KINGDOM OF TONGA

TECHNOLOGY NEEDS ASSESSMENT

MITIGATION REPORT

(October,2023)

TECHNOLOGY NEEDS ASSESSMENT(TNA[1]) REPORT

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[1] The TNA is a stakeholders prioritization of energy technologies in the energy and transport..

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List of Abbreviation

AC – Alternating Current
ADB – Asian Development Bank
AFOLU - Agriculture, Forestry and Other Land Use
BAEF- Barrier and Analysis and Enabling Framework
BAU - Business-As-Usual
BESS – Battery Energy Storage System
CAPEX – Capital ExpenditureCEO – Chief Executive Officer
CO_2 – Carbon Dioxide
CRS - Carbon Reduction Strategy
CTCN – Climate Technology Centre and Network

DoE - Department of Environment
DC – Direct Current
ECOS – Electricity Cooperatives
EE – Energy Efficiency
EU – European Union
EPU – Energy Planning Unit
ESCAP – Economic and Social Commission for Asia and the Pacific
ESMP - Environmental and Social Management Plan
EV – Electric Vehicle
FIT - Feed-In Tariff
GCF - Green Climate Fund
GDP – Gross Domestic Product
GEF- Global Environment Facility (GEF

GHGs – Green House Gases
GOT – Government of Tonga
GoG – Government of Guyana
ICT – Information Communication Technology
IEA – International Energy Agency
INDC – Intended Nationally Determined Contribution IPCC –Inter-govermental Panels on Climate Change
IPP- Independent Power Producers
IRENA – International Renewable Energy Agency
ISA – International Solar Alliance
ITS – Information Technology System
JNAP - Joint National Action Plan
kW - Kilowatt
kWh – Kilowatt Hour
LCOE - Levelized Cost Of Electricity
LCOE - Levelized Cost of Electricity
LPG – Liquified Petroleum Gas
LTS - Long Term Strategy
MCA – Multi-Criteria Analysis
MEIDECC- Ministry of Meteorology, Energy, Information, Disaster, Environment, Climate Change and Communication
MEPSL - Minimum Energy Performances Standard and Labelling
MTED – Ministry of Trade and Economic Development
MW – Megawatt
MWh – MegaWatt Hour
N/A – Not Available
NCCP - National Climate Change Policy

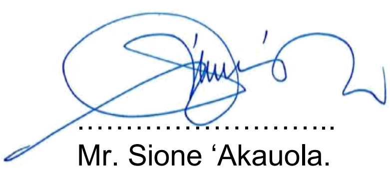
NDC - Nationally Determined Contribution
NDC IP - Nationally Determined Contribution Implementation Plan
NDC - Nationally Determined Contribution
NREL - National Renewable Energy Laboratory
ODS - Ozone Depleting Substances
O&M – Operation and Maintenance
OIREP – Outer Islands Renewable Energy Project
OPEX – Operating Expenditure
PDOE - Philippine Department of Energy

PICs – Pacific Island Countries
PIFDS – Pacific Islands Forum Development States
PPA – Power Purchase Agreement
PV – Photovoltaic
R&D - research and development
RE - Renewable Energy
RESAT - Renewable Energy Satellite Analytical Platform
SHS – Solar Home System
SIDS – Smal Islands Developing States
SOPAC – South Pacific Applied Geoscience Commission
SPREP - South Pacific Regional Environment Programme
TAPs -Technology Action Plans
TEC - Tonga Electricity Commission
TERM - Tonga Energy Road Map
TEEMP – Tonga Energy Efficiency Master Plan
TNA – Technology Needs Assessment
TNC = Third National Communication
TOP – Tongan Paanga, $

TPL – Tonga Power Limited
TREP – Tonga Renewable Energy Project
UNDP – United Nation Development Programme
UNEP - United Nations Environment Programme
UNEP/CCC-United Nations Environment Programme (UNEP) and Copenhagen Climate Centre)
UNFCCC - United Nation Framework Convention Climate Change
WEC – World Energy Council

Foreword

The harmful effects of Climate Change constantly challenge the Kingdom of Tonga like most of its Pacific Island neighbors. Every year natural hazards like tropical cyclones become more frequent and severe, ocean acidification as global temperatures continue to rise, and prolonged droughts are only a few of such occurrences that citizens experience annually. The biggest injustice of all is considering that Pacific Island Countries (PICs) contribute very little to global emissions yet are some of the most vulnerable in the world. However, the response by the Tongan Government has been swift, spearheaded by the Ministry of Meteorology, Energy, Information, Disaster Risk Management, Environment, Communications and Climate Change (MEIDECC) with assistance from the United Nations Framework on Climate Change (UNFCCC). With policy frameworks in place like Tonga's Second Nationally Determined Contribution 2020, Tonga Strategic Development Framework II 2015-2025, and Tonga Energy Road Map (TERM Plus 2021-2035), Joint National Action Plan on Climate Change and Disaster Risk Management (JNAP2) and Tonga's Climate Change Policy. This is a clear indicator that Tonga is willing to do its part to achieve the goal of the Paris Agreement. This is where the Technology Needs Assessments (TNA) Project plays a vital role by transversing through multiple sectors to meet the demands stated in the policy frameworks mentioned above. Tonga is part of TNA Phase IV meaning that this process has been tried, tested, and successfully implemented in countries before. The key focus of the TNA Project is to identify the Technology Needs of a country to assist in lowering greenhouse emissions. The Department of Energy of the Ministry of MEIDECC has been tapped to take charge of this Project with funding provided by the Global Environment Facility (GEF) in collaboration with the United Nations Environment Programme Copenhagen Climate Change Center (UNEP-CCC) and technical assistance from the local consultant and the University of the South Pacific (USP). The TNA process is a sector-focused multi-stakeholder consultation making it a truly country driven initiative because it involves government officials from all line ministries, NGOs, Private organizations, businesses, and technical institutions. Stakeholders involved were identified as key drivers of the four sectors identified for the TNA project—Water and Agriculture (Adaptation) Energy and Transport (Mitigation). Currently, the Tonga TNA team has completed an Inception Workshop, a Multi-Criteria Analysis (MCA) which is a tool used in the TNA Process to identify and prioritize the top three technologies for each of the Sectors, and the Project is looking forward to the Barrier Analysis and Enabling Framework (BAEF) and also producing a Technology Action Plan (TAP) for the diffusion of these prioritized technologies



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Mr. Sione 'Akauola.
CEO for the Ministry of MEIDECC.

Executive Summary

To sum up, Tonga and South Pacific Islands as a whole face some unique challenges to sustainable energy development and will therefore need to be addressed on a case-by-case basis, informed by an understanding of their specific context in terms of the key challenges and opportunities to overcome them. This report is a Technology Needs Assessment (TNA) for Mitigation of the Friendly Islands. The methodology for the TNA assessment is based on the World Energy Council's (WEC) sustainable energy objectives framework, also known as the Accessibility, Availability & Acceptability (3As) framework (WEC, 2008). This framework is used to assess the Nationally Determined Contribution (NDC) of Tonga and the Implementation Plan (IP) of Tonga pursuant to the Paris Agreement. To this end, the TNA focuses on the two sectors covered by the National Determined Contribution (NDC) and its Implementation Plan (NDC-IP), i.e., the energy sector and the transport sector, as these sectors have been identified as the most critical sectors where technological interventions are required for the development and implementation of carbon mitigation and reduction strategies, the need to meet the NDC targets as well as those set in the national climate change policy (NCCP), including the implementation of the low carbon development plan. As a result, the TNA was therefore designed to fulfil both the NDC achievement as well as national development policy objectives.

The TNA therefore drew heavily on the substantive work already completed in developing the NDC, and the NDC IP, which involved multi-criteria analysis (MCA) and extensive stakeholder consultation to identify mitigation intervention options for the two identified sectors. The MCA included consideration of emissions reduction potential, and cost/benefit analysis of the identified mitigation measures and associated potential technologies. Stakeholders were consulted on a factsheet of the identified technologies and the MCA used.

The results of the MCA prioritized technologies in the listed order for the Energy and Transport sectors as follows:

1. Electricity generation:
    a. On-Grid Solar Power Generation
    b. On-Grid Wind Power Generation
    c. Energy Efficient Home Appliances
    d. Diesel-Solar Hybrid Power Generation
    e. Stand Alone Solar Home System
    f. Diesel-Solar-Wind Hybrid Power Generation
    g. Biogas Energy Generation
2. Transportation Sector
    a. Battery Powered Electric Vehicle
    b. Hybrid Vehicle
    c. On-Grid Electric Vehicle
    d. LPG Vehicle Transport System

e. Vehicle Emission Standard
f. Vehicle Emission Technology
g. Energy Saving Speed Control Motor

The priority technologies have been identified and will be taken into account in the next TNA step, the Barriers Analysis and Enabling Framework.

1 Chapter 1: INTRODUCTION

1.1 About The TNA Project

Through the Department of Energy and the Department of Climate Change of MEIDECC, the Government of Tonga has partnered with the UNEP (United Nations Environment Programme) and UNEP/CCC (Copenhagen Climate Centre) to implement the 'Technology Needs Assessment' (TNA) – Phase III. The implementation of the TNA - Phase III is supported by GCF (Global Environment Facility) funding and technical support provided by the University of the South Pacific (Mona), acting as TNA Regional Centre (TCI) for the Pacific Islands. The project aims to deliver targeted financial and technical assistance to help participating developing countries conduct TNAs and develop National Technology Action Plans (TAP) for priority technologies.

Following the ratification of the Paris Agreement by the Government of Tonga, the project aims to support the implementation of technologies to reduce GHG emissions in accordance with the country's NDC, support mitigation and adaptation, and more importantly, inform national development strategies and support sustainable development goals. The Technology Needs Assessment (TNA) is therefore intended to focus on national development challenges towards the implementation of the National Climate Change Policy (NCCP) and low carbon development path. The TNA focuses on the technology needs assessment of the power generation sector and transport sector as NDC sectors to support the execution of the NDC Implementation Plan (NDC IP). Additionally, it will support Tonga in further defining the national technology barriers for the prioritized sectors and technologies and developing technology action plans (TAPs) to overcome these barriers for mitigation. These TAPs will then facilitate countries' efforts to access funding for implementation of these strategies (UNEP CCC 2014).

1.2 Existing National Policies on Climate Change Mitigation and Development Priorities

The national policy and legislative framework to support TNA process and deliverables in line with TNA priorities, especially in relation to the NCCP, is summarised in Table 1 below.

Table 1 Existing policies on climate change mitigation and NDC in Tonga

Policy/Legislation Provision	**Relevance to technological innovation, mitigation to climate change and development priorities**
National Climate Change Policy , 2006; 2016 (NCCP)	The National Climate Change Policy is developed and coordinated by the Ministry of Meteorology, Energy, Information, Disaster, Environment, Climate Change and Communication (MEIDECC). The National Climate Change Policy outlines the broad climate change mitigation objectives and strategies, such as Renewable Energy, clean technologies,

	and reseach and development (R&D). In 2019, the Government launched an update of the Policy to include the Paris Agreement provisions, including the implementation of National Determined Contribution (NDCs)..
Nationally Determined Contributions ,2015,2016,2020	The NDC for Tonga identified technologies and areas for three (3) sectors: power generation, industry and transportation.
Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management, 2010-2018; 2018-2028	The Joint National Action Plan (JNAP) 2010-2018 is a Joint Action Plan (JAP) prepared by the Ministry of Meteorology, Energy, Information, Disaster, Environment, Climate Change and Communication (MEIDECC. The JNAP 2020-2028 is an Action Plan specifically designed for Climate Change Adaptation. This Action Plan consists of Joint Action Plans (JAPs) prepared by various stakeholders on Climate Change
Green Climate Fund (GCF) Country Programme, 2018	The National Programme for utilising the Green Climate Fund (GCF) in the country was prepared in 2018 by MEIDECC, the Department of Climate Change, in consultation with other relevant stakeholders.
HCFC Phasing Out Management Plan , 2016	In order to comply with its Montreal Protocol obligations, the Department of the Environment (DoE) concluded a contract with SPREP, through which an external consultant assisted DoE in the preparation of a national Compliance Action Plan (NCAP) for the phase out of ozone-depleting substances (ODS)
Carbon Reduction Strategy (CRS)	The Carbon Reduction Strategy (CRS) was established in 2015 and includes cost/benefit analysis of identified and proposed mitigation actions in the power generation, transport, and industry sectors. The National Determined Contribution is based on the CRS and derived from it. The baseline for the CRS is based on a BAU (Business As Usual) emissions projection for 2040. In 2020, the baseline was revised to 2050 and is included in the country's long-term strategy (LTS)
Tonga Environmental Management Act , 2010	Programs for the management of the environment, including air pollution, are mandated by the Environmental Management Act, 2000. The act empowers the minister responsible for environment to adopt rules (subsidiary law), including rules on air pollution, to support the Authority's programs..

Ozone Layer Protection Act, 2010, 2014	This act amends the Convention for the Protection of the Ozone Layer and the Protocol on Substances that Deplete the Ozone Layer for the purpose of regulating the use of ozone-depleting substances.
Ozone Layer Protection Bill, 2021	The ozone layer protection principle Act is amended by the addition of new Section 3A for Codes of Practice and Operating Procedures and testing by prescribed new regulations.
Tonga Climate Change Fund Bill, 2021	Act establishing a National Climate Change Fund for Tonga for the purpose of receiving monies from domestic and international sources for the purpose of financing national climate change mitigation projects and adaptation.
Environment Impact Assessment Act, 2010	Under the Environmental Management Act, the certificate of environmental clearance allows for the mitigation of potential adverse environmental effects (e.g. emissions of carbon dioxide and other greenhouse gases)
National Environmental Policy	The National Environment Policy (2018) includes provisions for climate change mitigation and adaptation.
Environmental Management (Litter and Waste Control Regulation, 2016	Regulation under the Environment Management Act 2010 Tonga Waste Control Regulation, 2016.The Environment Management (Litter and Waste Control) Regulations 2016 define the activities and offences that relate to waste pollution. These include the dumping of waste and hazardous waste, waste that causes pollution, and the burning of litter and waste.
Tonga Climate Change Fund Act, 2021	An Act to establish a national climate change fund for Tonga to receive monies from national and international sources and to finance national climate change projects which deal with climate change and climate change mitigation and adaptation
Policy/Legislation Provision	**Relevance to technological innovation, adaptation to climate change and development priorities**
Tonga Energy Road Map 2010-2020	The Ministry of MEIDECC is the ministry responsible for the energy, which was developed in 2015. The draft strategy outlines the national energy target of share of RE in the total electricity mix of 50% by 2020 , 70% by 2030 and 100% by 2035.

Tonga Electricity Commission Act , 2007	The Tonga Electricity Commission (TEC) was mandated in 2007 to regulate electricity services and Tariffs in Tonga, under the established Tariff Contract between Government and Tonga Power Utility.
Tonga Renewable Energy and Energy Efficiency Policy Framework	The Renewable Energy Policy Framework identifies action plan and activities for renewable energy (RE) implementation and and Energy Efficiency for all sectors in Tonga.
Tonga Energy Targets	A renewable energy target of 50% in the national energy mix by 2020.
Tonga IPP Policy Feed-in Tariff (FIT) Policy	A Feed-In Tariff (FIT) Policy is being developed by the Power Utility. The draft policy develops a framework for policy and legislation to govern Feed-In tariffs for renewable energy feed into the national grid.
Tonga Incorporated Society Act	The Department of Energy of MEIDECC has established electrification societies to manage and operate off-grid electrification projects in the remote islands .
Tonga Minimum Energy Performances Standard and Labelling MEPSL	The program is to implement a minimum Energy Performances standards and labelling program for energy-using equipment such as **fridges/freezers**, **air conditioners** and **lighting appliances**
Tonga Incorporated Society Act	An act to make provision for the incorporation of societies, like the outer islands solar electrification societies, which are not established for the purpose of profit generation alone.
Tonga Cooperative Society Act	An act to provide for the formation of co-operative societies and to regulate their operations.
Petroleum Act	The Petroleum Act (1969) provides for any licensee "to take care that gas is not liberated in such manner as to cause pollution of the surrounding air and to prevent all waste". This section can be used to control the flaring of natural gas.
Tonga Traffic Policy	Established in 1967, the National Transport Plan outlines strategy for development of road networks and was scheduled for complete revision by 1986.
Tonga Traffic Act	The Motor Vehicle and Road Traffic Act (2010) identifies the rules and regulations for licensing and owning a vehicle. There is also an amendment to the Act which includes a fine for visible emissions from vehicle. GHG emissions are however not explicitly included in the Act, although there is potential for its inclusion.

1.3 Vulnerability Assessment of National Policies on Climate Change Mitigation and Development Priorities

Tonga is listed as the 2nd most vulnerable country to natural hazards in the world, according to the 2017 World Risk Report. These natural hazards include cyclones, flooding, sea level rise, etc. Tonga contributes very little to global greenhouse gas emissions, but there is no denying that climate change has already had a significant impact on Tonga's development and on the well-being of the people of Tonga and their future (NDC, 2020). As a result of this, Tonga has already put in place a number of climate change related policies to address the negative impacts of climate change. In 2010, Tonga put in place the Tonga energy Road Map plan for the period 2010-2020. In 2015, Tonga presented its INDC under the Paris Agreement. After the Paris Agreement, other national related policies such as Climate Change policies, Environmental Policies, and Energy Policies were also put in place. In addition, national communications on climate change including 1st, 2nd, and 3rd Communications had already been supported and submitted to the UNFCCC.. Legal frameworks and technical standards are already in place to mitigate climate change and based on the Tonga energy road map plus 2020 to 2030 and the Tonga third national determined contribution (NDC), a Mitigation target has already been established as shown in the following table (Table 2) below as per the Tonga 2nd NDC Report

Target	Means	Requirements
13% (16 Gg) reduction in GHG emissions from energy by 2030 compared to 2006	70% of electricity generated from renewable sources by 2030 through combination of solar, wind and battery storage	• Financing • Upgrade of network infrastructure
	Mandatory vehicle standards and/or incentives through tax, fees, import tariffs	• Alignment of price signals for consumers with targets • Public acceptance
	Adoption of minimum energy performance standards	• Financing • Public acceptance • Enforcement
Identification of a GHG emission target for agriculture, forestry and other land use for Tonga's Third NDC in 2025	Establishment of a forest inventory	• Financing • Technical capacity
Planting one million trees by 2023	To be determined: kind of trees to be planted, land on which trees to be planted, and who will be responsible for planting the trees	• Financing • Technical capacity • Consent from various stakeholders
Identification of a GHG emission target for waste for Tonga's Third NDC in 2025	Expansion of the formal waste collection system	• Financing • Technical capacity

Source : Tonga NDC Report 2020

A review of the measures and requirements to meet Tonga‘s mitigation objectives showed that technology transfer, capacity development and external financial support would be needed to build, operate and maintain the infrastructure (NDC, 2020). In order to achieve a 2% efficiency improvement per year for newly acquired light-duty vehicles, either mandatory vehicle standards or incentives to purchase more efficient vehicles in the form of taxes, fees or import tariffs (NDC 2020). Setting mandatory standards and offering price incentives will necessitate public acceptance, as both are likely to affect vehicle prices and (or vehicle size). For both vehicle standards and appliance incentives (NDC 2020), technology transfer and capacity building, as well as external financial support, may be necessary. In summary, the main obstacles to climate change mitigation are technology transfer, capability building, financial support, and public acceptance of decision making. In the future, I will review and identify all relevant barriers to technology transfer mitigation and climate change mitigation in Tonga.

1.4 Sector Selection

Tonga's National Determined Contribution (NDC) targets were based on a number of national policy documents, such as the National Climate Change Policy (NCP) and the National Energy Road Map (TERM) (established in 2010 and running until 2020). The TERM (Tonga Energy Road Map) is a 10-year plan that aims to meet the National Energy Target (NET) of 50% of total electricity generation from renewable energy sources by 2020.

The NDC also aims to reduce overall electricity network losses to 9% by 2020. In general, the NDC is dedicated to meeting the National Energy Targets The NDC also aimed to reduce cumulative GHG emissions by 15% by 2030 in the industrial, power generation and transportation sectors compared to a business as usual baseline.\

The sectors covered in the National Decarbonisation Plan (NDP) have been identified as priorities for the TNA, taking into account the need to meet its objectives, as well as the previous stakeholder consultations that led to the development of the Carbon Reduction Strategy, from which the NDP was derived. A considerable amount of work has already been done and the TNA will now progress the implementation of the NDC, as well as lay the technology roadmap for a low carbon trajectory in line with the NCCP's objectives. The

Tonga's National Determined Contribution (NDC) is outlined in the Tonga's Energy Road Map Implementation Plan (IP) which outlines the measures needed to achieve the NDC target, according to Tonga's Third National Communication (TNC) on Climate Change to the United Nations Framework Convention on Climate Change. In 2006, Tonga emitted 310,4 Gg of C02-equivalent in CO2-equivalents. The electricity sector accounted for 39%, AFOLU accounted for 61% and Waste accounted for 0,3% of total greenhouse gas emissions (GHG emissions) (Tonga NDC 2020). Since electricity and Transport are the most dominant sectors

1.4.1 Electricity Sector

Tonga Electricity Power Board was fully privatized by the government in 1998 under the management of Shoreline Group Ltd. This was followed by protests against the government's electricity management in 2005, resulting in the burning down of businesses and public offices. In 2008, Shoreline Group Ltd was taken over by the government and transformed into Tonga Power Limited, or TPL, which is a government-owned, corporatized organization.The Tongan electricity utility is currently managed by a government-owned corporatized organization, Tonga Power Limited (TPL). The goal of TPL is to attract private investment in the electricity industry.

TPL operates the electricity networks on the four main islands (Tonga, Vava'u, Ha'apai and 'Eua), two larger islands (Niuas) and four smaller islands (Haapai). The remaining small remote islands (Tongatapu, Nuku'aland and Haifa) are electrified by solar/diesel microgrids. Every household and community hall in TPL operates a fixed Solar Home System. TPL has implemented major institutional changes in the Tonga electricity industry from 1998-2008.

Diesel generation is usually the major power source for electrical power generation, but solar power and wind power generation are more cleaner fuel, and they contributed significant share to the total electricity generation mix in the country. However, moving to more energy efficient electricity network is also more important for reducing emissions from this sector so the deployment of renewable energy sources, coupled with efficient use of energy are two major solutions for reducing carbon emissions. It is estimated 13% reduction in GHG emissions by 2030 compared to 2006 (Tonga NDC, IP 2020).

The power generation sector in the country is monopolized by Tonga Power Limited (TPL) with four grid systems operated by TPL and distributes about 85 percent of the grid-supplied energy in Tonga. All of the diesel power energy for the main grid located Tongatapu is generated at the Popua power station, which contains eight diesel generating units with a combined capacity of 12.68 MW. The numbers, size, and key characteristics of the diesel units in the power stations are varied from one island to another. The output is transmitted throughout the island on an 11 kV system and distributed at 415 volts. The sector has limited renewable energy experience regarding utility scale generation of electricity. There are also separate government ministries tasked with the responsibility for power generation, transmission and distribution for especially in the remote islands. There are other renewable energy resource options (other than solar and wind but potential for other renewable energy like ocean and biomass power generation, yet to be explored), limited land available for renewable energy and limited data available for applicable renewable energy studies. Additionally, there are weak fiscal support mechanisms for energy conservation or alternative cleaner energy sources.

Enabling the environment for renewable energy requires significant work as the current policy and legislative framework – although being revised – is not sufficient. Current subsidies on fuel and electricity further impede the uptake of renewable energy.

Currently, the legislation does not allow electricity generation outside of the current monopolistic arrangements, apart from the IPP and PPPA of solar power generation. However, work is ongoing and considerable progress is being made to develop demand-side management (DMI) initiatives, a feed in tariff policy framework (FITP) for renewable energy via PPA, and legislation has been amended to encourage and allow power generation via PPA..

1.4.2 Transport Sector

Domestic transport in Tonga includes sea, land and air travel. The current transport system evolved as a consequence of the fuel-subsidy policies of the country and has resulted in a large number of privately-owned cars due to the unattractiveness, inadequacy and inefficiency of existing public transport systems to meet the needs of the population. The fuel subsidy is carded to be eliminated in Jan 2021.

According to the joint partnership of the World Bank and Inter-American Development Bank(IDB),the global transport sector is the main consumer of the 20% of local consumption of the daily oil production (IDB, 2013). The transport sector contributed 5.6% of total GHG emissions in 2018 (GORTT, 2018). It is estimated for an optimistic economic growth scenario under a business-as-usual (BAU) trajectory that GHG emissions for transport could grow to as much as 144% from 2018 figures up to 2050 (NDC, IP 2020).

1.5 National TNA Team

As one of the most vulnerable countries in terms of climate change vulnerability and natural disaster risk, Tonga has developed strategic strategies for stakeholders and local communities to transition to renewable energy sources and energy efficiency in order to mitigate carbon emissions and mitigate climate change and its negative impacts on local communities. In the context of climate change mitigation, the energy and transport sectors are two of the most dominant contributors to carbon emissions. Despite Tonga's level of carbon emissions is minuscule and small but Tonga main climate challenges is to build resilience by building the country's capacity to managing the financial risks that natural disaster pose. In order to increase resilient in the energy and transportation sector, small island countries must tackle the financial risks since more funding will be wisely used to mitigate climate changes in the energy and transport sector. Climate resilience is not just access to funding but spending it better (Daniel J et al, 2020). In this assessment, we select the energy and transport sector.

The National TNA team consisted of the contracted consultants for Mitigation and Adaptation along with staff from the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change, and Communication; MEIDECC (National Coordinator). The National Standing Committee consisted of CEO MEIDECC and Director of Energy, Director of Climate Change and CEO for Ministry of Infrastructure, and they are responsible for TNA advisory committee as well as approval of project implementation and oversee of TNA Implementation Processes and their linkages to high level decision making. The TNA Advisory Committee represented the following organisations:

1. The Department of Climate Change
2. Department of Energy Department of Environment
3. The University of the South Pacific
5. The United Nation Environmental Program –Danish Technical University Partnership
5. Department of Environment
6. Department of Marines and Wharf
7. Tonga Water Board
8. Tonga Waste Authority
9. National Emergency Management Office and Disaster Management Office
10. Tonga Meteorological Office Services
11. The Tonga Power Limited
12. Ministry of Revenue and Customs
13. Ministry of Fisheries
14. Power Purchase Agreement Companies
15. Ministry of Infrastructure
16. Waste Authority Limited
17. Tonga Gas Limited
18. Ministry of Tourism
19. Traffic Department of the Ministry of Police

1.6 Stakeholder Engagement Process Followed in the TNA –Overall Assessment

The 8-10 Factsheet for Energy and 8-10 factsheet for Transportation have been distributed to stakeholders to familiarise them with the type of information shown on the factsheets, as well as to also note the names of technologies, cost benefit measures and related criteria for each technology for the MCA and analysis process. The multi-criteria assessment (MCA) process and step by step process has enabled us to develop and analyse the technology needs assessment (TNA) framework for all stakeholders in the energy and transport sectors to develop and analyze mitigation measures for the main emitters of greenhouse gases (GHG) identified in the National Determined Contribution (NDC). The MCA process includes cost/benefit analysis, emissions projections and potential technological approaches for these two sectors.

Identification of Technologies to be included in Factsheets were based on Responsible Institutions involved in Designing, Management and even Use of the Technology in the Country. Literature Review of Technologies and Plans for Low Energy Technologies was based on Commitments made by the Government of Tonga on Energy Plan and Targets, National Determined Contribution (NDC), and identified Technologies to address climate change. All technologies are included on Factsheets (Annex I) for Key Stakeholders to be used in MCA on Energy/Electricity sector and MCA on Transport Sector. Based on this, MCA was adopted along the lines of the Tonga's NDC and Tonga energy Road, Map (TERM) (Including Cost/Benefit, Mitigation potential, Socio-economic issues), and applied to identified technologies. Draft report was prepared, and key stakeholders were consulted on this report.

The stakeholders consulted during the development of the background documents (TERM, NDC,) were identified as important having been already involved in the process and familiar with the mitigation issues, such as the MCA, identified mitigation measures, and applicable technologies. Some of these stakeholders are also included on the TNA Advisory Committee. Stakeholders were invited to comment and give feedback on the first draft of the TNA Report for Mitigation as well as identify potential barriers and the enabling framework to be covered in detail in the later stage of the project. This approach was taken as stakeholders for the climate mitigation process in Tonga are consistently engaged and are key collaborators for the implementation of all mitigation work.

1.7 Consideration of Gender Aspect in the TNA Process

There are policies related to the operation of each mitigation technology that affect men or women, which should be avoided in the designing and formulation of policies. It relevant to conduct consultation with stakeholders in order to identify such policy issues and to see if those identified issues can be removed through TNA assessment and analysis. In the implementation and operation of solar power grid-connected technologies, men can dominate recruitment of technician due to their ability to climb trees without fear and also their capability to work at a higher height using security uniform assistances. Most women are reluctant to climb to certain height even if security and safety uniforms and measures are taken by women. Consultation with key stakeholders reveal the idea of suitability to have the protected ladder or truck pocket ladder to be part of the implementation of solar projects and the need to train women to be more capable of working at heights or elevated location. It is important to collect gender-disaggregated data and gender information related to these key identified policy areas, conduct gender analysis to determine differentiated outcomes or impacts for men and women of proposed policy areas, design policy which incorporates actions to address these differentiated outcomes and impacts so that inequality is avoided, and ensure that institutional mechanisms for the implementation and monitoring of policy actions include women and men in equal opportunities.

An Action Plan for mainstreaming gender in the climate change sector and NDC implementation in Tonga was created and incorporated into TNA process. In TNA process, women's involvement and participation in decision-making and the identification and scoring of related technologies became priorities.

2 Technology Prioritization for Electricity/Energy Sector

2.1 GHG Emissions and Existing Technologies for Electricity Energy Generation

According to Tonga's National Communication to the UNFCCC and specifically the Tonga's second NDC in December, 2020, the total carbon emission from Tonga reached 310.4 Gigagram in 2006 with the energy sector accounting for 39%. The Agriculture, forestry and other land use (AFOLU) accounting for 61%, and Waste accounting for 0.3% of total GHG emissions (Tonga NDC, 2020). Tonga wishes to reduce 13% of carbon emissions from the energy sector, that is, 16 Gigagram by the end of 2030 compared to volume in 2006. Tonga has established energy targets and energy technology implementation plans in order to achieve the 13% carbon emissions reduction. For instance, the Government of Tonga approved 70% total electricity generation from renewable sources by end of 2030 through a mix of solar, wind, and battery storage. To achieve this high penetration of renewable energy in the grid, it is necessary to secure financing of renewable energy technologies and to upgrade electricity network infrastructure. Other ways to reduce carbon emissions within the energy sector are improving vehicle efficiency standards by adopting policy incentives such as taxes, fees, and import tariffs. Tonga is also aiming to adopt minimum energy performance standards (MES) for imports of electrical appliances to reduce carbon emissions in the electricity sector

Tonga's current power generation is generated by diesel power generation, supported by solar power generation, wind power generation and battery storage. Up to now, around 13% of the country's total generation comes from renewable energy sources. However, some RE power installations have not yet been connected to national grid because of technical issues. Tonga has already met its national energy reduction target of 12% of electricity national losses by 2020. To date, the total network losses amount to around 9% which is below the 12% target. Tonga's 2nd NDC has also set a target of reducing carbon emissions by 2% per year by using light duty vehicles (LDVs). Tonga plans to limit the growth of grid connected residential end-use by 1% per annum over the next five years. This is achieved by adopting minimum performance standards for electrical appliances, lighting, and other electrical equipment.

In Tonga, electricity is generated by TPL, Other Independent Power Providers (IPP) on the basis of agreed Power Purchase Agreements (PPA). Independent Power Providers include Snazzier Company, Chinese Company, Community Cooperative Society for Outer Islands mini-grid, Incorporated Electricity Society, which generates electricity through Solar Home Systems, in residential houses in remote islands.

All electricity grid customers in Tonga except cooperated electricity & incorporated electricity users are subject to one tariff. Both diesel fuel & electricity tariff are subsidized by the government which may be one of the main barriers to uptake of Energy efficient appliances campaign by consumers and also makes the use of Renewable Energy Technology (RE) uncompetitive.

2.2 Decision Context for Electrical Power Generation

2.2.1 An Overview of Selected Mitigation Technology Options in Electrical Power Generation Mitigation Potentials

Table 2:List of Technologies for MCA of Power Generation Technologies

No	Technology	CO_2 Mitigation Potential
1	Solar Powered Roof-Top	Maximum Power from Solar Power Plant installed in households to reduce fossil fuel consumption.
2	Energy Efficient Home Appliances	Maximize the efficiency of using home appliances through saving energy or retrofitting of appliances to reduce fossil fuel consumption
3	Solar Water Heater	Avoiding using diesel power electricity and gas for water heating.
4	Efficient Woodstoves	Updating of efficiency of utilization of firewood by wood stove
5	Diesel Solar Wind Power Co-generation	Reduce fossil fuel power consumption
6	Diesel and Solar Power Co-Generation	Reduce Electricity Consumption saving cost and consumption of electricity
7	Stand Alone Solar Home System	Reduce Cost and Use of Fossil Fuel in the outer islands of Tonga
8	ON-Grid Solar Farm	Gradual replacement of fossil-based power generation by solar power plants
9	On-Grid Wind Farm	Gradual replacement of fossil-based power generation by wind power plants
10	Biogas	The use of animal wastes or plant waste to reduce using of fossil fuels for power generation or using of LPG for cooking

2.3 Criteria and Process of Technology Prioritization for Energy

The Performance Matrix Table uses the following technology prioritization criteria for the power generation technologies. The list of criteria is shown at the top of this Performance Matrix Table. The stakeholders have provided their agreed mark under each technology for each of the criteria and indicators below. The following technology prioritization criteria are applied in the All indicators based on each of the criteria are assigned their criterion weight subject to final approval and confirmation by the key stakeholders attending the workshop. Since there are 9 technologies in total, stakeholders have marked these indicators using a mark-range (1-9). A new technology, Biogas, was agreed upon and therefore added by the stakeholders. However, the marking range (1-9) was never changed, so it remains 1-9. All indicator and criteria weighted by stakeholders are added to 100, and high criterion weights support national climate change policy and political support for scaling up renewable energy. The highest criterion weight marks support high policy coherence and green support for the technology.

. *Table 3: Decision Matrix and Weighted Scores of Energy Technologies*

Decision Matrix: Weighted Scores																						
					Benefits												Other					
	Costs				Economic				Social				Environmental			Climate related	Institutional/Implementation			Political		
	Cost to install the technology CAPEX	Cost to Operate and maintain the Technology OPEX	Level of beneficiary for the country	Increasing or Decreasing Value of $ to Buy the Technology	Level of Investment in the country	Market Potential and Sufficient framework for Software, Hardware and Orgware	Job creation	Trigger private investment	Income to reduce Poverty reduction potential	Acceptability to Local Stakeholders	Ability to improve Education and Learning	Health Promotion	Level of Reduction of Carbon Emissions	Supporting Gender equality	Reduce Air Pollution	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation and Timeframe	Level opportunities and Bariiers	replicability and National Status of Technology	Coherence with national development policies and priority	Total Benefit	Technology Rank
1 Solar Powered Roof-Top	300	150	0	150	0	150	100	100	50	50	200	75	437.5	700	600	250	100	312.5	150	1062.5	4937.5	8
2 Energy Efficient Home Appliances	300	150	300	200	50	300	300	300	300	300	400	225	350	700	600	750	350	312.5	200	1487.5	7875	3
3 Solar Water Heater	350	175	37.5	300	12.5	187.5	50	50	0	0	250	37.5	87.5	700	600	125	250	312.5	300	850	4675	9
4 Efficient Woodstoves	400	200	75	100	25	112.5	50	50	250	250	150	37.5	0	700	0	125	400	312.5	100	637.5	3975	10
5 Diesel Solar Wind Power Co-generation	0	0	300	250	100	225	400	400	400	400	300	300	175	700	75	1000	0	312.5	250	1700	7287.5	6
6 Diesel and Solar Power Co-Generfation	100	50	300	250	87.5	262.5	400	400	400	400	350	300	262.5	700	150	1000	50	312.5	250	1700	7725	4
7 Stand Alone Solar Home System	300	150	187.5	350	37.5	225	300	300	300	300	300	225	525	700	600	750	100	312.5	350	1275	7587.5	5
8 ON-Grid Solar Farm	300	150	300	400	75	225	400	400	400	400	300	300	700	700	600	1000	0	312.5	400	1700	9062.5	1
9 On-Grid Wind Farm	50	25	300	400	62.5	225	400	400	400	400	300	300	612.5	700	600	1000	0	312.5	400	1700	8587.5	2
10 Biogas	250	150	187.5	150	62.5	187.5	150	300	250	300	350	187.5	87.5	700	225	625	250	312.5	250	1062.5	6037.5	7
Criterion weight	4	2	3	4	1	3	4	4	4	4	4	3	7	7	6	10	4	5	4	17	100	

2.4 Result of Technology Prioritization

Table 4: List of Prioritized Technology based on MCA

List of Technology	EE Technology	RE Technology	Total Benefit Mark	Technology Rank
Energy Efficient Home Appliances	×		7875	3
On-Grid Wind Farm		×	8587.5	2
On-Grid Solar Farm		×	9062.5	1

3 Technology Prioritization for Transport Sector

3.1 GHG Emissions and Existing Technologies of Transportation Sector

In Tonga, of the total 100% of the country's emission 39% come from the energy sector of which the transport sector is the main contributor for energy sector emissions beside the electricity sector. According to Tonga's second NDC report in 2020, Tonga puts emphasis on improving and modernizing vehicle standard and to enable the use of more efficient engines vehicles. The imports of more modern vehicles through import of new model vehicles and imposing of policy or economic incentives to allow users to buy latest model of vehicles. Imposing of taxes, fees and import tariffs to enable the import of more efficient vehicles are key policy implementation in the transport sector.

The availability of historical data on GHG emissions of the transport sector in Tonga is limited, and there are several data gaps that make it difficult to obtain a comprehensive and coherent picture of the transport sector's emissions. The baseline assessment of Tonga's GHG emissions was built off of Tonga's Intended Nationally Determined Contribution (INDC) published in 2015, which identifies the key emitting sectors as transport (40%), electricity generation (23%), agriculture (21%), waste (11%), and other energy (5%). The TEEMP addressed 55% of these total greenhouse gases: electricity generation (23%) and ground transportation (32%) (Tonga's INDC , 2015).

EV and hybrid vehicles have already been used in Tonga. There also needs to be development of infrastructure to power as well as service these types of vehicles. It is also important to note however, the use of electricity to power an electric or hybrid vehicle still accounts for indirect GHG emissions, although there are policy indications that ideally the country intends to move to emissions-free transport through electric vehicles charged by renewable energy.

3.2 Decision Context for Transportation Sector

The Tonga Energy Efficiency Master Plan (TEEMP) was designed by CTCN and one of its objectives is to address the 55% of these total greenhouse gases: elect ricity generation (23%) and ground transportation (32%) (UNCTCN, 2020). The other fuel source for transportation is 100% petrol. According to TERM, there would be expected growth in energy consumption of 28% by 2020 compared to 2010 volume(GOT, 2010), may be the case, since more than half of total fossil fuels import should be consumed in the transport sector. An estimated baseline for transportation is over 16,000 vehicles in Tonga for residential, commercial, and government use in 2016 (GOT, 2010). The majority of vehicles were either cars (6,031) or light trucks/vans/SUVs (7,103). Heavy duty vehicles, taxis and rentals, motorcycles, and buses accounted for the remaining 3,690 vehicles. Current average vehicle kilometers travelled per person was estimated to be 2,289 in 2016 and is projected to grow to 5,103 by 2050, tracking with anticipated GDP increases (TEEMP, 2020).

3.2.1 An overview of possible mitigation technology options in Transport Sector and their mitigation potential and other co-benefits

Table 5: List of Technologies Chosen for MCA Transportation Sector.

No	Technology	CO_2 Mitigation Potential
1	***Battery Powered Electric Vehicle***	Vehicle is Powered by Electricity recharge with battery storage without fossil fuel.
2	***Energy Saving Speed Control Motor Drive***	Automatic speed control without any influence the drive in order to save fuel consumption.
3	***Vehicle Emission Technology***	Vehicle emission technologies is installed in the muffler to control and reduce emission from vehicle.
4	***LPG Vehicle Transport System***	Using of cleaner fuel by vehicles and so thus reduce emissions.
5	***Biofuel Vehicle***	Reduce fossil fuel consumption and emission by blending
6	***On-Grid Electric Vehicle***	Reduce use of petroleum products from gas stations
7	***ICT For Vehicle Emission Standard***	Information and communication technologies are used to help guide the driver to monitor speed to reduce emissions.
8	***ITS for Management of Vehicle Transportation System***	Information Technology to improve management of the Transport system to reduce release of emissions.
9	***Bioethanol Vehicle***	Use of ethanol for vehicle as clean fuel and less emissions release.
10	***Hybrid Vehicle***	Use of various sources of fuels to power one vehicle to reduce cost of operation and emissions
11	***Vehicle Emission Standard***	The use of vehicle emission standard for import less emission standard vehicles.

3.3 Criteria and Process of Technology Prioritization for Transport

The criteria for the technology prioritization of the Transport Sector are identical with the criteria used for prioritization of energy technologies, since the same criteria was adopted in the Factsheets. The process involved weighting each of the 11 identified technologies based on quantity of CO2 reduced through various indicators shown by each criteria.

The environmental impact in the form of amount of CO2 reduction was weighted as 15% for improvement resilience to climate change and another 15% for Reduce air pollution; 15% for ability for coherence with political policies. There are 10% of total criteria weight assigned for technology that trigger immediate private investment; 10% for ability of the country to invest in the technology and 9% for cost of technology and 8% ability to ease timeframe for implementation of the technology. The results of the MCA are shown in Table 7 below : The top three technologies were moved forward to the Barrier and Analysis and Enabling Framework (BAEF) stage.

3.4 Results of Technology Prioritization for Transportation Sector

Table 6: Decision Matrix and Weighted Scores of Transport Technologies

		Costs				Benefits												Other					
						Economic				Social				Environmental			Climate related	Institutional/Implementation			Political		
		Cost to install the technology CAPEX	Cost to Operate and maintain the Technology OPEX	Level of beneficiary for the country	Increasing or Decreasing Value of $ to Buy the Technology	Level of Investment in the country	Market Potential and Sufficient framework for Software, Hardware and Orgware	Job creation	Trigger private investment	Income to reduce Poverty reduction potential	Acceptability to Local Stakeholders	Ability to improve Education and Learning	Health Promotion	Level of Reduction of Carbon Emissions	Supporting Gender equality	Reduce Air Pollution	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation and Timeframe	Level opportunities and Bariiers	replicability and National Status of Technology	Coherence with national development policies and priority	Total Benefit	Technology Rank
1	*Battery Powered Electric Vehicle*	787.5	87.5	100	100	800	60	100	1000	100	90	90	90	100	100	1500	1500	560	80	420	1500	9165	1
2	*Energy Saving Speed Control*	112.5	12.5	12.5	12.5	400	50	80	800	80	40	70	70	60	100	900	900	480	70	360	600	5210	7
3	*Vehicle Emission Technology*	112.5	12.5	75	75	400	40	70	700	70	80	60	40	50	100	750	750	800	70	600	1350	6205	6
4	*LPG Vehcle Transport System*	675	75	62.5	100	400	40	40	400	40	50	50	50	80	100	1200	1200	640	70	480	1200	6952.5	4
5	*Biofuel Vehicle*	0	0	0	0	300	60	60	600	60	60	40	60	60	100	1050	1050	160	70	120	450	4300	9
6	*On-Grid Electric Vehicle*	900	100	87.5	100	875	50	87.5	875	87.5	75	75	75	100	100	1500	1500	400	62.5	300	1500	8850	3
7	*ICT Foe Vehicle Emission Standard*	675	75	87.5	87.5	500	25	25	250	25	12.5	37.5	37.5	37.5	100	562.5	562.5	400	62.5	300	1312.5	5175	8
8	*ITS for Management of Vehicle*	562.5	62.5	50	50	500	25	37.5	375	37.5	12.5	12.5	12.5	25	100	375	375	300	62.5	225	375	3575	10
9	*Biethanol Vehicle*	0	0	0	25	250	25	12.5	125	12.5	12.5	12.5	0	87.5	100	375	1125	0	62.5	0	187.5	2412.5	11
10	*Hybrid Vehicle*	787.5	87.5	87.5	100	1000	62.5	100	1000	100	100	100	100	87.5	100	1312.5	1312.5	700	62.5	525	1312.5	9037.5	2
11	*Vehicle Emission Standard*	675	75	75	75	750	75	0	0	0	37.5	75	0	62.5	100	937.5	937.5	800	62.5	600	1312.5	6650	5
	Criterion weight	9	1	1	1	10	1	1	10	1	1	1	1	1	1	15	15	8	1	6	15	100	

Table 7: Results of MCA for Transportation Technologies

List of Technology	EE Transportation	RE Transportation	Total Benefit Mark	Technology Rank
On-Grid Electric Vehicle	×		8850	3
Hybrid Vehicle		×	9037.5	2
Battery powered Electric Vehicle	×		9165	1

Please note that Hybrid Vehicle option is a new choice decided by the stakeholders and so they incorporated their preferred option to the list. The factsheet was fully relied on participants experiences on hybrid vehicles especially the participants from vehicle dealers companies.

4 Summary and Conclusion

4.1 Final List of Technologies Chosen to Move to BAEF

The final list of technologies for both Energy and Transport Sectors are shown in Table 11, arranging the top three technologies from high priority technology on top to low priority technology at the bottom.

Table 8: Final List of Technologies

RANK	Energy Technologies	Transport Technologies
1	On-Grid Solar Farm	Battery powered Electric Vehicle
2	On-Grid Wind Farm	Hybrid Vehicle
3	Energy Efficient Home Appliances	On-Grid Electric Vehicle

4.2 Conclusions

The focus on energy technologies and the focus on transport technologies differ in terms of weighting criteria, but they both share a common approach to reducing emissions by adopting three main effects: reducing emissions, increasing climate resilience and increasing energy independence. Tonga's NDC has specified the emissions reduction targets of13% reduction in GHG emission by 2030 compared to 2006, through a transition to 70% RE electricity as well as energy efficiency measures (GOT NDC, 2020). Tonga’s ambitious Road Map targets a high level of renewable penetration. The increased adoption of energy-efficient home appliances or the efficient use of energy-saving home appliances will reduce overall electricity demand, reduce total capacity requirements, and reduce the cost of power generation. Load reduction is the most effective way to reduce emissions, so it makes sense for Tonga to align its ambitious renewable targets with equally ambitious EE targets, which are fully reflected in our energy technologies priorities. Secondly, recent events have highlighted the impact of tropical cyclones (cyclones) and other natural disasters on small island developing states (SIDS). Tonga has direct experience with this, and has expressed strong support for policies to address the negative impacts of climate change through international level financial and technical support and by setting high priorities for reducing negative impacts of climate changes. While the international community is striving to combat climate change, damage to the Earth's climate poses immediate risks to the infrastructure and national power grids of Tonga.

Many of the Energy Efficiency (EE) projects outlined in the Tonga Energy Master plan (TEEMP) contribute to climate resilience in Tonga by decreasing unnecessary grid load, diversifying the power generation mix, strengthening vulnerable infrastructure, and identifying opportunities for Energy Efficiency and Renewable Energy (RE) projects. Climate resilience is therefore a key component of the TEEMP. By increasing the penetration of renewables and reducing fuel consumption from the Business as Usual (BAU) scenario, Tonga's dependency on imported fuel – as measured by energy intensity – stabilizes. The stabilization of volatile fuel prices does not impact Tonga's electricity, transportation or cost of living, resulting in improved public welfare outcomes.

MEIDECC could lead an effective working group to promote identified and prioritized technologies in Tonga. Members of the working group should include MOI (Government of Tonga), TPL (Ministry of Industry, Trade and Industry), MCCTIL (Ministry of Commerce, Industry and Energy), PCREE (Government of Statistics), and other Tongan organisations. The working group should strengthen links with international organizations and funding partners that have expressed a strong interest in increasing high penetration of solar, wind power grid connection and improving efficiency of domestic appliances by identifying and removing various obstacles that limit maximum penetration of RE & EE technologies in the grid. The working group, and international partners, could then facilitate the central reporting, use and storage of necessary data. This would enable the implementation of RE and EE technologies within the energy sector and the adoption of electric vehicle (EV) and hybrid vehicles (HV) in the transport sector, thus ensuring the presence of appropriate infrastructure to support TNA development. Such collaboration and progress are essential to ensure that Tonga's energy and transportation system transformation is feasible and can meet the emission reduction and independence targets set in the TERM, in an efficient, well-structured and cost-effective way (CTCN, 2018)

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6 Annexes

6.1 Annex 1: Technology Factsheets

6.1.1 : Energy Factsheets

The following factsheets for Energy technologies were formulated by the consultant and submitted for comments and finalization of the Project Coordinators and overseas Consultants for the TNA project. Technology Number 10, that is, the Biogas Technology was only included by Stakeholders without any factsheet, so the TNA for this technology was based on their experiences especially the representative from the Chamber of Commerce and private sector.

FACTSHEET 1

TECHNOLOGY FACTSHEET 1 - SOLAR POWERED ROOFTOP	
• A SHS can eliminate or 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. The size of the system (typically 10 to 100Wp) determines the number of 'light-hours' or 'TV-hours' available. It is estimated that there are more than 2 million such systems in use globally, the majority in Bangladesh, China, India, South Africa and Kenya (REN21, 2010). • There are increasing interest to use solar roof top in Tonga due to concern on land space needed for installation of solar. However, only few institutions have managed to install their rooftop solar system. One issue is high arrival cost of technology as well as lack of *incentives and right policy in the country.	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	• There are no solar manufacturers in Tonga. The Department of Energy (DoE) has few solar technicians and there are also solar technicians trained in different organizations and communities. The DoE also has experience in procuring solar PV products from the overseas suppliers before select the winning suppliers to the country.
Size of Beneficiary Group	• All population of Tonga if the technology is motivated and affordable
Operation and Maintenance	• Tonga has good solar energy potential. The solar energy assessment was done by the U.S. National Renewable Energy Laboratory (NREL) under the financing from the GCF.
Disadvantages	• PV systems involve the use of toxic materials, e.g. the production of poly-silicon, and therefore require diligence in following environmental and safety guidelines. • In terms of land use, the area required by PV is less than that of traditional fossil fuel cycles and does not involve any disturbance of the ground, fuel transport, or water contamination (IPCC, 2010).
Capital Costs	

Cost to Implement the Technology	• the average global PV module price dropped from about 22 USD/W in 1980 to less than 4 USD/W in 2009, while for larger grid connected applications prices have dropped to roughly 2 USD/W in 2009 (IPCC, 2010) and has continued to be dropped in recent years.
Additional Cost to Implement the Technology	• Breyer et al. (2009) estimated that the "cost of PV electricity generation in regions of high solar irradiance will decrease from 17 to 7 €ct/kWh in the EU and from 20 to 8 $ct/kWh in the US in the years 2012 to 2020, respectively
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• Capable of reducing climate changes due to reducing carbon emissions
Economic Benefits	
Employment	• Government Incentives and rebates offered by governments and utilities can compensate for the high prices of PV equipment
Investment	• Though initial investment is high, all the electricity produced or utilized is free sunshine resources and should be profitable in the long run.
Public and Private Expenditures	• with advancements in the technology, cost of solar panels are decreasing while efficiency is increasing
Social Benefits	
Income	• Solar energy can help provide a source of energy to far and isolated communities dwelling in areas,
Learning	• There can be many jobs created in the solar sector, such as meet the demand for trainers and technicians
Health	• Schools are examples of social establishments where grid extension is made impossible because of costs. The main environmental impacts of solar cells are related to their production and decommissioning
Environmental Benefits	
Gender	• Solar Power Roof Top can be considered, particularly when installed on brownfield homes, as it is close for women in view of transfer knowledge as well as environmentally benign during operation..
Air Pollution	• Solar PV systems, once manufactured, are closed systems; during operation and electricity production they require no inputs such as fuels, nor generate any outputs such as solids, liquids, or gases (apart from electricity).
Local Context	
Opportunities and Barriers	

	• Efforts have been made to reduce the installation costs of the technology but revenue collection continues to be unsustainable (Pearson., T and Gavin Pereira., G, 2016) • It is very expensive to move from just having single diesel generators to having new solar plants, new hydro power plants, new wind farms. So the financing gap is something that is a big barrier (ADB, 2019)...
Market potential	• The warnings of global destruction and climate change have become major issues. • Required better Regulation of Tariff and services but islanders have improved their quality of life by accessing to renewable energy in the grid.
National Status of Technology	• Electricity tariffs are still very expensive for mini-grids to operate. The revenue collection by the society is not always sufficient because cost of diesel is expensive compare to the main islands and tariff is often fixed despite of increasing prices in diesel.
Timeframe	• Long Term
Acceptability to Local Stakeholders	• Now, in 2020, is the right time to reinvestigate past experiences, present activities **(**Kim. S.A and Kim J.H, 2020).

FACTSHEET 2

TECHNOLOGY FACTSHEET -2 ENERGY EFFICIENT HOME APPLIANCES	
• Introduction: amount of energy used. It is therefore necessary to implement as widely as possible efficient energy devices of class that reduce electricity consumption.	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	• There is already Energy Efficiency Master Plan established in 2020 and Energy Efficiency is included in the Tonga Energy Road Map. However, Pacific Minimum Energy Performances and Labelling Standard is still yet to be adopted in Tonga in order to allow import of more energy efficient appliances to the country.
Size of Beneficiary Group	• All population of Tonga
Operation and Maintenance	• Due to increasing energy prices, Tongan families put more emphasis on saving energy in order to reduce expenditure.
Disadvantages	• Maintenance of electricity appliances has attracted a lot of attention due to increasing electricity tariffs
Capital Costs	
Cost to Implement the Technology	• Energy efficient appliances are sometimes more expensive • Millions have been spent on energy efficient appliances all over the world
Additional Cost to Implement the Technology	• In Tonga, change of attitude for wise consuming of appliances have been realized and practiced in the country.
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• Reduction of 0.9 mil.t CO_2 in 2010 – 2030
Economic Benefits	
Public and Private Expenditures	• Electrical companies and wiring usually conducted this work
Social Benefits	
Income	• Reduce consumer spending
Learning	
Health	
Environmental Benefits	
Gender	

Air Pollution	• Reduce harmful emissions
Local Context	• Energy saving is popular practices
Opportunities and Barriers	• Long life of home appliances of 15-20 years and relatively high cost. Consumers are reluctant to change an old fridge, a TV, a washing machine, etc. which is functional but not energy efficient
Market potential	• Market potential is huge but its either cost or attitude challenge that force people to undo adoption of energy saving at homes.
National Status of Technology	• Very widely adopted by households
Timeframe	• Long Term
Acceptability to Local Stakeholders	• Acceptable to local people and companies

FACTSHEET 3

TECHNOLOGY FACTSHEET -3 SOLAR WATER HEATER	
Introduction: a set of solar panels are used to collect energy to heat water before the heated water is circulated into a tank. Large-capacity tanks can be used to store hot water during the night or when there is no sunlight.	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	In Tonga most solar water heater systems are imported by local company owned by a German business man. .
Size of Beneficiary Group	All population of Tonga
Operation and Maintenance	• The local German company as well as other private businesses are responsible for importation of solar water heater equipment and installation in residential houses and other buildings.
Disadvantages	• The local German company and other solar water heater companies are not performing well due to high penetration of cheaper and more reliable technology such as LPG-source water heater and electricity-source water heater.
Capital Costs	
Cost to Implement the Technology	• The cost of electricity-source is much cheaper than solar water heater, for instance, one can spent about T$3000 to have a 20-liter solar water heater compare to $300 T$ for 8litres electricity or gas-source water heater.
Additional Cost to Implement the Technology	• Very less maintenance cost for solar water heater but gas-source water heater is even more less maintenance cost since we add $67 for 13kg gas tank per month.
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• If 50-65% of households is equivalent to 125 million households, use solar water heaters by 2030, the emission reduction potential can reach 10,039 million tonnes of CO_2.
Economic Benefits	
Employment	• It can help provide work, enhance life quality and reduce energy costs and reliance on fossil fuel imports and impacts of oil price fluctuation.
Investment	• This technology has a good prospect, and will help to cut costs on fuel importing. As a result, the money saved can be averted to other socio-economic needs.

Public and Private Expenditures	• solar water heaters have a significant role in reducing heating energy consumption in public and residential sectors.
Social Benefits	
Income	• Household income, especially in big cities, has increased in many parts of the country, and hot water has become a basic necessity. Many families want to include solar water heaters to their house's rooftop and hot water system designs.
Learning	• In terms of social benefits, this technology can contribute to the sustainable development, as it is simple enough for local people to carry out with a little training
Health	• Solar water heaters are widely used by communities because it is an environmentally friendly technology and user-friendly because it can easily be installed on the rooftop
Environmental Benefits	
Gender	
Air Pollution	• Moreover, hotels and motels in urban and rural areas also use electric water heaters to supply hot water to customers. All of these create a prosperous market future for solar water heaters.
Local Context	
Opportunities and Barriers	• Solar energy potential in Tonga is abundant, but development of this energy is still stagnant because of the following reasons: • Solar energy is not a stable source, thus unable to meet the demand, especially in the winter. • Extracting solar energy in areas where solar radiation is low and not stable is expensive. • Lack of a support policy to appeal to investors and users.
Market potential	• Other technologies on water heater is currently more cost effective than solar water heater.
National Status of Technology	• It is unpopular nowadays due to popularity of using gas and electricity heater
Timeframe	Long Term
Acceptability to Local Stakeholders	• Not fully acceptable due to low popularity and performances of the solar system

FACTSHEET 4

TECHNOLOGY FACTSHEET -4 **EFFICIENT WOOD STOVES**	
Introduction: Replacement of inefficient wood stoves with efficient ones provides saving on wood fuel that can reduce deforestation. Efficient (80% efficiency) stoves require up to 4 times less wood logs per heating season. Leveled cost of energy in such stoves is the lowest.	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	This WOOD STOVE creates an incentive for people not to switch to gas for heating and helps to avoid increase in CO2 -emissions. Additionally, this stove is more comfortable and safe that can reduce number of accidents. It burns wood more effectively, so the amount of dangerous particles that might be released is reduced.
Size of Beneficiary Group	All population of Tonga
Operation and Maintenance	Information campaign is needed prior to implementation of efficient wood stoves to inform people of all benefits that the stove can bring. Additionally, incentive campaigns are needed, such as loan schemes to help people to finance purchase of efficient stoves and to assist producers of stoves, assist market development through providing training, tax incentive schemes, grants, etc.
Disadvantages	• Deforestation is always the disadvantages.
Capital Costs	
Cost to Implement the Technology	• The cost of an efficient wood stove varies according to design features and materials used. It ranges within 150-180$. Since more than 100 000 families use inefficient stoves, cost of implementation of efficient ones can be 15 000 000-18 000 000 $ over 10 years. Lifetime of quality stoves exceeds 10 years.
Additional Cost to Implement the Technology	• . This measure saves the fuel costs to consumers compared to current usage of inefficient stoves. Thus the effect on operation costs is positive.
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• Estimated reduction of GHG emissions over the 10 year period is 2.9mil tones of CO2.
Economic Benefits	
Employment	• Sustainable economic development, rural development. Implementation of efficient stoves can assist rural development through job creation
Investment	• prevent migration of people from villages.

Public and Private Expenditures	• Very few company operating and less practice on private expenditure
Social Benefits	
Income	• cost-saving for low-income rural residents
Learning	• The project directly benefits individual households through installation of efficient stoves which will result in energy savings and lower expenditures,
Health	• and contribute to national objectives to reduce poverty and deforestation
Environmental Benefits	
Gender	• The major benefit of energy efficient wood stoves is reduction in consumption of wood for all sex.
Air Pollution	• In addition, use of such stoves lead to cost-savings for the consumer over the life-cycle of the appliance, and improve local air quality
Opportunities and Barriers	• Deforestation is even tough to control in Tonga due to land tenure and rights of the land owner especially the right of the people to their own land and properties.
Market potential	• The market is undeveloped and production is low scale. The use of wood market can be considerably improved if enabling environment is in place (awareness, financial incentive, policy and regulation, etc.).
National Status of Technology	• Tonga deforestation is critical and there must be sufficient consideration for use of woodstove and promotion of efficient woodstoves should be promoted and incentivized.
Timeframe	• Long Term
Acceptability to Local Stakeholders	• Very acceptable technology due to sufficient supply of fuelwood resources

FACTSHEET 5

TECHNOLOGY FACTSHEET-5 DIESEL CO-GENERATION WITH SOLAR AND WIND POWER

- Introduction: Utility Electricity is a grid-connected source of electricity generated by the Tonga Power Limited (monopoly power utility) for electricity consumers in the four main islands of Tonga. All grid-connected electricity consumers are operated in the four main islands of Tonga. Tonga has four separate electricity grids in the main island districts of Tongatapu, Vavaú, Ha'apai and 'Eua. There are two other districts on the main island of Niuas with electricity grids currently being installed under OIREP and TREP. The total population of Tonga was about 101,000 (2006 Census) which increased to 103,000 in the provisional 2011 census According to 2016 Census, approximately 96% of the total population of Tonga lived in the area that are benefitted from the electricity-grids produced and operated by the Tonga Power Limited, while 2% benefitted from the Cooperative Electricity and another 2% is benefitted from the Incorporated Electricity Model. Government of Tonga had set-up the nationai energy target in 2010 as shown in the Tonga Energy Road Map Plan for achieving 50% share of renewable energy in the total electricity consumption by 2020; 70% by 2025 and 100% by 2035
- Biggest Generation mix of Diesel, Solar, Wind and BESS as per shown in Table I above.

Name of Main Island	Total Capacity Diesel (MW)	Total Capacity Solar(MW)	Total Capacity Wind(MW)	Total Capacity BESS (MW/MWh)
Tongatapu	17.12	12.5	1.100	7.2/5.3 & 6/24
Vavaú	2.872	0.420	na	0.2/1.8
Haapai	0.672	0.550	na	0.550/0.900
Eua	1.772	0.200	na	0.350/0.900
Overall Total	22.436	13.67	1.100	

Timeframe	Short to Long Timeframe
TECHNOLOGY CHARACTERISTICS	
Institutional and Organizational Requirements.	• In 1998, the government's monopoly Tonga Electricity Power Board was transferred to full privatization under the new management of the Shoreline Group Ltd (Swales, 2009; World Bank, 2010). After protests against the privatized electricity management, leading to riots in which businesses and public offices were burned down in 2005, the industry was taken over by government and was corporatized in 2008 to form Tonga Power Limited or TPL (World Bank, 2010). The intention was to attract private investment (Swales, 2009), thus adopting a regulated concession contract for tariff formulation and services. The Tonga electricity industry has implemented significant institutional changes during the period 1998-2008 (Swales, 2009). The government registered TPL as a state-owned enterprise in 2008 under the Tonga Public Enterprise Act of 2002. The regulator is registered under the Tonga Electricity Commission Act of 2007 and operates under the concession contract noted above. The monitoring and assessment of implemented electricity services in Tonga are mandated by law, thus assigning the responsibility for monitoring and assessment to a specific government authority. • Utility (TPL) • Regulator (EC) • Concession Contract

<table>
<tr><td></td><td>Tonga Electricity Act/Public Enterprises Act
Key Implementer for National Energy Policy Target RE Share: 50% by 2020 70% by 2025
Key Implementer for NDC, SDG and Climate Change Policy and Plan
Regulation Is enforced</td></tr>
<tr><td>Size of Beneficiary Group.</td><td>The main island districts of Tonga (Tongatapu, Vavaú, Haapai, Eua) are isolated from each other and each surrounded by sparsely inhabited remote islands. Approximately 75% of the population live in the capital island of Tongatapu (Tonga Statistics Department, 2008; Swales, 2009), which comprises the major share of the energy market and which therefore utilizes the highest share of energy imports. The recent Census in 2016 indicated 74% of total population lived in Tongatapu, which had been increased from 73% recorded from the previous census in 2011.
96% of the total population; the other 4% live in the remote islands and not accessible to the grid
Monopoly Utility, no competition on services or tariffs</td></tr>
<tr><td>Operation and Maintenance</td><td>The main four grid systems in Tonga with details shown in Table 1 below serves all of Tonga (Swales, 2009). The Tongatapu grid system is the largest of the four grid systems operated by TPL. It distributes about 85% of the electricity grid-supplied energy in Tonga The electricity output is transmitted throughout the island on an 11kV system and distributed at 415volts. Based on obtained data, it is reasonable to conclude that the primary source of growth of energy is higher use by customers (Swales, 2009).
TPL Utility to produce and provide electricity services to customers and conduct maintenance of the technology(Diesel, wind, solar, BESS and electricity network)
EC to regulate services and electricity tariffs</td></tr>
<tr><td>Disadvantages</td><td>Increasing energy prices have justified the promotion of energy efficiency in the whole market.
Political issues, lack of a strong implementation of operational plan and insufficient financial resources as well as the lack of country technical experts are key reasons behind the delay in TERM progress (Panday, S et al, 2013).
Increasing Energy prices and public concerns on tariffs
Low achievement of high penetration of RE since finance is key issue for high investment cost RE project
Maintenance and repair of RE equipment is sometimes delayed causing low production of RE</td></tr>
<tr><td colspan="2">Capital Costs</td></tr>
<tr><td>Cost to Implement the Technology</td><td>The utility electricity consists of more than one source of energy including diesel, wind, solar power generation and BESS.
Table 1: Capex (T$/kW) of TPL Generators<table><tr><th>Type of Generator</th><th>Capex (T$/kW)</th></tr><tr><td>Diesel (Caterpillar)</td><td>1854</td></tr></table></td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>Solar (SunPower)</td><td>7861</td></tr>
<tr><td>Wind (Vergnet)</td><td>34327</td></tr>
<tr><td>BESS (Samsung)</td><td>1417</td></tr>
</table>
Source: ☹TPL Generation Manger, 2023)

Power Utility usually supported meet the cost of diesel engine, and IPP Contract and foreign donors have added solar power facilities into the grid. In the capital island various donors added wind power and more solar power.
Diesel Generator shows cheapest Capex compare to Solar and Wind
Utility co-generation electricity is a mixture of generation technologies

</td></tr>
<tr><td>Additional Cost to Implement the Technology</td><td>
The Opex ((T$/kW) of TPL Generators
<table>
<tr><th>Type of Generator</th><th>Opex (T$/kW)</th></tr>
<tr><td>Diesel (Caterpillar)</td><td>52.12</td></tr>
<tr><td>Solar (Sunpower)</td><td>65.38</td></tr>
<tr><td>Wind (Vergnet)</td><td>163.64</td></tr>
<tr><td>BESS (Samsung)</td><td>37.74</td></tr>
</table>
Source: Source (TPL Generation Manger, 2023)

Diesel generator is most cheapest to operate and maintain
Tonga- electricity tariff is a fixed tariff for all , so the biggest island Of Tongatapu is likely to cross-subsidized tariff in the small other main islands.

</td></tr>
<tr><td colspan="2">Development Impacts, Indirect Benefits</td></tr>
<tr><td>Reduction of Vulnerability to Climate Change</td><td>

The generated renewable electricity in the grid will directly offset the burning of 250 liters of diesel per Megawatt hour, reducing Tonga Power's diesel consumption by approximately 425,000 – 475,000 liters per year and displace around 1,100 tonnes of CO2 emissions annually (Meridian, 2011)

RE offset 250 litres per MWh
Reduce diesel consumption of approximately 475,000 litres per yr.
1100 tonnes/MW of carbon emission as annual saving (Meridian,2011)
For 13.67 MW Solar and 1.1MW Wind, we expected to have

</td></tr>
<tr><td colspan="2">Economic Benefits</td></tr>
<tr><td>Employment</td><td>
Number of new jobs annually

New jobs for wind and solar power generation as well as BESS

</td></tr>
<tr><td>Investment</td><td>

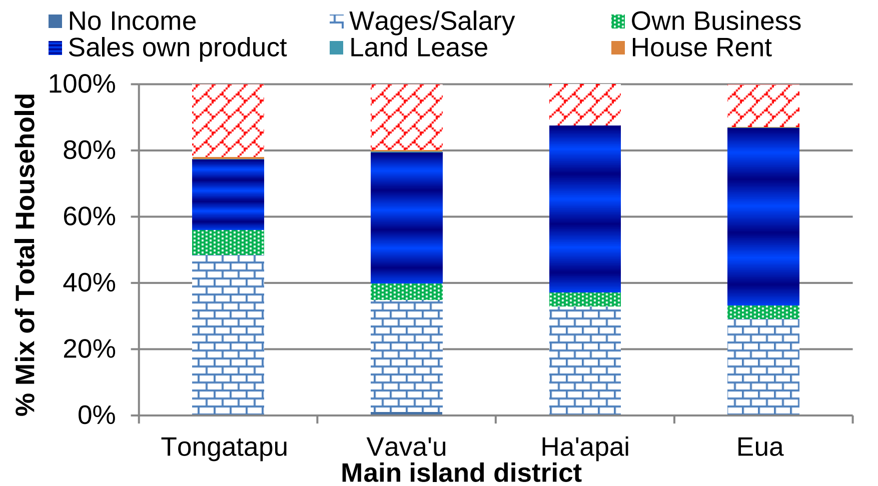
New investments in the production of mix of electricity sources in the electricity grid especially on renewable energy and energy efficiency are both essential to address the high cost of energy investment.
An effective energy efficiency policy should promote efficiency on both the supply and demand sides by identifying and monitoring policy incentives to support investors.

<table>
<tr><th>Item#</th><th>Generator #</th><th>Island</th><th>Asset owner</th><th>Energy source</th><th>Capex T$</th><th>Opex T$/kW</th></tr>
<tr><td>1</td><td>Maama Mai</td><td>Tongatapu</td><td>TPL</td><td>Solar</td><td>10,220,000</td><td>65.38</td></tr>
</table>
</td></tr>
</table>

2	Mata 'Oe La'a	Tongatapu	TPL	Solar	35,400,000	80.00
3	Matatoa	Tongatapu	Singyes	Solar	na	n/a
4	Ii ' Manum #1	Tongatapu	TPL	Wind		163.64
5	Ii Manum #2	Tongatapu	TPL	Wind		163.64
6	Ii Manum#3	Tongatapu	TPL	Wind		163.64
7	Ii Manum #4	Tongatapu	TPL	Wind		163.64
8	Ii 'Manum #5	Tongatapu	TPL	Wind	47,200,000.	163.64
9	Liukava	Tongatapu	Sunegise	Solar	na	n/a
10	Masilamea	Tongatapu	Sunegise	Solar	na	n/a
11	Fualu	Tongatapu	Sunrgise	Solar	na	n/a
12	Popua BESS	Tongatapu	TPL	Battery	10,220,000	37.74
13	Matatoa BESS	Tongatapu	TPL	Battery	na	29.17
14	Hahake Solar	Tongatapu	G.E.T	Solar	na	n/a
15	La'a Lahi	Vava'u	TPL	Solar	5,900,000	66.67
16	TREP / bess	Vava'u	TPL	Battery	3,140,000	75.00
17	Ha Masani	Ha'apai	TPL	Battery	2,355,000	55.56
18	Huelo	'Eua	TPL	Solar	1,884,000	63.64
19	TREP / bess	'Eua	TPL	Battery	3.140,000	68.18

- High Capital investment on RE technologies but low cost of maintenance and operation, but still cheapest investment cost compare to outer islands.

Public and Private Expenditures	• Reduce public and private expenditures associated with using electricity utility. • Higher % of RE penetration is able to reduce electricity tariff in Tonga, but increasing electricity demand and fossil fuel prices have affected the impacts of RE on electricity tariffs. • Increasing efficiency of electricity grid due to donors financial assistance led by NZAID have improved electricity losses in the grids. • Significant reduction of fossil fuel consumption through use of RE will reduce public and private expenditure if electricty tariff is cheaper • Two IPP are now invested in Solar in the capital of Tonga
Social Benefits	
Income	• In 2006, more than 50% of Tongan families in all districts had relied on unstable sources of income, like remittances, sales of their own products at market or to tourists and their own small businesses as shown in Figure 3. Figure 3 also shows the percentage distribution

	of the main sources of income for all residential households in the four main island districts. Figure 3: Private households by main source of income in 2006 Census  *Source:Tonga Statistics Department 2006* • Electricity consumption in Tonga is directly proportional with increasing income from international remittances. • Most Tongan families are dependence on remittances.
Learning	• Capacity to improve learning in local communities. • Moving to clean energy resources is not only good for health but also for environment and local communities would improved knowledge and experiences on using renewable energy sources. • Add new knowledge and experiences on RE and generation mix especially in the outer islands. This will build capacity on new knowledge and employment opportunities in the four locations.
Health	• Capacity to improve health standard and environment in the local communities • Improvement by using more sustainable energy resources like RE sources because of high pollution capacity of fossil fuel consumption
Environmental Benefit	
Gender	• One of the social impacts of delivering electricity services in the residential sector is the ability of women to demand electricity more than men. Such social characteristic suggests a need for a better understanding of socio-economic activities as well as cultural values like the overconsumption of electricity by men in drinking Kava in the kava clubs. • The characteristics of energy demand in the community are varied and unexpected increase in electricity demand may cause power shut down, due to specific gender interest for electricity consumption that have been identified and properly addressed

Air Pollution	• The power sector is still planning to use heavy fuel oil in future power generation activity. Indeed, it may be difficult to appropriately weigh economic, social and environmental priorities in Tonga and most PIFDS. For example, there is still a priority electricity management plan to use cheap fuel oil instead of diesel oil which would penalize environmental sustainability and favor economics. • The level of carbon emissions in Tonga has dropped in some sectors, but they are still on the rise in the energy sector. There is clear evidence of environmental impacts of fossil fuel consumption in the atmosphere, but increasing use of RE in the grid has addressed the situation
Local Context	
Opportunities and Barriers	• • Barriers such as no regulation for election of equipment renewable energy and energy efficiency installation (PPA, 2020). • Building and consolidating a strong policy environment for the development and dissemination of Tonga Energy Road Map, (*Fogarty M., 2012).* • Significant barriers are not technological but institutional, social and financial. • Government and regional energy institutions have a strong interest in planning to ensure the future security and availability of fossil fuel in the market. However, the required investment to improve security of supply has relied on donor financial support which is not wholly certain (*Fogarty M., 2012).*
Market Potential	• The regional energy institution has also contributed expertise to efficiency benchmarking of PIFDS's power utilities with indicators for network efficiency to improve coordination on network efficiency (PPA, 2020). However, there are also uncoordinated monitoring roles in the electricity industry which also need urgent attention. • Tonga's most predominant barriers are unsupportive policies, the lack of awareness, lack of financial resources, and the *bureaucratic* processes for the private sector to feed in electricity into the national TPL grid (Meier',, N, 2021). • The grid should be made ready for absorption of high penetration RE, especially policies for the regulation RE and IPP
National Status of Technology	• The security and reliability of energy supply is important for a small isolated market which is heavily reliant on imported fossil fuel supplies. • There are four on-grid installations of this type of electricity generation in Tonga installed in the four main islands of the country. Security of supply for solar and wind are sustainable and despite their installation are still donor dependence, but number of IPP investors on-grid solar is on the rise.
Timeframe	Long term

Acceptability to Local Stakeholders	Based on consultations with the government authorities, it appears that monitoring regulatory performance is currently hindered by insufficient coordination between the various monitoring authorities. • The effectiveness of regulatory and monitoring performance in Tonga could be evaluated through independent assessments to ensure all authorities comply with mandates in the electricity sector

FACTSHEET 6

TECHNOLOGY FACTSHEET -6
CO-GENERATION OF DIESEL AND SOLAR POWER.

- Introduction: Cooperative Electricity is a source of electricity produced through diesel mini-grids for bigger remote islands of the main islands of Tonga. Tonga has 2% of its total population benefitted from the Cooperative Electrification Model (Mini-grid of diesel and recently hybrid with solar supported by BESS). The diesel systems are managed by community-based Electricity Co- operatives (ECOs) which are licensed, trained in operations, accounting and management, and supervised by the Department of Cooperatives and Credit Unions. The ECOs establish tariffs, which are meant to cover operating and maintenance (O&M) costs plus – in principle – replacement of the generators after seven years or as required. The aim of the cooperative program is to provide basic energy services at the lowest cost to the greatest number of people (Pearson., T and Gavin Pereira., G, 2016), especially for the four bigger remote islands of Haapai (Nomuka, Uiha, Haafeva and Haano Islands) as well as Niuatoputapu Island. In Tonga

Table 1: Technology Information

Name of Main Island	Total Capacity Diesel (kWp)	Total Capacity Solar(kWp	Total Capacity Wind(kWp	Total Capacity BESS (MW/MWh)
Nomuka	50	100	na	210
Haafeva	30	60	na	110
Uiha	50	100	na	210
Haano	50	100	na	210
Niuatoputapu	80	150	na	295
Overall Total	260	510	na	1035

- Total Diesel Capacity of the minigrids is about 1.16% of the total TPL Diesel Capacity Grids
- Total Solar power capacity of the Mini grids is about 4% of the total TPL solar power capacity

Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	The Cooperative Electricity was adopted in 2002 for four outer islands of Haapai, Tonga through Australia-France joint funding. The adopted cooperative electricity scheme is much different from that of the Utility electricity, as the operator of the mini-grids and end-users. The Cooperative is set-up as a non-profit entity under a Cooperative Act (as in some PICTs) (Mario., R, 2009). Other aspects of maintenance, repairs, operation and fee collection are the responsibility of the Cooperative (Mario., R, 2009) • Government Ministry is the regulator of tariff and services • Committee selected by the Local Community is the Utility as monopoly • Tonga Cooperative Act

<table>
<tr><td></td><td>

Constitution registered in the Ministry of Trade and Economic Development(MTED) as the governing policy
Regulation is the responsibility of the MTED and they are mandated to regulate the tariff and services

</td></tr>
<tr><td>Size of Beneficiary Group</td><td>

The Haapai outer islands group (Haafeva, Nomuka, ‘Uiha and Ha’ano, with a total of about 450 households) were electrified through an AusAID assistance scheme commissioned between 2002 and October 2003. There are four main outer islands that have surrounded the Haapai main island, which are Nomuka, Haafeva, Uiha , Haano and Niutoputapu Island with total population of 2% of the total population of Tonga.
About 2%-3% of the total total population of the country

</td></tr>
<tr><td>Operation and Maintenance</td><td>
<table>
<tr><th>Islands</th><th>Solar (kWp)</th><th>Battery (kWp)</th><th>Gene-set (kW)</th><th>Capex (TOP$)</th><th>Capex ($T/kW)</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nomuka</td><td>100</td><td>210</td><td>50</td><td>1,574,948</td><td>872.5474</td></tr>
<tr><td>Haafeva</td><td>60</td><td>110</td><td>30</td><td>1,165,664</td><td>645.7972</td></tr>
<tr><td>Uiha</td><td>100</td><td>210</td><td>50</td><td>1,668,219</td><td>924.2211</td></tr>
<tr><td>Haano</td><td>100</td><td>210</td><td>50</td><td>1,719,616</td><td>952.6958</td></tr>
<tr><td>Niuatoputapu</td><td>150</td><td>295</td><td>80</td><td>3,967,569</td><td>2198.099</td></tr>
<tr><td>Total</td><td>510</td><td>1035</td><td>260</td><td>10,096,016.17</td><td>5593.361</td></tr>
<tr><td colspan="4">Source: (OIREP, 2023)</td><td></td><td></td></tr>
</table>
Table 1: Installed Capacity and Capex

The four Outer Islands of Haapai have individual electricity grid systems with details of generation mix shown in Table 1 below. The high cost of remoteness of the remotes has influenced the operation and maintenance of the assets, so the electricity tariffs are always expensive compare to the bigger outer islands. Figure 1 below have shown the expensive tariffs experienced by customers.
Setting up of Electricity Tariff is fully control by the selected committee from the local community and customers, However the regulation of services and tariff should done by MTED
Tariff has never been changed since the beginning of the project.

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</table>

Disadvantages

Table 2: Suggested Electricity Tariffs for Cooperative Electricity Islands

Raw Tariffs	2024	2025	2026	2027	2028	2029	2030
Niuatoputapu	4.40	4.16	3.93	3.70	3.49	3.28	3.09
Ha'ano	2.00	1.90	1.80	1.71	1.61	1.52	1.44
Ha'afeva	1.34	1.27	1.21	1.14	1.08	1.02	0.96
Uiha	1.94	1.84	1.75	1.65	1.56	1.48	1.39
Nomuka	1.82	1.73	1.64	1.55	1.47	1.39	1.31
Levelised Tariffs	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Niuatoputapu	3.94	3.94	3.94	3.94	3.94	2.91	2.91
Ha'ano	1.81	1.81	1.81	1.81	1.81	1.36	1.36
Ha'afeva	1.21	1.21	1.21	1.21	1.21	0.91	0.91
Uiha	1.75	1.75	1.75	1.75	1.75	1.32	1.32
Nomuka	1.64	1.64	1.64	1.64	1.64	1.25	1.25
One Tariff	2.10	2.10	2.10	2.10	2.10	1.60	1.60

Source: (OIREP, 2023)

- Due to smallness and remoteness the Cooperative Electricity is not always price to its real cost.
- This cooperative approach places the end user as the owner and customer who normally cause problems with the management and setting of fees in some countries (Mario., R, 2009).
- Expensive and insufficient cash flow is ofthen experienced.
- Maintenance and replacement of spare parts are often delayed due to less availability in the sites.

Table 3: Current Tariffs for Cooperative Islands.

Islands	Tariff Charged
Ha'ano	TOP $60.00 per month per household
Ha'afeva	TOP $1.00 per Unit and $20.00 per month per household.
'Uiha	TOP $70.00 per month per household
Nomuka	TOP $0.90 per Unit and TOP $10.00 per month per househo
Niuatoputapu	N/A

- lack of adequately trained operators and mechanics to be a major factor in the poor performance and short life of diesel generators(*Allison; SOPAC, 2007*).

Capital Costs

Cost to Implement the Technology

Table 4: Cost to Implement the technology

Type of Generator	Capex (T$/kW)
Diesel	3898.23
Solar	7737.03
Wind	na
BESS	15337.75

Source: (OIREP, 2023)

- very expensive to install grid technologies in the outer islands

- The Capex for miniogrids in the Pacific is average to USD 1000/kW *(Allison; SOPAC,2007)*

Additional Cost to Implement the Technology	• The Opex for minigrids in the remote islands was around 193USD/kW *(Mario R; SOPAC, 2009), which is expensive compare to the Opex of same technologies in the capital island.* • For OPEX, Mini grids would need 5% of initial capital costs annually, which are the following: engine overhaul costs at 25% of initial capital costs every 5 years; generator and switching system overhaul every 7 years at a cost of 20% of initial capital costs; and major engine overhaul costs at 100% of initial capital cost every 10 years (*Allison; SOPAC, 2007)*.
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• The conclusions of these analyses suggest that OTEC has the potential to minimize carbon emissions, increase efficiencies, and create new high-quality green-technology industries and livelihoods (Kim J.H et al, 2021). • For Mini grids, Fuel efficiency is assumed to be 0.2 litres/kWh (Allison; SOPAC, 2007). • 788 litre/month of diesel saved by wind power (2 X 20 KW Turbine) Diesel savings realised by the addition of the two wind turbines (Allison; SOPAC, 2007). OR • 240 tonnes of greenhouse gas emissions are saved during the lifetime (20 yrs) of the project. Allison; SOPAC, 2007). Having stated that, • In Tonga with a total installed capacity of 1545 kW of solar and BESS for Mini grids, we would save 463 tons of carbon emission per year.
Economic Benefits	
Employment	• Increasing number of people are recruited and trained in the local communities • New equipment such as solar equipment is introduced into the local communities, will create new employment opportunities for less educated people in the society
Investment	The electricity industry has high investment needs and potential local investors may not wish to invest due to the large sums involved and challenges noted above, so foreign investment is encouraged to initiate investment. • Very expensive investment cost compare to that in the main islands
Public and Private Expenditures	Private public and private companies preferred to have the following in the markets (i) reduce fuel imports (ii) improve annual savings from reduced fossil fuel consumption, and (iii) reduced\ tariff (ADB, 2021) • No IPP prefer to invest in the outer islands compare to more IPP investors in the capital island
Social Benefits	
Income	• The project has had transformative impacts on quality of life and income generation on the outer islands. Improved electricity supply has expanded access to information and communication technology, including computers, televisions, radios, the internet, and mobile connectivity.

	• Outer islanders are increasingly using electric appliances for income generating activities such as producing coconut oil, sauce, and jam from local produce (ADB, 2021)
Learning	• Building on this experience in Ghana, UNDP will provide technical assistance to further support countries on seven core thematic areas (UNDP, 2020). • Longer hours at night with electricity so important for study at nighttime • Build up technical capacity on new skill of co-generation of diesel and RE in the remote islands
Health	• Small Islands of Pacific are committed to maintaining a clean and healthy environment by identifying and developing sustainable solutions to protect the oceans and marine life.(Johnson G, 2019) • Reduce using unclean source of energy for lighting like kerosene and candles
Environmental Benefits	
Gender	• In addition to avoiding greenhouse gas emissions, replacing diesel generation with renewables is supporting the Pacific nations to strengthen their fuel security, and build resilience to economic shocks (ADB, 2021), thus improve economic development and promote gender equity in the task force. • High electricity load at night time is often dominated by women as dominant use of light and other appliances at homes in the night time.
Air Pollution	• The level of carbon emissions in Tonga has dropped in some sectors, but they are still on the rise in the energy sector. There is clear evidence of environmental impacts of fossil fuel consumption in the atmosphere.
Local Context	
Opportunities and Barriers	• The growth of environmental awareness and the rising demand for energy has urged researchers to identify other sources of renewable energy. • The outer islands are dispersed and some are difficult to access. This complicates installation and maintenance programs. • . Efforts have been made to reduce the installation costs but revenue collection continues to be unsustainable (Pearson., T and Gavin Pereira., G, 2016) • It is very expensive to move from just having single diesel generators to having new solar plants, new hydro power plants, new wind farms. So the financing gap is something that is a big barrier (ADB, 2019)... • Actual tariffs are insufficient to cover capital replacement and in some cases, do not even cover operating costs; separate fund raising activities have had to be held by some islands to raise money for fuel purchases (Mario., R, 2009)

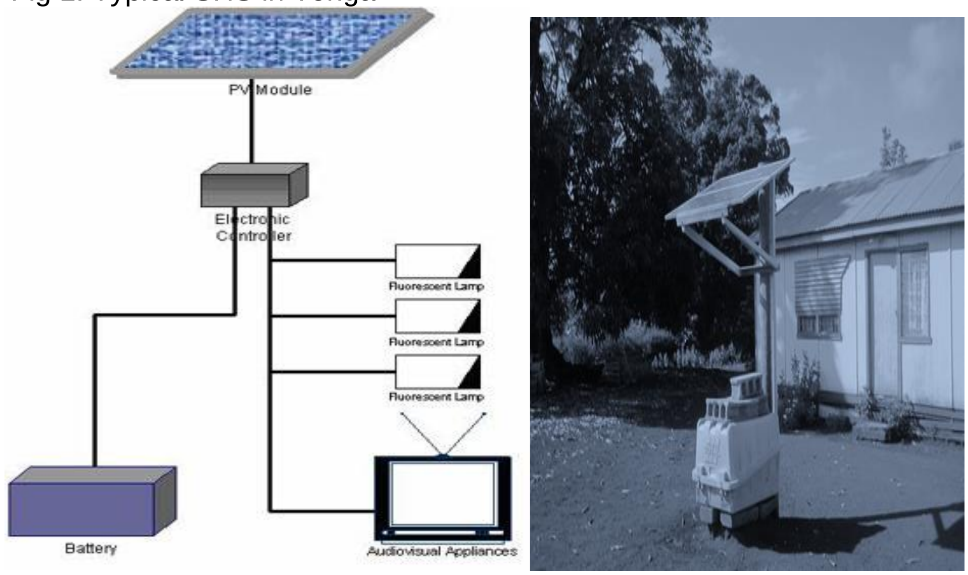
Market potential	• The Pacific island countries are heavily dependent on fossil fuels to meet their increasing energy needs for economic development. The high costs associated with fossil fuels are placing an increasing strain on the economies in the region (Mario.R, 2001) • Warning of global destruction and climate change have become major issues. • Required better Regulation of Tariff and services but islanders have improved their quality of life by accessing to renewable energy in the grid.
National Status of Technology	• Electricity tariffs are still very expensive for mini-grids to operate. The revenue collection by the society is not always sufficient because cost of diesel is expensive compare to the main islands and tariff is often fixed despite of increasing prices in diesel. • The population is the outer islands is slowly decreasing due to migration
Timeframe	Long Term
Acceptability to Local Stakeholders	• Now, in 2020, is the right time to reinvestigate past experiences, present activities, and future perspectives of OTEC and other RE in various holistic aspects—from the fundamental, microscopic science level to long-term operations/maintenance in harmony with **human engineering and Mother Nature (**Kim .S.A and Kim J.H, 2020) .

FACTSHEET 7

TECHNOLOGY FACTSHEET 3 STAND ALONE SOLAR HOME SYSTEM (SHS)	
• The main island districts of Tonga are isolated from each other and each surrounded by sparsely inhabited remote islands, of which government of Tonga adopted the Incorporated Electrification model by installing the standalone Solar Home System (SHS PV-off grid) as source of electricity in the households and community buildings. • The first off-grid standalone SHS project in Tonga was adopted in 1988 under government based model that controlled the entire electricity operations(Lefale and Lloyd, 1993), and further transformed in 2002 to the incorporated society model (Sefana et al., 2009). • Off-grid PV systems can make positive contribution to the sustainable development of remote /isolated communities in the developing countries, that do not access to the electricity grid (Outhred., H. et al, 2004)	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	• The Incorporated Electrification Society model is within the legal umbrella of the Tonga Incorporated Society Act of 2002, which will be later consolidated under the new legal framework provided by the Tonga Renewable Energy Act of 2009 (Sefana et al., 2009). This in turn reflected the increased priority placed on renewable energy development by the government of Tonga (Sefana et al., 2009, pg 20) in the Tonga Energy Road Map (TERM) of 2008 (GOT, 2009; GOT, 2010). • Accessibility to poor installation practices; inadequate or unworkable maintenance arrangements. and poor or inadequate supporting institutional infrastructure (Outhred., H. et al, 2004).
Size of Beneficiary Group	• According to 2016 Census, approximately 2% of the total population is benefitted from the Incorporated Electrification Society Model.
Operation and Maintenance	• Tonga uses the PV-off grid standalone household SHS design shown in Figure I. It supports 3 indoor fluorescent lamps (3 x 11W) and a night light (1x 5W); 1 outdoor fluorescent lamp (13W) and one radio plug (10W) for small DC radio (Sefana et al., 2009). The two

solar panels (2 x 80 W), battery (130 Ah, 12V) and controller (10A) are pole-mounted near the house.

Fig 1: Typical SHS in Tonga



Source: www.solarserver.com

- Off-grid PV systems are usually used in areas without interconnection to the public grid. (GoG, 2015c).
- SHS is cheaper than the construction of new grid in the small remote island context. The main components of a solar PV off-grid system are: the photo voltaic array, charge controller, battery bank, and direct current to alternating current (DC-AC) converter. Off-grid PV systems are available in all sizes from small appliances like a calculator to large scale systems (GoG, 2015c).
- The size of the system (typically 10 to 100Wp) determines the number of 'light-hours' or 'radio-hours' available
- Longer hours of electricity at night compare to the Cooperative Model, as it is designed to operate at most 8 hours of operation in the night time.

Disadvantages	• The technology is restricted to D.C. lighting and plug for radio.
Capital Cost	
Cost to Implement the Technology	(see table below)

	Niuatotapu	Niuafoóu	Vavau	Haapai	Tongatapu	Éua
Number of SHS installed	28	169	491	203	58	2
Monthly Generation (kWh)	463.01	2794.58	8119.18	3356.81	959.09	33.07

<table>
<tr><td></td><td>
<table>
<tr><td>Average Annual Generations (kWh)</td><td>5633.26</td><td>34,000.77</td><td>98783.3</td><td>40841.2</td><td>11,668.90</td><td>402.4</td></tr>
<tr><td>CAPEX /$T</td><td>4000</td><td>4000</td><td>3800</td><td>3700</td><td>3600</td><td>3600</td></tr>
</table>
Table 1: Details of SHS in the remote islands of stated main islands
Source: Department of Energy

which means that in the two Niuas the Capex to install the technology is T$25000/kW, which is the most expensive solar technology to be implemented compare to Utility solar or Cooperative technology.
The average global PV module price dropped from about 22 USD/W in 1980 to less than 4 USD/W in 2009, while for the price of larger grid connected applications has dropped to roughly 2 USD/W in 2009 (IPCC, 2010).

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<tr><td>Additional Cost to Implement the Technology</td><td>
<table>
<tr><td></td><td>Niuatotapu</td><td>Niuafoóu</td><td>Vavau</td><td>Haapai</td><td>Tongatapu</td><td>Eua</td></tr>
<tr><td>Number of SHS installed</td><td>28</td><td>169</td><td>491</td><td>203</td><td>58</td><td>2</td></tr>
<tr><td>Freight to Site(T$)</td><td>100</td><td>100</td><td>80</td><td>75</td><td>50</td><td>60</td></tr>
<tr><td>Labour (T$)</td><td>300</td><td>300</td><td>300</td><td>300</td><td>300</td><td>300</td></tr>
<tr><td>TOTAL (T$)</td><td>400</td><td>400</td><td>380</td><td>375</td><td>350</td><td>360</td></tr>
</table>
Table 2: Additional Cost to Implement SHS

The cost of the above system is approximately $4000 TOP OR $2000 USD. This does not include installation cost which is approximately $300 TOP per system.
Once technical feasibility for a given system is established, the costs involved, and the expected returns are calculated using financial feasibility analysis (ISA, 2018).
$T 300/160W OR $2500/kW.
In a grid-parity study, Breyer et al. (2009) estimated that the “cost of PV electricity generation in regions of high solar irradiance will decrease from 17 to 7 €ct/kWh in the EU and from 20 to 8 $ct/kWh in the US in the years 2012 to 2020, respectively

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<tr><td>Reduction of Vulnerability to Climate Change</td><td>

The sustainability of PV systems in Tonga would be enhanced through the utilization of mature PV technologies under appropriate economic, technical and institutional frameworks that reduce environmental problems and meet the socioeconomic needs of target communities. This will require a new direction for energy investment and changed institutional arrangements (Tukunga., T et al, 2002)
SHS saved 15-30L of Kerosene per month (Allison; SOPAC, 2007). , thus for 951 SHS in Tonga, they will saved 244.54 Tonne of Carbon emission per year.

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	• Solar PV has energy payback periods ranging from 2 to 5 years for good to moderate locations and life cycle of GHG emissions vary from 30 to 70 gCO_2e/kWh (IPCC, 2010), depending on panel type, solar resource, manufacturing method and installation size. • Comparing to emission factors for coal fired plants of more than 900 gCO_2e/kWh and for gas fired power stations of more than 400 gCO_2e/kWh (Sovacool, 2008) showing the large potential for solar PV to contribute to reductions in carbon emissions from the electricity sector.
Economic Benefits	
Employment	• A new institutional structure was formed with an improved management body, involving communities and the local and central government, in place to oversee the rural electrification projects on each island. As a result, quite a number of new jobs have been created annually in the local communities in order to support and provide capacity to the operation and maintenance of SHS.
Investment	• Tonga government's level of support and current management, financial and institutional structure is not sustainable (Fifita. S., 1998, Sefana,O, 2009; Tukunga T, 2013) • The users' financial contribution to PV operation and development depends on the ability to collect sufficient fees and will be determined by the removal of all barriers to fee collection (Tukunga., T et al, 2002). • Highest Investment Cost of all technologies adopted in Tonga.
Public and Private Expenditure	• Funding of solar home system (SHS) power supplies, including recent upgrades, have all been provided by various donor grants. Therefore, size and design have not always been able to fully • address the community`s needs and aspirations (Pearson., T and Gavin Pereira., G, 2016). • Public and Private investors are therefore reluctant to invest on supplying spare parts after the installation of donor funding SHS projects. • Transferring ownership of the existing PV system to the users must be negotiated together with the transfer of users upfront payment; which is the 20% of the total capital cost to the Renewable Capital Fund (Fifita,S., 1998) • No IPP yet for SHS invest beside from donors and government investment cost.
Social Benefits	
Income	• The high solar insolation and a current fossil fuel dependency of 87% is an obvious indication for its socioeconomic potential (Meier',, N, 2021)

	• Remote households are mainly rely on unstable sources of income like weaving, agriculture, fishing, tourism and remittances, so having more hours of electricity at night will result in more weaving and more income.
Learning	Adoption of a reliable PV technology will depend on access to proper testing facilities, good system design that meets user needs, the application of PV codes and standards for installation and maintenance, consideration of social and cultural impacts, and the promotion of public awareness and understanding (Sefana., O, 2015). • Insufficient knowledge on Regulation of Tariff and Electricity Services.
Health	• The national energy policy framework "Tonga Energy Road Map 2010-2020" outlines the ambitious target to replace half of the diesel-generated electricity with solar and wind energy until 2020. • The study further indicates that solar will contribute slightly more than half of the needed RE production, which equals an amount of 14,5 MW installed solar capacity (Meier', N, 2021). • Higher % of RE production in the grid is supportive for health
Environmental Benefits	
Gender	• The technical feasibility would analyze the site-specific conditions to determine whether such system can be installed considering the different technical aspects such as solar irradiance, size availability, panel size, tracking systems, water table depth etc. • Cultural values of using SHS is important especially the activities that women and men are willing to use SHS for; and the amount of time they need to use SHS for their interests.
Air Pollution	• Successful project design, installation and operation of off-grid PV system in Tonga and Indonesia should consider the economic, environmental, institutional and technical aspects of project sustainability (Outhred., H. et al, 2004). • Using 100% RE such as SHS for lighting would reflect no pollution in the production of electricity in the remote islands. • IPCC (2010) summarizes literature that indicates that solar PV has a very low lifecycle cost of pollution per kilowatt-hour (compared to other technologies).
Local Context	
Opportunities and Barriers	• There is urgent need for an adoption of accessibility to sufficient regulation tools such a comprehensive Tonga solar rural electrification policy (TSREP) statement and guidelines by the government of Tonga (Fifita. S., 1998) • PV system off-grid technology in developing countries have identified problems such as system designs poorly matched to user needs (Outhred., H. et al, 2004).

	• Sufficient investment, reliable technology, and a proper institutional framework operating under a suitable legal and policy framework, are all required (Tukunga., T et al, 2002). • Adoption of a reliable PV technology will depend on access to proper testing facilities, good system design that meets user needs, the application of PV codes and standards for installation and maintenance, consideration of social and cultural impacts, and the promotion of public awareness and understanding (Tukunga., T et al, 2002) • Accessibility: Fiscal and Financial Barriers At the top of the list of barriers must be those relating to the relative cost of renewable energy, (Johnston., P, 2005). • Physical Barriers Rural population is dispersed over many islands separated by long distances. Most of the renewable energy activity to date has been on outer islands (Johnston., P, 2005). • Market Barriers Accessibility to rural sites. The cost of access to rural islands is high making maintenance, spare parts provision and project support difficult and expensive(Johnston., P, 2005). • Informational and Public Awareness Barriers Lack of information about renewable energy and energy efficiency at all levels. Johnston., P, 2005). • Availability: Legislative, Regulatory and Policy Barriers. There is no energy policy defining the role of the EPU or the place of renewable energy in Tonga. No definition as to who regulates PV (Johnston., P, 2005). • Technical Barriers As with most PICs, electrical and mechanical equipment is at risk due to the tropical, marine environment. Solar PV, wind, biofuels and possibly biogas are the technologies most likely to be used in Tonga and all are mature technologies. c(Johnston., P, 2005); • Institutional Barriers i.e.; Lack of technical and management capacity in the outer islands.; (Johnston., P, 2005) • Sufficient investment should cover both the hardware and software aspects of PV technology. PV investment must be framed by an appropriate business model and directly support the socio-economic activities of the recipient community (Tukunga., T et al, 2002)
Market Potential	• Sufficient investment should cover both the hardware and software aspects of PV technology. PV investment must be

	framed by an appropriate business model and directly support the socio-economic activities of the recipient community (Tukunga., T et al, 2002). • Sufficient investment, reliable technology, and a proper institutional framework operating under a suitable legal and policy framework, are all required (Tukunga., T et al, 2002). • The IEA (2010) forecasts an average annual market growth rate of 17% in the next decade, leading to a global cumulative installed PV power capacity of 200 GW by 2020 and 3000GW by 2040 (with repowering of older systems).
National Status of Technology	• In view of financial barriers for financing key support activities in the islands ,the 20% upfront cost should be used to finance the EPU's training and advisory services and could also be used to set up a credit fund for the expansion of the program (Fifita,S., 1998) • Solar PV market has experienced rapid expansion, with an average annual growth rate of 40% (IEA, 2010) • Maintenance and availability of spare parts are key issue and inability to change electricity tariff reflected the domination of electricity users during key decision making
Timeframe	• Short to Long Term
Acceptability to Local Stakeholders	• The sustainability of the institutional framework will be determined by the effectiveness of the processes of governance indicating that these must involve stakeholder participation in policy formulation and decision-making (Tukunga., T et al, 2002).

FACTSHEET 8

<table>
<tr><th colspan="3">TECHNOLOGY FACTSHEET – 8
On-Grid Solar Electricity</th></tr>
<tr><td colspan="3">

- Introduction: The generation of electricity using PV solar technology has advanced significantly through installations of grid- connected solar PV. The International Energy Agency (IEA) ran a number of potential deployment scenarios and projected a contribution from solar PV of 10% by 2050 to the global electricity supply (Arvizu al, 2011). The electricity sector was the second largest consumer of imported petroleum-based products in Tonga. The residential sub-categories, accounted for significant consumption according to recent statistics from the Department of Energy. Grid tied PV systems feed some or all electricity produced into the public grid. Therefore, significant potential exists to develop and install solar farms using PV power systems for integration into the national grid. The output of a PV system mainly depends on the sun light absorb by PV modules or panels. Consequently modules have to be kept clean and unshaded. Another important factor is the PV module temperature; the higher the temperature the lower the output.

- A structural shift is taking place in the Pacific islands, as countries move away from fossil fuels in favor of more climate friendly forms of energy (ADB, 2019), and the main interests are to reduce dependence on fossil fuel and to address climate changes . ADB's approach for the Pacific has three levels: promoting energy efficiency and renewable energy, maximizing access to energy for all, and promoting energy sector reform, capacity building, and effective governance (ADB, 2019). At the moment we have 14 projects worth around $400 million across 11 countries and these projects are mainly grid connected solar power projects that have been implemented at the moment in Tonga and other countries. Moving forward, we're looking to about double that support over the next two years alone. And also helping the Pacific islands moving toward more of a sustainable future (ADB, 2019).

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<tr><td colspan="2">Timeframe</td><td>Short to Long Term</td></tr>
<tr><td colspan="3">Technology Characteristics</td></tr>
<tr><td>Institutional and Organizational Requirements.</td><td colspan="2">

- Photovoltaic (PV) solar technologies allow for the direct conversion of light to electricity are classified into two (2) types – those connected to the traditional power grid (grid-connected applications) and those not connected to the grid (off-grid applications. In Tonga, about 10MW of solar power projects owned by government utility, including some IPP solar projects owned by private companies that are connected to the national grid together with BESS facility. We're moving from a situation where you have a single generation source to having multiple generations of renewable energy (ADB, 2019a).

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- The institutional and organizational requirements for solar PV systems in Tonga are embodied in the mandates of the Tonga Power Limited and private IPP companies.
- Planning and Managing renewable energy production technologies require a good understanding of the variability in the natural phenomena such as clouds, wind and wave (IEA, 2021).
- Accessibility to limited number of weather stations infrastructure to understand significant geographic variability and records can be interrupted by operation disturbances leading to missing data (IEA, 2021).
- Grid-connected PV systems use an inverter to convert electricity from direct current (DC) to alternating current (AC) and the generated electricity is then supplied through the distribution network to consumers.

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<tr><td>Size of Beneficiary Group</td><td>96% of the total Census Population</td></tr>
<tr><td>Operation and Maintenance</td><td>
<table>
<tr><th>Name of Solar Farm</th><th>Location Name of the Island</th><th>Installed Capacity in kW</th><th>Capex in T$</th><th>Opex in T$/kW</th></tr>
<tr><td>Maama Mai</td><td>Tongatapu</td><td>1,300</td><td>10,220,000</td><td>65.38</td></tr>
<tr><td>Mata 'Oe La'a</td><td>Tongatapu</td><td>1,000</td><td>35,400,000</td><td>80.00</td></tr>
<tr><td>Matatoa</td><td>Tongatapu</td><td>2,200</td><td>na</td><td>n/a</td></tr>
<tr><td>Liukava</td><td>Tongatapu</td><td>2,300</td><td>na</td><td>n/a</td></tr>
<tr><td>Masilamea</td><td>Tongatapu</td><td>2,300</td><td>na</td><td>n/a</td></tr>
<tr><td>Fualu</td><td>Tongatapu</td><td>2,300</td><td>na</td><td>n/a</td></tr>
<tr><td>Popua BESS</td><td>Tongatapu</td><td>7.2MW / 5.3MWh</td><td>10,220,000</td><td>37.74</td></tr>
<tr><td>Matatoa BESS</td><td>Tongatapu</td><td>6MW / 24MWh</td><td>na</td><td>29.17</td></tr>
<tr><td>Hahake Solar</td><td>Tongatapu</td><td>6,000</td><td>na</td><td>n/a</td></tr>
<tr><td>La'a Lahi</td><td>Vava'u</td><td>420</td><td>5,900,000</td><td>66.67</td></tr>
<tr><td>TREP bess</td><td>Vava'u</td><td>200</td><td>3,140,000</td><td>75.00</td></tr>
<tr><td>TREP BESS</td><td>Ha'apai</td><td>900kWh</td><td>2,355,000</td><td>55.56</td></tr>
<tr><td>Ha Masani</td><td>'Eua</td><td>550</td><td>1,884,000</td><td>63.64</td></tr>
<tr><td>Huelo</td><td>Éua</td><td>880kWh</td><td>3.140,000</td><td>68.18</td></tr>
</table>
Table y: Cost of Capex and Opex
</td></tr>
<tr><td colspan="2">Capital Costs</td></tr>
<tr><td>Cost to Implement the Technology</td><td>

- In Tonga, TPL estimated the cost of PV to be around T$ 7861/kW without BESS

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	• TPL statistics indicated cost to be around T$ 35400/kW with BESS, including labour and freight of materials to the sites. • The cost of the PV module takes up the largest component of the investment cost (Arvizuet al, 2011). • Globally, the average PV module price dropped from 22USD/W in 1980 to less than 4USD/W in 2009
Additional Cost to Implement the Technology	• The Opex cost per kW is varied from 30-75 TOP$/kW depending on distances of the host island from the capital island. • Local conditions and cost of individual system. components contribute significantly to the localized cost of electricity (Arvizuet al, 2011). • The operating and maintenance costs of PV electricity generation systems were found to be low and in the range of 0.5 and 1.5% annually of the capital investment costs[37] • ADB's main way of supporting is through financing, but they also do a lot of technical assistance. The technical assistance component is very important, and things like making sure the tariffs are adequate, making sure there's reform in the utility if it's required, making sure the acts and the laws are in place before we get to the procurement system (ADB, 2019a).
Development Impacts, and Indirect Benefits	
Reduction of Climate Changes	• The potential of PV electricity could reduce greenhouse gas emissions by 64 kTon of CO_2 equivalent through the replacement of diesel fuel for electricity generation- (GoG, 2015b). • Tonga Power Limited have actively pursue and support the installation of solar PV systems around the country given that supporting policies are in place. In other small island countries, additional sources of energy for electricity generation are encouraged and PV systems are easily acceptable by all stakeholders (GoG, 2015). • Acceptability for public attitude in view of climate change to have Tonga's contribution of 50% share of RE by 2020 (GCF, 2018), but achievement of the target over time is still approximated such as 9% of total generation in 2015 and expected to increase to 13% by 2016 (GCF, 2018). • Availability of energy in the local context or energy security is part of reason for setting NDC target which

	included phase one to have at least 1MW RE in Tongatapu as well as energy production from coconut oil and landfill gas (GCF, 2018). Renewable generated electricity, which doesn't require expensive transportation of diesel over long distances, is a natural fit for the Pacific (ADB, 2019).. Secondly, you see benefits through greenhouse gas reductions (ADB, 2019). • Solar PV systems have significant direct GHG mitigation potential by displacing fossil fuel-based electricity generation plants and reducing the amount of carbon emissions produced through fuel consumption in the sector (GoG, 2015)
Economic Benefits	
Employment	• Job opportunities for technically skilled (tertiary education) people in the fields of installation as well as operation and maintenance • Very low health and environmental risks • Approx. 2.3 MW of grid tied PV systems are under operation in Grenada. Half of the capacity is owned and operated by GRENLEC the other half belongs to residential and commercial customers. Grid tied PV systems cover approx. 1.8 % of Grenada's total electricity demand(GoG, 2015b) • There is positive public attitude for solar energy if more jobs secured in the construction phases of the project.(Sunergie, 2021) .
Investment	• In many ways, the move toward renewable forms of energy plays to the Pacific islands' natural advantage (ADB, 2019). • And secondly, good, cheap renewable energy options allow the Pacific islands to expand the reach of the electricity grid. So you get more people with more electricity in their homes (ADB, 2019). • Most environmental risks and impacts of solar energy will occur during the construction stage, which will largely be site-specific, temporary and localized and can be managed and/or mitigated through implementation of measures identified in the Project's Environmental and

	Social Management Plan (ESMP)(Sunergie, 2021).
Public and Private Expenditures	• The main ones we see in the Pacific are lower costs. So it's much cheaper to generate power using renewable energy than it is using diesel. So that brings down the cost of power for the people in the Pacific islands, which is really important from a social benefit, but also from an economic benefit (ADB, 2019). • Accessibility to solar energy will ensure affordability by using energy less dependency on diesel and associated price fluctuations.(Sunergie, 2021)
Social Benefits	
Income	• The availability and increasing use of renewable energy on island states will improve energy security and tackle climate change, leading ultimately to a more sustainable economic growth in the SIDS(IEA, 2021). • On an international level hardware costs have reduced by more than 80 % in the last 15 years and continue to decrease making PV the cheapest form of electricity generation in some parts of the world (GoG, 2015b) • Increases the risk of social inequality – medium to high income households can bear the upfront cost and enjoy lower electricity costs while low income households will be threatened by high non-fuel costs from the utility (GoG, 2015b).
Learning	• Acceptability of solar energy is realized by its ability to show significant reduction of carbon dioxide and greenhouse gas emissions .(Sunergie, 2021). • Accessibility to RE-SAT or renewable energy satellite analytical platform to support transition to renewable energy would require use weather observations, satellite data products and modelling techniques to enhance and fill in gaps in the weather data record(IEA, 2021)
Health	• Being a country within the tropics Grenada receives a lot of sun. Irradiation ranges between 1750 kWh/m² a in the north west of

	Grenada and 2200 kWh/m² a in the south of the Island as well as Carriacou and Petite Martinique. To put this into perspective irradiation in the Sahara desert is around 2400 kWh/m² a while in most parts of the UK there is less than 1000 kWh/m² a. Consequently, irradiation conditions in Grenada are very good. • However, since most of the populated parts of the island have the grid within reasonable distance • Assuming replacing small scale diesel generators and diesel pumps with PV systems could lead to a greenhouse gas reduction of approx. 1.8 kT31 of CO2 equivalent (GoG, 2015c)
Environmental Benefits	
Gender	• Accessibility to Solar Technology will provide substantial environment and social benefits.(Sunergie, 2021), especially the gender specific of using electricity at homes. The availability of Solar Technology will increase energy security and resilience for Tonga (Sunergie, 2021) , leading to promotion of specific consumption of electricity in the local community level. • Accessibility for Project performance reporting and annual reports will also collect and include gender disaggregated data. To ensure this process, a training for the Implementing Agency will be conducted in collecting sex disaggregated data(ADB, 2019b) • Accessibility for institutional infrastructure support is needed for active participation of women in the solar project sites, including separate sanitation , locks and lighting so appointed contractors for construction will be informed of these requirements(ADB, 2019b). • To ensure women's increase involvement in renewable solar project Accessibility for financial access and control with indicators built into the monitoring and evaluation framework infrastructure to track women's and men's perceptions(ADB, 2019b).

Air Pollution	• RE can be considered environmentally benign - no noise or vibration from the operations(GoG, 2015a) • Proven, mature and reliable technology • Very good scalability • Very low health and environmental risks (GoG, 2015c) • It is quite acceptable the despite emitting less than 1% of global greenhouse gases, SIDS are very vulnerable to the effects of climate change including rising sea levels, seawater infiltration, land erosion and severe storms(IEA, 2021).
Local Context	
Opportunities and Barriers	• It is very expensive to move from just having single diesel generators to having new solar plants, new hydro power plants, new wind farms. So the financing gap is something that is a big barrier (ADBa, 2019)... • The main issues related to PV electricity generation systems are siting and the land requirements for PV plants and solar farms. ♣ Lack of access to transmission lines for large projects far from electric load centers • Generation of electricity by PV systems could vary systematically – during the day, year and based on weather conditions. ♣ The production and decommissioning of solar cells could have environmental impacts. ♣ The legal framework to allow for interconnection to the national grid through power purchase agreement since the local utility (Guyana Power and Light) holds a monopoly on the generation and supply of electricity (GoG, 2015) • The small volumes imported lead to high prices since there is no leverage for negotiations with wholesalers or manufacturers. Additionally, shipping costs are higher with smaller volumes leading to prices 29 Based on UNFCCC “Standardised baseline: Grid emission factor for Grenada” and an electricity generation distribution of 95.7 % in Grenada, 3.9 % in Carriacou and 0.4

	% in Petite Martinique. 61 for small scale systems ranging between 2,500 US$/kW and 3,500 US$/kW. This is 50 % to 80 % more than in some parts of Europe or the United States. • Furthermore, the lack of experience and appropriate financial products increases cost of capital making PV systems less viable. High investment costs and cost of capital result in electricity generation cost (levelized cost of electricity, LCOE) between 0.18 US$/kWh and 0.33 US$/kWh. To put this in perspective the current fuel charge is approx. 0.14 US$/kWh and IRENAs global weighted average LCOE in 2017 was 0.10 US$/kWh (GoG, 2015b) • Limited capacity and expertise in Grenada increasing the risk of malfunctioning systems • New technology for farmers to adapt to • High upfront costs • Batteries have to be replaced every 2 to 10 years depending on battery type and quality (GoG, 2015c)
	• During 2010 Government of Tonga established the Tonga Energy Road Map with the main objective and target to have 50% share of renewable in the total electricity generation by 2020. By now(2023), the share of renewable has reached 13% and up to 20% only. Solar power generation contributed the major share of renewable into the grid. It looks as if some problems are due to technical problems faced by equipment in stalled , but the main one is all related to the capacity of the electricity grid to allow high penetration of renewable energy. • Variable source of energy increasing the demand for storage and/or backup capacities • Limited human capacity and expertise in Grenada increasing the risk of malfunctioning systems • Due to small market size and high cost of capital, system and energy generation costs are still considerably above international average despite very good irradiation
Market Potential	• As national renewable energy target Tonga established its Tonga Energy Road Map *in

	2010 with a target of 50% share of renewable by 2020. • In 2018, ADB's loan and grant portfolio for energy in the Pacific consisted of 14 projects totaling $371 million, with plans to roll out more than $1 billion in energy investments between now and 2021 (ADB, 2019).
National Status of Technology	•
Timeframe	Short to Long Term
Acceptability to Local Stakeholders	• Accessibility for sufficient regulated tools would required review of approved national policies and strategic framework the Tonga National Strategic Development Framework (2015-2025), the National Climate Change Policy (2016), the Second Joint National Action Plan on Climate Change and Disaster Risk Management (JNAP 2), (2018 – 2028), the Tonga Nationally Determined Contribution (NDC) and the Energy Road Map(GCF, 2018)

FACTSHEET 9

<table>
<tr><td colspan="2">TECHNOLOGY FACTSHEET -9
WIND FARM GRID CONNECTED</td></tr>
<tr><td colspan="2">The conversion of the kinetic energy in the wind into electrical power is known as wind energy. There are a number of ways in which this conversion can be done. However after a period of experimentation and development one design has come to dominate the market. This is known as the horizontal axis wind turbine (HAWT) with its archetypal three-bladed rotor.
A large wind turbine primarily consists of a main supporting tower upon which sits a nacelle (the structure containing the mechanical to electrical conversion equipment). Extending from the nacelle is the large rotor (three blades attached to a central hub) that acts to turn a main shaft, which in turn drives a gearbox and subsequently an electrical generator. In addition to this there will be a control system, an emergency brake (to shut down the turbine in the event of a major fault) and various other ancillary systems that act to maintain or monitor the wind turbine.
Modern multi megawatt wind turbines have main towers that are typically 70 to 120 metres high supporting rotors with a similar range of diameters. Inside the tower there is a mechanism that ensures that the nacelle/rotor faces into the wind (i.e. is yawed correctly) to give maximum generation and maintain symmetric loads on the three blades and drive shaft..</td></tr>
<tr><td>Timeframe</td><td>Short to Long Timeframe</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Institutional and Organizational Requirements.</td><td>The technology transfer is not mature, since the transfer of this technology came through donor financial assistances and local private companies are not yet well equipped with resources and capacities to widely involve in technology transfer.</td></tr>
<tr><td>Size of Beneficiary Group</td><td>Power utility grid connected project funded by overseas donors is the only application of technology in Tonga</td></tr>
<tr><td>Operation and Maintenance</td><td>& M costs are related to a limited number of cost components, and include: Insurance, Regular maintenance, Repair, Spare parts, Administration. Based on experiences in Germany, Spain, the UK and Denmark, O&M costs are generally estimated to be around 1,7 to 2,1 c$ per kWh of wind power produced over the total lifetime of a turbine . We recommend for Moldova to use 1,7 c$/kWh.
Even for indirect systems, differences exist in the type of generator that can be used. Older designs tend to be classed as ‘fixed speed’ meaning that the rotor always rotates at the same speed under all wind conditions. For a number of reasons many modern turbines use generators that allow for variable speed generation whereby the rotational speed is optimised to the incoming wind speed and the generator provides output at a range of frequencies. The resulting fluctuations in voltage and frequency are corrected by power electronics in order to provide electricity suitable for export to the grid. The advantages of this approach include reduced harmful torque</td></tr>
</table>

	fluctuations into the gearbox, increased conversion efficiency, the ability to continue operation during a grid disturbance and the ability to provide reactive power. These last two are increasingly being demanded of wind parks by transmission system operators. Further improvements to the level of energy capture are obtained by most modern turbines by changing the angle of the blades. This 'variable pitch' system rotates the blades about their own axes so that for changing wind conditions the optimum efficiency is achieved. The system also acts to control the turbine, angling the blades 'out of the wind' during periods of high wind speed to prevent damage and providing the primary method for disabling the device.
Disadvantages	• In spite of continuing advances in turbine technology, there is an inherent physical limit as to the amount of energy in the wind that can be extracted. A theoretically perfect (yet infeasible to construct) wind turbine could only ever extract 59 percent of the available energy, also known as the Betz limit. Modern turbines reach a conversion efficiency of approximately 50 percent, close to this theoretical limit and very close to the practical limit that is imposed by the drag of the blades
Capital Costs	
Cost to Implement the Technology	• Investment costs are the most significant costs of wind generation. The upfront investment costs, such as the cost of the turbine, foundation, electrical equipment, grid connection, etc, typically make up around three-quarters of the levelised cost of wind generation. • There is some variation between the investment costs reported in our different data sources. • We recommend using an investment cost of $2100 per kW of installed capacity. This cost is Capacity-Weighted Average Investment Cost from IPCC Special Report that was published in June 2011. We use this source because it is a recent estimate of investment costs and is also a reasonable average of different data sources.
Additional Cost to Implement the Technology	• All spare parts and maintenance cost and repairing must be relying on supply and skills from overseas
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• Assuming that the next 20 years will be installed 550 MW wind power, by 2030 CO_2 emissions will be reduced by 834,8·103 t annually • Cost of GHG reduction is 69,2 USD /tCO_2
Economic Benefits	
Employment	• Increased energy security. Lack of own natural fossil fuel reserves is obliging the country to import 95 % of energy resources needed. 70 % of electricity demand is covered by import. All natural gas is coming from GAZP
Investment	

Public and Private Expenditures	• Very limited investment on wind power business
Social Benefits	
Income	• Reduce unemployment. Will be created about 220 new jobs [7] (Operations & maintenance & other direct employment).
Learning	• Need more capacity building and knowledges about wind power
Health	• Support health and improve air quality
Environmental Benefits	
Gender	• Wind energy has a net positive impact on climate change mitigation (see Reduction in GHG emissions above). In terms of other ecological effects related to the installation, the turbines have a relatively small environmental footprint and are often constructed on agricultural or brown-field sites, which limit their impact on local habitats or ecosystems..
Air Pollution	• Reduce air pollution
Local Context	• Government target to supportive local energy production
Opportunities and Barriers	• To date there have been a large number of studies of the integration of wind energy into electricity networks. IPCC study [6] provides a good summary of the related literature which broadly concludes that at levels of penetration of up to 20 percent of supply the effects of variability and associated costs are relatively low. Thus, for Moldova in the next 5 years installed wind power capacity will be limited to about 250 MW.
Market potential	• The first requirement when considering the possibility for wind energy is the identification of a suitable site that has a high level of resource, i.e. it is windy. More specifically it should be windy at the height above the ground at which the rotor will be situated. The surface friction of the earth's surface, local topology and surface cover means that wind speeds are lower near the ground than they are higher up. Even at good sites there will be many times when a wind turbine is operating below its rated power (its nominal capacity) or producing no power at all because of a lack of wind. This means that although a turbine may be rated at, for example, 2 MW it will produce a certain percentage of the theoretical power it could have produced had it operated continuously. This percentage is the capacity factor. • For onshore wind turbines this capacity factor varies between sites depending on the amount and consistency of the wind. In Europe capacity factors are in the order of 20 to 30 percent, in China on average approximately 23 percent, in India around 20 percent while in the US roughly 30 percent [6]. • Based on measurements made in different locations were calculated annual average wind speeds at 90 m height above the ground. Annual

	average wind speed varies between 6,17 and 7,78 m/s. When using wind turbines designed for Wind Class IEC IIIA we get a capacity factor of 0,3.
National Status of Technology	• Lack of investments
Timeframe	Long Term
Acceptability to Local Stakeholders	Now, in 2020, is the right time to reinvestigate past experiences, present activities**(**Kim .S.A and Kim J.H, 2020) .

6.1.2 : Transport Factsheets

The following factsheets were prepared by consultant and submitted for comments of the overseas consultants and resources personnel of the TNA experts and Project management team.

FACTSHEET 1

TECHNOLOGY FACTSHEET -1 **ENERGY SAVING BY SPEED CONTROL OF MOTOR DRIVE**	
• Introduction: The variable speed control system or an electronic drive can adjust the speed to suit the application not only by adjusting the speed but also torque characteristics of the motor. Since the speed controller is electronic, the energy loss in the controller very much less than that of a mechanical speed controller and also very compact. However, electronic drives should have stable supply for its trouble-free operation. Various manufacturers provide other technologies to achieve fine improvements of motor operation to achieve more energy saving and optimizing the operation.	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	• In Tonga, variable Speed control of motor drive is not allowed, but there are several ESCOs who can provide such solutions, but prefer established organizations in view of regulation policy and institutional support.
Size of Beneficiary Group	• All population of Tonga
Operation and Maintenance	• Variable speed drives are generally programmed to operate automatically.However, involvement of a trained technical personnel or supplier may require in case of a problem.
Disadvantages	• Initial expenses and technology know how that has to be applied to different types of industries..
Capital Costs	
Cost to Implement the Technology	• Cost varies widely with the application from a few thousand to a few million local T$.
Additional Cost to Implement the Technology	• The technology add more cost to the capital cost of the vehicle .
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• It has potential to reduce carbon emission

Economic Benefits	
Employment	• It has capacity to add more employment opportunities to the local labour force
Investment	• Not too many investment
Public and Private Expenditures	• Very little interest add the technology to their vehicles.
Social Benefits	
Income	• It has potential to reduce the amount of fuel for the vehicle
Learning	• Need more interest and capacity to install the technology
Health	Reduce emissions
Environmental Benefits	
Gender	• More safe for driving and especially for ladies.
Air Pollution	As a rule of thumb, reduction of one unit of electrical energy can save nearly twice the equivalent energy of primary energy. If non-renewable energy is used, such technologies can provide higher mitigation effects in energy usage applications compared to renewable energy generating and usage.
Opportunities and Barriers	• Save fuel and safe
Market potential	• Yes it has potential but not fully supported by local drivers
National Status of Technology	• Not widely adopted
Timeframe	Long Term
Acceptability to Local Stakeholders	• Not fully acceptable due to more cost added

FACTSHEET 2

TECHNOLOGY FACTSHEET -2 BATTERY POWERED ELECTRIC VEHICLE (BPEV)	
• Introduction: By design, a battery powered electric vehicle (BPEV) has no fuel tank or internal combustion engine (ICE) but derives all its power for propulsion from chemical energy stored in rechargeable battery packs. Advances in battery technology in particular are addressing qualitative issues such as limited travel ranges.	
Timeframe	• Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	• a functional BPEV has three distinctive components: 1) an energy storage unit; 2) a control unit; and 3) a propulsion unit.
Size of Beneficiary Group	• All population of Tonga
Operation and Maintenance	• The energy storage unit is a high capacity chemical battery pack made from high energy density materials that store and deliver electricity to the vehicle's onboard motor on-demand. The control unit or controller provides intelligent energy management; regulating power and supplying either variable pulse width direct current (DC) or variable frequency and variable amplitude alternating current (AC), depending on the type of onboard motor and driving conditions. The controller also provides a mechanism for charging the batteries during deceleration, and a DC-to-DC converter to recharge the BPEV's 12-volt accessory battery. The propulsion unit comprising an electric motor and integrated power electronics converts electrical energy into mechanical energy that turns a drive axle transmitting full torque to the BPEV wheels.
Disadvantages	• High initial cost Short battery life and high cost of batteries (Kobayashi et al., 2009), even though some recent costs shown online are generally decreasing but some new discovered batteries like Lithium battery is still high in cost • Requires recharging infrastructure analogous to refueling stations (Thomas, 2009) and now there is none in the country
Capital Costs	
Cost to Implement the Technology	• Thiel et al. (2010) report the cost of a BPEV powered by 80kW electric motor at around 35,000 Euro of which 14,400 Euro goes to cover the cost of a 24 volt lithium-ion (Li-ion) battery pack, corresponding to a battery specific cost of 600 Euro/kWh. In the same study, an electric motor costs up to 2,160 Euro, otherwise expressed as electric motor specific costs 27 Euro/kW.
Additional Cost to Implement the Technology	• Perujo and Ciuffo (2010) found that lifecycle costs of BHEV is approximately USD45,000 are considerably higher than comparable BPEV costs, except for some extensive range vehicles using nickel metal hydride (NiMH) batteries.
Development Impacts, Indirect Benefits	

Reduction of vulnerability to Climate Change	• To fix some ideas, the TtW CO_2 abatement derived • for the Subaru Stella electric vehicle with energy consumption of 11.25 kWh/100km is roughly 105gCO_2/km.
Economic Benefits	
Employment	• Electricity generally cheaper than fuel oil
Investment	• Higher energy efficiency compared to an ICE (Kobayashi et al., 2009)
Public and Private Expenditures	• Few components (less maintenance requirements)
Social Benefits	
Income	• Electric car will improve long term income due low operating cost
Learning	• More knowledge and skills on operation and maintenance are needed
Health	• Silent propulsion system (reducing noise pollution from traffic)
Environmental Benefits	
Gender	• Opportunity for all
Air Pollution	• Zero emissions
Opportunities and Barriers	• Fueling Infrastructure • High Quality road
Market potential	• Electricity generally cheaper than fuel oil
National Status of Technology	• High initial cost
Timeframe	Long Term
Acceptability to Local Stakeholders	.acceptable but still high cost

FACTSHEET 3

VEHICLE EMISSION DUTY (VED) or VEHICLE EMISSION PERFORMANCE STANDARD TECHNOLOGY	
• Introduction: It is the intention of this technology intervention to formulate a system (Vehicle Emission Duty - VED) that charges duties on an imported vehicle not by the number of cylinders it has, but by the amount of Carbon Dioxide (CO_2) it emits per unit distance travelled (g CO_2/mile)..	
Timeframe	Short to Long Timeframe
Technology Characteristics	
Institutional and Organizational Requirements.	• The main requirement for this technology transfer (i.e. VED Concept) will be the choice of a reliable and consistent vehicle emission testing protocol. Two systems that can be used are: 1) A laboratory emission testing facility; 2) Portable emissions measurement system. • There is enough in-country capacity to conduct this exercise. Lawyers, Engineers etc. The National Determined Contribution (NDC) for Tonga expresses the need for the development of a domestic transportation policy as part of the National Transportation Plan.
Size of Beneficiary Group	• All population of Tonga
Operation and Maintenance	• A Laboratory Emission Testing facility is a major infrastructure and institutional investment that requires planning and institutional capacity. The cost – benefits has to be closely evaluated. • A portable emissions measurement system (PEMS) is a lightweight 'laboratory' that is used to test and/or assess mobile source emissions (i.e. cars, trucks, buses, construction equipment, generators, trains, cranes, etc.) for the purposes of compliance, regulation, or decision-making [3]. The PEMS technology for emission testing has its advantages and advantages, but the technology is being improved, • The VED proposal will have to investigate these and other vehicle emissions measurement systems and protocols, and make recommendations to the government on the most appropriate systems that can be used to achieve the goals carbon emission reduction in the transport industry and reduce the health risks to country.
Disadvantages	• No disadvantages
Capital Costs	
Cost to Implement the Technology	Total cost is about 100, 000 USD, which include 20 day work per month = 80,000 USD Travel to/from Tonga =4500 USD Contingency 15% =15,500 USD

Additional Cost to Implement the Technology	Total = 100,000 USD
Development Impacts, Indirect Benefits	
Reduction of vulnerability to Climate Change	• The benefits will be a reduction in the transport sector carbon emissions, reduced air pollution and health risks, and a mode of assessing fuel quality
Economic Benefits	
Employment	○ Country will spend less money on fuel , and more on other areas of economic development
Social Benefits	
Health	• More money spend on health care
Environmental Benefits	
Air Pollution	• Lower emissions
Opportunities and Barriers	• Cultural change. Urgent need of a cultural shift as a society to driving smaller, more fuel-efficient vehicles; • lack of political will-power to implement this carbon emission based vehicle duty system if it results in lower revenues
Market potential	• Electricity generally cheaper than fuel oil
National Status of Technology	• High initial cost
Timeframe	Long Term
Acceptability to Local Stakeholders	. Acceptable but not widely adopted

FACTSHEET 4:

<table>
<tr><td colspan="2">TECHNOLOGY FACTSHEET - 4
LPG Vehicle Transport System</td></tr>
<tr><td colspan="2">• Liquefied Petroleum Gas (LPG) is a liquefied mixture of propane and butane. It is an inevitable side product of the crude oil refining process and of natural gas processing. LPG can be used as an alternative fuel in vehicles, and may lead to lower vehicle maintenance costs, lower emissions, and fuel costs savings compared to conventional gasoline and diesel.
• LPG is gaseous at room temperature and a pressurized storage tank is required at the fuelling station as well as in the vehicle. In the vehicle, liquid LPG is converted to vapor in the vehicle's engine. The vapor is then mixed with filtered air before it enters the combustion chamber where it is burned to produce the energy to propel the vehicle. There are also liquid propane injection engines, which do not depend on vaporizing the LPG, but instead burn the liquid fuel (US DOE, 2010).</td></tr>
<tr><td>Timeframe</td><td>Long term implementation Public transport bus technologies</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Institutional and Organizational Requirements</td><td>• LPG can be used in dedicated LPG vehicles or in vehicles converted from gasoline use. The availability of dedicated LPG models is limited, and most LPG powered passenger vehicles have a modified combustion engine. Such converted vehicles normally operate in bi-fuel mode, using either LPG or regular gasoline. The advantage of a bi-fuel vehicle is that the car owner is less dependent on a LPG refueling infrastructure with sufficient coverage. In areas, where LPG is not available, regular gasoline can be used. A drawback of the bi-fuel vehicle is that two fueling tanks need to be available, lowering the available space in the vehicle. Usually, to save space in the trunk of the vehicle LPG tank is located where normally the spare tire is stored.</td></tr>
<tr><td>Size of Beneficiary</td><td>Transport Sector and Vehicle Owners and Drivers</td></tr>
<tr><td>Operation and Maintenance</td><td>• LPG could account for 10% of Europe's passenger car fuel mix by 2020. The most developed LPG market is in South Korea, with more than 2 million LPG vehicles. In 2007, more than 13 million vehicles were powered by LPG worldwide (AEGPL, 2009s).
• were considered at 10% of annual investment costs or $ 315 / year and for the total number of cars these costs amount to $ 154 million.</td></tr>
<tr><td>Disadvantages</td><td>• Lack of a well developed LPG fueling infrastructure.</td></tr>
<tr><td>Cost to Implement the Technology</td><td>• In Europe the purchase cost for an LPG vehicle is estimated to be € 1.500 to € 2.500 higher than for a comparable fossil fuel powered car (Roeterdink et al, 2010). However, fuel costs are considerably lower . At present, the price of LPG in the country</td></tr>
</table>

	is 1.9 times lower than the price of gasoline or diesel oil. Much of this difference in fuel prices is due to lower taxes for LPG. Given the budgetary fiscal policy for 2012 of the Republic of Moldova, LPG will become less attractive, as the final price difference to petrol and diesel was reduced to 1.5 - 1.6 times.
Additional Cost to Implement the Technology	• An additional investment of $ 2.025 thousand (1,500 Euro × 1.35 USD / Euro) was taken into account for calculations for LPG powered car, the total cost of such a vehicle amounting to $ 22,000.
Market Potential	Using LPG may also increase energy security as it diversifies the country's fossil fuel sources.
Development Impacts, Indirect Benefits	
Reduction of Vulnerability to Climate change	• GHG emissions reduction (megatons CO2 equivalent) – 106 thousand tons CO2 in 2030.
Economic Benefits	
Employment	• Lower maintenance costs and a longer engine life-time (the higher octane rating, the
Investment	• The initial infrastructure costs required to expand the sales of LPG in the transport sector, are mainly determined by the investment costs of the LPG refueling infrastructure.
Public and Private Expenditures	• Increasing investment interest if LPG is cheaper than diesel and gasoline.
Social Benefits	
Income	• Investment on LPG vehicle need more data on saving cost of operation
Learning	• Education on operation and maintenance is needed
Health	• Less pollution of atmosphere to support fresh air breathing
Environmental Benefits	
Gender	• LPG vehicle is not gender bias.
Air Pollution	Reducing air pollution and reduce carbon emissions
Opportunities and Barriers	• Lack of a well developed LPG fueling infrastructure. • GHG emissions reduction (megatons CO2 equivalent) – 106 thousand tons CO2 in 2030.
Market Potential	• LPG can be used in dedicated LPG vehicles or in vehicles converted from gasoline use. The availability of dedicated LPG models is limited, and most LPG powered passenger vehicles have a modified combustion engine. Such converted vehicles normally operate in bi-fuel mode, using either LPG or regular gasoline.

National Satus of Technology	• There are also liquid propane injection engines, which do not depend on vaporizing the LPG, but instead burn the liquid fuel (US DOE, 2010).
Acceptability to Local Stakeholders	• the future it is even more important that the government and the private sector work together in informing, managing and controlling traffic flows(Shutterstock , 2015).

FACTSHEET 5

Biofuel Vehicle	
• Introduction: Many countries have prepared their own technical standard on Biofuel like Vietnam National Standards on biofuel, In the year 2007, Ministry of Science and Technology of Vietnam declared voluntary Vietnam National Standard for biodiesel. TCVN 7717: 2007 Biodiesel fuel blend stock (B100) – Specification. This TCVN 7717: 2007 is prepared on the base of ASTM D 6751–06e1 and EN 14214:2003 (Oguma, S., M., and Chollacoop, N. , 2010). To be economically attractive, a biodiesel displacement figure of at least 2% must be targeted. However, the results also show that at this level of displacement, there is the potential for the country to reduce expenditure by between $0.5 and $1.3 Million USD per year for the first 10 years *(Nathaniel., C, 2010)*. As seen from the rich content and journey of biofuel policies and implementation schemes in the selected EAS countries of India, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam, each country has its own unique approach and target (ERIA, 2020)	
Timeframe	
Institutional and Organizational Requirements	• For Malaysia, the effective role of the Ministry of Plantation Industries & Commodities (MPIC), together with the Malaysian Palm Oil Board (MPOB), has served as a framework for biodiesel industry development in Malaysia(ERIA, 2020) • Ministry Responsible for Biofuel Resources • Institution responsible for production of biofuel
Size of Beneficiary	Biofuel engine owners
Operation and Maintenance	• The key to the success of renewable energy initiatives in these cases will be to propose solutions that make sense in the context of the country, and which can be proven to be economically viable. In this regard, the production of biodiesel from an existing feedstock is an ideal way forward for renewable energy in Trinidad and Tobago, since it shows that there is potential for reduction in government expenditure while at the same time benefitting the welfare of the country's inhabitants *(Nathaniel., C, 2010)* For Indonesia and Malaysia, biodiesel is more focused than bioethanol due to the large oil palm industry with higher blending ratio (B30) in Indonesia. • For the Philippines, both bioethanol and biodiesel are being mandated as E10 and B2

	by the Philippine Department of Energy (PDOE) with unique feedstock for biodiesel from coconut(ERIA, 2020) • For Thailand, both bioethanol and biodiesel are being promoted as commercial fuels with various blends (E10, E20, E85 and B7, B10, B20) under the cross-subsidy schemes levied from less biofuel blending to subsidising high blending ratios so that retail prices of higher biofuel blending are more attractive. (ERIA, 2020) • For Viet Nam, bioethanol is more focused with nation-wide blending and especially the ban of RON92 gasoline (but RON95 gasoline still available) in 2018, which significantly boosted bioethanol consumption(ERIA, 2020) • Assessment and Identification of Raw Material Resources for production of biofuel • Identification of types of biofuels for production • Source of Funding for the project • Prices for biofuel
Disadvantages	• Data base on existing biomass is dated so the potential for biomass to be used as feedstock is very uncertain. Some feedstock might be available from harvesting senile coconut trees. • Experience elsewhere suggests that such projects are most cost effective where feedstock is available as a waste product from other agricultural or related biomass developments. Existing land use practice is expected to limit options to develop dedicated energy cropping schemes (GOT,2010). • Technology: India has focused more on bioethanol than biodiesel due to its large sugarcane industry, even with second generation cellulosic ethanol under the PM-JIVAN scheme. While 10% bioethanol blend (E10) is sold by various retailers, only 50% of gasoline sold in the market is E10 (ERIA, 2020)

Cost to Implement the Technology	• Experiences in the region show a niche for vegetable oil, especially coconut oil, fuel blends with diesel or kerosene, in certain cases, but will lead to additional maintenance and repair cost. Vegetable oil fuel that respects quality standards such as DIN 51 605 can be used in blends in indirect injection engines only (Cloin, J, Woodruff., A., and Fürstenwerth, D., 2007). • Unit costs will be affected strongly by material handling and transport to a plant. This option can supply energy as needed to meet electric system needs at all times (GOT,2010). Similar to the CNO option. Cannot be considered without a CNO plant (GOT,2010). • Modification of engines can lead to high up-front cost for a car or generator, however the additional repair cost of not following standards, suitable types of engines and operational characteristics are significantly higher over the life cycle of the engine (Cloin, J, Woodruff., A., and Fürstenwerth, D., 2007).
Additional Cost to Implement the Technology	• Low energy costs if the gasifier is located close to the CNO plant. These gasifiers can supply energy to meet electric system needs. • Annual yield linked to the CNO project size and would be between 917,000kW-h at the POC plant and 5,506,000kW-h at the full scale plant (GOT,2010) • There is considerable potential for using existing biomass for either direct combustion in a steamturbine-generator or in gasifiers where combustible gas is generated and subsequently burned in a gas engine generator)(GOT,2010)
Market Potential	• According to a report prepared by Mr. Dinesh Aggarwal for the Japan-Caribbean Climate Change Partnership there are approximately 100 agricultural pumps with capacities between 5 HP to 20 HP. In addition there are areas that are dwellings in the interior that use diesel generators due to the absence of the public grid. In total it seems reasonable to assume that there is a potential for off-grid

	PV systems in the range of 1 MW(GoG, 2015c) • Assuming replacing small scale diesel generators and diesel pumps with PV systems could lead to a greenhouse gas reduction of approx. 1.8 kT31 of CO2 equivalent(GoG, 2015c) • Effective biodiesel promotion mechanism in Indonesia comes from the Palm Plantation Fund, which is collected from fees and export levies from palm oil plantation products or derivatives for biodiesel subsidy to gain market price attractiveness(ERIA, 2020)
Development Impacts, Indirect Benefits	
Reduction of Vulnerability to Climate change	• The production of ethanol following the proposed ANZ Standard (or equivalent) can replace petrol in vehicles up to 10% with no modification and up to 22% with some modifications according to the model and year of production- (Cloin, J, Woodruff., A., and Fürstenwerth, D., 2007)
Economic Benefits	
Employment	• Ethanol produced from sugar cane and starchy crops can partly replace petrol as a fuel. • Potential to add employment
Investment	• and estimate of 40,000 – 50,000 liters of oil is produced per months for biodiesel, indicating that an estimated 70 - 80 tons of copra being used for biodiesel production (Kua., N., 2012).
Public and Private Expenditures	• The cost of 1 liter of oil is K1.50 in Karkar and K1.83 in Madang town. By selling biodiesel within this range is not commercially viable as production cost (including cost of methanol and potassium hydroxide) is yet to be factored in. • The price of biodiesel was set to be around K0.15 less than the cost of landed diesel, which should be around K3.01 (Kua., N., 2012)
Social Benefits	
Income	• PNG Biodiesel of the Kulili Estate produces about 40,000 to 50,000 liters of biodiesel per month. From these production more than

	10,000 liters is used for power generation; about 15,000 liters for powering it cargo and game fishing boats and an estimated 10,000 liters for it trucks other machineries (Kua., N., 2012). • The remaining 15,000 liters are up for sale. The main buyers are the Karkar Local Level Government (LLG) for its vehicles; the Karkar High School and the general public from Karkar and Madang (Kua., N., 2012)
Learning	• SIDS' challenges to development include resource scarcity, locational isolation, and expensive energy imports *(Smit, E.,and Doberstein., B, 2011)* • National Technical Regulation on gasoline, diesel fuel oils and biofuels. Among other requirements, the regulation specified the mandatory properties for: (1) Diesel fuel oils and biodiesel B5 and (2) Biodiesel fuel blend stock (B100) (Oguma, S., M., and Chollacoop, N. , 2010).. Balancing between existing biofuel implementation and emerging electric mobility trends towards sustainable future mobility scenario can be harnessed through careful policy directions (ERIA, 2020. • It is imperative to enhance regional co-operation and information sharing and to establish quality standards on a national level. It is also imperative that guidelines for appropriate production methods are agreed upon, taking into account the total environmental impacts of biofuel production, use and the creation of side products (Cloin, J, Woodruff., A., and Fürstenwerth, D., 2007).
Health	• Target for Cost: to be economically attractive, a biodiesel displacement figure of at least 2% must be targeted. However, the results also show that at this level of displacement, there is the potential for the country to reduce expenditure by between $0.5 and $1.3 Million USD per year for the first 10 years *(Nathaniel., C, 2010)* • Economic advantages of indigenous biofuels include reduction of energy import dependence, increasing economic resilience, an improvement of the balance of trade and support to local farmer prices. It is suggested that not all fossil fuel duties are waived for

	biofuels as the overall impact on the country's finances might be negative, if subsequent losses of agricultural exports are also taken into account. Biofuels are part of the solution to make the Pacific countries' energy supply more renewable and will pave the way for a cleaner environment, creation of jobs and a more resilient economy (Cloin, J, Woodruff., A., and Fürstenwerth, D., 2007)
Environmental Benefits	
Gender	• The results of this study prove the numerous and interconnecting benefits of a biodiesel-based energy system. For example, biodiesel produced on the island of Barbados, using locallygenerated waste cooking oil, created a new local resource, and reduced resource scarcity and, to some extent, reliance on imported petroleum-based diesel *(Smit, E.,and Doberstein., B, 2011)*
Air Pollution	• Reducing greenhouse gas (GHG) emissions in the transport sector is now attracting attention worldwide, especially after the Paris Agreement in 2015. To meet this target, East Asia Summit (EAS) countries have been making great efforts to introduce biofuels on a large scale considering the potential of their resources (ERIA, 2020) • to present experiences lessons learnt from coconut plantation owners in Karkar islands , PNG with specific attention to biodiesel production for power generation and as fuel for transportation. • This is in the context of GHG emission and sustainable energy production and consumption (Kua., N., 2012) • Climate Change : In addition, multiple benefits of biofuel implementation not only lie in reduced fossil fuel imports and reduced tank-to-wheel CO2 emissions, but also value added and demand creation for agriculture products(ERIA, 2020)
Opportunities and Barriers	• The measure includes regulations and incentives for biodiesel production and blends (Oguma, S., M., and Chollacoop, N. , 2010)..

	• The pump price of diesel in Port Moresby in March is K2.98 per liter (Kua., N., 2012) • The incentives provided to the oil blender are the tax exemption and payment exemption to the Oil Fund for B100. In addition, oil blender or oil trader get compensation for the price of biodiesel B100 from the Oil Fund. The Department of Energy Business (DOEB) also sets the retail price for 5% FAME blended diesel oil or so-called B5 high speed diesel oil cheaper than regular high speed diesel oil (B2) by at least 0.70 baht/Litre (Oguma, S., M., and Chollacoop, N. , 2010) • Public Attitude: Create an information pamphlet or poster specifically for staff in order to 1) educate employees how to properly set aside oil for collection and 2) increase awareness of biodiesel in the community. (Smit, E.,and Doberstein., B, 2011) • Finally, it is recommended that sustainable development initiatives, such as a biodiesel energy system, first develop a mandate to define their vision for benefitting the community and the local environment(Smit, E., and Doberstein., B, 2011) • Energy Security: However, these biofuel policies and implementation schemes must be carefully pursued within the context of sustainability, especially during the transition towards electric mobility in the future target *(ERIA, 2020).* • Climate Change : Improving the sustainability profile of any country can be challenging – this is evidenced by the slower than-expected progress observed by most countries and the overall global reluctance to commit to legally binding emissions reduction targets *(Oguma, S., M., and Chollacoop, N. , 2010)* • It is also recommended that SIDS beginning a biodiesel operation apply for funding as a single, small operation then proceed with scaling-up activities effectiveness of the system and how it can address the challenges facing the individual island *(Smit, E.,and Doberstein., B, 2011)*

	• Infrastructure: A case study in Barbados reveals the benefits and challenges of setting up and maintaining a biodiesel energy system.*(Smit, E.,and Doberstein., B, 2011)*
National Satus of Technology	• Most countries in the Pacific region have the resources to produce large amounts of coconut oil based fuels, while the larger countries also have a vast potential for the production of ethanol. 30% of all regional transport fuels could be replaced by biofuels in 2015, if plantations are revived and industries restructured (Cloin, J, Woodruff., A., and Fürstenwerth, D., 2007). • Security of Supply: Infrastructure: The community-based biodiesel is used for agricultural machines in the communities, while commercial biodiesel is used to be blended with normal diesel for selling at fuel service stations.(Oguma, S., M., and Chollacoop, N. , 2010)
Acceptability to Local Stakeholders	• The quality of diesel in Vietnam is regulated by Vietnam National Technical Regulation QCVN 01: 2009/BKHCN and Vietnam national Standards TCVN 5689: 2005 Diesel – Specifications (Oguma, S., M., and Chollacoop, N. , 2010). • Not sufficient technical regulation in Tonga • To maintain its market, PNG Biodiesel sells a liter of biodiesel at a price which is K0.15 (15 toea) less than the landing retailing cost of diesel in Kakar Island and the surrounding Madang Province. The landing prices range from K3.06 to K3.16 per liter. Regulation : • For biodiesel fuel blend stock (B100), Table 49 shows the specification regulated by TCVN 7717: 2007, prepared on the base of ASTM D 6751–06e1 and EN 14214:2003. Table 50 shows the comparison with other biodiesel standard. Table 49 Biodiesel fuel blend stock (B100) (Oguma, S., M., and Chollacoop, N. , 2010). • Reliability: The Estates usage of its own biodiesel for the past 5 or more years saw no apparent problems with the engines. This had consolidated public confidence in biodiesel resulting in an increasing number of

	customers opting to use biodiesel from PNG Biodiesels(Kua., N., 2012)

FACTSHEET 6

ELECTRIC VEHICLE	
Introduction: The existence of charging facilities for electric vehicles needs to be given enough publicity and awareness, with substantial details on who and where to contact regarding the charging business. This electric vehicle charging system should be especially applicable in industrial zones and busy city areas, and passengers should have sufficient information about the charging process and time.	
Timeframe	Easily adopted in Tonga as few electric cars are already used in the country. However, adoption of appropriate RE recharging station is more suitable for this technology transfer
Institutional and Organizational Requirements.	Tonga is one of the small island countries that is experiencing an early starting point with few existing electric cars. • There is still absence of national EV transition policies in the national policy documents and its NDCs.
Size of Beneficiary Group.	Transitioning from petroleum fueled vehicles to EVs is greatly • beneficial for both the island nations and the global community.
Operation and Maintenance	• We recommend more targeted regulations and concrete goal settings; low-carbon infrastructure and regulatory capacity; using collective actions and support
Disadvantages	• Unavailable Infrastructure and Policies: Encouraging purchase of EV's through incentives and infrastructure, and ensuring the electricity grid can manage an increase in electricity use. • Pilot projects such as electric vehicles are ideal for islands currently in the take-off stage to demonstrate how a rapid transition is possible, and help in public acceptance and perception for electric mobility, a considerable hurdle that must be overcome to increase EV uptake(K U. Shah, M., Awojobi, and Zakia S., 2021
Capital Costs	
Cost to Implement the Technology	• 12000 US$ for electric car in China (fleet maintenance.com accessed:2023), but in the charging infrastructure website, the cost in Europe is even down to 9700 USD. (https://www.iea.org/reports/global-ev-outlook-2023/trends-in-charging-infrastructure
Additional Cost to Implement the Technology	• Maintenance Cost/Year is 949USD for electric car compared to 1279 USD for non-electric car (fleet maintenance.com accessed:2023)
Development Impacts, Indirect Benefits	

Reduction of Vulnerability to Climate Change	• The passenger-kilometer efficiency of bus technologies is higher than passenger cars, which is the main reason why public transport can lower the GHG and pollutant emissions of road traffic and reduce the total energy use of oil. • EV fuel cycle emissions based on the UK electricity carbon intensity in 2019 for year one and gradual improvement towards a 2030 target of 100gCO2/kWh and beyond. their occupancy. • Regarding capacity and energy consumption, the e6 is the EV with the greatest level of autonomy ever tested in Ecuador (around 225 km with average energy consumption of 27.28 kWh/100 km) (Díaz-Samaniego .P.J et al, 2019) • In this context, regular use fuel costs for the e6 are around 50% less than those of conventional cars in Ecuador (Díaz-Samaniego .P.J et al, 2019).
Economic Benefits	
Employment	• It will increase human capacity and employment in the country in view of the level of vehicle and market size in Tonga compare to total population. However, it could be of interest in the future to develop the research further to include costs related to homeowners having a fast charging system installed, in addition to considerations for eventual car battery replacement.
Investment	• New jobs for recharging stations and electric vehicle maintenance.
Public and Private Expenditure	• A comprehensive suite of policy actions was adopted by cities to promote electric cars. The Manufacturers have seen fewer barriers in selling in their home markets (Hui., He, et al , 2018) • Incentives remain a key part of driving the private market for electric vehicles. New vehicle registration incentives in mega cities were the major appeal to private consumers (Hui., He, et al , 2018)
Social Benefits	
Income	• National policies incentivizing EVs and then align with long-term goals of achieving decarbonization and help islands transition to new investment and income from new technology.
Learning	• To properly baseline the transportation fuel use in Tonga, it is important to first document the fuel used and trends thereof. Then it is possible to estimate the annual miles travelled and assess what vehicles were doing the travelling (NREL, 2018)
Health	• A faster upscale of EVs on islands will far outweigh climatic benefits, and increase impacts such as reducing air pollution, alleviating congestion, and improving energy security (K U. Shah, M., Awojobi, and Zakia S., 2021.
Environmental Benefits	
Gender	

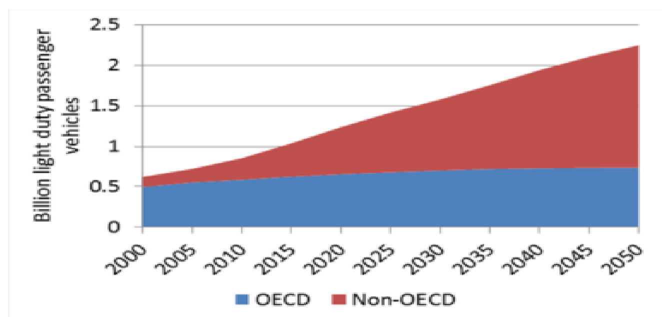
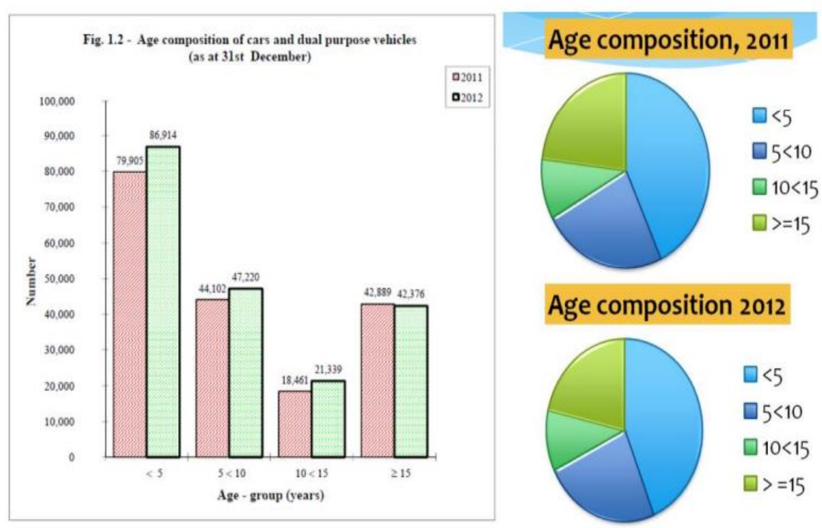
	• SIS are primed to be ideal locations for the first national EV transitions due to their reliance on imported fuels, and gender balance in the electric vehicle industry will allow further development of expertise in the country.
Air Pollution	Environmental – Low GHG emissions and low air pollution – Reduced noise through milder traffic (Jayaweera, 2011).
Local Context	
Opportunities and Barriers	island-specific opportunities in the current revisions of NDCs and sustainable national roadmaps or long-term planning. • Specific targets need to factor in the lack of charging infrastructure, technical support capability and capacity and standards (K U. Shah, M., Awojobi, and Zakia S., 2021.
Market Potential	• SIS have repeatedly stated that they need accessible climate funding for a low-carbon transport transition. Therefore, there is a need for the international climate arenas, such as the UN Climate Action Summit and the United Nations Framework Convention on Climate Change (UNFCC) to significantly support the SIS' sustainable development goals (K U. Shah, M., Awojobi, and Zakia S., 2021)
National Status of Technology	• The BYD e6 has demonstrated to be easily adaptive to the local conditions of Quito, since its characteristics both in performance and running costs satisfy the standards and demands of the local market (Díaz-Samaniego .P.J et al, 2019)
Timeframe	Long Term
Acceptability to Local Stakeholders	• One of the more powerful policy tools driving the electric car market was giving electric vehicle owners privileges in acquiring license plates. Also, EV-based urban micro public transit system were innovated and piloted in cities. A comprehensive package of local policies is key to unlocking the electric car market (Hui., He, Et al , 2018)

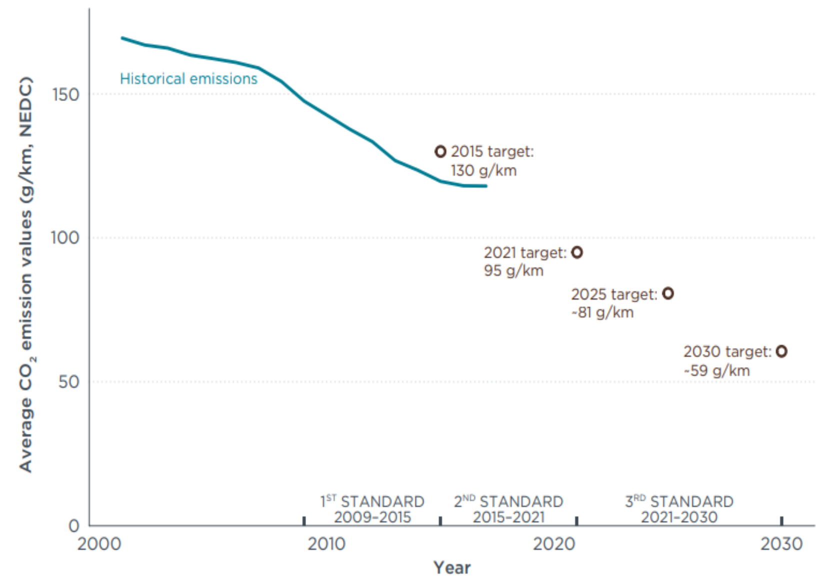
FACTSHEET 7

<table>
<tr><td colspan="2">TECHNOLOGY FACTSHEET - 7
ICT for Vehicle Emission Standard</td></tr>
<tr><td colspan="2">• Introduction: Reducing carbon emissions from the transportation sector is very significant if we want to reduce the overall total carbon emission in Tonga. One way of achieving reduction in carbon emissions is to ensure vehicles are to comply with a vehicle emission standard. For example, fuel efficient vehicles are intended to cover all conventional gasoline vehicles equipped with advanced technologies and presenting advantages of consumption and emissions reduction comparing to similar vehicles within same vehicle class (two-seaters, subcompact, compact, mid-size, full-size, station-wagon).
• These ICT can show that the vehicle was successfully designed to reduce emissions such as
1. A lightweight vehicle design showing low rolling resistance tyres and aerodynamic improvement
2. An Econometer of vehicle showing both the average and instantaneous consumption ; the shift indicator light; and Tyre inflation monitoring system.
3. A gasoline direct injection; Engine downsizing; Engine turbocharging - Variable valve actuation; Cylinder deactivation (for large engine displacements); Exhaust gas recirculation - Fast engine warm-up; Efficient use of auxiliaries (Air Condition system); Idling stop/start
4. Transmission technologies: - Manual transmissions ; Automated manual transmissions; Dual clutch transmissions ; speed automatic transmissions; Continuously variable transmissions(I. Nuez , A. Ruiz-García, and J. Osorio , 2022</td></tr>
<tr><td>Timeframe</td><td>Short to Long Timeframe</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Institutional and Organizational Requirements</td><td>• Users of light vehicles or heavy vehicles like cars should be aware of ICT to indicate low emissions vehicle standard; so that consumers are not risk by missing out on the benefits of zero-emission vehicles if these vehicles are not sufficiently deployed on the market (EU, 2019).</td></tr>
<tr><td>Sise of Beneficiary</td><td>Owner of vehicles equipped with ICT</td></tr>
<tr><td>Operation and Maintenance</td><td>• With the current fuel price trend (~1.2 USD/liter), over 250 USD could be saved per year with mini-, sub-compact and compact cars.
• Note that additional savings are achieved by comparing to the average fuel consumption cost of the whole 2005 Lebanese car fleet, since the average consumption far exceeds the world average of 8.07 l/100km.</td></tr>
<tr><td>Disadvantages</td><td>• Insufficient contribution of light-duty vehicles to increased ambition on GHG emissions reduction</td></tr>
</table>

	• Automotive value chain in the EU risks losing its technological leadership (EU, 2019)
Cost to Implement the Technology	• Cost to implement the technology in Europe has shown and increased in the manufacturing cost of car by €3272 in 2013and €2765 by 2020 and € 2,265 by 2025(EU, 2019)
Additional Cost to Implement the Technology	• Increasing maintenance cost due to more knowledge needed
Market Potential	• Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2019/631 as regards strengthening the CO2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition(EU, 2021). Not yet implemented in Tonga
Development Impacts, Indirect Beenfits	
Reduction of Vulnerability to Climate change	• Reduction of 23-24% of level of carbon emissions compare to vehicle without ICT. • Fuel efficient vehicles are intended to cover all conventional gasoline vehicles equipped with advanced technologies and presenting advantages of consumption and emissions reduction comparing to similar vehicles within same vehicle class (two-seaters, subcompact, compact, mid-size, full-size, station-wagon).
Economic Benefits	
Employment	• New Employment in the vehicle industry
Investment	• New Investment for vehicle manufacturing
Public and Private Expenditures	• It will raise the overall cost of vehicle but will reduce carbon emission by same vehicle
Social benefits	
Income	• Until the end of 2022, vehicles with CO2 emissions below 50 g/km count as more than one car when calculating the average specific CO2 emissions. These 'super-credits' were introduced to encourage investment in new technologies (EU, 2021).
Learning	• A calculation was performed of the CO2 emissions that result from the charging of a reference BEV in the different isolated electrical power systems of the Canary Islands (Spain). The results are then compared with the CO2 emissions of ICVs. • Results show that the Canary electrical power systems that consume the least energy are the most contaminating and that charging a BEV entails higher CO2 emissions than those generated by an ICV (I.Nuez , A. Ruiz-García, and J. Osorio , 2022)

<table>
<tr><td>Health</td><td>Zero-emission vehicles include battery electric or fuel cell vehicles. Low-emission vehicles with tailpipe CO2 emissions of less than 50 g/km (EU, 2021).
Fuel and CO2 savings range from 5 to 50%, depending on the vehicle segment.
A mechanism to take into account the potential contribution of renewable and low carbon fuels for the purpose of target compliance assessment(EU, 2019)</td></tr>
<tr><td colspan="2">Environmental Benefits</td></tr>
<tr><td>Gender</td><td>New car buyers are not informed on vehicle efficiency ratings, fuel economy, emissions ratings, annual operating costs, etc. In addition, though information on power train technologies and transmission technologies are sometimes mentioned, they are not highlighted. Such awareness has direct influence on decision-making while buying a new car; results are observed in the French car fleet where 65% of engines are lower than 1.4 liters.</td></tr>
<tr><td>Air Pollution</td><td>Calculation of CO2 Levy payable (> 150g/km) in Mauritius<table><tr><th>CO_2 Emission Range (g/km)</th><th>Rate (Rs/g/km)</th></tr><tr><td>151-190</td><td>Rs 2000 (U$ 57)</td></tr><tr><td>191-225</td><td>Rs 3000 (U$ 85)</td></tr><tr><td>226-290</td><td>Rs 4000 (U$ 114)</td></tr><tr><td>Over 290</td><td>Rs 5000 (U$ 142)</td></tr></table>Source: (Ally, 2016)</td></tr>
<tr><td colspan="2">Local Context</td></tr>
<tr><td>Opportunities and Barriers</td><td>The CO2 reduction effort is distributed among manufacturers on the basis of the average mass of the vehicle fleet over a certain period. The reference mass for each manufacturer is adjusted every three years before 2025, and every two years with effect from 2025, so that changes in the average test mass and their effect on the positioning of manufacturers on the limit value curve can be taken into account earlier (EU, 2021)
It is estimated that 50000 of pre-owned cars are imported to Lebanon per year. Recently, most of these cars are imported from the US market, characterized by been heavy/luxury cars with engine displacement above 2.0 liters.
Unfortunately that there are no available information on the passive or active systems of fuel efficient vehicles of the Lebanese car fleet, like the share of manual/automatic</td></tr>
</table>

	transmissions. However, it is noticeable particularly from sale of new vehicles that automatic transmissions share the Lion's part. • Inadequate data or information and technical capacity for timely and effective adaptation planning(UNFCCC, 2005)
Market Potential	 Source: IEA Energy Technology Perspectives, 2012
National Status of Technology	Age composition of light duty vehicles in Mauritius  Source: Statistics Mauritius, 2012
Timeframe	

Acceptability to Local Stakeholders	 **Figure 1.** Average historical CO_2 emission values and adopted CO_2 standards for new passenger cars in the EU. All CO_2 values refer to New European Driving Cycle (NEDC) measurements.

FACTSHEET 8

TECHNOLOGY FACTSHEET - 8 ITS For Management of Vehicle Transportation System
• Intelligent Transport Systems (ITS) apply information and communication technologies to vehicles and to transport infrastructure. This may increase the reliability, safety, efficiency and quality of transport systems. ITS has a supporting role for the successful implementation of transport emission reduction strategies such as low-carbon fuels, energy efficient vehicles, public and non-motorized transport, mostly by supporting a more efficient organization of the transport system. • Examples of ITS include electronic road pricing, online travel information, vehicle-to-vehicle communication, computerized traffic signaling and automatic and eco-driver assistance. Automatic driver assistance could for example inform the driver about the ideal speed to pass the next green traffic light, whilst eco-driving systems inform the driver whether he is driving in the most fuel-efficient manner and how he can improve his driving style. • Mobile technologies, Intelligent Transport Systems and Big Data have the potential to provide safer, smarter and greener transport options, improving services and influencing travel behavior (World Bank, 2015) • ESCAP has conducted a study, to understand the combination of technologies, most of which involve information and communications technology (ICT) as a platform, that are embedded within conventional transport infrastructure. These systems are a combination of technologies based on the new capabilities offered by modern ICT systems (ESCAP, 2017).

• The World Bank is collaborating on ICT ideas for simpler, cheaper and easier transport systems in developing countries (World Bank, 2015)	
Timeframe	• Long term implementation Public transport bus technologies implementation could start immediately. The partnerships should have clear start and end dates, set timelines for its deliverables (O., Goransson, M., Vierros, and C., Borrevik ,2019)
Technology Characteristics	
Institutional and Organizational Requirements	• Improving road network management, including road pricing. • Improving road safety, by reducing collisions, casualties and deaths. • Better travel and traveler information, helping to match supply and demand by providing better information so that travelers can make informed choices on when and how to travel. • Better public transport on the roads, supporting more reliable, more accessible, safer and more efficient services. • Supporting the efficiency of the road freight industry. • Reducing negative environmental impacts. • Supporting security, crime reduction and emergency planning measures. • These recommendations focus on leveraging ICTs and knowledge management to overcome the challenges associated with dispersed geography and insularity (ECLAC, 2020) .
Size of Beneficiary	Transport Sector and Vehicle Owners and Drivers
Operation and Maintenance	• It is more energy efficient than passenger cars and conventional buses (per person-kilometer), due to the higher speeds and higher capacity buses. • The Asia-Pacific Information Superhighway initiative74 supported by ESCAP, calls for the deployment of fibre optic cables along major road networks as an option to build a connectivity space in Asia-Pacific (ESCAP, 2015) . • Diversifying ITS services through allocating and improving frequency bandwidth and fibre optics(ESCAP, 2015)
Disadvantages	• High initial investments and chicken-and-egg problem, i.e. decision makers only recognize the need for investments once they experience the benefits of a fully functional ITS system. • Complex implementation process due to roll-out to large numbers of end-users • Technological complexity • Uncertainty regarding costs, benefits and public acceptance • Protection of privacy, security and legal issues • High data requirement for ITS operations

	• In this regard, development of general principles, rules and regulations in consultation with the member countries and sharing of knowledge would contribute to uniform practices across the region (ESCAP, 2017)
Cost to Implement the Technology	• Investments in infrastructure, e.g. toll gantries, traffic detectors, road-side information displays and communication systems • Investments in vehicles, such as on-board electronic meters, GPS systems • Investments in travel time information systems • Policy implementation, including awareness campaigns • Operation and maintenance of the systems • Depending on the required capacity, urban context and complexity of the project, BRT systems can be delivered for 1-15 million USD/km, with most existing BRTs in developing countries in the lower part of this range.
Additional Cost to Implement the Technology	• For many partnerships, there are challenges related to obtaining adequate fnancial resources and securing sufficient human resources capacities (O., Goransson, M., Vierros, and C., Borrevik ,2019)
Market Potential	• Providing information on following area is not yet practiced but some can be implemented such as Advanced Traffic Management System (ATMS) - real-time traffic monitoring and control - provide traffic control information - speed violation vehicle enforcement - Variable Message Signs (VMS) - incident detection/monitoring - traffic facility maintenance/operation/management support - Tunnel Traffic Management System (TTMS) - provide road surface status information -Weather Information System (WIS) • Electronic Toll Collection System (ETCS) - electronic toll collection • Advanced Traveler Information System (ATIS) - provide basic traffic information - provide destination information before leaving - provide traffic information to vehicles on the road - en-route driving guide • Advanced Public Transportation System (APTS) - bus information system (location/arrival notification) - public bus operation management (ESCAP, 2017) infrastructure development should take into account SIDS’ particular contexts, vulnerabilities and needs, as well as international best practices*(Adeoti T et al, 2020)*.
Development Impacts, Indirect Benefits	

Reduction of Vulnerability to Climate change	• UNOPS supports governments in the construction of sustainable, resilient and inclusive infrastructure assets while ensuring carbon emissions are minimized*(Adeoti T et al, 2020)* • The passenger-kilometer efficiency of bus technologies is higher than passenger cars, which is the main reason why public transport can lower the GHG and pollutant emissions of road traffic and reduce the total energy use of oil. • *GHG emissions reduction (megatons CO2 equivalent) – data not available.* • *A recent study has shown that several in-vehicle or infrastructure ICT applications can lead to significant reductions in CO2 emissions (Klunder et al., 2009),*
Economic Benefits	
Employment	• New employment for the control and operation of ITS for safe flow of vehicles
Investment	• The results show that STL can minimize the average waiting times of vehicles at an intersection when two streets are crowded, and the use of social media and drones to detect traffic congestion can increase the reliability and accuracy of the STL (Alsaawy, Y.et al , 2022)
Public and Private Expenditures	• Developing countries may need to cooperate with private-sector partners who already have world-class experience in ITS implementation. One model of collaboration is establishing a testbed region for validating advanced ITS services and technologies(ESCAP, 2015).
Social Benefits	
Income	• Investment on data management could increase income in the transport sector .This open approach to data exchange contributes to better traffic predictions and more efficient traffic management(Shutterstock , 2015)
Learning	• Education on Flexible work environments will be more common and this has implications for residential locations, departure times, and commuting distances. • This could call for a more flexible deployment of the infrastructure and services and a proactive influence on the traffic demand
Health	• ITS must increasingly prioritize passenger safety above traffic flow. Most leading ITS countries are investing on V2X technologies by focusing on commercialization of systems that will help improve road safety (ESCAP,2015)
Environmental Benefits	
Gender	• Infrastructure can also enable equal access to services for women, girls and vulnerable and marginalized groups, helping

	reduce inequalities such as the gender gap in SIDS*(Adeoti T et al, 2020)*.
Air Pollution	• The distinct characteristics of Small Island Developing States (SIDS), including their smallness, geographic remoteness and vulnerability to environmental threats, pose particular challenges to their development *(Adeoti T et al, 2020)* • A key outcome of the SIDS Conference was the establishment of a SIDS Partnership Framework designed to monitor progress of existing, and stimulate the launch of new, genuine and durable partnerships for the sustainable development of SIDS (O., Goransson, M., Vierros, and C., Borrevik ,2019)
Opportunities and Barriers	• Four major barriers in developing the model ITS deployments could be identified: i) lack of priority ranking systems for ITS related project planning and implementation in the member countries, ii) overlap with other transport network plans, iii) differences and possibility of conflicts in technologies and systems in the member countries, and iv) lack of consideration for an ITS based integrated highway network system in the region. • A very large gap exists in financial resources and necessary ITS services among the member countries of the region. It is most important to select the best model of ITS deployment in consideration of the suitability of individual countries (ESCAP, 2017).
Market Potential	• Establish transport service standards including ITS services. - Select a suitable ETCS technology and system according to the country highway management institution, demand and technical level. • The leading-edge technology is not suited for all the countries. • Government should support the ATIS technology development and implementation while the private sector would be responsible for the market development. • Further develop floating car and smartphone applications related to ITS technology. • Disaster prevention and control should be a priority while designing the TTMS. • Traffic safety, disaster prevention and control should be priorities while designing the BTMS (ESCAP, 2017)
National Satus of Technology	• We demonstrated that at each level various technologies can be used for addressing the issues relevant to that level. • We proposed a smart-traffic-light algorithm in level 1 for the efficient management of congestion at intersections, tweet-classification and image-processing algorithms in level 2 for reliable and accurate decision support, and support services at level 4 of the functional model (Alsaawy, Y.et al , 2022)

Acceptability to Local Stakeholders	• ‘Open data’ is a term that is used increasingly. More and more public transport operators and road authorities are sharing their traffic and transport data so that these data can be used by service providers(Shutterstock , 2015) • the future it is even more important that the government and the private sector work together in informing, managing and controlling traffic flows(Shutterstock , 2015).

FACTSHEET 9

Bio-ethanol from sugar and starch based crops[i] /http://climatetechwiki.org/technology/ethanol/

General description

Liquid bio-fuels for transport have to a certain extent been in use for a very long time. In recent years however, they are enjoying renewed interest in both developed and developing countries as a result of the need to curb rising emissions from the transport sector, reduce dependence on increasingly expensive fossil oil imports and increase farm incomes. An important advantage of bio-fuels is that they can easily be integrated into the existing transport infrastructure, thus avoiding the significant investment costs associated with other renewable options for the transport sector. (Source: climatetechwiki.org).

Depending on the feedstock and conversion route, we can distinguish 1st and 2nd generation bio-ethanol. 1st generation bio-ethanol, also known as carbohydrate ethanol, can be produced from sugar or starch based crops. When replacing gasoline in transport, it can lead to substantial reduction in CO2 emission. The main countries producing 1st generation bio-ethanol are the US and Brazil.

Bio-ethanol is mixed with gasoline in proportions varying from 5 to 85%. The lower blends are compatible with conventional gasoline engines. Blends above 10% ethanol content are only suitable for use in modified engines. The least complicated way to produce ethanol is to use biomass that contains so-called six-carbon sugars that can be fermented directly to ethanol. If producing ethanol from starch based crops another processing step is required.

Production of ethanol from sugars starts by grinding up the feedstock to extract the sugar, which is then added to yeast for the fermentation process. In a closed anaerobic chamber, the yeast secretes enzymes that digest the sugar, yielding several products, including lactic acid, hydrogen, carbon dioxide and ethanol (WWI, 2007). The most common feedstock include sugarcane, sugar beets, sweet sorghum and other sugar containing plants.

Producing ethanol from starch-based crops requires another step in the process called saccharification, which entails breaking the large starch molecules into simpler sugars. There are two main methods for refining starches into sugars, primarily differing in the pre-treatment of feedstock. In the “wet milling” process the grains are soaked in water, usually with a sulphurous acid, to separate the starch-rich endosperm from the high-protein germ and high-fiber husks. In addition to ethanol, the process results in a number of high-value co-products, such as grain oil, gluten feed, germ meal, starches, dextrin and sweeteners. (WWI, 2006) The simpler “dry milling process” entails grinding the unprocessed heterogeneous seed into granules. Compared to wet mills, dry mills are less capital intensive and produce fewer co-products. #

Implementation

Production of ethanol through biological fermentation of sugars extracted from sugar and starch crops is a technically mature and commercially available process. Bio-fuels are generally not yet competitive with fossil fuels, therefore many governments around the world offer special incentives for non-fossil based fuels. In Brazil, the successful implementation of ethanol program resulted in bio-ethanol contributing some 50% of fuel consumption in the gasoline market from sugar-cane ethanol (Pelkmans et al., 2009). Similar program is underway and a number of other countries worldwide. Over 50% of global bio-ethanol production is concentrated in the U.S.A.

Implementation of bio-ethanol technologies is part of the commitment of the Republic of Moldova to mitigate emissions in transport sector, one of the measures being to accomplish a 20% share of bio-fuel in conventional fuels mix.

Implementation barriers

- Production of bio-ethanol depends mainly on sufficient provision of economical biomass used as feedstock. The production of 1st generation bio-ethanol is limited by the availability of suitable land and water resources and crop yields.

- The production of bio-ethanol involves moving and storing large amount of feedstock. Therefore a bio-ethanol production plant should be located close to the source of feedstock or in (or very close to) a logistical hub, such as a harbor, if the biomass needs to be imported. - The specific properties of biomass: low energy density, often requiring drying and densification; seasonal availability and problematic storage requiring further pre-treatment.

- Factors limiting the supply: availability and appropriateness of mechanized equipment; and inadequate infrastructure to access conversion facilities and markets.

GHG emissions reduction (megatons CO_2 equivalent) – 175 thousand tons CO_2 in 2030.

Impact on development priorities:

a) Social

- Job creation in the agriculture and forestry sectors, which is particularly relevant for developing countries with significant unused land resources and a large pool of unskilled workers;

- Job creation in the industrial sector (e.g. a 125 million liter ethanol plant would employ cca 270 people (Gnansounou et al., 2005);

- Increasing farm incomes: provided the additional income is distributed equitably, increasing the income in the primary sector, which employs the majority of the workforce, can support rural development and significantly improve living standards;

- Increasing inclusion in the economic system: well-organized farmers unions can gain access to energy markets.

b) Economic

- Increasing energy security by producing and using bio-fuels locally, thus reducing the dependence on imported fossil oil;

- Saving foreign currency by displacing fossil oil imports; - Earning foreign currency by producing bio-fuels for export.

- Diversifying the industrial sector. *c) Environmental*

- GHG emissions reduction: most bio-fuels offer a net GHG savings compared to fossil fuels, unless forest land area is cleared to make way for bio-fuel feedstock plantations. *d) other*

Investments

Depending on the feedstock used and scale of the plant, production costs can differ significantly.

Because of lower average costs, larger plants (of capacity greater than 200 million liters per year) have dominated among new installation. Production costs vary from US$0.31/l to US$0.87/l (IEA Bioenergy, 2009). For a plant with a production capacity of 250 million liters / year investment is $ 53.6 million. *Operation and maintenance costs* are estimated at 0,02 $/liter or, taking into account the plant capacity of 250 million liters/year, of $5.0 million /year.

GHG reduction cost – 334 $/ton CO_2.

Technology lifetime – 50 years.

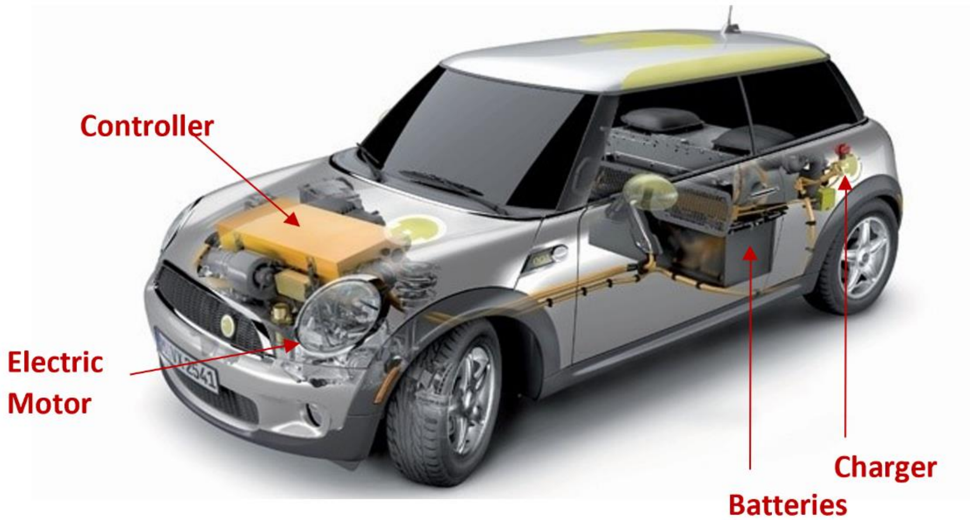
Other
Source: http://climatetechwiki.org/technology/ethanol

FACTSHEET 10

Sector	ENERGY
Subsector	Transport
Technology name	Vehicle Emission Standard
Scale	Medium to large scale
Availability	Short to Medium term
Technology to be included in prioritization	This type of technology is prioritized nationally and has been considered in various transport-related plans. Vehicle emission standards could be implemented locally (for example at the city level), regionally (at the provincial level), nationally (for the whole of Cambodia).
Background/notes	The general goal of a vehicle emission standards program is to reduce emissions and control pollution from motor vehicles in use. A comprehensive strategy may include the following components: stricter emission standards for new vehicles, specifications for clean fuels, proper maintenance of vehicles in use.
Implementation assumptions	It is assumed that air quality problems are related to vehicle emissions, which are the main contributors to pollution in urban area. Private cars, commercial vehicles and motorbikes are the main modes of transportation in Cambodia. In the absence of reliable mass public transport, motor vehicles will continue to be the main contributor of the transport mix in Cambodia in the foreseeable future. The main obstacles to the implementation of vehicle emission standards in Cambodia are: the availability of higher quality fuels (level of lead and sulphur) which are dependent on imports from neighboring countries, the low level of awareness of consumers which may see stricter standards as costly in terms of vehicles to be purchased (newer versus second hand) and cleaner more expensive fuels. In order to maximize current catalyst technologies (which reduce CO, HC and NOx), sulfur concentrations in gasoline need to be limited to 500 ppm. Future technologies may require even lower concentrations of 30-50 ppm such as in Europe, the USA and Japan. It will be necessary to phase in stricter standards year by year and step by step as the average fleet age of vehicle decreases (following the examples of Europe, California, Japan, China etc).
Impact Statements (how this option impacts the country development priorities)	

Country social development priorities	Fuel quality standards should be set not only to reduce GHG emissions but also because they contribute to improved public health and cleaner environment.
Country development priorities	Stricter vehicle emission standards will promote higher efficiency and is a priority of the Cambodian Government
	with regards to energy security, reducing dependency on imported energy. Reduced air pollution will improve public health and improve environmental conditions.
Country environmental development priorities	Vehicle emission standards can help Reduce air pollution; Reduce GHG emissions; Increase energy supply security due to reduction of imported oil.
Other consideration and priorities such as market potential	The RGC recognizes and supports efforts in environmental protection, addressing climate change, and improving efficiency of energy resource use.
Costs (US$)	
Capital costs over 10 years	N/a
Operational costs over 10 years	International studies of costs and fuel indicate opportunities to achieve further fleet fuel economy gains from more stringent standards, even in Europe and the US. Savings potential in Cambodia would be significant due to the old age of the vehicle fleet. However, without regulatory emission standards the market will not necessary adopt cleaner vehicles (hybrid, electric, etc), as buyers may trade economies in fuels for larger and more powerful vehicles. Basing stringency decisions on existing standards elsewhere requires careful consideration of differences between the home market and compared markets in fuel quality and availability; fuel economy testing methods; types and sizes of vehicles sold; road conditions that may affectthe robustness of key technologies; and conditions that may affect the availability of technologies, for example,availability of sophisticated repair facilities.
Other costs over 10 years	N/a

FACTSHEET 11

N. Battery Electric Vehicles [i]	
Sector : Transport	
Subsector : Advanced powertrains for passenger cars	
Technology characteristics	
Introduction	Battery Electric Vehicles (BEV) are propelled by an electric motor (or motors) powered by rechargeable battery packs. They derive all the power from the battery packs and thus have no internal combustion engine, fuel cell, or fuel tank (figure 1).  Figure 1. Battery electric powertrain
Technology characteristics	BEV is a real medium to long-term solution to today's environmental and noise pollution issues in cities. Technological innovations now make it possible to mass market an electric vehicle at reasonable cost. In addition, changes in vehicle use make electric cars ideal for the majority of trips, with 87% of Europeans currently driving less than 60 km a day. **Powertrain** There are three main technical differences between the powertrains of an ICE vehicle and a BEV: · The internal combustion engine is substituted by an electric motor · The electric motor is powered by a controller · The controller in turn is connected to rechargeable batteries, by which it is powered **Battery energy storage** Battery energy capacity depends on vehicle requested mileage before recharging. As an example, the capacity of Renault Fluence Z.E.'s lithium-ion battery is 22kWh for 185 km of autonomy, estimated on the New European Driving Cycle (NEDC). BEV batteries operate as energy storage device rather than power buffers as in conventional HEVs. Hence, BEVs typically require deeper battery charging and discharging cycles than conventional HEVs. Because the number of full cycles influences the battery life, this may be less than in traditional HEVs which do not fully deplete their batteries. However, advanced battery

	technology is under development, particularly Li-Ion technology, promising greater energy densities by both mass and volume, and battery life expectancy is expected to increase.
Operation and maintenance	Maintenance of BEV is simpler and cheaper than conventional thermal vehicles and HEVs. However, special technician trainings are required in order to perform adequate and safe maintenance and repair. BEVs may need a battery change over the vehicle life. Battery costs range between 800 USD/kWh and 1000 USD/kWh. The long term battery costs are expected to be 300-500 USD/kWh by 2015.
Endorsement by experts	· BEVs are endorsed by automotive manufacturers, in order to avoid paying excess emissions penalties.
Advantages	· **Energy efficient**: Electric motors convert 75% of the chemical energy from the batteries to power the wheels, where internal combustion engines only convert 20-30% of the energy stored in gasoline on highway and less than 15% in urban area. · **Environmentally friendly**: BEVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear-, hydro-, solar-, or wind-powered plants causes no air pollutants. · **Performance benefits**: Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than ICEs (estimated by Renault to be half of an equivalent ICE). · **Reduce energy dependence**: Electricity is a domestic energy source. · **Lower operating costs**: though BEVs will cost more than comparable conventional vehicles, operating costs will be less since electricity is much cheaper than gasoline, but it is unclear whether these savings will offset the vehicle cost when BEVs are first introduced. Incentives will play a decisive role in promoting BEVs.
Disadvantages	· **Driving range**: Most BEVs can only go about 160 km before recharging, where gasoline vehicles can go over 500 km before refueling. The low driving range of BEVs is mainly affected by the low specific energy of batteries compared to gasoline. · **Recharge time**: Fully recharging the battery pack can take 4 to 8 hours. Even a "quick charge" to 80% capacity can take 30 min. However, the concept of quickdrop in battery swap stations is under study. · **Battery cost**: The large battery packs are expensive and may need to be replaced. To reduce the cost impact, some automotive manufacturers will be renting the batteries. As an example, Renault Fluence Z.E. will be sold in certain countries at prices similar to those of comparably diesel versions. In France, for example, prices will start at 20900 Euros (5000 Euros tax incentive deducted). Regarding the batteries, customers will have to subscribe to a monthly lease starting from 82 Euros including VAT (assistance included) to cover the battery at a level of 10000km/year. · **Bulk and weight**: Battery packs are heavy and may take up considerable vehicle space. · **Recharging infrastructure**: It is assumed that BEV recharging will take place overnight at home. However, residents of cities, apartments, dormitories, and

	townhouses do not have garages or driveways with available power outlets, and they might be less likely to buy BEVs unless recharging infrastructure is developed. Electrical outlets or charging stations near their places of residence, or in commercial or public parking lots or streets or workplaces are required for these potential users to gain the full advantage of BEVs. However, this infrastructure is not in place today and it will require investments by both the private and public sectors.
Capital costs	
Additional cost to implement mitigation technology, compared to "business as usual"	Additional costs must be considered at two levels: · **Batteries**: current lithium-ion batteries cost around 15000 Euros in BEV prototypes, and are expected to be reduced to 3000 USD by 2020. This requires the battery to be about 200-250 USD/kWh. · **Recharging infrastructure**: in addition to the battery extra costs, there is a need for investment into the recharging infrastructure: − a simple recharging point at a private house or at an office costs about 1800 USD − a public recharging station, with the necessary electronics to make contact with the bank costs about 18000 USD A considerable advantage of BEVs is that the operating costs are considerably lower than the costs of a conventional vehicle. However, it depends strongly on the fuel and electricity prices to decide whether it is worth to invest the additional costs compared to a conventional gasoline powered vehicle.
Development impacts, direct and indirect benefits	
Cost benefits	Figure 2 illustrates the operating cost savings of BEV, HEV and PHEV, compared to the average new vehicle fleet operating cost of 2005. The total vehicle kilometers traveled per year is estimated 10000km, and the electricity tariff 0.15 USD/kWh. · With the current fuel price trend (~1.2 USD/liter), savings of the Nissan Leaf are 600 USD/year, comparing to the average fuel consumption cost of the 2005 world new car fleet. · These savings can reach 750 USD/year with other BEVs presenting better vehicle efficiency. Note that additional savings are achieved by comparing to the average fuel consumption cost of the whole 2005 Lebanese car fleet, since the average consumption far exceeds the 2005 world average of 8.07 l/100km. Figure 3 highlights the influence of electricity tariff increase with a fuel price estimated at 1.2 USD/liter and 10000 km/year. As electricity tariff increases, operating cost saving of BEVs are lowered, and PHEVs and HEVs would become more beneficial. As an example, the plug-in Prius presents better cost savings than the Nissan Leaf as electricity tariff exceeds 0.2 USD/kWh; same for the HEV Prius as electricity tariff exceeds 0.25 USD/kWh.

6.2 Annex 2: List of Stakeholders Attended the Workshop

TNA PROJECT: Mitigation Workgroups MCA Training

Day 1 22nd of August: Participant List

	Name	Organisation
1	Talo Fonua	Tonga Power Limited
2	‘Eliate Laulaupeaalu	Department of Energy (Energy Policy)
3	Fea’ao Lalaki	Tonga Institute of Science and Technology
4	Siale Hola	National Electrical Contractors Association for Tonga (NECAT)
5	Samisoni Tupou	Department of Climate Change
6	Mosese Vaipulu	Tonga Electricity Commission
7	Sam Vea	Tonga Chamber of Commerce and Industries
8	‘Alifeleti Lynch	Department of Customs
9	Malini Teulilo	Tonga Chamber of Commerce and Industries
10	Samiuela Matakaiongo	Department of Energy (Renewable Energy)
11	Tevita Tukunga	TNA Project (Mitigation Consultant)
12	Fine Tui’onetoa	Tonga Power Limited
13	Calvin Maharaj	Spare Parts Zone
14	Daniel Hamala	Consultant
15	Ma’u Leha	Prime Minister’s Office (National Planning)
16	‘Opeti Moala	Department of Energy (Renewable Energy)
17	Mele Lupe McLeod	Department of Energy (Renewable Energy)
18	Beatrice Namoa	Department of Energy (Energy Efficiency)
19	Filimone Fifita	TNA Project (National Coordinator)
20	Na’uli Tufui	Department of Energy (OISES Project)
21	Katalina Laume	Department of Energy (Energy Policy)
22	Sione Misi	Department of Energy (Energy Efficiency)
23	Pesi Henwood	Department of Energy (OIREP Project)
24	Louveve Malolo	MEIDECC
25	Lilly Tano’a	Department of Energy (OISES Project)
26	‘Ofa Takai	Department of Energy (Renewable Energy)
27	Sosefo Tofu	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)
28	Paea Tauaika	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)
29	Solomone Fifita	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)
30	Tapu Fisi’ihoi	MEIDECC

Day 2 23rd of August: Participant List

	Name	Organisation
1	Filimone Fifita	TNA Project (National Coordinator)
2	Maika Leha	ASCO Motors Tonga
3	Calvin Maharaj	Spare Parts Zone
4	Fine Tui’onetoa	Tonga Power Limited

5	Mosese Vaipulu	Tonga Electricity Commission
6	Lupe Fe'iloaki	Prime Minister's Office (National Planning)
7	'Alifeleti Lynch	Department of Customs
8	Sam Vea	Tonga Chamber of Commerce and Industries
9	Sosefo Tofu	Pacific Center for Renewable Energy and Energy Efficiency
10	Siale Hola	National Electrical Contractors Association for Tonga (NECAT)
11	Dan Hamala	Consultant
12	Talo Fonua	Tonga Power Limited
13	Fe'ao Lalaki	Tonga Institute of Science and Technology
14	Samisoni Tupou	Department of Climate Change
15	Tevita Tukunga	TNA Project (Mitigation Consultant)
16	Pesi Henwood	Department of Energy (OIREP Project)
17	Sione Misi	Department of Energy (Energy Efficiency)
18	Eliate Laulaupea'alu	Department of Energy (Energy Policy)
19	Tupou Tevi	Department of Energy (Energy Policy)
20	Toutai Vaea	Department of Energy (OISES Project)
21	Beatrice Namoa	Department of Energy (Energy Efficiency)
22	Opeti Moala	Department of Energy (Renewable Energy)
23	Na'uli Tufui	Department of Energy (OISES Project)
24	Mele Lupe McLeod	Department of Energy (Renewable Energy)
25	Lute Tupou	MEIDECC
26	Katalina Laume	Department of Energy (Energy Policy)
27	Sione Taunsinga	Department of Energy (Acting Director for Energy)
28	Louveve Malolo	MEIDECC
29	Ofa Takai	Department of Energy (Renewable Energy)
30	Paea Tauaika	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)

Day 3 24th of August: Participant List

	Name	Organisation
1	Lupe Fe'iloaki	Prime Minister's Office (National Planning)
2	Alifeleti Lynch	Department of Customs
3	Mosese Vaipulu	Tonga Electricity Commission
4	Fe'aoTeutau	National Electrical Contractors Association for Tonga (NECAT)
5	Calvin Maharaj	Spare Parts Zone
6	Maika Leha	Asco Motors Tonga
7	Sione Misi	Department of Energy (Energy Efficiency)
8	Toutai Vaea	Department of Energy (Renewable Energy)
9	Lute Tupou	MEIDECC
10	Mele Lupe McLeod	Department of Energy (Renewable Energy)
11	Ofa Takai	Department of Energy (Renewable Energy)
12	Louveve Malolo	MEIDECC
13	Sione Tausinga	Department of Energy (Acting Director for Energy)
14	Kipola Sootanga	Department of Energy (Renewable Energy)

15	Samuela Matakaiongo	Department of Energy (Renewable Energy)
16	Filimone Fifita	TNA National Coordinator
17	Pesi Henwood	Department of Energy (OIREP Project)
18	Paea Tauaika	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)
19	Sosefo Tofu	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)
20	Solomone Fifita	Pacific Center for Renewable Energy and Energy Efficiency (PCREEE)
21	Katalina Laume	Department of Energy (Energy Policy)
22	Na'uli Tufui	Department of Energy (Energy Policy)
23	Eliate Laulaupea'alu	Department of Energy (Energy Policy)
24	Fe'ao Lalaki	Tonga Institute of Science and Technology
25	Tevita Tukunga	TNA Project (Mitigation Consultant)
26	Talo Fonua	Tonga Power Limited
27	Vahid Ffita	Department of Energy (Renewable Energy)
28	Samisoni Tupou	Department of Climate Change
29	Beatrice Namoa	Department of Energy (Energy Efficiency)
30	Opeti Moala	Department of Energy (Renewable Energy)

7 ANNEX 3

Table 9: Performance Matrix Energy Technologies

	Performance Matrix- Energy/Electricity																					
		Costs				Benefits												Other				
						Economic				Social				Environmental			Climate related	Institutional/Implementation			Political	
		Cost to install the technology CAPEX	Cost to Operate and maintain the Technology OPEX	Level of beneficiary for the country	Increasing or Decreasing Value of $ to Buy the Technology	Level of Investment in the country	Market Potential and Sufficient framework for Software, Hardware and Orgware	Job creation	Trigger private investment	Income to reduce Poverty reduction potential	Acceptability to Local Stakeholders	Ability to improve Education and Learning	Health Promotion	Level of Reduction of Carbon Emissions	Supporting Gender equality	Reduce Air Pollution	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation and Timeframe	Level opportunities and barriers	replicability and National Status of Technology	Coherence with national development policies and priority	
1	*Solar Powered Roof-Top*	3	3	9	6	9	5	7	7	8	8	5	7	4	1	1	7	7	4	6	4	
2	*Energy Efficient Home Appliances*	3	3	1	5	5	1	3	3	3	3	1	3	5	1	1	3	2	4	5	2	
3	*Solar Water Heater*	2	2	8	3	8	4	8	8	9	9	4	8	8	1	1	8	4	4	3	5	
4	*Efficient Woodstoves*	1	1	7	7	7	6	8	8	4	4	6	8	9	1	9	8	1	4	7	6	
5	*Diesel Solar Wind Power Co-generation*	9	9	1	4	1	3	1	1	1	1	3	1	7	1	8	1	9	4	4	1	
6	*Diesel and Solar Power Co-Generfation*	7	7	1	4	2	2	1	1	1	1	2	1	6	1	7	1	8	4	4	1	
7	*StandAlone Solar Home System*	3	3	4	2	6	3	3	3	3	3	3	3	3	1	1	3	7	4	2	3	
8	*ON-Grid Solar Farm*	3	3	1	1	3	3	1	1	1	1	3	1	1	1	1	1	9	4	1	1	
9	*On-Grid Wind Farm*	8	8	1	1	4	3	1	1	1	1	3	1	2	1	1	1	9	4	1	1	
	Biogas	4	3	4	6	4	4	6	3	4	3	2	4	8	1	6	4	4	4	4	4	
	Scoring scale	0=very high cost --> 100=very low cost				0= Very low --> 100= Very high			0= Very low --> 100= Very high	0= Very low --> 100= Very high						0= Very low --> 100= Very high	0=Very Difficult -->100=Very Easy	0=Very Difficult -->100=Very Easy		0=Very Difficult -->100=Very Easy	0= Very low --> 100= Very high	
	Criterion weight	4	2	3	4	1	3	4	4	4	4	4	3	7	7	6	10	4	5	4	17	100
	Criterion weight, sensitivity	4	2	3	4	1	3	4	4	4	4	4	3	7	7	6	10	4	5	4	17	100

Figure 1: Formulae for MCA

Table 10: Scoring Matrix of Energy/Electricity Technologies

Scoring Matrix- Energy/Electricity

		Costs				Benefits												Other			
		Costs				Economic				Social				Environmental			Climate related	Institutional/Implementation			Political
		Cost to install the technology CAPEX	Cost to Operate and maintain the Technology OPEX	Level of beneficiary for the country	Increasing or Decreasing Value of $ to Buy the Technology	Level of Investment in the country	Market Potential and Sufficient framework for Software, Hardware and Orgware	Job creation	Trigger private investment	Income to reduce Poverty reduction potential	Acceptability to Local Stakeholders	Ability to improve Education and Learning	Health Promotion	Level of Reduction of Carbon Emissions	Supporting Gender equality	Reduce Air Pollution	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation and Timeframe	Level opportunities and Bariiers	replicability and National Status of Technology	Coherence with national development policies and priority
1	*Solar Powered Roof-Top*	75	75	0	37.5	0	50	25	25	12.5	12.5	50	25	62.5	100	100	25	25	62.5	37.5	62.5
2	*Energy Efficient Home Appliances*	75	75	100	50	50	100	75	75	75	75	100	75	50	100	100	75	87.5	62.5	50	87.5
3	*Solar Water Heater*	87.5	87.5	12.5	75	12.5	62.5	12.5	12.5	0	0	62.5	12.5	12.5	100	100	12.5	62.5	62.5	75	50
4	*Efficient Woodstoves*	100	100	25	25	25	37.5	12.5	12.5	62.5	62.5	37.5	12.5	0	100	0	12.5	100	62.5	25	37.5
5	*Diesel Solar Wind Power Co-generation*	0	0	100	62.5	100	75	100	100	100	100	75	100	25	100	12.5	100	0	62.5	62.5	100
6	*Diesel and Solar Power Co-Generfation*	25	25	100	62.5	87.5	87.5	100	100	100	100	87.5	100	37.5	100	25	100	12.5	62.5	62.5	100
7	*StandAlone Solar Home System*	75	75	62.5	87.5	37.5	75	75	75	75	75	75	75	75	100	100	75	25	62.5	87.5	75
8	*ON-Grid Solar Farm*	75	75	100	100	75	75	100	100	100	100	75	100	100	100	100	100	0	62.5	100	100
9	*On-Grid Wind Farm*	12.5	12.5	100	100	62.5	75	100	100	100	100	75	100	87.5	100	100	100	0	62.5	100	100
10	*Biogas*	62.5	75	62.5	37.5	62.5	62.5	37.5	75	62.5	75	87.5	62.5	12.5	100	37.5	62.5	62.5	62.5	62.5	62.5

Table 11: Performance Matrix Transportation Technologies

						Benefits												Other				
		Costs				Economic				Social				Environmental			Climate related	Institutional/Implementation			Political	
		Cost to install the technology CAPEX	Cost to Operate and maintain the Technology OPEX	Level of beneficiary for the country	Increasing or Decreasing Value of $ to Buy the Technology	Level of Investment in the country	Market Potential and Sufficient framework for Software, Hardware and Orgware	Job creation	Trigger private investment	Income to reduce Poverty reduction potential	Acceptability to Local Stakeholders	Ability to improve Education and Learning	Health Promotion	Level of Reduction of Carbon Emissions	Supporting Gender equality	Reduce Air Pollution	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation and Timeframe	Level opportunities and Bariiers	replicability and National Status of Technology	Coherence with national development policies and priority	
1	*Battery Powered Electric Vehicle*	2	2	1	1	3	5	1	1	1	2	2	2	1	1	1	1	4	3	4	1	
2	*Energy Saving Speed Control Motor Drive*	8	8	8	8	7	6	3	3	3	7	4	4	5	1	5	5	5	4	5	7	
3	*Vehicle Emission Technology*	8	8	3	3	7	7	4	4	4	3	5	7	6	1	6	6	1	4	1	2	
4	*LPG Vehcle Transport System*	3	3	4	1	7	7	7	7	7	6	6	6	3	1	3	3	3	4	3	3	
5	*Biofuel Vehicle*	9	9	9	9	8	5	5	5	5	5	7	5	5	1	4	4	9	4	9	8	
6	*On-Grid Electric Vehicle*	1	1	2	1	2	5	2	2	2	3	3	3	1	1	1	1	5	4	5	1	
7	*ICT Foe Vehicle Emission Standard*	3	3	2	2	5	7	7	7	7	8	6	6	6	1	6	6	5	4	5	2	
8	*ITS for Management of Vehicle Transportation System*	4	4	5	5	5	7	6	6	6	8	8	8	7	1	7	7	6	4	6	7	
9	*Biethanol Vehicle*	9	9	9	7	7	7	8	8	8	8	8	9	2	1	7	3	9	4	9	8	
10	*Hybrid Vehicle*	2	2	2	1	1	4	1	1	1	1	1	1	2	1	2	2	2	4	2	2	
11	*Vehicle Emission Standard*	3	3	3	3	3	3	9	9	9	6	3	9	4	1	4	4	1	4	1	2	
	Scoring scale	0=very high cost --> 100=very low cost	0=very high cost --> 100=very low cost			0= Very low --> 100= Very high			0= Very low --> 100= Very high	0= Very low --> 100= Very high						0= Very low --> 100= Very high	0=Very Difficult -->100=Very Easy	0=Very Difficult -->100=Very Easy		0=Very Difficult -->100=Very Easy	0= Very low --> 100= Very high	
	Criterion weight	9	1	1	1	10	1	1	10	1	1	1	1	1	1	15	15	8	1	6	15	100

Table 12: Scoring Matrix of Transport Technologies

		Costs				Benefits												Other			
						Economic				Social				Environmental			Climate related	Institutional/Implementation			Political
		Cost to install the technology CAPEX	Cost to Operate and maintain the Technology OPEX	Level of beneficiary for the country	Increasing or Decreasing Value of $ to Buy the Technology	Level of Investment in the country	Market Potential and Sufficient framework for Software, Hardware and Orgware	Job creation	Trigger private investment	Income to reduce Poverty reduction potential	Acceptability to Local Stakeholders	Ability to improve Education and Learning	Health Promotion	Level of Reduction of Carbon Emissions	Supporting Gender equality	Reduce Air Pollution	Improvement of Resilience to Climate Change (i.e. to what extent the technology will contribute to reduce vulnerability to climate change impacts)	ease of implementation and Timeframe	Level opportunities and Bariiers	replicability and National Status of Technology	Coherence with national development policies and priority
1	***Battery Powered Electric Vehicle***	87.5	87.5	100	100	80	60	100	100	100	90	90	90	100	100	100	100	70	80	70	100
2	***Energy Saving Speed Control Motor Drive***	12.5	12.5	12.5	12.5	40	50	80	80	80	40	70	70	60	100	60	60	60	70	60	40
3	***Vehicle Emission Technology***	12.5	12.5	75	75	40	40	70	70	70	80	60	40	50	100	50	50	100	70	100	90
4	***LPG Vehcle Transport System***	75	75	62.5	100	40	40	40	40	40	50	50	50	80	100	80	80	80	70	80	80
5	***Biofuel Vehicle***	0	0	0	0	30	60	60	60	60	60	40	60	60	100	70	70	20	70	20	30
6	***On-Grid Electric Vehicle***	100	100	87.5	100	87.5	50	87.5	87.5	87.5	75	75	75	100	100	100	100	50	62.5	50	100
7	***ICT Foe Vehicle Emission Standard***	75	75	87.5	87.5	50	25	25	25	25	12.5	37.5	37.5	37.5	100	37.5	37.5	50	62.5	50	87.5
8	***ITS for Management of Vehicle Transportation System***	62.5	62.5	50	50	50	25	37.5	37.5	37.5	12.5	12.5	12.5	25	100	25	25	37.5	62.5	37.5	25
9	***Biethanol Vehicle***	0	0	0	25	25	25	12.5	12.5	12.5	12.5	12.5	0	87.5	100	25	75	0	62.5	0	12.5
10	***Hybrid Vehicle***	87.5	87.5	87.5	100	100	62.5	100	100	100	100	100	100	87.5	100	87.5	87.5	87.5	62.5	87.5	87.5
11	***Vehicle Emission Standard***	75	75	75	75	75	75	0	0	0	37.5	75	0	62.5	100	62.5	62.5	100	62.5	100	87.5
		9	1	1	1	10	1	1	10	1	1	1	1	1	1	15	15	8	1	6	15