Fiji

TECHNOLOGY NEEDS ASSESSMENT REPORT MITIGATION

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This publication is produced by Fiji's National Technology Needs Assessment (TNA) team and the Ministry of Economy, which who are also the UNFCCC's National Designated Entity and Focal Point for the Fijian Government. It is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UN Environment) and the UNEP DTU Partnership (UDP) in collaboration with the University of the South Pacific. The views expressed in this publication are those of the authors and do not necessarily reflect the views of UDP, UN Environment or the University of the South Pacific. We regret any errors or omissions that may have been unwittingly made.

FOREWORD

As a Small Island Developing State, Fiji is severely impacted by both the slow and sudden onsets of climate change induced by global dependence on unsustainable fossil fuels. Rising sea levels engulfing low-lying coastal communities, saltwater intrusion reducing arable land, changing weather patterns impacting food security, and catastrophic cyclones reversing years of development progress while threatening fiscal stability are major climate-induced adversities Fiji faces. These adversities tremendously impact sustainable livelihoods, security and well-being and contribute to an increased incidence of poverty and undue pressure on social services.

These vulnerabilities present the apparent need for enhanced climate adaptation and resilience. While Fiji's National Adaptation Plan provides the strategy to reduce climate vulnerability, the need to identify relevant technologies to facilitate the implementation of this plan has never been so urgent. Fiji is also committed to transitioning towards a low-carbon future in line with its 5-year and 20-Year National Development Plan, its NDC commitments under the Paris Agreement and its Low Emission Development Strategy 2018-2050. Enhancing investments in resilient renewable solutions now will reduce the need for increased climate adaptation in the future. Additionally, minimum dependence on non-renewable energy would ultimately free up fiscal resources for investments in climate adaptation and socio-economic development while improving macro-economic stability.

Urgent climate action is imperative for Fiji to achieve its development aspirations. However, this is hindered by slow technological mobilisation coupled with inadequate knowledge transfer and limited financial capacity, all of which exacerbate systemic failures in addressing key drivers of climate vulnerability and inaction. This Technology Needs Assessment (TNA) process is fundamental in helping to bridge this gap and ascertain the technological needs for transformative climate adaptation and mitigation initiatives at the national and sub-national level.

In this regard, the Fiji TNA has been developed through extensive stakeholder engagements with Government agencies, private sector, financial institutions, academia, project developers and local technology experts. This collaborative approach enabled the identification of various technology needs for the agriculture sector and low-lying coastal communities that, according to the National Adaptation Plan and Fiji's Climate Vulnerability Assessment, are amongst the most climate-vulnerable sectors in Fiji. From a mitigation perspective, the Fiji TNA takes a two-pronged approach of increasing access to renewable energy and reducing economy-wide dependence on fossil fuels to identifying rural electrification and greening domestic maritime shipping as priority sectors for Fiji's TNA.

Fiji is proud to have completed its TNA as a proactive step towards effective resource mobilisation for climate action. We look forward to undertaking further assessments to identify technological gaps and operationalise Fiji's TNA by developing sectorial Technology Action Plans as the next important step in the process. Technology is regarded as humankind's greatest enabler against perils, and Fiji stands ready to harness this potential in order to address the adversities of climate change.

Makereta Konrote
Permanent Secretary for Economy

ACRONYMS

ALOFU	Agriculture, Forestry, and Other Land Use
BAU	Business-As-Usual
CCICD	Climate Change and International Cooperation Division
CNO	Coconut oil
COP	Conference of Parties
DTU	Denmark Technical University
ESS	Energy Storage Systems
FDoE	Fiji Department of Energy
EFL	Energy Fiji Limited
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Gigagrams
GGF	Green Growth Framework
GHG	Greenhouse Gas
GloMEEP	Global Maritime Energy Efficiency Partnership
GSS	Government Shipping Service
GWP	Global Warming Potential
IMO	International Maritime Organization
INC	Initial National Communication
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LED	Light-emitting Diode
LEDS	Fiji Low Emission Development Strategy
LPG	Liquefied Petroleum gas
MCA	Multi-Criteria Analysis
MCST	Micronesian Center for Sustainable Transport
MDG	Millennium Development Goals
MoIT	Ministry of Infrastructure and Transport

MSAF	Maritime Safety Authority of Fiji
NAP	National Adaptation Plan
NCCP	National Climate Change Policy 2018-2030
NEP	National Energy Policy
NDC	Fiji's Nationally Determined Contribution
NDP	5-Year & 20-Year National Development Plan – (2017-2036)
PBCF	Propeller Boss Cap Fins
PCCPP	Peoples Charter for Change, Peace and Progress
PIESAP	Pacific Islands Energy and Strategic Action Plan
PV	Photovoltaic
RDSSED	Roadmap for Democracy and Sustainable Socio-Economic Development
REBREPPE	Renewable Energy Based Rural Electrification with Participation of Private Enterprise
RESCO	Renewable Energy Service Companies
REP	Rural Electrification Policy
REU	Rural Electrification Unit
SAR	Second Assessment Report
SC	Steering Committee
SDG	Sustainable Development Goals
SE4ALL	Sustainable Energy for All
SHS	Solar Home Systems
SNC	Second National Communication
TA	Thematic Areas
TFS	Technology Factsheets
TNA	Technology Needs Assessment
TNC	Third National Communications (draft)
UDP	UNEP-DTU Partnership
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
WG	Working Group

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EXECUTIVE SUMMARY

A Technology Needs Assessment (TNA) is a set of activities that identify and analyse technology priorities for mitigation and adaptation of developing countries such as Fiji. The TNA project has allowed Fiji to identify climate technology pathways that assist in the implementation of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The process is country-driven, requiring heavy stakeholder engagement and local capacity building. The scope and depth of the Fiji TNA is well aligned to our national development objectives and allows national stakeholders to explore synergies with other national processes, striving towards the implementation of Nationally Determined Contributions and National Adaptation Plans.

The TNA is entailed in a three-stage process and has three key objectives:

a) To identify and prioritise mitigation and adaptation technologies for selected sectors;

b) To identify, analyse and address barriers hindering the deployment and diffusion of the prioritised technologies, including the enabling framework for these technologies;

c) To conduct a Technology Action Plan, which is a medium/long-term plan for increasing the implementation of identified technologies, based on the inputs obtained from the previous two steps. The Technology Action Plan outlines actions to be undertaken.

Fiji's TNA is focused on agriculture and coastal communities as priority sectors under the adaptation component of the project. On the mitigation forefront, the sectors selected to undergo a needs assessment included domestic maritime shipping and rural electrification. The sectors undergone assessment were informed by national policies and selected by the technical team at the Climate Change and International Cooperation Division (CCICD). CCICD has the responsibility of mainstreaming development in Fiji that is related to climate change mitigation and adaptation. As part of this first deliverable of the three in this process, the national consultants prepared technology factsheets (TFS) for several technologies with the assistant of sectoral experts. Technologies were streamlined by the technical working group before being presented before a wider national stakeholder audience. Three technologies prioritised under each sector underwent a thorough selection and scoring process. This selection process was referred to as the Multiple Criteria Analysis (MCA). The MCA is an 8-step process involving: (1.) providing decision context on the sectors; (2.) identifying technologies; (3.) identifying objectives and criteria; (4.) scoring; (5.) weighting of criteria; (6.) combing scores and weights; (7.) examination and validation of results; and (8.) sensitivity analysis based on the social, economic and environmental aspects needed for the successful implementation of the technology. To validate the results, the outcomes of the MCA underwent a sensitivity analysis repeating steps 4 to 7 of the MCA.

Fiji is a group of 332 or so islands dispersed over 1.3 million km^2 of the Ocean, with a national population of 884, 887 people, 55.9% of whom live in urban areas and 44.1% of whom reside in rural communities including islands and highlands. Fiji's contribution to global greenhouse-gas emissions is insignificant in comparison to our level of vulnerability due to climate change. Some of our key challenges as an archipelago country include inter-island travelling, food security, rising tides and sea levels, and providing Fijians living in remote areas with basic electricity. Hence the choice of sectors for our TNA.

A comprehensive stakeholder engagement process was required to undertake the country-driven technology needs assessment. The heart of this stakeholder engagement process lay in bilateral between stakeholders on the TFS, email exchanges, and workshops to enhance understanding and transfer vital information about the sector plans and priorities. While the comprehensive reports on the TNA for mitigation and adaptation have been presented as two separate reports, this summary will shed light on the technologies that have been prioritised by the people of Fiji. The technologies will contribute to and enhance the Fijian Government's ongoing efforts in ensuring a resilient and low-carbon economy.

For the 34% rural homes that are dependent on off-grid electricity, the technologies prioritised include: standalone ground mount solar PV with ESS (community based electrification - micro-grids); ground mount PV with dual fuel (CNO/diesel) generator hybrid systems with ESS; and micro/pico-hydro in micro grid configuration., Similarly, for domestic maritime shipping the most preferable and prioritised technologies included: propulsion (main) engine replacement; propeller boss cap fins (PBCF); and bilge keel optimisation. These technologies will contribute towards achieving Fiji Nationally Determined Contributions (NDCs) and Low Emission Development Strategy (LEDS) under the Paris Agreement.

The results and outcomes from the prioritisation exercise will next undergo a barrier assessment in the implementation of prioritised technologies and the preparation of technology action plans for the deployment of these technologies.

CHAPTER 1: INTRODUCTION

1.1 ABOUT THE TNA PROJECT

The Technology Needs Assessment (TNA) process originated from the Poznan Strategic Programme on Technology Transfer established at the Fourteenth Conference of the Parties (COP 14) to the United Nations Framework Convention on Climate Change (UNFCCC), with the purpose to scale up investment in technology transfer thus empowering developing countries to address their requirements for environmentally sound technologies.

In February 1993, Fiji ratified the United Nations Framework Convention on Climate Change (UNFCCC) as a Non-Annex I Party and later, in September 1998, Fiji ratified the Kyoto Protocol. Under the agreement, Fiji is committed to submitting the National Communication Reports comprising greenhouse gas (GHG) inventories, identification of vulnerable sectors and actions that need to be taken for sustainable future socio-economic development without further increase in GHG emissions. The Initial National Communication (INC) was presented to the UNFCCC in 2005. After the submission of Fiji's INC, the key development was the launch of the cabinet-approved National Climate Change Policy in 2012. Then the Second National Communication (SNC), which was a follow up to the INC and built on and continued the work under the convention, was completed in 2013.

Fiji embarked on achieving eight Millennium Development Goals by the year 2015 in keeping with its adoption of the United Nations Millennium Declaration in the year 2000. With the focus on a global development with-and-for sustainability, the Sustainable Development Goals (SDGs) emerged in 2015 with 17 goals that were demarcated and refined, to a certain extent, from the predecessor MDG goals with the achievement target year of 2030. Additionally, in September 2017, Fiji became a signatory to the Doha Amendment, under Annex I of which signatories are to ensure that their aggregate GHG emissions do not exceed the assigned amounts, with a view to reducing their overall emissions at least by 18% below 1990 levels during the second amendment period (2013-2020). This ratification of the Doha Amendment not only aligns Fiji's laws and practices with international standards, but also solidified Fiji's commitment to reducing GHG emissions.

TNA is also referenced in the Paris Agreement (Article 10) and plays a key role in the new Technology Framework under the UN Climate Change Convention. This TNA project highly complements the efforts made by the Fijian government in undertaking measures to combat climate change with the aim to unveil new and additional information in shaping our future plans for climate action interventions.

A TNA is a country-driven process, grounded in national sustainable development plans, building national capacity and facilitating the analysis and prioritization of climate technologies to support the implementation of the UNFCCC Paris Agreement. TNAs are central to the work of Parties to the Convention on technology transfer and present an opportunity to track evolving needs for new equipment, techniques, and practical knowledge and skills, which are necessary to mitigate greenhouse gas emissions and reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change. The enhancement of technology development and its transfer, deployment, and dissemination is a key pillar of the international response to climate change.

The Cabinet officially endorsed Fiji's participation in the third phase of the Technology Needs Assessments (TNA Phase III) Project (GEF-6, 2017) in January 2019. This was followed by the signing of a Memorandum of Understanding with UNEP DTU Partnership (UDP) for conducting a Technology Needs Assessment Project in Fiji in February 2019. The scope and depth of the TNA are well aligned to national development objectives and allow national stakeholders to explore synergies with other national processes, striving towards the implementation of Fiji's Nationally Determined Contributions and National Adaptation Plan.

The TNA is a three-stage process and has three key objectives:

a) To identify and prioritise mitigation and adaptation technologies for selected sectors;

b) To identify, analyse and address barriers hindering the deployment and diffusion of the prioritised technologies, including the enabling framework for these technologies; and

c) To conduct, based on the inputs obtained from the previous two steps, a Technology Action Plan, which is a medium/long term plan for increasing the implementation of identified technologies. The Technology Action Plan outlines actions to be undertaken.

1.2 EXISTING NATIONAL POLICIES ON CLIMATE CHANGE MITIGATION AND DEVELOPMENT PRIORITIES

The islands in the Fiji group are very susceptible to the effects of climate change and have been experiencing the impacts of extreme weather events. The frequencies of such extreme events together with the associated risks are projected to increase as a result of climate change. It is important to understand the geographical context of the Fiji Islands to understand the holistic view of Fiji's National Development Policies, mitigation strategies and the development priorities.

Fiji is an archipelago consisting of more than 332 islands dispersed over 1.3 million km^2 of the ocean in the South Pacific region. Out of this, 110 islands are permanently inhabited, with diverse landscapes and climate. The islands are characterized by diverse ecosystems including significant areas of natural forest and wide ranges of coastal and marine ecosystems from broad expanses of mangroves to various coral reef formations. The two largest islands are Viti Levu and Vanua Levu. Viti Levu is the largest island, and together, these islands comprise 87% of the total land area.

Under the UNFCCC and IPCC's categories, being a small island nation, Fiji is categorised as a 'vulnerable' small island nation under serious threat from various climate change impacts, including the rise in sea level and extreme weather events *i.e.*, floods and droughts (IPCC, 2001; UNFCCC, 1992). With many low-lying islands and coastal agricultural, industrial and residential zones, the projected climate change and sea-level rise could have drastic impacts, hence strategic and prudent policies and planning are a necessity. Over the last two decades, Fiji has made a significant contribution towards strengthening national policy, legal and institutional capabilities, thus creating an enabling environment for implementation of the obligations under UNFCCC.

To mitigate the impacts and reduce GHG emissions, Fiji developed its first National Energy Policy (NEP), which got Cabinet's approval in 2006. The NEP was developed with guidance from Pacific Islands Energy and Strategic Action Plan (PIESAP) (Government of the Republic of Fiji, 2014). The key strategies were to i) Promote the development of indigenous energy sources such as hydropower, geothermal, solar, wind and biomass; ii) Promote energy efficiency and energy conservation in all sectors; and iii) Strengthen energy security and improve energy supply mix for the country (Department of Energy, 2006). The NEP-2006 was reviewed and the report finalised in 2013 by Economic Consulting Associates Limited (2013) to reflect the recent changes and trends in the energy sector. Later, in 2013 the updated draft National Energy Policy (NEP) was formulated, which was led by the Fiji Department of Energy (FDoE) with the assistance of an advisory committee (Fiji Department of Energy, 2013).

The draft NEP is the product of the Fijian government's strategic directions as stipulated in the Roadmap for Democracy and Sustainable Socio-Economic Development (RDSSED) 2010-2014, with the Fijian Government envisioning the energy sector to be resource-efficient, cost-effective, and environmentally sustainable. The draft NEP is further aligned with the People's Charter for Change, Peace, and Progress (PCCPP) and the Sustainable Energy for All (SE4ALL) rapid assessment and gap analysis initiative of the United Nations. Keeping all this in the background, the objectives of draft NEP-2013 are:

i. To provide all Fijians with access to affordable and reliable modern energy services with an aim of a100% electrification rate;
ii. To establish environmentally sound and sustainable systems for energy production, procurement, transportation, distribution, and end-use; and
iii. To increase the efficient use of energy and the use of indigenous energy sources to reduce the financial burden of energy imports on Fiji (Fiji Department of Energy, 2013).

The draft NEP-2013 further aims to encourage non-governmental involvement in rural electrification and also aims to improve the effectiveness and sustainability of the existing management models for off-grid rural electrification including Renewable Energy Service Companies (RESCO) and community cooperatives being used to provide electricity to isolated communities and areas not served by the grid extensions (Fiji Department of Energy, 2013). It also seeks to promote research on new renewable energy technologies and the potential and cost-effectiveness of energy efficiency and renewable energy solutions for maritime vessels.

Additionally, the Green Growth Framework (GGF-2014) intends to support and complement the PCCPP and the RDSSED 2010-2014, sharing the same vision of ‘A Better Fiji for All’ (Ministry of Strategic Planning National Development and Statistics, 2014). There are three pillars enshrined in GGF-2014, Environment, Social and Economic, which are further demarcated into ten thematic areas (TA). The imperative TAs pertaining to TNA are Building Resilience to Climate Change and Disasters (TA-1); Energy Security (TA-7); Sustainable Transportation (TA-8); and Technology and Innovation (TA-9). The overall manifestation of the GGF-2014 is to reduce carbon ‘footprints’ at all levels, developing a new integrated approach, with all stakeholders collaborating and collectively working together for the common good that will prompt harmony and synergy in the formulation of strategies (Ministry of Strategic Planning National Development and Statistics, 2014).

In further pursuit of achieving a low carbon economy, Fiji launched its first 20-Year National Development Plan – NDP (2017-2036) and a comprehensive 5-Year Development Plan (2017-2021) (Ministry of Economy-The Republic of Fiji, 2017). The vision of NDP is ‘Transforming Fiji’ towards an even more progressive, vibrant and inclusive society. The 5-Year Development Plan works in sync with the 20-Year Development plan; the former provides a detailed action agenda with specific targets and policies, while the latter is the long-term transformational plan. The Plan consists of two mutually inclusive and reinforcing prongs/approaches *viz*., ‘Inclusive Socio-economic Development’ and ‘Transformational Strategic Thrusts’. In achieving socio-economic development and subsequently improving the living standards of Fijians, the NDP intends to achieve sustained economic growth with an increase in per capita GDP, reduced government debt, a reduced unemployment rate, eradicated poverty, and provision of electricity to 100% of the population by 2036. It also intends to eliminate gender inequality and discrimination by having more women partaking in development.

1.2.1 Fiji’s Nationally Determined Contribution (NDC)

Prior to the Conference of the Parties (COP 21) in 2015, the Fijian Government outlined and prepared its Intended Nationally Determined Contribution (INDC). Fiji was the first country to ratify the Paris Climate Change Agreement, on 22nd April 2016, and developed the NDC Implementation Roadmap 2017-2030 in 2017 (Ministry of Economy - Republic of Fiji, 2017). Fiji’s current NDC is specific to the energy sector, with the baseline year as 2013.

The NDC outlines the potential mitigation actions including CO_2 abatement from electricity, industry, and transportation. The overall mitigation target in the NDC is to reduce CO_2 emissions by 30% from a Business as Usual (BAU) baseline scenario in 2030 in comparison to baseline year – 2013. The government is striving to reach 100% renewable energy power generation, including through economy-wide energy efficiency. The current share of renewable electricity generation hovers around 45-60%. The financing needs together with the progressive pathway on mitigation are expressed in the NDC Implementation Roadmap (2017-2030).

1.2.2 Fiji Low Emission Development Strategy

This Fiji Low Emissions Development Strategy (LEDS) serves as Fiji's vision of, and a pathway towards, a sustainable, resilient low-carbon economy. As articulated in the Paris Agreement to hold "the increase in the global average temperature to 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change", the LEDS depicts Fiji's contributions in achieving the global climate action goal.

The LEDS essentially builds onto existing mitigation and adaptation actions that are being undertaken by the Fijian government and it defines pathways through which Fiji aims to reach net-zero carbon emissions by 2050 across all sectors of its economy. This is the central aim of the LEDS. The LEDS essentially sketches ambitious scenarios and systematic top-down and bottom-up approaches in developing an economy-wide plan to deeply decarbonize all sectors of Fiji's economy by or before 2050. A logical approach is adopted in developing sector-by-sector pathways to decarbonization via modeling of baseline scenarios to achieve decarbonization in each sector (Ministry of Economy, 2018), in comparison to the scenarios associated with i) Business-As-Usual (BAU) Unconditional pathways (undertaken domestically); ii) BAU Conditional pathways (requiring international support); iii) High Ambition Scenario and iv) Very High Ambition scenario. The focus of the LEDS is primarily on mitigation rather than adaptation, which is the key focus of Fiji's National Adaptation Plan. The sectors included in the LEDS were; a) electricity and other energy generation and use; b) land transport; c) domestic maritime transport; d) domestic air transport; e) agriculture, forestry, and other land use (AFOLU); f) wetlands (i.e., coastal wetlands, also referred to as blue carbon); g) waste; and h) the cross-cutting sectors of tourism, commerce, industry, and manufacturing.

The scenarios elaborated in the LEDS are expected not only to decarbonize the economy, but also to make Fiji's economy more innovative, sustainable and resilient by leveraging a variety of sustainable development and adaptation co-benefits of mitigation actions (Ministry of Economy, 2018). The transition to a low-carbon economy is critical for Fiji in meeting the government's development objectives as elaborated in the 5 & 20-Year Development Plan – NDP (2017-2036) and the Green Growth Framework (GGF-2014), as well as the internationally agreed Sustainable Development Goals (SDGs) and the 2030 Sustainable Development Agenda. Furthermore, the LEDS is expected to provide a point of reference against which short- and medium-term planning will be measured, including national development planning and new or revised NDCs to be submitted to the UNFCCC (Ministry of Economy, 2018).

1.2.3 Evolution of Fiji's National Climate Change Policy

All in all, the overarching national policy on climate change, i.e., National Climate Change Policy, was initially developed in 2007 (2007-NCCP) for proper environment and natural resources management in ensuring future social and economic prosperity (Government of the Republic of Fiji, 2014). The 2007-NCCP materialized from the foundations of the Climate Change Policy Framework, which was also in line with the RDSSED (2009-2014). It bears the theme "A Better Fiji for All" and focusses on capacity building among low-income households. The 2007-NCCP was reviewed in 2011 such that the revised version could incorporate the recent and emerging climate change issues at the local, national and international levels and was approved in 2012 (Government of the Republic of Fiji, 2014). This 2012-NCCP provides a guiding framework on issues pertaining to climate change in terms of national planning, policy formulation, awareness-raising, adaptation, mitigation and financing, while encouraging the incorporation of scientifically and technically sound information together with traditional knowledge into decision making (Government of the Republic of Fiji, 2012). Particularly, the mitigation component of the 2012-NCCP concentrates on the reduction of imported fossil fuel for the transport sector via efficiency as well as for electricity generations via development of renewable energy sources including solar, wind, hydro, biofuel and biomass (Government of the Republic of Fiji, 2012). Furthermore, the 2012-NCCP provides a platform for coordination among sectors and direction on national positions and priorities regarding climate change mitigation and adaptation. The implementation framework of the policy has allowed Fiji to develop a Coordination Guideline, Finance Guideline and Relocation Guideline that will enable the policy to achieve its goals in addressing climate change in Fiji.

With the recent intensification of climate change threats, the Government of Fiji saw the need to endorse a revised National Climate Change Policy 2018-2030 (NCCP) in 2019. The NCCP takes a woven approach that integrates development priorities in a strategic and cohesive manner to reinforce the priorities outlined in the NDP and SDGs and aims to provide a long-term direction to climate change response mechanisms for Fiji. Resilient development as defined in the NCCP entails GHG mitigation and net-zero transition, environmental protection, economic and social development, climate change adaptation and disaster risk reductions within a three-pillared structure of objectives and strategies: i) Foundation, ii) Dimensions and iii) Pathways. The NCCP is largely driven towards Vision 2050, which envsions *"a resilient and prosperous Fiji, in which the wellbeing of current and future generations is supported and protected by a socially inclusive, equitable, environmentally sustainable, net-zero emissions economy.*" (The Government of Fiji, 2019).

Hence, a whole-of-Government approach was adopted by Fiji to reduce GHG emissions and achieve the SDGs,. With the vision of transforming Fiji, the Fijian Government launched its 5-Year & 20-Year National Development Plan (NDP) in 2017, after a nationwide consultation process. Fiji also outlined the Intended National Determined Contributions and later developed the Nationally Determined Contributions for GHG emissions reductions, with the NCCP serving as the overarching and interwoven approach to resilient development. As a result, Fiji is committed to reducing GHG emissions via adoption and implementations of climate-smart technologies, renewable energy, and energy-efficiency approaches.

1.3 SECTOR SELECTION

The baseline for the selection of the priority mitigation sectors for Fiji was Fiji's Second National Communication to the UNFCCC (SNC-Fiji), aligned with the National Climate Change Policy (NCCP), Green Growth Framework (GGF-2014), 5 & 20-Year Development Plan – NDP (2017-2036), the Nationally Determined Contribution NDC Implementation Roadmap 2017-2030, the Fiji Low Emissions Development Strategy (LEDS) and the most recent draft of the Third National Communications. The SNC report submitted to the UNFCCCC secretariat in 2013 presents the country's GHG inventory for the year 2004. The country built on this in preparing Fiji's NDC, and the recent LEDS document sheds light and devices proposed strategies that can possibly decarbonize the Fijian economy based on participatory and modelling approach, while the NCCP, NDP and GGF provide a supporting framework in achieving a carbon-neutral economy in conjunction with sustained economic growth and development.

1.3.1 An overview of sectors, projected climate change, and GHG emissions status and trends of the different sectors

Fiji's national GHG inventories presented to the UNFCCC, including the Initial National Communication (INC) in 2005 [based on 1994 data], the Second National Communication (SNC) [based 2004 data] and the current draft Third National Communications (TNC) based on data from 2006-2011 reporting period, are presented in Figure 1.1. In the INC, the total GHG emissions are relatively low, with a gradual increase peaking in 2004-2005 and then a decrease in the current reporting period.

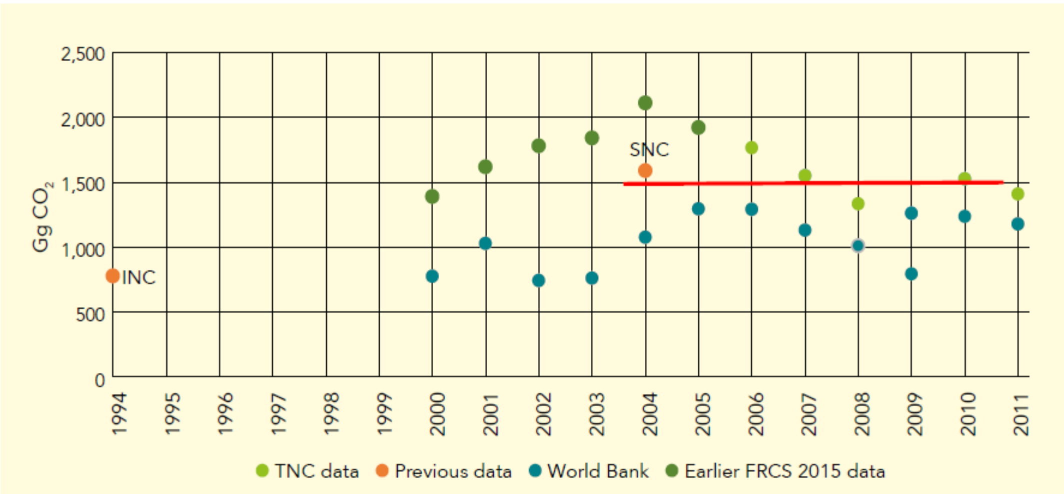

Figure 1.1: Comparison of GHG emissions between TNC, SNC, INC and World Bank data in a time-series layout (Republic of Fiji, 2019). FRCS - Fiji Revenue and Customs Services

Both the INC and SNC inventories were based on limited datasets and may have underestimated national GHG emissions, as they both lacked data from CO_2 emissions calculated from the agriculture and the waste sectors. It must also be noted that the values pertaining to CH_4 and N_2O emissions reported in the SNC were calculated using the Global Warming Potential (GWP_{100}) values listed in the Second Assessment Report (SAR), published by the IPCC in 1995. These GWP values were 21 and 310 for CH_4 and N_2O, respectively (IPCC, 1995). The more recent values from the 2014 Fifth Assessment Report (AR5) are 28 for CH_4 and 265 for NO_2 over a 100-year time-horizon (IPCC, 2013).

As per the TNC, Fiji's main GHG emissions consist mostly of carbon dioxide (CO_2) from the energy sector, with smaller amounts of methane (CH_4) and nitrous oxide (N_2O) from agriculture and waste (Figure 1.2).

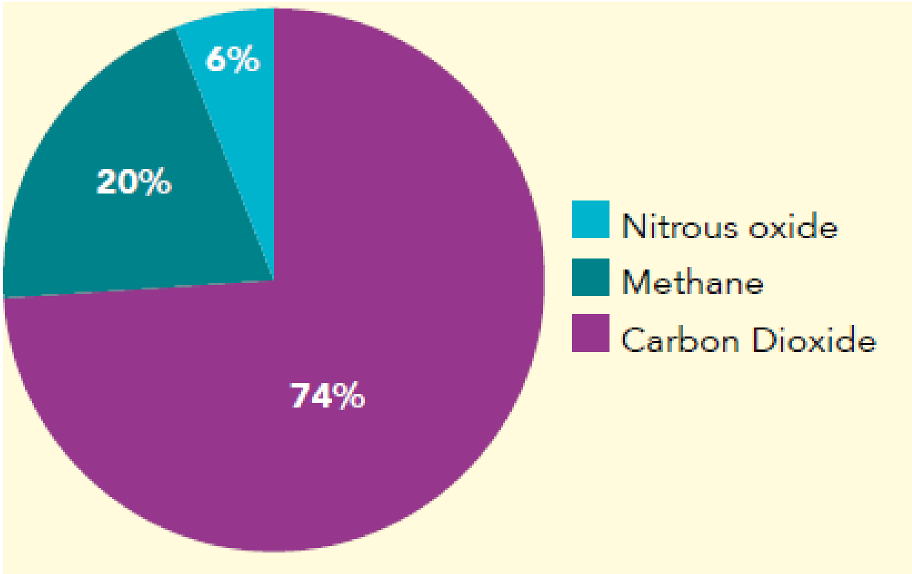

Figure 1.2: GHG emissions by gas type (Republic of Fiji, 2019).

In addition, the sectors were disaggregated as shown in Figure 1.3, which illustrates Fiji's Total GHG emissions by sector per annum over the reporting period. It shows that the energy sector is the largest emitter of GHGs, with 64% of this sector's emissions attributable to transportation, which is approximately 39% of overall emissions (Republic of Fiji, 2019). Both the INC (based on 1994 data) and the SNC (based 2004 data) also showed that the largest contributor of GHG emissions was the Energy sector, representing between 59.6% (SNC) equating to 1570 Gg CO_2eq and 55.7% (INC) equating to 776 Gg CO_2eq.

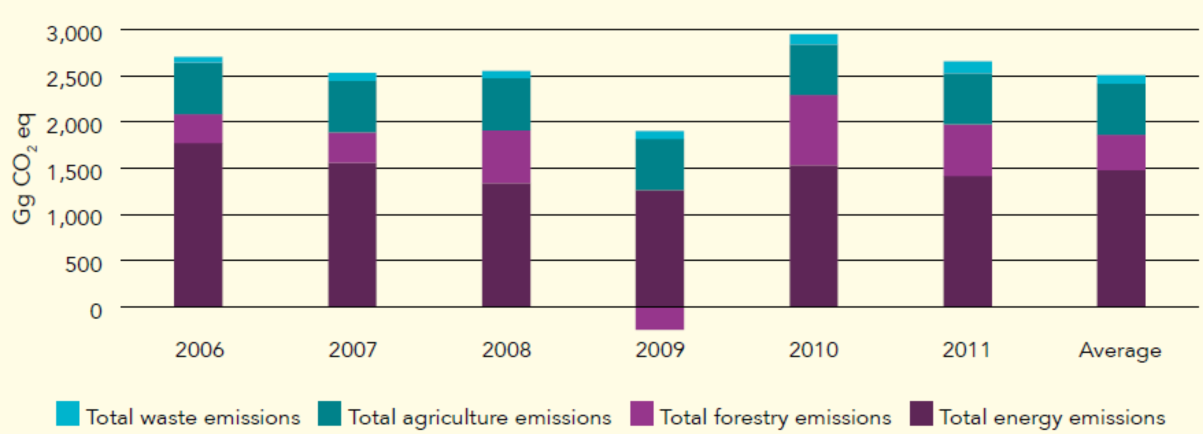

Figure 1.3: Fiji's Sectoral Total GHG Emissions (Republic of Fiji, 2019).

The TNC further shows that Forestry emissions were assessed to be slightly positive at around 400 Gg p.a. while the overall estimated emissions fluctuated around 2500 Gg p.a. throughout the reporting period (Republic of Fiji, 2019). In SNC, the main source of CO_2 emissions was found to be fuel combustion, of which the largest chunk was emitted by the transport sector, accounting for approximately 47% of total emissions (Government of the Republic of Fiji, 2014). An average GHG emission over the period from 2006 to 2011 is also presented in Figure 1.4, and the averaged data also shows that the Energy sector is the predominant emitter.

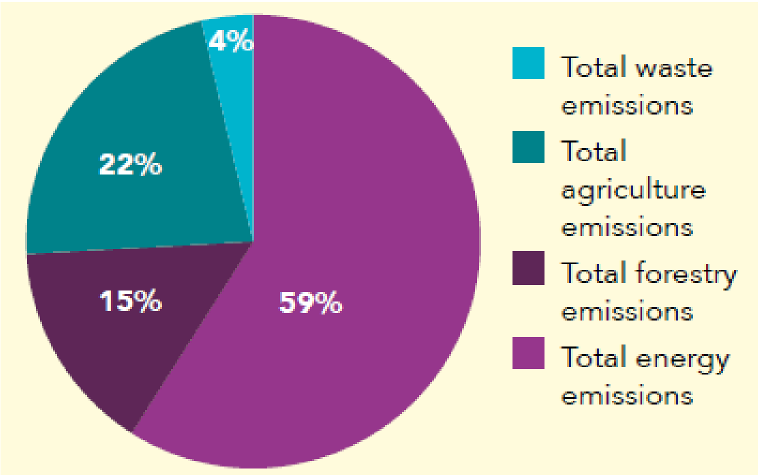

Figure 1.4: Average GHG emissions over the reporting period (2006-2011) (Republic of Fiji, 2019).

To further its commitment to addressing the climate-induced calamities faced by Small Island Developing States, prior to COP 21 in 2015 the Fijian Government issued the iNDC, which later was addressed in the Nationally Determined Contributions Implementation Roadmap (NDC-IR) of Fiji. The government has set a target of 30% reduction in emissions from the Business-As-Usual (BAU) baseline for the period of 2020 to 2030. A emission reduction total of 627 000 tCO_2 per annum is projected (Ministry of Economy - Republic of Fiji, 2017). The NDC-IR is closely aligned to existing national policies, strategies and plans, while the mitigation actions under the energy sector are divided among the three sub-sectors of Electricity Generation and Transmission, Demand-Side Energy Efficiency, and Transportation.

Out of the 30% reduction of BAU baseline CO_2 emissions, the Fijian government expects that 10% of the business-as-usual (BAU) baseline emissions mitigation will be achieved "unconditionally" using available resources in the country, and 20% achieved "conditionally" (Ministry of Economy - Republic of Fiji, 2017) as shown in the Figure 1.2 below.

For electricity generation, the NDC focusses on the integration of renewables into grid electrification including hydro, solar PV generation, Waste to Energy, biomass, wind, geothermal, and wastewater treatment and biogas. An ambitious endeavour of 100% electrification by the year 2036 is targeted in the sub-sector of rural electrification despite the complexity resulting from the geographically dispersed nature of the maritime population, which makes grid extensions exorbitantly expensive. In terms of transportation, the mitigation actions include vehicle replacement programmes for land transport, while the mitigation actions for maritime transportation include improved maintenance for sea vessels, increased utilisation of fuel-efficient outboard motors, and alternative propulsion systems.

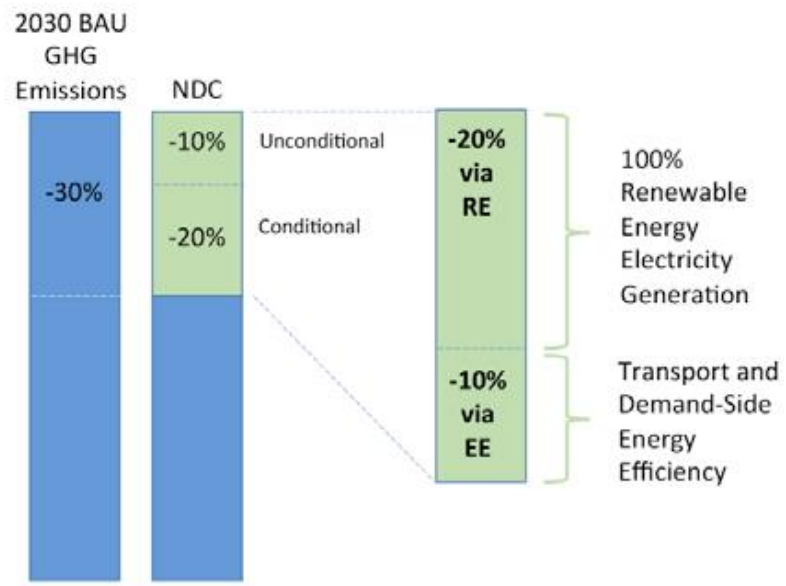

Figure 1.5: Mitigation commitments as depicted in the NDC under unconditional/conditional contributions for renewable energy electricity generation and transport and demand-side energy efficiency [Source: Ministry of Economy - Republic of Fiji (2017)].

To further affirm its actions, the Fijian government developed the LEDS after an extensive stakeholder consultation, analysis, and modelling of different scenarios for each sector including electricity and other energy use; land transport; domestic maritime transport; domestic air transport; agriculture, forestry, and other land use (AFOLU); waste; and coastal wetlands (blue carbon). Using the whole-of-economy emission reductions approach, it was seen that under the Very High Ambition scenario, net-zero emissions can be achieved during the year 2041, and the emissions would increasingly become net-negative thereafter. Table 1.1 and the subsequent Figure 1.6 illustrate these.

To achieve this core objective of net-negative emissions, the LEDS has elaborated four possible low-emission scenarios for Fiji as:

i. A "**Business-as-Usual (BAU) Unconditional scenario**," which reflects the implementation of existing and official policies, targets, and technologies that are unconditional in the sense that Fiji would implement and finance them without reliance on external or international financing.

ii. A "**BAU Conditional scenario**," which reflects the implementation of existing and official policies, targets, and technologies that are conditional in the sense that Fiji would rely on external or international financing to implement mitigation actions; thus this scenario would have a higher ambition than "BAU Unconditional."

iii. A "**High Ambition scenario**" projects ambitions beyond those already specified in policies, relying on the adoption of new, more ambitious policies and technologies and availability of additional financing to implement mitigation actions, and achieves significant emission reductions by 2050 compared with the business-as-usual scenarios.

iv. A "**Very High Ambition scenario**" projects ambitions well beyond those already specified in policies, thus relying on the adoption of new, significantly more ambitious policies and availability of new technologies and additional financing to implement mitigation actions, and in which most sectors achieve net zero or negative emissions, by 2050.

(Ministry of Economy, 2018)

Table 1.1: Total Net Emissions for Fiji under four LEDS scenarios (all values in metric tonnes CO2eq)

Scenario	2020	2025	2030	2035	2040	2045	2050
BAU Unconditional	2,344,868	2,511,395	2,812,491	3,204,777	3,602,674	4,047,357	4,544,058
BAU Conditional	2,279,948	2,200,437	2,232,885	2,259,745	2,300,641	2,286,008	2,363,344
High Ambition	2,259,578	2,032,107	1,897,665	1,732,042	1,592,815	1,499,357	1,399,040
Very High Ambition	2,250,564	1,712,595	1,264,809	637,601	136,430	-422,128	-782,767

[Source: Ministry of Economy (2018))].

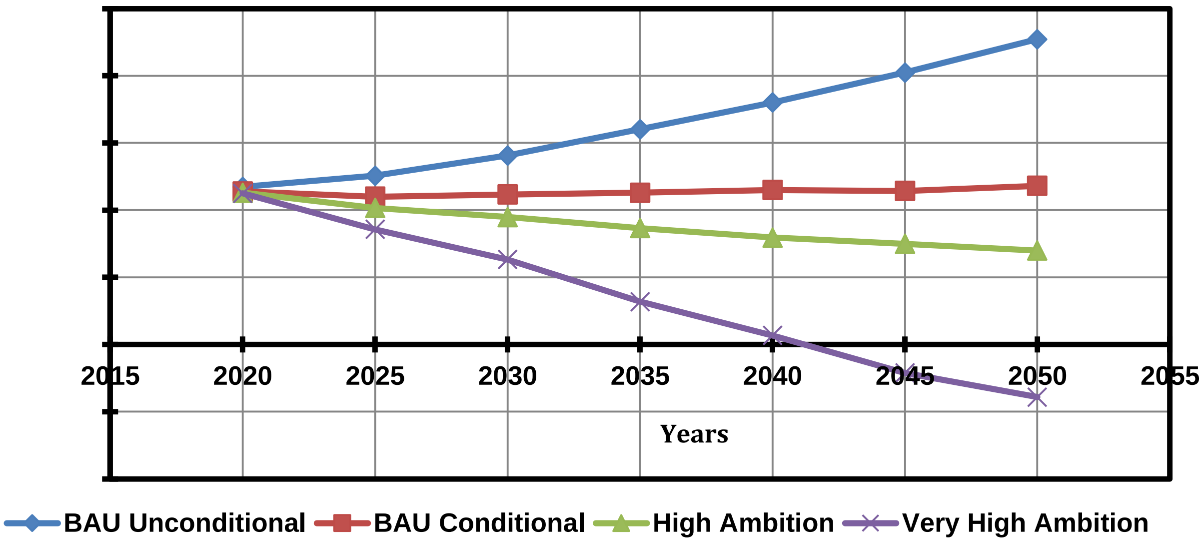

Figure 1.6: Total Net Emissions for Fiji under the four LEDS scenarios (all values in metric tonnes CO2eq) [Source: Ministry of Economy (2018)].

The LEDS conjectures that a complete transformation of Fiji's energy sector to one based on a wide variety of on-grid and off-grid renewable energy generation is required for achieving the most significant mitigation of emissions. To transform the transportation sector, the conversion of most of Fiji's land transport systems to electric vehicles is required together with introducing measures in the domestic aviation and maritime sectors that will drastically reduce emissions, eventually converting to electricity at a more modest scale. Forming the Transformational Strategic Thrusts, the National Development Plan also aspires to improve transportation within the country by continued modernising of Fiji's maritime and land transportation. The NDP explicitly outlines that the inter-island sea-transport network, which is critical for Fijians living in the maritime islands, will be improved to ensure reliability, safety, efficiency and affordability of ferry services. Additionally, the Government will continue to subsidise uneconomical sea routes to ensure that shipping services are provided on a regular basis to these regions (Ministry of Economy-The Republic of Fiji, 2017). The improved and modernised shipping is bound to increase commerce and income-generating opportunities in the maritime region.

This TNA project ventures into determining and prioritising climate-smart technologies, further supporting the government's endeavour to achieve decarbonisation for two of the selected sectors, and may later be extended to other sectors. This TNA is aligned with Fiji's NCCP, GGF-2014, 5 & 20-year NDP, NDCs, LEDS and the draft TNC for a decarbonised Fiji and a more attractive Fiji. Such an effort will be the key to eliminating poverty and supporting the achievement of the SDGs as well (Ministry of Economy-The Republic of Fiji, 2017).

1.3.2 Process and results of sector selection

Following extensive review and analysis of policy documents and other documents pertaining to climate change and mitigation actions, combined with stakeholder consultations, the Ministry of Economy of the Government of the Republic of Fiji presented the key priority areas in terms of emissions reductions, economic growth, poverty reduction and empowerment of the rural and maritime sector. An inception workshop to discuss sector prioritisation was held on Thursday 13 September, 2018, with the representatives of various ministries to introduce the project in its global and national context and to prioritise the sectors. The Ministry of Economy played a significant role in sector prioritisations. As the Ministry responsible for mainstreaming climate change adaptation and mitigation into the economy, the technical team at the Ministry of Economy's Climate Change and International Cooperation Division acted as an Advisory team and informed the sector prioritisation process based on the mitigation, adaptation and development priorities of the country.

Deciding how the different sectors would be prioritised for mitigation was based mainly on the findings of the national GHG inventories (INC and SNC. The selection criteria were:

- ✓ GHG reduction potential
- ✓ Availability of technologies
- ✓ Market potential
- ✓ Cost of mitigation
- ✓ Poverty reduction
- ✓ Economic growth

The discussions and deliberations led to a unanimous agreement that the energy and transport sectors need to be prioritised for the TNA process, since they the largest contributors of GHG emissions and are priority areas for the development of the country, as reflected in National Development Plans and Green Growth Frameworks. Further subsector discussions led to the consensus that Rural Electrification and Domestic Maritime Transportation, from the Energy and Transportation sectors, respectively, could assist in the development of rural and maritime regions, reduce resource pressure on urban centres, assist in decentralisation of industries/businesses and increase economic activities in these areas but were lagging behind and needed more technological support and advancements. Almost all rural and maritime communities are caught in a vicious cycle whereby they have very few income-generating activities at commercial level, leading to relatively low cash flow and lower development rates. In order to break this cycle, the government is vying to channel more development in these regions that could empower the people and allow them to venture into income-generating opportunities.

CHAPTER 2: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

The Climate Change and International Cooperation Division (CCICD) acts as the coordinating agency for the implementation of the National Climate Change Policy 2018-2030 (NCCP). CCICD is responsible for the coordination of climate finance and the implementation, support and reporting associated with Fiji's National Development Plan (NDP), Low Emission Development Strategy (LEDS), Nationally Determined Contributions (NDC) and National Adaptation Plan (NAP) commitments. CCICD is responsible for liaising with and reporting to the United Nations Framework Convention on Climate Change (UNFCCC) as well as providing national reports of Sustainable Development Goals (SDGs) and ensuring transparency, integrity, and consistency of reporting. As the Coordinating Agency for NCCP, CCICD supports climate-change knowledge management by developing communications strategies, developing and maintaining data repositories, and supporting functions and knowledge products designed to raise awareness of key climate change issues in government, the private sector, and civil society. CCICD works to provide support to government ministries in national efforts to mainstream climate change into development planning, sectoral planning and strategies, decision making, and policy.

CCICD, as the UNFCCC National Designated Entity and Focal Point, is also the National Contracting Entity for the TNA Project. Through the Technology Needs Assessment Project, CCICD aims to uphold the principles of the NCCP to achieve a resilient and prosperous Fiji in which the wellbeing of current and future generations is supported and protected by a socially inclusive, equitable, environmentally sustainable, net-zero emissions economy. The TNA will allow Fiji to assess technologies that are vital for a resilient and low-carbon Fiji. A TNA is a solution for developing countries such as Fiji that struggle to secure climate finance to address their development needs.

2.1 NATIONAL TNA TEAM

The country-driven nature of the TNA required an inclusive and participatory process that ensured that the prioritised technologies were a true reflection of the national needs. The Ministry of Economy is the designated national institution that leads and coordinates the TNA process in Fiji. The Ministry of Economy is also the Focal Point for the United Nations Framework Convention on Climate Change (UNFCCC).

The key elements of the institutional setup of the national TNA process include the Cabinet, the TNA Project Steering Committee (SC), the TNA Coordinator, the National Consultants, and the Sectoral Working Groups. Figure 2.1 maps out the institutional arrangement for the TNA project in Fiji.

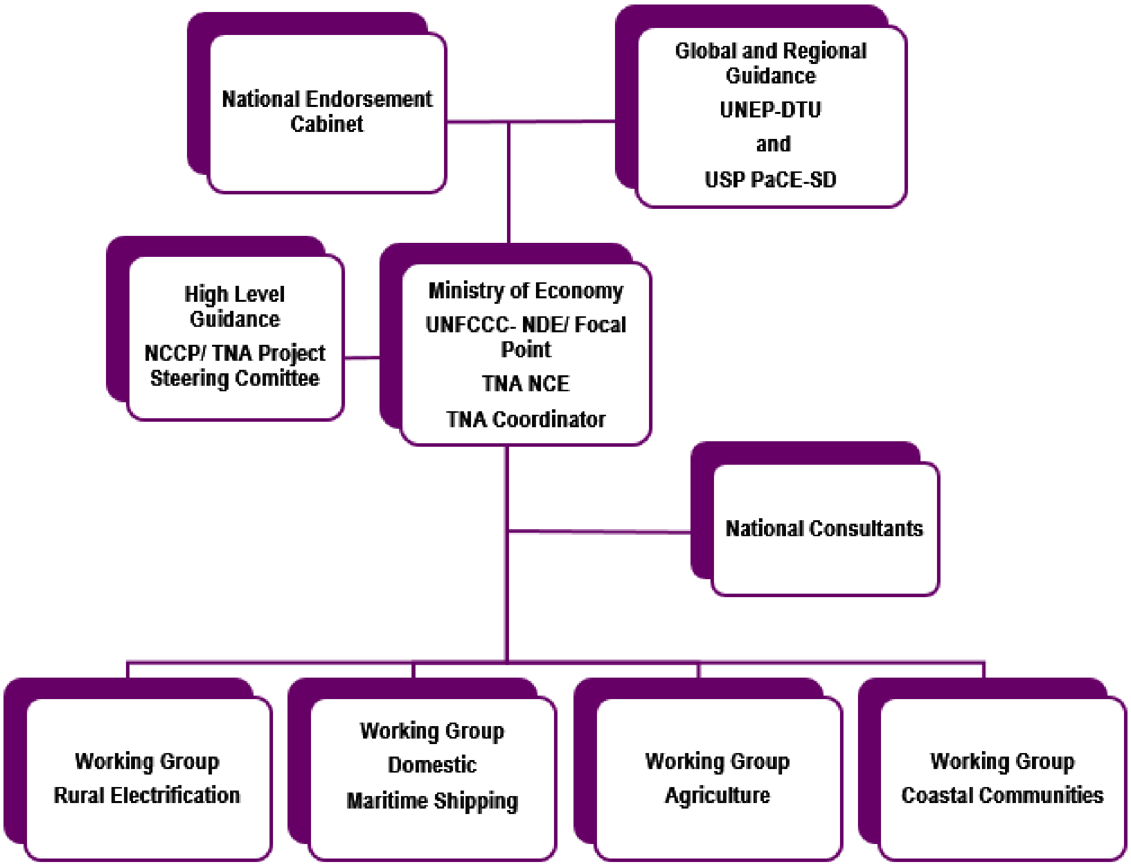

Figure 2.1: National Institutional Arrangement.

Cabinet

The Cabinet's role is to provide political endorsement for the National TNA Deliverables.

TNA Project Steering Committee

The NCCP Steering Committee was appointed as the TNA project Steering Committee. The role of the Steering Committee is to provide high-level guidance and approval for the TNA process and the outcomes. Representation on the Steering Committee is at a senior government officer levels, and the members include:

1. Permanent Secretary for Economy
2. Permanent Secretary for the Ministry of Health
3. Permanent Secretary for the Ministry of Agriculture
4. Permanent Secretary for the Ministry of Forestry
5. Permanent Secretary for the Ministry of Fisheries

6. Permanent Secretary for Local Government, Housing and Community Development
7. Permanent Secretary for Waterways and Environment
8. Director Meteorology
9. Director Energy
10. Director National Disaster Management Office
11. Solicitor General

The National TNA Coordinator

The role of the National TNA Coordinator is to act as focal point for the Ministry of Economy, guiding the development and progress of the TNA within the country. The National TNA Coordinator, Ms Deepitika Chand, was appointed from the Climate Change and International Cooperation Division (CCICD) at the Ministry of Economy. Ms Chand is the Climate Change Officer (Mitigation) and has a Master of Science Degree in Chemistry focused on the evaluation of methane emissions from the agriculture sector and high-precision ambient methane measurements in Fiji.

The CCICD plays a central coordinating role in implementing Fiji's National Climate Change Policy 2018-2030, which envisions a resilient and prosperous Fiji in which the wellbeing of current and future generations is supported and protected by a socially inclusive, equitable, environmentally sustainable, net-zero emissions economy.

National TNA Consultants

TNA in Fiji was performed with the involvement of local mitigation and adaptation experts. The lead national consultants were selected by the National TNA coordinator in close consultation with UDP and the Pacific Regional TNA Hub, following an open and transparent selection process.

The Mitigation Consultant is Dr. Ramendra Prasad, a Senior Lecturer in Physics at The University of Fiji. Dr. Prasad has contributed to many studies pertaining to renewable energy and energy modelling and forecasting in Fiji. The Adaptation Consultant is Dr. Francis Mani, a Senior Lecturer in Chemistry and Associate Dean for Teaching and Learning at the Faculty of Science Technology and Environment at The University of the South Pacific (USP). Dr. Mani has experience in preparing the Fiji Greenhouse Gas Inventory for the Second and Third National Communications and is the lead consultant for the work on the waste sector for the Fiji Low Emission Development Strategy (LEDS).

National expert consultants are responsible for finalising the TNA Report after thoroughly identifying and prioritising technologies for the two sectors identified under climate change adaptation and mitigation after exhaustive consultation with the relevant stakeholders and experts. The National Consultants lead the process of multiple-criteria analysis, along with the national stakeholder groups, and facilitate the process of technology prioritisation, addressing the barriers and developing an enabling framework.

TNA Sectoral Working Groups

A Sectoral Working Group (WG) was established for each sector assessed in the Fiji TNA. Each group consisted of five to six experts from academic institutions, private companies, and nongovernmental organizations. The WG contributed towards the development and production of the technology factsheets.

2.2 STAKEHOLDER ENGAGEMENT PROCESS FOLLOWED IN THE TNA – OVERALL ASSESSMENT

The stakeholder consultation process for the TNA work in Fiji followed the principles of sustainable wellbeing, inclusivity, social cohesion, partnership, agility, urgency, transparency and communication, and integrated learning as deliberated by Fiji's NCCP 2018-2030. Stakeholders include government agencies, private sector, non-government organisations, civil-service organisations, and academic institutions. See Annex II for the list of stakeholders consulted.

The TNA report was prepared after an extensive stakeholder process. The stakeholder engagement methods included:

- Email correspondence and exchanges on the Technology Factsheets (TFS);
- Bilateral;
- Awareness workshop for selected sectors that facilitated the formation of a technical working group; and
- National stakeholder consultation of key stakeholders for technology prioritisation.

2.3 CONSIDERATION OF GENDER ASPECTS IN THE TNA PROCESS

Fiji developed a National Gender Policy in 2014 to promote gender equity, equality, social justice, and sustainable development, and the Gender Action Plan under the Lima work programme on gender was finally adopted at the 23rd Conference of Parties hosted by Fiji. Gender responsiveness is also a key pillar of the 2018-2030 NCCP. Women play a unique role in natural resource management. Women are vulnerable to climate change however, women are also the agents of change in societies. Improving and enhancing the incorporation of women's knowledge, skills, participation, and leadership into planning processes at the local and national level creates opportunities to maximise both women's and men's contributions to environmental sustainability.

The TNA work on Fiji builds up with the guidance of the NCCP and Sustainable Development Goal 5. Women's civil society representatives have been included in the technical working groups and the stakeholder consultations. Equal opportunities have been provided to both men and women to voice their opinions and standpoints. The Fiji TNA was also inclusive of groups representing persons with disabilities and the Lesbian, Gay, Bisexual, Transgender and Queer (or questioning) and others (LGBTQ+) groups.

CHAPTER 3: TECHNOLOGY PRIORITISATION FOR ENERGY (OFF-GRID RURAL ELECTRIFICATION) SECTOR

3.1 GHG EMISSIONS AND EXISTING TECHNOLOGIES OF ENERGY (OFF-GRID RURAL ELECTRIFICATION) SECTOR

Fiji has set targets of generating 100% of grid electricity from renewable energy resources by the year 2030 and having a fully renewable energy-based electricity sector by 2036. The NDC envisions reducing Fiji's carbon emissions by 30% (Ministry of Economy - Republic of Fiji, 2017) by combining this transition to renewable resources with economy-wide energy efficiency measures. Sustainable Energy For All (SE4All) Gap Analysis Report, Fiji's Green Growth Framework (GGF) and LEDS support these targets, and Fiji expects to achieve 10% of the targeted emissions reductions through the implementation of the GGF (unconditional), while the rest are conditional (i.e., contingent upon external funding). The TNA project is aligned with Fiji's National Development Plan under the 'Electricity for All' initiative and aims to achieve an ambitious 100% electrification of the Fiji population by the year 2021. The key concern is electrifying the most remote and maritime communities, where grid extensions generally are not feasible.

Fiji does not have any fuel reserve and does not produce any primary fuels. Fiji also does not have facilities such as refineries to process primary fuels, hence all refined fossil fuels are imported. The GHG emitted is contingent upon the fuels used for electricity generation. The key GHG emitted by this sector is CO_2, yet methane and nitrous oxides are also emitted by stationary combustion of fuels for electricity generation. According to SNC, the energy sector emitted an estimated 1,591 Gg of CO_2eq in 2004, can increase of 105% over the 1994 total of 776 Gg of CO_2eq. Petrol is used for transport and electricity generation, particularly from small generator sets for households and small businesses. This fuel is responsible for 7.3% of Fiji's carbon dioxide emissions. Kerosene is also widely used for cooking and lighting and is often referred to as dual-purpose kerosene (DPK). Kerosene used for both jet fuel and other purposes such as lighting contribute 19% to Fiji's carbon dioxide emissions (Government of the Republic of Fiji, 2014). The diesel fuel referred to as Gas/Diesel Oil under the IPCC guidelines is widely used in Fiji for transport, both road and marine, as well as for electricity generation. Generators are commonly used by consumers ranging from rural households and businesses to resorts. Diesel, which includes 'Industrial Diesel Oil' (IDO) and 'Automotive Diesel Oil' (ADO), is the source of 70% of carbon dioxide emissions in Fiji (Government of the Republic of Fiji, 2014).

According to the draft Third National Communication, Fiji's GHG emissions are estimated to be around 2,500 Gg CO_2eq for the year 2011, of which 59% is from the energy sector, 22% from agriculture, 15% from forestry, and 4% from the waste sector (Ministry of Economy - Republic of Fiji, 2017; Republic of Fiji, 2018, 2019). Fiji's energy sector is currently highly dependent on imported fossil fuels, which make up approximately 30% of Fiji's total imports (IRENA, 2015). A summary of Fiji's greenhouse gas emissions between 2006 and 2011 is presented in Table 3.1 below.

The main fuel types used for electricity generation for the off-grid rural electricity supply are diesel and premix (commonly known as two-stroke oil, 2-stroke fuel, 2-cycle oil or zoom) for generators, as well as naphtha and kerosene for lights, while in some cases solar lamps are used. There is a heavy dependence on imported fossil fuels in rural and maritime zones for use in lighting. Many people are not able to afford generators or solar PV and resort to kerosene lamps or benzene/naphtha lanterns. Other sources include fuel wood and LPG for cooking purposes. Producing electricity from diesel generators is becoming increasingly expensive in rural areas and is putting economic pressure on low-income communities (Ministry of Strategic Planning National Development and Statistics, 2014). The rising cost of fuel compounded by irregular shipping services to the outer islands is making electricity generation increasingly difficult in the maritime regions. Essentially, the distribution of poverty is skewed, with a much higher incidence in the rural population than the urban population (Ministry of Strategic Planning National Development and Statistics, 2014). The Off-Grid Rural Electrification sub-sector is characterised by a major lack of data and little sound research and constrained by the remoteness of communities in the scattered maritime islands.

Table 3.1: A summary of greenhouse gas emissions by sector (Republic of Fiji, 2019).

Emissions of gasses by sector in Gg of CO_2 equivalent							Average 2006-2011
	2006	2007	2008	2009	2010	2011	
Carbon Dioxide							
Energy (Gg CO_2)	1767	1550	1333	1260	1526	1410	1474
Forest (Gg CO_2)	310	330	570	-250	760	560	308
Total (Gg CO_2)	2077	1880	1903	1010	2286	1970	1854
Methane							
Energy (Gg CH_4 - CO_2eq)	2	2	1	1	2	1	1
Agriculture (Gg CH_4 - CO_2eq)	414	415	412	409	409	405	411
Waste (Gg CH_4 - CO_2eq)	63	84	80	86	111	130	92
Total (Gg CH_4 - CO_2eq)	479	500	494	496	521	537	504
Nitrous Oxide							
Energy (Gg N_2O - CO_2eq)	4	4	3	3	3	3	3
Agriculture (Gg N_2O - CO_2eq)	146	146	154	143	140	146	146

Emissions of gasses by sector in Gg of CO_2 equivalent							Average 2006-2011
	2006	2007	2008	2009	2010	2011	
Carbon Dioxide							
Total (Gg N_2O - CO_2eq)	149	149	157	146	143	149	149
Total Emissions (Gg CO_2eq)	**2700**	**2500**	**2600**	**1700**	**3000**	**2655**	**2500**

3.1.2 Current status of technologies for Off-grid Rural Electrification

In the rural and maritime regions where there is no connection to the main grid, the people resort to basic lighting sources according to their affordability in addition to the solar home system that is provided by the government. For very basic lighting purposes, the following technologies are available:

- Kerosene Lanterns
  People in rural and remote areas still use this for lighting as the initial costs are lower and fit into their budget.
- Benzene Lanterns
  This is somewhat expensive but has a better light intensity. The common fuel sources are benzene or naphtha.
- Solar Lanterns
  Solar lanterns are also in use in some of the households. They are placed in the sun during the daytime and provide light only during the night.
- Diesel Generators
  Some households have diesel generators for lighting and use of small appliances such as TVs, etc.
- Benzene/2 stroke oil generators
  Benzene/2 stroke oil (premix) fuelled small generators are also being used by people according to their affordability.

In some cases, communities are able to tap into grants from external agencies to have better lighting systems or are dependent on the government for lighting systems.

- Solar Home Systems

Solar home systems (SHS) are preferred among many rural communities due to continued rising costs of fuel and irregular shipping services to the outer islands. SHS provide a clean and uninterrupted supply of electricity. While the cost is still relatively high, the government owns the system and bears the cost of installation. The user pays a small monthly subscription to cover operational and maintenance costs. For rural off-grid electrified households, the Type I SHS (rolled out from 2009 – 2013) has 2 × 50 Wp flat-plate solar panels together with a 100 Ah battery and has one LED light (1 × 1W); DC CFL lights (3 × 11W DC & 1 × 7W DC) (Raturi and Nand, 2016). The Type II SHS (rolled out after 2014) has 2 × 135 Wp flat-plate solar panels together with a 200 Ah battery and has DC LED lights (3 × 9W; 1 × 7W; 1 × 1W) with a 300W inverter (Raturi and Nand, 2016). The most recent Type II SHS (being rolled out now) has 2 × 145 Wp flat-plate solar panels together with a 200 Ah battery and has DC LED lights (3 × 9W; 1 × 7W – outdoor lights; 1 × 0.5 – 1.2W) with a 300W inverter. So far, 12,000 SHS have been installed, and the plan is to install 2,500 more systems in the current fiscal year, contingent upon government funding. In some homes, international donor agencies (such as the European Commission) have provided the SHS, however, the full operational and maintenance costs are to be incurred by the user.

3.2 DECISION CONTEXT

The rural electrification subsector has always been a priority for the government, but geographical isolation, lack of funding opportunities and lack of income-generating opportunities in the rural areas have hindered progress. The National Climate Change Policy-2012 provides a platform for coordination among sectors and direction on national positions and priorities regarding climate change mitigation as well as adaptation. The implementation framework of the policy has allowed Fiji to develop guidelines such as National Climate Change Coordination Guidelines, Finance Guideline, Planned Relocation Guidelines and Displacement Guidelines, which will enable in achieving its goals in addressing climate change in Fiji. The sector prioritisation is aligned to Fiji's 5-Year and 20 Year National Development Plan (NDP), Nationally Determined Contribution (NDC) Implementation Roadmap, Low Emission Development Strategy (LEDS), and National Adaptation Plan (NAP).

Fiji has the vision of "Electricity for All" under which it is striving to provide 100% of the population with access to electricity by the year 2021 and achieving 100% of electricity generation from renewable sources by 2036. The NDP 2017-2036 is also aligned with this and promotes the decentralisation of renewable energy sources such as solar, mini-hydro and wind systems that will be used to electrify rural areas and the maritime zones where feasible (Ministry of Economy-The Republic of Fiji, 2017). Moreover, the government, through Green Growth Framework – Thematic Area 7, has also been promoting the development of indigenous local energy resources, in particular biofuels, in order to reduce dependence on imported fossil fuels for electricity generation (Ministry of Strategic Planning National Development and Statistics, 2014).

The overall objective of NDP is to achieve an annual real GDP growth rate of 4-5%, which could be possible through poverty reduction of 43% and an unemployment rate of under 4%. In addition, the NDP pursues climate-resilient electricity infrastructure projects for the future so that energy security is not compromised. The other important challenge for the off-grid rural electrification sector is the lack of involvement of non-government providers, including community-based organisations, NGOs, and the private sector, which is therefore promoted by the NDP. Under the NDP, the government plans to protect our pristine natural environment and make the economy more climate-resilient, so proper impact assessment and mitigating processes need to be outlined and maintained in all the projects, including for rural electrification.

Fiji has also developed a National Gender Policy that directly references climate change in relation to agriculture, rural development, and environment and "promotes increased regard for environmental sensitivity, climate change impacts, and disaster risks and the role of men and women at all levels in facilitating the harmonious and sustainable use of the country's limited natural resources, and the utilisation of gender impact assessments, gender analysis and gender-aware approaches in assessing environmental issues and on the utilisation, exploitation and preservation of natural resources in Fiji through training and continuous monitoring" (Ministry of Social Welfare Women and Poverty Alleviation, 2014).

The policy also specifically emphasises renewable energy, pointing out the need to "ensure and implement a policy of access to energy supplies to all persons in Fiji and to ensure that women in communities are consulted in any energy projects, and recognising that women in rural communities have the most limited access to renewable energy source" (Ministry of Social Welfare Women and Poverty Alleviation, 2014).

The main objective of the Technology Needs Assessment is "to identify and assess environmentally sound technologies that have synergy between reducing the impact of climate change and the rate of GHG emissions in Fiji within national development objectives". By adopting a consultative approach, the TNA aspires to conduct a set of country-driven activities in identifying and determining the most appropriate technologies for the rural-electrification sector for Fiji.

3.3 An overview of possible mitigation technology options in Off-grid rural electrification sector and their mitigation potential and other co-benefits

Approximately 18% of total households in Fiji depend on off-grid electricity as per the 2017 Fiji national census. Figure 3.1 a-c below provides an overview of the household electrification. More importantly, Figure 3.1b shows that 34% of the Rural Households are dependent on off-grid electricity, mostly in maritime and very remote localities.

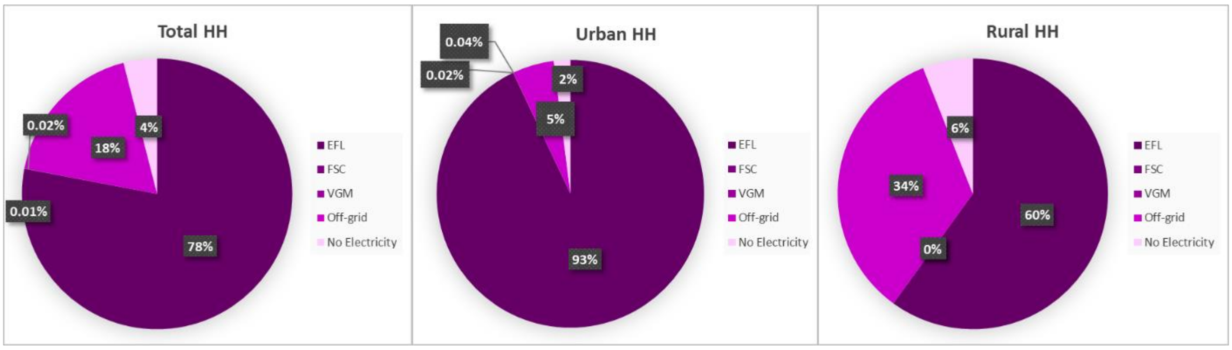

Figure 3.7: Percentage of households being electrified by different providers; a) Total Households, b) Urban Households; c) Rural Households [EFL – Energy Fiji Limited; FSC – Fiji Sugar Corporation; VGM – Vatukoula Gold Mines] (Source: LEDS)

The Fiji Department of Energy (FDoE) is the state entity responsible for energy policies and plans, energy efficiency and conservation, renewable energy (RE) research, and rural electrification. The guidance on promoting access to affordable and sustainable energy services to rural areas is highlighted in the Rural Electrification Policy (REP), which was approved by the Fiji Cabinet in 1993. To give the REP a practical dimension, FDoE setup the Rural Electrification Unit (REU). The policy stated that rural villages or settlements could request the Fiji government to provide rural electrification, which could be in the form of:

- EFL grid extension or government station mini-grid to provide 24 hours per day service;
- A diesel generator with a mini-grid system for evening lights and small electrical appliances; and
- Use of locally available renewable energy systems for electricity generation.

Later, in 2003, the Cabinet approved the Renewable Energy Based Rural Electrification with Participation of Private Enterprise (REBREPPE) Charter. This Charter called for integrating measures to stimulate private sector participation and funding from international institutions with the utilisation of indigenous renewable energy resources to provide electricity in rural areas. FDoE was given the role of the technical regulator that would assist and facilitate the setting up of quality and safety standards and technical specifications, and ensure the quality of systems by conducting equipment testing. A Renewable Energy Service Companies (RESCO) model was also devised for the implementation of solar home systems and for other RE sources including diesel generator schemes as well.

However, under the rural electrification programme, all projects are funded by the Fijian Government with only a few development partners. One of Fiji's development priorities is to promote the involvement of non-government providers, including community-based organisations, NGOs, and the private sector in off-grid rural electrification (Ministry of Economy-The Republic of Fiji, 2017). The overall goals of the NDP are to secure "a resource-efficient, cost-effective and environmentally sustainable energy sector" and develop electricity infrastructure projects that lead to a climate-resilient future. Currently, the REP is part of the NEP, and the current NEP is in the draft stages (NEP-2013). The excerpt for rural electrification is highlighted in Subsection 5.2.

5.2 Rural electrification

5.2.1 Develop a national electrification master plan, showing how each un-electrified area of Fiji will be served with least-cost solutions. Technological solutions to be considered in consultation with communities will include grid extension, diesel and hybrid mini-grids, and solar home systems. The plan will also clearly define a minimum level of service which qualifies as "electrification".

5.2.2 Establish a dedicated electrification fund and an associated framework that will be used to provide capital subsidies for electrification projects. The electrification fund will facilitate the implementation of the national electrification master plan. The fund framework should consider how to facilitate equitable electricity access, taking into account gender aspects and vulnerable groups. Moving forward, funding is provided by the Government for the implementation of rural electrification projects will be channelled into this fund, thereby making subsidies more transparent and easier to monitor and evaluate. Subsidies will leverage capital contributions from beneficiaries and project promoters as far as possible and will be provided as once-off capital contributions for viable projects. Recurrent costs will not be subsidised.

Source: Draft National Energy Policy – 2013 (Fiji Department of Energy, 2013)

Off-Grid Rural Electrification has ranked as one of the priority areas in the country's race to achieve low-carbon, inclusive socio-economic development that contributes to reducing poverty and empowering the rural and maritime sector[1]. An increase in investments for rural mini-grids and solar home systems, together with improved designs and installation standards and diversification of distributed generation options including mini-grids, will be needed in the future to ensure that these communities are resilient to a changing climate (Ministry of Economy, 2018).

3.3.1 Technologies Identified

A total of 46 technologies have been identified in an effort to align technology with the government's development and policy priorities. After the initial discussions and deliberations with the stakeholder and sectoral technical working group, a shortlist of technologies was created based on each technology's maturity, availability in the Pacific, renewability as a resource and past experiences. Only technologies that were technically mature were considered; technologies that were in Research & Development and/or Pilot Implementation phases were not considered. The following technologies were identified for further consideration[2]:

1. Solar Home System Type II - Standalone solar PV system with energy storage system-ESS that can cater for AC load as well.
2. Standalone Ground Mount Solar PV with energy storage system- ESS (Community Based Electrification - Microgrids)
3. Standalone Dual-Fuel (CNO/Diesel) Generator (Community Based Electrification - Microgrids)
4. Stand-alone wind systems with energy storage system- ESS
5. Micro/Pico-hydro in microgrid configuration
6. Hybrid Solar PV and Wind with energy storage system- ESS (Community Based Electrification - Microgrids).

[1] Fiji also needs support in the area of grid-connected electricity systems on the main islands in order to have 100% renewable electricity, but this TNA focusses on Off-grid rural electrification.

[2] Except for the standardised SHS, the applicability of renewable energy technologies is contingent upon availability of site-specific resources and the electricity demand. Comprehensive site-specific feasibility studies are recommended prior to deployment.

7. Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems without energy storage Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with energy storage system- ESS.
8. Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with energy storage system- ESS
9. Wind and Dual fuel (CNO/Diesel) Generator Hybrid with energy storage system- ESS (Community Based Electrification - Microgrids)

3.3.2 Overview of the Technologies Identified

1. **Solar Home System Type II - Standalone solar PV system with ESS that can cater for AC load as well.**

A type II solar home system is a standalone solar photovoltaic (PV) system consisting of an array of solar PV modules, battery bank, charge controller, wiring, LED DC lights, inverter, and outlets for other AC appliances. A standard solar PV system is developed as per the solar irradiance of an area and the average load demand for the household. The Type II SHS in Fiji compromises of 2 x 145 – 150Wp Solar panels, 1 x 20Amps PWM charge controllers, 1 x 200Ah 12V AGM VRLA Battery, 1 x 300W Pure Sine Wave Inverter, 3 x 9W LED 12V lights, 1 x 7W LED Outdoor light 12V and 1 x 0.5 – 1.2W Night Light 12Vdc. In remote/rural areas this system may require little local expertise to perform routine maintenance at the DC end, but highly qualified electricians will be required to work on the AC-end. Cleaning of the solar panels, etc., could be performed by the homeowners themselves to ensure that efficiencies are maintained.

2. **Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Microgrids)**

Solar PV only produces electricity in periods of sunlight, either direct light or diffuse sunlight on overcast days. During the night they will not produce power. This means that solar cells, if used for remote/off-grid generation purposes, need to be implemented in conjunction with some kind of energy storage system such as a battery or as a hybrid system with some other type of generator. This kind of application, as a remote or off-grid generator, is most commonly observed in developing countries and isolated areas. In Fiji, this could be implemented in remotely located communities where grid extension would not be feasible, particularly in remote maritime communities. The community-based electrification - Micro-Grids are deemed more stable and versatile for powering a small community's 24/7 electricity demands. The system generally includes tilted solar photovoltaic (PV) module, inverter, storage systems, and outlets for other AC appliances like television, a radio or cassette player, fans, laptops and charging of mobile devices. A 10 – 50 kW systems would likely be sufficient, depending on the respective community needs, yet a full feasibility study is recommended. Small off-grid systems in remote/rural areas can be installed with relatively little local expertise. Maintenance is minimal and mainly requires the cleaning of the solar panel to ensure efficiencies are maintained.

3. **Standalone Dual-Fuel (CNO/Diesel) Generator (Community Based Electrification - Microgrids)**

Standalone Dual-fuel Generator without any storage systems in a micro grid configuration can be used in many small islands provided there is a sufficient and sustained supply of biofuel. The coconut (CNO) as fuel and diesel when CNO supply is low together with B10 biofuels could be used whenever available. The assumption is that rural households use locally produced CNO as fuel for the duel-fuel generator at negligible cost. A 10 – 50 kW systems would likely be sufficient depending on the respective community needs, yet full feasibility study is recommended.

4. **Stand-alone wind systems with ESS**

Stand-alone wind systems equipped with small wind turbines (up to 20 kW) are mainly used to supply electric power to remote, off-grid loads such as for homes and other remote small consumers. Often they are used in combination with batteries and/or small diesel generation systems. The biggest difference between large and small wind turbines is the design of the transmission – generation system. Most small wind turbines are direct-driven, variable-speed systems with permanent magnet generators, hence a power converter is required to get a constant frequency if needed. Such a wind turbine design requires no gearbox. This approach is suitable for small wind turbines, which operate with a much higher rotor speed than large wind turbines, and is also more reliable and less costly for maintenance. Also, the power and speed regulation of small wind turbines vary significantly, e.g. through mechanically controlled pitch systems or yaw systems instead of electronically controlled systems. Vertical and horizontal furling is also used for power control in small systems. In high winds, a vertical-furling wind turbine will tilt the rotor skywards, giving the wind turbine the appearance of a helicopter. A horizontal-furling turbine swings the rotor towards the tail during high wind speeds. Most of the small wind turbines that are currently deployed around the world have three blades, but there are also models with two, four or more at the micro-scale.

The FDoE currently has 15 wind-monitoring masts installed for mesoscale wind resource assessments and a full feasibility study is recommended.

5. **Micro/Pico-hydro in microgrid configuration**

Hydro turbines smaller than 10 kW are usually called "pico". Pico hydropower is rarely fed into a power grid, but in most cases, pico hydro micro-grids are developed for electrification of a small community, a village or a workshop. Pico turbines can provide power for small clusters or even single households. As there are varying definitions of the power range of "micro" and "pico", it is advantageous to specify each project's power output in kW.

Micro-Hydro - Installations with a power output of 5 - 100 kW (usually provided power for a small community or rural industry in remote areas away from the grid). Proper site identification in terms of flow rate and head height needs to be determined prior to undertaking such a project. Usually, identifying, planning and managing take a higher proportion of the whole installation effort. Installation includes installing the turbine and grid installation to the appropriate point of need. Where applicable, it is one of the most cost-efficient solutions for supplying electrical energy. The success of micro/pico hydro schemes at Bukuya, Ba and Tukavesi, Buca, has led to the inclusion of these technologies, and resource monitoring is being done in Kadavu.

6. **Hybrid Solar PV and Wind with ESS (Community Based Electrification - Microgrids)**

Solar PV only produces electricity in periods of sunlight, either direct light or diffuse sunlight on overcast days. Wind is intermittent in nature and only produces electricity during windy periods, but is not dependent on sunlight. This hybrid could be implemented in remotely located communities where grid extension would not be feasible and in remote maritime communities.

The wind generator can either be a synchronous or an induction generator, or more often, permanent magnet synchronous generators (PMSG) or doubly-fed induction generators (DFIG). Induction generators require a source for excitation, either by excitation capacitors or by grid-connection. In modern stand-alone hybrid-systems, a direct-driven version of PMSG is the prevailing choice of a wind turbine because it does not require an external DC current for excitation. Problems to keep the frequency at 50 Hz during low wind velocities are avoided by modern construction concepts with a large number of poles. The Solar PV and Wind with ESS in a Micro-Grid configuration would be sufficient to power a small community's for their 24/7 lighting and energy demands.

7. **Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems without energy storage**

Solar PV only produces electricity in periods of sunlight, either direct light or diffuse sunlight on overcast days, and can only be implemented with a secondary supply system—in this case a dual-fuel (CNO/Diesel) generator as a hybrid system. This kind of application, though uncommon in Fiji, could be implemented in remotely located communities where grid extension would not be feasible and in remote maritime communities as simple micro-grid connected PV systems. The PV is estimated to meet daytime energy needs, yet the generator may need to run on standby if 24/7 electricity is required, particularly during overcast periods. The CNO/diesel generator would be used during the night, which would require appropriate fuel.

8. **Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS**

Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS is understood to power a small community for their 24/7 energy and lighting. Solar PV will be used during the day, and excess energy is stored using appropriate energy storage systems. At other times the ESS could be used to supply electricity, and the CNO/Diesel generator would make the micro-grid more climate-resilient. This kind of application, as a remote or off-grid generator, is not common in Fiji, but could be implemented in isolated areas and remotely located communities where grid extension would not be feasible, and in remote maritime communities.

9. **Wind and Dual fuel (CNO/Diesel) Generator Hybrid with ESS (Community Based Electrification - Microgrids)**

Wind and Dual-fuel (CNO/Diesel) Generator Hybrid with storage (Community Based Electrification - Micro-Grids) is understood to power a small community for their 24/7 energy and lighting demands.

The wind is intermittent in nature, and only produces electricity during windy periods. A hybrid Dual fuel generator system would cater for the demand at other times. The combination of a diesel generator and a wind turbine in a hybrid system is very common and frequently used in remote areas, but is uncommon in Fiji. This hybrid could be implemented in remotely located communities where grid extension would not be feasible and in remote maritime communities. The diesel Genset should be supplied with a synchronous generator. A first-order model with a single-time constant can be chosen. The single-time constant describes the ratio between fuel consumption and mechanical torque production. The action of the speed governor is controlled by an integral controller gain.

3.4 Criteria and process of technology prioritisation for Off-Grid rural electrification sector

To prioritise the technologies for the off-grid rural electrification sector, the Multi-Criteria Analysis (MCA) approach was used with stakeholder consultation. A total of 9 technologies were evaluated and appraised against a set of criteria that were established via stakeholder consultations.

In MCA, the first step is determining the criteria based on the decision context. After deliberations with the stakeholders in terms of country's development priorities, it was decided that the following evaluation categories need to be included: Costs; Benefits and Local Context.

The cost of technologies was considered on the basis of cost in US dollars for generating 1kW of Electricity and was further divided into Capital Costs and Operational and Management Costs.

The Benefits were demarcated into Economic, Social and Environmental Benefits. To keep this in line with the development priorities,

- Economic Benefits were further divided into Job Creation and Rural Economic Activity;
- Social Benefits were divided into Skill and Capacity Development and Energy Security;

- Environmental Benefits were divided into CO_2 reduction potential and Physical Space Requirement.

The criteria 'Skill and Capacity Development' and 'Physical Space Requirement' were considered as benefits by the stakeholders. For 'Skill and Capacity Development' the stakeholders were evaluating the extent which a particular technology is expected to develop skills and capacity in the local communities. For instance, the local communities can easily learn to change light bulbs, clean solar panels and check battery health in the case of SHS, while experts and expatriates will be required for maintenance in the case of implementation of very sophisticated technology (*e.g.*, artificial intelligence-enabled smart micro-grids).

Similarly, because physical space is at a premium on smaller islands, it was decided that a technology that requires minimum space would be more desirable and beneficial for the local environment, wildlife and biodiversity than a technology that requires considerable amount of space and could cause damage to the environment. Such a technology would likely score more points in the category 'Physical Space Requirement'.

In the Local Context, the key criteria were Market Potential and Acceptability to Local Stakeholders. Likert scales were used to evaluate Job Creation, Rural Economic Activity Skill, Capacity Development, Energy Security and Physical Space Requirement.

A performance matrix was constructed and the scoring carried out. During the national consultation, all the stakeholders involved in the rural electrification sectors referred to the Technology Fact Sheets (TFS) and used their experiences to deliberate each of the criteria. Then the stakeholders decided that all members would discuss together and come to a consensus during the scoring of technologies. All the technology factsheets and experiences of different stakeholders were discussed during this process.

Hence, a total of 10 criteria spanning 3 broad categories eventuated. Table 3.2 presents the Categories and Criteria used in the prioritisation process. The Performance Matrix (Annex III - Table A1) and Scoring Matrix (Annex III - Table A2) were constructed based on Table 3.2. Two levels of criteria resulted after the discussions. During the assigning of weights process, a total of 100 points was given for Level 1 Criteria, and each sub-criterion at Level 2 was further assigned a total of 100 points. The weightings were assigned by the stakeholders for each criterion at Level 1 and Level 2 based on their relative importance. The assigned weights for each criterion are presented in Table 3.2, while Figure 3.2 illustrates the weights with respect to each category. Figure 3.2 clearly shows that the benefits category has had a larger influence on the selection of respective technologies.

The calculations of total scores for these identified technologies were performed as described in the MCA manual. Since the Performance Matrix (Annex III - Table A1) consists of both quantitative and qualitative nominal data (from the Likert scales), these cannot be aggregated directly. Hence, a normalisation process was adopted whereby all nominal values were converted to scores in the range of 0 to 100. Particular attention was paid to preferred values together with benefits and costs, as the criteria that have higher preferred value need to have higher scores as well. Then the weights of each criterion were multiplied with the corresponding scores and aggregated across all criteria to ascertain the final scores. A summary of the scoring matrix for technology prioritisation for the rural electrification sector is provided in Annex III - Table A2. The technology options were ranked according to their total score, and the three best-scoring technologies were selected for further analysis. Finally, a sensitivity analysis was also carried out to confirm the results. During this process, the weights were varied to see if the ranking of the top three technologies would change. The purpose of sensitivity analysis is to remove any data uncertainties or differences in opinions that may have existed and thereby ensure that a small change in the weights does not bring about large changes in the technology rankings.

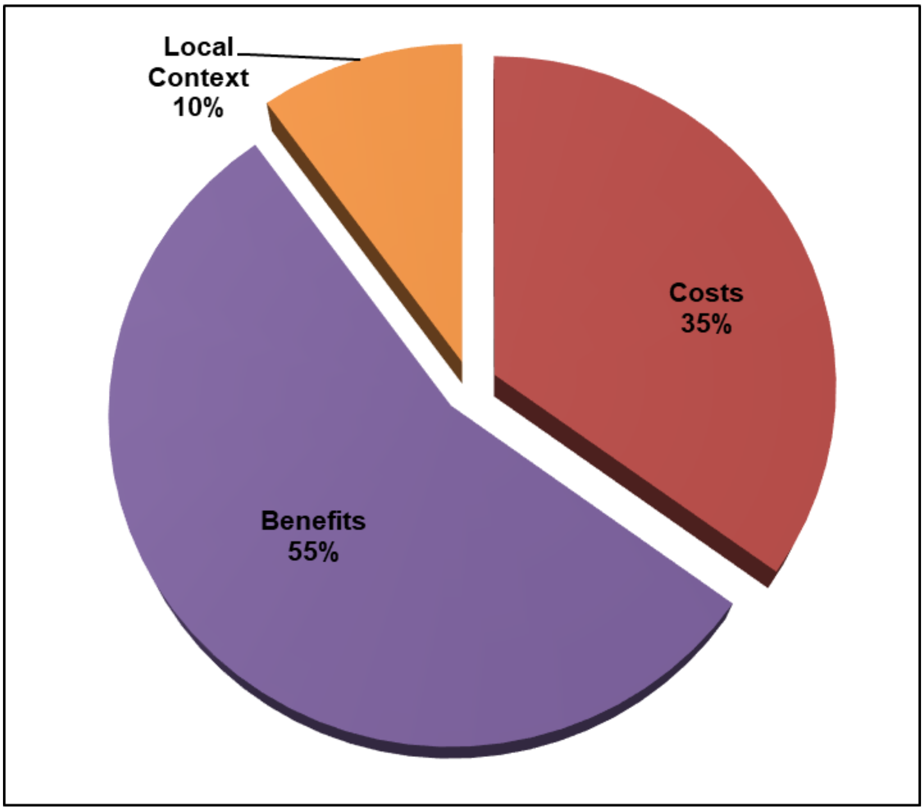

Figure 3.2: The weights assigned to the identified categories.

Table 3.2: Criteria and the respective assigned weights for off-grid rural electrification.

	Category										Total
	Costs		Benefits						Local Context		
			Economic		Social		Environmental				
Lev 1 Weights	35%		15%		15%		25%		10%		100%
	Capital Costs (USD/kW)*	Operational and Management (USD/kW)*	Job Creation	Rural Economic Activity	Skill & Capacity Development	Energy Security	CO_2 reduction potential (%)	Space requirement	Market Potential	Acceptability to local stakeholders	
Sources	Technology Providers, Operators	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Tech Specification, Research	Expert Judgement, tech providers, research	Expert Judgement	Expert Judgement	
Preferred value	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher	
Lev 2 Weights	50%	50%	30%	70%	50%	50%	50%	50%	40%	60%	
Combined	17.5	17.5	4.5	10.5	7.5	7.5	12.5	12.5	4	6	100

*The capital and operational costing would ideally be done on the basis of respective projects and largely depends on the location, technology, suppliers, capacity factors, etc. Since specific data is not available, generic costs are used for the technology prioritisation process. The costs mentioned in the fact sheets are averages gathered from the suppliers, and it only includes generic product and installation. It does not cover the costs of feasibility studies, capacity building or training, etc.

3.5 RESULTS OF TECHNOLOGY PRIORITISATION FOR OFF-GRID RURAL ELECTRIFICATION SECTOR

The performance matrix converted to a scoring matrix was utilised for technology prioritisation. The scales for all criteria data were confined in the range of 0 to 100, and the preferred technological option essentially has the highest score. Figure 3.3 displays the scoring and prioritisation in the form of bars, which clearly show that the scores of the technology Options 2 and 8 are relatively high, with Option 5 registering the next-highest score. The performance matrix, the scoring matrix and the resulting decision matrix are presented in Table A2 (Annex III).

To affirm the results, a sensitivity analysis was performed by varying the weights of the different criteria and performing a cost-benefit plotting as in Figure 3.4. An outcome summary of sensitivity analysis for the domestic maritime sector is provided in Annex III – Table A5.

Accordingly, the outcomes showed that the following prioritised technologies are recommended for further analysis:

1. **(*Technology Option 2*) - Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Microgrids)**
2. **(*Technology Option 8*) - Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS (Microgrids)**
3. **(*Technology Option 5*) - Micro/Pico-hydro in microgrid configuration**

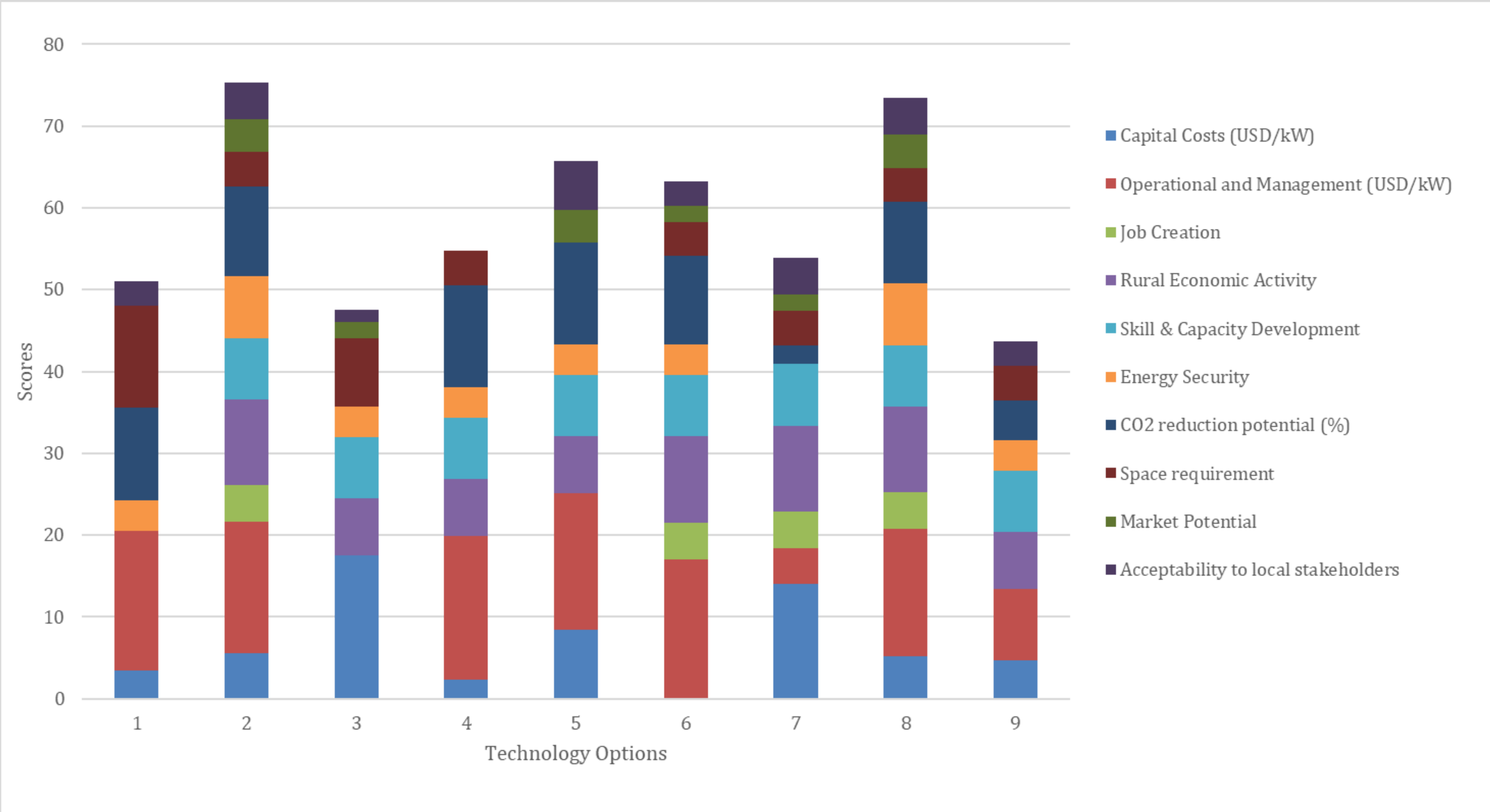

Figure 3.3: Technology scoring and prioritisation for rural electrification sector.

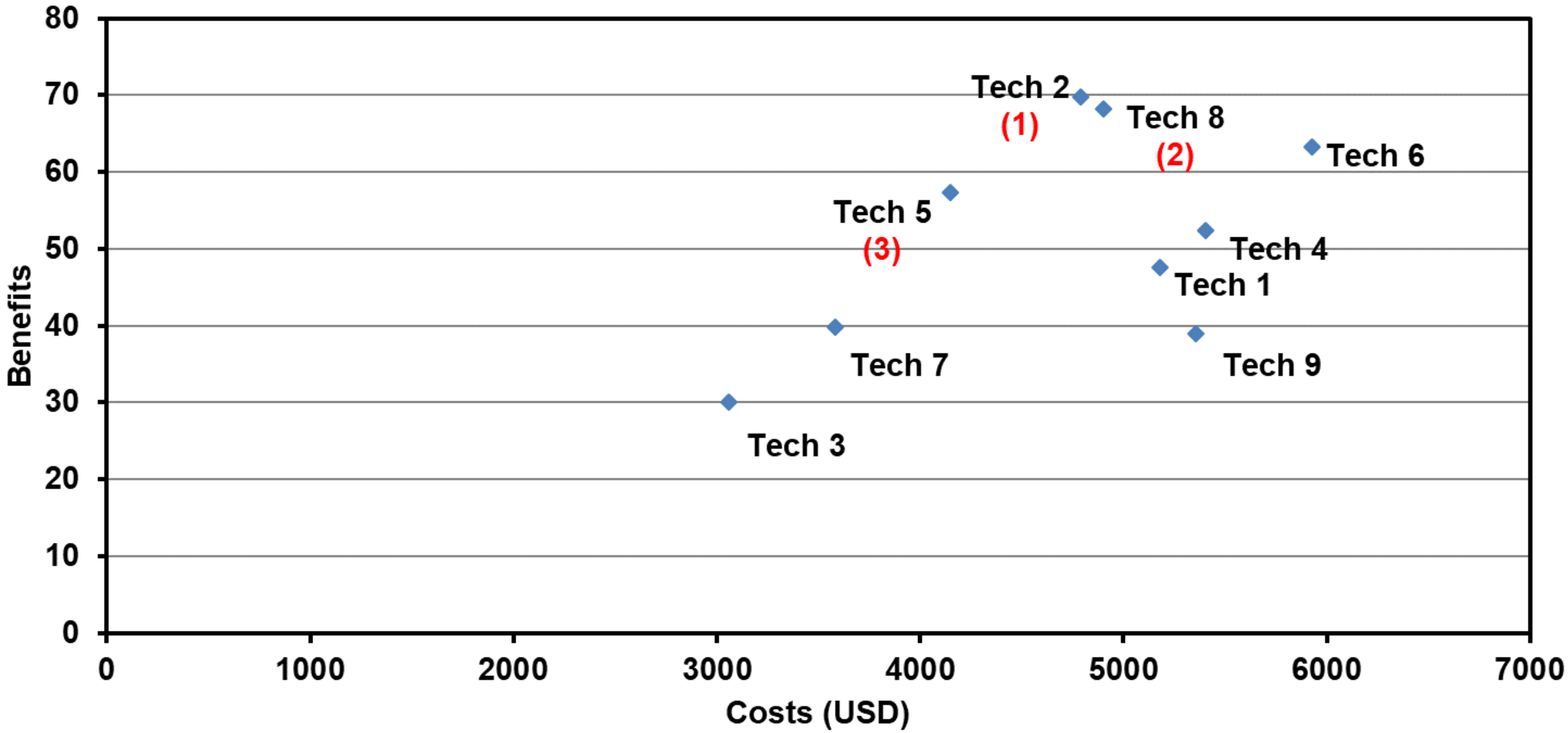

Figure 3.4: Costs and Benefits of the identified technologies for the rural electrification sector.

CHAPTER 4: TECHNOLOGY PRIORITISATION FOR DOMESTIC MARITIME TRANSPORTATION SECTOR

4.1 GHG EMISSIONS AND EXISTING TECHNOLOGIES OF DOMESTIC MARITIME TRANSPORTATION SECTOR

Since Fiji has 110 permanently inhabited islands in its archipelago, which spans over 1.3 million km^2 of ocean, domestic maritime transportation is very important for many purposes including trade, fishing, personal and cargo transportation as well as providing access to vital services such as education and health. The maritime transportation sector ties these islands into the realm and is crucial for most domestic economic, social, and environmental drivers (Ministry of Economy, 2018). The inter-island domestic maritime transportation network is critical for Fijians living in the maritime islands. The shipping services need to be reliable, safe, efficient and affordable.

With the aim of reducing reliance on fossil fuels and reducing GHG emissions, Fiji has committed to developing a 100% carbon-free shipping sector by 2050, reducing emissions by 40% by the year 2030 (World Resources Institute, 2019).

Due to resource constraints, limited data were available in the past, and historical data on GHG emissions from this sector is not available. During 2016, total emissions for the Fiji maritime sector were estimated to be 174 kilo-tonnes of CO_2eq (Ministry of Economy, 2018). The Fiji LEDS conjectured the emissions based on Maritime Safety Authority of Fiji (MSAF) ship register, and classified the marine vessels into the following classes:

- **GSS** – Government Shipping Service vessels;
- **Uneconomical** – Vessels operating on designated "Uneconomic Routes" – subsidised, privately owned shipping that services the "uneconomical routes" as defined by Ministry of Infrastructure and Transport (MoIT);
- **Economical** – Economical vessels – privately owned shipping that services the "economical routes" as defined by MoIT;
- **Tourism vessels**
- **Fishing vessels** – domestic-flagged vessels only;
- **Small boats** – under 15 m in length and predominantly powered by outboard motors;
- **Other vessels** – a range of "specialists" vessels such as tugs and dredgers.

It must be noted that the classification of vessels is based on length whereby small vessels are less than 15 m in length and large vessels are more than 15 m in length in the uneconomical and economical routes. Essentially, a ship differs in many aspects from other transportation modes, such as cars or trucks. A ship needs to have a high degree of self-sufficiency and be able to cater for its own energy supply under varying conditions (Environment Canada, 2003) to transport various types of goods and passengers and accommodate the on-board crew. Therefore, ships have to be well equipped with reliable energy-generation technologies. In the LEDs, it has been assumed that the small vessels are primarily powered by petrol motors and large vessels by diesel engines.

Total estimated CO_2 emitted from ships in 2018 increased to 227 kilo-tonnes as estimated by MSAF and the draft TNC (Republic of Fiji, 2019; Tunidau, 2018). A comparison of estimated emissions between the years 2016 and 2018 is shown in Figure 4.1. The figure shows that in 2016, the commercial vessels on “economical” routes were the largest carbon emitters, followed by the tourism vessels, while the 2018 estimates show that the small boats are the largest emitters, followed by commercial vessels on the “economical” routes.

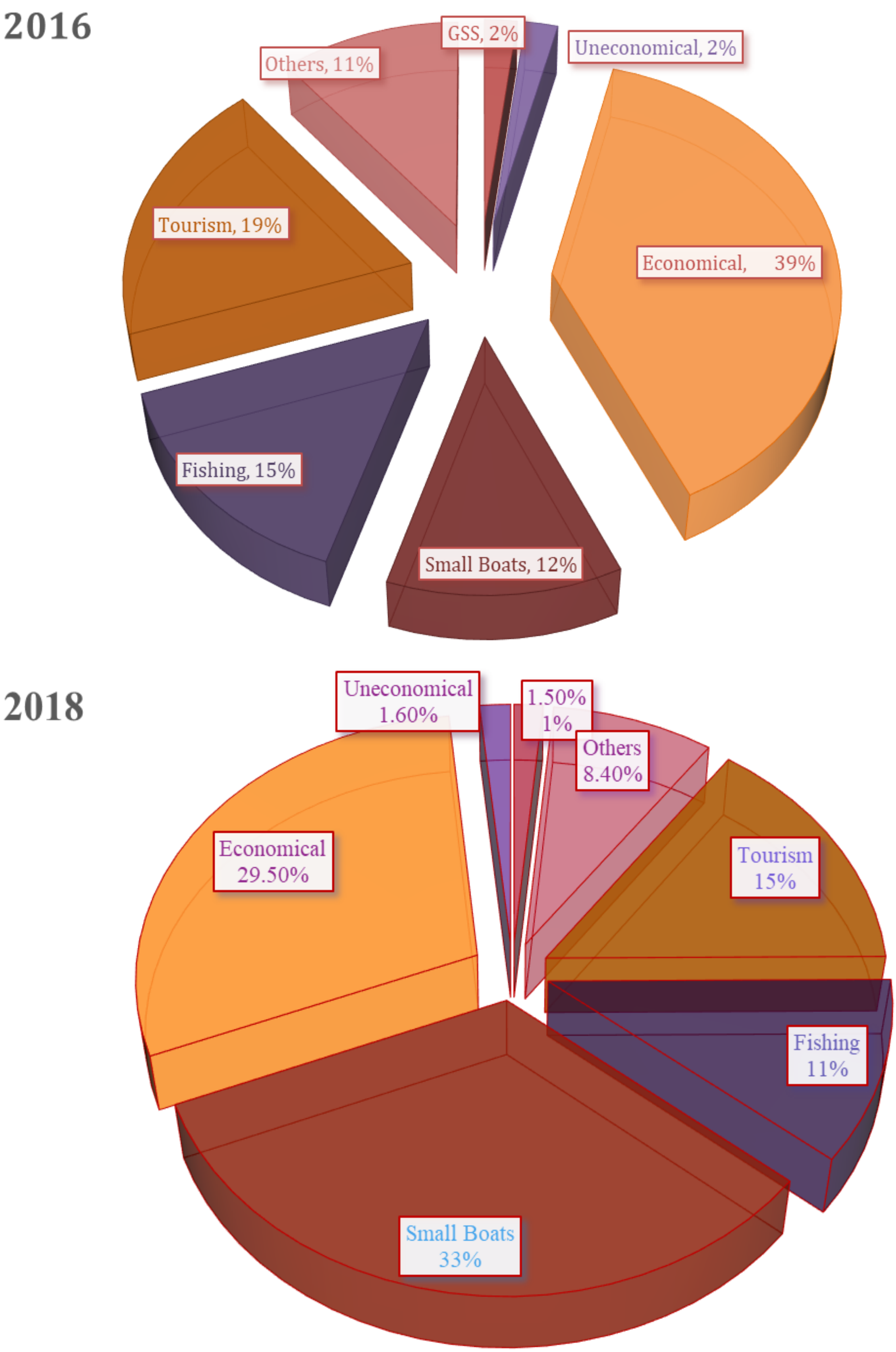

Figure 4.8: Comparison of estimated emissions from the domestic maritime sector in 2016 (Ministry of Economy, 2018) and 2018 (Republic of Fiji, 2019; Tunidau, 2018).

Yet in the 2018 estimate (Figure 4.2) there was a high degree of uncertainty over the emissions estimate for small boats due to the unavailability of data. This TNA focusses on retro-fitting large vessels over 15 m in length servicing economical routes to achieve a reduction in GHG emissions.

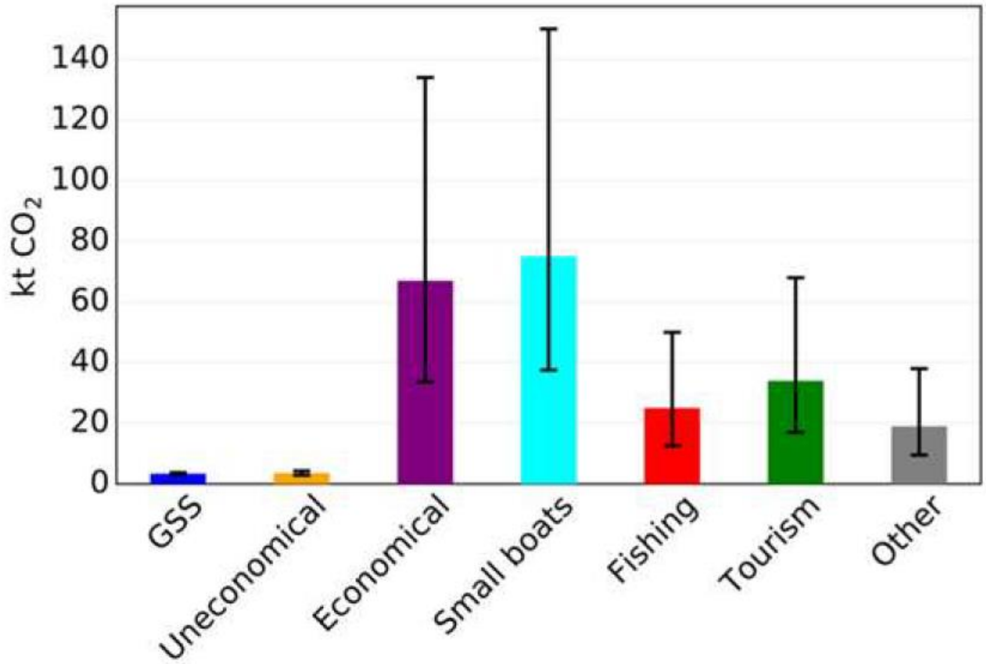

Figure 4.29: GHG (CO2) emissions from Fiji's shipping sector (Tunidau, 2018).

4.1.1 Current status of technologies for domestic maritime transportation

Two principal sources to power the marine vessels (not including sailboats) are:

- o Main engine – used for propulsion.
- o Auxiliary engine – used for electricity generation.

Due to the availability of professional diesel mechanics and spare parts, and the unavailability of bunkering facilities for alternative fuels (e.g., there is no bunkering facility for HFO), domestic shipping uses diesel engines. The following technologies are currently being used:

- **The main engine is mostly diesel-powered**.
- **Auxiliary engines also diesel-powered**.

It is commonly assumed that the large vessels are diesel-powered, yet there some vessels over 15 m that may be powered by large petrol outboard motors. The technologies identified are applicable to both diesel- and petrol-powered ships. In particular, the issue with the engines of the current domestic maritime ships operating on a commercial basis is that the engines were installed at the time the ships were bought and are based on outdated technologies that are very inefficient. To compound that problem, old ships are being replaced with other old ships (Nuttall et al., 2014). Smaller sailboats are used for personal travel/recreational purposes. Sails are also used in yachts but not in domestic maritime ships operating on a commercial basis. The other technologies adopted in reducing GHG emissions are:

- **Hull cleaning**

  All local registered ships of more than 15 meters are required to undertake an annual afloat survey (12 months interval) whereby approved underwater divers submit reports on hull condition and the state of underwater gears. Cleaning of hull, propellers, rudders and sea-strainer grids is usually carried out as per underwater report recommendation and requirements prior to issuance of the next Survey Certificate. Regulations prescribe that any ship over 24 years is required to be docked annually for hull cleaning as cleaner hulls raise fuel efficiency and lower fuel consumption (Tunidau, 2018).

  The most common type is of hull-cleaning system is freshwater using the high-pressure system. Sandblasting is not much in use as it creates a lot of dust, is time-consuming, and needs more equipment, etc. Presently there are only a few approved underwater divers that do underwater hull cleaning.

  Recent studies show that since slime and some macro-fouling build up over a period of time and biofouling between dry-docking periods essentially increases fuel usage and emissions, regular in-water wiping of hulls rather than annual haul-out is recommended (Hydrex, 2012; Vahs et al., 2019).

- **Anti-fouling**

  Coating of the hull with anti-fouling paints is a common practice, and advancement in this area was highlighted in consultations. Marine (Anti-fouling Systems on Ships) Regulations 2014 clearly defines its objectives and application regarding Anti-fouling. The Marine Notice 04-2017 DL Marigold in April 2017 strictly prohibits cleaning, scrapping of the hull and other external surfaces on any foreign vessels in any Fiji ports due to the risk of hull biofouling (Biofouling Management strategy).

  The hull-coating applications are conducted every 2 years for some ships and every 4 years for others. The effectiveness depends entirely on marine growth, which in turn is dependent on ongoing maintenance and operations of vessels (*i.e.*, regular in-water wiping and not having the vessel tied-up/berthed in port for prolonged periods). As per survey requirements, all ship owners must submit anti-fouling application specifications whenever the ship is on dry dock/slipway to confirm compliance to requirements. Only a few suppliers of anti-fouling products are approved by the Authority (MSAF), and names are circulated to ship owners through Marine Notices.

- **Weather routing**

  Ship-owners and operators perform optimised routing whenever possible.

- **Slow steaming**
  Ships in Fiji are normally run at economical speeds (less fuel consumption and therefore reduced CO_2 emissions (Tunidau, 2018). The usual recommended slow-steaming speeds are lower than 12 knots and most often less than 8 knots for RoRo/Ferries.

- **Planned maintenance**
  Planned maintenance of all systems and on-board equipment, including underwater gears, engines, gearbox, and other machinery, reduces wear and tear whilst increasing efficiency and lowering GHG emissions. The Fiji Maritime Laws require all domestic ships operating on a commercial basis to have a planned maintenance system in place and to implement it.

4.2 DECISION CONTEXT

The selection of the domestic maritime transportation sector is directly aligned with Fiji's 5-Year and 20-Year National Development Plan (NDP). The NDP 2017-2036 acknowledges that the inter-island sea-transport network is critical for Fijians living in the maritime islands, since it supports not only transportation but also commerce and income-generating opportunities in the maritime region. The aim of NDP is to make shipping services more reliable, safe, efficient and affordable, with the long-term objective of modernising the air, maritime and land transport networks to meet our long-term needs and aspirations (Ministry of Economy-The Republic of Fiji, 2017).

In addition, the Fiji NDC Implementation Roadmap points out two key measures for low-carbon maritime transportation, including; i) alternative propulsion systems, including a replacement programme for outboard motors and ii) improved maintenance of sea vessels to increase fuel efficiency (Ministry of Economy - Republic of Fiji, 2017). Together with that the Green Growth Framework: Thematic Area 8 on Sustainable Transportation encourages improved hull and propeller designs, purchase and trial of vessels fuelled by renewable energy, assessment of 4-stroke outboard motors, and more studies of incentives for low-carbon domestic shipping (Ministry of Strategic Planning National Development and Statistics, 2014).

The draft NEP section 5.4 – Transport, subsection 5.4.2 calls for efforts to "Investigate the potential and cost-effectiveness of energy efficiency and renewable energy solutions for sea vessels" (Fiji Department of Energy, 2013). The NEP-2013 aims to promote the adoption and use of improved models of maintenance to increase the efficiency of vessels as well as explore biofuels, solar and sail-assisted propulsion, more efficient motors and better ship designs. From a transportation perspective, a Maritime and Land Transport Policy (2015) was also developed to curtail GHG emissions. This policy also promotes better and fuel-efficient transport equipment and engines, better designs and renewable energy in propulsion. It further suggests technologies for emission reductions in the maritime transportation sector including:

- Improved port efficiency
- Introduction of renewable energy as fuel (biofuels)

- Renewable (solar, or sail-assisted) and/or low carbon propulsion alternatives (retrofitting of efficient propulsion and hull designs)
- Improved operation and maintenance
- Adoption of operational actions (such as slow steaming and weather routing)
- The use of smaller and well-suited vessels for inter-island routes
- The revival of traditional knowledge associated with the use of small canoes and camakau (traditional watercraft).

The main goals of the TNA would include the identification of technologies that reinforces the current policies in place, the NDC-IR, LEDS, and the current GGF and would contribute to the achievement of Fiji's 5-Year and 20 Year NDP.

4.3 AN OVERVIEW OF POSSIBLE MITIGATION TECHNOLOGY OPTIONS IN THE DOMESTIC MARITIME SHIPPING SECTOR AND THEIR MITIGATION POTENTIAL AND OTHER CO-BENEFITS

4.3.1 Technologies Identified

For maritime transportation, a total of 47 technology options were initially identified. Then via discussions among the National Expert Consultant, the Sector Working Groups members, and other stakeholders including current ship operators, the technologies were short-listed based on the applicability, technical maturity and local experiences of the relevant stakeholders. Only technologies that were technically mature were considered, and the ones that were in Research & Development and/or Pilot Implementation phases were not considered. Following this, 8 mitigation technologies[3] for the domestic maritime transportation sector (i.e., vessels greater than 15 m in length) were identified as follows:

1. Hull coating
2. Propeller polishing
3. High-efficiency lighting / Energy efficient lighting system
4. Bulbous bow optimisation
5. Bilge keel optimisation
6. Wind power: auxiliary soft sails
7. Propeller boss cap fins (PBCF)
8. Propulsion (main) engine replacement

[3] The effectiveness of these technologies is contingent upon the proper maintenance and capital development.

4.3.2 Overview of the Technologies Identified

Brief descriptions of the identified technologies are as follows:

1. **Hull coating**

Hull coatings are complex coatings used on the hulls of marine vessels. Hull coatings are applied to reduce bio-fouling and hydrodynamic drag that otherwise would increase the frictional resistance between water and the ship. Hull coatings improve the efficiency of ships by reducing the need for engine power in moving the ship, with a subsequent reduction in bunker-fuel consumption and CO_2 emissions. Hull coating is applicable for all vessel types and ages. FATHOM (2013) has provided a range of hull coatings available in the market, and MSAF has its own approved listings; however, high savings will be achieved by applying advanced hull coatings in combination with good hull condition monitoring and maintenance. GloMEEP (2017) Estimates an average emission reduction potential of 2.5%[4] with this technology.

2. **Propeller polishing**

Propeller polishing technology influences the efficiency of the propeller. Due to wear and tear, strain, corrosion, calcareous deposits and cavitation damage, the surface of a propeller becomes uneven and rough. Eventually, bio-fouling can also occur on the propeller. Hydrex (2012) estimated that even a 1 mm layer of accumulated fouling or calcium deposits on a propeller significantly increases its roughness from an ISO class I to an ISO class II, or a class II to a III, within a period of 12 months. Some propellers support marine growth up to 20 mm thick (Hydrex, 2012).

Propeller polishing removes the organic build-up and reduces the roughness that in turn reduces the frictional loss of the propeller, and regular polishing is recommended for optimal output (GloMEEP, 2017). The key advantage is that propeller polishing is applicable to all vessels of all ages. Improved propeller efficiency will reduce the power loss in the system and decrease the ship's fuel costs.

An average fuel reduction of 3.5%[4] on the main engine and subsequent emissions is achievable from this technology (GloMEEP, 2017), yet a gain of up to 6 to 12% is also possible by polishing a propeller from a class III condition to a class I condition (Hydrex, 2012).

3. **High-efficiency lighting / Energy efficient lighting system**

Efficient lighting systems have rapidly evolved in the last decade with the development of light-emitting diodes (LED). Low-energy halogen lamps, fluorescent-tube lights in combination with electronically controlled systems for dimming, and automatic shut-off

[4] GloMEEP does not have any local or Pacific domestic shipping baseline data. Detailed individual assessment ~~of individual ship~~ is needed in estimating fuel savings for any~~respective~~ ship~~s~~. Installation of fuel metering is recommended to ascertain the actual savings.

are also readily available. Implementing the energy-efficient light system will, in addition, reduce the maintenance hours and operating cost, and the additional operational costs are set to zero because most energy-efficient lighting systems have a lifetime that is equal to or longer than that of traditional lighting systems (GloMEEP, 2017).

An emission-reduction potential of 0.25-5%[4] (GloMEEP, 2017) of the total auxiliary engine consumption is possible with highly efficient lighting systems. A comparative average emission reduction of approximately 0.4% to that of the main engine is possible.

4. **Bulbous bow optimisation**

For many vessels, the current operating profiles deviate significantly from the profile or design point that determined the initial design of the vessel (GloMEEP, 2017). To reduce the ship-to-wave resistances, optimisation of the lines of the bulbous bow of a hull are carried out at design stages (Luo and Lan, 2017). In the case of Fiji, none of the vessels were specifically designed for local conditions and were purchased elsewhere. Accordingly, the vessels' hull profiles have had to be optimised for current operations.

For existing local ships where hull-form optimisations are limited, retrofitting of the bulbous bow can bring considerable fuel savings, with an average emission reduction potential of 4%[4] of the main engines achievable for ships that are greater than 4000 DWT or traveling at speeds greater than 12 kn (GloMEEP, 2017). No such study has been performed locally or in the Pacific.

5. **Bilge keel optimisation**

Bilge keels are employed in pairs to increase the hydrodynamic resistance to rolling. Ships usually have one bilge keel on each side reducing side-ways movement (rolling), but poorly designed or damaged bilge keels increase the resistance for forward movement. As a result, a vessel's bilge keel profile needs to be optimised for current operations. The position and structure of the bilge keel require optimisation to reduce the forward resistance, and an average reduction in emissions from the main engines of 1.1%[4] is possible (GloMEEP, 2017).

6. **Wind Power: auxiliary sails**

Wind-powered ships with soft sails have been used in the past for voyages in Fiji. Currently, retrofitting of ships for different types of wind-power is under study, including flexible-sail, rigid-sail or turbo-sail, kites, and Flettner rotors. The IMO and GloMEEP consider these to be not-mature technologies (GloMEEP, 2017), yet researchers at the Micronesian Center for Sustainable Transport (MCST) consider this the most mature technology of all. Soft sails are one of the oldest wind-propulsion techniques, used in many remarkable sailing journeys and discoveries. However, this soft sail-derived power depends on the availability of wind, weather conditions and the skill of the crew.

In the 1980s, retrofitting of auxiliary sail rigs in two small passenger/cargo ships resulted in fuel savings of 23–30% (Nuttall et al., 2014). Unfortunately, fuel savings and emission reductions are contingent upon the wind conditions in which the ship operates, and GloMEEP (2017) estimates the true average emission-reduction potential to be in the range of 5.5%[4] on main engine fuel consumption. The current local operators share GloMEEP's perception that this is an immature technology.

7. **Propeller boss cap fins (PBCF)**

The propeller, located at the stern of a ship, produces thrust axially using the power delivered from the main engine via a shaft. To increase the thrust, the hub vortex behind the propeller needs to be reduced or eliminated, which is achieved by one of the augmentation tools called the propeller boss cap fins **(**PBCF) (Ghassemi et al., 2012). The PBCF is an energy-saving device attached to the propeller of a vessel. In addition to reducing propulsion efficiency, the hub vortex also exposes the rudder to corrosion. The installation of PBCF is simple and straightforward, requiring only the removal of the propeller boss caps and replacement with the PBCF. No hull modification is needed. An average emission reduction potential of 4%[5] of the main engines is possible.

8. **Engine replacement**

Main-engine retrofit, which includes main-engine tuning and common-rail engine upgrades, are ways to improve the engine performance. Yet the engines that we currently have in many ships are relatively old and are projected to undergo little improvement. The "new" shipping vessels brought into the country are essentially second-hand vessels that are near the end of their working life (more than 20 years old) (Nuttall et al., 2014) and use older technologies that provide poor fuel economy. Hence, the challenge for stakeholders is to replace the current engines with newer and more efficient engines. The engines of petrol-powered boats also need to be replaced with the more efficient 4-stroke engines. The newer engines, if maintained and operated correctly, are expected to produce high fuel-efficiency, subsequently lowering GHG emissions including CO_2 and NO_X. These engines could also support the transition towards low sulphur emissions. Average emission reduction potentials of up to of 28%[5] is achievable.

The focus of the TNA was on retrofitting of large vessels (greater than 15m in length) on economical routes with energy-efficient technologies. Retrofits are not recommended for ships that are nearing their end of working life. Other stakeholders believe that a detailed maritime-transport needs assessment is needed, with relocation of jetties probable on economical routes, such as Natovi Jetty. Transportation logistics need to be optimised by operators, and regular maintenance of ships must be performed by each operator. A Ship Energy Efficiency Management Plan (SEEMP) also needs to be implemented, with a goal-based target with appropriate incentives that can be given to operators. For a newer fleet, the Energy Efficiency Design Index (EEDI) is a mandatory measure that promotes the use of more energy-efficient (less polluting) equipment and engines.

[5] Detailed individual assessment is needed in estimating fuel savings for any ship. Installation of fuel metering is recommended to ascertain the actual savings.

4.4 CRITERIA AND PROCESS OF TECHNOLOGY PRIORITISATION FOR THE DOMESTIC MARITIME TRANSPORTATION SECTOR

The 8 technologies were evaluated and appraised against a set of criteria that were established via stakeholder consultations, and the Multi-Criteria Analysis (MCA) was used to prioritise the technologies for the domestic maritime sector. In consultation with the stakeholders, it was decided that 10 criteria encompassing three categories (i.e., Costs, Benefits, and Local Context) are to be used to evaluate the technologies.

The cost of technologies was further divided into Capital Costs, Operational and Management Costs, and Lifetime of the technologies.

The Benefits included Economic, Social and Environmental benefits that were further delineated; Job Creation was regarded as the only Economic Benefit; the Social Benefits were divided into Time Efficiency and Travelling Comfort; while the Environmental Benefits were divided into CO_2 reduction potential and Impact on Marine Environment (Apart from CO_2).

In the Local Context, the key criteria were Market Potential and Acceptability to Local Stakeholders.

During the scoring process, the stakeholders for the domestic maritime transportation sector referred to the Technology Fact Sheets, used their experiences and deliberated on each of the criteria. Then they collectively decided to give individual scores and average out the scores for each of the criteria. Hence, a performance matrix was constructed, and the scoring was carried out after discussing the information provided in the technology factsheets and experiences of respective stakeholders.

Table 4.1 presents the Categories and Criteria used in the prioritisation process upon which the Performance Matrix (Annex III - Table A3) and Scoring Matrix (Annex III - Table A4) were constructed. Two levels of criteria resulted after the discussions. During the process of assigning weights, a total of 100 points was given for Level 1 Criteria and each sub-criterion at Level 2 was further assigned a total of 100 points. The weightings were assigned at Level 1 criterion by respective stakeholders and then averaged out. A similar approach was taken for Level 2 criterion as well. The assigned weights for each criterion are presented in Table 4.1, while Figure 4.3 illustrates the weights associated with respective categories. Figure 4.3 clearly shows that the benefits category (65%) has a larger influence on the selection of respective technologies.

The calculations of total scores for these identified technologies were performed as described in the MCA manual. Since the Performance Matrix (Annex III - Table A3) consists of both quantitative and qualitative nominal data (from the Likert scales), the scores cannot be aggregated directly. Hence, a normalisation process was adopted whereby all nominal values were converted to scores in the range of 0 to 100. Particular attention was paid to preferred values. Costs and Benefits were the criteria with higher preferred value and needed to have higher scores as well. Then the weights of each criterion were multiplied with the corresponding scores and aggregated across all criteria to ascertain the final scores. A summary of the scoring matrix for technology prioritisation for the domestic maritime transportation sector is provided in Annex III - Table A4. The technology options were ranked according to their total score, and the three best-scoring technologies were selected for further analysis. Finally, a sensitivity analysis was carried out to confirm the results. During this process, the weights were varied to see if the ranking of the top three technologies changed or not. The notion of sensitivity analysis is to remove any data uncertainties or differences of opinion that may have existed to ensure that a small change in the weights does not bring about large changes in the technology ranks.

Table 4.1: Criteria and the respective assigned weights for the maritime transportation sector.

	Category										Total
	Costs			Benefits					Local Context		
				Economic	Social		Environmental				
Lev 1 Weights	15%			15%	30%		20%		20%		100%
	Capital Costs (USD)	Operational and Management (USD)	Lifetime (Years)	Job Creation	Time Efficiency	Travelling Comfort	CO_2 reduction potential (%)	Impact on Marine Environment (Apart from CO_2)	Market Potential	Acceptability to local stakeholders	
Sources	Technology Providers, Operators	Technology Providers, Operators	Technology Providers, Operators	Expert Judgment	Expert Judgment	Expert Judgment	Expert Judgment, Tech Specification	Expert Judgment	Expert Judgment	Expert Judgment	
Preferred value	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Lower	Higher	Higher	
Lev 2 Weights	30%	35%	35%	100%	40%	60%	50%	50%	50%	50%	
Overall Weights	**4.5**	**5.25**	**5.25**	**15**	**12**	**18**	**10**	**10**	**10**	**10**	**100**

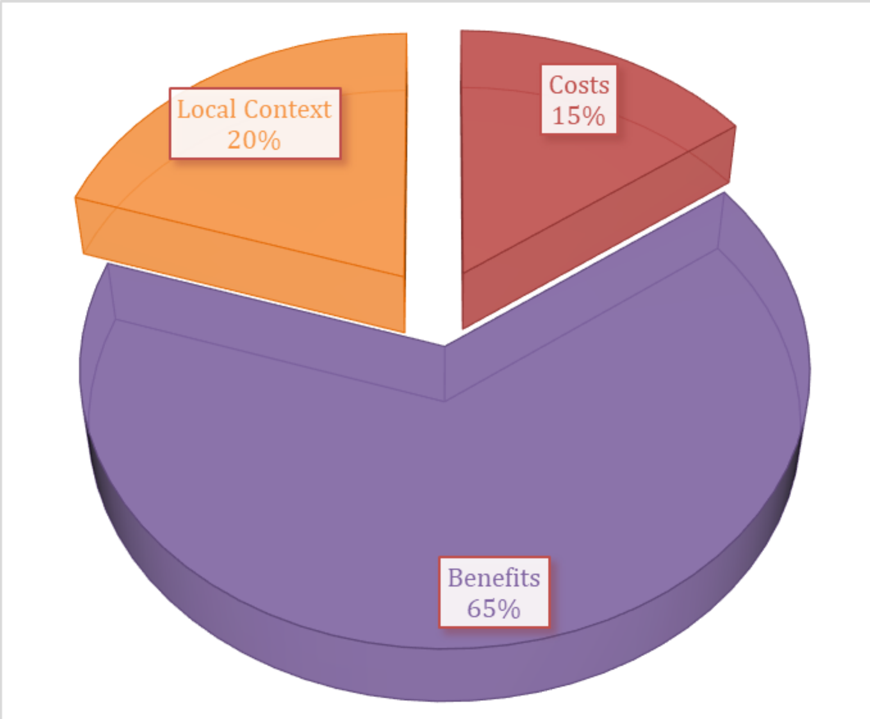

Figure 4.3: The weights assigned to the identified categories for the domestic maritime transportation sector.

4.5 RESULTS OF TECHNOLOGY PRIORITISATION FOR THE DOMESTIC MARITIME TRANSPORTATION SECTOR

The performance matrix converted to a scoring matrix was utilised for technology prioritisation. The scales for all criteria data were confined in the range of 0 to 100, and the most preferred technological option essentially has the highest score. Figure 4.4 shows the scoring and prioritisation in the form of bars which clearly illustrates that the scores of the technology Options 7 and 8 are relatively high in comparison to others. The performance matrix, the scoring matrix, and the resulting decision matrix are presented in Table A3 (Annex).

To affirm the results, a sensitivity analysis was performed by varying the weights of the different criteria and performing a cost-benefit plotting as in Figure 4.5. An outcome summary of sensitivity analysis for the domestic maritime sector is provided in Annex III – Table A6.

Accordingly, the outcomes show that the following technologies are recommended for further analysis:

1. **(*Technology 8*) - Propulsion (main) Engine Replacement**
2. **(*Technology 7*) - Propeller Boss Cap Fins (PBCF)**
3. **(*Technology 5*) - Bilge keel optimisation**

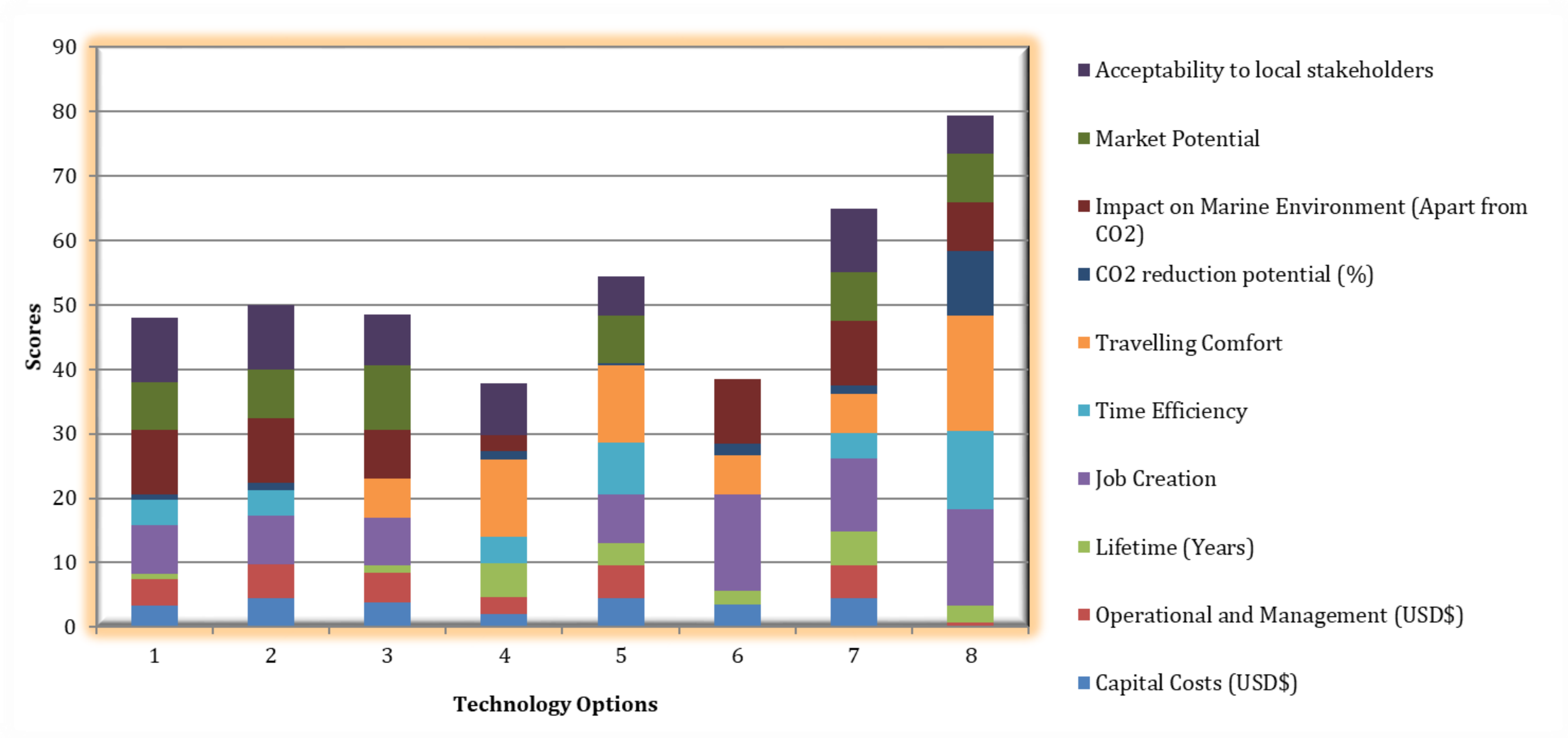

Figure 4.410: Technology scoring and prioritisation for the domestic maritime transportation sector.

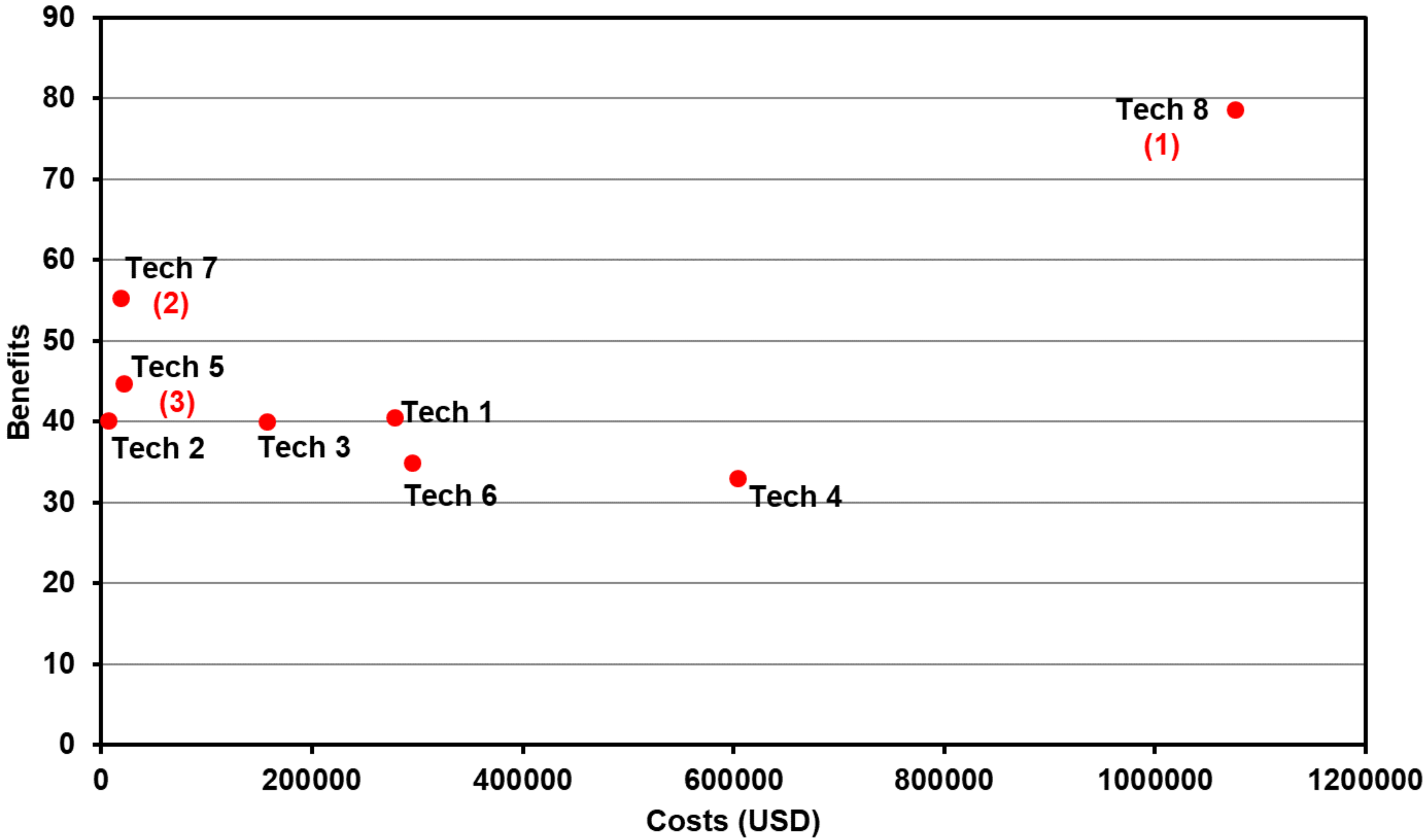

Figure 4.5: Costs and Benefits of the identified technologies for the domestic maritime transportation sector.

CHAPTER 5: SUMMARY AND CONCLUSIONS

After initial consultations with key decision-makers and stakeholders, the Off-grid rural electrification and domestic maritime transportation sectors were selected for the mitigation component of the TNA process.

A long list of technologies was identified and later shortlisted according to their maturity, applicability and local availability. The shortlisted technologies underwent further analysis and a prioritisation process. The decisions were based on economic, social and environmental benefits together with local context and the associated operational and capital costs. GHG emissions together with the development priorities of Fiji played a major role in the sector and technology prioritisation process.

A total of 17 technology facts sheets (TFSs) were developed (i.e., 9 for the Off-grid rural electrification sector and 8 for the Domestic maritime transportation sector). On the basis of the TNA methodology and MCA approach as described in the handbook, the TFS were scored and ranked for each sector separately and are presented in Chapters 3 and 4.

Finally, a sensitivity analysis was carried out by varying the respective weights is to make sure major changes in the rankings do not occur because of minor change in the weights particularly for the top-ranked technology options.

The following technologies were identified as the preferred technology options for the respective sector;

Off-grid rural electrification sector

1. Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Microgrids)
2. Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS (microgrid)
3. Micro/Pico-hydro in microgrid configuration

Domestic maritime transportation sector

1. Propulsion (main) Engine Replacement
2. Propeller Boss Cap Fins (PBCF)
3. Bilge keel optimisation

Barrier analysis and development of technology action plans will be carried out to reflect the need for actions related to these prioritised technologies in the respective sectors and subsectors. The results of the TNA project will assist in the ongoing efforts to enhance Fiji's NDC by reducing GHG emissions and will support Fiji's development priorities. Further TNAs are recommended for other sectors as well.

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ANNEXES

Annex I

Technology Factsheets for Selected Technologies

Off-Grid Rural Electrification Sector

Technology Fact Sheet

Technology	Standalone Ground Mount Solar PV with ESS (Community Based Electrification – Microgrids)
Sector	**Energy**
Sub-sector	**Off-grid Rural Electrification**
Sectoral GHG emission	Fiji's total greenhouse gas emissions are approximately 2,500 Gigagrams per year of which 1,500 Gigagrams (59%) are from the electricity sector.
Background/Notes, Short descriptions of the technology options	**Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Microgrids)** is understood to power a small community for their 24/7 electricity demands on top of lighting up. Solar PV only produces electricity in periods of sunlight, either direct light or diffuse sunlight on overcast days. During the night, they will not produce power. This means that solar cells if used for remote/off-grid generation purposes, need to be implemented in conjunction with some kind of energy storage system such as a battery or as a hybrid system with some other type of generator. Where solar cells are grid-connected, this is less of a problem. They can be used during the day to reduce the local demand from the grid (or even to export back to the grid) and then at night, or during periods of the low incident light, the grid can supply the necessary power. The former kind of application, as a remote or off-grid generator, is most commonly observed in developing countries and isolated areas and in Fiji, this could be easily implemented in remotely located communities where grid extension would not be feasible and in remote maritime communities. The system would include tilted solar photovoltaic (PV) module, inverter, storage, grid installation costs, etc. and outlets for other AC appliances like a television, radio or cassette player, fans, laptops, and charging of mobile devices. This will reduce the need for candles, kerosene, liquid propane gas, and/or battery charging, and provide increased convenience and safety, improved indoor air quality, and a higher quality of light than kerosene lamps for reading. 10 – 50 kW systems would likely be sufficient depending on the respective community needs, yet a full feasibility study is recommended. Small off-grid systems in remote/rural areas can be installed with relatively little local expertise. Maintenance is minimal and mainly requires the cleaning of the solar panel to ensure efficiencies are maintained. Source: climatetechwiki.org

Technology	Standalone Ground Mount Solar PV with ESS (Community Based Electrification – Microgrids)
Sector	Energy
Sub-sector	Off-grid Rural Electrification
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if technology could have some improvements in the country environment.	The suitable unobstructed land area needs to be acquired within the vicinity to have the solar PV units installed. The ground mount is more climate/cyclone resistance in comparison to roof-top mount systems. System sizing and proper feasibility will be carried out for the electricity need of the community prior to the implementation of the technology. **Funding could come from:** **Electrification fund** and an associated framework that will be used to provide capital subsidies for electrification projects that increase access for unserved communities. **Subsidies** to provide leverage on capital contributions from beneficiaries and project promoters as far as possible and will be provided as once-off capital contributions for viable projects. International funding agencies. • Fijian Government is offering a 5-year tax holiday to a taxpayer undertaking a new activity in renewable energy projects and power cogeneration. • Moreover, to entice greater uptake of renewable technology such as solar PVs, the Fijian Government is offering duty-free importation of renewable energy goods. • 100% write off (accelerated depreciation) is also available in the year expenditure was incurred on water storage facilities and renewable energy plants and machinery.
Country-Specific/Applicability	The location of Fiji in the tropical belt makes it suitable for solar PV installations, yet site-specific feasibility studies are important. The standalone solar PV is low maintenance; hence it is easier for communities to monitor the operations.
Implementations barriers	Lack of investment from communities and NGOs. Lack of pre-feasibility studies. Initial capital costs could be high. Sometimes deep-cycle batteries are stolen or used for other purposes.
% Reduction in GHG emissions in comparison to equivalent Power generations from conventional Diesel usage per kW	93.8%
Impact Statements – How this option impacts the country development priorities.	
Social benefits	• Allow greater involvement of non-government providers in off-grid rural electrification, including community-based organisations, NGOs, and the private sector. • Improved living standards. • Improved livelihoods. • More night-time social activities • Better education for children. • Income generation

Technology	Standalone Ground Mount Solar PV with ESS (Community Based Electrification – Microgrids)
Sector	**Energy**
Sub-sector	**Off-grid Rural Electrification**
	• Training in the technology may lead to more training and spread of technology application and capacity Development • Improvement of health conditions through improved comfort. • Better information communication technology penetration in rural areas. • Increases energy security. • Allow women to perform cooking chores and weaving activities.

Economic benefits	• Creation of jobs to install and commission systems (e.g. suppliers of hardware like PV modules and inverters; installers; energy resources assessments, service technicians, etc.)
	• Rural Economic activity
	  ○ 24/7 reliable electricity allows for better economic activities:
	  ○ Reduction in food waste as leftovers can be stored.
	  ○ Refrigeration and longer storage of excess food and produce hence better returns.
	  ○ Can create investment in developing and supplying consulting and training services.
	• Supports the Government's target to provide 100% of the population with access to electricity by the year 2021.
	• Facilitates the Government's target in achieving 100% of electricity generations from renewable sources by 2036.
	• Enables NDP 2017-2036 in decentralising renewable energy sources such as solar, mini-hydro, and wind systems to electrify rural areas and maritime zones where feasible.

Environment benefits	• Investments in future climate-resilient electricity infrastructure project. • Supports Green Growth Framework for Fiji – Thematic Area 7 Energy Security. • A large space for Solar PV array installation is required.
Costs	
System Capital costs: (PV, ESS, inverter, etc.)	3314 (USD/kW) + 1250 USD/connection = 4564[6]
Annual operational and maintenance costs + replacement	228 (USD/kW)
Lifetime	25 years
Others	
Local Context	
Opportunities and Barriers	Opportunities: Fiji Islands receive ample amounts of solar energy with some areas that have fewer no-sun days than others. Microgrid is more stable in comparison to standalone systems. Barriers: High Capital costs.
Market Potential	High potentials with many RESCOs providing solar PVs.
Acceptability to local stakeholders	Very High Acceptability. May require community engagement for routine maintenance/checks.

[6] The costs are approximate costs collated from vendors and may change at time of implementation for various reasons, including system sizing and fiscal policies/incentives. The cost is for equipment and installation only and does not include costs of feasibility studies, EIA and cartage, etc.

Technology Fact Sheet

Technology	Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS
Sector	Energy
Sub-sector	Off-grid Rural Electrification
Subsector GHG emission	Fiji's total greenhouse gas emissions are approximately 2,500 Gigagrams per year of which 1,500 Gigagrams (59%) are from the electricity sector.
Background/Notes, Short descriptions of the technology options	**Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS** is understood to power a small community for their 24/7 electricity demands on top of lighting up. Solar PV only produces electricity in periods of sunlight, either direct light or diffuse sunlight on overcast days, and excess energy is stored using appropriate energy storage systems. During the night, the PV will not produce power. This means that solar cells if used for remote/off-grid generation purposes, need to be implemented in conjunction with other mechanisms which in this case are energy storage systems as well as dual fuel (CNO/Diesel) generator as a hybrid system. This kind of application, as a remote or off-grid generator, is not common in Fiji, but could be easily implemented in isolated areas and remotely located communities where grid extension would not be feasible and in remote maritime communities. This would be in terms of simple microgrid connected PV systems with ESS and the dual-fuel generator. Solar Contribution is expected to be around 85-95% with a Battery Capacity of 1.5 - 2 days (of consumption). Fiji has the capacity to produce bio-fuels since it has large amounts of natural raw materials such as coconut oil (CNO). The successful blending of CNO with kerosene and diesel has been trialed during the past years in the Pacific region for electricity generation (Government of the Republic of Fiji, 2014). The FDoE has also implemented 60 dual-fuel kits for diesel generators whereby CNO can directly be used without blending. The government is currently reassessing the biofuels industry by realigning its priorities with the development of a biofuels testing lab at the Institute of Applied Sciences, USP and providing incentives to investors. The PV is estimated to meet daytime energy needs as well as excess for battery charging/storage, while during the night, battery supply is used and in extreme cases, appropriate fuel will be required. The projected annual generation mix is as follows: PV+ ESS = 70%; CNO = 25%; and Diesel = 5%.[7]
Implementation assumptions, How the technology will be implemented and	A suitable unobstructed land area needs to be acquired within the vicinity to have the solar PV units installed. The ground mount is more climate/cyclone-resistant in comparison with roof-top mount systems. Yet the initial capital costs are higher.

[7] The generation mix is projected values only and will depend on the system design, the availability of RE resources (Sun hours, CNO), and downtime, etc.

Technology	Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS
Sector	**Energy**
Sub-sector	**Off-grid Rural Electrification**
diffused across the subsector? Explain if the technology could have some improvements in the country environment.	**Funding could come from:** **Electrification fund** and an associated framework that will be used to provide capital subsidies for electrification projects that increase access for unserved communities. **Subsidies** to provide leverage on capital contributions from beneficiaries and project promoters as far as possible and will be provided as once-off capital contributions for viable projects. International funding agencies. • Fijian Government is offering a 5-year tax holiday to a taxpayer undertaking a new activity in renewable energy projects and power cogeneration. • Moreover, to entice greater uptake of renewable technology such as solar PVs, the Fijian Government is offering duty-free importation of renewable energy goods. • 100% write-off (accelerated depreciation) is also available in the year expenditure was incurred on water storage facilities and renewable energy plants and machinery.
Country-Specific/Applicability	The smaller islands and rural communities receive ample sunlight and have the potential to utilise coconut oil as the fuel to the dual-fuel generators. ESS gives an added leverage to GHG reduction and subsequent reliability concerns.
Implementations barriers	Lack of investment from communities and NGOs. Lack of pre-feasibility studies.
% Reduction in GHG emissions in comparison to equivalent Power generations from conventional Diesel usage per kW	90.5%
Impact Statements – How this option impacts the country development priorities.	
Social benefits	• Allow greater involvement of non-government providers in off-grid rural electrification, including community-based organisations, NGOs, and the private sector. • Improved living standards. • Improved livelihoods. • More night-time social activities • Better education for children. • Income generation • High capacity building and training for local communities. • Improvement of health conditions through improved comfort. • Better information communication technology penetration in rural areas. • Promotes the development of other indigenous local energy resources in particular biofuels, in order to reduce the dependence on imported fossil fuels for electricity generation supporting the Green Growth Framework – Thematic Area 7. • It requires diesel, and the price is not stable, hence negatively impacts energy security. • Allow women to perform cooking chores and weaving activities.

Technology	Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS
Sector	Energy
Sub-sector	Off-grid Rural Electrification
Economic benefits	• Creation of jobs to install and commission systems (e.g. suppliers of hardware like PV modules, ESS, inverters, and generators; installers; energy resources assessments, service technicians, etc.) • Rural Economic activity o 24/7 reliable electricity allows for better economic activities, yet the diesel supply needs to be consistent. o Reduction in food waste as leftovers can be stored. o Refrigeration and longer storage of excess food and produce, hence better returns. o Can create investment in developing and supplying consulting and training services. • Supports the Government's target to provide 100% of the population with access to electricity by the year 2021. • Facilitates the Government's target in achieving 100% of electricity generations from renewable sources by 2036. • Enables NDP 2017-2036 in decentralising renewable energy sources such as solar, mini-hydro, and wind systems to electrify rural areas and maritime zones where feasible.
Environment benefits	• Investments in the future climate-resilient electricity infrastructure project. • Supports Green Growth Framework for Fiji – Thematic Area 7 Energy Security. • When burnt in a Diesel engine, CNO emits less sulfur dioxide SO_2 (the primary contributor to tropical plant and rainforest depletion). • CNO oil emits 50% less particle matter (black smoke) than conventional diesel. • No chemicals are required to produce the fuel, so there are no harmful by-products. • Large space required for solar PV installation + generator and ESS housing
Costs	
Capital costs	3400 (USD/kW) + 1250 USD/connection = 4650[8]
Annual operations and maintenance costs + Replacement + Fuel	190.44 + 62.5 = 253 (USD/kW)
Lifetime	25 years
Others	
Local Context	
Opportunities and Barriers	Opportunities: Excellent reliability in terms of electricity supply. Barriers: Large capital investment required and the O&M cost is also substantial.
Market Potential	Very high market potential as these systems has been installed and tested.

[8] The costs are approximate costs collated from vendors and may change at time of implementation for various reasons, including system sizing and fiscal policies/incentives. The cost is for equipment and installation only and does not include costs of feasibility studies, EIA, cartage costs, and trainings, etc.

Technology	Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS
Sector	Energy
Sub-sector	Off-grid Rural Electrification
Acceptability to local stakeholders	The whole system acceptability (except for CNO generator) is high amongst stakeholders.

Technology Fact Sheet

Technology	Micro/Pico-hydro in microgrid configuration
Sector	**Energy**
Sub-sector	**Off-grid Rural Electrification**
Subsector GHG emission	Fiji's total greenhouse gas emissions are approximately 2,500 Gigagrams per year of which 1,500 Gigagrams (59%) are from the electricity sector.
Background/Notes, Short descriptions of the technology options	Pico hydro microgrids to power a small community for their electricity demands. Pico hydropower: Turbines smaller than 10 kW are usually called "pico". Pico hydropower is rarely fed into a power grid, but in most cases, electricity is delivered to a village or a workshop. As there are varying definitions of the power range of "micro" and "pico", it is advantageous to specify each project's power output in kW. Pico hydropower is the only form of small renewable energy production that works continuously without battery storage. Where applicable, it is one of the cost-efficient solutions to supply electrical energy. Pico turbines can provide power for small clusters or even single households. Individual hydropower supply cuts out the efforts of organising a community. Micro-Hydro - Installations with a power output of 5 - 100 kW (usually provided power for a small community or rural industry in remote areas away from the grid). A 100 kW Generic hydro has been presented for analysis; however, proper site identification in terms of flow rate and head height needs to be determined prior to undertaking such a project. Identifying, planning and managing take a higher proportion of the whole installation efforts. Installation includes installing the turbine and grid installation to the appropriate point of need. Source: https://energypedia.info/wiki/Pico_Hydro_Power
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	The first and foremost requirement would be to find a suitable site within the vicinity of the rural community that has a high level of hydro potential. The other requirement would be to acquire rights from traditional owners. **Funding could come from:** **Electrification fund** and an associated framework that will be used to provide capital subsidies for electrification projects that increase access for unserved communities. **Subsidies** to provide leverage on capital contributions from beneficiaries and project promoters as far as possible and will be provided as once-off capital contributions for viable projects. International funding agencies. • Fijian Government is offering a 5-year tax holiday to a taxpayer undertaking a new activity in renewable energy projects and power cogeneration.

Technology	Micro/Pico-hydro in microgrid configuration
Sector	**Energy**
Sub-sector	**Off-grid Rural Electrification**
	• Moreover, to entice greater uptake of renewable technology such as solar PVs, the Fijian Government is offering duty-free importation of renewable energy goods. • 100% write off (accelerated depreciation) is also available in the year expenditure was incurred on water storage facilities and renewable energy plants and machinery.
Country-Specific/Applicability	This is applicable to communities that are near rivers that have sufficient hydro potentials.
Implementations barriers	Lack of investment from communities and NGOs. Lack of pre-feasibility studies.
% Reduction in GHG emissions in comparison to equivalent Power generations from conventional Diesel usage per kW	98.3%
Impact Statements – How this option impacts the country development priorities.	
Social benefits	• Allow greater involvement of non-government providers in off-grid rural electrification, including community-based organisations, NGOs, and the private sector. • Improved living standards. • Improved livelihoods. • More night-time social activities • Better education for children. • Income generation • Very high capacity development is anticipated amongst the local communities • Improvement of health conditions through improved comfort. • Better information communication technology penetration in rural areas. • Contingent upon streamflow, head, etc., better energy security in comparison to VRE. • Allow women to perform cooking chores and weaving activities.

Economic benefits	• Creation of jobs to install and commission systems (e.g. suppliers of hardware like pico-hydro systems and inverters; installers; energy resources assessments, service technicians, etc.)
	• Rural Economic activity
	  o Electricity generation will be contingent upon streamflow and will be affected by prolonged drought/flood; hence the economic activity will be affected.
	  o Can create investment in developing and supplying consulting and training services.
	• Supports the Government's target to provide 100% of the population with access to electricity by the year 2021.
	• Facilitates the Government's target in achieving 100% of electricity generation from renewable sources by 2036.
	• Enables NDP 2017-2036 in decentralising renewable energy sources such as solar, mini-hydro, and wind systems to electrify rural areas and maritime zones where feasible.

Technology	Micro/Pico-hydro in microgrid configuration
Sector	**Energy**
Sub-sector	**Off-grid Rural Electrification**
Environment benefits	• Investments in the future climate-resilient electricity infrastructure project. • Supports Green Growth Framework for Fiji – Thematic Area 7 Energy Security. • River/stream with appropriate head and flow rate is required or damming would be required that will take a huge space.
Costs	
Capital costs	2700 (USD/kW) + 1250 USD/connection = 3950[9]
Annual operational and maintenance costs	135 + 62.5 = 197.5 (USD/kW)
Lifetime	25 years
Others	
Opportunities and Barriers	
Market Potential	Opportunities: most available does not need power storage devices Barriers: Changes in rainfall patterns will affect generation. May require dams to store water and generation is dependent on head and flow rate.
Market potential	The low market potential for micro/pico hydro as few installations have been done, although large hydro schemes are very popular.
Acceptability to local stakeholders	Dependent on factors such as: May affect water resources and land-use. Need for environmental impact assessment.

[9] The costs are approximate costs collated from vendors and may change at the in time of implementation for various reasons, including system sizing and fiscal policies/incentives. The cost is for equipment and installation only and does not include costs of feasibility studies, EIA cartage, and trainings, etc.

Domestic Maritime Transportation Sector

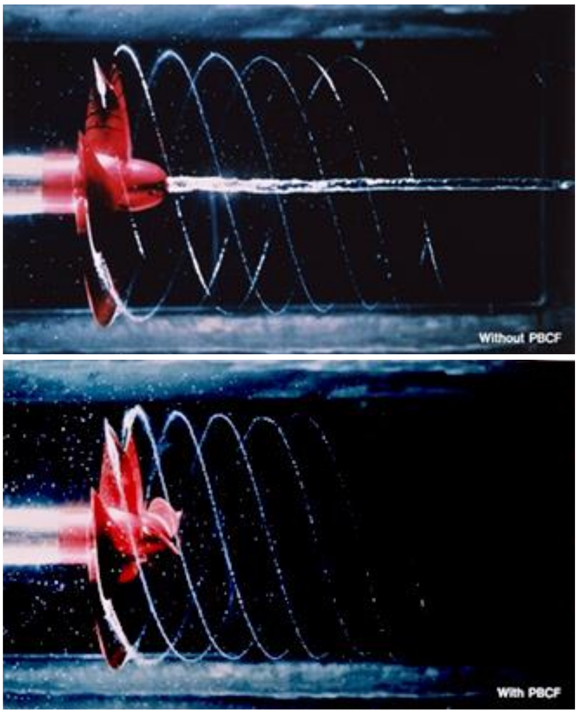
Technology Fact Sheet

Technology	Propulsion (main) Engine Replacement
Sector	**Transportation**
Sub-sector	**Maritime Transportation:** **Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.**
Sectoral GHG emission	Fiji's total greenhouse gas emissions are approximately 2,500 Gigagrams per year while total emissions for the Fiji maritime sector are estimated at 174 kilo-tonnes of CO_2 in 2016 Fiji LEDS
Background/Notes, Short descriptions of the technology options	Main engine retrofit, which includes main engine tuning and common rail engine upgrades is a way to improve the engine performance. Yet the engines that we currently have in many ships are relatively old and are not slated for significant improvements. Hence the challenge is to replace the current engines with newer and more efficient engines. The newer engines are fuel-efficient, with lower GHG emissions including CO_2 and NO_X.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	Main engine replacement could be performed while the ship is berthed and dry-docking is not mandatory. **Funding could come from:** The ship-owners will have to fund the capital expenditure and will be the beneficiary of the reduced fuel costs.
Technical Maturity	Mature Technology is available.
Applicability	All Vessels
Implementation barriers	Capital costs
Emission reduction potential	22-34%[5]
Impact Statements – How this option impacts the country development priorities.	
Social benefits	• Allows for better public-private partnership in the maritime transportation sector. • Awareness and training in technology may lead to more training and spread of technology applications. • This will greatly reduce travel time and increase the time efficiency as newer engines are better designed. • Newer engines have reduced noise and vibrations, increasing travelling comfort.

Technology	Propulsion (main) Engine Replacement
Sector	Transportation
Sub-sector	Maritime Transportation: Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.
Economic benefits	• Creation of jobs in the maritime diesel-engine installation and maintenance industry. • Lower fuel consumption and fuel imports. • It can create investment in developing and supplying consulting and training services in the maritime transport industry. • Supports the Government's NDP 2017-2036 plans in modernising the air, **maritime** and land transport networks to meet our long-term needs and aspirations. • It may improve shipping services by reducing costs and increasing reliability and efficiency.
Environment benefits	• Reduced CO_2 emissions. • Reduction in NOx and SO_2 emissions as well. • Lower diesel oil spillage with reduced impacts on the marine environment.
Other considerations and priorities such as co-benefits	Lower maintenance.
Costs	
Capital costs	$USD 120 000 (750 Hp 13.5 L engine) to USD 1.3 M (Depending on engine capacity/cylinder) Avg = $ 1,025,000[10]
Operational and maintenance costs	$51250 (USD)
Lifetime	15 years
Others	
Local Context	
Opportunities and Barriers	Large fuel savings can be achieved and subsequent reduction in GHG emissions.
Market Potential	Newer and efficient propulsion engines are available. IMO NOx Tier II and Tier III engines are also available at a higher cost.
Acceptability to local stakeholders	Highly acceptable amongst local operators.

[10] The costs are approximate costs collated from vendors and local shipping companies. This may change at the time of implementation for various reasons including size and type of ship and engines.

Technology Fact Sheet

Technology	**Propeller Boss Cap Fins (PBCF)**
Sector	**Transportation**
Sub-sector	**Maritime Transportation:** **Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.**
Sectoral GHG emission	Fiji's total greenhouse gas emissions are approximately 2,500 Gigagrams per year while the total emissions for the Fiji maritime sector are estimated at 174 kilo-tonnes of CO_2 in 2016. Fiji LEDS
Background/Notes, Short descriptions of the technology options	The PBCF is an energy-saving device attached to the propeller of a vessel. It breaks up the hub vortex generated behind the rotating propeller, resulting in a decrease of more than 9,000 tons of CO_2 emissions per year Research and development on the PBCF started in 1986, and sales began the following year. Since then an increasing number of ship-owners, mainly in Japan, have been adopting the system. By 2006, the 19th year since the start of sales, the PBCF had been ordered for 1,000 vessels. Backed by concerns over rising fuel prices and growing awareness of the need to reduce CO_2 emissions, it has gained worldwide recognition, and the owners and operators who believed in PBCF's high-quality and performance have repeatedly ordered.  Source: https://www.mol.co.jp/en/pr/2015/15033.html
Implementation assumptions, How the technology will be implemented and diffused across the	Installation is simple and straightforward, requiring only the removal of the propeller boss caps and replacement with the PBCF. No hull modification is needed.

Technology	Propeller Boss Cap Fins (PBCF)
Sector	**Transportation**
Sub-sector	**Maritime Transportation:** **Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.**
subsector? Explain if the technology could have some improvements in the country environment.	**Funding could come from:** The ship-owners will have to fund the capital expenditure and will be the beneficiary of the reduced fuel costs.
Technical Maturity	Not-Mature as per GloMEEP, yet MTCC-Pacific (SPC) and shipping companies consider it to be mature. The number of ships adopting it has doubled in just five years, reaching the 2,000 vessel milestone in 2011, and now exceeding the 3,000 milestones in just four years.
Applicability	All Vessels
Implementation barriers	Limited awareness.
Emission reduction potential (%)	3-5%[5] on Main Engine
Impact Statements – How this option impacts the country development priorities.	
Social benefits	• Allows for better public-private partnership in the maritime transportation sector. • Awareness and training in technology may lead to more training and spread of technology applications. • Likely to cut the travel time increasing the time efficiency. • Comfortable journey due to reduced vibration in the stern.
Economic benefits	• Creation of jobs in the shipbuilding and maintenance industry only. • Lower fuel consumption and fuel imports. • It can create investment in developing and supplying consulting and training services in the maritime transport industry. • Supports the Government's NDP 2017-2036 plans in modernising the air, **maritime** and land transport networks to meet our long term needs and aspirations. • It may improve shipping services by reducing costs and increasing reliability and efficiency.
Environment benefits	• Reduced CO_2 emissions. • Low to no added impact on the marine environment
Other considerations and priorities such as co-benefits	• A reduction in propeller torque • The PBCF is an integral part of the propeller, with no other moving parts. • The PBCF system is custom made, with a design optimised for the shape of the vessel's propeller. Lead time is three to four months, from order to delivery.

Technology	Propeller Boss Cap Fins (PBCF)
Sector	**Transportation**
Sub-sector	**Maritime Transportation:** **Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.**
	• It is maintenance-free after installation, requiring only inspection and polishing when the vessel is in dry dock, and performance does not decline over time. • Reduced rudder erosion.
Costs	
Capital costs	$ USD 5000-30000 Avg = $17500 (USD)[11]
Operational and maintenance costs	$ 875 (USD)
Lifetime	30 years
Others	
Local Context	
Opportunities and Barriers	Opportunities: Longer lifetime. Barriers: May requires dry-docking and custom made designs.
Market Potential	Very high potential as the technology is easily accessible.
Acceptability to local stakeholders	Stakeholders are very keen on this newer technology.

[11] Actual cost can be ascertained after a detailed assessment of individual ship and CFD analysis.

Technology Fact Sheet

Technology	Bilge keel optimisation
Sector	Transportation
Sub-sector	Maritime Transportation: **Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.**
Sectoral GHG emission	Fiji's total greenhouse gas emissions are approximately 2,500 Gigagrams per year while the total emissions for the Fiji maritime sector are estimated at 174 kilo-tonnes of CO_2 in 2016. Fiji LEDS
Background/Notes, Short descriptions of the technology options	Current operating profiles (speed-draught matrix) for many vessels deviate significantly from the profile or design point that determined the initial design of the vessel. Accordingly, the vessel's Bilge keel profile is not optimised for current operations. For existing vessels, where the degrees of freedom in hull form optimisation is limited compared to a new building project, retrofitting can bring considerable fuel savings. It is also possible to optimise the position of the bilge keel. The bilge keel positioning improves the resistance of the hull by optimising the positions of the bilge keels. Source: GloMEEP: Technology groups, Global Maritime Energy Efficiency Partnerships, 2017, http://glomeep.imo.org/technology-groups/
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment.	Requires dry-dock. **Funding could come from:** The ship-owners will have to fund the capital expenditure and will be the beneficiary of the reduced fuel costs.
Technical Maturity	Mature
Applicability	All Vessels
Implementation barriers	Limited awareness. High capital investment.
Emission reduction potential (%)	Bilge keel optimising: 0.25% to 1%[4]
Impact Statements – How this option impacts the country development priorities.	
Social benefits	• Allows for better public-private partnership in the maritime transportation sector.

Technology	Bilge keel optimisation
Sector	Transportation
Sub-sector	Maritime Transportation: **Focus is on retrofitting larger vessels, between 15 m and 130 m in length, which burn diesel for propulsion and auxiliary power.**
	• Awareness and training in technology may lead to more training and spread of technology applications. • Increases time efficiency with better stability. • Increases traveling comfort with a reduction in roll.
Economic benefits	• Creation of newer jobs in the shipbuilding and maintenance industry. • Lower fuel consumption and fuel imports. • It can create investment in developing and supplying consulting and training services in the maritime transport industry. • Supports the Government's NDP 2017-2036 plans in modernising the air, **maritime** and land transport networks to meet our long term needs and aspirations. • It may improve shipping services by reducing costs and increasing reliability and efficiency.
Environment benefits	• Reduced CO_2 emissions. • Lowers impact on marine environment with smoother travel, less roll.
Other considerations and priorities such as co-benefits	Requires dry-docking.
Costs	
Capital costs	Bilge keel optimising: $10,000 (USD) + $10,000 (USD) [detail design and docking cost] = $20,000 (USD)[11]
Operational and maintenance costs	$1000 (USD)
Lifetime	20 years
Others	
Local Context	
Opportunities and Barriers	Opportunities: Longer lifetime. Barriers: Requires dry-docking and loss of income during the period. Emission reduction is low.
Market Potential	Optimisation can be achieved with ease.
Acceptability to local stakeholders	Stakeholders are keen on this technology, yet not trialled in locally.

Annex II: List of stakeholders involved and their contacts

	Person	Department	Position	Email Contact
1	Mr. Vishal Prasad	Fiji Department of Energy	Energy Efficiency Officer	vishal001.prasad@govnet.gov.fj
2	Mr. Deepak Chand	Fiji Department of Energy	Assistant Director	deepak.chand@moit.gov.fj
3	Mr. Ashneil Reddy	Fiji Department of Energy	Energy Efficiency Officer	ashneil.reddy@moit.gov.fj
4	Ms. Lesi Vuatalevu	Department of Transport	Acting Director	lesi.vuatalevu@govnet.gov.fj
6	Mr. Srinath Dolage	Vision Energy Solution	Business Development Manager	srinathd@visionenergy.com.fj
7	Dr. Mohammed Asid Zullah	Global Maritime Technology Cooperation Centre (MTCC) Network -SPC	Maritime Industry Energy Efficiency Advisor	zullahm@spc.int
8	Dr. Peter Nuttal	USP -Micronesian Center for Sustainable Transport	Scientific and Technical Advisor	peter.nuttall@usp.ac.fj
9	Dr. Alison Newell	Sailing for Sustainability (Fiji) Ltd	Director, Strategic Planning and Policy	alison@s4fiji.com
10	Mr. Jakir Hussain	Fiji Sugar Corporation	Capital Projects Manager	jakirh@fsc.com.fj
11	Prof. Anirudh Singh	The University of Fiji	Professor of Renewable Energy	anirudhs@unifiji.ac.fj
12	Mr. Lopeti Radravu	Fiji Ships and Heavy Industries Limited	Operations Manager	lopeti@fijiports.com.fj
13	Mr. Akila Abeyrathne	Fiji Ships and Heavy Industries Limited (FSHIL)	Senior Maintenance Engineer	Akila@fijiports.com.fj
14	Dr. Ajal Kumar	The University of the South Pacific	Lecturer	ajal.kumar@usp.ac.fj
15	Ms. Dhrishna Charan	The University of Fiji	Assistant Lecturer	dhrishnac@unifiji.ac.fj
16	Mr. Amit Singh	CBS Power Solutions	General Manager/Director	amit@cbspowersolutions.com
17	Mr. Rajneel Singh	Energy Fiji Limited	Electrical Engineer	rajneels@efl.com.fj
18	Mr. Maika Tuicakau	Ministry of Infrastructure and Transport	Senior Engineer	Maika.tuicakau@govnet.gov.fj
19	Mr. Akarua Kua	Maritime Safety Authority of Fiji	Manager Ship Inspections	akua@msaf.com.fj
20	Mr. Ravuma Kurusiga	Maritime Safety Authority of Fiji	Flagstate Surveyor	rkurusiga@msaf.com.fj
21	Ms. Akisi Mavoa	Fiji National University	Manager CB NFE Sustainable Livelihoods Project	Akisi.mavoa@fnu.ac.fj
22	Ms. Jeannette Mani	CCICD	Climate Change Officer	jeannette.mani@economy.gov.fj
23	Ms. Aradhna Singh	CCICD	Mitigation Officer	aradhna.singh@economy.gov.fj
24	Ms. Ana Vesikula	Soqosoqo Vakamarama Taukei	Project Volunteer	Anavesikula22@gmail.com
25	Ms. Adi Finau Tabakaucoro	Soqosoqo Vakamarama Taukei	Project Volunteer	ftabakaucoro@gmail.com

26	Mr. Josefa Tagi	Victoria Marine Limited	Manager	victoriamarinelimited@gmail.com

Annex – III: Summary of Scoring Matrix

Table A1 Performance matrix with nominal values for the rural electrification sector.

		Category									
Criteria	**Lev 1**	**Costs**		**Benefits**							**Local Context**
				Economic		**Social**		**Environmental**			
	Lev 2	**Capital Costs (USD/kW)**	**Operational and Management (USD/kW)**	**Job Creation**	**Rural Economic Activity**	**Skill & Capacity Development**	**Energy Security**	***CO_2 reduction potential (%)**	**Space requirement**	**Market Potential**	**Acceptability to local stakeholders**
Preferred value		Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Technologies											
1	Solar Home System Type II - Standalone solar PV system with ESS that can cater for AC load as well. Type 2 (300Wp 12 VDC +240 VAC)	5000	180	3	3	4	4	94.7	6	3	4
2	Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Microgrids)	4564	228	4	6	5	5	93.8	4	5	5
3	Standalone Dual-Fuel (CNO/Diesel) Generator (Community Based Electrification - Microgrids)	2000	1057.5	3	5	5	4	58.3	5	4	3
4	Stand-alone wind systems with ESS	5250	154.5	3	5	5	4	98.5	4	3	2
5	Micro/Pico-hydro in microgrid configuration	3950	197.5	3	5	5	4	98.3	3	5	6
6	Hybrid Solar PV and Wind with ESS (Community Based Electrification - Microgrids)	5750	177.5	4	6	5	4	93	4	4	4

7	Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems without energy storage	2750	831.31	4	6	5	3	65.8	4	4	5
8	Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS	4650	253	4	6	5	5	90.5	4	5	5
9	Wind and Dual fuel (CNO/Diesel) Generator Hybrid with ESS (Community Based Electrification - Microgrids)	4750	608.5	3	5	5	4	73.9	4	3	4

*The estimate is used for the purpose of technology prioritisation only, and additional studies would be required to provide a more detailed evaluation of GHGs emission reduction potential for the technologies.

Table A2 Scoring matrix for technology prioritisation for rural electrification sector.

		Category											
Criteria	**Lev 1**	**Costs**		**Benefits**						**Local Context**			
				Economic		**Social**		**Environmental**					
	Lev 2	**Capital Costs (USD/kW)**	**Operational and Management (USD/kW)**	**Job Creation**	**Rural Economic Activity**	**Skill & Capacity Development**	**Energy Security**	**CO_2 reduction potential (%)**	**Space requirement**	**Market Potential**	**Acceptability to local stakeholders**		
Sources		**Technology Providers, Operators**	**Technology Providers, Operators**	**Expert Judgement**	**Expert Judgement**	**Expert Judgement**	**Expert Judgement**	**Tech Specification, Research**	**Expert Judgement, tech providers, research**	**Expert Judgement**	**Expert Judgement**		
Preferred value		Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher		
Technologies	Weights	17.5	17.5	4.5	10.5	7.5	7.5	12.5	12.5	4	6	Overall Score	Rank
1		20.00	97.18	0.00	0.00	0.00	50.00	90.55	100.00	0.00	50.00	51.07	7
2		31.63	91.86	100.00	100.00	100.00	100.00	88.31	33.33	100.00	75.00	75.32	1
3		100.00	0.00	0.00	66.67	100.00	50.00	0.00	66.67	50.00	25.00	47.58	8
4		13.33	100.00	0.00	66.67	100.00	50.00	100.00	33.33	0.00	0.00	54.75	5
5		48.00	95.24	0.00	66.67	100.00	50.00	99.50	0.00	100.00	100.00	65.75	3
6		0.00	97.45	100.00	100.00	100.00	50.00	86.32	33.33	50.00	50.00	63.26	4
7		80.00	25.05	100.00	100.00	100.00	0.00	18.66	33.33	50.00	75.00	53.88	6
8		29.33	89.09	100.00	100.00	100.00	100.00	80.10	33.33	100.00	75.00	73.40	2
9		26.67	49.72	0.00	66.67	100.00	50.00	38.81	33.33	0.00	50.00	43.64	9

Table A3 Performance matrix with nominal values for the domestic maritime transportation sector.

		Category									
Criteria	Lev 1	Costs			Benefits					Local Context	
					Economic	Social		Environmental			
	Lev 2	Capital Costs (USD)	Operational and Management (USD)	Lifetime (Years)	Job Creation	Time Efficiency	Travelling Comfort	CO_2 reduction potential (%)	Impact on Marine Environment (Apart from CO_2)	Market Potential	Acceptability to local stakeholders
Sources		Technology Providers, Operators	Technology Providers, Operators	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement, Tech Specification	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Higher	Higher	Higher	Higher	Higher	Lower	Higher	Higher
Technologies											
1		265000	13250	5	3	4	3	2.5	1	5	6
2		6000	300	0.5	3	4	3	3.5	1	5	6
3		150000	7500	6.5	3	3	4	0.4	2	6	5
4		575000	28750	30	1	4	5	4	4	2	5
5		20000	1000	20	3	5	5	1.13	5	5	4
6		235000	60000	12.5	5	3	4	5.5	1	2	1
7		17500	875	30	4	4	4	4	1	5	6
8		1025000	51250	15	5	6	6	28	2	5	4

Table A4 Scoring matrix for technology prioritisation for the domestic maritime transportation sector.

		Category											
Criteria	**Lev 1**	**Costs**			**Benefits**					**Local Context**			
					Economic	**Social**		**Environmental**					
	Lev 2	**Capital Costs (USD)**	**Operational and Management (USD)**	**Lifetime (Years)**	**Job Creation**	**Time Efficiency**	**Travelling Comfort**	**CO_2 reduction potential (%)**	**Impact on Marine Environment (Apart from CO_2)**	**Market Potential**	**Acceptability to local stakeholders**		
Sources		**Technology Providers, Operators**	**Technology Providers, Operators**	**Technology Providers, Operators**	**Expert Judgment**	**Expert Judgment**	**Expert Judgment**	**Expert Judgment, Tech Specification**	**Expert Judgment**	**Expert Judgment**	**Expert Judgment**		
Preferred value		Lower	Lower	Higher	Higher	Higher	Higher	Higher	Lower	Higher	Higher		
Technologies	Weights	4.5	5.25	5.25	15	12	18	10	10	10	10	Overall Score	Rank
1		74.58	78.31	15.25	50.00	33.33	0.00	7.61	100.00	75.00	100.00	48.03	6
2		100.00	100.00	0.00	50.00	33.33	0.00	11.23	100.00	75.00	100.00	49.87	4
3		85.87	87.94	20.34	50.00	0.00	33.33	0.00	75.00	100.00	80.00	48.55	5
4		44.16	52.35	100.00	0.00	33.33	66.67	13.04	25.00	0.00	80.00	37.79	8
5		98.63	98.83	66.10	50.00	66.67	66.67	2.64	0.00	75.00	60.00	54.36	3
6		77.53	0.00	40.68	100.00	0.00	33.33	18.48	100.00	0.00	0.00	38.47	7
7		98.87	99.04	100.00	75.00	33.33	33.33	13.04	100.00	75.00	100.00	64.95	2
8		0.00	14.66	49.15	100.00	100.00	100.00	100.00	75.00	75.00	60.00	79.35	1

Table A5 Sensitivity Analysis summary for the rural electrification sector.

	Analysis # 1		Analysis # 2		Analysis # 3	
Technologies	Overall Score	Rank	Overall Score	Rank	Overall Score	Rank
1	51.07422	7	50.2	5	43.7	7
2	75.31547	1	79.4	1	82.4	1
3	47.58333	8	40.2	8	42.8	8
4	54.75	5	50.0	6	44.5	6
5	65.75448	3	64.7	3	73.5	3
6	63.26073	4	63.7	4	64.0	4
7	53.88228	6	49.7	7	54.0	5
8	73.40352	2	77.4	2	80.8	2
9	43.63563	9	39.27937	9	40.14125	9

Table A6 Sensitivity Analysis summary for the domestic maritime transportation sector.

	Analysis # 1		**Analysis # 2**		**Analysis # 3**	
Technologies	**Overall Score**	**Rank**	**Overall Score**	**Rank**	**Overall Score**	**Rank**
1	48.02913	6	50.2	5	54.1	5
2	49.87319	4	54.3	4	56.8	4
3	48.54871	5	49.9	6	50.9	6
4	37.78971	8	36.8	8	41.6	7
5	54.36145	3	59.9	3	58.9	3
6	38.47213	7	45.7	7	37.6	8
7	64.953	2	69.2	2	71.6	2
8	79.34998	1	73.2	1	71.7	1

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