Fiji

BARRIER ANALYSIS AND ENABLING FRAMEWORK FOR TNA- MITIGATION

[August 2021]

This publication is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UN Environment) and the UNEP DTU Partnership (UDP) in collaboration with University of the South Pacific. The views expressed in this publication are those of the authors and do not necessarily reflect the views of UNEP DTU Partnership, UN Environment or the University of the South Pacific. We regret any errors or omissions that may have been unwittingly made. This publication may be reproduced in whole or in part and in any form for educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. No use of this publication may be made for resale or any other commercial purpose whatsoever without prior permission in writing from the UNEP DTU Partnership.

Executive Summary

A study to perform a country-driven technology assessment was carried out under the Technology Needs Assessment (TNA) project. TNA allowed for the identification of environmentally sound climate technologies in addressing climate change mitigation needs of the country at the same time achieving the targets set in the National Development Plan (NDP). The TNA is a set of activities that identifies and analyses mitigation and adaptation technology priorities of developing countries such as Fiji and aims to support the developing countries in identifying pathways to meet their obligations under the United Nations Framework Convention on Climate Change (UNFCCC).

The TNA for climate change mitigation in Fiji is focused on rural electrification and domestic maritime shipping sub-sectors which are delineated from larger Energy and Transport Sectors, respectively. With over 332 islands in the Fijian archipelago, about 44.1% of the people reside in rural communities including islands and highlands, which make them highly vulnerable to climate change. Rising sea levels and storm surges compounded by the necessity to travel between islands, food security, access to electricity for economic development have made these two sub-sectors critical not only for total greenhouse gas emissions but also for the overall development of the nation.

The second step of the TNA process is the barrier analysis and enabling framework (BAEF), which identifies the barriers in technological transfer and diffusion and hence conjectures an enabling framework for better diffusion of the prioritized technologies. During the TNA, the following technologies classified as publicly provided goods (non-market) goods were prioritized and selected for further examination of barriers and enabling framework for the rural electrification sector:

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

For the domestic maritime transportation sector, the technological prioritization is presented here to take into account the newer targets set for this sector in the Updated NDC - 2020, which is a reduction of carbon emissions by 40% from this sector by 2030. Based on the provided TNA methodology and Multi-criteria analysis (MCA) approach, the technology prioritization was carried out. This TNA process prioritized the following technologies (comprising capital goods and market goods), publicly provided and non-market goods) for the domestic maritime shipping sector and was selected for further examination of barriers and enabling framework:

1. Sail-powered Passenger/Cargo Ship
2. Zero Carbon Passenger Ferry Trials
3. Eco-Flettner Rotor – retrofit and new-build technology

For both the sectors: the rural electrification sector and the domestic maritime shipping sector, the report discusses in detail the barriers that prevent the promotion and diffusion of the three prioritized mitigation technologies. To facilitate the identification of barriers, logical problem analysis (LPA) was used to identify the root causes of the main barriers that hinder the implementation of each mitigation technology. Using a Problem Tree (PT), the main barriers were decomposed to identify the root causes of barriers, and an Objective Tree (OT) that mirrors the PT was developed to identify possible measures to overcome the root causes. For Rural electrification, face-to-face meetings and virtual meetings provided the much-needed information on the long list of barriers, which was short-listed and prioritized during the stakeholder workshop. In the case of domestic maritime transportations, google surveys were used for prioritization and surveying on barriers. Then the report aims to outline the analysis of existing barriers and present an enabling framework for prioritized technologies in the two sectors.

For rural electrification, it has been observed that the economic and financial barriers are the most dominant in all three technologies influenced by a high capital investment required with a lower return on investment for investors due to low population income with very few income-generating opportunities. In the domestic maritime shipping sector, the identified barriers including economic and financial barriers; regulatory barriers; capacity barriers; and infrastructural barriers impact all prioritized technologies though it is in varying degrees. The same regulatory barriers impact all these technologies and would affect the adoption of any mitigation technologies or low carbon technologies or energy-saving devices for the domestic maritime sector. In addition, the most important are the economic and financial barriers as domestic maritime shipping in Fiji is a marginal business. Capacity is very much technology specific as different technology will require different training.

The enabling environment has been identified using the problem and solution tree together with a market mapping technique, which illustrated the supply chain mapping and was performed with the information gathered from stakeholders in order to identify barriers at each stage. A proposition has been made for the rural electrification sector to have a sustainable financing facility and an overarching viable financial model that allows for better returns for investors, income generation for households at the same time keeps the tariffs low with enough finance for O&M. A longer-term strategic development of the maritime region is important with sufficient sustainable financing needs to be available for the private sector and community cooperatives with lower collateral and interest rates. For domestic maritime transportation, the important underpinning Maritime Transportation Act needs to be reviewed and aligned with the MARPOL Annex VI, together with the inclusion of mandatory Ship Energy Efficiency Management Plan (SEEMP). A policy for high quality, timely and reliable data recording and sharing on shipping routes and fuel usages, etc. is also required. Both the sectors require a suitable insurance facility for renewable energy technologies and maritime vessels averting the financial risks from investors and financiers alike.

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Acronyms

BAU	Business-As-Usual
CAPEX	Capital Expenditure
CCD	Climate Change Division
CNO	Coconut oil
DGSS	Department of Government Shipping Services
DoT	Department of Transport
ESS	Energy Storage Systems
EFL	Energy Fiji Limited
FDoE	Fiji Department of Energy
GDP	Gross Domestic Product
GEF	Global Environment Facility
Gg	Gigagrams
GGF	Green Growth Framework
GHG	Greenhouse Gas
GSS	Government Shipping Services
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency
KPI	Key Performance Indicator
LEDS	Fiji Low Emission Development Strategy
MARPOL	International Convention for the Prevention of Pollution from Ships
MCA	Multi-Criteria Analysis
MCST	Micronesian Centre for Sustainable Transport
MPWTMS	Ministry of Public Works, Meteorological Services & Transport
NCCP	National Climate Change Policy 2018-2030

NEP	National Energy Policy
NDC	Fiji’s Nationally Determined Contribution
NDC-IR	Fiji’s Nationally Determined Contribution-Implementation Roadmap
NDP	National Development Plan
NOx	Nitrous Oxides
O&M	Operation and Maintenance
ODS	Ozone Depleting Substances
OPEX	Operational Expenditure
PV	Photovoltaic
SDG	Sustainable Development Goals
SDP	Strategic Development Plan
SEEMP	Ship Energy Efficiency Management Plan
SOx	Sulphur Oxides
SPC	Pacific Community
TA	Thematic Areas
TFS	Technology Factsheets
TNA	Technology Needs Assessment
UDP	UNEP-DTU partnership
USP	The University of the South Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Program
VOC	Volatile Organic Compounds

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Chapter 1 Energy Sector (Subsector: Off-Grid Rural Electrification)

In a bid to curb the greenhouse gas (GHG) emissions, in 2015, 195 countries agreed under the Paris Agreement to aim at limiting the global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels and intend to strengthen the ability of countries to deal with the impacts of climate change. Countries are required to prepare, communicate, and maintain the Nationally Determined Contributions (NDC), which includes the description of mitigation measures. NDCs are at the heart of the Paris Agreement, which reflects the country's ambition for reducing emissions, taking into account its domestic circumstances and capabilities. Fiji submitted its intended NDC in 2015 and was the first country to ratify the Paris Agreement. Fiji subsequently prepared its NDC Implementation Roadmap 2017-2030 (NDC-IR) in outlining the pathway to achieve its first NDC target. The overall mitigation target in Fiji's NDC was to reduce CO_2 emissions by 30% from a BAU (Business As Usual) baseline scenario in 2030 in comparison to baseline year – 2013. This target was further reiterated in Fiji's Updated NDC submitted to the UNFCCC in 2020. Fiji's NDC is specific to the energy sector with the baseline year as 2013 and outlines the potential mitigation actions including CO_2 abatement from electricity, industry, and transportation. The government is striving to reach 100% renewable energy power generation and through economy-wide energy efficiency. The progressive pathways on mitigation together with financing needs are expressed in the NDC-IR (2017-2030).

Preliminary targets for technology transfer and diffusion in the Energy Sector

Greenhouse gases emissions from the electricity sub-sector

A significant portion of Fiji's energy sector GHG emissions is from electricity production. Carbon dioxide and methane are the key GHGs emitted by stationary combustions. In remote rural locations, diesel and premix (commonly known as two-stroke oil or zoom) are largely used in generators for electricity, and naptha, kerosene, and solar lamps for lights. Though petrol is more used for transportation, small petrol generators are also utilized for electricity generations for households and small businesses, which accounts for 7.3% of Fiji's CO_2 emissions. The Second National Communications revealed that Kerosene (dual-purpose kerosene (DPK)) is generally used for cooking, lighting as well as jet fuel contributed about 19% to Fiji's CO_2 and between 1994 and 2004, the estimated emissions for the energy sector increased by 105%. Over the years from 2006-2011, an average of 2,500 Gg CO_2eq GHG emissions was estimated, from which 59% comes from the energy as er the TNC. Table 1.1 shows the GHGs and emissions from 2006-2011 from the energy sector.

Table 1.1: A summary of greenhouse gas emissions from the Energy Sector (Republic of Fiji, 2019).

Emissions of gasses by sector in Gg of CO_2 equivalent							Average 2006-2011
	2006	2007	2008	2009	2010	2011	
Carbon Dioxide							
Energy (Gg CO_2)	1767	1550	1333	1260	1526	1410	1474
Methane							
Energy (Gg CH_4 - CO_2eq)	2	2	1	1	2	1	1
Nitrous Oxide							
Energy (Gg N_2O - CO_2eq)	4	4	3	3	3	3	3

Policy context

Under the NDP, the Government aims to increase electricity generation from renewable energy sources to 100% by the year 2036, yet IRENA (2015) estimated that imported fossil fuels approximately takes 30% share of the total imports for Fiji since Fiji's energy sector is currently highly dependent on imported fossil fuels.

The Green Growth Framework (GGF) was produced in 2014, with an overall aim of reducing carbon 'footprints' at all levels having three Pillars (Environment, Social and Economic) delineated into ten thematic areas (TA) of which Building Resilience to Climate Change and Disasters (TA-1); Energy Security (TA-7); and Technology and Innovation (TA-9) are relevant to rural electrification.

The key guiding policy for electrification and the adoption of renewable energy is the National Energy Policy. The first National Energy Policy (NEP) endorsed in 2006, was reviewed and an updated draft NEP (draft NEP-2014) was prepared but not endorsed. Another national review of the NEP was incepted in 2020, Fiji's SDG7 Roadmap was also being simultaneously developed during this time. The SDG7 Roadmap provided the needed technical input into the new NEP endorsed by the Cabinet in 2023. Since 2006 the scope and objectives of the NEP has evolved to further focus on increased efficiency, support inclusivity and gender equity in relation to energy and the energy sector, scale-up and diversify Fiji's renewable energy portfolio, and support Fiji's long-term energy resilience and security.

The Fiji Electricity Act 2017 focusses on regulations regarding grid-connected electricity supply by protecting the consumers and the supplying company alike via regulating the tariff rates, providing an independent regulator for the electricity industry; ensuring that the company is financially able to cover its capital and operational costs and receive a certain predicted revenue stream through a determined tariff scheme. The act also aims to; (*d*) create opportunities for independent power producers to provide electricity if economical and, from a system integrity perspective, more beneficial to Fiji and the consumers of electricity; (*e*) improve competition and efficiency in the system operations and wholesale markets within the electricity industry, and thereby enhance customer services.

Fiji's first 20-Year National Development Plan – NDP (2017-2036) and a comprehensive 5-Year Development Plan (2017-2021) were launched in 2017. With a forward-looking vision for "Transforming Fiji" the NDP consists of two mutually inclusive and reinforcing prongs/approaches named, 'Inclusive Socio-economic Development' and 'Transformational Strategic Thrusts', it intends to sustain economic growth with increased GDP per person, reduced government debt, reduced unemployment rate, eradicating poverty, and having the aim of providing electricity to all with the target of 100% by 2036. Elimination of gender inequality and discrimination by having more women partaking in development is also the aim of NDP.

To achieve the global climate action goal, Fiji developed its Low Emission Development Strategy (LEDS) in 2018 that builds onto existing mitigation and adaptation actions being undertaken by the Fijian government and further defines pathways through which net-zero carbon emissions by 2050 can be achieved by Fiji aims across all sectors of its economy. The Fiji LEDS focusses on mitigation in the following sectors; a) Electricity and other energy generation and use; b) Land transport; c) Domestic maritime transport; c) Domestic air transport; e) Agriculture, forestry, and other land use (AFOLU); f) Wetlands (i.e., coastal wetlands, also referred to as blue carbon); g) Waste; and h) The cross-cutting sectors of tourism, commerce, industry, and manufacturing.

Fiji's LEDS adopts a logical approach in proposing sector-by-sector pathways to decarbonisation using modelling of baseline scenarios and compared to the following scenarios i) Business-As-Usual (BAU) Unconditional pathways (undertaken domestically); ii) BAU Conditional pathways (requiring international support); iii) High Ambition Scenario and iv) Very High Ambition scenario to achieve decarbonisation in respective sectors. A sketch of ambitious scenarios with systematic top-down and bottom-up approaches in deeply decarbonising all sectors of the economy by or before 2050 is presented in LEDS.

In 2019, the National Climate Change Policy 2018-2030 (NCCP) was endorsed that integrates development priorities in a strategic and cohesive manner to reinforce termed the woven approach. Having three pillars of objectives and strategies; I) Foundation; II) Dimensions; and III) Pathways, the NCCP aims to achieve GHG mitigation and Net-zero transition, environmental protection, Economic and Social Development, Climate Change adaptation and Disaster risk reductions. The transition to a low carbon economy is critical for Fiji in meeting the government's development objectives as well as the internationally agreed Sustainable Development Goals (SDGs) and the 2030 Sustainable Development Agenda. The sub-sector pertaining to Off-grid rural electrification is in line with Fiji's National Development Plan under 'Electricity for All initiative', which aims to achieve an ambitious 100% electrification of the population of Fiji where the key concern is electrifying the most remote and maritime communities where the grid extensions are not feasible.

The draft NEP-2013 aimed to; encourage non-governmental involvement in rural electrification; improve the effectiveness and sustainability of the existing management models for off-grid rural electrification to provide electricity to isolated communities and areas not served by the grid extensions. The draft NEP-2013 is currently under review and it builds upon the NEP-2013 and the NCCP. "*A resilient resource-efficient, cost-effective, accessible, reliable and environmentally sustainable energy sector for all Fijians*" is the vision of this newer NEP draft (NEP 2021-2030). The NEP 2023-2030 has six cross-cutting principles; affordability; competitive neutrality; energy access for all; gender equity, equality and empowerment; just transition; and renewable energy and sustainability. While the objectives of this policy falls under five policy pillars: 1) Energy Security and Resilience; 2) Energy Access and Equity; 3) Energy Sustainability; 4) Energy Efficiency; 5) Energy Governance. The NEP 2021-2030 addresses many of the challenges and barriers as outlined in this recognizing the need to address the overlaps and interconnectivity between sectors and actors to achieve Fiji's development goals.

Prioritized climate mitigation technologies

Rural electrification has been a priority for the government and it has been striving to achieve 100% electricity access. Renewable-based systems such as standalone off-grid systems including micro/mini-grids, which generate and distribute electricity independently of a centralised electricity grid are classified as distributed renewables for energy access (DREA) systems (REN21, 2020). These systems provide a wide range of services including lighting, consumer, and productive appliances in largely rural areas of the developing world and are key least-cost options for fulfilling modern energy needs and improving livelihoods. Off-grid systems of micro/mini-grid electricity generations are suitable for the electrification of small clustered communities in remote areas that do not have access to the central electricity grid. The geographical distribution of islands in the Fiji group limits the viable extension of the grid. The technologies selected in this TNA are of DREA type since the off-grid electrification was the focus.

After the first stage, which was the TNA process, the following mitigation technologies have been prioritized taking into account development priorities, climate, energy, and environmental policy goals for the off-grid rural electrification sector:

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

These technologies are already available in Fiji in varying degrees. For Technology 1 - the standalone solar PV for a single household (also commonly known as Solar Home Systems) is available locally. The current standalone solar home systems provided by DoE are designed to cater for individual household lighting and small fixed loads. Since solar is a modular system, upscaling in micro-grid configuration is practicable. For Technology 2 – some small remote villages have diesel generators to power small micro-grids in the night time only. Some small island resorts in Fiji have installed solar PV systems with battery storage for supplying electricity with diesel generators as a backup (Prasad and Raturi, 2020). For Technology 3 – few systems have been installed with mixed outcomes. The level of penetration for up-scaled systems is however far less than their technological and economic potential. Specific policy tools and financial instruments to support further adoption of prioritized technologies should be developed taking into account the long-term effects of the technologies and based on the broad stakeholder engagement.

All three prioritized technologies could be categorized as publicly provided goods (non-market) since these are goods provided to the public by governments (free or paid) that require essentially a large capital investment. A few sites offer potential for Micro/Pico-hydro installations, yet full feasibility study is important. With that, these technologies are procured largely through national tenders with some international tenders as well. The funding is largely sought from the government with some international donor funding. These technologies also have a simple market chain. However, depending on the specifics of the technology to be implemented by a particular household, the technology could also be classified as consumer goods, as these can be bought as separate pieces or as part of a whole system from local vendors. Under the rural electrification project, the Fijian government has been providing Solar Home Systems as a publicly provided good, hence for the purpose of the TNA project, the focus is on the complex introduction of up-scaled technologies and hence, all these technologies are treated as publicly provided non-market goods.

Primary targets for micro-grids

The overall target is to provide all Fijians with access to affordable and reliable modern energy services with an aim of a 100% electrification rate. The NDP (2017-2036) outlines these targets clearly as depicted in Table 1.2.

Table 1.2: National Development Targets from NDP (2017-2036) (Ministry of Economy-The Republic of Fiji, 2017).

Inclusive Socio-economic Development	**2015**	**2021**	**2026**	**2031**	**2036**
Access to electricity (% of population) (SDG 7.1)	20	100	100	100	100
Percentage of population with primary reliance on wood fuels for cooking (%)	18	12	6	<1	0
Energy intensity (consumption of imported fuel per unit of GDP in MJ/FJD) (SDG 7.3)	2.89	2.86		2.73	
Energy intensity (power consumption per unit of GDP in kWh/FJD) (SDG 7.3)	0.219	0.215		0.209	
Renewable energy share in electricity generation (%) (SDG 7.2)	67	81	90	99	100
Renewable energy share in total energy consumption (%) (SDG 7.2)	13	18		25	

The Department of Energy (DoE) with assistance from the government has installed solar PV based solar home system (SHS). The initial ones were Type I[1] SHS and over 5000 systems were installed (Raturi and Nand, 2016). After 2014, Type II[2] SHS were installed and a total of 9000 SHS were installed by 2015-2016 (Raturi and Nand, 2016). Type 1 SHS are currently

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[1] Type I SHS: 2 × 50Wp solar panels; 1 × 100 Ah battery; 10A charge controller and DC lights.

[2] Type II SHS: 2× 135Wp solar panels; 1 × 200 Ah battery, 20A charge controller; DC LED lights and 1 × 300W inverter

being replaced with Type II SHS since Type II SHS are larger systems, which can handle larger loads with more electrical appliances including AC appliances (Prasad and Raturi, 2020). Essentially, the load demand or the households have increased within a short span of time in comparison to the expected lifetime of the system. One other thing that has been reported is that households tend to connect more appliances into the Type I SHS than the recommended load leading to problems (Prasad and Raturi, 2020). With increased household energy demand larger systems are required. More than 40% of daily electricity demands for three larger outer islands (Kadavu Island-249 kW; Lakeba Island- 153 kW; Rotuma Island- 153 kW) are to be supplied from solar microgrids established under the project funding provided by United Arab Emirates (Engerati, 2015). Since 40% of the demands for these small islands are met, more such projects are required to reach the 100% target.

Additionally, the NDC investment projects pipeline for transport and energy efficiency sectors plans to transition from less efficient 2-stroke to more efficient 4-stroke outboard motors and eventually transitioning to fully electric outboard motors under mitigation action T10 – Outboard Motor Transition. The investment opportunity does not include the investment required to increase power generation capacity and strengthen the power distribution system in Fiji (Fijian Ministry of Economy et al., 2020). The need for a larger stable renewable electricity supply particularly for smaller islands in the group is expected to soar.

The key strategies pertaining to the goal "*A resource-efficient, cost-effective and environmentally sustainable energy sector*" from Fiji's NDP (2017-2036):

1. Develop small grid systems in other islands where practical.
2. Continue to develop and improve the human resource capacity in the energy sector.
3. Review design and construction standards for energy facilities that are climate change resilient.
4. Implement various measures and programmes to reduce the volume and cost of imported petroleum products, while ensuring the safety and security of supply.
5. Continue research and implementation of programmes to develop and increase the production of biofuel where cost-effective.
6. Improve sustainable supply of copra to the rural biofuel mills through replanting programmes. There are 9 biofuel mills on the following islands: Koro, Cicia, Rotuma, Gau, Rabi, Lakeba, Vanuabalavu, Moala and Matuku.
7. Implement Green Growth Framework for Fiji, in particular Way Forward outlined in Thematic Area on Energy Security.
8. Improve the effectiveness and sustainability of existing management models for off-grid rural electrification including Renewable Energy Service Companies and community cooperatives to provide electricity to isolated communities and areas not served by EFL.

The NDP (2017-2036) aims to have decentralised renewable energy sources such as solar, mini-hydro, and wind systems to electrify rural areas and maritime zones where feasible (Ministry of Economy-The Republic of Fiji, 2017). The DoE plans to install solar PV/diesel hybrid systems with storage replacing the diesel generator only systems to supply electricity to 60–70 households in remote areas where national grid extension cannot penetrate (Prasad and Raturi, 2020). The preliminary targets of the micro-grid technologies would be to fulfil the NDP (2017-2036) targets as outlined in Table 1.3. Particularly for having at least 10 hybrid systems and 10 mini-hydro systems together with setting up of at least biofuel programmes wherever possible. The implementation targets would have to endure the electricity supply for the transitioning to electric hybrid motors for outboards as alluded to earlier on.

Table 1.3: Programmes and Projects from NDP (2017-2036) (Ministry of Economy-The Republic of Fiji, 2017).

Programme	Annual Target					Total Output Expected	Lead agencies
	2017-2018	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**		
Rural Electrification Programme							
Grid Extension Power Supply Programme (No. of Schemes)	150	150	100	100	100	600	DoE
Connections to households and house wiring (No. of Households)	2500	2500	2500	2000	2000	11500	DoE
Solar Home Systems (No. of Households)	400	300	200	100	100	1100	DoE
Hybrid Systems (No. of Systems)	2	2	2	2	2	10	DoE
Mini Hydro (No. of Systems)	2	2	2	2	2	10	DoE
Maintenance of diesel and/or Hybrid Schemes (No. of Schemes)	15	15	15	15	15	75	DoE
Bio-fuel (Ethanol/Biodiesel) Programme (No. of Plant)	2	1	1			4	DoE

In the Ministry of Infrastructure and Transport, Disaster Management and Meteorological Services (MITDMMS) now the Ministry of Public Works, Transport and Meteorological Services, Strategic Development Plan (SDP-2019-2022) under the NDP 3.1.2: “A resource-efficient, cost-effective and environmentally sustainable energy sector”, the DoE strategizes to develop small grid systems in other islands where practical with the Key Performance Indictor (KPI) of 2 small grid implementations per year (MITDMMS, 2019). The DoE also has a KPI as a Feasibility study for wind, hydro, solar, wave and tide resource assessment to be completed by 2023 (MITDMMS, 2019). This would show the resource potentials and further strategies towards renewable energy developments.

Consideration of Gender Equality

Gender equality is an important aspect of supporting the diffusion of many technologies women are also the agents of change in societies. Women in rural and remote areas of Fiji face gender-related challenges, particularly lack of social infrastructure such as medical services and transportation with limited employment possibilities. In traditional social organizations practices patriarchy whereby the male is the head of the family and the title is traced through the male line. To promote gender equity, equality, social justice, and sustainable development a National Gender Policy was developed in 2014. Later the Gender Action Plan under the Lima work programme on gender was also adopted by Fiji at the COP-23. The 2018-2030 NCCP under its gender responsiveness pillar advocates on improving and enhancing the incorporation of women's knowledge, skills, participation, and leadership into planning processes at the local and national level.

Barrier analysis and enabling framework development process

In the first stage of the TNA project, three mitigation technologies for off-grid rural electrification have been identified taking into account the sectoral development priorities, rural development, mitigation potentials together with energy and environmental policy goals. All three prioritized technologies are categorized as publicly provided goods (non-market) since these goods are provided by the Government. Keeping in context the availability of components in implementing these technologies, the market mapping was conducted which is provided in Annex II (Figures A7-A9). The draft market maps were developed initially and updated whenever new information was provided by stakeholders. These maps illustrate the supply chain mapping and were performed with the information gathered from stakeholders in order to identify barriers at each stage of the supply. Simultaneously, one-to-one and small group meetings with stakeholders were conducted to make a long list of barriers that have the potential to impede the diffusion of respective technologies. The review of position papers and other communications presented by institutions, private companies, and business associations was also conducted to identify probable barriers from previous projects and the way these were countered.

Finally, the national stakeholder meeting was conducted. The long list of barriers was screened and the most essential ones were identified. The selected barriers were classified into a hierarchy of categories and a logical problem tree-based approach was used to identify the underlying 'root' barriers. The enabling framework process encompassed the determination of measures for the identified barriers taking into account the existing market and technological conditions, institutions, policies and practices, which resulted in problem and solutions trees provided in Annex I (Figures A1-A6).

Barrier analysis and possible enabling measures for Technology A1 "Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Micro-Grids)"

The general description of technology A1 "Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Micro-Grids)"

This technology is expected to supply electricity to a small off-grid community with electricity not only for lighting but for other purposes as well. Solar PV generates electricity during the daytime, while a battery storage system or a hybrid system with the inclusion of a generator caters for the night time load. The remote or off-grid PV generator is more common in developing countries and isolated areas. Fiji is an archipelago of around 110 permanently inhabited islands scattered across the South Pacific Ocean, grid extensions to these maritime islands are not economically feasible. In tandem with SDG7 and 3, this technology could provide access to modern electricity to the remotely located maritime communities.

This technology will include the following components; tilted solar photovoltaic (PV) module, charge controller, storage, inverter with micro/mini-grid installation. Depending on the size of the system, AC appliances such as television, radio, fans, laptops and charging of mobile devices can be used. Brief descriptions of the components are given in Figure 1.1.

Photovoltaic (PV) modules**:** The solar photovoltaic (PV) cells convert sunlight through the 'Photovoltaic effect' into direct electric current. Multiple cells connected within a module produce the module power output. The cells are usually linked in series and fixed within weather-proof modules. The current from the cell or module is inherently direct current (DC). The solar PV modules are found to be reliable with no moving parts and require minimal maintenance except for regular cleaning. Commercial solar modules with proven encapsulation give trouble-free service so long as elementary abuse is avoided and lifetimes of at least 20 years are achievable (Twidell and Weir, 2006).

Battery storage**:** Solar PV systems require a battery bank to store energy. Storage is required since solar energy is available during the daytime and large usages are for lighting at the night. Storage also assists in power regulation usually additional controllers are required for this purpose. Mostly lead-acid deep cycle batteries are used in solar PV applications locally. Many of these systems are using flooded batteries, which require regular maintenance. Since lack of maintenance was found as the main cause for system failures, the flooded batteries were replaced with sealed maintenance-free gel batteries. The usual battery lifetime is between 3–6 years and needs replacements thereafter. With the advancement in battery chemistry, newer battery technologies such as lithium-ion (Li-ion) batteries are preferable to Lead-acid (LA) batteries, when considering the levelised cost of electricity (Parra et al., 2015).

Balance of system components**:** includes two key components: battery charge controller - to keep the battery within the limits of charge rate and depth of discharge as recommended by the manufacturer; and the maximum power tracker (MPPT) – a DC-to-DC converter, which keeps

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3 SDG7 - Ensure access to affordable, reliable, sustainable and modern energy for all.

the input voltage close to the maximum power point as the irradiance varies. Usually, the charge controller and the MPPT are integrated as a single unit.

***Inverter*:** The DC output is then converted to AC, usually using inverters and other components, for use by many household appliances as well as for distribution onto the micro-grid grid network. Inverters play a crucial role in any solar energy system and are often considered as the brains of a technology. Inverters are required to supply constant voltage and frequency, despite varying load conditions, and need to supply or absorb reactive power in the case of reactive loads (Nwaigwe et al., 2019). In cases where more than one inverter is required in a standalone microgrid system, the inverters will be needed to reconcile with each other.

This technology consists of these components in various configurations depending on the respective load requirements. A proper feasibility study with system sizing is recommended. Small off-grid systems in remote/rural areas can be installed with minimal maintenance since there are no moving parts, yet regular cleaning of the solar panel is required to ensure efficiencies are maintained.

In terms of solar resources, Fiji has good solar insolation. Using 1983–2005 NASA data (NASA 2017), Prasad and Raturi (2020) found that an average annual insolation on a horizontal surface in Fiji is 5.4 kWh/m^2/day with a standard deviation of 0.6 kWh/m^2/day. They also reported that the lowest insolation of 4.0 kWh/m^2/day is recorded during the mid-year, while from October to February the peak solar insolation of around 6 kWh/m^2/day is recorded.

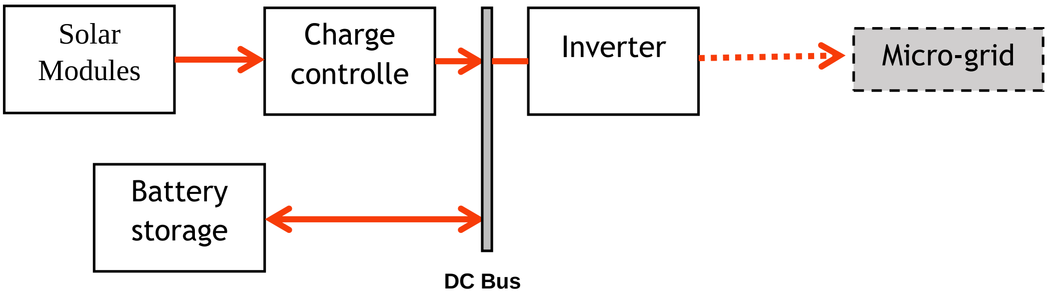

Figure 1.1: Schematics of *Technology A1* - Solar PV with ESS micro-grid technology.

Identification of barriers for technology A1

The barriers and respective measures for technology A1 - Solar PV with ESS micro-grid technology are discussed in the following sections while a summary is provided in Table 1.4 for brevity.

1. Economic and financial barriers

The average capital costs differ from system to system and from project to project. The costs of equipment can range from 5000 – 7500 USD/kW[4]. Previous experiences of stakeholders

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[4] The range provided is approximate costs collated from vendors and may change at the point in time of implementations due to many reasons including system sizing, type of Solar

show that the bulk of the funding is required for a proper feasibility study, cartage of equipment and heavy machinery to the islands, hire barges, helicopters, and take own heavy machinery and operators and workforce for site development and other logistics. At times the contractors have to develop infrastructure such as roads to the villages to cart the equipment. These costs are huge and need to be properly factored into the overall project budget to avoid a large overhead.

Operational costs have been noted to be high as well due to improper management of finances. A key barrier noted was the lack of an accurate and adoptable financial model for Solar PV micro-grid technology. In previous projects, there were no funding allocation for Operation and Maintenance (O&M) and poor capacity building for technicians or the trained technician migrating to Viti Levu. In considering market chain analysis, there were reputable local suppliers of solar PV modules, deep cycle batteries, electrical components and other installation equipment.

Non-financial barriers

The key non-financial implementation barriers for Solar PV micro-grid technology in Fiji include regulatory barriers, capacity barriers, and technology barriers.

Regulatory barriers

1. Under the regulatory barrier, gaps in regulations and regulatory system were the first level barriers. The stakeholder further identified that the regulations on asset ownership and micro-grid operations were not clear for donors. The Department of Energy is responsible for rolling out government-funded rural electrification projects, yet at times donor agencies did installations and there were no proper maintenance schedules made. Regulations in this regard need further attention.
2. The private sector felt that there was insufficient encouragement provided by the current policies.

Technological barriers

The technical barrier relates to complicated technological processes with Solar PV systems being very fragile when compared to diesel generator sets. In many villages, the people are more used to diesel generator-based micro-grids and they can connect as much load to the system. The system adjusts with the surge and the generator is not harmed. Due to a lack of awareness of the technicalities of solar PV micro-grids and know-how of it, communities are not able to regulate the load usages. For instance, they have a small TV when the system was sized and then a relative from overseas sends a very large TV since the village is electrified. Without realizing that the system was designed for a specific load, the people plug a larger load which damages the system.

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modules/batteries/other components and fiscal policies/incentives. The cost is for equipment and installation only does not include costs of feasibility studies, EIA and cartage costs etc.

Capacity barriers

The capacity barrier relates to an insufficient number of qualified technical, financial, and analytical expertise for Solar PV micro-grids with insufficient micro-grids design engineers. There is a lack of dedicated professional training programs in technical institutes in Fiji preparing micro-grids design engineers and solar PV micro-grid financial experts. Many PV project developers have to cooperate with technology suppliers and send their personnel for training abroad to gain relevant expertise. Some equipment, manuals and software are in foreign languages, which makes it difficult for personnel to have a full understanding. Usually, project-based training is provided that is usually short about 3 months or so and developers feel that it may not be sufficient. Some developers are using international project-based design teams and local engineers are not fully trained in the designing aspects of the system.

Identified measures

Economic and financial measures

Since the micro-grids are capital intensive but reliable therefore more access to capital funding is a dire need. An option for promoting the diffusion of technology is the introduction of incentives for solar PV micro-grids such as tax-holiday for the private sector that would like to develop and maintain the technology with income generation opportunities for communities. Direct capital investments and small grants provided by the government to the private sector can also attract more investors.

Many remote maritime communities have a low cash micro-economy, as a result, the operations and maintenance of the system are not carried out properly. The government has to bear the costs in the end. A clear and adoptable financial model for income generation opportunities for communities together with technology O&M is imperative to allow for more cash flow into these communities.

At the household level, smart pre-paid metering is one of the options that could allow users to monitor electricity usage. Pre-payment can allow ease of revenue collections and reduce the burden on the central government for O&M costs. Damages sustained to systems from extreme climate events such as cyclones exacerbate the O&M costs as climate-resilient infrastructure, in particular, civil works are expensive.

There should be a provision of subsidies to women who are financially constrained being made in the policies so that disadvantaged women can have equal access to electricity and improve their quality of life.

Non-financial measures

Regulatory measures

1. Donor-funded projects need to be monitored well to avoid the fix and forget nature of projects. The monitoring and evaluation frameworks of respective projects need to be properly adopted.
2. More incentives for the private sector could be provided by the newer policies.

3. The NEP 2023-2030 captures the needs of current stakeholders as much as possible with the evolving energy market however, needs reosures for implementation.

4. Since after communities have access to electricity, the demand usually rises with people buying more appliances and equipment. As such mandatory regular energy audits need to be carried out in order to cater for the increased demand and restrict the usage of unapproved equipment.

Technological measures

1. There needs to be proper and dedicated information and knowledge dissemination pertaining to the operations, economic, environmental and social benefits of solar micro-grid. The community needs to realize the know-how and an understanding of the impacts of non-designed load usages.
2. Another option would be to upsize the systems that can handle large surges, yet it needs to be feasible. Regular load analysis of the community needs to be carried out and the system needs to be up-scaled according to the increased demands. This provision needs to be made in the financial plan.

Capacity measures

3. Capacity-building activities should target the training of professionals to attain technical, financial and analytical expertise for solar PV micro-grids and also prepare micro-grids design engineers.

4. In particular, educational institutions should adjust their curriculum and train specialists that would meet current industry requirements. Currently, there are no local institutions training micro-grids design engineers.

5. Targeted capacity building for technicians.

6. An interesting measure suggested was to train women as technicians since women usually stay in the villages and rarely migrated.

7. Tailoring training and skills development with strengthening mentoring opportunities for women could be a possible measure and it is imperative to include gender quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities.

Barrier analysis and possible enabling measures for Technology A2 “Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS (micro-grid)”

The general description of technology A2 “Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS (micro-grid)”

This is a hybrid technology to provide round-the-clock electricity supply to small communities that largely depend on small solar home systems or generators. This hybrid system consists of a solar PV with battery bank and a dual fuel generator that could run on either diesel or coconut oil. In many remote communities, micro-grids with diesel generators have been installed by the Government. With increasing diesel costs in rural areas and a contracting economy, the electricity production from diesel generators is putting pressure on the income level of communities (Ministry of Strategic Planning National Development and Statistics, 2014). Some schools in remote locations also run on similar technology. These diesel-powered micro-grids are largely used for lighting at night.

Using this PV/generator hybrid technology, during the daytime, the solar PV would meet the demand using either direct light or diffuse sunlight, while excess energy will be using appropriate energy storage systems. The stored energy and dual fuel (CNO/Diesel) generator can be utilized during the night. In some cases, the days of battery autonomy can be reduced since the generator will cater for the energy deficit. This technology application is not common in Fiji, however, this could be implemented in remotely located communities and remote maritime communities where grid extension would not be feasible. A schematic of the technology is given in Figure 1.2.

The other benefit of the dual fuel generator is that it can run on coconut oil (CNO) as the fuel. There is significant potential for the copra industry and CNO production. If there is sufficient CNO for fuel, the community would not have to spend large sums of money on diesel fuel. Significant co-benefits in terms of income generation from localized copra industry, coconut oil production, and savings are possible.

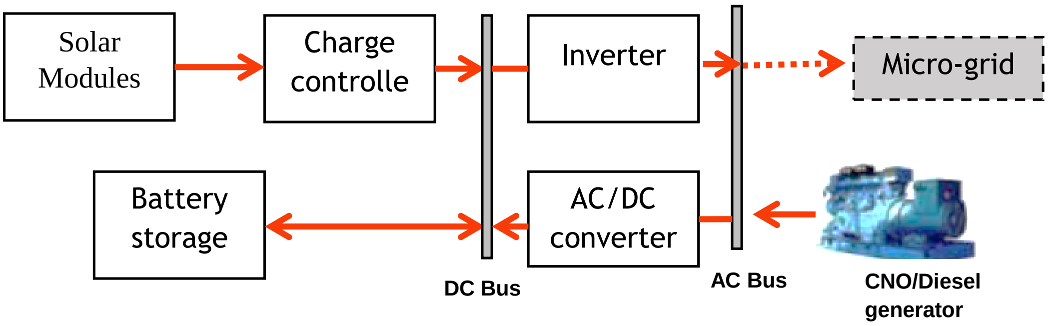

Figure 1.2: Schematics of *Technology A2* - PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS.

With hybrid systems, the utilization of solar energy for electricity generations needs to be maximized in consideration with economic feasibility. With an optimally designed system, the maximum GHG abatement would also be possible as the generator operations would be kept to minimal. Additionally, it is imperative to create proper load profiles based on information on household energy equipment of the community. Annual load based on household monthly energy consumption is also essential together with an estimation of load profile, PV area, and battery storage size.

Analysis of solar PV system design needs a collection of all necessary solar irradiance data, while the battery bank needs to be sized to supply the load and reduce CNO/diesel dual fuel generator operation time. Solar PV with diesel and battery storage mini-grid systems would make a reliable system for smaller remote islands (Prasad and Raturi, 2020). If a good supply chain of coconut oil could be developed, then this carbon-neutral fuel could be sourced at a cheaper rate. Analysis of changes in future load demand and load usage profiles needs to be factored in as the system lifetime is for 20-25 years.

Identification of barriers for technology A2

The barriers and respective measures for technology A2 - PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS are discussed in the following sections while a summary is provided in Table 1.4 for brevity.

Economic and financial barriers

This is a hybrid system with solar PV and ESS as in the above technology together with a dual fuel generator. As a result, the capital cost is huge in this hybrid system. Significant funding is also required for proper feasibility study and optimization of the system to reduce the dependence on the generator with minimization of the cost function. The costs of equipment can range from 6500–9000 USD/kW5. The feasibility study, cartage of equipment and heavy machinery to the islands, site development, workforce mobilization and other logistics incur huge costs according to the experiences of stakeholders. At times the contractors have to develop infrastructure such as roads to the villages to cart the equipment and need to be properly factored into the overall project budget to avoid a large overhead.

Improper financial management procedures have led to the unsustained operation. Reviving such a damaged system incurs large costs and is usually left unattended. Damages sustained to systems from extreme climate events such as cyclones exacerbate the O&M costs as and climate-resilient infrastructure, in particular, civil works are expensive. Lack of an accurate and adoptable financial model for solar PV/generator (CNO/diesel) micro-grid technology implementations is one of the important barriers. Dependence on diesel only micro-grid has proven to be expensive in terms of diesel fuel costs.

Provision should also be made to supply electricity to financially constrained women at a subsidized rate.

Non-financial barriers

The key non-financial implementation barriers for PV/generator hybrid micro-grid technology in Fiji include regulatory barriers, capacity barriers, and institutional barriers.

Regulatory barriers

1. Under the regulatory barrier, gaps in regulations and regulatory system were the top-level barriers. The stakeholders further identified that the regulations on asset

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5 The range provided is approximate costs collated from vendors and may change at the point in time of implementations due to many reasons including system sizing, type of Solar modules/batteries/components/genset and fiscal policies/incentives. The cost is for equipment and installation only does not include costs of feasibility studies, EIA, cartage costs and trainings etc.

ownership and micro-grid operations were not clear for donors. The DoE is responsible for rolling out government-funded rural electrification projects, yet at times donor agencies did installations and there were no proper maintenance schedules made. Regulations in this regard need further attention.

2. The private sector engagement also requires enhanced participation and encouragement in the rural electrifications.

3. Apt IPP framework needs to be developed in this regard together with Renewable Energy Service Companies and community cooperatives to provide electricity to isolated communities and carry out O&M.

Capacity barriers

1. The capacity barrier relates to an insufficient number of qualified technical, financial and analytical expertise for PV/generator micro-grids with insufficient micro-grids design engineers.

2. There are no professional training programs in technical institutes in Fiji preparing micro-grids design engineers and solar PV micro-grid financial experts.

3. Many PV project developers have to cooperate with technology suppliers and send their personnel for training abroad to gain relevant expertise. Some equipment, manuals and software are in foreign languages, which makes it difficult for personnel to have a full understanding. The training provided is usually short about 3 months or so and developers feel that it may not be sufficient. Some developers are using international design teams. Stakeholders shared the view that this problem can persist with PV/generator hybrid systems as well.

4. System optimization is crucial in hybrid systems to reduce the dependence on diesel for operations in order to realize the maximum economic, environmental and social benefits.

Institutional barriers

To have coconut oil (CNO) as fuel, consistent and high-quality oil needs to be produced at the local community level.

1. A huge distortion in the supply chain has been experienced in the past by stakeholders.
2. The underlying issue was the lack of confidence in the coconut and copra industry. Communities view copra as a low-value product generating low income, while high-value products like yaqona are preferred.
3. The competitive market for other high value uses for CNO for example the skincare industry.
4. If CNO is sourced from a nearby island, then irregular maritime transportation interrupts regular supply.

Identified measures

Economic and financial measures

1. More access to capital funding needs to be required. An option for promoting the diffusion of technology is the introduction of incentives for hybrid micro-grids such as tax-holiday for the private sector that would like to develop and maintain the technology with income generation opportunities for communities.
2. A Sustainable Energy Financing Project (SEFP): This offered funding to individual/community/private/businesses who want to use or supply energy efficiency, solar, hydro, or coconut oil fuel equipment for electrification purposes. The borrower needed to provide 50% security on the loan since the World Bank provided the other 50% as a guarantee. This was previously offered and ended in 2017. A similar financing facility should be developed for micro-grid technologies.
3. The Fiji Development Bank has a Sustainable Energy Financing Facility product that allows farmers and businesses to adopt sustainable energy technology: Hydro; Solar; Coconut oil fuel; Energy efficiency equipment; Wind; biomass; biogas; wave; tide; and feasible geothermal systems. Features: 20% equity required; interest rate is 5% per annum. (If Reserve Bank of Fiji funded: 5% applies, otherwise normal lending rates apply). This could further be extended to cooperatives to develop micro-grids.
4. A clear and adoptable financial model for increased income generation opportunities for communities together with technology O&M is needed for these remote maritime communities since there is very low cash flow. As a result, the government has to bear the O&M costs in the end.
5. A measure to have ample finance for O&M is to have smart pre-paid metering to monitor the electricity usage and implement user-pay systems. Pre-payment can allow ease of revenue collections and reduce the burden on the central government for O&M costs.
6. Climate-resilient infrastructure and civil works need to be carried out to reduce unwarranted damages to the PV system or the generator housing from extreme climate events such as cyclones, which can exacerbate the O&M costs.
7. Allocation of seed funding for O&M.
8. Targeted capacity building for technicians.
9. Provision of subsidies to women who are financially constrained, so that disadvantaged women can have equal access to electricity and improve their quality of life.

Non-financial measures

Regulatory measures

1. Regulations on asset ownership and micro-grid operations need to be clear with proper maintenance schedules outlined.
2. Enhanced participation and encouragement of the private sector in the rural electrifications are required with more tax incentives.

3. Subsidies on equipment and land purchases for CNO/biofuel production.
4. Apt IPP framework needs to be developed in this regard together with Renewable Energy Service Companies and community cooperatives to provide electricity to isolated communities and carry out O&M.
5. Foster an improvement in the effectiveness and sustainability of existing management models for off-grid rural electrification including Renewable Energy Service Companies and community cooperatives to provide electricity to isolated communities and areas not served by the EFL. This is also targeted in the NDP (Ministry of Economy-The Republic of Fiji, 2017).
6. Mandatory regular energy audits need to be carried out to cater for the increased demand and restrict the usage of unapproved equipment.

Capacity measures

1. More training of qualified professionals for technical, financial, and analytical evaluations of PV/generator micro-grids.
2. More trained micro-grid design engineers are required with technical institutes in Fiji training micro-grid design engineers and micro-grid financial experts.
3. Proper system optimizations by qualified experts are to be carried out.
4. An interesting measure suggested was to train women as technicians since women usually stay in the villages and rarely migrated
5. Tailoring training and skills development with strengthening mentoring opportunities for women could be a possible measure and it is imperative to include gender quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities.

Institutional measures

1. The positive economic benefit of biofuel development for rural areas needs to be capitalized on, by increasing demand for coconuts or other oil-bearing crops and increasing cash incomes in rural areas.
2. Maritime transport networks and frequency have to also improve to have proper fuel supply if sourced from a nearby island.

Barrier analysis and possible enabling measures for Technology A3 “Micro/Pico-hydro in micro-grid configuration”

The general description of technology A3 “Micro/Pico-hydro in micro-grid configuration”

Pico hydropower is rarely fed into a power grid, but in most cases, electricity is delivered to a village or a workshop. As there are varying definitions of the power range of "micro" and "pico", it is advantageous to specify each project's power output in kW. This technology presents pico hydro microgrids to power a small community for their energy demands. Micro hydropower is the only form of small renewable energy production, which works continuously without battery storage. Where applicable with enough resources, it is one of the cost-efficient solutions to supply electrical energy. Individual households or small clusters of households could be powered by micro/pico hydro turbines. Usually, this technology provides power for a small community or rural industry in remote areas away from the grid. Proper site identification in terms of the reservoir, flow rate and head height need to be determined before undertaking any hydro project. A schematic of micro/pico hydro technology is presented in Figure 1.3.

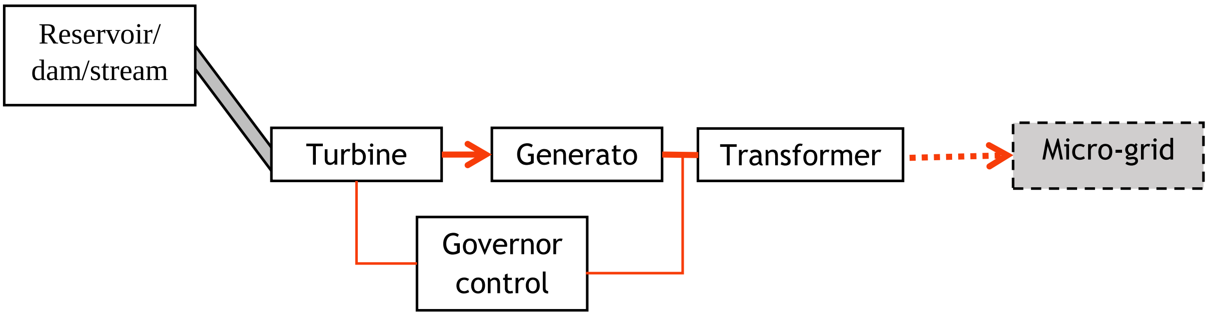

Figure 1.3: Schematics of *Technology A3* - Micro/Pico-hydro in micro-grid technology.

Identifying, planning and managing take a higher proportion of the whole installation efforts. Installation includes installing the turbine and grid installation to the appropriate point of need.

Identification of barriers for technology A3

The barriers and respective measures for technology A3 - Micro/Pico-hydro in micro-grid technology are discussed in the following sections while a summary is provided in Table 1.4 for brevity.

Economic and financial barriers

1. The development of micro/pico hydro systems incurs considerable capital investment. The costs of equipment can range from 4000 – 7500 USD/kW[6]. Funding is also required for a long-term feasibility study with the development of such as roads with cartage of equipment and heavy machinery to the site, site development, and workforce mobilization.

2. The absence of a micro/pico hydro industry has been noted (due to) lack of finance and viable financing mechanisms.

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[6] The range provided is approximate costs collated from vendors and may change at the point in time of implementations due to many reasons including system sizing, type of turbine and generator requirements and fiscal policies/incentives. The cost is for equipment and installation only does not include costs of feasibility studies, EIA, cartage costs and trainings etc.

3. Operational costs have been noted to be high as well due to improper financial management plans. Lack of accurate and adoptable financial model for hydro micro-grid technology implementations.
4. Access to finance for private project developers is also an issue with very difficult conditions in securing loans and high interest rates.

Non-financial barriers

Key non-financial implementation barriers for micro/pico hydro micro-grid technology in Fiji include regulatory barriers, capacity barriers, and institutional barriers.

Regulatory barriers

1. Incentives for private sector participation in assessment and development of sites are generally lacking, as well as a lack of interest in project implementation.
2. Apt IPP framework needs to be developed in this regard together with Renewable Energy Service Companies and community cooperatives to provide electricity to isolated communities and carry out O&M.

Capacity barriers

1. Under the capacity barrier, it was identified that there is a lack of technical expertise and resources to develop new small-scale hydroelectric power plants. Fiji does have a well-developed hydropower sector and has the capacity to operate and maintain the plants.
2. There are no local professional training programs for micro/pico hydro engineers. Many consultants are hired from abroad.
3. Insufficient personnel for installations is a barrier.
4. At the community level, there is a lack of awareness on maintaining rivers and streams as well as upkeep of micro/pico hydroelectric systems.

Institutional barriers

To have a successful micro/pico hydro project, a comprehensive feasibility study is imperative. It has been identified that insufficient knowledge of resources is a barrier, which is restrained by:

1. Limited resources to undertake full feasibility studies of identified sites. At times more resources and finances are required to perform long-term studies.
2. Site monitoring and assessment become more challenging under frequent extreme climatic events such as heavy rainfall, floods, and landslides.
3. Land tenure issues whereby landowners demanded large compensations were also identified as barriers.

4. Environment impacts are not aptly mitigated during the development of sites in few instances in the past leading to adverse impacts on the surrounding ecology.

Identified measures

Economic and financial measures

1. Reviving Sustainable Energy Financing Project (SEFP) which provides funding to individual/community/private/businesses for energy efficiency, solar, hydro, or coconut oil fuel equipment for electrification purposes.
2. The Fiji Development Bank has a Sustainable Energy Financing Facility that could be extended to cooperatives to develop micro-grids.
3. A clear and adoptable financial model for increased income generation opportunities for communities together with technology O&M is needed for these remote maritime communities since there is very low cash flow. As a result, the government has to bear the O&M costs in the end.
4. Access to finance for private project developers is also an issue with very difficult conditions in securing loans and high interest rates.

Non-financial measures

The following measure could be adopted as non-financial measures.

Regulatory measures

5. Giving incentives to the private sector is seen to entice them into increasing their interest and investment in technologies. Incentives could include both financial and tax incentives including seed investment funds, loan guarantees, direct working capital, grants, tax holiday, tax-free zoning, accelerated depreciation on assets, and funding on-the-job training for new employees. This is not a comprehensive list and more innovative incentive strategies could be added.
6. Development of the IPP framework with Renewable Energy Service Companies and community cooperatives is required.

Capacity measures

7. Local technical expertise and training in micro/pico hydro technology are essential to handle the new technologies.
8. More professional training programs for micro/pico hydro engineers are to be developed. Gender training quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities are to be developed to increase the participation of women.
9. Targeted capacity building for technicians and engineers. Professionals need to be trained more in areas where the skills and expertise are lacking.

10. Community-level awareness programmes on maintaining rivers and streams are to be developed with the inclusion of farmers and women who traditionally has been frequent users of rivers and streams for various purposes.

11. Information dissemination and awareness training on up keeping of micro/pico hydroelectric systems for communities is also an important measure.

Institutional measures

12. Increased resources for full feasibility studies of identified sites are required. At times more resources and finances are required to perform long-term studies.
13. Landowning units should be involved from the beginning of the project and an agreement could be sought if all stakeholders are working mutually.

14. Comprehensive EIA is to be carried out to mitigate the adverse impacts. More local personnel are to be trained in carrying out EIA.

Table 1.4: Summary of identified barriers and proposed measures for technology transfer in the Rural Electrification Sector.

Technology / **Barriers and measures**		**Standalone Ground Mount Solar PV with ESS (Community Based Electrification - Micro-Grids)**	**Ground Mount PV with Dual fuel (CNO/Diesel) Generator Hybrid systems with ESS (micro-grid)**	**Micro/Pico-hydro in micro-grid configuration**
Economic and financial barriers	**Barriers**	• Are capital intensive. • High capital and O&M costs	• hybrid systems are very costly. • unsustained operations • Improper financial management procedures	• lack of finance and viable financing mechanisms. • Capital intensive. • Large civil works required. • Lack of accurate and adoptable financial model
	Measure	• More access to capital funding • Tax incentives for the private sector. • Availability of direct capital investments and small grants. • Clear and adoptable financial model with income generation opportunities for communities. • Proper O&M planning and financing.	• More access to capital funding e.g., Sustainable Energy Financing Project (SEFP) with low equity and interest rates. • Availability of direct capital investments and small grants. • Clear and adoptable financial model with income generation opportunities for communities. • Proper O&M planning and financing. • smart pre-paid metering. • Climate-resilient infrastructure and civil works. • Subsidies to financially constrained women.	• Reviving Sustainable Energy Financing Project (SEFP) • Development of a clear and adoptable financial model. • Easy access to financing.

Regulatory barriers	**Barriers**	• No clear regulations on asset ownership and micro-grid operations. • insufficient encouragement for private sector	• No clear regulations on asset ownership and micro-grid operations. • insufficient encouragement for the private sector. • Unfavourable IPP framework for rural and remote electrifications.	• private sector participation in assessment and development is lacking. • Unfavourable IPP framework for rural and remote electrifications. • National Energy Policy was being reviewed
	Measure	• Proper monitoring and evaluation frameworks to be developed and followed closely. • Incentives for the private sector. • Mandatory regular energy audits	• Proper monitoring and evaluation frameworks to be developed and followed closely. • Private sector encouragement through policies is required. • Better IPP framework for rural and remote electrifications. • -Mandatory regular energy audits. • Subsidies on land purchases and CNO/biofuel production equipment	• Provision for financial and tax incentives. • Subsidies on land purchases. • Development of a better IPP framework
Technological barriers	**Barriers**	• Communities more used to diesel generators • Lack of awareness of the technicalities of solar PV micro-grids • Lack of know-how on load sizing.		

	Measure	• proper and dedicated information and knowledge dissemination. • upsize the systems that can handle large surges, yet economic feasibility is imperative.		
Capacity barriers	**Barriers**	• Insufficient number of qualified technical, financial, and analytical expertise for Solar PV micro-grids. • Insufficient micro-grids design engineers • Lack of dedicated professional training programs in technical institutes.	• Insufficient number of qualified technical, financial, and analytical expertise for Solar PV micro-grids. • Insufficient micro-grids design engineers • Lack of dedicated professional training programs in technical institutes. • System optimization is crucial for hybrid systems.	• Lack of technical expertise and resources to develop projects. • No local professional training programs for hydro engineers. • Lack of awareness at the community level.
	Measure	• training of professionals in technical, financial and analytical aspects. • Train to meet current industry requirements. • train women as technicians. • Inclusion of gender quotas for technical and non-technical training and skill development opportunities.	• More dedicated training of professionals. • Train to meet current industry requirements. • train women as technicians. • Inclusion of gender quotas for technical and non-technical training and skill development opportunities.	• Training in newer micro/pico hydro technologies. • More professional training programs with gender quotas for technical and non-technical training and skill development. • Community-level awareness programmes • Information dissemination and awareness training

Institutional barriers	**Barriers**		• Insufficient or intermittent supply of CNO fuel. • lack of confidence in the coconut and copra industry. • irregular maritime transportation for sourcing CNO from other islands.	• Limited resources for full feasibility studies. • Challenges in site monitoring and assessment. • Land tenure issues • Environment impacts are not aptly mitigated
	Measure		• Positive economic benefit of biofuel development for rural areas needs to be capitalized on. • Maritime transport networks and frequency have to be improved	• Increased resources for full feasibility studies. • Landowning units should be involved from the beginning. • Comprehensive EIA to mitigate the adverse impacts.

Linkages of the barriers identified

Linkages of the barriers have been assessed from two facets, i.e., barriers, which are common to all technologies, and linkages between barriers for respective technologies. The former would lead to common measures benefiting all technologies, while the latter would support a holistic or integrated approach during the implementation of measures leading to more effective scaling up of respective technologies.

Partial implementation of measures proposed for the mitigation technologies is to be avoided to realize the full potential. Technology-specific inter-barrier linkages are likely to increase the technology transfer and diffusion while disregarding it can prevent the implementation of the mitigation technologies. The integrated approach increases the cost-effectiveness of proposed measure implementation at the same time would ramp up the scaling up of technologies and promoting a higher degree of diffusion.

For instance, all the technologies face the same policy and regulatory barriers, and institutional coordination barriers are similar for power generations from Solar PV or Solar PV and generator hybrids. Some barriers are also linked with micro/pico hydroelectric technology. Hence, the cost of measures to overcome these barriers can be accounted for one technology only, while ensuring that the scope of measures covers all proposed mitigation technologies. Barriers were analysed by developing a market map and then building the problem trees for respective technologies. These are included in the market map presented in Annex II (Figures A7-A9) while the problem trees illustrating the causes/effects relations are presented in Annex I (Figures A1-A6).

Linkages across technologies

It can be seen that some of the identified barriers impact all prioritized technologies. The economic and financial barriers, regulatory barriers, and capacity barriers are common to all three technologies. All technologies are expected to benefit from reduced capital and operations costs where increased private sector participation and a good financial model are required. Fundamentally, common barriers allow for focusing on policy measures that would contribute to the mitigation of most important obstacles and trigger further diffusion of such technologies. The predominant regulatory framework, which is National Energy Policy will capture the setbacks.

The high capital costs are exacerbated by low-income generation opportunities in remote maritime communities. This has a domino effect on the economic development of these communities leading to a cash-deprived vicious cycle. Policy measures to break the vicious cycle are very important for the sustainability of any climate technology in any of the smaller maritime islands.

Across all technologies, the barriers are underpinned by:

i. High capital investment is required.
ii. Low population income with very few income-generating opportunities.

Technology specific inter-barrier linkages

In the case of capacity and institutional barriers are recurrent barriers for all mitigation technologies in the rural electrification sector, however, the capacity constraints are technology specific. Targeted training and development are to be developed to increase human capacity and expertise. With Fiji being a small country with a very small population, challenges in terms of human resources scarcity have been a recurring issue. Huge investment is being made for human capacity development, yet migration to better-paid jobs in the market or overseas has been common.

The other technology-specific barrier was the apt development of the biofuel supply chain. The current trend of declining copra industry is a concern and would hinder the success of the CNO fuelled electricity generations.

Enabling framework for overcoming the barriers in Sector A - Rural Electrification

Based on the similarities in barriers as described in Section 1.5 above and Table 1.4, some common measures could be introduced to streamline the climate technology diffusion process. These technologies are not one-off projects and have the scope for replicability, yet they are very much site-specific and renewable energy resource specific. From the private sector viewpoint, some projects are lacking economies of scale. The enabling framework to promote these technologies for upscaling rural electrification needs to take these local specificities into consideration.

From the community perspective, the vicious cycle of low cash micro-economy prevents these ventures from becoming economically viable. Cash-handouts and small grants are usually used as short-term measures, yet for the longer-term strategic development of the maritime region are important.

The main issue is the high initial cost burden of the projects, where enough sustainable financing needs to be available for the private sector and community cooperatives with lower collateral and interest rates. These finances are largely perceived as high-risk from the lender’s point of view. To mitigate some risks, a suitable insurance facility for renewable energy technologies needs to be developed. This could provide cover for loss against extreme climate events, theft, and fire, etc.

All equipment, installations, and civil works should be able to withstand high winds as extreme cyclones are becoming more frequent. With that, many of the small islands are low-lying and are prone to coastal flooding and storm surges, so the installation should handle these storm surges and salty conditions.

An overarching viable financial model that benefits both the private sector investors and the respective communities needs to be developed. This could aid in income generation opportunities, allow user-pay systems to be aptly implemented, and set aside funds for O&M.

For capacity development, a broader context of human resources management, including better salary schemes, motivation strategies, and continuous career development within the organisation could be promoted to retain the highly skilled human resource. Local training institutions could also develop newer training programmes. Companies can also undertake on-the-job training and apprenticeship schemes wherever possible.

The regulatory measures that would contribute to the diffusion of climate mitigation technologies in the rural electrification sector should address the following aspects:

1. encourage greater private sector participation and improving financial and fiscal incentives, small seed grants and easily accessible loans with low equity and interest rates.
2. investing in new skills and capacities to respond to evolving technical knowledge and consumer demands. Dedicated training to meet current industry requirements is essential together with training of women as technicians since women generally do not migrate from their respective villages. More inclusion of women in the RE sector as a whole is imperative and a measure is to have gender quotas for any technical and non-technical training and skill development opportunities.
3. investing in research and practical deployment of newer technologies via technical institutions and universities.
4. supply chain development for any fuel-based energy generation is also important. In this case, a proper supply of CNO with higher production and incentivizing the coconut industry is likely to boost the production. High-yielding coconut trees could also be trialled.

The NEP 2023-2030 addresses many of the challenges and barriers as outlined. This is a dynamic policy document that has incorporated many of the barriers and has policy objectives directly aligned to the needs and intends the creation of a better enabling environment. The key policy objectives are built on the policy pillars of energy security and resilience energy access amd equity, energy sustainability, energy edfficincy and energy.

The diffusion of climate technologies for rural electrification will have a positive impact on economic development, job creation, and environmental protection. In addition, the upscaled microgrid technologies will foster maritime and rural development which is the government's priority. All non-economic benefits need to be accounted for well in assessing the public costs pertaining to the review and introduction of supportive policies and frameworks. The implementation of the NEP 2023-2030 will further create an enabling environment for rural electrification sector as it strives to enable remote communities to work with the private sector to cooperatively manage off-grid renewable energy systems.

Chapter 2 Domestic Maritime Sector

The Fijian government's second sector prioritised under the TNA process for mitigation is the domestic maritime sector. This is one of the most vital sectors since it is the one that connects the commerce and trade between the 110 permanently inhabited islands in the archipelago spanning over 1.3 million km^2 of ocean. Maritime transportation provides access to vital services for these islands including education and health services. The domestic maritime transportation sector is directly aligned with Fiji's 5-Year and 20 Year National Development Plan (NDP). The inter-island sea-transport network is clearly acknowledged in the NDP 2017-2036 as critical not only for transportation but also for commerce and income-generating opportunities in the maritime region.

The initial set of technology prioritization was carried out under the TNA process that focussed on the retrofitting technologies of existing large vessels. The technologies were short-listed based on the applicability, technical maturity, and local experiences of the relevant stakeholders. With new scientific developments and commitments made in the updated NDC, the technology prioritization was revisited. Following Fiji's 2015 NDC which targeted to achieve a 30% reduction in BAU CO_2 emissions from the energy sector by 2030, the updated NDC in 2020 has an additional target (Target 4) that explicitly aims to reduce domestic maritime shipping emissions by 40% as a contribution to the initial target.

In this chapter, the re-visited technology prioritization is presented followed by the barriers delaying the diffusion of these prioritised technologies for the domestic maritime sector are identified and measures to overcome the barriers and enabling environment for successful diffusion of these technologies are discussed further.

Preliminary targets for technology transfer and diffusion in the Energy Sector

Greenhouse gases emissions from the Domestic Maritime sector

The past data availability on GHG emissions from this sector is a concern and estimations are largely used. An annual estimation of marine fuel consumption revealed around 8 million litres of diesel fuel consumed for the scheduled 2016 inter-island routes, while a total of 34 million litres of diesel was estimated to be consumed for the entire marine. The total emissions for the domestic maritime sector in 2016 were estimated to be 174 kilo-tonnes of CO_2eq as per Fiji's LEDS. A comparison of 2016 and 2018 emissions is presented in Figure 2.1, which shows greater emissions from the small boats followed by economical routes in 2018. However, it must be noted that "Government Shipping Services" (GSS) data was of the highest accuracy with an uncertainty ranging between ±1 percent, while the uncertainty in "Economical Routes" ranges between -50 percent and +100 percent.

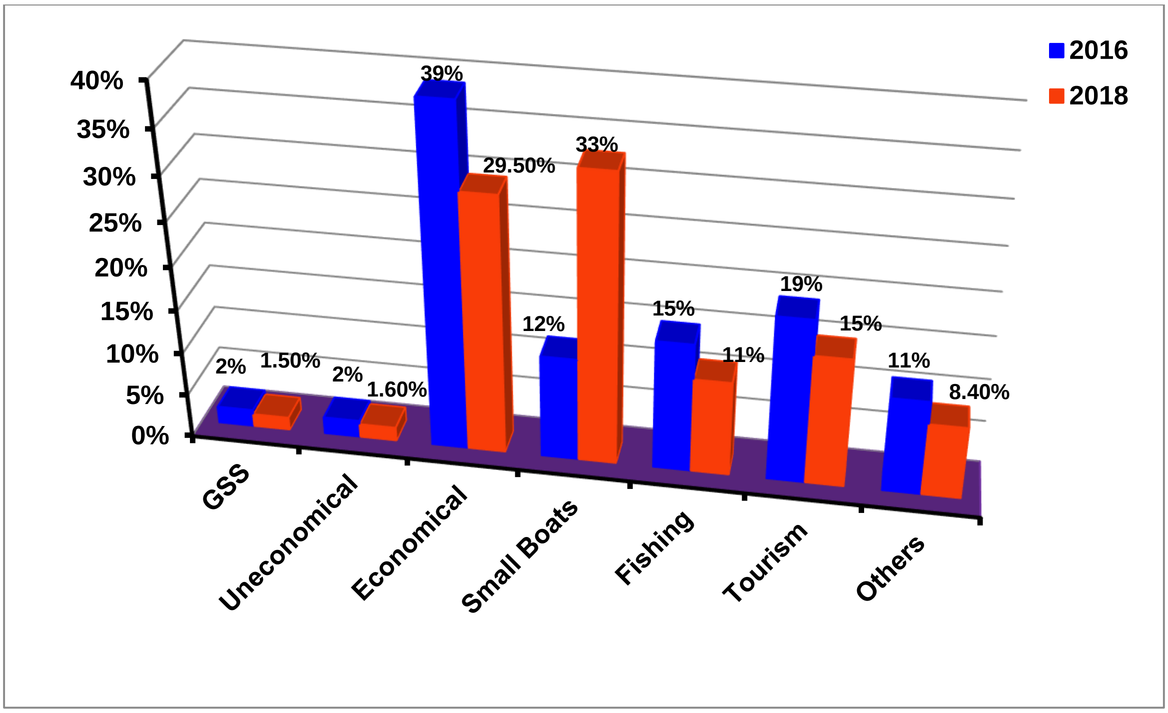


Figure 2.1: Estimated emissions from the domestic maritime sector in 2016 and 2018 from various vessel classifications obtained from the Fiji LEDS and TNC

Policy context

The prioritisation of the domestic maritime sector is aligned with the Fiji National Development Plan (NDP) 2017-2036 which envisions improving the shipping services making it reliable, safe, efficient, and affordable with an overarching objective to modernize the air, maritime, and land transport networks. Similarly, Fiji's NDC Implementation Roadmap-2017 focussed on improved maintenance of vessels and replacement of outboard motors. The Maritime and Land Transport Policy (2015) also embarks on better and fuel-efficient transport equipment and engines, better designs, and renewable energy propulsion systems. The other key synergetic policies include:

1. *Fiji's Updated NDC-2020*: An explicit addition in the update was the inclusion of Target 4 – reduction in domestic maritime shipping emissions by 40% in order to achieve the initial 30% reduction target. A target adopted from the coalition of six countries under the Pacific Blue Shipping Partnership.
2. *National Climate Change Policy 2018-2030* (NCCP): As part of Sub-Objective 4.1.1 – To decarbonize Fiji's Transport Sector, Fiji's NCCP strategizes to have improvements in shipping efficiency and adoption of low carbon maritime transport options to boost the frequency of inter-island shipping and to introduce new shipping routes aligned with the objectives of the NDP whilst improving the cost-effectiveness of the shipping industry.
3. *Fiji NDC Implementation Roadmap*: Highlights measures for low carbon maritime transportation including;
    - i. improved maintenance of sea vessels to increase the fuel efficiency
    - ii. alternative propulsion systems and

   iii. a replacement programme for outboard motors.

4. *Maritime and Land Transport Policy* (2015): promotes
   i. better and fuel-efficient transport and port equipment,
   ii. improved operations (slow steaming and weather routing) and maintenance
   iii. better designs: smaller and well-suited vessels for inter-island routes and use of small canoes and camakau (traditional watercraft).
   iv. low carbon propulsion alternatives (retrofitting of efficient propulsion and hull designs)
   v. renewable energy in propulsion (biofuels, solar, or sail-assisted).

5. *Green Growth Framework* - Thematic Area 8 on Sustainable Transportation (Ministry of Strategic Planning National Development and Statistics, 2014): encourages improved hull and propeller designs, trialling renewable energy fuelled marine vessels, feasibility assessment on 4-stroke outboard motors, and studies on incentives for low-carbon domestic shipping.

6. *The National Energy Policy* (2023-2030) Transport aims to scale-up and diversify Fiji's renewable energy portfolio, decarbonise the transport sector, and reduce national emissions in keeping with Fiji's Nationally Determined Contribution to the Paris Agreement. Increase national energy efficiency in support and alignment with Fiji's NDC targets.

Whilst the Enabling Objectives for domestic maritime shipping are:

1. To reduce emissions from domestic marine transport by 40% by 2030.

2. To explore options to reduce domestic aviation sector derived emissions through renewable energy, operational efficiency improvements, and sustainable alternative fuels.

The identification of newer technology options and subsequent barrier analysis is in support of the above policies and the updated NDC (2020) in particular.

Prioritized climate mitigation technologies

The re-visited technology prioritization was conducted with the stakeholders to identify newer technologies that have greater mitigation potential and at the same time contribute to the development of the sector as a whole. Despite the COVID-19 lockdowns and social distancing protocols in place, the work was carried out either in-person or via technological and virtual means.

Technologies Identified

For the domestic maritime transportation sector, the technology options identified in this case were via discussions between the National Experts, academia, the Sector Working Groups members, and other stakeholders on the basis of technologies that have high GHG mitigation potential in order to meet the 40% targeted commitment made in the updated NDC. The retrofitting technologies were disregarded. As a result, 4 mitigation technologies options were short-listed for the domestic maritime transportation sector as follows:

1. Eco-Flettner Rotor – retrofit and new-build technology
2. Zero Carbon Passenger Ferry Trials
3. Sail-powered Passenger/Cargo Ship
4. Outboard Motor Transition

Overview of the Technologies Identified

Brief descriptions of the identified technologies are as follows:

Eco-Flettner Rotor – retrofit and new-build technology

Flettner rotors harness wind power for auxiliary propulsion and are suited for both retrofitting of existing vessels and new-build designs in combination with conventional or new fuel or e-propulsion motors. This technology was invented and commercially demonstrated in the 1920s, and has been subject to a number of trials (Chou et al., 2021; Li et al., 2021; Tillig and Ringsberg, 2020). Flettner rotors are rotating cylinders mounted on the deck of the ship whereby one side of the rotors forms a low-pressure area while the other experiences high pressure generating lift similar to a sail, which is called the Magnus effect (Li et al., 2021). Flettner rotors can be fitted across a broad design of vessels as retrofits and also on new build vessels requiring relatively simple and cost-effective engineering, no additional crew, and minimal maintenance over the lifetime. Fuel/emissions savings ranged from 0.4% to 50% in many studies which are contingent upon the ship type, dimensions of the technology (No. of rotors, height, and diameter) and the route as well (Chou et al., 2021). Locally, experts conjecture savings of 8-25% for retrofits and 15-40%+ when incorporated into newbuild is achievable (Nuttall et al., 2016). Some pictures of the Flettner rotor applications are shown in Figure 2.2 and the details are provided in the Technology Fact Sheet 1 in Annex III.

Zero Carbon Passenger Ferry Trials

Fast ferries for passenger commute are vital for Fiji’s growing economy. To ease road traffic congestion in the Nausori-Suva corridor and Lami-Suva corridor, proposals for passenger ferries have been floated in recent years. Currently, fast ferries are servicing the tourism commute largely in Nadi, Denarau, Mamanuca, and Yasawa islands which use fossil fuels. Zero-carbon ferries could also be developed to provide services in Lautoka (focused on commuters); Nadi Waters (focused on tourism); Karoko to Rabi crossing and Natuvu (Bucabay) to Taveuni crossing. Review and redevelopment of shore-side infrastructure required for passenger pick-up/drop-off points in any of these locations are essential, while jetties and pontoons are already in place for tourism travels. Recharging stations and additional renewable electricity supply will also be a requirement. Harbour and short-distance routes are ideal for electric/hybrid zero-carbon harbour ferries. An important consideration would be given to vessel acquisition options (i.e., new build in Fiji or import from overseas such as Australia (Butcher, 2021) and Norway (Al-Falahi, 2019)), battery storage systems, renewable recharging, service, and maintenance support together with scrappage and recycling options. Tax exemptions on the importation of electric/hybrid vessels are in place, yet other favourable fiscal measures are required to make it commercialized. The electric ferry projects and initiatives that have been undertaken in other parts of the world could be replicated in Fiji. A few examples of these electric ferries are given in Figure 2.3 and the detailed information is provided in the Technology Fact Sheet 2 in Annex III.

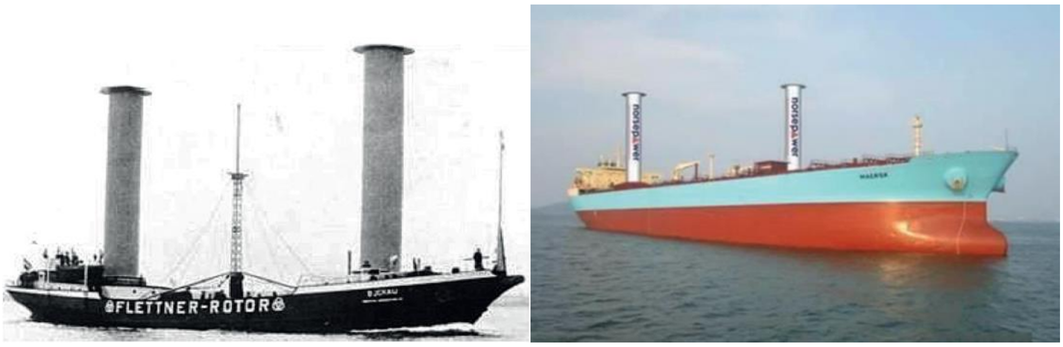


Figure 2.2: Applications of Flettner rotors on ships (Li et al., 2021; Tillig and Ringsberg, 2020).

MF Husavik, Norway
Year: **2018**
Owner: Fjord1
Type: Ro-ro ferry
Capacity: 45 cars, 146 passenger
Power system: ***Battery-powered ferry***

MF Gloppefjord, Norway
Year: **2017**
Owner: ***Fjord1***
Type: Ro-ro ferry
Capacity: 120 cars, 349 passenger
Power system: ***Battery-powered ferry***

Figure 2.3: Electric passenger ferries currently in operation in Norway (Al-Falahi, 2019).

Sail-powered Passenger/Cargo Ship

The main inter-island shipping routes connecting Fiji’s 330 islands have historically been serviced using aged, second-hand, Passenger, and Cargo ferries of up to 5,000 tonnes. These are usually retired ferries which are inefficient with high maintenance and operational costs. Such vessels may burn up to 12-15 tonnes of diesel/day. Wind-powered sailing RoRo/cargo ships designs, such as the Neoline vessel, now offer promising carbon and fuel savings in excess of 80% through a whole-of-ship design approach (including advanced hull and propulsion design, waste heat recovery, wind-hybrid drive, etc.) (Hakirevic, 2020; Hakirevic, 2021; Neoline, 2021a; Neoline, 2021b). A proof of concept needs to be developed and deployed in Fiji either by the Government Shipping Services or the private sector for the adoption of this technology. An example of a Neoline wind sail-powered ship is provided in Figure 2.4 and the detailed information is provided in the Technology Fact Sheet 3 in Annex III.

Figure 2.4: Neoline's wind sail powered ship design (Neoline, 2021a).

Outboard Motor Transition

Outboard motors are likely to be one of the largest sources of GHG emissions for Fiji's domestic maritime transport sector. However, there is no accurate data on the total number of outboards motors and/or the types. The Fiji LEDS calculations for "small boats" equates to approximately 7900 petrol outboards, which are largely powered by 2-stroke petrol engines. Due to this large number of 2-stroke petrol outboards, the emissions are estimated to be the largest from these small boats. This technology aims to achieve a reduction in emissions from outboards via switching from 2-stroke to 4-stroke petrol engines and slowly transitioning to electric outboards and revitalising sailing canoes.

The 4-stroke motors are considerably more energy-efficient (are up to 50% more fuel-efficient) than 2-stroke outboards. As small vessels make up a sizeable portion of the total emissions from maritime transport, a sizeable percentage of total emissions reduction for the sub-sector is available simply by transitioning from 2-stroke to 4-stroke outboards.

Transition to electric outboards requires consideration of boat design, battery storage systems (which are expensive), renewable-powered charging stations, and transition would involve several steps including data collection of outboard ownership, purpose (tourism, fishing, and/or commute), outboard motor type and fuel usages.

Both 4-stroke and electric outboard motors are commercially used in other parts of the world and are for sale in Fiji commercially, yet the uptake is very slow. Detailed information is provided in the Technology Fact Sheet 4 in Annex III.

Criteria and process of technology prioritisation for the domestic maritime transportation sector

These four technologies were evaluated and appraised against a set of criteria that were established via stakeholder consultations. For prioritizing the technologies for the domestic maritime sector, the Multi-Criteria Analysis (MCA) was used. 10 criteria encompassing three categories (i.e., Costs, Benefits, and Local Context) are to be used to evaluate the technologies.

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

The Benefits included Economic, Social, and Environmental benefits that were further delineated;

1. Job Creation was regarded as the only Economic Benefit,
2. the Social Benefits were divided into Time Efficiency and Travelling Comfort;
3. while the Environmental Benefits were divided into CO_2 reduction potential and Impact on Marine Environment (Apart from CO_2).

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

During the scoring process, the stakeholders for the domestic maritime transportation sector referred to the Technology Fact Sheets and used their experiences for each of the criteria. Then they gave individual scoring in the designed Google Form. The COVID19 pandemic did not allow for face-to-face deliberations. The scores for each of the criteria were averaged out and computations were performed in the template. Hence, a performance matrix was constructed, and the scoring was carried out after discussing the information provided in the technology factsheets and experiences of respective stakeholders.

Table 2.1 presents the Categories and Criteria used in the prioritisation process upon which the Performance Matrix (Annex IV - Table A1) and Scoring Matrix (Annex IV - Table A2) were constructed. Two levels of criteria resulted after the discussions. During the assigning of weights process, a total of 100 points were given for Level 1 Criteria and each sub-criterion at Level 2 was further assigned a total of 100 points. The weightings assigned in Google Forms at Level 1 criterion by respective stakeholders were averaged out. A similar approach was taken for the Level 2 criterion as well. The assigned weights for each criterion are presented in Table 2.1 while Figure 2.5 illustrates the weights associated with respective categories. Figure 2.5 clearly shows that the benefits category (65%) has a larger influence on the selection of respective technologies.

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

Results of technology prioritisation for the domestic maritime transportation sector

The performance matrix converted to a scoring matrix was utilised for technology prioritisation. The scales for all criteria data were confined in the range of 0 to 100 and the most preferred technological option essentially has the highest score. Figure 2.6 shows the scoring and prioritisation in the form of bars which clearly illustrates that the scores of the technology Options 3 and 2 are relatively high in comparison to others. The performance matrix, the scoring matrix, and the resulting decision matrix are presented in Table A1 (Annex IV).

To affirm the results, a sensitivity analysis was performed by varying the weights of the different criteria and performing a cost-benefit plotting as in Figure 2.7. An outcome summary of sensitivity analysis for the domestic maritime sector is provided in Annex IV – Table A3.

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

1. **(*Technology 3*) - Sail-powered Passenger/Cargo Ship**
2. **(*Technology 2*) - Zero Carbon Passenger Ferry Trials**
3. **(*Technology 1*) - Eco-Flettner Rotor – retrofit and new-build technology**

Table 2.1: Criteria and the respective assigned weights for the maritime transportation sector.

	Category										Total
	Costs			Benefits					Local Context		
				Economic	Social		Environmental				
Lev 1 Weights	39%			17%	12%		18%		14%		100%
	Capital Costs (USD$)	Operational and Management (USD$)	Lifetime (Years)	Job Creation	Time Efficiency	Travelling Comfort	CO$_2$ reduction potential (%)	Impact on Marine Environment (Apart from CO$_2$)	Market Potential	Acceptability to local stakeholders	
Sources	Technology Providers, Operators	Technology Providers, Operators	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement, Tech Specification	Expert Judgement	Expert Judgement	Expert Judgement	
Preferred value	Lower	Lower	Higher	Higher	Higher	Higher	Higher	Lower	Higher	Higher	
Lev 2 Weights	36.8%	31.6%	31.6%	100%	64.3%	35.7%	63.2%	36.8%	56.25%	43.75%	
Overall Weights	5.52	4.74	4.74	15	19.29	10.71	12.64	7.36	11.25	8.75	100

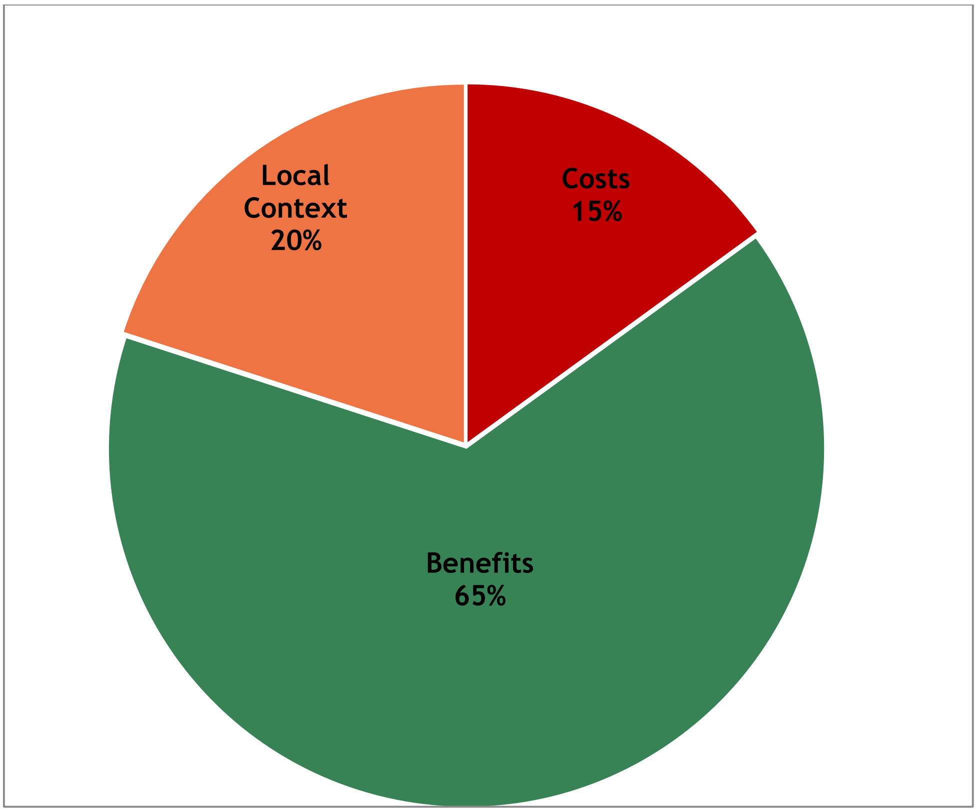


Figure 2.5: The weights assigned to the identified categories for the domestic maritime transportation sector.

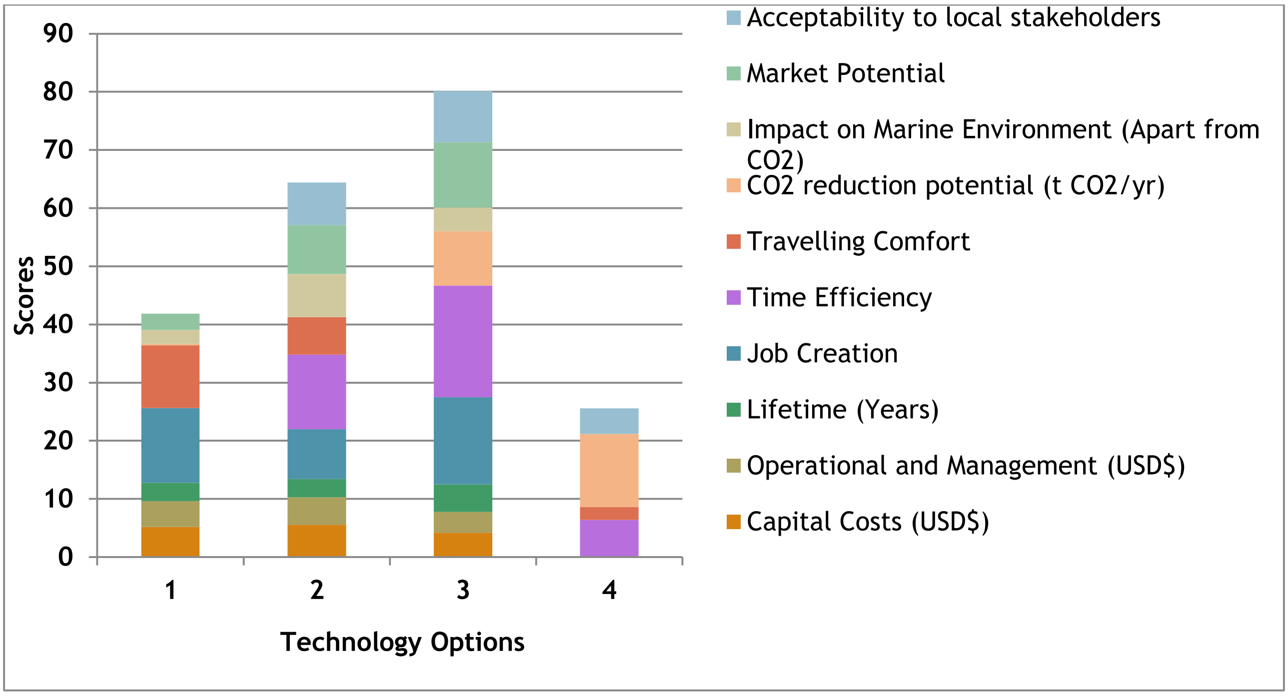


Figure 2.6: Technology scoring and prioritisation for the domestic maritime transportation sector.

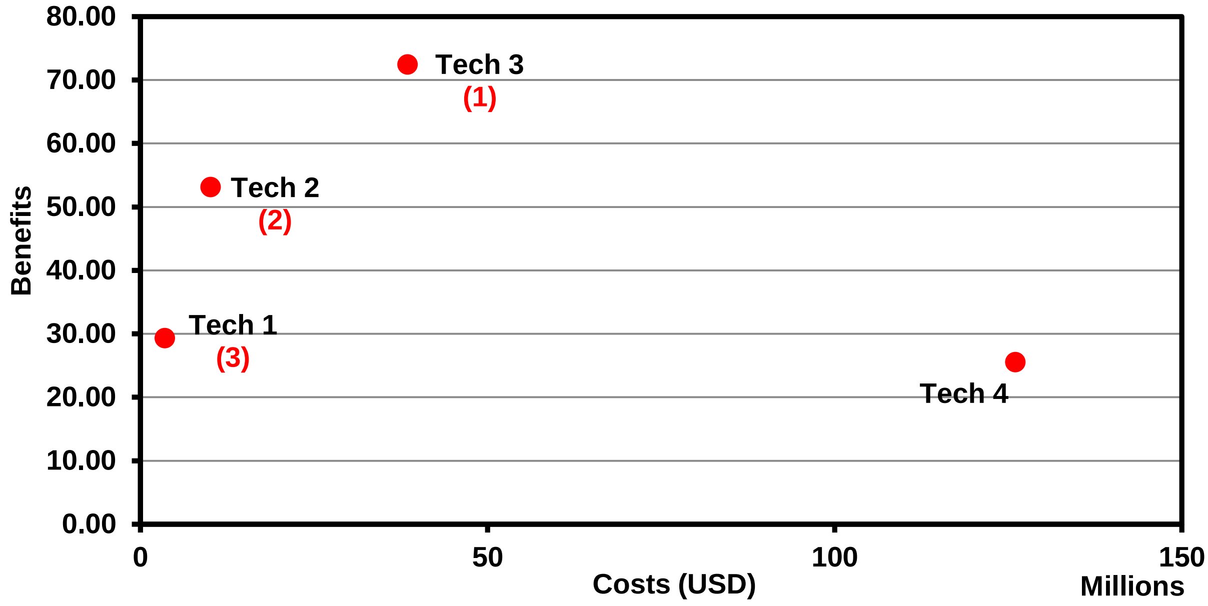


Figure 2.7: Costs and Benefits of the identified technologies for the domestic maritime transportation sector.

Summary

Finally, after a sensitivity analysis the following technologies were identified as the most preferred technology options for the domestic maritime transport sector;

1. **(*Technology 3*) - Sail-powered Passenger/Cargo Ship**
2. **(*Technology 2*) - Zero Carbon Passenger Ferry Trials**
3. **(*Technology 1*) - Eco-Flettner Rotor – retrofit and new-build technology**

For these prioritised technologies the barrier analysis and enabling framework are developed.

Primary targets for domestic maritime transport sectoral technologies

Fiji’s green growth approach encourages the utilization of low-carbon marine (and land transport) through innovative, cleaner, and renewable energy sources wherever practical. Currently, domestic maritime transportation falls in the purview of the Ministry of Public Works, Meteorological Services & Transport (MPWTMS). Under this Ministerial portfolio, the Department of Transport (DoT) looks after land and maritime transportation and is responsible for devising and mandating enabling frameworks in ensuring efficient and affordable land and maritime transportation systems. The MPWTMS aims to modernise land and maritime transport whilst ensuring safe, reliable, and affordable shipping services. The latter is paramount in transforming Fiji's maritime transport sector and interisland commerce and trade. The DoT provides policy advice and regulatory framework to facilitate, promote and support trade and tourism, through the transportation of goods and people.

The other important arm under the MPWTMS is the Department of Government Shipping Services (DGSS). With the target of enhancing economic growth in the Maritime sector, the DGSS strives to address the need for safe and affordable sea transportation systems and market accessibility for the maritime communities through reliable shipping services. The DGSS also provides quick response and support services during and after any natural disasters.

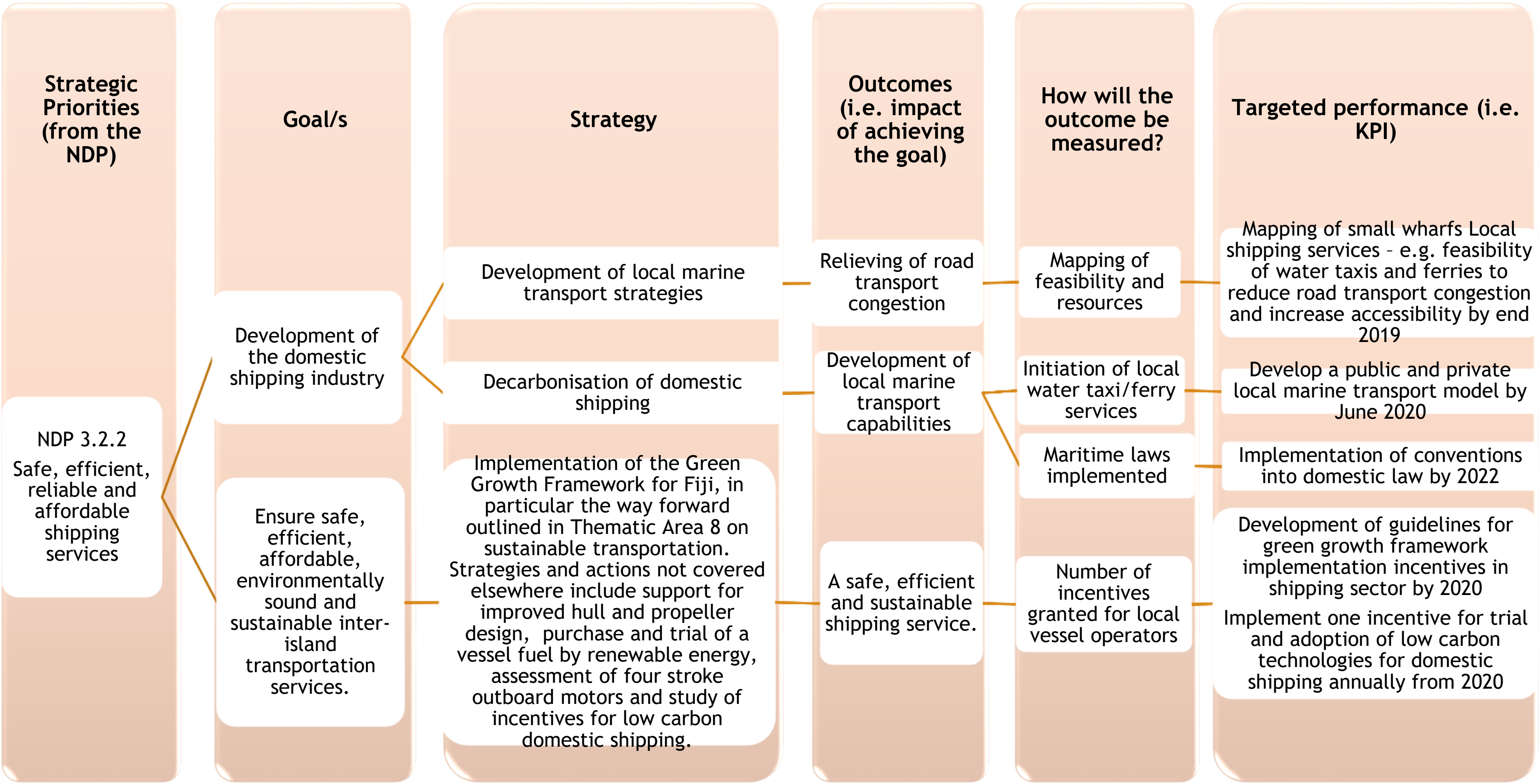
The NDP targets to provide Safe, Reliable, and Affordable Shipping Services, following that the key goals of MITDMMS SDP-2019-2022 are the development of the domestic shipping industry and to ensure safe, efficient, affordable, environmentally sound, and sustainable inter-island transportation services (Figure 2.8). The strategies include:

1. Development of local marine transport strategies
2. Green Growth Framework for Fiji, in particular, the way forward outlined in Thematic Area 8 on sustainable transportation. Strategies and actions not covered elsewhere include support for improved hull and propeller design, purchase and trial of a vessel fuel by renewable energy, assessment of four-stroke outboard motors, and study of incentives for low carbon domestic shipping.
3. Decarbonisation of the domestic shipping sector.

The KPIs for achieving these goals include

1. Mapping of small wharf's Local shipping services – e.g. feasibility of water taxis and ferries to reduce road transport congestion and increase accessibility by end of 2019
2. Develop public and private local marine transport model by June 2020
3. Implementation of conventions into domestic law by 2022
4. Development of guidelines for green growth framework implementation incentives in shipping sector by end of 2020
5. Implement one incentive for trial and adoption of low carbon technologies for domestic shipping annually from 2020

To achieve the targeted outcomes a lot of resource and feasibility is required. This TNA and barrier analysis will support the NDP target via trial and adoption of low carbon technologies for domestic shipping and develop the domestic maritime shipping industry.



Strategic Priorities (from the NDP)	Goal/s	Strategy	Outcomes (i.e. impact of achieving the goal)	How will the outcome be measured?	Targeted performance (i.e. KPI)
NDP 3.2.2 Safe, efficient, reliable and affordable shipping services	Development of the domestic shipping industry	Development of local marine transport strategies	Relieving of road transport congestion	Mapping of feasibility and resources	Mapping of small wharfs Local shipping services – e.g. feasibility of water taxis and ferries to reduce road transport congestion and increase accessibility by end 2019
		Decarbonisation of domestic shipping	Development of local marine transport capabilities	Initiation of local water taxi/ferry services	Develop a public and private local marine transport model by June 2020
				Maritime laws implemented	Implementation of conventions into domestic law by 2022
	Ensure safe, efficient, affordable, environmentally sound and sustainable inter-island transportation services.	Implementation of the Green Growth Framework for Fiji, in particular the way forward outlined in Thematic Area 8 on sustainable transportation. Strategies and actions not covered elsewhere include support for improved hull and propeller design, purchase and trial of a vessel fuel by renewable energy, assessment of four stroke outboard motors and study of incentives for low carbon domestic shipping.	A safe, efficient and sustainable shipping service.	Number of incentives granted for local vessel operators	Development of guidelines for green growth framework implementation incentives in shipping sector by 2020 Implement one incentive for trial and adoption of low carbon technologies for domestic shipping annually from 2020

Figure 2.8: Excerpt adopted from the MITDMMS SDP-2019-2022 (MITDMMS, 2018)

Consideration of Gender Equality

Gender equality and inclusivity are somewhat lagging in the domestic maritime transportation sector, however, all stakeholders are working towards making it more inclusive. To promote gender equity, equality, social justice, and sustainable development a National Gender Policy was developed in 2014. Later the Gender Action Plan under the Lima work programme on gender was also adopted by Fiji at the COP-23. The 2018-2030 NCCP under its gender responsiveness pillar advocates on improving and enhancing the incorporation of women's knowledge, skills, participation, and leadership into planning processes at the local and national level. The consideration of gender issues and support for improved gender balance in both the decision-making processes and related implementation arrangements is clearly emphasized in the NCCP in order to promote gender-equitable benefits.

Barrier Analayis and Enabling Framework Development Process

Taking into account the sectoral development priorities, rural and maritime development and mitigation potentials three mitigation technologies for domestic maritime transportation were re-prioritized as above. All three prioritized technologies into different types of goods. The Sail-powered Passenger/Cargo Ship and the Eco-Flettner Rotor – retrofit and new-build technologies were categorized as Capital goods (Market) since these were largely purchased and/or operated by private businesses with a limited number of sites requiring relatively large investment. While the Zero Carbon Passenger Ferry Trials were categorized as publicly provided goods (non-market) since it's a large infrastructure project provided to the public by the government.

A market mapping was conducted as provided in Annex VI (Figures A16-A18). The draft market maps were developed initially and updated whenever new information was provided by stakeholders. These maps illustrate the supply chain mapping and were performed with the information gathered from stakeholders in order to identify barriers at each stage of the supply. The review of position papers and other communications presented by institutions, private companies, and business associations was also conducted to identify probable barriers from previous projects and the way these were countered.

Due to COVID19 pandemic restrictions, Google forms-based surveys were used to gather information in classifying the selected barriers into a hierarchy of categories and a logical problem tree-based approach was used to identify the underlying 'root' barriers. The enabling framework process encompassed the determination of measures for the identified barriers taking into account the existing market and technological conditions, institutions, policies and practices, which resulted in problem and solutions trees provided in Annex V (Figures A10-A15).

Barrier analysis and possible enabling measures for Technology B1 "Sail-powered Passenger/Cargo Ship"

The general description of technology B1 "Sail-powered Passenger/Cargo Ship"

The wind-powered sailing RoRo/cargo ships designs, such as the Neoline vessel, could offer remarkable carbon and fuel savings. Through a whole-of-ship design approach (including advanced hull and propulsion design, waste heat recovery, wind-hybrid drive, etc.) in excess of 80% of savings are expected (Hakirevic, 2020; Hakirevic, 2021; Neoline, 2021a; Neoline, 2021b). These shipping services could be used for inter-island shipping routes connecting with increased trade and tourism whilst boosting the maritime economy. More details are provided in sub-section *2.1.3.2 Overview of the Technologies Identified.*

Identification of barriers for technology B1

The barriers and respective measures for technology B1 - Sail-powered Passenger/Cargo Ship is discussed in the following sections while a summary is provided in Table 2.2 for brevity.

Economic and financial barriers

The huge capital cost is the key financial barrier in the uptake of this technology. The current estimated capital investment needed for the physical implementation is approximately US$35m.

1. The much higher upfront CAPEX cost of purchasing a new purpose-built vessel was the main reason why the local operators purchased the second-hand vessel.

1. The root causes of the unaffordable maritime financing were the high loan interest rates, no insurance underwriters with unclear return on investment.

2. This makes the commercial bank more reluctant in financing as the risks were too high. The shipping companies also had to produce real estate as collateral for bank loans making it difficult to secure loans.

Non-financial barriers

The key non-financial implementation barriers for Sail-powered Passenger/Cargo Shipping technology in Fiji include regulatory barriers, capacity barriers, and technology barriers.

Regulatory barriers

1. Gaps in policy and regulations have been identified as the foremost barrier to the adoption of this technology.
2. Deliberations revealed that there are no emissions regulations for the maritime transportation sector that penalizes or incentives the operators into investing in low carbon shipping.
3. Ships also do not have Ship Energy Efficiency Management Plan (SEEMP). This has been identified as a critical component in achieving energy-efficient operations. The SEEMP is a planning tool devised by the International Maritime Organization (IMO). It is not only for controlling and reduction of GHG emissions from ships but also to improve efficiency whilst decrease fuel consumption.
4. The underpinning Marine Transportation Act is outdated

Capacity barriers

1. Under the capacity barrier, it was identified that there is generally a lack of interest or conflicting interests amongst the shipowners in terms of sail-powered low carbon technologies.
    1. The underlying reason is the old-fashioned business practices whereby a lower CAPEX is favoured in terms of investment prospects.
    2. The other cause that the lack of understanding of the newer technology in the local context as the operators are too attuned to diesel-powered ships.
    3. The root cause for this was the overall lack of local research and scientific studies on the effectiveness of low carbon shipping and the general lack of research funding for this.
2. This is compounded by data unavailability on fuel usages, passenger and cargo and as a result, the return on investment is not clearly presented to the investors and potential investors.
3. The other issue at the apex of the problem tree in terms of capacity is that the technology is perceived as inefficient.
4. This is due to no on-ground training for businesses, crew, and operators in sail-powered ship maneuvering and operations.
5. In addition, the other issue is the inefficient weather routing due to no dedicated wind and wave forecasting and early warning systems in place currently.

Infrastructural barriers

Even though sailing was the mode of maritime transportation in the past, the venture slowly eroded with the introduction of diesel-powered ships. Since then there has been a lack of infrastructure and development as fossil fuel-powered ships were preferred. Currently, there is no commercial sail-powered shipbuilding, backup, and maintenance industry. This is an inter-dependent industry and is vital for the uptake of the technology and better technology penetration. Stakeholders highlighted that without proper backup and maintenance, the technology is never a success. The overall commercial shipbuilding industry in Fiji is in an inactive stage which fundamentally prevents the localized based research and building of bespoke ships for the needs of the local market. The smaller fiberglass boats are locally built largely.

Identified measures

Economic and financial measures

Domestic maritime shipping is a marginal business and ship operators allude that it is becoming more constrained with rising fuel and maintenance costs. In Fiji, the routes are divided into economical and uneconomical routes. The economical routes do provide a return, yet are minimal. On the other hand, the uneconomical routes as the name suggest do not provide any turnover. These uneconomical routes are for servicing the smaller islands in the archipelago. The government has to provide fuel subsidies and fare subsidies so the shipping services can operational.

The remote maritime communities are of a low cash micro-economy, as a result, high shipping fares would make it even more difficult for the people to travel and to transport their goods.

Hence, in order to make shipping a profitable business, a clear return on investment needs to be established with high quality, timely and reliable data on shipping routes and fuel usages, etc. With those proper studies are to be done on the current operations and the implementations of the sail-powered ship to attract investors and the current shipping companies.

The initial capital cost for this technology is quite high and investors are reluctant to adopt it. To make financing easier, affordable interest loans need to be provided together with proper insurance. Insurance will allow the banks and other financial institutions to offer loans without the much sought-out real-estate as collateral. The development of concessional loans specific to investment into low carbon shipping technology should also be available with ease.

Non-financial measures

Regulatory measures

In terms of policy and regulations measures, the key gaps are to be addressed with:

1. Inclusion of emission reduction regulations with incentives and/or penalties. The notion was to ratify the International Convention for the Prevention of Pollution from Ships (MARPOL) in particular MARPOL Annex VI to limit the main air pollutants including sulphur oxides (SOx) and nitrous oxides (NOx) from ships exhaust. It also prohibits emissions of ozone-depleting substances (ODS) and regulates shipboard incineration and the emissions of volatile organic compounds (VOC) from tankers.
2. A progressive reduction in NOx emissions from marine diesel engines is proposed, yet to achieve higher impacts, transition to low carbon shipping such as sail-powered ships becomes necessary.
3. Development and adoption of Ship Energy Efficiency Management Plan (SEEMP) are also imperative to allow owners and operators to realize the possible savings that can result as a means of energy-efficient measures. This will allow for a swift transition towards low-carbon shipping technologies.
4. Revision of the Marine Transportation Act is required with the inclusion of low carbon shipping enterprises.

Capacity measures

To attract more shipowners to invest in low carbon sail-powered shipping technology, capacity building is required.

5. An increased understanding of the technology in the local context is required for this. The shipowners need to see and feel a locally based proof of concept to easily accept the technology.
6. Capacity building for modernised business practices is also imperative. The current business model is to invest in lower CAPEX ventures rather than a higher CAPEX venture that can yield higher profit in the longer term. Once the capacity is built in modern business practices, then it would be easier for current and prospective shipping companies to invest prudently.

7. Recording and availability of high quality, timely and reliable data on shipping routes and fuel usages, passenger and cargo together with proper studies would enable the development of proof of concept and the required business case for investors. The research and related organizations including; Pacific Community (SPC), The University of the South Pacific, Fiji National University, The University of Fiji, Sailing for Sustainability (Fiji) Ltd, and the Micronesian Centre for Sustainable Transport's (MCST-USP) to design and build low-cost sail-assisted inter-island vessel as a proof-of-concept.

The other measure is to develop ample capacity to make sail-powered shipping efficient as opposes to the current perception.

1. For this appropriate training and development for businesses, crew and operators are essential. Recruiting of the crew was also at times a drawback and the training institutions such as Fiji Maritime Academy can develop specialised training for operators and crew.
2. Tailoring training and skills development for women with specified gender quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities.
3. Use of traditional sailing knowledge and boat building knowledge and techniques in the use of newer sail-assisted maritime transportation.
4. Efficient weather routing is to be developed with dedicated wind and wave forecasting and early warning systems so the route could be planned effectively for efficient transportation.
5. Route analysis a detailed effective and efficient route analysis needs to be performed to determine the cost-effective routes with wind propulsion systems.

Infrastructural measures

Infrastructure and development for sail-powered ships are also required, even though the technology has existed in the Pacific for a long time. With the advent of newer technology and methods sail-powered shipbuilding and maintenance industry needs to be properly developed. In addition, cargo handling and passenger transit infrastructure in the maritime islands are to be effectively developed for efficient cartage and transportation.

Barrier analysis and possible enabling measures for Technology B2 "Zero Carbon Passenger Ferry Trials"

The general description of technology B2 "Zero Carbon Passenger Ferry Trials"

Currently, fast ferries are used to service the tourism industry. Fast ferries for passenger commute are vital for Fiji's growing economy, however, zero-carbon ferries are required to reap the full benefit. The zero-carbon vessel could be built locally after the revival of the shipbuilding industry or will have to be acquired from overseas such as Australia (Butcher,

2021) and Norway (Al-Falahi, 2019)). Harbour to short-distance routes is ideal for electric/hybrid zero-carbon harbour ferries. The support mechanisms for electric ferries would include recharging stations with electricity being generated from renewable sources. Ample battery storage with service and maintenance support will also require consideration. More details are provided in sub-section *2.1.3.2 Overview of the Technologies Identified*.

Identification of barriers for technology B2

Economic and financial barriers

The zero-carbon vessels are expensive and require a high upfront investment which deters the investors and local shipping companies from acquiring these vessels. The estimated capital investment needed for the physical implementation is US$9.2m. Additional costs associated with the enabling infrastructure, capacity building, and technical assistance will also be required. Since it is difficult to secure loans or finance for maritime transportation investments, it makes it difficult for shipowners and operators to undertake large investments. To compound that a lack of fiscal incentives is provided to businesses for zero-carbon vessels, there is a general lack of investor confidence. One important root cause is the unavailability of insurance underwriters to insure shipping vessels. The investment is huge and if not protected well, there is a high probability of huge losses. This made the commercial bank more reluctant in financing is the risks were too high.

This brings us to the next terminal barrier which is the lack of investors and government funding for such ventures. The investors are very hesitant to endeavour into electric mobility technology. The underlying barrier for this is the lack of understanding of the technology in the local context. Some investors related the bad experiences of hybrid cars to the electric hybrid ferries whereby maintenance was very difficult and costly. These all have been attributed to a lack of local studies and lack of research funding to carry out the proper scientific studies.

The other lower level barriers included the old-fashioned business practices where a low CAPEX investment is favoured over higher CAPEX and no specialized concessional loan facility as the maritime financing were unaffordable with high loan interest rates.

Non-financial barriers

Regulatory barriers

1. Gaps in policy and regulations have been identified as the foremost barrier to the adoption of this technology.
2. Deliberations revealed that there are no emissions regulations for the maritime transportation sector that penalizes or incentives the operators into investing in low carbon shipping. In addition, these policies are not aligned to stipulated emissions reduction targets.
3. The underpinning Marine Transportation Act is outdated

Capacity barriers

1. Under the capacity barrier, it was identified that generally there was a lack of capacity in Zero Carbon Passenger Ferry technology.
2. This is due to no on-ground training for businesses, crew, and operators in the operations of newer technologies.

Infrastructural barriers

An overall lack of infrastructure for the adoption of hybrid electric passenger ferries is the current status.

1. There are no charging stations from renewable resources.
2. The current electricity grid is not 100% renewable and the renewables generation mix fluctuates around 50-60%, hence this lack of renewable electricity in the grid is also a barrier in making the shipping zero-carbon based one. A full feasibility study will be required to determine the energy resource and generation potentials.
3. No dedicated passenger pick-up/drop-off points for electric passenger ferry.

Identified measures

Economic and financial measures

The important measure is to lower upfront investment costs. Since the development of bespoke ships is costly, enabling measures to support and lower the investment risks is necessary.

1. Realignment of maritime sector financing and loaning policies. An effortless finance mechanism needs to be developed whereby the ships themselves are to be used as collateral rather than real estate. With that concessional loan, facilities are also important. The Fiji Development Bank provides financing for *Off-shore fishing loans* of up to $325 000 for the purchase of drop line fully equipped fishing vessels & working capital. The other facility available is the *Transport – Freight Purposes facility*, which is available for the purchase of a vehicle for freight transportation. For freight-related goods, consignment, sea transport, land, and air transport. Loan Features: Maximum loan term for new vehicles 5 years, second-hand vehicles 3 years; Equity contribution of at least 35%. There needs to be a specialized loans facility developed for the uptake of newer passenger and cargo vessels. Concessional loans with easy financing and lower interests, fees, and charges are important to keep the businesses afloat. The maritime transportation sector is a marginal business and there are many uneconomical routes, which are heavily subsidized by the government.

2. The current loan facilities offer competitive interest rates; Terms available to suit your business cycle; Reasonable fees & charges; reduced administrative requirements. However, to increase the uptake of this technology, tailor-made fiscal incentives are to be provided such as income tax holidays, deduction from taxable income for the labour expense, Exemption from Taxes, and Duties on Imported Spare Parts, and Net Operating Loss Carryover. This technology requires high upfront or CAPEX and is the reason for better fiscal measures to give a buffer for the initial high investments.

3. Insurance facilities for all marine vessels are to be developed with the local insurance providers. These products will make the investments and financing less risky, protecting both the investor and the financier.

To attract more shipowners to invest in Zero-Carbon passenger ferry technology, capacity building is required.

6. An increased understanding of the technology in the local context is required for this. The shipowners need to see and feel a locally based proof of concept to easily accept the technology.
7. Capacity building for modernised business practices is also imperative. The current business model is to invest in lower CAPEX ventures rather than a higher CAPEX venture that can yield higher profit in the longer term. Once the capacity is built in modern business practices, then it would be easier for current and prospective shipping companies to invest prudently.
8. Recording and availability of high-quality, timely, and reliable data on shipping routes and fuel usages together with proper studies would enable the development of proof of concept and the required business case for investors. The research and related organizations including Pacific Community (SPC), The University of the South Pacific, Fiji National University, The University of Fiji, Sailing for Sustainability (Fiji) Ltd, and Micronesian Centre for Sustainable Transport's (MCST-USP) to design and build low-cost sail-assisted inter-island vessel as a proof-of-concept.
9. In addition, specialized concessional loan facilities are to be made available Zero-Carbon passenger ferry technology. The government can also provide a guarantee for the loans, yet a full risk assessment is to be undertaken for this venture.

Non-financial measures

Regulatory measures

Similar to the first technology, for policy and regulations measures, the key gaps are to be addressed with:

10. Inclusion of emission reduction regulations with incentives and/or penalties. The notion was to ratify the International Convention for the Prevention of Pollution from Ships (MARPOL) in particular MARPOL Annex VI to limit the main air pollutants including sulphur oxides (SOx) and nitrous oxides (NOx) from ships exhaust. It also prohibits emissions of ozone-depleting substances (ODS) and regulates shipboard incineration and the emissions of volatile organic compounds (VOC) from tankers.

11. A progressive reduction in NOx emissions from marine diesel engines is proposed, yet to achieve higher impacts, transition to low and zero-carbon shipping becomes necessary.

12. Development and adoption of Ship Energy Efficiency Management Plan (SEEMP) are also imperative to allow owners and operators to realize the possible savings that can

result as a means of energy-efficient measures. This will allow for a swift transition towards low-carbon shipping technologies.

13. Revision of the Marine Transportation Act is required with the inclusion of low carbon shipping enterprises as well as realignment with updated emissions reduction targets.

These will directly influence the shipowners and operators to look into alternative low carbon maritime shipping technology and to venture into newer Zero-Carbon electric-hybrid passenger ferries.

Capacity measures

Ample capacity development for Zero-Carbon electric-hybrid passenger ferry is also needed. For this appropriate training and development for businesses, crew and operators are essential. Recruiting of the crew was also at times a drawback and the training institutions such as Fiji Maritime Academy can develop specialised training for operators and crew. This is to ensure that the crew and the operators are well versed with the technology, its operations, and maintenance to reduce the costs.

Tailoring training and skills development for women with specified gender quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities.

Infrastructural measures

Development of infrastructure for the adoption of hybrid electric passenger ferry is required as follows:

1. The tailor-made infrastructure is required for this technology such as charging stations from renewable resources.
2. Increased renewable electricity generation mix in the grid for this additional resource and generation potentials need to be determined through feasibility studies.
3. Additional dedicated passenger pick-up/drop-off points are to be developed on the routes for ease of travel. The estimated development costs would be around US$30,000. This could be integrated with the charging stations.
4. Cargo handling and passenger transit infrastructure in the maritime islands are to be effectively developed for efficient cartage and transportation.

Barrier analysis and possible enabling measures for Technology B3 “Eco-Flettner Rotor – retrofit and new-build technology”

The general description of technology B3 “Eco-Flettner Rotor – retrofit and new-build technology”

Flettner rotors are rotating cylinders mounted on the deck of the ship whereby one side of the rotors forms a low-pressure area while the other experiences high pressure generating lift similar to a sail, which is called the Magnus effect (Li et al., 2021). These rotors harness wind power for auxiliary propulsion. These rotors can be fitted across a broad design of vessels as retrofits, requiring relatively simple and cost-effective engineering, no additional crew, and minimal maintenance over the lifetime. Yet it is preferable that the new build vessels have these rotors. Experts estimate that on a local scale retrofitting can bring about savings of up to 5% while incorporating into newbuild could have savings from 15-40%+ (Nuttall et al., 2016). More details are provided in sub-section *2.1.3.2 Overview of the Technologies Identified*.

Identification of barriers for technology B3

Economic and financial barriers

The initial costs associated with the installation of Flettner Rotors are quite exorbitant and are around US$3.2 m[7]. The assumption is to have 4 units at costs of USD 800,000 per unit, yet the costs can be more/less based on individual ship requirements. This initial capital cost is the key financial barrier in the uptake of this technology. The root causes of the unaffordable maritime financing are the high loan interest rates, no insurance underwriters with unclear return on investment. This made the commercial bank more reluctant in financing is the risks were too high. The shipping companies also had to produce real estate as collateral for bank loans making it difficult to secure loans.

The other important barrier is the lack of interest or conflicting interests of shipowners in this technology. The shipowners are reluctant in the adoption of energy-saving devices or low-carbon technologies.

1. The underlying reason is the old-fashioned business practices whereby a lower CAPEX is favoured in terms of investment prospects.
2. The other underlying cause is the old Shipping Fleet as many ships are older than 30 years old. The operators continue to purchase old ships.
3. In addition, there is a lack of understanding of the newer technology in the local context as the operators are too attuned to diesel-powered ships.
    i. The root cause for this was the overall lack of local research and scientific studies on the effectiveness of low carbon shipping and the general lack of research funding for this.
    ii. This is compounded by data unavailability on fuel usages and as a result, the return on investment is not clearly presented to the investors and potential investors.

Non-financial barriers

Regulatory barriers

4. It has been identified that one of the foremost non-financial barrier in the gaps in policy and regulations that is likely to impede the adoption of this technology.
5. There are no emissions regulations for the maritime transportation sector that penalizes or incentives the operators into investing in low carbon shipping.
6. Ships also do not have Ship Energy Efficiency Management Plan (SEEMP). SEEMP allows for controlling and reduction of GHG emissions from ships at the same time improves efficiency and decreases fuel consumption.
7. The underpinning Marine Transportation Act is outdated.

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[7] At least 10 ships need to have the initial installations to achieve sizeable results.

Capacity barriers

8. Under the capacity barrier category, the lack of local capacity in Flettner Rotor technology was identified as the apex of the problem tree.
9. This is due to no on-ground training for businesses and operators in Flettner Rotor technology installations and operations.
10. In addition, the other issue is that there are few naval architects available. Due to these issues, the overall benefits of the Flettner Rotor technology are not understood properly.

Infrastructural barriers

11. Lack of infrastructure in terms of Flettner Rotor assembly (as the components need to be imported) has been noted.
12. Lack of docking facility with qualified heavy industry engineers and maintenance crew for retro-fitting proper.
13. The overall commercial shipbuilding industry in Fiji is in an inactive stage which fundamentally prevents the localized based research and building of bespoke ships with Flettner rotors for the needs of the local market.

Identified measures

Economic and financial measures

The initial capital cost for Flettner Rotor technology is quite high and investors are reluctant to adopt it. To make it affordable, a number of measures are to be placed.

1. To make financing easier, affordable interest loans need to be provided.

2. The development of concessional loans schemes specific to investment into low carbon shipping technology should also be available with ease. This will also aid in fleet replacement since many ships are too old to achieve any further energy or fuel saving.

3. In addition, proper insurance products are to be developed. Insurance will allow the banks and other financial institutions to offer loans without the much sought-out real-estate as collateral.

4. An increased understanding of the technology in the local context is required for this. The shipowners need to see and feel a locally based proof of concept to easily accept the technology.
5. Training and capacity building for modernised business practices is also imperative. The current business model is to invest in lower CAPEX ventures rather than a higher CAPEX venture that can yield higher profit in the longer term. Once the capacity is built in modern business practices, then it would be easier for current and prospective shipping companies to invest prudently.
6. Recording and availability of high-quality, timely, and reliable data on shipping routes and fuel usages together with proper studies would enable the development of proof of concept and the required business case for investors. The research and related organizations including Pacific Community (SPC), The University of the South Pacific,

Fiji National University, The University of Fiji, Sailing for Sustainability (Fiji) Ltd, and Micronesian Centre for Sustainable Transport's (MCST-USP) to design and build low-cost sail-assisted inter-island vessel as a proof-of-concept.

7. Quality data with proper local research and scientific studies would enable a clear return on investment and the financial statistics to be available to the investor and ship operators.

Non-financial measures

Regulatory measures

The policy and regulations measures have been identified as the most influential enabler for the uptake of this technology.

8. The inclusion of emission reduction regulations with incentives and/or penalties in the policies are important which are to be in line with MARPOL Annex VI.

9. Development and adoption of Ship Energy Efficiency Management Plan (SEEMP) are also imperative to allow owners and operators to realize the possible savings that can result as a means of energy-efficient measures. This will allow for a swift transition towards low-carbon shipping technologies.

10. Revision of the Marine Transportation Act is required with the inclusion of low carbon shipping enterprises.

Capacity measures

An enhancement of local capacity for the Flettner Rotor technology is required.

11. For this appropriate training and development for businesses and operators is essential. The training institutions such as Fiji Maritime Academy can develop specialised training modules.

12. Training and skills development for women with specified gender quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities.

13. More naval architects are to be trained. This will benefit the local shipbuilding industry in addition to the design and installation of the Flettner rotors. The co-benefit is that more understanding of the Flettner Rotor technology would be available.

14. Building capacity is one aspect, and the other aspect is to retain the capacity within the country.

Infrastructural measures

Infrastructure development is critical for the adoption of any energy-saving technology in the maritime sector.

15. The assembly of Flettner Rotor is expected to evolve into an industry of its own and for this commercial Flettner Rotor industry is to be developed with the technical assistance of the Fiji Ships and Heavy Industries Limited.

16. For retrofitting proper docking facility will be required with qualified heavy industry engineers and maintenance crew. In order to have new-built, a robust shipbuilding industry is required.

Linkages of the barriers identified

Linkages of the barriers have been assessed from two aspects, i.e., barriers, which are common to all technologies, and linkages between barriers for respective technologies. The former would lead to common measures benefiting all technologies, while the latter is expected to support a holistic or integrated approach in the implementation of measures leading to more effective scaling up of respective technologies.

As stated earlier, partial implementation of measures proposed for the maritime transportation sector is to be avoided to realize the full potential. The integrated approach increases the cost-effectiveness of proposed measure implementation at the same time would ramp up the scaling up of technologies and promoting a higher degree of diffusion.

All the three prioritized technologies face the same policy and regulatory barriers, and Economic and financial barriers. Hence, the cost of measures to overcome these barriers can be accounted for one technology only, while ensuring that the scope of measures covers all proposed mitigation technologies. Barriers were analysed by developing a market map and then building the problem trees for respective technologies. These are included in the market map presented in Annex VI (Figures A16-A18) while the problem trees illustrating the causes/effects relations and the corresponding solution trees are presented in Annex V (Figures A10-A15).

Linkages across technologies

The identified barriers including economic and financial barriers; regulatory barriers; capacity barriers; and infrastructural barriers impact all prioritized technologies though it is in varying degrees. The same regulatory barriers impact all these technologies and would affect the adoption of any mitigation technologies or low carbon technologies or energy-saving devices for the domestic maritime sector.

In addition, the most important is the economic and financial barriers. There is a considerable consensus amongst local as well as international experts that sufficient technology exists to produce low-or zero-carbon vessels at most scales, however, the financial drivers are to commercialize those technologies to enable market-scale deployment is the missing link (Nuttall et al., 2020). Domestic maritime shipping in Fiji is a marginal business. The low cash micro-economy of the remote maritime communities together with rising fuel and maintenance costs, further constraints the investment into newer vessels or technologies. The maritime transportation routes in Fiji are divided into economical and uneconomical routes. The economical routes do provide some return, yet the uneconomical routes do not provide any turnover. The uneconomical routes are for servicing the smaller islands in the archipelago where the government has to provide fuel and fare subsidies so the shipping services can be kept operational. Low-income generation opportunities in remote maritime island communities are also a very important aspect to consider since the fare has to be kept reasonable and the government has to subsidize it.

Table 2.2: Summary of identified barriers and proposed measures for technology transfer in the Domestic Maritime Sector.

Technology **Barriers and measures**		**Sail-powered Passenger/Cargo Ship**	**Zero Carbon Passenger Ferry Trials**	**Eco-Flettner Rotor – retrofit and new-build technology**
Economic and financial barriers	**Barriers**	1. Higher upfront Capex 2. Unaffordable maritime financing 3. No insurance underwriters 4. Unclear return on investment 5. High-risk financing	6. Higher upfront Capex 7. Unaffordable maritime financing 8. No insurance underwriters 9. Unclear return on investment 10. High-risk financing 11. Previous bad experiences 12. Difficult for shipowners and operators to undertake large investments 13. Lack of investor confidence 14. High-risk financing 15. Lack of fiscal incentives	16. High initial capital cost 17. Unaffordable maritime financing 18. High loan interest rates 19. No insurance underwriters 20. Unclear return on investment 21. Lack of interest or conflicting interests 22. Shipowners are reluctant in the adoption of the energy-saving devices 23. Old fashioned business practices 24. Old Shipping Fleet 25. Lack of understanding of the newer technology

				26. Lack of local research and scientific studies 27. Data unavailability 28. Unclear return on investment
	Measure	29. A clear return on investment needs to be established 30. High quality, timely and reliable data on shipping routes and fuel usages, etc. Needs to be available. 31. Proper scientific studies 32. Easier financing 33. Affordable interest loans 34. Concessional loans specific to investment into low carbon shipping technology 35. Vessel Insurance Scheme	36. Realignment of maritime sector financing and loaning policies 37. Effortless finance mechanism 38. Concessional loans with easy financing and lower interests, fees, and charges 39. Tailor-made fiscal incentives 40. Insurance facilities for all marine vessels 41. An increased understanding of the technology 42. Capacity building for modernised business practices 43. Recording and availability of high quality, timely and reliable data 44. Specialized concessional loan facilities	45. Easy financing 46. Affordable interest loans 47. Concessional loans schemes 48. Proper insurance products 49. Increased understanding of the technology in the local context 50. Training and capacity building for modernised business practices 51. Recording and availability of high quality, timely and reliable data 52. Proper local research and scientific studies

Regulatory barriers	**Barriers**	53. Gaps in policy and regulations 54. No emissions regulations 55. No Ship Energy Efficiency Management Plan (SEEMP) 56. Marine Transportation Act is outdated	57. Gaps in policy and regulations 58. No emissions regulations 59. No Ship Energy Efficiency Management Plan (SEEMP) 60. Marine Transportation Act is outdated	61. Gaps in policy and regulations 62. No emissions regulations 63. No Ship Energy Efficiency Management Plan (SEEMP) 64. Marine Transportation Act is outdated
	Measure	65. Inclusion on emission reduction regulations with incentives and/or penalties 66. Ratify MARPOL Annex VI 67. Regulates shipboard incineration, and the emissions 68. A progressive reduction in NOx emissions 69. Development and adoption of SEEMP	70. Inclusion on emission reduction regulations with incentives and/or penalties 71. Ratify MARPOL Annex VI 72. Regulates shipboard incineration, and the emissions 73. A progressive reduction in NOx emissions 74. Development and adoption of SEEMP 75. Policies to influence the shipowners and operators to look into alternative low carbon maritime shipping technology	76. Inclusion on emission reduction regulations with incentives and/or penalties 77. Ratify MARPOL Annex VI 78. Regulates shipboard incineration, and the emissions 79. A progressive reduction in NOx emissions 80. Development and adoption of SEEMP

Capacity barriers	**Barriers**	81. Lack of interest or conflicting interests amongst the shipowners 82. Old fashioned business practices 83. Lack of understanding of the newer technology 84. Lack of local research and scientific studies 85. Lack of research funding 86. Data unavailability 87. Technology is perceived as inefficient 88. No on-ground training 89. Inefficient weather routing 90. No dedicated wind and wave forecasting and early warning systems	91. Lack of understanding of the newer technology 92. No on-ground training	93. Lack of local capacity 94. No on-ground training 95. Few naval architects available
	Measure	96. Attract more shipowners to invest in low carbon sail-powered shipping technology 97. An increased understanding of the technology in the local context	107. Appropriate training and development 108. Recruiting of the right crew 109. Develop specialised training for operators and crew	111. Appropriate training and development 112. Training and skills development for women 113. Training more naval architects

		98. Capacity building for modernised business practice 99. Recording and availability of high quality, timely and reliable data 100. Development of a proof of concept 101. Appropriate training and development 102. Training and skills development for women 103. Use of traditional sailing knowledge and boat building knowledge 104. Efficient weather routing 105. Dedicated wind and wave forecasting and early warning systems 106. Route analysis	110. Training and skills development for women	114. Retain the capacity within the country
Infrastructural barriers	**Barriers**	115. No commercial sail powered shipbuilding 116. No backup and maintenance industry	118. No charging stations 119. Lack of renewable electricity in the grid	121. Lack of infrastructure for rotor assembly 122. Lack of docking facility

		117. The inactive commercial shipbuilding industry	120. No dedicated passenger pick-up/drop-off points for electric passenger ferry	123. Lack of qualified heavy industry engineers 124. Lack of maintenance crew for retro-fitting proper 125. The inactive commercial shipbuilding industry 126. Lack of localized based research and building of bespoke ships
	Measure	127. Revival of shipbuilding 128. Development of maintenance industry 129. Cargo handling and passenger transit infrastructure	130. Tailor-made infrastructure 131. Increased renewable electricity generation mix in the grid 132. Dedicated passenger pick-up/drop-off points 133. Cargo handling and passenger transit infrastructure	134. Commercial Flettner Rotor industry is to be developed 135. Qualified heavy industry engineers 136. More maintenance crew 137. The robust shipbuilding industry is to be developed

Fiji as a developing nation faces capacity barriers, which are common to all three technologies. With Fiji being a small country with a very small population, challenges in terms of human resources scarcity have been a recurring issue. The mitigation technologies prioritized have high mitigation potentials and require a high skilled workforce with a whole-of-sectoral paradigm shift in the way it is functioning from business and operational to the basics of record-keeping and data collection. Training and development need to be devised to increase human capacity and expertise. Investment for human capacity development is usually hampered by the migration of trained individuals.

Technology specific inter-barrier linkages

Capacity is very much technology-specific as different technology will require different training. For instance, for the Sail powered ship, skills development of the crew will be required specific to the sail technology being adopted. Similarly, for zero-carbon ferry technology, training for the maintenance of onboard electrical propulsion systems is imperative for the success of the technology. Development of training courses for marine mechanics to work on electric motors and batteries/accumulators will be required. While for the Flettner Rotor technology, the additional crew is not required, yet capacity development for installation and naval architecture is more sought out.

The other technology-specific barrier is the infrastructure. For zero-carbon ferry technology, bespoke docking and charging stations from renewable electricity is a must to make it carbon neutral. In the case of Flettner Rotor technology, a rotor installation firm will be required to do the job with specialized machinery.

Enabling framework for overcoming the barriers in Sector B – Domestic Maritime Transportation Sector

Based on the similarities in barriers as described in Section 3.5 above and Table 2.4, some common measures could be introduced to streamline the climate technology diffusion process. The mitigation technologies require higher CAPEX and are not one-off projects. The scope for replicability is high with a long-term commitment is required to make it successful. For a better return on investment, a whole of sector transformation is required rather than unsystematic piecemeal kind of partial measures. The enabling framework to promote the uptake of these technologies needs to take into account the local considerations as well.

The important underpinning Maritime Transportation Act needs to be reviewed. The current shipping fleet in Fiji is very older and many are over 30 years old. These vessels have very small to no room for energy efficiency. Thus a proper review of the act with the inclusion of a strict vessel age is very important. Then the act needs to be aligned with the MARPOL Annex VI, the inclusion of mandatory SEEMP as well as the incorporation of dedicated emission reduction regulations with incentives and/or penalties. This will allow the operators to shift investment into low carbon shipping vessels and technology. The other enabling policies include:

1. Establishment of a policy for high quality, timely, and reliable data recording and sharing on shipping routes and fuel usages, etc. This will allow for better economic planning.

2. Development and adoption of Ship Energy Efficiency Management Plan (SEEMP) are also imperative to allow owners and operators to realize the possible savings that can result as a means of energy-efficient measures. This will allow for a swift transition towards low-carbon shipping technologies.

Shipping is the industry that connects the islands with the transport of people, goods, and other services like medical services. Hence, the following measures are likely to provide an enabling environment:

1. A reduction in capital and operations costs would benefit the whole industry and allow for better diffusion of newer energy-saving technologies and transitioning into low carbon shipping.
2. High CAPEX technologies further burden the marginal maritime business. Specific sustainable financing (with lower collateral, interest rates, and charges) needs to be made available to the private sector to easily access and invest in low carbon shipping opportunities.
3. A modernized business model and practices with higher CAPEX and lower OPEX is to be developed as the low carbon shipping does require a higher CAPEX. This will benefit both the private sector investors and the respective maritime communities.
4. Maritime financing is a high-risk undertaking from the lender's perspective and are reluctant to finance. As a result, a suitable insurance facility for maritime shipping needs to be developed to cover for loss against unforeseen circumstances protecting both the investor and the financier.
5. The development of concessional loans specific to investment into low carbon shipping technology should also be available with ease. Concessional loans with easy financing and lower interests, fees, and charges are important to keep the businesses afloat.
6. Attract more shipowners to invest with locally-based proof of concept. For this, an increased understanding of the technology in the local context is required.

In terms of capacity the development of human resources together with retention of personnel is important:

1. Appropriate training and development for businesses, crew, and operators are essential. Training and capacity building is technology-specific and hence it is to be carried out according to the needs of the technology.
2. Tailoring training and skills development for women with specified gender quotas for technical (design, engineering, and maintenance) and non-technical (business and leadership) training and skill development opportunities.
3. Incorporation of traditional knowledge and boat building knowledge and techniques in the use of newer sail-assisted maritime transportation is important.
4. For retention of capacity better salary schemes, motivation strategies, and continuous career development within the organisation are to be developed. Local training institutions could also develop newer training programmes. Companies can also undertake on-the-job training and apprenticeship schemes wherever possible.

The tailor-made infrastructural development will be required for all the prioritized technologies. This will further increase the efficiency of passenger and cargo transit. The cargo handling and passenger transit infrastructure in the maritime islands currently are under-developed. Infrastructure development is critical for the adoption of any energy-saving technology in the maritime sector.

Efficient weather routing route analysis is also needed to determine the cost-effective routes with wind propulsion systems as well as to determine economical routes. In addition, from the maritime community perspective, longer-term strategic development of the maritime region intertwined with a targeted Maritime Action Plan as proposed by Fiji's NDC Investment Plan is important to allow for better income-generating opportunities.

The robust NEP 2023-2030 includes a number of overarching objectives and priorities for maritime sector and is going to support the low carbon transition and development in the maritime sector. Some of the enabling o overarching objectives and priorities include.

1. To develop a national transport decarbonisation strategy in alignment with Fiji's net-zero emissions by 2050 target.
    i. A targeted '*Maritime Action Plan'* and a national '*Transport Decarbonisation Strategy*' is targeted to be developed by the DoE and DoT under this overarching objective with support activities to promoting transport modal shifts, reduced fossil fuel consumption, influence behaviour, planning, and investment, and improve the efficiency of Fiji's transport sector.

1. To reduce emissions from domestic marine transport by 40% by 2030.
    i. Proactively promote the operational and physical efficiency improvements (ship energy management plans, route planning, ballast optimization, speed regulation, propeller replacement and maintenance regimes, engine tuning, and retrofitting to include additional sources of low emissions propulsion) on large ships and ferries via introduction of new incentives and standards.
    ii. Promote the import and sale of high-efficiency small engines whilst phasing out the import and sale of inefficient 2 stroke outboard engines by 2025.
    iii. Seek support and access to technical assistance and demonstration finance for marine propulsion modal shifts and clean port infrastructure through engagement with key partners and international organisations.

2. To improve energy sector data collection, management, and dissemination.
    i. DOT will support MSAF to improve its collection and analysis of energy consumption data within the marine transport sector.
3. To promote research and innovation.
    i. To support Fiji's 2050 net-zero target, DOE and DOT will work with relevant ministries and stakeholders to encourage strategies designed to increase access

to financing equivalent to 1% of Fiji's GDP annually by 2030 to support context-specific research, technical assistance, technology transfer, and innovation.

ii. Promote national investment in research and innovation aligned to the Fiji's development priorities and commitments.

The need to connect people in some 110 inhabited islands outweighs any barriers and calls for urgent action in the sector. Better shipping services in terms of frequency and reliability would enhance the interconnectivity of islands allowing better trade and tourism opportunities. This could aid in more income generation opportunities for communities. The COVID19 pandemic has taught that remote working is the new normal and has been proven to be successful in many instances. Hence, the government and other industries can try to decentralize some of their services to extend the development in other remote communities as well.

References

Al-Falahi, M., 2019. E-ferry Concept Implementation. Beyond EVs: Batteries in the water-2019 Energy Insider.

Butcher, L., 2021. Austal Australia debuts fast electric ferry. Electric and Hybrid: Marine Technology International.

Chou, T., Kosmas, V., Acciaro, M. and Renken, K., 2021. A Comeback of Wind Power in Shipping: An Economic and Operational Review on the Wind-Assisted Ship Propulsion Technology. Sustainability, 13(4): 1880.

Engerati, 2015. Solar microgrids for Fiji.

Fiji Department of Energy, 2014. Final DRAFT Fiji National Energy Policy - 2014. The Government of Fiji.

Fijian Ministry of Economy, Regional Pacific NDC Hub and GGGI, 2020. draft Projects Pipeline for the Transport and Energy Efficiency Sectors Contribution to Fiji's NDC.

Government of the Republic of Fiji, 2014. Republic of Fiji: Second National Communication to the United Nations Framework Convention on Climate Change. Ministry of Foreign Affairs.

Hakirevic, N., 2020. Neoline finds work for wind-powered sailing RoRo ships. Offshore Energy.

Hakirevic, N., 2021. Neoline's sailing cargo ships to transport Michelin products. Offshore Energy.

IRENA, 2015. Fiji Renewable Readiness Assessment, International Renewable Energy Agency, Abu Dhabi.

Li, B., Zhang, R., Li, Y., Zhang, B. and Guo, C., 2021. Study of a New Type of Flettner Rotor in Merchant. Polish Maritime Research, 28: 28-41.

Ministry of Economy-The Republic of Fiji, 2017. 5-Year & 20-Year-National Development Plan.

Ministry of Economy - Republic of Fiji, 2017. Fiji NDC Implementation Roadmap 2017-2030. Setting a pathway for emissions reductions target under the Paris Agreement.

Ministry of Economy, 2018. Fiji Low Emissions Development Strategy 2018-2050. Government of the Republic of Fiji.

Ministry of Strategic Planning National Development and Statistics, 2014. Green Growth Framework for Fiji. Restoring the balance in development that is sustainable for the future.

MITDMMS, 2018. Strategic Development Plan 2019-2022. Ministry of Infrastructure and Transport, Disaster Management and Meteorological Services.

MITDMMS, 2019. Strategic Development Plan 2019-2022, Minister, Ministry of Infrastructure and Transport, Disaster Management and Meteorological Services.

Neoline, 2021a. Neoline.

Neoline, 2021b. With NEOLINE, the Michelin Group's logistics is on the rise.

Nuttall, P., A., N., Rojon, I., Milligan and Irvin, A., 2020. Pacific island domestic shipping emissions abatement measures and technology transition pathways for selected ship types.

Nuttall, P., Vahs, M., Morshead, J. and Newell, A., 2016. The case for field trialing and technology/knowledge transfer of emerging low carbon maritime technologies to Pacific Island Countries. Renewable Energy: Sources, Applications and Emerging Technologies. Nova Science Publishers, New York.

Nwaigwe, K.N., Mutabilwa, P. and Dintwa, E., 2019. An overview of solar power (PV systems) integration into electricity grids. Materials Science for Energy Technologies, 2(3): 629-633.

Parra, D., Gillott, M., Norman, S.A. and Walker, G.S., 2015. Optimum community energy storage system for PV energy time-shift. Applied Energy, 137: 576-587.

Prasad, R.D. and Raturi, A., 2020. Solar Energy for Power Generation in Fiji: History, Barriers and Potentials. In: A. Singh (Editor), Translating the Paris Agreement into Action. Springer, pp. 177-199.

Raturi, A. and Nand, R.T., 2016. Rural Electrification Initiatives in Fiji – A Case Study of Solar Home Systems. 1-7.

REN21, 2020. Renewables 2020 - Global Status Report. Paris: REN21 Secretariat.

Republic of Fiji, 2020. Third National Communications Report to the United Nations Framework Convention on Climate Change. , Suva, Fiji.

Republic of Fiji, 2023. National Energy Policy 2021-2030.

The Government of Fiji, 2019. National Climate Change Policy 2018-2030. Suva, Fiji.

The Government of Fiji, 2020. Fiji’s Updated Nationally Determined Contribution.

Tillig, F. and Ringsberg, J.W., 2020. Design, operation and analysis of wind-assisted cargo ships. Ocean Engineering, 211: 107603.

Twidell, J. and Weir, T., 2006. Renewable Energy Resources. Taylor & Francis, NY, USA.

UNFCCC, 2020a. Nationally Determined Contributions (NDCs). United Nations Framework Convention on Climate Change.

UNFCCC, 2020b. Paris Agreement - Status of Ratification. United Nations Framework Convention on Climate Change.

ANNEXES

ANNEX I

Problem and Solution Trees: Rural Electrification

Figure A1: Problem Tree for Solar PV Community Micro Grids

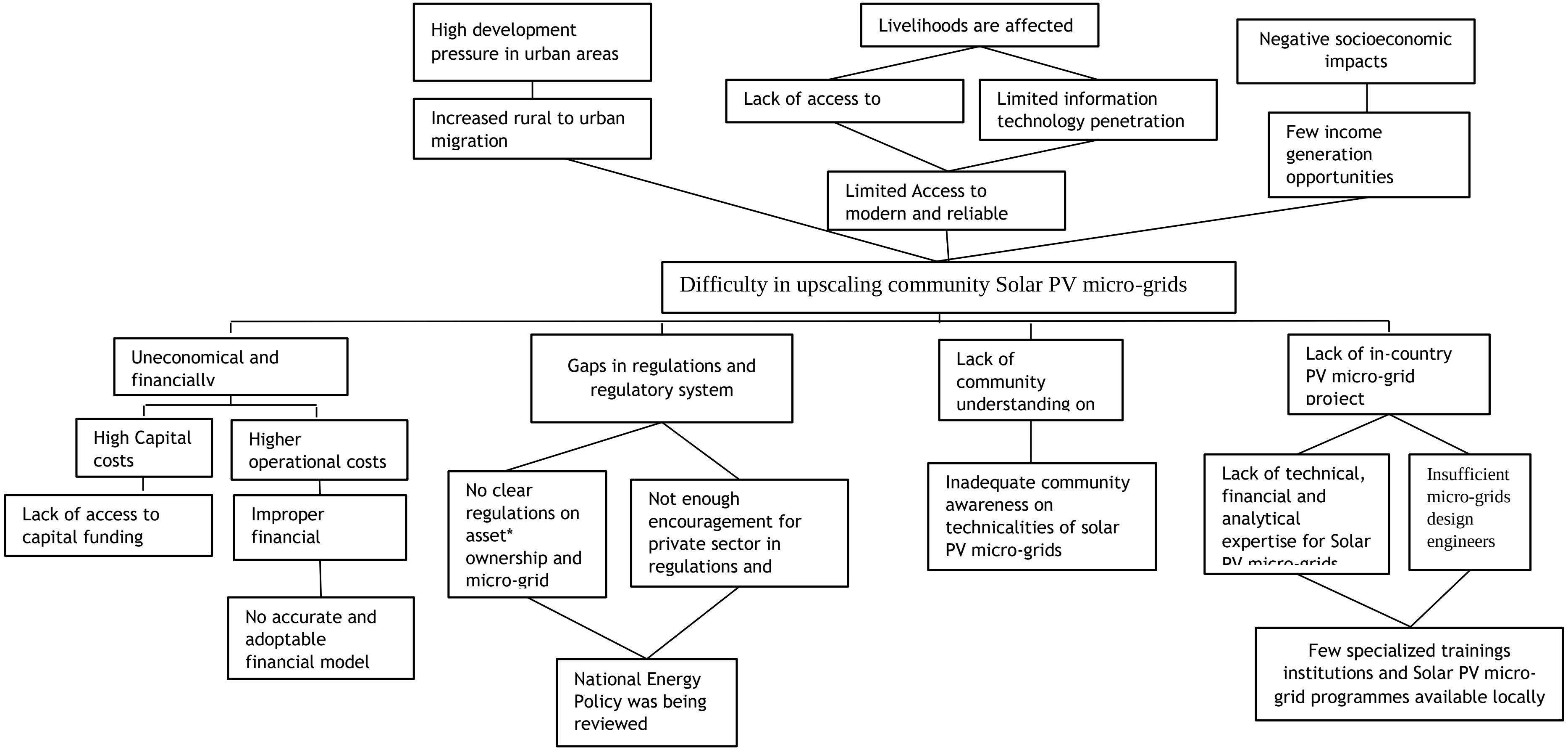


Figure A2: Solution Tree for Solar PV Community Micro Grids

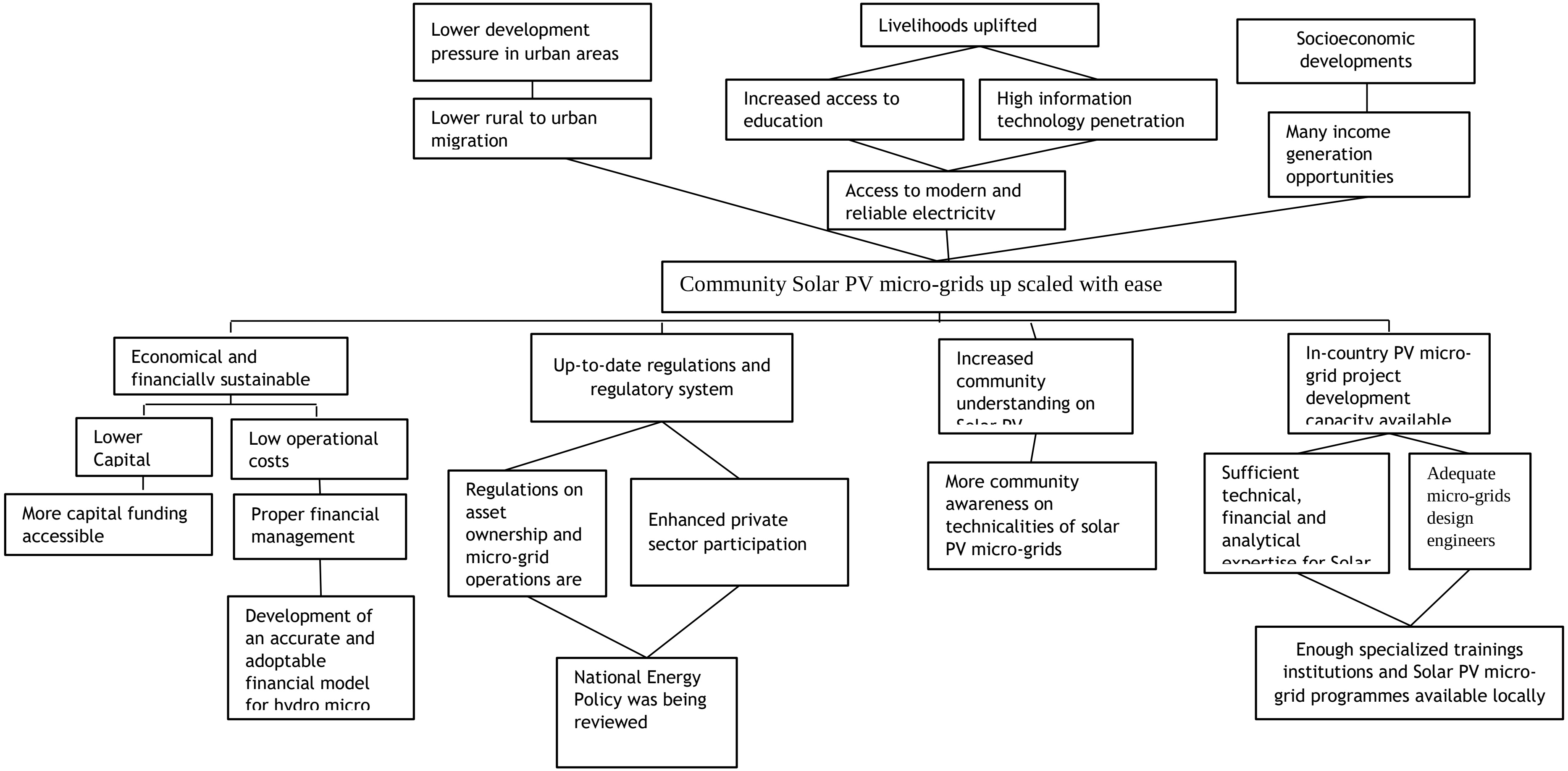


Figure A3: Problem Tree for Solar PV- CNO Community Micro Grids

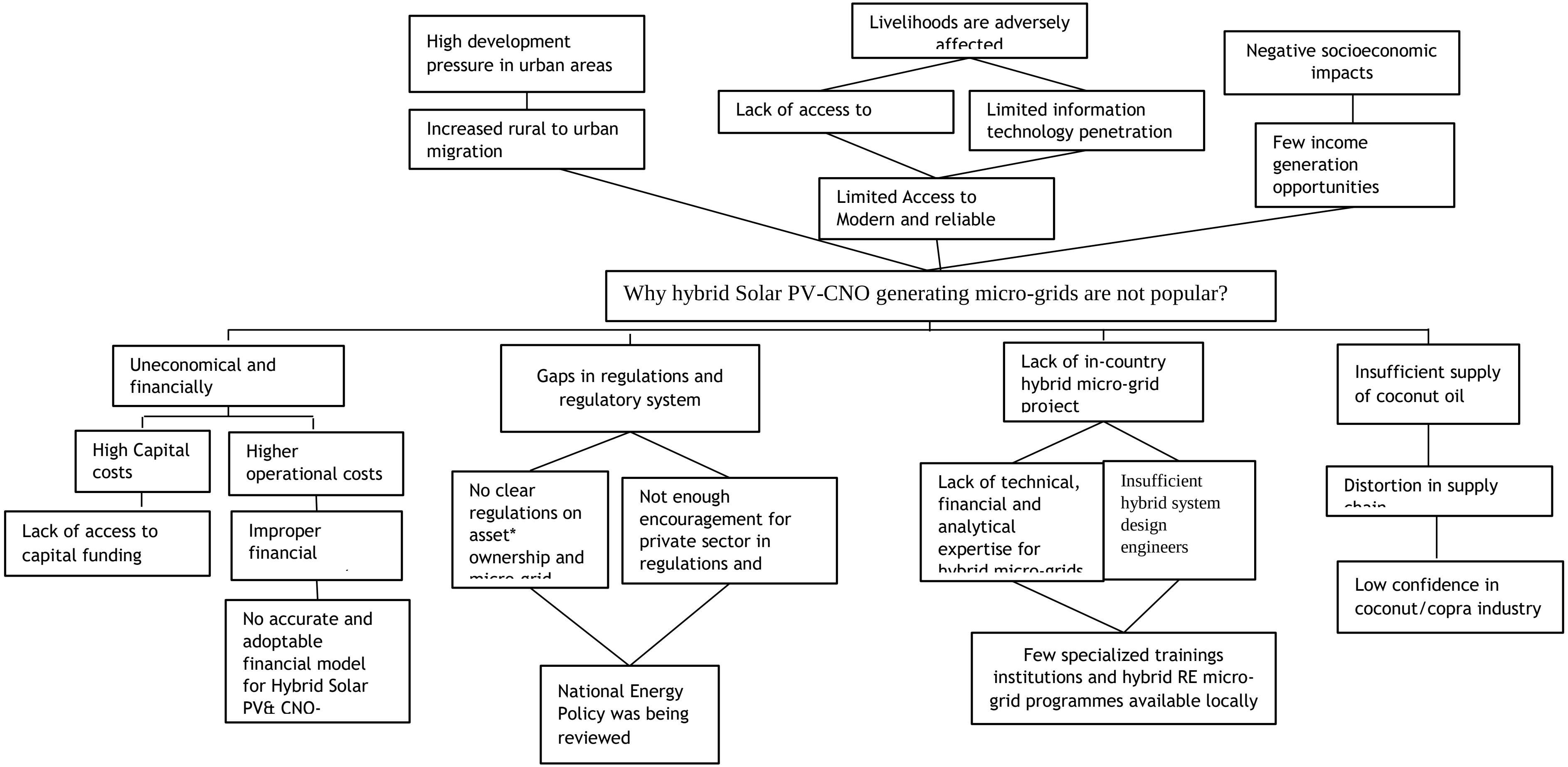


Figure A4: Solution Tree for Solar PV- CNO Community Micro Grids

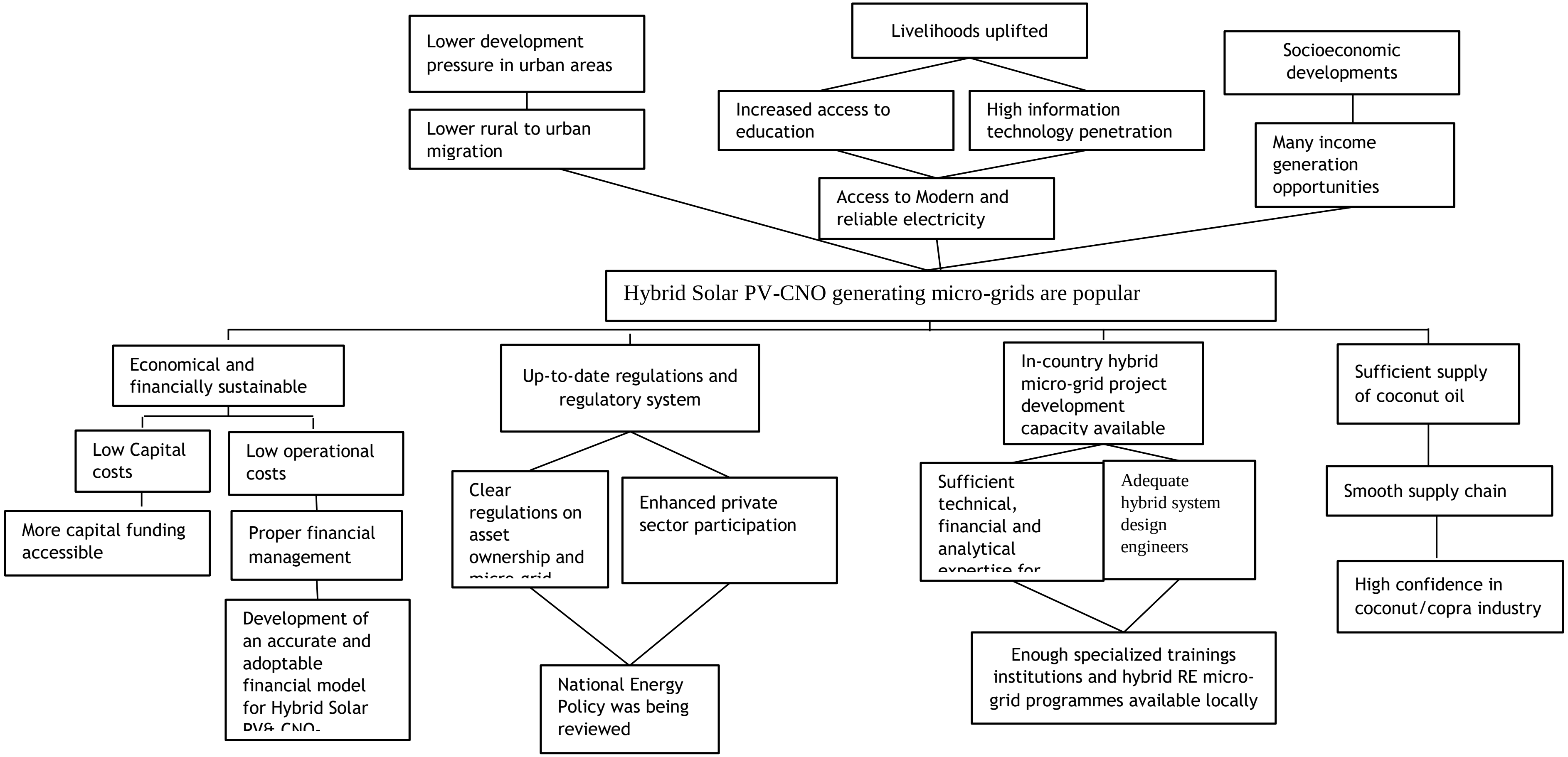


Figure A5: Problem Tree for Micro/Pico Hydro Community Micro Grids

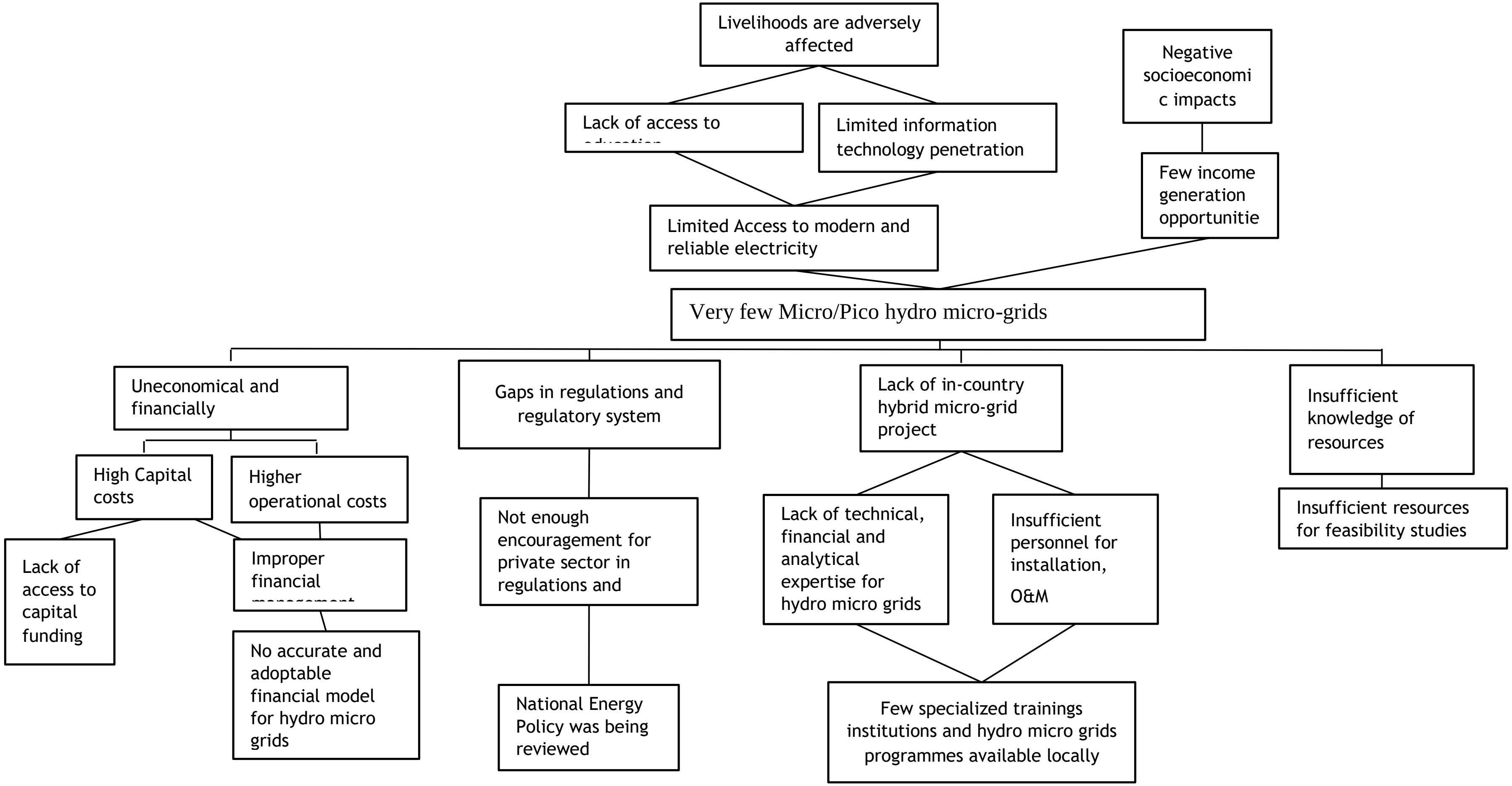
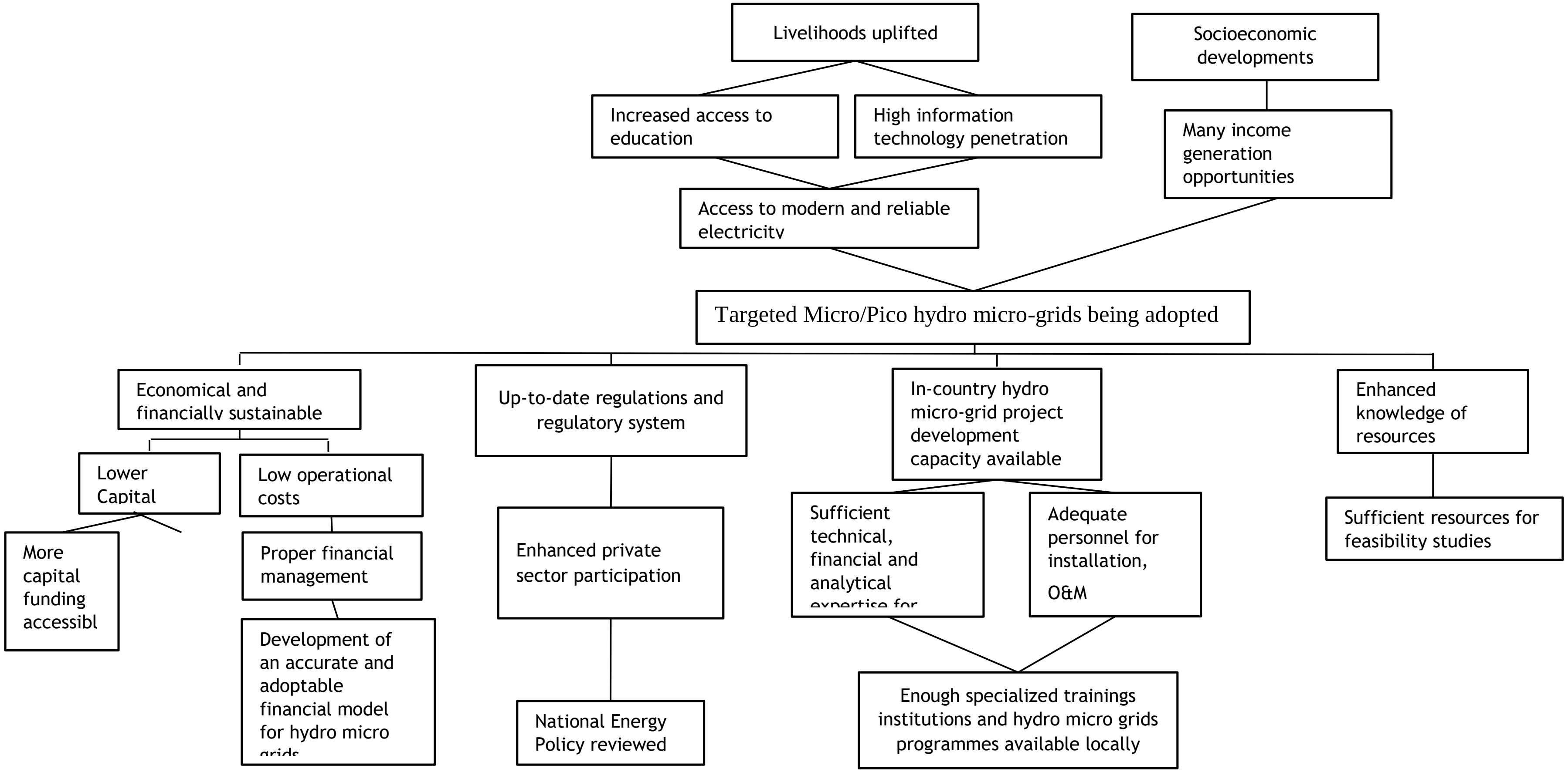


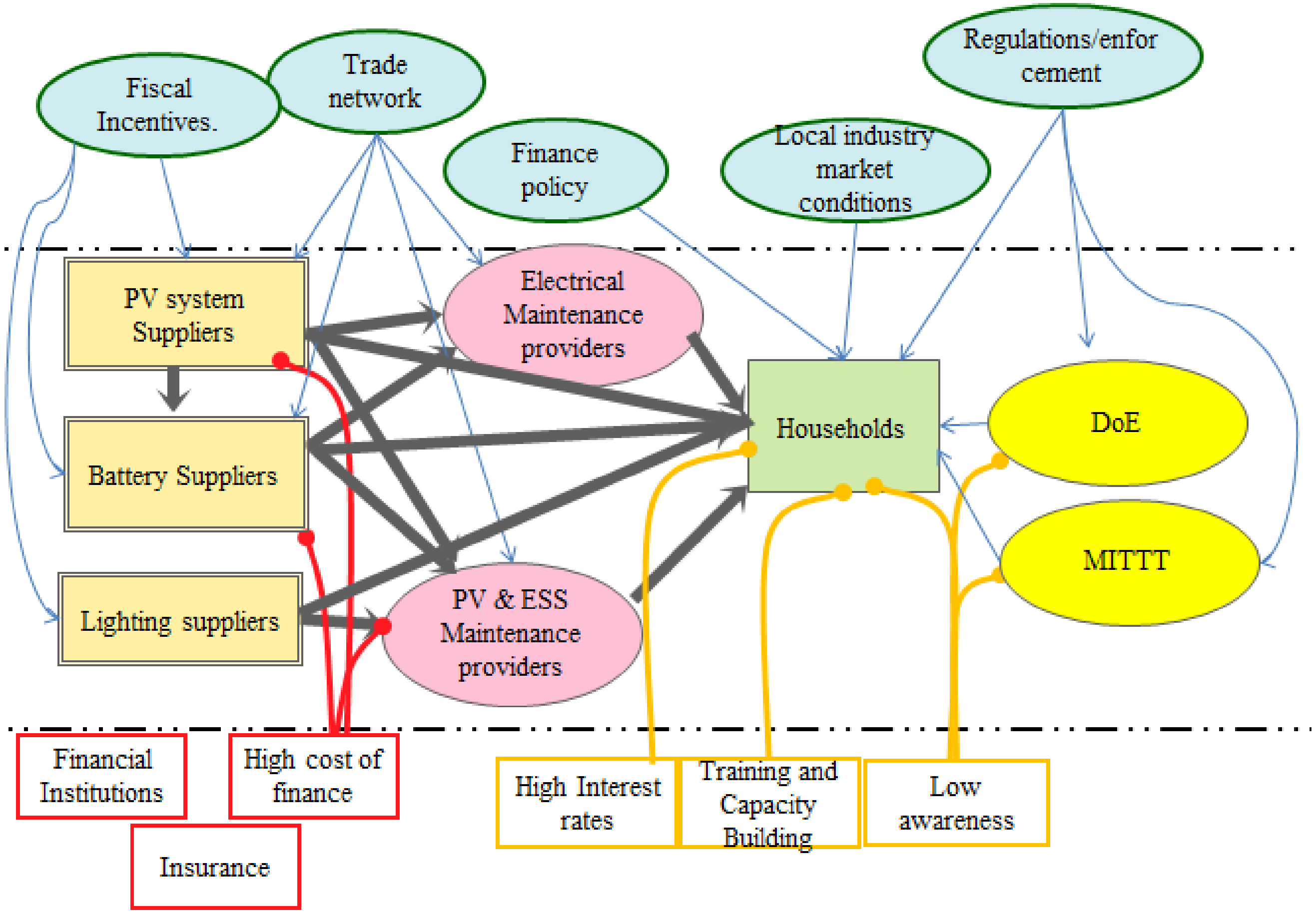
Figure A6: Solution Tree for Micro/Pico Hydro Community Micro Grids



ANNEX II

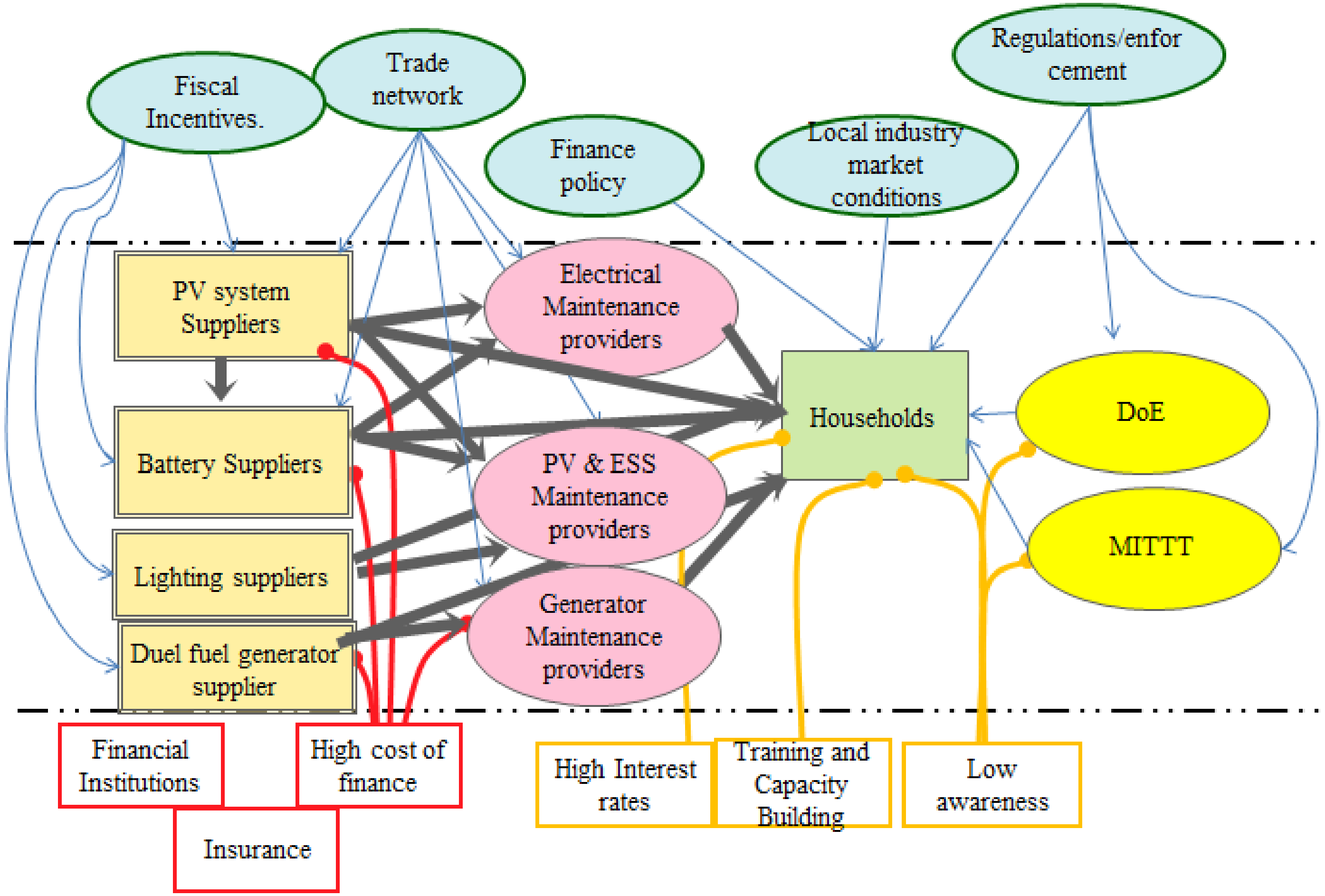
Market Mapping: Rural Electrification

Figure A7: **Market Mapping for Solar PV with ESS Micro-Grids.**



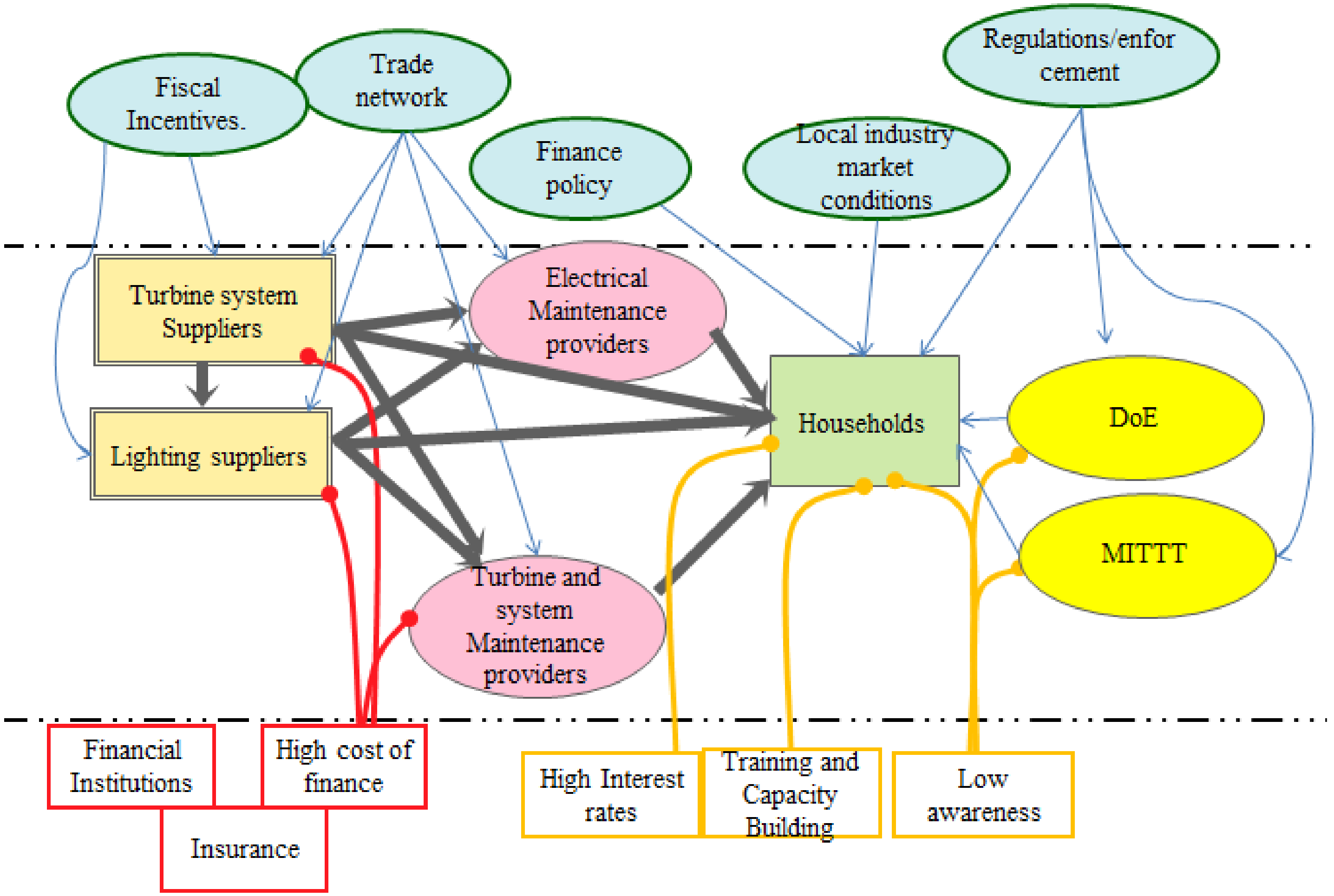
Non-Market Good – Publicly Provided

Figure A8: Market Mapping for PV with Dual fuel (CNO/Diesel) Generator Hybrid system with ESS (micro-grid)).



Non-Market Good – Publicly Provided

Figure A9: Micro/Pico-hydro in micro-grid configuration



Non-Market Good – Publicly Provided

ANNEX III

Technology Fact Sheets (TFS): Domestic Maritime Transportation Sector

Technology Fact Sheet 1

Technology	**Eco-Flettner Rotor[8] – retrofit and newbuild technology**
Sector	**Transport**
Sub-sector	**Maritime**
Sectoral GHG emission	Estimated at 174 Kilotonnes CO_2 emissions from Fiji's domestic shipping in 2016. Under a BAU scenario, emissions are modelled to increase to over 600kt by 2050 (Fiji LEDS).
Background/Notes, Short descriptions of the technology options	Flettner rotors are a proven technology for harnessing wind power for auxiliary propulsion and therefore suitable for both retrofit and new-build designs in combination with conventional or new fuel or e-propulsion motors. Invented and commercially demonstrated in the 1920s, they have been subject to numerous trials since 20119 and are now fitted on designs across a broad vessel fleet10 and are increasingly being incorporated into new build designs at various scales and applications11. A relatively simple and cost-effective engineering construct, it requires no additional crew and minimal servicing over vessel life for fuel/emissions saving returns of 8-25% for retrofits and 15-40%+ when incorporated into newbuild with rates of return estimates varying between 2.5 – 7 years12. Rotors have been found to be applicable to Pacific domestic deployment13 and are considered ready for immediate proof of concept trials, both retrofit, and newbuild in Fiji. Rotor sizes can be scaled according to vessel size/use and have potential application at most large vessel scales found in Fiji. The lightweight design and flexible foundation of the Eco Flettner require minimum space and only limited structural changes. This modular system makes it suitable for many different types of ships in the global merchant

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8 http://www.eco-flettner-rotor.com

9 https://www.tandfonline.com/doi/full/10.1080/17445302.2019.1612544 ; https://www.researchgate.net/publication/337858674_Wind-assisted_ship_propulsion_performance_prediction_routing_and_economic_analysis_-_a_corrected_case_study ; https://www.researchgate.net/publication/287081987_The_use_of_Flettner_rotors_in_efficient_ship_design

10 https://www.dnvgl.com/expert-story/maritime-impact/ECO-FLETTNER-rotor-sail-stands-the-test.html ; https://www.cnbc.com/2018/08/31/maersk-tankers-installs-two-huge-rotor-sails-on-one-of-its-vessels.html ;

11 https://www.offshore-energy.biz/wartsila-anemoi-marine-technologies-join-forces-on-rotor-sails-solutions/

12 This is a coarse estimate from a range of international trials. A finer analysis is needed before making more definite projections for a Fiji operating scenario.

13 http://www.pimrisregional.library.usp.ac.fj/gsdl/collect/jps/index/assoc/HASH46e3.dir/doc.pdf ; Nuttall, P., Vahs, M. Morshead, J. et al (2016) *The case for field trialing and technology/knowledge transfer of emerging low carbon maritime technologies to Pacific Island Countries*. Renewable Energy: Sources, Applications and Emerging Technologies. Nova Science Publishers, New York, pp. 159-185. ISBN 9781634856515.

	fleet, including coasters as demonstrated on MV Fehn Pollux[14]. Wind-assisted propulsion systems have been accepted by IMO for EEDI calculation. A ship-specific installation of one or more rotor sails on deck could have a positive effect on the manoeuvrability of the vessel and the performance of the rotor sail.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country's environment.	Greater savings and application come with incorporating into newbuild designs. Retrofits require engineering solutions to be accommodated on existing deck configurations. Application is quick, requiring only a few days of downtime for fitting and commissioning, and can be timetabled with scheduled maintenance outhauls. Precise availability and the full market potential are unknown given the data issues associated with this sector. However, it is assumed that rotors have potential commercial retrofit applications on 5-30% of current large fleets and 20-80% of newbuilds. There are no additional crew costs, marginal additional training costs, and extremely marginal maintenance costs. There is no impact on a ship's operating ability or cargo capacity. There are minimal regulatory changes required to introduce. There is a needed capacity development component required in the specialist knowledge of the technology and its use. There are multiple potential multipliers, including in-country secondary fabrication and maintenance for a regional market and improved stability and therefore safety of the vessel[15]. There are a number of commercially available packages now available[16]. A long term research partnership is recommended with the Eco-Flettner project being developed by existing partners Hochschule Emden-Leer[17] to: 1. assess the GSS fleet for a proof of concept technology trial on 2 vessels of differing scale and complete a 2-year monitored trial across representative Fiji routes 2. assess the existing and projected potential across the government and Pacific private sector domestic fleets 3. develop a Pacific technology transfer manufacturing and distribution hub as a PPP under the PIDF Pacific Green Business initiative and PBSP financing modalities for SME's. The hub would initially import kitset prefabricated rotors before scaling to local fabrication.

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[14] https://www.dnvgl.com/expert-story/maritime-impact/ECO-FLETTNER-rotor-sail-stands-the-test.html, Vahs, M. (2018) Project MV Fehn Pollux http://www.eco-flettner-rotor.com Eco Flettner GmbH

[15] https://www.sciencedirect.com/science/article/abs/pii/S0308597X17303780 ; https://www.semanticscholar.org/paper/Bridging-islands-and-calming-seas%3A-A-material-flow-Searcy/8c713f6718f3062843b02a848457857eb7ba6590

[16] E.g. http://www.eco-flettner-rotor.com; https://www.anemoimarine.com/home/; https://www.norsepower.com/; http://www.magnuss.com/index.html

[17] https://www.hs-emden-leer.de/en/

	4. Provide low-interest underwritten loans (via PBSP) to private sector operators for uptake
Technical Maturity	**Mature.** See the notes above. Rotors of various configurations and designs are under trial and now operationalized on bulkers, tankers, cruise liners, ro-ro's, general-purpose, and specialist vessels of varying tonnage in retrofit and newbuild configurations. For one example, Finnish maritime technology group Wartsila will fully integrate the Anemoi rotor for newbuild and for retrofitting to existing ships.
Applicability	Retrofits require a case-by-case evaluation. Precise availability to the fleet is unknown. However, it is assumed that rotors have potential commercial retrofit applications on 5-30% of current large fleets and 20-80% of newbuilds, with between 1-4 rotors per application. ROI rates will vary according to the application but are equivalent to the reduction in OPEX from fuel savings. Applicability is a function of the transport work of the vessel, its size, speed, etc. and the available wind patterns: 1. Slower vessels have greater savings. 2. Smaller vessels have higher potential savings. 3. Crosswind routes have the greatest savings.
Implementation barriers	The only technology constraint is local HR capacity. This is needed for design, engineering, fabrication, installation, operation, and maintenance. Installation, operation, and maintenance barriers can be overcome with minor training. Fabrication can be achieved with more advanced training. Design and engineering require specialized training. All are achievable over time and existing partnerships can provide this. There are engineering constraints for retrofits caused primarily by deck and axillary machinery configuration. Most can be overcome but the solution will impact the investment case and ROI. There are minimal regulatory barriers requiring minor changes to survey and registration processes. There are large perceptual barriers in introducing a new, foreign, and highly visible technology. These are easily overcome with proof of concept. There is a current investment financing barrier which the PBSP is designed to overcome. There could be political barriers in terms of prioritization.
Emission reduction potential (%)	Dependent on a number of factors including size and number of rotors, vessel size, speed, route, predominant wind patterns, etc. Based on current research trials, retrofit savings can be estimated at **10-25% fuel savings** in

	annual fuel use average with much higher savings when incorporated into new build low carbon designs. ~1000 t CO_2/yr. could potentially be saved 1. Assumes a conventional ship would burn ~12-tonne MDO/day operational 270 days/year. There could be up to 50% variance on this figure 2. Assumes at least 10% efficiencies achievable[18]
Impact Statements – How this option impacts the country's development priorities.	
Social benefits	Decreased transport costs. Increased passage speed, increased stability, and passenger comfort. Decreased public health effects from air and water emissions.
Economic benefits	Decreased transport fuel costs, increased passage speed, improved stability, no additional crew required, low training costs, secondary industry opportunity.
Environment benefits	Decreased emissions, Less CO_2, SO_x, NO_x, and other emissions
Other considerations and priorities such as co-benefits	Ability to assemble and ultimately manufacture, fit and maintain in Fiji and service the region
Costs	
Capital costs	Dependent on size and power and number of orders. ROI varies from 3.5 -7 years. A single-rotor retrofit might cost USD350-800,000 per unit, although this would decrease with efficiencies of scale of multiple orders. US$3.2 m[19] - assuming 4 units at costs of USD 800,000 per unit, yet the costs can be more/less based on individual ship requirements.
Operational and maintenance costs	Low. Again, this is dependent on a range of factors including quality of manufacture and installation but likely less than 10% of CAPEX

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[18] Retrofit savings can be estimated 10-25% fuel savings in annual fuel use average with much higher savings when incorporated into new build low carbon designs. A modest 10% is used in this factsheet.

[19] At least 10 ships need to have the initial installations to achieve sizeable results.

Lifetime	Again, dependent on a range of factors but a 15-year depreciation cycle can be assumed.
Others	There are no additional crew costs, marginal additional training costs, and extremely marginal maintenance costs. There is no impact on a ship's operating ability or cargo capacity. There are minimal regulatory changes required to introduce. There is a needed capacity development component required in the specialist knowledge of the technology and its use.
Local Context	
Opportunities and Barriers	Even a small production run of 5 rotors would be sufficient to set up a bespoke engineering opportunity.
Market Potential	Potentially 10-30% of existing large ship retrofits and 20-80% of new build applications across the Pacific fleet.
Acceptability to local stakeholders	The only barrier is perception, understanding, and access to appropriate investment financing. An obvious candidate for immediate proof of concept trial.

Technology Fact Sheet 2

Technology	**Zero Carbon Passenger Ferry Trials**
Sector	**Transport**
Sub-sector	**Maritime**
Sectoral GHG emission	Estimated at 174 Kilotonnes CO_2 emissions from Fiji's domestic shipping in 2016. Under a BAU scenario, emissions are modelled to increase to over 600kt by 2050 (Fiji LEDS).
Background/Notes, Short descriptions of the technology options	Various proposals for trials of harbour ferries to reduce road congestion in Suva have been floated in recent years, including a review of shore-side infrastructure requirements for passenger pick-up/drop-off points for both the Lami-Suva corridor and Nausori-Suva corridor. There are already several fast ferries[20] using fossil fuels servicing the tourism market predominantly in Nadi waters including Mamanuca and Yasawa, where jetties and pontoons are already in place. Harbour and short-distance routes (such as inside Suva harbour and Denarau-Mamanucas) are ideal for trialling electric/hybrid vessels and there are now numerous examples around the world of zero-carbon harbour ferries in operation or being built. Trials of zero-carbon ferries could either be conducted in Suva or Lautoka (focused on commuters); Nadi Waters (focused on tourism); Karoko to Rabi crossing and Natuvu (Bucabay) to Taveuni crossing. Concept development should consider vessel acquisition options (new build in Fiji or import from overseas), recharging stations, including scrappage/recycling. Tax exemptions are already in place for the import of electric/hybrid vessels, but other fiscal policies require realignment with emissions reduction targets. The project could replicate the initiatives that have been undertaken in other parts of the world where governments[21] have provided grants to support private sector trials and the development of zero-emissions ferries, or concessionary loans.
Implementation assumptions, How the technology will be implemented and diffused across the subsector?	1. Practical trials of electric harbour ferries in two locations as "proof of concept" lead by the private sector 2. Reduced fuel use for passenger transfers (tourism sector and commuters) 3. An assessment of shore infrastructure on the prospective route(s) will be required prior to deployment and adoption.

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[20] There is already interest expressed by several existing companies (South Seas Cruises, Greenco, Rakola, Goundar Shipping, Pacific Ferries, etc.) in trialing of electric motors and/or harbour ferries for passenger transport purposes in both Suva and in the west of Viti Levu, as well as existing and planned boat building facilities capable of building the vessels, depending on the design. Other companies are also known to be interested in investing in Fiji in this area (Deva De Silva, IFC pers. com. 12 February 2020).

[21] See for example https://www.regjeringen.no/contentassets/2ccd2f4e14d44bc88c93ac4effe78b2f/the-governments-action-plan-for-green-shipping.pdf and https://www.eeca.govt.nz/news-and-events/media-releases/marine-electrification-fund-recipients-announced/

Explain if the technology could have some improvements in the country's environment.	4. Improved shore-side infrastructure for recharging from renewable sources. 5. Improved passenger drop-off/pick-up pontoons/jetties in the greater Suva area for water-based transport The time needed for development: At least 1 year is needed for feasibility studies for zero-carbon commuter ferry trials, including identification of shore-side infrastructure needs, passenger demand, and routes The time needed for securing finance: 1-2 years needed to secure financing for the establishment of financial mechanisms (tax/excise incentives, concessionary loans, grants, etc.) The time needed for implementation: 1-3 years needed for vessel construction/acquisition and monitored operational trials. This project focuses on support private sector investment and once vessels are operational, would run on a purely economic business model. One of the first steps is to undertake detailed feasibility studies to assess the transport demand, infrastructure investment requirements, and the appropriateness of electric harbour ferries for the prospective routes. The grants to assist with vessel purchase/acquisition and to upgrade and install shore-side infrastructure would only proceed if favourable outcomes were projected from the feasibility studies.
Technical Maturity	Mature
Applicability	There are already several fast ferries[22] using fossil fuels servicing the tourism market predominantly in Nadi waters including Mamanuca and Yasawa, where jetties and pontoons are already in place. Harbour and short-distance routes (such as inside Suva harbour and Denarau-Mamanucas) are ideal.
Implementation barriers	1. High capital investment. 2. Data on infrastructure and shore-based requirements (recharging, pontoons, jetties), etc. as well as an assessment of potential demand for commuters on ferry routes/stops. 3. Lack of shore-side infrastructure (e.g. jetties, pontoons) and recharging systems 4. Financing and insurance for private sector purchase and trial of zero-carbon vessels 5. Fiscal policy – includes disincentives to invest in zero-carbon vessels as well as incentives currently

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[22] There is already interest expressed by several existing companies (South Seas Cruises, Greenco, Rakola, Goundar Shipping, Pacific Ferries, etc.) in trialing of electric motors and/or harbour ferries for passenger transport purposes in both Suva and in the west of Viti Levu, as well as existing and planned boat building facilities capable of building the vessels, depending on the design. Other companies are also known to be interested in investing in Fiji in this area (Deva De Silva, IFC pers. com. 12 February 2020).

Emission reduction potential (%)	~860 tCO_2/yr. and a total of 5,160 tCO_2 for 2020 – 2030 Key Assumptions: 1. Assumes vessels operational in 2024 2. Assumes a conventional ship would burn ~2-3 tonne MDO p.d. operational 300 days/year. There could be up to 50% variance on this figure. 3. Assumes 100% electric propulsion is achievable[23] and that all recharging is from renewables. Does not include savings if a successful pilot is replicated/scaled in Fiji or elsewhere
Impact Statements – How this option impacts the country's development priorities.	
Social benefits	1. Reduced road congestion on prospective routes.
Economic benefits	2. More employment – dockworkers, stevedores, seafarers, etc. 3. More competitive commuter fares
Environment benefits	1. Reduced emissions.
Other considerations and priorities such as co-benefits	
Costs	
Capital costs	The estimated capital investment needed for the physical implementation is US$9.2m
Operational and maintenance costs	Low, yet dependent on factors such as infrastructure, vessel type, operating conditions, and maintenance, etc. likely to be less than 10% of CAPEX
Lifetime	Again, dependent on a range of factors but a 15-year depreciation cycle can be assumed.
Others	Estimated development costs US$30,000 Estimated Enabling, Capacity Building, and Technical Assistance Needs US$90,000

	Commuters can enjoy daily ferry rides instead of monotonous daily bus/car commute.
Local Context	
Opportunities and Barriers	1. Reduction in demand for land transport by providing alternate transport modality of travellers whilst reducing traffic congestion. (200,000 commuter trips/yr by harbour ferry would equate to a 9% diversion of commuters from the road on a Lami-Suva route (based on the recorded 6,000 round commuter trips/day passing the Lami speed camera, which is 2.2 million/year). Full feasibility in all prospective routes needs to be well established. 2. Demonstration to other tourism operators operating passenger transfer vessels. 3. Opportunity for cadet training increasing opportunity for Fiji seafarers familiar with low carbon shipping operations access to international shipping employment 4. Reduction in emissions of air pollutants such as SOx and particulate matter, which are harmful to human health. 5. Replicable and scalable 6. If a Pacific construction is possible, the project will contribute significantly to strengthening regional maritime construction capacity 7. Relevant SDGs include 1,7,8,12,13,14,17.
Market Potential	High market potential.
Acceptability to local stakeholders	Very high There is already interest expressed by several existing companies (South Seas Cruises, Greenco, Rakola, Goundar Shipping, Pacific Ferries, etc.) in trialling of electric motors and/or harbour ferries for passenger transport purposes in both Suva and the west of Viti Levu, as well as existing and planned boat building facilities capable of building the vessels, depending on the design. Other companies can also come on board.

Technology Fact Sheet 3

Technology	**Sail-powered Passenger/Cargo Ship**
Sector	**Transport**
Sub-sector	**Maritime**
Sectoral GHG emission	Estimated at 174 Kilotonnes CO_2 emissions from Fiji's domestic shipping in 2016. Under a BAU scenario, emissions are modelled to increase to over 600kt by 2050 (Fiji LEDS).
Background/Notes, Short descriptions of the technology options	The main inter-island shipping routes connecting Fiji's 330 islands have historically been serviced using aged, second-hand, Pax/Cargo ferries of up to 5,000 tonnes. This vessel type is the largest in the domestic maritime fleet and produces the greatest proportion of emissions for the sector/vessel. Usually retired ferries at the end of their service life, are bought at low cost or scrap value. Related high fuel costs and low-profit margins, combined with systemic issues of affordable maritime finance and insurance underwriting, means operators employ a low asset cost approach with ever-increasing maintenance and operational costs. Such vessels may burn up to 12-15 tonnes of diesel/day. There are minimal options for any major efficiency or abatement of such vessels given their age and design and little incentive (or even available options) for ship operators to vary the established business model. The situation is replicated in many other island and maritime countries. Designs, such as the Neoline vessel, now offer an alternative promising in excess of 80% efficiency savings through a whole-of-ship design approach (including advanced hull and propulsion design, waste heat recovery, wind-hybrid drive, etc.). Deploying this level of technology would require a change in business model to a high CAPEX/low OPEX approach. A demonstration model is proposed where Government Shipping Services (GSS) initially owns and operates a new build vessel under strictly monitored trials to demonstrate the efficiency and financial savings potential to the private sector. If successful, the vessel would then be put up for sale in Fiji for purchase by the private sector.
Implementation assumptions, How the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in	It is projected that the vessel design (i.e., low carbon, utilising wind to assist in vessel propulsion, use of solar PV for auxiliary power needs) would lead to considerable operational savings, both as the vessel would be new and purpose-built, but also due to reduced need for diesel fuel for the main engines. Whilst the higher Capex costs would have to be covered by grant initially, the Opex costs over the anticipated lifespan of the vessel (25 years) due to reduced fuel consumption should result in a financially sustainable ship when compared to other vessels currently used for inter-island passenger/cargo transport. Without grants, this project is not financially sustainable in the short term, due to the considerably higher Capex involved as a "first mover". Longer-term financial sustainability is possible once GSS

the country's environment.	sells the vessel to the private sector, dependent on a range of external factors (such as operations, maintenance, etc). The time needed for development: 1-2 years needed for feasibility/business case, vessel design confirmation/costings, tender The time needed for securing finance: 1-3 years needed to secure financing for vessel acquisition and monitored trials. The time needed for vessel acquisition: 1-2 years construction, trials, commissioning, business plan, management structure, operational SOPs, MRV plan The time needed for monitored trials: 3 years needed for MRV of the effectiveness of vessel in both return on investment projections and for reducing emissions
Technical Maturity	Mature
Applicability	Designs, such as the Neoline vessel, now offer an alternative promising in excess of 80% efficiency savings through a whole-of-ship design approach (including advanced hull and propulsion design, waste heat recovery, wind-hybrid drive, etc.). Deploying this level of technology would require a change in business model to a high CAPEX/low OPEX approach. A demonstration model is proposed where GSS initially owns and operates a new build vessel under strictly monitored trials to demonstrate the efficiency and financial savings potential to the private sector. If successful, the vessel would then be put up for sale in Fiji for purchase by the private sector.
Implementation barriers	1. High CAPEX 2. Unaffordable maritime finance. 3. Issues of insurance underwriting
Emission reduction potential (%)	~8,000t CO_2/yr. and a total of ~40,000t CO_2 for 2020 – 2030 (assumes vessel operational in 2024) 4. Assumes vessel would be operational by 2026 5. Assumes a conventional ship would burn ~12-tonne MDO/day operational 270 days/year. There could be up to 50% variance on this figure 6. Assumes at least 70% efficiencies achievable[24] Does not include savings if a successful pilot is replicated/scaled. There is an immediate national market and a larger regional market for vessels of this size
Impact Statements – How this option impacts the country's development priorities.	

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[24] Neoline claim "The Neoline transport solution will reduce GHG emissions by up to 90% on an ocean crossing, and eliminate SOx and NOx emissions." https://www.neoline.eu/en/the-neoline-solution/#neoliner

Social benefits	1. Essential national connectivity for main Fijian centers and communities, primary logistics mover for all aspects of cargo, trade, and internal passenger movements at this scale, enabler of sustainable development initiatives and essential government services throughout the island groups through regular logistic network provision. 2. Improved service delivery to end consumers.
Economic benefits	1. Proof of concept vessel to provide real data for Fiji's shipping private sector 2. Newer more energy-efficient vessels are available to the domestic private fleet after positive trials.
Environment benefits	3. Reduced fossil fuel consumption and emissions from vessel type which is one of the major sources of maritime emissions
Other considerations and priorities such as co-benefits	4. Demonstrated leadership by Fiji Government in area of great investment globally
Costs	
Capital costs	The estimated capital investment needed for the physical implementation is US$35m
Operational and maintenance costs	Low, yet dependent on factors such as infrastructure, vessel type, operating conditions, and maintenance, etc. likely to be less than 10% of CAPEX
Lifetime	Dependent on a range of factors but a 20-year depreciation cycle can be assumed.
Others	Estimated development costs US$50,000 Estimated Enabling, Capacity Building, and Technical Assistance Needs US$1.3m Improved service delivery
Local Context	
Opportunities and Barriers	1. Essential national connectivity for main Fijian centers and communities, primary logistics mover for all aspects of cargo, trade, and internal passenger movements at this scale, enabler of sustainable development initiatives and essential government services throughout the island groups through regular logistic network provision.

	2. If it results in reduced transport costs due to improved operational efficiencies this will result in savings for both state maritime budgets and improved service delivery to end consumers. 3. The critical and vital link in the national logistics chain 4. Potential for fabrication, manufacture of some local components, maintenance, supply, provisioning contracts, etc. with potential increases if the regional application as Fiji as a logical hub. 5. Greatly increased safety potential 6. Replicable and scalable 7. Relevant SDGs include 1,7,8,12,13,14,17. Barriers: 1. Unaffordable maritime finance. The much higher upfront Capex costs of purchasing a new purpose-built vessel versus a second-hand vessel limit commercial bank options (neither ADB nor WB have funded the purchase of vessels, instead have provided grants and loans for ports, jetties, and other maritime transport infrastructure). 2. Issues of insurance underwriting.
Market Potential	Change in perception and understanding is required to realize the full market potential.
Acceptability to local stakeholders	A change in business model to a high CAPEX/low OPEX approach will be required by local operators.

ANNEX IV

Summary of Scoring Matrix: Domestic Maritime Transportation Sector

Table A1: Performance matrix with nominal values for the domestic maritime transportation sector.

		Category									
Criteria	Lev 1	Costs			Benefits					Local Context	
					Economic	Social		Environmental			
	Lev 2	Capital Costs (USD$)	Operational and Management (USD$)	Lifetime (Years)	Job Creation	Time Efficiency	Travelling Comfort	CO_2 reduction potential (%)	Impact on Marine Environment (Apart from CO_2)	Market Potential	Acceptability to local stakeholders
Sources		Technology Providers, Operators	Technology Providers, Operators	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement, Tech Specification	Expert Judgement	Expert Judgement	Expert Judgement
Preferred value		Lower	Lower	Higher	Higher	Higher	Higher	Higher	Lower	Higher	Higher
Technologies											
1		3200000	320000	15	5.4	4.6	5.8	1000	3	4.4	3.6
2		9200000	920000	15	5.0	5	5.4	860	1.8	5.2	4.6
3		35000000	3500000	20	5.6	5.2	4.8	8000	2.6	5.6	4.8
4		114550000	11455000	5	4.2	4.8	5	10500	3.6	4.4	4.2

Table A2: Scoring matrix for technology prioritisation for the domestic maritime transportation sector.

		Category											
Criteria	Lev 1	Costs			Benefits					Local Context			
					Economic	Social		Environmental					
	Lev 2	Capital Costs (USD$)	Operational and Management (USD$)	Lifetime (Years)	Job Creation	Time Efficiency	Travelling Comfort	CO_2 reduction potential (%)	Impact on Marine Environment (Apart from CO_2)	Market Potential	Acceptability to local stakeholders		
Sources		Technology Providers, Operators	Technology Providers, Operators	Technology Providers, Operators	Expert Judgement	Expert Judgement	Expert Judgement	Expert Judgement, Tech Specification	Expert Judgement	Expert Judgement	Expert Judgement		
Preferred value		Lower	Lower	Higher	Higher	Higher	Higher	Higher	Lower	Higher	Higher		
Technologies	Weights	5.52	4.74	4.74	15	19.29	10.71	12.64	7.36	11.25	8.75	Overall Score	Rank
1		100.00	100.00	66.67	85.71	0.00	100.00	1.45	33.33	0.00	0.00	39.62	3
2		94.61	94.61	66.67	57.14	66.67	60.00	0.00	100.00	66.67	83.33	62.88	2
3		71.44	71.44	100.00	100.00	100.00	0.00	74.07	55.56	100.00	100.00	79.81	1
4		0.00	0.00	0.00	0.00	33.33	20.00	100.00	0.00	0.00	50.00	25.59	4

Table A3: Sensitivity Analysis summary for the domestic maritime transportation sector.

	Analysis # 1		Analysis # 2		Analysis # 3	
Technologies	Overall Score	Rank	Overall Score	Rank	Overall Score	Rank
1	39.6	**3**	43.0	**3**	53.6	**3**
2	62.9	**2**	66.3	**2**	74.8	**2**
3	79.8	**1**	84.5	**1**	82.9	**1**
4	25.6	**4**	21.8	**4**	15.2	**4**

ANNEX V

Problem and Solution Trees: Domestic Maritime Transportation Sector

Figure A10: Problem Tree for Sail-powered Passenger/Cargo Ship

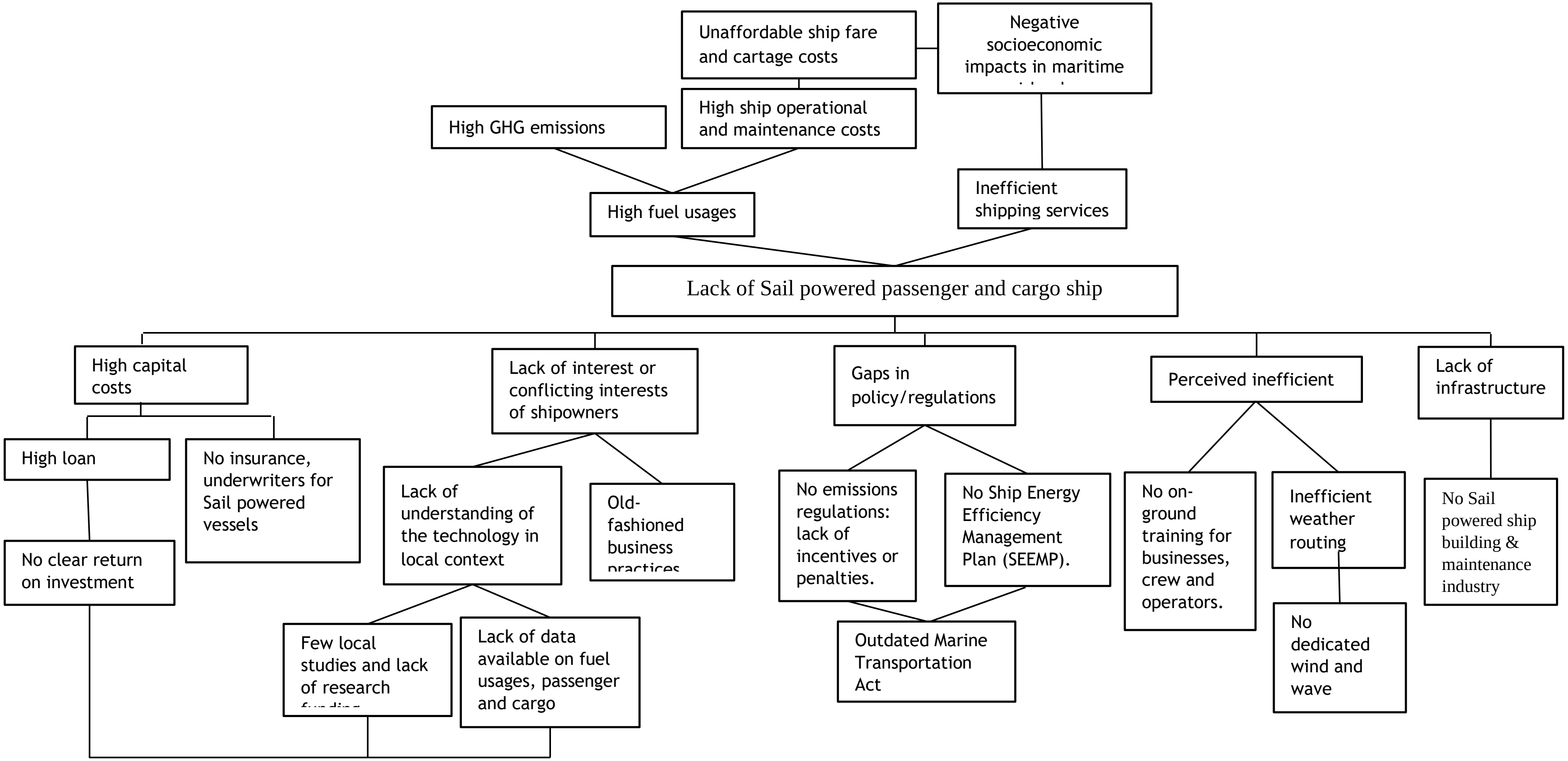


Figure A11: Solution Tree for Sail-powered Passenger/Cargo Ship

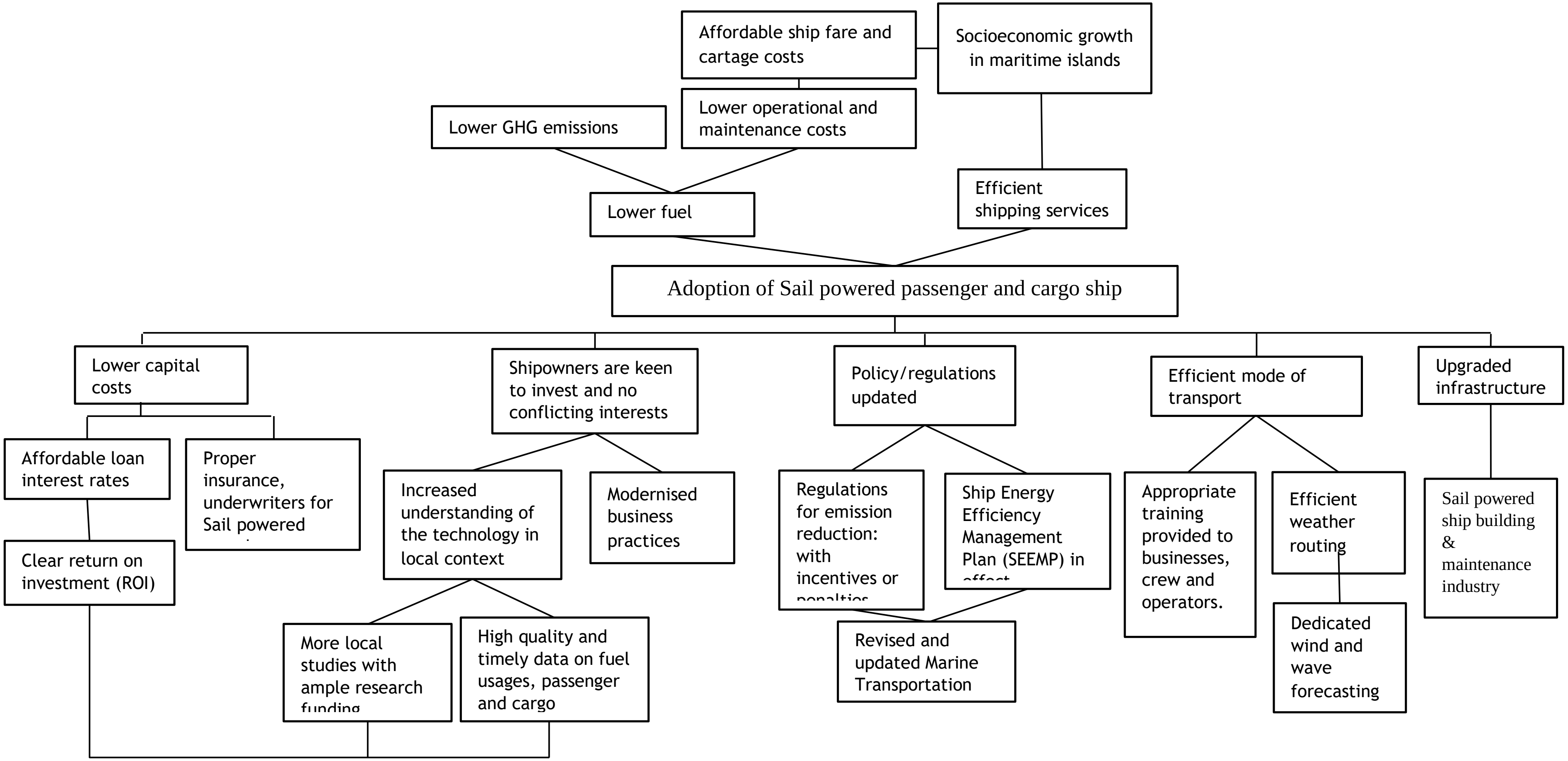


Figure A12: Problem Tree for Zero Carbon Passenger Ferry Trials

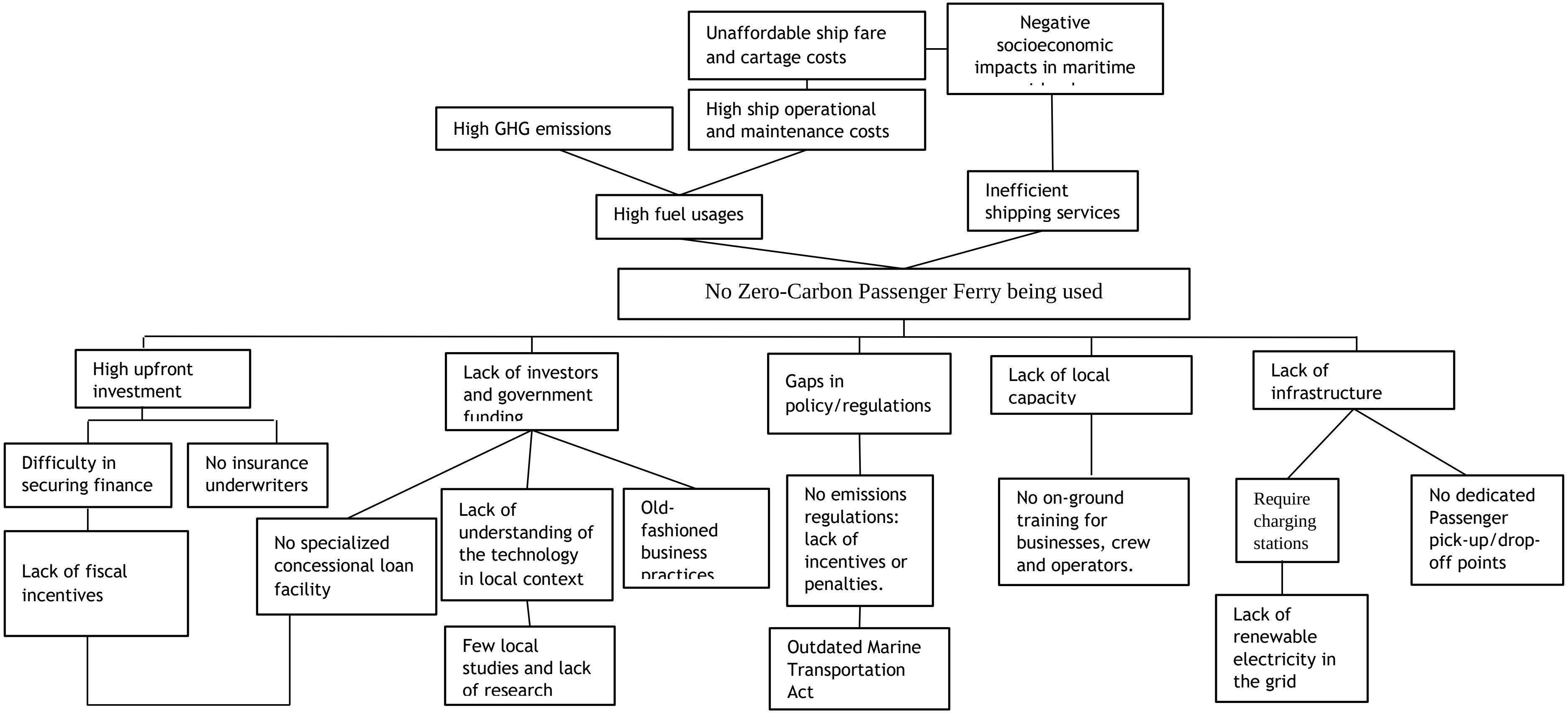


Figure A13: Solution Tree for Zero Carbon Passenger Ferry Trials

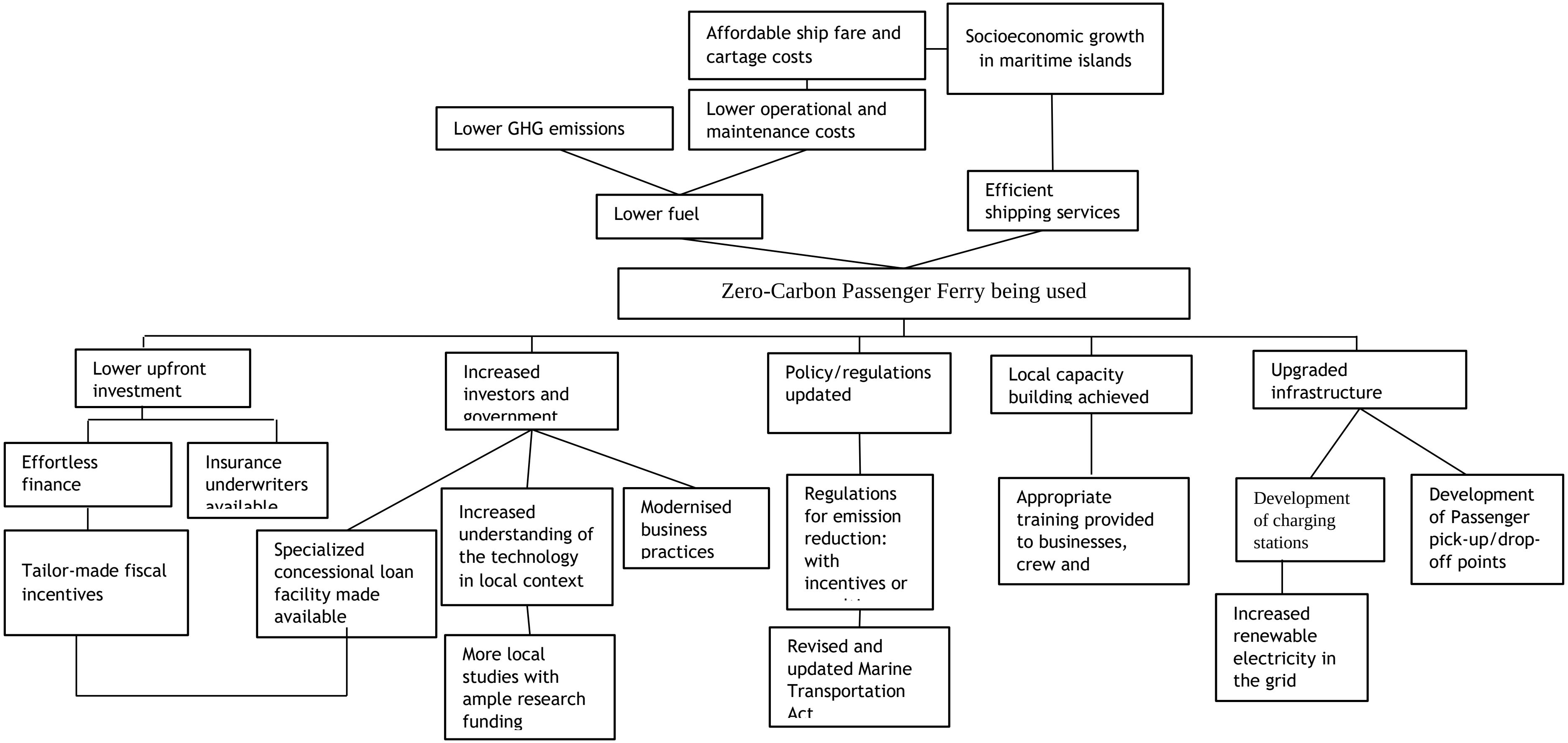


Figure A14: Problem Tree for Eco-Flettner Rotor – retrofit and new-build technology

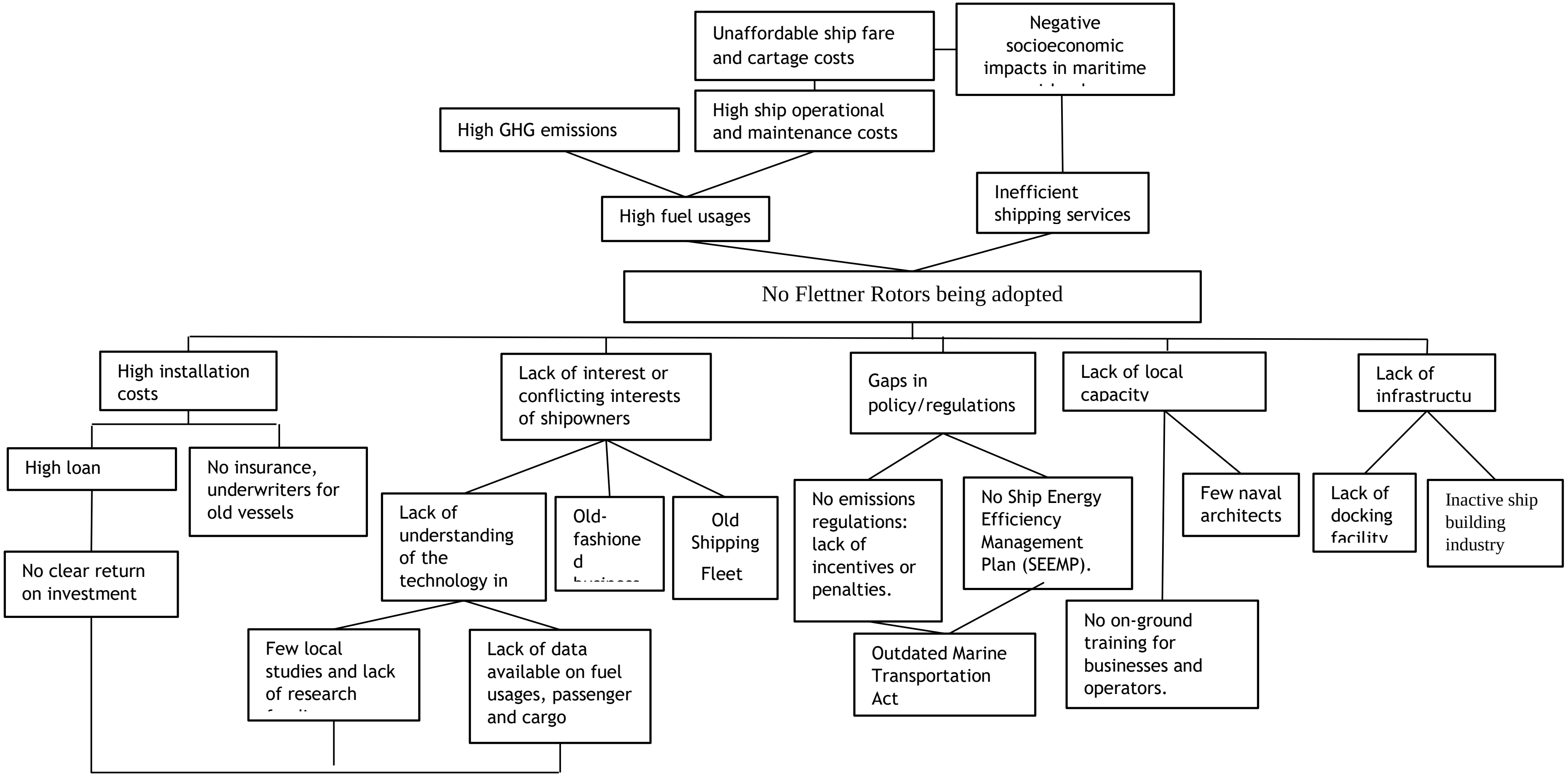
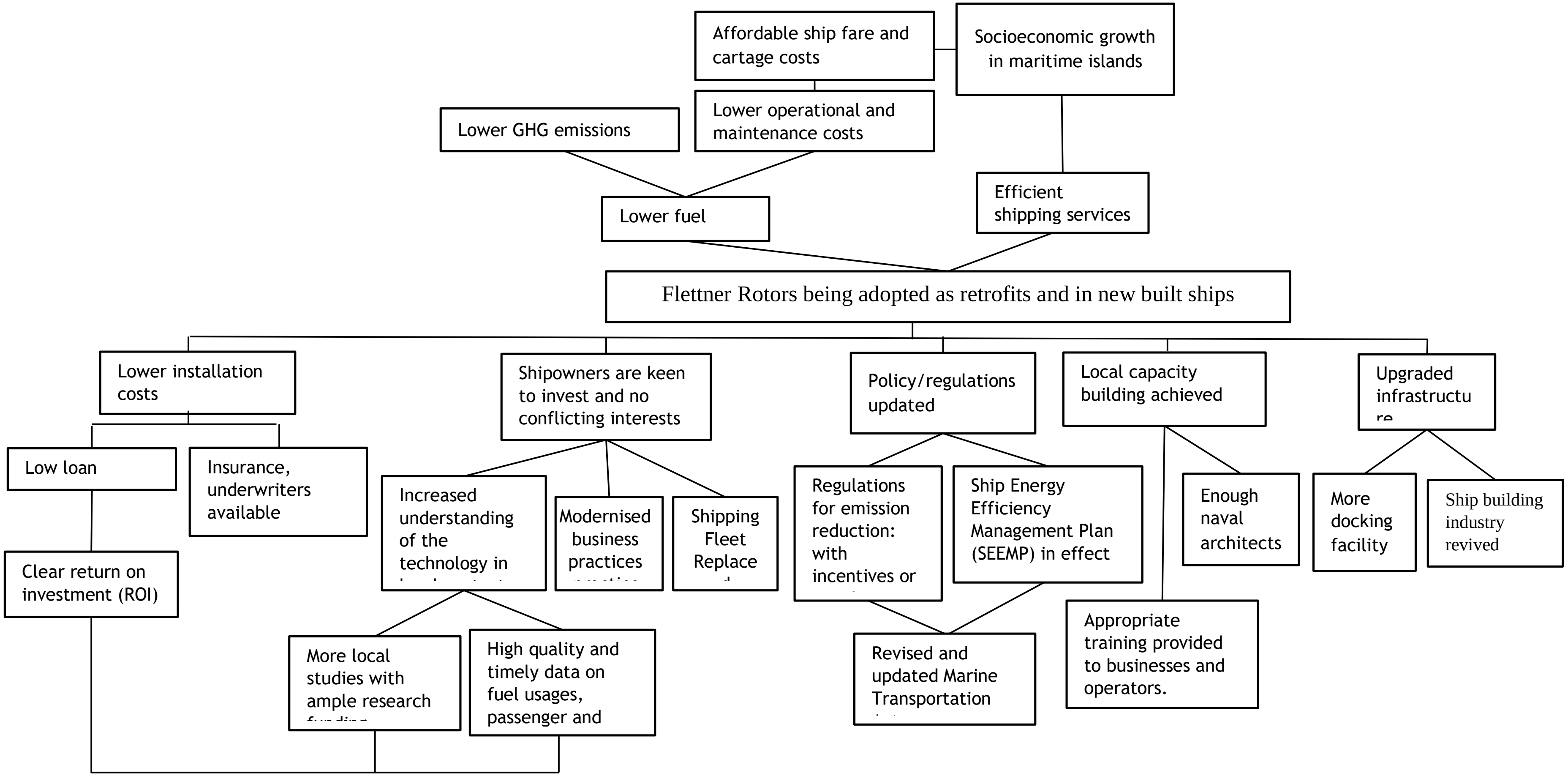


Figure A15: Solution Tree for Eco-Flettner Rotor – retrofit and new-build technology



ANNEX VI

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Market Mapping: Domestic Maritime Transportation Sector

Figure A16: Market Mapping for Sail-powered Passenger/Cargo Ship

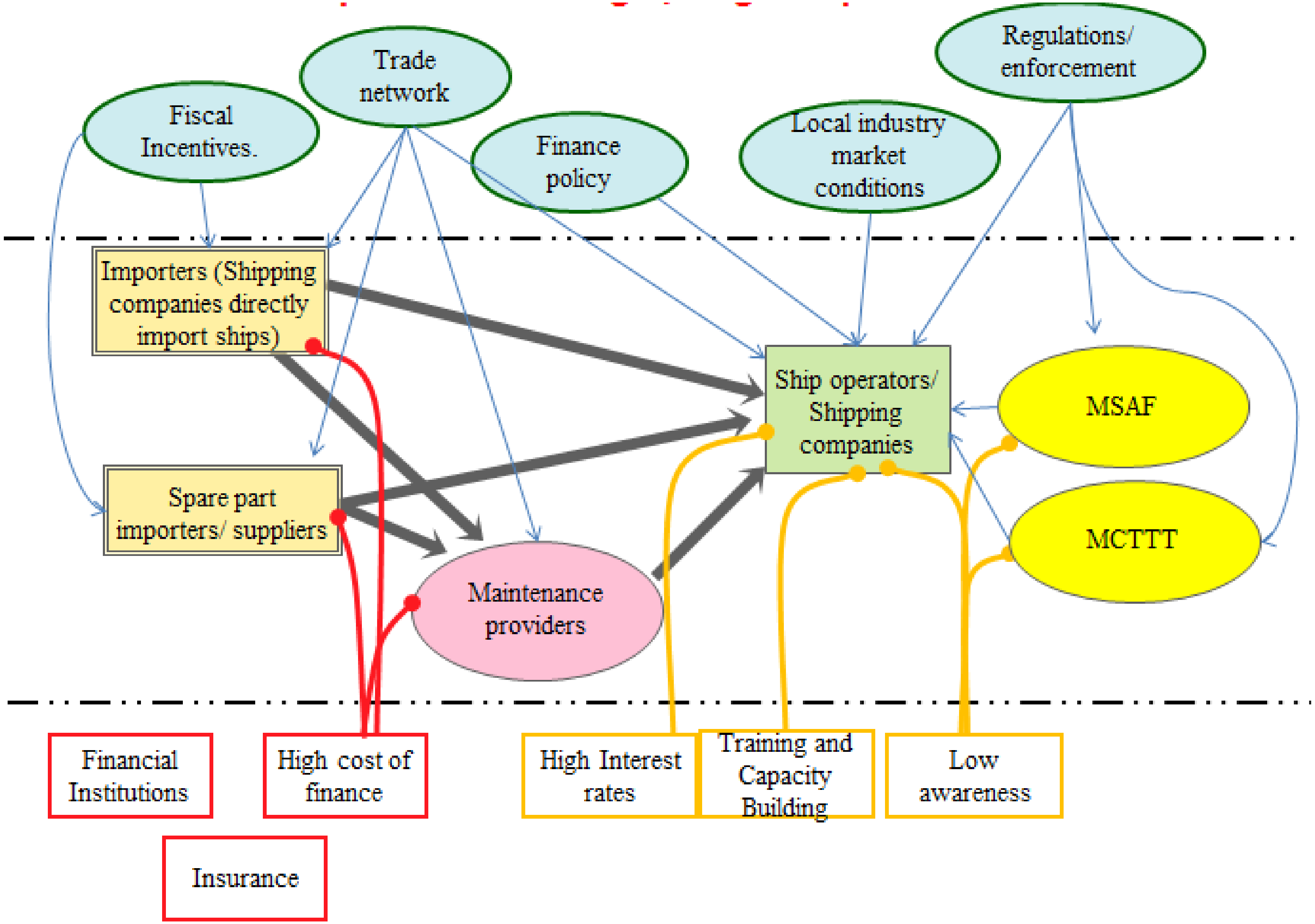


Figure A17: Market Mapping for Zero Carbon Passenger Ferry Trials

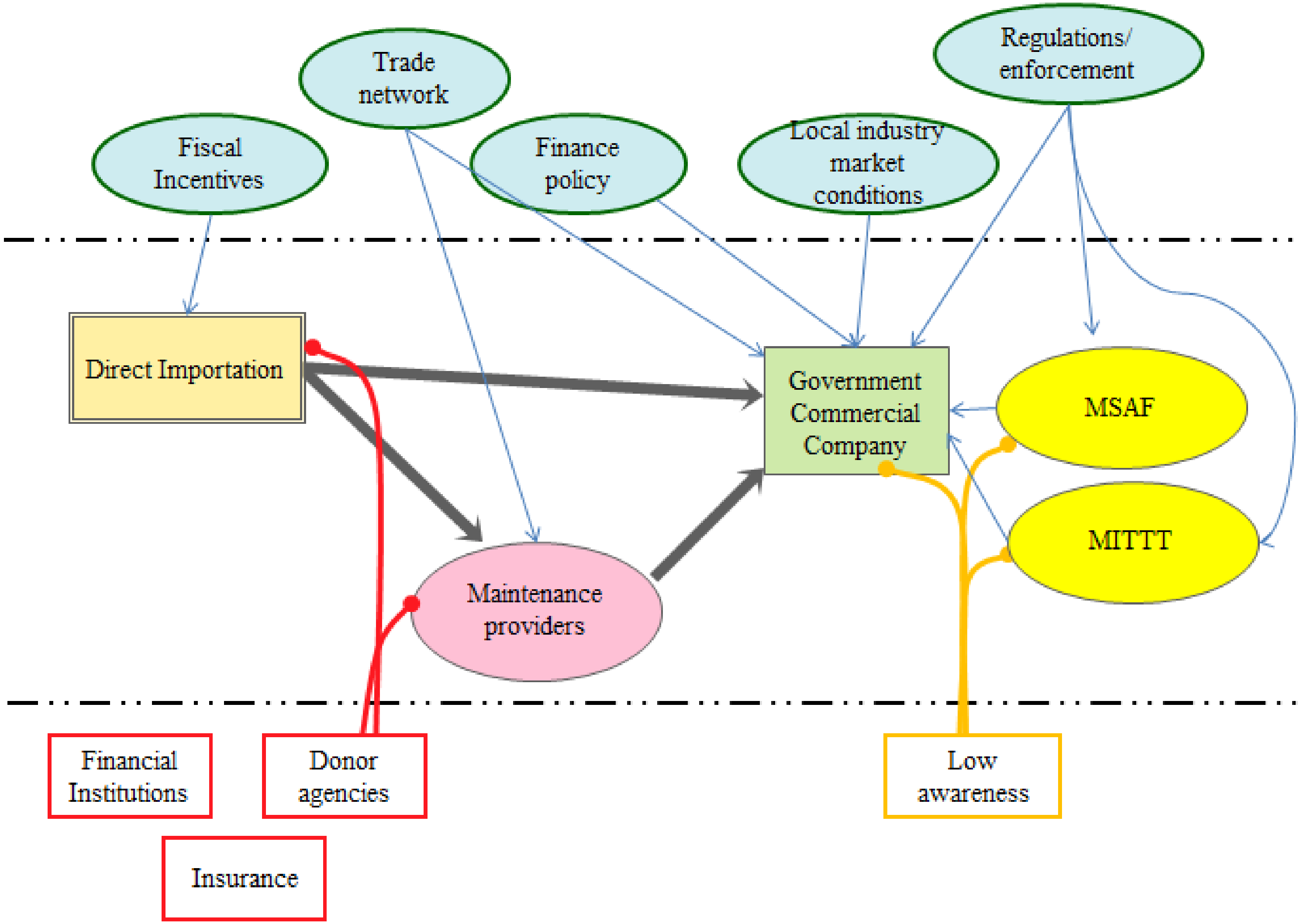
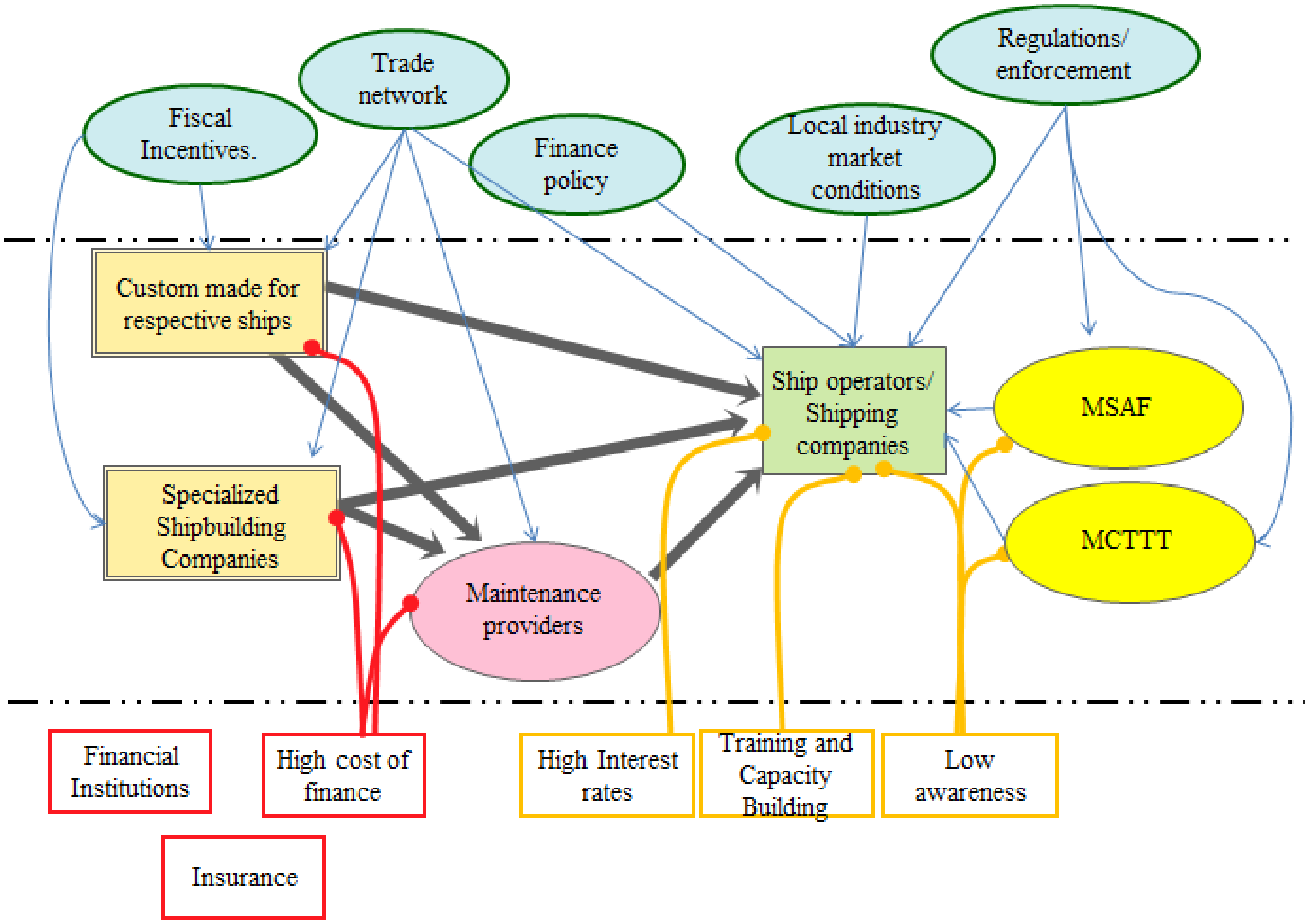


Figure A18: Market Mapping for Eco-Flettner Rotor – retrofit and new-build technology



ANNEX VII

List of stakeholders involved and their contacts

No.	Name	Organisation	Designation	Email
	Domestic Maritime Sector			
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7.	Mohammed Asid Zullah	MTCC Pacific - SPC	Head of MTCC-Pacific / Maritime Safety & Energy Adviser	zullahm@spc.int
8.	Mahesa Abeynayaka	Fiji Maritime Academy	Director in-charge / Chief Executive Officer	ceo-fma@fnu.ac.fj
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