge Diffusion	Not many products making the market to address needs. Investment required into technology development and deployment, commercialisation vehicles, product development centres, seed funding, etc. to shift balance more towards research being translated into full adoption.
Readiness to do Research™	
Capacity	Smaller number of groups are distributed between universities, public entities, and private organisations. Most groups are emerging or building, with only a few established and none mature. Investment focus should be on strengthening the existing research groups.
Strength	Too high a proportion of research groups at mid-level. Funding insufficient to grow the strength of institutions. Alignment and refocus of research may be required to increase strength and bring resources together. TRP needed.
RDI Infrastructure	
Install, Expand	Investment required into technology development and deployment, information dissemination and utilisation.
Customers and Partners	
Government and Stakeholders	DWS, NPC, DST, DHS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies
Research	
Agencies	NRF, WRC, TIA
Science Councils and Universities	Broad range of partnerships at HEIs, science councils, with specific partners depending on RFA ,discipline, and scale of technology
Other Partnerships	SWPN, NBI

Agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms. **Science Councils and Universities** have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes. '**Other' partners** will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks

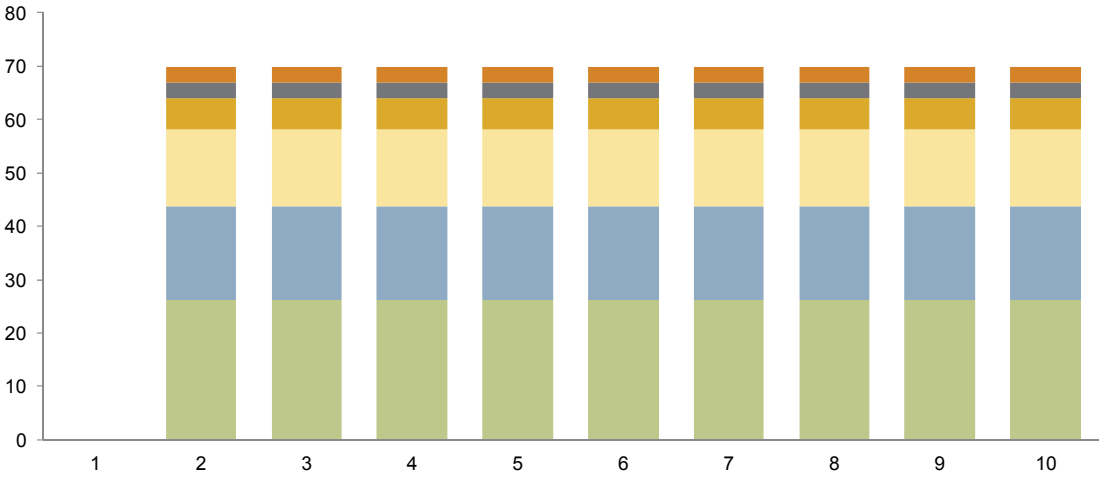
2.5.3 RDD Impact: Operational performance

Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Extremely high. Reduced withdrawal of raw water resources. Reduced consumption of raw and treated water. Improved water quality. Improved productivity of use.
Economic	
Wealth	Impact
Productivity	Moderate to high impact on increased product per drop (Water Use Efficiency (WUE): tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	Impact due to beneficial effects increasing average revenues per unit product and per m^3 delivered, and increasing average revenue per producer (e.g. farmer, ecosystem, environment).
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	Impact will be made through the reduction of the incidence of waterborne sickness and disease
Wellness and Mortality	Some impact will result from reduced absenteeism and early retirement – through increased wellness – and a reduced mortality rate.
Society	
Food and livestock	Effects will include: increased food security – livestock, crops, reduced loss of animals – and reduced environmental debt
Education	Increased school attendance (driven by access and quality) and improved educational outcomes
Relations and rights	Satisfaction of rights and demands of those without access to water. Improved availability and quality of environmental goods and services.
Awareness and Behaviour	Raised awareness of the value of water, driving increased willingness to pay (augmented by improved confidence in the public sector)
Environment	
Emissions, contaminants, pollution	Reduction in the following: carbon emissions, soil erosion, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Improved availability and quality of environmental goods and services.

2.5.4 Strategic RDD Programme: Operational performance

	Immediate 2015	Short Term 2016 - 2018	Medium Term 2019 - 2021	Long term 2022 – 2024
Focus	**Explore.** Develop a RP – objectives, research streams, plan	**Research Programme** of policy implementation **Research Programme** for industrial and organisational psychology around service delivery	**Centre of Excellence**	**Professional Service Centre** / Technical Assistance Centre serving municipalities
Objective	Informed by measures proposed in NWR2 in respect of Blue, Green and No-Drop certification, explore and define requirements to improve: ▶ **Monitoring and evaluation** of the public sector system – improving metering and billing, volumetrics (flow, use, quality), leak detection. (Link to cluster on Pricing, Monitoring, Billing) ▶ **Financial sustainability** of the public water supply system	▶ Develop and Demonstrate; technologies for predictive and faster leak detection and response ▶ Understand relationship between consumers, free basic water, and willingness / ability to pay for water	▶ Implement policies that maximise revenue water	▶ Deploy metering systems that are precise, accurate, and increase the proportion of revenue water
Ops Performance	Identify and describe opportunities (**policy**, **technology** and human **capacity**) to: ▶ Improve the monitoring throughout the system ▶ Improve the ability to monitor flow, use and quality (water balance) ▶ **Technology**: identify metering requirements for the SA context in terms of functionality, cost and uptake (explore range of smart meters, fault reporting apps, etc. already on the SA market, differences in uptake) ▶ **Capacity**: Discover reasons for failure in systems which do not attain or maintain Blue or Green Drop status ▶ Pilot No Drop certification scheme in metropolitan areas	**Policy** ▶ Provide evidence in support of revised policy around requirement to pay (Link to Pricing, Monitoring, Billing) **Technology** ▶ Test and demonstrate range of SA appropriate smart meters, fault reporting apps for improved M&E of water flow, use and quality **Capacity** ▶ Increase the range of tariffs ▶ Extend No Drop certification to municipalities: Number of accredited process controllers and Blue / Green / No Drop auditors increased by 50%	▶ Increase willingness and ability to define, absorb and implement new approaches – such as co-creation and co-responsibility with consumers, earlier involvement in development of solutions	

2.5.5 HCD Outline Plans: Operational performance



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	3	3	3	3	3	3	3	3	3
Principal researchers	0	3	3	3	3	3	3	3	3	3
Senior researchers	0	6	6	6	6	6	6	6	6	6
Researchers	0	15	15	15	15	15	15	15	15	15
Doctoral students	0	17	17	17	17	17	17	17	17	17
Masters students	0	26	26	26	26	26	26	26	26	26

Figure 9: Research Capacity required each year to carry out RDD Programme, for the Operational Performance Cluster

Table 8: Mapping of capacity in underlying science (RFA) required to conduct research into "Operational Performance"

Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.6 DEMAND CLUSTER 5: IMPROVE GOVERNANCE, PLANNING, AND MANAGEMENT OF DEMAND AND USE

2.6.1 Cluster definition, scope, and research initiatives

2.6.1.1 Sector Objective

Improve **governance planning** and its implementation in the **management of demand** and use.

2.6.1.2 Target RDD Outcome for 2025

There is equitable and transparent access to water supplies that are managed at catchment level by DWS co-operatively with DoH, DAFF, DHS, and DEA.

Transparency over rights, quotas, allocations, and transfers has been achieved and co-operative governance with respect to planning and management has been improved.

2.6.1.3 Research Initiatives

This cluster contains two research initiatives, which are:

Demand Governance	Design and enable implementation of improved and more co-operative governance with respect to planning and management of demand, including regulatory frameworks, decision-making and achieving optimum balance between economic growth and development and the need for water and food security
Demand Planning and Management	Improve quality and effectiveness of context-specific decision-making, planning implementation and regulation processes in respect of water use authorisation - rights, quotas, allocation and transfers. Increase institutional efficiencies through support for implementation and uptake of WCDM measures proposed in NWRS2, including provision of strategic and management information to enable effective functioning of Catchment Management agencies

2.6.2 RDD Response: Governance, Planning, and Management of Demand

RDD Activity	
RDD Focus and Progression	Explore new tools for public policy, administration, and management and for information dissemination. Demonstrate and deploy technologies and build capacity.
Underlying Science	Multiple disciplines within economics, management, political science, and social science.
Know-How	
Intellectual Property	No / little potential for commercial IP envisaged.
Knowledge Diffusion	Not many products making the market to address needs. Investment required into technology development and deployment, commercialisation vehicles, product development centres, seed funding, etc. to shift balance more towards research being translated into full adoption.
Readiness to do Research™	
Capacity	Research groups are distributed between universities, public entities, and private organisations. Most groups are emerging or building, with only a few established and none mature. Investment focus should be on strengthening the existing research groups and improving collaboration between public sector, private sector, and academic research.
Strength	Too high a proportion of research groups at mid level. Funding insufficient to grow the strength of institutions. Alignment and refocus of research may be required to increase strength and bring resources together. RP needed.
RDI Infrastructure	
Install, Expand	Desktop-based RDD cluster – office infrastructure
Customers and Partners	
Government and Stakeholders	DWS, NPC, DST, DHS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies
Research	
Agencies	NRF, WRC, TIA
Science Councils and Universities	Broad range of partnerships at HEIs, science councils, with specific partners depending on RFA ,discipline, and scale of technology
Other Partnerships	SWPN, NBI

Agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms. **Science Councils and Universities** have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes. '**Other' partners** will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks

2.6.3 RDD Impact: Governance, Planning, and Management of Demand

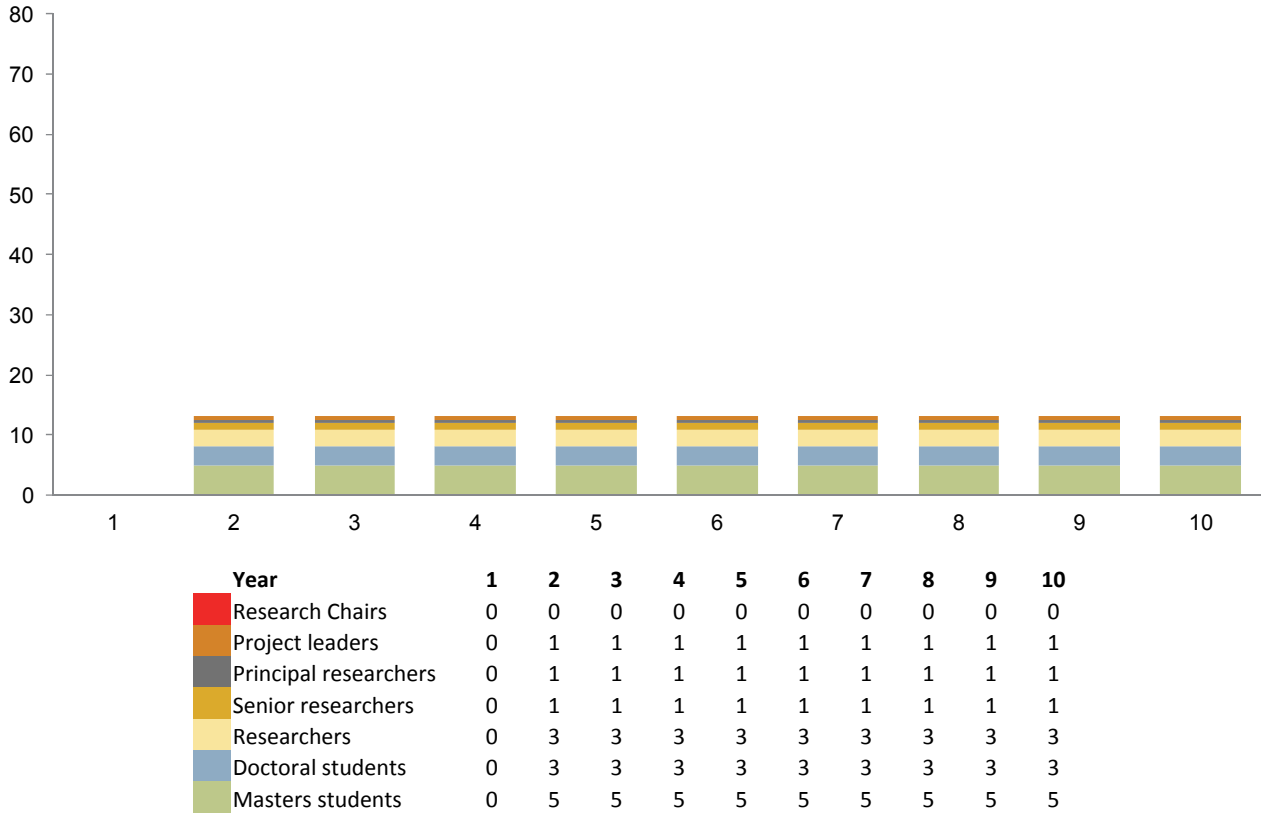
Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Moderate to high impact. Reduced withdrawal of raw water resources. Improved water quality. Improved productivity of use.
Economic	
Wealth	Impact
Productivity	Moderate to high impact on increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	No impact
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	Impact will be made through the reduction of the incidence of waterborne sickness and disease
Wellness and Mortality	Some impact will result from reduced absenteeism and early retirement - through increased wellness - and a reduced mortality rate.
Society	
Food and livestock	Effects will include: increased food security – livestock, crops, reduced loss of animals – and reduced environmental debt
Education	Increased school attendance (driven by access and quality) and improved educational outcomes
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water. Improved availability and quality of environmental goods and services.
Awareness and Behaviour	Raised awareness of the value of water, driving increased willingness to pay
Environment	
Emissions, contaminants, pollution	Reduction in the following: carbon emissions, soil erosion, area of salinised land, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Reduced or reversed decline in biodiversity, preservation of riverine habitants, reduced soil erosion, and improved health of terrestrial environment. Improved availability and quality of environmental goods and services.

2.6.4 Strategic RDD Programme: Governance, Planning, and Management of Demand

Research Initiatives	Immediate 2015	Short Term 2016 - 2018	Medium Term 2019-2024*	Long term 2022 – 2024*
Focus	**Explore:** Develop a RP – objectives, research streams, plan (aligned with NWRS2 and desalination strategy - link to Sources)	**Research Programme** relating to policy implementation **Research Chair** for Transboundary Water (cooperative governance)	**Centre of Competence** in Transboundary Water established. Works in collaboration with relevant policy-makers (e.g. DEA, DWS) **Centre of Excellence** in Planning and Management	**Professional Service Centre** focused on the implementation, uptake and support
Objective		▶ Publish and maintain the Ecological Reserve ▶ Refine, align and implement current legislation and strategy - WRN, NWA, NEMA, NWRS2	▶ Maintain the Ecological Reserve ▶ Increase institutional efficiencies, including via technology support	
Governance	▶ **Governance:** Confirm impediments (institutional, organisational, actors) to implementation of effective governance relating inter alia to issues of transparency, mandates, responsibility and accountability around decision-making and compliance	▶ **Governance:** Reduce impediments to implementation. Improve co-operative governance with respect to planning and management	Extend development of Governance, Planning and Management aspects of Demand across sectors. Periodic performance reviews: ▶ Improve regulatory frameworks, especially for the public service sector ▶ Improve the quality of decision-making ▶ Better balance eeconomic growth and development w. water and food security	
Planning and Management	**Planning:** ▶ Identify requirements to improve decision-making processes for rights, quotas, allocation and transfers **Management:** ▶ Determine required improvements to enable more efficient trading and transfer of water entitlement	**Planning**: ▶ Improve quality and effectiveness of context-specific planning and implementation. Improve regulation and decision making processes for water use authorisation. **Management**: ▶ Increase institutional efficiencies (link to Ops Performance). Enable water ordering, improve management of distribution. ▶ Implement WCDM measures proposed in NWRS2 (link to Asset management and Productive Use) – Demonstrate and Deploy focus	**Planning:** ▶ Review and maintain **Management**: ▶ Increase institutional efficiencies ▶ Implement WCDM measures proposed in NWRS2	▶ **Professional Service Centre** focused on the implementation, uptake and support and specifically – provides strategic and management information to enable effective functioning of Catchment Management agencies

2.6.5 HCD Outline Plans per research initiative: Governance, Planning, and Management of Demand

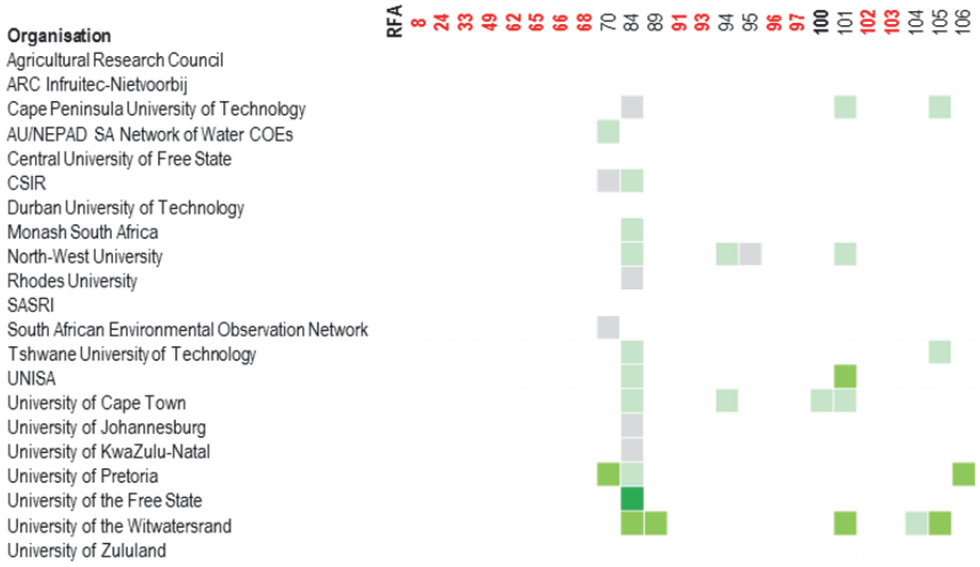
2.6.5.1 Governance (Demand)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	1	1	1	1	1	1	1	1	1
Principal researchers	0	1	1	1	1	1	1	1	1	1
Senior researchers	0	1	1	1	1	1	1	1	1	1
Researchers	0	3	3	3	3	3	3	3	3	3
Doctoral students	0	3	3	3	3	3	3	3	3	3
Masters students	0	5	5	5	5	5	5	5	5	5

Figure 10: Research Capacity required each year to carry out RDD Programme, for "Governance" in the Cluster, Governance, Planning, and Management of Demand

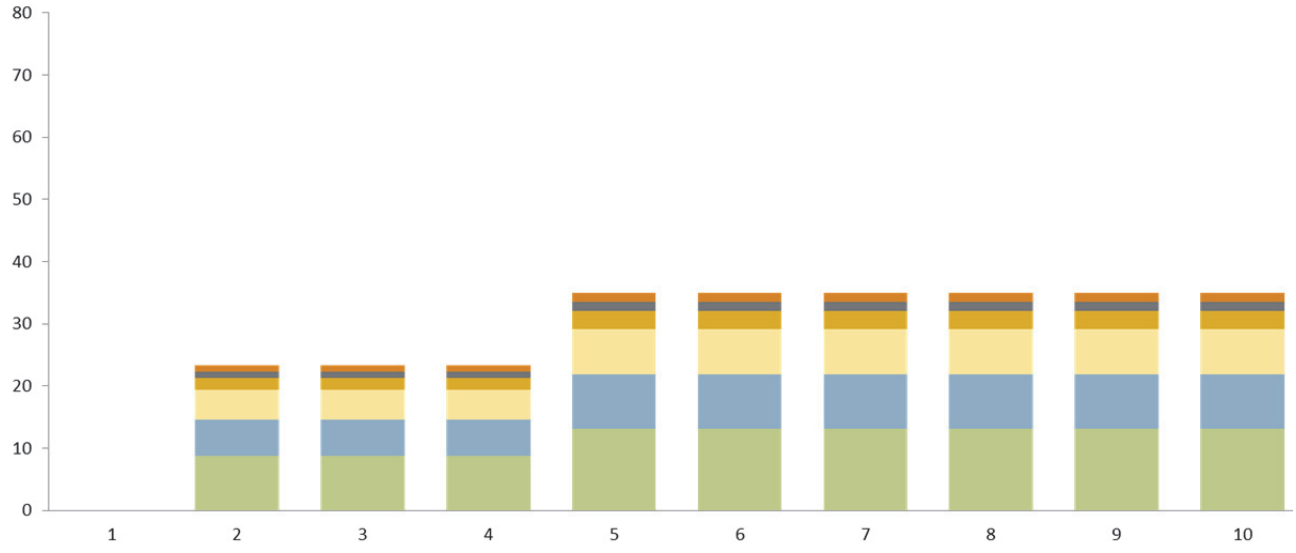
Table 9: Mapping of capacity in underlying science (RFA) required to conduct research into "Governance"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.6.5.2 Planning and Management (Demand)



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	1	1	1	1	1	1	1	1	1
Principal researchers	0	1	1	1	1	1	1	1	1	1
Senior researchers	0	2	2	2	3	3	3	3	3	3
Researchers	0	5	5	5	7	7	7	7	7	7
Doctoral students	0	6	6	6	9	9	9	9	9	9
Masters students	0	9	9	9	13	13	13	13	13	13

Figure 11: Research Capacity required each year to carry out RDD Programme, for "Planning and Management" in the Cluster, Governance, Planning, and Management of Demand

Table 10: Mapping of capacity in underlying science (RFA) required to conduct research into "Planning"

Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

Table 11: Mapping of capacity in underlying science (RFA) required to conduct research into "Management"

Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.7 DEMAND CLUSTER 6: REDUCE LOSSES AND INCREASE EFFICIENCY OF PRODUCTIVE USE

2.7.1 Cluster definition, scope, and research initiatives

2.7.1.1 Sector Objective

Reduce unintended losses and increase efficiency of **productive use**.

2.7.1.2 Target RDD Outcome for 2025

Non-productive uses of water have been eliminated or minimised.

This is evinced by reductions in: water transport losses, leakages, volume of water use, output to unrecoverable sources, volume and toxicity of pollution, and discharge of poor quality water. There have been concomitant increases in: conjunctive use of water, the area under irrigation, efficiency of water use, and levels of water reuse.

2.7.1.3 Research Initiatives

This cluster contains two research initiatives, which are:

Technical Loss	Identify, enable and support (municipalities in) targeted improvements in prioritised water loss situations through prevention, mitigation and reduction measures including technology solutions, operational practices and institutional efficiencies.
Deliberate Demand	Support demand side decision-making intended to optimise balance between the right to water and productive use of this water. Develop and test technologies focused on efficiency of use, fitness for use, transfer of water and waste minimisation (with transfer to WADER for demonstration and deployment where appropriate)

2.7.2 RDD Response: Productive use

RDD Activity	
RDD Focus and Progression	Explore new tools for management and administration of pricing and tariffs. Test, demonstrate and deploy M&E technologies and build human capacity.
Underlying Science	Multiple disciplines within natural and political/social sciences, engineering, business, economics, law, and resources planning..
Know-How	
Intellectual Property	No / little potential for commercial IP envisaged with possible exception of WCDM and/or metering methods.
Knowledge Diffusion	Most RFAs at levels 1 to 3, therefore not enough products making it into the market. Technology development and deployment requires investment.
Readiness to do Research™	
Capacity	Large number of research groups that are widely distributed between universities, science councils, and a mixture of public and private organisations. Most groups are emerging or building. Small number of established groups, only two mature..
Strength	Most groups at level 3 to 4, indicating that investment into knowledge generation, HCD and RP is required.
RDI Infrastructure	
Install, Expand	Investment required into capacity building, technology development, and management methods. Including one research chair, one CoE and one PSC
Customers and Partners	
Government and Stakeholders	DWS, NPC, DHS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies, manufacturing
Research	
Agencies	NRF, WRC
Science Councils and Universities	Broad range of partnerships at HEIs, private and public companies, and science councils, with specific partners depending on RFA, discipline, and scale of technology
Other Partnerships	NBI, NGOs, communities

Agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms. **Science Councils and Universities** have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes. '**Other' partners** will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks

2.7.3 RDD Impact: Productive use

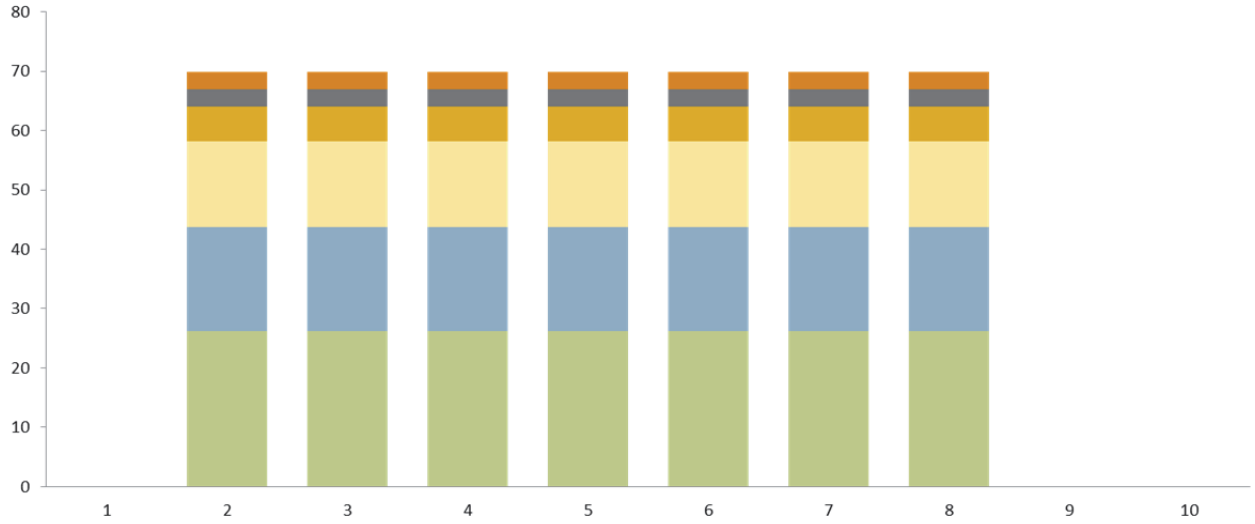
Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Moderate to high impact. Reduced withdrawal of raw water resources. Reduced consumption of raw and treated water. Improved productivity of use.
Economic	
Wealth	No impact
Productivity	Moderate to high impact on increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	Impact due to beneficial effects increasing average revenues per unit product and per m^3 delivered, and increasing average revenue per producer (e.g. farmer, ecosystem, environment).
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	No impact
Wellness and Mortality	No impact
Society	
Food and livestock	Effects will include: reduced environmental debt and improved availability and quality of environmental goods and services.
Education	No impact
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water. Improved availability and quality of environmental goods and services.
Awareness and Behaviour	No impact
Environment	
Emissions, contaminants, pollution	Reduction in the following: carbon emissions, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Preservation of riverine habitants, and improved health of terrestrial environment.

2.7.4 Strategic RDD Programme: Productive use

Research Initiatives	Immediate 2015	Short Term 2016 - 2017	Medium Term 2018 – 2020*	Long term 2020 – 2022/3*
Focus	**Explore:** Develop a RP – objectives, research streams, plan	**RP: Technical Loss –** solutions deployment; research programme around social and behavioural science **RP: Deliberate Demand –** technology development and testing Research Chair for Water Conservation and Demand Management	**Technical Loss: Professional Service Centre** established **Deliberate Demand** – Centre of Excellence for Productive Use - channel promising technologies to WADER (link to Sources)	**Technical Loss: Professional Service Centre** continues **Deliberate Demand: Centre of Excellence** for Productive Use continues
Technical Loss	**Objective:** ▶ Reduce water transport losses and leakages pre- and post-treatment **RDD Focus** ▶ Identify and quantify root causes of loss (eg water tank overflows, bulk supply losses, transmission systems, theft) in order to define opportunity for research in the mitigation or reduction of such losses	**Objective:** ▶ Target situations that have higher levels of loss ▶ Increase institutional efficiencies to minimise losses **RDD Focus** ▶ Demonstrate and deploy developed research and technology solutions eg for asset management, pressure reduction, support for No Drop certification ▶ Identify and explore successful practices in other geographies in respect of reduction of theft	**Technical Loss: Professional Service Centre** provides a) technical assistance to municipalities in respect of Technical Loss (specifications, technical and professional advice, support with tender evaluation) b)advice and implementation support for initiatives to change behaviour relating to theft **Objective and RDD Focus as per short term**	Provide technical advice to municipalities about water loss prevention, technologies for detection and repair of leaks, reduction of theft
Deliberate Demand	**Objective:** ▶ Optimise conjunctive use of water ▶ Reduce volume of water use ▶ Increase levels of water reuse **RDD Focus** ▶ **Identify opportunity** for Research – within and across segments – relating to minimising water use, application and losses in primary processes, ancillary processes, reduction in demand for domestic water, minimise production and reuse of waste by-products (link to reuse/recycling CoE in **Sources**)	**Objective:** ▶ Balance use of all sources in an integrated manner. Minimise demand on supplier (e.g. municipality) ▶ Implement WCDM measures proposed in NWRS2 **RDD Focus** ▶ Targeted programme of technology development and testing relating to efficiency of use, fitness for use, transfer of water, waste minimisation – for transfer to WADER (for demonstration and deployment)	**Objective:** ▶ Balance use of all sources in an integrated manner. Minimise demand on supplier (e.g. municipality) ▶ Implement WCDM measures proposed in NWRS2 **RDD Focus** ▶ Targeted programme of technology development and testing relating to efficiency of use, fitness for use, transfer of water, waste minimisation – for transfer to WADER (for demonstration and deployment)	Support demand side decision-making to optimise balance between the right to water and productive use of this water

2.7.5 HCD Outline Plans per research initiative: Productive use

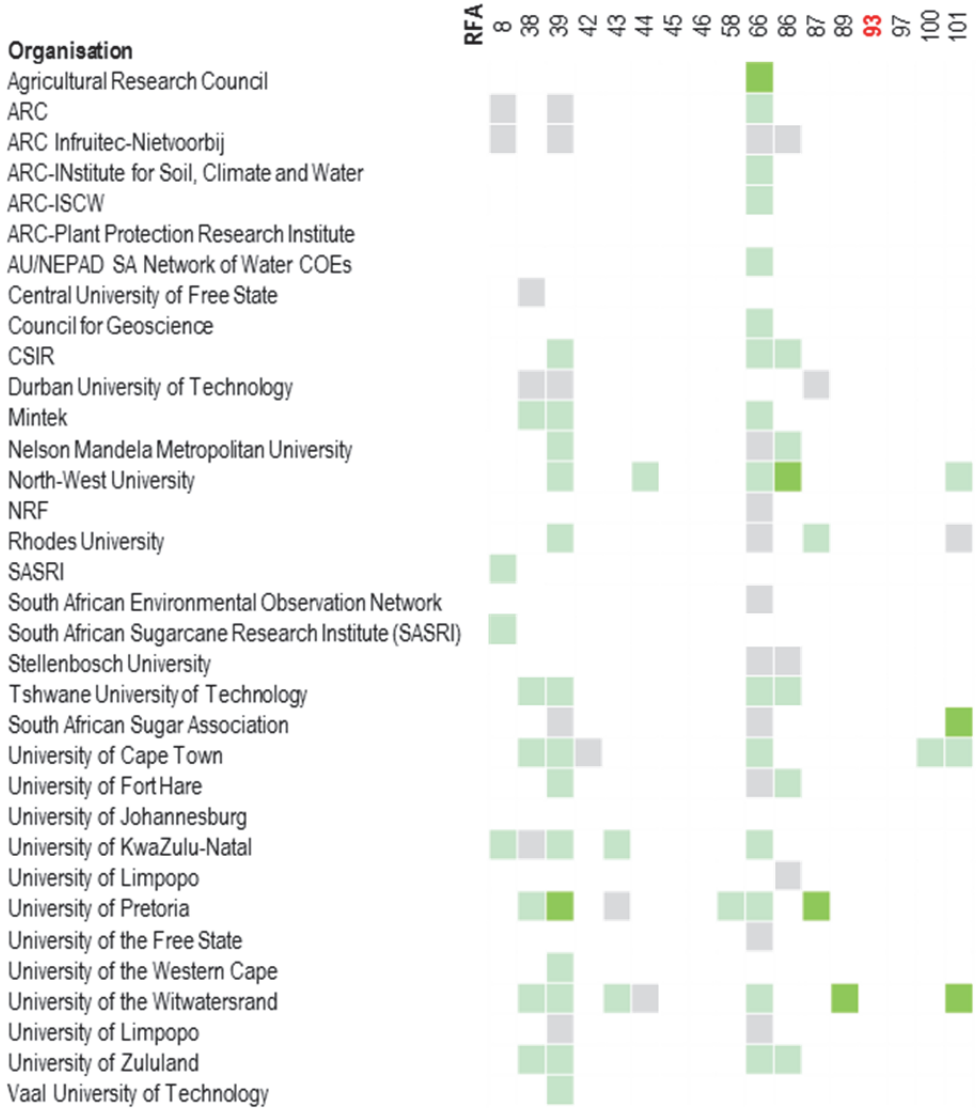
2.7.5.1 Technical Loss



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	3	3	3	3	3	3	3	0	0
Principal researchers	0	3	3	3	3	3	3	3	0	0
Senior researchers	0	6	6	6	6	6	6	6	0	0
Researchers	0	15	15	15	15	15	15	15	0	0
Doctoral students	0	17	17	17	17	17	17	17	0	0
Masters students	0	26	26	26	26	26	26	26	0	0

Figure 12: Research Capacity required each year to carry out RDD Programme, for "Technical Loss" in the Cluster, Productive Use

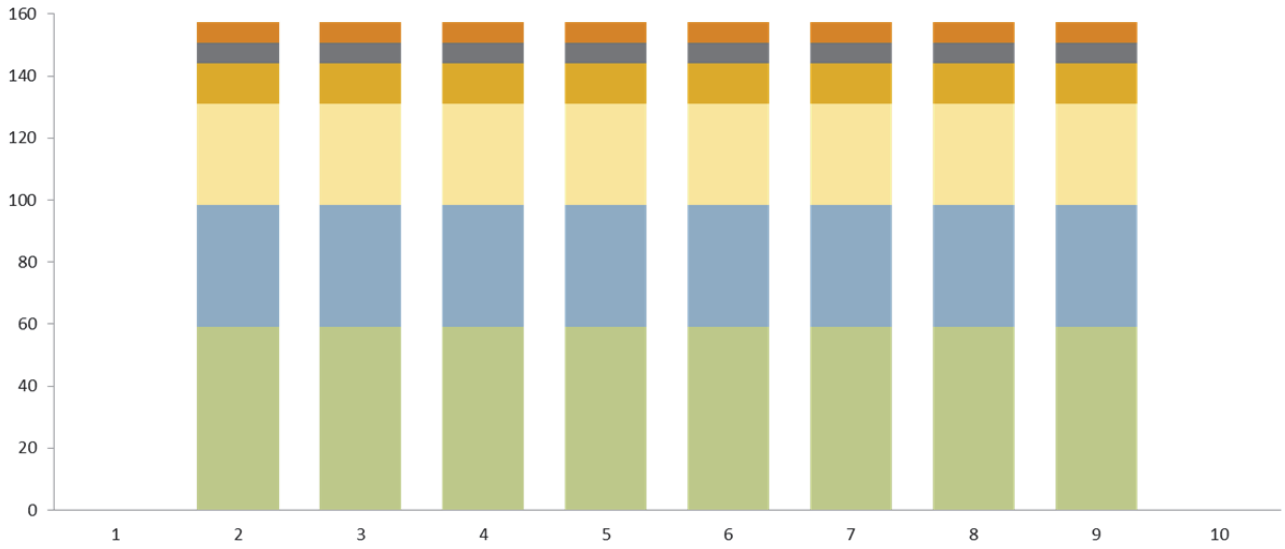
Table 12: Mapping of capacity in underlying science (RFA) required to conduct research into "Technical Loss"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.7.5.2 Deliberate Demand



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	7	7	7	7	7	7	7	7	0
Principal researchers	0	7	7	7	7	7	7	7	7	0
Senior researchers	0	13	13	13	13	13	13	13	13	0
Researchers	0	33	33	33	33	33	33	33	33	0
Doctoral students	0	39	39	39	39	39	39	39	39	0
Masters students	0	59	59	59	59	59	59	59	59	0

Figure 13: Research Capacity required each year to carry out RDD Programme, for "Technical Loss" in the Cluster, Productive Use

Table 13: Mapping of capacity in underlying science (RFA) required to conduct research into "Technical Loss"

Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

2.8 DEMAND CLUSTER 7: IMPROVE PERFORMANCE OF PRICING, MONITORING, BILLING, METERING AND COLLECTION

2.8.1 Cluster definition, scope, and research initiatives

2.8.1.1 Sector Objective

Improve performance of **Pricing, Monitoring, Billing**, Metering and Collection.

2.8.1.2 Target RDD Outcome for 2025

Improved accuracy has been attained in water use monitoring, billing and management

Pricing is equitable, the attribution of water use is accurate. Non-revenue water is below 15% and revenues are collected punctually.

2.8.1.3 Research Initiatives

This cluster contains two research initiatives, which are:

Cost	Improve equity of pricing by creating and optimising pricing and tariffing systems that are representative of true cost of water and sanitation services
Volume	Improve the performance (coverage and accuracy) of flow monitoring, metering, attribution, billing and collection practices and systems

2.8.2 RDD Response: Pricing, Monitoring, Billing

RDD Activity	
RDD Focus and Progression	Explore new tools for management and metering. Test, demonstrate and deploy technologies and build human capacity.
Underlying Science	Multiple disciplines within WCDM, loss minimisation, M&E and automation / control.
Know-How	
Intellectual Property	No / little potential for commercial IP envisaged
Knowledge Diffusion	Extremely small pool of expertise. Too many groups at levels 0 to 3, thus investment into technology import and deployment is needed.
Readiness to do Research™	
Capacity	Small number of research groups that are distributed between universities, and a mixture of public and private organisations. Most groups are emerging or building. Only six RFAs represented.
Strength	Investment needed into knowledge generation, and HCD. Research groups require strengthening and multiplying. TRP needed to focus funding.
RDI Infrastructure	
Install, Expand	Investment required into capacity building, technology demonstration and deployment, and metering methods.
Customers and Partners	
Government and Stakeholders	DWS, SALGA, Water Boards, Water Services Authorities, Water Services Providers
Private Sector	Private sector engineering companies.
Research	
Agencies	WRC, possibly TIA
Science Councils and Universities	Partnerships at HEIs, private and public companies, and science councils, with specific partners depending on RFA, discipline, and scale of technology
Other Partnerships	Ofwat

Agencies are largely responsible for enablement, such as funding, providing partnerships, or other support mechanisms. **Science Councils and Universities** have roles and mandates relating to fundamental research, applied research, industrial development, and scale-up of innovative products and processes. '**Other' partners** will be involved in diverse activities, for example, dissemination of new knowledge, assistance with finding and securing sites and/or partners for piloting / demonstration, co-funding, promotion of the RDI Outputs to their networks

2.8.3 RDD Impact: Pricing, Monitoring, Billing

Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Moderate to high impact. Reduced withdrawal of raw water resources. Reduced consumption of raw and treated water. Improved productivity of use.
Economic	
Wealth	Impact
Productivity	Moderate to high impact on increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agroindustry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	Impact due to beneficial effects increasing average revenues per unit product and per m^3 delivered, and increasing average revenue per producer (e.g. farmer, ecosystem, environment).
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	No impact
Wellness and Mortality	No impact
Society	
Food and livestock	Effects will include: reduced environmental debt and improved availability and quality of environmental goods and services.
Education	No impact
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water.
Awareness and Behaviour	Raised awareness of the value of water, driving increased willingness to pay.
Environment	
Emissions, contaminants, pollution	Reduction in the following: carbon emissions, contamination of surface water, downstream pollution.
Preservation and health	No impact

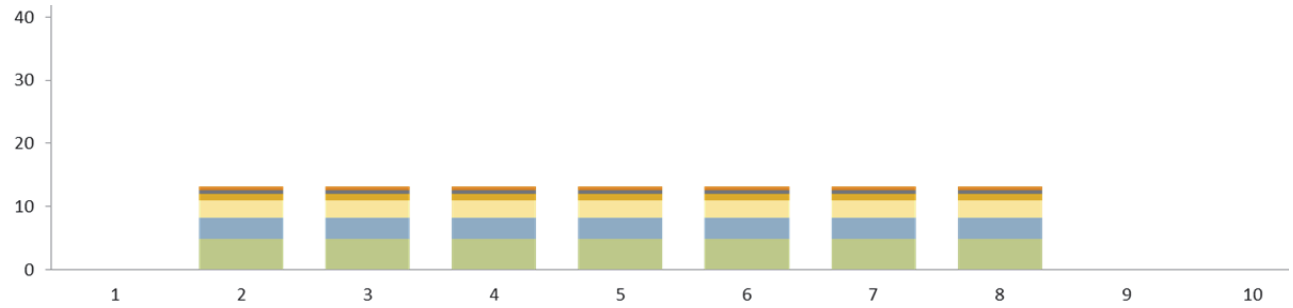
2.8.4 Strategic RDD Programme: Pricing, Monitoring, Billing

		Immediate 2015	Short Term 2016-2018*	Medium Term 2018-2020*	Long term 2020 – 2023*
Research Initiatives	Focus	**Explore** Develop RPs for Cost and Volume – objectives, research streams, plan	**Cost**: Research Programme **Volume**: Research Programme Research Chair in Water Resource Economics	**Cost: Professional Service Centre** for the Water Economy **Volume**: RP continues	**Volume: Professional Service Centre / Technical Assistance Centre** serving water service providers
	Cost	**Objective:** ▶ Understand current inequity in pricing, effectiveness of current pricing models **RDD Focus** ▶ Explore and benchmark international practices in tariffing and pricing; define requirements to model and simulate pricing system	**Objective:** ▶ Improve equity of pricing; create pricing and tariffing systems representative of true cost of water and sanitation services **RDD Focus** ▶ Develop and test pricing model including for cost of discharge to sewer - to inform WCDS (link to Ops Performance around revised policy requirement to pay for water and sanitation services)	**Objective:** ▶ Optimise pricing and tariffing **RDD Focus** ▶ Further development of pricing and tariffing, including evaluation of effectiveness of pricing systems in encouraging desirable practice	
	Volume	**Objective:** ▶ Understand current performance of monitoring, billing and collection practices and systems **RDD Focus** ▶ Determine requirements in respect of monitoring and metering, including requirement to increase coverage and accuracy of environmental monitoring (link to metering technology for domestic and industrial use in Ops Performance)	**Objective:** ▶ Improve accuracy: monitoring of use, billing, and revenue collection **RDD Focus** ▶ Targeted programme of technology demonstration for precise and accurate flow monitoring, metering, attribution and billing – managed via WADER	**Objective:** ▶ Improve equity of pricing; create pricing and tariffing systems representative of true cost of water and sanitation services **RDD Focus** ▶ Support improvements in monitoring, metering, billing and revenue collection practices	

* Time frames overlap, due to difference in duration of RPs for Cost and Volume.

2.8.5 HCD Outline Plans per research initiative: Pricing, Monitoring, Billing

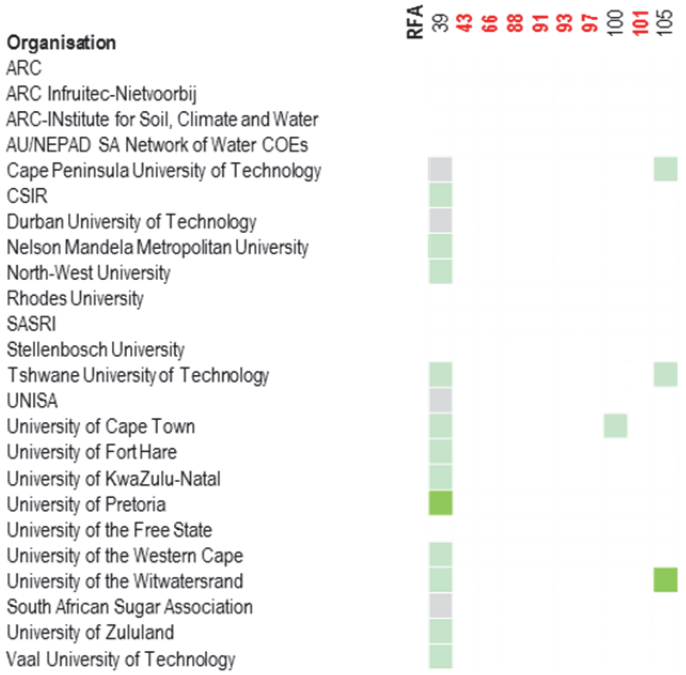
2.8.5.1 Cost



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	0	0	0	0	0	0	0	0	0
Project leaders	0	1	1	1	1	1	1	1	0	0
Principal researchers	0	1	1	1	1	1	1	1	0	0
Senior researchers	0	1	1	1	1	1	1	1	0	0
Researchers	0	3	3	3	3	3	3	3	0	0
Doctoral students	0	3	3	3	3	3	3	3	0	0
Masters students	0	5	5	5	5	5	5	5	0	0

Figure 14: Research Capacity required each year to carry out RDD Programme, for "Cost" in the Cluster, Price, Monitor, Bill

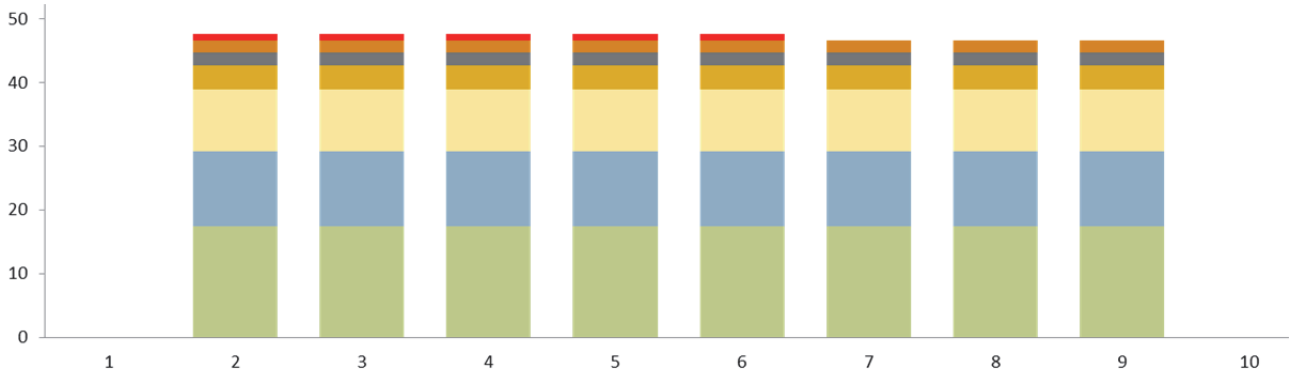
Table 14: Mapping of capacity in underlying science (RFA) required to conduct research into "Cost"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

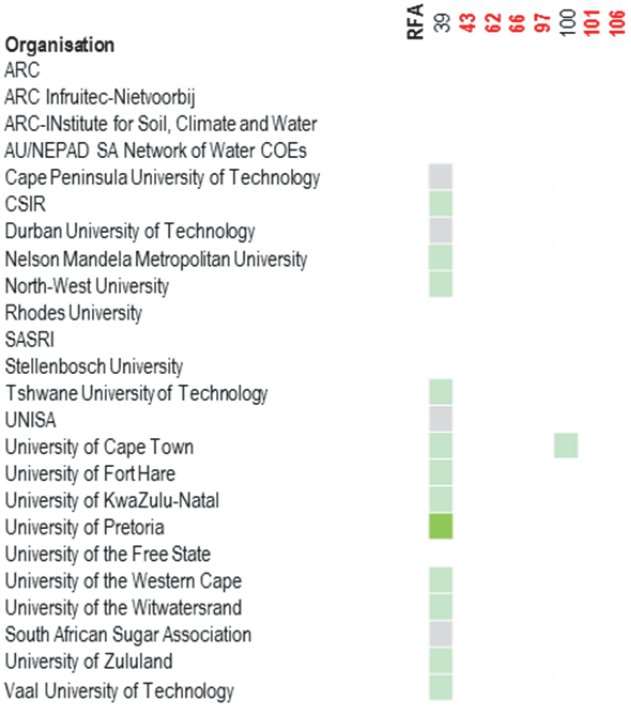
2.8.5.2 Volume



Year	1	2	3	4	5	6	7	8	9	10
Research Chairs	0	1	1	1	1	1	0	0	0	0
Project leaders	0	2	2	2	2	2	2	2	2	0
Principal researchers	0	2	2	2	2	2	2	2	2	0
Senior researchers	0	4	4	4	4	4	4	4	4	0
Researchers	0	10	10	10	10	10	10	10	10	0
Doctoral students	0	12	12	12	12	12	12	12	12	0
Masters students	0	17	17	17	17	17	17	17	17	0

Figure 15: Research Capacity required each year to carry out RDD Programme, for "Volume" in the Cluster, Price, Monitor, Bill

Table 15: Mapping of capacity in underlying science (RFA) required to conduct research into "Volume"



Key: Emerging Building Established Mature

Source: Mutualfruit Readiness to do Research™ 2014 survey, data analysis. n=209 RDD units
Note: RFA = Research Focus Area (please see RFA Taxonomy in Table 21, page 72). An RFA in red indicates no capacity identified at any academic units or research institutions.

CHAPTER 3: RETURNS AND INVESTMENTS

Section 3.1 presents the anticipated returns, in the form of impact and outputs, that results from the successful implementation of the Research, Development, and innovation / deployment programmes that have been designed for the seven Clusters listed in sections 2.2 to 2.8 above.

Section 3.2 presents the associated investment requirements that enable the ten-year programmes. These were quantified for each Cluster based on the respective RDD programmes. A structured, parameter-driven investment modelling approach was used, based on a set of established investment instruments.

3.1 ANTICIPATED RETURNS ON INVESTMENT

There are broadly three areas that the return on the roadmap investment can be considered.

1) Medium to long term savings that are unlocked by making the projected 10 year RDI investment;
2) Socio-economic impacts that investment in and implementation of the roadmap create;
3) Direct and measurable outputs that will be created from the roadmap investment.

At present there is not a clear idea of the over system level savings that can be achieved by making the projected 10 year RDI investment. This area of work will be explored as part of the implementation programme of the water roadmap. It is however, possible to derive some early estimates from specific sub-sectors and case studies within the water sector.

The investment model is systemic and focused on delivering socio-economic impact. These socio-economic impacts were illustrated in Chapter 2 in terms of the anticipated impact of each cluster. The anticipated impacts of implementing the roadmap are beneficial effects on water scarcity, economics, public health, society, and the natural and built environment.

There are also many direct and measurable RDI related outputs that will emerge from the roadmap investment. Figure 16 illustrates an overview of the RDI investment focus and returns. To realise the socio-economic impacts, investments are required to support technology development, knowledge generation, and human capital development.

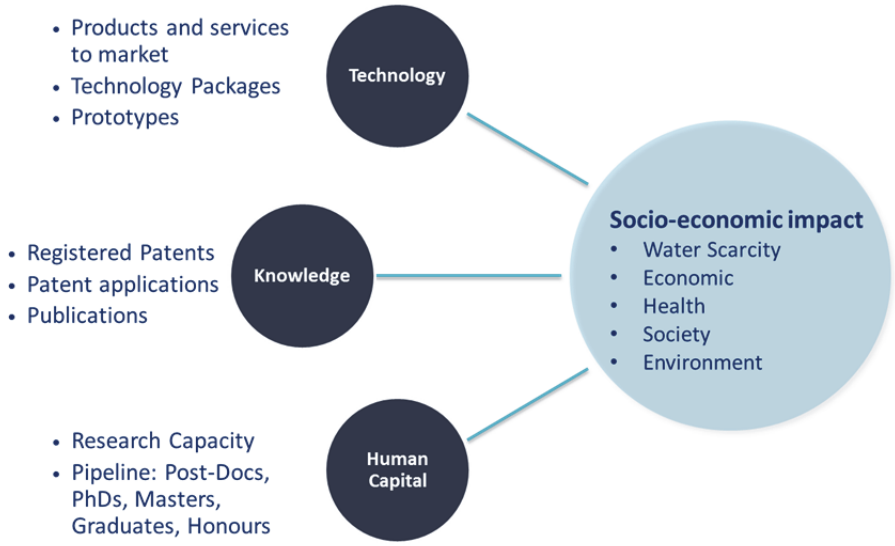


Figure 16: Overview of the investment focus and returns

The return on the investment includes a set of RDI Outputs, as shown in Table 16. These values assume that a) total investment indicated is made and b) RDD Productivity assumptions (please see Table 17) are achieved in practice.

Assumptions in respect of investment in Human Capital Development and Knowledge Generation are derived from prior domain experience in South Africa. Anticipated conversion rates in technology development are consistent with international benchmarks in the translation of science to end-use technology. The investment per patent application refers to the level of investment in R&D activity that typically results in one patent application, and not to the cost of patent application fees and management.

The return on investment in terms of research capacity is considerable. Figure 17 indicates that significant strengthening of research capacity can be expected if the seven Cluster RDD programmes are implemented.

Table 16: Anticipated RDD Outputs, by Objective and Indicator

Objectives	Key Performance Indicator	RDD Outputs*	Explanatory notes
Technology Development	Breakthrough products and services to market	2	Breakthrough technologies
	Technology packages	11	New technols. developed / deployed
	Prototypes	32	Brand new technols. developed
Knowledge Generation	Registered full patents	78	New, full patents
	Provisional patents / applications	224	Provisional patent applications
	Publications	1937	Peer-reviewed
	In addition to current national HCD numbers in water SET, which are (ASSAf, 2010[1]):		
Human Capital Development	Post-doctoral researchers	215	425
	Doctorates	537	1274
	Masters	805	7516

Note that Table 16 and 17 need to be read together in order to understand output assumptions.

Table 17: RDD Productivity Assumptions

Objectives	Assumption	Value	Explanatory notes
Technology Development	Investment per tech development prototype	R10 million	Average, from national experience
	Prototype iterations per technology package	3	Average no. prototype generations
	Success rate for transfer	60%	From research to development
	Success rate for commercialisation	30%	From development to implementation / commercialised product or service
Knowledge Generation	Investment to point of patent appl.	R21 million	Value of R&D activity resulting in patent
	Success rate of registered patents	35%	No. successfully licensed / commercialised
Human Capital Development	Success rate of M and D level candidates	80%	20% drop-out rate (ASSAf, 2010[1])
	No. of years to graduation	2.5 Masters 4 Doctoral	Average time to achieve degree (ASSAf, 2010[1])
	Multiplier to pay for overheads such as office space and equipment	1%	Cost estimate for research group office and communications equipment

[1] ASSAf (2010). *The PhD Study*. Academy of Science of South Africa

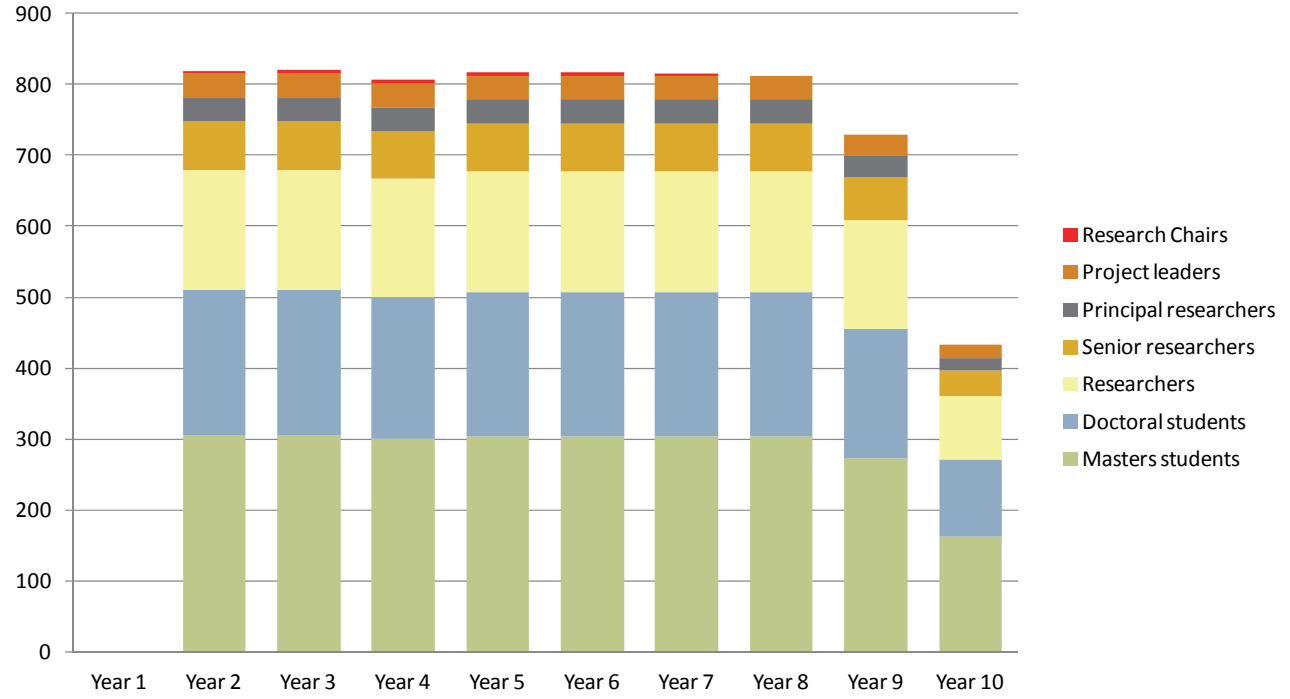


Figure 17: Number of additional people entering water-related SET research via the ten year RDI programme, categorised by research seniority

The root contribution of the Roadmap to sector success comes through allowing better coordination, improved decision-making, and greater enablement, principally through the systematic translation of research into operational practice

Products and services delivered to market is but the end point of a total pipeline of technology development that includes attempts and failures. This is expressed by the conversion ratios in Table 17.

The principal purpose of technology in the water RDI Roadmap is deployment to solve national needs. The return on the total investment over 10 years is expressed clearly on page 11 (South Africa's water and wastewater industry outperforms) – i.e. if we are successful in the execution of our RDD Objectives (listed in full on page 77), we will have enabled the water sector to have achieved its objectives (right-most column)

If the purpose of investment in technology were for the purpose of export, this would have driven a different strategy. Our target market would have been different and our approach to developing a market strategy would have assessed needs and South Africa's ability to satisfy them better, faster (and possibly cheaper) than the competition.

We assessed the Impact and summarised this in Table 18. However, due to the lack of underlying data and associated models – as identified in discussions with a leading resource economist – this project could not provide a more specific and quantified estimation of the overall value, as was the case for the ICT and Waste Roadmaps.

However, it should be noted that some of the impacts may be semi-quantifiable. For example, "the country loses R7 billion a year to water losses[1]". One of the performance measures of the RDI Roadmap is the reduction of water losses from a national average of approx. 35% to 15%; this would indirectly create a saving of approx. R3.5 billion per annum to the nation. Quantifying the benefits of the Water RDI Roadmap is an ongoing initiative.

[1] President Zuma, State of the Nation Address 2015

Table 18: Significant Impact anticipated on five dimensions – Summary

Water Scarcity	
Withdrawal, Consumption, Quality, Productive use	Reduced withdrawal of raw water resources. Reduced consumption of raw and treated water. Improved water quality. Improved productivity of use.
Economic	
Wealth	Impact not yet fully quantified
Productivity	Increased product per drop (WUE: tonnes/ ton of water) including manufacturing and agro-industry, and reduced down-time (e.g. caused by severe maintenance schedules necessitated by poor quality or intermittent water supply).
Revenue	Impact due to beneficial effects increasing average revenues per unit product and per m^3 delivered, and increasing average revenue per producer (e.g. farmer, ecosystem, environment).
Cost Reduction	Impact resulting from decreased water footprint per unit produced, reduced material inputs (and cost), reduced energy inputs (and cost), reduced labour requirement (and cost), and reduced cost of healthcare. Reduced cost of treating process water and potable water due to decrease in contamination of raw resources.
Investment	Impact due to reduced capex requirements and reduced maintenance costs.
Health	
Sickness and Disease	Impact will be made through the reduction of waterborne sickness and disease
Wellness and Mortality	Impact will be result from reduced absenteeism and early retirement – through increased wellness – and a reduced mortality rate
Society	
Food and livestock	Effects will include: increased food security – livestock, crops, and reduced loss of animals.
Education	Increased school attendance (driven by water access and quality) and improved educational outcomes will exert moderate influence on education
Relations and rights	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers). Satisfaction of rights and demands of those without access to water.
Awareness and Behaviour	Raised awareness of the value of water, driving increased willingness to pay
Environment	
Emissions, contaminants, pollution	Reduction in the following: carbon emissions, area of salinised land, groundwater contamination, contamination of surface water, downstream pollution.
Preservation and health	Reduced or reversed decline in biodiversity, preservation of riverine habitats, reduced soil erosion and improved health of terrestrial environment, improved availability and quality of environmental goods and services, reduced environmental debt

3.2 INVESTMENT REQUIREMENTS

The overall investment ambition required to achieve all aspects of the roadmap over a 10 year period is R 8.419 billion. The investment required can be itemised according to source of funding, to Cluster of needs / interventions, and to investment instrument.

The sources of funding contemplated are the Water Levy (via the WRC), the DST and its organisations (such as the NRF and TIA), other government departments (for example focused programmes of the DWS, DEA, and DAFF), and industrial funding (including the private sector and SOEs such as Eskom).

A table itemising the investment requirements breakdown is shown on page 79. This section presents summaries of the same figures, showing investment per Cluster year-on-year (Figure 18) and in total (Figure 19), investment instrument year on year (Figure 20) and in total (Figure 21). Finally Figure 22 and 23 illustrate how catalytic public funding investment unlocks co-funding and industry leverage.

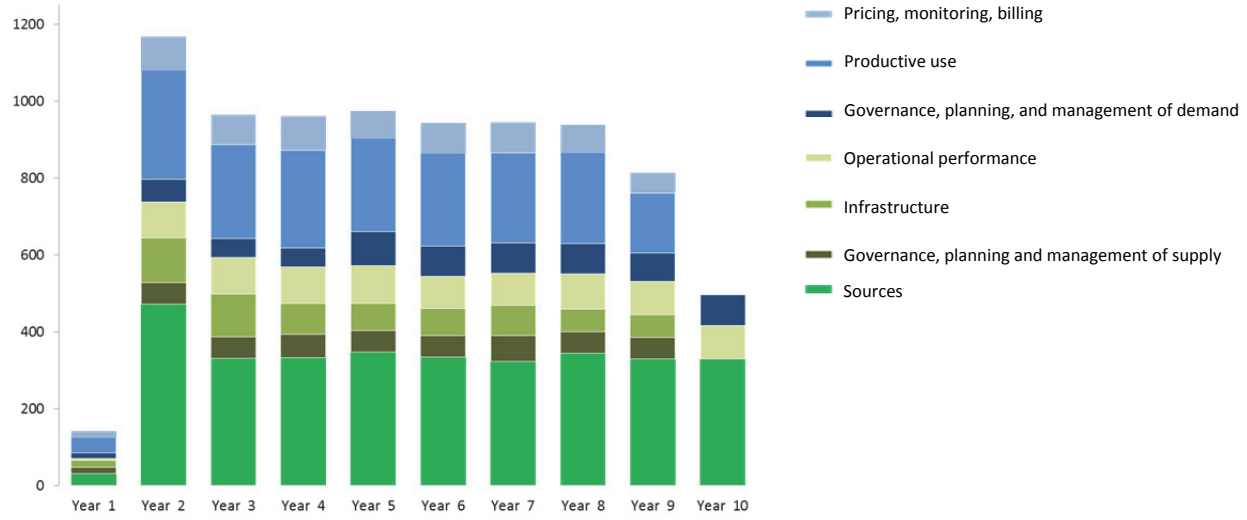


Figure 18: Investment requirement per year, by cluster, in ZARm

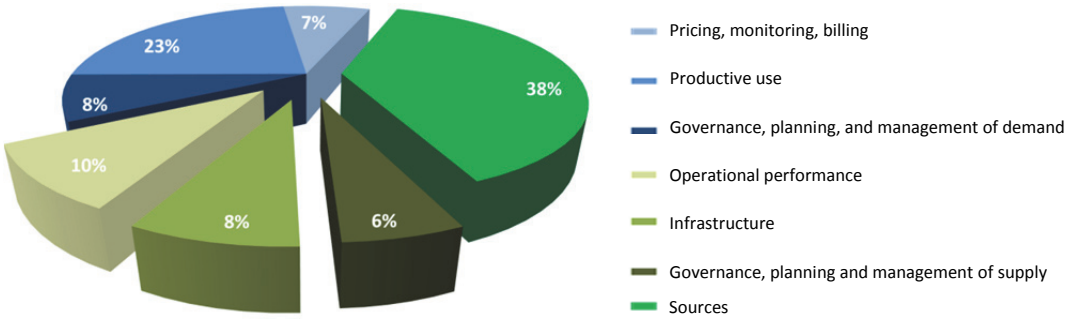


Figure 19: Total investment requirement, proportion of investment per Cluster

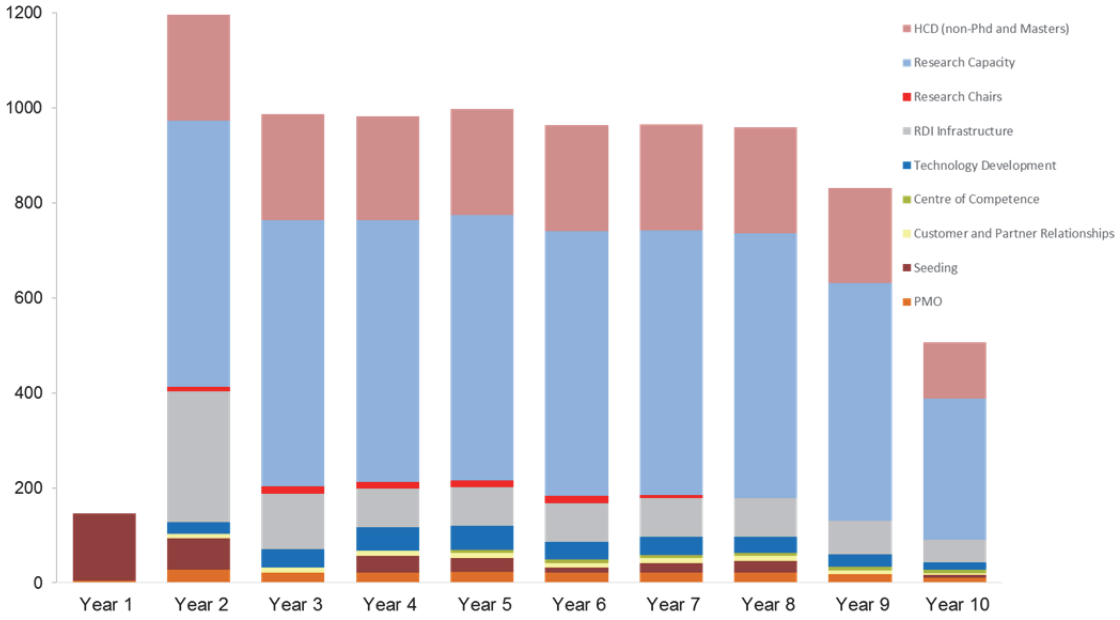


Figure 20: Investment requirement per year, by investment instrument, in ZARm

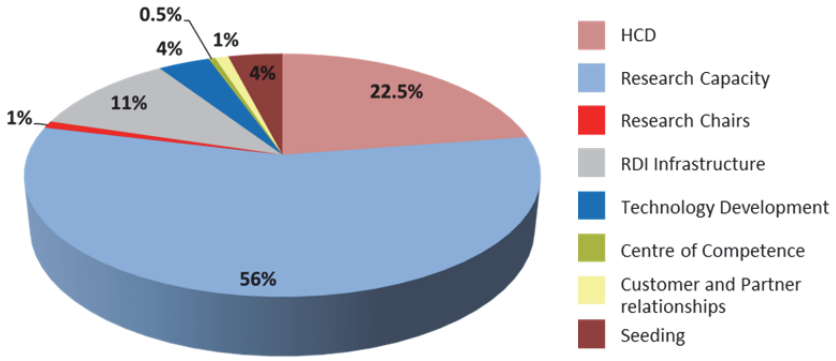


Figure 21: Total investment requirement, proportion of investment per instrument

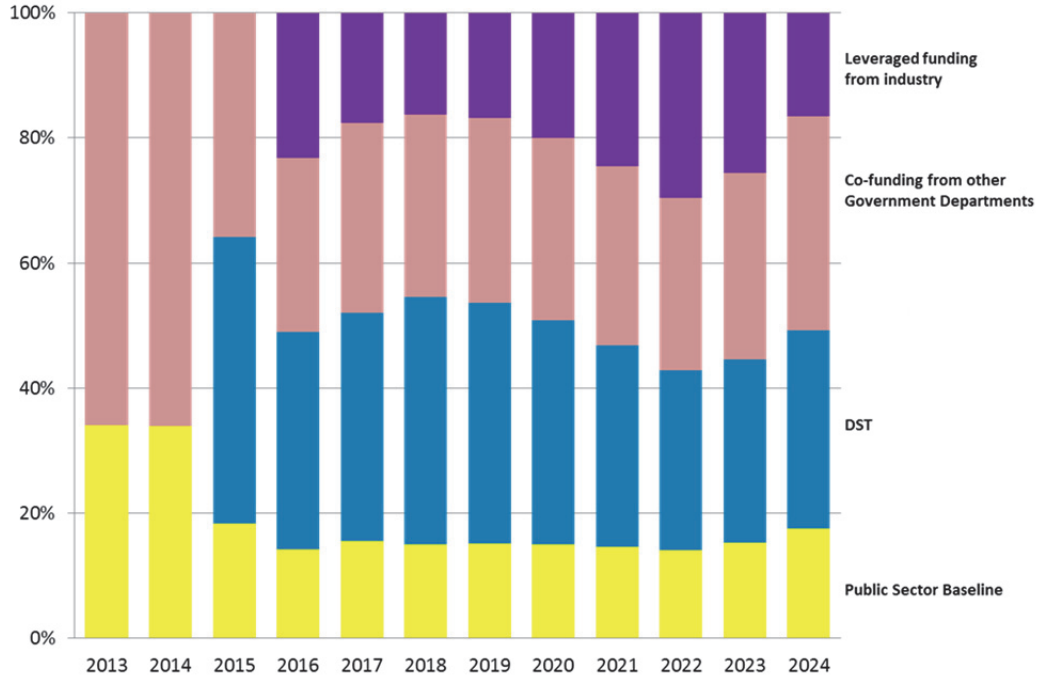


Figure 22: Funding by source as % of investment requirement, by year

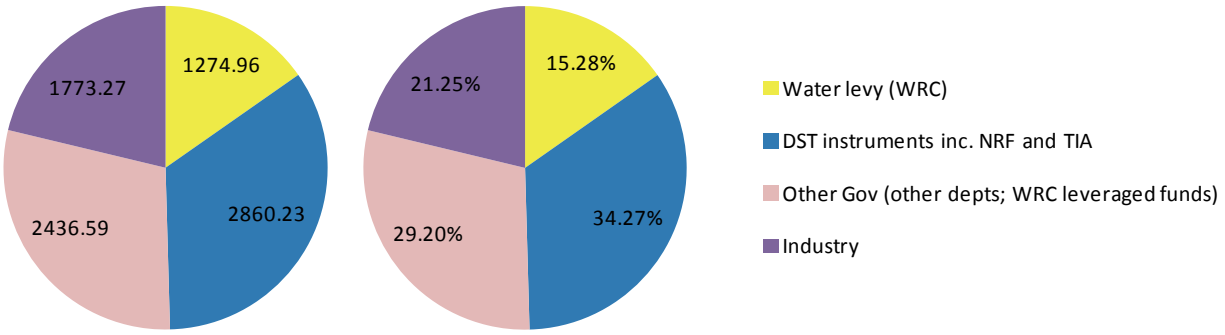


Figure 23: Funding by source in total, over ten years in R million (left) and as proportion of total investment requirement (right)

CHAPTER 4: APPROACH AND PARTICIPATION

Having provided the context and case for action in Chapter 1, and the roadmap itself in Chapter 2, and investments with returns on investments in Chapter 3, this chapter presents the two-stage, customer-driven approach to development of the Roadmap (Figure 24).

Step 1 was an exploration of what customers want provided the basis for a focused approach to developing South Africa's Research, Development, and Deployment (RDD) Response. Step 2 was framing the RDD response, and developing out the roadmap itself. The two steps were broken down into eleven phases of work, which are summarised in chronological order in Figure 24 and will be described in the following sections.

4.1 WHAT DO CUSTOMERS WANT?

4.1.1 Identify customer needs

The 'customers' in this context were members of the water community of professionals, which were divided into four sectors:

- Agriculture
- Industry
- The public sector
- Environmental protection

A comprehensive series of 32 work sessions and workshops took place between June 2013 and January 2015.

To identify customers' needs, the four sectors were initially engaged separately. The premise of the roadmap was explained in summary, and then they were given a blank slate upon which to write simple statements of needs specific to their sector. The four sectors' lists of needs were captured into a first long list of 154 statements (Table A1, Appendix A). The statements of each sector were not shared with the other three sectors until the second round of work sessions, as each sector was required to provide their own, sector-specific list of needs rather than to choose needs from a menu of previous inputs.

4.1.2 Review needs, and articulate interventions

The second series of sector work sessions used the list of 154 needs as a departure point. The participants were provided with the list, and asked to review it for clarity and mutual understanding. They were then asked to describe what interventions they deemed would enable each need to be met.

The participants were asked to provide the **nature** of the intervention required to satisfy the need, without prescribing a solution. The interventions were drawn up by breakaway groups within each sector work session, and then exchanged in plenary. A satisfying level of convergence emerged during these sessions. The interventions are listed in full in Table A1 (Appendix A).

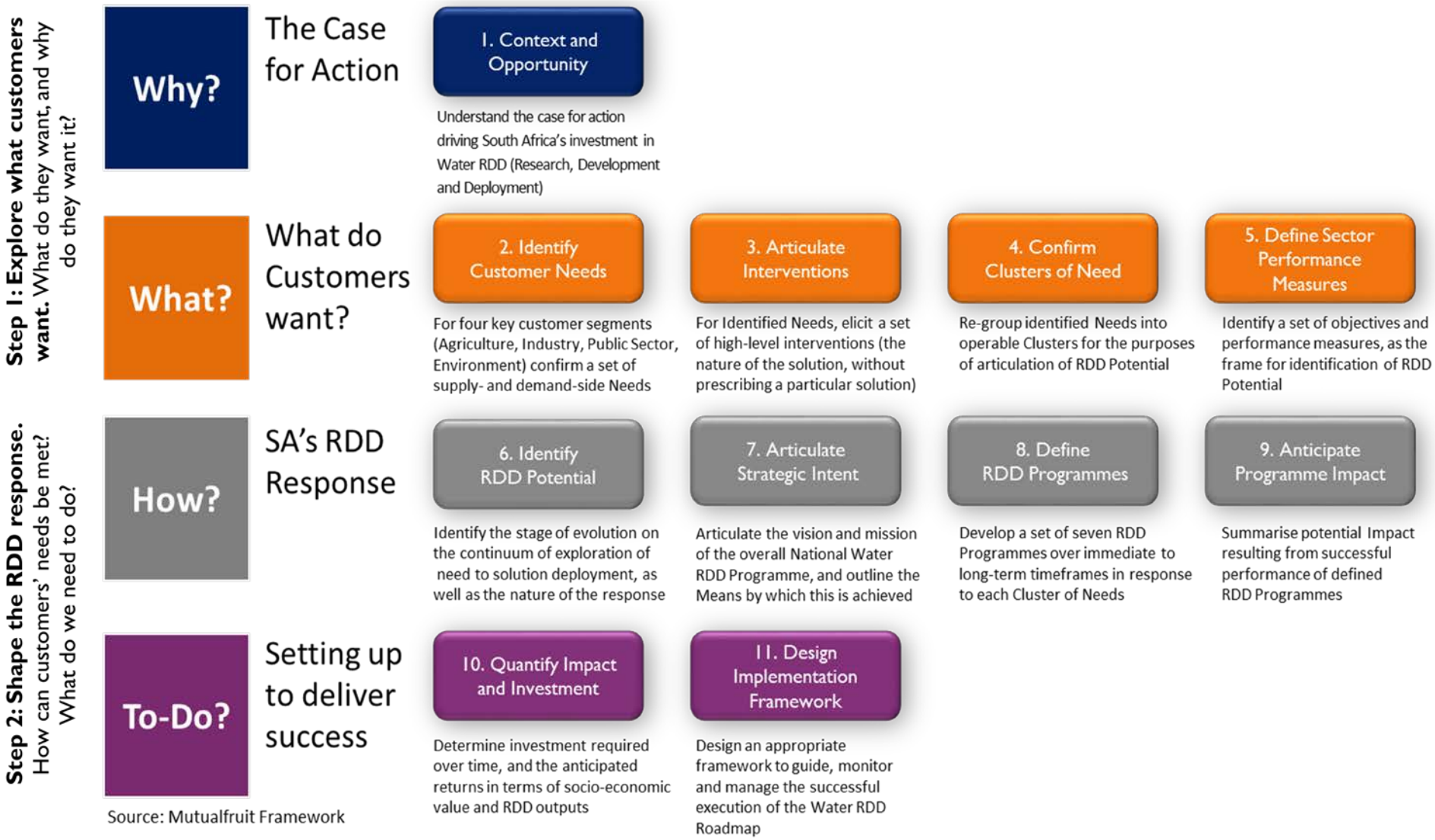


Figure 24: Flow chart of the approach and methodology of the road mapping process

4.1.3 Confirm clusters of needs and interventions

Several of the needs stated were either the same, but phrased differently, or were so similar that they could be combined into a single rewritten definition of a need. The individual statements of need and their associated interventions (Table A1) were therefore collated by the project team into a shorter list of 41 (Table A2, Appendix A), which simply removed duplicate needs and recorded which needs had been expressed by which sector. The frequency with which each need was expressed was later used as an input into the assessment of impact (boxes 9 and 10 in Figure 24 above).

The list of needs shown in Table A2 was used as the basis for a second round of sector-specific work sessions in which the same participants were asked back to review the list, both for clarity and insurance of common understanding, and to ensure that the nuanced meaning they had intended to convey had not been lost during the collation process. The participants were then asked to group the individual needs into clusters of needs which could be readily related to one another. These clusters form the basis of the programme of work of the roadmap.

The resulting clusters of needs that emerged were:

Water supply

1. Increase ability to make use of more **sources** of water, including alternatives
2. Improve **governance, planning and management of supply** and delivery
3. Improve adequacy and performance of supply **infrastructure**
4. Run water as a financially sustainable "**business**" by improving **operational performance**

Water demand

5. Improve **governance, planning, and management of demand** and use
6. Reduce losses and increase efficiency of **productive use**
7. Improve performance of **pricing**, **monitoring**, **billing**, metering and collection

The clustering exercise enabled the project team to collate the interventions according to the newly defined clusters. Table 19 shows which needs were identified by which sectors, and what the summarised interventions were.

Table 19: Clustered needs identified by the four sectors, and their summarised interventions

Table 17		Agriculture	Industry	Public Sector	Environment
Increase ability to make use of more sources of water, including alternatives					
1	Increase the ability to identify and make use of alternative supplies	Identify suitable sites; improve yields – e.g. from enhanced rainfall, fog harvesting for strategic uses		Identify suitable sites; improve yields – e.g. from enhanced rainfall, fog harvesting for strategic uses	
2	Increase use of treated effluent	Implement efficient treatment management system. Address public perception issue. Catalyse linkages between those that discharge between producers and users – e.g. mines and farms	Improve regulatory frameworks; improve the quality of decision-making information.	Improve regulatory frameworks; improve the quality of decision-making information. Implement efficient treatment management system. Address public perception issue.	Investigate treated effluent to artificial recharge of ground water as potential conjunctive source. Increase ability to optimise mix for context
3	Decrease levels of salinity	Increase soil integrity – Regularise soil sampling at site level, introduce more efficient irrigation system suited to individual farms and particular regions; create detailed soil maps; models: co-operatives and delivery of extension services			

Table 17		Agriculture	Industry	Public Sector	Environment
4	Increase levels of desalination	Increase performance of purification technologies and processes	Increase levels of reclamation. Improve performance of purification technologies and processes – reduce energy requirement and materials costs	Increase levels of reclamation. Improve performance of purification technologies and processes – reduce energy requirement and materials costs	Improve performance of desalination technologies and processes – reduce energy requirement and materials costs
5	Increase rainwater harvesting	Increase and sustain levels of water harvesting and efficiency of conservation methods. Conduct scientific-economic evaluation of alternative approaches (Jonathon Denison)	Incentivise adoption. Separate rain water and polluted water	N/A	Improve good land use practices
6	Increase use of wastewater	1 and 5 linked: fitness for use	Integrate better with agriculture and energy production	Improve regulatory frameworks; improve the quality of decision-making information. Implement efficient treatment management system. Address public perception issue.	Improve performance and cost of purification.
7	Increase levels of groundwater use	Make better use of local water resources	Identify groundwater sources, yields and uses. Make better use of local water resources	Identify groundwater sources, yields and uses. Make better use of local water resources	Identify, map, declare and adopt Priority Water Areas. Design and introduce regulation and management mechanisms
8	Increase stormwater harvesting and management	Investigate potential of infield rainwater harvesting. Identify legislation gap on stormwater management and use _ recharge, aquifers	Incentivise broader adoption and uptake	Improve regulatory frameworks; improve the quality of decision-making information. Objective? Decrease runoff into foul sewers and increase use of rainwater in urban setting.	Improve regulatory frameworks; improve the quality of decision-making information. Objective? Decrease runoff and increase percolation. Develop and implement national design philosophy for storm water management – provide ToR (SUDS) (larger metros) Neil Armitage UCT.
9	Increase capture of floodwaters	infrastructure		N/A	Improve land use practices and flood control measures
Improve governance, planning and management of supply and delivery					
10	Enable optimised reallocation and distribution	Enable optimised reallocation and distribution	Enable transfers between end uses: client-client, community	Enable easier transfers between end uses: client-client, community	
13	Improve effectiveness of Institutional landscape in respect of governance, planning and supply management (actors, management, institutions)	Improve effectiveness of Institutional landscape in respect of governance, planning and supply management (actors, management, institutions)	Training and capacity development. Staff turn-over (capacity) sustainable knowledge-transfer. Revised understanding of the policy positions irt Water Act. Enforcement and compliance – institutions missing, not capacitated to perform/ mandate	Training and capacity development. Staff turn-over (capacity) sustainable knowledge-transfer. Revised understanding of the policy positions irt Water Act. Enforcement and compliance – institutions missing, not capacitated to perform/ mandate	Refine accountability along the value chain

Table 17		Agriculture	Industry	Public Sector	Environment
14	Improve the ability to manage water flows. Align allocation and mix to requirements	Improve the ability to manage water flows. Align allocation and mix to requirements	Explore macro-economic models	Explore macro-economic models	Integrated planning – water reconciliation plans, revised allocations system, incentivise WCDM and wastewater reuse. Linked to no. 10.
15	Improve quality and resilience of planning for the future – ability to respond to volatility	Improve quality and resilience of planning for the future – ability to respond to volatility			Integrated planning – water reconciliation plans? Are they based on lowest cost or strategic consideration Social systems and demand – Development of rural areas
16	Optimise the ability to manage water resources from source to source in an integrated way	Optimise the ability to manage water resources from source to source in an integrated way			Refine accountability along the value chain. Implement current legislation – WRN NWA NWRS
Improve adequacy and performance of supply infrastructure					
11	Increase adaptability of storage capacity	Enhance artificial recharge – aquifers, rainwater tanks, existing capacity – small dams	Increase suitability, availability, capacity, flexibility – add tanks, man-made dams, underground or alternative storage (e.g. in mining void)		Improve control of alien invasive plants and wetland rehabilitation. Recognise volatility – Uprate competence and introduce adaptive practices to increase flexibility to plan and respond to the water effects of climate change
12	Increase protection and reliability of ecological infrastructure				Improve land use practices and conserve natural ecological infrastructure
23	Improve performance, optimise investment in infrastructure			Improve visibility and management of asset base. Develop and implement plans to optimise investment in supply infrastructure – to increase flexibility and responsiveness. Role of Technology?	
Run water as a financially sustainable "business" by improving operational performance					
18	Improve the financial sustainability of the water system			Ring fence – "Run water as a business in municipality"	
19	Improve the equity of pricing			Revise policy around requirement to pay. Increase the range of tariffs	
20	Increase the accuracy of attribution of water use			Increase customer confidence in Billing system – able to pay but don't trust it	
21	Increase proportion of water that is paid for			Reduce undesirable or unproductive political involvement in enforcement	

Table 17		Agriculture	Industry	Public Sector	Environment
22	Improve performance of revenue collection			Improve metering, billing systems, attitudes, prepaid meters. Improve the monitoring throughout the system — inflow. At system level, improve the ability to monitor flow, use and quality (water balance)	
24	Improve operational efficiencies			Ring fence — "Run water as a business in municipality"	
Improve governance, planning, and management of demand and use					
36	Increase transparency over rights, quotas, allocation and transfers	Explore SA potential for trading and transfer of water entitlement	Improve Regulation and Decision making processes for water use authorisation	Improve Regulation and Decision making processes for water use authorisation. Standardise policy application across regions.	Publish and maintain the Ecological Reserve
37	Improve co-operative governance with respect to planning and management. Cross-sectoral.	Reduce impediments to implementation — issues of mandates, responsibility and accountability around decision-making. Institutional, organisational, actors. Programmes (e.g. for emerging farmers), capacity	Increase institutional efficiencies, including via technology support	Resolve conflicts of mandate / jurisdiction between local, provincial and national government.	Increase institutional efficiencies and create functional Catchment Management agencies
38	Improve quality and effectiveness of context-specific planning and implementation	Enable water ordering, improve management of distribution	Systematically increase water independence: map footprint, develop reduction strategy	Provide alignment with NWRS2 in terms of policy instruments and regulations governing licence applications granted or denied.	
Reduce losses and increase efficiency of productive use					
25	Reduce water transport losses	Refurbish irrigation networks, incentivise improved management of losses	Minimise water tank overflows and bulk supply losses; protect transmission systems against corrosion	Maintenance? Prioritise funds, improve allocation of funds for operations.	Reduce consumption by alien invasive species
26	Reduce leakages	Improve ability to detect leakages; uprate repair performance	Implement preventive maintenance plans; Introduce monitoring and early warning systems	Encourage and support customers in detection of leakages and performance of repairs	
27	Optimise conjunctive use of water	Balance use of all sources in an integrated manner	Balance use of all sources in an integrated manner. Minimise demand on supplier (e.g. municipality)	Increase the degree of alignment of the quality of water with use	
28	Reduce volume of water use	Use water-saving crops and varieties	Minimise water use, application and losses in primary processes: avoid use of water (e.g. optimised or new no-water processes), recover and recycle condensate, reduce steam leakage, manage water pressure	Stimulate growth more economically (use of water). Highlight the importance of water and its scarcity to encourage consumers to reduce demand. Improve dry solution systems and encourage acceptance	

Table 17		Agriculture	Industry	Public Sector	Environment
29	Increase the area under irrigation	Use savings in current water use. Change NDP word "irrigation" to "agricultural water use" (in line with the rest of the world)			
30	Improve efficiency of water use	Encourage uptake of land and water use practices Introduce irrigation systems and improve performance: Optimise irrigation: Plan, meter, schedule; Monitor soil moisture; Reduce evapo-transpiration; Optimise fertiliser use. Increase effectiveness of knowledge transfer. Increase levels of rehabilitation	Reduce water in ancillary processes, reduce demand for domestic water		
31	Increase levels of water reuse	Reduce volume of wastewater, recover and recycle	Reduce volume of wastewater, increase levels of recovery and recycling;		
32	Minimise output to unrecoverable sources	Reduce wastewater released to sewers	Reduce volume of wastewater released to sewers. Recycle water streams for water and wastewater treatment		
33	Minimise volume and toxicity of pollution	Reduce rainwater runoff	Minimise production of waste (e.g. cleaner production methods)	Increase number of WWTW with Green Drop certification to >95%. Link to no. 35	Maximise natural water resource function (aquatic response)
34	Optimise balance between the right to water and productive use of this water	Reduce downstream pollution (point-sources and diffuse sources)			Investigate and develop economic modelling on the use and value of environmental goods and services. Inform greater clarity at a macro level in order to inform decision-making and policy evidencing
35	Minimise discharge of poor quality water		Minimise production of effluent (e.g. cleaner production methods)	Increase number of WWTW with Green Drop certification to >95%	
Improve performance of pricing, monitoring, billing, metering, and collection					
39	Improve equity of pricing, encourage desirable practice	Introduce tariffs and incentives ("real cost" of water); enforce quotas	Introduce tariffs and incentives ("real cost" of water). Increase cost of discharge to sewer	Improve pricing structures based on full cost pricing to reflect the "real cost" of water, including equitable charging.	
40	Improve accuracy: use monitoring, billing and management	Increase coverage, accuracy of flow monitoring, attribution; introduce management systems	Increase coverage and accuracy of monitoring, metering, attribution and billing. Target reductions	Improve coverage and accuracy and hence confidence in metering — similar to electricity metering	Increase coverage and accuracy of monitoring
41	Reduce levels of unmetered use	Detect and remove unmetered supplies; ensure meters are operating	Detect and remove unmetered supplies; ensure meters are operating; improve management of collection	Define, implement and support policy on billing control	

4.1.4 Define Sector Performance Measures

The satisfaction of the customers' needs has value, which can be expressed in relation to measures of performance (speed, reliance, cost). In order to be motivated to adopt a new or improved solution in the pursuit of the satisfaction of their needs, customers have an expectation (a minimum requirement for an improvement in performance) that a solution must deliver. These expectations should be specifically quantifiable in terms of a target (e.g. cost less than R100 per m^3), a percentage (e.g. faster by 20%). These expectations were elicited from the sectors through a series of sessions in which the expectations were sought and then reviewed. An example is shown in Table 18, and the full list of performance measures is shown in Table A4, Appendix A.

To the extent that RDD can make a contribution to developing and delivering a solution a) these expectations were used to later set the objectives for the RDD activity, and the value that the customer attached to adopting the solution underpins the case for investing in RDD.

A joint scoring workshop was held to assess the attractiveness of the seven agreed clusters of RDD opportunities which had been listed as responses to the needs and their interventions. The participants, from all four sectors of the water community, evaluated the opportunities and interventions in a structured and consistent manner using the dimensions of Customer Need, Market Opportunity, and the potential Value and Impact that attaches to successful realisation. Four follow-up sessions were held to cross-check the validity and level of ambition of the performance measures on which the sectors settled.

Table 20: Example Performance Measures created by the water community

Need		Performance Measures	Minimum change required
10	Enable optimised reallocation and distribution	DWA water allocations remapped	A new map completed by 2016
36	Increase transparency over rights, quotas, allocation and transfers	Consumers within catchments know everyone's water allocation	Nine functional Catchment Management Agencies

The Sector Objectives and Performance Measures (determined as described in Section 4.1.3 and 4.1.4) can be summarised as (Table 21):

Table 21: Sector Objectives and Performance Measures

Sector Objective	Increase ability to make use of more sources of water, including alternatives	Improve governance, planning and management of supply and delivery	Improve adequacy and performance of supply infrastructure	Run water as a financially sustainable "business" by improving operational performance	Improve governance, planning, and management of demand and use	Reduce losses and increase efficiency of productive use	Improve performance of pricing, monitoring, billing, metering and collection
Sector Performance Measure	▸ 75% of treated wastewater reused ▸ Coastal communities obtain 5% of the water supply from seawater; inland 5-10% of water is abstracted from groundwater and recharge, and 20% water supply from treated wastewater. ▸ All metropolitan areas have rainwater and stormwater drainage and storage	▸ A new DWS allocations map completed by 2016 ▸ Nine functional Catchment Management Agencies ▸ The new reconciliation strategy and allocations map include groundwater, seawater, and wastewater	▸ Storage facilities similar to Rand Water's Fountains Treatment Works exist in all metropolitan areas. ▸ New rainfall maps have led to a new limit for the ecological reserve, which is protected by regulation ▸ Adequate ICT infrastructure exists for automation and M&E	▸ Non-revenue water is below 15% ▸ All domestic and industrial users are on metered supplies ▸ All leaks are detected in under 12 hours and repaired in under 48	▸ Nine functional Catchment Management Agencies ▸ Storage facilities similar to Johannesburg Water's Northern Treatment Works exist in all metropolitan areas ▸ >95% functional municipalities (capable of carrying out their functions and responsibilities)	▸ Non-revenue water is below 15% ▸ All leaks are detected in under 12 hours and repaired fin under 48 ▸ PICWAT and SAPWAT, or equivalents, are in use on all commercial farms and 30% of family farms ▸ 75% of treated domestic and industrial wastewater reused ▸ 90% of wastewater treatment works attain Green Drop status ▸ >75% of sludge from sanitation put to beneficial use	▸ Free basic water remains free; reasonable use is reasonably priced; wasted water is prohibitively expensive ▸ All domestic and industrial users are on metered supplies ▸ Non-revenue water is below 15% ▸ All industries are benchmarked with fair and honest targets set

These Sector Objectives and Performance Measures were then used to help frame the RDI Success Factors, RDD Potential and RDD Opportunity.

The Success Factors (required in enabling achievement of the RDD Objectives) were defined as:

RDI Success Factors*	Target Objective by 2025
1. Faster and more comprehensive deployment of context-appropriate performance improvements ▸ the capability to design, develop, evaluate and localise local and inbound technologies, process improvements and models	▸ Established and well-regarded Water Technology Demonstration Centre ▸ Technical assessments of local and inbound technologies from abroad ▸ Convincing demonstrations of South African inventions in the water and wastewater technology space
2. Stronger RDI capability and capacity	▸ Strong pipeline of demand-driven SET skills relating to water care, economics, business, policy and law; modelling, analysis and design; disciplines of engineering; information technology; design, modelling and optimisation of logistics networks and systems; disciplines of the natural sciences; and sociology, political science and psychology; organisational behaviour; environmental and public health
3. Focussed export of SA know-how and technology ▸ in the form of operational services, technologies, intellectual property, research knowledge and advisory services to targeted markets worldwide	▸ Catalysation unit focused on the guidance, coordination and support of initiatives to commercialise (market, sell and deliver) South Africa's know-how, technology and services

4.2 SOUTH AFRICA'S RDD RESPONSE

4.2.1 Articulate and assess RDD Potential

Step 2 of the road mapping process was to shape South Africa's RDD response, by asking and answering two questions: How could the customers' need be met? What do we need to do?

The clustered needs and interventions were then given back to the work groups in a further set of work sessions, and to the WRC's research managers in a separate session. The participants were asked to provide their assessments of whether undertaking each intervention presented an opportunity in terms of research, development, and deployment (RDD).

When RDD opportunities were identified, the participants were then asked to decide at what stage in the innovation chain the opportunity presented itself, from Explore to Deploy:

- **Explore** – exploration is the earliest stage in the innovation chain and represents quantification of a possibility.
- **Test** – testing is fundamental or early applied research, and includes proof of concept and feasibility studies.
- **Demonstrate** – demonstration is late stage research, in which a proven concept (such as a prototype) is piloted, trialled, or otherwise demonstrated in a context approximating the situation or conditions under which the technology is intended to be utilised.
- **Deploy** – deployment is roll-out, or more widespread introduction and implementation of a new technology, technique, or piece of know-how so that it becomes mainstream / accepted, rather than being perceived as novel.

In addition, the participants were required to decide what the nature of the RDD potential was:

- **Management** – the potential to satisfy a particular need through better management of existing technology and/or know-how.
- **Information** – the potential to satisfy a particular need through providing higher quality and/or more commonly available information about existing technology and/or know-how.
- **Technology** – the potential to satisfy a particular need through the creation of a new technological item or process.
- **Capacity** – the potential to satisfy a particular need through increasing the number of people in the water community who possess the skills required to implement and operate appropriate technology and/or know-how.

The results of this round of sessions (provided in Table A3, in Appendix A) were synthesised to quantify the RDD potential in terms of both stage (**E**xplore, **T**est, **Dem**onstrate, **Dep**loy) and nature (Management, Information, Technology, Capacity). Figure 25 (page 70) shows that the method of applying each opportunity to each need, within each cluster allowed the team to identify where in the innovation chain the opportunities presented themselves and what the nature of the opportunity was.

Figure 25 requires some scrutiny in order to make the most of the information presented. At this point it is useful to recap the process so far using an example, as shown on page 76.

The RDD Potential was identified per cluster of needs using a structured drill down into each individual need and intervention. The evaluation framework (Figure 26) enabled us to understand the fit – the likelihood with which South Africa can respond to customer needs through successful delivery of identified RDD potential.

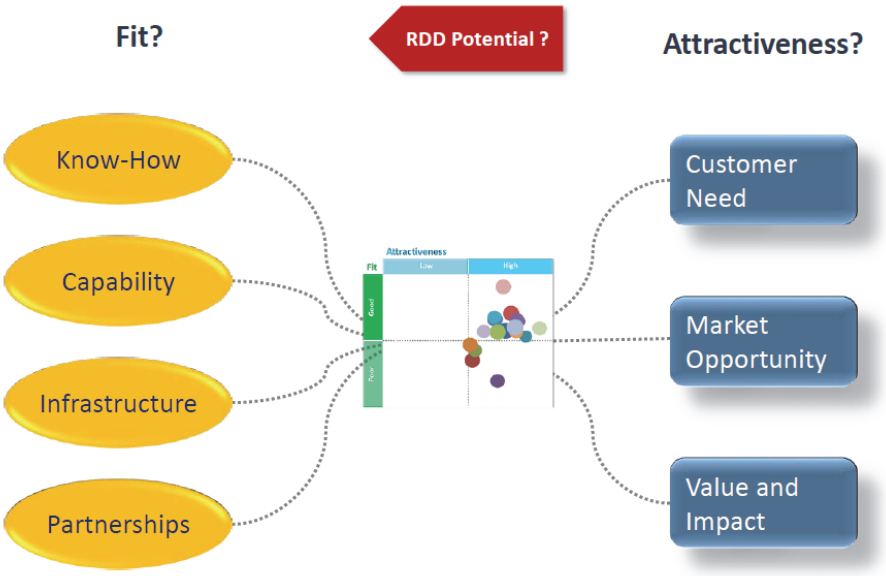


Figure 26: Evaluation Framework for RDD Potential

The attractiveness and fit of the interventions per cluster and per sector were determined and are shown in Appendix B.

Figure 25: RDD Potential by Nature and Stage in the innovation chain, expressed in % of needs per cluster, all sectors

Stage (**E**xplore, **T**est, **Dem**onstrate, **Dep**loy) and Nature (Management, Information, Technology, Capacity) are explained at the top of page 11.

Example: What do customers want?

Let us use the water supply cluster of Source (Increase ability to make use of more sources of water, including alternatives) as our example.

Table A1 (page 81) shows us the raw inputs – the long list of needs and matching interventions as provided in the initial sector work sessions, such as in this excerpt:

	Needs Agriculture	Interventions Agriculture
S	Increase diversity and optimisation of mix	
1	Increase use of treated effluent	Implement efficient treatment management system. Address public perception issue. Catalyse linkages between those that discharge between producers and users – e.g. mines and farms
... 11		

Table A2 (page 87) then shows the creation of a cluster of nine needs which could be categorised as being related to sources of water, and it tells us which sectors identified which need:

		Agriculture	Industry	Public Sector	Environment
SUPPLY: Increase ability to make use of more sources of water, including alternatives					
1	Increase the ability to identify and make use of alternative supplies			•	
to					
9	Increase capture of floodwaters	•			•

Finally, Table A3 (page 88) provides us with the identified opportunities for a research, development, or deployment response, for example:

		Management	Information	Technology	Capacity
S	Increase ability to make use of more sources of water, including alternatives				
1	Increase the ability to identify and make use of alternative supplies	E T **DM** DP	**DM** DP	E T **DM** DP	**DM** DP
to					
9	Increase capture of floodwaters				

Legend for **stage**: E = **E**xploration; T = **T**esting; DM = **DeM**onstration; DP = **DeP**loyment

These tables together allow us to see that wherever there are opportunities to undertake research, demonstration, or deployment to implement any of the interventions that were identified as being able to satisfy the need, those opportunities always include a demonstration of Technology. Therefore the summary of RDD opportunities shown in Figure 25 (page 70) lists the Demonstration stage as representing an opportunity 100% of the time, for all four natures of opportunity:

4.2.2 Research capability mapping

Concurrently, the project team ran two questionnaires in order to map the existing capacity and capability of South African researchers. Individual and institutional questionnaires were designed and respondents asked to identify their relevant areas of expertise. The areas of expertise were defined both by the underlying academic discipline (e.g. microbiology) and the research focus area (RFA), or area of interest (e.g. potable water quality). The full list of RFAs is shown in Appendix C. The 106 unique RFAs (Table 22) were mapped onto the clusters by the WRC research managers (Appendix C). Questionnaire respondents who felt that their particular discipline or RFA was not already represented were able to select 'Other' and add their self-defined discipline or RFA.

Table 22: Taxonomy of Research Focus Areas (RFAs)

RFA no.	RFA name
1	Agroforestry
2	Business efficiency
3	Crop production *Genetics and Plant Breeding*
4	Efficient agriculture
5	Food security and business efficiency
6	Horticulture
7	Improved food production
8	Irrigation and Drainage
9	Soil chemistry
10	Soil fertility
11	Soil management
12	Soil microbiology and biochemistry
13	Soil morphology and genesis
14	Soil physics
15	Animal, human, public, and environmental health *Endocrinology*
16	Ecosystem functioning
17	Wastewater treatment *Microbiology and Chemistry*
18	Animal, human, public, and environmental health Fate and behaviour of pollutants
19	Human health
20	Process automation and control – potable and waste water treatment
21	Wastewater treatment *Bioinformatics*
22	Environmental water quality
23	Environmental health and ecosystem functioning *Remote sensing*
24	Food security and business efficiency
25	Econometrics
26	Macroeconomics
27	Microeconomics
28	Applied economics
29	Computational economics
30	Economic modelling
31	Decision sciences
32	Entrepreneurship and Management
33	Technoeconomics
34	Insurance *Mathematics and Economics*
35	Forecasting and Game Theory
36	Behavioural finance
37	Business and Economic Statistics
38	Civil engineering aspects of water cycle
39	Wastewater and Potable water treatment *Domestic*
40	Treatment and distribution
41	Stormwater management
42	Water /wastewater and industrial Process optimisation
43	Wastewater and potable treatment *Industrial*
44	Mine water desalination

RFA no.	RFA name
45	Mine water membrane treatment
46	Mine water passive treatment
47	Industrial wastewater treatment (urban) water management / engineering
48	Crop production *Applied Engineering in agriculture*
49	Flood defence
50	Hydrology and hydrogeology
51	Hydrodynamics
52	Hydrologic engineering
53	Hydromechanics
54	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health *Marine Science*
56	Agriculture *Ecosystems and Environment*
57	Aquatic ecosystems
58	Ecology Evolution and Systematics
59	Biodiversity and Conservation
60	Systems ecology
61	Ecological informatics and modelling
62	Corporate social responsibility and environmental management
63	Bioremediation
64	Rehabilitation of contaminated land and water
65	Environmental protection & pollution control
66	Environmental health and ecosystem functioning *Water Resources*
67	Weather and Forecasting
68	Agricultural meteorology
70	Climate dynamics, resilience, adaptation
71	Environmental health and ecosystem functioning *Geology*
72	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health *Earth Science Informatics*
73	Subsurface hydrology
74	Contaminant hydrology
75	Unsaturated zone
77	Land surface hydrology
78	Catchment hydrology
79	Hydro-meteorology
80	Ecohydrology
81	Animal, human, public, and environmental health *Virology, Bacteriology, Mycology*
82	Animal, human, public, and environmental health *Toxicity of engineered materials*
83	Wastewater and potable treatment, ecosystem functioning, environmental water quality, animal, human, public, and environmental health
84	Animal, human, public, and environmental health *pathogens and parasites*
85	Public health
86	Water treatment *Biological processes*
87	Wastewater treatment *Biological Processes*
88	Wastewater and potable treatment *Advanced Biological Processes*
89	Wastewater and potable treatment *Chemical and Materials Safety*
90	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health *Applied Entomology*
91	Improved food security
93	Education
94	Development studies
95	Gender studies
96	History
97	Law
98	Library and information science
99	Bioethics
100	Public policy

RFA no.	RFA name
101	Public administration
102	International relations
103	Security studies
104	Human, public, and environmental health *Health Planning*
105	Sociology
106	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health *Land use*

The resulting capability maps show us in which RFAs South Africa already has expertise, and where that expertise can be found. The complete maps found on pages 8, 10, 12, 18, 19, 25, 27, 32, 37, 38, 39, 45, 47, 52 and 53, and as an example, Figure 27 shows the relevant RFAs for the water supply cluster, *Run water as a financially sustainable "business" by improving operational performance* across the top of the map, using the numbers in Table 22 above. Each organisation with an individual or an organisational capacity identified through questionnaire response is listed on the left hand side, and the shaded blocks indicate in which RFA their expertise lies, and the level of expertise. Four levels of capacity were used: *Emerging*, *Building*, *Established*, and *Mature*, based on composite score on a scale of 0-10 based on number of people, budget, publications and products and technical services.

The maps enable the prioritization of attention in terms of funding and capacity building over the next ten years. An RFA in red indicates no capacity identified at academic units or in research institutions. For example, Figure 27 shows that expertise in RFA 3, which Table 22 tells us is *Crop production genetics and plant breeding*, was identified as being required in order to frame and carry out the desired RDD response in terms of implementing the interventions that were identified in order to meet the needs which fell into the Cluster, yet we were unable to elicit a response from any South African research group who described themselves as having capacity in this research field.

The questionnaire responses were used to perform analyses of Fit, using a Readiness to do Research™ framework (Figure 28). The framework analyses the depth and diffusion of research knowledge (i.e. how well a RFA is understood, and whether the know-how resides in research only, in pockets of implementation, or is widespread practice).

The questionnaires were sent to all project leaders and collaborators named on proposals submitted to the WRC over the past five years, and were also circulated to all member of the Water Institute of Southern Africa (WISA) via the WISA's member mailshot system.

An additional analysis of water-related intellectual property held by the WRC and NIPMO was also carried out.

Figure 27: Mapping of capacity in underlying science (RFA) required to conduct research for the Cluster: Operational Performance. An RFA in red indicates no capacity identified at academic units or in research institutions.

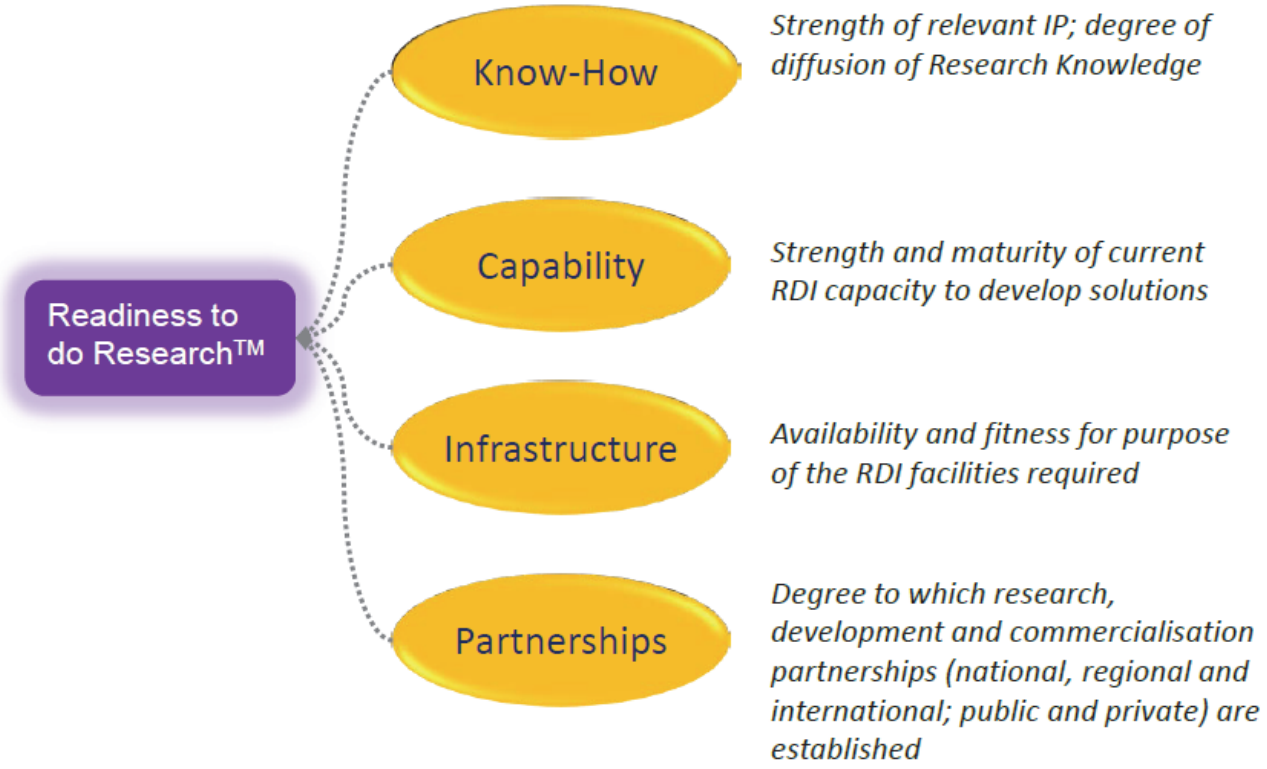


Figure 28: Readiness to do Research™ framework

The resulting data were summarised to indicate two sets of information, the extent of research knowledge diffusion into practice (Appendix D), and the country's RDI capability (Appendix E). These were later used as the basis on which in identify real RDD opportunities that could be taken up, and the additional research capability required to be built in order to take up those opportunities.

4.2.3 Articulate strategic intent

The participants of the previous work sessions of the four sectors, along with stakeholders who had engaged with the WRC in workshops that preceding the RDI road map project, were invited to review the progress of the road map, and to help define its vision (i.e. ideal future state of affairs), mission (i.e. how the ideal state of affairs has come to pass), and the means by which the vision and mission could be accomplished.

The resulting consensus was:

Vision

South Africa leads the developing world in the development and deployment of water management practices and technologies. It competes with leading countries in providing sustainable solutions.

Mission

This has been achieved by means of a National Water RDD Programme focused on: delivery of at least one breakthrough technology every five years; increasing the number of small and medium sized enterprises (SMMEs) operating in the water sector; increasing access to water for rural communities, including provision of sanitation for all in a sustainable manner. Together, this creates significant economic, health, social and environmental benefit

Means

RDD contributes to achieving this Vision, via a focus on four key **Objectives**:

1. Increase the availability of water
2. Improve the governance, planning and management of supply and delivery
3. Operate water and sanitation services as a sustainable "business"
4. Increase the efficiency and productivity of water use

Three key **RDD success factors** are:

1. Faster, more comprehensive deployment of context-appropriate performance improvements
2. Stronger RDI capability and capacity
3. Focused export of SA know-how and technology

The four RDD Objectives distil and summarise the Needs and Interventions documented in Sections 4.1.2, and 4.1.3, and in Appendix A, and were further defined as:

RDD Objectives	(in support of) Target Sector Objective by 2025
1. Increase the availability of water ▸ Increase technical ability to make use of more sources of water – in order to utilise a diversified mix of ground-, surface-, sea-, and waste-waters as resources in domestic, industrial, and agro industrial environments ▸ Optimise the mix of sources in relation to appropriateness of use	▸ More treated effluent is reused instead of discharged to the environment ▸ Cost-effective and energy- efficient seawater desalination in coastal communities and wastewater desalination inland are routine operations ▸ More water used is sourced from groundwater supplies through a sustainable use and recharge management programme ▸ Stormwater in urban areas is harvested, stored, and used
2. Improve governance, planning and management of supply and delivery ▸ Improve the ability to make better-informed choices; make these decisions more transparent and accessible ▸ Strengthen the capability to co-operatively manage water at catchment level	▸ DWS water supply allocations remapped ▸ Water supply and demand governance is managed at catchment level ▸ Consumers within catchments know everyone's water allocation ▸ DWS, DoH, DEA and DHS are involved in CMAs
3. Operate water and sanitation services as a sustainable "business" ▸ Improve the performance of pricing, monitoring, metering, billing and revenue collection ▸ Optimising extraction and perception of water's value	▸ Non-revenue water is reduced to <15%. ▸ All domestic and industrial users are on metered supplies ▸ Leak detection is improved; water loss reduced ▸ Revised volumetric sliding scale for water tariffs ▸ Sanitation services are extended to the whole population
4. Increase the efficiency and productivity of water use ▸ Reduce water losses ▸ Eliminate non-productive use of water ▸ Maximise efficiency of consumptive use	▸ Non-revenue water is controlled and leak detection is improved ▸ Roll-out of irrigation scheduling expertise ▸ More treated effluent is reused instead of discharged to the environment ▸ All wastewater is adequately treated to fit for use standards

4.2.4 Define RDD Programmes

The RDD programmes were developed out using the inputs gained during all the preceding steps. The development was guided by a decision tree that led the work groups to make selections from a prescribed short list. The four stages in the programmes are Explore, Build critical mass, Embed capability, and Commercialise. At each stage a choice had to be made from two or more methods by which each stage could be accomplished. An example of this is the choice to be made to build critical mass – this can be achieved through a Targeted Research Programme (TRP) aimed at a single research group, or a Centre of Excellence which would involve a consortium of more than one research group.

An RDD Programme was developed for each of the seven clusters, as shown on pages 6, 16, 23, 31, 36, 43, and 51.

4.2.5 Anticipate Programme Impact

The impacts of each RDD programme were assessed using the expertise of the water community. Participants from all sectors, and the WRC Research Managers, were presented with a list of all the areas in which the RDI Roadmap is intended to make an impact. The five broad areas: *Water Scarcity*, *Economic*, *Health*, *Society*, and *Environment* were subdivided into discrete sub-areas, and the participants deliberated, then indicated whether or not implementing the interventions that had been listed as appropriate responses to the needs would make an impact in each sub-area. The exact nature of the impact and its extent were not necessary at this stage, only an assessment as to whether an impact could reasonably be expected. Inevitably, the debating method used to reach consensus extended to the nature and extent of the impacts that were anticipated as the participants exchanged and justified their personal assessments within the work groups.

- **Water Scarcity**
  - Reduced withdrawal
  - Reduced consumption
  - Improved water quality
  - Improved productivity of use
- **Economic**
  - Wealth
    - Number of jobs created or sustained

        - Number of new businesses created or sustained
    - Productivity
        - Increased product per drop (water use efficiency (WUE), tonnes/ ton of water)
        - Increased crop yield per drop
        - Reduce down-time (e.g. caused by maintenance)
    - Revenue
        - Increased average revenues per unit product and per m^3 delivered
        - Increased average revenue per producer (e.g. farmer, ecosystem, environment)
    - Cost reduction
        - Decreased water footprint per unit produced
        - Reduced material inputs (and cost)
        - Reduced energy inputs (and cost)
        - Reduced labour requirement (and cost)
        - Reduced cost of healthcare
    - Investment
        - Reduced capex requirements
        - Reduced maintenance costs
- **Health**
    - Reduced incidence of water-borne sickness and disease
    - Reduced incidence of sickness and disease from air pollution
    - Reduced incidence of sickness and disease from chemical contaminants
    - Reduced absenteeism and early retirement – through increased wellness
    - Reduced mortality rate
- **Society**
    - Improved availability and quality of environmental goods and services
    - Increased food security – livestock, crops
    - Reduced loss of animals
    - Increased school attendance (driven by access and quality) and improved educational outcomes
    - Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers)
    - Satisfaction of rights and demands of those without access to water
    - Reduced environmental debt
    - Raised awareness of the value of water, driving increased willingness to pay
- **Environment**
    - Reduction in carbon emissions
    - Reduction in area of salinised land
    - Reduced levels of groundwater contamination
    - Reduced cost of treating process water and potable water
    - Reduced contamination of surface water
    - Reduced downstream pollution
    - Reduced levels of soil erosion
    - Reduced or reversed decline in biodiversity
    - Preservation of riverine habitants
    - Improved health of terrestrial environment

The results of the impact assessment are shown in Appendix F, and they have been summarised per cluster on pages 5, 15, 22, 30, 35, 42, and 50..

4.3 SETTING UP TO DELIVER SUCCESS

This last stage of the roadmapping process was the stage in which all of the diverse and numerous data gathered during the steps 2 to 9 in Figure 24 (p. 60) were collated and related to one another. The results have already been presented in sections 2.2 to 2.8, so the following sections merely serve to explain the methodology, and not to present the results.

4.3.1 Quantify impact and investment

In stage 10 (Figure 24, p. 60), the project team determined the investment required over time, and the anticipated returns in terms of socio-economic value and RDI outputs. The progression paths described in section 4.2.3 were used as the basis of a process in which stakeholders whose expertise was research funding and administration developed out estimates of the type and size of research capacity required to implement the pathways.

The average size and shape of a research group (in academia, or research group equivalent outside of academia) was measured using data about project teams on all proposals submitted to the WRC for funding over the past five financial years. Numbers and roles of team members per team per proposal were used to provide a definition of a "normal" research group. It was not surprising to find that the range of research group size extended from one to almost twenty people, but for investment requirement purposes the modal averages were used to define Small, Medium, and Extended research groups (Table 23).

Table 23: Numbers of different research group members found in average Small, Medium, and Large Research Groups defined according groups described in WRC proposals received from 2009 to 2014

Group member type	Small group	Medium (base) group	Extended group, or research centre
Research Chair	0	0	1
Project leader, who is Faculty staff (Prof, A/Prof, Lecturer) or non-academic equivalent	1	1	1 or 2
Principal Researcher (often a Lecturer or Postdoctoral research fellow / officer)	0	1	2
Senior Researcher (often a Postdoctoral research fellow / officer)	1	1 or 2	2
Researcher (often a research officer)	0	1	2
PhD student	1	2-3	4-6
Masters student	1-2	2-4	5-10
Honours student	1-2	1-3	5-10
3rd year student / intern	0-2	1-2	2-4

Research chairs we additionally used in investment and human capacity requirement planning, and were defined as holders of clearly defined, separately funded chairs supported by SARChI or by industrial or other sources, following the SARChI model.

Values for Research Chairs, and researcher costs were predicted based on NRF values for postgraduate and postdoctoral researchers (Appendix G), and on the apocryphal norm of R15 million over five years.

Standard office and communications equipment (but NOT laboratory or other specialised equipment) was included as 1% of the total research capacity costs. Specialised research costs were estimated based on modal equipment and running costs budgeted in proposals submitted to the WRC between 2009 and 2014, and related back to the average research group sizes.

The total investment required to deliver all seven of the Cluster-based ten-year plans is detailed in Table 24. These figures are summarised according to source of funding, to Cluster of needs / interventions, and to investment instrument in section 4.1.2.

The exact international investment ask is not quantified at this point. This figure is currently included in the "Other Govt (government)" funding source in Table 24. This will be a priority task for the Roadmap Project Management Unit to clarify on inception in the first quarter of 2015/2016. Currently, the exact international ask required is dependent of DWS's NWRSII alignment and resourcing process that is underway and the WRC strategic planning process that is required to support roadmap implementation.

4.3.2 Design implementation framework

The final stage (box 11, Figure 24, p. 65) was to design an appropriate framework to guide, monitor, and manage the successful execution of the roadmap; five options for managing and co-ordinating the implementation of the RDD programmes were proposed for discussion and do not form part of this report.

Table 24: Total investment plan for the Water RDI Roadmap

Investment by Cluster		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total (R million)	Total (%)
Increase ability to make use of more sources of water, including alternatives	***Investment Ask***	***26.3***	***473.7***	***332.3***	***335.6***	***348.7***	***335.6***	***322.4***	***345.4***	***329.0***	***329.0***	***3178.0***	***100***
	Water levy (WRC)	4.9	67.1	52.3	51.5	53.5	51.5	49.5	53.0	50.5	50.5	484.5	**15.2**
	DST instruments inc. NRF and TIA	12.0	162.3	121.7	132.1	134.5	120.2	102.8	95.2	97.1	102.3	1080.3	**34.0**
	Other Gov (int, other depts; WRC leveraged funds)	9.4	130.6	100.7	97.8	101.6	97.8	91.4	95.2	97.1	111.4	933.0	**29.4**
	Industry	0.0	113.8	57.6	54.2	59.0	66.1	78.7	102.0	84.2	64.8	680.2	**21.4**
Improve governance, planning and management of supply and delivery	***Investment Ask***	***12.9***	***51.6***	***51.6***	***58.0***	***51.6***	***54.8***	***61.2***	***51.6***	***83.8***	***0.0***	***477.0***	***100***
	Water levy (WRC)	2.4	7.3	8.1	8.9	7.9	8.4	9.4	7.9	12.9	0.0	73.2	**15.4**
	DST instruments inc. NRF and TIA	5.9	17.7	18.9	22.8	19.9	19.6	19.5	14.2	24.7	0.0	163.3	**34.2**
	Other Gov (int, other depts; WRC leveraged funds)	4.6	14.2	15.6	16.9	15.0	16.0	17.4	14.2	24.7	0.0	138.7	**29.1**
	Industry	0.0	12.4	8.9	9.4	8.7	10.8	14.9	15.2	21.4	0.0	101.8	**21.3**
Improve adequacy and performance of supply infrastructure	***Investment Ask***	***13.6***	***115.7***	***108.9***	***81.6***	***71.4***	***68.0***	***78.2***	***61.2***	***61.2***	***0.0***	***660.0***	***100***
	Water levy (WRC)	2.5	16.4	17.1	12.5	11.0	10.4	12.0	9.4	9.4	0.0	100.8	**15.3**
	DST instruments inc. NRF and TIA	6.2	39.6	39.9	32.1	27.6	24.4	25.0	16.9	18.1	0.0	229.7	**34.8**
	Other Gov (int, other depts; WRC leveraged funds)	4.9	31.9	33.0	23.8	20.8	19.8	22.2	16.9	18.1	0.0	191.3	**29.0**
	Industry	0.0	27.8	18.9	13.2	12.1	13.4	19.1	18.1	15.7	0.0	138.2	**20.9**
Run Water as a "business"	***Investment Ask***	***6.5***	***91.1***	***97.6***	***94.4***	***97.6***	***84.6***	***84.6***	***91.1***	***84.6***	***84.6***	***817.0***	***100***
	Water levy (WRC)	1.2	12.9	15.4	14.5	15.0	13.0	13.0	14.0	13.0	13.0	125.0	**15.3**
	DST instruments inc. NRF and TIA	3.0	31.2	35.8	37.2	37.7	30.3	27.0	25.1	25.0	26.3	278.5	**34.1**
	Other Gov (int, other depts; WRC leveraged funds)	2.3	25.1	29.6	27.5	28.4	24.7	24.0	25.1	25.0	28.7	240.4	**29.4**
	Industry	0.0	21.9	16.9	15.2	16.5	16.7	20.7	26.9	21.7	16.7	173.1	**21.2**
Improve governance planning and its implementation in the management of demand and use	***Investment Ask***	***10.3***	***61.8***	***48.0***	***48.0***	***89.2***	***78.9***	***78.9***	***78.9***	***75.5***	***82.4***	***652.0***	***100***
	Water levy (WRC)	1.9	8.8	7.6	7.4	13.7	12.1	12.1	12.1	11.6	12.6	99.9	**15.3**
	DST instruments inc. NRF and TIA	4.7	21.2	17.6	18.9	34.4	28.3	25.2	21.8	22.3	25.6	219.9	**33.7**
	Other Gov (int, other depts; WRC leveraged funds)	3.7	17.0	14.6	14.0	26.0	23.0	22.4	21.8	22.3	27.9	192.6	**29.5**
	Industry	0.0	14.8	8.3	7.8	15.1	15.5	19.3	23.3	19.3	16.2	139.7	**21.4**
Reduce losses and increase efficiency of use	***Investment Ask***	***32.8***	***282.4***	***243.0***	***256.2***	***243.0***	***243.0***	***236.4***	***236.4***	***157.6***	***0.0***	***1931.0***	***100***
	Water levy (WRC)	6.1	40.0	38.3	39.3	37.3	37.3	36.3	36.3	24.2	0.0	295.1	**15.3**
	DST instruments inc. NRF and TIA	15.0	96.7	89.0	100.8	93.8	87.1	75.4	65.2	46.5	0.0	669.5	**34.7**
	Other Gov (int, other depts; WRC leveraged funds)	11.8	77.8	73.7	74.6	70.8	70.8	67.0	65.2	46.5	0.0	558.2	**28.9**
	Industry	0.0	67.8	42.1	41.3	41.1	47.8	57.7	69.8	40.3	0.0	408.1	**21.1**
Improve performance of Pricing, Monitoring, Metering, Billing and Collection	***Investment Ask***	***16.4***	***98.4***	***75.5***	***88.6***	***68.9***	***78.8***	***78.8***	***72.2***	***52.5***	***0.0***	***630.0***	***100***
	Water levy (WRC)	3.0	14.0	11.9	13.6	10.6	12.1	12.1	11.1	8.1	0.0	96.4	**15.3**
	DST instruments inc. NRF and TIA	7.5	33.7	27.6	34.9	26.6	28.2	25.1	19.9	15.5	0.0	219.0	**34.8**
	Other Gov (int, other depts; WRC leveraged funds)	5.9	27.1	22.9	25.8	20.1	22.9	22.3	19.9	15.5	0.0	182.4	**29.0**
	Industry	0.0	23.6	13.1	14.3	11.7	15.5	19.2	21.3	13.4	0.0	132.2	**21.0**
Totals		118.9	1174.8	956.9	962.4	970.5	943.7	940.6	936.9	844.3	496.0	8345.0	
Project management office (PMO)	**Investment Ask**	**3.2**	**4.2**	**5.5**	**6.5**	**7.1**	**7.9**	**8.7**	**9.5**	**10.4**	**11.5**	**74.5**	
Totals		**122.1**	**1179.0**	**962.4**	**968.9**	**977.6**	**951.6**	**949.3**	**946.4**	**854.7**	**507.5**	**8419.6**	

APPENDIX A: WORK SESSION DATA

Table A1: Statements of need (unabridged) and interventions provided during work sessions with the four sectors of the water community.

	Needs Agriculture	Interventions Agriculture
Supply	**Increase diversity and optimisation of mix**	
1	Increase use of treated effluent	Implement efficient treatment management system. Address public perception issue. Catalyse linkages between those that discharge between producers and users – e.g. mines and farms
2	Increase levels of desalination	Regularise soil sampling at site level, introduce more efficient irrigation system suited to individual farms and particular regions; create detailed soil maps; models: cooperatives and delivery of extension services
3	Increase rainwater harvesting	Increase and sustain water harvesting and conservation methods. Conduct scientific-economic evaluation of alternative approaches
4	Increase use of wastewater	
5	Increase water transfers	Enable transfers between end uses: inter-basin, client-client
6	Increase storage capacity	
7	Increase ground water use	Make use of local water resources
8	Increase stormwater management	Revise legislation on stormwater management and use
9	Increase capture of floodwaters	
10	Improve governance structures – Management	Training and capacity development. Staff turn-over (capacity) sustainable knowledge-transfer. Revised understanding of the policy positions irt Water Act. Enforcement and compliance – institutions missing, not capacitated to perform/ mandate ??? Catchment Management Agencies – to be replaced / up and running in 2016
11	Align allocations of water with requirements	
Demand	**Reduce Non-consumptive Use**	
12	Reduce water transport losses	Refurbish irrigation networks, incentivise improved management of losses
13	Reduce leakages	Detect and repair leakages
Demand	**Reduce Consumptive Use**	
14	Optimise ground water use	Minimise allocation requirement
15	Reduce volume of water use	Use water-saving crops and varieties
16	Increase the area under irrigation	Use savings in current water use. Change NDP word "irrigation" to "agricultural water use" (in line with the rest of the world)
17	Improve efficiency of land and water use practices (of farmers)	Introduce irrigation systems and improve performance
		Optimise irrigation: Plan, meter, schedule
		Optimise irrigation: Monitor soil moisture
		Optimise irrigation: Reduce evapotranspiration
		Optimise irrigation: Optimise fertiliser use
		Increase effectiveness of knowledge transfer
18	Increase levels of wastewater reuse	Reduce volume of wastewater, recover and recycle
		Reduce wastewater released to sewers
19	Minimise volumes to unrecoverable sources	Reduce rainwater runoff
20	Minimise volume and toxicity of pollution – point-sources and diffuse sources	Reduce downstream pollution
21	Optimise the balance between the right to water and the productive use of this water	
Demand	**Improve management of Customer demand and use**	
22	Increase transparency over rights, quotas, allocation, transfers	Enable trading and transfer of water entitlement

	Needs Agriculture	Interventions Agriculture
23	Improve quality and effectiveness of context of planning and implementation	Enable water ordering, improve management of distribution
24	Improve equity of pricing, encourage desirable practice	Introduce tariffs and incentives ("real cost" of water); enforce quotas
25	Improve accuracy: use monitoring, billing and management	Increase coverage, accuracy of flow monitoring, attribution; introduce management systems
26	Reduce levels of unmetered water use	Detect and remove unmetered supplies; ensure meters are operating
27	Increase effectiveness of cross-sectoral planning and implementation (e.g. watershed)	
28	Reduce impediments to implementation	
	Needs Industry	**Interventions Industry**
Supply	**Increase diversity and optimisation of mix**	
1	Increase use of treated effluent	Reduce cost of effluent treatment
2	Increase levels of desalination	Reduce energy requirement and material costs. Increase reclamation.
3	Increase rainwater harvesting	Incentivise adoption. Use all hard surfaces; separate rain water and polluted water
4	Increase use of wastewater	Integrate agriculture and energy production
5	Increase water transfers	Enable easier transfer between uses and users. Enable transfers between end uses: inter-basin, client-client
6	Increase adaptability of storage capacity	Suitability, availability, capacity, flexibility. Add tanks, man-made dams, underground or alternative storage (e.g. in mining void)
7	Increase ground water use	Identify groundwater sources, yields and uses
8	Increase stormwater harvesting and management	Incentivise broader adoption and uptake; Separate clean and dirty (CSO)
9	Increase capture of floodwaters	
10	Increase protection of existing ecological infrastructure	Rehabilitation and protection. Increase awareness; improve monitoring and evaluation
11	Increase the reliability of the infrastructure	Improve performance of planning design, operations and maintenance
12	Increase ecological treatment	Improve performance of alternatives, relative to current solutions (and perception)
13	Improve the reliability of bulk supply	Enable cooperative solution development and implementation
14	Increase water quality between uses	Enable more effective and integrated processes – increase competence and capacity
15	Increase transparency over rights, quotas, allocation, transfers (at a system level)	
Demand	**Reduce Non-consumptive Use**	
16	Reduce water transport losses	Minimise water tank overflows and bulk supply losses; protect transmission against corrosion
17	Reduce leakages and evaporative losses	Implement preventive maintenance plans; Introduce monitoring and early warning systems
Demand	**Reduce Consumptive Use**	
18	Minimise ground water abstraction (ultimately to zero)	Minimise demand on supplier (e.g. municipality). Reduce rainwater runoff, enforce use of groundwater resources
		Minimise ground water abstraction (ultimately to zero)
19	Reduce volume of water use , avoid the need for water	Minimise water use, application and losses in primary processes
		Primary: Avoid use of water (e.g. optimised or new no-water processes)
		Ancillary: Recover condensate. Reduce steam leakage.
		Domestic: Manage water pressure
		Product water
20	Improve efficiency of water use	Reduce water use in ancillary processes
		Reduce demand for domestic water
21	Increase levels of wastewater reuse	Increase knowledge and sharing of best practices
		Recover and recycle – at acceptable cost
		Recover and recycle process, domestic and wastewater

	Needs Industry	Interventions Industry
		Recycle waste streams from water and wastewater treatment
22	Minimise volumes to unrecoverable sources	Cleaner production
		Minimise production of waste (e.g. cleaner production methods)
		Reduce volume of wastewater released to sewers
23	Minimise volume and toxicity of discharge; increase beneficiation	Cleaner production, process optimisation
		Minimise liquid discharge, sludge; improve brine handling
		Minimise production of effluent (e.g. cleaner production methods)
24	Minimise poor water quality discharge	Minimise discharge of poor quality water
Demand	**Improve management of Customer demand and use**	
25	Increase transparency over rights, quotas, allocation, transfers	
26	Improve quality of planning	Systematically increase water independence: map footprint, develop reduction strategy
27	Improve equity of pricing, encourage desirable practice	Tariffs, incentives. Ensure prices are a better and full reflection of economic value. Review and remodel pricing structure
		Introduce tariffs and incentives ("real cost" of water)
28	Increase knowledge and sharing of best practices	Increase cost of discharge to sewer
29	Improve accuracy of monitoring and billing (both raw and within municipal services)	Increase precision of attribution, granularity of the impact evaluation
		Install meters, monitor use and target reductions
30	Reduce levels of unmetered water use	Detect and remove unmetered supplies; ensure meters are operating; Manage collection
		Detect and remove unmetered supplies; ensure meters are operating
31	Improve co-operative governance and management of supply	Technology and institutional efficiencies
32	Increase security of supply	

	Needs Environment	Interventions Environment
Supply	**Increase diversity and optimisation of mix**	
1	Increase /Encourage ground water use sources	Investigate groundwater potential as a conjunctive source
		Optimise Mix for context (mgmt. consumptive use)
2	Increase runoff	Improve control of alien invasive plants and wetland rehabilitation
3	Increase recharge of Groundwater sources (Biodiversity, vegetation, land use mgmt.	Improve control of alien invasive plants and wetland rehabilitation
		Improve good land use practices
		Increase artificial recharge
4	Increase reuse of used water (Treated, Returned artificial	Improve performance and cost of purification
5	Encourage rainwater capture and use	Introduce legislation and incentives to encourage uptake
6	Increase effectiveness of Governance (authorisation, governance, enforcement, compliance)	Up-rate competence and increase capacity
7	Ensure conservation of Priority Water areas	Identify, map declare and adopt. Design and introduce regulation and management mechanisms
8	Protect – Reduce/minimise Quantity & Quality	Improve regulatory frameworks; improve the quality of decision-making information
9	Increase /substitute levels of desalination	Improve performance and cost of purification
10	Enhance Rainfall	Identify suitable sites; improve yields
11	Harvest fog for strategic use water	Identify suitable sites; improve yields
12	Increase effective management of water reticulation & treatment infrastructure	Raise priority of this activity. Augment capacity, increase funding (improve access to funding), management
13	Quantity & characteristic of Groundwater & Surface water	Develop clear understanding for variety of geological settings

	Needs Environment	Interventions Environment
	interaction – minimise pollution & contaminants	Account for allocation of water
14	Increase retention (source control/local control) of water in: wetlands, flood plains, percolation	Develop and implement national design philosophy for storm water management – provide terms of reference (SUDS) (larger metros) Neil Armitage UCT
15	Increase the effectiveness, efficiency and cost of the production of ecological goods and services	Ensure sustainable use of Ecological Infrastructure – wetlands, floodplains, estuaries
16	Increase adaptability and flexibility to plan for respond to the water effects of climate change	Recognise volatility; introduce adaptive practices
Demand	**Reduce Non-Consumptive Use**	
17	Reduce Evaporative and transpiration losses (alien invasion)	Reduce consumption by alien invasive species
		Reduce in-situ evaporation (e.g. abandoned sand mining operations)
18	Reduce water transport losses	
Demand	**Reduce Consumptive Use**	
19	Minimise ground water abstraction (ultimately to zero)	
20	Optimise flow regime (flow, water quality, sediment transport processes) Biotic	
21	Reduce volume of water use , avoid the need for water	
22	Improve efficiency of water use	
23	Increase levels of wastewater reuse	
24	Minimise volumes to unrecoverable sources	
25	Minimise toxicity discharged to next use (dilution & concentration)	Maximise natural water resource function (aquatic response)
26	Minimise poor water quality discharge	
Demand	**Improve management of Customer demand and use**	
27	Improve coverage and effective use of decision-making information for water quality and quantity	Improve resourcing: competence, capacity, funding; improve collaboration; enhance data basis and data integration
		Availability, quality of information – National water integrated resources system
28	Deliver better on negotiated water resource quality objectives	Encourage levels of cooperation; increase levels and effectiveness of compliance and enforcement
29	Reduce excessive lawful, unlawful use, verification and validation	Encourage levels of cooperation; increase levels and effectiveness of compliance and enforcement
30	Quantify with more precision and objectively the customer value proposition of providing and maintaining ecological infrastructure	Develop ability to value
31	Encourage and incentivise self-regulation at all levels	(certification); increase understanding. demystify
32	Reduce levels of unmetered water use	
33	Increase security of supply	

	Needs Public Sector	Interventions Public Sector
Supply	**Increase diversity and optimisation of mix**	
1	Increase / Encourage ground water use and sources	Investigate groundwater potential as a conjunctive source
		Optimise Mix for context (mgmt. consumptive use)
2	Increase runoff	Improve control of alien invasive plants and wetland rehabilitation
3	Increase recharge of Groundwater sources	Improve control of alien invasive plants and wetland rehabilitation
		Improve good land use practices
		Increase artificial recharge

	Needs Public Sector	Interventions Public Sector
4	Increase reuse of used water (Treated, Returned, artificial – from industry and mining)	Improve performance and cost of purification
5	Encourage rainwater capture and use	Increase proportion captured; incentivise uptake
6	Increase effectiveness of Governance (authorisation, governance, enforcement, compliance)	Up-rate competence and increase capacity
7	Ensure conservation of Priority Water areas	Identify, map declare and adopt. Design and introduce regulation and management mechanisms
8	Protect – Reduce/minimise Quantity & Quality	Improve regulatory frameworks; improve the quality of decision-making information
9	Increase /substitute levels of desalination	Increase recovery from sources (wastewater, seawater, process and brackish) Improve performance and cost of purification
10	Increase stormwater harvesting and management	Incentivise broader adoption and uptake; Separate clean and dirty (CSO)
11	Increase effective management of water reticulation & treatment infrastructure	Raise priority of this activity. Augment capacity, increase funding (improve access to funding), management
12	Quantity & characteristic of Groundwater & Surface water interaction – minimise pollution & contaminants	Develop clear understanding for variety of geological settings
13	Increase water transfers	Enable, strengthen interbasin transfers
14	Increase retention (source control/local control) of water in: wetlands, flood plains, percolation	Develop and implement national design philosophy for storm water management – provide terms of reference (SUDS) (larger metros) Neil Armitage UCT
15	Water loss -reduce water loss in the distribution system - abstraction, distribution, reticulation	Maintenance ? Prioritise the funds, improve allocation of funds for operations. Ring fence – "Run water as a business in municipality"
16	Improve visibility and management of asset base	Develop a plan to optimise the investment in Infrastructure – plan and develop (flexible and responsive)
17	Improve the financial sustainability of the water system	
18	Increase proportion of water that is paid for	Remove political interference in enforcement, reduce undesirable or unproductive political involvement
19	Increase the accuracy of attribution of water use	No confidence in Billing system – able to pay but don't trust it
20	Improve revenue collection performance	Improve metering, billing systems, attitudes, prepaid meters. Improve the monitoring throughout the system – inflow. At system level improve the ability to monitor the flow use and quality (water balance)
21	Improve the equity of pricing	Revise policy around requirement to pay? Increase the range of tariffs
22	Institutional landscape in the country? Governance, management,	Refine accountability along the value chain
23	Optimise the ability to manage from source to source in an integrated way	Refine accountability along the value chain
24	Improve water resource management -	implementing current legislation – WRN NWA NWRS
25	Improve the resource mix – groundwater effluent reuse, desalination	
26	Improve Planning for the future – ability to respond to volatility	Integrated planning – water reconciliation plans? Are they based on lowest cost or strategic consideration Social systems and demand – Development of rural areas
27	Improve performance and optimise investment in Infrastructure	Roll of Technology?
28	Increase the ability in identifying alternative supplies	
29	Increase non potable water	
30	Improve the ability to manage water flows	Improve Incentives for good operational practices
Demand	**Reduce Non-consumptive Use**	
31	Reduce water transport losses	Refurbish and maintain distribution infrastructure
32	Reduce water leakages and evaporative losses	Increase detection and repair performance; improve management of pressure; maintain appliances
Demand	**Reduce Consumptive Use**	

	Needs Public Sector	Interventions Public Sector
33	Minimise groundwater abstraction (ultimately to zero)	Introduce dual-piped water supply systems; align water quality better with use
34	Reduce volume of water use	Reduce demand for water (domestic and commercial (showers, taps, toilets)
35	Improve efficiency of water use	Increase use of water-saving appliances
36	Increase levels of wastewater reuse	Increase levels of recovery and recycling
37	Minimise volumes to unrecoverable sources	
38	Minimise volume and toxicity of discharge; increase beneficiation	
39	Minimise poor water quality discharge	
40	Minimise toxicity discharged to next use (dilution & concentration)	
41	Improve quality – increase the alignment of the quality of water with use	
42	Improve the pricing structures – full cost pricing "real cost" Equitable pricing	
43	Ring fencing money	
44	Improve operational efficiencies	
45	Reduce level of consumption of illegal water	Define, implement and support Billing control policy
46	Improve encourage acceptable wider water acceptable on dry solution systems	
47	Encourage consumers to reduce demand	Highlight the importance of water (scarcity)
48	Improve management of Customer demand and use	
49	Stimulate growth more economically (use of water)	
Demand	**Improve management of Customer demand and use**	
50	Increase transparency over rights, quotas, allocation, transfers	
51	Improve coverage and effective use of decision-making information relating to water quality and quantity	
52	Increase knowledge and sharing of best practices	
53	Improve equity of pricing, encourage desirable practice	Tariffs, incentives. Ensure prices are a better and full reflection of economic value. Review and remodel pricing structure Increase cost of discharge to sewer
54	Improve accuracy of monitoring and billing (within municipal services)	Install more accurate metering; monitor flow; improve billing and collection performance
55	Reduce levels of excessive lawful, unlawful use, verification and validation	Detect and remove unmetered supplies; ensure meters are operating
56	Improve co-operative governance and management of supply	
57	Encourage and incentivise self-regulation at all levels	
58	Improve quality of planning	
59	Improve the understanding of water consumption by consumers	Campaigning
60	Improve metering – similar to electricity metering	Institutional structures
61	Increase willing and ability to absorb and use new approaches – co-create, co-responsibility, earlier involvement in dev of solution	– co-create, co-responsibility, earlier involvement in dev of solution

Table A2: Statements of need grouped into clusters, indicating which sectors expressed which needs.

		Agriculture	Industry	Public Sector	Environment
SUPPLY: Increase ability to make use of more sources of water, including alternatives					
1	Increase the ability to identify and make use of alternative supplies	•		•	
2	Increase use of treated effluent	•	•	•	•
3	Decrease levels of salinity	•	•	•	•
4	Increase levels of desalination	•	•	•	•
5	Increase rainwater harvesting	•	•	•	•
6	Increase use of wastewater	•	•	•	•
7	Increase levels of groundwater use	•	•	•	•
8	Increase stormwater harvesting and management	•	•	•	•
9	Increase capture of floodwaters	•			•
SUPPLY: Improve governance, planning and management of supply and delivery					
10	Enable optimised reallocation and distribution	•	•		•
13	Improve effectiveness of Institutional landscape in respect of governance, planning and supply management (actors, management, institutions)	•	•	•	
14	Improve the ability to manage water flows. Align allocation and mix to requirements	•	•	•	
15	Improve quality and resilience of planning for the future – ability to respond to volatility			•	
16	Optimise the ability to manage water resources from source to source in an integrated way			•	
SUPPLY: Improve adequacy and performance of supply infrastructure					
11	Increase adaptability of storage capacity	•	•	•	•
12	Increase protection and reliability of ecological infrastructure			•	•
23	Improve performance, optimise investment in infrastructure			•	
SUPPLY: Run water as a financially sustainable "business" by improving operational performance					
18	Improve the financial sustainability of the water system			•	
19	Improve the equity of pricing			•	
20	Increase the accuracy of attribution of water use			•	
21	Increase proportion of water that is paid for			•	
22	Improve performance of revenue collection			•	
24	Improve operational efficiencies			•	
DEMAND: Improve governance planning and its implementation in the management of demand and use					
36	Increase transparency over rights, quotas, allocation and transfers	•	•		•
37	Improve co-operative governance with respect to planning and management. Cross-sectoral.	•	•		
38	Improve quality and effectiveness of context-specific planning and implementation	•	•	•	
DEMAND: Reduce losses and increase efficiency of productive use					
25	Reduce water transport losses	•	•	•	•
26	Reduce leakages	•	•	•	
27	Optimise conjunctive use of water	•	•	•	
28	Reduce volume of water use	•	•	•	
29	Increase the area under irrigation	•			
30	Improve efficiency of water use	•	•	•	
31	Increase levels of water reuse	•	•	•	
32	Minimise output to unrecoverable sources	•	•	•	
33	Minimise volume and toxicity of pollution	•	•	•	•
34	Optimise balance between the right to water and productive use of this water	•			•
35	Minimise discharge of poor quality water		•	•	
DEMAND: Improve performance of pricing, monitoring, metering, billing and collection					
39	Improve equity of pricing, encourage desirable practice	•	•	•	
40	Improve accuracy: use monitoring, billing and management	•	•	•	•
41	Reduce levels of unmetered use	•	•	•	

Table A3: Assessment of RDD potential according to the stage and nature of each identified opportunity.

	Legend for **stage**: E = **E**xploration; T = **T**esting; DM = **DeM**onstration; DP = **DeP**loyment	**Management**	**Information**	**Technology**	**Capacity**
S	**Increase ability to make use of more sources of water, including alternatives**				
1	Increase the ability to identify and make use of alternative supplies	E T DM DP	DM DP	E T DM DP	DM DP
2	Increase use of treated effluent	E T DM DP	DM DP	E T DM DP	DM DP
3	Decrease levels of salinity				
4	Increase levels of desalination	E T DM DP	DM DP	E T DM DP	DM DP
5	Increase rainwater harvesting	E T DM DP	DM DP	E T DM DP	DM DP
6	Increase use of wastewater	E T DM DP	DM DP	E T DM DP	DM DP
7	Increase levels of groundwater use	DM DP	DM DP	DM DP	DM DP
8	Increase storm water harvesting and management	E T DM DP	DM DP	E T DM DP	DM DP
9	Increase capture of floodwaters				
S	**Improve governance, planning and management of supply and delivery**				
10	Enable optimised reallocation and distribution	T DM DP	DM DP	T DM DP	DP
13	Improve effectiveness of Institutional landscape in respect of governance, planning and supply management	DM DP	DM DP	No	DP
14	Improve the ability to manage water flows. Align allocation and mix to requirements	T DM DP	DM DP	T DM DP	DP
15	Improve quality and resilience of planning for the future – ability to respond to volatility	T DM DP	DM DP	T DM DP	DP
16	Optimise the ability to manage water resources from source to source in an integrated way	DM DP	DM DP	No	DP
S	**Improve adequacy and performance of supply infrastructure**				
11	Increase adaptability of storage capacity	DM DP	DM DP	E	DM DP
12	Increase protection and reliability of ecological infrastructure	E DM DP	DP	E DM DP	DP
23	Improve performance, optimise investment in infrastructure	E DM DP	DP	E DM DP	DP
S	**Run water as a financially sustainable "business" by improving operational performance**				
18	Improve the financial sustainability of the water system	DP	DP	No	DM DP
19	Improve the equity of pricing	DT DM DP	DM DP	No	DP
20	Increase the accuracy of attribution of water use	DM DP	DM DP	T DM DP	DP
21	Increase proportion of water that is paid for	DM DP	DM DP	T DM DP	DP
22	Improve performance of revenue collection	DM DP	DM DP	T DM DP	DP
24	Improve operational efficiencies	DM DP	DM DP	No	DP
D	**Improve governance planning and its implementation in the management of demand and use**				
36	Increase transparency over rights, quotas, allocation and transfers	DT DM DP	DM DP	No	DP
37	Improve co-operative governance with respect to planning and management. Cross-sectoral.	DT DM DP	DM DP	No	DP

	Legend for **stage**: E = **E**xploration; T = **T**esting; DM = **DeM**onstration; DP = **DeP**loyment	**Management**	**Information**	**Technology**	**Capacity**
38	Improve quality and effectiveness of context-specific planning and implementation	DT DM DP	DM DP	No	DP
D	**Reduce losses and increase efficiency of productive use**				
25	Reduce water transport losses	T DM DP	DM DP	E DM DP	DP
26	Reduce leakages	T DM DP	DM DP	E DM DP	DP
27	Optimise conjunctive use of water	E DM DP	DP	No	DP
28	Reduce volume of water use	E DM DP	E DM DP	E DM DP	DP
29	Increase the area under irrigation	??	??	??	??
30	Improve efficiency of water use	DM DP	DM DP	??	??
31	Increase levels of water reuse	DM DP	T E DM DP	T E DM DP	DM DP
32	Minimise output to unrecoverable sources	E DM	E DM DP	E DM DP	DM DP
33	Minimise volume and toxicity of pollution	T E DM	DM DP	E DM DP	DM DP
34	Optimise balance between the right to water and productive use of this water	E DM	E DM DP	E DM DP	DM DP
35	Minimise discharge of poor quality water	E DM	E DM DP	E DM DP	DM DP
D	**Improve performance of Pricing, Monitoring, Metering, Billing and Collection**				
39	Improve equity of pricing, encourage desirable practice	E DM DP	E DM DP	E DM DP	E DM DP
40	Improve accuracy: use monitoring, billing and management	E DM DP	E DM DP	E DM DP	E DM DP
41	Reduce levels of unmetered use	E DM DP	E DM DP	E DM DP	E DM DP

Table A4: Assessment of RDD Performance Measures according to the seven Clusters of Needs, Interventions, and RDD Potential

		Performance Measures defined at Cluster Level (with reference to the Needs)	With respect to the identified Performance Measures, what is the minimum (quantified) change required?
S	**Increase ability to make use of more sources of water, including alternatives**		
1	Increase the ability to identify and make use of alternative supplies		
2	Increase use of treated effluent	More treated effluent is reused instead of discharged to the environment	75% of treated wastewater reused
3	Decrease levels of salinity		
4	Increase levels of desalination	Seawater desalination in coastal communities and wastewater desalination inland are routine operations	Coastal communities obtain 5% of the water supply from seawater; inland 75% of wastewater is desalinated and reused
5	Increase rainwater harvesting		
6	Increase use of wastewater	More treated effluent is reused instead of discharged to the environment	75% of treated wastewater reused
7	Increase levels of groundwater use	More water used is sourced from groundwater supplies	5-10% of water us abstracted from groundwater
8	Increase stormwater harvesting and management	Stormwater in urban areas is harvested	All metropolitan areas have sormwater drainage and storage
9	Increase capture of floodwaters		
S	**Improve governance, planning and management of supply and delivery**		
10	Enable optimised reallocation and distribution	DWA water allocations remapped	A new map completed by 2016
13	Improve effectiveness of Institutional landscape in respect of governance, planning and supply management	Governance is managed at catchment level	Nine functional Catchment Management Agencies
14	Improve the ability to manage water flows. Align allocation and mix to requirements		
15	Improve quality and resilience of planning for the future – ability to respond to volatility		
16	Optimise the ability to manage water resources from source to source in an integrated way	DWA water allocations remapped	The new map includes groundwater, seawater, and wastewater
S	**Improve adequacy and performance of supply infrastructure**		
11	Increase adaptability of storage capacity	Storage for treated effluent is available	Storage facilities similar to Jo'burg Water's Northern Works exist in all metropolitan areas.
12	Increase protection and reliability of ecological infrastructure	Ecological reserve is redefined and sufficient	New rainfall maps have led to a new limit for the ecological reserve, which is protected by regulation
23	Improve performance, optimise investment in infrastructure		
S	**Run water as a financially sustainable "business" by improving operational performance**		
18	Improve the financial sustainability of the water system	Non-revenue water is better controlled	Non-revenue water is below 15%
19	Improve the equity of pricing		
20	Increase the accuracy of attribution of water use	All domestic and industrial users are on metered supplies	All domestic and industrial users are on metered supplies
21	Increase proportion of water that is paid for		
22	Improve performance of revenue collection	Non-revenue water is better controlled	Non-revenue water is below 15%
24	Improve operational efficiencies	Leak detection is improved	All leaks are detected in under 12 hours and repaired fin under 48
D	**Improve governance planning and its implementation in the management of demand and use**		
36	Increase transparency over rights, quotas, allocation and transfers	Consumers within catchments know everyone's water allocation	Nine functional Catchment Management Agencies

		Performance Measures defined at Cluster Level (with reference to the Needs)	With respect to the identified Performance Measures, what is the minimum (quantified) change required?
37	Improve co-operative governance with respect to planning and management. Cross-sectoral.	DWS, DoH, DEA and DHS are involved in CMAs	Nine functional Catchment Management Agencies
38	Improve quality and effectiveness of context-specific planning and implementation	Governance is managed at catchment level	Nine functional Catchment Management Agencies
D	**Reduce losses and increase efficiency of productive use**		
25	Reduce water transport losses	Non-revenue water is better controlled	Non-revenue water is below 15%
26	Reduce leakages	Leak detection is improved	All leaks are detected in under 12 hours and repaired fin under 48
27	Optimise conjunctive use of water		
28	Reduce volume of water use	Roll out irrigation scheduling expertise	PICWAT and SAPWAT, or equivalents, are in use on all commercial farms and 30% of family farms
29	Increase the area under irrigation		
30	Improve efficiency of water use		
31	Increase levels of water reuse	More treated effluent is reused instead of discharged to the environment	75% of treated wastewater reused
32	Minimise output to unrecoverable sources	More treated effluent is reused instead of discharged to the environment	75% of treated wastewater reused
33	Minimise volume and toxicity of pollution	All wastewater is adequately treated	90% of wastewater treatment works attain Green Drop status
34	Optimise balance between the right to water and productive use of this water		
35	Minimise discharge of poor quality water	All wastewater is adequately treated	90% of wastewater treatment works attain Green Drop status
D	**Improve performance of Pricing, Monitoring, Metering, Billing and Collection**		
39	Improve equity of pricing, encourage desirable practice	Revise the volumetric sliding scale for water tariffs	Free basic water remains free; reasonable use is reasonably priced; wasted water is prohibitively expensive
40	Improve accuracy: use monitoring, billing and management	All domestic and industrial users are on metered supplies	All domestic and industrial users are on metered supplies
41	Reduce levels of unmetered use	Non-revenue water is better controlled	Non-revenue water is below 15%

APPENDIX B: ATTRACTIVENESS OF RDD OPPORTUNITIES ACCORDING TO EACH SECTOR, PER CLUSTER.

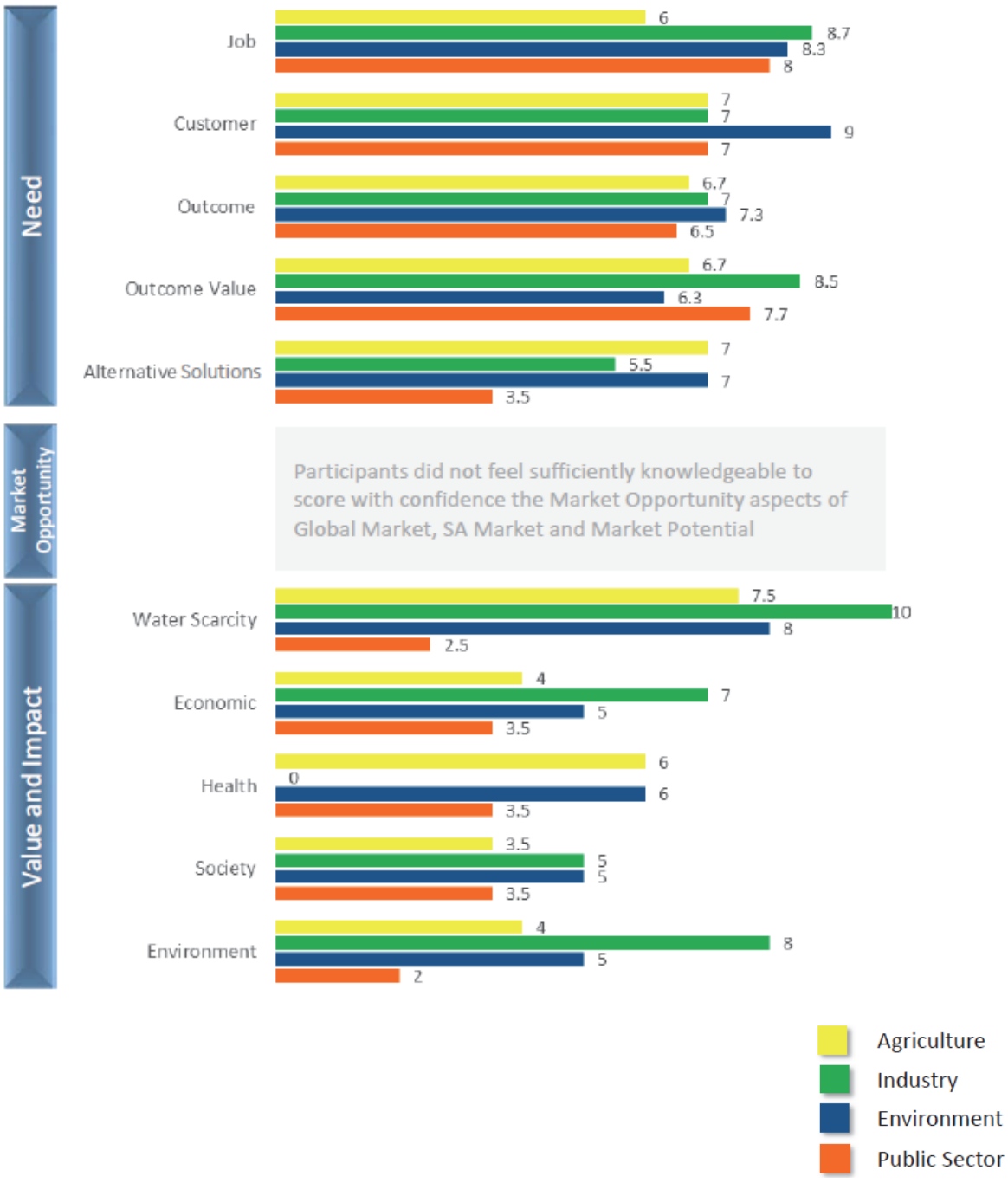


Figure B1: Increase ability to make use of more sources of water, including alternatives

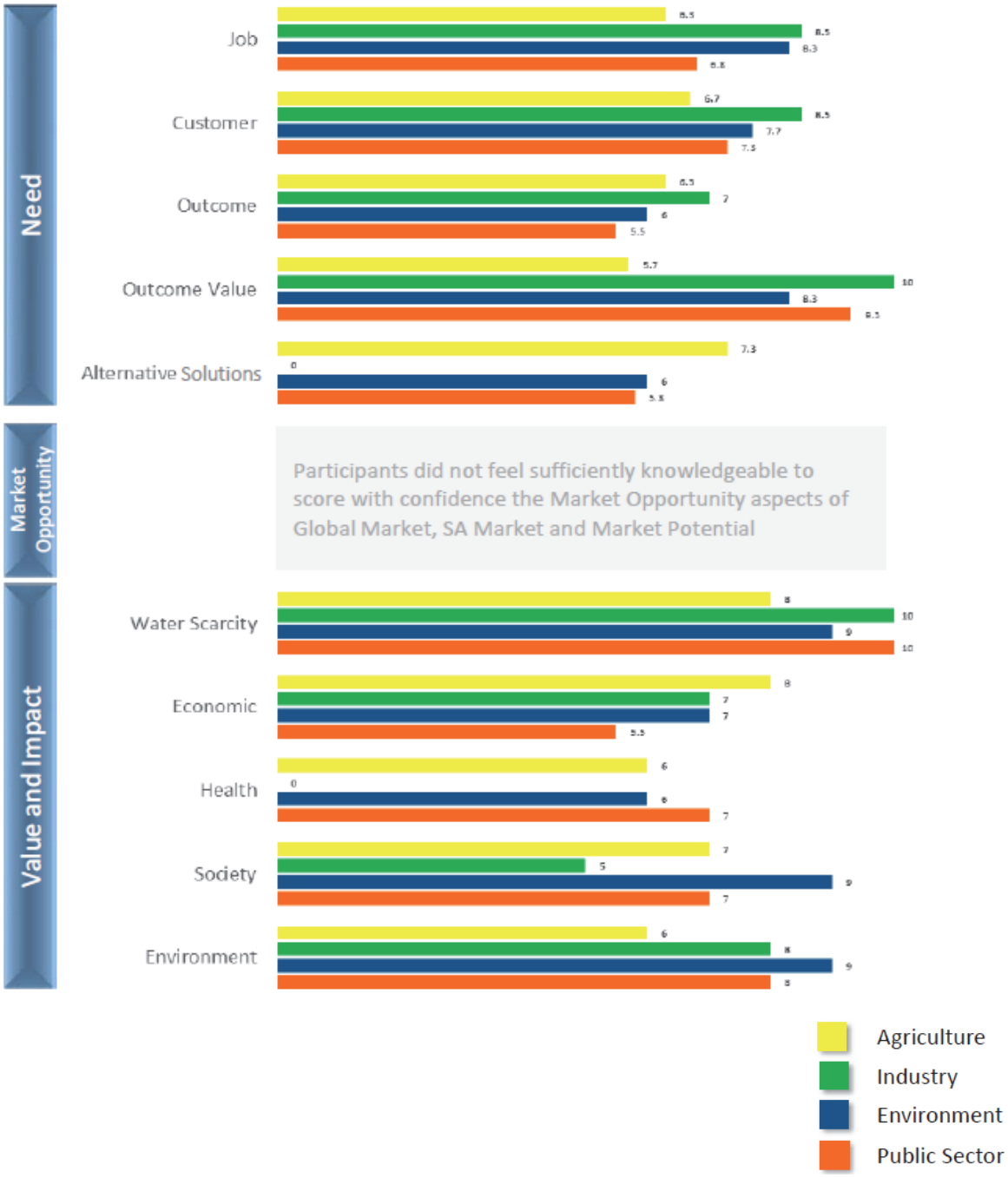


Figure B2: Improve governance, planning and management of supply and delivery

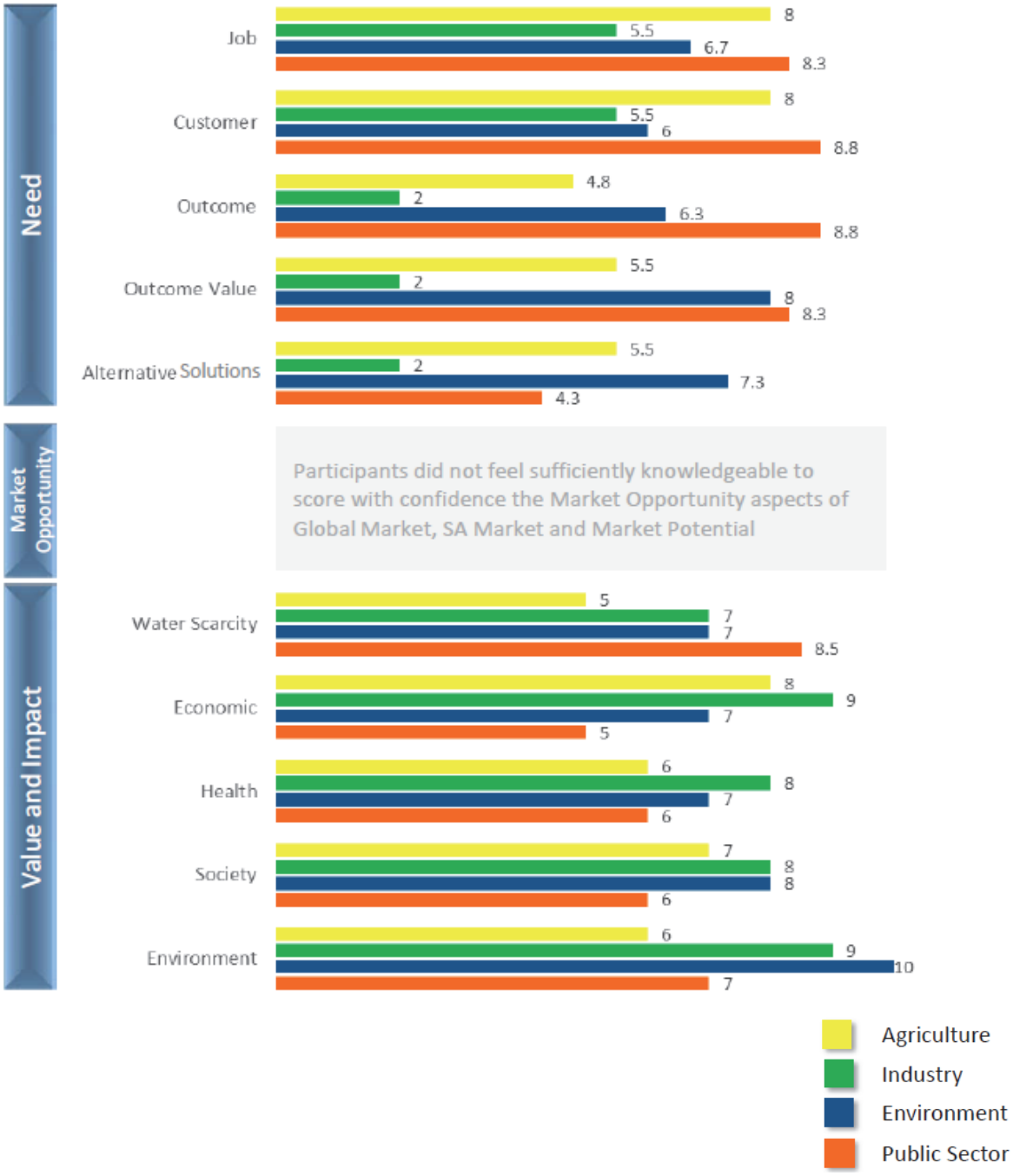


Figure B3: Improve adequacy and performance of supply infrastructure

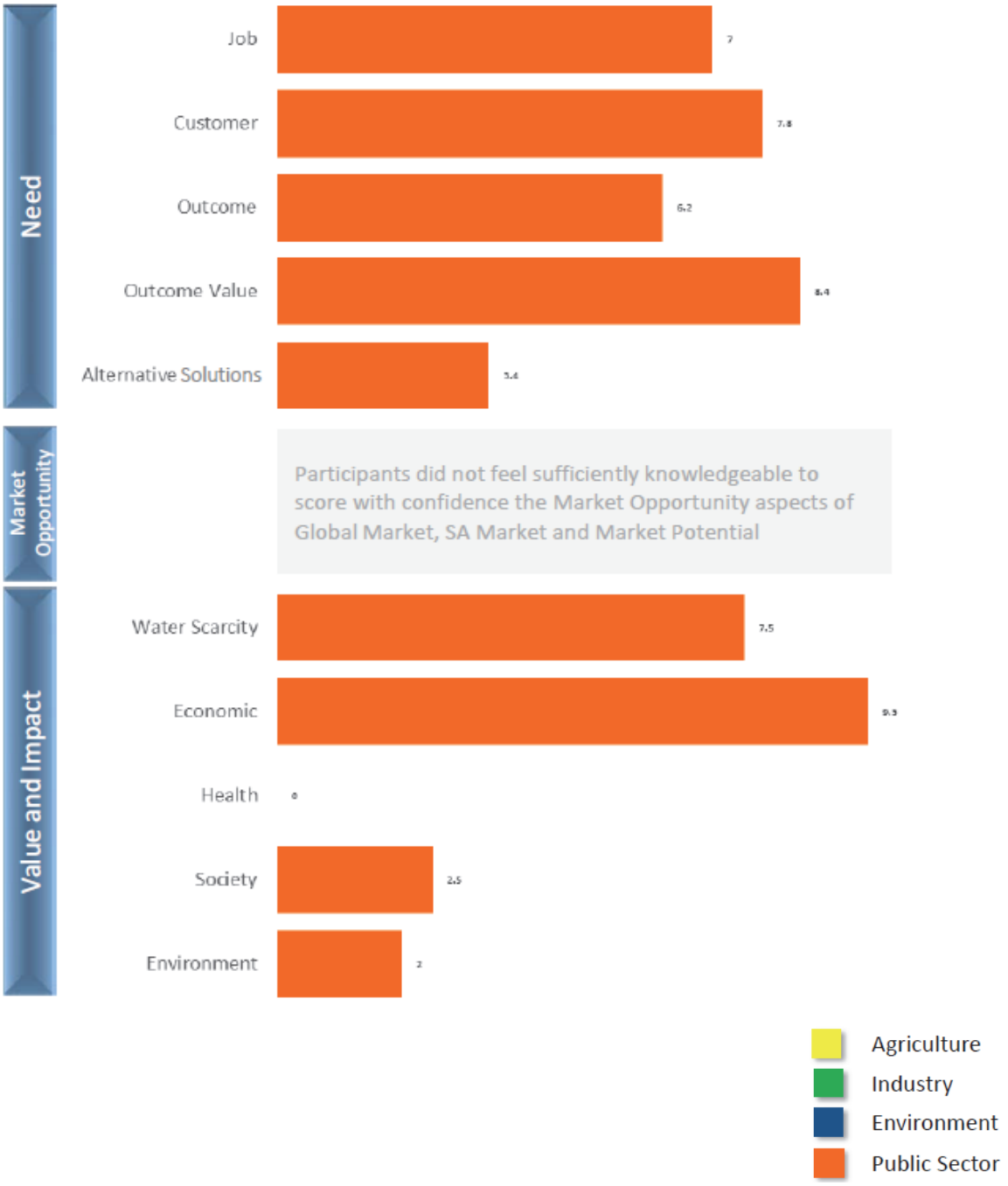


Figure B4: Run water as a financially sustainable "business" by improving operational performance

This cluster was identified as a set of needs only by the public sector, so estimates of the needs' attractiveness, opportunity, value, and impact were not sought from the other three sectors.

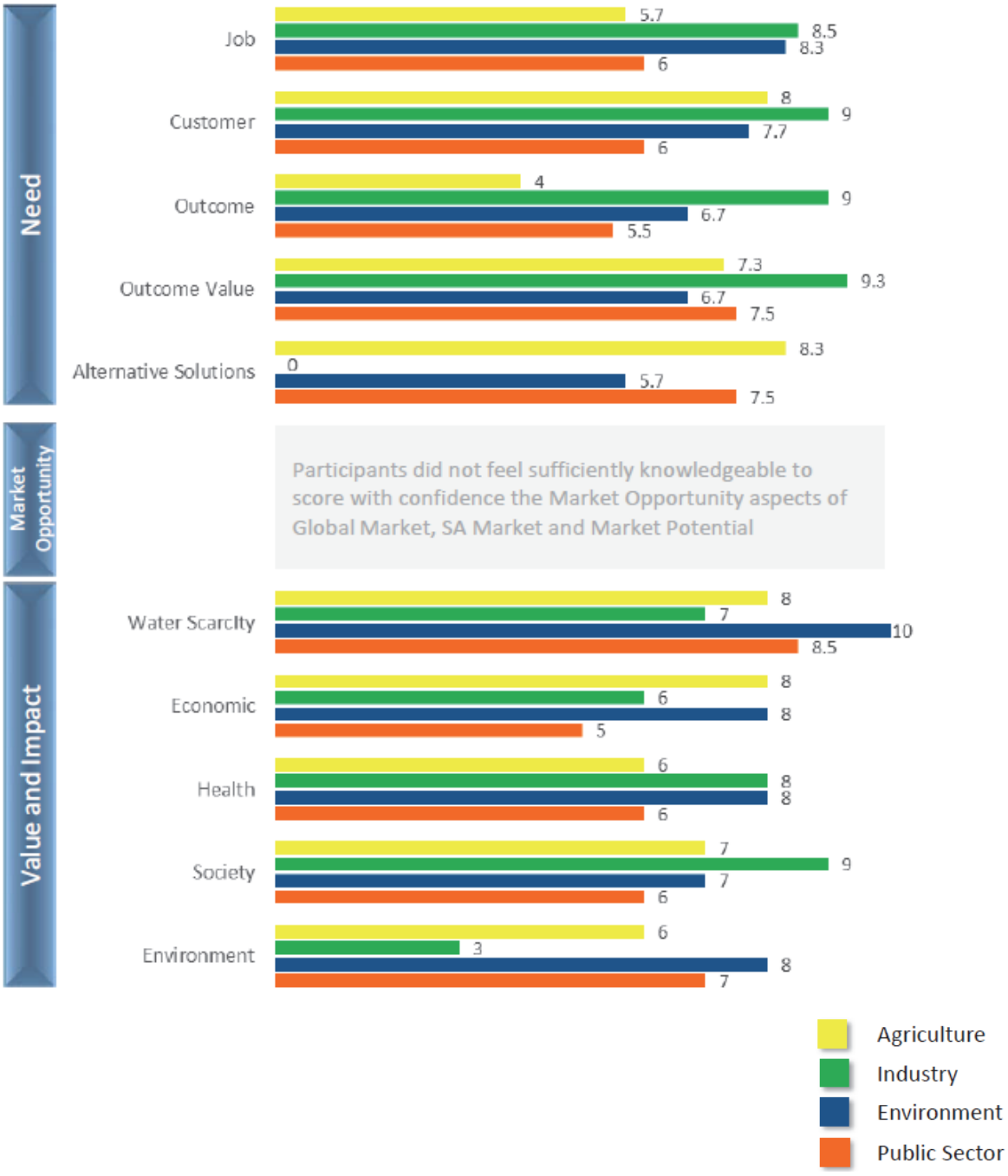


Figure B5: Improve governance, planning, and management of demand and use

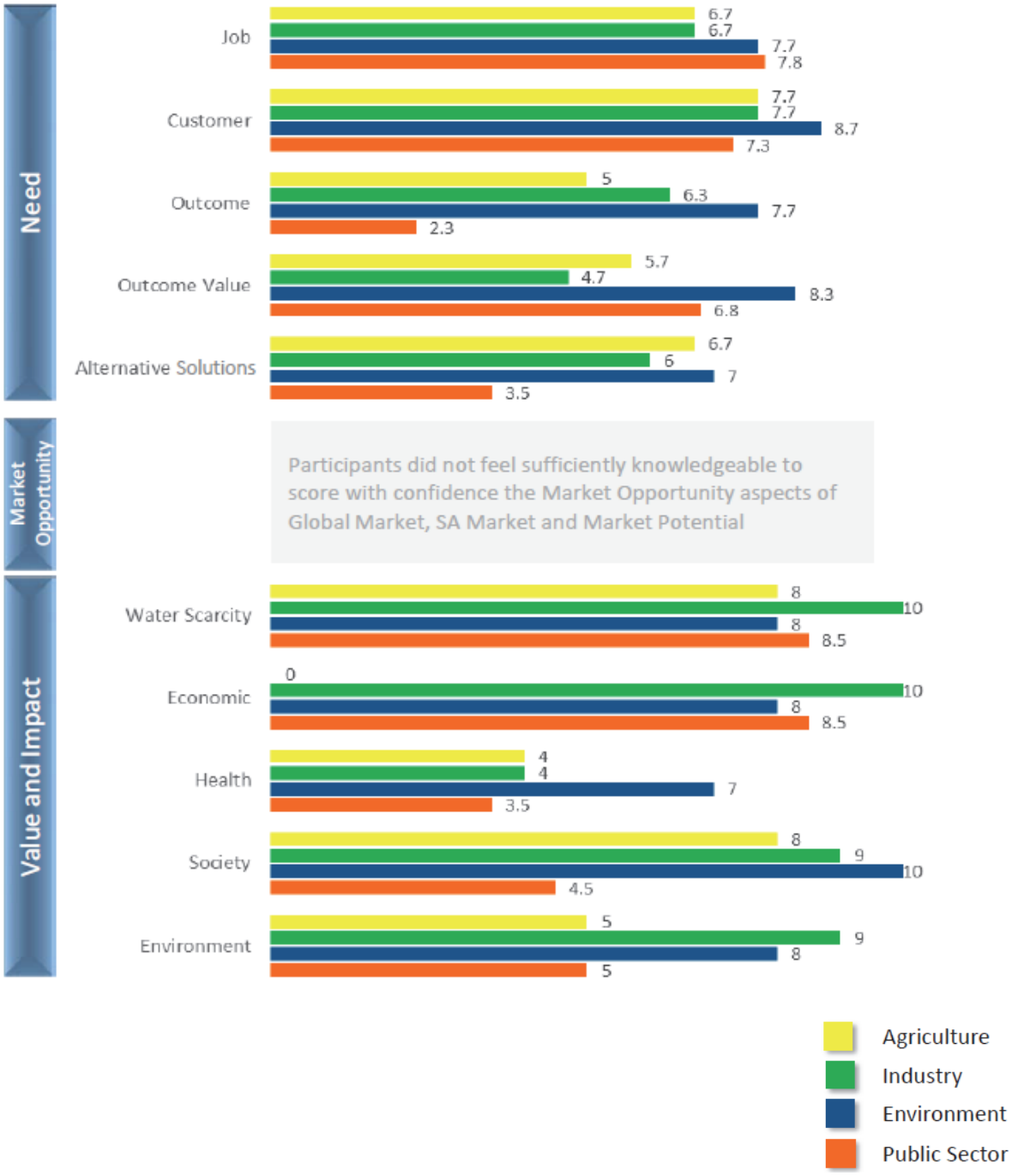


Figure B6: Reduce losses and increase efficiency of <u>productive use</u>

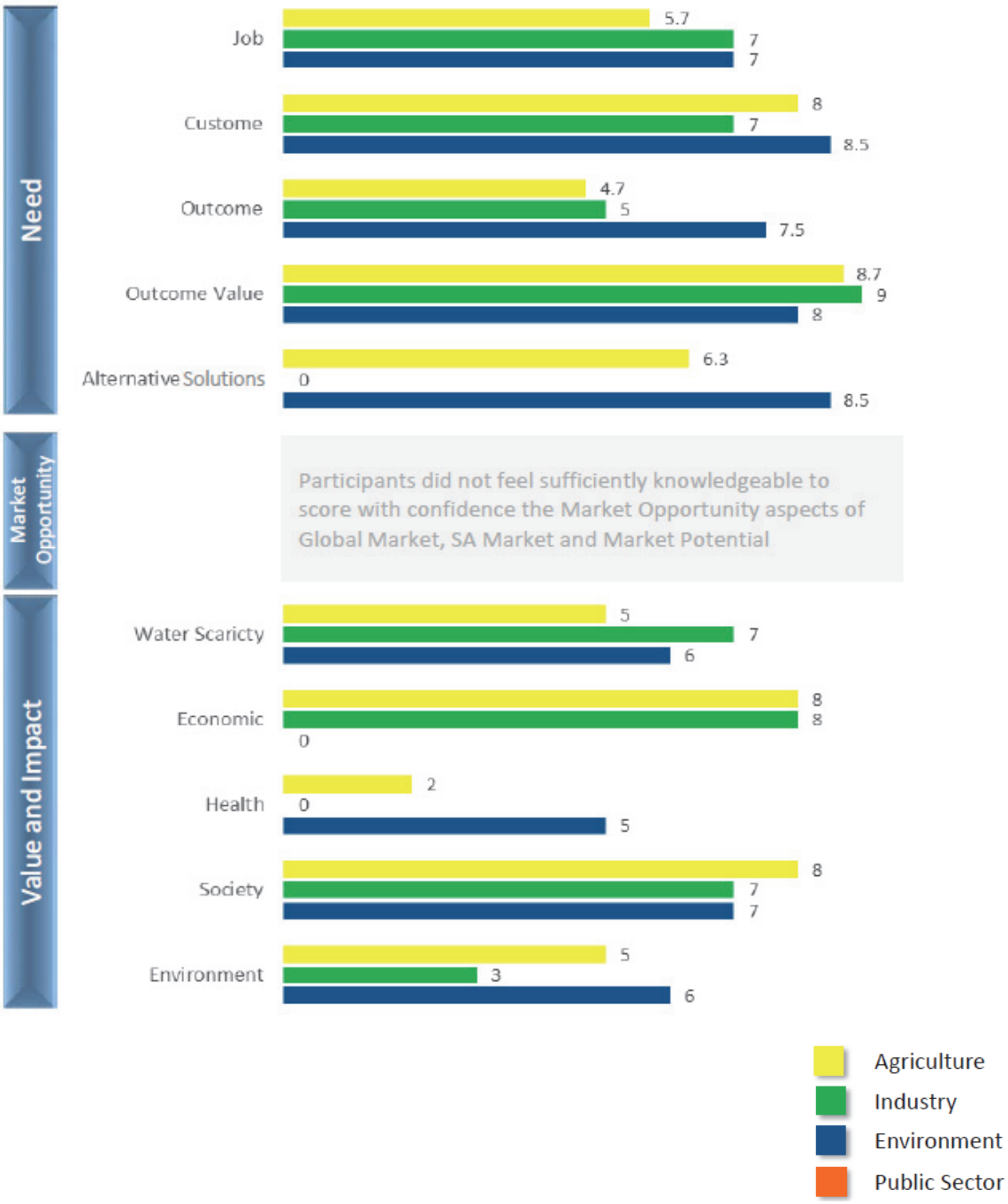


Figure B7: Improve performance of pricing, monitoring, billing, metering and collection

APPENDIX C: RESEARCH FOCUS AREAS AND THEIR UNDERLYING DISCIPLINES, MAPPED TO THE SEVEN CLUSTERS OF NEEDS AND INTERVENTIONS

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Agricultural sciences	Agribusiness	Agrichemicals	Improved food production	X						
Agricultural sciences	Agribusiness	Crop production	Improved food production	X	X			X	X	
Agricultural sciences	Agribusiness	Distribution	Food security and business efficiency		X	X	X	X		
Agricultural sciences	Agribusiness	Machinery	Efficient agriculture						X	
Agricultural sciences	Agribusiness	Marketing	Business efficiency		X			X	X	
Agricultural sciences	Agribusiness	Processing	Efficient agriculture						X	
Agricultural sciences	Agribusiness	Sales	Business efficiency		X			X		
Agricultural sciences	Agribusiness	Seed supply	Crop production							
Agricultural sciences	Agroforestry	Agroforestry	Agroforestry			X				
Agricultural sciences	Agronomy	Horticulture	Horticulture	X					X	
Agricultural sciences	Agronomy	Precision agriculture	Improved food production						X	
Agricultural sciences	Crop science	Crop production and physiology	Crop production	X					X	
Agricultural sciences	Crop science	Genetics and plant breeding	Crop production						X	
Agricultural sciences	Irrigation and drainage science engineering	Irrigation and drainage science engineering	Irrigation and drainage	X	X	X	X	X	X	
Agricultural sciences	Soil science	Soil chemistry	Soil chemistry	X					X	
Agricultural sciences	Soil science	Soil fertility	Soil fertility	X					X	
Agricultural sciences	Soil science	Soil management	Soil management	X	X			X	X	
Agricultural sciences	Soil science	Soil microbiology and biochemistry	Soil microbiology and biochemistry	X					X	
Agricultural sciences	Soil science	Soil morphology and genesis	Soil morphology and genesis						X	

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Agricultural sciences	Soil science	Soil physics	Soil physics						X	
Agricultural sciences			Natural resource management	X	X	X	X	X	X	
Agrometeorology			Agrometeorology	X	X			X	X	
Aquaculture			Aquaculture		X	X	X	X	X	
Beneficial agricultural use of municipal sludge			Beneficial agricultural use of municipal sludge				X		X	
Biological science			Biological science							
Biology and Biochemistry	Genetics	Microbial ecology	Ecosystem functioning	X						
Biology and Biochemistry	Genetics	Microbial ecology	Wastewater treatment	X						
Biology and Biochemistry	Marine, Freshwater Biology	Ecosystem functioning	Ecosystem functioning	X		X				
Biology and Biochemistry	Marine, Freshwater Biology	Nutrient cycling	Ecosystem functioning	X						
Biology and Biochemistry	Metagenomics	Microbial ecology	Ecosystem functioning	X						
Biology and Biochemistry	Metagenomics	Microbial ecology	Wastewater treatment	X						
Biology and Biochemistry	Molecular biology	Microbial ecology	Ecosystem functioning	X					X	
Biology and Biochemistry	Molecular biology	Microbial ecology	Wastewater treatment	X						
Biology and Biochemistry	Physiology and endocrinology	Endocrinology	Animal, human, public, and environmental health	X						
Chemistry	Inorganic Chemistry	Fate and behaviour of metals in the environment	Animal, human, public, and environmental health	X						
Chemistry	Inorganic Chemistry	Metals: toxicity and micronutrient value	Animal, human, public, and environmental health	X						
Chemistry	Organic Chemistry	Degradation of priority pollutants	Animal, human, public, and environmental health	X						
Chemistry	Organic Chemistry	Fate and behaviour of pollutants	Animal, human, public, and environmental health	X					X	
Chemistry			Water treatment	X			X		X	
Chemistry			Environmental and Analytical Chemistry	X			X		X	
Clinical medicine	Chemicals in potable water	Fluoridosis	Human health	X	X			X		
Clinical medicine	Health-related microbiology	Emerging pathogens	Human health	X					X	

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Clinical medicine	Health-related microbiology	Potable water safety	Human health	X	X			X	X	
Computer sciences	Analytics and visualisation	Pattern recognition, machine learning	Process automation and control – potable and waste water treatment							
Computer sciences	Modelling and simulation	Dynamic systems	Environmental water quality	X	X	X	X	X	X	
Computer sciences	Presentation and user interaction		Process automation and control – potable and waste water treatment	X	X			X		
Computer sciences	Remote sensing		Environmental health and ecosystem functioning	X						
Computer sciences	Scientific programming	Bioinformatics	Wastewater treatment	X			X			
Computer sciences	Scientific programming	Computational geosciences	Environmental water quality	X						
Desalination			Desalination	X	X	X	X	X	X	
Economics and Business	Agricultural and Resource Economics		Food security and business efficiency	X	X	X	X	X		
Economics and Business	Applied Economics			X	X			X		
Economics and Business	Behavioural Finance				X			X		
Economics and Business	Business and Economic Statistics		Technoeconomics		X	X		X		
Economics and Business	Computational Economics				X			X		
Economics and Business	Decision Sciences			X	X	X		X		
Economics and Business	Development Economics		Technoeconomics		X			X		
Economics and Business	Econometrics				X			X		
Economics and Business	Economic Modelling			X	X		X	X		
Economics and Business	Entrepreneurship and Management			X	X			X		
Economics and Business	Environmental Economics		Technoeconomics	X	X	X		X		
Economics and Business	Forecasting and Game Theory									
Economics and Business	Insurance Mathematics and Economics				X			X		
Economics and Business	Macroeconomics			X	X			X		
Economics and Business	Microeconomics				X			X		

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Economics and Business			Development Economics		X			X		X
Economics and Business			Urban Economics		X			X		X
Ecosystem services and ecological infrastructure										
Engineering			Water Engineering	X		X	X		X	
Engineering			Non-Newtonian fluid mechanics				X		X	
Engineering			Plant life extension Technologies						X	
Engineering	(Urban) Water Management / Engineering		Wastewater and potable treatment	X	X	X	X	X	X	X
Engineering	Analytical Sciences		Wastewater and potable treatment	X		X	X		X	
Engineering	Applied Engineering in Agriculture		Crop production	X		X				
Engineering	Chemical		Wastewater and potable treatment	X		X	X			
Engineering	Civil	Safety	Civil engineering aspects of water cycle	X	X	X	X	X		
Engineering	Civil	Structural and Materials	Civil engineering aspects of water cycle	X		X	X		X	
Engineering	Coastal Engineering		Flood defence	X		X	X			
Engineering	Desalination and Water Treatment		Wastewater and potable treatment	X		X			X	
Engineering	Environmental Systems		Civil engineering aspects of water cycle	X		X				
Engineering	Hydrology and hydrogeology	Hydrodynamics	Hydrodynamics	X		X				
Engineering	Hydrology and hydrogeology	Hydrologic engineering	Hydrologic engineering			X	X			
Engineering	Hydrology and hydrogeology	Hydromechanics	Hydromechanics	X		X				
Engineering	Hydrology and hydrogeology	WRC – Water at work				X				
Engineering	Industrial		Wastewater and potable treatment	X		X	X			
Engineering	Irrigation and Drainage		Crop production	X		X				
Engineering	Marine science		Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X		X				

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Engineering	Nanoscience and Nanotechnology		Wastewater and potable treatment, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X		X				
Engineering	Ocean and Coastal Management		Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X	X	X		X		
Engineering	Waterway, Port, Coastal and Ocean Engineering		Flood defence	X	X	X	X	X		
Environment			Environment		X	X	X	X		
Environmental pollution			Environmental pollution	X	X	X	X	X		
Environmental sciences	Corporate social responsibility and environmental management	Corporate social responsibility and environmental management	Corporate social responsibility and environmental management	X	X			X	X	X
Environmental sciences	Earth observation	Remote sensing and gis	Environmental health and ecosystem functioning	X	X			X		
Environmental sciences	Ecology	Agriculture ecosystems and environment	Agriculture ecosystems and environment	X		X				
Environmental sciences	Ecology	Aquatic ecosystems	Aquatic ecosystems							
Environmental sciences	Ecology	Aquatic ecosystems	Aquatic ecosystems							
Environmental sciences	Ecology	Aquatic ecosystems	Aquatic ecosystems							
Environmental sciences	Ecology	Biodiversity and conservation	Biodiversity and conservation							
Environmental sciences	Ecology	Ecohydrology	Ecohydrology							
Environmental sciences	Ecology	Ecological informatics and modelling	Ecological informatics and modelling							
Environmental sciences	Ecology	Ecology evolution and systematics	Ecology evolution and systematics							
Environmental sciences	Ecology	Systems ecology	Systems ecology							
Environmental sciences	Environmental / resources management	Environmental law	Environmental protection & pollution control	X	X			X	X	X
Environmental sciences	Environmental / resources management	Protection	Environmental protection & pollution control	X						
Environmental sciences	Environmental / resources management	Water resources	Environmental health and ecosystem functioning	X	X	X	X	X	X	X
Environmental sciences			Sustainability in mining	X	X	X	X	X	X	X

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Environmental sciences			Climatology	X	X	X		X	X	
Environmental sciences			Ecosystem services and ecological infrastructure	X	X			X	X	
Environmental sciences			Water science	X			X		X	
Environmental sciences			Water resource governance and management	X	X	X	X	X		
Geomembrane linings and covers for potable water storage			Geomembrane linings and covers for potable water storage		X	X	X	X	X	
Geosciences	Atmospheric Sciences	Climatology	Climate dynamics, resilience, adaptation	X	X			X	X	
Geosciences	Atmospheric Sciences	Meteorology	Weather and Forecasting	X	X	X		X		
Geosciences	Atmospheric Sciences	Meteorology	Agricultural Meteorology	X						
Geosciences	Atmospheric Sciences	Meteorology	Hydrometeorology							
Geosciences	Earth Sciences	Earth Science Informatics	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X	X			X		
Geosciences	Earth Sciences	Geology	Environmental health and ecosystem functioning	X						
Geosciences	Earth Sciences	Geomorphology	Environmental health and ecosystem functioning							
Geosciences	Earth Sciences	Ichthyology	Water quality monitoring, ecosystem functioning, environmental water quality, animal health							
Geosciences	Earth Sciences	Mineralogy	Environmental health and ecosystem functioning							
Geosciences	Geography		Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health							
Geosciences	Hydrology	Ecohydrology	Ecohydrology	X						
Geosciences	Hydrology	Subsurface hydrology	Subsurface hydrology	X			X		X	
Geosciences	Hydrology	Subsurface hydrology	Hydrology	X	X	X		X		
Geosciences	Hydrology	Subsurface hydrology	Contaminant hydrology	X						
Geosciences	Hydrology	Subsurface hydrology	Unsaturated zone							
Geosciences	Hydrology	Surface hydrology	Catchment hydrology	X		X	X		X	
Geosciences	Hydrology	Surface hydrology	Land surface hydrology	X					X	
Geosciences	Hydrology	Surface hydrology	Hydrometeorology	X						

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Geosciences	Limnology		Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health							
Geosciences	Oceanography		Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health							
Geosciences			Water Resources Management	X	X	X		X	X	X
Governance			Governance		X			X		
Health			Health	X	X	X	X	X		
Hydrology and Water Resources			Hydrology and Water Resources	X	X	X	X	X		
Hydrometeorology			Hydrometeorology	X	X	X		X	X	
Immunology	Health-related microbiology	Bacteriology	Animal, human, public, and environmental health	X			X			
Immunology	Health-related microbiology	Mycology	Animal, human, public, and environmental health	X						
Immunology	Health-related microbiology	Virology	Animal, human, public, and environmental health	X			X			
Integrated water resources management (IWRM)			Integrated water resources management (iwrm)	X	X	X	X	X		
Local government			Local government		X			X		X
Management			Management							
Materials science	Materials safety	Emerging engineered nanomaterials	Wastewater and potable treatment, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Materials science	Materials safety	Toxicity of engineered materials	Animal, human, public, and environmental health	X						
Membrane technology			Membrane technology	X		X	X		X	
Microbiology	Health-related microbiology	Beneficial microbes	Animal, human, public, and environmental health	X						
Microbiology	Health-related microbiology	Pathogens and parasites	Animal, human, public, and environmental health	X						
Microbiology	Wastewater treatment	Biological processes	Wastewater treatment	X		X	X		X	
Microbiology	Water treatment	Biological processes	Water treatment	X		X	X		X	
Microbiology	Water treatment	Oxidation and disinfection	Public health	X		X	X		X	
Microbiology			Water and Wastewater Microbiology				X		X	

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Mining hydrogeology			Mining hydrogeology	X	X	X	X	X	X	X
Molecular Biology and Genetics	Biomolecular engineering	Advanced biological processes	Wastewater and potable treatment	X						
Molecular Biology and Genetics			Waterborne Pathogen characterisation	X	X		X	X		
Molecular Biology and Genetics			Ecosystem functioning and health	X			X			
Ocean wave power			Ocean wave power	X	X	X	X	X	X	
Om rural water services			Om rural water services	X			X		X	
Pharmacology & toxicology	Water treatment	Chemicals and materials safety	Wastewater and potable treatment	X			X			
Pharmacology & toxicology			Enzymes	X			X			
Plant and Animal Science	Aquaculture and Ichthyology	Aquaculture Research	Improved food security	X						
Plant and Animal Science	Aquatic biology	Aquatic Biology	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Plant and Animal Science	Botany	Aquatic Botany	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Plant and Animal Science	Entomology	Applied Entomology	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health							
Plant and Animal Science	Entomology	Aquatic Insects	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Plant and Animal Science	Herpetology	Applied Herpetology	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health							
Plant and Animal Science	Living resources	Aquatic Living Resources	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Plant and Animal Science	Mammalian biology	Aquatic Mammals	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Plant and Animal Science	Microbial ecology	Aquatic Microbial Ecology	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Plant and Animal Science	Toxicology	Aquatic Toxicology	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X						
Public participation			Public participation		X			X		
River Basin management			River Basin management	X	X	X	X	X		
Sanitation			Sanitation		X	X	X	X		X
Social Science and Humanities	Anthropology		Human, public, and environmental health	X	X		X	X		
Social Science and Humanities	Communications	Science Communication	Education	X	X	X	X	X	X	X
Social Science and Humanities	Development Studies				X			X		
Social Science and Humanities	Education	Agriculture	Education		X			X		
Social Science and Humanities	Education	Science Education	Education	X	X	X		X		
Social Science and Humanities	Gender Studies				X			X		
Social Science and Humanities	History				X			X		
Social Science and Humanities	Law			X	X	X	X	X		
Social Science and Humanities	Library and information science	Digital records management and archival studies								X
Social Science and Humanities	Philosophy		Bioethics	X						
Social Science and Humanities	Political Science	International Relations		X	X	X		X		
Social Science and Humanities	Political Science	Public Administration		X	X	X	X	X	X	X
Social Science and Humanities	Political Science	Public Policy		X	X		X	X	X	X
Social Science and Humanities	Political Science	Security Studies		X	X	X		X		
Social Science and Humanities	Public Health	Health Planning	Human, public, and environmental health	X	X		X	X	X	

Discipline level 1	Discipline level 2	Discipline level 3	Research focus area / field of research	Sources	Governance, Planning & Management – Supply	Infrastructure	Op performance	Governance, Planning & Management – Demand	Productive use	Pricing, monitoring, billing
Social Science and Humanities	Public Health	Population Health Management	Human, public, and environmental health	X	X			X		
Social Science and Humanities	Public Health	Population Health Management	Human, public, and environmental health		X			X		
Social Science and Humanities	Sociology			X	X			X		X
Space science	Land observation and remote sensing	Land use	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X	X	X		X		X
Space science	Land observation and remote sensing	Pollution detection and control	Water quality monitoring, ecosystem functioning, environmental water quality, animal, human, public, and environmental health	X		X				
Sustainability			Sustainability	X	X	X	X	X		
Water and wastewater treatment			Water and wastewater treatment			X	X		X	
Water infrastructure development			Water infrastructure development	X		X	X		X	
Water quality and water resources			Water quality and water resources	X	X	X		X	X	X
Water science management, policy and legislations			Water science management, policy and legislations	X	X			X		
Oceanography	Wave and tidal energy	Wave powered desalination	Wave powered desalination	X	X	X	X	X	X	

APPENDIX D: DEGREE OF DIFFUSION IN RESEARCH FOCUS AREAS, CATEGORISED BY CLUSTER AND SECTOR

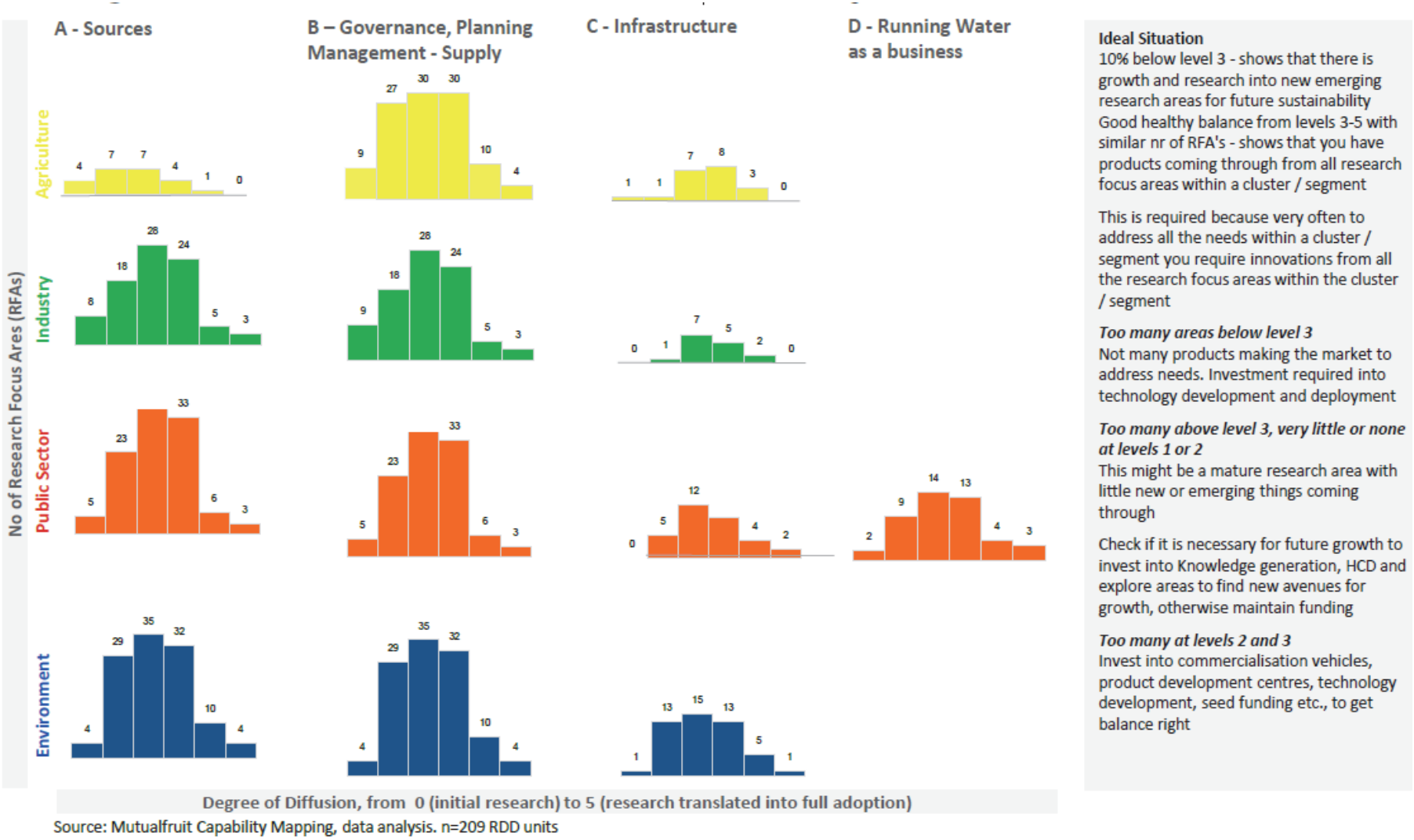
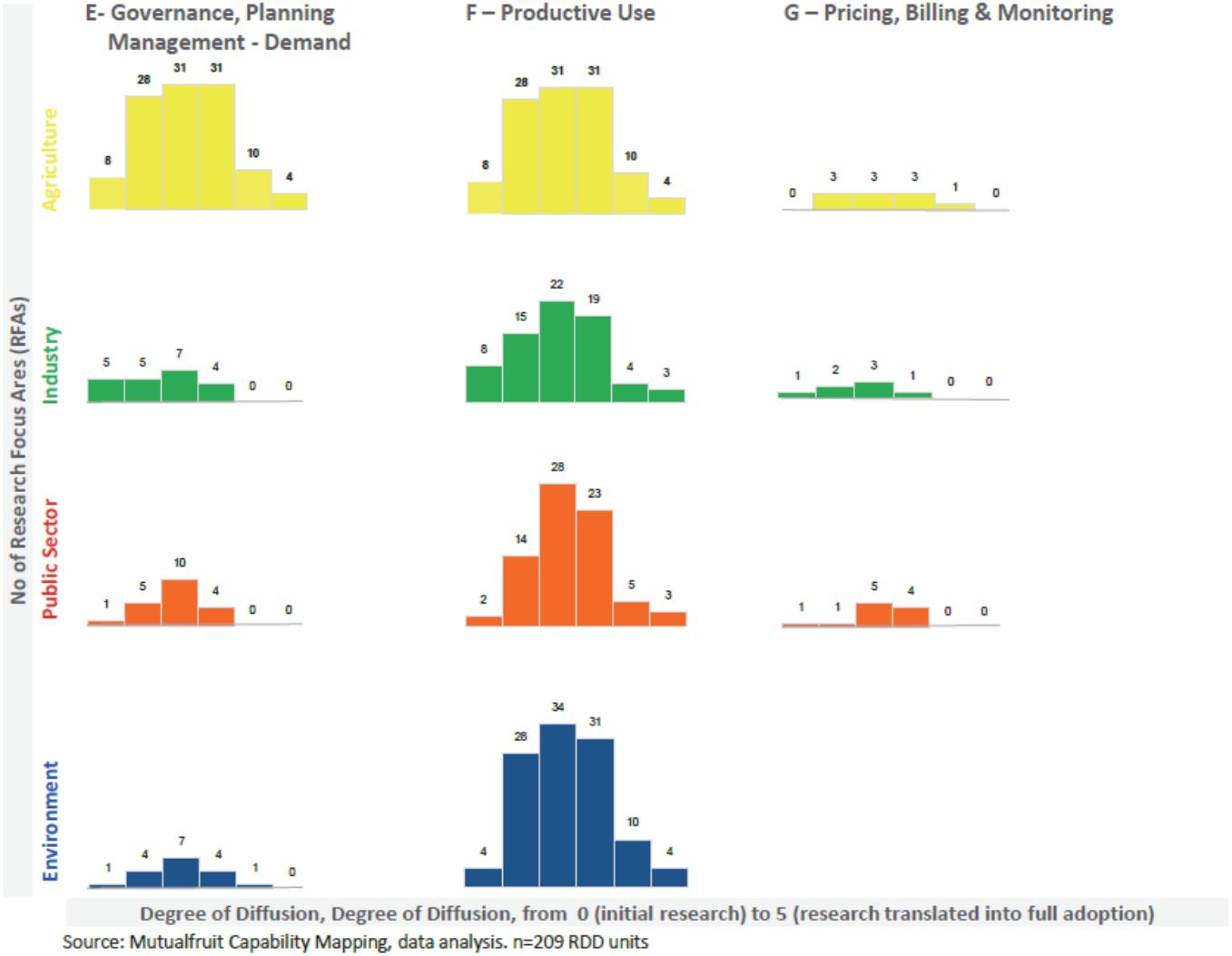


Figure D1: Degree of diffusion in water supply Clusters



Source: Mutualfruit Capability Mapping, data analysis. n=209 RDD units

Ideal Situation
10% below level 3 - shows that there is growth and research into new emerging research areas for future sustainability
Good healthy balance from levels 3-5 with similar nr of RFA's - shows that you have products coming through from all research focus areas within a cluster / segment

This is required because very often to address all the needs within a cluster / segment you require innovations from all the research focus areas within the cluster / segment

Too many areas below level 3
Not many products making the market to address needs. Investment required into technology development and deployment

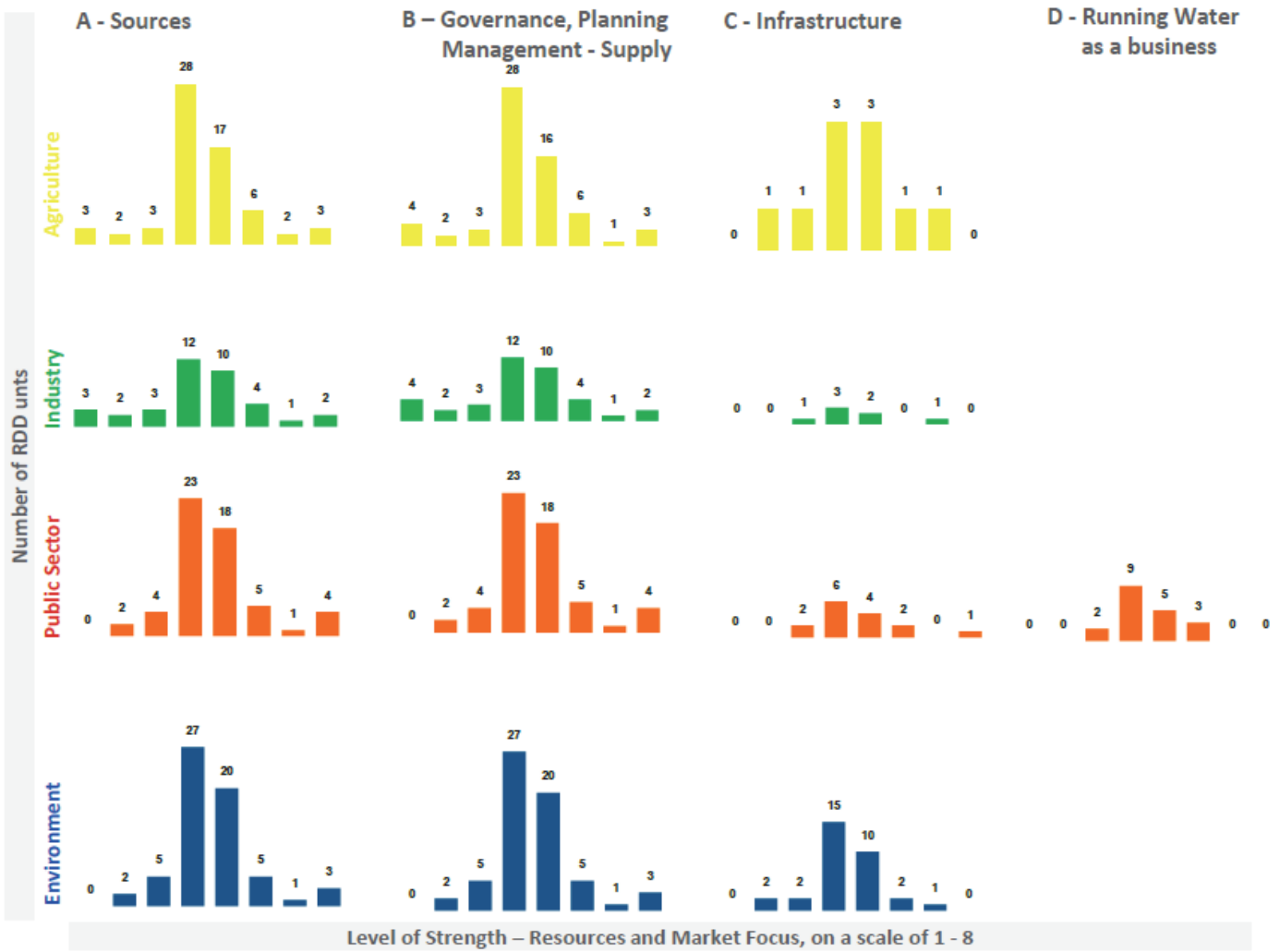
Too many above level 3, very little or none at levels 1 or 2
This might be a mature research area with little new or emerging things coming through

Check if it is necessary for future growth to invest into Knowledge generation, HCD and explore areas to find new avenues for growth, otherwise maintain funding

Too many at levels 2 and 3
Invest into commercialisation vehicles, product development centres, technology development, seed funding etc., to get balance right

Figure D2: Degree of diffusion in water demand Clusters

APPENDIX E: LEVEL OF RESEARCH STRENGTH OF INSTITUTES, CATEGORISED BY CLUSTER AND SECTOR



Source: Mutualfruit Capability Mapping, data analysis. n=209 RDD units

Ideal Situation

20% below level 4 - This shows that there are growth, meaning new institutions starting to work in this area

50% from levels 4 - 6 - Means that majority of institutions are at a building level

30% above level 7 - Meaning there is enough research at a strong enough level to address market needs.

Interventions

Ideal situation - Maintain levels of funding, use know-how sheets to see if products are being diffused into the market. Investment into things like seed funding, partnerships, technology development. Use capability map to invest into institutions with strength level below 4 to maintain pipeline.

Too many institution below level 4, with few at levels 7 and above

Investment into Knowledge generations, HCD, Research chairs required. Use capability map to understand which research focus areas to invest in and at which institutions to invest in.

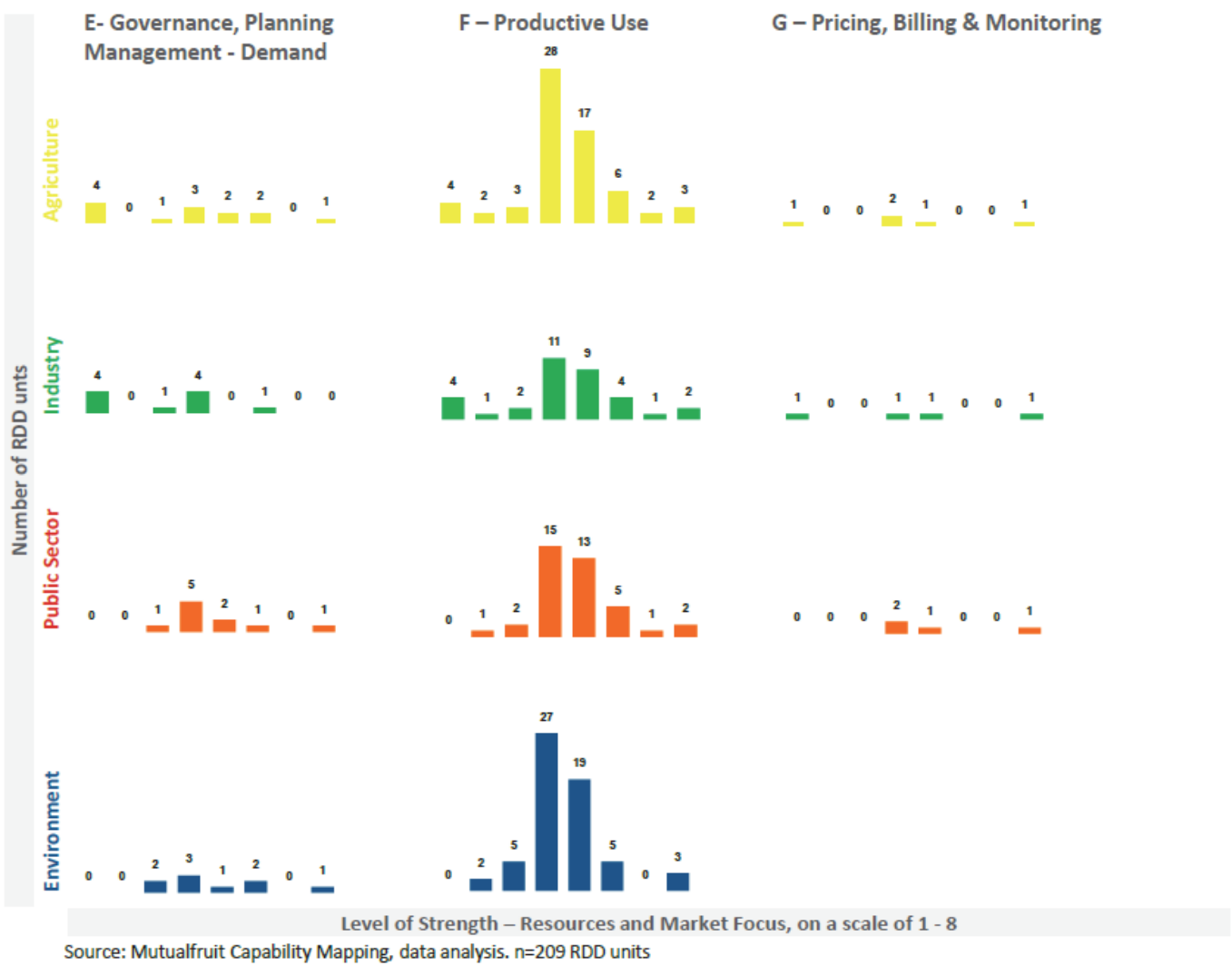
Too many institutions above level 7

Check if there is growth, some investment might be required at institutions outside of the normal big institutions (eg. previously disadvantages institutions). Capability map will identify which institutions.

Too many at mid level (4-6)

Check if funding is sufficient to grow the strength of institutions. Some alignment and focus of research might be required to ensure increase in strength levels and assist in bringing resources together. Targeted Research Programmes are likely instruments.

Figure E1: Level of strength in water supply Clusters



Source: Mutualfruit Capability Mapping, data analysis. n=209 RDD units

Ideal Situation
20% below level 4 - This shows that there are growth, meaning new institutions starting to work in this area
50% from levels 4 - 6 - Means that majority of institutions are at a building level
30% above level 7 - Meaning there is enough research at a strong enough level to address market needs.

Interventions
Ideal situation - Maintain levels of funding, use know-how sheets to see if products are being diffused into the market. Investment into things like seed funding, partnerships, technology development. Use capability map to invest into institutions with strength level below 4 to maintain pipeline.

Too many institution below level 4, with few at levels 7 and above
Investment into Knowledge generations, HCD, Research chairs required. Use capability map to understand which research focus areas to invest in and at which institutions to invest in.

Too many institutions above level 7
Check if there is growth, some investment might be required at institutions outside of the normal big institutions (eg. previously disadvantages institutions). Capability map will identify which institutions.

Too many at mid level (4-6)
Check if funding is sufficient to grow the strength of institutions. Some alignment and focus of research might be required to ensure increase in strength levels and assist in bringing resources together. Targeted Research Programmes are likely instruments.

Figure E2: Level of strength in water demand Clusters

APPENDIX F: IMPACT ANTICIPATED, BASED ON FIVE IMPACT AREAS – SUMMARY

The Impact Assessment Framework used required assessment of anticipated impacts in a set of nine areas:

Water Scarcity	**Produces positive net basin impact, via:**
	Reduced withdrawal
	Reduced consumption
	Improved water quality
	Improved productivity of use
Economic	**Wealth**
	Number of businesses created, sustained and grown
	Number of jobs created or sustained
	Productivity
	Increased product per drop (WUE: tonnes/ ton of water)
	Increased crop yield per drop
	Reduced down-time (eg caused by maintenance)
	Revenue
	Increased average revenues per unit product and per m3 delivered
	Increased average revenue per producer (eg farmer, ecosystem, environment)
	Cost reduction
	Decreased water footprint per unit produced
	Reduced material inputs (and cost)
	Reduced energy inputs (and cost)
	Reduced labour requirement (and cost)
	Reduced cost of healthcare
	Investment
	Reduced capex requirements
	Reduced maintenance costs
Health	Reduced incidence of water-borne sickness and disease
	Reduced incidence of sickness and disease from air pollution
	Reduced incidence of sickness and disease from chemical contaminants
	Reduced absenteeism and early retirement - through increased wellness
	Reduced mortality rate
Society	Improved availability and quality of environmental goods and services
	Increased food security - livestock, crops
	Reduced loss of animals
	Increased school attendance (driven by access and quality) and improved educational outcomes
	Improved relations between all suppliers and consumers in a catchment (eg WUAs and farmers)
	Satisfaction of rights and demands of those without access to water
	Reduced environmental debt
	Raised awareness of the value of water, driving increased willingness to pay
Environment	Reduction in carbon emissions
	Reduction in area of salinised land
	Reduced levels of groundwater contamination
	Reduced cost of treating process water and potable water
	Reduced contamination of surface water
	Reduced downstream pollution
	Reduced loss of nutrients from fields
	Reduced levels of soil erosion
	Reduced or reversed decline in biodiversity
	Preservation of riverine habitants
	Improved health of terrestrial environment

Table F1: Impact assessment: Water Scarcity

	Reduced withdrawal	Reduced consumption	Improved water quality	Improved productivity of use	**Overall score /10**
Increase ability to make use of more sources of water, including alternatives	1	1	1	1	**10**
Improve governance, planning and management of supply and delivery	1	0	0	1	**5.0**
Improve adequacy and performance of supply infrastructure	1	1	0	1	**7.5**
Run water as a financially sustainable "business" by improving operational performance	1	1	1	1	**10**
Improve governance, planning, and management of demand and use	1	0	1	1	**7.5**
Reduce losses and increase efficiency of productive use	1	1	0	1	**7.5**
Improve performance of pricing, monitoring, billing, metering and collection	1	1	0	1	**7.5**

A 0 in the box for a sub-area / cluster combination indicates that no impact is anticipated, whereas a 1 indicates that an impact in the area is anticipated. (The nature and extent of the impact was not required for this framework). The proportion of sub-areas in which impact was anticipated was then used to provide the overall score.

For example, the top row indicates that implementing the interventions listed under the cluster of needs, *Increase ability to make use of more sources of water, including alternatives*, was anticipated to make an impact in all four areas under Water Scarcity. Since all four boxes contain a 1, the overall score is 4/4 = 10/10. The interventions to meet the needs listed in the cluster, *Improve performance of pricing, monitoring, billing, metering and collection*, were anticipated to make impacts in three of the four areas, so the overall score was 3/4 = 7½/10.

Table F2: Impact assessment: Economic

	Wealth	Productivity	Revenue	Cost reduction	**Overall score /10**
Increase ability to make use of more sources of water, including alternatives	1	1	1	1	**10**
Improve governance, planning and management of supply and delivery	1	1	0	1	**7.5**
Improve adequacy and performance of supply infrastructure	1	1	1	1	**10**
Run water as a financially sustainable "business" by improving operational performance	1	1	1	1	**10**
Improve governance, planning, and management of demand and use	1	1	0	1	**7.5**
Reduce losses and increase efficiency of productive use	0	1	1	1	**7.5**
Improve performance of pricing, monitoring, billing, metering and collection	1	1	1	1	**10**

Table F3: Impact assessment: Health

	Reduced incidence of water-borne sickness and disease	Reduced incidence of sickness and disease from air pollution	Reduced incidence of sickness and disease from chemical contaminants	Reduced absenteeism and early retirement – through increased wellness	Reduced mortality rate	**Overall score /10**
Increase ability to make use of more sources of water, including alternatives	0	0	0	0	0	0
Improve governance, planning and management of supply and delivery	1	0	0	1	1	6
Improve adequacy and performance of supply infrastructure	1	1	1	1	1	10
Run water as a financially sustainable "business" by improving operational performance	1	0	0	1	1	6
Improve governance, planning, and management of demand and use	1	0	0	1	1	6
Reduce losses and increase efficiency of productive use	0	0	0	0	0	0
Improve performance of pricing, monitoring, billing, metering and collection	0	0	0	0	0	0

Table F4: Impact assessment: Society

	Improved availability and quality of environmental goods and services	Increased food security – livestock, crops	Reduced loss of animals	Increased school attendance (driven by access and quality) and improved educational outcomes	Improved relations between all suppliers and consumers in a catchment (e.g. WUAs and farmers)	Satisfaction of rights and demands of those without access to water	Reduced environmental debt	Raised awareness of the value of water, driving increased willingness to pay	**Overall score /10**
Increase ability to make use of more sources of water, including alternatives	1	1	1	0	1	1	1	0	**7.5**
Improve governance, planning and management of supply and delivery	0	1	1	1	1	1	1	1	**9**
Improve adequacy and performance of supply infrastructure	1	1	1	1	1	1	1	1	**10**
Run water as a financially sustainable "business" by improving operational performance	1	1	1	1	0	1	1	1	**9**
Improve governance, planning, and management of demand and use	1	1	1	1	1	1	1	1	**10**
Reduce losses and increase efficiency of productive use	1	0	0	0	1	1	1	0	**5**
Improve performance of pricing, monitoring, billing, metering and collection	0	0	0	0	1	1	1	1	**5**

Table F5: Impact assessment: Society

	Reduction in carbon emissions	Reduction in area of salinised land	Reduced levels of groundwater contamination	Reduced cost of treating process water and potable water	Reduced contamination of surface water	Reduced downstream pollution	Reduced levels of soil erosion	Reduced or reversed decline in biodiversity	Preservation of riverine habitants	Improved health of terrestrial environment	**Overall score /10**
Increase ability to make use of more sources of water, including alternatives	1	1	1	1	1	1	0	1	1	1	**9**
Improve governance, planning and management of supply and delivery	0	1	1	1	1	1	0	0	0	1	**6**
Improve adequacy and performance of supply infrastructure	1	1	1	1	1	1	1	1	1	1	**10**
Run water as a financially sustainable "business" by improving operational performance	1	0	1	1	1	1	1	0	0	0	**6**
Improve governance, planning, and management of demand and use	1	1	1	1	1	1	1	1	1	1	**10**
Reduce losses and increase efficiency of productive use	1	0	1	1	1	1	0	0	1	1	**7**
Improve performance of pricing, monitoring, billing, metering and collection	1	0	0	1	1	1	0	0	0	0	**4**

APPENDIX G: NATIONAL RESEARCH FOUNDATION VALUES FOR RESEARCH HUMAN CAPACITY

G.1 EXCERPTS FROM "FUNDING YOUR RESEARCH FUTURE"

(NRF, 2014. Available at http://www.nrf.ac.za/sites/default/files/documents/Funding%20your%20Research%20Future%20NRF%20Bursary%2C%20Scholarships%20Value%20Rules%20and%20G....pdf (Accessed 11 November 2014).

a. NRF Freestanding Scholarships and Fellowships

This funding instrument is supported through funding from the NRF core parliamentary grant and has been made available to support honours, masters, doctoral and postdoctoral candidates. The aim of the funding instrument is to contribute towards increasing the number and quality of South African postgraduate students and fellows as well as provide support for doctoral and postdoctoral candidates to pursue studies abroad.

In South Africa	Value (p.a.)	Duration
Honours/Final-year BTech (Block grant)	R 20 000	1 year
Master's degree (Block grant)	R 40 000	2 years
Doctoral degree	R 60 000	3 years
Postdoctoral Fellowship	R 140 000	
Contribution towards running expenses	R 10 000	3 years
Abroad	**Value (p.a.)**	**Duration**
Doctoral degree	US$ 22 000	4 years
Postdoctoral Fellowship	US$ 24 000	3 years

Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 40 000	1 year
Master's degree	R 70 000	2 years
Doctoral degree	R 100 000	3 years
Postdoctoral Fellowships	R 220 000	
Contribution towards running expenses	R 45 000	3 years

PLEASE NOTE:

A once-off travel grant is awarded to Scarce Skills masters, doctoral and postdoctoral award-holders during the tenure of their award and upon completion and approval of a travel grant application. The conditions as stipulated in the NRF Guidelines on Travel are applicable. Master's award-holders are entitled to R15 000 for local or international travel. Doctoral award-holders are entitled to R15 000 for local travel and R50 000 for international travel. Postdoctoral Fellows are entitled to R25 000 for local travel and R50 000 for international travel.

c. DST Funded Innovation Scholarships and Fellowships

This funding instrument is supported through funding from the Department of Science and Technology (DST). Funding has been made available to support honours, masters, doctoral and postdoctoral candidates. The aim of the funding instrument is to contribute towards the pipeline of next generation researchers and to stimulate the knowledge economy through research and development in the country.

Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 50 000	1 year
Master's degree	R 80 000	2 years
Doctoral degree	R 110 000	3 years
Postdoctoral Fellowships	R 265 000	
Contribution towards running expenses	R 50 000	3 years

d. DAAD-NRF Joint In-Country Scholarships

DAAD Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

The German Academic Exchange Services (DAAD) in partnership with the NRF offers Joint In-Country scholarships for postgraduate students in South Africa studying towards a master's or doctoral degree. The programme is co-funded by the German Federal Ministry of Economic Cooperation and Development (BMZ). The aim of this programme is to increase the number of postgraduate candidates receiving quality education and training and contributing towards national efforts of human capital development in the country. The programme also focuses on staff development at doctoral level to build capacity within South African tertiary institutions. Supported students can also apply to DAAD for collaboration and training at any German university under the programme.

Scholarships	Value (p.a.)	Duration
Master's degree	R 70 000	2 years
Doctoral degree	R 90 000	3 years

e. Renewable & Sustainable Energy Scholarships

science and technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

This funding support focus is to provide scholarship grants at master's and doctoral levels focusing on research studies that support and facilitate the shift towards a sustainable energy sector. In line with the draft DST energy research focal areas, the scholarships are offered to candidates that do or want to do research on the following focus areas:

- Cleaner fossil fuel development, including clean coal technologies;
- Renewable energy (bioenergy including bio-fuels, solar energy, wind energy, etc.);
- Energy impact on the environment;
- Energy for socio-economic development;
- Energy system planning and modelling; and
- Energy policy research.

Scholarships	Value (p.a.)	Duration
Master's degree	R 85 000	2 years
Doctoral degree	R 100 000	3 years

f. SANHARP Scholarships

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

SANHARP aims at supporting the government's vision to expand nuclear energy in the South African energy mix by building skills for the nuclear sector. The programme was established by the Department of Science and Technology. The skills advancement ranges from basic and applied research and engineering disciplines to manufacturing and distinctive aspects of waste management. The strategy also looks at other nuclear applications like isotopes and radiopharmaceutical production, food preservation, material research, amongst others. The funding instrument supports undergraduate students until doctoral studies if they wish to continue under the programme towards capacity development.

Degree	Value (p.a.)	Duration
Undergraduate bursaries	Funding adjusted depending on Institution	3 years
Honours/Final year BTech degree		1 year
Master's degree	R 85 000	2 years
Doctoral degree	R 100 000	3 years

g. THRIP/NSTF Bursaries

Funds for this funding instrument are provided by the department of Trade and Industry (**the DTI**). THRIP-NSTF bursaries provide funding to students who are from the NSTF Brilliants Programme. The NSTF collects grade 12 national results annually and find sponsors for the top 18 students in the country. THRIP is one of the funders of the Brilliants who conduct undergraduate and Honours studies in Science, Engineering and Technology studies at HEIs.

Degree	Value (p.a.)	Duration
First-year undergraduate SET students	R 80 000	3 years
B Tech / Honours	R 80 000	1 year

h. Professional Development Programme (PDP)

science and technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

This funding instrument is supported through funding from the Department of Science and Technology (DST). Funding has been made available to address the challenges around human capital development within the National System of Innovation (NSI). The initial focus of the programme is on Science Councils, National Facilities and Research Museums. The programme objectives are to build capacity with the hosting institutions in relevant science and technology related skills development. The programme is modelled on a work preparation programme for masters and doctoral graduates that want to pursue careers in research to experience the workplace in a research environment and their skills and consequently improve their prospects of permanent employment in the science and technology system. In addition the programme attracts and retains young scientists and professionals of high caliber in the science and technology systems.

Degree	Value (p.a.)	Duration
Doctoral Position Minimum contribution from Science Council/National Facilities/Research Institutions towards research running and other indirect costs	R 210 000 R 70 000	3 years
Postdoctoral Position Minimum contribution from Science Council/National Facilities/Research Institutions towards research running and other indirect costs	R 315 000 R 100 000	2 years

j. Support for completing Part-time Doctoral Students

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

This funding instrument provides support to final year doctoral students studying on a part-time basis towards their degrees. Applicants must have registered part-time for a doctoral degree at a South African higher education institution and towards completion of the study. Applicants may apply for up to 12 months of support under the programme; however funding values are related with their leave period indicated by their employer. The aim of this programme is to assist working individuals towards the completion of their doctoral degree

Scholarships	Value (p.m.)	Duration
Support for completing part-time doctoral students	R 10 000 per month based on period of leave indicated by employer	1 year

k. Research Career Advancement Fellowships

The Department of Science and Technology (DST) has made available funding for Research Career Advancement Fellowships in order to strengthen research capacity and scientific research leadership in Science, Engineering and Technology by creating positions for senior postdoctoral fellows who have shown interest in furthering careers in research and academia and have demonstrated the potential and ability for research leadership. This is a lucrative funding award that allows talented emerging researchers to pursue a career in research and allows emerging researchers to be mentored and groomed by senior researchers. This development programme allows the emerging researchers to strengthen their research track record and become independent researchers.

Research Position	Value (p.a.)	Duration
Research Career Advancement Fellowship	R 350 000	
Contribution towards running expenses	R 100 000	5 years

Category	Honours	Masters	Doctoral	Postdoctoral Research
Bursary/Fellowship	R 50 000	R 80 000	R 110 000	R 265 000
Local travel		R 10 000	R 15 000	R 25 000
International travel			R 50 000	R 50 000
	Infrastructure and Operational costs (40%)			
Infrastructure	Small to medium-sized equipment costing no more than R 200 000			
Operational Costs	Science communication and outreach activities			

PLEASE NOTE:

The requested budget (human capital development, Infrastructure and Operational costs) under this programme cannot exceed R1 million.

m. NRF- MRC Health and Allied Scholarship

The National Research Foundation (NRF) and South African Medical Research Medical (MRC) entered into a partnership in delivering the masters and doctoral scholarships programme in the health, allied sciences and related fields at public higher education institutions in 2014. The programme is intended to contribute to the production of high-quality human resources, generation of high-quality knowledge, as well as the development and transfer of this knowledge to ensure tangible benefits to society especially in the health and allied research. Areas of support are Biochemistry, Pharmacology, Toxicology, Molecular Modelling, Medical Sciences, Immunology and all other disciplines aligned to health and allied sciences in general.

Scholarships	Value (p.a)	Duration
Master's Scholarships	R 80 000	2 year
Doctoral Scholarships	R 110 000	2 years

Type of Travel Grant	Value of Award	How to Apply
NRF Free-standing Masters Travel Grant	R 5 000	For an application form, contract your financial aid bursary/postgraduate office of the institution where you are based.
NRF Free-standing Doctoral Travel Grant	R 5 000	
NRF Free-standing Postdoctoral Travel Grant	R 15 000 (local) R 45 000 (abroad)	
DST Innovation Fund Masters Travel Grant	R 10 000 (local or abroad)	
Scarce Skills Development Fund Masters Travel Grant	R 15 000 (local or abroad)	
DST Innovation Fund Doctoral Travel Grant	R 15 000 (local) R 45 000 (abroad)	
Scarce Skills Development Fund Doctoral Travel Grant	R 15 000 (local) R 50 000 (abroad)	
DST Innovation and Scarce Skills Development Fund Postdoctoral Travel Grant	R 25 000 (local) R 45 000 (abroad)	

Number of years for obtaining undergraduate degree	Final Year Undergraduate Student Assistantships	Honours bursary
4	3rd year	4th year
5	4th year	5th year
6	5th year	6th year

Such nominations must be accompanied by a motivation, signed by the grantholder, confirming that the:

a) Particular undergraduate degree comprises of (number of) years and that is not followed by an Honours qualification;

b) Student has not failed any of the preceding academic years; and

c) Student is currently in the (state year, eg. 3rd) year of the undergraduate degree

- Masters and Doctoral bursaries are awarded according to the following ratios: 87% South African (including permanent resident), 5% SADC, 4% rest of African continent and 4% from non-African countries.
- Postdoctoral Fellowships: No ratio applies.
- Staff Development Grants: Only for South African staff members at a recognised South African research institution.

a) Blue Skies, Thuthuka, Competitive Programme for Rated Researchers, Competitive Support for Unrated Researchers and Nanotechnology Flagship Programme Funding Instruments

Full-time Student Assistantships	Value (p.a.)	Duration
Final year undergraduate degree/diploma	R 8 000	1 year
Honours/Final year BTech degree	R 20 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 40 000	2 years
Doctoral degree	R 60 000	3 years
Part-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 10 000	3 years
Doctoral degree	R 12 000	5 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 150 000 (pro rata per month)	3 years
Staff Development Grants	**Value (p.a.)**	**Duration**
Master's/Doctoral degree	Maximum R 30 000* 3 years (M)	5 years (PhD)
*Depending on nature of research and proximity of student to supervisor.		

b. South African National Antarctic Programme

Full-time Studentships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 30 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 40 000	2 years
Doctoral degree	R 65 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 150 000 (pro rata per month)	3 years
Staff Development Grants	**Value (p.a.)**	**Duration**
Master's/Doctoral degree	Maximum R 30 000*	3 years (M)
		5 years (PhD)
*Depending on nature of research and proximity of student to supervisor.		

c. Indigenous Knowledge Systems

Full-time Studentships	Value (p.a.)	Duration
Final year undergraduate degree/diploma	R 25 000	1 year
Honours/Final year BTech degree	R 35 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 60 000	2 years
Doctoral degree	R 90 000	3 years
Part-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 30 000	3 years
Doctoral degree	R 45 000	5 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 160 000 (pro rata per month)	3 years
Staff Development Grants	**Value (p.a.)**	**Duration**
Master's/Doctoral degree	Maximum R 45 000*	3 years (M)
		5 years (PhD)
*Depending on nature of research and proximity of student to supervisor.		

d. African Origins Programme

The Early Career Grants are comprised of a stipend and research running costs as follows:

Level Stipend allocation	Value (p.a)	Research costs Value (p.a)
Doctoral degree (3 years)	R 100 000	R 50 000
Postdoctoral fellowship (2 years)	R 150 000	R 75 000

PLEASE NOTE:

- The stipend will be managed as a scholarship, which will be awarded to the nominated candidate. The Principal Investigator will nominate the ECR candidate on the NRF system and then allocate the funds to the candidate.
- The research costs component will be ring-fenced for the sole use by the candidate, but held by the PI against their research grant

Full-time Studentships	Value (p.a.)	Duration
Honours	R 25 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 40 000	2 years
Doctoral degree	R 65 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 150 000 (pro rata per month)	3 years

e. African Coelacanth Ecosystems Programme

Full-time Studentships	Value (p.a.)	Duration
Honours	R 20 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 50 000	2 years
Doctoral degree	R 80 000	3 years
Part-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R12 000	3 years
Doctoral degree	R 12 000	5 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 100 000 (pro rata per month)	3 years

f. Global Change, Society & Sustainability Programme

Full-time Bursaries	Value (p.a.)	Duration
Master's degree	R 80 000	2 years
Doctoral degree	R 120 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 200 000 (pro rata per month)	3 years

g. Multi-wavelength Astronomy Programme

Full-time Studentships	Value (p.a.)	Duration
Honours	R 30 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 40 000	2 years
Doctoral degree	R 65 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 150 000 (pro rata per month)	3 years

h. Education Research in South Africa

Full-time Studentships	Value (p.a.)	Duration
Final year undergraduate degree/diploma	R 8 000	1 year
Honours/Final year BTech degree	R 20 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 40 000	2 years
Doctoral degree	R 60 000	3 years
Part-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 20 000	3 years
Doctoral degree	R 30 000	5 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 150 000 (pro rata per month)	3 years

i. South African Research Chairs Initiative (SARChI)

Full-time Studentships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 40 000	1 year
Full-time Bursaries	**Value (p.a.)**	**Duration**
Master's degree	R 70 000	2 years
Doctoral degree	R 100 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 200 000	3 years

SKA SARCHI Chairs				
Year	**2014**	**2015**	**2016**	**2017**
Bursaries				
Undergraduate degree	R 93 000	R 95 000	R 97 000	R 99 000
Honours degree	R 93 000	R 95 000	R 97 000	R 99 000
Undergraduate	R 93 000	R 95 000	R 97 000	R 99 000
Master's degree	R 90 000	R 92 000	R 95 000	R 97 000
Doctoral degree	R 115 000	R 117 000	R 119 000	R 121 000
Postdoctoral Fellowships	R 325 000	R 327 000	R 330 000	R 332 000

Equipment Grants				
Masters Students- For students whose funding began prior to, and including, 2013. The amount for the equipment grant is per year for the duration of the MSc degree (maximum two years).	R 12 000	R 12 000	NA	NA
Masters Students - For students whose funding began in, and after, 2014. The amount for the equipment grant is a once off amount for full degree, paid in the first year of the MSc degree.	R 18 000	R 20 000	R 22 000	R 22 000
Doctoral Students - For students whose funding began prior to, and including, 2013. The amount for the equipment grant is per year for the duration of the PhD degree (maximum three years).	R 14 000	R 14 000	R 16 000	NA
Doctoral Students - For students whose funding began in, and after, 2014. The amount for the equipment grant is a once off amount for the full degree, paid in the first year of the PhD degree.	R 30 000	R 30 000	R 32 000	R 32 000
Postdoctoral Fellows - For postdoctoral fellows whose funding began prior to, and including, 2013. The amount for the equipment grant is per year for the duration of the fellowship (maximum three years).	R 17 500	R 17 500	R 18 500	NA
Postdoctoral Fellows - For postdoctoral fellows whose funding began in, and after, 2014. The amount for the equipment grant is a once off amount for the full fellowship, paid in the first year of the fellowship.	R 50 000	R 50 000	R 52 000	R 52 000
Travel Grants				
Master's Students	R 15 000	R 16 000	R 17 000	R 18 000
Doctoral Students	R 20 000	R 21 000	R 22 000	R 23 000
Postdoctoral Fellows	R 23 500	R 24 000	R 25 000	R 26 000

k. Centres of Excellence

Centres of Excellence (CoEs) are physical or virtual entities of research which concentrate existing capacity and resources to enable researchers to collaborate across disciplines and institutions on long-term projects that are locally relevant and internationally competitive in order to enhance the pursuit of research excellence and capacity development. The Centres of Excellence have the autonomy to determine their own bursaries values. The values published may vary between the centres. The values indicated may not necessarily be allocated to the students or fellows.

1. Catalysis (c*change)

Full-time Scholarships	Value (p.a.)	Duration
Master's degree	R 74 250	2 years
Doctoral degree	R 88 550	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 176 000	3 years

PLEASE NOTE:

c*change allows an additional 50% top-up from other sources, where appropriate. In the case of a top-up beyond the additional 50%, c*change will reduce its contribution pro rata.

2. Strong Materials

Full-time Scholarships	Value (p.a.)	Duration
Master's degree	R 100 000	2 years
Doctoral degree	R 115 000	3 years

3. Invasion Biology

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 40 000	1 year
Master's degree	R 70 000	2 years
Doctoral degree	R 100 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 200 000	3 years

4. TB Research

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 12 000	1 year
Master's degree	R 70 000	2 years
Doctoral degree	R 100 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 180 000	3 years

5. Birds as key to Biodiversity (Fitzpatrick)

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 20 000	1 year
Master's degree	R 90 000	2 years
Doctoral degree	R 120 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 180 000	3 years

6. Tree Health Biotechnology

Full-time Scholarships	Value (p.a.)	Duration
Final year/undergraduate degree/diploma	R 8 000	1 year
Honours/ Final year BTech degree	R 20 000	1 year
Master's degree	R 60 000	2 years
Doctoral degree	R 80 000	3 years

7. Epidemiological Modelling and Analysis

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 15 000	1 year
Master's degree	R 70 000	2 years
Doctoral degree	R 100 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 220 000	3 years

8. Applied Centre for Climate and Earth Systems

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 25 000	1 year
Master's degree	R 75 000	2 years
Doctoral degree	R 120 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 200 000	3 years

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9. National Institute for Theoretical Physics

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 40 000	1 year
Master's degree	R 70 000	2 years
Doctoral degree	R 100 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R180 000- R270 000	3 years

10. Palaeoscience

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 30 000	1 year
Master's degree	R 80 000	2 years
Doctoral degree	R 120 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 220 000	3 years

11. Indigenous Knowledge Systems

Full-time Scholarships	Value (p.a.)	Duration
Honours/Final year BTech degree	R 25 000	1 year
Master's degree	R 60 000	2 years
Doctoral degree	R 120 000	3 years
Postdoctoral Fellowships	**Value (p.a.)**	**Duration**
Postdoctoral Fellowships	R 220 000	3 years

G.2 EXCERPTS FROM "OVERVIEW OF NRF FUNDING OPPORTUNITIES, GRANT MANAGEMENT, AND THE RATING OF RESEARCHERS 2015 TO 2017"

(NRF, 2014. Available at http://www.nrf.ac.za/sites/default/files/documents/Overview%20of%20NRF%20Funding%20Opportunities%2C%20Grant%20Management%2C%20and%20the%20Rating%20..._0.pdf (Accessed 11 November 2014).

Table 5: Duration of awards

Broad Investment Area	Funding Instrument	Award cycles/years	Maximum number of cycles	Total support period/years
EVALUATION OF INDIVIDUALS		6	Unlimited	
NEXT GENERATION	Sabbatical Grants for the Completion of Doctoral Degrees	1	1	1
	Professional Development Programme Doctoral Support	2	1	2
	Student Support (Free-standing and Grantholder-linked) **Honours**	1	1	1
	Student Support (Free-standing and Grantholder-linked) **Master's**	2	1	2
	Student Support (Free-standing and Grantholder-linked) **Doctoral**	3	1	3
	Thuthuka: PhD Track	3	3	9
EMERGING RESEARCHERS	Competitive Support for Unrated Researchers	3	Unlimited	Reapply
	Nanotechnology Flagships Project	3	Unlimited	Reapply
	Postdoctoral Fellowships	2	1	2
	Professional Development Programme Postdoctoral Support	2	1	2
	Research Career Advancement Fellowships	5	1	5
	Thuthuka: Post-PhD Track	3	2	6
	Thuthuka: NRF Rating Track	3	2	6
	African Coelacanth Ecosystem Programme	3	Unlimited	Reapply
	African Origins Platform	3	Unlimited	Reapply
	Bio-informatics & Functional Genomics	3	Unlimited	Reapply
ESTABLISHED RESEARCHERS	Blue Skies Research	3	Unlimited	Reapply
	Collaborative Postgraduate Training Programme	3	1	3
	Community Engagement Programme	3	Unlimited	Reapply
	Competitive Programme for Rated Researchers	3	Unlimited	Reapply
	Education Research in South Africa	3	Unlimited	Reapply
	Energy Research Programme	5	Performance-based	Performance-based
	Global Change, Society and Sustainability Research Programme	3	Unlimited	Reapply
	Human Capital Development for Multi-Wavelength Astronomy	3	Unlimited	Reapply
	Incentive Funding for Rated Researchers	6	Duration of valid NRF rating	Duration of valid NRF rating
	Indigenous Knowledge Systems	3	Unlimited	Reapply
	International Research Grants	Varies	Unlimited	Reapply
	Knowledge Fields Development	Once-off grants (period linked to activity)		
	SA National Antarctic Programme	3	Unlimited	Reapply
	Research and Technology Fund	3	3	9
	Technology and Human Resources for Industry Programme	3	3	9
STRATEGIC INVESTMENT	Centres of Excellence	10	1	10
	Knowledge Interchange Collaborations	1	1	1
	South African Research Chairs Initiative	5	3	15
INFRASTRUCTURE	Equipment-related Travel and Training Grants	1	Unlimited	Reapply
	Research Infrastructure Support Programme	1	1	1