Government of Tuvalu

TECHNOLOGY NEEDS ASSESSMENT MITIGATION REPORT

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Ministry of Home Affairs, Climate Change and Environment
Funafuti, Tuvalu

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DISCLAIMER

Acknowledgement

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The report was compiled by the National TNA Consultant under good guidance of the TNA Team and in particular the guideline instructions prepared by UNEP Copenhagen Climate Center and the University of the South Pacific (USP). It has been prepared for the Government of Tuvalu through the Climate Change Department coordination.

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Contents

REPORT I: TNA REPORT (MITIGATION)

Executive Summary

This report outlines consultations with stakeholders to identify technologies that will reduce Tuvalu's GHG emissions and meet its target of zero fossil fuel use for electricity generation by the year 2025. The report consists of the following sections:

1 Introduction

1.1 About the TNA project

The Tuvalu Technology Needs Assessment (TNA) project is implemented through the Tuvalu Third National Communications (TNC) which is funded under the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP).

The TNA processes in Tuvalu are based around three main areas. These are:

a) To identify and prioritise mitigation and adaptation technologies for selected sectors;
b) To identify, analyse and address barriers hindering the arrangement and dissemination of the prioritised technologies, including the enabling framework for technologies;
c) To produce a Technology Action Plan, which can be a medium or long-term plan for the implementation of identified technologies.

Enhancing technology transfer for the mitigation of greenhouse gas emissions (GHG) and adaptation to climate change through the TNA project is fundamental for Tuvalu's reaction to climate change.

The TNA Project is based at the Climate Change Department (CCD) under the Ministry of Finance. The Tuvalu TNA Project consists of the Project Coordinator who is housed in the Climate Change Department along with the Finikaso Consultants Firm who are responsible for the overall implementation of the TNA Project.

The TNA team is the steering committee which includes the Adaptation local expert and the Mitigation local expert. The team works with the Technical Working Group in the selected areas.

The TNA team consulted with relevant in-country stakeholders in the whole process of the project.

1.2 Existing national policies related to technological innovation, adaptation to climate change and development priorities

The table below outlines existing national documents consulted for plans and policies regarding reducing GHG emissions.

Table 1: National Policy Documents Reviewed	
1.	***Intended Nationally Determined Contributions***, Nov 2015, Government of Tuvalu;
2.	***Te Kete -Tuvalu National Strategy for Sustainable Development*** 2021-2030. Government of Tuvalu.
3.	***Tuvalu National Climate Change Policy*** 2020-2030, 2011. Government of Tuvalu
4.	***Tuvalu National Energy Policy*** 2010-2025, 2009; Government of Tuvalu.
5.	***Tuvalu State of Environment Report 2022***, Secretariat of the Pacific Regional Environment Programme (SPREP).
6.	**Tuvalu Integrated Waste Policy and Action Plan:** Towards Cleaner and Healthier Islands 2017-2026
7.	***Second National Communication of Tuvalu to the United Nations Framework Convention on Climate Change*** Dec. 2015., Government of Tuvalu.

1.2.1 Intended Nationally Determined Contributions, Nov 2015

Main points:

a) Reduction of GHGs from the electricity generation (power) sector by 100% by the year 2025.
b) National targeted reduction in total emissions of GHGs from the energy sector of 60% below 2010 levels by 2025.
c) GHG further emission reduction from other key sectors of agriculture and waste.
d) Achieving these targets is conditional on the necessary technology and finance.

1.2.2 Te Kete-Tuvalu National Strategy for Sustainable Development 2021-2030.

Main points:

a) National Outcome 19: Quality and Affordable Energy Supply refers “to affordable and reliable energy sources. Renewable energy supply is a priority consideration, and we will diligently pursue a coherent well-structured energy policy initiative.”

1.2.3 Tuvalu National Climate Change Policy 2020 - 2030.

Main points:

a) Strengthened access to climate finance and strategic partnerships (2 objectives and 7 priority actions).

b) Reduced vulnerability to climate change impacts through enhanced resilience (8 objectives and 26 priority actions); and

c) Managed human mobility and protection of national sovereignty (2 objectives and 7 priority actions).

1.2.4 Tuvalu National Energy Policy 2010-2025.

Main points include:

(a) Energy Sector Planning, Coordination, and Management:

a) Consolidate all energy sector planning, coordination, and management to rationalize decision-making and ensure more reliable and effective energy sector planning, management, and oversight.

b) Establish an Energy Coordinating Committee (ECC) and as required, convene ECC meetings to discuss and provide advice and recommendations to the Department of Energy on major energy sector issues and initiatives.

c) Promote Public Awareness programmes on energy and energy-related issues.

Petroleum:

a) Promote the use of cleaner petroleum products.

b) Reduce dependence on petroleum products by actively encouraging fuel conservation and efficient end-use and by actively searching for, providing, and utilising cost-effective alternatives as appropriate.

Transport:

a) Ensure that sea and land transport sectors promote fuel conservation and efficiency measures.

b) Promote public awareness programmes in the area of good transportation management practices including vehicle tuning and conservation measures.

Electricity:

a) Encourage the use of alternative fuels and renewable energy sources for power generation.

Renewable Energy:

a) Promote and implement the use of appropriate, proven, affordable and cost-effective renewable energy technologies both for urban and rural applications.

b) Establish and maintain a knowledge base for all available and appropriate renewable energy sources and technologies.

c) Ensure Tuvalu's limited biomass, copra biofuel, and other renewable energy resources are used efficiently, in an economically, environmentally, and culturally sustainable manner.

d) Develop local expertise in the installation, operation, management, and maintenance of technically and economically proven renewable energy systems.

e) Develop partnerships with potential foreign and local investors, donors, and agencies in seeking funding sources for the development of renewable energy programmes.

Energy Conservation and Efficiency:

a) Promote energy conservation and efficiency programmes in all sectors of the economy.

b) Promote the use of renewable energy as a means to achieve energy efficiency where attainable.

c) Promote public awareness of conservation and efficiency measures.

d) Promote the use of energy-saving measures including the use of efficient appliances and equipment.

e) Develop an energy efficiency and energy conservation target to assist in realizing the 100% renewable energy target for power generation.

Environment:

a) Promote Environmental Impact Assessment (EIA) in all energy sector development.

b) Ensure that all modes of transportation, specifically land and sea that use fossil fuels have minimum detrimental impact on the environment.

1.2.5 Tuvalu State of Environment Report 2022

a) 467 Gg CO_2-e, 11.214 Gg (61%) can be attributed to the energy sector. The main GHGs emitted by Tuvalu are CO_2 (60.4% of total emissions), CH_4 (16.4%), and N_2O (23.1%) (Figure 13: National CO_2-e emission by direct GHG (%), 2014).

b) The energy sector (including transport as a sub-sector) produces 100% of Tuvalu's CO_2 emissions. CH_4 emissions are largely produced by the waste sector (74.7%), although the agriculture sector also makes a significant contribution (24.7%). N_2O is primarily produced by the agriculture sector (90.7%), with the waste sector producing 8.7%.

c) Tuvalu's electricity generation is predominantly through diesel-fueled generators, which are a major source of Tuvalu's CO_2 emissions. However, since 2012 there has been significant donor-investment in developing renewable energy sources (particularly the development of rooftop solar photovoltaic systems.

d) In 2015 Tuvalu generated 6,353.71 MWh of electricity, 5,553.34 MWh of which (87%) was through diesel generation of which 5,306.06 MWh (84%) was generated in Funafuti. Tuvalu's reliance on diesel fuel for energy generation makes the country vulnerable to fluctuations in the price of diesel on the international market. (SPREP, 2022, p. 84)

1.2.6 Tuvalu Integrated Waste Policy and Action Plan: Towards Cleaner and Healthier Islands 2017-2026

This national policy is a cross-sectoral approach. The timeframe of this Policy is 10 years between 2017 and 2026. The overall purposes of the policy are:

i. waste minimisation,
ii. improved hazardous waste management,
iii. maximisation of socio-economic, health and environmental benefits,
iv. institutional capacity building, and
v. public awareness-raising.

The institutional and organisational structure of the waste sector will be strengthened in all the islands. Legal and policy framework will be developed to enforce waste management regulations, impose levies and ban certain imported items. Public awareness-raising programmes will be carried out on proper waste management, focusing on waste reduction, recycling, and reuse, with a gender-sensitive approach.

i. Incentive mechanisms will be developed to provide business and livelihood opportunities to ensure sustainable waste systems:
ii. The resilience of waste facilities and equipment to climate change will be increased for the protection of the health and well-being of the community and the environment.
iii. The cooperation between the Ministry of Health and the Department of Environment will be strengthened on the handling, storage, and disposal of hazardous wastes.
iv. The monitoring and reporting programmes and data collection mechanisms will be developed to ensure more informed decisions in the waste sector.

1.2.7 Tuvalu Second National Communication 2015

This Second National Communication (SNC) is an update on activities undertaken domestically since the initial communication covers the period from 2000 until 2015. It tends to provide information on the progress made by Tuvalu in implementing the United Nations Framework Convention on Climate Change (UNFCCC). It includes the national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol. In contrast with the initial national communication submitted in 1999, the SNC has achieved considerable progress in documenting Tuvalu's vulnerability assessment, adaptation measures and sectoral analyses of GHG emissions. The SNC consists of five main chapters:

i. National Circumstances
ii. GHG Inventory
iii. Vulnerability and Adaptation Assessment
iv. Mitigation Analysis
v. Other Information including technology transfer, public awareness, capacity building, and data availability and gaps.

1.3 Vulnerability assessments in the country

There are several key documents highlighting Tuvalu's climate vulnerability. These include Vulnerability Assessment Reports of islands in Tuvalu provided by the USP EU Global Climate Change Alliance Project; the Climate Change Department assessment reports on the island's vulnerability; Disaster Department reports on vulnerabilities encountered by islands during cyclone damages and other disasters phenomenon and study conducted by the GCCA.

1.3.1 The USP EU Global Climate Change Alliance Project 2012

This study covers all islands and focuses on Community Vulnerabilities in five sectors;

- Water resources and security.
- Health and Sanitation.
- Energy Resources and Information Communication Technology.
- Food Resources and Security and Natural Resources.
- Natural Resources (Terrestrial, Marine, Freshwater).

Each Sector was thoroughly discussed in groups to indicate the type of vulnerability that is of the most priority, then further identify the problem/s of each vulnerability and the cause of the problem/s. Finally, adaptation solutions were formulated to meet the context of Tuvalu, meaning that they are affordable and easy to implement.

1.3.2 Tuvalu Integrated Vulnerability Assessment 2018

The Tuvalu Integrated Vulnerability Assessment is a key instrument to identify and prepare a nation and its people to the risks posed by climate change and disasters.

The IVA recognises that climate change and non-climate change factors should be assessed in a multi-sectoral vulnerabilities' framework. It focuses the assessment of exposure, sensitivities, and adaptive capacity within a sustainable livelihoods' framework.

The IVA focuses on people's access to natural, infrastructure, human, financial resources to support their livelihood needs and the institutional structures and processes that influence resource access and use.

1.4 Sector selection

1.4.1 Methodology

The process and results of the selection of the TNA sectors for Tuvalu were conducted as follows.

- At the initial stage of the TNA project preparation, the TNA Team (Project Coordinator and Assistant Project Coordinator) convened meetings with the Consultants (Adaptation Consultant and Mitigation Consultant) several times to share a common understanding of the project. At this preparatory stage of meetings, deliberations focused on:
- Terms of Reference (TOR) which clearly defined the works of the Consultant and the processes that are required to achieve the implementation of the TNA project.
- Orientation inception workshop – going through the project objectives, outputs, and other requirements for the project implementation;
- Confirmation of sector's already identified in the project document and highlighted in the TOR of the Consultant;
- Consultant contract arrangement and signing.

As a result of the above deliberation and having gone through the project document and TORs for both Consultants, a mutual agreement for both the Consultants and the TNA Team confirmed that the Sectors for the Mitigation TNA will be focused on the proposed sectors of Energy and Transportation.

The above selection is based on reviewing and analysing appropriate documents that are essential to ensure the facilitation of the TNAs selection for the three sectors. The followings are the national policies, plans and strategies that are used as basis to technologies selection:

- Te Kete – National Strategy for Sustainable Development 2021-2030.
- Te Vaka Fenua o Tuvalu - National Climate Change Policy 2021-2030.
- Second National Communication of Tuvalu to the UNFCCC 2015.
- Tuvalu National Energy Policy 2010 - 2025
- Tuvalu Intended Nationally Determined Contributions 2015.
- Tuvalu State of the Environment Report 2022

In April 2022 a follow-up Inception Workshop was conducted by the TNA Project Team from the Department of Climate Change at the Government Convention Centre (Tomasi Puapua Convention Centre (TPCC)) to initially introduce the Technology Needs Assessment project and for proper awareness of the potential stakeholders in Tuvalu for both the Adaptation and Mitigation Stakeholders. During this workshop feedback was collected from the stakeholders on their collaborative support and availability on the project timeframe and identification of priority TNAs for each sector. All agreed and endorsed the three Sectors (Coastal, Water and Agriculture) as Tuvalu's priority sectors for this assignment.

In May 2022 a follow-up Mitigation Stakeholder Consultation was again convened at the same Government Convention Centre (TPCC) to identify the most priority TNAs for Tuvalu. The consultation objectives included:

- Group discussions to identify key TECHNOLOGY NEEDS under the Transport and Energy sectors.
- TNAs must be consistent with the Tuvalu context.
- Prioritization of the selected technologies.

The methodology used for the consultation comprised of the following steps:

Step 1: Introductory remarks and presentation of the key objectives of the consultation.

Step 2: PowerPoint presentation highlighting the overall overview of the exercise to be conducted. Also presenting some technology examples and definitions to facilitate the deliberation.

Step 3: Group deliberation as the main key of the consultation which includes:

- Identifying the most appropriate technologies under each sector that are most feasible to be implemented in Tuvalu.
- Prioritisation of the technologies by rankings of the technologies with brief description per technology on their relevancy and least relevance for Tuvalu context.

Step 4: Presentation of group works.

1.4.2 Technologies Discussed

The following are the technologies discussed in the consultation with in-country stakeholders.

1.4.2.1 Energy

Solar PVs (TEC/Energy dept); a recommended technology in all national policies; technologies include for solar powered air-conditioning of buildings, including for residences to mitigate the temperature rise; decrease importation of fossil-based fuels; reduction in noise pollution due to electricity generation, and pollution from smoke from power stations.

Solar PV technology is part of Tuvalu's Majuro Declaration to a commitment to implement power generation of 100% renewable energy (between 2013 and 2020). The ambitious proposal is to be implemented using Solar PV (95% of demand) and biodiesel (5% of demand).

In November 2019, the Asian Development Bank (ADB) approved a US$6 million grant to the Government of Tuvalu to fund the production of electricity from renewable energy sources from 15% to 32% in Funafuti and from around 70% to over 90% in Tuvalu's outer islands. Funafuti will receive rooftop solar photovoltaic and battery energy storage systems and the outer islands of Nukufetau, Nukulaelae, and Nui will receive climate-resilient, ground-mounted, solar photovoltaic systems. When the project is complete, 35% of electricity generation during daylight hours will be from renewable energy sources[1].

A new floating solar PV system is also being explored to be connected to the existing electricity grid. It is planned that these systems will be installed in Funafuti, Nukufetau, Nui and Nukulaelae.

As a technology that replaces fossil fuel use in electricity generation, and with ample coverage through implementation strategies, this technology is not explored further in this TNA project.

Wind energy (TEC): Research carried out recommended that because of the very low wind speeds, wind energy is not an economical source at this time, referring to onshore applications for large applications as wind speeds are too low at less than 12 km/hr. for most of the time. Individuals, however, can install smaller units that work in conjunction with solar PV as a system. Energy from wind is not considered further.

Efficiency of imported electrical appliances (TEC/Energy dept); energy efficiency of electrical appliances used as more of the population are using households. The Energy Department has in place a requirement that importers (individuals and businesses) of electrical appliances are required to apply for approval of the appliance(s) before procurement can proceed. The procedure is ongoing; thus, TNA will not pursue this further.

Biogas (Agriculture): reduce CH_4 emission via using animal manure for biogas, for cooking and possibly lighting; use sludge; treatment of animal waste such as from pig pens which also leads to contamination of the water table and left untreated, a source of foul smells, flies and disease.

Human waste is more nutrient-rich than that of pigs and poultry; if this is treated, it becomes the main feed for biogas production, the remaining sludge is more nutrient-rich than other animal waste; it is understood from the early discussions that the World Bank (WB) is projected to finance an infrastructure project that involves upgrading of roads on Funafuti, installation of new electrical mains cables for the TEC electrical grid, install new Tuvalu Telecommunication Corporation (TTC) grid as well as a reticulating system for human waste;

The biogas technology can be either centralised, which will require centralising of the piggery and human waste treatment facility, these treatment facilities are separated,

[1] (source:https://www.adb.org/news/adb-support-new-solar-project-tuvalu)

individual household biogas facilities for those with pig pens, while the human waste treatment is centralised and so on.

In any of the scenarios, the aim is the reduction in contamination to the soil, the water table, the ocean and lagoon marine biodiversity, public health, increase access to renewable cooking gas, decreased import of gas, increased organic matter for household gardening without the use of imported artificial fertiliser, further reducing GHG emissions of nitrogen oxides.

Biogas: food security; improve nutrition; decrease in NCDs: processing of the sludge from biogas production with the addition of green and brown vegetation for composting provides other benefits.

- For composting for individual house gardens (vegetables and fruits)
- Reduce imports of vegetables.
- A source for individuals to become more physically active and reduce NCD incidence.
- Improve nutrition, further reducing NCD incidence.
- Food security
- The biogas technology is further investigated in the section: Prioritisation of selected technologies using multi-criteria analysis.

1.4.2.2 Transport

In-country stakeholders could not identify any suitable mitigation measures for the Transport sector. However, research was done, and the following technologies were recommended to the stakeholders.

Electricity/batteries for motorised vehicles: Use of electricity-charged batteries for motorised vehicles; no GHG emissions, no pollution (although recycling of batteries is required).

Encourage use of bicycles & walking: Walking and cycling; no GHG emissions, decrease in NCDs, decrease national medical bill, increase labour productivity (and therefore increase in economic, social, and environmental output/performances); transportation technologies, including walking and using bikes, affect the physical layout of an area, in particular of urban areas.

1.4.2.3 Other technologies

In-country stakeholders could not identify any other mitigation measures for other sectors. However, research was done, and the following technologies were recommended to the stakeholders.

Buildings- insulation: The 2021 approved Tuvalu National Building Code (TNBC) does not address minimum comfort levels in buildings and therefore insulating buildings to minimise heat transfer into building interiors is left to the owners. Insulation slows down or eliminates heat transfer from the exterior into the interior which reduces the need for active systems requiring electricity or if active systems are used, reduces the energy required to maintain human comfort.

- The use of air-conditioning in government offices, including island Kaupule offices has increased from zero (0) in the early 1980s to 100% by 2022.
- Other government and public facilities have yet to be air conditioned but as temperature continues to rise coupled with the frequency and intensity of droughts, it is envisioned that in a decade or so, these buildings will need mechanical/active environmental control systems. These will include medical patient 'dormitories', school classrooms and dormitories, religious buildings, police stations, meeting halls (Falekaupule) and shops. The recent installations of mechanical fans in these buildings are in much the same development as those of the offices- it began with fans and gradually graduated into active air-conditioning.
- A starting point in the use of air-conditioning is with the arrival in Tuvalu of computers around 1988/1989[2];
- Reduce rise in internal temperature; decrease use of electricity (at present of fossil-fuel based electricity but also when solar PVs are used, which can be used for other uses- lighting, refrigeration, etc.
- Reducing electricity generation to buildings, whether fossil-fuel based or from renewable sources, is increasing the 'efficiency' of the item (building in this case) in the same manner that electrical appliances have efficiency standards.
- While GOT targets 100% electricity transmission by 2025 with renewable energy, building insulation as a means of reducing energy use in buildings was not raised.

Energy efficiency: Buildings- insulation in conjunction with building envelop design A fully compliant insulated building but with poorly designed envelopes will need more energy for interior environmental control than the same fully compliant insulated building but with the envelop adequately designed to minimise heat transfer/intrusion (infiltration/exfiltration).

This combination of technologies is explored in this TNA project in the next section- Prioritization of selected technologies using multi-criteria analysis.

Settlement planning & design: The geography of a settlement evolves as it is being populated- from scattered hamlets to a 'village' encouraged by the missionaries and supported by the colonial government. It led to the construction of

[2] Believed to be an Apple Mac SE40 donated by the Save the Children to the Public Works Department (author's experience).

churches, colonial government offices, school buildings and medical dispensaries. From footpaths to dirt roads to tar-sealed roads; from traditional-bush-material to reinforced concrete and metal roofed houses; from open fire for night light, to kerosene-fueled pressure lanterns to fluorescent lighting and many others. These changes have also led to the change in the geography of villages. In these changes, vegetation of food bearing medicinal plants are continuously eliminated.

1.4.3 Mitigation Technologies available & feasibility to use in Tuvalu

The following is a list of possible technologies for mitigation suggested by the IPCC WGIII AR6 *Mitigation for Climate Change*; Chapter 6- Energy systems; Chapter 10- Transport.

Energy	Transport
1. Solar energy **2.** Bioenergy **3.** Hydropower **4.** Geothermal energy **5.** Nuclear power **6.** Carbon capture & storage (CCS)	1. Fuel efficiency-light duty vehicle 2. Electric light-duty vehicles 3. Shift to public transport 4. Shift to bikes, e-bikes & non-motorized transport. 5. Fuel efficiency-heavy duty vehicle 6. Fuel shift (including electricity)- heavy-duty vehicle. 7. Shipping efficiency, logistics optimization, new fuels. 8. Aviation- energy efficiency, new fuels. 9. Biofuels.
Source: (IPCC WG III, 2021)[3]	Source: (IPCC WGIII, 2021)[4]

1.4.4 Technologies to compliment implementation of energy and transport technologies in mitigation for climate change: Feasibility to use in Tuvalu

Technology	Basic description	Feasible (Yes/No)
Piggery/ Biogas/ Sludge for organic fertiliser	• Individual house systems or community • Single large systems that house a large number of household pigs from the waste, with other additions, are used to generate biogas, the sludge of which is used as organic fertiliser.	Yes
Human waste (solids & wastewater) treatment;	• Human waste is treated for use as organic fertiliser; avoids leaching into ground and contaminating groundwater and leaching into the sea and contamination of seawater. • Wastewater treated for re-use in gardening. • Stormwater water treated for re-use. • Increase in water security as droughts occurrence and intensity increase as part of climate change	Yes
Integration gardening and green development to increase vegetation	• Increased household gardening leads to increased consumption of locally organically fertilised food. • Increase in physical activity of the populace leads to decrease in non-communicable diseases (NCDs); • Increase in food security. • Increase in vegetation leads to more carbon sinks.	Yes

[3] IPCC WG III, 2021. *Chapter 6- Energy Systems*. Geneva: IPCC.
[4] IPCC WGIII, 2021. *Chapter 10 Transport*. Geneva: IPCC.

	• Increase in vegetation leads to better	
Demand for social services (demand for well-being)	• Demand-side mitigation and new ways of providing services can help *avoid*, *shift*, and *improve* final service demand. • Socio-cultural and lifestyle changes can accelerate climate change mitigation; identified actions that could change individual consumption, individual mobility choices have the largest potential to reduce carbon footprints. Prioritising car-free mobility by walking and cycling and adoption of electric mobility could save 2 tCO2eq cap-1 yr-1 (globally); • Demand side mitigations are achieved through changing ***S****ocio-cultural factors*, ***I****nfrastructure use* and ***T****echnology adoption* by various social actors in urban and other settlements, food choice and waste management. • Avoid-Shift-Improve options (ASI) framework. • Requires government policies for behavioural change; digitalization, the sharing economy, and the circular economy	Yes
Urban forms, physical geography	• Modify existing physical transportation infrastructure (roads) to allow for ease and safe use by pedestrians, non-motorized bikes & electrical bikes (e-bikes); • Allow for drainage of human waste. • Zoning	Yes

2 Institutional arrangement for the TNA and the stakeholder involvement

National Institutional Arrangement

Climate Change Policy formulation and implementation is the full responsibility of the Climate Change Department (CCD) in the Ministry of Finance. Generally, the CCD oversees the overall implementation of the policy at both the international, regional, and national levels. At the national level, the CCD is responsible to the National Advisory Committee on Climate Change (NACCC) which is composed of technical members from various Departments/Institutions in the Government as well as from NGOs.

Under the NACCC is the Technical Advisory Committee (TAC) that operates at the Departmental level to oversee all projects that operate under the CCD. This TAC is also involved in this TNA process.

1.1 National TNA team

The main structure of the national institutional setup of the project is managed under the CCD in the Ministry of Finance (MOF). The core team members of the project comprise of the National TNA Coordinator, Assistant Coordinator, National Steering Committee, Consultants (Adaptation/Mitigation), Sector Working Groups and Stakeholders.

1.1.1 National Coordinator

The Climate Change Department with proper supervision of the Ministry of Finance designated Ms. Faatupu Simeti as the TNA Coordinator and is involved in national reporting and coordination of the project. She is the focal point for the overall management and coordination of the TNA process. Also responsible for facilitating and managing the project, and communicating with national consultants, sectoral working groups, stakeholders, regional agencies and UDP.

1.1.2 Assistant Coordinator

Main role is to assist the TNA Coordinator in the overall implementation, administrative tasks, facilitation of tasks that may be required from time to time by consultants and assist Consultants on any requirement may be requested by the consultants.

1.1.3 National Steering Committee

The national steering committee is fundamental in providing guidance to the project. It provides high level and maximum guidance to the national TNA team and is responsible for policy making. Its role includes providing guidance to the national team and assisting in securing political acceptance for the TAP. It consists of members from relevant ministries, private sector, and other key stakeholders.

Under this TNA preparation, the steering committee is labelled as the Technical Advisory Committee (TAC) for the TNA is established as a subcommittee under the National Advisory Committee on Climate Change (NACCC). There are two primary role(s) of the TAC which include:

- Providing technical assistance and guidance on the development of the TNA report, updating, and adding the relevant information that may be required to facilitate the diffusion of the technologies to the country.
- Provide technical assistance and guidance in prioritising the technologies and identifying barriers, development of Technology Action Plans and concept notes to attract funding.

This TAC will work closely with other project management units in order to achieve its primary roles. Composition of the TAC can be obtained from the Climate Change Department.

1.1.4 National Consultants

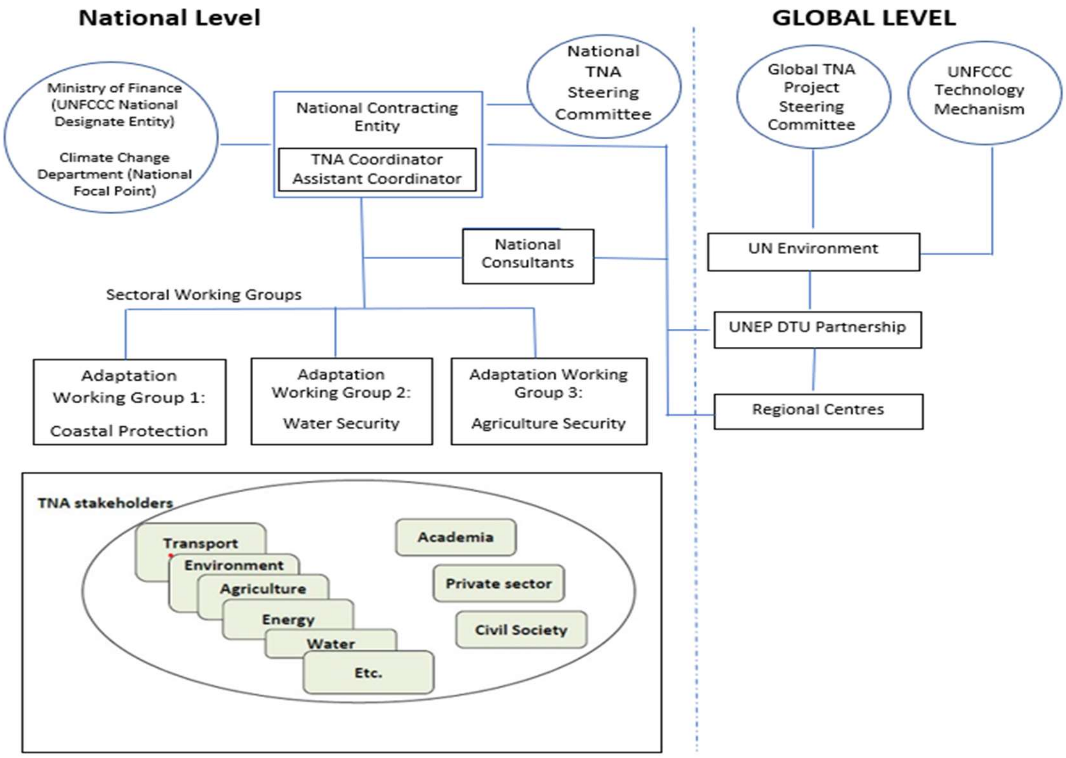
Mr. Mataio Tekinene as TNA adaptation expert, and Mr. Lomiata Niuatui was recruited initially as the mitigation expert, but resigned mid-2023, whereas the Assistant Coordinator picked up the workload of the Mitigation Expert. The adaptation and mitigation experts are responsible for consulting relevant stakeholders; identifying and prioritising technologies for specific sectors under good guidance of stakeholders; leading the analysis process with stakeholders and sector working groups; participating in capacity-building workshops; working with the national coordinator and assistant coordinator, sector working groups, and stakeholders; and preparing the TNA, BAEF and TAP reports.

1.1.5 Sector working groups.

The Climate Change Department, on the suggestion of the co-coordinators and national consultants and in line with UDP guidelines for the project, established two working groups on the mitigation technologies for the transport and waste sectors, and two working groups on adaptation technologies for Coastal Protection, Agriculture and Water Security. The composition of the sectoral working group includes representatives from government ministries, private sector, academia, the area of climate change and civil society.

1.1.6 Stakeholders

Stakeholders include representatives of the government ministries, private sector, academia, climate change experts and civil society.



1.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

1.2.1 Initial Engagement and Stakeholder Consultation

Initially, the Consultant for the TNA Adaptation was awarded a contract in June 2021, followed on by participating in the TNA online workshop facilitated by collaborating partners including the UN Environment Programme and DTU (UNEP DTU), Asian Institute of Technology (AIT) and the University of the South Pacific (USP). The main purpose of the workshop is to provide an overall overview of the TNA project and its implementation processes and stages. These technical and academic institutions will aid, and facilitation roles as may be required from time to time.

At the national level in April 2022, an inception workshop was conducted with key stakeholders to familiarise them with the project and to confirm their support and availability for the project. It is an opportunity as well as the first step to discuss the project at the national level context. Sector selection and identification of some potential technologies are the highlights of the discussion. Then a timetable including interviews, desktop research, and further consultations of target groups was drawn up and confirmed as a starting point for implementation.

Follow-up interviews through face-to-face and emails sharing were conducted by the Consultant by approaching firstly the Energy Sector stakeholders including the Energy Department, Pacific Energy, TEC, Kaupule of Funafuti, and the Department of Transport for the Transport Sector.

In May 2022, a follow-up consultation with the Mitigation Working Group Stakeholders was convened at the TPCC to identify and prioritise the most appropriate technologies that are viable, affordable, robust, and meet the needs of the people at the national level.

1.1.1 Stakeholder Analysis

The intention was to involve as broad a cross-section of the stakeholder group as possible. The following table illustrates the initial consideration of which stakeholders would be consulted in the development of the long list of technologies, while taking into accounts the prioritised sectors.

Sector	Institution/Organization	Relevance
Government/ Public	Climate Change Department	**High**. The lead department of the project.
	Department of Environment	**High**. Provide appropriate information on environmental aspects to a certain extent.
	Department of Waste and Management	**High**. Provide necessary information on waste risk or pollution.
	Planning, Budget, and Aid Coordination Department	**High.** Provide necessary data on funds and assist on financial advice.
	Department of Local Government	**High**. Provide local data from the community level.
	Department of Marine and Transport	**High**. Advise and provide most appropriate technologies in Marine and Land Transport
	Department of Energy	**High**. Essential energy data required and advice.
	Tuvalu Revenue and Customs Department	**High**. Provide data and advise with customs clearances.
	Gender Affairs Department	**High**. Gender is key to any project as they categorised vulnerable groups.
	Department of Disaster Management	High. Given the impact of climate change in Tuvalu, DDM will provide assistance and required information.
	Funafuti Kaupule	**High**. Act on behalf of the indigenous people.
NGOs/Civil Society	Tuvalu Climate Action Network (TUCAN)	**High.** Its roles in climate change are relevant in the TNA process.
	Tuvalu National Council of Women	**High**. Representing the nation on behalf of women, the vulnerable group.
	Fuligafou Group (Youth group)	**High**. Representing the youth group and their involvement in the TNA MCA is vital.
Academia	University of the South Pacific	**High**. The only academic regional centre that provides necessary information on academic issues.

1.2 Consideration of Gender Aspects in the TNA Process:

Gender mainstreaming in policies, plans and workplaces is a required practice for all Ministries and Departments in the Government. This applies as well to NGOs and civil society. The Gender Affairs Department has its own Gender Policy.

In the TNA process, we must ensure that the perspectives of both men and women are given equal opportunities and consideration during the engagement and prioritisation process. During the wider inception workshop in April 2022, there were 8 females and 13 males attending the consultation. However, the opportunity of deliberation was equally shared. In a follow-up workshop of identifying technologies in May 2022, both females and males from the three sectors are allowed to facilitate their group discussions as well as present the results of their group work. Gender considerations will be maintained as an important part of the design and implementation of the selected technologies, throughout implementation.

3 Technology Prioritisation for the Energy Sector.

1.1 GHG Emissions and Existing Technologies for the Energy Sector:

Technology	GHG Emission Reduction Potential	Feasible (Yes/No)
Solar energy	• Solar panels emit around **50** g CO_2/ kWh. • A 0.4MW solar power system can generate up to 60MWh of electricity with a stable monthly production average to account for 5% of Funafuti's peak demand (1.3MWh)	Yes
Bioenergy	• Biomass energy has the fourth-highest carbon footprint of all energy types with 230 CO_2/ kWh. • It will also assist Tuvalu in the reduction of petroleum-based energy sources.	No

1.2 Decision Context

The three main technologies for the Energy sector were all advocated for by the stakeholders and will be included in the prioritisation matrix.

1.3 Overview of possible mitigation technologies in the Energy sector and their mitigation potential and other co-benefits

Technology	Basic description	Feasible (Yes/No)
Solar energy	● Converting the sun's energy to electricity. ● In combination with batteries (BESS), the energy is stored in batteries which can then be used for longer periods and in instances where there is cloud cover and at night.	Yes
Bioenergy	● Use of biomass (plant-based material used as fuel to produce heat or electricity. Examples are wood and wood residues, energy crops, agricultural residues, and waste from industry, farms, and households. ● Tuvalu does not have the required biomass volume to use this technology at an economical scale;	No
Hydropower	● Using dams to generate power. ● There are no rivers in Tuvalu, so this is not possible. ● Using waves and ocean currents is still very much in its initial development.	No
Geothermal energy	● Energy from the Earth's crust originates from the Earth's formation and the radioactive decay of materials. ● This energy source is not available in Tuvalu and cannot be imported.	No
Nuclear power	● Using radioactive materials to generate energy. ● Raw material is not available in Tuvalu and cannot be imported as in the case of fossil fuels.	No

1.3.1 Criteria and process of technology prioritisation for the Energy Sector: Scoring Matrix for Energy Sector: Nominal Values[5]

		Category										
Criteria	Lev 1	Costs			Benefits							
					Economic	Environmental		Social			Political	
	Lev 2	Estimated Cost of Equipment (USD)	Assoc. implementation costs - freight, local clearances,	Maintenance Cost (USD/Year)	Improving balance of payment	GHG Reduction potential	Reduce Other Pollution (not including GHG)	Improved health & wellbeing	Development of local expertise	Job Creation Potential	Alignment to current priorities	Political Will
Sources		Technology Providers, Operators	Proxies	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Technologies												
1	Solar PV (National Grid electricity generation) + BESS	50,000,000	450,000	200,000	3.90	5	2.38	4.90	4.75	4.90	5	5.00
2	Solar Home System (Solar PV + BESS) + Rooftop	10,803,200	640,000	540,161	3.90	5	3	5	5	4	5	3.75
3	Biofuels	32,775,000	1,725,000	1,702,500	4	4	4	4	4	4	4	3.4

[5] Costs are based on electrifying 5,000 households.

1.3.2 Criteria and process of technology prioritisation for the Energy Sector Scoring Matrix: Normalization

		Category										
Criteria	Lev 1	Costs			Benefits							
					Economic	Environmental		Social			Political	
	Lev 2	Estimated Cost of Equipment (USD)	Assoc. implementation costs - freight, local clearances,	Maintenance Cost (USD/Year)	Improving balance of payment	GHG Reduction potential	Reduce Other Pollution (not including GHG)	Improved health & wellbeing	Development of local expertise	Job Creation Potential	Alignment to current priorities	Political Will
Sources		Technology Providers, Operators	Proxies	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Technologies												
1	Solar PV (National Grid electricity generation) + BESS	0.00	100.00	0.00	0	100	0	90.00	75.00	100.00	100.00	100.00
2	Solar Home System (Solar PV + BESS) + Rooftop	100.00	93.51	22.64	0	100	38.27	100.00	100.00	0.00	100.00	21.88
3	Biofuels	43.94	56.43	100.00	100	0	100	0.00	0.00	0.00	0.00	0.00

1.3.3 Criteria and process of technology prioritisation for the Energy Sector: Scoring Matrix for Energy Sector: Combining Weights

		Category	Category									
Criteria	Lev 1	Costs			Benefits							
				0	Economic	Environmental		Social			Political	
	Lev 2	Estimated Cost of Equipment (USD)	Assoc. implementation costs - freight, local clearances,	Maintenance Cost (USD/Year)	Improving balance of payment	GHG Reduction potential	Reduce Other Pollution (not including GHG)	Improved health & wellbeing	Development of local expertise	Job Creation Potential	Alignment to current priorities	Political Will
Sources		Technology Providers, Operators	Proxies	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Technologies	Weights	6.5	3.25	3.25	5	16	16	9	4.5	4.5	16	16
1	Solar PV (National Grid electricity generation) + BESS	0.00	100.00	0.00	0.00	100.00	0.00	90.00	75.00	100.00	100.00	100.00
2	Solar Home System (Solar PV + BESS) + Rooftop	100.00	93.51	22.64	0.00	100.00	38.27	100.00	100.00	0.00	100.00	21.88
3	Biofuels	43.94	56.43	100.00	100.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00

1.4 Results of Technology Prioritisation for the Energy Sector:

SECTOR	Technology	Prioritization Score	Ranking
Energy	Solar Home System (Solar PV + BESS + rooftop)	67.23	1
Energy	Solar PV (National Grid electricity generation) + BESS	65.40	2
Energy	Biofuels	28.84	3

Priority Ranking	Technology	Relevance/Importance for Mitigation	Barriers
Energy Sector Technologies			
1	Solar Home System (Solar PV + BESS + Rooftop)	• Solar system is highly available and robust.	• High cost of installation for households
2	Solar PV (National grid electricity generation) + BESS	• Not available	• Maintenance issues. • Cost issues. • Limited access to information about the technology.
3	Biofuels	• Technology is viable and makes use of green waste and pig waste	• Not sustainable on a large scale

4 Technology Prioritisation for the Transport Sector:

1.5 GHG Emissions and existing technologies for the Transport sector:

Technology	GHG Emission Reduction Potential	Feasible (Yes/No)
Fuel efficiency-light duty vehicle	• Emit less pollution than similar vehicles per distance travelled.	Yes
Electric light duty vehicles	• Produce lower emissions than conventional vehicles (even less than fuel efficient vehicles)	Yes
Shift to public transport	• Regular and efficient public transportation reduces the need for private transportation, thus reducing the number of vehicles needed, therefore reducing emissions	Yes
Shift to bikes & non-motorized transport.	• A shift to non-motorized transport will reduce fossil fuel dependency.	Yes
Shipping efficiency, logistics optimization, new fuels.	• A shift to more fuel-efficient engines on ships. A change to blended fuels can reduce carbon dioxide emissions to an estimated 15% to 20%.	Yes

4.1 Decision Context

All technologies for the Transport Sector were advocated for by the stakeholders and will be included in the prioritisation matrix.

4.2 Overview of possible mitigation technologies in the Transport sector and their mitigation potential and other co-benefits

Table 4: Feasibility of Application of Technologies in Tuvalu: Transport

Technology	Basic description	Feasible (Yes/No)
Fuel efficiency-light duty vehicle	• Reduction in CO emissions. • Cheaper to operate as it uses less fuel than similar non fuel efficient vehicles.	Yes
Electric light duty vehicles	• Electric vehicles are a necessary step in decarbonizing the transport sector.[6]	Yes
Shift to public transport	• Regular and efficient public transportation reduces the need for private transportation, thus reducing the number of vehicles needed.	Yes
Shift to bikes & non-motorized transport.	• A shift to non-motorized transport will reduce fossil fuel dependency.	Yes
Shipping efficiency, logistics optimization, new fuels.	• A shift to more fuel-efficient engines on ships.	Yes

[6] According to the International Energy Agency, limiting the global temperature increase to below 2 degrees, will require at least 20% of all road transportation to be electrically driven by 2030.

4.2.1 Decision Context: Scoring Matrix for Transport Sector (Nominal Values)

		Category										
Criteria	Lev 1	Costs			Benefits							
					Economic	Environmental		Social			Political	
	Lev 2	Estimated Cost of Equipment (USD)	Assoc. implementation costs - freight, local clearances,	Maintenance Cost (USD/Year)	Improving balance of payment	GHG Reduction potential	Reduce Other Pollution (not including GHG)	Improved health & wellbeing	Development of local expertise	Job Creation Potential	Alignment to current priorities	Political Will
Sources		Technology Providers, Operators	Proxies	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Technologies												
1	Fuel efficiency light-duty vehicles	4,260,000	625,000	213,000	3.00	4	2	2	4.00	3.00	5	3.20
2	Electric Light duty vehicle	800,000	40,000	16,000	4.00	4	2.38	4	4	4	5	3.20
3	Shift to bikes, ebikes, & non motorized transport	12,557,495	1,330,220	627,874.75	4	5	5	5	4	4	5	3.2
4	Fuel efficiency heavy duty vehicles	10,280,000	670,000.00	514,000	4	4	2.38	4	4	4	5	3.2
5	Electric heavy duty vehicle	350,000	7,000	17500	4	4	2.38	3.4	4	3	5	3
6	Hydrogen-powered shipping vessel	85,500,000	4,275,000	1,710,000.00	4	3.8	5	3.8	5	5	1	5
7	Shore-side electrical supply for at berth vessels	95,000	5000	10,000	4	3.2	4	4	2	2	4	3.2

Assumptions

Currency used is USD

Hydrogen Technology includes other costs such as production, refueling, cost of compliance, operation & maintenancen, transportation & storage

Light Duty Vehicle (fuel efficient + electricity) include van (qty = 15), pickup truck (qty = 30), SUVs (qty = 50)

Fuel efficient Heavy Duty vehicle include dumb truck (qty = 5), bulldozer (qty = 4), excavator (qty = 4), front loader (qty = 8), crane truck (qty = 10), forklife (qty = 2), concrete mixer (qty = 2), garbage truck (qty = 9), tractor & trailer (qty = 10), oil tanker (qty = 2), fire engine (qty = 2)

Electric heavy duty vehicle - forklift (qty = 2)

Maintenance is biennally.

4.2.2 Decision Context: Scoring Matrix for Transport Sector (Normalisation)

		Category										
Criteria	Lev 1	Costs			Benefits							
					Economic	Environmental		Social			Political	
	Lev 2	Estimated Cost of Equipment (USD)	Assoc. implementation costs - freight, local clearances, etc (USD)	Maintenance Cost (USD/Year)	Improving balance of payment	GHG Reduction potential	Reduce Other Pollution (not including GHG)	Improved health & wellbeing	Development of local expertise	Job Creation Potential	Alignment to current priorities	Political Will
Sources		Technology Providers, Operators	Proxies	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Technologies												
1	Fuel efficiency light-duty vehicles	95.12	85.48	88.06	0	44.44	0.00	0.00	66.67	33.33	100.00	10.00
2	Electric Light duty vehicle	99.17	99.18	99.65	100	44.44	12.67	66.67	66.67	66.67	100.00	10.00
3	Shift to bikes, ebikes, & non motorized transport	85.41	68.96	63.65	100	100.00	100.00	100.00	66.67	66.67	100.00	10.00
4	Fuel efficiency heavy duty vehicles	88.07	84.43	70.35	100	44.44	12.67	66.67	66.67	66.67	100.00	10.00
5	Electric heavy duty vehicle	99.70	99.95	99.56	100	44.44	12.67	46.67	66.67	33.33	100.00	0.00
6	Hydrogen-powered shipping vessel	0.00	0.00	0.00	100	33.33	100.00	60.00	100.00	100.00	0.00	100.00
7	Shore-side electrical supply for at berth vessels	100.00	100.00	100.00	100	0.00	66.67	66.67	0.00	0.00	75.00	10.00

4.2.3 Decision Context: Scoring Matrix for Transport Sector (Combining Weights)

		Category	Category											
Criteria	Lev 1	Costs			Benefits									
				0	Economic	Environmental		Social			Political			
	Lev 2	Estimated Cost of Equipment (USD)	Assoc. implementation costs - freight, local clearances,	Maintenance Cost (USD/Year)	Improving balance of payment	GHG Reduction potential	Reduce Other Pollution (not including GHG)	Improved health & wellbeing	Development of local expertise	Job Creation Potential	Alignment to current priorities	Political Will		
Sources		Technology Providers, Operators	Proxies	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement		
Preferred value		Lower	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher		
Technologies	Weights	6.5	3.25	3.25	5	16	16	9	4.5	4.5	16	16	Overall Score	Rank
1	Fuel efficiency light-duty vehicles	95.12	85.48	88.06	0.00	44.44	0.00	0.00	66.67	33.33	100.00	10.00	41.03	7
2	Electric Light duty vehicle	99.17	99.18	99.65	100.00	44.44	12.67	66.67	66.67	66.67	100.00	10.00	56.65	3
3	Shift to bikes, ebikes, & non motorized transport	85.41	68.96	63.65	100.00	100.00	100.00	100.00	66.67	66.67	100.00	10.00	79.46	1
4	Fuel efficiency heavy duty vehicles	88.07	84.43	70.35	100.00	44.44	12.67	66.67	66.67	66.67	100.00	10.00	54.49	4
5	Electric heavy duty vehicle	99.70	99.95	99.56	100.00	44.44	12.67	46.67	66.67	33.33	100.00	0.00	51.80	5
6	Hydrogen-powered shipping vessel	0.00	0.00	0.00	100.00	33.33	100.00	60.00	100.00	100.00	0.00	100.00	56.73	2
7	Shore-side electrical supply for at berth vessels	100.00	100.00	100.00	100.00	0.00	66.67	66.67	0.00	0.00	75.00	10.00	48.27	6

2.1 Results of Technology Prioritisation for the Transport Sector

SECTOR	Technology	Prioritisation score	Ranking
Transport	Shift to bikes, e-bikes, & non-motorized transport	79.46	1
Transport	Hydrogen-powered shipping vessel	56.73	2
Transport	Electric light-duty vehicle	56.65	3
Transport	Fuel-efficient heavy-duty vehicle	54.49	4
Transport	Fuel Shift (including electricity) heavy-duty vehicles	51.80	5
Transport	Shore-side electricity supply for at-berth vessels	48.27	6
Transport	Fuel efficient light-duty vehicles	41.03	7

3 Summary and Conclusions

3.1 Energy Sector:

Priority Ranking	Technology	Relevance/Importance for Mitigation	Barriers
Energy Sector Technologies			
1	Solar Home System (Solar PV + BESS + Rooftop)	• Solar system is highly available and robust.	• High cost of installation for households
2	Solar PV (National grid electricity generation) + BESS	• Not available in Tuvalu and requires trial.	• Maintenance issues. • Cost issues. • Limited access to information about the technology.
3	Biofuels	• Technology is viable and makes use of green waste and pig waste	• Not sustainable on a large scale

3.2 Transport Sector

Priority Ranking	Technology	Relevance/Importance for Mitigation	Barriers
Transport Sector Technologies			
1	Shift to bikes, e-bikes, & non-motorized transport	• Reduction in GHG emissions	• Limited driving range and suitability for rainy weather conditions • Social perceptions and stigma associated with biking, such as being seen poor, unprofessional, or unsafe.
2	Hydrogen-powered shipping vessel	• Reduction in GHG emissions and marine pollution	• High cost and complexity of hydrogen production, storage, and distribution • Lack of safety standards and regulations for hydrogen operators. • Technical challenges and uncertainties regarding hydrogen fuel cells, engines, and tanks
3	Electric light-duty vehicle	• Reduction in GHG emissions	• High cost of purchasing and maintaining electric vehicles • Limited driving range and suitability for different terrains and weather conditions • Lack of adequate charging infrastructure and availability of EV parts and repair stations
4	Fuel-efficient heavy-duty vehicle	• Reduction in GHG emissions	• High cost and complexity of diesel engines which are the dominant technology for heavy duty vehicles

Priority Ranking	Technology	Relevance/Importance for Mitigation	Barriers
Transport Sector Technologies			
5	Fuel shift (including electricity) heavy-duty vehicles	• Reduction in GHG emissions	• Lack of adequate infrastructure for refuelling especially for long-distance freight transport
6	Shore-side electricity supply for at-berth vessels	• Reduction in GHG emissions	• High capital and operations costs • Lack of harmonised standards and regulations
7	Fuel-efficient light-duty vehicles	• Reduction in GHG emissions	• High costs for fuel-efficient light-duty vehicles.

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Annex 1: Technology Fact Sheets for Energy & Transport Sectors

a) Energy Sector Technologies for Mitigation of Climate Change

Technology name: Solar PV (national grid electricity generation) + BESS NATIONAL GRID:
1. **Introduction/Background** Solar photovoltaic, or simply photovoltaic (SPV or PV), refers to the technology of using solar cells to convert solar radiation directly into electricity. A solar cell works based on the photovoltaic effect. Research & Development (R&D and practical experience with photovoltaics have led to the development of three generations of solar cells: Crystalline silicon-based solar cells, thin film solar cells and third-generation PV.
2. **Technology Characteristics** ● ***Renewable Energy Generation***: Solar PV panels generate electricity from sunlight, which is a clean and renewable energy source. This reduces the reliance on fossil fuels for electricity generation and helps reduce greenhouse gas emissions. ● ***Grid Integration***: The solar PV system is integrated into the national grid infrastructure, allowing excess electricity to be exported to the grid when it's generated in excess of on-site demand and drawing power from the grid when needed, providing stability and flexibility to the grid. ● ***Energy Storage***: Energy storage batteries, such as lithium-ion batteries, are coupled with the solar PV system. These batteries store excess electricity generated during sunny periods and discharge it during cloudy days or at night, ensuring a continuous power supply and grid stability. ● ***Peak Demand Management***: Battery storage systems can be used to manage peak electricity demand by supplying stored electricity during periods of high demand. This reduces the need for expensive Peaker plants and grid infrastructure upgrades. ● ***Grid Resilience***: Solar PV + Battery systems can enhance the resilience of the national grid by providing backup power during grid failures or emergencies. This feature is especially important for critical facilities like hospitals and emergency services. ● ***Load Shifting***: Energy storage allows for load shifting, which means electricity generated during off-peak hours can be stored and used during peak demand times, reducing electricity costs and strain on the grid. ● ***Energy Independence***: Solar PV + Battery systems can reduce a nation's dependence on imported fossil fuels for electricity generation, increasing energy security. ● ***Environmental Benefits***: By reducing reliance on fossil fuels and lowering greenhouse gas emissions, this technology contributes to environmental sustainability and helps combat climate change. ● ***Grid Balancing***: The system can help balance the grid by smoothing out fluctuations in electricity supply and demand, making the grid more stable and reliable. ● ***Distributed Energy Resources (DERs):*** Solar PV + Battery systems are considered distributed energy resources, allowing for a more decentralized and resilient energy infrastructure, as power generation is closer to end-users. ● ***Economic Benefits***: Over time, these systems can result in cost savings for both consumers and utilities, as they reduce the need for grid infrastructure investments, improve energy efficiency, and lower electricity bills. ● ***Scalability***: Solar PV + Battery systems can be scaled to meet the needs of a national grid, making them suitable for a wide range of applications, from small-scale installations to large utility-scale projects. ● ***Technological Advancements:*** Ongoing advancements in solar PV and battery technologies continue to improve the efficiency, affordability, and reliability of these systems, making them increasingly attractive for national grid integration.
3. **Country specific/ applicability:**

Capacity

There is limited capacity at the Tuvalu Electric Corporation (TEC), however, most of the solar systems have been installed by overseas companies and thus the need for further/continuous capacity building for TEC staff for installation and maintenance as well.

Scale of Application
This technology should cover the whole of Tuvalu with the appropriate support & monitoring from TEC.

Time Horizon - Short/Medium/ Long Term
Medium Term

4. **Status of the technology in the country and its future market potential:**

Technology use for national electrical energy sources has been for some decades since Tuvalu targeted a renewable energy strategy of 100% by 2030. Initial installations for public transmission were in 2008 for Funafuti and in 2009 for Vaitupu. Solar technology has been expanded to all islands in Tuvalu.

5. **Barriers**
   (a) High capital cost
   (b) Limited land space for large (usually more economical) installations and therefore competing with other needs for land.

6. **Mitigation Benefits**
   (a) Reduced GHG emissions

7. **Development benefits**
   (a) **Social**
      (i) Improved health due to lesser pollution from fossil fuels
      (ii) Global contribution to lesser GHG emissions

   (b) **Economic:**
      (i) Decrease in fossil fuel imports leading to improved balance of payment in this area of financial drain out of Tuvalu's financial systems;
      (ii) Diversification of energy sources and therefore decreasing Tuvalu's current dependency on imported fossil fuels;
      (iii) Cleaner energy sources

   (c) **Environmental**
      (i) Lower fuel consumption and higher energy efficiency lead to lower GHG emissions.
      (ii) Lower the possibility of contamination from fuels shipped from Funafuti to outer island;

8. **Operations:**
   It was used by TEC for electricity generation to supplement carbon-based generators on all islands of Tuvalu.

9. **Costs:** Government/TEC/donor funded; current projects in millions.
   Stage 1 - Funded by World Bank & ADB
   Stage 2 & 3: - Unfunded USD50,000.000 (Cost of Equipment), USD450,000 (Associated costs), USD200,000 Maintenance cost

Technology name: Solar PV + BESS (Solar Home System)

1. **Introduction/Background:** Solar photovoltaic, or simply photovoltaic (SPV or PV), refers to the technology of using solar cells to convert solar radiation directly into electricity. A solar cell works based on the photovoltaic effect. R&D and practical experience with photovoltaics have led to the development of three generations of solar cells: Crystalline silicon-based solar cells, thin film solar cells and third-generation PV.
2. **Technology characteristics:** Solar Home Systems are stand-alone PV systems that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. In rural areas, which are not connected to the grid, SHS can be used to meet a household's energy demand fulfilling basic electric needs. Globally SHS provides power to hundreds of thousands of households in remote locations where electrification by the grid is not feasible.
3. **Country specific/ applicability:** Tuvalu is a tropical country with ample sunshine hours to use this technology.

   Capacity: There is capacity at TEC and the private sector to carry out installation.

   Timeframe: Long-Term
4. **Status of the technology in the country and its future market potential:**
   These systems were installed in the 1980s and administered cooperatively by the Tuvalu Solar Cooperative. A single panel is connected to a battery and used for lighting only.
   The technology is slowly coming into use with direct imports as well as national sales from Funafuti-based businesses and the new systems are able to fully supply electrical needs for air-conditioning (cooling), cooking, lighting and equipment.
5. **Barriers**
   (a) Capital costs
   (b) The public being unaware of the technology
   (c) Unaware of availability in the country or that it can be relatively easy to procure by individuals from overseas suppliers;
6. **Mitigation Benefits**
   (a) Reduced GHG emissions
   (b) Global contribution to lesser GHG emissions
7. **Development benefits**
   (a) **Social**
      (i) Improved health due to lesser pollution from fossil fuels
   (b) **Economic**
      (i) Decrease in fossil imports leading to improved balance of payment;
      (ii) Diversification of energy sources
      (iii) Cleaner energy sources
   (c) Environmental
      (i) Lower fuel consumption and higher energy efficiency lead to lower GHG emissions.
8. **Operations:** Small-scale at present.
9. **Costs:**

Est. USD10,803,200 (Cost of equipment)
USD 640,000 (Associated cost)
USD 540,160 (Maintenance cost)

Technology name: Biofuels

1. **Introduction/Background:**

Biofuels are a category of renewable fuels derived from organic materials such as crops, algae, and organic waste. These sustainable alternatives to conventional fossil fuels hold the promise of significantly reducing greenhouse gas emissions and dependence on finite fossil fuel resources. Biofuels are versatile, compatible with existing infrastructure, and can be used in various applications, including transportation, heating, and electricity generation. They offer a critical pathway toward addressing environmental concerns, enhancing energy security, and promoting a more sustainable and low-carbon future.

The development and adoption of biofuels have gained momentum in recent decades as a response to mounting concerns over climate change and the need for more sustainable energy sources. Biofuels are considered a key component of strategies to reduce greenhouse gas emissions from the transportation sector, which is a major contributor to global CO_2 emissions. Common types of biofuels include bioethanol, which is primarily derived from crops like corn and sugarcane, and biodiesel, typically produced from sources such as soybeans and canola. Additionally, advancements in technology have spurred research into advanced biofuels, like cellulosic ethanol and algae-based fuels, which offer even greater potential for carbon reduction and sustainability. However, the biofuels industry also faces challenges related to land use, food security, resource management, and sustainability standards, which must be carefully addressed to ensure the positive environmental and economic impacts of biofuels are maximised.

2. **Technology characteristics:**

Biofuels, as a renewable energy source, have several distinct characteristics that differentiate them from fossil fuels. Understanding these characteristics is key to evaluating their suitability and potential impact in various applications. Here are some of the main characteristics of biofuels:

- Renewable Source: Biofuels are derived from biomass materials, such as plants, algae, or organic waste, which can be replenished relatively quickly compared to fossil fuels that take millions of years to form.
- *Biodegradability*: Most biofuels are biodegradable, which means they break down naturally in the environment and are less likely to cause long-lasting pollution.
- *Lower Carbon Emissions*: When burned, biofuels typically release fewer greenhouse gases compared to traditional fossil fuels. This is mainly because the carbon dioxide they emit is part of the carbon cycle, having been absorbed by the plants during their growth phase.
- *Energy Content*: Biofuels generally have a lower energy density compared to fossil fuels. This means a larger volume of biofuel may be required to produce the same amount of energy as a smaller volume of fossil fuels.
- *Variability in Quality*: The quality of biofuel can vary depending on the feedstock used and the production process. This variability can affect performance and suitability for different engines or applications.
- *Types of Biofuels*: There are different types of biofuels, such as bioethanol (made from crops like corn and sugarcane), biodiesel (produced from vegetable oils, animal fats, or recycled greases), and biogas (produced from anaerobic digestion of organic matter).
- *Compatibility with Existing Infrastructure*: Some biofuels can be used in existing engines and fuel infrastructure with little or no modification, while others may require specialised equipment.
- *Production Methods*: The methods for producing biofuels can vary widely, from fermentation and distillation for ethanol to chemical processes like transesterification for biodiesel.
- *Environmental Impact*: While biofuels are generally considered environmentally friendly, their overall impact depends on various factors, including how the feedstock is grown, processed, and transported.
- *Economic Factors*: The production and use of biofuels are influenced by economic factors such as feedstock availability, production costs, market demand, and government policies or subsidies.

3. **Country specific/ applicability:**

Capacity

- *Limited Land Area*: Tuvalu, with its small landmass, has limited capacity for large-scale biofuel crop production. This restricts the potential types of biofuels that can be produced domestically.
- *Potential for Microalgae*: Given the limited land, exploring biofuel sources like microalgae, which can be cultivated in tanks or ponds, might be more feasible.
- *Coconut-based Biofuel*: Tuvalu could consider utilising its existing coconut resources for producing biofuel, as coconuts are abundant and already an integral part of the local economy.

Scale of Application

- *Transportation Sector*: The primary application of biofuel in Tuvalu could be in the transportation sector, both for land vehicles and marine vessels, to reduce dependence on imported fossil fuels.
- *Power Generation*: Biofuel could potentially supplement Tuvalu's energy mix for electricity generation, especially to support more remote communities or during periods of low renewable energy generation.
- *Small-scale Pilot Projects*: Initiating small-scale pilot projects would allow Tuvalu to assess the practicality and impact of biofuel use before broader implementation.

Timeframe

- *Short-term Goals*: In the short term, Tuvalu could focus on feasibility studies, pilot projects, and small-scale implementation, particularly in areas where the transition to biofuel would be most beneficial and least disruptive.
- *Medium to Long-term Expansion*: Depending on the success of initial projects and the development of sustainable supply chains, Tuvalu could gradually expand biofuel use. This would involve scaling up production capabilities, establishing more comprehensive distribution networks, and integrating biofuels more significantly into the energy mix.
- *Ongoing Research and Development*: Long-term success would depend on continuous research into sustainable biofuel production methods that are environmentally friendly and economically viable for Tuvalu.

4. **Status of the technology in the country and its future market potential**

Current Status

- *Limited Development*: Tuvalu, with its small size and limited resources, may not have had significant development in biofuel technology. The country's focus has primarily been on adapting to and mitigating the effects of climate change, with an emphasis on sustainable practices.

- *Reliance on Imported Fuels*: Given Tuvalu's remote location and lack of extensive natural resources, the nation has traditionally relied heavily on imported fossil fuels for energy and transportation needs.

- *Potential in Coconut Biofuel*: Tuvalu has a natural abundance of coconuts, which could be utilized for producing coconut oil-based biofuel. However, as of my last update, large-scale production and usage might not yet be in place.

Future Market Potential

- *Renewable Energy Goals*: Tuvalu's commitment to renewable energy and reducing carbon emissions could serve as a driver for exploring biofuel as an alternative energy source, particularly for transportation and power generation.

- *Small-scale Applications*: The future market potential for biofuel in Tuvalu might be more viable on a small scale, such as in local transport systems or for powering machinery and generators, considering the limited demand and infrastructure.

- *Sustainable Practices*: Utilising locally available resources like coconut oil for biofuel production could align with sustainable development practices, reducing reliance on imported fuels and promoting environmental conservation.

- *International Support*: Tuvalu's efforts in renewable energy and sustainability often receive support from international organisations and developed countries. This support could extend to the development of biofuel technologies and infrastructure.

- *Economic Diversification*: Developing a biofuel industry could provide Tuvalu with an opportunity to diversify its economy, potentially creating new jobs and business opportunities.

- *Challenges in Scalability and Logistics*: The scalability of biofuel production in Tuvalu would face challenges due to limited land area and resources. Additionally, logistical challenges in distribution and storage would need to be addressed.

- *Research and Development*: Continued research and development, possibly supported by international partnerships, would be crucial to adapt biofuel technology to Tuvalu's unique context and to maximise its efficiency and sustainability.

5. **Barriers:**
   - Whilst most vehicles can use blended components of biofuel, this will mean a shift towards hybrid vehicles to make use of biofuels.
   - Biofuels cannot be used for motorcycles and outboard motors in Tuvalu
   - Biofuels are more expensive than fossil fuels

6. **Mitigation Benefits**
   - Reduction in GHG emissions

7. **Potential development benefits**
   a. **Social**
   - Improved health due to lesser pollution
   - Global contribution to lesser GHG emissions

   b. **Economic**
   - Decrease in fossil imports leading to improved balance of payment.

   c. **Environmental**
   - Lower fuel consumption and higher energy efficiency lead to lower GHG emissions.

8. **Operations**:

The operation of a biofuel program encompasses several stages, from the production of biomass to the final use of biofuel in various applications. Here's an overview of the typical operational process for biofuel:

Biomass Production
- *Feedstock Cultivation*: This involves growing bioenergy crops or collecting organic waste materials that serve as the feedstock for biofuel. Common feedstocks include corn, sugarcane, soybeans, and oilseeds for biodiesel, as well as agricultural and forestry residues.
- *Sustainable Practices*: It's crucial to employ sustainable agricultural practices to minimise the environmental impact, especially in sensitive areas like Tuvalu. This includes efficient water use, avoiding deforestation, and maintaining soil health.

Feedstock Processing
- *Harvesting and Collection*: Once the biomass is ready, it's harvested and collected. For waste-based feedstock, this involves gathering and transporting the waste to a processing facility.
- *Pre-treatment*: The biomass is then pre-treated to prepare it for conversion. This may include drying, grinding, or other forms of physical processing.

Biofuel Production
- *Conversion Process*: The processed biomass undergoes a conversion process to turn it into biofuel. The specific process depends on the type of biofuel:
- *Biodiesel*: Typically produced through a chemical process called transesterification, where oils and fats are reacted with alcohol.
- *Ethanol*: Produced through fermentation, where sugars in the biomass are converted into ethanol by the action of microorganisms.
- *Quality Control*: The produced biofuel is tested and refined to ensure it meets quality and safety standards.

Distribution and Storage
- *Transportation*: Biofuel is transported to distribution centres or directly to users. This can be done using existing fuel distribution infrastructure with some modifications.

- *Storage*: Biofuel must be stored properly to maintain its quality. This includes ensuring clean, moisture-free storage tanks and facilities.

End Use
- *Fuel Blending*: Biofuel is often blended with traditional fuels. For example, biodiesel is mixed with diesel, and ethanol is blended with gasoline.
- *Vehicle and Engine Compatibility*: Biofuels are used in engines and vehicles. The compatibility and efficiency of engines with biofuels are important considerations.

Environmental and Economic Monitoring

- *Sustainability Assessment*: Continuous assessment of the environmental impact of biofuel production and use is vital, especially in monitoring carbon emissions, land use changes, and biodiversity impacts.
- *Economic Viability*: Regular analysis of the economic aspects of biofuel operations, including cost-effectiveness, market prices, and return on investment.

Challenges and Solutions

- *Technological Advances*: Continuous research and development are needed to improve the efficiency and reduce the costs of biofuel production.
- *Policy Support*: Government policies and incentives can play a crucial role in supporting the biofuel sector.
- *Public Awareness and Acceptance*: Educating the public about the benefits and use of biofuels is important for its wider acceptance and use.

9. **Costs:**
   - Biofuels are more expensive than fossil fuels
   - Est. USD32,775,000 (Est. Cost of equipment), USD1,725,000 (Associated cost), USD 1,702,500 (Maintenance cost)

b) Transport sector technologies for mitigation of Climate Change

Technology name: Fuel efficiency-light duty vehicle

1. **Introduction/Background:**

Introduction:

Fuel efficiency in light-duty vehicles is a crucial aspect of the transport sector's ongoing efforts to reduce its environmental impact and dependence on fossil fuels. These vehicles, which include passenger cars, SUVs, and small trucks, play a significant role in everyday transportation. Improving their fuel efficiency contributes not only to cost savings for consumers but also to lower greenhouse gas emissions and reduced air pollution.

The automotive industry has been working on enhancing the fuel efficiency of light-duty vehicles for several decades. The push for improved fuel efficiency gained momentum due to concerns about global energy security, the environmental impact of vehicle emissions, and the need to meet stricter emissions standards.

2. **Technology characteristics:**
   - Engine Downsizing and Turbocharging: Downsizing involves using smaller engines with turbochargers to maintain or increase power output. Turbochargers force more air into the engine, improving combustion efficiency and power while reducing fuel consumption.
   - Start-Stop Systems: These systems automatically turn off the engine when the vehicle is stationary, such as at traffic lights, and restart it when the driver presses the accelerator. This reduces idling time and fuel consumption.
   - Tire Technology: Low rolling resistance tires minimise friction between the tires and the road, enhancing fuel efficiency.
   - Advanced Sensors and Electronics: Sensors and electronic systems monitor vehicle performance and optimise engine and transmission operations for better fuel economy.

3. **Country specific/ applicability:**

Capacity

In the context of implementing fuel efficiency technologies for light-duty vehicles in Tuvalu, "capacity" refers to the maximum number of vehicles that can realistically and practically adopt these technologies within the island's specific circumstances. It's a measure of how many vehicles can be equipped with fuel-efficient features or transitioned to alternative fuel sources while considering factors such as available resources, infrastructure, funding, and the size of the vehicle fleet.

Given Tuvalu's small size and limited resources, the initial capacity for adopting fuel efficiency technologies might range from a few dozen to a few hundred vehicles, depending on the level of investment, infrastructure development, and the willingness of vehicle owners to switch to fuel-efficient options. As awareness grows, infrastructure improves, and policies are put in place to support these technologies, the capacity for adoption can potentially expand over time.

The capacity assessment involves analysing factors such as the island's road network, the number of vehicles currently in use, available charging infrastructure (if considering electric vehicles), funding availability, public acceptance, and the readiness of local industries to provide necessary services (e.g., vehicle conversions, maintenance). It's important to approach capacity planning with a realistic understanding of Tuvalu's unique context and limitations.

Scale of Application

The "scale of application" in the context of implementing fuel efficiency technologies for light-duty vehicles in Tuvalu refers to the extent to which these technologies are introduced, adopted, and integrated into the island nation's transportation system. It involves determining how widely and comprehensively fuel efficiency measures will be implemented within the existing vehicle fleet and infrastructure.

Given Tuvalu's small size and limited resources, the scale of application for fuel efficiency technologies would likely start at a modest level and gradually expand as the necessary conditions are met

Time Horizon: Medium Term

4. **Status of the technology in the country and its future market potential**

In Tuvalu, the absence of a designated authority responsible for overseeing vehicle standards and regulations presents a significant challenge in determining the presence and prevalence of fuel-efficient vehicles within the country. This lack of oversight makes it difficult to ascertain whether vehicles in Tuvalu meet certain efficiency criteria or environmental standards. Additionally, it is important to note that the majority of light-duty vehicles imported into Tuvalu are second-hand, a factor that further complicates the assessment of their fuel efficiency. Regarding the cost factor, if fuel-efficient vehicles are significantly more expensive compared to standard models, which is often the case due to advanced technology and higher manufacturing costs, their adoption in Tuvalu becomes highly unlikely. This is particularly relevant for Tuvalu, considering its economic profile and the potential financial constraints associated with importing newer, more expensive vehicle technologies.

5. **Barriers:**
- *Limited Resources:* Tuvalu has limited financial, human, and technological resources to invest in the development and implementation of advanced fuel efficiency technologies and infrastructure.
- *Economies of Scale:* Due to Tuvalu's small populations and markets, Tuvalu may struggle to achieve economies of scale in vehicle purchases, infrastructure development, and technology deployment, which can drive up costs.
- *Geographic Isolation:* Tuvalu being isolated from larger markets can result in higher transportation costs for importing vehicles, parts, and technology. This isolation can also limit the availability of technical expertise and skilled labour.
- *Infrastructure Challenges:* Tuvalu has inadequate road networks, lack of charging or refuelling infrastructure for alternative fuels, and limited access to maintenance and repair facilities for advanced vehicles and technologies.
- *High Vehicle Age:* Importing vehicles can be expensive, leading to older vehicles circulating in Tuvalu. Older vehicles are typically less fuel-efficient and emit higher levels of pollutants, contributing to environmental degradation.
- *Climate and Terrain:* Harsh climate conditions, such as high temperatures and humidity, can affect the performance and durability of fuel efficiency technologies. Additionally, challenging terrains may require vehicles with specific characteristics.
- *Policy and Regulatory Challenges:* Developing and implementing effective policies, regulations, and standards for fuel efficiency and emissions reduction can be complex. Challenges include adapting international standards to local conditions and enforcing compliance.
- *Institutional Capacity:* Building the necessary institutional capacity to support the research, development, implementation, and enforcement of fuel efficiency initiatives can be a challenge for Tuvalu.
- *Market Demand and Consumer Behaviour:* Limited consumer demand for fuel-efficient vehicles, coupled with cultural preferences for larger and cheaper vehicles, can hinder the adoption of sustainable transportation solutions.
- *Data and Information Gaps*: A lack of accurate and up-to-date data on fuel consumption, vehicle emissions, and traffic patterns can make it challenging to formulate effective policies and strategies.
- *Dependency on Imported Fuel:* Tuvalu heavily rely on imported fossil fuels for energy, which can make them vulnerable to global oil price fluctuations.
- *Land Constraints:* The limited availability of land in Tuvalu can make it difficult to establish charging infrastructure, public transportation routes, and alternative fuel production facilities.
- *Public Awareness and Education:* Lack of awareness about the benefits of fuel efficiency and sustainable transportation practices can hinder public support and engagement.

- *Increased solid waste*: an issue in Tuvalu attributed to the prevalent practice of importing larger and more affordable second-hand cars, predominantly used for less than a couple of year.

6. **Mitigation Benefits**

- *Reduced Greenhouse Gas Emissions:* Fuel efficiency technologies help lower the amount of fuel consumed by vehicles, resulting in decreased carbon dioxide (CO2) emissions. This contributes to global efforts to mitigate climate change and meet emissions reduction targets set under international agreements like the Paris Agreement.

- *Improved Air Quality:* Fuel-efficient vehicles produce fewer pollutants and harmful emissions. This leads to better air quality, reducing health risks for residents and visitors and mitigating respiratory and cardiovascular diseases.

- *Energy Security:* By reducing dependency on imported fossil fuels, Tuvalu can enhance their energy security and resilience.

- *Cost Savings:* Fuel-efficient vehicles consume less fuel, resulting in lower fuel costs for individuals, businesses, and the government. This can free up resources for other important investments and services.

- *Sustainable Tourism:* Implementing sustainable transportation solutions can enhance the appeal of these destinations to eco-conscious travellers and contribute to a positive image.

- *Fulfilment of International Commitments:* Tuvalu have committed to international agreements and initiatives focused on sustainable development and emissions reduction. Implementing fuel efficiency measures helps fulfill these commitments and demonstrates global leadership.

- *Local Job Creation:* Developing and maintaining charging infrastructure, public transportation systems, and alternative fuel production facilities can create job opportunities in areas such as construction, maintenance, and operations.

- *Promotion of Sustainable Mobility:* Implementing sustainable transportation solutions encourages the use of walking, cycling, and public transit.

- *Community Resilience:* Sustainable transportation solutions can enhance community resilience by reducing the impact of fuel price fluctuations and supply disruptions.

7. **Potential development benefits**

Social

- *Improved Public Health:* Cleaner air resulting from reduced vehicle emissions leads to fewer cases of respiratory illnesses and other health issues, improving overall public health and quality of life.

- *Enhanced Liveability:* Sustainable transportation solutions promote walking, cycling, and public transit, leading to less congestion and safer streets, which contribute to more liveable and vibrant urban environments.

- *Equitable Access to Mobility:* Efficient public transportation systems and shared mobility options provide affordable transportation choices for all residents, including those who may not own private vehicles.

- *Community Engagement:* Implementing sustainable transportation solutions often involves community engagement, fostering a sense of ownership and empowerment among residents

Economic

- *Cost Savings:* Fuel-efficient vehicles consume less fuel, leading to reduced fuel expenses for individuals, businesses, and the government. This frees up resources for other investments and economic activities.

- *Job Creation:* Developing and maintaining charging infrastructure, public transportation systems, and alternative fuel production facilities can create jobs in construction, operations, maintenance, and related sectors.

- *Tourism Promotion:* Sustainable transportation options, such as electric or hybrid vehicles, can attract eco-conscious tourists and enhance the appeal of Tuvalu as sustainable travel destinations.

- *Reduced Energy Dependency:* Transitioning to electric vehicles and alternative fuels can reduce Tuvalu's dependence on imported fossil fuels, enhancing energy security and resilience.

Environmental

- *Emissions Reduction:* Fuel efficiency technologies and cleaner transportation options lead to lower carbon dioxide (CO2) and pollutant emissions, contributing to global efforts to combat climate change.

- *Air and Water Quality:* Lower emissions improve air quality and reduce the pollution of water bodies, contributing to healthier ecosystems and marine environments.

- *Mitigation of Climate Impact:* Lower greenhouse gas emissions from transportation contribute to the mitigation of climate change, protecting vulnerable islands like from the impacts of sea-level rise and extreme weather events.

- *Eco-Friendly Image:* Implementing sustainable transportation solutions will enhance Tuvalu's global reputation as environmentally responsible and forward-thinking nations.

8. **Operations**:
   - *Planning and Strategy Development:* Develop a comprehensive transportation plan that outlines the goals, strategies, and action steps for implementing fuel efficiency technologies and sustainable transportation solutions.

   - *Infrastructure Development:* Identify and plan for the necessary infrastructure, such as charging stations for electric vehicles (EVs), refuelling stations for alternative fuels, and maintenance facilities for advanced vehicles.

   - *Vehicle Procurement and Fleet Management:* If feasible, consider transitioning government-owned vehicles to fuel-efficient options. Develop a fleet management strategy that prioritises fuel efficiency, maintenance, and lifecycle management.

   - *Public Transportation Enhancement:* Invest in and expand public transportation options, including buses, shuttles, and shared mobility services, to provide viable alternatives to private vehicle ownership.

   - *Alternative Fuel Implementation:* Assess the feasibility of locally producing or sourcing alternative fuels, such as biofuels, hydrogen, or natural gas, to reduce fossil fuel dependency.

   - *Regulatory Framework:* Establish or update regulations and standards related to emissions, fuel efficiency, and vehicle safety to create a supportive environment for sustainable transportation solutions.

   - *Incentives and Subsidies:* Develop financial incentives and subsidies for consumers and businesses to adopt fuel-efficient vehicles and technologies, making them more accessible.

   - *Education and Awareness:* Launch public awareness campaigns to educate residents about the benefits of fuel efficiency and sustainable transportation practices, encouraging behavioural changes.

   - *Training and Capacity Building:* Provide training and capacity-building programs for technicians, mechanics, and professionals to handle advanced vehicle technologies and infrastructure maintenance.

   - *Data Collection and Monitoring:* Implement systems for collecting and analysing data on fuel consumption, emissions, and transportation patterns to measure progress and inform future decisions.

   - *Public-Private Partnerships:* Collaborate with private sector partners, technology providers, and international organisations to leverage expertise, funding, and resources for successful implementation.

	- *Pilot Programs:* Initiate pilot programs to test new technologies, assess their viability in the local context, and gather feedback from users. - *Continuous Improvement:* Continuously assess the effectiveness of implemented strategies and adjust plans based on feedback and changing circumstances.
9.	**Costs:** USD4,260,000 (Est. Cost of the equipment) USD 625,000 (Associated cost) USD 213,000 (Maintenance cost)

Technology name: Electric light duty vehicles

Introduction/Background: Electric light-duty vehicles (EVs) are a crucial element in the pursuit of sustainable transportation solutions in Tuvalu. These vehicles, powered by electricity stored in batteries, offer significant benefits such as reduced greenhouse gas emissions, improved air quality, and decreased dependence on imported fossil fuels.

EV technology has evolved significantly, with advancements in battery chemistry, electric motors, and charging infrastructure. The push for EV adoption aligns with the goals to reduce their carbon footprint, enhance energy security, and create more livable urban environments

Technology characteristics:

- *Battery Technology:* Advanced lithium-ion batteries offer higher energy density, longer ranges, and faster charging capabilities, making EVs more practical for various travel needs.
- *Charging Infrastructure:* Charging options range from standard home charging to fast chargers that can provide a significant charge in a short time, enhancing convenience.
- *Electric Motors:* High-efficiency electric motors provide instant torque, contributing to smooth acceleration and reducing energy consumption.
- *Vehicle-to-Grid (V2G) Integration:* EVs can feed surplus energy back into the grid when not in use, helping stabilise the energy supply and potentially earning revenue for owners.
- *Smart Charging Solutions:* Smart charging systems can optimise charging times to take advantage of off-peak electricity rates, reducing charging costs.
- *Battery Management Systems:* These systems monitor battery health, optimising charging and discharging cycles for longer battery life.
- *Energy Efficiency Programs:* Implementing energy-efficient driving programs tailored to EVs can help drivers maximise their range and efficiency.

Country specific/ applicability:

Capacity

Given Tuvalu's small size, limited resources, and population, the capacity for adopting electric light-duty vehicles might be modest but impactful:

- *Initial Capacity:* Tuvalu's compactness enables a gradual introduction of EVs. The initial capacity could range from a few dozen to a few hundred EVs.
- *Charging Infrastructure:* The charging infrastructure's capacity to support EVs is a critical consideration. Establishing a scalable and strategically located network of charging stations is essential.

The capacity assessment involves analysing factors such as the island's road network, population density, available charging infrastructure, financial resources, consumer preferences, and the willingness of vehicle owners to transition to EVs. Approaching capacity planning with a realistic understanding of Tuvalu's unique context will ensure a successful and sustainable adoption of electric light-duty vehicles.

Scale of Application

The scale of application should be tailored to Tuvalu's specific circumstances, considering factors such as available resources, infrastructure development, funding availability, and the willingness of the public to adopt EVs. Starting with a manageable scale and gradually expanding as infrastructure and awareness grow can lead to a successful and sustainable adoption of electric mobility.

- Begin with a pilot project involving a small number of EVs, potentially focusing on government vehicles, public transportation, and essential services.
- The number of EVs initially introduced might range from a few to several units, depending on factors like available budget and charging infrastructure.
- Focus on urban centres and transportation hubs to maximise the benefits and feasibility of EV adoption.

Time Horizon: Long Term.

It's important to note that while the transition to electric light-duty vehicles offers numerous benefits, it also requires careful planning and investment in charging infrastructure, local capacity building, and supportive policies. Adapting the approach to Tuvalu's specific circumstances and gradually increasing the scale of adoption can lead to a successful and sustainable transition to electric mobility.

Status of the technology in the country and its future market potential

In Tuvalu, the automotive landscape includes a number of light-duty vehicles, reflecting the transportation needs of this small island nation. Additionally, a handful of electric motorcycles have been introduced, indicating a budding interest in electric mobility. Remarkably, there are only two electric cars currently present in Tuvalu, which is essentially demonstration or sample vehicles. These electric cars are utilised by the Tuvalu Electricity Corporation (TEC), playing a pivotal role in their efforts to assess the practicality and feasibility of electric vehicle (EV) adoption in the country. TEC's initiative in this regard is a crucial step towards understanding how electric cars might fit into Tuvalu's unique environmental and infrastructural context, potentially paving the way for more sustainable transportation solutions in the future.

Barriers:

- *Limited Resources:* Tuvalu may face challenges in allocating resources for EV infrastructure development and incentives due to financial constraints.
- *Infrastructure Challenges:* Establishing a comprehensive charging network can be costly and challenging, especially in remote areas.
- *Import Dependency:* Tuvalu may rely on imported EVs and components, increasing costs and potential supply chain disruptions.
- *Electricity Generation:* Ensuring a stable and sustainable electricity supply from renewable sources is essential to power EVs effectively.
- *Consumer Awareness:* Overcoming misconceptions and concerns about EVs, such as range anxiety, is necessary to drive adoption.
- *Local Industry Capacity:* Building local expertise in EV technology, manufacturing, and maintenance may take time and investment.

Mitigation Benefits

- *Reduced Greenhouse Gas Emissions:* EVs produce zero tailpipe emissions, contributing to climate change mitigation and meeting emissions reduction targets.
- *Energy Security:* Transitioning to locally generate renewable energy to power EVs enhances energy security and reduces vulnerability to global oil price fluctuations.
- *Cost Savings:* Lower operating and maintenance costs for EVs compared to conventional vehicles result in significant long-term savings for consumers and governments.
- *Local Job Creation:* Developing charging infrastructure and local EV manufacturing can create jobs and stimulate economic growth.
- *Sustainable Tourism:* EV adoption enhances the appeal of Tuvalu as eco-friendly tourist destinations, attracting environmentally conscious travellers.

Potential development benefits

Social

- *Equitable Mobility:* EVs provide accessible and affordable transportation options for all residents, ensuring equitable mobility and reducing transport-related disparities.
- *Enhanced Liveability:* Widespread EV adoption leads to quieter streets, less air pollution, and reduced traffic congestion, creating more liveable and vibrant urban environments.
- *Safer Roads:* EVs' quiet operation and advanced safety features contribute to safer roads, reducing accidents and fatalities.

Economic

- *Cost Savings:* Lower operating and maintenance costs of EVs compared to conventional vehicles result in substantial long-term savings for consumers, businesses, and governments.
- *Tourism Promotion:* EV adoption enhances Tuvalu's reputation as sustainable travel destinations, attracting eco-conscious tourists and boosting the tourism sector.
- *Energy Resilience:* Transitioning to locally generate renewable energy to power EVs enhances energy security and reduces vulnerability to global oil price fluctuations.

Environmental

- *Emissions Reduction:* EVs produce zero tailpipe emissions, contributing to climate change mitigation and meeting emissions reduction targets.
- *Mitigation of Climate Impact:* Lower greenhouse gas emissions from EVs contribute to mitigating climate change impacts and protecting vulnerable Tuvalu from sea-level rise and extreme weather events.

- **Operations**:

The operation of electric light-duty vehicles in Tuvalu, a small island nation, involves unique considerations given the country's geographical and infrastructural characteristics. The limited presence of electric vehicles (EVs), primarily for demonstration and assessment purposes by the Tuvalu Electricity Corporation (TEC), provides insight into the practicality and potential challenges of EV operation in such a setting.

- *Charging Infrastructure*: Essential to the operation of EVs is the availability of charging infrastructure. In Tuvalu, the development of EV charging stations is in its nascent stages, likely focused around key areas such as government facilities or main business districts. The limited range requirements due to Tuvalu's small size could be an advantage, reducing the need for an extensive network of charging stations.

- *Energy Supply*: Tuvalu's electricity supply, largely dependent on imported fossil fuels, poses a challenge. However, the country's shift towards renewable energy sources, such as solar power, could provide a sustainable and environmentally friendly energy source for charging EVs.

- *Vehicle Maintenance*: Maintenance of electric light-duty vehicles in Tuvalu might require specific skills and resources, which could be limited. Training local technicians and establishing maintenance facilities would be important for the successful operation of these vehicles.

- *Environmental Conditions*: Tuvalu's tropical climate and susceptibility to saltwater corrosion can affect the longevity and performance of electric vehicles. EVs operating in Tuvalu must be suitable for these conditions to ensure reliability and efficiency.

- *Range and Efficiency*: Given the small size of Tuvalu, range anxiety is less of a concern for EVs compared to larger countries. The efficient use of energy and the ability to meet daily transportation needs with limited charging are key operational considerations.

- *Regulatory Framework*: The development of a regulatory framework governing the use and operation of EVs, including safety standards, registration, and roadworthiness, is crucial for their successful integration into Tuvalu's transportation system.

- *Public Awareness and Acceptance*: Promoting public awareness about the benefits of electric vehicles, such as reduced emissions and lower operational costs, is essential. Acceptance and adoption by the public and businesses will be key to the successful operation of EVs in Tuvalu.

- **Costs:**

USD800,000 (Est. Cost of equipment)
USD 40,00 (Associated implementation cost)
USD 16,000 (Maintenance cost)

Technology name: Shift to bikes, ebikes & non-motorised transport.

1. **Introduction/Background:**

A bicycle, often simply referred to as a bike, is a human-powered, two-wheeled vehicle designed for transportation and recreational purposes. It is one of the most widely use modes of non-motorized transport around the world. Bicycles are propelled by the rider's pedalling motion, converting human energy into mechanical energy that propels the bike forward. They are renowned for their energy efficiency, being environmentally friendly, and ability to provide exercise while simultaneously offering practical means of transportation.

An e-bike, short for an electrical bicycle, is a bicycle that incorporates an electric motor to assist the rider's pedalling effort. E-bikes are designed to enhance the riding experience by providing electric assistance, which can make pedalling more accessible, particularly when navigating uphill or covering long distances.

Non-motorized transport refers to various modes of transportation that do not rely on internal combustion engines or motors for propulsion. Instead, these modes of transport utilise human energy or natural forces for movement. Non-motorized transport options are typically more environmentally friendly, and energy-efficient, and often contribute to healthier lifestyles. Some common forms of non-motorized transport that can be used in Tuvalu include, walking, bicycles, e-bikes, scooters and kick-scooters, skateboards and longboards, rollerblades and roller skates, and wheelchair and mobility aids.

Bikes, e-bikes, and non-motorized transport are effective tools for mitigating climate change due to their capacity to reduce greenhouse gas emissions, lower energy consumption, improve air quality, and promote more sustainable urban and individual behaviours.

2. **Technology characteristics:**

- Human powered
- Energy efficient
- Cost-effective
- Reduced traffic congestion
- Access and equity
- Flexible and agile

3. **Country specific/ applicability:**

- **Capacity** - one of the characteristics of non-motorized transport is "Access and Equity" meaning that it is accessible to a wide range of people including those who cannot afford motorised vehicles or those with limited mobility options. The skills required to operate non-motorized transport such as walking and cycling are generally minimal and easily attainable for most individuals.

- **Scale of application** - Non-motorized transport is perfect for the small Tuvalu roads and thus, applies to the whole of Tuvalu.

- **Time-horizon - Short/Medium/Long Term –** Short to Medium Term

4. **Status of the technology in the country and its future market potential**

Non-motorized transport was widely used in Tuvalu prior to the early 90s. With the introduction of motorised vehicles such as motorcycles and cars, adults, in particular, have been using mostly motorised vehicles, and non-motorized transport is widely used by children under the legal driving age.

5. **Barriers:**

- *Infrastructure Deficiencies:* Inadequate or unsafe infrastructure for pedestrians and cyclists, such as lack of sidewalks, bike lanes, and safe crossing points, can discourage people from using non-motorized transport.

- *Safety Concerns*: Fear of accidents and personal safety issues, especially when sharing the road with motorised vehicles, can deter individuals from walking or cycling.

- *Traffic Congestion*: In areas with heavy traffic congestion, walking and cycling might not be perceived as efficient modes of transport due to longer travel times.

- *Distance and Connectivity*: Longer distances between destinations can make walking or cycling less practical, particularly if there are limited direct routes or connections.

- *Weather Conditions:* Adverse weather conditions like rain, extreme heat, or cold temperatures can discourage people from choosing non-motorized transport.

- *Lack of Facilities*: Insufficient facilities such as bike parking, changing rooms, and shower facilities at workplaces or public spaces can deter people from using non-motorized transport.

- *Time Constraints:* Longer travel times associated with non-motorized transport might be perceived as a barrier, especially for individuals with busy schedules.

- *Perceived Inconvenience:* People might perceive walking or cycling as less convenient compared to motorised options, especially for tasks like carrying groceries or commuting longer distances.

- *Limited Urban Planning:* Inadequate urban planning that prioritises motorised transport over non-motorized options can contribute to barriers.

6. **Mitigation Benefits**

- *Reduced Greenhouse Gas Emissions:* Non-motorized transport, such as walking and cycling, produce zero tailpipe emissions. By choosing these modes of transportation over motorised vehicles, individuals can directly reduce the release of greenhouse gases like carbon dioxide (CO2) into the atmosphere, which is a primary driver of climate change.

- *Energy Efficiency:* Non-motorized transport is incredibly energy-efficient compared to motorised options. Walking and cycling require minimal energy inputs, relying on human power rather than fossil fuels.

- *Decreased Air Pollution:* Non-motorized transport helps reduce air pollution in urban areas. By avoiding the use of internal combustion engines, non-motorized modes of transport contribute to cleaner air and better respiratory health for city residents.

- *Lower Carbon Footprint:* The carbon footprint associated with non-motorized transport, including the manufacturing, use, and disposal of bicycles, is significantly lower compared to motorised vehicles, which require substantial amounts of energy and resources to produce and operate.

- *Traffic Congestion Reduction:* Non-motorized transport helps alleviate traffic congestion by reducing the number of vehicles on the road. This leads to smoother traffic flow, reduced idling, and fewer emissions from congested vehicles.

- *Resilient Urban Infrastructure:* Prioritising non-motorized transport encourages the development of pedestrian-friendly and bike-friendly urban infrastructure. This not only reduces carbon emissions but also builds more resilient cities designed to withstand climate challenges.

- *Enhanced Public Health:* Encouraging walking and cycling promotes physical activity, which can have positive effects on public health. Active transportation helps combat sedentary lifestyles, reducing obesity, cardiovascular diseases, and related health issues.

- *Sustainable Urban Development:* Incorporating non-motorized transport into urban planning supports sustainable development goals by creating livable, walkable, and bikeable communities. This reduces the need for expansive road networks and encourages mixed land use.

- *Carbon Offsetting:* Choosing non-motorized transport can be seen as a personal action to offset carbon emissions. By reducing personal reliance on motorised vehicles, individuals contribute to lowering the overall carbon footprint.

7. **Potential development benefits**

Social

- *Improved Public Health:* Walking and cycling are forms of physical activity that promote cardiovascular fitness, muscle strength, and overall well-being. Regular physical activity reduces the risk of chronic diseases such as obesity, diabetes, and heart disease, leading to healthier populations.

- *Enhanced Mental Health:* Active transportation has positive effects on mental health by reducing stress, anxiety, and depression. The act of walking or cycling can be therapeutic, offering time for reflection and relaxation.

- *Community Interaction:* Non-motorized transport encourages people to interact with their surroundings and with each other. Walking and cycling provide opportunities for spontaneous conversations, social interactions, and a sense of belonging within the community.

- *Enhanced Social Equity:* Non-motorized transport is accessible to people of various ages, abilities, and socio-economic backgrounds. Promoting walking and cycling helps create more inclusive urban environments that cater to diverse populations.

- *Safer Streets:* A focus on non-motorized transport often leads to traffic calming measures, safer intersections, and improved pedestrian infrastructure. This contributes to safer streets for all road users, including pedestrians and cyclists.

- *Reduced Noise Pollution:* Non-motorized transport reduces noise pollution, creating quieter and more peaceful urban environments that contribute to residents' well-being.

- *Childhood Development:* Encouraging walking and cycling promotes healthy habits from an early age. Children who walk or cycle to school develop independence, self-confidence, and a sense of responsibility.

- *Community Vitality:* Pedestrian-friendly streets and cycling lanes encourage people to spend more time outdoors and engage with local businesses, contributing to the vitality and economic growth of neighbourhoods.

- *Reduced Isolation:* Active transportation encourages people to step outside and engage with their surroundings, reducing feelings of social isolation and fostering a greater connection to the community.

- *Active Ageing:* Walking and cycling are low-impact activities suitable for people of all ages. Active transportation supports healthy ageing by promoting physical activity and maintaining mobility.

Economic

- *Reduced Infrastructure Costs:* Building and maintaining infrastructure for non-motorized transport, such as sidewalks and bike lanes, is generally more cost-effective than constructing and maintaining roads and highways for motorised vehicles. This leads to lower public expenditure on transportation infrastructure.

- *Savings on Healthcare Costs:* Increased physical activity resulting from walking and cycling can lead to better health outcomes and reduced healthcare costs. A healthier population requires fewer medical resources and contributes to lower public health expenditures.

- *Boost to Local Businesses:* Pedestrian-friendly streets and cycling infrastructure can attract more foot traffic to local businesses, leading to increased sales and economic activity. Cyclists and pedestrians are more likely to stop and shop, contributing to the vitality of commercial areas.

- *Tourism and Recreation:* Non-motorized transport facilities, such as scenic walking paths and cycling trails, can attract tourists and recreational users, boosting local tourism and generating revenue for businesses in the area.

- *Employment Opportunities:* The development and maintenance of non-motorized transport infrastructure, such as bike lanes and pedestrian zones, can create jobs in construction, design, urban planning, and maintenance.

- *Reduced Traffic Congestion Costs:* Promoting walking and cycling can help alleviate traffic congestion, leading to reduced travel times, fuel consumption, and wear and tear on roads. This results in cost savings for individuals and businesses.
- *Decreased Air Pollution Costs:* A shift toward non-motorized transport reduces air pollution and its associated health care costs. Fewer cases of respiratory illnesses and related medical expenses contribute to economic savings.
- *Real Estate Value:* Proximity to pedestrian-friendly and bike-friendly areas is often associated with higher property values, contributing to increased revenue for property owners and municipalities through property taxes.
- *Lower Fuel Expenditures:* Walking and cycling are cost-effective alternatives to driving, as they require no fuel expenditures. Individuals can save money on gasoline and public transportation fees.
- *Reduced Wear and Tear:* Non-motorized transport places minimal stress on road surfaces compared to motorised vehicles, leading to lower maintenance costs for road infrastructure.
- *Parking Cost Savings:* Fewer motorised vehicles on the road reduce the demand for parking spaces. This can lead to cost savings in terms of parking facility construction and maintenance.
- *Decreased Dependence on Fossil Fuels:* Encouraging non-motorized transport reduces reliance on fossil fuels, contributing to energy security and reducing vulnerability to fluctuations in fuel prices.
- *Healthcare Industry Savings:* A healthier population due to increased walking and cycling can lead to lower absenteeism rates and higher workforce productivity, reducing costs for employers and the healthcare industry.

Environmental

- *Air Quality Improvement:* Non-motorized transport reduces air pollution, which contributes to smog, respiratory illnesses, and other health issues. By decreasing the number of motorised vehicles on the road, non-motorized transport leads to cleaner air and improved public health.
- *Noise Reduction:* Non-motorized modes of transport generate minimal noise compared to motorised vehicles. This reduces noise pollution in urban areas, contributing to quieter and more peaceful living environments.
- *Conservation of Resources:* Non-motorized transport requires minimal resources for operation and maintenance. This reduces the demand for fossil fuels, energy, and materials associated with the production and operation of motorised vehicles.
- *Biodiversity Preservation:* Encouraging non-motorized transport helps protect natural habitats and biodiversity by minimising the fragmentation and destruction caused by road construction and vehicular traffic.
- *Water Quality Protection:* Reduced vehicle emissions and runoff from road surfaces improve water quality in nearby bodies of water. Non-motorized transport contributes to cleaner water sources and healthier aquatic ecosystems.
- *Land Use Efficiency:* Non-motorized transport requires less land for infrastructure compared to motorised transportation. This allows for more efficient land use, reducing urban sprawl and preserving open spaces.
- *Reduced Light Pollution:* Non-motorized transport contributes to reduced light pollution at night by decreasing the number of vehicles and minimising the need for bright artificial lighting.
- *Ecosystem Health***:** By minimising habitat destruction and pollution associated with motorised transportation, non-motorized transport supports the health and integrity of ecosystems.
- *Sustainable Tourism:* Walking and cycling paths, trails, and eco-friendly transportation options contribute to sustainable tourism practices that minimise negative impacts on local ecosystems and communities.

- *Carbon Sequestration:* Non-motorized transport does not contribute to deforestation or land degradation associated with road construction, allowing natural landscapes to continue acting as carbon sinks.
- *Visual Aesthetics:* The promotion of non-motorized transport can lead to more visually appealing urban environments with reduced traffic congestion and more green spaces.

8. **Operations**:

The shift towards bikes, e-bikes, and non-motorized transport in any setting, including island nations like Tuvalu, involves a multifaceted approach encompassing infrastructure development, policy initiatives, and cultural adaptation. Here's an overview of how such a transition can be operationalized:

Infrastructure Development

- *Dedicated Cycling Lanes*: Establishing safe, dedicated lanes for bicycles and e-bikes is crucial. This encourages usage by ensuring safety for cyclists, especially in areas with vehicular traffic.
- *Parking and Storage Facilities*: Providing secure parking and storage options for bikes and e-bikes encourages people to use them without worrying about theft or damage.
- *Charging Stations for E-bikes*: For e-bikes, accessible charging stations are necessary. These should be conveniently located and possibly powered by renewable energy sources.

Policy Initiatives

- *Incentives for Non-Motorized Transport*: Implementing incentives to encourage the use of bikes and e-bikes, such as subsidies, tax breaks, or financial assistance programs, can boost their adoption.
- *Traffic Regulations*: Amending traffic regulations to prioritise non-motorized transport, ensuring the safety of cyclists and pedestrians.
- *Public Awareness Campaigns*: Conducting campaigns to raise awareness about the benefits of non-motorized transport, including health, environmental, and economic advantages.
- *Educational Programs*: Introducing programs in schools and community centres to educate about bicycle safety and maintenance.

Cultural Adaptation

- *Community Engagement*: Engaging with the community to understand their needs and reservations regarding non-motorized transport and addressing them effectively.
- *Promotion of Health and Environmental Benefits*: Highlighting the health benefits of cycling and walking, as well as the positive impact on the environment, can encourage a cultural shift.
- *Role Models and Public Endorsement*: Encouraging local leaders and influencers to use and endorse non-motorized transport can create a positive image and encourage wider acceptance.

Challenges and Considerations

- *Geographical and Weather Considerations*: In places like Tuvalu, considerations include the impact of weather (like high heat or rain) and the geographical layout on the practicality of non-motorized transport.
- *Economic Factors*: Considering the economic aspects, such as the affordability of bicycles and e-bikes for the general population.
- *Maintenance and Repair Services*: Establishing services for the maintenance and repair of bicycles and e-bikes is essential to ensure their longevity and reliability.
- *Integration with Other Modes of Transport*: Creating a seamless integration with other modes of transport, such as public buses or ferries, can enhance the utility and attractiveness of non-motorized transportation options.

9. **Costs:** USD 12,557,495 (Est. Cost of equipment) USD 1,330,220 (Associated implementation cost) USD 627,874.75 (Maintenance cost)

Technology name: Fuel efficiency heavy-duty vehicles

1. **Introduction/Background:**

Fuel efficiency terminology means the efficiency of the process within internal combustion engines for converting chemical energy contained in fuel into mechanical energy to drive the vehicle. It is given in km/l or in its reciprocal form in l/100km, known by fuel consumption. Though fuel efficient vehicles are commonly known as vehicles with low consumption (estimated < 6,5 l/100km), fuel efficient vehicles are intended to cover all conventional gasoline vehicles equipped with advanced technologies and presenting advantages of consumption and emissions reduction compared to similar vehicles. Passive systems have indirect impact on reducing fuel consumption, like reducing the vehicle weight; and active systems have direct impact on consumption reduction like engine idle stop/start systems and automated manual transmissions.

2. **Technology characteristics:**

Fuel efficient heavy-duty powered vehicles offer several advantages:

- No major modifications within the powertrain (similar to conventional vehicles); hence, drivers don't have to adapt their driving techniques to these new technologies.
- Technologies can be applied on the basis of modular flexibility where different combinations of features can be observed.
- With the addition of stop/start systems, combinations of technologies and the use of turbo charging technology to downsize the engine lead to 15-25% improvement compared to today's gasoline engines.
- Additional costs are observed according to the added features, but still cheaper than alternative technologies like hybrid vehicles. Including the different available technologies into the gasoline engine results in a cost increase up to 150% of the baseline value.

3. **Country specific/ applicability:**

Capacity

- *Limited Industrial Activity*: Tuvalu's economy is relatively small with limited industrial activity. This could mean that the demand for forklifts, in general, might be low.
- *Energy Capacity*: The national grid's capacity to support electric forklift charging, especially if there's a significant adoption, needs to be evaluated. Given Tuvalu's current reliance on imported fossil fuels for electricity, integrating renewable energy sources would be ideal for supporting electric forklifts.

Scale of Application

- *Warehouse and Port Operations*: The primary utilization of electric forklifts in Tuvalu is expected to be centred around warehouse and port operations. Considering the relatively modest scale of these sectors in the country, a small number of electric forklifts would likely be adequate to meet the operational needs.
- *Adaptation to Local Needs*: The size and type of electric forklifts should be tailored to the specific requirements of the local businesses, considering factors like warehouse size, aisle width, and weight of goods commonly handled.

Time Horizon

- *Short-Term*: In the short term, the implementation of electric forklifts in Tuvalu could face challenges such as the initial cost of acquisition, establishing charging infrastructure, and training personnel.
- *Long-Term*: Over a longer time horizon, the benefits of lower operational costs, reduced environmental impact, and alignment with sustainable practices could become more apparent. As technology advances and becomes more affordable, it may become more feasible for Tuvalu to adopt electric forklifts more widely.

4. **Status of the technology in the country and its future market potential**

Fuel-efficient heavy-duty vehicles are endorsed by the government and its agencies, in order to avoid paying excess emissions penalties. In addition, heavy duty vehicles in Tuvalu are mainly used for large construction projects led by either government or projects supported by donor agencies.

5. **Barriers:**

Additional costs compared to conventional natural aspirated engines · Sources of energy savings are still not exploited in conventional vehicles (i.e. brake energy losses) · Still depending on fossil fuels · Encourage use of fuel-efficient heavy-duty vehicles if intelligent taxation policies are not adopted.

6. **Mitigation Benefits**
   - Reduction in GHG emissions

7. **Potential development benefits**

Social
- Improved health due to lesser pollution
- Global contribution to lesser GHG emissions

Economic
- Decrease in fossil imports leading to improved balance of payment.

Environmental
- Lower fuel consumption and higher energy efficiency lead to lower GHG emissions.

8. Operations:
Operation and maintenance are similar to conventional heavy-duty powered vehicles. There are some needed exceptional trainings and adaptations that are required.

9. Costs:
USD 10,280,000 (est. cost of equipment)
USD 670,000 (Associated implementation cost)
USD 514,000 (Maintenance cost)

Technology name: Electric heavy-duty vehicles FORKLIFT

1. **Introduction/Background:**

Electric forklifts have emerged as a pivotal innovation in material handling and warehouse management, offering an environmentally friendly alternative to traditional internal combustion (IC) forklifts. These forklifts are powered by electric motors and run on rechargeable industrial batteries, eliminating the need for fossil fuels. This shift not only represents a significant reduction in emissions of greenhouse gases and pollutants but also contributes to a quieter and safer working environment, as electric forklifts produce less noise and do not emit exhaust gases. Their design is particularly suited for indoor use, where ventilation for gas-powered vehicles can be a concern. Additionally, electric forklifts are often more compact and manoeuvrable, making them ideal for tight spaces commonly found in warehouses and storage facilities. With advancements in battery technology, these forklifts have seen improvements in power efficiency, operational time, and reduced charging periods, enhancing their viability and popularity in various industrial settings. The adoption of electric forklifts aligns with broader trends in sustainability and energy efficiency, reflecting a growing consciousness in industries to reduce their carbon footprint and optimises operational efficiency.

2. **Technology characteristics:**

Electric forklifts, known for their efficiency and environmental benefits, possess several distinct characteristics that set them apart from their internal combustion counterparts. These features include:

- *Power Source*: Electric forklifts are powered by rechargeable batteries, typically lead-acid or lithium-ion, which provide the electrical energy needed to run the motor and hydraulic systems.
- *Emissions*: One of the key advantages of electric forklifts is their zero tailpipe emissions. This makes them ideal for indoor use, as they do not release harmful exhaust gases like carbon monoxide or nitrogen oxides.
- *Noise Level*: They operate much more quietly compared to internal combustion forklifts, reducing noise pollution in the workplace, which is beneficial for operator comfort and communication.
- *Performance*: Electric forklifts offer smooth acceleration and deceleration. They also tend to have better torque at low speeds, making them efficient for stop-and-go operations.
- *Maintenance Requirements*: These forklifts typically require less maintenance than their gas-powered counterparts because they have fewer moving parts, no engine oil, fuel filters, or radiators.
- *Operational Cost*: The operational cost of electric forklifts can be lower over their lifetime, despite a higher initial purchase price, due to lower fuel costs and reduced maintenance needs.
- *Manoeuvrability*: Electric forklifts are often more compact and have a smaller turning radius, which makes them suitable for tight spaces and indoor environments.
- *Lifting Capacity and Height*: While traditionally less powerful than IC forklifts, modern electric forklifts have significantly improved in terms of lifting capacity and height, making them competitive in various applications.
- *Energy Efficiency*: They are generally more energy-efficient, converting more of their input energy into actual work, which can be a critical factor in reducing operational costs.
- *Battery Charging and Management*: Managing the battery life and charging is an essential part of operating an electric forklift. Fast-charging and opportunity-charging technologies have evolved to reduce downtime.
- *Environmental Impact*: By using electricity, especially when sourced from renewable energy, electric forklifts can significantly reduce the carbon footprint of warehouse and logistics operations.
- *Lifecycle*: The lifespan of an electric forklift's battery and the forklift itself can vary based on usage patterns, maintenance, and charging practices.

3. **Country specific/ applicability:**

Capacity

- *Small Scale Operations*: Given Tuvalu's small-scale industrial and commercial activities, the capacity requirements for electric forklifts would likely be modest. Electric forklifts suited for smaller loads and manoeuvring in limited spaces would be more appropriate for Tuvalu's context.
- *Power Supply and Charging*: The capacity of the local power grid to support electric forklift charging needs to be assessed. Tuvalu's current electricity infrastructure may require upgrades, especially if multiple forklifts are to be charged simultaneously.

Scale of Application

- *Warehouse and Port Use*: The most likely areas of application for electric forklifts in Tuvalu are in warehouse operations and at ports. These are environments where the benefits of electric forklifts, such as zero emissions and low noise, are particularly valuable.
- *Limited Number Required*: Due to the limited scale of industrial activities, Tuvalu would not require a large fleet of electric forklifts. A few strategically deployed units could suffice to meet the current demand.

Time Horizon

- *Short-Term Implementation*: In the short term, Tuvalu could face challenges such as the initial cost of acquiring electric forklifts, setting up charging stations, and training personnel.
- *Long-Term Viability*: Over the long term, electric forklifts could offer economic benefits in terms of lower operational costs (from fuel savings and reduced maintenance) and environmental benefits from reduced greenhouse gas emissions.
- *Progressive Adoption Strategy*: A gradual, phased approach to adoption might be most effective, starting with a pilot program to assess the practicality and benefits before moving to a broader implementation.

4. **Status of the technology in the country and its future market potential**

In Tuvalu, electric forklift technology is yet to be introduced, marking an untapped area in the nation's industrial and logistics sectors. The absence of electric forklifts highlights a starting point for technological advancement in material handling within the country.

The barriers to adopting electric forklift technology in Tuvalu are minimal. This situation is likely due to the small scale of operations in areas where these forklifts would be primarily used, such as warehouses and ports. This smaller scale makes the transition more manageable compared to larger industrial contexts. However, considerations such as the development of charging infrastructure and the training of operators and maintenance personnel are essential for a smooth transition.

Cost-wise, transitioning to electric forklifts in Tuvalu is relatively low, an encouraging factor for their adoption. This affordability is partly due to the decreasing global costs of electric forklifts and batteries, coupled with the potential for long-term operational savings. These savings arise from reduced fuel costs and lower maintenance requirements compared to traditional combustion engine forklifts.

Looking ahead, the future market potential for electric forklifts in Tuvalu appears promising. There's a growing global trend towards sustainable industrial practices, and as such, technologies like electric forklifts, which align with environmental goals, are gaining traction. Additionally, Tuvalu, being a small island developing state, might have opportunities to access development aid and grants aimed at sustainable technology investments.

5. **Barriers:**

While electric forklifts offer numerous advantages, there are several barriers to their adoption and effective use, particularly in certain operational contexts or industries. These barriers include:

- *Initial Cost*: Electric forklifts typically have a higher upfront cost compared to traditional internal combustion (IC) forklifts. This cost includes not only the vehicle itself but also the necessary charging infrastructure and battery systems.

- *Battery Life and Charging Infrastructure*: The need for robust battery systems and charging stations can be a logistical challenge. Batteries may require several hours to fully charge, and their lifespan can vary, necessitating eventual replacement.

- *Operational Limitations*: Electric forklifts, while ideal for indoor use, may not always be suitable for outdoor conditions, particularly in extreme weather or rough terrain. Their performance can also be limited by battery life, impacting their suitability for long or continuous operation shifts.

- *Energy Supply and Costs*: In areas where electricity costs are high or where there is limited access to reliable electricity, the operation of electric forklifts can be less feasible. Additionally, if the electricity used for charging comes from fossil fuels, the environmental benefits of electric forklifts are reduced.

- *Limited Range and Speed*: Compared to IC forklifts, some electric models may offer lower maximum speeds and a limited range before needing a recharge, which can be a hindrance in high-intensity or large-scale operations.

- *Maintenance and Technical Expertise*: While electric forklifts generally require less maintenance than IC forklifts, repairing them or maintaining their electrical and battery systems may require specialised skills and knowledge, which can be a barrier in areas with a limited pool of qualified technicians.

- *Adaptation and Change Management*: Transitioning from IC to electric forklifts requires organisational change management, including training for operators and maintenance staff, which can be a barrier in terms of both time and resources.

- *Weight and Size*: Electric forklifts can be heavier due to their battery systems, impacting their suitability for use on floors with weight limitations. Their design might also be bulkier, affecting manoeuvrability in tight spaces.

- *Economic and Policy Environment*: In regions where there is limited governmental support or incentives for electric vehicles, the transition to electric forklifts can be slower. The lack of policies encouraging sustainable practices or providing financial incentives can be a barrier.

6. **Mitigation Benefits**

Electric forklifts offer several climate change mitigation benefits, mainly due to their mode of operation and energy source. These benefits are increasingly relevant as industries and businesses seek sustainable solutions to reduce their carbon footprint. Here are the key benefits:

- *Reduction in Greenhouse Gas Emissions*: Unlike traditional internal combustion engine forklifts that burn fossil fuels, electric forklifts produce zero emissions at the point of use. This significantly reduces the emission of greenhouse gases like carbon dioxide ($CO2$), a major contributor to climate change.
- *Improved Energy Efficiency*: Electric forklifts are generally more energy-efficient compared to their gasoline or diesel counterparts. They convert a higher percentage of electrical energy into mechanical energy, reducing overall energy consumption.
- *Reduced Air Pollution*: By not emitting exhaust gases, electric forklifts contribute to better air quality in the areas they operate, especially important in enclosed spaces like warehouses. This helps in reducing pollutants that contribute to smog and poor air quality, which are also factors in climate change.
- *Utilisation of Renewable Energy*: When electric forklifts are charged using electricity generated from renewable sources such as solar or wind power, their overall environmental impact is further reduced, contributing to a decrease in the reliance on fossil fuels.
- *Noise Pollution Reduction*: While not directly related to climate change, electric forklifts operate much more quietly than combustion engine forklifts, contributing to a more pleasant and less polluted working environment.
- *Lower Carbon Footprint of Operations*: Businesses using electric forklifts can significantly lower the carbon footprint of their operations, aligning with global efforts to combat climate change and achieving sustainability targets.
- *Life Cycle Emission Reductions*: Over their life cycle, electric forklifts can have a lower total environmental impact than traditional forklifts, especially as advancements in battery technology and recycling continue to improve.
- *Promoting Cleaner Technologies*: The adoption of electric forklifts encourages further development and investment in clean energy technologies, which is vital for long-term climate change mitigation.

7. **Potential development benefits**

Social Benefits

- *Improved Workplace Health and Safety*: Electric forklifts produce no exhaust emissions, which is crucial for indoor operations, leading to better air quality and reduced health risks for workers.
- *Noise Reduction*: These forklifts operate more quietly compared to diesel or gas-powered ones, leading to a quieter, less stressful working environment. This can be particularly beneficial in closed spaces like warehouses.

- *Job Creation and Skill Development*: Implementing electric forklift technology might create new job opportunities related to their maintenance and operation, along with the potential for skill development in new technology areas.

Economic Benefits

- *Reduced Operational Costs*: Electric forklifts typically have lower running costs than internal combustion forklifts because electricity is cheaper than fuel, and they require less maintenance.
- *Longevity and Efficiency*: These forklifts often have a longer operational life due to fewer moving parts, leading to cost savings over time. They are also generally more efficient in energy use.
- *Potential for Renewable Energy Use*: If paired with renewable energy sources, like solar power, the cost of operating electric forklifts could be further reduced, providing economic benefits in terms of energy spending.

Environmental Benefits

- *Reduction in Greenhouse Gas Emissions*: By not relying on fossil fuels, electric forklifts contribute to a significant reduction in greenhouse gas emissions, aligning with global efforts to combat climate change.
- *Energy Efficiency*: Electric forklifts are more energy-efficient than traditional forklifts, which contributes to the overall reduction of energy consumption.
- *Reduced Pollution*: Beyond reducing air pollution, electric forklifts also eliminate the risk of fuel spills, contributing to a cleaner and safer environment.

8. **Operations**:

Infrastructure Setup

- *Charging Stations*: Establishing reliable charging infrastructure is crucial. Given Tuvalu's limited size, a few strategically placed charging stations could suffice. These stations should be easily accessible and capable of charging the forklifts efficiently.
- *Power Supply*: Ensuring a consistent and reliable electricity supply is essential for the charging stations. Integrating renewable energy sources, like solar power, could be beneficial given Tuvalu's geographical location and sustainability goals.

Operational Management

- *Scheduling for Charging*: Efficient operation of electric forklifts requires careful planning around charging times to ensure forklifts are available when needed. Implementing a charging schedule that aligns with operational downtimes, like during breaks or off-peak hours, can optimise availability.
- *Maintenance and Servicing:* Regular maintenance is necessary to keep the electric forklifts in good working condition. This includes checking battery health, electrical systems, and mechanical parts.
- *Training for Operators*: Operators need training not just in driving the forklifts but also in safe handling during charging and understanding the limitations and features of electric models.

9. **Costs:**

USD 350,000 Est. cost of equipment
USD 7,000 Associated implementation cost
USD 17,500 Maintenance cost

Technology name: Hydrogen-powered shipping vessel.

1. **Introduction/Background:**

Hydrogen-powered shipping vessels represent a revolutionary development in maritime transport, offering a sustainable alternative to traditional fossil fuel-powered ships. This innovation is particularly significant given the global shipping industry's substantial environmental footprint, primarily due to its reliance on heavy fuel oils.

- *Environmental Concerns and Regulations*: The maritime industry is under increasing pressure to reduce its environmental impact, particularly its greenhouse gas (GHG) emissions. The International Maritime Organization (IMO) has set ambitious targets to cut GHG emissions from international shipping by at least 50% by 2050 compared to 2008 levels.
- *Shift to Sustainable Fuels*: In response to these environmental concerns and regulatory pressures, the industry has been exploring various alternative fuels. Hydrogen has emerged as a promising option due to its potential for zero-emission operations.
- *Technological Advancements*: The development of hydrogen fuel cell technology, which converts hydrogen into electricity to power electric motors, has been pivotal. This technology has seen significant advancements in recent years, making it more viable for larger-scale applications like shipping.

2. **Technology characteristics:**

Hydrogen-powered shipping vessels, a significant innovation in maritime technology, are characterised by several distinctive features that differentiate them from traditional fossil fuel-powered ships. These characteristics revolve around their design, operational capabilities, environmental impact, and the technology used. Here's an overview:

- *Fuel Cell Technology*: These vessels primarily use hydrogen fuel cells to generate power. The fuel cells convert hydrogen into electricity through a chemical reaction, with water and heat as the only by-products. This technology is key to the vessel's operation, replacing conventional internal combustion engines.
- *Zero Emission Operations*: One of the most notable characteristics of hydrogen-powered ships is their potential for zero-emission operations. Unlike ships that burn fossil fuels, hydrogen fuel cells emit no carbon dioxide, nitrogen oxides, sulphur oxides, or particulate matter, making them environmentally friendly.
- *Storage of Hydrogen Fuel*: Hydrogen can be stored in different forms - as compressed gas, liquefied hydrogen, or within chemical compounds like ammonia. The storage method chosen impacts the vessel's design, particularly in terms of space utilisation and safety measures.
- *Energy Efficiency*: Hydrogen fuel cells are generally more efficient than traditional combustion engines. They convert a higher percentage of fuel energy into usable power, which can lead to improved operational efficiency.
- *Safety Design Considerations*: Hydrogen has specific characteristics, such as being lighter than air and having a wide flammability range, which necessitate special safety considerations in vessel design and operation, including robust containment systems and ventilation.
- *Infrastructure Requirements*: The use of hydrogen fuel requires specialised infrastructure for production, storage, and refuelling. This includes the need for hydrogen refuelling stations at ports, which are currently limited but gradually being developed.
- *Reduced Operational Costs*: Although the initial investment in hydrogen technology can be high, the operational costs of hydrogen-powered vessels can be lower in the long run due to the efficiency of fuel cells and the potential for hydrogen to become a cheaper fuel as production scales up.
- *Range and Speed Considerations*: Current hydrogen-powered vessels may have limitations in terms of range and speed compared to conventional ships, largely due to current constraints in hydrogen storage capacity and fuel cell power output.
- *Renewable Energy Integration*: Hydrogen is an effective medium for storing and transporting renewable energy. When the hydrogen used is produced via electrolysis using renewable energy sources, the entire energy chain becomes sustainable.
- *Versatility and Adaptability*: Hydrogen technology can be adapted for various types of vessels, from small passenger ferries to larger cargo ships, although the current focus has been on smaller vessels due to technological and infrastructure constraints.

In summary, hydrogen-powered shipping vessels represent a leap forward in maritime technology, offering a cleaner, more efficient alternative to traditional shipping methods. Their development and broader adoption, however, hinge on advancements in hydrogen fuel cell technology, the expansion of hydrogen infrastructure, and continued efforts in addressing the challenges related to storage, safety, and cost.

3. **Country specific/ applicability:**

The applicability of a hydrogen-powered shipping vessel in Tuvalu is an intriguing concept, especially considering the unique challenges and opportunities presented by Tuvalu. Let's explore various aspects of this idea:

- *Environmental Benefits*: Tuvalu, like many small island nations, is highly vulnerable to climate change, especially sea-level rise. Hydrogen-powered vessels produce zero emissions at the point of use, which aligns with the environmental sustainability goals of such island nations. Using such technology can significantly reduce the carbon footprint of maritime transport.

- *Energy Source and Supply*: The key question for Tuvalu would be the source of hydrogen. Green hydrogen, produced using renewable energy sources like solar or wind power, would be ideal. However, Tuvalu would need to establish infrastructure for hydrogen production, storage, and refuelling. This requires significant investment and technical expertise.

- *Economic Viability*: The initial cost of hydrogen-powered ships and the necessary infrastructure can be high. Tuvalu, with its limited financial resources, might find this challenging. However, long-term operational costs could be lower due to the potential decreasing costs of hydrogen fuel and the maintenance benefits of electric engines. External funding or partnerships might be required.

- *Technical and Maintenance Support*: Hydrogen technology in maritime vessels is relatively new. Maintenance and technical support for such vessels could be a challenge in remote and small island nations like Tuvalu. Training local personnel and establishing technical support systems would be crucial.

- *Regulatory Framework*: Implementing hydrogen-powered shipping would require a robust regulatory framework. This includes safety regulations specific to hydrogen fuel, environmental regulations, and port facility upgrades to handle hydrogen fuel.

- *Range and Capacity*: Hydrogen-powered vessels currently have limitations in range and cargo capacity compared to traditional ships. For Tuvalu, which relies heavily on maritime transport for imports and exports, the suitability of hydrogen ships would depend on their ability to meet the nation's specific transportation needs.

- *International Collaboration and Funding*: Tuvalu could benefit from international collaborations for technology transfer, funding, and expertise. Partnerships with international organisations, other nations, and private entities interested in sustainable maritime technologies could be explored.

- *Pilot Projects and Feasibility Studies*: Before full-scale implementation, pilot projects and comprehensive feasibility studies would be essential. This would provide data on practical challenges, economic viability, and environmental impact.

4. **Status of the technology in the country and its future market potential**

The potential of hydrogen production in Tuvalu has garnered significant interest from foreign investors, including the US Government, marking a promising development in the nation's energy sector. This interest is fuelled by the growing global focus on sustainable and alternative energy sources, with hydrogen being recognized for its potential in contributing to a greener future. Complementing this external interest is a strong sense of political will within Tuvalu itself, reflecting a commitment at the highest levels of government to explore and potentially embrace new energy technologies. Recognizing the importance of this opportunity, a comprehensive feasibility study on hydrogen production is currently underway. This study aims to assess the practical aspects, economic viability, and environmental impacts of establishing hydrogen production facilities in Tuvalu. The outcomes of this study could potentially pave the way for significant advancements in Tuvalu's energy infrastructure and position the nation as a pioneer in sustainable energy production in the Pacific region.

5. **Barriers:**

Implementing hydrogen-powered shipping vessels in Tuvalu faces several barriers, stemming from both the nascent nature of the technology and the specific challenges of the country's context. These barriers include:

- *Technological Maturity*: Hydrogen fuel technology for shipping is still in the early stages of development. The lack of proven, commercially viable models for large-scale hydrogen-powered vessels poses a significant challenge.

- *Infrastructure Requirements*: Establishing the necessary infrastructure for hydrogen fuel, including production facilities, storage, and refuelling stations at ports, requires substantial investment. For a small island nation like Tuvalu, this could represent a significant financial and logistical hurdle.

- *Supply Chain and Availability*: Creating a reliable supply chain for hydrogen fuel in Tuvalu, particularly green hydrogen produced using renewable energy, is a complex task. The availability and consistent supply of hydrogen are crucial for the operation of such vessels.

- *High Costs*: Currently, hydrogen-powered technology and the infrastructure required for its support are relatively expensive. The high costs associated with transitioning to hydrogen-powered shipping could be a prohibitive factor for Tuvalu.

- *Safety and Regulatory Framework*: Hydrogen poses unique safety risks due to its high flammability and low density. Establishing a comprehensive safety and regulatory framework for handling and storing hydrogen is necessary but can be challenging.

- *Skilled Workforce*: Operating and maintaining hydrogen-powered vessels and the associated infrastructure require specialised skills and training. Developing a local workforce with these capabilities is a significant challenge for Tuvalu.

- *Economic Viability*: For Tuvalu, assessing the economic viability of shifting to hydrogen-powered shipping in comparison to conventional fuel options is crucial. The return on investment and long-term economic benefits need to be clearly understood.

- *Environmental Considerations*: While hydrogen is a clean fuel, its production method is crucial in determining its overall environmental impact. Ensuring that hydrogen production in Tuvalu is sustainable and does not negatively impact the fragile island ecosystem is essential.

- *International Collaboration and Standards*: As hydrogen-powered shipping is a global innovation, aligning with international standards and collaborating with other nations for technology transfer and best practices is important, yet it can be a complex process.

- *Public Perception and Acceptance*: Gaining public support and trust in new technologies like hydrogen-powered vessels is vital for their successful implementation, requiring awareness and education initiatives.

6. **Mitigation Benefits**

The adoption of hydrogen-powered shipping vessels presents significant climate change mitigation benefits, particularly in reducing greenhouse gas emissions and improving air quality. Here are some key advantages:

- *Zero Greenhouse Gas Emissions at Point of Use*: Hydrogen fuel cells emit only water vapour and heat, making them a clean energy source that does not contribute to greenhouse gas emissions during operation. This is a significant advantage over traditional fossil fuel-powered vessels, which emit carbon dioxide (CO_2), a major contributor to global warming.

- *Reduction in Air Pollution*: Hydrogen-powered vessels significantly reduce air pollutants such as sulphur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter, which are common by-products of burning diesel and heavy fuel oil. This reduction in air pollutants is beneficial for both environmental and public health, particularly in port cities and coastal areas.

- *Potential for Renewable Energy Integration*: If hydrogen is produced using renewable energy sources, such as wind or solar power, the entire supply chain of hydrogen fuel can be carbon-neutral. This 'green hydrogen' production would further enhance the climate change mitigation benefits by reducing reliance on fossil fuels for both the shipping industry and hydrogen production.

- *Encouraging a Shift to Clean Energy*: The development and adoption of hydrogen-powered vessels can accelerate the shift towards clean energy in the maritime sector, which is traditionally one of the more challenging sectors to decarbonize due to its heavy reliance on fossil fuels.

- *Noise Reduction*: Hydrogen fuel cells operate more quietly than traditional internal combustion engines. This reduction in noise pollution contributes to a better marine environment, particularly benefiting marine wildlife.

- *Indirect Climate Benefits*: By leading the way in adopting hydrogen technology, the shipping industry can drive advancements in hydrogen production, storage, and distribution, benefiting other sectors and contributing to a broader societal shift away from fossil fuels.

- Sustainable Development**: Transitioning to hydrogen-powered shipping aligns with sustainable development goals by promoting clean energy technologies and reducing environmental impact, thereby contributing to a more sustainable and resilient future.

These climate change mitigation benefits position hydrogen-powered shipping as a promising part of the solution to reduce the maritime industry's environmental footprint and help combat global climate change. However, realizing these benefits depends on how the hydrogen is produced and the readiness of the maritime industry to adopt and integrate this technology on a large scale.

7. **Potential development benefits**

Social Benefits

- *Improved Air Quality and Public Health*: Hydrogen-powered vessels emit no harmful pollutants, significantly improving air quality around ports and coastal areas. This reduction in air pollution can lead to better overall public health, particularly in reducing respiratory diseases.
- *Enhanced Quality of Life*: Cleaner and quieter maritime operations contribute to a more pleasant living environment for communities in coastal areas, improving the quality of life for residents.
- *Job Creation and Skills Development*: The development and maintenance of hydrogen-powered maritime infrastructure can create new job opportunities and demand for specialised skills, contributing to local employment and skill development.

Economic Benefits

- *Reduced Fuel Costs*: Over time, hydrogen fuel could become more economically viable compared to traditional maritime fuels, particularly if global supply chains for hydrogen are established and scaled.
- *Diversification of the Economy*: Investing in hydrogen technology could diversify Tuvalu's economy, reducing dependency on certain industries and creating new opportunities in green technology sectors.
- *Attracting Investment and Innovation*: By adopting hydrogen-powered vessels, Tuvalu can position itself as a leader in innovative maritime technology in the Pacific region, potentially attracting investment and partnerships.

Environmental Benefits

- *Significant Emission Reductions*: The primary environmental benefit is the substantial reduction in greenhouse gas emissions, helping mitigate climate change impacts, which is crucial for a vulnerable nation like Tuvalu.
- *Protection of Marine Ecosystems*: Hydrogen-powered vessels contribute to cleaner seas by eliminating oil spills and reducing water pollution, thereby protecting marine biodiversity and ecosystems.
- *Sustainable Energy Transition*: The move towards hydrogen aligns with global efforts to transition to sustainable energy sources, reducing reliance on fossil fuels and promoting environmental stewardship.

8. **Operations**:

Operating hydrogen-powered vessels and the associated hydrogen production involves several key components and processes. Each stage must be carefully managed to ensure efficiency, safety, and sustainability. Here's an overview of these operations:

Operations of Hydrogen-Powered Vessels

- *Fuel Cell Technology*: Hydrogen-powered vessels typically use fuel cell technology to convert hydrogen gas into electricity, which powers the vessel's propulsion system. The fuel cells combine hydrogen with oxygen from the air, producing electricity and water as by-products.
- *Hydrogen Storage*: Hydrogen is stored on board in either compressed gas or liquefied form. Efficient and safe storage systems are critical, given hydrogen's high flammability and low density.

- *Fuelling Infrastructure*: Vessels require specialised fuelling stations for refilling their hydrogen tanks. These stations need to be equipped with pumps and storage facilities capable of handling hydrogen's unique properties.

- *Safety and Emergency Procedures*: Given hydrogen’s flammability, robust safety protocols are essential. This includes sensor systems for leak detection, fire suppression systems, and emergency response procedures.

- *Maintenance and Training*: Regular maintenance of the fuel cell system and storage tanks is necessary. Crew members and port staff must be trained in handling hydrogen and operating the fuel cell systems.

9. **Costs:**

USD 85,500,000 (est. cost of equipment)
USD 4,275,000 (associated implementation cost)
USD 1,710,000 (maintenance cost)

Technology name: Shore-side electrical supply for at berth vessels

1. **Introduction/Background:**

Shore-side electrical supply, also known as "Cold Ironing," "Shore Power," or "Alternative Maritime Power (AMP)," is a method that allows docked ships to switch off their diesel engines and connect to a land-based electrical grid for their power needs. This technology is akin to an electric car plugging into a charging station. The concept emerged in the early 2000s, driven by the need to mitigate air pollution in port areas, which are often close to dense urban regions.

The environmental benefits of using shore-side electrical supply are significant. It enables ships to drastically reduce the emission of harmful substances such as sulphur oxides (SOx), nitrogen oxides (NOx), carbon dioxide (CO2), and particulate matter. Additionally, it contributes to lowering noise pollution in port areas. The technical aspects of this system involve accommodating the varying power needs of different ships, which necessitates versatile and often complex infrastructure. There's an ongoing effort to standardise these systems globally to ensure compatibility between ships and port facilities.

However, the implementation of shore-side electrical supply is not without challenges. Ports need substantial investments to install the necessary infrastructure. Also, ship operators may need to retrofit older vessels to make them compatible with these systems. The economic and operational considerations are significant factors in the adoption rate of this technology.

Globally, the uptake of shore-side electrical supply varies. It's more prevalent in regions with stringent environmental regulations. Many governments and international bodies like the International Maritime Organization (IMO) are pushing for the use of shore power to meet environmental targets. As environmental awareness increases, more ports and shipping companies are expected to adopt shore power. Technological advancements are also underway to enhance the efficiency and cost-effectiveness of these systems.

Shore-side electrical supply is a critical development in the maritime industry, signifying a shift towards more sustainable and environmentally responsible operations. By enabling ships to switch off their engines while docked, it not only contributes to reducing pollution but also represents a broader move towards cleaner maritime activities.

2. **Technology characteristics:**

Shore-side electrical supply for at berth vessels, commonly known as "Cold Ironing," "Shore Power," or "Alternative Maritime Power (AMP)," has several key characteristics that define its technology and application:

- *Emission Reduction*: The primary characteristic of shore-side electrical supply is its ability to significantly reduce emissions from ships while docked. By connecting to land-based power sources, ships can turn off their diesel engines, leading to a decrease in air pollutants like sulphur oxides (SOx), nitrogen oxides (NOx), carbon dioxide (CO2), and particulate matter.

- *Noise Pollution Reduction*: Apart from lowering air pollution, this technology also reduces noise pollution in port areas. The use of shore power leads to quieter operations as the ship's main and auxiliary engines, which are typically noisy, can be turned off.

- *Compatibility and Standardization*: A critical aspect of shore-side electrical supply is the need for compatibility between the ship's electrical systems and the port's infrastructure. This includes standardising connections, voltage, and frequency to ensure that ships can seamlessly connect to the shore-side power.

- *Infrastructure Requirements*: Ports need to install specialised infrastructure to provide shore-side electrical supply. This includes transformers, switchgears, frequency converters, and cabling systems designed to handle the high power demands of large vessels.

- *Power Capacity and Versatility*: The system must be capable of supplying enough electricity to meet the varied demands of different types of vessels, from small passenger ships to large container ships and cruise liners. This requires a versatile and robust power supply system.

- *Environmental Regulations Compliance*: Shore-side electrical supply helps ports and shipping companies comply with increasingly stringent environmental regulations aimed at reducing emissions from maritime operations.

- *Operational Changes for Vessels*: Ships need to be equipped with onboard equipment to connect to shore-side power. This might include retrofitting older vessels with new electrical systems and training crew in the use of this technology.

- *Cost Considerations*: The installation of shore-side power infrastructure and the retrofitting of ships entail significant costs. However, these costs can be offset by the environmental and health benefits, and potential savings in fuel costs for ships while docked.

- *Energy Source Variability*: The environmental impact of shore-side electrical supply also depends on the source of the electricity provided by the port. If the electricity comes from renewable sources, the environmental benefits are maximised.

- *Global Adoption Trends*: The adoption of this technology varies globally, influenced by factors like local environmental policies, the cost of implementation, and the availability of necessary infrastructure.

3. **Country specific/ applicability:**

Capacity

Tuvalu's current electricity generation capacity and infrastructure may need significant upgrades to support shore-side power supply. Considering the small scale of Tuvalu's economy and its energy sector, this could be a substantial investment. The country's reliance on imported fossil fuels for electricity generation means that transitioning to shore-side power would ideally involve developing renewable energy sources to ensure sustainability and cost-effectiveness.

Scale of Application

The scale of application in Tuvalu would likely be small compared to larger ports globally due to the lower volume of maritime traffic. The focus might be on specific types of vessels that frequently dock at Tuvalu's ports, such as cargo ships or cruise liners, if applicable.

Time Horizon - Short/Medium/ Long Term

The time frame for implementing shore-side power in Tuvalu would depend on factors like funding availability, infrastructure development, and technological access. Given the small scale and limited resources, a phased approach might be more feasible, starting with pilot projects and gradually expanding.

4. **Status of the technology in the country and its future market potential**

In Tuvalu, the availability of shore power is a notable advancement, yet its usage is currently limited to the HMTSS Te Mataili, which is the only vessel equipped with the appropriate fittings to connect to this facility. This unique capability of the Te Mataili demonstrates the practical application of shore power within Tuvalu's maritime infrastructure. The crew of the HMTSS Te Mataili, along with the Tuvalu Electricity Corporation, are well-equipped and have the necessary skills to maintain and operate the shore power system efficiently. Their combined expertise ensures the successful utilization of this environmentally friendly power source for the Te Mataili, showcasing the effective implementation of shore power technology in Tuvalu.

5. **Barriers:**

Implementing shore-side power supply for vessels at berth in Tuvalu faces several barriers, mainly due to the country's unique geographical, economic, and infrastructural characteristics. Understanding these challenges is crucial for planning and executing such a project effectively.

- *Limited Infrastructure and Technological Resources:* Tuvalu's existing electrical infrastructure may not be capable of supporting the additional load required for shore-side power without significant upgrades. The country's limited access to advanced technology and expertise in this area can be a major barrier to implementation.

- *High Initial Investment Costs*: The cost of setting up shore-side power facilities, including retrofitting ports and upgrading power generation and distribution systems, can be prohibitively high, especially for a small economy like Tuvalu. Funding such projects can be challenging, requiring significant external aid or investment.

- *Dependence on Imported Fossil Fuels*: Tuvalu largely depends on imported fossil fuels for power generation, which may diminish the environmental benefits of shore-side power unless the electricity is sourced from renewable energy. Transitioning to renewable energy sources to support shore-side power would require additional investments and infrastructural changes.

- *Environmental and Geographical Constraints*: Being a low-lying atoll nation, Tuvalu faces significant environmental challenges, including the threat of sea-level rise, which can impact port infrastructure. Limited land area may restrict the expansion of power generation facilities, especially for renewable energy sources like solar or wind.

- *Regulatory and Policy Barriers:* The absence of a regulatory framework supporting the adoption of shore-side power can be a hindrance. Policies and incentives to encourage the use of shore-side power by shipping companies are necessary but may be challenging to implement.

- *Operational and Technical Challenges*: Ensuring compatibility between ship systems and shore-side power infrastructure is a technical barrier, as different ships may have different power requirements and standards. There may be a lack of skilled workforce to operate and maintain shore-side power systems, necessitating training and capacity building.

- *Small Scale of Maritime Traffic*: Given Tuvalu's small size and limited maritime traffic, the cost-benefit ratio of investing in shore-side power may not be as favourable as in larger ports, reducing the economic feasibility of such projects.

- *Global Shipping Industry Dynamics*: Convincing international shipping lines to adapt to new systems in a small market like Tuvalu could be challenging. There may be a lack of immediate incentive for shipping companies to retrofit their vessels to use shore-side power, especially if it's not widely adopted in the region.

6. **Mitigation Benefits**

Implementing shore-side power supply for vessels at berth in Tuvalu can offer several climate change mitigation benefits, particularly in reducing greenhouse gas emissions and other pollutants associated with maritime activities. These benefits are crucial for a country like Tuvalu, which is significantly affected by climate change. Some of the key benefits include:

- *Reduction in Greenhouse Gas Emissions*: When vessels switch from their diesel-powered auxiliary engines to shore-side power, it leads to a significant reduction in emissions of greenhouse gases (GHGs) like carbon dioxide (CO_2). If the shore-side power is generated from renewable energy sources, this reduction is even more impactful in mitigating climate change.

- *Decrease in Air Pollution*: Using shore-side power helps in reducing emissions of harmful air pollutants like sulphur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter from ships. These pollutants contribute to air quality issues and have adverse health effects. Cleaner air contributes to a healthier environment for both local populations and marine ecosystems.

- *Noise Reduction*: Shore-side power reduces noise pollution since vessels no longer need to run their diesel engines while at berth. This creates a quieter and more pleasant environment, which is beneficial for both marine life and local communities.

- *Energy Efficiency*: Shore-side power systems can be more energy-efficient compared to ship-based auxiliary engines. Improved energy efficiency contributes to overall efforts to combat climate change.

- *Promotion of Renewable Energy*: The implementation of shore-side power can serve as an impetus for developing renewable energy infrastructure in Tuvalu, such as solar or wind power. This not only provides power for ships but also contributes to the nation's overall renewable energy capacity.

- *Reduction in Fossil Fuel Dependence*: By enabling ships to use electricity from the local grid, there is a reduced reliance on fossil fuels. For Tuvalu, this means less dependence on imported fuel, aligning with broader goals of energy independence and sustainability.

- *Setting a Precedent for Climate Action*: Implementing shore-side power in Tuvalu could set an example for other small island nations and contribute to global efforts in reducing the carbon footprint of the maritime industry. It demonstrates a commitment to innovative solutions in the face of climate change challenges.

- *Encouraging Sustainable Maritime Practices*: The adoption of shore-side power can encourage more environmentally friendly practices within the maritime industry, contributing to global climate change mitigation efforts.

7. **Potential development benefits**

Social Benefits

- *Improved Air Quality and Public Health*: Reducing emissions from ships while at berth directly translates to cleaner air, which can have a profound impact on public health, especially in reducing respiratory and cardiovascular diseases. Better air quality contributes to overall community well-being and can improve life quality for residents near port areas.

- *Noise Pollution Reduction*: Shore-side power leads to quieter operations at ports, as ships no longer need to run diesel engines. This reduction in noise pollution enhances the living conditions for nearby communities.

- *Employment and Skills Development*: Implementing and maintaining shore-side power infrastructure can create new jobs and demand for specialised skills, contributing to local employment opportunities. This also provides an avenue for capacity building and professional development in new technologies and green energy sectors.

Economic Benefits

- *Energy Cost Savings for Shipping Companies*: Using shore-side electricity can be more cost-effective for shipping companies in the long run compared to running ship-based auxiliary engines, leading to operational cost savings.

- *Boost to Local Economy*: The development and maintenance of shore-side power infrastructure can stimulate local economic activity, including construction, engineering, and ongoing maintenance services. The use of local renewable energy sources for shore-side power can also reduce the national reliance on imported fuels, contributing to economic stability and energy independence.

- *Attracting Eco-friendly Shipping Lines*: Ports equipped with shore-side power can attract environmentally conscious shipping companies, potentially increasing maritime traffic and associated economic activities.

Environmental Benefits

- Reduction of Greenhouse Gas Emissions: By switching from diesel-powered generators to shore-side electricity, there is a significant reduction in greenhouse gas emissions, contributing to global efforts against climate change.

- *Lower Emissions of Pollutants*: Shore-side power reduces emissions of sulphur oxides, nitrogen oxides, and particulate matter, leading to a cleaner and healthier environment.

- *Promotion of Renewable Energy*: Implementing shore-side power can accelerate the development and integration of renewable energy sources into the national grid, enhancing environmental sustainability.

- *Reduced Impact on Marine Ecosystems*: Lower pollution levels benefit marine ecosystems, preserving biodiversity and contributing to the health of ocean habitats.

Integrative Benefits

- *Resilience and Adaptation to Climate Change*: For a country like Tuvalu, which is particularly vulnerable to the impacts of climate change, transitioning to cleaner energy sources and reducing emissions are critical steps in building resilience.

- *Alignment with Sustainable Development Goals (SDGs)*: Implementing shore-side power aligns with multiple SDGs, including affordable and clean energy, sustainable cities and communities, and climate action.

8. **Operations**:

The implementation and operation of shore-side power supply (SSPS) in Tuvalu involves establishing a reliable power source, possibly integrating renewable energy, and modifying port infrastructure with power supply stations and standardised connection systems. Safety is paramount, necessitating strict protocols and systems to manage the risks associated with high-voltage power transfers.

Ships docking in Tuvalu may require retrofitting to ensure compatibility with the shore-side power infrastructure. Standard operating procedures for safe connection and disconnection to the power supply are essential, alongside regular monitoring and maintenance of the infrastructure. Regulatory frameworks and guidelines for SSPS usage are necessary, possibly coupled with incentives for shipping companies using shore-side power. Monitoring emission reductions and conducting a continuous cost-benefit analysis of the SSPS operation are important for assessing environmental and economic impacts. Given Tuvalu's limited resources and vulnerability to climate change, the sustainability and resilience of the SSPS infrastructure are crucial. Developing a local skilled workforce for the operation and maintenance of SSPS, and conducting regular training for port staff and vessel crew, are also key aspects of the project.
9. **Costs:** USD 95,000 (est. cost of equipment) USD 5,000 (associated implementation costs) USD 10,000 (maintenance/installation)