NAURU

TECHNOLOGY NEEDS ASSESSMENT

FOR

CLIMATE CHANGE ADAPTATION

Barrier Analysis and Enabling Framework

JUNE 2021

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR CLIMATE CHANGE ADAPTATION TECHNOLOGIES

REPORT II

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This document is an output of the Technology Needs Assessment (TNA) project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Program (UNEP) and the UNEP DTU Partnership (UDP) in collaboration with the University of the South Pacific (USP). The present report is the output of a fully country-led process and the views and information contained herein is a product of the TNA team, led by the Department of Climate Change and National Resilience, Republic of Nauru.

Forward

“The lessons of the past are clear not only for Nauruans but for the rest of the world as well. Waste not this precious planet, or you shall want. Squander non-renewable resources at your risk. Destroy land, and you destroy human culture. Devastate the forest, and you will lose the coral reef as well, for the forest and the reef are like husband and wife. (extract from Nauru's Plenary Address to the "United Nations Global Conference on the Sustainable Development of Small Island Developing States", Bridgetown, Barbados, 1994)

The Republic of Nauru’s high vulnerability to adverse impacts of climate change, in particular extreme climatic events, sea level rise and water scarcity on the Island means that the country is in dire need of innovative adaptation technologies to lessen damage to life, property, natural eco-systems, and its economy. I am confident that the Technology Needs Assessment (TNA) process initiated by the Department of Climate Change and National Resilience (DCCNR) in partnership with the United Nations Environment Program (UNEP), University of the South Pacific (USP) and UNEP DTU Partnership will play an effective role in increasing resilience against climate change vulnerabilities through transfer and diffusion of prioritized technologies in prioritised sectors including water, coastal area vegetation restoration and removing barriers in their adoption. I am pleased to note that the entire process to set preliminary targets for transfer and diffusion of technologies, identify barriers and suggest an enabling framework for overcoming the barriers in this phase-II of the TNA project has been country-driven despite of the impact of the current covid 19 pandemic. Being highly consultative, it involved a number of stakeholders and experts from the government, private sector, and non-government organisations. I strongly believe that the implementation of adaptation technologies prioritized in TNA Adaptation Report Phase-II will help the country in building resilience to the impacts of climate change. I would like to thank the members of the TNA National Team and my colleagues in the Department and experts of the Adaptation Working Group for their invaluable contributions to the preparation of this Report. I also thankfully acknowledge the contributions of Dr. Michael Otoara Ha’apio, Adaptation national consultant, Abraham Aremwa, Mitigation national consultant and other experts of USP, United UNEP, UNEP-DTU Partnership and the Asian Institute for Technology (AIT) for their constant support and guidance for implementation of the TNA project.

Mr Reagan Moses,
Secretary for Climate Change and National Resilience

List of Abbreviations

AEWG	:	Adaptation Expert Working Group
AIT	:	Asian Institute for Technology,
CBO	:	Community Based Organisation,
CED	:	Climate Change and Environment division,
DCIE	:	Departments of Commerce, Industry and Employment,
DCNR	:	Department of Climate Change and National Resilience
DoE	:	Department of Education (DoE),
DTU	:	Technical University of Denmark,
GCF	:	Green Climate Fund
GEF	:	Global Environment Facility
LMMA	:	Locally Managed Marine Area,
NFMRA	:	Nauru Fisheries and Marine resource authority,
NGO	:	None Government Organisation,
NSDS	:	National Sustainable Development Strategy,
NUC	:	Nauru Utility corporation,
NWSHIP	:	National Water, Sanitation and Hygiene Implementation Plan,
NWSHP	:	National Water, Sanitation and Hygiene Policy,
RO	:	Reverse Osmosis,
RoNAdat	:	Republic of Nauru Framework for climate Change and Disaster Risk Reduction.
RT RWHT	:	Rooftop Rainwater Harvesting Technology,
RTRWH	:	Rooftop Rainwater Harvesting,
TNA	:	Technological Need Assessment,
UNEP	:	United Nation Environment Program,
USP	:	University of the South Pacific
WRS	:	Water Reticulation System

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Executive Summary

Nauru is a small island developing state (SIDS) with a land area of 21km^2. The population of just over 10,000 people is mostly settled on the coastal perimeter of the island, in a thin strip between the reef and the elevated interior. Most of the island's raised interior has been mined for phosphorous over several decades, with the result that the land surface is severely degraded. Phosphate rock has provided Nauru's main export income, and although primary mining is winding up there are plans to continue secondary mining (removing rock pillars at the surface followed by extraction of deeper phosphates). At one stage mining created a wealthy society, during which the government provided most basic services such as – housing, electricity, water – free of charge to its population. However, mining revenues are now in decline, and so too is the government's ability to provide or maintain infrastructure around the island (Connell,2006)[1]. This situation is enhanced by Nauru's need to import most of its necessities to support its growing population. With virtually no agriculture, almost all food is imported apart from fish. Similarly, with virtually no renewable energy capacity all energy resources are imported in the form of fossil fuels, including those needed to run the power station. Consequently, Nauru is highly vulnerable to external market shocks which raise the price of food or fuel. Prior to 1995, drinking water was also imported. Since then, however, a succession of five (5[2]) desalination plants have provided treated water, which is delivered, on request, to household tanks by trucks. The other main sources of water are rainfall captured in household or small community tanks and in some areas brackish groundwater which has become increasingly contaminated and is not suitable for drinking.

Technology Needs assessment (TNA) is a country-driven participatory process which aims to identify and prioritize environmentally viable technologies in the sectors of water, coastal adaptation, renewable energy, and waste management in Nauru. The purpose is to increase the coping capacity of individuals and communities across the island to better prepare for the potential negative consequences of the impacts of climate change. During the first phase of TNA, through stakeholders' consultation meetings, Nauru has selected and prioritized eight (8) technologies (combined) under water and coastal area management sectors and a further 8 technologies (combined) under renewable energy and waste

[1] Connell, J. (2006). Nauru: The first failed Pacific state? *The Round Table*, *95*(383), 47-63.

[2] One large evaporative desalination plant and four small RO desalination plants.

management, respectively. In water sector, the four technologies selected include: *Roof top rainwater harvesting*, *water reticulation system*, *non-potable water access*, and *tanker truck technologies*. While in coastal area management the following technologies are selected: *Coastal vegetation restoration*, *locally managed marine area*, *policy formulation* (over coastal area and resource management) and *sea wall construction*.

This report is the output of the second phase of the TNA process which covers barrier analysis on transfer and diffusion of the prioritised adaptation technologies in the selected two sectors across the country. In addition, the report also outlines the enabling framework and measures to overcoming identified barriers. For example, for each of the 8 technologies identified for water and coastal area sectors, a systematic approach of describing and analysing technological barriers and identification measures and enabling framework is also outlined, discussed, and adopted. The process included:

1. Identification of preliminary targets for the technology development and diffusion sectoral scale.
2. Describe each technology properties and potential adaptation benefits, categorize technology either as market or a public good and briefly elaborate on its current status in the country.
3. Identify important barriers to diffusion of technologies through expert opinions, literature reviews, consultation meetings with important stakeholders, development of barrier analysis tools including problem and objective trees and marketing mapping tools. The report also categorises the barriers into financial and non-financial barriers.
4. The last process includes, identifying the measures for overcoming the barriers, possible linkages between different technology barriers within a sector and outline a technology enabling framework that would help to overcome barriers and create a supporting environment for the development and successful diffusion of the selected technologies.

The whole process of technology barrier identification was drawn from various literature reviews, stakeholder meetings, stakeholder bilateral meetings, Adaptation expert working group and respective technology experts. Adaptation consultant also seek reference to the TNA barrier analysis guideline, resources, information, and templates provided by specialists UNEP-DTU and USP partnership during and after regional capacity building workshops.

Technology barriers and measures in water and coastal area management sectors (Adaptation).

Each of the four adaptation technologies in the water sector, namely *roof top rainwater harvesting*, *water reticulation system*, *non-potable water access and tanker water technologies* were all categorised as public goods or non-market good which requires public sector support for its development and successful replication at different implementation scales at local levels. From literatures and stakeholders' discussions with reviews of barriers it was noted that economic and financial barriers were closely associated with high cost of development of technologies which were due to the lack of incentives and assistance offered to individuals and communities, due to high cost of construction materials, unavailability to technological expertise and labour at the local levels. The **Table 1** below summarizes the sectors and barriers identified with measures taken overcome respective barriers.

Table 1: Identified barriers and measures taken to overcome respective barriers.

Key Sectors	Identified Barriers	Measures taken to overcome barriers
Water Sector	Economic barrier	Subsidy by government
1) Rooftop rainwater harvesting	High Capital Cost	Government offering incentives, i.e., import duty free.
2) Water Reticulation system	High Capital Cost	Subsidy by government to water authority, NUC
3) None-potable water access	Water contamination/	Improved alternate clean water access sources
4) Tanker water	High Establishment Cost	Increased fleet reduced usage
Coastal Sector	Under capacity	Training and awareness
1) Coastal Vegetation restoration	Land tenure ship	Policy to regulate access
2) LMMA	Lack of skills	Training of locals
3) Policy & guideline formulation	No capacity to formulated guideline	Training of locals/ Hiring of consultancy
4) Construction of seawall	Cost of capital	Government subsidy and regulation, Import subsidy

Source: In country consultation, 2020

The nonfinancial barriers include lack of ineffective policy on water sectors (was developed but no political-will) to effectively implement components of the water policy. Moreover, there was not a policy regarding the coastal area and resource management in the country. In absence of such a policy framework that oversees the coastal area and resource management with effective water sector resource in the country will also fail to adopt an effective coastal area and resource management to ensure that not only the current but future generations also benefit from the scares resources on the island.

Nevertheless, the barriers in the water and coastal area resource management can be overcome by putting in place appropriate financial and technical resources for the development and diffusion of these technologies at the local levels. The non-financial barriers can be tackled through formulating and approving a coastal area resource management and enforcement of the current integrated water policy in the country. It is critical that any policy of this nature must be agreed to by the stakeholders, individuals, and communities across the country.

Chapter 1: **Water Sector**

1.1 Preliminary targets for technology transfer and diffusion in Water Sector

The National Water, Sanitation and Hygiene Implementation Plan (NWSHIP) is a fifteen-year plan to implement the Republic of Nauru's 2011 National Water, Sanitation and Hygiene Policy (NWSHP), which sets out the visions, goals, and objectives of the Government of the Republic of Nauru for water and sanitation. Despite this well-designed initiative, the country continues to experience water challenges as it faces multi-dimensional factors from impacts of climate change and extreme events. According to NWSHIP (2012)[3] the existing water resources in Republic of Nauru (RoN) are under substantial stress due to the growing population, fast rate of urbanization and subsequent unplanned land use changes. The document outlines a multi-level of challenges that need to be addressed to achieve a reliable, safe, affordable, secure, efficient, and sustainable water supply on the islands. This is in line with the Nauru National Sustainable Development Strategy's (NSDS) (2005-2025)[4] goal to achieve better standard of living to all Nauruan. However, this objective will not be easily achieved as it also has its own constraints and challenges. One of the identified constraints factors to achieve better standard of living in Nauru is the poor quality and expensive water cost on the island. As matter of fact, the Nauru's water supplies are vulnerable to fluctuations in rainfall, embedded with the effects of climate change on temperatures, humidity, rainfall, and weather extremes are affecting the quality and quantity of water resources available on the Islands. This increases the risks for Nauruan households to depend on the expensive RO water supplied by Nauru Utility Corporation (NUC) for sustenance and livelihoods.

Additionally, the island nation continues to face challenges in the water sector includes: No water quality standards, high rate of diarrhoea and health impacts from poor quality water especially from groundwater resources, groundwater contaminated by sewage, oil, waste pits and other contaminants, reliance on energy intensive desalinated water (up to 1/3 of Nauru

[3] The National Water, Sanitation and Hygiene Implementation Plan (NWSHIP) a blue print document of fifteen-year plan to implement the Republic of Nauru's 2011 National Water, Sanitation and Hygiene Policy (NWSHP),

[4] Nauru National Sustainable Development Strategy (2005). Department of Commerce, Industry and Employment, Republic of Nauru.

power production), lack of storage at both household and national levels, maintenance of infrastructure (includes existing water tanks, tanker trucks, RO equipment's) and delivery capacity for Reverse Osmosis (RO) water, RO production capacity of desalinated water is insufficient in major droughts, unaccounted for water and water loss up to 85 percent of RO production, effective strategy needed for water delivery to priority users such as schools, the hospital and dialysis unit, public and household rainwater harvesting and storage is insufficient, and is poorly maintained and inefficient, and list goes on.

With the above backdrop, the technological development and innovation in water sector could play a critical role to achieve food and water security targets of the country considering uncertain climatic conditions cast by climate change, sea level rise and other extreme events. Republic of Nauru NSDS (2005-2025) vision as a focal policy roadmap document for the country, stresses on investing in proven methods and technologies to minimize wastage of water and to promote its conservation to achieve its goal of water security by the year 2025 (NSDS2005). Below we will explain in brief two major impacts of climate change events on water across the Island.

Sea Level Rise – Sea level rise is a climatic event, which sees change in sea level could affect people through flooding (Neumann, et al, 2015)[5], when water in rivers cannot flow into the ocean because the sea is too high and when seawater surges onto the land during storms. On the Island nation, sea level rises contaminate ground water wells and destroy coastal vegetations. Thus, investing in roof top rainwater harvesting technology would be beneficial to coastal communities.

Frequent precipitation - global warming increase in the intensity and frequency of heavy precipitation events. This heavy precipitation on the Island pollutes the ground water available for usage by households and business houses.

Moreover at the first phase of Technology Needs Assessment (TNA) in the country, with consensus from CC Adaptation Expert Working Group (AEWG) members and other important stakeholders, a set of eight adaptation technologies were identified in areas of water and coastal area management sectors and finally four technologies were prioritized through multi-criteria assessment process based on their importance in reducing vulnerability of communities and individuals to the severe impacts of climate change.

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[5] Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding-a global assessment. *PloS one*, *10*(3), e0118571.

The prioritized technologies were as follow:

1. Roof top rainwater harvesting technology
2. Water reticulation system
3. Non potable water access
4. Tanker Truck

Current Level of Experience – Prioritised Technologies

In terms of experience, the Republic of Nauru have some levels of experience with all the above short-listed technologies (4) which are available and are also in use at various levels across the country. From observation, the major challenge lies with the cost relating to the establishment and construction of the prioritized technologies to ensure that those technologies can be implemented and sustained across the country.

To ensure sustainability of these technologies, the TNA project during this second phase of barrier analysis and enabling framework sets some preliminary targets for the transfer and diffusion of these above-mentioned technologies in water sector which are as below:

1. To construct 50 community-run rainwater harvesting facilities at selected sites around the island each with a capacity between 15,000- 50,000 m^3 by 2026.
2. Modernize and upgrade water storage infrastructures by 2026,
3. To construct infrastructure that assist to providing water reticulation system on parts of the Island by 2023.

To achieve these preliminary targets of transfer and diffusion of technologies in water sector the relevant stakeholders and players must get involved and play active role in the successful implementation of the identified technologies. The important stakeholders include water related policy makers, experts, relevant authorities such as Departments of Climate Change and National Resilience (DCCNR), Nauru Utility corporation (NUC), provider of water and electricity, Nauru Fisheries and Marine resource authority (NFMRA), Department of Education (DoE) and Department of Industries, Employment and Environment. Other players include technology dealers, technicians, and experts in water sector. The implementers include Non-Government Organisations (NGOs) and Community based organisations

(CBOs) focusing on water issues, advocacy groups of women, youth and community leaders active at local and national levels.

Figure 1: Different stages of TNA project implementation followed in Nauru

Phase I	Phase II	Phase III
TNA Report -1 Main elements: • Sector Identification and prioritisation • Technology Identification and prioritisation in each sector	**Barrier Analysis and Enabling Framework Report II** Main elements: • Barrier analysis for each technology and enablers addressing the barriers – Enabling framework.	**Technology Action Plan & Project Ideas Report III** Main elements: • Action Plan for each of the prioritised technology • Cross cutting issues • Specific project ideas in each prioritised sector.

Source: Adapted from UNEP Risco Centre Flyer (March 2014). What are the technology needs of developing countries?

1.2 Methodology

This report is the output of the Second Phase of the TNA process for Adaptation for the Republic of Nauru. The report covers mainly barriers analysis on transfer diffusion, enabling framework and key measures identified to overcoming the barriers. For each of the prioritised technologies identified for adaptation (water and coastal management sectors), a systematic approach of describing and analysing each technology barrier, and identification of measures and enabling framework was adopted. The following steps were taken as part of the process:

1. Identifying the preliminary targets for the technology development and diffusion at sectoral scale.
2. Description of the technologies identified. Provision of its potential adaptation benefits. Determine and categorise whether such technology is market or public goods with some description of its status in the country.
3. Identification of key measures for overcoming the barriers, possible linkage between different technology barriers within a sector and device a technology enabling

framework would help overcome potential barriers while creating a supporting environment for the development and successful diffusion of the selected technologies.

Since the closure of the borders, the adaptation consultant undertook most of its review and analysis work off country while the mitigation consultant has undertaken its role mainly in country. Most of the work were collated through desktop review especially from adaptation sector and validated through the process of in-country bilateral meetings and group discussions by the mitigation expert. The purpose of the validation process is to ensure that the views and ideas of the stakeholders on the ground are correctly reflected in the report.

1.2.1 Desktop Reviews

The consultant undertook extensive literature review of reports and articles in the areas of water and coastal sector management (Adaptation) across the country. According to Lurie et al, (2013) desktop review is critical to understanding any topic under research. Thus, we undertook literature review to understand the context of water and coastal area management in Nauru. The reports we study include the National Water, Sanitation and Hygiene Implementation Plan, the national water sanitation and hygiene policy of Nauru, The National Sustainable Development Strategy (2005-2025), Climate Change and Water Security in Nauru (SPC report), Expanding water national storage capacity for Nauru Report and the Phase I TNA report (2020). This process helped to formulate and draft the Second Phase of the TNA report.

1.2.2 Validation Consultation meetings.

After the desktop review process, a series of bilateral and group meetings were held by consultants through the adaptation expert. The validation consultations and meetings were critical to ensure that the ideas that were captured through the desktop review and first round of consultation meetings are correctly interpreted and applied according to the local context.

Figure 3: Methods followed in conducting TNA barriers analysis and enabling frameworks.

Main Stages of Analysis	Methods and Tools

1. Identification of Stake holders	This was done during the Phase I of the TNA
2. Identification of potential barriers	Extensive Literature Review, consultation meetings and brainstorming
3. Analysis of barriers	Use of logic thinking, problem tree design, expert consultations, and bilateral meetings
4. Measures development to overcome barriers	Translating barriers into measures using logical solution tree during consultation meetings
5. Screening and validation of important barriers and measures	Validation through extensive consultation during Stakeholders /experts meetings
6. Preparation of the Draft BAEF Report	TNA Adaptation & Mitigation consultants drafted the report
7. Final BAEF Report	First DTU/USP experts reviewed and then DCIE officials reviewed /approved the report.

1.2.3 The Department of Commerce, Industry and Employment

The Climate Change Department (CCD) and stakeholders through national consultation at the TNA inception workshop had agreed on the sectors for the TNA process to concentrate. After the sector identification, then at the Phase I consultation, the stakeholders then have selected and prioritised the technologies under each sector. Also, at this stage the government through the Department of Commerce, Industry and Employment (DCIE) ensure that the sectors selected are in line with the national sustainable development strategy of the country (NSDS 2005-2025).

1.3 Barrier analysis and possible enabling measures for rooftop rainwater harvesting technology (RTRWHT)

1.3.1 General description of rooftop rainwater harvesting technology.

Nauru currently relies on desalinated water, rainwater harvesting, and poor-quality groundwater for its water needs (Freshwater et al, 2011)[6]. There is no whole of country

[6] Freshwater, A., Talagi, D., & Economics, A. S. N. R. (2011). Desalination in Pacific Island Countries.

reticulation distribution system across the Island. Desalinated water is trucked to households on request and with relatively high cost. According to key informant, "a hand full of households across the Island could have access to rooftop rainwater facility but it's not a facility that could be easily accessible within the communities because of financial constraints". (Personal Interview May 2019). Rooftop rainwater harvesting (RTRWH) is the collection and storage of rain, rather than allowing it to run off. Rainwater is collected from a roof-like surface and redirected to a tank, cistern, deep pit (well, shaft, or borehole), aquifer or a reservoir with percolation. According to Lee et al (2010)[7] for more than three centuries, rooftop catchments and storage of water facility have been used by households and communities around the world at diverse locations especially the areas with no natural safe ground water or streams for consumption. Rainwater collected from the rooftop is typically used for both potable and non-potable purposes, including domestic uses and drinking. There are three main types of rainwater harvesting system: direct pumped, indirect pumped, and indirect gravity. In certain situations, it may be possible to have a purely gravity system, though such occasions are rare in the country.

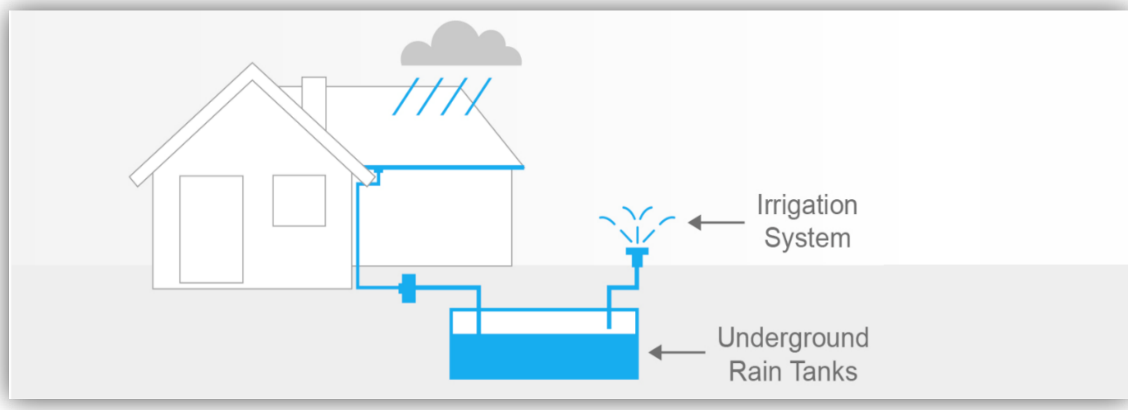
Direct-Pumped (Submersible/underground tank)

This is the most common type of semiprofessional rainwater harvesting system, particularly for domestic properties, and is generally the easiest to install (Casolco, 2007)[8]. The pump is located underground, and harvested water is simply pumped directly to the water tank or other appliances. If the tank should be in danger of running dry, a small amount of mains water is fed to it to maintain supply. For commercial projects, such systems tend to be dual pump arrangements (duty standby).

[7] Lee, J. Y., Yang, J. S., Han, M., & Choi, J. (2010). Comparison of the microbiological and chemical characterization of harvested rainwater and reservoir water as alternative water resources. *Science of the Total Environment*, *408*(4), 896-905.

[8] Casolco, R. (2007). *U.S. Patent Application No. 11/271,347*.

Figure 4: Direct pump or underground pump water tank system



Source: PDP Services (2021)

According to Pederson **(1965)**[9] this system has a pump and control system inside a building or enclosures rather than inside the water tank itself. This makes maintenance of the pump and filters easier rather than a system which has the pump inside the tank. This also use a mains water back up so as not to run dry.

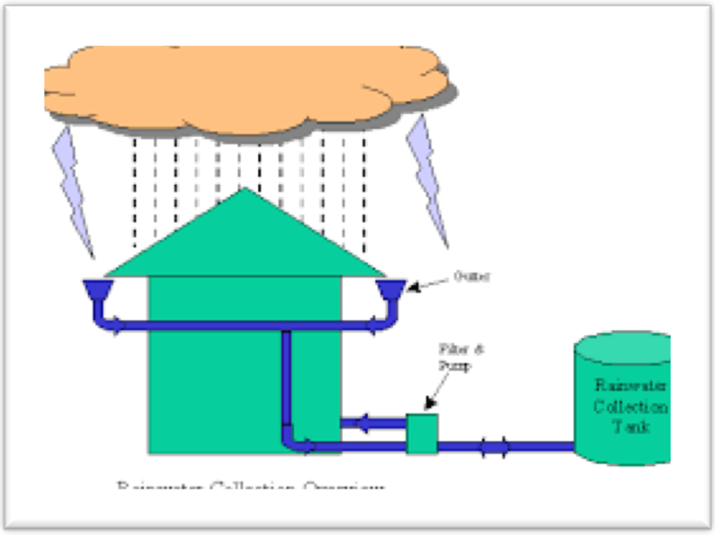
Indirect Gravity

This type of system differs in that the harvested water is first pumped to a high-level tank (header tank)[10], then allowed to supply the outlets by gravity alone. With this arrangement, the pump only must work when the header tank needs filling. Also, the mains water is fed directly to the header tank, as it can only be filled from the main harvesting tank.

[9] Pedersen, H. O. (1965). *U.S. Patent No. 3,203,354*. Washington, DC: U.S. Patent and Trademark Office.

[10] They use hand pumps to pump water up to a higher storage tank before using gravity to distribute water for usage in the house.

Figure 5: Indirect gravity rainwater harvesting system

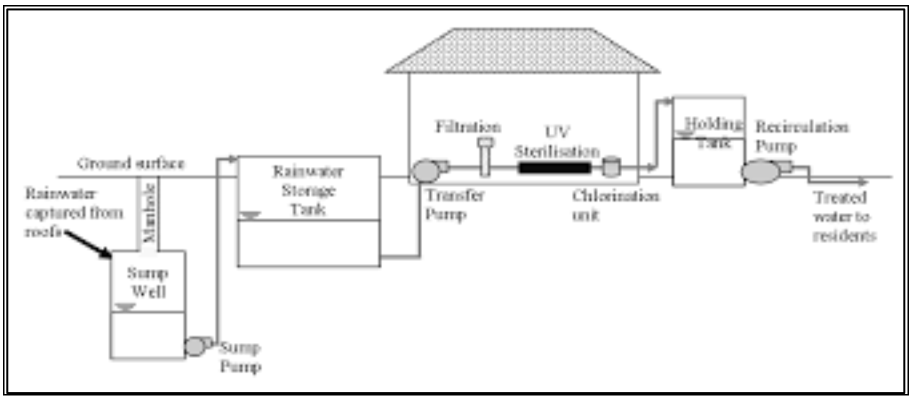


***Source*:** Total Water system (2020).

Indirect Pumped

This arrangement is similar to the indirect gravity system as earlier described, with the exception that the internal tank can be at any level in the building, as it does not rely on gravity to supply the outlets. Instead, a booster pump set is used to provide a pressurized supply. This system employs the benefit of not having to feed mains back-up water to the underground tank, whilst also offering great flexibility as the booster pumps can be tailored to suit the flow and pressure requirements of the building.

Figure 6: Indirect pump water harvesting system

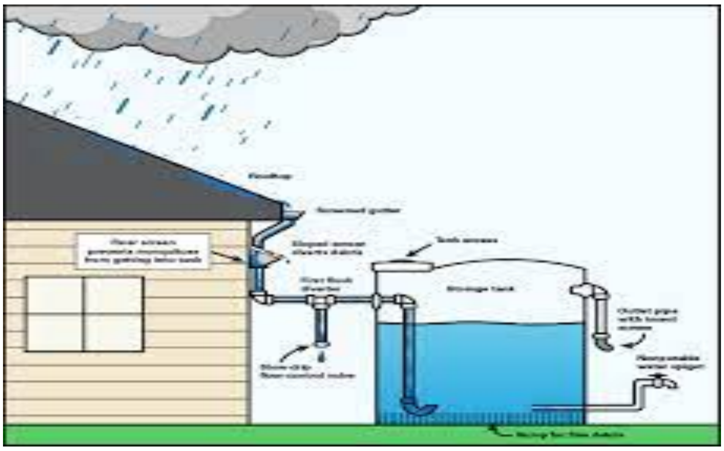


Source: Gurung, Thuli Ram, Sharma, Ashok (2014)

Gravity Only

In some situations, it may be possible to have a system that functions purely through gravity, requiring no pump and therefore no energy use. With this arrangement, rainwater is collected from a part of the roof which has gutters above the filter and collection tank which are in turn above all the outlets. This arrangement is only ever possible where the storage tank can be located below the level of the gutters, yet higher that the outlets that it will supply. Only the power of gravity is needed to feed collected and filtered water to various parts of the home for use, so it is an ultra-energy efficient option.

Figure 7: Gravity only rooftop rainwater harvesting system



Source: Total Water services (2020)

This RTRW technology with various products described above offers many benefits during seasonal dry periods and droughts especially in the face of climate change that is projected to increase long term drought and dry season in the long run. Roof top rainwater collection helps to stabilize the depleting groundwater level while the storage infrastructure can reduce land erosion and flood inflow in the sea. In Sub-Sahara, this technology acts as a convenient source of stored water that could enhance agricultural productivity, decrease travel time for rural women to remote water resources that would result in better health and time for social activities (Rosen & Vincent, 1999)[11].

1.3.1.1 Technology status in Nauru

RTRWH is widely practiced across the country during the late 80's and 90's, the periods which were regarded as the prosperous days of the country (Personal Interviews, May 2019)[12].

[11] Rosen, S., & Vincent, J. R. (1999). *Household water resources and rural productivity in Sub-Saharan Africa: A review of the evidence* (Vol. 673). Cambridge, MA: Harvard Institute for International Development, Harvard University.

[12] Personal Interviews (2019). Water sector senior employee, Nauru Utility Corporation.

This is because many family units can afford this type of water collection system around the country. Nowadays, household units in Nauru can take advantage of rainwater system installed on some roofs of domestic and commercial buildings. A structure of tubes or gutters direct rain towards a small tank in which household units could store water, which can later be used for drinking, cooking, and other domestic purposes.

Figure 8: Rooftop rainwater harvesting system

***Source**:* Total water system (2020).

Ground water - However, between rainy seasons groundwater is the major source of water on the island. Unfortunately, the low water quality in Nauru means that groundwater is contaminated or unsafe for human consumption. According to key informants[13], groundwater quality in Nauru is affected by wastewater disposal from houses, shops, commercial buildings and the refugee camp. In addition, some zones have an increasing salinity rate, which makes the water inadequate for human usage. To resolve this problem, Nauru government has launched an expansion of the national water storage capacity in order to improve the water supply. The project consists of installation of more water tanks which will prevent water shortage during periods of drought. Thus, if this technology is to be supported and sustained, donor partners should invest money to support the government's initiative to provide clean and quality water to its citizens. The solution from this technology will also protect the environment since the desalination plants are energy-intensive and use fossil fuels for power

[13] Key informants- Senior People who worked in the water sector in the country for the past 20 to 30 years.

generation. The use of rooftop water harvesting technology may reduce the energy required to produce the same litters of water on the Island.

1.3.1.2. Technology category and market characteristics

The Rooftop rainwater harvesting technology can be categorized as a non-market public good when established at a community level and requires state level support to develop and manage the system. The technology option in this report is community or State-managed Rooftop rainwater harvesting system and thus considered as a non-market public good. But if it is to be provided by the Nauru Utility Corporation (NUC) as the primary provider of desalinated water across the country, then to some extend it would be a market product. In this context, the RTRWHT may have to be classified as private or market product.

1.3.2 Identification of barriers for rooftop rainwater harvesting technology.

A desktop-review was carried out by the adaptation consultant on some important policy papers and documents on rooftop and rainwater harvesting in general in the country. This process was supplemented by interviews, group discussions with water experts, key stakeholders and workshop brainstorming on the Island. A list of potential barriers to the development, transfer, and diffusion of RTRWH technology was identified, prepared, and categorized into two broad main categories of economic and financial barriers, and non-financial barriers. The non-financial barriers were further segregated down into policy, legal and regulatory barriers, technical barriers, institutional and organizational capacity barriers, social, cultural, and behavioural barriers, information and awareness barriers. In random order, the identified barriers included the following:

i. High cost of capital,
ii. Insufficient legal and regulatory framework for rainwater harvesting systems,
iii. Poor inter-departmental interaction and coordination,
iv. Lack of incentives for community ownership and participation,
v. Uncertain frequency of rain falls and irregular water flows over the country,
vi. Low or no preference to research and training,
vii. Inadequate information on societal benefits of technology,
viii. Limited institutional capacity and management skills of government departments,
ix. Health issues arising from water – bone vectors.

Screening and Prioritization of identified barriers

After the compilation of the potential barriers list, it was presented to the participants of the technology barrier analysis workshop to screen the list and to identify the essential barriers that need to be addressed for technology transfer and diffusion to occur – as well as the non-essential barriers that were to be ignored (See annex 3). The barrier analysis tools such as the starter problem and solution trees were used to expedite process of prioritization of barriers. Through consensus among participants, the final list of barriers was achieved and briefly discussed below.

1.3.2.1 Economic and financial barriers

a) *Capital and Maintenance cost* - As the technology is classified as a public good, so its development, operation and maintenance would also remain under the same public domain. Having said that, this is one of the technologies which the relevant Department or government authority dealing with water resource sector within the country should provide public fund to support. But as from the feedback at the consultation, it is something the government would really want to invest-in but does not have the financial capacity to support. In terms of the maintenance cost would be minimal as it involves only in cleaning of the gutters.

b) *Capital cost.*

As you could see from the **Table 2** below, the cost of producing a single household rooftop rainwater harvesting system is estimated about AUD$7,000. This is relatively costly for households and individuals on the Islands. Direct cost for installation of 50 units across the Island would cost AUD$350,000.

Table 2: Expenses related to building a single rooftop water harvesting system.

Main costs of producing roof top rainwater harvesting system in Nauru		
Activities	**Details**	**Costs**
Roofing	Not included – Pre-installed	0
Guttering	$10 meter @ 46 m for above roofing area.	$460
Down pipes	$5 meter @ approx. 30 m	$150

Water catchment	Storage system	$6,000
Additional costs		390
Total cost estimated		**$7,000**

Table 3: Cost of water to consumers both domestic and commercial

Details	**Cost**
Average cost to produce a litre of water is	0.0206
Domestic rate –	$0.0084/l
Commercial rate –	$0.0118/l
Government rate –	$0.01533/l
Domestic delivery rate	– $5 ≤ 5kl | $10 > 5kl
Commercial delivery rate	– $263 per truck load (any capacity)
Government delivery rate –	$165 per truck load (any capacity)

c) *Inherited Risk of the RTRWHT* – This cost relates to maintenance and repairs which the household and communities will inherit from taking ownership to the technologies into the future. Nevertheless, as you can see from the **Table 3** above, providing rooftop rainwater harvesting system to households will ease their budget from meeting expensive cost of water delivery across the Island. On average a household would require one truck delivery per month, this would cost about AUD$3,156 while cost of installing one Unit of RTRWHT would be only AUD$7,000. Investing in the RTRWHT would see the money invested would have return just over 2 years.

1.3.2.2 Non-financial barriers

Policy, Legal and Regulatory

a) *Ineffective water policy - (The National Water, Sanitation and Hygiene Policy)* – This is the policy that over sees the water, sanitation, and hygiene in the country. This policy outlines how water is managed in the country, but it lacks the government's strong support to ensure its people achieve quality levels of safe and clean water at very minimum cost. The support refers to include implementation and monitoring of the types of rooftop rainwater system that households implement at their homes.

b) *Lack of understanding of existing rights and rules on water* – Since there is no running river on the Island, there seems to be lack of knowledge of indigenous people's rights and rules on access to water. During the prosperous years of the Island nation water is freely supplied and thus there no intension to promote effective rooftop rainwater harvesting technology.

c) *Inequitable distribution of water among water users* – There is unequal distribution of water among users. This is because water is being commercially distributed by NUC authority across the Island. Households and business houses must pay for their water usage on the island.

Water Contamination – There is high level of ground water contamination at the local levels. Thus, in order to address this contamination issue, use of rooftop rainwater technology could be seen as an option aims at achieving cleaner water.

Technical Level

a) *Limited local capacity:* The technology may sometime require some technical skills to construct the infrastructure of such system. The government must train locals to start installing these technologies across the island.

Social, cultural and behaviour

a) *Land tenure* – Most of the land around the Island are customary or privately owned. Thus, community members often dispute where such communal structures to be built. But if the technology is built on existing community halls or buildings, there wouldn't be dispute. Ideally, these RTRWHT should be built on individual households across the Island.

b) *Ownership Question* – There is a limitation in communal properties or structures for public uses. Often such assets not well looked after and sustain in the long run. To counter such situation, there would be bylaws formulated and enforced surrounding the operations of communal RTRWHT.

c) *Perception of such Technology*- General perception about such technology acquired under project or donor assistance, it's only for short term and won't last for that long.

Information and awareness

a) *Potential benefits of such Technology* – There is limited knowledge and awareness of the potential benefits from Rooftop Rainwater Harvesting Technology at community levels.

b) *Limited awareness of climate change* and disasters– Although there might be some awareness but little seriousness about the impact of climate change and its impact on the water sector across the country.

c) *Need for community cooperation through communal participation*. There is little awareness of the need for community engagement and participation to embrace community harmony in such a public good.

1.3.3 Identified measures.

This part of the document attempts to discuss the measures needed to overcome the identified barriers to possible implementation of RTRWHT in Nauru. The principal methodology engaged for the identification of appropriate measures was the development of problem and tree solution or fish bone approach through stakeholder's consultation and participation. Besides, there was also a detail analysis of the current national practices in the relevant sectors. The series of discussions during the face-to-face consultation led to the identification of some of the key measures necessary to overcome and eliminate the identified barriers above (Refer to annex 3 for participant list).

1.3.3.1 Economic and financial measures

a) *High Initial and capital cost* – To offset the high capital cost the Republic of Nauru may consider waiving tax and duties on materials imported to build this technology should there is potential for the donor aid partners invest in this technology on the Island.

b) *High maintenance cost* – The communities may meet some of the maintenance and running cost of maintaining the technology. This means they will have to clean the gutters and tanks frequently.

c) *Inherited Risk* – In the event of no or little rain on the Island, the government will leverage any economic implication on the community to ensure there is safe and clean water available or accessible to the households.

1.3.3.2 Non –financial measures

In almost all the Small Islands Developing States (SIDS) or even other poor and developing countries the existing non-financial technology management practices are predominantly reactional due to the limited understanding of technological, socio- economic, and institutional aspects of the implementation of technology management and diffusion. For instance, non-financial barriers to the implementation of technology, the following measures need to be taken:

Policy, legal and regulatory

a) *Ineffective water Policy* (The National Water, Sanitation and Hygiene Policy) – This is the base line policy to implement effective strategies on water resource management in the country. The government must financially support such initiative to be effective across the country.

b) *Poor understanding of existing rights and rules on water* – There must be awareness and civic education to increase the knowledge of indigenous people's rights and rules on access to water. Safe and clean water is often seen as a foreign product because, mainly its either imported or brought in through some other means.

c) *Inequitable distribution of water among water users* – When the Technology is implemented there must be equal distribution or access to this public good technology.

d) *Water Contamination* **–** There must be effective implementation and monitoring of the current national water, sanitation and hygiene policy to include how to build sewage facilities and disposal of the same (sewage) in the country to prevent even ground water contamination. In the event of drought, the communities have no alternative but resort to ground water resources.

Technical Level

a) *Weak Research Capacity* – The government must collaborate with regional organisations such as the South Pacific Applied Geoscience Commission (SOPAC), South Pacific Commission (SPC) which have undertaken several studies in the past on the types of RTRWHT is viable and could withstand extreme weather events across the Pacific, mainly the low-lying islands.

b) *Limited local capacity* – According to respondents, there is a need for the government to assist local business entrepreneurs to invest in this technology. The investment would include locals acting as dealers or agents to importing and distributing of RTRWHT parts across the Island. In addition, the entrepreneur must be able to recruit and train locals that would be able to assemble and install the system at houses whenever the demand arises.

Social, cultural and behaviour

a) *Ownership* – There must be high level of community education and awareness about the benefit of such infrastructure to the community if its installed and use communally by all. Additionally, those who have installed the technology on their private homes must be able to learn the basic skills to clean and take care of such investment for the long term.

b) *Perception of such Technology*- Community training and capacity awareness will be able to change the mind-set of the community members' perception about such technology acquired under project or donor assistance. This is for the good of such technology to impact the livelihoods of the people.

Information and awareness

a) *Potential benefits of such technology* – There is a need to take this awareness strategy to the rural communities across the Islands. Such awareness of the potential benefits from rooftop rainwater harvesting technology at community levels will increase the support and ownership of such investment.

b) *Limited awareness of climate change* – The relevant government stakeholders must increase the climate change awareness and its impact on the community. Only by this increase of knowledge and civic education by where villagers will support this communal technology structure.

1.4 Barrier analysis and possible enabling measures for water reticulation technology.

1.4.1 General description of a water reticulation technology

Water reticulation system is a series of pipes that are connected to help transfer water from its original source to consumers. It is an efficient and vital structure by where water is distributed within a house or community. According to Conradie et al, (2018), water reticulation system saves more than 30% of energy in a study undertaking to reconfigure mine water reticulation system in South Africa. In Nauru, the construction of water reticulation system is aimed to distribute RO water from selective water reservoirs around the Islands and distribute to hospitals, schools, hotels, and households at the same with minimal costs.

Republic of Nauru lacks the national capacity to store potable water (Climate Change Adaptation in Nauru,2015).[14] Presently, both business and private household units rely on rainwater harvesting as the primary source, desalination as secondary and groundwater (poor quality) for its water needs. Having said that, there is no country-wide reticulated system available to distribute water to essential services such as schools and hospital (Personal Observation, May 2019)[15]. Desalinated water is trucked to consumers on request.

Nauru's secondary source of water which is the desalination water has four desalination plants throughout the island. However, the desalination plants require high quantities of energy to power and operate. The desalination process is also expensive and affects the beach environment (Nauru Environmental law planning and Assessment 1976)[16]. In 2014, water quality in Nauru took a remarkable turn with the development of a project by the Nauruan government to install a solar PV system and desalination plant. It was projected that this project could produce 100 cubic meters of safe water per day. In addition, the PV system would generate 1.3 percent of the energy demand in the island, doubling the then existing energy production of solar energy.

Regardless of this noble intension, there is no country-wide safe drinking water reticulation system across the Island nation. Although at a certain location of the Island there was a project which was implemented to provide an alternate source of water for non-potable uses in that locality, thus saving precious potable water for other domestic uses. Reticulation water technology although would be seen as a public good, it would be sustainable if it is managed by the Nauru Utility Corporation.

1.4.1.1 Water reticulation system status in Nauru

There is no country-wide water reticulation system in operation across the Island, beside pumping of some brackish water from the coastal area to the hilltop at a certain location. The main sources of water across the Islands are rainwater, imported water, shallow unconfirmed ground water and desalination water. Regardless of this statement, water reticulation system

[14] Climate Change Adaptation in Nauru (2015)- A report on Expanding national water storage capacity and improving water security in Nauru by EU, GCCA, SPC and Government of Nauru.

[15] CCA national consultant observation trip in May (2019)

[16] Environmental Law Planning and Assessment (1976)

is not a new concept as part of the Island once experienced such technology in the past 20 to 30 years (Oral history, May 2019).

According to key informants, there were some parts of the Island which experienced the service of a water reticulation system during the prosperous years of the island nation. There is still an existing infrastructure to support that key informant's claim. There is a tank right at peak of the hilltop of the Island, where water was used to be pumped from the shipping lines. From that storage tank then water is being reticulated to other parts of the Islands and then to the nearby households. The system mainly supported the senior executive management members of the Phosphate Mining company and some members of the diplomatic communities. Now the system is inoperative as there is no financial investment to support such technology.

Support for this technology

Over the past decades the Republic of Nauru was seeking financial assistance from donor aid partners to revisit and support the concept of water reticulation technology again across the Islands nation. Although this may be seeing as expensive and capital intensive it would be an effective way of fulfilling one of the obligations that the government owes to its citizens, to provide them with clean and safe drinking water. The intention is that the government through NUC –Water authority to continue to produce desalination water as it is currently doing. It then pumps those desalinated water into central tank facilities at the hilltop and reticulate the water through the technology from the storage to essential services such as hospital, schools and other services including, police force, fire department and then to households and business houses. According to an insider one of the reasons, the aid donors are reluctant to support such initiative is they do not want to invest in an sector which the national government should take the leading role in provision of funds for and furthermore, there need to be high level of accountability and transparency for projects of that scale in the country (Key informant, 2020)[17].

1.4.1.2. Technology category and market characteristics

The water reticulation system (WRS) could be categorized as a non - market public good when established at a community level and requires state level support to develop and manage

[17] The view does not represent that of the government nor the real reason but is only of her/his opinion.

the system. The technology option in this report is community or State-managed water reticulation system and thus considered as a non-market public good. But the water that runs through the pipe or the system will be provided by the Nauru Utility Corporation (NUC) as the primary provider of desalinated water across the country, then to some extend the water will be a market product. In this context, reticulation system (pipelines) is a public good while it will be used by the NUC to sell a private good which is the water (as commodity).

1.4.2 Identification of barriers for water reticulation technology

i. High capital cost,
ii. Aged (old) infrastructure for water reticulation system,
iii. No natural water source availability on the Island,
iv. Contamination of ground water,
v. Poor governance.
vi. Weak coordination amongst among public departments
vii. Land ownership issues,
viii. Impact of Climate Change
ix. Lack of land use and planning policy
x. Lack of technical expertise

Screening and Prioritization of identification barriers

After the compilation of the potential barriers list, it was presented to the participants of the technology barrier analysis workshop to screen the list and to identify the essential barriers that need to be addressed for technology transfer and diffusion to occur – as well as the non-essential barriers that were to be ignored. The barrier analysis tools such as the starter problem and solution trees were used to expedite process of prioritization of barriers. Through consensus among participants the final list of barriers was achieved and briefly discussed below.

1.4.2.1 Economic and financial barriers

a) *High capital cost* – From a cost perspective, the technology would cost about AUD$2.5M to AUD$3.5 M. The cost includes refurbishment and improvement of some existing structures already in place. The project would be used to replace old pipes and build new structure from the NUC, the desalination plant to selected essential service sites.

From a structural view point the good is identified as a non-market public good. Thus, if such good is constructed it will be initially a public good, owned and operated by the government before it could be finally corporatized or transferred to a relevant authority to manage and sustain it into the long term. But as it stands now, it must remain a public good and as such the Department responsible for water management resources will initially take charge over the operation of the technology. Usually, it requires high capital cost for establishment.

b) *Project continuity* - In case of donor funding, where international funding institutions such as the World Bank or Global Climate Fund (GCF) are providing funding for such project, there is always a cloud of uncertainty over the continuity and long-term success of such investments when the project duration lapses. This calls for some level of institutional ownership from either the community or governmental level.

1.4.2.2 Non-financial barriers

Policy, legal and regulatory

a) *The National Water, Sanitation and Hygiene Policy* – This is a policy on Water Sanitation and Hygiene. Although its objective is noble, the government must take substantive action to fulfilling its mandate under this policy framework.
b) *Poor understanding of existing rights and rules on water* – The general public at large (Nauruan) need to know that basic things as health, clean and safe drinking water are their rights which the government must provide opportunities communities to access to.
c) *Water distribution* – There must be better policy on how water is been distributed around the island nation.

Social, cultural and behavioural

a) This technology will be owned collectively by the people within the community. – There is likely an attitude problem towards community ownership of such large-scale investment.

Technical

a) This will be a large investment done at the community level. The question is whether there is an adequate level of expertise to run such technology effectively.

b) Poor knowledge about the reticulation system and how it operates at community level. The last time, part of the island nation has experienced having a water reticulation system was more than 30 years ago during the phosphate days.

Information and awareness

a) There is limited information on the cost-effective of such a large-scale infrastructure development.
b) *Climate change and disaster* – there is limited meaningful data on climate change and how will it affect the community, in terms of water security.
c) Need to know the benefit from such technology to the essential service providers, such as hospital, school (education), police and fire department.

1.4.3 Identified measures.

The following measures were considered important to overcome the barriers.

1.4.3.1 Economic and financial measures

a) The government through the relevant Department should allocate budget for better design and development, construction and subsequent operation and maintenance of the reticulation technology infrastructure in the country. As stated above, the system would cost within the range of AUD$2.5 to AUD$3.5M. This is a huge capital investment for the country, this will ensure that water is reticulated across all areas of the island nation. To meet maintain and repairs in the long term, both private and commercial demands, users will have to pay for their water bills through a body like the NUC.
b) The government should explore and develop bankable projects with this technology and compete for donor funding opportunities particularly from international climate adaptation financing for the diffusion and transfer of green reticulation infrastructure system.
c) There must be incentive provided by the national government to potential authority who would manage and take over the operation and management of the reticulation system in the long term.

1.4.3.2 Non –financial measures

Policy and regulatory

a) There should be a specific policy design explicitly around the implementation of the water reticulation in the country. This will include the ownership, operational issues, technology and long-term management and future direction of such entity.
b) Increase coordination and cooperation among various districts around the island nation over this national infrastructure system.
c) Prepare and implement standard operational procedures for the operation of the reticulation system.

Technical

a) The government should strengthen its skill development at national level to ensure that water engineers are well equipped and prepare to manage the system in the long run.
b) The government should start negotiation and collaborating with the NUC management for possible take-over and collaboration of management over the reticulation system.
c) The government should promote and support public and private partnership collaboration to ensure investments of such magnitude (water reticulation system) is established and effectively implemented on the ground. This means giving incentives such as duty exemptions and other benefits to companies importing parts into the country.

1.5 Barrier analysis and possible enabling measures for non-potable water access technology.

1.5.1 General description of non-potable water access technology

Most of the potable water supply comes from domestic rainwater harvesting (mainly rooftops), and desalinated seawater produced by reverse osmosis (RO) system. The non-potable water supply comes from groundwater and the ocean. Groundwater in Nauru is not potable due to salination and pollution. Almost every household in Nauru have access to non-potable water, either from ground water or saltwater along the coast. Non-potable water is used mainly by households for toilet flushing and other domestic and commercial uses. The difficulty is finding an affordable system that could be used to pump or extract non-potable water supply into the houses from the seashore. Although this technology is ranked 3rd of the prioritized technologies there are literatures indicated that use of non-potable water such as salt water to flush toilets is not favourable because the high salinity that kills micro-organisms needed to breakdown wastes. Furthermore, the use of salinity content water for washing increases rusting and damage household and kitchen items. The only reason, it was selected as one of the priorities is to ease the pressure on household to use potable water due to climate change for both drinking and other household uses such as washing and toilet flashing. Having access to such water source may ensure that households utilize their limited potable water access and other resources to build resilience against impact of climate change.

1.5.1.1 Technology status in Nauru

Non-potable water is abundantly found around the island. This is either sourced from ground water or saltwater at the coastal areas. The difficulty of this technology is the ability to source them together through a reticulation system and distribute to homes and business houses for usage. A specific area of the Island uses this technology, plumbing mainly brackish water from the coastal area up the hilltop for usage especially.

1.5.1.2 Technology category and market characteristics

The non-potable water harvesting could be categorised as a non-market public good when established at national wide across the island. It however will require government support to sustain such investment in the long term. The technology option in this report is a community or government –managed non-potable water supply system across the districts and communities thus considered as non-market public good.

1.5.2 Identification of barriers for non-potable water access technology

Preliminary barrier Identification:

Like other technologies, the initial step was we performed a desk top study of important policy papers and other relevant documents was conducted, supplemented by interviews with experts, key stakeholders and workshop brainstorming. As part of the study, a list of potential barriers to the development, transfer and diffusion of NPWA technology in the country was identified. The list was prepared and categorized into two broad main categories of economic and financial barriers and non-financial barriers. The non-financial barriers were further segregated down into policy, legal and regulatory barriers, technical barriers, institutional and organizational capacity barriers, social, cultural and behaviour barriers, information and awareness barriers. In random order, the identified barriers included the following:

i. High capital cost,
ii. Poor infrastructure for water access,

iii. No natural water source availability on the Island
iv. Contamination of ground water
v. Poor governance
vi. Land ownership issues
vii. Climate Change and disasters
viii. Lack or inadequate access to financial resources.
ix. Consumer preferences and social biases
x. Lack of social acceptance due to water quality consideration

Screening and prioritization of identified barriers

After the compilation of the list, it was presented to the participants of the technology barriers analysis workshop to screen the list and identify the essential barriers – that need to be addressed for technology transfer and diffusion to occur. This was done alongside the non-essential barriers that were then ignored. The barrier analysis tools such as starter problem and solution trees were used to determine the process of prioritization of barriers. Through consensus among participants, the final list of barriers was achieved and briefly discussed below:

1.5.2.1 Economic and financial barriers

a) As the technology is identified as public good, so its development and operational maintenance and running costs will remain under the public sector domain. The ministry responsible for water and utility may access finance to support such investment. This however may not be that feasible as access to funding may be difficult for the government to secure and support such a service to its people.

1.5.2.2 Non-financial barriers

Policy, Legal, and Regulatory

a) Republic of Nauru has a general Policy on Water and Sanitation, but it does not have a specific policy on water distribution on the Island nation. This water distribution policy should include both potable and non –potable water technology system. Like other related water technologies, the policy should include the rights, the rules and specifically the non-potable water distribution on the Island. This provide a good compressive a ray of strategies to on how to handle this technology throughout the country.

Technical

b) High labour and capital cost to construct such a structure of magnitude would be technically a challenge. This would be similar concept of a potable water reticulation technology system, but the difference is its non-potable water distribution.
c) Like reticulation of potable water, such technology would require high capacity of communities, in terms of know-how and material resources to sustainably maintain and manage the technology beyond the project duration.

Social, cultural and behaviour

a) Land is privately owned either by individual or family groups. Thus, the government will have to acquire some of the land for public assets or structural construction. Often people don't want to allow their private property for a communal purpose.
b) Government must acquire or lease the privately-owned properties for public benefits.
c) Communities must aware of the need to have access even to non-=potable water at district level across the Island.

Information and awareness

a) Limited knowledge and awareness about the potential benefits of Non-potable water access technology at community level is limited.
b) Limited awareness of the impact of climate change and this identified technology solution at community level.

1.5.3 Identified measures

This section outlines the measures needed to overcome the barriers to implementation of Access to non-potable water technology on the island nation. Like the other earlier types of technologies discussed, the methodology we engaged to arrive at this stage was the development of a problem and solution trees and through stakeholder participation we narrowed the down the identified barriers with potential strategies in overcoming them.

1.5.3.1 Economic and financial measures

a) To compensate the projected high initial cost of construction of a structural infrastructure needed to build such a technology government should again reduce or apply tax remission for imported material required for construction of the structure by the contractor.

b) The central government should provide through its development annual budget money to support such investment at the local levels.
c) The international donor grants may be used for subsidizing the initial construction of large structural infrastructure to supply water through the reticulation of non-potable water system.

Policy, Legal, and Regulatory

a) Republic of Nauru to approve and implement a specific policy on water distribution on the Island nation. This water distribution policy must include both potable and non –potable water technology system. Like other related water technologies, the policy must include the rights, the rules and specifically the none-potable water distribution on the Island. This provide a good compressive a ray of strategies to on how to handle this technology throughout the country.

Technical

a) Train locals to participate to construct such a structure of magnitude would a technically a challenge. This would be similar concept of a potable water reticulation technology system, but the difference is its non-potable water distribution.
b) Train women and young girls to participate in construction of structures at local level to distribute potable water across the country.

Social, cultural and behaviour

a) Understand the local context of the community and design a technology that will be useful to the community. The land and social cultural context must be carefully addressed for long sustainability.
b) Government must acquire or lease the privately-owned properties for public benefits.

Information and awareness

a) Awareness program need to be promoted at local level to increase knowledge and potential benefits of Non-potable water access technology at community level is limited.
b) Run awareness campaign to increase knowledge about the impact of climate change and this identified technology solution at community level.

1.6 Barrier analysis and possible enabling measures for Tanker Truck Water Distribution technology.

1.6.1 General description of Tanker Truck Water Distribution technology (TTWDT)

Tanker trucks are fitted with a cistern or storage tank to transport and distribute water from a point of supply to the point of use, particularly to areas not served by a piped supply. If water is not supplied from a central treatment facility, it is usually extracted from the closest natural source (canals, reservoirs, or groundwater sources) and transported by the trucks to the point of use. Water thus transported may be pumped into a storage cistern, dispensed directly into household or other containers, or discharged into a small-scale treatment facility for centralized distribution. The tanks on the trucks are usually manufactured locally, and some trucks are equipped to carry potable pumps to extract the water from its source. In Nauru, desalinated water is stored at a storage facility at the Utility compound and is trucked to the customers both private and business houses upon request or order. Although rooftop rainwater harvesting is said to be the primary source of potable water on the Island, due to the impact of Climate change, there is reduced number of rainfalls or prolong dry spells therefore making people more dependent on Nauru Utility for Potable water.

1.6.1.1 Technology status in Nauru

There are currently about 5 Tanker Trucks water distribution technology (TTWDT) in operation on the Island nation. These are of course need regular maintenance and repair of the pumps, pipes, fittings and periodic upgrading of the facilities. Problems with water leaks, pumps, and storage facilities, mechanical defaults to the truck require immediate attention in order to avoid interruption of services.

Maintenance of this distribution system includes servicing the pumps and other treatment plant components, inspecting the diversion systems and pipelines, repairing leaks, and replacing electrical motors and other moving parts. Several problems were encountered in the operation and maintenance of a distribution system in the island. The level of skill needed to operate these systems is medium to high and involves some technical training of the operators. Currently, the Nauru Utility Corporation is the body which is responsible for distribution of water from the storage facility to consumers. It is done on a commercial basis.

1.6.1.2 Technology category and market characteristics

The current TTWD technologies which are up in running in the country are owned by the NUC a corporation owned by the government. It sells water upon request to private and business consumers at a subsidized rate. Therefore, we can say is partially a market product. The NUC is currently charging money from the consumers to cover cost of maintenance and administration of the technology. This was in operation for more than three (3) decades.

Market characteristics for tanker truck water technology systems are identified as:

i. Usually are relatively big trucks and have the capacity to hold thousands of litters of water at same time,
ii. Usually imported from overseas, but can be modified with pumps and other parts at local level or in country to suit level context,
iii. Awareness raising about the usefulness of this technology needs to be undertaken mainly by relevant institutions and supported by the government.
iv. It is a current technology, thus there are some levels of awareness about the technology in the community but just need remind users of its usefulness in the community.

1.6.2 Identification of barriers for tanker truck water distribution technology

The barrier identification process for the diffusion of tanker truck water technology is done through literature review and by interviews with the NUC expert staff, consultation, brain storming sessions with stakeholders including NGO representatives, employees of the NUC and household representatives. The number of barriers were identified and summarized into two major categories- economic/financial barriers and non-economic/financial barriers. Non-economic/financial barriers are further divided into other sub-categories: policies/regulatory, technical, social, cultural, and behavioural barriers. The other sub-categories include, institutional capacity barriers, information and awareness barriers, human skills barriers, environment barrier and market failure barriers.

Listed below is a list of generalized potential barriers to diffusion and transfer of higher efficiency tanker truck water distribution technology:

i. High cost of set up additional fleet,
ii. High maintenance and operational cost,
iii. Poor infrastructure, bridges etc. for such technology to be operative,
iv. Lack of financial resources- Repairs to older tanker trucks,

v. Water prices are increased because of the expense of transporting relatively small quantities by road.
vi. There is a lack of quality control over transported water,
vii. Water distribution is costly and slow,
viii. Adequate roads are required to transport water from one area to another,
ix. High Operational costs to ensure all of most of the tanker trucks are in operation,
x. There should be storage facilities build across the island nation as reservoir.

1.6.2.1 Economic and financial barriers

a) There is a high initial investment required to acquire additional tankers truck for water distribution across the island nation. Although, it is an existing technology, half of the fleet (three (3) out of six (6) tankers) are inoperative due to mechanical reasons. Thus having the ability to fix and maintain the existing fleet with spare parts is just as important as getting the new additional tankers.
b) Furthermore, since additional tankers are needed more for dry spells their utilisation is low other and therefore become more expensive.

1.6.2.2 Non- economic / financial barriers

The non-economic / financial barriers identified are grouped under different categories as described below:

Market failure and imperfection

a) Since it is a market good, the TTWDT faces a ray of market challenges that are major obstacles in the deployment and successful replication of the technology across the country. But since the technology is already in operation in the country for more than three decades, there are a lot of lesson learned that this technology could learn from to ensure successful implementation. Currently, there are 3 tankers truck in operation by the NUC, the additional fleet should subsidize the cost of water to consumers both household and businesses.
b) In the case where the fleet is owned and run by another body, it will promote competition and thus drop the prices of water loads which the consumers will greatly benefit from such development.

Policy, legal and regulatory

a) Absence of approved designed water distribution policy across the island. This to protect household and business consumers.
b) Current pricing of water distribution business in the country is not that conducive, thus itself is a barrier to further expansion.
c) Water and Property rights conflict over of constructing water storage tanks or reservoirs strategically at locations around the Island nation.

Technical

a) Require special mechanics to service the tanker truck on regular basis
b) Limited repair and maintenance technical know-how on the Islands
c) Lack of Scientific data or proper socio-economic analysis of the current technology at the national level
d) Limited research on quantifying the real water saving from using this technology compared to another technology. For example, the new reticulation technology
e) Need for well-trained local mechanics and water engineers to support the technology.
f) Need a proper road and bridge infrastructure to support this technology around the country.

Social, cultural and behavioural barriers

a) Resistance of households from using current rainwater harvesting system and ground water with this new and added fleet of Tanker truck water distribution technology.
b) Preference of other households and business consumers from changing their means of water source (ground water or rainwater harvesting system) to this tankers truck water distribution technology.
c) Fear of water shortage during periods which there is no fuel or energy to power the RO into water to distribute to households.
d) If there is a disaster and there is no water reserve at the distribution facility base for distribution to households and business houses

Institutional capacity barriers

a) The NUC must have the capacity to store water at various strategic locations around the Islands. This would be useful if there is disaster and disruption to the road and bridge infrastructure.
b) Limited good knowledge and practical experience which is necessary to coordinate such tanker truck water distribution technology around the Island.

Information and awareness barriers

a) Absence of communication between producers of spare parts and the operators (NUC) of the current technology.
b) Inadequate access to training and service and information by operators.

1.6.3 Identified Measures.

This part of the section identifies and discusses measures needed to overcome the barriers identified in earlier section to implement effective Tankers Truck Water Distribution Technology in Nauru. The main methodology engaged for the identification of appropriate measures is the development of problem and solution trees through the stakeholders' participation. Additionally, there is a detail analysis of current national practice by way of interview with the NUC, who's role as the primary entity responsible for distribution of desalinated water around the Island country. Finally, these discussion during a stakeholders' workshop conducted by the mitigation team with experts in water sector on the island.

1.7 Linkages of the barriers identified.

This section discusses the different barriers common to *rooftop rainwater harvesting system, water reticulation system*, *non-potable water access* and *tanker truck technologies.* These four prioritized technologies in water sector serve the common goal for communities to have access to potable and non-potable water. Non potable water access seemed to be oldest technology of harvesting on the island nation, then followed by roof top rainwater harvesting technology, tanker truck and ideally the water reticulation system.

The country once had a reticulation system on certain part of the Island, but it was abandoned after the scaling down and closure of the phosphate in the early 90's. Now the island country depends largely on desalination water and distribution by way of tanker trucks, but this technology is expensive and often inconvenient to consumers. Currently, the government through the NUC is strategically working towards construction of some form of water reticulation system for essential services such as hospital, schools, police, and utility corporations, although sustainability of technology selected is questionable.

All prioritized four technologies share many common barriers in the context of similarity in the development and use, therefore it is only imperative to take a holistic approach towards finding linkages in order to find potentially more efficient approaches and opportunities to address their combined effect. Refer to **Table 4** that shows the key common barriers identified for the four technologies in water sector in Nauru.

Table 4: Common barriers identified in different prioritised technologies in water sector

Barrier Category	Barriers
Economic & Financial	High capital and maintenance cost
	Limited financial allocation by national government
	Inadequate loan and donor funding
Policy, legal and regulatory	Lack of sound and robust cross –sectorial policies – resource protection, development, and management.
	When there are policies, they are ineffective and meaningless.
Information & Awareness	Lack of public information and awareness about the existence and usefulness of the technology.
	When there is information, they are insufficient and ineffective.
Institutional & organizational capacity	Limited institutional capacities specially at national level in integrating climate change risks in development planning.
	Limited human skills and maintenance specially at local level

1.8 Enabling framework for overcoming the barriers in the water sector.

A key component of the enabling framework for overcoming the barriers to the diffusion of prioritized technologies in the water sector is operationalization of the existing Republic of Nauru Framework for climate Change and Disaster Risk Reduction (RoNAdapt) policy and its implementation framework recommendations. The next step should include the increased budgetary allocation for increasing the resilience of the vulnerable communities from the impact of climate change on water resources. So that the diffusion of above-mentioned prioritized technologies can be facilitated through the mobilization of external donor agencies and getting access to international climate finance funds specifically GCF and adaptation fund. For that to happen we may need to devise effective technology-based adaptation projects that would promise to deliver the potential benefits of these technologies to the resource managers, users and other beneficiaries alike.

The next important component of sustainable water sector management in Nauru is the need to ensure that social, economic and environmental aspects of water are integrated into the across-cutting themes of water access, equity and hazards.

Based on this theme, the prioritized technologies implementing strategy needs to be focusing on prioritised water resources, such as rooftop rainwater harvesting system, water reticulation system, potable water access or distribution and tanker truck technologies.

In the category, we easily can place institutional capacities enhancement, strengthening laws, and regulations, ensuring climate change informed decision making and planning, promoting research and technology awareness, and implementing pilot demonstration projects on the islands. In addition, ensuring the required investment will continue to be the fundamental enabling factors all water sector technologies implementation.

Based on the above discussion, barriers and measure may cover broad issues:

1. Ensuring appropriate financial mechanism to support implementation,
2. Mainstreaming of climate change considerations into relevant sectoral policies, plans and strategies,
3. Strengthening research, training and technology awareness – rising among stake holders,
4. Strengthening institutional capacities at national and sub-national levels,
5. Designing and implementing practical pilot demonstration projects.

A brief account of important enabling measures needed to diffuse water sector prioritized technologies is given in **Table 5** below.

Table 5: Key measures identified for three technologies in water sector.

Key measures identified
Economic & financial
a. Ensure the availability of enough local development funding from national government as well as international funding sources for the diffusion of water technology.
Policy, legal and regulatory

a. Strengthen the current water policy with special attention to effective and coordinated national water management and framework for government to take the lead in an area of vital national concern. b. Define administrative boundary of saltwater desalination and authorize a single distributor across the country (currently the Nauru Utility Corporation). c. Resolve ownership right to water and land property rights through improved policy coordination.
Information and awareness
a. Prepare extensive information and awareness material about the existence and usefulness of water sector technologies and disseminate them improved right to water and land property rights through workshops and training sessions.
Technical –Institution and organisation capacity
a. Invest in technology capacity building of R & D and governmental institutions. b. Ensure the local training and availability of resources and maintenance staff.

Key water sector measures and enabling framework.

The key enabling measures needed to ensure diffusion of above-mentioned prioritized water sector technologies and to achieve the preliminary technology transfer and diffusion targets are as follow:

a) *Financing***:** High capital cost is a key issue in all four water sector technologies. So, we need to ensure that the national development planning process give required priority to the diffusion of these technologies in the country. Furthermore, as national development funds are limited 'Department of Finance -Nauru' should made every effort to obtain project specific grants /soft loans from international donor agencies particularly from international climate financing mechanism such as 'Adaptation Fund', 'Green Climate Fund' etc. The government must subsidise the cost of these technologies at the local levels across the country.

b) *Skills & Institutional capacity development:* Need to ensure that sufficient financial resources are allocated in annual budget towards skill & Institution capacity development to enhance their technical skills dealing with respective technologies. So, they can undertake feasibilities studies to select most suitable sites for surface rainwater harvesting (non-potable water), groundwater recharge based on hydro-geological conditions. Further, for designing the most appropriate urban storm water drainage system based on future climate projection also require skills and institutional capacity development.

c) *Operation and maintenance capacity*: To ensure the sustainability of all four water sector technologies enough financial resources needed to make available for enhancing the technical capacity of R&D and other line departments. Further, special training programs be undertaken to train local technicians in operation and maintenance of these technologies.

Chapter 2: **Coastal Sector**

2.1 Preliminary targets for technology transfer and diffusion

Nauru is a single, raised coralline island with a land area of only 21 sq. km. but with an EEZ which extends over more than 431 000 sq. km. The island lies 41 km south of the equator. The island nation was formerly rich in phosphate, which has been the country's principal source of income for many years. Phosphate resources are now depleting, and the country needs to develop alternate sources of income to replace the declining mining revenues. With porous soils and uncertain rainfall, Nauru offers limited opportunity for agricultural production, while fisheries development is a major economic prospect for the future. Although the island nation possessed only a very shallow lagoon, much of which dries at low tide, and a narrow fringing reef, the food produced by fishing in these inshore areas is very important in the Nauru diet. Nauru's open ocean areas are frequented by an abundance of tuna and other pelagic species. The harvests of tuna in Nauru waters is substantial, but the vast majority of the catch is taken by overseas-based industrial fishing vessels. The access fees paid by those vessels form a large portion of the government revenue.

The Island nation has a fertile coastal strip of only 150 to 300m, and people are settled around the narrow coastal belt where coconut palms flourish and is continually under pressure from sea level rise, coastal flooding, and impact of climate change. According to Kopp et al, (2014) Nauru records one of the highest sea level rise in the world. Following the initial TNA consultation on the Island in 2019, both the government and private stakeholders have agreed that alongside with water sector, the TNA process would also focus on Coastal Area resource management in its endeavour to safeguard the Island nation coastal resources.

During the TNA phase 1, participants have discussed and selected with ranks, 4 potential technologies which the TNA process would have to pursue and prioritise under its process. The focus on these selected technologies is deemed necessary to arrest the increasing impact of sea level rise, destruction of coastal beaches and removal of corals and other resources along the decreasing strips of narrow beach, around the Island nation. Below is the list of technologies which the TNA process has selected by listing them in their ranked order.

Prioritised coastal areas Technologies:

a) Coastal vegetation restoration,
b) Locally Managed Marine area (LMMA).
c) Policy Formulation over coastal area and resource Management
d) Sea Wall Construction

2.2 Barrier analysis and possible enabling measures for coastal vegetation restoration technology.

2.2.1 General description of coastal vegetation restoration technology (CVRT)

The only fertile land areas in Nauru are the narrow coastal belt, where there are coconut palms, pandanus trees and indigenous hardwoods such as the tomano tree (Fa'anunu, 2012)[18]. Thaman, et al, (1994)[19] in an earlier study also found that the land surrounding Buada lagoon, where bananas, pineapples and some vegetables are grown are also fertile. Furthermore, some secondary vegetation grows over the coral pinnacles at various locations around the Island.

Sea level rise

Below the belt of land as described above (also refer to **Figure 9** below), the coastal vegetation protects coastal areas from saltwater inundation as result of sea level rise, saltwater intrusion and costal erosion or washing away of beaches and soil into the ocean. According to PCCSP 2014[20] Satellite data indicates the sea level has risen near Nauru by about 5 mm per year since 1993. This is larger than the global average of 2.8–3.6 mm per year. This higher rate of rise may be related to natural fluctuations that take place year to year or decade to decade caused by phenomena such as the El Niño-Southern Oscillation. Sea level rise mainly destroys and washes away vegetation along the beaches (Kopp et al,2014).

[18] Fa'anunu, M. H. (2012). Prepared by Mr Haniteli Fa'anunu (FAO Consultant–Tropical Agriculture Specialist).

[19] Thaman, R. R., Fosberg, F. R., Manner, H. I., & Hassall, D. C. (1994). The flora of Nauru. *Atoll Research Bulletin*.

[20] PCCSP (2014), Pacific Climate Change Science Program for Nauru,

Figure 9: Ariel view of Nauru showing the coastal plain and mined out interior (photo Torsten Blackwood, AFP)

Coastal Flooding

More frequent coastal flooding is a direct impact of global warming and subsequent sea-level rise (IPCC 2012). Based on the global tides and surge reanalysis by Muis et al., (2016)[21], it is estimated that the extreme coastal water level could increase from 0.2 – 2.8m over the mean level. While in extreme cases like China and the Netherlands it could experience 5-10m of extreme sea levels. Henceforth, the coastal local flood level is added on top of the projected SLR. Because of the above projection, the country is expected to experience the impact of sea level rise, especially along the coast lines.

- [21] Muis, S., Verlaan, M., Winsemius, H. C., Aerts, J. C. J. H. & Ward, P. J. (2016). A Global Reanalysis of Storm Surges and Extreme Sea Levels. *Nature Communications*, 7.

2.2.1.1 Technology status in Nauru

The coastal vegetation restoration technology is not a new concept on the island nation. Communities around the island nation now realised the importance to plant trees and replenish the vegetation between the beaches and identified fertile land inland to prevent coastal flooding and beach erosion. While some random actions of the communities in this space are not well coordinated, literature found that some of the main drivers to soil erosion mainly in the shore zones areas are mainly cause by human activities, such as sand extraction through beach mining for construction and reclamation purposes always result in long term depletion of the sand resources on the beach (Gillie, R. D. (1997)[22] Thus, it significantly reduces the natural protection that the beach provides to the coastal communities. For replenishment of vegetation to hold, communities must learn from past mistakes and committed to this initiative.

2.2.1.2 Technology category and market characteristics

The Coastal vegetation restoration technology can be categorized as a non-market public good as when established at a community level requires state and community level support to develop and implement such technology at the local level. The technology option in this report is a community or State-coordinated coastal vegetation restoration technology and thus considered as a non-market public good. The government, land owning groups and district administrators must collaborate in this endeavour to ensure long term sustainability.

2.2.3 Identification of barriers for Coastal Vegetation Restoration technology

Preliminary barrier identification

The barrier identification process for the diffusion of Coastal vegetation restoration technology is done through literature review and by interviews with government officials, consultation, brain storming sessions with stakeholders including NGO representatives and community leaders. The number of barriers were identified and summarized into two major categories- economic/financial barriers and non-economic/financial barriers. Non-economic/financial barriers are further divided into other sub-categories: policies/regulatory, technical, social, cultural, and behavioural barriers. The other sub-categories include,

[22] Gillie, R. D. (1997). Causes of coastal erosion in Pacific island nations. *Journal of Coastal Research*, 173-204.

institutional capacity barriers, information and awareness barriers, human skills barriers, environment barrier and market failure barriers.

Listed below is a list of generalized potential barriers to diffusion and transfer of coastal vegetation restoration technology:

i. Land tenure system
ii. Financial constraints
iii. Awareness – attitude problem
iv. Climate Change and Disasters
v. Introduction of new types of trees to be planted at the coastal sites.
vi. Coastal Flooding
vii. Coastal area development is not national government priority areas.
viii. Local government politics
ix. No policy on coastal vegetation destruction

Screening and prioritization of identified barriers

After the compilation of the list, it was presented to the participants of the technology barrier analysis workshop to screen the list and to identify the essential barriers – that need to be addressed for technology transfer and diffusion to occur. Also, at this stage, the participants decided to ignore the non-essential barriers to the technology as identified in the process. Through consultation and consensus among participants, the final list of barriers was accepted as discussed below in brief.

2.2.2.1 Economic and financial barriers

a) Economic hardship – Coastal area land owning groups see this opportunity of beach mining and extraction for economic purpose as source of income. Thus, land owning groups will always be negatively induced to allow their beaches to be removed in bulk for other development purposes and in the process deforesting the coastal vegetation.
b) Financing barrier – The cost of individual investing in coastal vegetation replenishment program may be expensive for land owning group to sponsor by themselves.
c) Types of Vegetation to plant at the coastal areas- The types of vegetation and how to grow them is also important. They are expensive to collect them or import them to Nauru. To address the concern, the project may do a nursery to raise them in, multiply them. Additionally, cost of sands, soils, nursery bags, distribution, planting tools are also costly.

2.2.2.2 Non-financial barriers

The non-economic / financial barriers identified are grouped under different categories as described below:

a) Land Tenure system – The coastal land areas are owned by individuals or family units. Often the people who owns these coastal areas have authority over the activities that take place within their boundaries.
b) Awareness – Landowning group and general public may not understand the importance of growing the coastal area vegetation to the community.
c) Policy – There is no national policy on how communities should be managing and extracting resources within this designated boundary – coastal area.
d) Not priority area – Coastal area management is not priority area of the government and communities to invest funding into. Unlike schools, hospitals and law and order.

Technical

This technology was a simpler one and does not require a high level of technical expert to lead the revegetation process. Nevertheless, it requires the technical knowledge of what to plant, what to rehabilitate and what to protect at the coastal areas. Knowing what, where and how to plant are some of the essential skills that are critical for this technology. Furthermore, it requires government and community support to ensure that such technology is planned, accepted and well implemented at the community levels.

Social, cultural and behaviour

Land owning groups must recognise the need to allow their land plots to be revegetated at the coastal areas to protect the Island from experiencing coastal flooding and beach erosion. Culturally, it is the prerogative right of landowners to have control over their land and boundaries along the coast lines but some of those rights must be forgone for the public good of all.

Information and Awareness

a) There is limited knowledge about revegetation if native trees along the beach to prevent soil erosion and flooding.
b) There is limited knowledge at the local level that such vegetation may project the coastal land areas from sea level rise.

2.3 Barrier analysis and possible enabling measures for locally managed marine area (LMMA)

2.3.1 General description of LMMA

A Locally Managed Marine Area (LMMA) is an area of nearshore waters and its associated coastal and marine resources that is largely or wholly managed at a local level by the coastal communities, land-owning groups, partner organizations, and/or collaborative government representatives who reside or are based in the designated area (Kawaka, et al, 2017)[23]. Community-based management and co-management are mainstream approaches to marine conservation and sustainable resource management. In the tropical Pacific, these approaches have proliferated through the spread of locally managed marine areas. LMMAs have garnered support because they can be adapted to different contexts and focus on locally identified objectives, negotiated and implemented by the people involved. While LMMA managers may be knowledgeable about their specific sites, broader understanding of objectives, management actions and outcomes of local management efforts remain limited. According to Key Informants, the Ridge to Reef information on the Island is limited. Despite this limitation some communities along the coastline are keen to participate in the LMMA purposively to conserves the marine resources but at the same time renourish the coastal beaches to grow and rebuild against sea level rise and coastal erosion including man made removal of beaches along the coast lines.

2.3.1.1 LMMA status in Nauru

There is not much data available on this technology across the Islands. Although there was recently an outreach by the Ridge to Reef program on this concept, but still yet to be aggressively pursued. According to key informants, some communities on the Islands intend to rigorously pursue this concept because it is seen as the only chance to conserve and rehabilitate their coastal areas. The LMMA is common across most Pacific Island countries. This is because LMMA across the region are developed at national levels are built on a unique feature of the region, customary tenure and resource access, and make use of, in most cases, existing community strengths in traditional knowledge and governance, combined with a local awareness of the need for action, resulting in what have been most aptly termed LMMAs. The

[23] Kawaka, J. A., Samoilys, M. A., Murunga, M., Church, J., Abunge, C., & Maina, G. W. (2017). Developing locally managed marine areas: lessons learnt from Kenya. *Ocean & Coastal Management*, *135*, 1-10.

main driver in most cases, is a community desire to maintain or improve livelihoods, often related to perceived threats to food security or local economic revenue and prevent coastal erosions from impacts of climate change.

2.3.1.2 Technology category and market characteristics

The Locally Managed Marine Area technology could be categorised as a non-market public good when it's established at the community level. This is because although it will be established within the private area of some landowning group on the Island, but it will need state assistance to support and implement such technology.

2.3.2 Identification of barriers for Locally Managed Marine Area technology

As a first step, the consultation team with relevant stake holders including members from some NGOs and land owing groups have identified a list of potential barriers to diffusion of LMMA technology in Nauru with addition of literature. (It must be noted that literature is not helpful at all as there is little data available about the LMMA in the public domain). Regardless of hurdles, this is the list of barriers as identified:

i. Lack of coastal area development policy document,
ii. Land ownership at coastal area- decision making,
iii. Limited funding to support such initiative,
iv. Awareness by communities of importance of LMMA
v. Enforcement issues
vi. Livelihood needs vs need to conserve the resources,
vii. Low institutional capacity
viii. Coastal flooding
ix. Low capacity

Screening and prioritization

The final screening and prioritization of the above barriers to diffusion of this technology were undertaken through extensive consultation and brain storming led by the National Mitigation expert while on the Island. The need to be addressed for technology transfer and diffusion to occur – as well as the non-essential barriers that were to be ignored. The barrier analysis tools such as starter problem and solution trees were used to expedite process of prioritization of barriers. Through consensus among participants, the final list of barriers was achieved and discussed as below in brief.

2.3.2.1 Economic and financial barriers

As the technology is identified as public good, so its base line study where to establish LMMA, surveillance, operations including enforcement, monitoring of shoreline areas as well other related costs will be met by the state or government. There is a lot of information needed to create a baseline and make an assessment on what and where to be considered as an LMMA. These surveys include marine and terrestrials, thus this is also costly if there is no local capacity to do. These will be expensive exercise for the government to go down this part. Below are some descriptions of the economic barriers are detailed as follows:

a) Baseline study – Before deciding on the actual locations for establishment of the LMMA, the government through relevant stakeholders must participate in a study determine what resources or species to conservation and the type of conversation that is applicable to that community.

b) Surveillance – It will be costly to land owning groups and communities who participate in this technology to run such initiatives by themselves. Thus, it is preferable that the government under the responsible Department funds such technology.

c) Enforcement and Monitoring costs - enforcement and monitoring of vast offshore areas will be proven expensive to local land-owning groups and community residences. It will be effective if the government invest into the monitoring and enforcement.

d) Staffing costs - This will be a burden on to the communities or land-owning groups if they decide to establish this technology. In the past, there were some similar technologies to this LMMA established but due to economic reasons, communities and land-owning groups discontinue those good intensions. The government must absorb this cost into its recurrent expenses to ensure the long-term sustainability of this technology on the ground.

2.3.5.2 Non-financial barriers

On the other hand, there were some non-financial barriers which were identified and needs specific attention to either absorb or minimise these barriers. The barriers are categorised under Policy, Legal, and regulatory.

a) **Policy** – There is no clear policy to provide guidance on development of the coastal area to link with the policy on marine protected areas or even locally managed marine areas. In absence of this, communities wanting to venture into this technology are usually left with no direction.

b) **Legal and regulatory** – The government has to establish a legal framework purposively to protect the locally managed marine areas in the country. Without such instrument or regulation, the communities will not effectively adopt and implement such noble intension- to conserve the environment across the country.

c) **Land ownership issues** – This is also an area which needs to be addressed at both the national and district levels across the country. From past experiences, land ownership issues amongst tribal groups and communities' distrusts and discontinue such noble investments.

Technical

a) Establishing a LMMA on the Island could also be challenging. For example, it may require scientifically based, comprehensive nationally designed model of MPA representing diverse, marine ecosystems, and the Nation's natural and cultural resources. Often there are few locals who has the capacity to design such technology.

Social, cultural and behavioural

b) Coastal area including the sea areas around the Island are very much part of how people live and go about their livelihoods across the Island. They depend on the sea for food and other recreational purposes. Allocating a specific area for conservation will test how community members behave and manage their resources.

c) Community members must accept that conserving the environment or marine resource is a critical for long term sustainability of future generations.

Information and awareness

a) Develop and maintain the database on Ridge to Reef matters in the country. This is important to ensure that people know the importance of locally managed marine resources. On the short term is to protect their coastline areas but in the long term ensuring that there are marine resources conserve for future generations.

2.4 Barrier analysis and possible enabling measures for Policy and Guideline formulation over Coastal Resource Management

2.4.1 General description of Policy and Guideline formulation over coastal resource management

Policy is a deliberate system of principles to guide decisions and achieve rational outcomes. Policies are generally adopted by a governance body within an organization or country. Policies can assist in both subjective and objective decision making. For example, in Nauru there are various policies which are put in place for the government to operate within to achieve long and sustainable development to all Nauruan (National Development Strategy 2005-2025). Additionally, the Integrated Water Resource Management Policy (IWRM) of Nauru which provide guiding principles on how to manage the scarce water resources in the country. This policy and guideline formulation as technology is aimed to develop set of rules and guidelines surrounding the extraction of resource alone the coast lines including extraction of vegetation and sand beaches.

The benefit of having such a technology is to provide some level of control and oversight over the extraction and removal of sand beach which could lead to further coastal erosion and washing away of beaches.

2.4.2 Technology category and market characteristics

Policy and Guideline formulation over coastal resource management technology is categorised as a non-market and publicly provided good. This means, the national government will have to allocate the relevant expertise and resources to design this technology for the good of society and country.

2.4.2 Identification of barriers for Policy and guideline formulation

Screening and Prioritization process.

The screening and prioritization process for this technology has not much complications compared to other technologies. This is mainly because there aren't a lot of barriers identified during the consultation and workshop process regarding this specific technology. Nevertheless, it went through the process for potential barriers to the diffusion and transfer of policy guideline formulation over resource technology. The barriers identified were as follows:

i. No capacity to engage legal experts,
ii. No prioritized funding from the state
iii. Cultural issues
iv. Government support
v. Enforcement issues

The key identified barriers are discussed below:

2.4.2.1 Economic and financial barriers

b) **Legal Cost** – Usually it will cost the Nauruan government or state, thousands of dollars to hire a legal counsel to design and develop such policy. The participants urged as part of this process if this technology could be developed to ensure engagement of a legal counsel to lead in formulation and development of policy over coastal resource management.

c) **Economic benefits** – There is perception that coastal area resources are owned by land owning groups or individuals. Thus, any economic or authority regulating this process, rests on land owing groups and not the state.

d) Enforcement cost – When such policy is formulated there must be an authority who has the resources and capacity (laws and institutional) available to enforce such instrument.

2.4.2.2 Non-financial barriers

a) **Political will –** The government must support this initiative. The technology was overwhelmingly supported during the consultation and workshop but, it must have the political will by the government of the day.

b) **Land ownership –** Development of any technology to safe guard the extraction and harvesting of resources at the national level will face some barriers or views of some sort by the land owning groups and individuals.

c) **Enforcement issues -** There will be clash between land owners and government official over enforcement issues if proper awareness and education is not done at the local levels.

d) **Regulatory** – The government must take ownership to such technology establish a regulatory body to regulate the design, development, adoption and implementation of such policy.

Social and Cultural

a) **Community support** – The communities including landowners should promote development of such important technology.

Technical

b) As this is a new area across the country, there is little or no technical expert available to design, formulate or lead in drafting such technology (coastal resource management policy).
c) Poor knowledge in coastal resource management design or formulation in the face of climate change.

Information and Awareness

a) There is limited information on the need to have such a technology over resource management in the country.
b) Absence of data and information on the negative impact consequences of climate change at the national level to support the call for such policy technology formulation.
c) Need to inform the general public on the potential benefit of having such a technology in the country.

2.5 Barrier analysis and possible enabling measures for Seawall Construction technology

2.5.1 General description of Seawall Construction technology

A seawall (or sea wall) is a form of coastal defence constructed where the sea, and associated coastal processes, impact directly upon the landforms of the coast. The purpose of a sea wall is to protect areas of human habitation, conservation and leisure activities from the action of tides, waves, sea level rise or tsunamis. In some Small Pacific Island countries a few governments resort to sea walls as temporary measures against the increasing sea level rise, storm surges and coastal erosion. In Nauru a new seawall in the district of Anetan will help alleviate sand erosion and the effects of king tides on the community. The Government of India donated AUD 500, 000 to its Nauru counterpart to help construct the 200-metre seawall on the north side of the island. According to Key respondents on the Island, the barrier helps the community to build resilience against King tides and provides them with some comfort of hope that their community will not immediately be washed away by the looming impact of climate change.

The downside of this technology is that, it is costly and capital intensive. Furthermore, it could also have some environmental impact on the beaches if not properly planned and constructed. For example, in the neighbouring Island country of Kiribati at the Aonebuka community, the villagers have banned construction of sea wall because, they believed that building a seawall is not best for their community, so they setup a community agreement, that nobody, no family, or no clan is allowed to build a seawall on the coastline. The sea wall rearranges the flows of waves and currents around the Island.

According to a key informant, Seawalls can sometimes increase the rate of erosion in front of the seawall due to wave reflection and at the ends of the structure caused by wave focussing. When all available sediment has been removed in front of the wall, down drift areas will no longer receive sediment and erosion may be accelerated as a result of building the wall.

2.5.2.1 Technology category and market characteristics

Depending on scale and who is formulating the application, Seawall construction technology in this context is a non-market public good. This is because the applicant is the government and most likely general public will benefit from such technology and the state will meet the cost of such infrastructure. Thus, in our discussion, the on the technology barrier, it is considered as a public good.

2.5.3 Identification of barriers for Seawall Construction technology

Preliminary barrier identification.

As an initial step, a desk top review was made on various key documents and policy papers to determine any immediate major barrier to sea wall construction technology in the country. Such exercise was supplemented by interviews with experts, key stakeholders and brainstorming. During the process a list of potential barriers to development, transfer and diffusion of seawall construction technology in the country was prepared and categorised into two broad main categories. These were economic and financial barriers and non-financial barriers. The non-financial barriers were then further divided down into policy, legal, and regulatory barriers, technical barriers, institutional and organisational capacity barriers, social barriers, informational and barriers. These barriers were discussed in detail below.

i. High capital cost,

ii. Funding allocation by government,

iii. Land ownership issues,

iv. Material Intensive,

v. Technical expertise,

vi. Community perception,

Screening and Prioritization of identified barriers

After the compilation of the list (barriers), it was then presented to the stakeholders during a technology analysis workshop. The list was further scrutinised and reduced to identify the essential barriers – that need to be addressed for technology transfer and diffusion to occur while the non-financial barriers identified and were ignored from the same process. As most of the barriers above, a barrier analysis tool such as starter problem and solution tree were used to speed up prioritization of barriers. Through consensus among stakeholders and expert participants the final list of barriers was achieved and discussed in brief below:

2.5.2.1 Economic and financial barriers

a) **High capital cost –** The cost to build a seawall is relatively expensive at the local level. For example, the total project cost of the recent sea wall donated by Government of India was AUD$500,000, this is including imported materials such as cements, reinforce wires to construct the technology. Additionally, it requires transportation of rocks and from the mining.
b) **Funding Allocation** – There is no government budgetary allocations into this sea wall construction around the Island. And with such limited funding opportunities, sea walls are prioritised by the government of the day.
c) **Donor Funding** – Donors could be approached to fund one of the TNA projects in the country.

2.5.2.2 Non-financial barriers

a) **Policy** – There is no policy on how and where to construct seawall technology across the Island nation.
b) **Legal –** The Island nation like many others through the region don't have the legal framework that guides communities and individuals on how to build sea walls at their own areas.

c) **Regulatory** – In absence of policy around construction of sea wall, there isn't a requirement such as Environment Impact Assessment (EIA) and Cost Benefit Analysis (CBA) as approval process for construction of these structures.

2.6 Linkages of the barriers identified.

This section looks at different barriers that are common to; *roof top –rainwater harvesting, water reticulation system*, *non-potable water access* and *tanker-truck technologies* under water sector. Likewise, it also looks at *linkages which coastal vegetation restoration*, *locally managed marine area*, *policy formulation over coastal area* and *resource management* and *sea walls construction technologies may have in common at the local level.*

For the water sector; the identified four technologies are geared towards enabling the individuals and communities having access to both potable and non-potable water improving the health and livelihood of the communities. The barriers identified are similar, with all the technologies, and that they are all expensive and costly to establish. This implies that individual households and communities may find it difficult to privately acquire these technologies.

2.7 Enabling framework for overcoming the barriers in the coastal sectors

A key component of the enabling framework for overcoming the barriers to diffusion of prioritised technologies in the coastal sectors is the operationalizing of existing national climate change policy and its implementation framework recommendations related to the coastal area management. The next step should include the increase budgetary support allocation for increasing the resilience of the vulnerable communities from impact of climate change on coastal areas. Thus, the diffusion of above-mentioned prioritised technologies can be facilitated through the mobilization of external donor agencies and getting access to international climate finance funds especially Green Climate Fund (GCF), Global Environment Facility (GEF) and Adaptation Fund (AF). For that to happen, the country needs to devise effective technology-based adaptation projects that would promise to deliver the potential benefits of these technologies to the resource's owners, managers, users, and other beneficiaries alike.

Similarly, the next important component of sustainable coastal area resource management in the country is needed to ensure that social, economic and environmental aspects of coastal area management are integrated into sectoral policies and plans of the government and communities across the country. Since communities across the country are settled mostly along the coastal areas, any plans and programs should be taking guidance from the cross-cutting themes of coastal protection, water equity and hazards.

Based on the above themes, the prioritised technologies' implementing strategy, need to focus on ensuring that there is effective design and implementation of the eventually approved and funded technologies that are aimed at benefit households and communities at large. Furthermore, though several measures are proposed to improve diffusion of coastal sector prioritised technologies, it is important to address the most fundamental, practical urgent ones first.

At this stage, we could potentially link institutional capacities' enhancement, strengthening laws and regulations, ensuring climate informed decision making and planning, promoting research and technology awareness, and implementing pilot demonstration projects at various locations across the country. In addition, ensuring the required investment will continue to be the fundamental enabling factors across all water and coastal sectors technologies implementations at national and local levels.

Based on the above themes, discussions, barriers and measures may cover these 5 broad issues for both water and coastal sectors:

1. The national government must ensure that there is appropriate financial mechanism to support any implementation.
2. The appropriate authority to mainstream climate change considerations into relevant sectorial policies, plans and strategies.
3. There is need to strengthen institutional research, training, and technology awareness –raising among stakeholders
4. There is need for strengthening institutional capacities at national and sub-national levels
5. Prior to full implementation, there must be proper designing and implementing practical pilot demonstration projects at the local levels.

A brief account of important enabling measures needed to diffuse water and coastal area sectors prioritised technologies is given in the **Table 6**.

Table 6: Key measures identified for the four technologies in coastal area resource management

Key Measured Identified
Economic & financial
a. Ensure availability of fund of sufficient local development funding from National as well as international funding sources for diffusion technologies.
Policy, legal, and regulatory
b. Formulate a coastal area resource management policy with special attention to conserve the coastal areas from soil mining and extraction by human activities. c. Define administrative boundary for landowners with restriction on what they could do and what they shouldn't do even in their own areas along the coastline zones. d. Recognise the role and authority of land-owning groups along the coastlines but must setup process on how they could still have access to their coastal area without any damage or disturbances to the land.
Information and awareness
e. Prepare extensive information, and awareness material about the importance of keeping or conservation coastal area (land) vegetation intact, pretending soil erosion and impact of climate change.
Technical – Institutional and organisational capacity
f. Invest in technical capacity building of R & D and local government institutions g. Ensure the local training and availability of local experts to maintain coastal areas and resources.

Key coastal area measures and enabling framework.

The key enabling measures needed to ensure diffusion of the above mentioned prioritised coastal sector technologies and achieve the preliminary technology transfer and diffusion targets includes the following:

a) ***Financing***: High capital cost is a key issue in all of the identified technologies in the coastal area sector management. Because of this we need to ensure that the national development planning process provides the maximum required priority to the diffusion of these technologies into the country. Additionally, since the funds since there is limited development fund available to fund these investments the Department of Finance must seek external climate financing mechanism such as Adaptation Fund and Green Climate Fund etc. to fund developments.

b) ***R & D institutional capacity:*** There will be some research and institutional capacity training especially in the area of LMMA and conservation. Besides, building of sea wall must be done with proper research on the sea and wave current and etc. thus enough budgetary support should always be available to support such technologies.

c) ***Operational and maintenance:*** To ensure sustainability with the identified technologies, there must be always enough funding and budgetary support available for operational and maintenance of the identified technologies**.**

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Annex 1: Water Sector - Market mapping, problem/ solution trees

1.1 Rooftop Rainwater Harvesting Technology

1.1.1 Market Mapping – *Rooftop Rainwater Harvesting Technology*

BUSINESS ENVIRONMENT	1. Government Scheme for Subsidy/Loan 2. Support for production 3. Trade and Quality standard 4. Skill workers
MARKET ACTORS	1. Household Units 2. NGOs, CSOs and Communities 3.Local Importers 4. Retailers of the technology, Tanks, Pipes, & pumps 5. Maintenance Providers
SERVICE PROVIDERS	1. Financial Support Services 2. Technical Support 3. Quality control 4. Training and capacity Building 5.Market Information 6. Awareness

1.1.2 Problem Tree – *Rooftop Rainwater Harvesting Technology*

Livelihood Improved	Sustainable livelihood	Stability in Food security	Local expertise capacity building	Wider use of technology	
Improved community health	Accessible water by essential services such as schools and hospital	Stability in Food security	Local dealers in parts	Information sharing	EFFECTS
improved community harmony	Improved hygienic levels of communities	Vegetation beautification	Local ownership	Potential benefit knowledge of technology	
Accessible water by communities					PROBLEM
Strengthen Institutional Capacity	Increased opportunity to participate in back yard gardening	Improved vegetation replenishment	Accessible to information and technical know how	Access to management and capacity development	CAUSES
External funding is affordable	Increased water access to households	Improved community health	Effective community coordination	Capacity development	

1.1.3 Solution Tree – *Rooftop Rainwater Harvesting Technology*

RESULTS

Water Policy and regulation	Improved Technology Design	Vegetation replenishment	Capacity Training	More awareness
Customized Technology design	Community ownership	Use of modern and quality of roofing irons	Community training and capacity building	More inter-governmental department cooperation
Increased water access	Information Dissemination	Access to clean water	Community harmony	Effective water harvesting policy

STARTER PROBLEM

Availability of donor funding

MEASURES

More Financial options	Could be easily installed	Green environment	Acquired Skills	More awareness about the technology
Government Subsidy	Improved Community Ownership	Improved Livelihoods	Improved Information on the benefits of the technology	High level of cooperation
Access to high technology	Communal cooperation	Improved community harmony	Effective coordination	Effective policy and regulation on rainwater harvesting

1.2 Water Reticulation Technology

1.2.1 Market Mapping – *Water Reticulation Technology*

BUSINESS ENVIRONMENT	1. Government Scheme for Subsidy/Loan 2. Support for production 3. Skilled workers 4. Political environments
MARKET ACTORS	1. Nauru Utility Corporation 2. Household units 3. NGOs and Private Sectors 4. Importers of materials
SERVICE PROVIDERS	1. Financial Support Services 2. Technical Support 3. Quality control 4. Training and capacity Building 5.Market Information 6. Awareness

1.2.2 Problem Tree – *Water Reticulation Technology*

EFFECTS

Reduced Quality Water for competing uses	Water Scarcity	Unstainable Livelihoods	Poor performances	poor water infrastructure support
Poor Technologies	unsustainable Livelihood	Food insecurity	land ownership issues	In access to basic water services
Poor feasibility studies	Poor Community Health	Contaminated ground water	Community disharmony	Poverty driven community

PROBLEM

High capital cost

CAUSES

ECONOMIC/FINANCE	**SOCIAL**	**ENVIRONMENT**	**HUMAN CAPACITY**	**INSTITUTIONAL**
High capital cost	Land ownership issues	Impact of Climate Change	Unskilled workers	Poor governance
Land ownership issues	Contamination of ground water	No surface water in the country	Lack of land use and planning policy	Weak coordination
High Interest rate	Weak coordination	Aged infrastructure	Non cooperative community	Poor information sharing

1.2.3 Solution Tree – *Water Reticulation Technology*

RESULTS

Water Policy and regulation	Increased livelihood levels	Access to clean water	Capacity building	Better land use planning policy
Access to Financial support	Increased ownership	Effective water distribution method	Increased Local expertise	increased governance
Increased water access	Information dissemination	Use for Agricultural production	Increased local ownership	Improved coordination

STARTER PROBLEM

Community having access to clean and safe water

MEASURES

Improved water policy and regulation	Community ownership	Use of modern infrastructures	Increased labor skills	Capacity building trainings
Improved Financial options	Better use planning policy	Environment fertilization	Increased capacity to support community management of the technology	information sharing
Improved technology design	Better understanding of project initiatives	Improved community health	Community participation	Effective coordination
High financial options	Community support	Increase positive perception of the project	Community harmony	Good governance

1.3 Non-potable Water Access Technology

1.3.1 Market Mapping – *Non-potable Water Access Technology*

BUSINESS ENVIRONMENT	1. Government Scheme for Subsidy/Loan 2. Support for production 3. Trade and Quality standard 4. Skill workers
MARKET ACTORS	1. Nauru Utility Corporation 2. Household units 3. NGOs and Private Sectors 4. Importers of materials
SERVICE PROVIDERS	1. Financial Support Services 2. Technical Support 3. Quality control 4. Training and capacity Building 5.Market Information 6. Awareness

1.3.2 Problem Tree – *Non-potable Water Access Technology*

EFFECTS

Reduced water availability for competing uses	Water Security	unsustainable livelihoods	Poor workmanship	Poor governance
Poor technologies	Poor Health	Food security	Fault in infrastructure	Poor Service
Under performance	Unsustainable livelihood	Vector bone diseases	poor design	Health effects

PROBLEM

High cost of Capital

CAUSES

ECONOMIC/FINANCE	SOCIAL	ENVIRONMENT	HUMAN CAPACITY	INSTITUTIONAL
High Capital Cost	Land ownership issues	Unhealthy family units	Under capacity	Poor coordination
Limited Financial Access	Information dissemination	Unhealthy communities	Unskilled laborers	Weak Management
High Interest rate	Weak Coordination	Contaminated underground water	Poor human capital	Information sharing

1.3.3 Solution Tree – *Non-potable Water Access Technology*

Government subsidy	Improved Land use planning policy	Improved health of family units	Capacity Training	Effective coordination	
Better policy on water	More awareness and	Improved community health	Skilled workers	Strong management	RESULTS
Financial Access options	Strong coordination	Have access to better water	increase water experts	More information sharing and awareness	
Government support through budgetary and aid coordination					STARTER PROBLEM
Government Subsidy	Land use planning policy	Heathy families	Superior Work experts	Team commitments	
Water Policy and regulation	High level of department cooperation	Healthy communities	High performance	Knowledge management and learning	MEASURES

1.4 Water Tanker Truck

1.4.1 Market Mapping – *Water Tanker Truck Technology*

BUSINESS ENVIRONMENT	1. Government Scheme for Subsidy/Loan 2. Support for production 3. Trade and Quality standard 4. Skill workers
MARKET ACTORS	1. Household Units 2. NGOs, CSOs and Communities 3.Local Importers 4. Retailers of the technology, Tanks, Pipes, & pumps 5. Maintenance Providers
SERVICE PROVIDERS	1. Financial Support Services 2. Technical Support 3. Quality control 4. Training and capacity Building 5.Market Information 6. Awareness

1.4.2 Problem Tree – *Water Tanker Truck Technology*

EFFECTS

Expensive to purchase	Little knowledge of benefit of water tanker technology	Fluctuating rain fall	Limited local capacity to deal with water distribution	Poor water management and distributions systems
Expensive to maintain	No community ownership	Poor infrastructure to support technology	No local importers of parts	Ineffective water distribution policy
Required experts - engineers to maintain	Requires promotion at schools for importance of water	Deteriorating state of road and bridge	Low support by community	Weak governance

PROBLEM

Required specialized trained expert to run or operation

CAUSES

ECONOMIC/FINANCE	SOCIAL	ENVIRONMENT	HUMAN CAPACITY	INSTITUTIONAL
High Capital cost	Low awareness	Little option for water harvesting	Limited existing services	Weak regulatory system
High Research Investment	More expensive than traditional water collection	Impact of climate change	Week access to high technology	Limited Institutional Research
High Maintenances cost	Perception of benefits from technology	Other priorities	Low community awareness	Quality control

1.4.3 Solution Tree – *Water Tanker Truck Technology*

RESULTS

Livelihood Improved	Sustainable livelihood	Stability in Food security	Local expertise capacity building	Wider use of technology
Improved community health	Accessible water by essential services such as schools and hospital	Stability in Food security	Local dealers in parts	Information sharing
improved community harmony	Improved hygienic levels of communities	Vegetation beautification	Increased community support	Increased community awareness

STARTER PROBLEM

Accessible water by communities

MEASURES

Strengthen Institutional Capacity	Increased opportunity to participate in back yard gardening	Improved vegetation replenishment	Accessible to information and technical know how	Access to management and capacity development
External funding is affordable	Increased water access to households	Healthy community	Increased local experts	Effective communication
Reduced Tax through Subsidy and tax	Sustainable livelihoods	Community in harmony	Increased knowledge sharing	Increased governance

Annex 2: Market mapping, problem/ solution trees for Coastal Sector Technologies

2.1 Coastal Vegetation Restoration

2.1.1 Market Mapping – *Coastal Vegetation Restoration Technology*

BUSINESS ENVIRONMENT	1. Government Scheme for Loan subsidy 2. Policy formulation for coastal area 3. Technical Skills 4. Local Politics
MARKET ACTORS	1. NGOs, CBOs, and associations 2. Land owning groups 3. Household units 4. Consumer trends
SERVICE PROVIDERS	1. Financial support 2. Technical Support 3. Market information 4. Training and capacity building 5. Awareness

2.1.2 Problem Tree – *Coastal Vegetation Restoration Technology*

EFFECTS

Sea level rise	Over extraction of resources	Sand dune mining	Knowledge Gap about resource management	Department working in silos
Saltwater intrusion	unwanted removal of vegetation's	Extraction for economic purposes	Limited skills for planting of trees	Noncooperative environment
Coastal erosion	Human induced activities	Removal of vegetation's for coastal development		

PROBLEM

Extraction of corals and sand beach along the coastlines

CAUSES

ECONOMIC/FINANCE	SOCIAL	ENVIRONMENT	HUMAN CAPACITY	INSTITUTIONAL
High capital cost	Land owning groups right to resources	Impact of Climate Change	Limited awareness about over extraction	Ineffective coordination of relevant Departments
No funding alternatives	Insufficient Policy and regulation	Increased storm surges	Little knowledge about vegetation replenishment	Information sharing & awareness
Low local skills	Attitude problems	Sea level rise	Capacity training building	Policy Formulation

2.1.3 Solution Tree – *Coastal Vegetation Restoration Technology*

RESULTS

Reduced coastal erosion	controlled usage over resources	Vegetation prevents further erosion	Improved level of awareness	Increased awareness
Prevent saltwater intrusion	Better policy over resources	Vegetation protects the coastline areas	Increased technical know how's	Increased coordination
Improved vegetation	Awareness and understanding	Vegetation provide barriers against saltwater intrusion	Ownership of the technology	contained malpractices

STARTER PROBLEM

Restoration of coastal vegetation prevents coastal erosion

MEASURES

Clear government policy on coastal area management	Understand the importance to regrow vegetation	Replenishment of vegetation	Mass awareness	Policy and Regulation design
Community ownership of conservation activities	Improved vegetation growth at the shorelines	Improved beach barriers	Climate Change trainings	Public awareness
Community skills training	Lessen picnics and activities that will destroy vegetation's	Minimized saltwater intrusions	Basic training skills	Policy Coordination
Awareness of Coastal vegetation	Cooperative attitude	Soil replenishment	Community ownership	Effective communication

2.2 LMMA Technology

2.2.1 Market Mapping – *LMMA Technology*

BUSINESS ENVIRONMENT	1. Government Policy on LMMA 2. Limited funding to support LMMA 3. Technical Skills 4.Local Politics
MARKET ACTORS	1. NGOs, CSO, and associations 2.Land owning Groups 3. Ministry of Fisheries 4. Household owners
SERVICE PROVIDERS	1. Financial Support 2. Technical Support 3. Market Information 4. Training capacity

2.2.2 Problem Tree – *LMMA Technology*

EFFECTS

High extraction of resources	Reduced coastal area for public uses	Unstainable environmental harvesting	Unstainable livelihood	Poor coordination
Unstainable Livelihoods	Reduced area for fishing	Weak environment planning	Local incapacity	Weak government policy
Financial Access in capacity	Reduced area for recreational purposes	short term environment benefits	Reduced resource access	No local government regulation

PROBLEM

There is not incentive to conserve coastal area resources

CAUSES

ECONOMIC/FINANCE	SOCIAL	ENVIRONMENT	HUMAN CAPACITY	INSTITUTIONAL
Food insecurity	Resort to illegal fishing technique	High exploitation of environment and coastal resources	Poor resource planning	Insufficient policy
Financial insecurity	travelled long distance for fishing	Limited awareness about potential benefits	Poor Coordination	Weak Surveillance
Fast cash return	land ownership issues	Importance of environment to communities	poor knowledge about climate change	Poor coordination

2.2.3 Solution Tree – *LMMA Technology*

RESULTS

Improved governance surrounding harvesting resources	reduced over harvesting of fish	vulnerable coastal communities restored	increased local knowledge	Stable in food security
Focus on the long-term benefit of conservation	reduced over exploitation of resources	Exposures to storm surges reduced	Improved coordination	Better coastal resource management
Increase fish catch	reduced land disputes	Exposure to sea level rises managed	Improved Information sharing	Better coordination

STARTER PROBLEM

Locally managed marine areas help to conserve marine resource from extractions etc

MEASURES

More financial options	Designated area for fishing	Preservation of the coastal environments	Community participation	Clear government Policy
Increased community ownership	Approved fishing technique	Replenishment of coastal vegetation	Landowning group awareness	Improved social & cultural acceptability
Increased subsidy	Improved social and cultural access to resources	reduced exposure to sea level rise	Household participation	Increased local government participation

2.3 Policy Formulation Technology

2.3.1 Market Mapping – *Policy Formulation Technology*

BUSINESS ENVIRONMENT	1. Government Priorities 2. Policy formulation for coastal area 3. Technical Skills 4. Local Politics 5. Donor Aid partners
MARKET ACTORS	1. NGOs, CSO, and associations 2.Land owning Groups 3. Department of Employment, Industry and Environment 4. Household owners
SERVICE PROVIDERS	1. Financial Services 2. Technical Support 3.Local Experts 4. Training and capacity building 5. Public awareness

2.3.2 Problem Tree – *Policy Formulation Technology*

EFFECTS

No government Priority	Community exposures	Increasing impact of climate change	Unstainable livelihood	Weak information sharing
No funding support	Little government support	Increased in sea level rise	Local incapacity	Competing objectives at community level
Conflicting priorities	Increasing poverty line	Increased in saltwater intrusion	Not locally prioritized	Weak governance

PROBLEM

Not a government Priority to formulate coastal area resources

CAUSES

ECONOMIC/FINANCE	**SOCIAL**	**ENVIRONMENT**	**HUMAN CAPACITY**	**INSTITUTIONAL**
High legal fees	Low level of community support	High extraction level of resources	Little support	Poor government Priority
Limited capacity	Low level of capacity to understand climate change	Lander ownership's right	No incentives	Weak Government Departments' awareness and support
No government Policy	Low involvement by land owning groups	Short economic benefit	No perception of future benefits	Policy inefficiency

2.3.3 Solution Tree – *Policy Formulation Technology*

RESULTS

Increased awareness	Increased community resilience	Controlled resource management	increased Livelihood awareness	increased Coordination
Increased Policy coordination	Community support	Proper Planning	Clear policy drafting	Effective planning
Increased community participation	Livelihood sustainability	Long-term focus over resources	Community harmony	Good governance

STARTER PROBLEM

Policy formulation will control over extraction of resources

MEASURES

Information sharing	Training capacity	Conservation of environment	Community participation	Increased Awareness
Community training	Local exposure	awareness of the need to support policy formulation	Local government Support	Effective coordination
Financial Support	Government support	All of resource owners' views	Local support	Effective Surveillance
Regional Support	Donor aid partners support	Community awareness	Increased Information sharing	Strong perception of benefits

2.4 Seawall Technology

2.4.1 Market Mapping – *Seawall Technology*

BUSINESS ENVIRONMENT	1. Government Scheme for Loan subsidy 2. Policy formulation for coastal area 3. Technical Skills 4. Local Politics 5. Donor Aid partners
MARKET ACTORS	1. NGOs, CSO, and associations 2.Land owning Groups 3. Ministry of Fisheries 4. Household owners
SERVICE PROVIDERS	1. Financial Services 2. Technical Support 3.Local Importers 4. Training and capacity building 5. Public awareness

2.4.2 Problem Tree – *Seawall Technology*

EFFECTS

Impact of Sea level Rise	Coastal land ownership issues	Unsustainable communities	Poor local skills	Poor Management skills
Costal Erosion	Community perception	Landownership attitudes	Poor capacity	Poor idea sharing
Storm Surges	Material incentive	Extraction for social or economic gains	Poor coordination	No cooperation between local government & national government

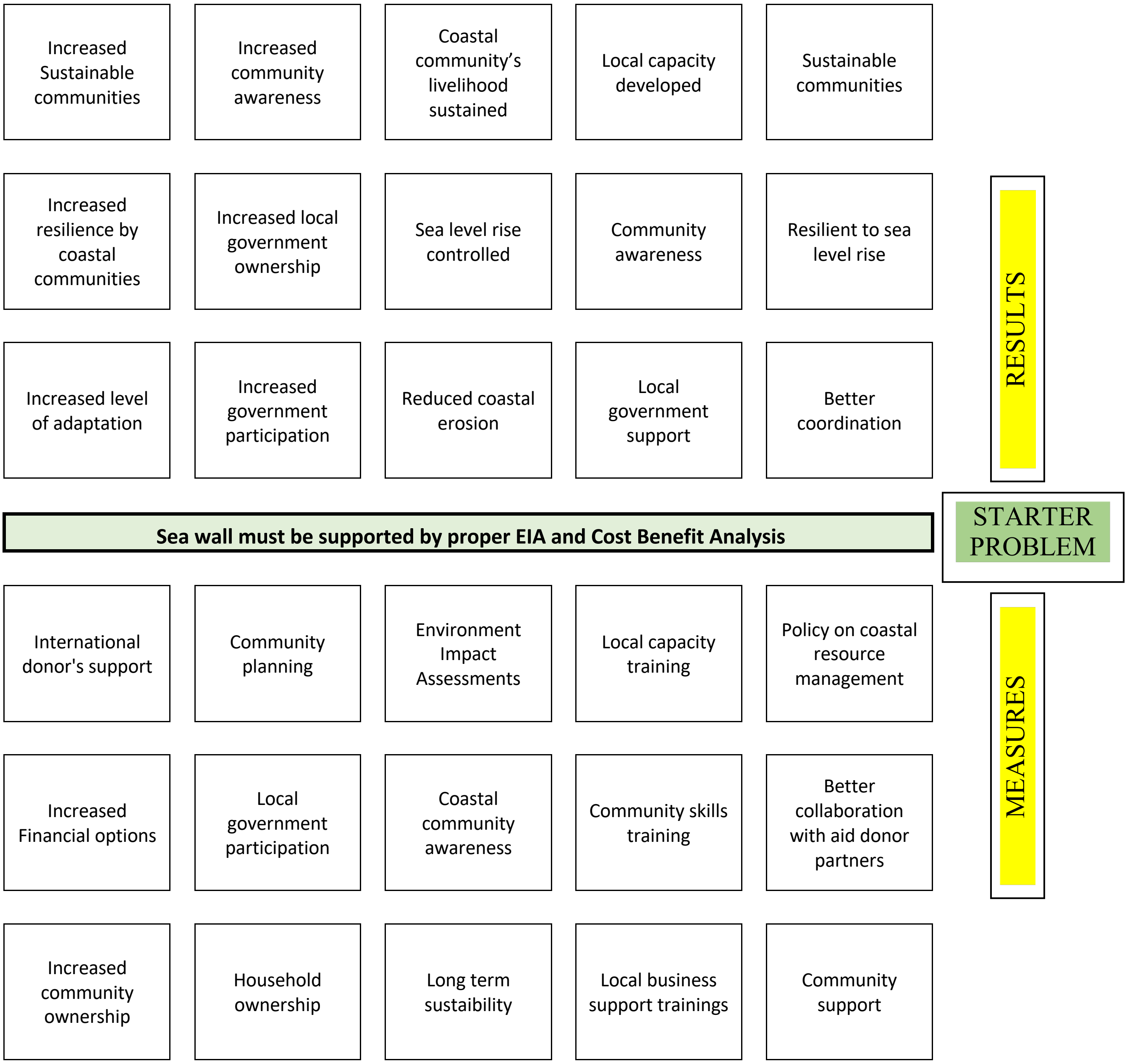
PROBLEM

Community perception of sea wall benefits

CAUSES

ECONOMIC/FINANCE	**SOCIAL**	**ENVIRONMENT**	**HUMAN CAPACITY**	**INSTITUTIONAL**
High capital cost	Regulatory Requirement	Destruction of natural environment	Low local skills	little knowledge of role to play
Low financial capacity of the community	Community awareness	Redirection of sea current	Low local capacity to support	No direction
Unsustainable coastal management	Priority of coastal communities	Proper R & D	High Initial support	No collaboration of stakeholders

2.4.3 Solution Tree – *Seawall Technology*



Annex 3: Technology Experts Consulted

3.1 Water Sector Working Group

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ii.	Jayden Agir	Water Strategy Manager, Dept. CC&NR, GoN
iii.	Mark Hiram	Water Services Manager, NUC
iv.	Abraham Aremwa	TNA Mitigation Consultant

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ii.	Bryan Star	Director for Environment, Dept. CIE, GoN
iii.	Frankie Ribauw	Director for Coastal (Seawall), Dept. CIE, GoN
iv.	Abraham Aremwa	TNA Mitigation Consultant