Government of Tuvalu

BARRIER ANALYSIS AND ENABLING FRAMEWORK OF MITIGATION TECHNOLOGIES

TNA TECHNOLOGY NEEDS ASSESSMENT

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USP THE UNIVERSITY OF THE SOUTH PACIFIC

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Foreword

Climate change poses significant challenges to the small island nation of Tuvalu, particularly in the sectors of energy and transport. As we strive to adapt to these changes, it is crucial to identify and overcome the barriers that hinder our progress and to establish an enabling framework that supports the implementation of priority innovative technologies, and reduce damage to life, property, natural eco-systems and the Tuvalu economy.

This Barrier Analysis and Enabling Framework report focuses on two critical sectors:

1. **Energy**: Tuvalu is aiming to be 100% reliant on renewable energy by 2025. By prioritizing renewable energy technologies, Tuvalu is reducing its reliance on fossil fuels and focusing more on renewable energy technologies to meet its targets. **Transport**: Transport is a sector that has a high carbon footprint. Tuvalu is looking at technologies that not only reduce its carbon footprint, but also technologies that are more viable and sustainable for Tuvalu.

This report was developed in partnership with the UNEP Copenhagen Climate Centre (UNEP CCC) and the University of the South Pacific (USP) aims to provide a comprehensive assessment of the barriers to technology adoption in these sectors and to propose actionable strategies to create an enabling environment for their implementation. By addressing these challenges, we can build a more resilient and sustainable future for Tuvalu.

As the Minister responsible for climate change concerns, it gives me great pleasure to present both adaptation and mitigation technologies outlined in report, to build greater resilience in Tuvalu and mitigate the impacts of Climate Change.

I would like to thank te TNA National team, UNEP CCC and USP for their invaluable contributions to preparing this report.

Hon. Dr. Maina Vakafua Talia
Minister for Home Affairs, Climate Change, and Environment

Acknowledgement

The Climate Change Department through the TNA Project Coordinator, the Assistant Project Coordinator and the National TNA Consultant would like to acknowledge the contribution of all public and private stakeholders from different sectors who were involved in preparing and finalizing this Technology Needs Assessment report for Tuvalu. 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. Lastly, enormous gratitude to the Global Environment Facility (GEF) for providing financial support and the UNEP Copenhagen Climate Centre for their technical support and guidance.

Contents

Executive Summary

The Technology Needs Assessment (TNA) for Mitigation report aims to identify and analyze the barriers to adopting low-emission technologies in Tuvalu's energy and transport sectors. It also outlines enabling frameworks to overcome these barriers, promoting the country's transition towards a more sustainable future. Given Tuvalu's vulnerability to climate change and reliance on imported fossil fuels, this report focuses on technologies that reduce greenhouse gas emissions and enhance energy security.

In the energy sector, the report examines technologies such as **Solar PV + Battery Energy Storage Systems (BESS), Small-scale Wind turbines, and Biogass (Biogas)**. The main barriers identified include high initial capital costs, limited access to financing, and inadequate technical expertise. To address these challenges, the report recommends implementing financial incentives, developing a robust regulatory framework, and investing in capacity-building programs. These measures aim to reduce dependency on fossil fuels, stabilize the energy supply, and improve overall energy resilience.

In the transport sector, the report assesses the potential of **electric light-duty vehicles, fuel-efficient heavy-duty vehicles, and shore side electrical supply for at berth vessels (shore-power)**. The barriers in this sector include the high cost of technology adoption, insufficient infrastructure, and a lack of public awareness. The proposed solutions involve providing subsidies and tax incentives, developing a comprehensive network of charging and refueling stations, and conducting public awareness campaigns to increase the adoption of these technologies.

The report emphasizes the importance of a coordinated approach, highlighting the need for collaboration between government agencies, the private sector, and international partners. By addressing both economic and non-financial barriers through a mix of targeted measures, Tuvalu can effectively promote the adoption of low-emission technologies. This transition will contribute significantly to the country's climate change mitigation efforts, reduce operational costs, and enhance energy security.

Overall, the TNA Mitigation BAEF Draft Report provides a comprehensive roadmap for Tuvalu's sustainable development, emphasizing the critical role of technology in achieving the country's environmental and economic goals.

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Chapter 1 Energy Sector

Tuvalu's energy sector faces significant challenges, with a current over-reliance on imported diesel for electricity generation. This dependence exposes the country to vulnerabilities such as fluctuating global fuel prices and supply chain disruptions. To mitigate these risks and address the broader impacts of climate change, Tuvalu has committed to a transition towards renewable energy sources, aiming to enhance energy security, reduce greenhouse gas (GHG) emissions, and build a more resilient energy infrastructure.

Guided by the Tuvalu National Energy Policy (TNEP) and its Intended Nationally Determined Contributions (INDCs) under international climate frameworks, Tuvalu has set ambitious targets to achieve 100% renewable energy in electricity generation by 2025. As of the latest reports, renewable energy contributes to about 5% of the total electricity generation in Funafuti, primarily from solar photovoltaic (PV) systems. Diesel generators, however, still dominate the energy mix, with significant reliance on imported fuel for electricity generation across the islands. The Tuvalu Electricity Corporation (TEC) has taken steps to diversify the energy sources with solar and wind projects and aims to extend renewable energy to outer islands. The current energy access rate stands at near 100%, but the focus remains on expanding renewable sources, including solar PV, Battery Energy Storage Systems (BESS), Small-Scale Wind Turbines, and Biogas technologies, to meet the 2025 goal.

This chapter introduces the Mitigation Barrier Analysis and Enabling Framework (BAEF) for Tuvalu's energy sector. It provides an overview of the preliminary targets for renewable energy technology transfer and diffusion, aligning these targets with national energy and climate policies. The chapter also sets the stage for identifying and analyzing the barriers that could hinder the deployment of these technologies, such as financial limitations, technical expertise gaps, institutional challenges, and social acceptance issues.

The report proposes a series of measures to overcome these barriers, including policy interventions, financial support mechanisms, and capacity-building initiatives. Each proposed measure is evaluated for its feasibility and potential impact, ensuring that the recommendations are contextually relevant to Tuvalu's unique energy landscape.

The subsequent analysis is intended to guide policymakers and stakeholders in addressing these barriers through targeted interventions. These include policy reforms, capacity-building programs, financial mechanisms, and technological innovations tailored to Tuvalu's unique circumstances. By offering practical and context-specific solutions, the report aims to create an enabling environment for the successful adoption of renewable energy technologies.

This structured approach lays the foundation for Tuvalu's energy transition, ensuring that the country can achieve its energy goals while contributing to global climate commitments. The detailed examination of barriers and proposed enabling measures presented in the following sections will provide a comprehensive roadmap for Tuvalu's sustainable energy future.

1.1 Preliminary targets for technology transfer and diffusion

The energy sector plays a central role in Tuvalu's socio-economic development and climate change mitigation strategy. Given the country's heavy reliance on imported diesel for electricity generation, transitioning to renewable energy is crucial to reduce vulnerability to fluctuating international fuel prices and supply disruptions. The Tuvalu National Energy Policy (TNEP) and Intended Nationally Determined

Contributions (INDCs) underscore the importance of enhancing energy security, increasing energy efficiency, and cutting greenhouse gas (GHG) emissions.

The Technology Needs Assessment (TNA) project, conducted in collaboration with the Global Environment Facility (GEF) and the United Nations Environment Programme (UNEP), has prioritized three key renewable energy technologies for Tuvalu: Solar Photovoltaic (PV) systems integrated with Battery Energy Storage Systems (BESS), Small-Scale Wind Turbines, and Biogas systems. These technologies are expected to drive Tuvalu's transition to a more sustainable and resilient energy system, supporting the national goal of 100% renewable energy by 2025.

National Strategies and Policies

Several national frameworks guide Tuvalu's energy sector transformation:

Tuvalu National Energy Policy (TNEP 2009):

- Goals: Achieve 100% renewable energy in electricity generation by 2025, improve energy efficiency, and reduce reliance on imported fossil fuels.
- Relevance to the Report: The 2009 TNEP outlines the strategic importance of integrating Solar PV + BESS, Small-Scale Wind Turbines, and Biogas technologies to meet energy security goals while reducing fossil fuel dependency. This report aligns with the 2009 TNEP's objectives by identifying practical strategies to deploy these renewable technologies.

Intended Nationally Determined Contributions (INDCs):

- Goals: Achieve a 100% reduction in GHG emissions from electricity generation by 2025, with a 60% reduction in total GHG emissions across the energy sector compared to 2010 levels.
- Relevance to the Report: The deployment of Solar PV + BESS, Biogas, and Small-Scale Wind Turbines is critical to achieving Tuvalu's INDC targets, especially for reducing emissions in the electricity and agricultural sectors. Biogas technologies, in particular, address waste management and agricultural emissions, providing a dual benefit.

These strategies and goals reflect Tuvalu's commitment to sustainable energy development and its proactive approach to addressing the challenges posed by climate change. The successful implementation of these strategies will require concerted efforts from all stakeholders, including government agencies, private sector entities, and international partners.

Table 1: National Strategies and Goals

Strategy	Short-term Milestones (2025)	Medium-term Milestones (2030)	Long-term Milestones (2035)	Responsibility
Increased use of renewable energy and other alternative forms of energy	Develop and integrate 10 MW of solar PV capacity with 5 MW of BESS	Achieve 50% of grid electricity supplied from renewable energy sources	Explore and evaluate other alternative forms of energy	Tuvalu Electricity Corporation (TEC), Department of Energy

Improve energy efficiency (Demand & Generation)	Implement energy efficiency measures in residential, commercial, and government sectors Enhance efficiency in electricity generation (Generation side)	Achieve 30% improvement in energy efficiency Universal access to energy-efficient technologies and practices	Ensure continuous improvement in demand-side and generation-side efficiency	TEC, Department of Energy Consumers (for demand side energy and efficiency)

Market Mapping for Key Renewable Technologies

Understanding the market structure for Solar PV + BESS, Small-Scale Wind Turbines, and Biogas technologies is essential for identifying stakeholders, financial mechanisms, and potential supply chain challenges.

Table 2: Market Mapping

Market Component	Solar PV + BESS	Small-Scale Wind Turbines	Biogas
Government Agencies	Ministry of Energy, Tuvalu Electricity Corporation (TEC)	Ministry of Energy, Department of Environment	Ministry of Agriculture, Ministry of Waste Management
Private Sector	International solar suppliers, local contractors	Wind turbine manufacturers, local contractors	Agricultural producers, biogas technology suppliers
Financial Institutions	Global Environment Facility (GEF), Green Climate Fund	International development banks, GCF	Development banks, public-private partnerships
Consumers	Households, businesses, public sector	Coastal communities, off-grid users	Agricultural sector, waste processing facilities
Supply Chain	Imported solar panels, batteries	Imported wind turbines, locally assembled components	Local waste feedstock, imported biogas processing units

Technology-Specific Targets for Tuvalu

The following preliminary targets for each technology are proposed to meet Tuvalu's national energy goals and GHG reduction commitments.

Table 3: Technology Specific Targets

Technology	Target Deployment	Expected Impact
Solar PV with Battery Energy Storage Systems (BESS)	Develop and integrate 10 MW of solar PV capacity with 5 MW of BESS into the national grid by 2028	Enhance grid stability, reduce reliance on imported fossil fuels, and cut annual carbon emissions by approximately 12,000 tons
Biogass	Achieve 10% biogas blending in the national fuel supply by 2030	Reduce carbon emissions by approximately 20,000 tons annually
Small-Scale Wind Turbines	Install 50 small-scale wind turbines (each with a capacity of 10 kW) in coastal and island communities by 2030	Supplement local power supply, reduce diesel usage, and cut annual carbon emissions by approximately 2,000 tons

The adoption of these renewable energy technologies directly contributes to the goals set by both the TNEP and INDCs:

- **TNEP:** The deployment of Solar PV + BESS, Small-Scale Wind Turbines, and Biogas will help achieve Tuvalu's 100% renewable energy target by 2025. This strengthens energy security while reducing dependency on fossil fuels.
- **INDCs:** These technologies enable Tuvalu to meet its emissions reduction targets, particularly in electricity generation. The integration of biogas technologies also addresses the INDCs' broader objectives in the agriculture and waste sectors.

By aligning with these strategic priorities, the deployment of these technologies ensures that Tuvalu can meet its climate and energy goals while promoting sustainable development and resilience against climate change. This holistic approach sets the foundation for the comprehensive analysis that follows, addressing both the opportunities and challenges of implementing these technologies within Tuvalu's unique context.

1.2 Barrier analysis and possible enabling measures for Solar PV with Battery Energy Storage System (BESS)

1.2.1 General Description

Solar Photovoltaic (PV) systems for national grid electricity generation, combined with Battery Energy Storage Systems (BESS), represent a critical advancement in renewable energy technology. These systems harness solar energy through photovoltaic panels and store the generated electricity in batteries, ensuring a reliable supply even during periods of low solar activity or high demand. This technology mitigates the

intermittency of solar power, thereby stabilizing the grid, balancing supply and demand, and providing backup power during peak usage times or when solar generation is low. In the context of Tuvalu, the deployment of Solar PV + BESS systems aim to reduce reliance on imported diesel, enhance energy security, and contribute to climate change mitigation efforts by lowering greenhouse gas emissions.

1.2.1.1 Technology Status in Tuvalu

As of 2020, Tuvalu has made significant progress in adopting renewable energy, particularly through solar PV installations. In Funafuti, the capital, the total installed generation capacity is 2,550 kW, with 74% still reliant on diesel. (Government of Tuvalu, 2022, 10) Off-grid generators and solar PV installations contribute to the remaining capacity. In the outer islands, 80% to 90% of electricity is already being generated from renewable sources, primarily solar PV. However, due to high demand, solar PV panels alone cannot meet the full energy needs, and diesel generators are used to cover the remaining 10% to 20% of electricity generation. The integration of Solar PV with Battery Energy Storage Systems (BESS) will be key to further reducing reliance on diesel and enhancing energy sustainability across the islands.

1.2.1.2 Category and Market Characteristics

Solar PV (national grid) combined with Battery Energy Storage Systems (BESS) can be characterized as a publicly provided good, managed and supplied by the Government to benefit the public. As a large infrastructure project, it requires substantial investment, which is often sourced through donor funding and international partnerships. The deployment of this technology at a national scale aims to provide clean and reliable energy across Tuvalu, reducing reliance on diesel and contributing to energy security. Given its size and the capital investment needed, government coordination and support are essential for its successful implementation and long-term management.

1.2.2 Identification of Barriers for Technology A1(Solar PV (National Grid electricity generation) + BESS)

1.2.2.1 Preliminary Barrier Identification

As a first step, a list of potential barriers to the diffusion of Solar PV + BESS technology in Tuvalu was identified through a literature review supplemented by expert opinion. In random order, the identified barriers included the following:

1. High initial capital costs
2. Limited access to financing
3. Lack of skilled personnel for installation and maintenance
4. Insufficient grid infrastructure for solar integration
5. High logistical costs due to Tuvalu's remote location
6. Vulnerability to climate impacts, such as storms and rising sea levels
7. Dependence on external donors for project funding
8. Limited public awareness of renewable energy benefits
9. Inconsistent government policies supporting renewable energy
10. Challenges in land availability for large solar installations
11. Short lifespan of battery systems and high replacement costs
12. Low community engagement in solar energy projects
13. Poor coordination between stakeholders and departments

14. Fluctuations in energy demand and intermittent energy supply from solar sources

The final screening and prioritization of the above-mentioned identified barriers to the diffusion of this technology were undertaken through extensive consultation and interviews with experts and stakeholders in addition to the use root cause analysis tool with a starter problem and the subsequent solution trees. Key identified barriers are briefly discussed below.

1.2.2.2 Economic and Financial Barriers

a. High initial investment and maintenance cost

The deployment of Solar PV + BESS technology in Tuvalu involves significant upfront capital expenses. These costs include the purchase and installation of solar panels, inverters, and battery systems. The remoteness of Tuvalu also increases import and logistical expenses, contributing to elevated overall costs. Recent solar PV projects, such as the 500 kW Solar PV Hybrid Power System installed in Funafuti by Tuvalu Electricity Corporation (TEC) and funded by Abu Dhabi through Masdar, suggest costs in the range of USD 1,100 to USD 1,400 per kW (Singh, 2023). Additionally, BESS installations, like the 500 kW system, are essential for ensuring energy reliability, with estimated costs between USD 600 to 700 per kWh (Lotolua, 2021).

Further illustrating these financial barriers, the 182 kW Solar Mini-Grid System installed in three outer islands (Nukufetau, Nui, Nukulaelae), funded by the European Union, aligns with typical costs in the Pacific Islands region, with solar PV systems ranging from USD 1,000 to USD 1,500 per kW (Singh, 2023). These examples highlight both the potential for renewable energy growth and the financial challenges faced by small island nations like Tuvalu. The integration of Battery Energy Storage Systems (BESS) will be key to further reducing reliance on diesel and ensuring sustainable energy access across Tuvalu (UNDP, 2021).

b. Limited access to financing

Despite the potential of Solar PV + BESS to significantly reduce Tuvalu's reliance on expensive diesel imports, securing the necessary financing for these technologies remains a substantial challenge. Local financing options are scarce, and private investment in the energy sector is minimal, largely due to the perceived high risks associated with renewable energy projects in small, climate-vulnerable nations like Tuvalu. The capital-intensive nature of these projects, particularly for infrastructure such as solar photovoltaic systems and battery energy storage, makes financing difficult without international support.

Tuvalu's energy transition efforts have relied heavily on international donor-funded projects. For instance, the 500 kW Solar PV Hybrid Power System installed in Funafuti, funded by Abu Dhabi through Masdar, demonstrates how external financing plays a critical role in deploying renewable energy solutions (Singh, 2023). Additionally, the Asian Development Bank's (ADB) Increasing Access to Renewable Energy Project (IAREP) is another example of external funding supporting Tuvalu’s renewable energy efforts, including the installation of 500 kW of solar capacity in Funafuti and 224 kW in the outer islands, paired with a Battery Energy Storage System (ADB, 2023).

These examples underscore the essential role of international aid in financing Solar PV and BESS projects in Tuvalu. Local markets are currently unable to generate the capital required for such large-scale, transformative infrastructure, reinforcing the country’s dependence on donor-funded initiatives to achieve its 100% renewable energy target by 2025. Without continued external support, the development and integration of solar PV and battery storage systems remain uncertain.

1.2.2.3 Non-Financial Barriers

Policy, Legal, and Regulatory Barriers

a. Limited capacity of the Department of Energy

Although Tuvalu has a central Department of Energy, responsible for overseeing energy matters, the department is currently understaffed and cannot effectively manage and scale renewable energy projects like large Solar PV + BESS installations. This lack of capacity slows down decision-making, project management, and the implementation of critical energy policies.

Furthermore, while Tuvalu's National Energy Policy (TNEP, 2009) sets ambitious targets for 100% renewable energy by 2025, there are instances where policy clarity is lacking, particularly regarding grid integration for renewable energy. The lack of a clear framework for how independent solar PV systems can feed into the national grid has created delays and confusion for both project developers and the Tuvalu Electricity Corporation (TEC). For example, the absence of specific regulations for the connection and compensation of privately owned solar installations hinders the wider adoption of renewable energy systems across the islands.

b. Unclear roles and responsibilities among supporting institutions

While the Department of Energy leads energy-related initiatives in Tuvalu, there are often gaps in coordination with other governmental and technical bodies, such as the Tuvalu Electricity Corporation (TEC) and the Ministry of Public Works. These entities play crucial roles in infrastructure development and energy transition efforts, yet the lack of a defined structure and clear responsibilities among these institutions results in delays in policy implementation and creates operational challenges.

For instance, during the implementation of certain Solar PV + BESS projects, unclear protocols between TEC and the Department of Energy have caused confusion regarding grid integration and maintenance responsibilities. This ambiguity has led to delays in project timelines and operational inefficiencies, as overlapping duties are neither clearly assigned nor well-coordinated. The absence of streamlined communication pathways between these bodies further exacerbates the issue, causing fragmentation in Tuvalu's overall renewable energy strategy.

Technical Barriers

a. Limited technical expertise in installation and maintenance

Tuvalu faces a shortage of trained professionals who can design, install, and maintain Solar PV + BESS systems. This gap in local expertise leads to heavy reliance on foreign consultants, increasing project costs. Moreover, maintaining BESS systems over time requires specialized skills that are currently lacking in the country, which affects the long-term sustainability of these projects.

b. Grid limitations and energy demand fluctuations

Tuvalu's existing grid infrastructure is limited in its ability to support the integration of large-scale renewable energy sources, particularly when combined with BESS. The system is not fully equipped to handle fluctuations in energy supply, integration of large amounts of variable renewable energy (such as solar) and demand, causing challenges in maintaining grid stability, particularly in times of low solar generation. Upgrading the grid to handle these fluctuations would require further investments.

Environmental and Geographic Barriers

a. Vulnerability to climate impacts

Tuvalu is highly vulnerable to the impacts of climate change, including sea-level rise, extreme weather events, and coastal erosion. These factors pose significant risks to the infrastructure needed for Solar PV + BESS systems, which require land and structural resilience. Additionally, with 100% of the population residing within 1km of the coast (Pacific Community, 2023), the exposure to these risks is heightened. Climate-proofing these systems involves additional costs, further complicating the financial viability of such projects.

Information and Awareness Barriers

a. Low public awareness of renewable energy benefits

The general public in Tuvalu is not fully aware of the long-term benefits of Solar PV + BESS, such as reduced dependence on diesel, energy security, and environmental sustainability. Without widespread awareness campaigns, public buy-in for these projects may remain limited, potentially hindering the adoption of the technology.

1.2.3 Identified Measures

This section discusses the measures needed to overcome the barriers to the implementation of Solar PV + Battery Energy Storage Systems (BESS) in Tuvalu. The main methodology employed for the identification of appropriate measures was the development of problem and solution trees through stakeholder participation, alongside the detailed analysis of existing national policies and practices in renewable energy (Annex 1.4). A series of discussions held during the barrier analysis workshop led to the identification of key measures needed to address and eliminate the barriers mentioned earlier.

1.2.3.1 Economic and Financial Measures

a. **Reduce Import Tariffs and Taxes**: To offset the high initial cost of Solar PV panels and BESS equipment, the government should reduce import tariffs and taxes on renewable energy technologies. Currently, import duties and taxes on renewable energy technologies present a significant financial barrier. By implementing targeted tax exemptions or reductions on solar PV and BESS components, the government can make these technologies more affordable for local businesses and households.

b. **Subsidize Solar PV + BESS Projects**: The government should allocate development funds and seek international donor assistance to subsidize the initial costs of installing Solar PV + BESS. This could involve providing financial incentives or low-interest loans to households, businesses, and community projects to promote wider adoption of these technologies.

c. **Encourage Public-Private Partnerships (PPPs):** To overcome the high upfront costs and operational challenges, the government could facilitate public-private partnerships to share the financial and technical burden of installing and maintaining Solar PV + BESS systems. Such partnerships can leverage private sector investment and technical expertise while minimizing the financial risks for the government. Given that the capacity of the domestic private sector in Tuvalu is limited, the government should prioritize attracting foreign investors to bridge this gap. Offering incentives and a stable regulatory framework will help encourage long-term commitments and sustainable energy development from international investors.

1.2.3.2 Non-Financial Measures

The existing non-financial technology management practices in Tuvalu are limited by institutional and capacity challenges. To overcome these non-financial barriers to the adoption of Solar PV + BESS, the following measures should be considered:

Policy, Legal, and Regulatory

a. **Update and Develop a Comprehensive Renewable Energy Policy:** The government should develop and implement a clear and comprehensive renewable energy policy that prioritizes the integration of Solar PV + BESS into Tuvalu's energy system. Given that the current Tuvalu Energy Policy was developed in 2009, it needs to be updated to reflect modern technologies and energy needs. The revised policy should provide a regulatory framework that encourages investment, sets renewable energy targets, and outlines incentives for renewable energy projects.

b. **Strengthen Institutional Capacity:** Government agencies responsible for energy should work with local authorities and international partners to strengthen institutional capacity. This includes providing training to energy regulators and policymakers on renewable energy technologies and establishing clearer procedures for approving solar PV projects.

Technical

a. **Enhance Local Technical Expertise:** The government, in partnership with educational institutions and international donors, should provide training programs to develop a skilled workforce capable of installing, operating, and maintaining Solar PV + BESS systems. This will ensure the long-term sustainability of renewable energy infrastructure in Tuvalu.

b. **Conduct Feasibility Studies and Resource Assessments:** There is a need to conduct detailed feasibility studies to identify optimal locations for Solar PV + BESS installations. These studies should include identification of sites, assessments of grid compatibility, energy demand, and environmental conditions to ensure the long-term viability of projects.

Information and Awareness

a. **Community Awareness Campaigns:** A widespread public awareness campaign is essential to inform local communities and businesses about the benefits of Solar PV + BESS. This can be achieved through media, workshops, and partnerships with local organizations. Increasing awareness will help overcome cultural and behavioural resistance to the transition from traditional energy sources.

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b. **Climate Change Education Programs:** The Ministry of Climate Change and other relevant bodies should run educational programs that link the adoption of renewable energy technologies with climate change mitigation. This can be done through schools, community groups, and public events to ensure the public understands the environmental and economic benefits of shifting to solar energy.

Social, Cultural, and Behavioral

a. **Engage Local Communities in Project Design**: To ensure the successful transfer and sustainability of Solar PV + BESS systems, it is essential to engage local communities early in the project design phase. Consulting with community leaders, local businesses, and households will ensure the technology is aligned with local needs and conditions, and it will foster a sense of ownership over the projects.

b. **Promote Gender-Inclusive Energy Programs:** Solar PV + BESS projects should include gender-inclusive approaches by involving women in the decision-making process and providing them with equal access to renewable energy resources and training opportunities. Ensuring that women, particularly in rural areas, are part of the solution will improve technology adoption and social equity.

These measures reflect a holistic approach to addressing the economic, financial, and non-financial barriers associated with the adoption of Solar PV + BESS in Tuvalu. By implementing these strategies, Tuvalu can increase energy security, reduce reliance on imported fossil fuels, and contribute to its climate change mitigation goals.

1.3 Barrier analysis and possible enabling measures for Biogas

1.3.1 General description

Biogass are renewable energy sources derived from organic materials such as crops, algae, organic waste, and even animal byproducts like pig manure. These fuels are produced through various processes such as fermentation, transesterification, and gasification, and can be used in applications ranging from transportation and heating to cooking and electricity generation. A key advantage of biogass is their potential to significantly reduce greenhouse gas emissions compared to fossil fuels, thus contributing to climate change mitigation and energy security.

One specific type of biogas is produced by the anaerobic digestion of organic materials like household waste and animal manure. It is a versatile renewable energy source that can be used for cooking, electricity generation, and heating. In addition to its energy applications, biogas systems also produce organic fertilizer as a byproduct, making it valuable for agricultural use. Biogas technology is particularly promising for small island nations like Tuvalu, where locally available organic materials can be harnessed to generate energy and reduce reliance on imported fossil fuels.

For the Barrier Analysis and Enabling Framework (BAEF) exercise, biogas will be used as an example of biogas. This choice is based on its renewability, local sourcing potential, and relevance to Tuvalu's goals for energy security and climate change mitigation.

1.4.1.2 Technology Status in Tuvalu

The adoption of biogass, including biogas, in Tuvalu is still in its early stages. While the potential of biogass has been recognized in the country's National Energy Policy, large-scale production and use remain limited.

- **Early Trials (2012):** Biogas technology was first trialed in Tuvalu in 2012. The specific biogas system used was a fixed dome digester, which is a common technology for small-scale biogas production. The feedstock targeted for the trial was pig waste, a readily available resource in Tuvalu's agricultural communities. However, the system faced several challenges. The biogas digesters were primarily community-based but required significant effort to maintain, and many users found them difficult to integrate into their daily routines. The complexity of operating and maintaining the digesters, combined with a lack of familiarity with the technology, contributed to the low adoption rate.
- **Recent Developments (2023):** In 2023, a new trial of biogas technology was introduced through a collaboration between the Pacific Community (SPC), the US Embassy, and the European Union (EU). This trial used fixed dome digesters, an updated version of the technology that was previously trialed in Tuvalu. The primary feedstock targeted for the 2023 trial was pig waste, continuing from the earlier trials as it remains an abundant and accessible resource for many households in Tuvalu. The newer biogas systems have been praised for being more user-friendly and requiring less operational effort compared to earlier versions, which had been more labor-intensive. These updated systems feature a cleaner, more aesthetic design, making them more appealing and acceptable to households. These improvements are expected to enhance the adoption and sustainability of biogas in Tuvalu, marking a positive shift towards integrating biogas technology into the country's energy mix

Despite these advancements, there are still several economic, technical, and institutional barriers that need to be addressed to facilitate the widespread adoption of biogas and other biogass in Tuvalu.

However, the recent success of the new biogas trial suggests that biogas technologies have significant potential to reduce reliance on imported diesel, contribute to energy security, and support Tuvalu's climate change mitigation goals.

1.4.1.3 Category and Market Characteristics

Biogas in Tuvalu can be characterized as a publicly provided good, supported by donor-funded projects and international partnerships aimed at benefiting individual households and the broader community. As part of a renewable energy initiative, biogas systems are installed in homes to convert organic waste into clean cooking fuel, reducing reliance on imported diesel and enhancing energy security. These systems are often provided free of charge or at a subsidized rate, thanks to donor contributions, making them accessible to households across Tuvalu. Given the technical and financial support required for the installation and maintenance of biogas systems, coordination between the government, donors, and local communities is crucial for ensuring the sustainability and widespread adoption of this technology.

1.3.2 Identification of Barriers for Biogas (Biogas)

1.3.2.1 Preliminary barrier identification

As a first step, a list of potential barriers to the diffusion of biogas technology, in Tuvalu was identified through a literature review supplemented by expert opinion. In random order, the identified barriers included the following:

1. High Initial Investment Costs
2. High Operational and Maintenance Costs
3. Limited Access to Financing
4. Market Competition from Fossil Fuels
5. Lack of Technological Expertise
6. Inconsistent Biogas Yield and Feedstock Quality
7. Public Awareness and Acceptance Issues
8. Weak Institutional Capacity
9. Underdeveloped Regulatory Frameworks
10. Feedstock Supply Challenges
11. High Logistical Costs Due to Remoteness
12. Dependence on External Donors
13. Climate Vulnerability
14. Limited Land Availability
15. Lack of Coordination Among Stakeholders

The final screening and prioritization of the above-mentioned barriers to the diffusion of biogas technology in Tuvalu were undertaken through extensive consultation and interviews with experts, in addition to the use of barrier analysis tools such as problem and solution trees. Key identified barriers are briefly discussed below.

1.3.2.2 Economic and Financial Barriers:

a. High initial investment and maintenance costs

Biogas systems, especially large-scale fixed dome digesters, require substantial upfront investment for infrastructure, such as digesters and pipelines. Tuvalu's remote location compounds these costs due to high import and logistical expenses. However, more recent biogas technologies, such as balloon biogas digesters, offer a more cost-effective alternative. Balloon digesters are easy to install and cost between $300-$600 USD for household systems, significantly less than traditional fixed-dome systems, which can range from $1,000 to $5,000 USD depending on scale and complexity.

While maintenance costs for balloon digesters are relatively lower and simpler to manage, the plastic material used in these systems generally requires replacement every 2-5 years. In comparison, fixed-dome systems have a longer lifespan but are more costly to maintain. Without ongoing financial support or subsidies, many families may continue relying on kerosene or gas, as the long-term affordability of biogas remains a concern, particularly for lower-income households.

b. Limited access to financing

Securing the necessary financing for biogas systems in Tuvalu is difficult due to the high perceived risks of renewable energy projects. Local financing options are scarce, and private investment in the biogas or bioenergy projects remains low. Biogas projects, especially at the household level, often require international donor support, as Tuvalu's small economy and financial institutions are not well-positioned to fund large-scale or long-term investments in renewable energy.

1.3.2.3 Non-financial barriers

Policy, Legal, and Regulatory Barriers

a. Limited institutional capacity to manage biogas projects

The institutions responsible for energy management in Tuvalu face a lack of capacity, both in terms of human resources and technical expertise. This limitation slows down decision-making and project implementation, hindering the progress of biogas adoption. There is also a lack of clear procedures for approving and regulating biogas systems, creating uncertainty for investors and project developers.

b. Unclear roles and responsibilities among institutions

Coordination between government ministries, local authorities, and international donors is often weak. This lack of clarity and collaboration results in delays in project approval and implementation, as well as inefficient use of resources.

Technical Barriers

a. Shortage of local technical expertise

Tuvalu faces a shortage of trained professionals who can install, maintain, and manage large biogas systems, such as fixed-dome digesters. This lack of local expertise has led to increased reliance on external consultants, driving up overall project costs. Although small-scale biogas systems like balloon digesters

are easier to install, they still require technical knowledge for troubleshooting and maintenance, which is not widely available locally.

While biogas technology has been present in Tuvalu for several years, the implementation of larger systems has been limited, and there remains a lack of well-documented local knowledge for both installation and long-term system management. Therefore, ongoing capacity-building efforts are essential to develop a local workforce skilled in handling both small and large biogas systems, reducing reliance on external expertise and fostering sustainable biogas use in the community.

b. Resource limitations

Biogas production requires a steady supply of feedstock (such as manure or kitchen waste), which is limited in Tuvalu due to its small population and agricultural sector. Additionally, biogas production requires substantial freshwater water, a resource that is often scarce in Tuvalu, particularly during prolonged drought periods.

1.3.3 Identified measures

The successful adoption and diffusion of biogas (biogas) technology in Tuvalu require a comprehensive set of measures addressing both economic and non-financial barriers. These measures are crucial for overcoming the challenges identified and ensuring the sustainable development of the biogas sector.

1.3.3.1 Economic and Financial Measures

a. Reduce import tariffs and taxes

The government should reduce or eliminate import tariffs and taxes on biogas equipment and materials to lower the initial investment costs. By making components such as digesters and pipelines more affordable, biogas systems can become more accessible to households and communities.

b. Subsidize biogas projects

Tuvalu's government, in partnership with international donors, should provide financial incentives to encourage the adoption of biogas systems. These incentives could include subsidies for equipment installation, low-interest loans, or grants to offset the high upfront costs for households and businesses.

c. Promote public-private partnerships (PPPs)

To address the high capital requirements and operational costs of biogas systems, the government should foster partnerships between public institutions and private companies. These partnerships can attract private sector investment and technical expertise while mitigating financial risk. While there are a few local suppliers providing small-scale biogas solutions, a market mapping exercise is needed to identify gaps and opportunities for scaling up through international partnerships

1.3.3.2 Non-financial measures

Policy, Legal, and Regulatory

a. Develop a clear renewable energy policy for biogas

The government should implement a comprehensive policy specifically addressing the adoption and integration of biogas systems. This policy should include clear goals, guidelines for project approval, and incentives for both small- and large-scale biogas projects. Additionally, it would be beneficial to develop a biogas implementation roadmap that outlines the required steps for biogas adoption, including estimated investment requirements. This roadmap would provide a clear path for investors and stakeholders, helping to align resources and timelines for achieving the targets. It should cover short-, medium-, and long-term objectives, as well as highlight areas where external investment and partnerships will be essential for scaling biogas technology across Tuvalu.

b. Strengthen institutional capacity

Building the capacity of relevant institutions through training and partnerships with international organizations is essential. This includes developing the technical knowledge and project management skills necessary to implement, monitor, and maintain biogas projects across the country.

Technical

a. Train local technicians

The government, in collaboration with educational institutions and international partners, should invest in training programs to create a skilled local workforce capable of designing, installing, and maintaining biogas systems. Developing local expertise is critical for the long-term sustainability of biogas systems in Tuvalu.

Currently, there are no dedicated programs offered by Tuvalu's tertiary or Technical and Vocational Education and Training (TVET) institutions focused specifically on renewable energy systems, including biogas. This presents an opportunity for the government to work with local institutions and international partners to introduce relevant training modules. By partnering with organizations like the Pacific Community (SPC) and the Asian Development Bank (ADB), Tuvalu can benefit from regional training programs that focus on clean energy solutions. Building local capacity in this area will reduce dependence on external expertise and lower the long-term costs associated with maintaining biogas systems.

b. Explore sustainable feedstock and water solutions

For biogas projects to succeed in Tuvalu, it is crucial to ensure a reliable and sustainable supply of feedstock. Potential feedstock sources include animal waste (such as pig and chicken manure), kitchen waste, agricultural refuse, organic municipal waste, and even human waste. Given the small size and remote nature of many of Tuvalu's islands, an assessment of feedstock availability should be conducted at both the household and community levels before implementing any biogas technology. This assessment will help identify the most abundant and sustainable sources of organic material, ensuring the system's long-term viability.

Additionally, Tuvalu's water scarcity presents a challenge for biogas production, which traditionally requires significant water input. Technologies that reduce water usage or reuse water within the biogas system should be explored to align with Tuvalu's limited freshwater resources. By implementing sustainable agricultural practices and integrating innovative water solutions, the country can better support its biogas initiatives while addressing environmental and resource constraints.

Information and Awareness

a. Run public awareness campaigns

To ensure the success of biogas projects, widespread public awareness campaigns are needed to highlight the benefits of biogas over traditional fuels. This will foster community buy-in and increase the likelihood of successful project implementation.

b. Integrate biogas into climate change education

Biogas adoption should be tied into broader climate change education initiatives. By raising awareness of the environmental and economic benefits of biogas, the government can encourage its adoption as part of Tuvalu's climate change mitigation strategy.

1.4 Barrier analysis and possible enabling measures for Small-Scale Wind Turbine

1.4.1 General Description

Small-scale wind turbines, typically ranging from 5 to 10 kilowatts (kW) in capacity, are designed to harness wind energy and convert it into electrical power on a smaller scale compared to large commercial wind farms. These turbines are typically used for residential, agricultural, or small industrial applications. They are mounted on towers to capture wind at higher altitudes, where wind speeds are generally laminar and stronger. Small-scale wind turbines can function independently or be connected to the grid, offering a renewable energy source that can reduce dependence on fossil fuels. For Tuvalu, this technology is particularly crucial for mitigating the impacts of climate change and enhancing energy security.

1.4.1.1 Technology Status in Tuvalu

Currently, there are no wind turbines installed in Tuvalu. However, during stakeholder consultations, there was strong support for incorporating wind turbine technology into Tuvalu's renewable energy mix. Various research publications including the *TuvaluWi* (Ecology Management ApS, 2010) a*nd Power Development - Wind Study and Feasibility Report* and the *Funafuti Road Map* (Hydro-Electric Corporation, 2019)*,* have identified wind turbines as a potential renewable energy option for the country.

Previous assessments of the wind resource in Funafuti have indicated modest potential for wind turbines, with an average wind speed of 5.79 m/s at 29.2 meters above ground level. However, these studies have not reached the feasibility stage (Ecology Management ApS, 2010, 12). There has been no comprehensive evaluation of available land, environmental concerns, or noise impacts, which are critical for determining the viability of wind power in Tuvalu.

Wind turbines, particularly larger ones used in other Pacific islands like Vanuatu and Tonga, could be suitable for Tuvalu if appropriate land or shallow water areas are found. These turbines have proven their durability in extreme weather conditions, such as surviving Cyclone Pam in Vanuatu. However, their installation and maintenance in Funafuti would require specialized equipment and skills, which might pose logistical challenges.

Another consideration for wind turbine implementation in Tuvalu is the seasonal nature of wind. While trade winds provide energy at certain times of the year, there are long periods of minimal wind activity, particularly in May, October and December, when average wind speeds fall to as low as 3.3 to 4.9n/s at 20 meters above ground level. (Ecology Management ApS, 2010, 17) This suggests that wind turbines would serve as a complementary energy source to solar PV rather than a standalone solution.

1.4.1.2 Category and Market Characteristics

Small-scale wind turbines in Tuvalu can be characterized as a *capital good,* as they would be privately owned and used by households or businesses to generate electricity. As a capital good, a small-scale wind turbine serves as an investment, providing long-term energy benefits rather than being consumed directly.

Currently, no small-scale wind turbines have been introduced in Tuvalu, and it remains uncertain whether such projects will be funded by donors. While several feasibility studies have been conducted, no donor has yet come forward to support the implementation of wind turbine technology in the country. Solar PV

+ BESS has emerged as a more feasible option, receiving greater support from international donors due to its proven track record in Tuvalu and the Pacific region.

The feasibility studies conducted for wind turbines in Funafuti highlighted modest potential for wind power generation, but challenges related to land availability, environmental impacts, and logistical complexities have hindered the introduction of wind technology. These studies, such as the *Tuvalu Wind Power Development - Wind Study Report* (Ecology Management ApS, 2010) and the *Funafuti Road Map* (Hydro-Electric Corporation, 2019), have not yet reached a detailed feasibility level, with key issues such as available land, noise concerns, and environmental impacts remains unresolved.

For comparison, the installed capacity of wind turbines in Vanuatu is 750kW. with small-scale installations forming part of the country's renewable energy strategy. (European Investment Bank, 2010). However, reports also indicate that Vanuatu's energy infrastructure has seen investments in wind projects aiming to enhance renewable energy capacity, although large-scale wind farms remain limited. In Tonga, the Ii 'o Manumataongo Wind Farm, which was completed in 2019, has an installed capacity of 1.3 MW. This is Tonga's first large-scale wind farm, contributing significantly to reducing reliance on diesel for electricity generation. (*Ii 'O Manumataongo Wind Farm*, n.d.)

However, the seasonal nature of wind in Tuvalu and the long periods of low wind activity limit the potential for small-scale domestic wind turbines as a standalone solution. These factors, combined with a lack of donor interest, have made wind power less competitive compared to solar PV in Tuvalu's renewable energy landscape. That said, a hybrid system combining Wind and Solar PV and BESS could offer a more reliable solution by balancing in the intermittency of both solar and wind resources, ensuring a steady supply of renewable energy throughout the year.

The success of small-scale wind turbines in Tuvalu would likely depend on securing donor support or public-private partnerships, similar to other renewable energy initiatives in the region. Given the logistical challenges of installing and maintaining wind turbines—particularly the need for specialized equipment and expertise—donor involvement could play a crucial role in financing and capacity building.

If introduced, small-scale wind turbines would need to complement existing renewable energy technologies like solar PV, providing a diversified energy mix to improve energy security and reduce reliance on imported fossil fuels. However, without clear donor commitment or market incentives, the widespread adoption of wind turbines remains uncertain.

1.5.2 Identification of Barriers for Small-Scale Wind Turbines.

1.5.2.1 Preliminary Barrier Identification

As a first step, a list of potential barriers to the diffusion of small-scale wind turbine technology in Tuvalu was identified through a review of existing studies and supplemented by expert opinion. The identified barriers, in random order, included the following:

1. High Initial Investment Costs

2. High Operational and Maintenance Costs

3. Limited Access to Financing

4. Seasonal Variability of Wind

5. Absence of Technological Expertise for Installation and Maintenance

6. Unresolved Environmental and Noise Concerns

7. Limited Land Availability

8. Weak Institutional Capacity

9. Underdeveloped Regulatory Frameworks

10. Logistical Challenges Due to Tuvalu's Remote Location

11. Dependence on External Donors for Funding

12. Competing Priorities with Solar PV + BESS Projects

13. Lack of Public Awareness and Acceptance of Wind Technology

14. Potential Conflicts with Aviation Pathways

15. Need for Specialized Equipment for Turbine Operations

The final screening and prioritization of the above-mentioned barriers to the diffusion of small-scale wind turbine technology in Tuvalu were conducted through stakeholder consultations and expert interviews. Barrier analysis tools, such as problem and solution trees, were used to identify the key challenges that need to be addressed for the successful adoption of wind technology in Tuvalu. Key identified barriers are briefly discussed below.

1.5.2.1.1 Economic and Financial Barriers

The adoption of small-scale wind turbine technology in Tuvalu presents significant economic and financial challenges. One of the primary barriers is the high initial investment required for purchasing and installing these turbines, which includes the costs of turbines, towers, and necessary infrastructure. The upfront costs for a small-scale wind turbine system can range from USD 3,000 to USD 5,000 per kW. For a 10-kW system, this translates to an investment of USD 30,000 to USD 50,000, posing a substantial financial burden for a small economy like Tuvalu, which has limited financial resources.

Additionally, wind turbine projects have never been trialed in Tuvalu, which further complicates their adoption. The lack of pilot projects or concrete data on performance increases the perceived risk for financial institutions and potential investors. This uncertainty limits the availability of financing options, as banks and lending institutions may be hesitant to provide loans without clear proof of the turbines' viability. Moreover, the typical payback period for wind turbine investments is 5 to 10 years, which adds to financial hesitancy. In contrast, solar PV + BESS has been heavily supported by donors and is considered a more familiar and tested technology in the region, making it more attractive for investment.

In addition to the high initial capital costs, ongoing operational and maintenance costs are substantial for small-scale wind turbines. These costs can range from USD 200 to USD 500 per year per kW of installed capacity, adding long-term financial strain to both the government and households. Wind turbines require

specialized equipment and skilled labor for maintenance, further driving up costs and complicating the financial viability of these systems in the long run.

Market competitiveness is another significant barrier. Small-scale wind turbines face competition from other renewable energy technologies, particularly solar PV, which is more widely understood and often more cost-effective. The cost per kW for solar PV systems can be as low as USD 1,000 to USD 2,000, making them a much more accessible option for Tuvalu's energy needs. The established donor backing, and reduced costs of solar PV further tilt the balance in favor of solar over wind energy in the country.

Given the economic challenges and the lack of proven success with wind turbines in Tuvalu, the path forward will require a combination of financial incentives and technical support. To address the high initial capital costs, the government could implement subsidies or financial incentives, such as grants that cover a portion of the upfront costs. Establishing low-interest loan schemes tailored for wind energy projects could also help attract private sector investment, and public-private partnerships could spread the financial risks associated with wind turbine projects. Additionally, pilot projects are necessary to gather concrete data on the feasibility of wind turbines in Tuvalu, which would help reduce the perceived risk for investors and financial institutions.

In conclusion, while small-scale wind turbines hold potential as part of Tuvalu's renewable energy mix, significant barriers—particularly high costs, financing challenges, and competition from solar PV—must be overcome to make wind energy a viable option. Through a combination of pilot projects, financial incentives, and capacity building, Tuvalu can explore the possibility of diversifying its renewable energy sources and achieving its long-term energy security goals.

1.5.2.1.2 Non-Financial Barriers

1. Site Suitability and Resource Assessment
Identifying appropriate sites with adequate wind resources is crucial for the effectiveness of small-scale wind turbines. A wind study in Funafuti indicated an average wind speed of around 6 m/s, which is marginal for small-scale turbines. This variability can lead to suboptimal performance and reduced energy output, making wind less reliable compared to other renewable sources.

2. Technological Challenges
Small-scale wind turbines face significant technological hurdles related to design, durability, and compatibility with existing infrastructure. Ensuring these systems are reliable and efficient in Tuvalu's geographical and environmental context is challenging, particularly given the need to withstand local weather conditions and the general lack of experience with wind turbine technology in the country.

3. Institutional Capacity
Tuvalu's energy institutions, particularly the Tuvalu Electricity Corporation, lack the necessary technical expertise to manage wind energy projects. The current reliance on foreign consultants adds complexity and costs to projects, while weak coordination between government agencies, stakeholders, and donors hinders efficient planning and implementation. Without strengthening institutional capacity, the widespread adoption of wind turbines remains difficult.

4. Regulatory and Policy Barriers
The regulatory framework for wind turbine installations is underdeveloped, with inconsistent policies and unclear regulations creating uncertainty for investors and developers. Lengthy bureaucratic processes

further delay project implementation, while a lack of clear guidelines on land use, noise pollution, and environmental impacts contributes to hesitancy in adopting wind energy.

5. Public Awareness and Acceptance
There is limited public awareness and understanding of the benefits and capabilities of small-scale wind turbines in Tuvalu. This lack of familiarity contributes to resistance and hesitancy in adopting the technology. Additionally, concerns about environmental impacts, such as noise and potential land use conflicts, further reduce public acceptance of wind turbine projects.

These non-financial barriers significantly impact the feasibility and success of wind turbine technology in Tuvalu, necessitating targeted interventions to build local capacity, streamline regulatory processes, and improve public engagement.

1.5.3 Identified Measures

The successful adoption and diffusion of small-scale wind turbine technology in Tuvalu will require a comprehensive set of measures addressing both economic and non-financial barriers.

1.5.3.1 Economic and Financial Measures

To mitigate the high initial capital costs, the government can implement targeted financial incentives, such as capital subsidies or grants that cover a portion of the upfront investment. This would help lower the financial barrier for potential investors and encourage the installation of wind turbines.

In addition to subsidies, tax incentives on wind turbine components and equipment could reduce project costs. The government can also facilitate low-interest loan schemes or secure concessional financing from international development banks to reduce the financial risks for investors. Encouraging public-private partnerships (PPPs) is another key strategy to share both the financial burden and the risks associated with wind turbine projects. These partnerships can leverage public funds to attract private sector investment, creating a more favorable financial environment for wind energy development.

Given Tuvalu's goal of achieving 100% renewable energy by 2030, the government should also consider diverting funds from other sectors to support the training and implementation of wind turbines, ensuring that this technology contributes to the overall renewable energy mix.

1.5.3.2 Non-Financial Measures

Building local technical capacity is essential for the long-term success of wind turbine projects in Tuvalu. This can be achieved by developing training programs for engineers at the Tuvalu Electricity Corporation, equipping them with the skills to install, operate, and maintain wind turbines. Training programs can be developed in partnership with international institutions and donors to ensure that local technicians have the expertise required to support wind energy projects.

Public awareness campaigns are also crucial to inform communities about the benefits of wind energy and address concerns related to environmental impacts, such as noise and land use conflicts. Increasing public understanding of wind energy's role in reducing dependence on fossil fuels and enhancing energy security will be important for gaining local support for wind projects.

The regulatory framework for wind energy in Tuvalu needs to be strengthened. The government should establish clear policies and guidelines that streamline the approval and installation processes for wind turbines. This includes addressing potential conflicts with aviation pathways, land use issues, and ensuring environmental protection. Furthermore, the government should prioritize pilot projects to gather data on the feasibility of wind turbines in Tuvalu's specific conditions, helping to build confidence among investors and stakeholders.

Investing in research and development (R&D) is also necessary to optimize wind turbine performance in the context of Tuvalu's seasonal wind patterns. R&D efforts should focus on selecting appropriate turbine designs and technologies that can withstand the environmental challenges of the island nation, including cyclones and high humidity.

1.5 Linkages of the Barriers Identified

Identifying and understanding the linkages between the barriers faced by different prioritized renewable energy technologies is crucial to developing integrated strategies that maximize synergies and address overarching challenges effectively. This section explores the interconnections between the barriers identified for Solar PV + Battery Energy Storage Systems (BESS), Biogas, and Small-Scale Wind Turbines.

1.5.1.1 Economic and Financial Barriers

A significant barrier for all three technologies is the high initial capital investment required for installation and deployment. Whether it is the procurement of solar panels and battery systems, building biogas plants, or setting up wind turbines, the upfront costs are prohibitive. Limited access to financing compounds this issue, as financial institutions in Tuvalu are often hesitant to fund projects due to perceived risks associated with renewable energy technologies.

- Linkages: By addressing financing for renewable technologies holistically, a unified approach can be implemented. Mechanisms such as green financing initiatives, public-private partnerships (PPPs), and subsidies can be applied across these technologies to alleviate the burden of high upfront costs. Pooling resources to finance multiple technologies at once can create economies of scale, reducing costs overall and facilitating more widespread adoption of renewable energy in Tuvalu.

1.5.1.2 Non-financial measures

Technical and Operational Barriers

Each technology also faces unique technical challenges. For example, Solar PV + BESS systems require specialized knowledge for installation and maintenance, and wind turbines demand a high level of technical expertise for site assessment and installation. Similarly, biogas systems need skilled operators for proper functioning and maintenance. Additionally, maintenance costs across all technologies are high due to Tuvalu's reliance on imported components and foreign technical expertise.

- **Linkages**: A shared approach to capacity building across all technologies is essential. Developing training programs that cover multiple renewable technologies will help build local expertise and reduce the long-term dependence on foreign specialists. By creating an integrated technical support system, Tuvalu can foster the development of a skilled workforce capable of managing Solar PV, wind turbines, and biogas plants effectively.

Regulatory and Policy Barriers

The absence of a comprehensive regulatory framework affects all three technologies. Lack of clear policies on renewable energy, land use regulations for wind turbine installations, and unclear guidelines for biogas projects create uncertainty for investors and developers.

- **Linkages:** Streamlining and harmonizing regulatory frameworks for all renewable energy projects will create a more supportive environment for investment. Establishing clear guidelines for land use, permitting processes, and financial incentives will reduce bureaucratic delays and encourage private sector participation in the renewable energy sector. A unified policy framework can promote better coordination among government agencies, facilitating smoother project implementation for all technologies.

Public Awareness and Social Acceptance

One of the common non-financial barriers is the lack of public awareness and acceptance of renewable technologies. There is limited understanding of the long-term economic and environmental benefits of Solar PV, biogas, and wind turbines. This results in low social acceptance and resistance to transitioning away from traditional energy sources like diesel.

- **Linkages:** Joint public awareness campaigns can be launched to educate communities about the benefits of all renewable technologies. By leveraging successful case studies and demonstrating cost savings, the government can increase social acceptance across the board. Promoting these technologies as part of Tuvalu's national energy strategy will further enhance community buy-in.

Grid Integration and Infrastructure Barriers

The integration of variable renewable energy sources such as Solar PV and wind turbines into Tuvalu's grid poses a significant challenge due to the limited capacity of the existing infrastructure. Biogas, while not directly linked to the electricity grid, faces its own infrastructural challenges, particularly in terms of storage and distribution.

- **Linkages:** Investing in advanced grid management technologies such as smart grids and upgrading existing infrastructure is essential. These improvements will facilitate the integration of renewable energy sources like Solar PV and wind, ensuring grid stability. Additionally, expanding energy storage capacity will enhance the resilience of the energy system, making it more adaptable to the variability of renewable energy generation.

By addressing these barriers through targeted interventions, Tuvalu can create an enabling environment that supports the widespread adoption of renewable energy technologies. The proposed strategy is not only practical but also flexible, allowing for adjustments as new information and resources become available.

1.6 Enabling framework for overcoming the barriers for the Energy Sector

The successful implementation of renewable energy technologies such as Solar PV + Battery Energy Storage Systems (BESS), Small-Scale Wind Turbines, and Biogas in Tuvalu requires a well-structured enabling framework. This framework must be designed to address the economic, financial, technical, institutional, social, and environmental barriers previously identified. Through this approach, Tuvalu can

strengthen its renewable energy infrastructure and achieve its ambitious targets for greenhouse gas (GHG) emissions reduction and energy security.

Institutional Strengthening

For Tuvalu, institutional strengthening is a key component of the enabling framework. Currently, a lack of cohesive policies and limited coordination among various governmental bodies hinders renewable energy deployment. To overcome this, the following institutional measures are proposed:

- Energy Governance: Establish a dedicated energy policy unit within the Ministry of Energy to streamline the development, implementation, and monitoring of renewable energy projects. This unit will coordinate activities between Tuvalu Electricity Corporation (TEC), the Department of Environment, and the Ministry of Agriculture.
- Policy and Regulation Development: Develop clear policies for power purchase agreements (PPAs), feed-in tariffs (FiTs), and grid integration to provide regulatory certainty and encourage private sector participation in renewable energy development.

Common Barriers Across Multiple Technologies

Economic and Financial Measures:

The high upfront capital costs for Solar PV + BESS, Small-Scale Wind Turbines, and Biogas systems represent a significant barrier to widespread adoption in Tuvalu. A multifaceted approach is required to address these challenges:

- Green Financing: Facilitate access to low-interest loans and financial instruments such as the Green Climate Fund (GCF) and Global Environment Facility (GEF) to reduce the financial burden on households and businesses.
- Public-Private Partnerships (PPPs): Encourage partnerships between the government and private sector to share the costs of infrastructure development and enable long-term investments in renewable energy.
- Incentives and Subsidies: Introduce subsidies covering up to 30% of the capital costs for renewable energy installations, along with tax incentives for renewable energy technology imports.

Non-Financial Measures:

Technical Capacity Building

Tuvalu must build local technical capacity to install, maintain, and manage renewable energy systems. Training programs should focus on:

- Technical Training Programs: Partner with international technical institutions to provide certified training for local technicians in solar PV installation, wind turbine maintenance, and biogas plant operations.
- Knowledge Transfer: Establish programs to transfer knowledge from international experts to local stakeholders through workshops, exchange programs, and on-the-job training during project implementation phases.

Social and Public Awareness

Increased public awareness and social acceptance of renewable energy technologies are crucial to ensuring long-term sustainability. Measures to foster this include:

- **Public Awareness Campaigns**: Conduct nationwide campaigns to raise awareness of the economic and environmental benefits of renewable energy systems. Demonstration projects can be used to showcase the real-world impacts of Solar PV + BESS and biogas systems in local communities.
- **Community Involvement:** Engage local communities in the planning and implementation stages to ensure buy-in and ownership of renewable energy projects.

Environmental and Climate Resilience Considerations

Given Tuvalu's vulnerability to climate change impacts such as sea level rise, renewable energy projects must be designed with environmental and climate resilience in mind. Recommendations include:

- **Resilience in Design**: Ensure that renewable energy installations, particularly small-scale wind turbines, are designed to withstand extreme weather conditions such as cyclones.
- **Sustainable Resource Management**: Encourage sustainable management of local resources, particularly in biogas projects, to ensure they contribute to both waste management and energy production goals.

Table 4: Technology-Specific Enabling Framework for Overcoming Barriers

Technology	Specific Measures	Description
Solar PV + BESS	Incentives for Energy Storage	Provide tax credits and grants to encourage the adoption of energy storage systems.
	Standardized Grid Interconnection Protocols	Develop standardized protocols for grid interconnection to streamline the integration process.
	Training Programs for Battery Technology	Implement specialized training programs focusing on battery installation, maintenance, and energy management systems to build local expertise.
	Battery Recycling and Disposal Systems	Develop programs for safe disposal and recycling of used batteries to address environmental impacts
	Maintenance and Monitoring Guidelines	Create clear guidelines for the maintenance and monitoring of energy storage systems to ensure longevity and performance.
Small-Scale Wind	Site Assessment and Resource Mapping	Conduct detailed assessments to identify optimal sites with adequate wind resources, and develop guidelines for environmental impact assessments.

	National Wind Energy Registry	Establish a central registry for wind energy resources to streamline data collection and planning.
	Community Engagement and Education	Promote understanding and acceptance of wind energy projects through public consultations and educational programs.
Biogass	Sustainable Feedstock Supply Chains	Develop policies to encourage the use of non-food crops and waste materials, ensuring a reliable and sustainable supply of feedstock.
	Research and Development	Collaborate with international research institutions to improve biogas production technologies and adapt them to Tuvalu's conditions.
	Incentives for Local Production and Use	Introduce incentives for local production and utilization of biogass, such as subsidies and tax exemptions.

The enabling framework presented in this section is designed to address both common and technology-specific barriers, providing a comprehensive strategy for advancing Tuvalu's renewable energy sector. By aligning the framework with the barrier analysis and identified linkages, the strategy maximizes synergies and optimizes the effectiveness of the recommended measures. The integration of these measures will not only facilitate the adoption of prioritized technologies but also contribute significantly to Tuvalu's broader goals of energy security, economic development, and climate change mitigation.

Chapter 2 TRANSPORT

The transport sector is essential to Tuvalu's socio-economic development, enabling the movement of people and goods while maintaining inter-island connectivity. However, the sector remains overwhelmingly dependent on imported fossil fuels, which exacerbates the nation's vulnerability to global fuel price fluctuations and contributes significantly to its greenhouse gas (GHG) emissions. As Tuvalu seeks to advance its climate and energy transition goals, transforming the transport sector toward more sustainable, low-emission alternatives is critical to reducing emissions and enhancing energy resilience.

Aligned with the objectives outlined in the Tuvalu National Energy Policy (TNEP) and Intended Nationally Determined Contributions (INDCs), this chapter examines the barriers that hinder the adoption and diffusion of cleaner transportation technologies. The technologies under consideration include electric vehicles (EVs), hybrid vehicles, non-motorized transport options such as bikes and e-bikes, and hydrogen-powered shipping vessels for inter-island transport. Transitioning to these sustainable solutions is vital for decreasing GHG emissions, improving energy efficiency, and achieving long-term energy security in Tuvalu's transport sector.

The sector faces several key barriers to adopting clean transport technologies, including high initial capital costs, limited access to financing, and inadequate infrastructure. These financial constraints are compounded by institutional and regulatory hurdles, along with low public awareness of the benefits of transitioning to low-emission transportation. A comprehensive understanding of these barriers is required to design effective interventions that will support the sector's transformation.

To address these challenges, this chapter presents an enabling framework aimed at facilitating the widespread adoption of cleaner transport technologies. The proposed measures include the development of supportive financial mechanisms, targeted infrastructure investments, and capacity-building initiatives to develop a skilled workforce capable of operating and maintaining these technologies. Furthermore, regulatory reforms and policy adjustments will be crucial in creating a supportive environment for the integration of low-emission vehicles and sustainable transport systems.

In addition, the chapter explores how integrating sustainable transport solutions aligns with Tuvalu's broader development goals and its commitments to climate change mitigation. Reducing the reliance on imported fuels and promoting energy efficiency will not only enhance national energy security but also contribute to global efforts to reduce GHG emissions. The analysis and recommendations provided in this chapter identify key interventions necessary to overcome the barriers, enabling the successful transition to a low-emission, sustainable transport sector in Tuvalu.

2.1 Preliminary targets for technology transfer and diffusion

The transport sector plays an integral role in Tuvalu's economic and social structure, supporting the movement of people and goods across its islands. However, the sector is highly dependent on imported fossil fuels, which increases vulnerability to global fuel price fluctuations and contributes significantly to the nation's greenhouse gas (GHG) emissions. In 2017, maritime transport alone consumed 1,161,974 liters of diesel, costing AUD 1.4 million - equivalent to nearly 2.4% of Tuvalu's AUD 59.1 million GDP. This highlights the economic impact of fuel imports. Transitioning the transport sector to sustainable, low-emission technologies is therefore a key priority in Tuvalu's climate change mitigation strategy.

This section outlines the preliminary targets for the deployment of clean transport technologies, aligned with national policies such as the Tuvalu National Energy Policy (TNEP) and the Intended Nationally

Determined Contributions (INDCs). The emphasis is on reducing reliance on fossil fuels and enhancing energy security while contributing to the global fight against climate change.

Several priority technologies have been identified for Tuvalu's transport sector, including electric vehicles (EVs), hybrid vehicles, non-motorized transport options (bikes and e-bikes), and hydrogen-powered shipping vessels. These technologies not only offer a pathway for reducing carbon emissions but also provide opportunities for improving energy efficiency and modernizing Tuvalu's transport infrastructure.

The targets outlined in this section reflect Tuvalu's ambition to establish a resilient and sustainable transport sector. These goals include introducing electric vehicles into public and private transport systems, encouraging the adoption of non-motorized transport in urban areas, and exploring innovative solutions like hydrogen-powered vessels for inter-island travel. By implementing these technologies, Tuvalu aims to significantly reduce its GHG emissions and improve its overall energy security.

National Policies and Strategies

Tuvalu's commitment to sustainable transport is underscored by several national policies:

- Tuvalu National Energy Policy (TNEP): Aims for a 100% transition to renewable energy by 2025, which includes the integration of clean transport technologies.
- Te Kete-Tuvalu National Strategy for Sustainable Development (2021-2030): Prioritizes energy security and environmental sustainability, with the transport sector playing a central role.
- Intended Nationally Determined Contributions (INDCs): Sets ambitious targets for GHG reduction across all sectors, with specific goals for reducing emissions from the transport sector.

Transport Sector Targets

The preliminary targets for the transport sector encompass a range of technologies and initiatives aimed at reducing carbon emissions, enhancing energy efficiency, and promoting sustainable transport solutions. The following table outlines the key targets and their expected impacts:

Table 5: Transport Sector Targets

Technology	Target Deployment	Expected Impact
Electric vehicles (EVs)	Introduce 10 electric vehicles by 2030	Reduce carbon emissions by approximately 75 tons annually and decrease fossil fuel imports.
Hybrid Vehicles	Integrate 10 hybrid vehicles into public transport by 2030	Enhance fuel efficiency, cut emissions by 80 tons annually
Non-Motorized Transport (Bikes and E-Bikes)	Facilitate the use of 200 bikes and e-bikes in urban areas by 2030	Improve air quality, reduce emissions by 100 tons annually, and enhance public health
Hydrogen Powered Vessels	Introduce 1 hydrogen-powered vessel for inter-island transport by 2030	Cut maritime emissions by 240 tons annually

Linkages to Broader Development Goals

These targets are designed to support Tuvalu's transition to a low-carbon transport sector, with a focus on reducing dependency on imported fossil fuels and aligning with the country's commitments under international climate agreements. The implementation of these technologies will not only help meet Tuvalu's emissions reduction targets but also contribute to the nation's broader development goals by fostering a more efficient and sustainable transport system.

2.2 Barrier analysis and possible enabling measures for bikes, e-bikes and non-motorized transport

The transition to bikes, e-bikes, and other non-motorized transport represents a critical component of Tuvalu's strategy to develop a sustainable and resilient transport sector. This section explores the barriers to adopting and diffusing these technologies and identifies measures to overcome these challenges. The analysis is structured to cover economic and financial barriers as well as non-financial barriers, followed by recommended enabling measures.

2.2.1 General description

Bikes, e-bikes, and other forms of non-motorized transport represent a sustainable and cost-effective solution for reducing greenhouse gas emissions and improving public health. These technologies offer numerous benefits, including lower operational costs, reduced air pollution, and decreased traffic congestion. In the context of Tuvalu, where transportation largely depends on imported fossil fuels, promoting non-motorized transport can significantly contribute to energy security and environmental sustainability.

Bikes are traditional human-powered bicycles that provide a reliable mode of transport without emitting greenhouse gases. They are particularly suitable for short distances and urban commuting. E-bikes, on the other hand, are bicycles equipped with an electric motor that assists with propulsion. This feature makes them accessible to a broader range of users, including the elderly and those with physical limitations. E-bikes can cover longer distances and tackle challenging terrains with ease, making them a versatile option for diverse transportation needs.

The transition to non-motorized transport in Tuvalu can mitigate the country's reliance on imported fossil fuels, reduce carbon emissions, and promote active lifestyles. However, the adoption of these technologies faces several barriers that must be addressed to facilitate their widespread use.

2.2.1.1 Technology Status in Tuvalu

Currently, bicycles in Tuvalu are primarily used by children, with limited popularity among adults, who tend to prefer motorcycles powered by fossil fuels. While there are a handful of electric bikes (e-bikes), they have been introduced solely for demonstration purposes through donor-funded climate change projects and are not widely available or in regular use.

In the past, both cycling and walking were common modes of commuting for people of all ages. However, with the increasing availability of motorcycles and light-duty cars, the use of bikes and walking has gradually declined. Extreme heat conditions further discourage walking, particularly during the hotter parts of the day, reducing the overall appeal of non-motorized transport. Despite the introduction of e-bikes, the shift towards motorized vehicles continues to dominate the transportation landscape.

Nevertheless, stakeholders have recognized the importance of returning to traditional modes of transport, such as biking and walking, due to the associated environmental benefits and the potential to improve public health. This growing awareness reflects a desire to reduce reliance on fossil fuels while promoting a more active and sustainable lifestyle in Tuvalu.

2.2.1.2 Category and Market Characteristics

Bikes, e-bikes, and non-motorized transport in Tuvalu can be categorized as consumer goods, as they are purchased and used by individuals for personal mobility. Bicycles, while once a popular mode of transport, especially in the past, have seen a decline in use among adults due to the increasing preference for motorcycles and light-duty vehicles. However, there is a small market for bikes, primarily among children, while e-bikes have been introduced only in limited numbers through donor-funded projects for demonstration purposes.

Despite the availability of financing options for green products, these are underutilized for bikes and e-bikes due to their limited popularity. Introducing targeted financial schemes or subsidies could help increase their adoption, particularly for e-bikes, which offer an environmentally friendly alternative to motorcycles.

Although road conditions in Tuvalu are generally adequate for cycling, the absence of designated cycling lanes makes cycling less appealing for many. In addition, extreme heat conditions discourage both walking and cycling, particularly during the hottest times of the day and year as well.

The potential success of e-bikes and non-motorized transport would depend on the implementation of supportive measures, such as government incentives, improved road infrastructure, and public awareness campaigns. Designated cycling lanes and technical support for e-bikes, including maintenance services and spare parts availability, would be critical in encouraging the shift towards sustainable transport options. Stakeholders have recognized the importance of returning to traditional modes of transport to improve both environmental outcomes and public health.

2.2.2 Identification of Barriers

2.2.2.1 Preliminary barrier identification

As a first step, a list of potential barriers to the diffusion of bikes, e-bikes, and non-motorized transport in Tuvalu was identified through a review of current practices and supplemented by expert opinion. The identified barriers, in random order, included the following:

1. Limited Popularity Among Adults

2. Lack of Designated Cycling Lanes

3. High Upfront Costs for E-Bikes

4. Underutilization of Existing Financing Options

5. Limited Availability of Maintenance Services for E-Bikes

6. Lack of Public Awareness About Health and Environmental Benefits

7. Social Preference for Motorized Transport (Motorcycles and Cars)

8. Extreme Heat Conditions Discouraging Walking and Cycling

9. Limited Technical Expertise for E-Bike Maintenance

10. Weak Government Incentives for Non-Motorized Transport

11. Competition with Motorized Transport (Motorcycles, Light-Duty Vehicles)

12. Lack of Donor Support for E-Bike Adoption

13. Absence of Spare Parts and Repair Centers for E-Bikes

14. Cultural and Social Resistance to Non-Motorized Transport

15. Inconsistent Policy Framework to Support Non-Motorized Transport

Including discussions on insurance coverage could help address this barrier by providing a safety net for consumers and encouraging greater adoption of non-motorized transport options.

The final screening and prioritization of the above-mentioned barriers to the diffusion of bikes, e-bikes, and non-motorized transport in Tuvalu were conducted through stakeholder consultations and expert interviews. The barrier analysis tool, root cause analysis with problem and solution trees, were used to identify the key challenges that need to be addressed to successfully promote the adoption of sustainable transport options in Tuvalu. Key identified barriers will be discussed further in the following sections.

2.2.2.2 Economic and Financial Barriers

The initial cost of e-bikes can be prohibitively high for many potential users in Tuvalu. E-bikes, which typically range from USD 1,000.00 to USD 3,000, are significantly more expensive than traditional bikes, posing a substantial financial barrier. In contrast, pedal/push bikes in Tuvalu generally cost between USD 40 and USD 200, making them a more accessible option for many residents. This significant price difference underscores the financial challenges associated with transitioning to e-bikes. This significant price difference underscores the financial challenges associated with transitioning to e-bikes. Additionally, the need for regular maintenance, particularly for battery replacements, increases the long-term cost of owning an e-bike. Although traditional bikes are more affordable, their declining popularity among adults, coupled with the high costs of e-bikes, limits the adoption of non-motorized transport in Tuvalu.

While financing options for green products exist, they are underutilized for bikes and e-bikes due to their low demand. Limited awareness and low adoption rates mean that these financing mechanisms, such as loans or payment plans, are rarely accessed by consumers.

Further complicating the financial landscape is the lack of necessary infrastructure to support e-bikes. The development of charging stations and secure parking facilities presents a significant financial investment for the public and private sectors, hindering the practicality and usability of e-bikes in Tuvalu. Without this infrastructure, the widespread adoption of e-bikes will remain financially challenging.

The high costs of e-bikes, lack of designated infrastructure, and limited access to financing are interconnected, leading to a limited adoption of non-motorized transport options. Economic barriers are reinforced by the lack of incentives and the minimal use of existing green financing schemes.

2.2.2.3 Non-Financial Barriers

Several non-financial barriers also hinder the adoption of bikes, e-bikes, and other non-motorized transport in Tuvalu. A major cultural barrier exists, as motorized transport, particularly motorcycles and light-duty cars, is often seen as more prestigious and convenient. This cultural bias makes it difficult to promote bikes and e-bikes as viable alternatives.

Safety concerns also play a critical role in limiting adoption. While the road conditions in Tuvalu are generally safe, the absence of designated cycling lanes reduces the appeal of cycling, especially for adults. Furthermore, there is a lack of secure bike parking facilities, which increases the risk of theft and further deters potential users. Limited public awareness about the environmental, health, and cost-saving benefits of non-motorized transport adds to this barrier. Without concerted efforts to raise awareness, many people remain uninformed about the advantages of adopting bikes and e-bikes over motorized vehicles.

Moreover, extreme heat conditions present a unique challenge. During the hottest parts of the day, both cycling and walking become impractical for many individuals, further reducing the likelihood of adopting non-motorized transport. In addition, the limited availability of technical expertise for e-bike maintenance discourages users who might otherwise consider adopting e-bikes.

Non-financial barriers, such as cultural preferences for motorized transport, safety concerns, and environmental factors like extreme heat, are interconnected with the lack of public awareness and infrastructure. Together, they contribute to the overall reluctance to adopt bikes and e-bikes in Tuvalu.

2.2.3 Identified Measures

2.2.3.1 Economic and Financial Measures

To overcome the economic and financial barriers identified, targeted measures are necessary to make bikes and e-bikes more affordable and accessible. One key measure is to introduce subsidies or tax incentives that reduce the upfront cost of purchasing e-bikes. For instance, a subsidy covering 20-30% of the purchase price could significantly lower the financial burden on consumers, making e-bikes a more viable option for a wider population.

Another essential measure is to promote the use of existing green financing options. Encouraging financial institutions to offer low-interest loans or instalment payment plans specifically for bikes and e-bikes could provide consumers with more flexible ways to invest in these technologies. To mitigate risks for financial institutions, these loans would ideally be accompanied by insurance products that protect against potential defaults. Public-private partnerships (PPPs) should also be explored to fund the development of necessary infrastructure, such as e-bike charging stations and secure bike parking facilities.

Subsidies, financing options, and infrastructure development are critical components of a solution framework that reduces the economic barriers to adopting bikes and e-bikes in Tuvalu. These measures, combined with the development of support infrastructure, can facilitate the shift to sustainable transport.

2.2.3.2 Non-Financial Measures

To address non-financial barriers, a comprehensive strategy is needed, including infrastructure improvements, public awareness campaigns, and supportive policies. A public awareness campaign focused on the health, environmental, and financial benefits of non-motorized transport would help

change the cultural perception that motorized transport is more prestigious. These campaigns should emphasize the cost savings and convenience of e-bikes, especially in regions experiencing extreme heat, where motorized options may be less feasible.

Safety improvements are also essential. The creation of designated bike lanes, secure parking facilities, and enhanced road infrastructure will make cycling more appealing and safer for users. Implementing these safety measures, along with traffic management policies such as speed limits and traffic calming devices, will create a more welcoming environment for non-motorized transport.

Policy interventions should include incentives for using non-motorized transport, such as bike-to-work programs and urban planning initiatives that integrate cycling infrastructure into future developments. These policies can help ensure the long-term sustainability of bikes and e-bikes in Tuvalu.

Public awareness campaigns, safety improvements, and supportive policies are essential measures that address the non-financial barriers to adopting bikes and e-bikes. These solutions create a comprehensive approach to encouraging the shift to non-motorized transport, ensuring both public acceptance and infrastructure development.

2.3 Barrier analysis and possible enabling measures for Electric Light-Duty Vehicle

2.3.1 General description

Electric Light-Duty Vehicles (ELDVs) are powered by rechargeable batteries, producing zero tailpipe emissions and offering a cleaner alternative to conventional internal combustion engine vehicles. ELDVs reduce greenhouse gas emissions and air pollution, while also offering to lower operating costs and decreased reliance on fossil fuels. Their quieter operation further enhances their appeal for urban environment.

In Tuvalu, adopting ELDVs aligns with the nation's climate change mitigation goals and efforts to improve urban air quality. These vehicles, available as passenger cars and small vans, are suitable for both personal and light commercial use. By shifting toe electric vehicles, Tuvalu can reduce its carbon footprint and dependence on imported fossil fuels, thereby enhancing energy security and supporting environmental sustainability.

2.3.1.1 Technology Status in Tuvalu

Currently, electric light-duty vehicles (ELDVs) in Tuvalu are limited, with only two electric SUVs introduced through a donor-funded project. These vehicles have been brought in as part of a demonstration initiative to showcase the potential of electric mobility in the country. However, the use of ELDVs remains minimal, and they are not yet a regular feature of Tuvalu's transportation landscape.

Most light-duty vehicles imported by households are typically second-hand, primarily from Japan, as these are more affordable. Brand-new vehicles, including electric options, are usually procured by the government or through donor-funded projects. This reliance on second-hand vehicles means that the market for electric vehicles remains largely undeveloped.

While ELDVs represent a promising solution for reducing reliance on fossil fuels, the current infrastructure, including charging stations and technical support, is not yet in place to support widespread adoption. Additionally, the preference for conventional, fossil fuel-powered vehicles continue to dominate the transportation landscape. However, with growing international interest in supporting sustainable mobility in small island nations, electric vehicles could play a more significant role in the future.

2.3.1.2 Category and Market Characteristics

Electric light-duty vehicles (ELDVs) in Tuvalu can be categorized as consumer goods, though their adoption is still at an early stage. Given the high upfront costs and limited consumer awareness, the government and donor-funded projects currently play a pivotal role in introducing these vehicles into the country. By importing ELDVs for public and project use, the government and development partners can help demonstrate their benefits, making consumers more familiar with this sustainable transport option.

Once the benefits of ELDVs become more apparent through government and project-based usage, this could pave the way for broader consumer interest. As more electric vehicles enter the market, the government would likely be incentivized to provide necessary support infrastructure, such as charging stations, and introduce financial incentives like subsidies or tax breaks to further encourage adoption.

In this way, the initial push from government and donor projects can help establish the groundwork for a consumer market for ELDVs in Tuvalu, while also aligning with the broader goals of reducing reliance on imported fossil fuels and achieving environmental sustainability.

2.3.2 Identification of barriers

Through comprehensive stakeholder consultations and analysis, various barriers to the adoption of electric LDVs in Tuvalu have been identified. These barriers are categorized into economic and financial barriers, as well as non-financial barriers.

2.3.2.1 Preliminary barrier identification

As a first step, a list of potential barriers to the diffusion of electric light-duty vehicles (ELDVs) in Tuvalu was identified through a review of current practices and supplemented by expert opinion. The identified barriers, in random order, included the following:

1. High Upfront Costs for ELDVs

2. Lack of Charging Infrastructure

3. Limited Availability of Financing Options for ELDVs

4. High Import Costs Due to Tuvalu's Remote Location

5. Lack of Technical Expertise for ELDV Maintenance and Repair

6. Limited Public Awareness of Environmental and Cost Benefits

7. Preference for Conventional, Fossil Fuel-Powered Vehicles

8. Dependence on Donor Support for ELDV Importation

9. Lack of Government Incentives for ELDV Adoption

10. Limited Availability of Spare Parts and Technical Support

11. Inconsistent Government Policy on Electric Vehicle Adoption

12. Skepticism About ELDV Reliability in Tuvalu's Climate and Road Conditions

13. Potential Concerns About Electricity Supply for Charging ELDVs

14. High Maintenance Costs and Need for Specialized Equipment

15. Social and Cultural Resistance to Electric Vehicle Use

The final screening and prioritization of the above-mentioned barriers to the diffusion of ELDVs in Tuvalu were conducted through stakeholder consultations and expert interviews. Barrier analysis tools, such as problem and solution trees, were used to identify the key challenges that need to be addressed to successfully promote the adoption of electric vehicles in Tuvalu. Key identified barriers will be discussed further in the following sections.

2.3.2.2 Economic and Financial Barriers

A significant economic barrier is the high initial purchase cost of electric light-duty vehicles (ELDVs), which is 30-50% higher than conventional vehicles. This elevated cost is largely due to the expensive batteries and electronic components required for electric vehicles. The average cost of an electric LDV ranges from USD 40,000 to USD 60,000, compared to USD 25,000 to USD 35,000 for conventional vehicles, creating a substantial financial hurdle for potential buyers in Tuvalu. The lack of financial incentives, such as subsidies, tax rebates, and low-interest loans, exacerbates this issue, making it even more difficult for individuals and businesses to afford electric vehicles.

Another economic challenge is the recurring costs of battery replacements, which typically occur every 5-7 years and range from USD 5,000 to USD 10,000. These expenses add to the total cost of ownership and present a long-term financial burden. Furthermore, local financial institutions do not offer specialized loans for electric LDVs, leading to higher interest rates—about 8%, compared to more favorable 2-3% rates available in other markets. This lack of affordable financing options limits accessibility for consumers.

Additionally, the absence of insurance products designed to reduce financial risks associated with electric vehicle ownership further exacerbates these challenges. With insurance being fairly new to Tuvalu, and the current provider operating for only around two years, there is an opportunity for the insurance market to expand and introduce policies tailored to cover risks like battery replacement and maintenance costs. This could help mitigate the financial burden on potential buyers and make electric LDV ownership more manageable in the long term.

Moreover, the development of charging infrastructure requires significant capital investment, which may be difficult to obtain given Tuvalu's limited financial resources and competing priorities. Furthermore, sourcing electricity from renewable resources is essential to ensure that the charging infrastructure aligns with sustainability goals. Without proper infrastructure and a commitment to renewable energy, the feasibility of adopting electric light-duty vehicles (ELDVs) remains limited.

2.3.2.3 non-financial barriers

Several non-financial barriers further obstruct the widespread adoption of electric LDVs. One major issue is the lack of charging infrastructure, especially in remote and rural areas. The absence of a reliable and extensive network of charging stations makes it inconvenient for users to recharge their vehicles, and upgrading the electricity grid to support increased demand is necessary for ELDV adoption. The costs of installing fast-charging stations, which range from USD 20,000 to USD 50,000, add to the challenge.

Another concern is the limited driving range of electric LDVs (100-300 miles per charge). While this range should be sufficient for daily commutes in Tuvalu, there are doubts about their performance in Tuvalu's climate and road conditions. Additionally, without sufficient charging infrastructure, potential users may still feel restricted in their mobility, especially for longer trips or during holiday periods, which could further deter widespread adoption.

There is also a general lack of public awareness about the benefits and advantages of electric LDVs. The preference for conventional vehicles, due to familiarity and perceived reliability, continues to slow the shift towards electric mobility. Inconsistent policies and insufficient regulatory frameworks regarding electric vehicles further create uncertainty, making it difficult to attract investment in both the vehicles and the supporting infrastructure. Additionally, a shortage of skilled technicians capable of maintaining and repairing electric LDVs hinders the long-term sustainability of the technology.

2.3.3 Identified measures

To overcome the barriers associated with the adoption of electric light-duty vehicles (ELDVs) in Tuvalu, a comprehensive set of measures has been identified, targeting both economic and non-financial challenges. These measures aim to reduce the high upfront costs, improve financing options, and address the lack of supportive infrastructure. They also focus on raising public awareness, enhancing policy frameworks, and building the technical capacity required for maintaining and supporting electric vehicle technology. By addressing these barriers holistically, Tuvalu can create an enabling environment for the successful adoption of ELDVs, contributing to its sustainability goals and reducing reliance on imported fossil fuels.

2.3.3.1 Economic and Financial Measures

To address the high upfront costs of ELDVs, implementing subsidies and financial incentives is critical. A 20% subsidy on the purchase price could significantly reduce financial barriers for consumers. For example, a 20% subsidy on an electric LDV priced at USD 50,000 would provide USD 10,000 per vehicle, with a total subsidy cost of USD 1,000,000 for 100 vehicles. Additionally, providing tax rebates and exemptions on import duties could further reduce costs. A 10% exemption on a vehicle priced at USD 50,000 would save USD 5,000 per unit, totaling savings of USD 500,000 for 100 vehicles.

Establishing green financing schemes with lower interest rates (3% instead of 8%) could also make electric LDVs more accessible. For example, with an average loan amount of USD 40,000 for 100 vehicles, reducing the interest rate from 8% to 3% over 10 years could save approximately USD 1,200,000. Battery leasing programs would further ease the financial burden, allowing users to lease batteries every month, spreading out the cost over time and making electric LDVs more affordable.

Encouraging public-private partnerships (PPPs) to develop charging infrastructure and promote electric LDVs is another important strategy. A joint investment of USD 1,000,000 from the government and the private sector could establish 20 charging stations, enhancing infrastructure and incentivizing further investment in electric mobility.

2.3.3.2 Non-Financial measures

To support the successful adoption of ELDVs, investment in charging infrastructure is essential. A comprehensive network of charging stations, prioritizing urban centers and expanding to remote and rural areas, should be developed. Installing 20 charging stations at USD 50,000 each would require an investment of USD 1,000,000. Additionally, integrating renewable energy sources, such as solar or wind, to power these charging stations will enhance sustainability and reduce reliance on fossil fuels. Upgrading the electricity grid to handle increased demand from electric vehicles is also crucial to ensure reliability and consumer confidence.

Public awareness campaigns should be launched to educate the community about the environmental and economic benefits of electric LDVs. An annual budget of USD 50,000 for media campaigns, workshops, and educational programs could help bridge the knowledge gap and foster greater acceptance of electric vehicles.

Clear, consistent policies and regulations that support electric vehicle adoption are vital. These policies should include mandatory targets for ELDV penetration, incentives for private sector investment in charging infrastructure, and stricter emission standards for conventional vehicles. Establishing a regulatory framework that encourages compliance, and adoption will create a more stable investment environment.

Developing technical training programs is also essential. Investing USD 100,000 in training facilities and programs would ensure that local technicians and mechanics have the skills needed to maintain and repair electric LDVs, supporting long-term sustainability. Finally, encouraging government agencies and large businesses to transition their vehicle fleets to electric LDVs would create a significant demand and demonstrate the viability of electric vehicles. Allocating USD 500,000 in incentives for fleet transitions could significantly boost market adoption and drive the broader shift to electric mobility.

2.4 Barrier analysis and possible enabling measures for Shore-side electricity supply for at-berth vessels

2.4.1 General Description

Shore-side electricity supply, also known as cold ironing or shore power, enables ships docked at port to shut down their auxiliary engines and draw electrical power from the shore. This technology allows vessels to maintain necessary operations, such as lighting, heating, cooling, and communications, without relying on onboard diesel generators. By utilizing shore-side electricity, emissions of air pollutants and greenhouse gases are significantly reduced, improving air quality and minimizing the environmental impact of maritime activities.

In the current context of Tuvalu, shore power is only feasible on the main island of Funafuti, as it is the only location with berthing facilities for ships. Currently, shore power is available, but it is limited to a patrol boat, which is much smaller compared to the larger vessels that berth at the main wharf. The goal is to expand shore power capability to accommodate all types of ships that dock at the Funafuti wharf.

The shore-side electricity supply is considered a public good in this context, provided by the Government of Tuvalu who is also the Port Authority. The Government would need to invest in the infrastructure, with the expectation that non-government vessels using the facility would pay a fee, as stipulated under the Wharfage, Harbour Dues and Port Charges Regulation. Future implementation will need to focus on retrofitting the port infrastructure with the necessary electrical requirements, and the electricity source for shore power will likely come from a combination of solar PV + BESS and existing grid capacity to ensure a sustainable energy supply.

2.4.2 Identification of Barriers

Despite the clear benefits of shore-side electricity supply, its implementation in Tuvalu faces several economic, financial, and non-financial barriers. These challenges must be thoroughly understood and addressed to ensure successful adoption and integration into the country's maritime infrastructure.

2.4.2.1 Economic and Financial Barriers

The high initial capital investment required for installing shore-side electricity infrastructure is a significant economic barrier. This includes the costs of retrofitting existing ports with electrical infrastructure, such as transformers, power distribution systems, and connection equipment. The installation of these systems can be particularly costly in Tuvalu due to its geographical isolation and limited local manufacturing capabilities. For instance, the average cost of establishing shore power infrastructure can range from USD 1 million to USD 5 million, depending on the port size and the power demand of vessels.

Moreover, the operational costs associated with providing electricity, such as maintenance of the infrastructure and the purchase of electricity, can also be substantial. Given Tuvalu's reliance on imported fossil fuels for power generation, the cost of electricity can be relatively high, making it less economically attractive for ship operators to switch from onboard generators to shore-side electricity.

The availability of financial support, such as subsidies or low-interest loans, is limited. Local financial institutions may be reluctant to finance such projects due to perceived risks and long payback periods. The lack of tailored financial products for green maritime infrastructure further complicates the financing landscape.

2.4.2.2 Non-Financial Barriers

Non-financial barriers also present significant challenges to the adoption of shore-side electricity supply in Tuvalu. One of the primary obstacles is the lack of technical expertise and institutional capacity to design, implement, and manage such infrastructure projects. The limited availability of skilled personnel and technical training programs hampers the development and maintenance of the required systems.

Regulatory and policy barriers further complicate the implementation of shore-side electricity supply. The absence of clear regulations and standards for shore power in Tuvalu creates uncertainty for port authorities and shipping companies. Additionally, the lack of incentives for adopting this technology, such as tax breaks or regulatory mandates, diminishes its attractiveness. While the Tuvalu National Energy Policy (TNEP), developed in 2009, does not mention shore power, the 2022 Updated Nationally Determined Contributions (NDC) included provisions for this technology, signaling a shift in policy focus. This highlights the need for future policy revisions to fully support the implementation of shore-side electricity supply.

There is also a general lack of awareness and understanding of the benefits of shore-side electricity among key stakeholders, including port authorities, ship operators, and the public. This lack of knowledge can lead to resistance to change and a preference for conventional practices.

Finally, the physical and logistical challenges associated with Tuvalu's geographical characteristics, such as small and dispersed islands, complicate the deployment of shore-side electricity infrastructure. The need for specialized equipment and the logistical complexities of transporting and installing such systems add to the overall difficulty.

2.4.3 Identified Measures

Based on stakeholder consultations, comprehensive research, and analysis of international experiences, the following measures are proposed to overcome the identified barriers in Tuvalu:

2.4.3.1 Economic and Financial Measures

To mitigate the high capital costs, it is recommended that the Government of Tuvalu implement subsidies and financial incentives for the installation of shoreside electricity infrastructure. For example, providing a subsidy covering 30% of the installation costs could significantly lower the financial burden on port authorities. If the estimated installation cost is USD 2 million, a 30% subsidy would amount to USD 600,000 per port, making the project more financially viable.

Additionally, offering low-interest loans specifically tailored for green maritime infrastructure can facilitate access to capital. Establishing a green financing scheme with interest rates of around 3% instead of the typical market rates of 6-8% can make it easier for stakeholders to secure funding. For example, if the total financing requirement is USD 2 million, the interest subsidy to reduce the rate from 8% to 3% over 10 years would amount to approximately USD 500,000.

Implementing tariff incentives for electricity used by ships at berth can encourage the adoption of shore-side electricity. For instance, offering reduced electricity rates during off-peak hours can make shore power more attractive compared to onboard diesel generators.

2.4.3.2 Non-Financial Measures

To address the technical and institutional capacity barriers, developing training programs and capacity-building initiatives is crucial. Partnerships with international organizations and academic institutions can facilitate these programs, ensuring that local personnel have the necessary skills to design, install, and maintain shore-side electricity systems.

Strengthening the regulatory and policy framework is essential for promoting shore-side electricity supply. This includes developing and enforcing standards for shore power connections, setting emissions reduction targets for at-berth vessels, and providing incentives for compliance. Clear and supportive policies can create a more predictable and stable environment for investors and operators.

Public awareness campaigns are necessary to educate stakeholders about the environmental and economic benefits of shore-side electricity. These campaigns should target port authorities, ship operators, and the public, highlighting the advantages of reduced emissions, improved air quality, and cost savings. For instance, an annual budget of USD 50,000 could be allocated for media campaigns, workshops, and informational brochures.

Investing in research and development (R&D) to adapt shore-side electricity technology to Tuvalu's unique conditions is also important. Collaborations with international research institutions can drive innovations in infrastructure design, power management, and energy efficiency, making the technology more suitable and cost-effective for the local context.

By addressing these economic and non-financial barriers through comprehensive measures, Tuvalu can effectively implement shore-side electricity supply for at-berth vessels. This transition will contribute to the country's climate change mitigation efforts, enhance air quality, and reduce operational costs, supporting Tuvalu's broader goals of sustainable development and environmental conservation.

2.5 Linkages of the Barriers Identified

Identifying and understanding the linkages between the various barriers encountered by prioritized technologies in Tuvalu's transport sector is essential for developing comprehensive strategies that maximize synergies and optimize the effectiveness of proposed measures. This section explores the interconnections among the barriers faced by technologies such as electric light-duty vehicles, fuel-efficient heavy-duty vehicles, and shore-side electricity supply for at-berth vessels. By addressing these linkages, Tuvalu can create a cohesive and efficient approach to overcoming challenges and facilitating the adoption of sustainable technologies.

Economic and Financial Barriers

High Initial Capital Costs: A significant barrier across all prioritized technologies is the high initial investment required. Electric light-duty vehicles, fuel-efficient heavy-duty vehicles, and infrastructure for shore-side electricity all involve substantial upfront costs. This commonality presents an opportunity to implement a unified financial support mechanism, such as subsidies or low-interest loans, which can be applied across different technologies. For instance, a single subsidy program could offer financial assistance for the purchase of both electric and fuel-efficient vehicles, as well as the development of charging infrastructure.

Limited Access to Financing: Access to affordable financing is a shared challenge for all technologies. Local financial institutions often lack specialized loan products tailored for sustainable technologies, resulting

in higher interest rates. Developing targeted green financing programs can provide lower interest rates and longer repayment terms, benefiting all technologies. A centralized green financing initiative could pool resources, making it easier to secure international funding and offering more favorable terms to consumers and businesses.

Operational and Maintenance Costs: The ongoing costs associated with maintaining advanced technologies, such as electric vehicles and fuel-efficient systems, can be prohibitive. A shared maintenance support program could provide cost-effective solutions by leveraging economies of scale. For example, a government-supported maintenance subsidy could reduce the financial burden on operators and ensure the availability of skilled technicians for multiple technologies.

Non-Financial Barriers

Inadequate Infrastructure: The lack of essential infrastructure, including charging stations for electric vehicles and shore-side electricity facilities, is a critical barrier. A coordinated approach to infrastructure development can address these gaps more efficiently. For instance, a comprehensive infrastructure plan could integrate charging stations and shore-side electricity supply points, optimizing resource allocation and ensuring that infrastructure development is holistic and interconnected.

Regulatory and Policy Barriers: Inconsistent and unclear policies hinder the adoption of all prioritized technologies. A harmonized regulatory framework that sets clear standards and incentives for sustainable technologies can create a stable and predictable environment for investment. For example, establishing uniform emissions standards and providing tax incentives for low-emission vehicles can encourage the adoption of both electric and fuel-efficient technologies.

Public Awareness and Acceptance: A general lack of awareness and understanding of the benefits of advanced technologies is a common barrier. Coordinated public awareness campaigns can educate the public about the environmental and economic advantages of adopting sustainable technologies. A unified messaging strategy can enhance the effectiveness of outreach efforts, making it easier to shift public perception and increase acceptance.

Technical and Institutional Capacity: The scarcity of skilled technicians and the limited capacity of Government institutions to manage new technologies are significant barriers. A comprehensive capacity-building initiative can provide training for technicians and support for institutional development, ensuring that the necessary skills and knowledge are available across all technologies. For example, a government-sponsored training program could include courses on electric vehicle maintenance, energy management systems, and shore-side electricity operations.

By understanding and addressing the linkages among these barriers, Tuvalu can develop integrated strategies that not only tackle individual challenges but also create synergies across different technologies. This holistic approach will enable a more efficient allocation of resources, streamline the implementation process, and enhance the overall impact of the interventions. The coordinated efforts will ultimately support Tuvalu's transition to a sustainable and resilient transport sector, contributing to the nation's climate change mitigation goals and overall socio-economic development.

2.6 Enabling framework for overcoming the barriers in Sector B

The enabling framework for overcoming the barriers to the adoption and diffusion of prioritized technologies in Tuvalu's transport sector is structured at two levels: addressing common barriers across multiple technologies and implementing technology-specific measures. This dual approach ensures a comprehensive strategy that caters to both overarching and unique challenges.

Common Barriers

Economic and Financial Barriers

To tackle the economic and financial barriers, the framework includes two primary approaches. The first approach involves a unified financial support mechanism. This mechanism proposes the implementation of subsidies and incentives, such as a 20% subsidy on the purchase price of electric light-duty vehicles, fuel-efficient heavy-duty vehicles, and infrastructure projects. Additionally, a centralized green financing scheme with significantly lower interest rates, around 3%, compared to the typical 8% in the market, would make these technologies more accessible. Public-private partnerships (PPPs) are encouraged to share financial risks and attract private investment, particularly in infrastructure development like charging stations and shore-side electricity facilities.

The second approach focuses on targeted incentives and financial instruments. Under this approach, targeted subsidies are offered for specific technologies based on market readiness and demand. For example, higher subsidies for electric vehicles could be balanced with tax incentives for companies investing in fuel-efficient heavy-duty vehicles. This approach also includes specialized loan products with tailored terms, such as longer repayment periods for heavy-duty vehicles, making the transition more financially feasible. Performance-based incentives, like rebates for meeting specific fuel efficiency or emission reduction goals, are introduced to encourage continuous improvement and adoption of the latest technologies.

Non-Financial Barriers

Addressing non-financial barriers involves a comprehensive public awareness and capacity-building initiative. This includes launching a coordinated campaign to educate the public on the benefits of sustainable transport technologies. The campaign would utilize multimedia advertising, community workshops, and partnerships with educational institutions. Comprehensive training programs for technicians and mechanics are also proposed to ensure the local workforce is equipped to support new technologies. This initiative includes the development of institutional capacity to manage and support these technologies.

A standardized regulatory framework is another crucial component. This framework involves developing consistent regulations for emissions standards and safety requirements across all technologies. This approach provides clarity and predictability, fostering a conducive environment for investment and adoption.

The second approach for non-financial barriers involves technology-specific initiatives. These include focused education and training programs that address unique benefits and challenges associated with each technology. For instance, specific workshops for fleet operators could emphasize the operational advantages of fuel-efficient heavy-duty vehicles. Additionally, infrastructure projects are prioritized based on the immediate needs of each technology. For example, rapid expansion of charging infrastructure for electric vehicles in urban areas, with a gradual rollout for shore-side electricity. Incentive structures are also proposed for institutional adoption, such as grants for pilot projects or tax breaks for early adopters, to demonstrate feasibility and build confidence.

Technology-Specific Enabling Framework

For each prioritized technology, the enabling framework proposes two alternative sets of measures aimed at achieving similar goals. These sets of measures are designed to provide flexibility in policy implementation, allowing for adaptations based on changing economic and social conditions.

Table 6: Technology-Specific Enabling Framework

Technology	Measure Set 1	Measure Set 2
Electric Light-Duty Vehicles (LDVs)	High subsidies at 20% of the purchase price to lower the barrier for initial adoption. Comprehensive public awareness campaigns aimed at educating consumers and businesses about the benefits of electric LDVs, encouraging rapid market penetration. Development of a robust charging infrastructure network to support the growing number of electric vehicles.	Moderate subsidies to provide financial relief without extensive government expenditure. Strong green financing options, such as low-interest loans at around 3% interest rate, to make electric LDVs more accessible. Gradual market adoption with targeted incentives for key sectors, ensuring a steady transition to electric vehicles.
Fuel-Efficient Heavy-Duty Vehicles	Direct financial incentives to reduce the upfront cost and encourage adoption among transport operators. Reduction or elimination of import duties on fuel-efficient technologies to lower total acquisition costs. A focus on lower upfront costs to make the transition to fuel-efficient vehicles more attractive.	Leasing model for fuel-efficient technologies, allowing operators to pay over a period rather than upfront, making it financially manageable. Introduction of government-backed leasing programs to spread the financial burden and reduce initial capital requirements. Smooth transition with phased implementation and incentives for early adopters.

Shore-Side Electricity Supply for At-Berth Vessels	Substantial investment in infrastructure development to establish a comprehensive network of shore-side electricity supply points. A policy requiring all new ports to have shore power should be implemented to ensure long-term sustainability. The focus should be on achieving high initial capital investment to quickly establish a widespread and effective system. Encouraging private sector partnerships can help share the financial load and expertise.	A gradual implementation strategy, with phased roll-out of shore-side electricity infrastructure, targeting key ports and high-traffic areas first. Offering incentives for early adopters, including reduced port fees and operational discounts, to encourage initial uptake. Incremental growth to allow for adjustments and scaling based on demand and technological advancements.

The proposed enabling framework, whether through common or technology-specific measures, is tailored to Tuvalu's unique socio-economic and environmental context. It aims to provide a strategic, flexible, and comprehensive roadmap for overcoming the identified barriers, thereby facilitating a successful transition to a sustainable transport sector in Tuvalu.

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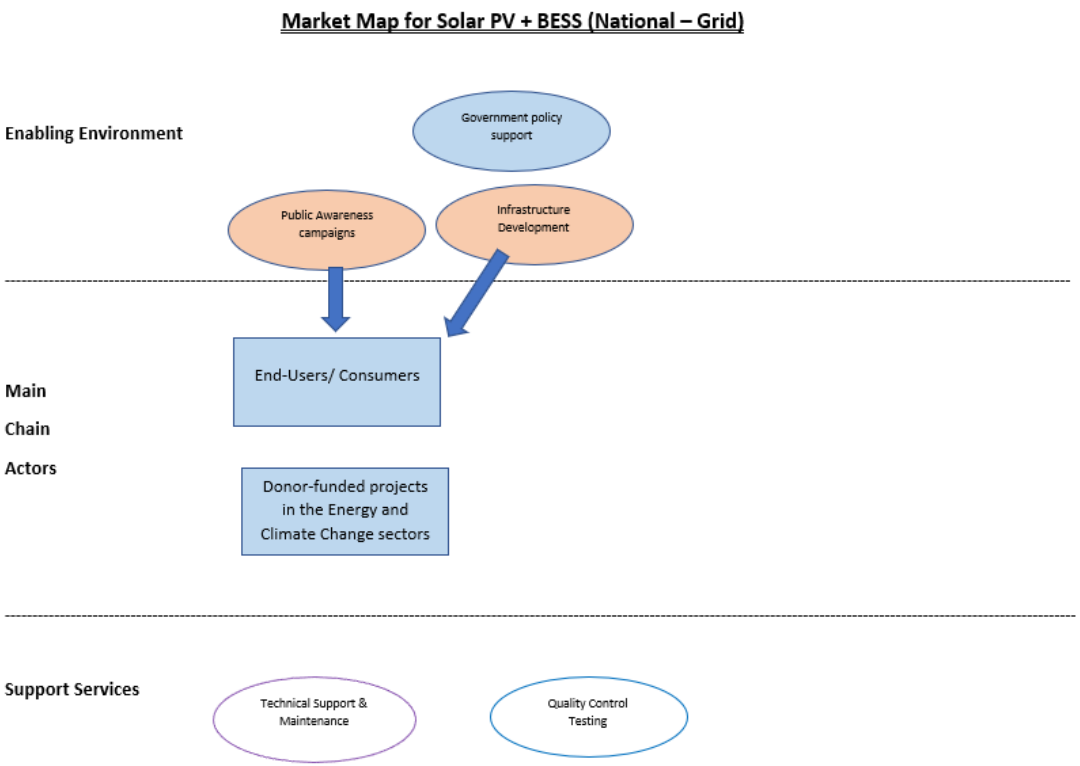
Annex I: Market maps and problem trees

Annex 1.1: Market Mapping



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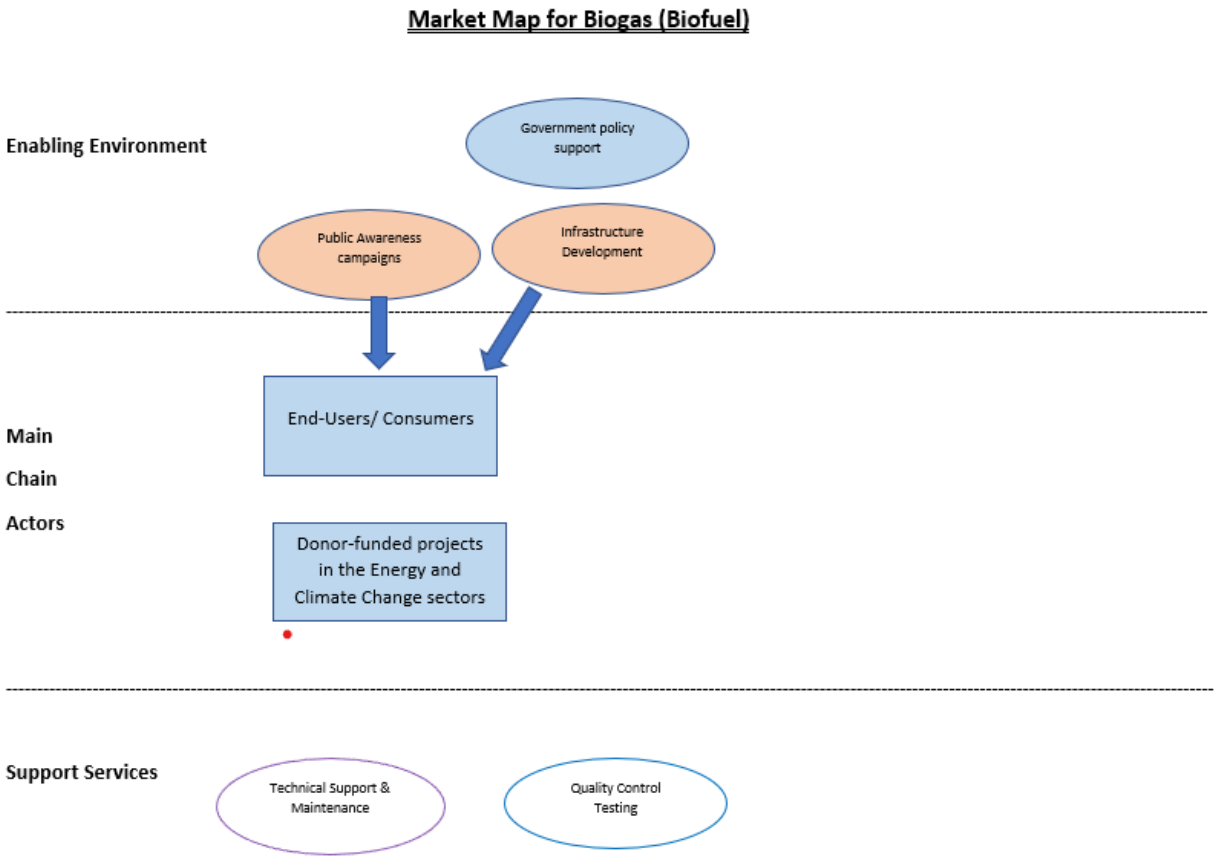

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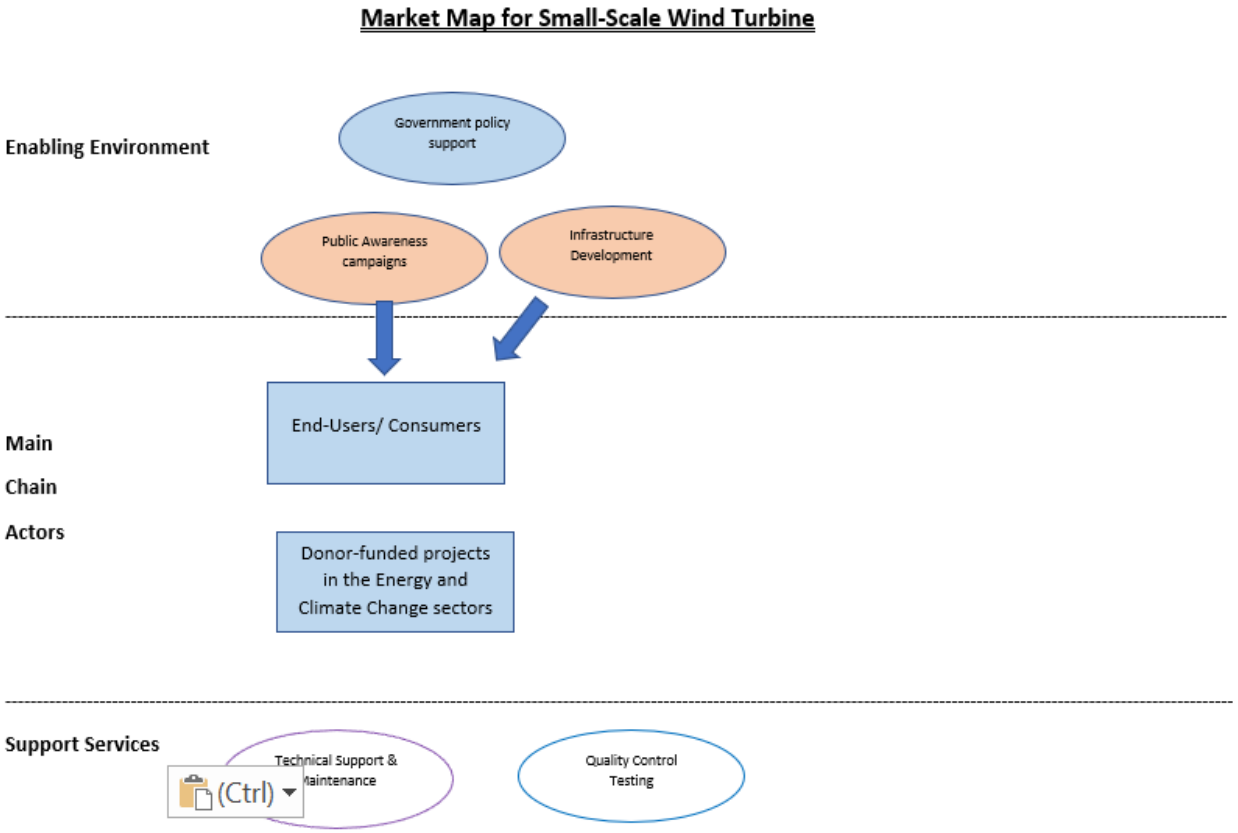

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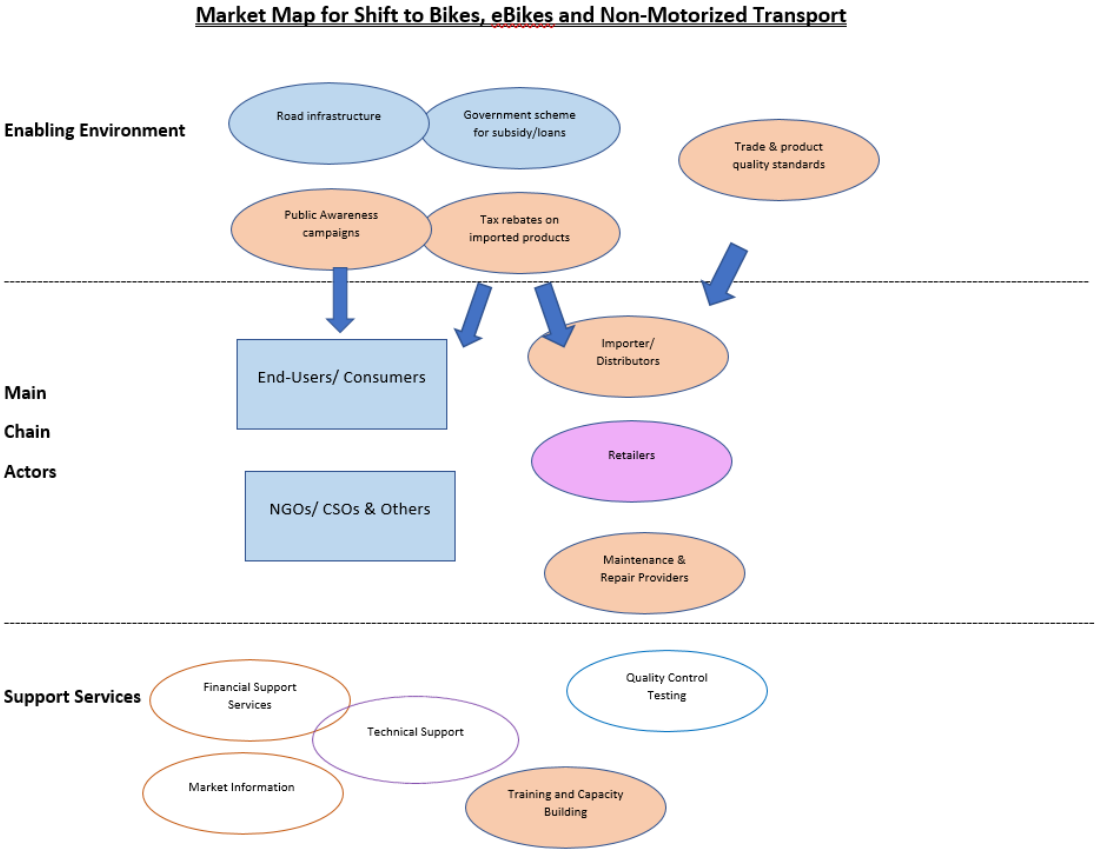

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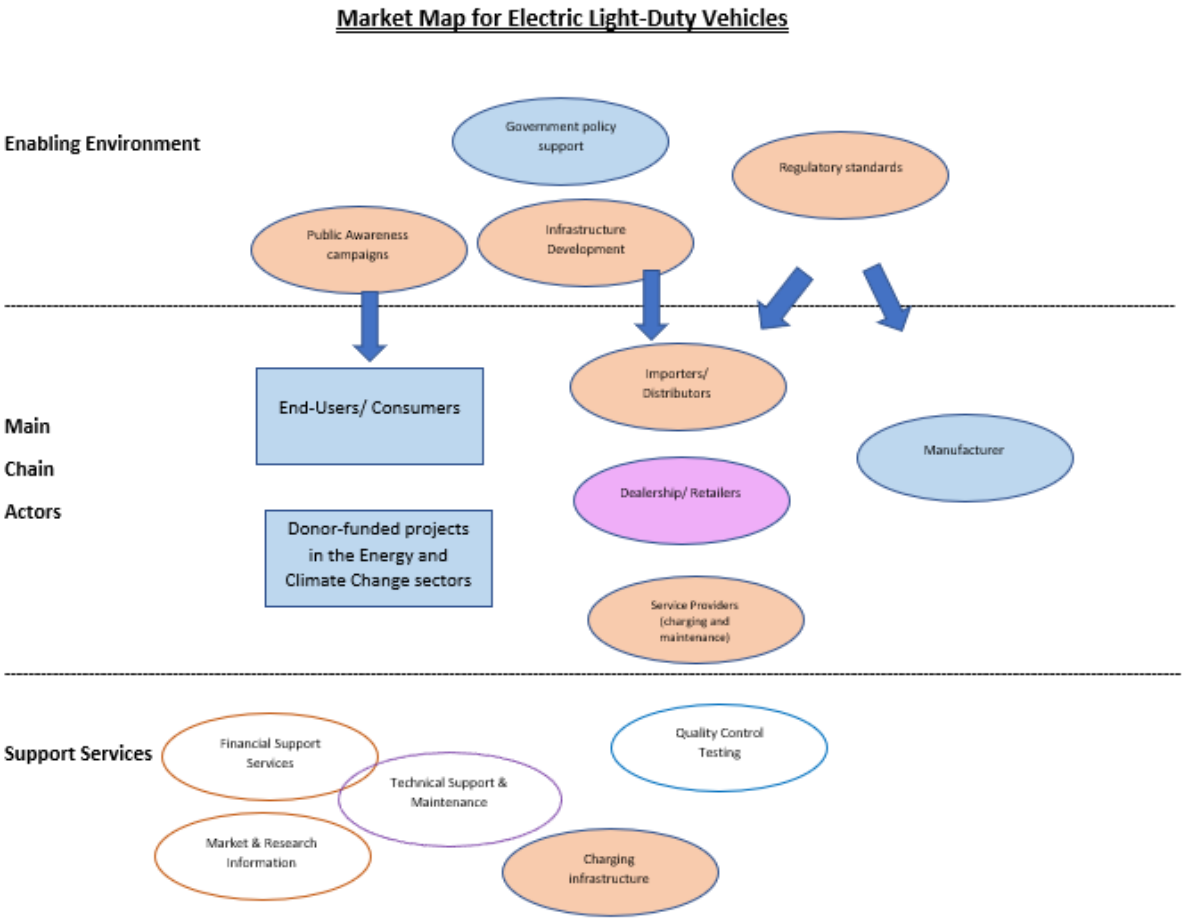

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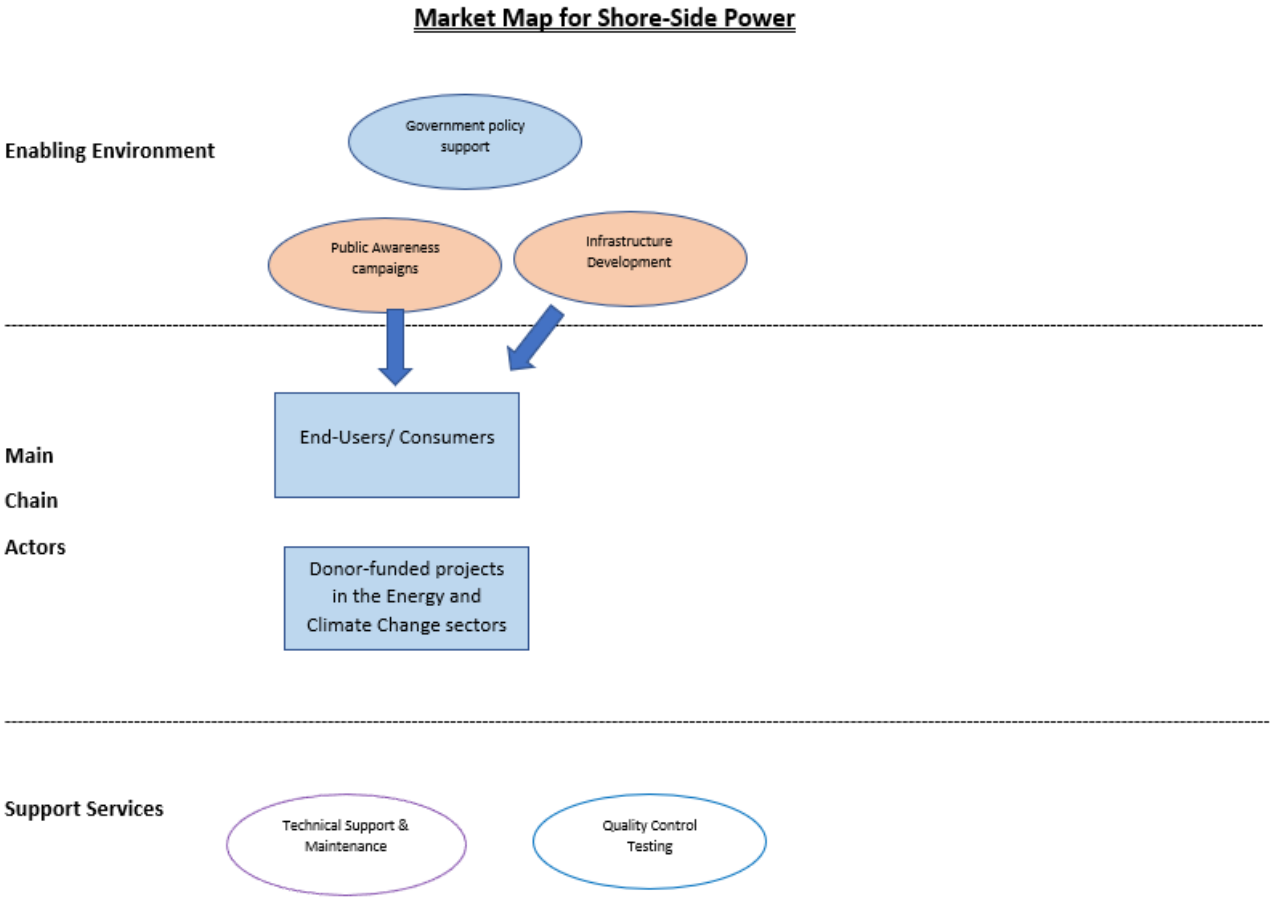
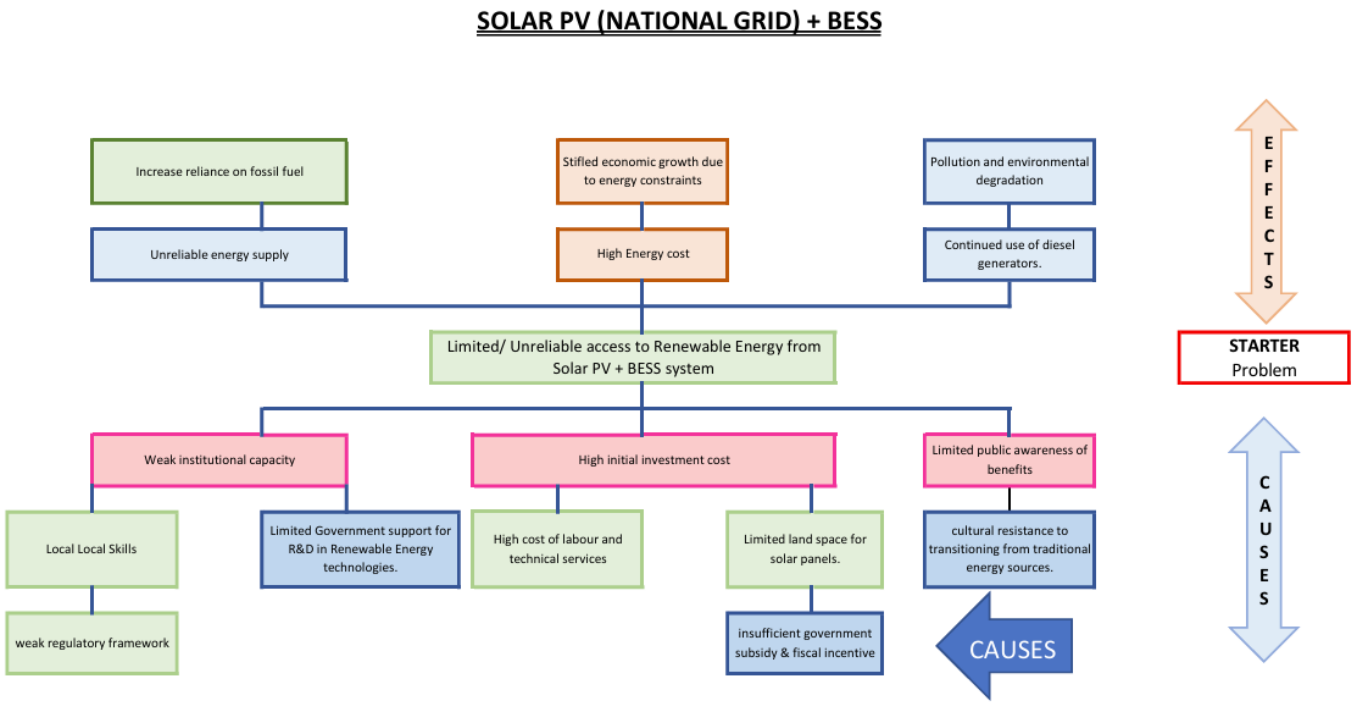
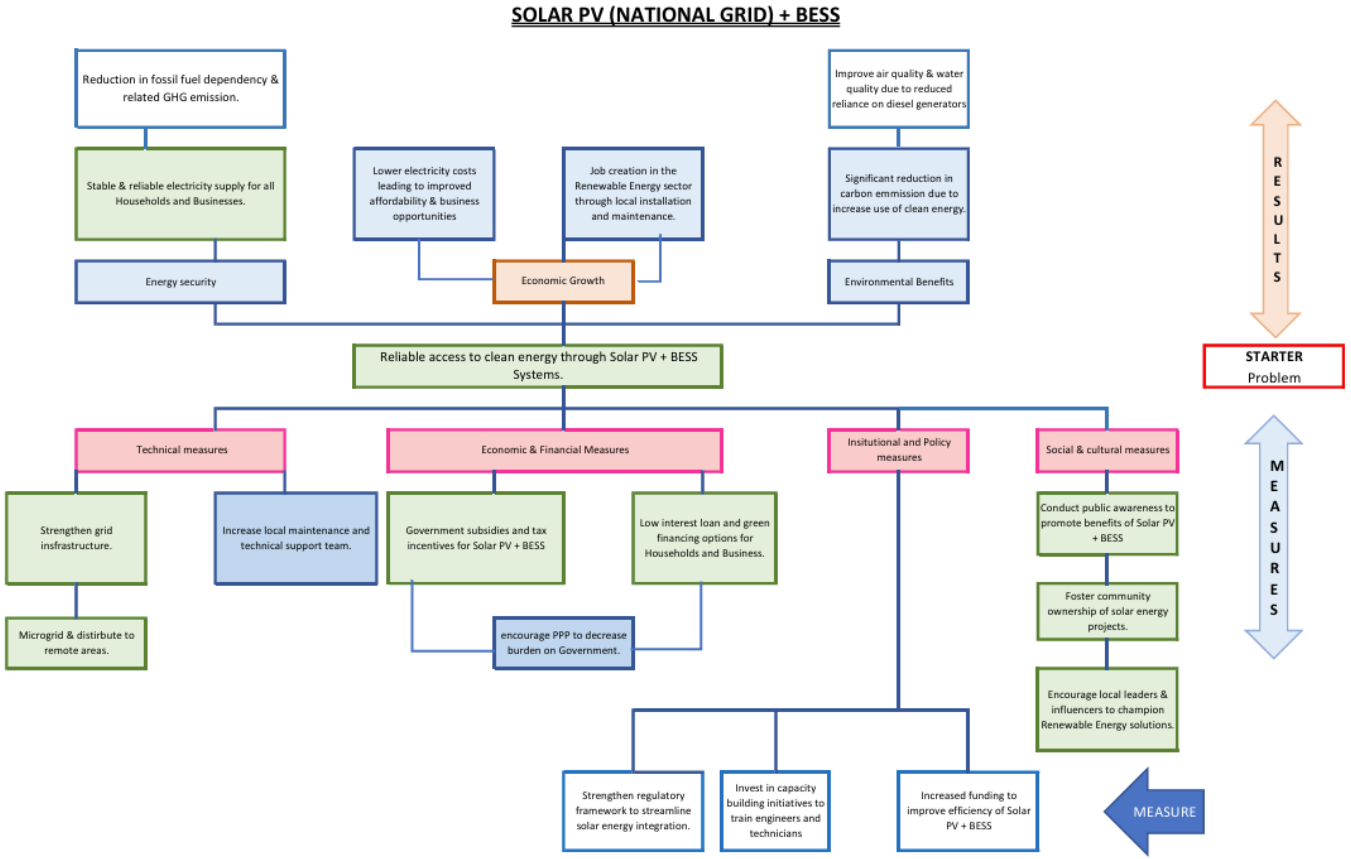


Annex 1.7: Problem Tree



Annex 1.8: Solution Tree



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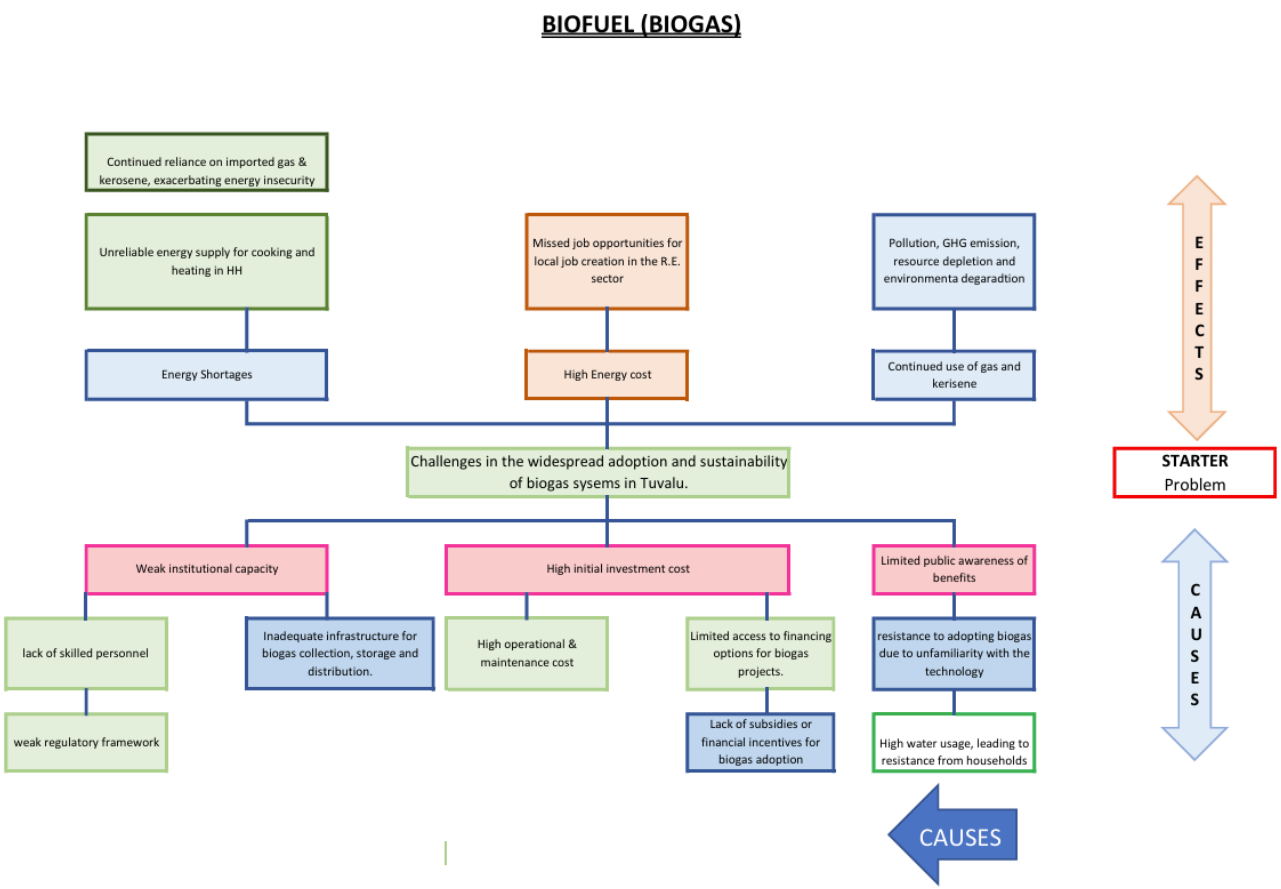

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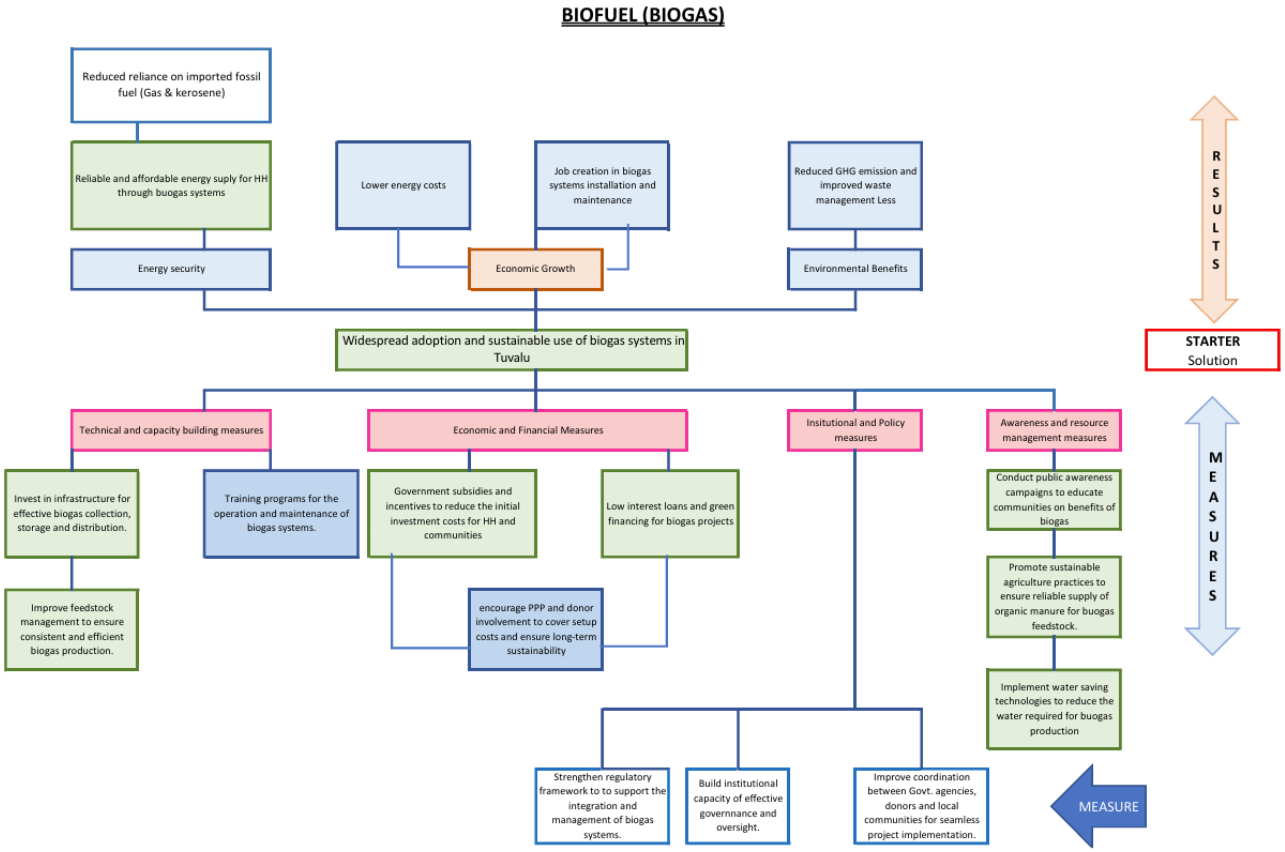

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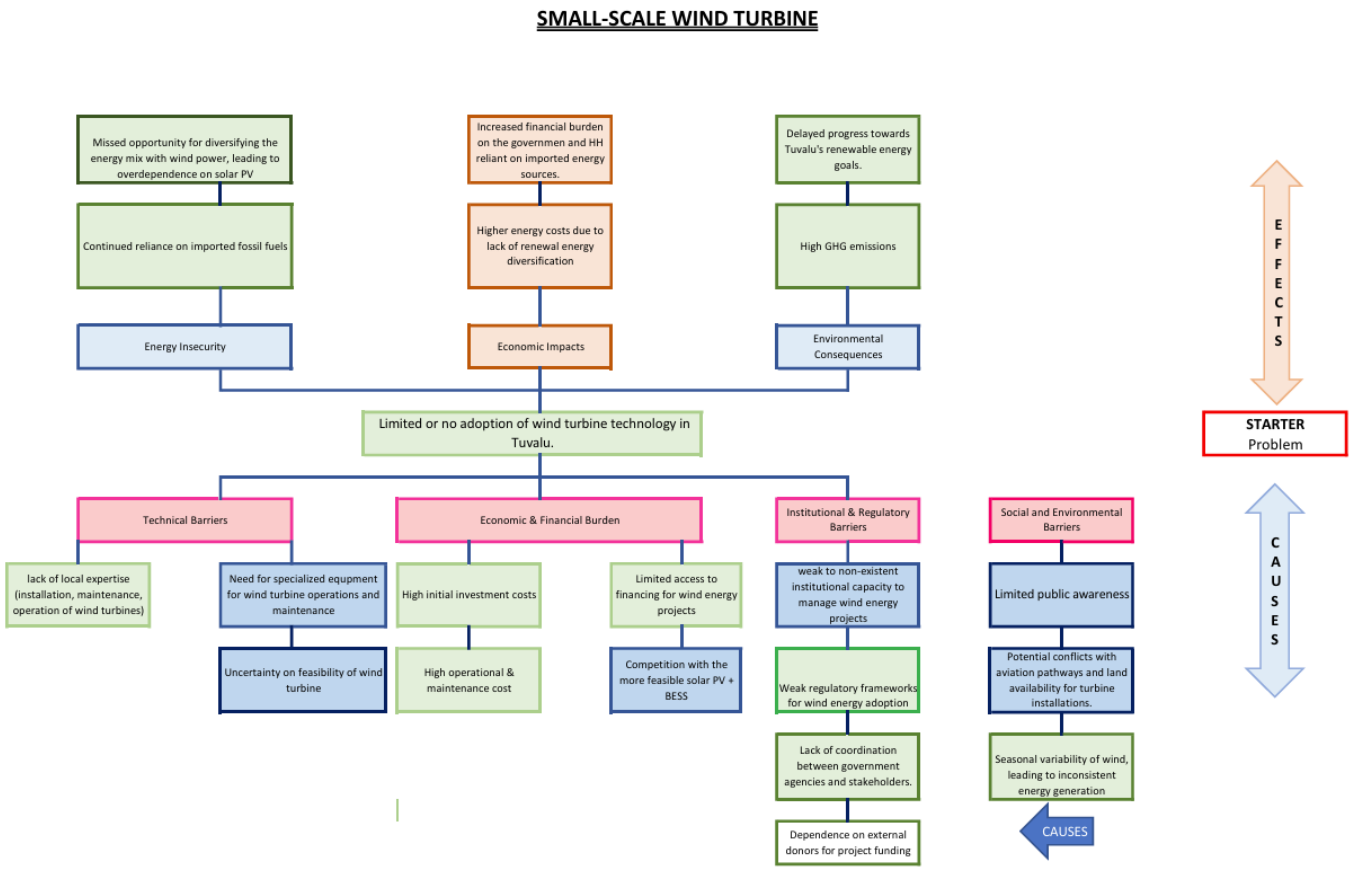

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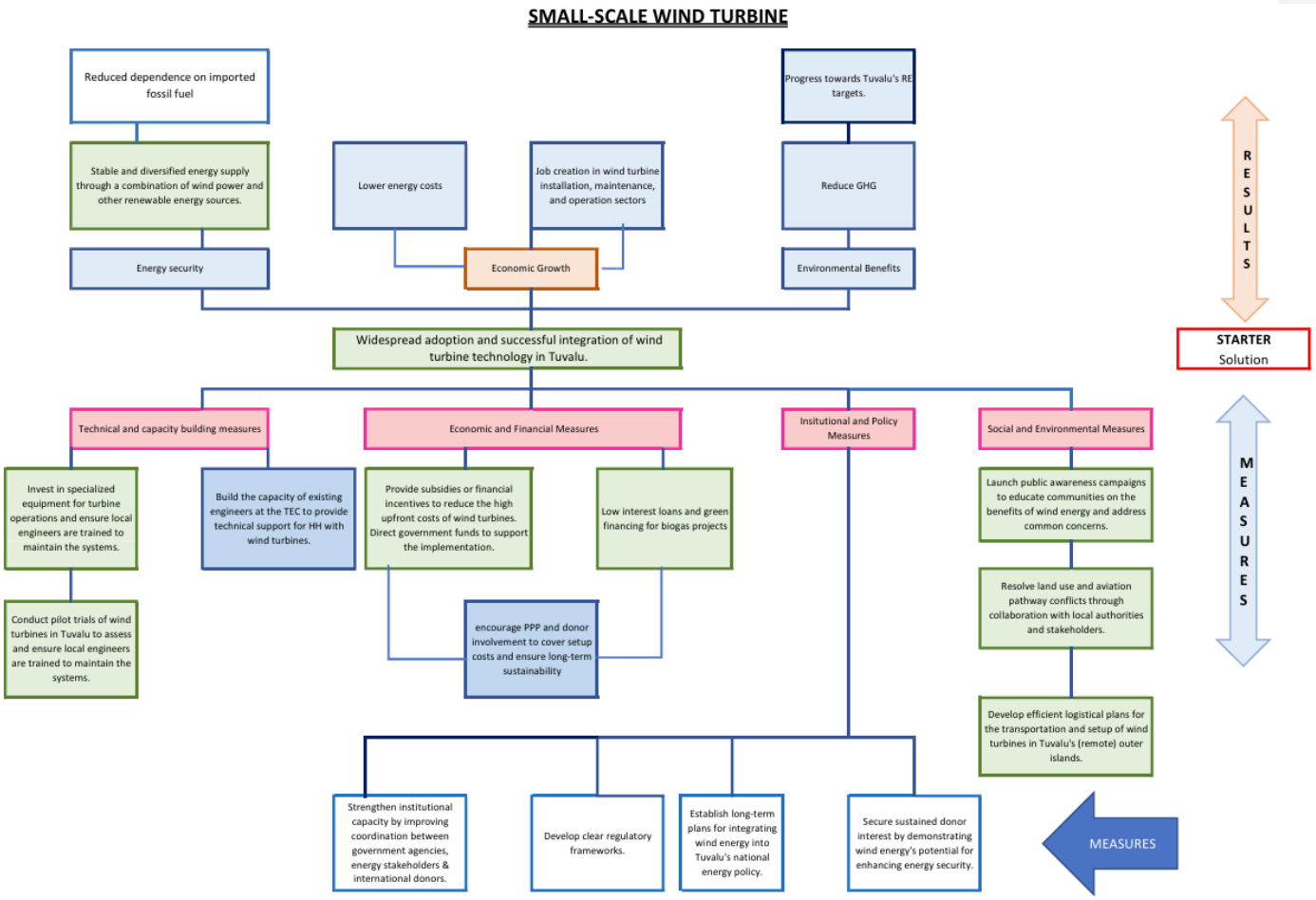

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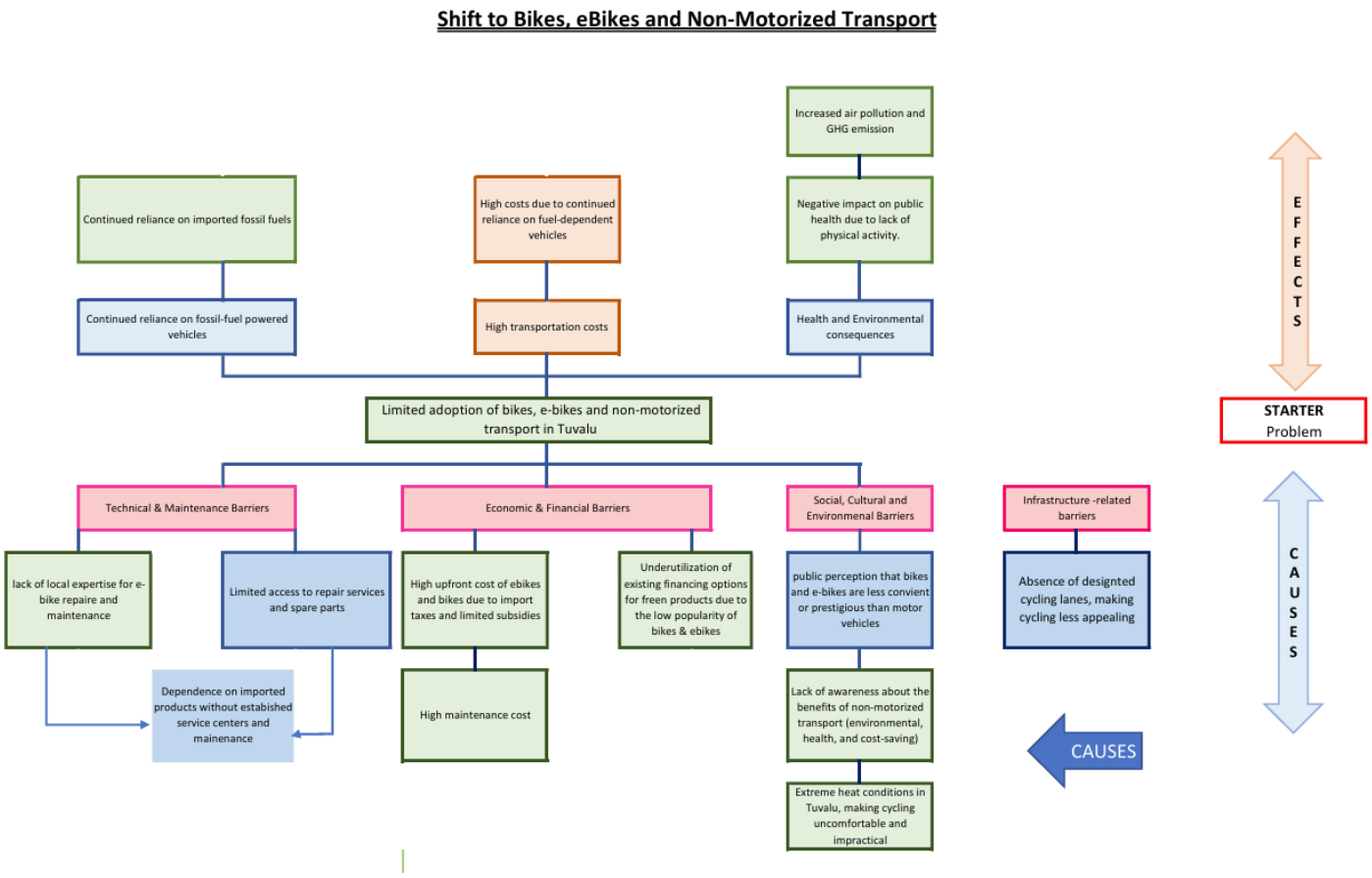
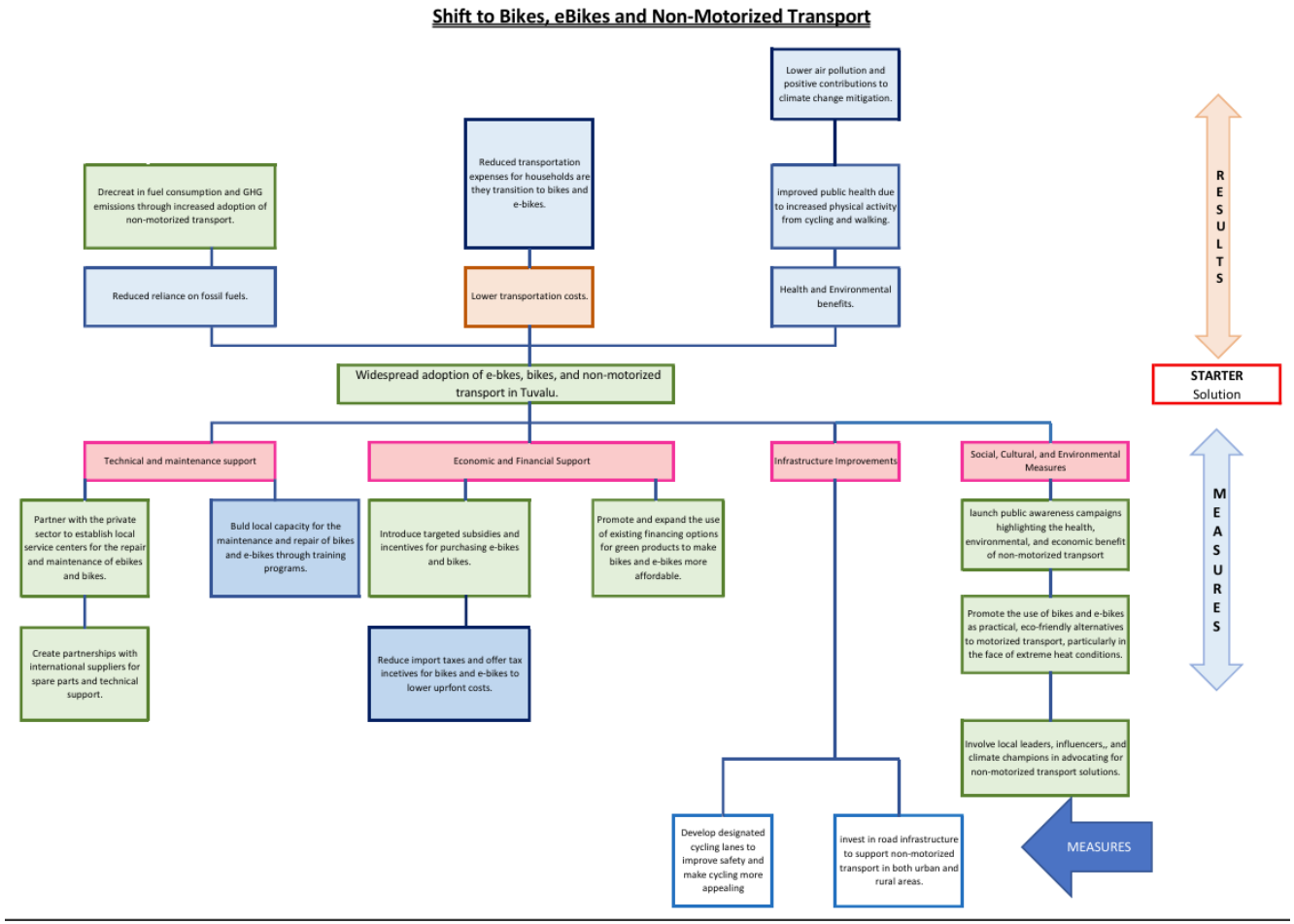
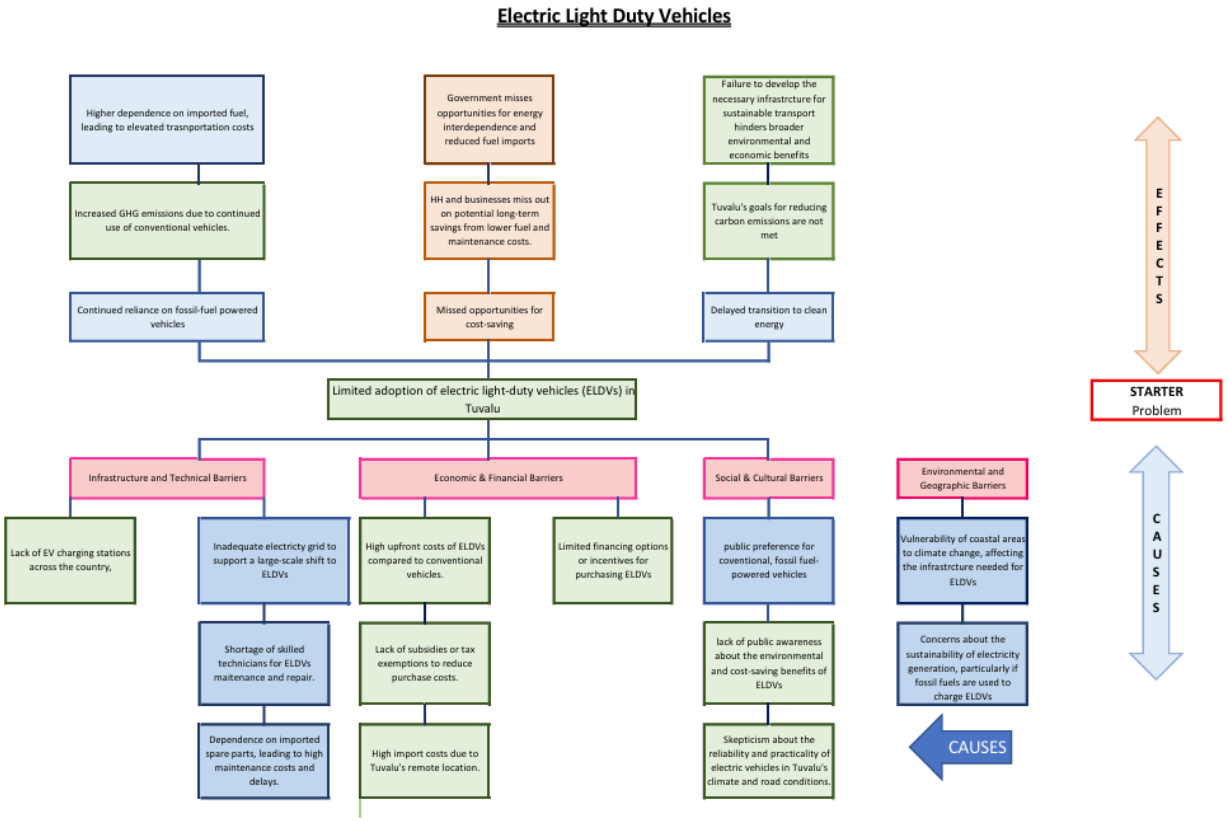


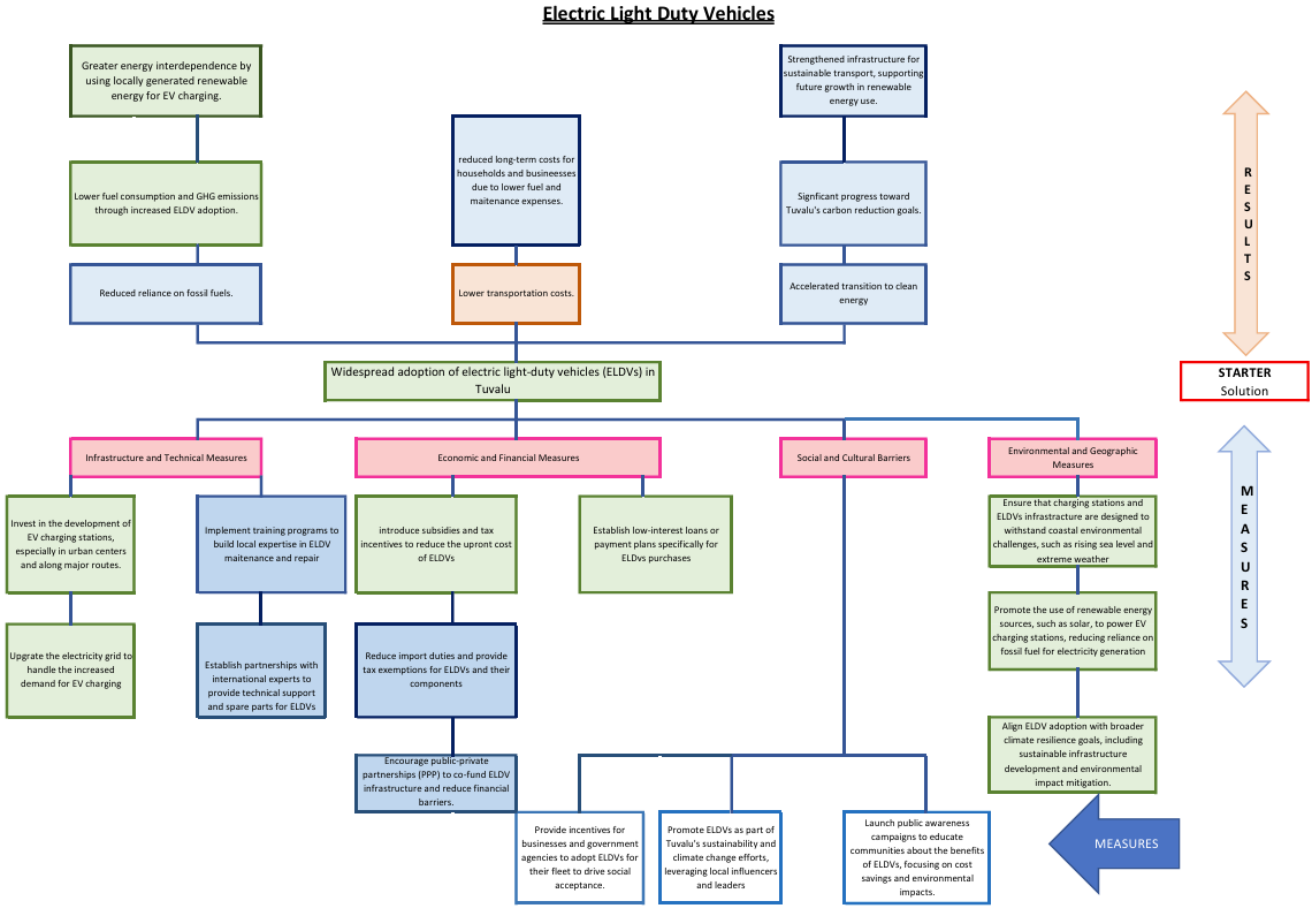
Annex 1.14: Solution Tree



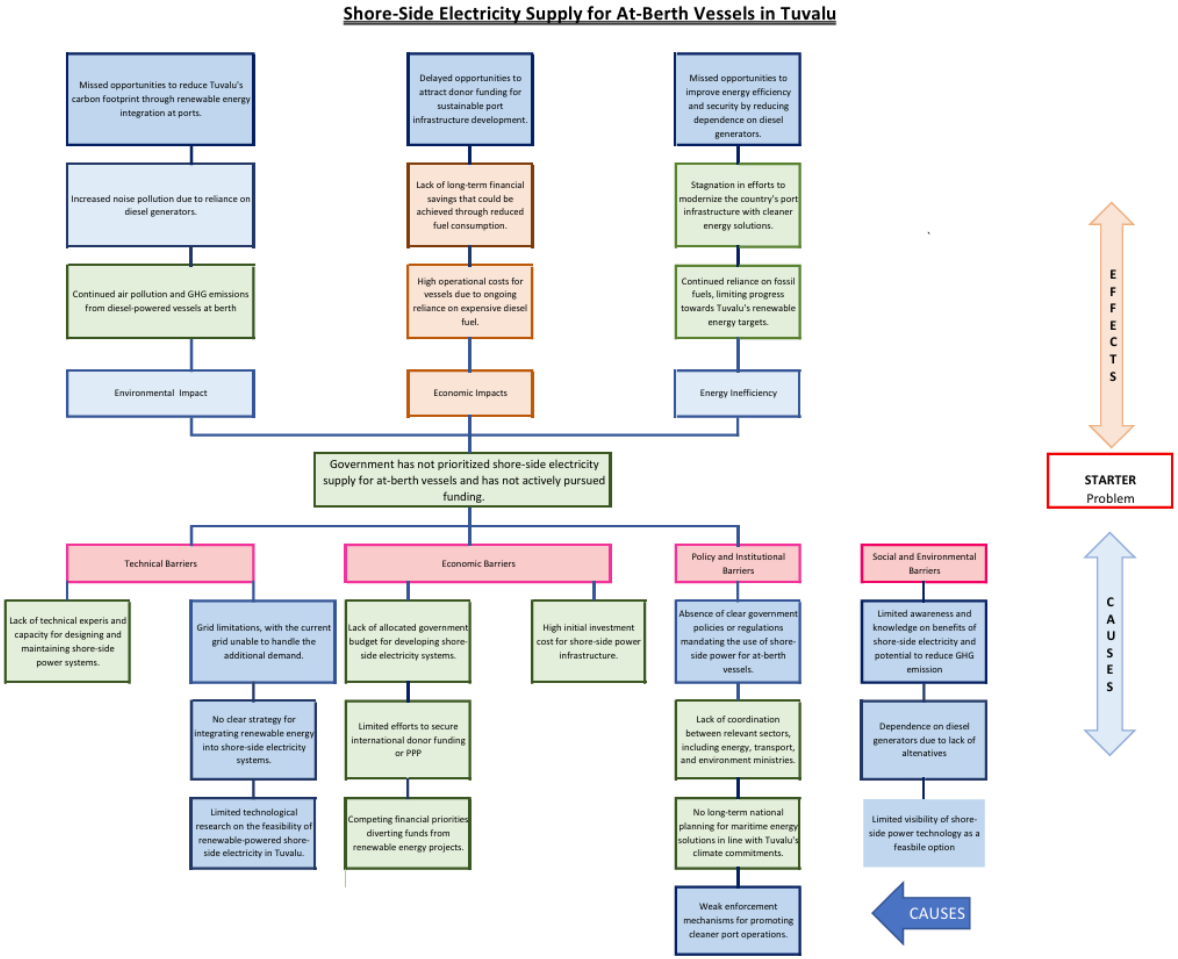
Annex 1.15 Problem Tree



Annex 1.16: Solution Tree



Annex 1.17: Problem Tree



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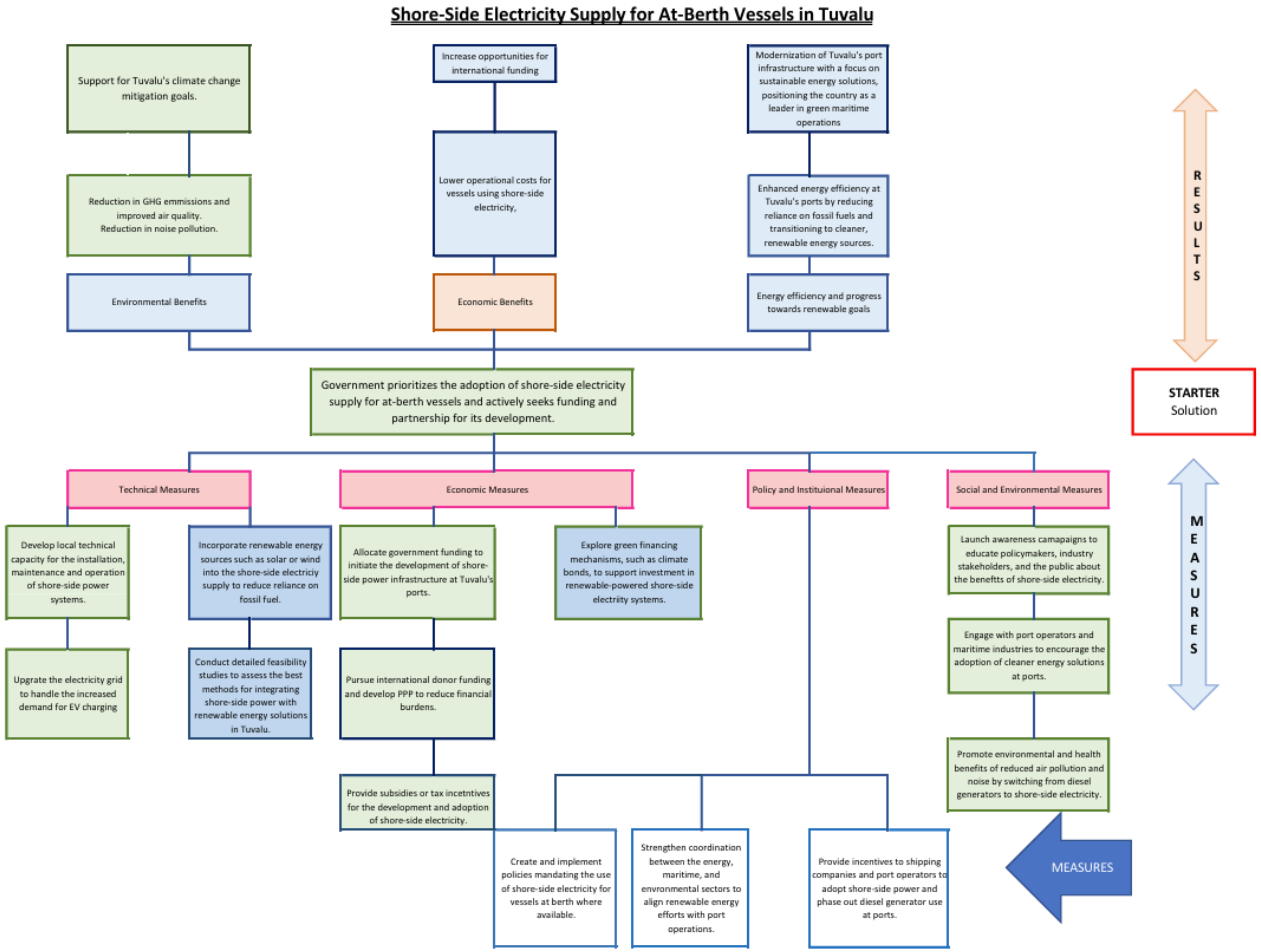

Annex II: List of stakeholders involved and their contacts

List of stakeholders involved in the identification of barriers and development of enabling framework, including their names, organisation, approach of consultation (e.g. interview, meeting discussion, questionnaire, etc.), time, and topics.

List of participants of TNA Mitigation Stakeholders			
	Name	**Designation**	**Organization**
1	Simona Kilei	Director	Department of Energy
2	Fakalogo Houati	Renewable Energy Specialist	Department of Energy
3	Mafalu Lotolua	General Manager	Tuvalu Electricity Corporation
4	Taaku Sekielu	Ag. General Manager	Tuvalu Electricity Corporation
5	Jamie Ovia	Mitigation Adviser	Climate Change Department
6	Lae Peleti	Senior Statitician	Central Statistics Department
7	Scott Pelesala	Senior Fisheries Officer	Tuvalu Fisheries Department
8	Siila Tapuaiga	Captain/ Master	Tualu Marine & Ports Services

9	Nito Lipine	Acting Director	Tualu Marine & Ports Services
10	Telaulini Niuatui		Civil Aviation
11	Seleta Taupo	Member	Tuvalu National Council of Women
12	Talua Nivaga	Secretary General	Fuliigafou Youth Association
13	Lemau Afamasaga	Technical Adviser	NDMO
14	Davis Vaea	Disaster Policy Officer	NDMO
15	Talafou Esekia	Disaster Recovery Officer	NDMO
16	Siliako Letueti	Waste Management Officer	Department of Waste Management
17	Reuben Kausea	Information and Knowledge Management Officer	Department of Environment
18	Faatupu Simeti	Project Coordinator	Tuvalu Third National Communications Project - Climate Change Department
19	Vaiaoga Lameko	Project Coordinator	Readiness 1 Project - Climate Change Department

20	Sulufaiga Uota	Project Coordinator	FASTNETT Project, Department of Energy
21	Sokotia Kulene	Director	Gender Affairs Department
22	Salesa Salesa	Communications Campaign Officer	Gender Affairs Department
23	Richard Gorkrun	Project Officer	Tuvalu Climate Action Network
24	Sania Teisini	Director	Customs & Revenue Department
25	Temukisa Pesega	General Manager	Development Bank of Tuvalu