NAURU

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

Identification and Prioritisation of Adaptation and Mitigation Technologies for Nauru

gef
UN environment programme
USP THE UNIVERSITY OF THE SOUTH PACIFIC
UNEP DTU PARTNERSHIP

07 APRIL, 2020

Foreword

It is unequivocal that climate change threatened all regions of the world with profound effects on all human activities such as in agriculture, hydrology and water resources, human habitat, forest, wildlife, finance, insurance, energy, industry, sea level rise and coastal erosions. Nauru is no different, the adverse effects of climate change continues to negatively impact its population's livelihood because of its limited resources to respond to these adverse effects.

It is with that backdrop that this Technology Need Assessment (TNA) has been compiled in relation to the recommendation of the Conference of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) decision 4/CP.4. Under this decision the Non-Annex 1 parties which Republic of Nauru is grouped, are encouraged to submit their prioritized technology needs for possible financial assistance. Furthermore, Article 4.5 of the UNFCCC urges developing countries like ours to identify technologies, incorporate practices and reforms in various sectors of the economy to reduce greenhouse gas emissions, climate variability and the same time contribute to national development goals.

In pursuit of the above objectives, The Nauru Framework for Climate Change Adaptation and Disaster Risk Reduction has identified vulnerable sectors of the economy with options and measure to adapt and mitigate climate change impacts. As a result this report presents the result of the TNA process which took place in Nauru for both the climate change adaptation and mitigation technologies for the government to pursue in its development endeavor.

For example in the adaptation sector, it is strongly believed that if the identified products in this report are implemented, they would greatly benefit communities and improve their quality of lives which is in line with the National Sustainable Development Strategy of Nauru. Likewise under mitigation, technologies identified in the report are aimed at reducing the greenhouse gas emission into the atmosphere and at the same time positively transforming the lives and standard of living of all Nauruan's. Therefore, this a very important document for the Republic of Nauru, in terms of Climate Change Adaptation and Mitigation but also development of strategies into the future.

I take this opportunity to thank the, UNEP, USP and GEF for supporting this whole TNA process. UNEP/DTU for the technical and financial support including the facilitation of the national workshop. All national stakeholders, experts, and scientists are highly commended.

Berilyn Jeremiah
Permanent Secretary
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List of Abbreviations

AD	Agriculture Division
AIT	Asian Institution of Technology
CCA	Climate Change Adaptation
COP	Conference of Parties
DCIE	Department of Commerce, Industries and Environment
DoE	Department of Education
DoF	Department of Finance
DRR	Disaster risk reduction
GCF	Green Climate Fund
GEF	Global Environment Fund
GHG	Greenhouse gas
LCOE	Levelized Cost of Electricity
LMMA	Locally managed marine area
NDC	National Determine Contribution
NGO	None government organisation
NPE	National Policy of Energy
NSC	National Steering Committee (TNA)
NSDS	National Sustainable Development Strategy
NUC	Nauru Utility Corporation
OTEC	Ocean thermal energy conversion
PHES	Pumped hydroelectric storage
PICs	Pacific Island Countries
ROS	Reverse Osmosis system
RONAdapt	Republic of Nauru Adaptation Framework
RON	Republic of Nauru
SLR	Sea level rise
SOE	State own Enterprise
TFS	Technology Fact Sheets
TNA	Technology Need Assessment

UDP	UNEP DTU Partnership
UNEP	United Nation Environment Program
UNFCCC	United Nation Framework for Convention on Climate Change
USP	University of the South Pacific

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Executive Summary

The Climate Change Technology Transfer and Needs Assessment report (CCTTNAR) is in line with the UNFCCC especially articles 4.5 and various National Climate Change enabling activities. The aspects have been captured in the National communication and National Sustainable Development Strategy of Nauru. The National Communication and the National Determine Contribution which were submitted to the conference of Parties through UNFCCC Secretariat have also provided support for this TNA process.

Nauru has already designed and established a National Policy of Energy (NPE) which will provide a pathway towards achieving and long term sustainable renewable energy sector. The NPE of Nauru will enhance the use and utilisation of renewable energy technologies for sustainable development taking into account adaptation and mitigation needs to climate change. Besides the energy sector, the country also looked at the waste management sector which is also critical to the development, at the same time reduction of greenhouse gasses into the atmosphere. Additionally, addressing the waste management sector will also reduce the level of methane gas emission into the atmosphere.

With the adaptation sector, the government and stakeholders have considered water sector as the priority area for consideration under the TNA process. This priority has strong backings from the NSDS which promised better quality of life and livelihood for all Nauruan’s. The second sector which was considered under the TNA process for adaptation was the coastal area soil erosion. This second option has come about because of the increasing sea level rise, coastal erosion and human induces anthropogenic impact of climate change at coastal areas. This technology transfer need assessment will enable the communities to mitigate and build resilience to impacts of climate change.

Need Assessment

In this process the assessments included development and climate change response needs and opportunities in the country based on some of the outlined activities in both the NDCs and the NSDS of Nauru. The need to focus on the priority area of NSDS was adopted when assessing the various sectors. The assessment is only an initial phase and may not be very comprehensive.

Technology Prioritisation by Stakeholders

Technology transfer was considered as a flow of experience, know-how, and equipment between and within nations. Standard criteria were used such as development benefits, market readiness, GHG emission reduction potential, environmental benefits, job creation etc. The analysis has potential for expansion in future.

Although at this stage, there is not final decision on which technologies to prioritise, the technologies considered by the stakeholders for this purpose under *Adaptation I – water sector,* include rainwater harvesting, non-potable water access, water reticulation and water distribution by water trucks; *Adaptation II – coastal area management sector* include policy and guideline formulation, coastal vegetation restoration, construction of seawalls and locally managed protected area. Additionally, these technologies were also considered by the stakeholders for *Mitigation I – energy sector* to include pumped hydroelectric storage, biogas, OTEC and rooftop PV; and *Mitigation II – waste sector* to include semi-aerobic landfill, waste segregation, baling and composting.

Adaptation I: Water sector technologies

Rooftop rain water harvesting system

Roof top rain water harvesting technology was introduced on the Island many years ago. It is a technique through which rainwater is captured from the roof catchment and stored in reservoirs such as tanks by individual household units. Re-introduction of technology will see potable water is accessible to larger households and population of the country.

Non-potable water

Brackish or underground water is a very vital source of non-potable water for non-potable use that basically include washing and toilet flushing, thus reducing the use of potable water. Access to underground water require excavation of a well with depths ranging from 2 to 8 meters depending on land elevation. To reticulate water within the household, a domestic electric water pressure pump is required.

Water reticulation system

Water reticulation system was introduced at some part of the Island some years ago, during the mining boom period. This however discontinued due to cost and service issues. This new technology will see construction of reservoirs at certain locations and then distribution to households across the Island.

Water Distribution

Currently desalinated water is being distributed around the island by using water trucks upon request. This technology though effective, but is costly on the part of the service provider to maintain the fleet i.e. costs of spare parts and fuel. This new technology will ensure additional water truck suppliers are acquired to the current fleet and distribute water more frequently to the households around the Island.

Adaptation II: Coastal sector technologies

Building of sea wall at selected sites

Construction of sea wall around the island at selected sites will provide relief to the respective communities and help build resilience against impact of climate change especially sea level rise and costal soil erosion. Currently there is only one sea wall structure jointly funded by government of India and the Republic of Nauru. This technology will ensure that similar structures will also be built at vulnerable and exposed sites around the Island.

Coastal Vegetation replenishment

Coastal vegetation replenishment is a technology that is aimed to replant trees and vegetation at coastal areas around the Island. The native vegetation in coastal areas plays an important role in stabilising the surface against wind erosion and provides habitat for wildlife. This technology will prevent further washing away of land by SLR and human induced anthropogenic activities at these coastal areas.

Locally managed marine area

Locally managed marine areas are projected areas that largely or wholly managed by coastal communities and/ or land owning groups, with the support of government and partner representatives. The communities impose restrictions on areas such as “no take zones” and on certain equipment, practices, species or sizes of catches. The purpose of this technology is to conserve the area from over fishing or harvesting but at the same time managing the coastal beaches from soil erosion and extraction by individuals in the community.

Formulation of coastal area management policy

The objective of this technology is to ensure that the government formulate and develop a policy to prevent people/ individual or business houses from extraction of beaches at the coastal area. Any person or business houses intending to do development along the beaches must apply to an authority or government body to assess potential impact of such development on the environment prior to approval. This body oversees approval of constructions or structures as sea walls, building construction, wharfs, land reclamation etc.

Mitigation I: Energy sector technologies

Pumped hydroelectric storage (PHES)

PHES is a technology that would use the surplus power from a renewable source to pump water from a lower reservoir to a second reservoir on top of the hill. This creates the potential energy that can be released when needed through letting the water flow from the upper reservoir through a conventional hydro turbine at sea level which generates power into the grid. The main applications of pumped hydro are for energy management, frequency control and provision of reserves.

Biogas

Biogas is a modern form of bioenergy that can be produced through anaerobic digestion or fermentation of a variety of biomass sources. It is a versatile fuel that can be used for cooking, heating, lighting, power generation and combined heat and power generation, as well as, when upgraded to boost its methane content, in transport applications.

Ocean thermal energy conversion (OTEC)

OTEC is a proven technology that produces clean baseload electricity using the temperature differential (>20ºC) between warm surface water and cold deep water in the world’s tropical oceans. The warm seawater is used to produce a vapour that acts as a working fluid to drive turbines. OTEC can also be used for ocean water desalination. The cold water is used to condense the vapour and ensure the vapour pressure difference drives the turbine.

Grid-connected rooftop solar PV

A grid-connected solar PV system is connected to the utility grid through an inverter. The inverter converts the DC electricity produced by the solar panels into 240 V AC electricity, which can then be used by the property/household. If a grid connect system is producing more power than the home consumes, the surplus is fed into the power grid. The main advantage of a grid connected PV system is its simplicity, relatively low operating and maintenance costs as well as reduced electricity bills.

Mitigation II: Waste sector technologies

Semi-aerobic landfill

Also known as the Fukuoka method, this semi-aerobic landfill is a low cost technology that utilizes materials and methods readily available in developing countries to install leachate drainage pipes to prevent groundwater contamination and gas vents that enlarges the aerobic region in the landfill waste layers. In addition the volume of methane gas emitted by the landfill is reduced, contributing to efforts to prevent global warming.

Segregation

Waste segregation refers to the separation of wet waste and dry waste where the purpose is to recycle dry waste easily and to use wet waste as compost. When waste is segregated, there is reduction of waste that gets landfilled and occupies space, air and water pollution rates are considerably lowered. Segregation at the source reduces the amount of recyclable wastes ending up at the landfill where it usually becomes impractical to sort.

Baling

Baling is a process that compresses mainly recyclable wastes into a block (bale) which is secured by plastic or wire strapping. Baling reduces the volume of waste product and has a number of benefits that include (i) reduction of space taken up by waste on site; (ii) easier to store due to regular shape; (iii) ease of transportation; (iv) reduced storage, transportation and waste disposal costs; and (v) increased revenue as some baled materials can be sold to recyclers. Installing balers at the source of waste generation is highly recommended for Nauru.

Composting

Composting is an aerobic method (meaning that it requires the presence of air) of decomposing organic solid wastes. It can therefore be used to recycle organic material. The process involves decomposition of organic material into a humus-like material, known as compost, which is a good fertilizer for plants.

Household waste consists of organic waste and compostable materials. If everyone on Nauru starts composting at home, tons of organic waste would be diverted from landfills, reducing GHG from hitting the atmosphere. Hence, encouraging and implementing home composting will not only improve and sustain kitchen gardening crops but will also help save the environment.

MCA process and results

The technology fact sheets together with the MCA spreadsheet were prepared by the national consultants and emailed to all stakeholders. Stakeholders were advised and encouraged to review the fact sheets and MCA spreadsheet results and to provide feedbacks on whether agreeable or not on the outcome of the TNA process. The outcome of the multi-criteria analysis (MCA) rankings is presented below.

Water sector (Adaptation)

- Rainwater harvesting 1st
- Water reticulation 2nd
- Non-potable water 3rd
- Water distribution 4th

Coastal sector (Adaptation)

- Coastal vegetation restoration 1st
- LMMA 2nd
- Policy & guideline formulation 3rd
- Construction of seawalls 4th

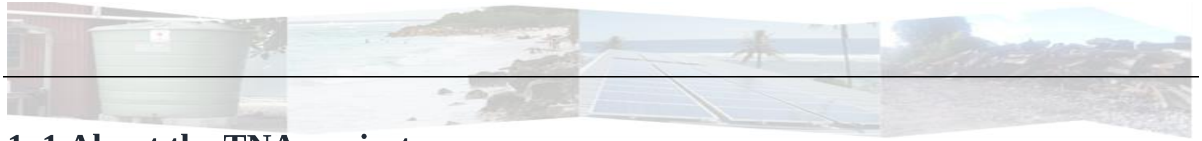
Energy sector (Mitigation)

- OTEC 1st
- Rooftop PV 2nd
- Biogas 3rd
- PHES 4th

Waste sector (Mitigation)

- Composting 1st
- Segregation 2nd
- Semi-aerobic landfill 3rd
- Baling 4th

Chapter 1: **Introduction**



1. 1 About the TNA project

It is unequivocal that the increasing amount of greenhouse gases (GHGs) into the atmosphere will have adverse effects on the global weather systems. The warming is not expected to be globally uniform but could differ significantly between geographical regions and vary between seasons (Xia, et al., 2014). This will negatively affect the scarce natural resources, particularly within the small island islands states (SIDS) that are heavily depended on for their sustenance and livelihoods. The primary natural resource sectors that might be susceptible to changes in climate include agricultural crops, livestock, forests, water resources, coastal resources, fisheries, and wildlife (Huq, et al, 2015). SIDS, especially the Pacific Island countries are more vulnerable than industrialized countries to the effects of climatic change for several reasons. First, they have relatively weaker economic base that weakened the capacity of many developing countries in the region to adjust to drastic economic changes. Second, most of the people depend on agriculture and fisheries for their subsistence, and agriculture including fisheries depend on a great deal on climatic and weather patterns, thirdly mostly of these countries are aid dependent and thus when priorities of donors divert from climate change focus to other emerging issues these countries are left with none but have to improvise their strategies in order to support their vast populations.

Nauru ratified the UN Framework Convention on Climate Change (UNFCCC) on 11 November 1993 and has submitted its Initial National Communication (INC) to the UNFCCC on 30 October 1999.

Article 4.5 of the UNFCCC states that developed countries who are members of the UNFCCC “shall take all practicable steps to promote facilitate , and finance , as appropriate , the transfer of, or access to, environmentally sound technologies and knowledge to other parties, particular developing country parties, to enable them implement the provisions of the convention”.

Prior to the UNFCCC era, technology transfer had occurred in all socio-economic sectors but the focus was not to address climate change through adaptation and mitigation of climate change, although indirectly some of them were met by climate change needs.

With the above backdrop, the Republic of Nauru (RON) seek the opportunity from the United Nation Environment Program (UNEP) to participate in the third phase of the Technological Need Assessment (TNA) process. The purpose of this exercise is to identify and align potential technologies (adaptation and mitigation) to the national development priorities of the country. The government could then use those identified technologies to seek funding from potential investors or financial institutions such as Green Climate Fund (GCF), Global Environment Facility (GEF).

The inception workshop which facilitated the above process took place in March 2019 in Nauru and was facilitated by the representatives of UNEP, Asia Institute of Technology (AIT) and the University of the South Pacific (USP) together with government officials of Nauru and relevant stakeholders.

1.2 Existing national policies on climate change mitigation and adaptation, and their development priorities

The Department of Commerce, Industries and Environment (DCIE) has undertaken a desktop review on existing policies and documents to identify potential areas for inclusion into the TNA process. The purpose of this review is to identify relevant priority areas and develop ideas from those identified sectors into potential technologies under adaptation or mitigation in the country.

The government of Nauru has established its National Sustainable Development Strategy (NSDS) (2005-2025) as the founding policy to facilitate adaptation and mitigation activities in the country. One of the primary objectives of the Nauru NSDS is to achieve quality life to all Nauruan’s across the country. The objective is to maximised benefit from resources but at the same time ensures that those limited natural resources are sustainably managed for future generations. This implies, great care must be taken while government, investors and households extract or harvest its limited resources.

Beside the NSDS, the Nationally Determined Contribution (NDC) also set the priorities for both the public and private sectors to reduce their anthropogenic emission of GHG into the atmosphere. This calls for investment in clean and renewable energy across the country. As noted, the country depends heavily on diesel oil for energy and thus any investment in energy sector would go a long way in meeting their international obligation to reduce the level of their emission as stated in the NDC.

The Republic of Nauru (RON) has also developed and implemented a National Policy of Energy (NPE) in 2014. The objective of this NPE is to provide clear practical pathway towards achieving sustainable development across the country. The following strategic policy areas and policy statements have been identified as critical to achieving the overall vision of the NPE – "Reliable, affordable and sustainable energy, enabling the socio-economic development of Nauru".

(i) Power – *A reliable, affordable and safe power supply and services*.
(ii) Petroleum – *A reliable and safe supply of fossil fuels*.
(iii) Renewable Energy – *50% of energy used in Nauru comes from renewable sources by 2020.*
(iv) Customers – *Universal access to reliable and affordable energy services*.
(v) Finance – *Financial sustainability of the energy sector.*
(vi) Institutional Strengthening and Capacity Building – *Efficient, robust and well-resourced institutions for energy planning and implementation.*
(vii) Energy Efficiency and Conservation – *An efficient supply and use of energy.*

Additionally, the RON government has also established a Framework for Climate Change Adaptation and Disaster Risk Reduction (RONAdapt) in 2015. The document - represents the Government of Nauru's response to the risks to sustainable development posed by climate change and disasters. It aims to do two things.

First, it identifies immediate priorities relating to climate change adaptation (CCA) and disaster risk reduction (DRR), in order to clearly articulate these for all government ministries, state owned enterprises (SOE), the private sector, civil society, communities and development partners to engage with.

Second, it provides a general framework for longer term planning and programming of CCA and DRR activities, including guidance on their mainstreaming in national and sectoral development policies. This includes setting out the key principles that are expected to guide CCA and DRR planning in Nauru, as well as clarity on the roles and responsibilities of different stakeholders. The priority areas of the RONAdapt are also in agreement with most of the priorities in this TNA process.

1.3 An overview of Sectors, projected Climate Change and GHG emissions status and trends of the different sectors

The NSDS outlines the major climate change impacts and geo-hazards for Nauru. The RONAdapt – represents the Government of Nauru's response to the risks to sustainable development posed by climate change and disasters. RONAdapt is intended to support progress towards the country's national development priorities and the goal of environmental sustainability, by ensuring that a focus on reducing vulnerabilities and risks is incorporated into planning and activities across all sectors of the economy and society. The priority actions identified here are not intended to be an exhaustive list of CCA and DRR needs. The priorities outlined in the RONAdapt are intended to contribute to the achievement of the NSDS and to increasing Nauru's resilience to climate change and disasters, by targeting the following goals:

- Water security
- Energy security
- Food security
- A healthy environment
- A healthy people
- Productive, secure land resources

The Nauru TNA process began in March 2018. The government and various stakeholders participated in that inception workshop as alluded to earlier. As a result of the TNA inception workshop, the participants have agreed on the priority sectors; as listed in Table 1 for the TNA process.

Table 1: TNA Priority sectors

Adaptation	**Mitigation**
Water Sector	Energy Sector
Coastal Area Management Sector	Waste Management Sector

Adaptation

Small island developing States (SIDS) are highly vulnerable to impacts of climate change and sea level rise owing partly to their small land masses surrounded by ocean, and their location in regions prone to natural disasters. The SIDS which Republic of Nauru is classified under are often characterized by having relatively large populations for the area they occupy with high growth rates and densities; poorly developed infrastructure and limited natural, human and economic resources, and their high dependence on marine resources for their livelihood needs. Most of their economies are reliant on a limited resource base and are vulnerable to external forces, such as changing terms of trade, trade liberalization, and migration flows. Adaptive capacity to climate change is generally low.
In the Pacific region where the Nauru Island (0º 32 S, 166º 55 E) is situated, the climates are influenced by a number of factors such as trade wind regimes, the paired Hadley cells and Walker circulation, seasonally varying convergence zones such as the South Pacific Convergence Zone (SPCZ), semi-permanent subtropical high-pressure belts, and zonal westerlies to the south, with the El Niño Southern Oscillation (ENSO) as the dominant mode of year to year variability (Fitzharris, 2001; Folland *et al.*, 2002; Griffiths *et al.*, 2003). The Madden-Julian Oscillation (MJO) also is a major mode of variability of the tropical atmosphere-ocean system of the Pacific on times scales of 30 to 70 days (Revell, 2004), while the leading mode with decadal time-scale is the Interdecadal Pacific Oscillation (IPO) (Salinger *et al.*, 2001). A number of studies suggest the influence of global warming could be a major factor in accentuating the current climate regimes and the changes from normal that come with ENSO events (Hay *et al.*, 2003; Folland *et al.*, 2003)

Because of the above backdrop, the initial TNA consultation workshop has identified these sectors as priority sectors for the country to address both for Adaptation and Mitigation.

(i) Water sector

Nauru lacks the national capacity to store potable water. Presently Nauru relies on desalinated water, rainwater harvesting, and (poor quality) groundwater for its water needs. There is no reticulated distribution system. Desalinated water is trucked to households on request. Annual and seasonal rainfall in Nauru are not statistically significance. This means, it can change due to looming climatic change should it arise. Furthermore, being so close to the equator, Nauru does not experience tropical cyclones. However, the main climate extreme experienced by Nauru is drought, which can last as long as three years. Droughts occur when La Niña events decrease the surrounding sea-surface temperature, resulting in less cloud and rainfall. Prolonged droughts cause a lowering of the underground freshwater lens, resulting in water supply problems and severe stress on natural systems. When this happens it affects the majority of population on the Island because they depend on rainwater for portable and non-portable uses.

(ii) Coastal Area Erosion

Almost all of the population of Nauru lives on the coastline areas due to the lack of habitable land in the interior of the island (because of extensive phosphate mining). Due to the high population on the coast lines, households are exposed to sea-level rise (SLR) and coastal erosion. With the looming impact of climate change, storm surges and increasingly high projection of SLR, increase in storms intensity, duration, and frequency over the years, communities will continue to be affected by these extreme events.

Mitigation

(i) Energy sector

Electricity on Nauru is generated by diesel generators and solar PV panels where the annual electrical energy consumption for Nauru is approximately 28 GWh with a daily peak of 4 MW. Diesel engines generate power with an LCOE of AUD0.41. Because diesel is imported, this poses a risk to Nauru’s generation capacity should that diesel be interrupted. In addition, the cost of generating electricity is heavily dependent on the cost of diesel. Should that spike, the cost of power generation will also spike. .

(ii) Waste sector

Nauru faces a range of environmental, social and economic threats from waste management and pollution. From the environmental perspective, dumpsites threaten underground sources of water, and air quality, and can also reduce the ability of natural systems such as coral reefs to cope with other events such as climate change. From a public health standpoint, poor waste disposal practices encourage mosquitoes, rodents, and other vermin populations, which can spread diseases. Respiratory and other health problems can also arise from breathing the fumes from dumpsite fires. Economically, poorly managed wastes affect tourism, fisheries and agriculture.[1]

1.3.1 Process and results of sector selection for adaptation and mitigation

Both the National Sustainable Development Strategy (NSDS) of Nauru (2005-2025) and various national adaptation workshops leading up to the TNA inception workshop have concluded that water sector, coastal erosion, energy and waste management are amongst the high priority areas for adaptation and mitigation across the country. With this backdrop, the Republic of Nauru has requested UNEP if they could be considered as one of the recipients of the 3rd phase of TNA assistance to the Asia Pacific region.

As part of the TNA preparatory process, the Department of Commerce, Industries and Environment (DCIE) together with USP and stakeholders had organised an inception workshop on the Island in March 2018. Part of the process, the DCIE had consulted several government departments and non-government organisations (NGOs) across the island to gauge their views on the sectors identified earlier that are vulnerable and likely to be selected into the TNA initiative.

At the inception workshop that was held in August 2018, the National TNA Coordinator together with UDP and USP representatives provided an introduction on the objective and process of the TNA. The team explained the need for the process to be transparent and tailored towards achieving national priorities and goals. The team introduced the vulnerable sectors as discovered by desktop review and earlier consultations. The participants have deliberated on the sectors and selected water and Coastal area management as priority sectors for adaptation while energy and waste management as priority sectors for mitigation. According to the participants these are priority sectors that needs urgent consideration for the TNA process.

[1] National Solid Waste Management Strategy 2017-2026 (unpublished version)

The participants who participated in the process were well represented by relevant government departments, SOE's, NGO's and community representatives. Gender issues were also discussed and considered to finally decide on the four sectors identified above.

Chapter 2: **Institutional Arrangement for the TNA and the Stakeholder Involvement**

2.1 National TNA team

A schematic of the institutional arrangement for the National Technology Needs Assessment Phase III Project for Nauru is shown in Figure 1 below.

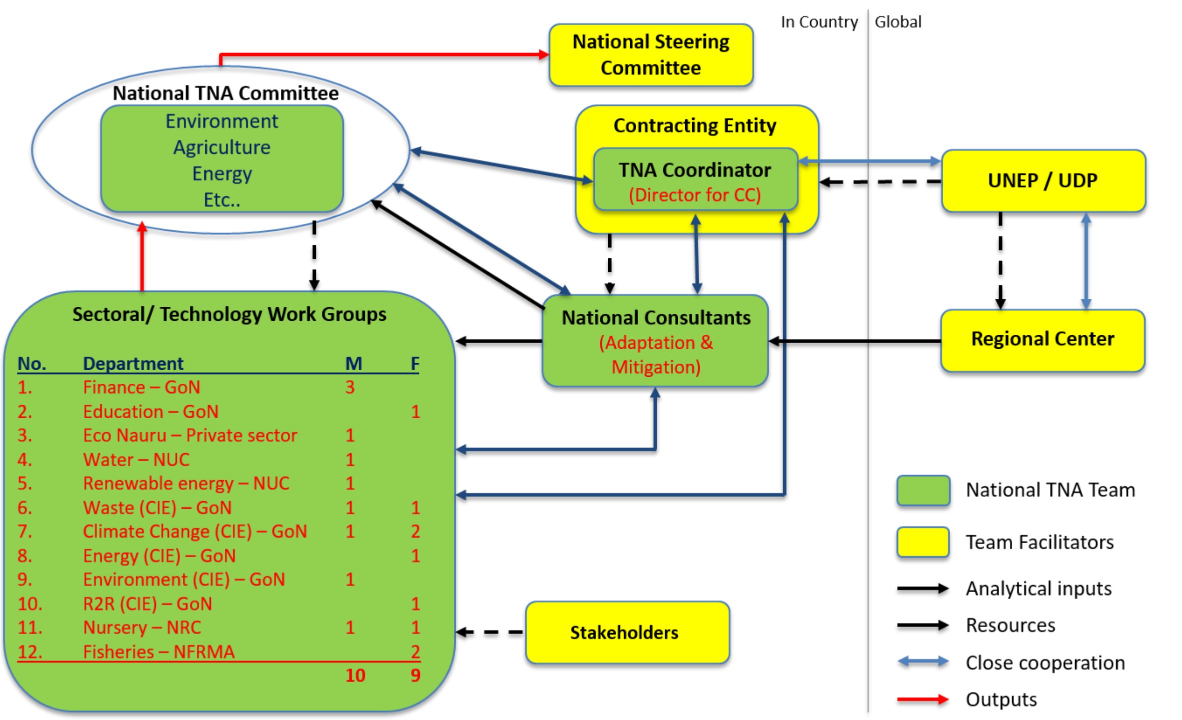


Figure 1: National TNA Team Structure

2.1.1 National Steering Committee

There was not a full time dedicated steering committee established purposely for the TNA process. However, the already existing National Steering Committee members that are currently involved with ongoing DCIE projects are invited to participate in the TNA process. These includes, members from DCIE, Department of Fisheries, (DoF), Department of Education (DoE), Department of Agriculture (DoA), Representatives from the Utility and NGO representatives.

2.1.2 The National TNA Coordinator

The Director of the Climate Change division within the DCIE assumes the responsibility as national TNA coordinator in the country. The Director oversees the recruitment of national consultants (adaptation and mitigation) for the TNA process and ensure that there are consultations and workshops held to identify the priority sectors for the TNA process. The role of the Coordinator also includes presentation of report findings to the NSC for endorsement.

2.1.3 Sector working groups

Although there are four sectors that has been identified for the TNA process that included (i) water and coastal area management for adaptation, and (ii) energy and waste management for mitigation, it was deemed appropriate that the TNA national coordinator and consultants liaise with and involve the same stakeholders across all four sectors to finalise submissions. This arrangement is installed due to the small number of stakeholders and also to prevent duplication of working committees as almost the same people are also responsible for the various sectors.

2.1.4 TNA National Consultants

The Nauru government has engaged two national consultants, one for adaptation and mitigation respectively. The roles of the two national consultant are to liaise through the TNA Coordinator and sector working groups to assess and develop potential technologies for each of the four identified sectors as provided in Table 1. The consultants also ensure that these potential technologies are categorised under the priority areas of the country. Consultants will synthesize findings from the prioritisation process using TFS and MCA for each technology undertaken during a working group meeting into the TNA report.

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

2.2.1 Consultant's capacity building workshop in Bangkok,

In February 2019 the national consultants for both adaptation and mitigation together with the designated national TNA authority representative attended a 3-day capacity building training in Bangkok, Thailand. As part of the training the national TNA team are taught the basic skills required for the overall planning and conducting a stakeholder's engagement process in their country. The national TNA team also had consultation meetings with the UNEP/AIT/USP representatives on the progress of their TNA process.

2.2.2 Stakeholder selection process

During a bi-lateral session that was conducted during the capacity building workshop in Bangkok, it was agreed upon by the project coordinators from UNEP DTU Partnership that due to the small number of stakeholders, it will not be necessary for the Nauru TNA team to form two sectoral working groups – one each for adaptation and mitigation. Hence a single working group comprising a wider range of expertise was considered more appropriate for Nauru's TNA process.

2.2.3 National Consultation

A TNA inception workshop that was attended by a wide range of stakeholders was held in March 2018. At this inception workshop, the participants have identified four potential sectors for the technological need assessment (TNA) process to focus. Latter in June 2019, during the initial national consultative workshop the participants have reaffirmed the earlier decision to use the TNA process to identify most relevant potential technologies under those respective identified sectors to adapt and mitigate the impact of climate change, at the same addressing some key development priorities of the country. Table 2 represents the technologies as identified during the national consultation workshop prior to prioritization.

Table 2: TNA Technologies before Prioritization

Adaptation	**Mitigation**
Water Sector Technologies i. Rainwater harvesting ii. Non-potable water iii. Water reticulation iv. Water distribution	**Energy Sector Technologies** i. Pumped hydroelectric storage ii. Biogas iii. OTEC iv. Rooftop PV
Coastal Area Management Sector Technologies i. Policy & guideline formulation ii. Coastal vegetation restoration	**Waste Management Sector Technologies** i. Semi-aerobic landfill ii. Waste segregation iii. Baling iv. Composting

iii. Construction of seawalls iv. LMMA	

2.2.4 Bi-lateral Meetings

Besides the desktop review and national stakeholder consultations, the national consultants also undertook a series of "one on one" bilateral meetings with relevant stakeholders across the country. These stakeholders included some government departments, SOE's and NGOs. These bi-laterals were to purposely share views on the likely sectors that are critical for urgent development or investment by the TNA process. There was not any selection done at this stage but more awareness about the potential TNA initiative. Part of the process, the DCIE reminds the participating members of the identified vulnerable sectors as stipulated in various documents such as NSDS and RONAdapt etc.

2.2.5 Technology Need Assessment consultation and reporting

The national TNA team held the second consultation workshop in June 2019. The workshop was attended by government stakeholders, representatives of the community, non-government organizations (NGOs) and other invited members of the community. The list of participants and their respective organizations is provided in Annex 3.

At this workshop the consultants assisted the participants to identify ideas that could potentially build into technologies under the TNA process. The consultative workshop produced a number of outputs vital for the technology transfer and needs assessment process in the country. The following are some of the outputs:

- Stakeholders identified and agreed on the potential technologies that should be pursued and developed further for consideration under the TNA process;
- The participants were guided; based on their general understanding of each technology, on how to initially rank and prioritize these potential technologies under basic criteria that basically include their viability and capital costs.
- The technology taskforce team were also selected and endorsed, this is based on the technologies that are related to expert areas of participants;
- No dedicated steering committee will be formed but the TNA designated authority with relevant government departments and NGOs will work as steering committee

when needed (this is a capacity limitation, as these are almost the same people working in the space of climate change in the country);

- The step forward for finalizing the technologies were explained to the participants that initially included preparation of the TFS and inputting fact sheet data to the MCA spreadsheet.

During the 2-day TNA stakeholder consultation in June 2019, the National consultants realized that they needed more time for research to prepare realistic TFS' for the stakeholder prioritized technologies that were identified in day one. Stakeholders were advised that without the TFS, the MCA cannot be carried out. This matter was discussed by both consultants before making recommendations to the Project Coordinator that the consultants will each need to prepare their respective TFS and have these validated by the stakeholders prior to using in the MCA process. Unfortunately, this was not possible as very few stakeholders turned up on the proposed workshop day to go through the MCA process. Alternatively, due to time limitations, the MCA process was carried out by the consultants and results; together with the TFS were emailed to all stakeholders for their comments. The outcome of this MCA process are presented in the next four chapters and the TFS in Annex 1.

2.3 Consideration of Gender Aspects in the TNA process

Climate change affects all members of society and its impacts can be different for men and women. Hence it is important to understand the gender dimension when working on climate change adaptation and mitigation measures, because of the different gender roles that women and men play in their society or community. In the Pacific region the different gender roles are influenced by culture, social systems, local institutions and religion, and it varies across communities. One of the vital factors in society structural system is the gender relations between men and women, to understand the power relations between women and men through the different gender roles they play in their families and community. In general this factor often place a woman in a vulnerable situation compared to men even during disastrous or important and critical events.

To rectify that imbalance between men and women in the Nauru context in this TNA process, there is a high level of gender participation across all sectors as shown in Table 3. This was demonstrated through the engagement of the women and girls at the consultation stage within the community, government and private sectors. The intension to engage women and young girls to participate in the process is to ensure that their views and concerns are incorporated into deciding on which sector and technologies are to be selected under the TNA process. The TNA process provides for not only engagement but allowing them to participate in the decision making process.

Table 3: TNA Gender Sectoral/ Technology Working Group

No.	Departments	Gender	
		Male	**Female**
1.	Finance – GoN	3	-
2.	Education – GoN	-	1
3.	Eco-Nauru - Private sector	1	-
4.	Water – NUC	1	-
5.	Renewable energy – NUC	1	-
6.	Waste (CIE) - GoN	1	1
7.	Climate Change (CIE) – GoN	1	2
8.	Energy (CIE) – GoN	-	1
9.	Environment (CIE) – GoN	1	-
10.	R2R (CIE) – GoN	-	1
11.	Nursery – NRC	1	1
12.	Fisheries – NFRMA	-	2
	Total:	**10**	**9**

2.4 National Policies supporting Gender mainstreaming into the TNA process.

To support the TNA process, the Nauru National Development Strategy (2005-2025) and the Republic of Nauru, Framework for climate change adaptation and disaster risk reduction (2015) ensure that children and women are considered and involved in the community development and resilience program at the local level. This set the foundation for the TNA process to engage these vulnerable members of the community in the planning, decision making and future management of these projects when implemented.

During the TNA inception workshop and consultations, the DCIE was vested with the responsibility as the leading Government Department dealing with the process of TNA in the country. The DCIE acts at the designated National Authority that will oversee the TNA process within the next two years.

Chapter 3: **Technology Prioritisation for Adaptation in the Water Sector**

3.1 Key Climate Change Vulnerabilities in the water sector

Nauru has little or no source of surface freshwater and is susceptible to extreme climate events such as prolonged droughts, which can cause severe damage to socio-economic activities, infrastructure, agriculture and biodiversity[2]. During periods where there is little or no rain for more than 3 months, Nauru's water supply situation deteriorates dramatically, and production capacity becomes stressed. If the RO units break down during drought periods, Nauru faces a social and health disaster.[3]

3.2 Decision context

Small island nations in the Pacific, such as Nauru, have critical water supply problems. Nauru is a permeable island with very little surface runoff and no rivers or reservoirs. Potable water is collected in rainwater tanks from the roofs of domestic and commercial buildings. Water for non-potable uses is obtained from domestic bores at houses around the island. There are four small desalination plants on the island, of which two are operating and supply Menen Hotel and the refugee camp.[4]

3.3 Overview of Existing Technologies in the water sector

3.3.1 Production

Nauru currently rely on 5 reverse-osmosis units that are illustrated in Table 4. All these are operational to produce desalinated water for potable use around the island. NUC is responsible

[2] http://www.asiapacificadapt.net/adaptation-practices/piloting-climate-change-adaptation-water-resources-management-nauru

[3] https://www.pacificclimatechange.net/country/nauru

[4] National IWRM Diagnostic Report 2007

for maintaining all five desalination units to ensure they produce at their maximum potential. Three of the five units are operated by the Refugee Processing Center (RPC).

Table 4: RO desalination units on Nauru

No.	Reverse-osmosis brand	Capacity (kL/day)	Operated & serviced by
1.	Osmoflo	900	NUC/ RPC
2.	Avanale	800	NUC/ RPC
3.	Avanale	480	NUC/ RPC
4.	Hitachi	100	NUC
5.	Avanale	100	NUC

In total, Nauru's current water production capacity is 2,380 kL per day. With an estimated population of 12,000, the water production capacity equates to approximately 200 l/ c/ d. The WHO optimal level of water access to eliminate health concerns is 100 l/ c/ d.[5]

3.3.2 Storage

NUC has seven (7) water storage tanks that are currently in use; as illustrated in Table 5, with a total storage capacity of 4,420 kL. NUC recently purchased a 300 kL tank that is yet to arrive and to be installed next to tank B13. This additional storage will increase capacity to 4,700 kL. In comparison with water production capacity, storage capacity is almost double.

Table 5: NUC water storage capacity

No.	Water storage tank	Capacity (kL)	Type
1.	B13	2,800	Steel
2.	C1	270	Concrete (underground)
3.	C2	270	Concrete (underground)
4.	C3	270	Concrete (underground)
5.	C4	270	Concrete (underground)
6.	C5	270	Concrete (underground)
7.	C6	270	Concrete (underground)

[5] https://www.who.int/water_sanitation_health/diseases/WSH0302.pdf

3.3.3 Delivery

There is no potable water reticulation system on Nauru apart from a brackish or non-potable water reticulation system that was installed in Meneng under the USP-PACE SD/ EU-GCCA adaptation project 2013-2017. The system pumps brackish water from the coast up to to several reservoirs which then provides gravity fed water to residential homes at Meneng Statehouse and Terrace for non-potable use such as toilet flushing and washing.

NUC is also responsible for the delivery of water right around the island. Water delivery is normally carried out during the week, however, during dry period's water trucks will need to work around the clock 7 days a week to meet the demand. NUC currently own and operate 4 water trucks with an additional 3 to be added to existing fleet. Tank capacity for these trucks are provided in Table 6.

Table 6: NUC water trucks

No.	Water delivery truck number	Capacity (L)	In-service
1.	AAB 487	12,000	Yes
2.	AAB 488	12,000	Yes
3.	AAB 135	7,000	Yes
4.	AAB 466	5,000	Yes
5.	N/A	8,000	Not yet
6.	N/A	8,000	Not yet
7.	N/A	5,000	Not yet

3.3.4 Rainwater harvesting from rooftop catchments

Rainwater is a critical resource that is captured from the rooftop and stored in storage tanks. However, rainwater is significantly reduced during droughts or dry seasons, thus people cannot rely on rainwater to meet their water needs.

3.3.5 Groundwater access and quality

Groundwater is available in some locations, but these supplies are contaminated and not suitable for drinking. Domestic well depth to groundwater around the island ranges from 0.6 to 11.2m with salinity level ranging from 300 – 20,300 µS/ cm. The main use of groundwater is for showering, washing (kitchen & laundry), toilet flushing and for lawn and garden irrigation.

3.4 Adaptation Technology Options for water sector and their Main Adaptation benefits

The following adaptation technologies were identified in consultation with stakeholders as key technologies in the water resources sector in Nauru. The TFS for each of the technologies were prepared by the National adaptation consultant and was emailed to all the stakeholders for validation. For this process, stakeholders were given ample time for the opportunity to provide their comments and suggestions. Main adaptation benefits for these technologies are summarised below and fact sheets are provided in Annex 1.

3.4.1 Rainwater harvesting

Rooftop rainwater harvesting is a combination of water catchment and storage system. This system is effective and has always been a sustainable solution for climate adaptation in Nauru given its very limited water resource. Every building on Nauru; commercial and domestic, have in place rooftop rainwater harvesting systems that include guttering, downpipes and water catchment systems. With an average annual rainfall of 2,000 mm, an average roofing footprint area of 50 m^2 can capture as much as 100,000 litres of rainwater per year. Rainwater harvesting systems not only used to catch rainwater for daily consumption, but also as a source for water storage during dry periods. The demand for rainwater harvesting systems on Nauru is endless given the ongoing building and construction of new domestic and commercial buildings and maintenance and repairs with aging systems.

3.4.2 Non-potable water

Nauru's sources of non-potable water include brackish and sea water. Brackish water can supply 80 % per capita requirements per day when based on WHO 100 L/c/d requirements. This equates to 80 litres of brackish water that can be used for showering, washing clothes and dishes and toilet flushing per person. While 20 litres of potable water is considered sufficient for daily use for cooking and drinking per person. In Nauru, brackish water is available to some 60% of domestic homes and is available to some commercial and government buildings mainly for lavatory use. An increase in the percentage of household access to brackish water is key to reduction of potable-water demand and hence production.

3.4.3 Water reticulation

Water reticulation system is a form or ease of water accessibility technology where water is easily obtainable through household taps. This system is common in developed countries where water resources are available in abundance. However, for developing countries with limited water resources like Nauru, not only the high infrastructure costs is a concern, but more also on the behavioural use of reticulated water can become an issue. This system if introduced in Nauru will need to be managed properly.

3.4.4 Water distribution

Water is currently distributed to household water tanks by water trucks. These same water tanks also serve as part or storage for rainwater harvesting systems. The demand for water delivery is usually peak during drought periods with delivery rate restricted to the number of water trucks available. The water production rates and storage capacity can be a contributing factor to the restriction of water availability. One major advantage or benefit of water distribution by water trucks is the capacity to control the frequency of deliveries while maintaining control of water production.

3.5 Criteria and process of technology prioritisation for water sector

During this process, the multi-criteria analysis (MCA) tool is used in ranking the four (4) identified technologies in their priority order based on a set of criteria that are relevant to country context. A list of criteria categories, sub-categories and criterion to be considered for the water sector technology prioritisation are provided in Table 7.

Table 7: Selection criteria for technologies in the water sector

Criteria Category	Criteria Sub-Category	Criterion
Cost	Cost	Cost to set-up & operate per beneficiary/ year
Benefits	Economic	Improving household income & ability to re-invest
		Trigger private investment
	Social	Poverty reduction

		Gender aspects
	Environment	Contribution to protect & sustain ecosystem services
	Climate related	Improvement of resilience to CC
Others	Institutional/ implementation	Ease of implementation
		Replicability
	Political	Coherence with national development policies & priority

Each criterion is given a scoring range (0-100) and a preferred scoring value (0 or 100) as shown in Table 8.

Table 8: Criteria scoring scales & preferred values for Water Sector

No.	Criteria Category	Criteria Sub-Category	Criterion	Scoring Scale	Preferred Value
1.	**Cost**		Set-up & operation cost/ beneficiary/year	0 = very low cost 100 = high cost	0 = very low cost
2.	Benefits	Economic	Improving household income & ability to re-invest	0 = very low 100 = very high	100 = very high
3.			Trigger private investment	0 = very low 100 = very high	100 = very high
4.		Social	Poverty reduction	0 = very low 100 = very high	100 = very high
5.			Gender aspects	0 = no consideration of gender issues 100= High consideration	100= mainstreaming & high consideration of gender issues
6.		Environment	Contribution to protect & sustain ecosystem services	0 = very low 100 = very high	100 = very high
7.		Climate related	Improvement of resilience to CC	0 = very low 100 = very high	100 = very high
8.	Others	Institutional/ implementation	Ease of implementation	0 = very difficult 100 = very easy	100 = very easy
9.			Replicability	0 = very difficult 100 = very easy	100 = very easy
10.		Political	Coherence with national development policies & priority	0 = very low 100 = very high	100 = very high

3.6 Results of technology prioritisation for water sector

At the beginning of the MCA process, scores (1-100) are manually inputted for each technology criterion in the Excel performance matrix table as illustrated in Table 9. These scores are automatically calculated and displayed in the Normalised scoring matrix (Table 10) and the scores and weights combined tables (Table 11).

Table 9: Performance matrix table for water sector

No.	Criteria	Technology			
		Rainwater harvesting	Non-potable water	Water reticulation	Water distribution
1.	Cost to set-up & operate per beneficiary/ year	85	65	45	75
2.	Improving household income & ability to re-invest	85	80	80	60
3.	Trigger private investment	60	40	80	60
4.	Poverty reduction	100	100	100	80
5.	Gender aspect	100	80	100	100
6.	Contribution to protect & sustain ecosystem services	100	100	60	80
7.	Improvement of resilience to CC	100	60	100	60
8.	Ease of implementation	100	80	80	80
9.	Replicability	80	60	70	80
10.	Coherence with national development policies & priority	100	100	100	80

The normalised scoring results in Table 10 are obtained from the equations provided in Annex 6. At this stage, no ranking is provided.

Table 10: Normalised scoring matrix table for water sector

No.	Criterion	Technology			
		Rainwater harvesting	Non-potable water	Water reticulation	Water distribution
1.	Cost to set-up & operate per beneficiary/ year	0	50	100	25
2.	Improving household income & ability to re-invest	100	80	80	0
3.	Trigger private investment	50	0	100	50
4.	Poverty reduction	100	100	100	0
5.	Gender aspects	100	0	100	100

6.	Contribution to protect & sustain ecosystem services	100	100	0	50
7.	Improvement of resilience to CC	100	0	100	0
8.	Ease of implementation	100	0	0	0
9.	Replicability	100	0	50	100
10.	Coherence with national development policies & priority	100	100	100	0

In Table 11, the scores are obtained by multiplying the scores in the normalised scoring matrix table by the applied criterion weight. In this case the criterion weights are all the same and add up to 100.

Table 11: Scores & equal weights combined for water sector

No.	Criterion weight	Criterion	Technology			
			Rainwater harvesting	**Non-potable water**	**Water reticulation**	**Water distribution**
1.	**10**	Cost to set-up & operate per beneficiary/ year	0	500	1,000	250
2.	**10**	Improving household income & ability to re-invest	1,000	800	800	0
3.	**10**	Trigger private investment	500	0	1,000	500
4.	**10**	Poverty reduction	1,000	1,000	1000	0
5.	**10**	Gender aspects	1,000	0	1,000	1,000
6.	**10**	Contribution to protect & sustain ecosystem services	1,000	1,000	0	500
7.	**10**	Improvement of resilience to CC	1,000	0	1,000	0
8.	**10**	Ease of implementation	1,000	0	0	0
9.	**10**	Replicability	1,000	0	500	1,000
10.	**10**	Coherence with national development policies & priority	1,000	1,000	1,000	0
	100	Total scores	**8,500**	**4,300**	**7,300**	**3,250**
Ranking			**1**	**3**	**2**	**4**

For equal criterion weights, rainwater harvesting was awarded the highest score with water reticulation in second.

Because the criteria that are selected for evaluating the usefulness of each technology may not be equally important to the decision, or to the achievement of the overall goal, different weights can be given for each criterion that reflect their relative importance in the choice of technology options. In Table 12, different criterion weights are applied noting that a weight of 14 is applied to criterion 7 (Improvement of resilience to CC) with the least weight of 6 applied to criterion 9 (Replicability). The sum of all these weights should add up to 100.

Table 12: Scores and different weights combined for water sector

No.	Criterion weight	Criterion	Technology			
			Rainwater harvesting	**Non-potable water**	**Water reticulation**	**Water distribution**
1.	**11**	Cost to set-up & operate per beneficiary/ year	0	550	1,000	275
2.	**10**	Improving household income & ability to re-invest	1,000	800	800	0
3.	**8**	Trigger private investment	400	0	800	400
4.	**12**	Poverty reduction	1,200	1,200	1,200	0
5.	**10**	Gender aspects	1,000	0	1,000	1,000
6.	**12**	Contribution to protect & sustain ecosystem services	1,200	1,200	0	600
7.	**14**	Improvement of resilience to CC	1,400	0	1,400	0
8.	**10**	Ease of implementation	1,000	0	0	0
9.	**6**	Replicability	600	0	300	600
10.	**7**	Coherence with national development policies & priority	700	700	700	0
	100	Total scores	**8,500**	**4,450**	**7,300**	**2,875**
Ranking			**1**	**3**	**2**	**4**

Results of MCA technology prioritisation for the water sector for equal and different criterion weights are further illustrated in Figure 2 and Figure 3. For both criterion weight divisions, rainwater harvesting is awarded the highest score and ranked first followed by water reticulation, non-potable water and water distribution.

At this stage of the TNA process, all these four technologies will still be recommended for inclusion for further analysis in the next TNA process – Barrier Analysis and Enabling Framework.

Figure 2: Water sector technology ranking – equal criteria weights

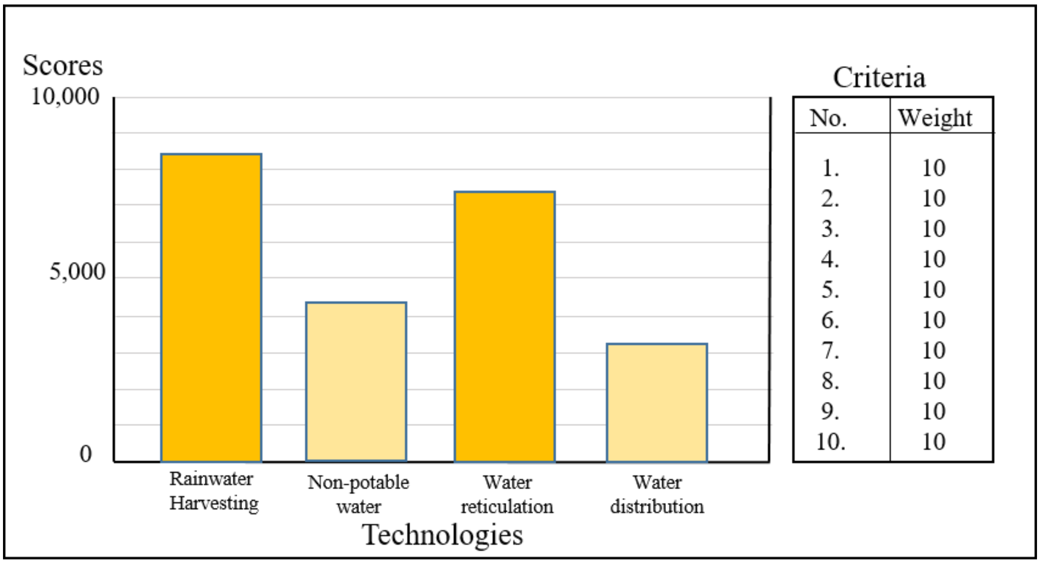
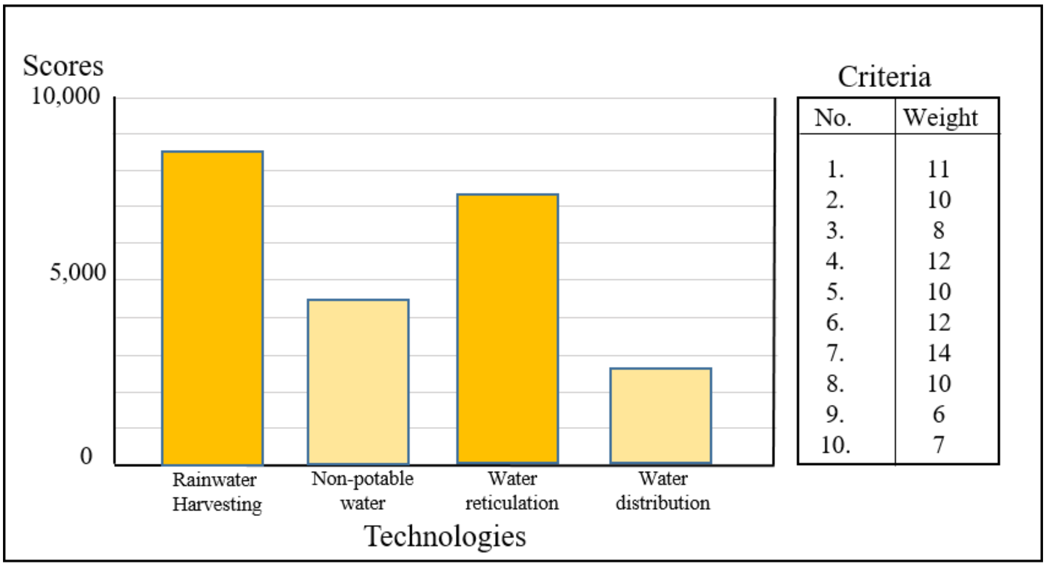


Figure 3: Water sector technology ranking – different criteria weights



Reason for use of Multiple Criteria Weights Analysis (MCWA) for water technology

We use different MCWA for water technology to get the different insights into the different judgements and perceptions the participants have on water technology to their community. This is important because water technology is one of the resources that the country is of dire need even without the impact of climate change. This is similar to a sensitive analysis test, which is performed to determine, if the changes in the weightings would change the types of the water technology the respondents would prefer as part of the TNA process.

Chapter 4: **Technology Prioritisation for Adaptation in the Coastal Sector**

4.1 Key Climate Change Vulnerabilities in the coastal sector

At the national and community scale in Nauru, some of the factors that create vulnerability are; scare water resources, limited land soil resources, environmental degradation, and high concentration on income activities, dependent on imports, geographical isolation, low human capacity, chronic health problems and recently sea level rise and coastal erosions. Sea level rise was estimated to be 5mm average mean per annum which was more than the average global mean of about 3.2mm. This challenge embedded with high population density along the coast line area, there is virtually the risk of coastal erosion and land degradation at these vulnerable zones.

4.2 Decision context

The increasing coastal erosion, soil inundation and SLR surrounding the inhabited areas on the Island makes communities resort to options aimed to prevent them from impacts of these climate induced events and disasters. The communities resort to participating in preventive options such as replenishment of vegetation along the coast line area, building sea walls, reclaiming of land and potential establishment of locally management marine protected area (LMPA) as means of costal area management at designated sites.

4.3 Overview of Existing Technologies in the coastal sector

Sea walls – There are several location along the coast line which the government, aid donor partners and communities have invested in building of sea walls and barriers against the coastal erosion and SLR. The barriers are costly but provide the short term solutions to the increasing impact of climate change especially salt water inundation, coastal soil erosion, and land degradation along the coast lines.

Coastal line revegetation -The communities also participate in coastal line revegetation at various locations around the island. This is aimed to restore the natural vegetation that were removed along the coast line area due to over population or human anthropogenic activities over the past years.

4.4 Adaptation Technology Options for coastal sector and their Main Adaptation benefits

The stakeholders consultations has overwhelmingly identify and agreed that these are the potential technologies that should be pursuit through the TNA process. These technologies would benefit the communities in many ways.

4.4.1 Policy & guideline formulation

The consultation process has agreed that there should be a development of Policy and guideline formulation to oversee future coastal line area development across the Island. The participants have pointed out during the consultation process that currently there is no policy or framework to provide guidance on coast line area development so there is penalty imposed on developers who destroy the coast line area during development.

The consultation process also agreed that there should be a vulnerability assessment (V&A) done across the country to identify vulnerable zones or areas so that future sea walls or soil erosion barriers should be erected at these identified sites. The benefit from this strategy is to ensure that sea walls and barriers are built at areas that are mostly vulnerable and needs urgent preventive measure against further erosions.

Besides this, the country should also develop a policy to ensure that any development initiative along the coast line must undergo an Environment Impact Assessment (EIA) requirement. The EIA process should be a compulsory requirement for granting permit to potential developers along the coastline areas. The benefit of this procedural policy requirement is that developers identify potential damage to the environment and proper measures are taken prior to such development is initiated to minimise and mitigate such potential loss to the environment.

4.4.2 Coastal vegetation restoration

There are handful of coastal vegetation restoration along the coast line areas across the island. This initiative needs to be enhanced and advocated nation-wide as these communities are exposed to increasing impacts of climate change and soil erosion.

The benefit of these coast revegetation is that it will bring back the much needed coast vegetation such as local mangroves and trees along the coast against SLR but also help to hold the soil together from being washed away by land degradation and erosion.

4.4.3 Construction of seawalls

Sea wall construction is potentially seeing as the short to medium term solution to the impact of climate change, especially against soil erosion and sea level rise around the island. The benefit of this technology is that it provide refuge immediately to the low lying communities (since about 90% of the houses are built at the coast areas). The down side to this technology is that, there are no policy surrounding construction of these structures and no V&A, EIA or even cost benefit analysis (CBA) made before committing to such development.

Going forward, the responsible authority must ensure that such structure (sea wall) is assessed well before any decision to invest into it. The collateral costs on vegetation and other habitat in the area must also be assessed.

4.4.4 LMMA

The fourth technology is the introduction of locally managed marine protected area (LMMA) at selective sites around the island. The benefit of this LMMA is that community participate in protecting their marine resources from depletion as part of food security but at the same time participate in managing the coastal areas from soil erosion and land degradation. For this technology the communities have to identify potential sea area (preferably coral reef area) and declare this location as “taboo” place not to fish but at the same time protect its adjacent beaches from extraction as well.

This could be seen as integrated approach towards conservation as and resource management as the beaches and marine resources are protected from exploitation. The downside of this could be the complexity of land ownership and sometimes individuals or tribal groups who own the land may not have subscribe to the idea and may not have agreed to this technology. In some PICs this LMMA technology is also adopted as an effective way to combating food security and climate change at the same time.

4.5 Criteria and process of technology prioritisation for coastal sector

During this process, the multi-criteria analysis (MCA) tool is used in ranking the four (4) identified technologies in their priority order based on a set of criteria that are relevant to country context. A list of criteria categories, sub-categories and criterion to be considered for the coastal sector technology prioritisation are provided in Table 13.

Table 13: Selection criteria for technologies in coastal sector

Criteria Category	**Criteria Sub-Category**	**Criterion**
Cost	Cost	Cost to set-up & operate per beneficiary/ year
Benefits	Economic	Improving household income & ability to re-invest
		Trigger private investment
	Social	Poverty reduction
		Gender aspects
	Environment	Contribution to protect & sustain ecosystem services
	Climate related	Improvement of resilience to CC
Others	Institutional/ implementation	Ease of implementation
		Replicability
	Political	Coherence with national development policies & priority

Each criterion is given a scoring range (0-100) and a preferred scoring value (0 or 100) as shown in Table 14.

Table 14: Criteria scoring units an preferred values for Coastal Sector

No.	**Criteria Category**	**Criteria Sub-Category**	**Criterion**	**Scoring Scale**	**Preferred Value**
1.	Cost		Set-up & operation cost/ beneficiary/year	0 = very low cost 100 = high cost	0 = very low cost
2.	Benefits	Economic	Improving household income &	0 = very low 100 = very high	100 = very high

			ability to re-invest		
3.			Trigger private investment	0 = very low 100 = very high	100 = very high
4.		Social	Poverty reduction	0 = very low 100 = very high	100 = very high
5.			Gender aspects	0 = no consideration of gender issues 100= High consideration	100= mainstreaming & high consideration of gender issues
6.		Environment	Contribution to protect & sustain ecosystem services	0 = very low 100 = very high	100 = very high
7.		Climate related	Improvement of resilience to CC	0 = very low 100 = very high	100 = very high
8.	Others	Institutional/ implementation	Ease of implementation	0 = very difficult 100 = very easy	100 = very easy
9.			Replicability	0 = very difficult 100 = very easy	100 = very easy
10.		Political	Coherence with national development policies & priority	0 = very low 100 = very high	100 = very high

4.6 Results of technology prioritisation for coastal sector

At the beginning of the MCA process, scores are manually inputted for each criterion in the performance matrix table as illustrated in Table 15. These scores are based on the TFS. These scores are automatically calculated and displayed in the Normalised scoring matrix (Table 16). The results in Table 16 are further calculated with results produced in the Scores and weights combined tables (Table 17).

Table 15: Performance matrix table for coastal sector

No.	Criterion	Technology			
		Policy & guideline formulation	Coastal vegetation restoration	Construction of seawalls	LMMA
1.	Set-up & operation cost/ beneficiary/ year	15	25	90	25
2.	Improving household income & ability to re-invest	65	60	40	65
3.	Trigger private investment	75	65	55	60

4.	Poverty reduction	45	55	35	60
5.	Gender aspects	85	100	85	85
6.	Contribution to protect & sustain ecosystem services	100	100	95	100
7.	Improvement of resilience to CC	95	95	85	90
8.	Ease of implementation	50	55	35	85
9.	Replicability	65	75	45	85
10.	Coherence with national development policies & priority	100	100	85	95

The normalised scoring results in Table 16 are obtained from the equations provided in Annex 6.

Table 16: Normalised scoring matrix table for coastal sector

No.	Criterion	Technology			
		Policy & guideline formulation	Coastal vegetation restoration	Construction of seawalls	LMMA
1.	Set-up & operation cost/ beneficiary/ year	100	87	0	87
2.	Improving household income & ability to re-invest	100	80	0	100
3.	Trigger private investment	100	50	0	25
4.	Poverty reduction	40	80	0	100
5.	Gender aspects	0	100	0	0
6.	Contribution to protect & sustain ecosystem services	100	100	0	100
7.	Improvement of resilience to CC	100	100	0	50
8.	Ease of implementation	30	40	0	100
9.	Replicability	50	75	0	100
10.	Coherence with national development policies & priority	100	100	0	67

Note the final scores and rankings in Table 17 are obtained by multiplying the criterion weights with each criterion result from the normalised scoring matrix (Table 16).

Table 17: Scores & equal weights combined table for coastal sector

No.	Criterion Weight	Criterion	Technology			
			Policy & guideline formulation	Coastal vegetation restoration	Construction of seawalls	LMMA
1.	10	Set-up & operation cost/ beneficiary/ year	1,000	867	0	867
2.	10	Improving household income & ability to re-invest	1,000	800	0	1,000
3.	10	Trigger private investment	1,000	500	0	250
4.	10	Poverty reduction	400	800	0	1,000
5.	10	Gender aspects	0	1,000	0	0
6.	10	Contribution to protect & sustain ecosystem services	1,000	1,000	0	1,000
7.	10	Improvement of resilience to CC	1,000	1,000	0	500
8.	10	Ease of implementation	300	400	0	1,000
9.	10	Replicability	500	750	0	1,000
10.	10	Coherence with national development policies & priority	1,000	1,000	0	667
	100	TOTAL SCORES:	**7,200**	**8,117**	**0**	**7,283**
RANKING:			**3**	**1**	**4**	**2**

In the case for equal criterion weights (Table 17), coastal vegetation restoration is awarded the highest score with LMMA in second place. However, for different criterion weights as shown in Table 18, we note that policy and guidance formulation is awarded the highest score with coastal vegetation restoration in second place.

Table 18: Scores & different weights combined table for coastal sector

No.	Criterion Weight	Criterion	Technology			
			Policy & guideline formulation	Coastal vegetation restoration	Construction of seawalls	LMMA
1.	5	Set-up & operation cost/ beneficiary/ year	500	433	0	433
2.	10	Improving household income & ability to re-invest	1,000	800	0	1,000
3.	20	Trigger private investment	2,000	1,000	0	500
4.	5	Poverty reduction	200	400	0	500

5.	5	Gender aspects	0	500	0	0
6.	25	Contribution to protect & sustain ecosystem services	2,500	2,500	0	2,500
7.	10	Improvement of resilience to CC	1,000	1,000	0	500
8.	5	Ease of implementation	150	200	0	500
9.	5	Replicability	250	375	0	500
10.	10	Coherence with national development policies & priority	1,000	1,000	0	667
	100	TOTAL SCORES:	**8,600**	**8,208**	**0**	**7,100**
RANKING:			**1**	**2**	**4**	**3**

The tabulated results for coastal sector are reproduce in graph form in Figure 4 and Figure 5.

However, at this stage the ranking is not final as all these four technologies will be recommended for inclusion for further analysis in the next TNA process – Barrier Analysis and Enabling Framework.

Figure 4: Coatal sector technology ranking – equal criteria weights

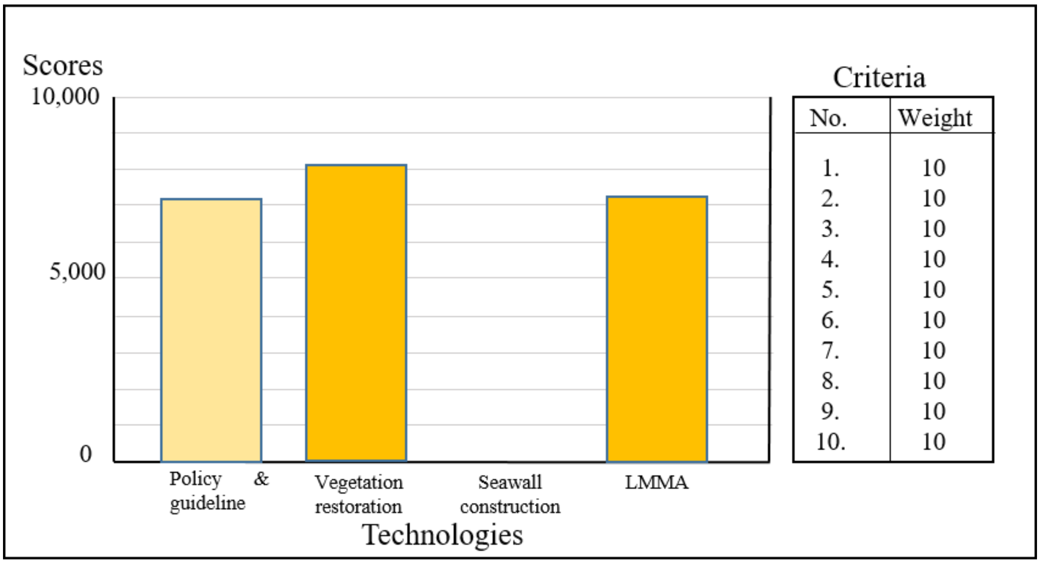
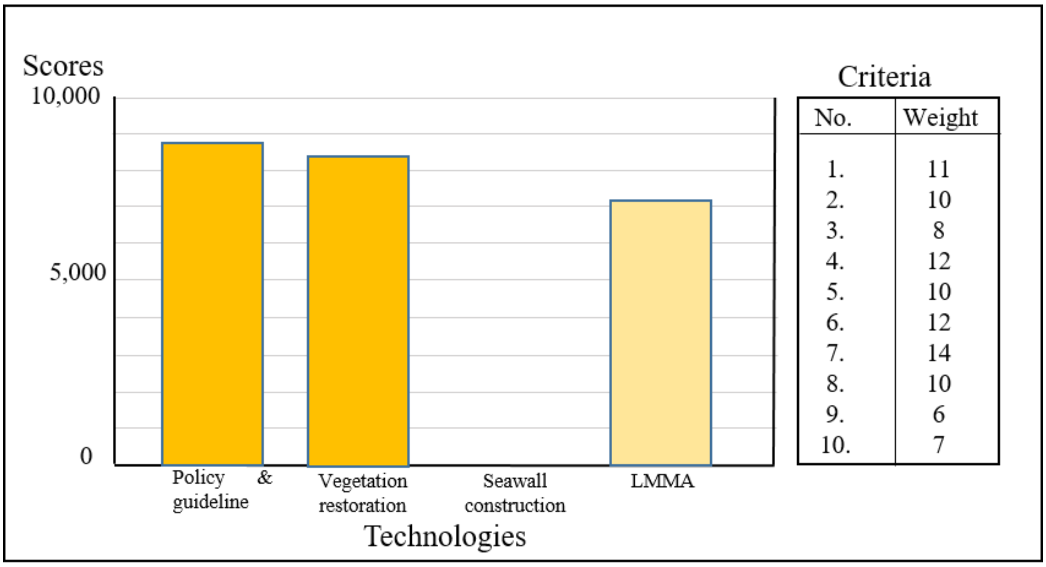


Figure 5: Coastal sector technology ranking – different criteria weights



Chapter 5: Technology Prioritisation for Mitigation in the Energy Sector

5.1 Existing technologies and GHG emissions for the energy sector

5.1.1 Diesel Power Generation

The NUC power station has 13 diesel generators with design capacities ranging from 1 MW to 2.8 MW as illustrated in Table 19. Six of these generators are medium speed sets used mainly for base and continuous load while the high speed generator sets are for standby emergency power.

Table 19: NUC diesel generating sets

No.	Generator	Speed	Design Capacity (MW)	Operational Capacity (MW)	Status
1.	G1 – Ruston	Medium	2.8	2.4	Not in service. To be refurbished & commissioned Nov. 2018.
2.	G2 – MAN Diesel	Medium	2.8	2.8	In service/ Standby Operational
3.	G3 – MAN Diesel	Medium	2.8	2.8	In service/ Standby Operational
4.	G4 – Ruston	Medium	2.8	2.6	Not in service. Commissioning planned for Aug. 2018
5.	G5 – Ruston	Medium	1.0	0.8	Not in service. Major overhaul planned for completion by March 2019
6.	G6 – Ruston	Medium	2.0	2.0	Not in service. Major refurbishment in progress. Planned commissioning by July 2018
7.	G2A – Cummins	High	1.0	0.8	In service/ Stand-by Operational.
8.	G2B – Cummins	High	1.0	0.8	In service/ Stand-by Operational.
9.	G3 – Cummins	High	1.0	0.8	In service/ Stand-by Operational
10.	G4 – Cummins	High	1.0	0.8	In service/ Stand-by Operational
11.	G5 – Cummins	High	1.0	0.8	In service/ Standby Operational
12.	G7A – MTU	High	1.0	0.8	In service/ Stand-by Operational.
13.	G7B – Cummins	High	1.0	0.8	In-service/ Stand-by Operational.

Nauru currently has an installed design capacity of 21.2 MW with an operational capacity of 19 MW. However, out of the 13 generators that are installed, 9 of these are operational with total capacity of 11.2 MW.

5.1.2 Renewable Energy

There are also a number of existing solar systems in Nauru that are monitored by NUC. Currently, there is an installed solar panel capacity of 807 kW that represents 5% of the island's current energy demand. The planned Meneng (MFAT) 1,000 kW solar farm project is in its final construction stages and is scheduled for commissioning in late August 2019. This will increase the installed solar panel capacity to 1,807 kW.

Site clearing is in progress for the installation of a 6 MW grid-connected solar farm that is being funded by ADB. There are also potential installations of 2,030 kW. More information on these solar panels are provided in the Table 20.

Table 20: Existing, planned and potential solar panels

Name	**Connection**	**System**	**Capacity (kW)**
Existing			807
Buada (UAE)	Grid connected	Ground-mounted	500
Noddy Building	Grid connected	Roof-mounted	138
Government Building	Grid connected	Roof-mounted	52
NUC Office	Grid connected	Roof-mounted	20
NGH (Hospital)	Behind the meter	Roof-mounted	22
Od-N-Aiwo Hotel	Behind the meter	Roof-mounted	5
Nauru College	Behind the meter	Roof-mounted	40
Capelle Apartments	Behind the meter	Roof-mounted	30
Angelique Ika	Behind the meter	Roof-mounted	N/A
Menen Disabled School	Behind the meter	Roof-mounted	N/A
Planned			7,100
Meneng (MFAT)	Grid connected	Ground-mounted	1,000
Capelle & Partner	Behind the meter	Roof-mounted	100
Meneng – (ADB)	Grid connected	Ground-mounted	6,000
Potential			2,030
Capelle & Partner	Behind the meter	Roof-mounted	200
Prison	Grid connected	Roof-mounted	300
Sports Centre	Grid connected	Roof-mounted	330
Hospital	Grid connected	Roof-mounted	200
Civic Centre	Grid connected	Roof-mounted	500
Private property	Behind the meter	Roof-mounted	500

Total	**9,937**

5.1.3 GHG emissions

Nauru submitted its Second National Communications report to the United Nations Framework Convention on Climate Change in December 2014. As a non-Annex I country and a developing country, Nauru has chosen year 2000 as the base year for estimating GHG inventory as part of its Second National Communication. In 2000, the total estimated GHG emission from the energy sector was 13.3371 Gg CO_2e.

GHG emissions in the energy sector are primarily associated with fuel combustion and fugitive emissions from fuels. Since Nauru is 100% dependent on imported fossil fuels to meet its energy demand and has no energy resource mining and exploration activities, fugitive emissions from fuels are not considered for the GHG Inventory. GHG Emissions from the energy sector from fuel combustion are presented in Table 21.

Table 21: GHG emission per energy sector

No.	Energy Sector	GHG Emission
1.	Energy Industries	54.1 %
2.	Manufacturing/ Construction Industries	20.3 %
3.	Road Transport	24.98 %
4.	Residential	0.6 %

(Source: Nauru SNC – 2014)

5.2 Decision context

The energy sector is the main contributor of GHG emissions in Nauru as well as the largest consumer of imported petroleum-based fossil fuel. NUC diesel generators are the largest consumers of fossil fuel and main contributors of GHG emissions. This high consumption rate of fossil fuels is to meet 100% of its domestic and commercial customer's electrical power needs. The cost of fossil fuels and increasing threats from climate change necessitate a diversified energy mix and transition to alternative sources of energy. In this regard, a number of national plans, initiatives and policy documents such as the NSDS is being followed to transform and diversify the energy sector. Nauru's energy vision as documented in the energy sector goals of the NSDS is to:

'Provide a reliable, affordable, secure and sustainable energy supply to meet the socio economic development needs of Nauru.'

Original NSDS energy sector targets for 2020 include:

i) 24/7 grid electricity supply with minimal interruptions.
ii) 50% of grid electricity supplied from renewable energy sources.
iii) 30% improvement in energy efficiency in the residential, commercial and government sectors.

NUC has well achieved (i) and (iii) of the NSDS objectives above and is now well in the process of accomplishing 50% of grid electricity to be supplied from a renewable energy source. The 50% RE-source project is being funded by ADB who has commissioned GHD[6] to assist NUC in the development of project documentations that include feasibility, tendering and procurement. The NSDS prioritisation process is therefore being undertaken in the context of climate change and development priorities of the Nauru.

Technology prioritisation in the energy sector is not only based on the concept that leads to reduction of imported fossil fuel and GHG emission, but also their contribution to sustainable development.

5.3 Possible mitigation technology options for the energy sector

During the first stakeholder consultation, a brainstorming session was conducted with stakeholder participation to list all known or possible RE technology options that have mitigation potential and other co-benefits. The outcome of this session resulted in six technologies that included (i) pumped hydroelectric systems; (ii) biogas; (iii) OTEC; (iv) rooftop PV; (v) wave energy conversion; and (vi) tidal energy conversion. Each of these technologies were reviewed extensively with stakeholders not so much in terms of their cost (capital, operation & maintenance) but more so on their viability given Nauru's limited resources. In ranking these technologies, the potentials of wave and tidal energy for Nauru

[6] GHD – one of the world's leading professional services companies operating in the global market sectors of water, energy and resources, environment, property and buildings, and transportation.

were least favourable and were excluded. The ranking of the remaining four favourable technologies are shown in Table 22.

Table 22: Stakeholder prioritised ranking of identified RE technologies

No.	Mitigation Technologies - RE	Overall stakeholder ranking
1.	Pumped hydroelectric storage	1^{st}
2.	Biogas	2^{nd}
3.	OTEC	3^{rd}
4.	Rooftop PV	4^{th}

Technology fact sheets for the four RE technologies prioritised by the stakeholders are provided in Annex 2. An overview for each of these technologies are presented below.

5.3.1 Pumped hydroelectric storage (PHES)

A PHES system is the most developed energy storage technology, with facilities dating from the 1890s in Italy and Switzerland. PHES is a technology that would use the surplus power from a renewable source to pump water from a lower reservoir to a second reservoir on top of the hill. This creates the potential energy that can be released when needed through letting the water flow from the upper reservoir through a conventional hydro turbine at sea level which generates power into the grid.

PHES systems are GHG emission free that operates freely from a RE source that operates the pump, and gravity to turn the turbine to generate power.

PHES has the potential to significantly contribute towards Nauru's long-term energy storage needs and as an alternative for BESS (battery energy storage system) to facilitate the increasing number of grid-connected solar panels as shown in Table 20. The main applications of pumped hydro are for energy management, frequency control and provision of reserves. The advantages that a PHES system has over battery storage is that the pumped hydro installation is generally less expensive and expected to have a lifespan of over 50 years, whereas battery modules are limited in their lifespan to around 10 years.

Nauru has the potential of developing this energy storage technology given its highest point at 70 meters is located at the Command Ridge. A reservoir at Command Ridge can also serve as a fire hydrant source for the nearby fuel tank farm and as a source for non-potable use like toilet flushing at nearby residences that do not have access to brackish water.

A pre-feasibility study was recently carried out by GHD in New Zealand in 2019 through NZ MFAT funding which fully supported its potential on Nauru. A feasibility study is now being considered to be completed in 2020.

5.3.2 Biogas

Biogas is a modern form of bioenergy that can be produced through anaerobic digestion or fermentation of a variety of biomass sources. These include, but are not limited to, livestock manure, food waste, agricultural residues, energy crops, sewage and organic waste from landfills. It is a versatile fuel that can be used for cooking, heating, lighting, power generation and combined heat and power generation, as well as, when upgraded to boost its methane content, in transport applications. It also can provide dispatchable energy to power grids so that a higher share of electricity can be generated from variable wind and solar energy. Biogas typically consists of 50–75% methane, which provides its energy content, and 25–50% carbon dioxide, which potentially can be captured and stored.

5.3.3 OTEC

OTEC is another proven technology that produces clean baseload electricity; 24/7 using the temperature differential (>20ºC) between warm surface water and cold deep water in the world’s tropical oceans. The warm seawater is used to produce a vapour that acts as a working fluid to drive turbines. The cold water is used to condense the vapour and ensure the vapour pressure difference drives the turbine. OTEC technologies are differentiated by the working fluids that can be used. Open Cycle OTEC uses seawater as the working fluid, Closed Cycle OTEC uses mostly ammonia. A variation of a Closed Cycle OTEC, called the Kalina Cycle, uses a mixture of water and ammonia. The use of ammonia as a working fluid reduces the size of the turbines and heat exchangers required.

OTEC can also be used for ocean water desalination. Ocean thermal energy can easily provide 40 MJ of thermal energy to get 1 cubic meter of fresh water. System analysis indicate that a

2 MW plant can produce 4,300 cubic meter desalination water each day[7]. The cost of desalinated ocean water can be less than 10 cents for each cubic meter.

Nauru is considered an excellent location for an OTEC plant because the temperature differences between the surface warm waters and the deeper cool waters surrounding Nauru are relatively great and because the seabed nearby has a steep inclination. One of the first small-scale and operational OTEC pilot plants was built in Nauru in 1981. This plant was rated at 100 kW and produced 31.5 kW of OTEC net power continuously to the grid for 10 days. However, the intake pipes that were mounted over the reef were damaged during a storm which resulted in the system being dismantled. For future OTEC development proposals on Nauru, the coral reef must be cut and excavated for laying of the intake pipes.

General perceptions of OTEC applicable to SIDS apart from being very expensive are; (i) major technical barriers have been removed; (ii) design studies have been performed to show techno-economic viability; (iii) competitive to petroleum liquid-fueled power generation in the island states; (iv) co-production of power and desalinated water favourable to island states that have limited or no water resources like Nauru.

5.3.4 Grid-connected rooftop solar PV system

Solar PV (photovoltaic) refers to the technology of using solar cells to convert solar radiation directly into electricity. The technology has been developed steadily since the 1960s and is now seeing a period of very rapid commercialization.

A rooftop solar PV system is a photovoltaic system that has its electricity-generating solar panels mounted on the rooftop of a residential or commercial building or structure. The two solar PV connection systems include grid interconnection and stand-alone.

Stand-alone systems have no interconnection to the grid but rely on energy storage devices such as batteries to store energy during the day for use at night.

A grid connected PV systems is connected to the utility grid through an inverter. The inverter converts the DC electricity produced by the solar panels into 240 V AC electricity, which can then be used by the property/household. If a grid connect system is producing more power than the home consumes, the surplus is fed into the power grid.

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[7] https://www.slideshare.net/naveen1nk/ocean-thermal-energy-conversion-systems

The main advantage of a grid connected PV system is its simplicity, relatively low operating and maintenance costs as well as reduced electricity bills.

5.4 Criteria and process for technology prioritisation for renewable energy sector

During this process, the multi-criteria analysis (MCA) tool is used to rank the four (4) identified technologies in their priority order based on a set of criteria that are relevant to country context. A maximum of 10 criterions have been selected by the consultant that come under two major criteria catogories that include (i) technology diffusion and (ii) sustainable development impacts and benefits as shown in Table 23

Table 23: Selection criteria for technologies in energy sector

Criteria Category	Criteria Sub-Category	Criterion
Technology diffusion	Cost	Capital cost
		O&M
	Implementation potential	Maturity
		Stakeholder acceptability
	Institutional	Capacity
Sustainable development impacts/ benefits	Economic	Energy saving
	Social	Potential to create job
		Scale/ size of beneficiary group
		Gender aspects
	Environmental	Reduction in GHG emissions

Each criterion is given a scoring range (0-100) and a preferred scoring value (0 or 100) as shown in Table 24 except for the capital cost. The unit for capital cost is provided in USD per kilowatt with a low cost technology as the most preferred.

Table 24: Criteria scoring scales and preferred values for energy sector

No.	Criteria Category	Criteria Sub-Category	Criterion	Scoring Scale/ Unit	Preferred Value
1.	Technology diffusion	Cost	Capital cost	USD/ kW	Low cost
2.			O&M	0 = very low 100 = very high	0 = very low

3.		Implementation potential	Maturity	0 = not mature 100 = very mature	100 = very mature
4.			Stakeholder acceptability	0 = not accepted 100 = highly accepted	100 = highly accepted
5.		Institutional	Capacity	0 = no-one trained 100 = high number trained	100 = high number trained
6.	Sustainable development impacts/ benefits	Economic	Energy saving	0 = no energy saved 100 = very high energy saved	100 = very high energy saved
7.		Social	Potential to create job	0 = very low 100 = very high	100 = Very high
8.			Scale/ size of beneficiary group	0 = very low 100 = very high	100 = Very high
9.			Gender aspects	0 = very low 100 = very high	100 = Very high
10.		Environmental	Reduction in GHG emissions	0 = very low 100 = very high	100 = Very high

5.5 Results of technology prioritisation for renewable energy sector

At the beginning of the MCA process, scores are manually inputted; based on data from TFS, for each technology criterion in the performance matrix table as illustrated in Table 25. These scores are automatically calculated and displayed in the Normalised scoring matrix (Table 26) and the Scores and weights combined tables (Table 27).

Table 25: Performance matrix table for energy sector

No.	Criterion	Technology			
		PHES	Biogas	OTEC	Rooftop PV
1.	Capital cost (USD/ kW)	17,700	4,500	14,000	1,800
2.	O&M	60	5	100	5
3.	Maturity	100	90	70	100
4.	Stakeholder acceptability	100	80	60	40
5.	Capacity	5	0	0	20
6.	Energy saving	30	10	100	25
7.	Potential to create job	15	30	90	15
8.	Scale/ size of beneficiary group	30	5	100	25
9.	Gender aspects	10	25	30	10
10.	Reduction in GHG emissions	20	15	100	40

The normalised scoring results in Table 26 are obtained from the equations provided in Annex 6. These scores are further multiplied by criterion weights and produced in Table 27

Table 26: Normalised scoring matrix table for energy sector

No.	Criterion	Technology			
		PHES	Biogas	OTEC	Rooftop PV
1.	Capital cost	0	83	23	100
2.	O&M	42	100	0	100
3.	Maturity	100	67	0	100
4.	Stakeholder acceptability	100	67	33	0
5.	Capacity	25	0	0	100
6.	Energy saving	22	0	100	17
7.	Potential to create job	0	20	100	0
8.	Scale/ size of beneficiary group	26	0	100	21
9.	Gender aspects	0	75	100	0
10.	Reduction in GHG emissions	6	0	100	29

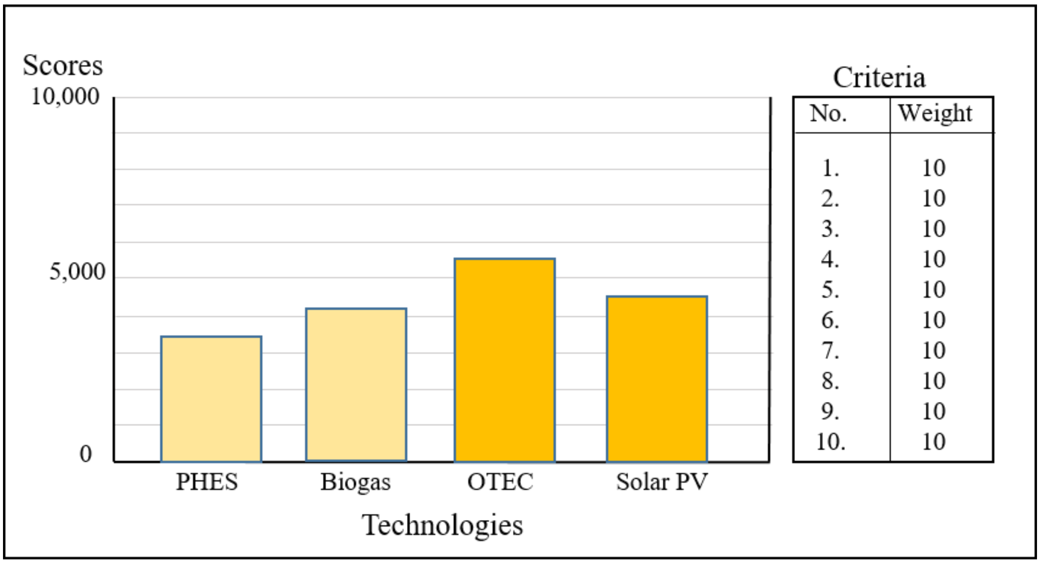
Each criterion is provided with a weight as shown in column 2 of Table 27. Note that for this scoring table, the criterion weights are all equal. A bar graph for Table 27 is shown in Figure 6.

Table 27: Scores & equal weights combined table for energy sector

No.	Criterion Weight	Criterion	Technology			
			PHES	Biogas	OTEC	Rooftop PV
1.	**10**	Capital cost	0	830	233	1,000
2.	**10**	O&M	421	1,000	0	1,000
3.	**10**	Maturity	1,000	500	0	1,000
4.	**10**	Stakeholder acceptability	1,000	667	333	0
5.	**10**	Capacity	250	0	0	1,000
6.	**10**	Energy saving	222	0	1,000	167
7.	**10**	Potential to create job	0	200	1,000	0
8.	**10**	Scale/ size of beneficiary group	1263	0	1,000	211
9.	**10**	Gender aspects	0	750	1,000	0
10.	**10**	Reduction in GHG emissions	59	0	1,000	294
	100	TOTAL SCORES:	**3,215**	**4,114**	**5,566**	**4,671**
RANKING:			**4**	**3**	**1**	**2**

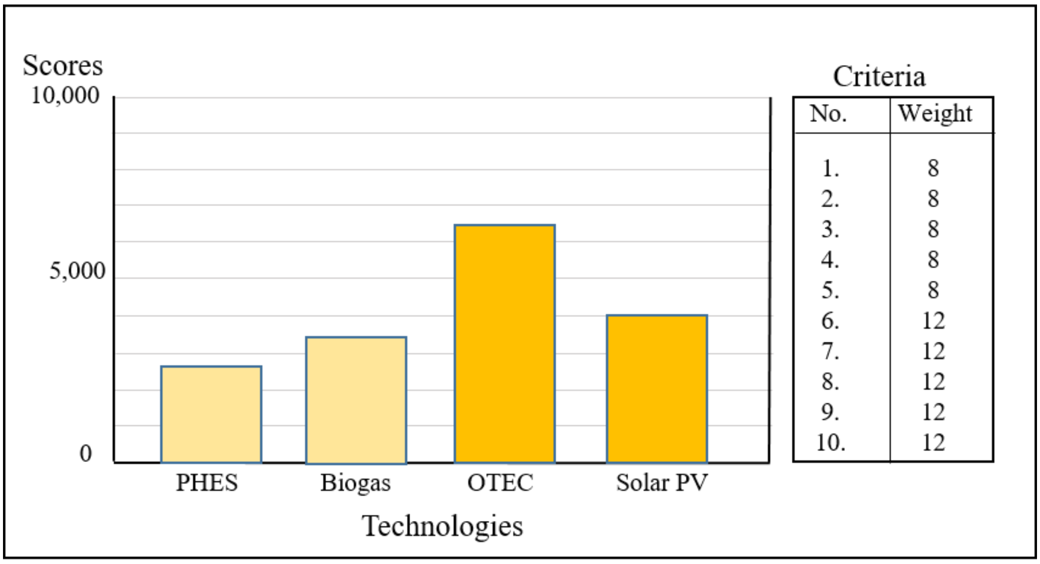
With equal criterion weights, OTEC technology is ranked first followed by rooftop PV, biogas and PHES technologies respectively as shown in Figure 6.

Figure 6: Energy sector MCA technology ranking – equal criteria weights



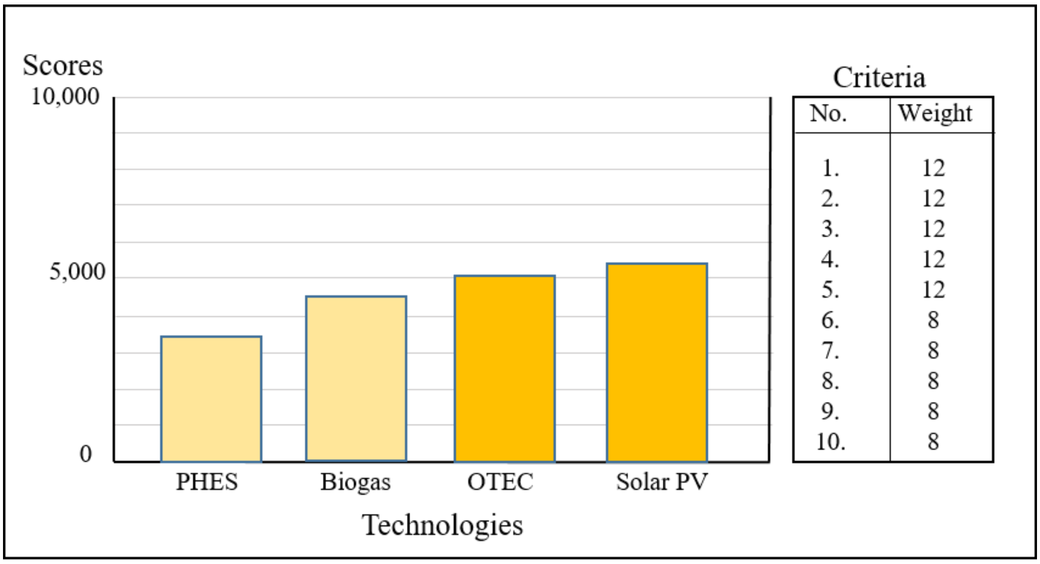
The outcome for a reduced criterion weight for the *technology diffusion criteria* (criteria No.'s 1-5) and an increased weight for *sustainable development impact/ benefit criteria* (criterion No.' 6-10) is shown in Figure 7. Note that OTEC and Solar PV technologies are still ranked first and second respectively.

Figure 7: Energy sector MCA technology ranking – different criteria weights A



The outcome for an increased criterion weight for the *technology diffusion criteria* and a reduced weights for *sustainable development impact/ benefit criteria* is shown in Figure 8. Here it is noted that solar PV technology is now ranked first and OTEC in second.

Figure 8: Energy sector MCA technology ranking – different criteria weights B



OTEC is ranked highly in the sustainable development impact/ benefit criteria category (criterion weights 6-10) whereas solar PV I highly ranked in the technology diffusion criteria category (criterion weights 1-5). The outcome of these ranking are based entirely on the respective TFS information and the performance scores that were prepared and provided by the consultant and shared to all the stakeholders. However, at this stage, all these four technologies will still be recommended for inclusion for further analysis in the next TNA process – Barrier Analysis and Enabling Framework.

Chapter 6: **Technology Prioritisation for Mitigation in the Waste Sector**

6.1 Existing technologies and GHG emissions for solid waste management sector

6.1.1 Solid waste disposal

The disposal method on Nauru is an open dump method at the NRC-managed dumpsite located in the south-west of the island. The dumpsite covers a fairly large area and is a pollution threat to underground water reserves.

6.1.2 Segregation

Bays are constructed for the separation of recyclables, garden waste and cardboard (for the manufacture of compost). Segregation is not encouraged at the household level, hence dumping is uncontrolled. Where possible site staff are also separating white goods, tyres and scrap steel. The waste management sector of CIE has rolled out a segregation initiative that include the provision of coloured bins for different recyclable waste to all schools on Nauru.

6.1.3 Composting

The dumpsite has a bay where vegetation waste are piled for further mulching/ chipping for the manufacture of compost. NRC currently has three mulching machines that are listed in Table 28.

Table 28: Existing composting machines with NRC

No.	Mulching machine make/ model	Branch diameter chipping capacity	Status
1.	Vermeer BC 1500	Up to 38 cm	Not in service. To be repaired.
2.	Red Roo CMS 100	Up to 10 cm	In service.

6.1.4 Clean and green

Clean and green is a government funded community-based initiative where 4 to 6 members of each district apply to sweep the road kerbside and trim off any overgrown vegetation next to the footpaths within their respective district boundaries. This campaign keeps the road and kerbside clean and also clears the rainwater drainage system. Community leaders are responsible for delegating community groups who take turns in this weekly clean-up campaign. This however is not a permanent post, rather it is targeted for those in need of financial assistance.

6.1.5 Waste collection

Waste collection services using garbage trucks is currently being provided by the private sector. The frequency of waste collection differs for each district. In Boe District, waste is collected on the kerbside three times a week, whereas waste collection for most other districts is done once a week.

6.1.6 GHG emissions

Nauru submitted its Second National Communications report to the United Nations Framework Convention on Climate Change in December 2014. As a non-Annex I country and a developing country, Nauru has chosen year 2000 as the base year for estimating GHG inventory as part of its Second National Communication. In 2000, the total estimated GHG emission from the waste sector; excluding removals was **4.5460** Gg CO_2e.

Methane is the most prominent gas emitted from the waste sector. Unmanaged solid waste (SW) and waste water sites, lead to methane emissions. The methane emissions so emitted are estimated using the quantity of waste generated the management of the waste, the proportion of carbon that may be transformed into methane etc.

6.2 Decision context

The main decision context for solid waste management on Nauru is founded on the NSDS where the vision for the waste and sewerage sector is:

"Effective management of waste and pollution that minimizes negative impacts on public health and environment".

Key Performance Indicators include:

(i) Proportion of waste effectively and sustainably managed.

(ii) Number of national and sector policies, plans and programs in which waste and pollution issues have been integrated.

The NSDS also provides a set of waste and sewerage strategy milestones and responsible departments as illustrated in Table 29.

Table 29: Waste & sewerage strategy milestones

Strategies	Short-term Milestones 2012	Medium-term Milestones 2015	Long-term Milestones 2025	Responsibility
Strengthen the waste and sewerage sector by enhancing the capacity to manage solid and hazardous waste and sewerage	National solid waste management strategy finalized and implemented Hazardous waste management strategy developed (Waigani Convention)	National implementation plan (NIP) developed (Stockholm Convention) and implemented	Pollution and waste management efforts become sustainable	Department of Environment and Nauru Rehab Corporation

6.3 Possible mitigation technology options in solid waste management

Mitigation technology options in solid waste management that are being considered for Nauru are not only based on current proven technologies and their effectiveness but more so on their potential contribution to reducing GHG emissions and other co-benefits. Although some technologies may have already been considered and being practiced like baling and composting, it is important that the technologies used and their effectiveness are examined. The approaches to baling and composting can either be implemented at community or household level or on a more centralised location. During an initial TNA consultation with stakeholders, the four (4) technologies that were identified for further prioritisation are shown in Table 30.

Table 30: Stakeholder selection on waste management technologies

	Mitigation Technologies – Solid waste management	**Stakeholder ranking**
1.	Semi-aerobic landfill	1st
2.	Waste segregation at household level	2nd
3.	Baling at commercial level	3rd
4.	Composting at household level	4th

6.3.1 Semi-aerobic landfill

Also known as the Fukuoka method, this semi-aerobic structured landfill is a technology offering improved landfill sites simply and at low cost utilizing materials and methods readily available in developing countries to install leachate drainage pipes and gas vents, thereby enlarging the aerobic region in the landfill waste layers. This technology also minimizes impact on the environment surrounding the site because it promotes the degradation of landfilled waste, rapid landfill stabilization and leachate is drained promptly from the landfill. In addition the volume of methane gas emitted by the landfill is reduced, contributing to efforts to prevent global warming. A semi-aerobic landfill is a landfill where waste goes through a decomposition process in the presence of oxygen. This type of landfilling method has several advantages including reduction in the amount of landfill gas produced, faster stabilisation of the waste landfilled and eliminates leachate from soaking through the ground and contaminating ground water resources.

6.3.2 Segregation

Waste segregation refers to the separation of wet waste and dry waste where the purpose is to recycle dry waste easily and to use wet waste as compost. When waste is segregated, there is reduction of waste that gets landfilled and occupies space, air and water pollution rates are considerably lowered. Segregation at the source reduces the amount of recyclable wastes ending up at the landfill where it usually becomes impractical to sort. Segregation at the community level can be achieved with the support of the GoN through consultations, workshops and the provision of proper colour coded bins for specific types of recyclable wastes.

CIE is currently promoting segregation practices in schools by providing them with the proper bins with pictures of recyclable wastes pasted on the side. This segregation campaign is aimed to encourage school children to carry out the same at home.

6.3.3 Baling

Baling is a process that compresses mainly recyclable wastes into a block (bale) which is secured by plastic or wire strapping. Baling reduces the volume of waste product and has a number of benefits that include (i) reduction of space taken up by waste on site; (ii) easier to store due to regular shape; (iii) ease of transportation; (iv) reduced storage, transportation and waste disposal costs; and (v) increased revenue as some baled materials can be sold to recyclers. Installing balers at the source of waste generation is recommended for Nauru.

Baling of aluminium cans at domestic level is a common practice in the past, however exporting of these never eventuated due to strict quarantine regulations.

Medium sized balers should be installed at sources of waste generations that may include the government offices; main shopping complexes like Civic Centre and Capelle and Partners; hotels and hospitals. The dumpsite should also have a baling machine of bigger size to compact household recyclable wastes before they end up in the landfills.

6.3.4 Composting

Composting is an aerobic method (meaning that it requires the presence of air) of decomposing organic solid wastes. It can therefore be used to recycle organic material. The process involves decomposition of organic material into a humus-like material, known as compost, which is a good fertilizer for plants.

Household waste consists of organic waste and compostable materials. If everyone on Nauru starts composting at home, tons of organic waste would be diverted from landfills, reducing GHG from hitting the atmosphere. Hence, starting a backyard compost pile will help save the environment.

As in the past, NRC provides a mulching and chipping services to the community as required where wood chips and mulched leaves can either be left at the site for community or household composting or these can be transported back to the dumpsite for compost production.

6.4 Criteria and process for technology prioritisation for solid waste sector

During this process, the multi-criteria analysis (MCA) tool is used in ranking the four (4) identified technologies in their priority order based on a set of criteria that are relevant to country context. The criteria are provided in Table 31. Each criterion is given a scoring range (0-100) and a preferred scoring value (0 or 100) as shown in Table 32.

6.4.1 Criteria identification

Table 31: Selection criteria for technologies in waste sector

Criteria Category	Criteria Sub-Category	Criterion
Technology diffusion	Cost	Capital cost
		O&M
	Implementation potential	Maturity
		Stakeholder acceptability
	Institutional	Capacity
Sustainable development impacts/ benefits	Economic	Energy saving
	Social	Potential to create job
		Scale/ size of beneficiary group
		Gender aspects
	Environmental	Reduction in GHG emissions

6.4.2 Scoring Units and preferred values

Table 32: Performance matrix scoring scale and preferred values for each criteria

	Criteria Category	Criteria Sub-Category	Criterion	Scoring Scale/ Unit	Preferred Value
1.	Technology diffusion	Cost	Capital cost	0 = very low 100 = very high	0 = Low cost
2.			O&M	0 = very low 100 = very high	0 = very low

3.		Implementation potential	Maturity	0 = not mature 100 = very mature	100 = very mature
4.			Stakeholder acceptability	0 = not accepted 100 = highly accepted	100 = highly accepted
5.		Institutional	Capacity	0 = no-one trained 100 = high number trained	100 = high number trained
6.	Sustainable development impacts/ benefits	Economic	Waste reduction reaching landfill	0 = no reduction 100 = very high reduction	100 = very high reduction
7.		Social	Potential to create job	0 = very low 100 = very high	100 = Very high
8.			Scale/ size of beneficiary group	0 = very low 100 = very high	100 = Very high
9.			Gender aspects	0 = very low 100 = very high	100 = Very high
10.		Environmental	Reduction in GHG emissions	0 = very low 100 = very high	100 = Very high

6.5 Results of technology prioritisation for waste sector

At the beginning of the MCA process, scores are manually inputted for each technology criterion in the Excel performance matrix table as illustrated in Table 33Table 15. Results are automatically calculated and displayed in the Normalised scoring matrix (Table 34) and the scores and weights combined tables (The criterion weights are provided in column 2 of Table 35. Note that for this scoring table, the criterion weights are all equal. Household composting is ranked first followed by waste segregation, landfilling and baling. A bar graph for Table 35 is shown in Figure 9.

Table 35).

Table 33: Performance matrix table for waste sector

No.	Criterion	Technology			
		Semi-aerobic landfill	**Household waste segregation**	**Commercial level baling**	**Household composting**
1.	Capital cost (USD)	100	60	20	0
2.	O&M	100	20	40	5
3.	Maturity	100	50	100	100
4.	Stakeholder acceptability	100	80	60	40
5.	Capacity	30	10	5	25

6.	Reduced waste reaching landfill	0	80	75	70
7.	Potential to create job	100	5	20	5
8.	Scale/ size of beneficiary group	20	90	30	100
9.	Gender aspects	20	50	50	90
10.	Reduction in GHG emissions	90	80	70	60

The normalised scoring results in Table 34 are obtained from the equations provided in Annex 6. These scores are further multiplied by criterion weights and produced in The criterion weights are provided in column 2 of Table 35. Note that for this scoring table, the criterion weights are all equal. Household composting is ranked first followed by waste segregation, landfilling and baling. A bar graph for Table 35 is shown in Figure 9.

Table 35.

Table 34: Normalised scoring matrix table for waste sector

No.	Criterion	Technology			
		Semi-aerobic landfill	Household waste segregation	Commercial level baling	Household composting
1.	Capital cost	0	40	80	100
2.	O&M	0	84	63	100
3.	Maturity	100	0	100	100
4.	Stakeholder acceptability	100	67	33	0
5.	Capacity	100	20	0	80
6.	Reduced waste reaching landfill	0	100	94	88
7.	Potential to create job	100	0	16	0
8.	Scale/ size of beneficiary group	0	88	13	100
9.	Gender aspects	0	43	43	100
10.	Reduction in GHG emissions	100	67	33	0

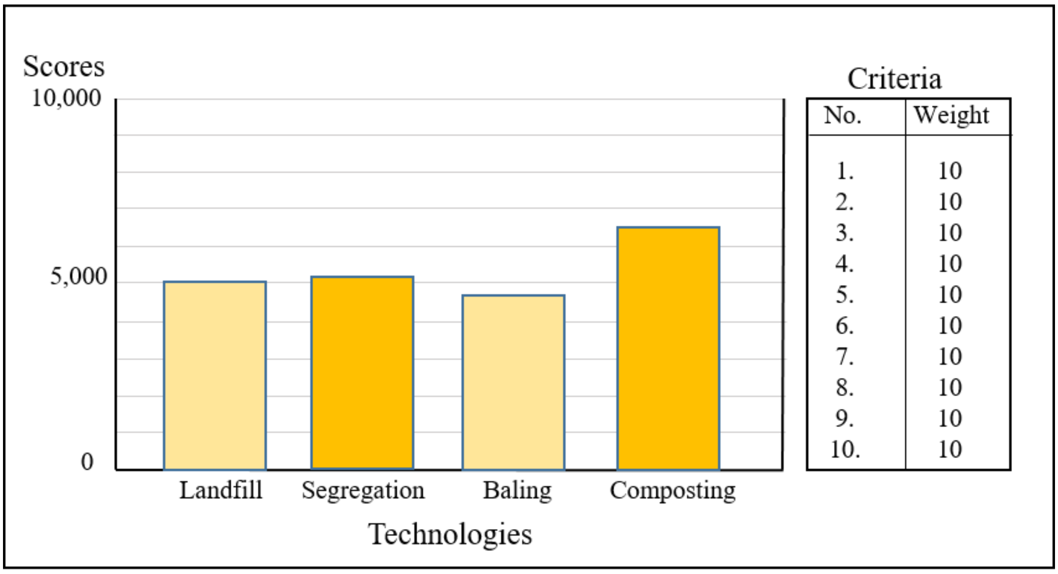
The criterion weights are provided in column 2 of Table 35. Note that for this scoring table, the criterion weights are all equal. Household composting is ranked first followed by waste segregation, landfilling and baling. A bar graph for Table 35 is shown in Figure 9.

Table 35: Scores & weights combined table for waste sector

No.	Criterion Weight	Criterion	Technology			
			Semi-aerobic landfill	Household waste segregation	Commercia l level baling	Household composting
1.	10	Capital cost	0	400	800	1,000

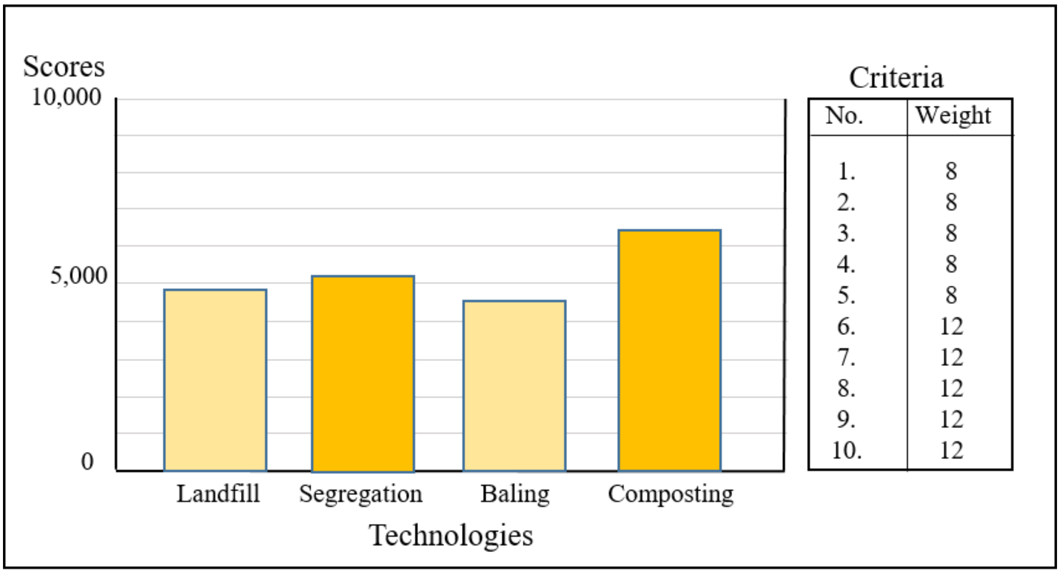
2.	10	O&M	0	842.1	631.6	1,000
3.	10	Maturity	1,000	0	1,000	1,000
4.	10	Stakeholder acceptability	1,000	666.7	333.3	0
5.	10	Capacity	1,000	200	0	800
6.	10	Reduced waste reaching landfill	0	1,000	937.5	875
7.	10	Potential to create job	1,000	0	157.9	0
8.	10	Scale/ size of beneficiary group	0	875	125	1,000
9.	10	Gender aspects	0	428.6	428.6	1,000
10.	10	Reduction in GHG emissions	1,000	666.7	333.3	0
	100	TOTAL SCORES:	**5,000**	**5,079**	**4,747**	**6,675**
RANKING:			**3**	**2**	**4**	**1**

Figure 9: Waste sector MCA technology ranking – equal criteria weights



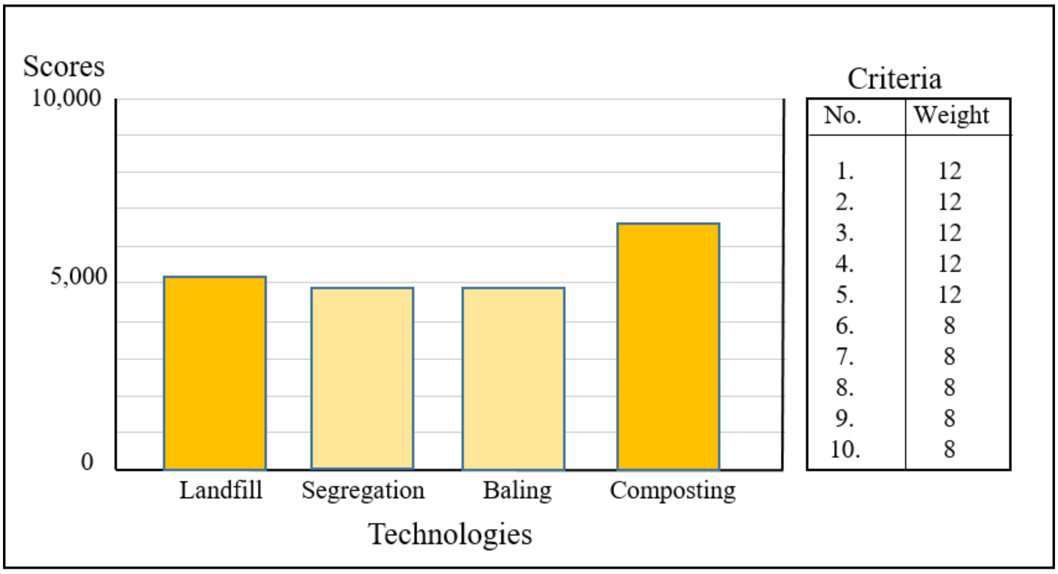
The outcome for a reduced criterion weight for the *technology diffusion criteria* (criteria No.'s 1-5) and an increased weight for *sustainable development impact/ benefit criteria* (criterion No.' 6-10) is shown in Figure 7. Note that OTEC and Solar PV technologies are still ranked first and second respectively.

Figure 10: Energy sector MCA technology ranking – different criteria weights A



The outcome for an increased criterion weight for the *technology diffusion criteria* and a reduced weights for *sustainable development impact/ benefit criteria* is shown in Figure 11. Here it shows that composting technology is still ranked first with landfilling in second.

Figure 11: Energy sector MCA technology ranking – different criteria weights B



Therefore composting technology is considered most favourable within waste sector with the other three technologies having very close scoring differences. The outcome of these ranking are based entirely on the respective TFS information and the performance scores that were prepared and provided by the consultant and shared to all the stakeholders. However, at this stage, all these four technologies will still be recommended for inclusion for further analysis in the next TNA process – Barrier Analysis and Enabling Framework.

Chapter 7: **Summary and Conclusions**

The Nauru TNA study has identified the four most vulnerable sectors for adaptation and mitigation and have also prioritised 16 technologies that relate to each of these vulnerable sectors.

7.1 Adaptation

For adaptation, water sector and coastal area management were identified as most vulnerable to CC. Stakeholder participation in further identifying and prioritising technologies for these sectors has been covered in this report.

From the desktop reviews of priority areas and national objectives/ goals, workshops and consultations it was evidenced and generally agreed that water sector is one of the sectors that needs urgent attention in the efforts to combat climate change adaptation on the Island. The consultants have engaged in a high level of transparent and inclusive process to identify and rank the potential technologies under water sector for consideration under the TNA process: Accordingly, these technologies are identified and ranked:

Table 36: MCA ranking of technologies in water sector – equal criterion weights

Adaptation - Water Sector	
Technology	**Rank**
Roof top rain water harvest for better water management and uses at household level	1st
Efficient water use and management through reticulation distribution system on the island	2nd
Efficient water use and management through non-potable water distribution system on the island	3rd
Enhanced manual water distribution throughout the Island	4th

The second sector which was transparently selected under the adaptation strategy through the consultation process is coastal area or beaches erosion management. The objective of this sector is specifically to counter the beach and soil erosion which is further threatened by climate change and sea level rise. The sector has gone through the TNA process again and these technologies were selected and ranked accordingly.

Table 37: MCA ranking of technologies in coastal sector – equal criterion weights

Adaptation - Coastal area Erosion Management Sector	
Technology	Rank
Coastal beaches and vegetation replenishment for community resilience against soil erosion.	1st
Integrated locally managed marine areas, coastal area revegetation and beach nourishment resilience for food security and adaptation against soil erosion.	2nd
Establishment of National Policy and guideline on coastal area development	3rd
Construction of sea wall structures at selective sites around the Island	4th

7.2 Mitigation

For mitigation, energy and waste management were identified as most vulnerable sectors to CC. Stakeholder participation in further identifying and prioritising technologies for these sectors has been covered in this report using the MCA process.

Nauru is committed to formulating strategies, national policies and best practices for addressing GHG emissions and making a practical contribution to the global mitigation efforts. Since Nauru's primary energy needs are mainly met by imported petroleum fuel, it is now exploring potential technology opportunities through this TNA process to further expand its current renewable energy sources. The outcome of the MCA ranking for the energy sector is shown in the table below.

Table 38: MCA ranking of technologies in the energy sector – equal criterion weights

Mitigation – Energy Sector	
Technology	**Rank**
Ocean thermal energy conversion (OTEC)	1st
Grid-connect rooftop solar PV	2nd
Biogas	3rd
Pumped hydroelectric storage (PHES) system	4th

The method of solid waste disposal on Nauru is uncontrolled open dumping. Although Nauru has a National Solid Waste Management Strategy (2017-2026) that contains a range of actions intended to improve solid waste management in Nauru, these have not yet been enforced.

However, the outcome of the MCA ranking of prioritised technologies show that composting and segregation at household level are most favoured based on relevance of criterion identified for this MCA. It makes logical sense that by controlling waste at the source, this will greatly reduce the amount of waste entering the dumpsite. Not to mention there are also socioeconomic benefits from household composting – for kitchen gardening, and segregation for recycling.

Table 39: MCA ranking of technologies in waste sector – equal criterion weights

Mitigation – Waste Sector	
Technology	**Rank**
Composting at household level	1st
Waste segregation at household level	2nd
Semi-aerobic landfill – Fukuoka system	3rd
Baling or compacting at commercial level	4th

Both CC adaptation and mitigation are critical considerations for the region's small island developing states. Nauru like any other SIDS does not have adequate technological capacity to adapt to and mitigate climate change impacts hence it is for this reason that Nauru has been included in this third phase of the TNA process.

All the stakeholder-identified technologies for CC adaptation and mitigation have yet to get wide acceptability and application in the country, hence at this stage none of these technologies have been finalised. Following this initial TNA process where the technology rankings are based on equal criterion weights, each of these technologies will now undergo analyses of market conditions and to identify barriers for enhanced deployment including appropriate technical, financial and policy instruments to facilitate implementation and deployment of the technologies.

7.3 Conclusion

The report presents the true result of the TNA process which took place nation-wide across the country between, January to June 2019. The result presented both adaptation and mitigation priority areas as presented in the summary above. The consultation took an inclusive approach which means wider spectrum of both the public and private sectors were thoroughly consulted and views taken on board. Gender issues were also taken on-board to reflect the wider consultation and participation of female, youth and older people in the process. There is no undue influence by any party or person involved in the process to influence the final result of the technologies presented. The consultants therefore recommend the report for your consideration and further perusal.

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Annexes

Annex 1: Technology Fact Sheets for Adaptation

A.1.1 Adaptation Technology # 1 – Water Sector

Rooftop rainwater harvest for better water management and uses	
1. Sector	Water
2. Technology Characteristics	
2.1 Technology Name :	Rainwater harvesting
2.2 Introduction:	Water is a scarce resource on the Island and due to climate change impact, its consequences will be aggravated more in years to come. Besides potential water reticulation systems and manual water distribution, rooftop rain water harvesting is a supportive method that can be used to increase the water use efficiency and reduce wastage and ensure that effective use of water by households, business houses, and government departments including essential services like health centers, schools and general populace around the Island. A well design roof top rain water harvesting system at household level is vital in getting water to all households on the Island effectively. This however would be a challenging technology as it benefits more on individual households as opposed to the potential reticulation system and manual water distributions where it focusses on the benefit of all in the community. The population on the Island is more than 12,000 people and the demand for potable water is increasing steadily over the years. The current situation is that water is supplied to households, government ministries and business houses around the country by manual delivery. The water department has three water-trucks and dispatches water around the country on a daily basis which is deemed expensive. This proposed technology would enable the households to take ownership and implement their own water use and management.
2.3 Technology Characteristics/ Highlights:	medium cost (potentially high initial cost) Low technology (requires roofing, gutters, pipes and tanks) Hard Technology

Few bullet points, i.e. low/high cost; advance technology; low technology.	
2.4 Institutional and Organizational Requirement :	
3.0 Operations and maintenance	
3.1 Endorsement by Experts:	To increase water use and management at household level roof top rain water harvesting systems must be introduced across the island. This would ensure that households take ownership on their effective management and use of their rooftop rain water harvesting system. The challenge would be each home must ensure that they have a proper roof top structure to facilitate installation of water harvesting units. This will provide the much needed potable water at lower price since the households now owns and manage the unit themselves. Such reliable water supply at household's level would allow households to participate even in agricultural ventures as home or backyard farming. The NUC -water department will focus only on their current manual distribution and may further extend into water investment opportunities if these households could now have access to rain water harvesting.
3.2 Adequacy for current climate: Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	This technology fits well for both the current and future expected climate change across the Island. Since the forecasts are predicting future draught and long period of low precipitation such household roof-top rain water harvesting systems would allow communities the potential opportunity to manage and use their water effectively at household level.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	Beneficiaries of the technology will mainly the household sectors and some business houses. The government departments will likely to be serviced by the NUC including schools, health and police force.
4. Costs	
4.1 Cost to implement adaptation options : Cost measures	Initial cost includes; the cost of guttering system, pipes, tanks and additional plumbing related expenses. The cost of pipes, guttering and tanks for 1,600 households would roughly estimate USD1.7m And related costs USD 1.8 = Total cost USD3.5m

4.2 Additional costs to implement adaptation option, compared to "business as usual"	The households would need additional adaptation technology, compared to "business as usual" to operate the roof top rain water harvesting system effectively. Among the additional costs we mention: cost of designing the roof top rain water harvesting system itself, cost of training to community members and employees on how to use this technology, and cost of monitoring and maintaining the piping system. Each household is responsible for providing a space for the construction of tanks for water storage at the household level.
5.0 Benefits	
5.1 Development impact, indirect	Roof top rain water harvesting system would relief the households' budget on water utility. Currently the NUC distribute water by using load trucks and tanks around the Island and transferring the cost to households and consumers. The new initiative would reduce costs and bring new benefits to the community especially household income. Below would likely be some of the major benefits for consumers. Saving cost on water expenses at household level by producing it at home. It is the primary motivator for the implementation of the roof top rain water system. The rain water collected on rooftops could be used to improve vegetation on the ground meaning more plant/household uses and hygienic environment for less water on the Island. Rooftop rain water harvesting system could reach an overall efficiency of almost 95% compared to manual distribution currently practiced on the island. Contributing to food security by increasing crop yields for households who participate in backyard gardening since they now have access to water their gardens or crops, one of the supplementary sources of growing their own food crops. Efficient production of water may now see reduction in in water bills and thus increase savings by households and business consumers alike to free some expenses and invest in options to benefit households/business houses respectively.
5.2 Economic: Employment –Jobs	Construction of the rooftop rainwater harvesting system around the Island would create tens of jobs to Nauruan for the next 12 to 24 months.

Investment – Capital requirements	This will ensure that Nauruan's participate in construction or installation and maintenance of the system during the implementation years. Besides, this will also provide investment opportunity for the NUC to potentially invest in water bottling as locals now households could now harvest their supply of water relatively cheaper. This would allow space for the NUC to build water storage facilities strategically around the Island purposively to store adequate supply of water for the country usage in events of climate distress or natural catastrophic events. For example, NUC current water storage capacity could only hold up more than a week of supply of water in the event of drought the NUC would unable to supply water to the communities on the Island.
5.3 Social: Income- Income generation and distribution Education – Time available for education Health – Number of people with different diseases.	The Social benefit of this technology on the households is that they have access to clean potable water at their homes, save money from buying expensive water and invest in other livelihood income generating activities to improve their livelihood. The rooftop rain water harvesting system will likely be installed at primary and secondary schools across the island. This will ensure there is supply of quality water to these youths of the country. On a civic education perspective, the responsible authority would use that opportunity the importance of having quality potable water at primary and secondary level. Subsequently, the safe and quality water from this prospective technology will also be connected to the health facilities across the Island. This will ensure that people using these facilities have access to quality water and reducing the number of diseases that could be preventable by using clean and quality water.
5.4 Environmental: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	The improved water quality and the reduction of manual distribution of water around the Island by vehicles would reduce the air pollution and emission of GHG into the atmosphere.
6. Local context	
6.1 Opportunities and Barriers :	Rooftop rain water harvesting system is a technology that can be employed in conjunction with other adaptation measures such as manual distribution of water, water reticulation and borehole drilling etc. In

Barriers to implementation and issues such as the need to adjust other policies.	our local context there has to be a lot of investment in these options to make them viable - Water savings through roof top rain water harvesting system increase the opportunities of better using water reserves for different purposes (domestic, agriculture use, etc.) - Barriers include lack of access to finance for purchasing the materials needed and installation of rooftop rain water harvesting water system on every homes on the Island - A higher amount of initial investment may be required at household level with some technical requirement to solve. Each household must take the initiative to replace their roofing structure so that the system could be easily installed at their homes. At schools and other public areas the government or respective community must build in new roof structures to accommodate and facilitate rooftop rain water harvesting system at their areas. Where there is not place available the government has to intervene with landowners to ensure that proper arrangement are reached to ensure tanks or rooftop rainwater harvesting facilities are stationed to serve the community.
6.2 Status: Status of technology in the country	Some private homes and business houses are currently producing their own potable water through rooftop rain water harvesting. Although the country depends on salt water desalination it is still an expensive option at domestic level on the Island. Currently the NUC produce about 70% of potable water and distribute for commercial and domestic use in the country. Timeframe is continuous.
6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

A.1.2 Adaptation Technology # 2 – Water Sector

Efficient water use and management through non-potable water distribution system on the island	
1. Sector	Water
2. Technology Characteristics	
2.1 Technology Name :	Efficient water use and management through non-potable water distribution system on the island
2.2 Introduction:	Water is a scare resource on the Island and due to climate change impact; its consequences will be aggravated more in years to come. Island such as Nauru must invest in proper adaptive strategies to build resilience amidst these looming negative impacts. Besides prospective desalinated water reticulation system, existing manual water distribution and rooftop – rain water harvesting, non-potable water reticulation is a supportive method that can also be used to increase the water use efficiency and reduce wastage by households, business houses, government departments including essential services like health centres, schools and general populace around the Island. This technology aims to provide an alternative source of water for non-potable uses in selected area on the Island, thus saving precious potable water. This is a rehabilitation project of the once operational and effective seawater reticulation system built to supply water for industrial, domestic and emergency uses. The intended use for its rehabilitation is toilet flushing only, however it could also provide for other uses if necessary. There were similar projects implemented in the past at several locations on the Island. This potential reviving of the similar technology must learned from the past experiences. Lessons learned from experiences during the past projects include: (1) projects need to be community specific; (2) it is important to consider ongoing costs and capacity needs; (3) it is also necessary to identify operating and maintenance needs during project design; and (4) health and environment issues should also inform the project design. Besides the points discussed above, some of the challenges of this technology may encounter are related to land tenure-ship, design of the system and maintenance of such infrastructure into the future. The government may have to intervene in these

	matters for the benefit of the community. Nevertheless, the technology should benefit more households and not only certain individuals in the community. The population on the Island is more than 12,000 people and the demand for potable water is increasing steadily over the years. The current situation is that water is supplied to households, government ministries and business houses around the country by manual delivery. The water department has three trucks and dispatches water around the Island on daily basis which is deemed expensive. This propose technology would ensure there is less pressure on the potable water usage on the Island.
2.3 Technology Characteristics/ Highlights: Few bullet points, i.e. low/high cost; advance technology; low technology.	high cost (potentially high initial cost) Low technology (requires only pipes and tanks) Hard Technology
2.4 Institutional and Organizational Requirement :	
3.0 Operations and Maintenance	
3.1 Endorsement by Experts:	To increase water use and management at household level reticulation of non-potable water must also be introduced across the island. This would ensure that households have access to both potable and non-potable water and use the potable water more effectively. Currently households have no option but use their scarce potable water for all other domestic uses including toilet flushing etc. The challenge would be each home must have the facility and the capacity to store both potable and non-potable water at the same time and ensuring to use them more effectively. When both potable and non-potable water supplies are available, households would be able to participate even in agricultural ventures as home or backyard farming which is critical to improving their livelihoods. The NUC -water department will at the same work towards reticulation of potable water to ensure all households have access to both potable and non-potable water thus improving the quality of life on the Island.
3.2 Adequacy for current climate: Are there negative consequences of the adaptation option in the current	This technology fits well for both the current and future expected climate change across the Island. Since the forecasts are predicting future draught and long period of low precipitation, reticulation of non-

climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	potable water is critical to allow households opportunity to manage and use their potable water effectively.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	Beneficiaries of the technology will mainly the household sectors and some business houses. The government departments will likely to be serviced by the NUC including schools, health and police force.
4. Costs	
4.1 Cost to implement adaptation options : Cost measures	Initial cost includes; the cost of pipes, tanks and additional plumbing related expenses. The cost of pipes for 1,600 households would roughly estimate USD2.5 And related costs USD 1.5 = Total cost USD4m
4.2 Additional costs to implement adaptation option, compared to "business as usual"	The households would need additional adaptation technology, compared to "business as usual" to operate the non-potable water reticulation system effectively. Among the additional costs we mention: cost of designing the reticulation system itself, cost of training of community members and employees on how to use this technology, and cost of monitoring and maintaining the piping system.
5.0 Benefits	
5.1 Development impact, indirect /benefits	Non-potable water reticulation system would relief the households' budget on potable water utility bills. Currently the NUC distribute water by using load trucks and tanks around the Island and transferring the cost to households and consumers. The new initiative would reduce costs on potable water and bring new benefits to the community especially household income. Below are likely be some of the major benefits for consumers. Saving cost on water bills at household level by using the non-potable water which should be relatively cheaper and at the same time relieving the dependency on potable water also for toilet flashing and other household uses. It is the primary motivator for the implementation of the non-potable water reticulation system. The potable water saved from this process could be used to improve vegetation on the ground meaning

	more plant/household uses and hygienic environment for less water on the Island. Potable water accessed through manual distribution could be effectively managed and even stored for uses during drought and other catastrophic events. Contributing to food security by increasing crop yields for households who participate in backyard gardening since the potable water saved could now use to water their gardens or crops, one of the supplementary sources of growing their own food crops. Effective potable water use may now see reduction in water bills and thus increase savings by households and business consumers alike to free some expenses and invest in options to benefit households/business houses respectively.
5.2 Economic benefits : Employment –Jobs Investment – Capital requirements	Construction of non-potable water reticulation system around the Island would create tens of jobs to Nauruan for the next 12 to 24 months. This will ensure that Nauruan's participate in construction or installation and maintenance of the system during the implementation years. Besides, this will also provide investment opportunity for the NUC to potentially invest in water bottling as there will be now more supply of potable water available on the Island. This would allow space for the NUC to build potable water storage facilities strategically around the Island purposively to store adequate supply for the country usage in events of climate distress or natural catastrophic events. For example, NUC current water storage capacity could only hold up more than a week of supply of water in event of drought the NUC would unable to supply water to the communities on the Island.
5.3 Social benefits : Income- Income generation and distribution Education – Time available for education Health – Number of people with different diseases.	The Social benefit of this technology on the households is that they have access to clean potable water at their homes, save money from buying expensive water and invest in other livelihood income generating activities to improve their livelihood. The non-potable water harvesting system will also connected to primary and secondary schools across the island. This will ensure there is supply of non-potable water to the youths of the country. On a civic education perspective, the responsible authority

	would use that opportunity the importance of having non-potable water at primary and secondary levels. Subsequently, the non-potable water reticulation system will also be connected to the health facilities across the Island. This will ensure that people using these facilities have access to non-potable water and allow less dependency on potable water reducing the number of diseases that could be preventable by using clean and quality water.
5.4 Environment benefits: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	The improved non-potable water reticulation system would reduce the manual water distribution around the Island by vehicles thus reduce the air pollution and emission of GHG into the atmosphere.
6. Local context	
6.1 Opportunities and Barriers : Barriers to implementation and issues such as the need to adjust other policies.	Non-potable reticulation system is a technology that can be employed in conjunction with other adaptation strategies such as manual water distribution system, water reticulation and borehole drilling etc. In our local context there has to be a lot of investment in these options to make them viable – Potable water savings through non-potable water reticulation system increase the opportunities of better usage of water reserves for different purposes (domestic, agriculture use, etc.) - Barriers include lack of access to finance for purchasing the materials needed and installation of non-potable water reticulation harvesting water system on induvial house level on the Island - A higher amount of initial investment may be required at household level with some technical requirement to solve. Land owning groups must collaborate with the government to allow storage facilities and pipes to run through their land and connect to homes and public amenities across the Island. At schools and other public areas the government or respective communities must build in new accommodate and facilitate rooftop rain water harvesting system at their areas.
6.2 Status: Status of technology in the country	Some private homes and business houses are currently producing their own potable water through rooftop rain water harvesting. Although the country depends on salt water desalination it is still an expensive option at domestic level on the Island.

	Currently the NUC produce about 70% of potable water and distribute for commercial and domestic use in the country. Timeframe is continuous.
6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

A.1.3 Adaptation Technology # 3 – Water Sector

Reticulation distribution system for efficient water and management on the islands	
1.0 Sector	Water
2.0 Technology Characteristics	
2.1 Technology Name :	Reticulation distribution system for efficient water use and management on the Islands
2.2 Introduction:	Water is a scare resource on the Island and due to climate change impact; its consequences will be aggravated more than the past. Reticulation distribution is a supportive method that can be used to increase the water use efficiency and reduce wastage , reduce evaporation, runoff and ensure that effective use of water by households, essential services like clinics, schools and general businesses populace around the Island. A water reticulation system is vital in getting water all the way from the source i.e. desalination plants to the consumer around the island. Working together with water department, communities and business houses water could be effectively distributed to the consumers. Water reticulation distribution system would enable the domestic water department to establish dedicated storage facility strategically around the Island. These dedicated storage facilities (tanks) could be used as reservoir and should be used only during drought period or unexpected catastrophic situations. The population on the Island is more than 12,000 people and the demand for potable water is increasing steadily over the years. The current situation is that water is supplied to households, government ministries and business houses around the country by manual delivery. The water department has three trucks and dispatches water around the country on daily basis which is deemed expensive.
2.3 Technology Characteristics/ Highlights: Few bullet points, i.e. low/high cost; advance technology; low technology.	• High cost (potentially high initial cost) • Low technology (requires only pipes and tanks) • Hard Technology
2.4 Institutional and Organizational Requirement :	

3.0 Operations and maintenance	
3.1 Endorsement by Experts:	To increase water use efficiency and effectively water saving technologies including piping system, water storage reservoir and reticulation must be introduced across the island. This would ensure continuity of supply even during drought and catastrophe events. Business houses would concentrate on business operations and not have to worry about the water reliability on the Island. Such reliable water supply to households and business would allow households to participate even in agricultural ventures as home or backyard farming. The Water Utility department will ensure that such system is fully established and operative on the Island.
3.2 Adequacy for current climate: Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	Fits well for both the current and future expected climate change across the Island. Since the forecasts are predicting future draught and long period of law precipitation such reticulation and storage facility around the island would be beneficial to the communities.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	Beneficiaries include the household sectors, business houses, government departments, schools, health and private sectors. The water reticulation system will ensure that water is pumped up from the desalination plant and is stored uphill around the Island at two to three locations before distributing to consumers around the islands. The benefits are distributed and shared among almost everyone on the Islands.
4. Costs	
4.1 Cost to implement adaptation options : Cost measures	Initial cost includes the cost of the reticulation system, pipes, storage facilities (tanks), land acquisition and design of the project. Meanwhile, the NUC has the capacity to produce the volume of water needed to distribute on the

	Islands but is constraint by no proper storage facility to store water before distribution on the Island either for normal consumption or for use during disaster periods. The cost of pipe would roughly estimate USD1.2m while storage facility would cost additional USD.6m. And related costs USD 1.2m = Total cost USD3m.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	The NUC would need additional adaptation technology, compared to "business as usual" to operate the reticulation system effectively. Among the additional costs we mention: cost of designing the reticulation system, the energy (electricity/diesel to pressurize water), cost of the training to NUC employees on how to use this technology, and cost of monitoring and maintaining the piping system. Nevertheless, if the project is to be given priority the government through NUC may have to obtain lease or some agreement on the plots of land by which the storage facilities would have to locate before distribution to households and public users around the Island.
5.0 Benefits	
5.1 Development impact, indirect /benefits	Reticulation system would enable reduction in the cost of operation to distribute water around the Island. Currently the NUC distribute water by using load trucks and tanks around the Island a costly exercise. The new initiative would reduce costs and bring new benefits to the community. Below would likely be some of the major benefits for consumers. Saving water by improving water delivery efficiency: it is the primary motivator for the implementation of the reticulation system, meaning more plant/household uses and hygienic environment for less water on the Island. Water reticulation system could reach an overall efficiency of almost 90% compared to manual distribution currently practiced on the island. Contributing to food security by increasing crop yields for households who participate in backyard gardening since they now have access to water their gardens or crops, one of the supplementary sources of growing their own food crops.

	With the Water storage system the NUC now be able to treat the water appropriately before distribution to the households for consumption around the Island. This may prevent any water related dieses or negative impact on the communities. Efficient production of water may now see reduction in in costs and thus increase savings by the NUC and consumers alike to free some expenses and invest in options to benefit the corporation and households/business houses respectively.
5.2 Economic benefits : Employment –Jobs Investment – Capital requirements	Construction of the reticulating system and water tank bulk storage facilities around the Island would create tens or more than a hundred jobs to Nauruan for the next 12 to 24 months. This will ensure that Nauruan's participate in construction, maintenance and manning of the reticulation system during the construction to operation years ahead. Besides, this will also provide investment opportunity for private sector to potentially investment in water bottling by locals or joint ventures which ultimately will increase the quality and supply of water to the people of Nauru. The water storage facilities build around the Island as part of this technology could be able to store adequate supply of water for the country usage up to one month in time of climate distress of natural catastrophic event. This is enough time for the NUC to find alternate solution to rectify such situation. For example, NUC current water storage capacity could only hold up more than a week of supply of water. The country would run out of water if current productions shuts down for more than 2 weeks.
5.3 Social benefits : Income- Income generation and distribution Education – Time available for education Health – Number of people with different diseases.	The Social benefit of this technology on the households is that they have access to clean potable water at their homes, save money from buying expensive water and invest in other livelihood income generating activities to improve their livelihood. The reticulation system will also be connected to primary and secondary schools across the island. This will ensure there is supply of quality water to these youths of the country. On a civic education perspective, the responsible authority would use that opportunity the importance of having quality potable water at primary and secondary level.

	Subsequently, the safe and quality water from this prospective technology will also be connected to the health facilities across the Island. This will ensure that people using these facilities have access to quality water and reducing the number of diseases that could be preventable by using clean and quality water.
5.4 Environment benefits: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	The improved water quality and the reduction of manual distribution of water around the Island by vehicles would reduce the air pollution and emission of GHG into the atmosphere.
6. Local context	
6.1 Opportunities and Barriers : Barriers to implementation and issues such as the need to adjust other policies.	Water reticulation is a technology that can be employed in conjunction with other adaptation measures such as rooftop- rainwater harvesting and borehole drilling etc. In the case of Nauru there has to be a lot of investment in these options to make them viable - Water savings through reticulation system increase the opportunities of better using water reserves for different purposes (domestic, agriculture use, etc.) - Barriers include lack of access to finance for purchasing the equipment, and the procurement of energy source. - A higher amount of initial investment involved than other systems. - Technical conditions such as proper calculations of pressure, land tenure ship, community politics can further complicate and increase implementation and maintenance costs or affect system efficiency. - The manual distribution of water as of the existing system can be costly and expensive exercise on the longer term. - A low level of public awareness for the importance of sustainable water management and use, and the lack of technicians providing monitoring of water needs and reticulation system is critical for the island community. The government has to intervene with landowners to ensure that proper arrangement are reached to ensure tanks or water storage facilities are stationed strategically around the island to ease access by the community once needed.
6.2 Status: Status of technology in the country	Some private homes and business houses are currently producing their own water through rain water harvesting. Desalination of salt water is still an expensive option at domestic level on the Island. Currently the NUC produce about 70% of potable water and distribute for commercial and domestic use in the country. Timeframe is continuous.

6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

A.1.4 Adaptation Technology # 4 – Water Sector

Enhanced manual water distribution throughout the island	
1. Sector	Water
2. Technology Characteristics	
2.1 Technology Name :	Enhanced manual water distribution throughout the Island.
2.2 Introduction:	Water is a scare resource on the Island and due to climate change impact, its consequences will be aggravated more than the past. Enhanced manual water truck distribution is aimed at increasing the number of fleets that distribute potable water around the Island. Currently NUC uses about three water trucks and addition of further three trucks would see the number of fleet increases and adequate to supply schools, clinics, business houses, government departments and private homes effectively. An increase to the current fleet is critical in order to increase the volume of water distribution on daily basis around the Island. Working with the Nauru Utility Corporation (NUC), communities and business houses water could be effectively distributed to the consumers across the Island. The population on the Island is more than 12,000 people and the demand for potable water is increasing steadily over the years. The current situation is that water is supplied to households, government ministries and business houses around the country by manual delivery. The water department has three trucks and dispatches water around the country on daily basis which is deemed expensive.
2.3 Technology Characteristics/ Highlights: Few bullet points, i.e. low/high cost; advance technology; low technology.	• High cost (potentially high initial cost) • Low technology (requires only three water trucks to the current fleet) • Hard Technology
2.4 Institutional and Organizational Requirement : How much additional capacity building and knowledge transfer is required for the adaptation to be implemented?	Capacity building is required both institutional level, i.e. knowhow to effectively manage the manual water truck distribution network and maintain sustainably. Building on the skills and expertise already on the ground.
3.0 Operations and maintenance	

3.1 Endorsement by Experts:	• To increase water use efficiency and effectively, this water saving technologies including additional trucks and water storage facility must be introduced across the island. • This would ensure continuity of supply even during drought and catastrophe events. Business houses would concentrate on operations and not have to worry about the water reliability on the Island. • Such reliable water supply to households and business would allow households to participate even in agricultural ventures as home or backyard gardening or farming. • The Water Utility department will ensure that such system is fully established and operative on the Island.
3.2 Adequacy for current climate: Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	Adaptation of this technology non-related to adaptation can be reaped even in the current climate thereby making its early adoption economically and socially desirable. Under conditions of increased water stress resulting from climate change the benefits of the technology rises quite significantly.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	The scale of the enhanced manual distribution technology is relatively high making it beneficial to all and less individual.
4. Costs	
4.1 Cost to implement adaptation options : Cost measures	USD$3 M Cost of three additional water loading trucks and construction of two reserve water facilities at selected sites on the Island.
4.2 Additional costs to implement adaptation option, compared to "business as usual"	This is not a relatively new technology on the Island as the NUC is already distribution water on the ground. Perhaps construction of new water tanks strategically around the Island is a new component of this technology.
5.0 Development impact, indirect /benefits	
5.1 Economic benefits : Employment –Jobs	• Increase productivity and reduced running cost of current manual distribution of water around the island.

Investment – Capital requirements	• Reduced costs of production and higher prices enabled realizing nominal income for running of the essential service • Cost effective –since investing in capital expenditure will last for the next 25 to 35 years.
5.2 Social benefits : Income- Income generation and distribution Education – Time available for education Health – Number of people with different diseases. Gender - considerations	• Cost of water should be stabled or even reduced on the Island saving the much needed disposable income of households to spend on other family commitments. • Storage of water will allow for better treatment of the water before supplying for households • Students may have accessible and treated water at home and school and other learning centres • Improved personal hygiene, • Women could now have access to water at home easily and participate in other communal or development matters
5.3 Environment benefits: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	• Use of manual distribution from water storage facilities is being one of the most environmentally friendly alternatives. It reduces or zero the gas emission made from manual distribution mode on daily basis. • Effective use of water also allow households to use water domestically for agriculture which is beneficial to the environment.
6. Local context	
6.1 Opportunities and Barriers : Barriers to implementation and issues such as the need to adjust other policies.	Manual distribution of water is a technology that is being used on the Islands for the past decades. This technology could be used conjunction with other adaptation measures such as rooftop- rainwater harvesting and borehole drilling etc. In the case of Nauru borehole drilling has to be done at selective areas as there is a huge problem with sewage contamination. But there is opportunity to invest in other systems such as water reticulation on the Island. Water savings through manual distribution system increase the opportunities of better using water reserves for different purposes (domestic, agriculture use, etc.) - Barriers include lack of access to finance for purchasing the equipment, and the construction of water reserves at strategic locations around the Island. - A relatively high amount of initial investment involved if we construct water storage facilities as well at 2 or 3 locations around the Island- Technical conditions

	such as, land tenure ship, community politics can further complicate and increase implementation and maintenance costs or affect system efficiency. - The manual distribution of water as of the existing system can be costly and expensive exercise on the longer term but it is the technology we could manage to implement at the moment. - A low level of public awareness for the importance of sustainable water management and use, and the lack of technicians providing monitoring of water needs and water storage facility is critical for the Island in times of disasters and long term effects of climate change. The government has to intervene with landowners to ensure that proper arrangement are reached to ensure tanks or water storage facilities are stationed strategically around the island to ease access by the community once needed.
6.2 Status: Status of technology in the country	Manual distribution of water is an old technology on the Island but the safe water storage facilities at strategic locations on the Island would be new and critical to counter water crisis during future catastrophe events.
6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

A.1.5 Adaptation Technology # 5 – Coastal Sector

Coastal beaches and vegetation replenishment for community resilience against social erosion.	
1.0 Sector	Coastal areas management - soil erosion
2.0 Technology Characteristics	
2.1 Technology Name :	Coastal beaches and vegetation replenishment for community resilience against social erosion.
2.2 Introduction:	Nauru's coast, the only habitable area, is threatened by sea level rise (SLR) and steadily erosion. Soil erosion is the displacement of the upper layer of soil either into the ocean or downhill depending on the location, it is a form of soil degradation. There are many reasons for this soil erosion across the Island. These include human activities such as digging of beaches and destroying the natural habitat in name of development, sea level rise, coastal flooding and storm surges. With the melting of the glaciers and ice sheet continues to accelerate the warming of the ocean, the negatively impact this may have on the Pacific Island countries will also continue because of their proximity to coastal areas. Satellite data indicates that Nauru experienced SLR 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 SLR may also 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. Due to increasing impact of climate change, it is unequivocal that its consequences will be aggravated more than the past, particularly on these coastal communities along the Island. Replanting of vegetation and beach nourishment is therefore seen as supportive strategy that can be used to increase resilience and adaptation around the Island. Replanting of vegetation and beach nourishment is therefore critical to protect communities including facilities such as clinics, schools, homes and general businesses populace. Beach vegetation replanting strategy may also provide opportunity for the communities to re nourish the beaches, replant vegetation as form of natural re-enforcement against coastal erosion and SLR. Working together with Department of Commerce, Industry and Environment (CIE), the participating communities would identify the coastal areas which are in urgent need to restore their beaches from coastal erosion.

	The population on the Island is more than 12,000 people and the destruction of the coastal areas through human actions are also increasing. This calls for this technology to include civic component – i.e. ensure awareness of general public on the need to look after the beaches and not to destroy them as the island faces the reality of climate change across the country.
2.3 Technology Characteristics/ Highlights: Few bullet points, i.e. low/high cost; advance technology; low technology.	• medium cost (potentially high initial cost) • Low technology (requires landfills, grasses,) • Hard Technology
2.4 Institutional and Organizational Requirement :	
3.0 Operations and maintenance	
3.1 Endorsement by Experts:	To increase community resilience and prevent coastal erosion, the replanting of vegetation and refurbishment of coastal areas at selected vulnerable sites across the island is important. This would prevent soil erosion and ensure continuity of business along the coastal areas even during strong winds, storm surges and catastrophic events. Coastal communities would felt protected against the exposure and vulnerability that climate change and extreme storm events brought if there is no buffer of vegetation and natural beaches these identified sites. Households and business houses would concentrate on their normal day to day operations and not have to worry about their homes and businesses been carried away in the next disaster events.
3.2 Adequacy for current climate: Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	Fits well for both the current and future expected climate change across the Island. Since the forecasts are predicting future SLR with increasing intensity and frequency of storm surges which may cause further coastal erosion and washing away of beaches, such beach vegetation replanting and nourishment at identified vulnerable locations around the island would be beneficial to the communities at large.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	Beneficiaries include the household sectors, business houses, government departments, schools, health and private sectors. The beach vegetation and nourishment would ensure the general community at large is protected. There will be no individual or group of people who would be primary beneficiaries of such developments. While homes located closer to the identified locations may directly benefit from

	such undertakings, the positive externalities to the community at large is immeasurable. The benefits are distributed and shared among almost everyone on the Islands.
4.0 Costs	
4.1 Cost to implement adaptation options : Cost measures	Initial cost includes the cost "grounds work' (landfills), cost of V&A reports and beach replenishment or nourishment. The CIE although over sees the environment management in the country, it does not have the capacity to provide some of the costs as mentioned above. Therefore the technology would requires the following costs to fully implement this adaptation option: The cost of groundworks (landfills) USD 3m Additional costs (V&A, EIA, & beach nourishment) 1.5 Total cost = USD4.5m
4.2 Additional costs to implement adaptation option, compared to "business as usual"	The additional costs which may be required to implement this technology includes cost for beach nourishment and replanting of trees to ensure long term resilience is achieved at these coastal areas. The cost is factored into the initial costs above.
5.0 Benefits	
5.1 Development impact, indirect /benefits	The new initiative would reduce coastal erosion and bring confidence in the communities along the coastal areas that their properties are safe and can continue with development initiatives at these sites. Below would likely be some of the major benefits on the communities. • Safety and security of the community alone the coast lines: it is the primary motivator for the implementation the beach vegetation replenishment and nourishment, meaning more households/ public depends on the secure and safer environment from coastal erosion. • Contributing to food security by households participating in backyard gardening since they now have access to safer land, growing some of their basic crops supplementing their budgets. • There wouldn't be disruptions on major infrastructures such as roads, electricity and perhaps water supply manual distribution on the Island. • More funding will spend on economic development by the government rather than

	just building a seawall or barriers which would be seen uneconomical to this cash trapped nation.
5.2 Economic benefits : Employment –Jobs Investment – Capital requirements	Investment into coastal area vegetation and replenishment around selected areas around the Island would create tens of jobs to Nauruan for the next 12 to 16 months. • This will ensure that Nauruan's participate in landfilling, soil nourishment and rehabilitation of the beaches during the implementation and maintenance stages of the technology. • The general community will continue to live and operate their business at the coastal areas thus contributing to the economic growth of the country. • Nauruan's that participate in this technology would earn the income and support their families to meet school fees and other livelihood expenses.
5.3 Social benefits : Income- Income generation and distribution Education – Time available for education Health – Number of people with different diseases.	• The Social benefit of this technology on the households is that they are secured and protected from impact of SLR and coastal erosion. The little money they earn could now be invested in other income generating activities to improve their livelihood rather than worrying about the coastal erosion. • The coastal areas which are vulnerable to coastal erosion and SLR will now have some buffer against salt water intrusion. The responsible authorities must ensure that primary and secondary schools across the island are safe and secure from such impact of SLR. This will ensure the youths and the weak are protected from the SLR and soil erosion. • Subsequently, health and gender issues will be considered and filtered through every process of decision making in this project.
5.4 Environment benefits: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	Soil erosion caused by SLR will be controlled and managed at these sites because of coastal land vegetation and beach nourishment etc. Replanting of vegetation at these sites may also contribute towards reduction of the GHG and pollution into the atmosphere.

6.0 Local context	
6.1 Opportunities and Barriers : Barriers to implementation and issues such as the need to adjust other policies.	Coastal land vegetation and beach nourishment is a technology that can be employed in conjunction with other adaptation measures such as coastal zone management – Locally managed protected area including and sea wall construction etc. In the case of Nauru there has to be a lot of investment and commitment into these options to make them viable. Coastal land vegetation and beach nourishment would increase the opportunities for effective resilience with different purposes (domestic, agriculture use, etc.) - Barriers include lack of access to finance to invest in land fillings along the vulnerable coastal areas, policies by the National government surrounding management of beaches and awareness by communities on the devastation impact of climate change etc. This option would be relatively cheaper compare to other adaptations options. - Technical requirements such as V&A, EIA and structural design may increase implementation and maintenance costs. Although coastal land vegetation and beach nourishment may be accrue some initial costs, it is cheaper on the longer run. - A low level of public awareness is critical to support the technology.
6.2 Status: Status of technology in the country	Certain communities have already participated in programs design to protect coastal soil erosion around the Island. However, the rate of soil erosion is worrisome and thus calls for prioritizing of this technology at selected vulnerable sites across the Island. Timeframe is continuous.
6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

A.1.6 Adaptation Technology # 6 – Coastal Sector

Construction of sea wall for resilience at selective sites around the Island	
1. Sector	Coastal areas management - soil erosion,
2. Technology Characteristics	
2.1 Technology Name :	Construction of sea wall for resilience at selective sites around the Island
2.2 Introduction:	The melting of the glaciers and ice sheet together with the warming of the ocean will continue to negatively impact the Pacific Island countries because of their proximity to coastlines. As ocean water warms it expands causing the sea level rise (SLR), salt water inundation and coastal area erosion. Satellite data indicates that Nauru experienced SLR 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 SLR may also 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. Due to increasing impact of climate change, it is unequivocal that its consequences will be aggravated more than the past, particularly on these coastal communities along the Island. Sea wall construction is therefore seen as supportive strategy that can be used to increase resilience and adaptation around the Island. Sea wall construction is therefore critical to protect communities including facilities such as clinics, schools, homes and general businesses populace. Sea wall construction may also provide opportunity for the communities to replenish the beaches, replant vegetation as form of natural re-enforcement against coastal erosion. Working together with Department of Commerce, Industry and Environment (CIE), participating communities would identify the sites which are in urgent need to restore by building these structured sea walls. The population on the Island is more than 12,000 people and the destruction of the coastal areas through human actions are also increasing. Thus through this technology, they should also include a civic component which responsible authorities would do awareness on the need to look after the beaches and not to destroy them as we face the reality of climate change across the region and particularly this the country.

2.3 Technology Characteristics/ Highlights: Few bullet points, i.e. low/high cost; advance technology; low technology.	• High cost (potentially high initial cost) • Low technology (requires cements, concretes,etc) • Hard Technology
2.4 Institutional and Organizational Requirement :	The CIE together with Department of Lands & Management will provide the Institutional and organizational support to the formulation and implementation of this project.
3.0 Operations and maintenance	
3.1 Endorsement by Experts:	To increase community resilience and prevent coastal erosion, the use of sea wall structures and refurbishment of coast line areas at selected vulnerable sites across the island is important. This would ensure continuity of business along the coastal areas even during strong winds, storm surges and catastrophic events. Coastal communities would felt protected against the exposure and vulnerability that climate change and extreme storm events brought if there is no wall build at these identified sites. Business houses would concentrate on business operations and not have to worry about their homes been carried away in the next few years.
3.2 Adequacy for current climate: Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	Fits well for both the current and future expected climate change across the Island. Since the forecasts are predicting future SLR with increasing intensity and frequency of storm surges which may cause further coastal erosion and washing away of beaches, such sea wall constructions at identified vulnerable locations around the island would be beneficial to the communities at large.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	Beneficiaries include the household sectors, business houses, government departments, schools, health and private sectors. The sea wall structure build would ensure the general community at large is protected. There will be no individual or group of people who would be primary beneficiaries of such developments. While homes located at the identified locations may directly benefit from such undertakings, the positive externalities to the community at large is immeasurable. The benefits are distributed and shared among almost everyone on the Islands.
4. Costs	
4.1 Cost to implement adaptation options :	Initial cost includes the cost of the sea wall structure, cost of design, cost of EIA, cost of V&A reports and beach replenishment or nourishment.

Cost measures	The CIE although over sees the environment management in the country, it does not have the capacity to provide some of the costs as mentioned above. Therefore the technology would requires the following costs to fully implement this adaptation option: The cost of Sea wall structures USD4.5 Additional costs (V&A, EIA, Design, & beach nourishment) 1.5 Total cost = USD6.0m
4.2 Additional costs to implement adaptation option, compared to "business as usual"	The additional costs which may be required to implement this technology includes cost for beach nourishment and replanting of trees to ensure long term resilience is achieved at these coastal areas. The cost is factored into the initial costs above.
5.0 Benefits	
5.1 <u>Development impact, indirect /benefits</u>	The new initiative would reduce coastal erosion and bring confidence in the communities along the coast lines areas that their properties are safe and can continue with development initiatives at these sites. Below would likely be some of the major benefits on the communities. • Safety and security of the community alone the coast lines: it is the primary motivator for the implementation this sea wall structure, meaning more households/ public depends on the secure and safer environment from coastal erosion. • Contributing to food security by households participating in backyard gardening since they now have access to safer land growing some of their basic crops supplementing their budgets. • There wouldn't be disruptions on major infrastructures such as roads, electricity and perhaps water when it is reticulated. • More funding will spend on economic development by the government rather than just building a seawall or barriers which would be seen uneconomical to this cash trapped nation.
5.2 Economic benefits : **Employment –Jobs** **Investment** – Capital requirements	Construction of the sea wall around the Island would create tens of jobs to Nauruan for the next 12 to 16 months.

	• This will ensure that Nauruan's participate in construction, maintenance and rehabilitation of the beaches during the implementation stages. • The general community will continue to live and operate their business at the coastal areas thus contributing to the economic growth of the country. • Nauruan's that participate in this technology would earn the income and support their families to meet school fees and other related expenses.
5.3 Social benefits : **Income**- Income generation and distribution **Education** – Time available for education **Health** – Number of people with different diseases.	• The Social benefit of this technology on the households is that they are secured and protected from impact of SLR and coastal erosion. The little money they earn could now be invested in other income generating activities to improve their livelihood rather than worrying about the coastal erosion. • The sea wall will be constructed at areas which are vulnerable to coastal erosion and SLR. The responsible authorities must ensure that primary and secondary schools across the island are safe and secure from such impact of SLR. This will ensure the youths and the weak are protected from the SLR and soil erosion. • Subsequently, health and gender issues will be considered and filtered through every process of decision making in this project.
5.4 Environment benefits: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	Coastal erosion caused by SLR will be controlled and managed at these sites because of Sea wall structure construction etc. Replanting of vegetation at these sites may also contribute towards reduction of the GHG and pollution into the atmosphere.
6. Local context	
6.1 Opportunities and Barriers : Barriers to implementation and issues such as the need to adjust other policies.	Sea wall construction is a technology that can be employed in conjunction with other adaptation measures such as Coastal zone management – and Locally managed protected area etc. In the case of Nauru there has to be a lot of investment and commitment into these options to make them viable- Sea wall construction increase the opportunities for effective resilience with different purposes (domestic, agriculture use, etc.) - Barriers include

	lack of access to finance for purchasing of these structures and awareness by communities etc. - A higher amount of initial investment may involve compare to other adaptations options. - Technical requirements such as V&A, EIA and structural design may increase implementation and maintenance costs. – Although sea wall structural construction may be costly and expensive, it is cheaper on the longer run. - A low level of public awareness is critical to support the technology.
6.2 Status: Status of technology in the country	Certain communities have already constructed some structures of sea wall around the Island. However, the rate of soil erosion is worrisome and thus calls for prioritizing of this technology at selected vulnerable sites across the Island. Timeframe is continuous.
6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

A.1.7 Adaptation Technology # 7 – Coastal Sector

Coastal areas management - soil erosion	
1. Sector	Coastal areas management - soil erosion
2. Technology Characteristics	
2.1 Technology Name :	Integrated locally managed marine areas, coastal area revegetation and beach nourishment resilience for food security and adaptation against soil erosion
2.2 Introduction:	Nauru's coast, the only habitable area, is threatened by sea level rise (SLR) and steadily erosion. Soil erosion is the washing of the upper layer of soil either into the ocean or downhill depending on the location, it is a form of soil degradation. There are many reasons for coastal soil erosion around the Island. These include human activities such as removal of beaches and destroying the natural habitat in pursuit of development, SLR, coastal flooding and storm surges. With the melting of the glaciers and ice sheet continues to accelerate the warming of the ocean, the negative impact this may have on the Pacific Island countries will also continue because of their proximity to coast line areas. Satellite data indicates that Nauru experienced SLR by about 5 mm per year since 1993. This doubles the global average of 2.8–3.6 mm per year. This higher rate of SLR may also related to natural fluctuations that take place year to year or decade to decade caused by phenomena such as the El Niño-Southern Oscillation. Due to increasing impact of climate change, it is unequivocal that its consequences will be aggravated more than the past, particularly on these coastal communities along the Island. Integration of locally managed marine areas (LMMA)with the coastal area revegetation and beach nourishment at certain locations along the coastal areas could be perhaps seen as supportive strategy that can be used to increase resilience , adaptation and food security around the Island. Engaging in LMMA together with beach nourishment is critical to protect communities from soil erosion but at same time participating in conserving the marine resources from exploitation as food security for future generations. Integration of LMMA together with vegetation replanting strategy may also provide opportunity for the communities to nourish the beaches, replant vegetation as form of natural re-enforcement against

	coastal erosion and SLR. Working together with Department of Commerce, Industry and Environment (CIE) and the Department of Fisheries and Marine resources (FMR), the participating communities would identify the coastal areas which are in urgent need to restore their beaches from coastal erosion and at the same protecting the sea boundary from fishing and over harvesting. The population on the Island is more than 12,000 people and the destruction of the coastal areas through human actions are also accelerating. This calls for civic awareness on this integration approach to be inserted as part of this technology – i.e. ensure awareness of general public on the need to look after the beaches including designated LMMAs and as food security for future generations.
2.3 Technology Characteristics/ Highlights: Few bullet points, i.e. low/high cost; advance technology; low technology.	• medium cost (potentially high but medium initial cost) • Low technology (requires landfills on beaches and revegetation) • Soft and Hard Technology • Soft technology includes the policies surrounding LLMA
2.4 Institutional and Organizational Requirement :	There needs to be soft technology- Regulation about the LMMA and coastal area removal of beaches The responsible authorities includes: CIE , MFR and respective communities
3.0 Operations and maintenance	
3.1 Endorsement by Experts:	To increase community resilience and prevent coastal erosion, replanting of vegetation refurbishment of coastal areas and establishment of LMMAs at selected vulnerable sites across the island is important. This would ensure integrated strategies against soil erosion and marine resource management. It further ensure continuity of business along the coastal areas even during strong winds, storm surges and catastrophic events and also food security at these locally managed marine areas. Coastal communities would felt protected against the exposure and vulnerability that climate change and extreme storm events brought if there is no buffer of vegetation and natural beaches at these identified sites. Both private and business houses would concentrate on their normal day to day operations and not have to worry about their homes and businesses been carried away in the next disaster events, and at the same time conservation of marine resources for future uses.
3.2 Adequacy for current climate:	Fits well for both the current and future expected climate change across the Island. Since the forecasts

Are there negative consequences of the adaptation option in the current climate? Some adaptation may be targeted at the future climate but may have costs and consequences under the current climate.	are predicting future SLR with increasing intensity and frequency of storm surges which may cause further coastal erosion and washing away of beaches, such integrated beach revegetation and nourishment and LMMAs at identified vulnerable locations around the island would be beneficial to the communities at large. The LMMA would conserve the marine resources for future use as we face impacts of climate change.
3.3 Size of beneficiaries group: Technology that provides small benefits to larger number of people will often be favored over those that provide larger benefits, but to fewer people.	Beneficiaries include the household sectors, business houses, government departments, schools, health and private sectors and communities who have owned the land adjacent to the LMMAs. The beach vegetation and nourishment would ensure the general community at large is protected. There will be no individual or group of people who would be primary beneficiaries of such developments. While homes located closer to the identified locations may directly benefit from such undertakings, the positive externalities to the community at large is immeasurable. The benefits are distributed and shared among almost everyone on the Islands.
4. Costs	
4.1 Cost to implement adaptation options : Cost measures	Initial cost includes the cost of “grounds work’ (landfills), cost of V&A reports and beach nourishment and cost of the LMMA regulation drafting. The CIE and FMR although are responsible for overseeing the environment and marine resource management in the country, they do not have the capacity to provide some of the costs as mentioned above. Therefore this integrated technology would require the following costs to fully implement this adaptation option: The cost of groundworks (landfills) USD 3.3m Additional costs (V&A, EIA, & beach nourishment) .5 Cost of LMMA regulation and monitoring .7 Total cost = USD4.5m
4.2 Additional costs to implement adaptation option, compared to “business as usual”	The additional costs which may be required to implement this technology includes cost for beach nourishment, replanting of trees to ensure long term resilience is achieved at these coastal areas and cost of monitoring of LMMA. The cost is factored into the initial costs above.
5.0 Benefits	

5.1 <u>Development impact, indirect /benefits</u>	The new integrated LMMA and coastal area revegetation and beach nourishment would reduce coastal erosion and bring confidence in the communities along the coastal areas that their properties are safe and can continue with development initiatives at these sites. At the same time provide food security and conservation of marine resources. Below are likely be some of the major benefits on the communities from the technology. • Safety and food security of the community alone the coast lines: it is the primary motivator for the implementation the beach vegetation replenishment and nourishment, meaning more households/ public depends on the secure and safer environment from coastal erosion. • Contributing to food security by households participating in backyard gardening since they now have access to safer land, growing some of their basic crops supplementing their budgets. Reallocate funding to spend on other economic development by the government rather than just building a seawall or barriers which would be seen uneconomical to this cash trapped nation. • The marine resources and environment are also protected with the inclusion of LMMA into this integrated approach of conservation around the Island. This investing in resources for future generations.
5.2 Economic benefits : Employment –Jobs Investment – Capital requirements	Investment into coastal area vegetation and replenishment around the Island would create tens and hundreds of jobs to Nauruan for the next 12 to 24 months. • This will ensure that Nauruan's participate in landfilling, soil nourishment, rehabilitation of the beaches and monitoring and surveillance over LMMA during the implementation and monitoring stages of the technology. • The general community will continue to live and operate their business at the coastal areas thus contributing to the economic growth of the country. • Nauruan's that participate in this technology would earn the income and support their families to meet school fees and other livelihood expenses.

	• The integration of the approach ensures that communities benefit from these resources.
5.3 Social benefits : Income- Income generation and distribution Education – Time available for education Health – Number of people with different diseases.	• The Social benefit of this technology on the households is that they are secured and protected from impact of SLR and coastal erosion. The little money they earn could now be invested in other income generating activities to improve their livelihood rather than worrying about the coastal erosion. • The coastal areas which are vulnerable to coastal erosion and SLR will now have some buffer against salt water intrusion and conservation of their marine resources. The responsible authorities must ensure that primary and secondary schools across the island are safe and secure from such impact of SLR. This will ensure the youths and the weak are protected from the SLR and soil erosion. • Subsequently, health and gender issues will be considered and filtered through every process of decision making in this project.
5.4 Environment benefits: Reductions in GHG emissions, local pollutants, Ecosystem degradation etc.	Soil erosion caused by SLR will be controlled and managed at these sites because of coastal land vegetation and beach nourishment etc. Replanting of vegetation at these sites may also contribute towards reduction of the GHG and pollution into the atmosphere. A healthy marine resource habitat will also produce more oxygen into the air which is critical for our survival.
6.0 Local context	
6.1 Opportunities and Barriers : Barriers to implementation and issues such as the need to adjust other policies.	LMMA is a technology that can be employed in conjunction with other adaptation measures such as coastal zone management, sea wall and barrier constructions, coral reef rehabilitation etc. In the case of Nauru there has to be a lot of investment and commitment into these options to make them viable. Integrated coastal land vegetation, beach nourishment and LMMA would increase the opportunities for effective resilience with different purposes (domestic, agriculture use, etc.) - Barriers include lack of access to finance to invest in land fillings along the vulnerable coastal areas, policies by the National government surrounding management of beaches including LMMA and awareness by communities on the devastation impact of climate change etc. This option would be relatively cheaper compare to other adaptations options. - Technical requirements such as V&A, EIA and structural design may increase implementation

	and maintenance costs. Although coastal land vegetation and beach nourishment may be accrue some initial costs, it is cheaper on the longer run. - A low level of public awareness is critical to support the technology.
6.2 Status: Status of technology in the country	Certain communities have already participated in programs design to protect coastal soil erosion around the Island. However, the rate of soil erosion is worrisome and thus calls for prioritizing of this technology at selected vulnerable sites across the Island. LMMA will be the drivers to protect the coastal areas from erosion. Timeframe is continuous.
6.3 Timeframe : Specify timeframe for implementation	Life time
6.4 Acceptability to local stakeholders : Where the technology will be attractive to stakeholders	Yes

Annex 2: Technology Fact Sheets for Mitigation

A.2.1 Mitigation Technology # 1 – Energy Sector

Pumped hydroelectric storage (PHES) system	
1.0 Sector	Energy
2.0 Technology Characteristics	
2.1 Technology Name :	**Pumped hydroelectric storage (PHES) system**
2.2 Introduction:	Pumped hydro is the most developed energy storage technology, with facilities dating from the 1890s in Italy and Switzerland. Currently, there is over 90 GW of pumped storage capacity in operation worldwide, which is about 3% of global generation capacity. The main applications of pumped hydro are for energy management, frequency control and provision of reserves. Pumped storage plants are characterized by long construction times and high capital expenditure. However, with rising electricity prices and increasing use of intermittent energy sources, it can be very economic to store electricity for later use[8]. The advantages that a PHES system has over battery storage is that the pumped hydro installation is generally less expensive and expected to have a lifespan of over 50 years, whereas battery modules are limited in their lifespan to around 10 years.
2.3 Brief Technology Description	PHES is a technology that would use the surplus power from a renewable source to pump water from a lower reservoir to a second reservoir on top of the hill. This creates the potential energy that can be released when needed through letting the water flow from the upper reservoir through a conventional hydro turbine at sea level which generates power into the grid. The majority of modern pumped storage hydropower projects use reversible pump/turbine units that act as both a pump and a turbine. See Figure 1.
3.0 Cost	
3.1 Capital cost	Looking purely at capital costs for longer term, pumped hydro has lower capital costs due to the

[8] http://climatetechwiki.org/category/energy-services/electricity?page=1

	lower storage costs while for shorter periods batteries are lower due to the lower power costs[9]. Capital cost of PHES is around USD17,700/ kW[10].
3.2 Operations and maintenance	While initial capital costs are high for pumped storage hydropower projects, they typically have long project lives of up to 100 years and low operation and maintenance costs. Similar to initial capital costs, operation and maintenance costs can be highly site specific, and depend on a number of factors[11].
4.0 Application Potential in Nauru	
4.1 Energy Storage	By 2022, Nauru will have reached its 50% renewable energy goal which will be produced by approximately 8MWac of grid-connected solar PV with 5MW/ 2.5MWh of battery storage. However, the risk with exceeding 50% renewable penetration is that the Levelised Cost of Energy (LCOE) of the generated power will increase. At some level of solar penetration, it will become more expensive to generate power through solar and battery than it will to generate power through diesel generators as battery stored power is significantly more expensive than solar power or diesel generation.
4.2 Feasibility	Nauru enjoys some fortunate pump storage advantages. Command Ridge is 70m above sea level and already has the facility to store a capacity of 1,200 m^3. The site has seawater concrete tanks each with a storage capacity of 400 m^3 and have a relatively short pipeline distance to the sea. Seawater is the assumed medium due to the scarcity of bulk water on the island.
5.0 Gender Aspects	
5.1 Employment	Opportunity for women technicians in the field electrical, mechanical and civil engineering.
6.0 Impacts/ Benefits	
6.1 Mitigation:	There is a big necessity of mitigating global warming, and reducing the burning of fossil fuels is the major mean to achieve this final goal. This burning of fossil fuels may only be reduced if some

[9] https://arena.gov.au/assets/2018/10/ANU-STORES-STORES-Storage-Comparison-.pdf

[10] MFAT GHD. Nauru Pumped Hydroelectric Energy Storage Pre-feasibility Study – Final Report. Nov. 2019

[11] Antal. B . A., 2014. Pumped Storage Hydropower: A Technical Review. MSc. University of Colorado, Denver.

	kind of energy exists to replace it. The option of renewable energy is a very popular one, but in order to be competitive and available at all time, it needs to be stored. Pumped-storage is therefore a piece of high importance in the puzzle of the mitigation of the global warming.
6.2 Social:	Social benefits may include: • Standard of living; • Education; • Community; • Equal Opportunity.
6.3 Economics:	Refurbishment of the three existing concrete seawater tanks at Command Ridges requires no initial investment apart from building new layers within the tanks and installing new pipelines. Pumped storage hydropower projects are a net consumer of electricity. During periods of the day when there is excess low cost energy generated from solar, this energy is used to pump water from the lower reservoir to the upper reservoir. During high value peak power or sudden drop in solar generation, water from the upper reservoir is released back down to the lower reservoir, via the turbine to provide energy. Economic benefits may include: • Profit Cost Savings; • Economic growth; • Research and Development.
6.4 Environmental:	Although overseas PHES systems causes destruction of their soil's physical and chemical characteristics, and therefore with higher risks of erosion and soil contamination, the existing top reservoirs on Nauru are built with concrete foundations and walls. Environmental benefits may include: • Natural resources use (seawater); • Environmental Management (soil erosion and contamination; • Pollution Prevention (no GHG emission).

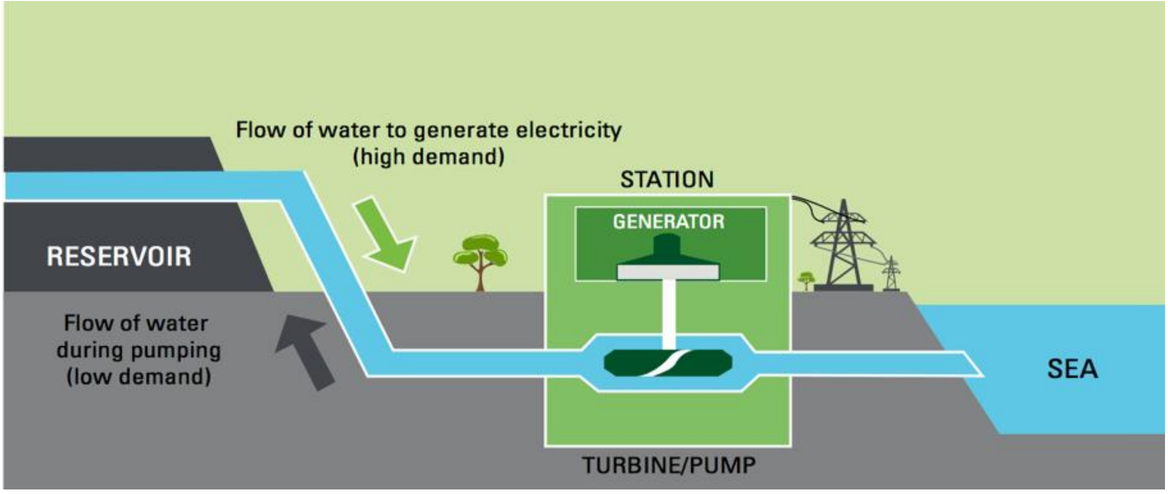

Figure 1: Pumped hydroelectric storage scheme

A.2.2 Mitigation Technology # 2 – Energy Sector

Small-scale Biogas Digester	
1.0 Sector	Energy
2.0 Technology Characteristics	
2.1 Technology Name :	Small-scale Biogas Digester
2.2 Introduction:	The first digestion plant was built at a leper colony in Bombay, India in 1859. AD reached England in 1895 when biogas was recovered from a "carefully designed" sewage treatment facility and used to fuel street lamps in Exeter.[12] Biogas digester is any structure that converts organic material (waste) into energy in the absence of oxygen. • Various materials and geometric configuration have been used for the design of biogas digester system. • Examples of the geometric configuration are horizontal, spherical, cylindrical and dome shape • Examples of common materials used are brick, cements, fiber glass for the dome shape and metal (stainless steel and mild steel). • Biogas is a good source of renewable energy, composing of 50-70% of methane and 30-50% of carbon dioxide with other traces of gases.
2.3 Brief Technology Description	Biogas is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source. Biogas is produced by anaerobic digestion with methanogen or anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials. This closed system is called an anaerobic digester, biodigester or a bioreactor. Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen.

[12] https://extension.psu.edu/a-short-history-of-anaerobic-digestion

	This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat. Biogas is primarily methane (CH4) and carbon dioxide (CO2) and may have small amounts of hydrogen sulfide (H2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.[13]
3.0 Cost	
3.1 Capital cost	The capital cost of a 1 m³ compact biogas plant is US$ 500. This unit will generate equivalent of 182.5 kg of LPG. = 8413.25 MJ = 8413.25 x 4.18 Mcal = 35167.385 Mcal = 3.5167 toe. Hence the capital cost required to generate 1 toe = 500/3.5167 = USD 142.18/toe/y. The capital costs for a digester-generator with a capacity of about 100-kW would be about USD450,000 (USD4,500/kW) (without NOx controls), exclusive of land costs.[14]
3.2 Operations and maintenance	Minimal cost. If operated and maintained properly, this technology can have a life-span of at least 20 years.
4.0 Application Potential in Nauru	
4.1 Feasibility	Although there is no record of any installed or operable biogas digesters on island nor any feasibility studies, there is a great interest from stakeholders to include this technology amongst other renewable energy technologies for further analysis. Although not favorable to be fueled by toilet run-offs, it is favored more to be fueled by kitchen waste, pig manure and garden clippings.
5.0 Gender Aspects	
5.1 Potential Impact	Yes
6.0 Benefits	

[13] https://en.wikipedia.org/wiki/Biogas#Biogas_plants

[14] http://www.suscon.org/pdfs/cowpower/biomethaneSourcebook/Chapter_8.pdf

6.1 Mitigation:	The 1 m³ biogas unit introduced through this technology is capable of generating biogas which is equivalent to 0.5 kg of LPG per day. On a yearly basis this would replace182.5 kg of LPG with a calorific value of 46.1 MJ/kg. The emission factor for LPG is 63.1 tCO2/TJ. Hence each biogas unit introduced with this technology would reduce emission by 0.530 tCO2/y. On a national basis, in the short term of say 1,000 households in the country, if 10% of the households resort to this technology, the emission reduction would be 0.530 x 100 = 53 tCO2/y.
6.2 Social:	• Employment opportunities for the supply and installation of biogas digesters. • Skill and capacity development.
6.3 Economics:	• Reduction in cost of fuel used for cooking by switching from expensive LPG to cheap biomass feed materials. • Biogas provides a potential needs to provide sustainable, affordable and reliable energy sources for domestic cooking.
6.4 Environmental:	• A reduction in emission by 0.53 tCO2/y for every 1 m³ of biogas digester installed. • Reduced environmental problems associated with pig waste disposal; • Increased agriculture production.

Biogas digester

Figures 1 & 2: Biogas digesters can be built and buried in the ground or used on ground surface.

Figure 3: Biogas schematic

A.2.3 Mitigation Technology # 3 – Energy Sector

OTEC plant	
1.0 Sector	Energy
2.0 Technology Characteristics	
2.1 Technology Name :	OTEC (Ocean Thermal Energy Conversion)
2.2 Introduction	In 1870, Jules Verne introduced the concept of ocean thermal energy conversion (OTEC) in Twenty Thousand Leagues Under the Sea. Within a decade, American, French and Italian scientists are said to have been working on the concept but the Frenchman, physicist Jacques-Arsene d'Arsonval, is generally credited as the father of the concept for using ocean temperature differences to create power. D'Arsonval's student, Georges Claude, built the first OTEC power plant in 1930 in Cuba, which produced 22 kilowatts of electricity. This led to an on-shore open cycle plant, with a pipe extending out to sea. Despite initial problems, power was generated.[15] French research continued in earnest through the 1940s and into the 1950s. Research also began in California in the 1940s. In all cases, work was slowed or halted by cheaper alternatives to power generation. OTEC is a proven technology that produces clean baseload (24/7) electricity using the temperature differential (>20ºC) between warm surface water and cold deep water in the world's tropical oceans. OTEC can also be used for ocean water desalination. The dominant natural desalination is the evaporation/condensation distillation process. The theoretical energy requirement for making 1 cubic meter of fresh water from ocean water is 1 kwh (3,6 MJ). Even though reverse osmosis is able to get 1 cubic meter of fresh water from ocean water at 3 kwh energy. The energy need to be in the form of electrical energy or some mechanical form. A better desalination procedure using the ocean is to use ocean thermal energy directly. The warm ocean surface water can provide the thermal energy to generate water vapor at the evaporator. The

[15] http://www.oteci.com/otec-at-work/test-page/

	cooler deep ocean water can condense the vapor into water. The energy required to move the heating and cooling ocean water through the heat exchangers can be much less than the theoretical energy requirement of 1 kwh for each cubic meter. Ocean thermal energy can easily provide 40 MJ of thermal energy to get 1 cubic meter of fresh water. The cost of desalinate ocean watercan be less than 10 cents for each cubic meter.[16]
2.3 Brief Technology Description	The warm seawater is used to produce a vapour that acts as a working fluid to drive turbines. The cold water is used to condense the vapour and ensure the vapour pressure difference drives the turbine. OTEC technologies are differentiated by the working fluids that can be used. Open Cycle OTEC uses seawater as the working fluid, Closed Cycle OTEC uses mostly ammonia. A variation of a Closed Cycle OTEC, called the Kalina Cycle, uses a mixture of water and ammonia. The use of ammonia as a working fluid reduces the size of the turbines and heat exchangers required.
2.4 CO2 Emission Comparison	The amount of CO2 released from electricity-producing plants (expressed in gr of CO2 per kWh) ranges from 1000 for coal fired plants, to 700 for fuel-oil plants, while for OTEC plants it is at most ~ 1 % of the amount released by fuel oil plants.
3.0 Cost	
3.1 Capital cost	The cost of a proposed 50 megawatt (MW, net power) OTEC plant is approximately 75 million dollars. The Moody graph can be used to support the design of smaller scale 7 MW or 140 KW models at cost of 20 and 2 million dollars or **USD3,000/kW** (7 MW plant) to approximately **USD14,000/kW** (140 kW plant). Note a smaller scale OTEC plant has very high capital cost.
4.0 Application Potential in Nauru	
4.1 Background	Nauru relies greatly on fossil fuel for electricity generation and potable water production. Electricity is generated by medium-speed diesel generators and since 1995, potable water was produced by a 1.2 ML/ day multiple-effect distillation (MED) desalination plant. This cost-effective desalination plant operated from steam that was produced by waste-heat boilers that were coupled to the diesel generator exhaust system. A minimum of 4MW of

[16] https://www.climatecolab.org/contests/2015/harnessing-the-power-of-mit-alumni/c/proposal/1325332

	electrical power generation was needed to effectively operate the desalination plant. However, during the economic downturn in 2005, GoN was barely able to supply diesel fuel to generate sufficient electrical power for the island. The desalination plant on the other hand could not be maintained nor operated due to the low generating capacity of the generators. Since 2003, reverse-osmosis technology was introduced to produce water. The capital, operating and maintenance cost of RO plants are quite substantial compared to MED plants. With the very rapid increase in depth that occurs beyond the reef, there is an opportunity for OTEC energy development on Nauru. OTEC technology utilizes the temperature difference between the warm ocean surface water and the deep cold ocean water at depth between 600-1,000 meters to generate electricity. Tropical waters, defined as extending from the equatorial region boundary to, respectively, 20°N and 20°S, are adequate.
4.2 OTEC Demonstration Plant	The government of the Republic of Nauru along with engineers of the Tokyo Electric Power Co. and the Toshiba Corporation constructed a closed-cycle OTEC plant at a site on the island of Nauru in 1980. The Nauru Island is a high coral reef surrounded by a lagoon of 50-150m wide. Where the plant is located, the seabed is irregular up to 50 m deep from the coast and after that leans at an angle of 40-45 degrees up to 700 m deep. Although the seabed become porous further from the coast, the bearing capacity is sufficient for seabed emplacements. A schematic of the Japanese Shore-Based OTEC is shown below, demonstrating the depth of the CWP to be about 670 m. This plant was the first OTEC with power connected to the utility grid. It was also the first OTEC located on land that generated net power and hit a record in total production of net power 31.5 kW, with a corresponding gross power of 120 MW (Avery and Wu, 1994). From this data, the total power generation efficiency was calculated to be 31.5/120 = 26%.
5.0 Gender Aspects	
6.0 Impacts/ Benefits	

6.1 Mitigation:	OTEC systems directly contribute to climate change mitigation by providing a completely renewable energy source free of GHG emissions[17].
6.2 Social:	Reduced cost of electricity and water. Employment opportunities for plant operations and maintenance.
6.3 Economics:	One of the main benefits of OTEC systems is that they could potentially be used to provide baseload as there is no intermittency associated with their resource[18]. OTEC systems produce electricity and fresh water as well, which is highly beneficial for island regions where fresh water availability is limited. It also helps reduce the country's dependence on imported fossil fuel[19]. (Reduce national expenditure on importation of petroleum-based products.)
6.4 Environmental:	OTEC makes use of renewable, clean, natural resources. Fossil fuels are replaced by warm surface seawater and cold water from deep sea to generate electricity. OTEC plants do not pollute the environment by releasing carbon dioxide emissions or other polluting substances.

[17] https://www.ctc-n.org/technologies/ocean-thermal-energy-conversion

[18] https://www.ctc-n.org/technologies/ocean-thermal-energy-conversion

[19] https://www.azocleantech.com/article.aspx?ArticleID=343s

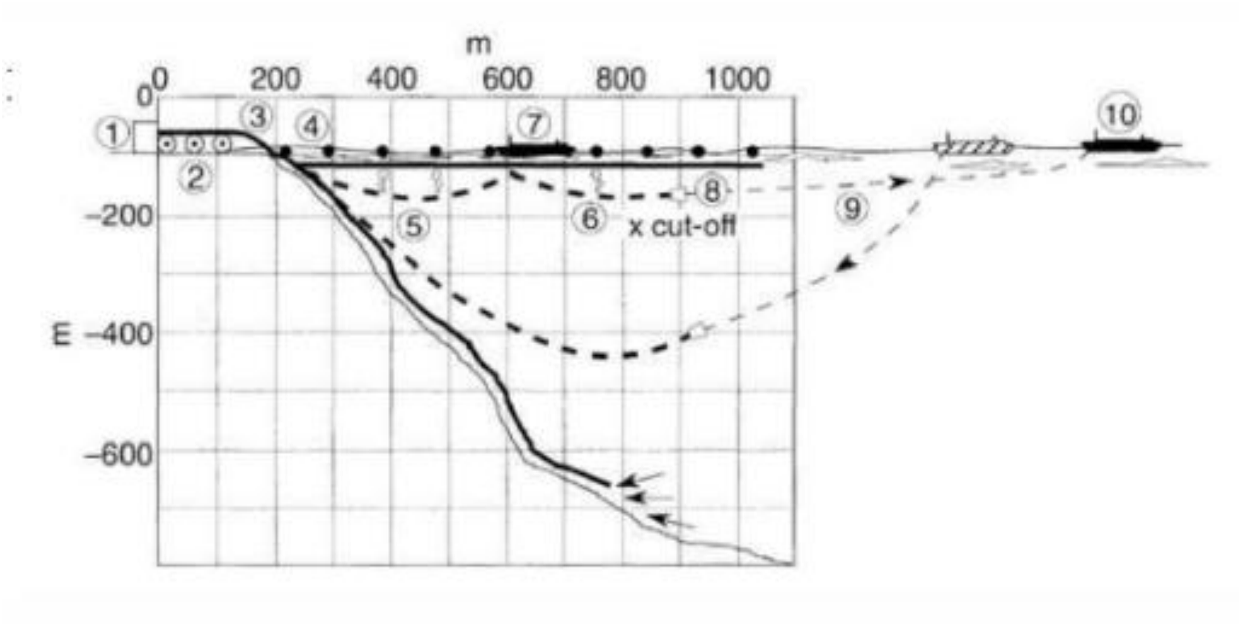

Figure 1: Deployment procedure for the CWP installation for the Japanese Shore-Based OTEC on the Island of Nauru (Avery and Wu, 1993, p. 292).

A.2.4 Mitigation Technology # 4 – Energy Sector

Household Grid-connected Rooftop Solar PV System	
1.0 Sector	Energy
2.0 Technology Characteristics	
2.1 Technology Name :	Grid-connected Rooftop Solar PV System
2.2 Introduction:	In 1839 Alexandre Edmond Becquerel discovered the photovoltaic effect which explains how electricity can be generated from sunlight. He claimed that "shining light on an electrode submerged in a conductive solution would create an electric current." However, even after much research and development subsequent to the discovery, photovoltaic power continued to be very inefficient. People mainly used solar cells for the purpose of measuring light. Over 100 years later, in 1941, Russell Ohl invented the solar cell, shortly after the invention of the transistor.[20] Solar photovoltaic, or simply photovoltaic (SPV or PV), refers to the technology of using solar cells to convert solar radiation directly into electricity. Solar energy is one of the cleanest sources of energy, and it's an extremely effective way of making your household more efficient and sustainable. Solar panels don't use any water to generate electricity, they don't release harmful gases into the environment, and the source of their energy is abundant and, best of all, free.
2.3 Brief Technology Description	Grid interconnection of PV systems is accomplished through the inverter, which convert dc power generated from PV modules to ac power used for ordinary power supply to electric equipment. See Figure 1.
3.0 Cost	
3.1 Capital cost	For the purpose of this fact sheet, the following quotation for Nauru will be used that comprise of: 6 x Suntech 260W (1.56 kW) solar PV modules with components for installation and grid connection. Quote for this kit as provided in 2017 is approximately USD2,956 which include cost of freight to Nauru. Capital cost per kW is therefore

[20] https://www.energymatters.com.au/panels-modules/

	approximately USD1,800/ kW. Note installation cost is not included.
3.2 Operation and maintenance	Rooftop solar pv systems have very minimal cost to operate and maintain. Panels are self-cleaned whenever it rains.
4.0 Application Potential in Nauru	
4.1 Feasibility	Measurements show an average of over 6 kWhr/m2 /day (with solar panels tilted to the angle that maximises energy input) with a seasonal variation of around 10–15%. Although solar PV offers electricity generation that can supplement the existing diesel generation, the variable nature of solar energy will require energy storage systems for it to be connected to the grid at high levels of penetration. A dynamic model has not yet confirmed the maximum possible level of solar penetration before grid stability issues occur, but it is likely to be limited to around 20–30% of midday demand. Above this threshold, storage and control systems will have to be introduced to ensure grid stability. (Isaka, Mofor, & Wade, 2013)
5.0 Gender Aspects	
5.1 Potential impact	Yes
6.0 Benefits	
6.1 Mitigation:	Generating electricity from solar panels produce no harmful emissions, and the more homes and businesses that rely on solar power means less toxic emissions from fossil fuels into our air.
6.2 Social:	Reduced electricity bills. Very minimal maintenance.
6.3 Economics:	The chief factor that accentuates the importance of rooftop solar panels is that they require very less maintenance. They come with a service life of over 20 years if maintained properly. Reduces electricity bills.
6.4 Environmental:	Solar power systems derive clean, pure energy from the sun. Installing solar panels on your home helps combat greenhouse gas emissions and reduces our collective dependence on fossil fuel.

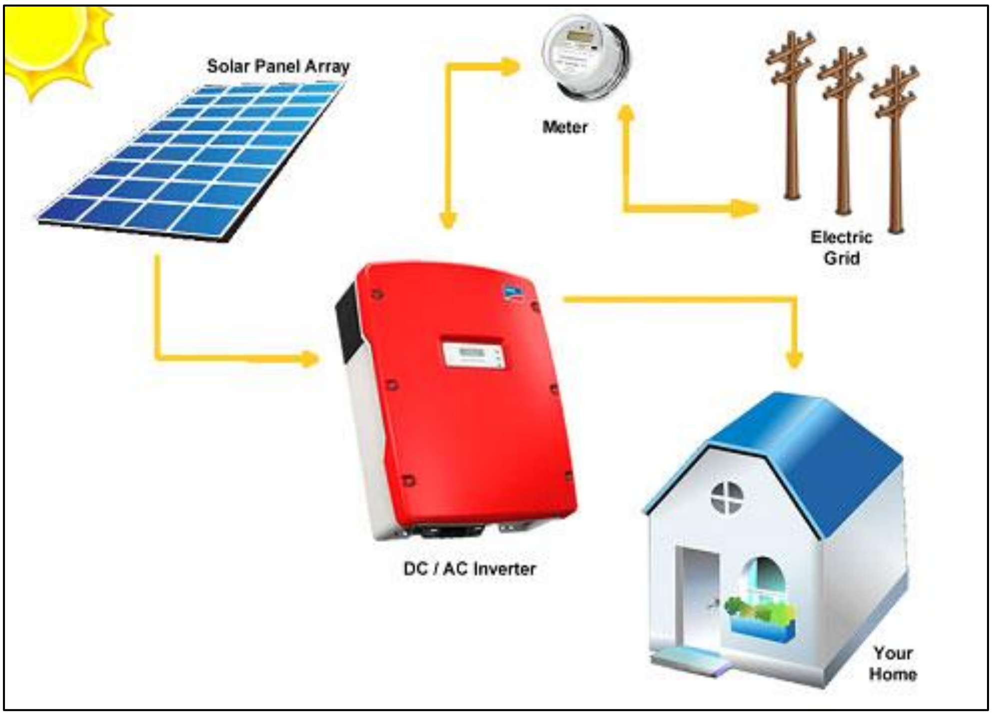

Figure 1: Grid-tied solar PV system diagram

(Source: http://www.progenenergy.com/products/residential-solar/grid-connected-roof-top-systems)

A.2.5 Mitigation Technology # 5 – Waste Sector

Semi-aerobic Landfill – Fukuoka System	
1.0 Sector	Solid Waste Management
2.0 Technology Characteristics	
2.1 Technology Name	Semi-aerobic Landfill
2.2 Introduction	The semi-aerobic landfill method was first tested at Shin-Kamata Landfill with close collaboration between Fukuoka University and Fukuoka City in 1975. After proving its positive effect on the environment, it was officially accepted in Japan as the 'Fukuoka Method' and was adopted as a national standard technology by the Ministry of Health and Welfare.
2.3 Brief Technology Description	A semi-aerobic landfill is a landfill where waste goes through a decomposition process in the presence of oxygen. This type of landfilling method has several advantages including reduction in the amount of landfill gas produced and faster stabilisation of the waste landfilled. In a semi-aerobic landfill, the leachate collection system consists of a central pipe (main collection pipe) with branch pipes on either side of it laid at a suitable spacing (holes with approximately one inch in diameter are cut into the pipe to allow leachate to enter). The leachate collection pipes offer a number of advantages: a) Leachate is drained out as quickly as possible, preventing it from fouling in the waste material and making it easier for fresh air to enter. This assists aerobic conditions in the waste layers. b) By creating aerobic conditions, microbial activity is enhanced and the decomposition of waste is increased. c) By laying the collection pipes in the rocks, the collection pipes are protected from clogging (blockage of the pipes from dirt) and damage during operation. d) By quickly draining out the leachate, there is reduced pressure caused by water on the bottom

	ground/liner, leading to a reduced risk of leachate seepage[21]. See Figure 1.
3.0 Subsector GHG Emission	
4.0 Cost	
4.1 Capital cost	Existing dumpsite upgrade = AUD 1.3M – 2.25M This include operation of heavy equipment to (i) construct new 0.5 Ha cell and (ii) to consolidate 15-20,000m³ of waste material. Cost of equipment (purchase only) = AUD 1.1M[22]
4.2 Operations and maintenance	In order to keep proper operations, landfill facilities must be regularly inspected and maintained in a good condition. Facilities to be maintained include access roads, landfill slopes, drainage, and leachate collection and the gas venting facility.
5.0 Application Potential in Nauru	
5.1 Background	• The current dump site operation involves open dumping at several locations on site resulting in a large 'active' tipping area. This in turn results in most of the rain water falling on the site percolating through exposed refuse, creating leachate. • With no leachate collection any leachate generated will percolate through the underlying soil and rock to groundwater . • Periodic fires have been addressed through excavation of waste resulting a number of stockpiles of exposed material around the site. • There is no liner system, leachate collection or separation of stormwater in place. • Waste is compacted using an excavator bucket when suitable equipment is available, nominally twice a week but often much less frequently. • General waste material entering the site is typical municipal solid waste from a Pacific Island community with a relatively low organic material content. • Waste entering the site from community or business collections is recorded and billed each month. Communities are billed $2.50 per cubic meter, businesses are charged $20 per cubic metre. • There is no detailed information available on waste quantity or composition. Based on materials

[21] Amano. S., (2005). A Practical Guide to Landfill Management in Pacific Island Countries. SPREP. JICA.

[22] Tonkin and Taylor (2018). Waste Management System Operations and Policy – Preliminary Advice

	received at the dump site in the week of 26 February 2018, an estimated 26,000 m3 or 4 to 5,000 tonnes1 of material is received each year. Open dumping creates a lot of problems, not only to the surrounding environment but more critically to public health and safety.
6.0 Gender Aspects	
6.1 Potential Impact	Yes
7.0 Benefits	
7.1 Mitigation:	GHG emissions from semi-aerobic landfill are estimated as being half as much as that in anaerobic landfills. This effect on the reduction of GHG emissions by semi-aerobic landfills is greatly influenced by the amount of passive air introduction into the waste layer.
7.2 Social:	• Employment opportunities. • Skill and capacity development. • Potential for gender impacts.
7.3 Economics:	Reconfiguring the dump site to make provision for resource recovery (sorting and stockpiling), management of garden waste and cardboard is anticipated to increase reuse and recycling of materials from across Nauru.
7.4 Environmental:	Implementing controlled disposal of residual waste with limited active dumping area, control of leachate and capping of previously dumped waste will significantly reduce the environmental risks posed by the dump site. Controlled dumping and capping of placed materials and will also reduce the potential for landfill fires[23].

[23] Tonkin and Taylor (2018). Waste Management System Operations and Policy – Preliminary Advice

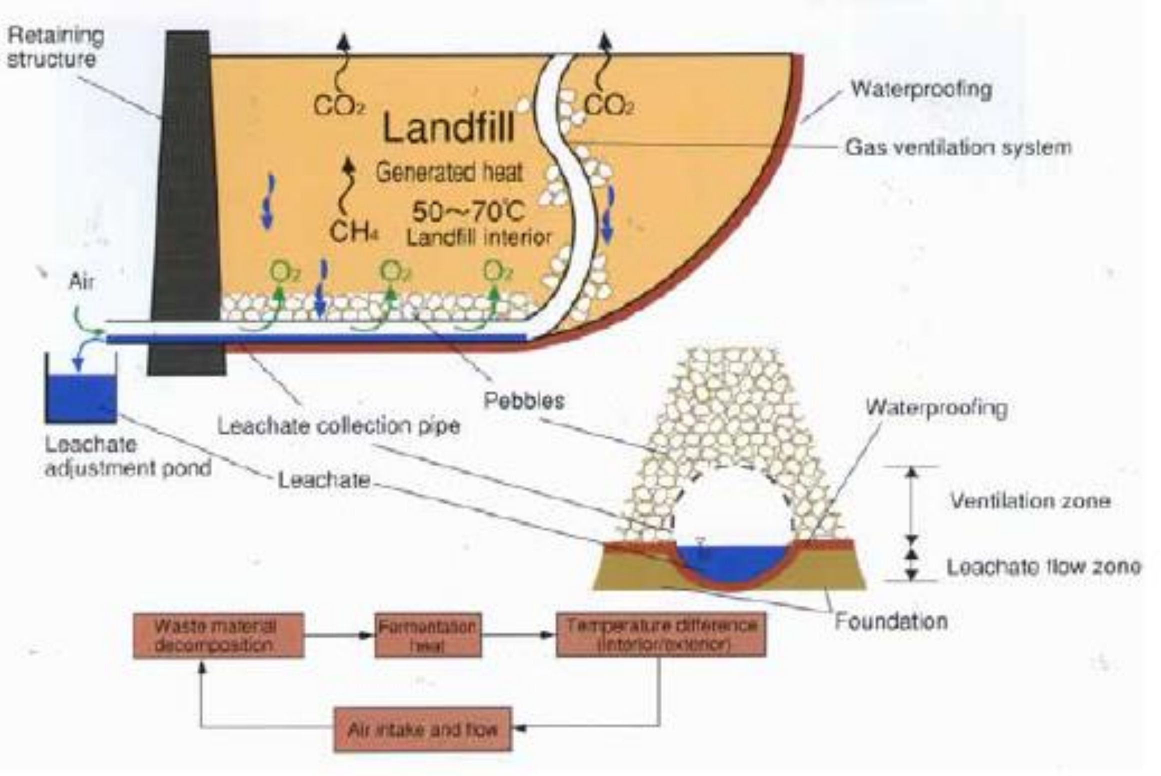

Figure- 1: Diagram of a semi-aerobic landfill
(Reference 1: Fukuoka City Environmental Bureau, 1999)

A.2.6 Mitigation Technology # 6 – Waste Sector

Waste segregation	
Sector	Solid Waste Management
2.0 Technology Characteristics	
2.1 Technology Name	Household Waste Sorting (Segregation)
2.2 Introduction	Waste poses a threat to public health and the environment if it is not stored, collected, and disposed of properly. Waste sorting or separation at the source, also called source separation, is the process of separating different fractions of waste at the place where it is generated, i.e., at home. Waste sorting is the process by which waste is separated into different elements. Waste sorting can occur manually at the household and collected through curbside collection schemes, or automatically separated in materials recovery facilities or mechanical biological treatment systems[24].
2.3 Brief Technology Description	Onsite handling, storage, and processing are the activities at the point of waste generation which facilitate easier collection. For example, waste bins are provided at the sites which generate sufficient waste. See Figure 1.
3.0 Subsector GHG Emission	
3.1 EPA's WARM model.	For every ton of mixed paper or cardboard that is recycled rather than landfilling avoids 3.61 metric tons of CO2 emission or equivalent to 9.37 cars taken off the road.[25]
4.0 Cost	
4.1 Capital cost	The price of 240 L wheelie bins ranges between AUD 50 to AUD 100 each. Capital cost will be dependent on the number and types of bins required per household multiplied (x) by number of households on Nauru multiplied (x) by the cost of each bin. Cost of freight is not included. Eg. For every 100 homes would require a capital investment of $10,000 for the supply of one recycle bin.

[24] https://en.wikipedia.org/wiki/Waste_sorting

[25] http://www.stopwaste.co/calculator/

5.0 Application Potential in Nauru	
5.1 Solid Waste Sorting Status at Community Level	Color-coded 240 L wheelie bins are being used effectively in developed countries for domestic solid waste segregation. CIE are currently promoting this concept to all schools on the island which is a great approach in educating our children first hand before it is disseminated at the community level. Solid waste separation at community level will reduce waste going into landfills. These separated solid waste can be further sorted at the dumpsite using mechanical-biological treatment (MBT) machines.
6.0 Gender Aspects	
6.1 Potential impact	Yes.
7.0 Benefits	
7.1 Mitigation:	Reduction in uncontrolled solid waste disposal at the dumpsite thus reducing GHG emissions.
7.2 Social:	Proper waste management at the source of generation is a public benefit. Employment opportunities. Educating
7.3 Economics:	Reduced solid waste for landfill. Reduction in heavy equipment use for landfilling.
7.4 Environmental:	Controlling what goes into the landfills in terms of household solid waste segregation can significantly reduce the emission of GHG.

The Australian three-bin system

Figure 1: Colored waste bins for different wastes as illustrated below in Table 1.

Food & Garden

- All food waste and scraps
- Meat, chicken and fish scraps & bones
- Tea bags, coffee grounds
- Fruit and vegetable scraps
- Cake, bread, rice, pasta
- Garden waste: lawn clippings, prunings, small sticks, twigs and flowers
- Shredded paper, paper towel, serviettes
- Council provided compostable caddy liner

- *Plastic bags, food packaging, cling wrap or recyclables.*

Recycling

- All recycling
- Steel, tin, aluminium cans, including empty aerosols
- Clear, brown and green glass bottles and jars (rinsed, no lids)
- Plastic bottles, soft drink bottles and containers (rinsed, no lids)
- Cardboard boxes, milk and juice cartons
- Newspapers, magazines, office paper and junk mail, including window envelopes

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- *Plastic bags, light bulbs, mirrors or drinking glasses, food or general waste ceramics, crockery or ovenware, foam or polystyrene, waxed cardboard boxes.*

Garbage

- General waste
- Plastic bags
- Packets, wrappers, cling wrap and bubble wrap
- Nappies and sanitary waste, wrapped tightly and stored in well-sealed bags
- Pet waste, kitty litter
- Foam, polystyrene
- Light globes, mirrors, ceramics, cookware and drinking glasses

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- *Building materials, syringes, oil or paint, gas bottles, hazardous or chemical waste*
- *Medical waste (speak to your doctor or pharmacy).*

A.2.7 Mitigation Technology # 7 – Waste Sector

Commercial baling	
1.0 Sector	Solid Waste Management
2.0 Technology Characteristics	
2.1 Technology Name :	Commercial Baling Machine
2.2 Introduction:	Industrial balers form an integral part of waste disposal systems for various industries, since they can easily compress and bind waste materials into compact bales for easier handling and transportation. These denser bales take up less space and are also more likely to be sent to a recycling center or purchased by businesses that use recycled materials, rather than ending up in a landfill. They are most often used in industries like agriculture, retail, oil, automotive and plastic products manufacturing, as well as restaurants, schools, recycling centers and junk yards. Garbage that cannot be recycled or reused is compacted to reduce the volume of trash in landfills, but balers also increase the convenience of handling and transportation for recyclable materials like plastic bottles, metal cans, cardboard boxes and paper products. The use of commercial balers allows companies to reduce the amount of labor, time and energy spent in the recycling process, since they can be operated by a single person in most cases or even automated completely. Balers can form the central point for the waste management processes in any business, by compacting and reducing the volume of materials that need to be recycled or disposed.[26] Balers are brilliant for segregating waste types. Cardboard and plastic are baled separately so recyclers do not need to segregate at the depot. Dry mixed recycling bins contain an array for different materials, which need to be segregated. This is additional labour hours for staff at the waste management depot, the cost of which will be passed on to the hotel.[27]

[26] https://www.norcalcompactors.net/industrial-commercial-balers/

[27] https://www.cardboardbalers.org/how-can-hotels-benefit-from-using-balers-over-recycling-bins/

2.3 Brief Technology Description	Industrial and commercial balers are available in a variety of different models that are designed for dealing with various kinds of waste material like cardboard, plastic and textile. Most commonly, they are classified according to the type of input and direction of material flow, i.e. vertical baler and horizontal baler. Vertical Cardboard Balers are perfect for manufacturing plants, hotels, restaurants, retailers, supermarkets, hospitals, distribution places, recycling stations, and other similar places. We make it possible for you to process and bale paper, cardboard, rags, aluminum, plastic, plastic bottles, shrink wrap, rags, and similar stuff. These balers are perfect for reducing labor expenses and generating extra revenue from recycling operations. These balers are known for their customization with hand fed tray, conveyor belt, air system and loader. They are designed to reduce labor expenses and aid the recycling process through increased payload. These machines are capable of baling newspapers, tin, paper, cardboard, plastic, shrink wraps, aluminum, foam, coated book stocks, rags, plastic bottles, steel, and other recyclable stuff. This makes them perfect for manufacturing plants, printing presses, recycling stations, distribution centers and other places with similar operations.
3.0 Cost	
3.1 Capital cost	The cost of the baler itself can run anywhere between $5,000 for a low-end vertical baler to more than $1 million for a top-of-the-line ferrous baler. Shear/baler/loggers can even cost as much as $1.5 million.
3.2 Operations and maintenance	Baler operators need to be trained on how to safely operate these machines. However, maintenance costs are very low.
4.0 Application Potential in Nauru	
4.1	Balers can be installed at government offices where the main source of wastes are papers and cardboards. Other recyclable wastes may include plastic bottles and aluminum cans.
5.0 Gender Aspects	
5.1 Potential impacts	Yes
6.0 Benefits	
6.1 Mitigation:	Reduces GHG emission by reducing recyclable waste ending up in landfills.
6.2 Social:	Job creation.

6.3 Economics:	Balers reduce shipping costs by densifying materials, improving the efficiency of each haul. Because of this, for many businesses (including manufacturers, distributors and retail stores), investing in baling equipment for recyclables can lead to significant economic benefits. Cost reduction in waste management.
6.4 Environmental:	Balers reduce a great amount of recyclable waste ending up in the landfills. Baling keeps all recyclable waste together unlike bins which can potentially make cardboard and plastic overflow into the general waste stream. Bales will stay compacted together, ensuring it is 100% recycled. This is where balers heavily defeat recycling bins in terms of green credentials.

A.2.8 Mitigation Technology # 8 – Energy Sector

Composting at household level	
1.0 Sector	Solid Waste Management
2.0 Technology Characteristics	
2.1 Technology Name	Composting
2.2 Introduction	The term composting is defined as biological degradation of waste under controlled aerobic conditions. The waste is decomposed into CO2, water and the soil amendment or mulch. In addition, some carbon storage also occurs in the residual compost. Today many developed and developing countries practice composting of mixed waste or biodegradable waste fractions (kitchen or restaurant wastes, garden waste, sewage sludge). It is best suited for source segregated biodegradable waste[28]. See Figure 1. Composting is one of the simplest ways to prevent emissions of methane because the organic fraction of the waste stream is diverted from landfill. While composting does release carbon dioxide, it is currently considered to be a neutral process since the removal of carbon dioxide from the atmosphere by photosynthesis to produce organic matter is also not considered. Compositing can be divided into home compositing and industrial compositing. Essentially, the same biological processes are involved in both scales of compositing. Different materials are suitable for decomposition, but carbon and nitrogen containing materials are normally preferred. These include green plant material, dry straw, leaves, paper and wood chips[29].
2.3 Brief Technology Description	Composting is a natural aerobic (with oxygen) process where microorganisms break down organic material producing stabilised material (compost), CO2, water and heat[30]. Generally there are two major approaches to compositing. Active and passive. Active (hot)

[28] TNA Factsheet – Mitigation for Bhutan – Composting

[29] TNA Factsheet – Mitigation for Kenya - Composting

[30] Tonkin and Taylor (2018). Waste Management System Operations and Policy – Preliminary Advice

	compositing is compositing close to ideal conditions allowing aerobic bacteria to thrive. To achieve good results the composite material must be kept warm, insulated and moist. Passive composition is compositing in which the level of physical intervention is kept to a minimum. Most industrial compositing operations use active compositing techniques while home compositing operations use passive techniques. Waste compositing involves, waste collection, segregation/sorting, piling and sprinkling with water[31].
3.0 Subsector GHG Emission	
3.1 EPA's WARM model CO2 emission calculator	For every ton of food scraps/ organics recycled or composted rather than landfilling avoids 0.88 metric tons of CO2 emissions. This is equivalent to 2.28 cars taken off the road.[32]
4.0 Cost	
4.1 Capital cost	The capital requirement for waste compositing depends on the scale of operations. At home compositing, the operation can be undertaken through household labor thereby minimizing costs. Commercial compositing can be undertaken at small scale or medium scale. In most operators using basic equipment that do not require large capital outlay.
4.0 Application Potential in Nauru	
4.1 Home vs Dumpsite composting	Home composting will require a compost bin that are available in stores or these can be home made. (See Figure 2). Promoting home composting for kitchen gardening provides a number of benefits in terms of organic waste management, sustainable kitchen gardening and healthy livelihood. Dumpsite composting on the other hand may restrict people from accessing compost for their kitchen gardening. Home composting should be integrated with kitchen gardening through CIE. This does not stop dumpsite composting initiatives as commercial and industrial organic wastes are in abundance.
5.0 Gender Aspects	
5.1 Potential impact	High
6.0 Benefits	

[31] TNA Factsheet – Mitigation for Kenya - Composting

[32] http://www.stopwaste.co/calculator/

6.1 Mitigation:	Waste compositing replace natural decomposition which takes place under anaerobic conditions that would result in emissions of methane gas. The carbon dioxide that is emitted during the de-compositing process is of lower global warming potential than methane and therefore contributor to climate change mitigation[33]. This directly prevents the emissions of methane (which is 25 times a more potent GHG than CO2) that would have occurred from waste disposal on land.
6.2 Social:	Composting provides benefits for waste handling agencies. Composting part of the waste the agency receives increases the landfill lifetime and provides the waste handling agency with a marketable product in the form of compost. The technology is applicable for both small scale and large scale applications. Either of these will support local employment generation[34].
6.3 Economics:	Composting programs launched by small communities can provide benefits to the local community in the form of increased local employment and reduced costs for waste removal. Producing compost is found to be a profitable business in many parts of the world if implemented in public private partnerships models and right choice of centralized and decentralized composting units[35].
6.4 Environmental:	Composting directly leads to avoidance of methane emissions thereby improving the air quality. Composting results in a reduced waste volume going into landfills.

[33] TNA Factsheet – Mitigation for Kenya – Composting

[34] TNA Factsheet – Mitigation for Bhutan – Composting

[35] TNA Factsheet – Mitigation for Bhutan – Composting

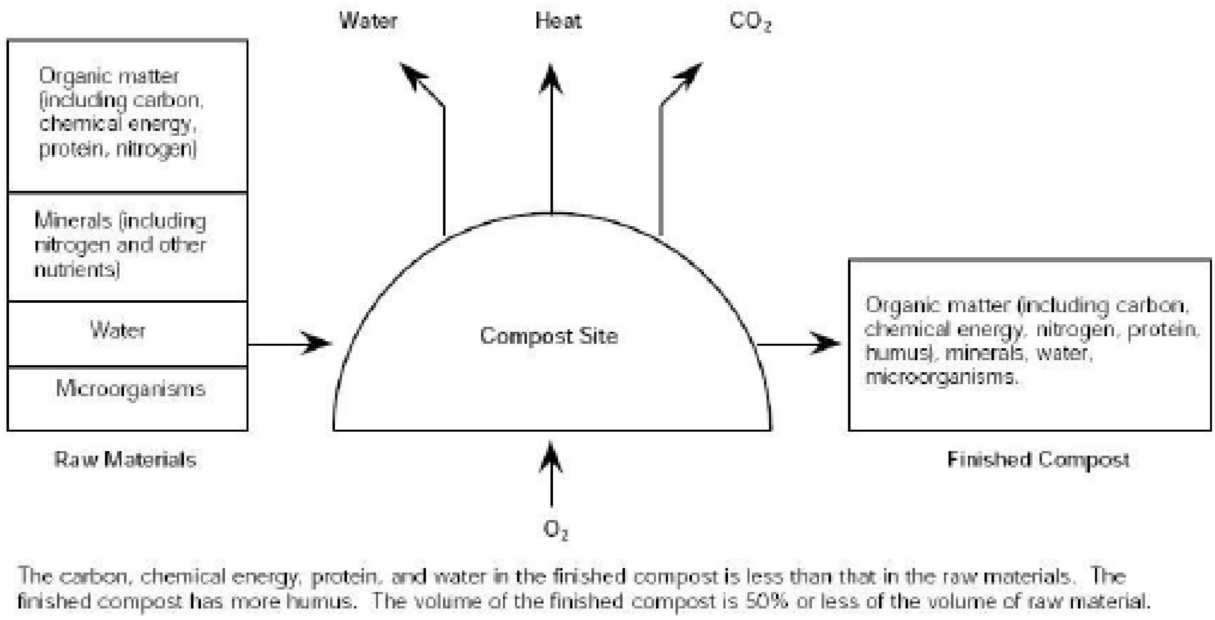

Figure 1: The composting process

Figure 2: Examples of DIY compost bins.

Annex 3: List of consultants and stakeholders involved and their contacts

	Name	Gender	Department	Position	E-mail
1.	Reagan Moses	M	CIE-CC	Director for CC/ TNA Project Coordinator	reagan.moses@gmail.com
2.	Dr. Michael Ha'apio	M	CIE-CC	TNA Adaptation Consultant	mhaapio@gmail.com
3.	Abraham Aremwa	M	CIE-CC	TNA Mitigation Consultant	abe.aremwa@rocketmail.com
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5.	Sereana Tagivakatini	F	Education	Strat. Plan Implement'n Manager	sereana.tagivakatini@gmail.com
6.	Haseldon Buraman	M	ECO Nauru	Director	haseldon@gmail.com
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20.	Zeth Jose	F	NFRMA	Officer	jzeth73@gmail.com
21.	Beuloria Derog	F	NFMRA	Officer	changeye07@gmail.com
22.	Evayne Gaubidi	F	CIE	IW R2R Officer	amomazegaubidi75@gmail.com

Annex 4: First TNA Workshop Program

NAURU TNA WORKSHOP PROGRAM

23 & 24 May, 2019

Venue: CIE Conference Room

Thursday 23 May, 2019

9.00am: Registration

9.30am: Opening prayer

9.35am: First National TNA Workshop Opening & Welcoming Speech
Speaker: **Reagan Moses** – Director for Climate Change; TNA Nauru Project Coordinator

9.45am **Overview of Workshop Sessions & Learning Outcomes**

Session 1: TNA Project Overview
Learning Outcome 1:
- To understand the basis, objective & process of a National TNA Project.

Session 2: Mitigation & Adaptation Sectors & Technologies
Learning Outcome 2:
- To be able to define, explain & differentiate mitigation & adaptation in terms of climate change.
- To be able to define, explain & identify sectors & their associated technologies in the context of climate change mitigation & adaptation.

Session 3: Multi-Criteria Analysis Tool
Learning Outcome 3:
- To be able to identify & categorise the selected technologies before applying them to the MCA.
- The purpose & how to implement a sensitivity analysis to the MCA.

Session One – TNA Project Overview

10.00am **TNA Project Introduction**
- *TNA origin, definition, objectives & deliverables, anticipated outcomes*

Presenter: **Reagan Moses** – National TNA Coordinator & Director for Climate Change

10.20am: Morning Tea

10.40am: **TNA Project Institutional Structure & Work Plan**
- *National TNA Team structure, roles & responsibilities*
- *Work plan*

Presenter: **Abraham Aremwa** – National Mitigation Consultant

11.10am: **TNA Project Process - Identification & Prioritization of Technologies**
- *Technology definition, selection process.*
- *MCA*

Presenter: **Michael Ha'apio** – National Adaptation Consultant

11.40am: **Learning Outcome 1 Evaluation**

12 – 1.00pm: LUNCH

Session Two – Mitigation & Adaptation Sectors & Technologies

1.00pm: **Mitigation Sectors & Technologies**

- *Sectors identified for Mitigation*
- *National Planning & Strategy Documents reviewed*
- *Mitigation Technologies identified*
- *Fact sheets presentation*

Presenter: **Abraham Aremwa** – National Mitigation Consultant

2.00pm: **Adaptation Sectors & Technologies**

- *Sectors identified for Adaptation*
- *National Planning & Strategy Documents reviewed*
- *Adaptation Technologies identified*
- *Fact sheets presentation*

Presenter: **Michael Ha'apio** – National Adaptation Consultant

3.00pm: Afternoon Tea

3.20pm: **Methodology Overview**

- *Tool introduction – MCA (Multi-Criteria Analysis)*
- *MCA for Mitigation example*
- *MCA for Adaptation example*

4.30 -5.00pm: **Learning Outcome 2 Evaluation**

Friday 24 May, 2019

Session Three – Multi-Criteria Analysis Tool

9.00am: **MCA for Mitigation**

10.00am: Morning Tea

10.20am: **MCA for Mitigation** (continue)

12 – 1.00pm: LUNCH

1.00pm: **MCA for Adaptation**

3.00pm: Afternoon Tea

3.20pm: **MCA for Adaptation** (continue)

4.00pm: **Technologies Identified & Prioritised through MCA**

- *Mitigation & Adaptation*

Presenters: **Mitigation & Adaptation Consultants**

4.30pm: **Nauru TNA Project Schedule**

- *Preparation & submission of 1st Report – **Technical Needs Assessment** due June 2019*
- *2nd Nauru TNA Working Group Workshop on **Barrier Analysis &Enabling** Framework – November 2019*
- *3rd Nauru TNA Working Group Workshop on **Technology Action Plan** (TAP) Q2 2020*

Presenter: **Reagan Moses** – National TNA Coordinator & Director for Climate Change

Annex 5: Second TNA Workshop Program

NAURU TNA WORKSHOP
Identification & Prioritization of Sectors & Technologies
Friday 14 June, 2019
Venue: CIE Conference Room

The main aim for this one-day workshop is to conclude; using the MCA tool, the climate technologies that were initially prioritized during our recent two-day workshop back in May 2019. Activities for the day will include:

(i) validating of the technology fact sheets; and
(ii) applying data from the fact sheets to the Multi-Criteria Analysis (MCA) tool for scoring.

Stakeholders are encouraged to bring along their laptops to load copy of the MS Excel-based MCA Tool.

Friday 14 June, 2019

9.00am: Registration

9.30am: Opening prayer

9.35am: Recap of topics discussed and the outcomes from our recent two-day TNA Workshop that was held on 23 & 24 May, 2019.

<u>Previous Workshop Sessions & Learning Outcomes</u>
Session 1: TNA Project Overview
Learning Outcome 1:

- Understand the basis, objective & process of a National TNA Project.

Session 2: Mitigation & Adaptation Sectors & Technologies
Learning Outcome 2:

- To be able to define, explain & differentiate mitigation & adaptation in terms of climate change.
- To be able to define, explain & identify sectors & their associated technologies in the context of climate change mitigation & adaptation.

Session 3: Multi-Criteria Analysis Tool
Learning Outcome 3:

- To be able to identify & categorise the selected technologies before applying them to the MCA.
- The purpose & how to implement a sensitivity analysis to the MCA.

10.00am: **Validating the Technology Fact Sheets**

A. Adaptation Technologies

	Sector	Technology Name
	Coastal Erosion Management	1. Construction of Barriers
		2. Locally Managed Areas
		3. Vegetation restoration
	Water	1. Manual Water Distribution
		2. Non-potable Water Access
		3. Rainwater Harvesting System
		4. Water Reticulation

B. Mitigation Technologies

	Sector	Technology Name
	Solid Waste Management	1. Semi-aerobic Landfill – Fukuoka System
		2. Household Sorting (segregation)
		3. Industrial Baling
		4. Household Composting
	Renewable Energy	1. Pumped Hydroelectric System
		2. Household Biogas System
		3. Ocean Thermal Energy Conversion (OTEC)
		4. Roof-top Grid-connected Solar PV System

11.00am Morning Tea

11.15am **Multi-Criteria Analysis (MCA) Session**

A. Adaptation Technologies
B. Mitigation Technologies

01.00pm Lunch

02.00pm **MCA Session (continue)**

03.00pm Afternoon Tea

03.15pm **MCA Session (continue)**

04.30pm **Discuss the outcome of the analysis (MCA)**

Nauru TNA Project Schedule

- Barrier Analysis and Enabling Framework Identification (Oct-Nov 2019)
- Technology Action Plan (Apr-May 2019)

Annex 6: The process in normalising the performance matrix table

The process in normalising the performance scoring matrix table results is achieved by utilising either one of the following equations. Where '100' is regarded as the most preferred value for a certain criteria then the Eq. 1 below is used.

$$Yi = \frac{Xi - Xmin}{Xmax - Xmin} \times 100 \qquad \text{(Eq.1)}$$

Where '0' is regarded as the most preferred value for a certain criteria, Eq. 2 is used.

$$Yi = \frac{Xmax - Xi}{Xmax - Xmin} \times 100 \qquad \text{(Eq.2)}$$

Here: *Yi* – score of option *i*; *Xi* – performance of option *i*; *Xmax, Xmin* – the highest and the lowest performance among all the options. This process is automatically calculated (in the actual MCA spreadsheet) for each criterion and results entered into the Normalised scoring matrix table