THE GOVERNMENT OF VANUATU

Barrier Analysis and Enabling Framework for Mitigation Technologies

April 2023

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Republic of Vanuatu

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Foreword

The adoption of climate technologies is key to reducing greenhouse gas emission while improving the competitiveness of major economic and industrial sectors, and thereby promoting low carbon and green growth in Vanuatu.

Recognizing these circumstances, the Republic of Vanuatu has implemented the second phase of the "Technology Needs Assessment (TNA)" project whose objective is to promote investments in technology transfer and to improve access to environmentally sound technologies that are relevant for achievement of Vanuatu's climate change adaptation and mitigation targets. Vanuatu developed a revised and enhanced 1 st National NDC in 2021 to confirm its commitment to climate change mitigation especially in the Energy, Agriculture, Forestry and Other Land Use and Waste and to adapt to the devastating effects of climate change in agriculture, biosecurity, fisheries, forestry, and so forth.

This "Barrier Analysis and Enabling Framework Report" was coordinated by the Ministry of Climate Change and Adaptation (MCCA) and through the Climate Change Department, with the help of national consultants and local experts. MoCC acknowledges that the TNA project is funded by the Global Environmental Facility (GEF). The project is implemented by the United Nations Environment Programme (UNEP) through the UNEP CCC Partnership with technical support from the University of the South Pacific.

This analysis utilized a standardized methodology, in which Climate Change Department facilitated stakeholders' consultation meetings, and the consultant conducted a series of bilateral meetings, and user interviews to identify barriers hindering development and adoption of the technologies' market supply-chain, and proposing enabling frameworks necessary to overcome identified barriers. Therefore, all of the identified barriers were identified from a bottom-up approach to reflect the situation of technologies as prioritized by key stakeholders within Vanuatu. I am honored to provide a foreword to the second report of the TNA Project.

I am happy to present this report to a wide range of stakeholders such as decision-makers, policymakers, potential investors, technology developers, scientists and researchers. I have high confidence that this report can be one of the solutions to achieving the government's commitment towards addressing the climate change-related issues, and to improve our county economic, environmental and social development goals by eliminating identify barriers. Additionally, this report is an alarm for us to take necessary steps to streamline policies, legislation, etc. to help transfer and diffusion of technologies prioritized.

Ms. Esline Garaebiti
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The Government of the Republic of Vanuatu

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The successful compilation of this report was attributed to divine wisdom from God, the everlasting Father, and the dedicated individuals involved in the process leading to its completion. Their assistance, support, and guidance were essential in enabling the TNA National Consultants to finalize and submit the TAP report. We would like to sincerely express our heartfelt appreciation to all these individuals.

We wish to thank the Director General to the Ministry of Climate Change, Mrs. Esline Garaebiti and the respective Directors for allowing the TNA National Consultants to participate in the Vanuatu Technology Needs Assessment Project. In addition, technical working group for mitigation that were nominated from the relevant line departments and the civil society. Your commitments and involvement have enabled us to complete the 2nd Phase of the TNA process.

Finally, we would like to express our sincere gratitude to the Global Environment Facility for funding this climate technology pathway for implementing the Paris Agreement and implemented by the UN Environment through the UNEP CCC Partnership.

List of abbreviations and Acronyms

AC	Alternate Current
BEV	Battery Electric Vehicle
CH_4	Methane
CO_2	Carbon Dioxide
CV	Conventional Vehicles
DC	Direct Current
DoE	Department of Energy
EV	Electrical Vehicle
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GoV	Government of Vanuatu
LPA	Logical Problem Analysis
LPG	Liquefied Petroleum Gas
MCCA	Ministry of Climate Change and Adaptation
NDC	National Determine Contribution
NEDC	New European Driving Cycle
NERM	National Energy Road Map
NGO	Non-Governmental Organization
R&D	Research and Development
TAP	Technology Action Plan
TNA	Technical Needs Assessment
UN	United Nation
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
URA	Utilities Regulatory Authority
VAT	Value Added Tax
VCCDRRP	Vanuatu Climate Change and Disaster Risk Reduction Policy

Physical Units

1 Gg = 1,000,000 g

1 Gg = 1,000 metric tonnes (mt)

I ha = 10,000 m^2

1 ha = 0.01 km^2

1 kV = 1,000 V

1 kW = 1,000 W

1 MW = 1,000 Kw

1 GW = 1,000 MW

1 US gallon = 3785.41 cc

1 Imperial gallon = 4546.09 cc

1 liter = 1,000 cc

1 mile = 1.6093 km

1 rad.s^{-1} = 0.5493 rpm

1 hp = 754.7 W

1 BTU = 1055.06 J

1 bar = 14.5038 psi

1 bar = 100 kPa

1 atm = 101.3 kPa

1 atm = 1013 mb

Executive Summary

This report is the second phase of the reports prepared for the Technology Needs Assessment and Technology Action Plan (TNA/TAP) for presenting the mitigation part of TNA project outcomes prepared by the Republic of Vanuatu. The report aims to identify barriers and measures addressing barriers to the transfer and diffusion of each technology, and based on these findings to establish an enabling framework for these technologies.

Stakeholder consultations are organized to understand the types and complexity of barriers to introduce potential mitigation technologies in the country. Vanuatu is committed following the low carbon development path to ensure sustainable development in one hand and reducing climate vulnerability on the other hand. Having no obligation, under the UNFCCC, to provide emphasis on the mitigation of GHGs, the Vanuatu Climate Change and Disaster Risk Reduction Policy (VCCDRRP) is identified mitigation action as one of the thematic areas of the strategy. Vanuatu, as one of the most climate vulnerable countries, explores all potential mitigation technologies to ensure energy security following a cleaner path and to reduce climate vulnerability in the long run.

However, while conducting the technology need assessment consultations, stakeholders recommended to consider as many as available technologies in this sector and the following mitigation technologies have been given priority: A) Efficient Wood Stove B) Battery Electric Vehicles C) Manure Based Biogas Digester and D) Compact Biogas Digester for Urban Household. These prioritized technologies have advantage to ensuring energy security within the context of mitigation efforts under low carbon path development.

These technologies are related to a wide spectrum of economic, social, environmental and political factors. Barriers and enabling measures for these technologies are described in chapters 1 and 2 accordingly.

Identifying barriers and measures could be characterized by the following general steps applied to the prioritized technologies named above:

1. The TNA national consultant prepared four sets of exercises and exercise was done by each of the workshop participants on the basis of experience, existing studies and policy documents and UNEP RISOE Centre Guidebook "Overcoming Barriers to the Transfer and Diffusion of Climate Technologies".
2. The exercises allow the participants to discuss and decide on the economic and financial barriers and non-financial barriers via the workshops. The purpose of discussion was to identify the essential barriers and non-essential barriers for each technology transfer and diffusion.
3. Barrier analysis was made at the workshop by screening and grouping them using brainstorming, Logical Problem Analysis tool, Market mapping, root cause analysis.
4. Identifying the relevant measures was also supported by detailed analysis of current practices at national and international levels and by applying a participatory approach during this analysis. The same procedure and workshop named above were applied for identification of measures.
5. The final step of this phase of the project is consolidating results including assessing measures and grouping them for prioritized technologies based on grouped barriers.

The sectoral working groups involved in TNA at the previous stage of the process were similar and formed the working group of stakeholders per each prioritized technology. These groups remain the same throughout the process, from barrier analysis to identification and proposing measures for the action plan. Stakeholders involve representatives from the ministries (Ministry of Climate Change, Ministry of Education, Ministry of Agriculture), NGOs and international organizations. The list of stakeholders involved is provided in Annex IV.

Using Logical Problem Analysis (LPA) the working groups were able to bring together the key elements of problems, apply logical analysis of interrelated elements, and identify linkages between problem elements and external factors. The cause/effect relations were organized in the Problem tree, having the main problem put as the starter problem, causes at the bottom of the tree and their effects in the upper part of the diagram. LPA analysis was also applied to the identification of measures process in order to get from problems to solutions.

In addition, Market mapping analysis for both sub sectors was applied to better understand the opportunities for the development of the local market for technologies. The whole system was considered in the context of its three main components: Enable business environment; Market chain actors and linkages and Service providers. Support of early adopters via pilot projects is important for facilitating the transfer and diffusion of technology is important.

LPA analysis and Market maps for prioritized technologies are presented in Annex1.

The diffusion of technologies is linked to market conditions. While identifying barriers it is important to classify the technologies, the categories of the selected technologies are presented as follows:

Table 1. The category of the selected technology

Selected technologies	Category of technology	Classification
Efficient Wood Stove	Market	Consumer goods
Battery Electric Vehicle	Market	Capital/Consumer goods
Manure Based Biogas Digester	Market	Capital goods
Compact biogas digester for Urban Households	Market	Capital goods

The outcomes of this report are the major barriers and proposed enabling measures for prioritized technologies.

Finally, barriers identified for the energy sector are summarized in the following categories:

- Economic/financial
- Policy/regulatory
- Capacity building and Information
- Other related to market imperfection and network failure.

Measures to overcome barriers of prioritized technologies have been identified according to grouped barriers for each technology.

Proposed measures will be considered by policy-makers to be included in the Technical Action Plan (TAP) which will be the third report of this project.

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CHAPTER 1

Energy Sector

1.1 Preliminary targets for Technology Transfer and diffusion

During the Technology Needs Assessment (TNA) process 8 technologies (4 for energy and 4 for Waste-to-Energy sector) were presented for the approval of the Project Steering Committee. The following prioritized technologies were identified in the energy sector with best potential for mitigation purposes:

- Efficient Wood Stove
- Battery Electric Vehicles

Transfer and diffusion of prioritized technologies in the energy sector will help to achieve the strategic objectives of environmental improvement and energy efficiency set in the strategic governmental documents.

General preliminary targets for energy sector development by 2030 compiled based on the National Energy Road Map (NERM) documents and taking into consideration operating information from the Department of Energy for the year 2016 are presented in Table 2.

Table 2. General Targets indicating annual rates for Energy Efficiency Improvement for the energy sector

Target	2020	2030
Improve transport (land and marine) energy efficiency	2%	10%
Improve biomass end-use (cooking and drying) efficiency	5%	14%

In accordance with the updated NERM of the Republic of Vanuatu until 2030 (approved by the Council of Ministers on June 30, 2016 No. 123). That is to develop and implement a campaign to promote efficient cook stoves and efficient dryers for agriculture products. And exploring options for promoting energy efficiency in the transport sector (including tourism uses) and developing an action plan for cost-effective implementation.

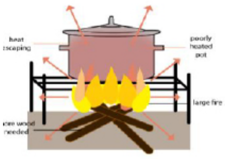
1.2 Barrier analysis and possible enabling measures for Efficient Wood Stove technology

1.2.1 GENERAL DESCRIPTION OF THE EFFICIENT WOOD STOVE

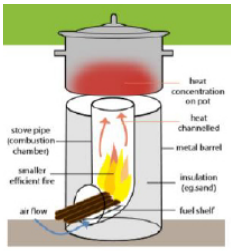
Cooking and drying account for almost all biomass consumption in Vanuatu. Rural (and many urban) households still rely heavily on biomass for cooking and for drying crops. Demand for firewood, charcoal, and biomass residues is rising due to population growth. Representing about half of the national energy demand (but much less in terms of monetary costs), with most cooking using very inefficient techniques, the potential for energy savings is significant. The replacement of traditional biomass with more efficient fuels, or shifting from open fires to Efficient Wood Stoves, could have potential health benefits by reducing the user's exposure to smoke. Efficient Wood Stoves can also help reduce GHG emissions, with advanced wood stoves able to limit emissions by 90 percent and improve fuel efficiency by more than 50 percent (DoE, 2016).

Also called a Jet Stove, a Rocket Stove or the Efficient Wood Stove is an efficient and hot burning stove requiring wood fuel with smaller diameter and a lower quantity. Fuel is burned in a simple combustion chamber containing an insulated vertical chimney, which ensures almost complete combustion prior to the flames reaching the cooking surface, resulting in less exhaust and hotter temperatures.

One may ask, how is the method of traditional cooking inefficient? In a traditional open fire approach, the combustion (burning) process is affected by some factors which decrease the efficiency of the whole process. See diagram below to learn more about these factors.



Traditional Fire[1]
Inefficient Combustion Chamber: combustion exposed to surrounding air, causing the heat to spread out rather than focus the pot.
Black smoke or Incomplete Combustion: a lack of oxygen to complete the combustion process, causing black smoke & causing heat
Inaccurate Heat Focus: when the pot is placed too low and the flames come up the side of the pot. Also makes more soot on the pots which means more cleaning later.
Excessive fuel required: since a large amount of energy is wasted into the air, more fuel is required to compensate for the loss. more cleaning later. loss.



Efficient Wood Stove[1]
Stove Pipe: means less external interferences on the fire such as airflow. A proper channel of heat to focus on the bottom of the pot as well as providing a minimal entry for sufficient oxygen
Minimal Fuel Required: almost 85-95% of the heat produced by the fuel is concentrates onto the pot, therefore less fuel is required.
Insulation: this makes sure the heat produces are not passing through the sides of the stove.

Therefore, as demonstrated above, the 'Efficient Wood Stove' technology is clearly a much more efficient and cost effective way of cooking our food at home.

1.2.2 IDENTIFICATION OF BARRIERS FOR EFFICIENT WOOD STOVE TECHNOLOGY

The identification of barriers for prioritized technologies is summarized in the Executive Summary. This section of report aims to explain what is currently preventing wide scale distribution of the efficiency wood stove technology while screening the barriers.

The working group representing relevant stakeholders was formed including members from sectoral working groups involved into TNA at previous stage of the process and with general knowledge of the efficiency wood stove technology. The following types of organizations were involved by stakeholders from the Department of Energy, Department of Climate Change, Department of Agriculture, Department of Forestry, Department of Education, Pacific Energy and Oxfam International.

As an initial step a group discussion was conducted in order to identify the primary reasons why the technology is not currently applied widely. The discussion was focused on the question of why the private and public sectors

[1] Figures are obtained from the Department of Energy Publication of 2017

Table 3. Identified barriers for the efficiency wood stove technology

Category	Barrier Dimension	Main Barriers
Economic and Financial barriers	Cost	a. High capital cost due to material importation b. Inappropriate financial incentives for the whole actors
Non-financial barriers	Policy, legal and regulatory	c. Weakness of GHG Emission Law
	Institutional and organizational capacity	d. Inadequate cooperation between key stakeholders e. Lack of Research and Development
	Information and awareness	f. Insufficient information about the technology

do not have enough financial incentives nor loaning schemes to implement the projects on efficiency wood stove. Participatory approach for barrier analysis and identification of enabling measures in the energy sector has been applied.

The consultation process was conducted through brain storming sessions during a set of organised workshops. The initial list of barriers was supplemented by barriers, proposed by participants during the discussion and the summarized list was screened (Table 1 Annex 2). The decomposition of barriers within category, with elements of barriers and dimension of barrier elements was applied.

In order to enable stakeholders to approach and delimit a problem area, the Logical Problem Analysis (LPA) tool was applied as an analysis technique. LPA tools help to create systematic and logical analysis of problems and to bring together all elements of the problem.

The major barriers in the wide diffusion of energy efficiency wood stove technology are categorized under economic and financial and non-financial barriers.

1.2.2.1 ECONOMIC AND FINANCIAL BARRIERS FOR THE EFFICIENCY WOOD STOVE TECHNOLOGY

Cost barriers

High capital cost due to material importation: High capital cost is one of the main barriers of the technology diffusion. The materials to produce the efficiency wood is mostly imported into the country. There is a need for studying best national practices and applying more feasible design of the technology. The cost of materials for producing an Efficient Wood Stove plant can reach even half or more than half the total cost of construction. The investments required for construction of the Efficiency Wood Stove is about USD 20. The total cost of materials is about USD 40 and so the capital cost for an Efficient Wood Stove would be around USD 60[2] and compared to the liquefied petroleum gas (LPG) of 11kg is around USD42.

Inappropriate financial incentives: Since this proposed

[2] USD 60 is equivalent to 7,000 Vatu

technology is market-driven products (consumer goods), consumers are not entitled to access to hire purchase or credit schemes, unlike other valuable home appliances. Moreover, both government and private sectors are not currently showing interest to provide subsidies for the household to encourage using efficiency wood stoves. Therefore, the lack of subsidy is one of the bottlenecks to promote the use of efficiency wood stove in the household cooking sector.

1.2.2.2 NON - FINANCIAL BARRIERS FOR THE EFFICIENT WOOD STOVE TECHNOLOGY

Policy, legal and regulatory barrier

Weakness of GHG Emission Law: Vanuatu currently does not have an adequate emission policy with clear strategies and action plans for each line ministry. It results in delaying and restricting progress not only in this sector and the underlying projects but also in renewable energy development and commercialization. Having an emission policy, strategy, and action plans can lead to moving forward the country's energy sector in a sustainable manner and attract both local and international investors to invest in the energy sector. Therefore, emission policy and associated action plans can be a guideline for the country to implement energy projects and commercialization.

Institutional and organizational capacity barrier

Inadequate cooperation between key stakeholders: There is no supportive collaboration between the designer, the user, the local researcher, the GoV, the line government agencies and the respective non-governmental organizations to fully endorse the energy project. And thus resulted in poor market diffusion of the technology. Moreover, no monitoring institution is in place to check the milestone. That target is not met due to insufficient cooperation between the GoV and other respective organizations and implementation body which may be from the manufacturer or supplier. On the other hand, insufficient cooperation between line ministries can be seen. For example, there is no initiative from line ministries to provide information on sustainable forest management initiatives.

Lack of Research and Development (R&D): There is very limited research on energy Efficient Wood Stove technology within the country. The interest to invest in R&D activities is almost negligible this is with regards to Efficient Cook Stove. This result is preventing to gain the theoretical knowledge to apply in the field and to achieve practical knowledge and design of the technology while the country has limited technical capacity.

Information and Awareness barrier

Insufficient Awareness about the Technology: Although Efficient Wood Stoves are recommended to be used in the country, the information of Efficient Wood Stove such as benefits, advantages, costs, sources of financing and potential of the market is insufficient for people to be aware. Moreover, the awareness-raising through social media and electronic media are insufficient to raise awareness in the urban and rural settings.

1.2.3 IDENTIFIED MEASURES FOR EFFICIENT WOOD STOVE

The following step-by-step process is applied to identify measures for Efficient Wood Stove technology.

i. Literature review

ii. Guidance from TNA Guidebook

iii. Stakeholder consultation meeting

During the stakeholder consultation meeting, market mapping and problem tree evaluation are presented to discuss to change from problems to the solution, then the measures are classified and evaluated. To have comprehensive measures, stakeholders from the technical working group are requested to give more comments and feedbacks by reviewing the report.

1.2.3.1 ECONOMIC AND FINANCIAL MEASURES FOR EFFICIENT WOOD STOVE

Measures for cost barriers

- **Barrier**: High capital cost due to material importation
- **Measure**: Create an enabling framework for the Reduction of Tax and customs duty

Local production of Efficiency Wood Stove and related accessories for proposed technology is almost negligible as mentioned in the barrier identification process. Therefore, a commercial tax and custom duty levy is placed on the material during the importation (~ USD 40). Moreover, manufacturers may produce their products at lower cost, adding to competition in the local markets. It is recommended that the GoV should review the tax policy to reduce tax and custom duty on the related accessories. Since Efficient Wood Stove consumes about 20% less wood or 2 off 6 fire woods than open fire that amounts to savings of up to 100 vatu per bundle of fire wood per day or 36,500 vatu per year that is equivalent to about USD 300 each and every year, and USD 3,000 over its lifetime. Thus, a reduction of 5% commercial tax is a benefit for technology users since the initial cost of technology can be decreased. Reducing tax and custom duty should be considered as a plan for sustainable development, and as an invitation for investment in this proposed technology.

- **Barrier**: Inappropriate financial incentives
- **Measure**: Appropriate financial resources and subsidies

The government could source funds to enable subsidy programs or through soft loan mechanisms from the existing National Green Energy Fund for the initiative. The government could also seek financial support for energy efficiency projects on not only energy intensive industries but also SME through international funding or supporting agencies as like as World Bank which is the performance-based financial institutions for SME to improve in main thematic areas, such as, to improve SME's access to finance and find innovative solutions to unlock sources of capital. Moreover, the government could introduce the concept of energy efficiency and conservation in the Industrial Sector to commercial banks by seeking cooperation between the government and commercial banking sector to offer low-interest rate loans for promoting energy efficiency projects.

1.2.3.2 NON-FINANCIAL MEASURES FOR EFFICIENT WOOD STOVE

Measures for Policy, legal and regulatory barriers

- **Barrier:** Weakness of GHG Emission Law
- **Measure:** Develop GHG Emission policy, strategy and its action plan

Developing a GHG Emission policy with clear strategy and proper action plans would allow the government to address current weaknesses that exist with regards to GHG emissions. The period of completing the draft and to publishing a policy might take considerable amount of time. The link to existing related laws depends on the priorities of the work to be done and identification of relevant preliminary targets for long term. The parts that need to be drafted should be differentiated, and the clear targets should be included as well. Therefore, having strong policy with clear strategy, and proper action plans can support the energy sector to move forward quickly and efficiently. Also, the coordination and cooperation among stakeholders and various ministers could be improved since policy has clear action plans for every related line ministries. Moreover, interested investors can directly invest in the area where the country prioritizes or where investors are interested in. The sooner it gets done, the sooner the benefit can be gained within the country. Therefore, the responsible line department should consider developing this official document at the earliest convenience.

Measures for institutional and organizational barrier

- **Barrier**: Inadequate cooperation between key stakeholders
- **Measures:** Enhance cooperation between key stakeholders

It is suggested that each respective stakeholders including the users, GoV, NGOs and local researchers, their roles identified and that each stakeholder should initiate to discuss and have understanding on the current tax policy for material importation with the relevant government departments. As a result, there will be proposals committed for Efficient Wood Stove business in terms of tax reduction or tax exemption. Moreover, the government and private sector should be engaged more than before to promote wood stove markets for wide penetration in the country. For example, a pilot project or economic feasibility assessment of Efficiency Wood Stove distribution in a rural area could be done through a public-private partnership.

- **Barrier**: Lack of Research and Development
- **Measures**: Develop R&D activities

The private sector, local universities, and Energy Department should initiate R&D activities in the area of energy-efficient wood stove. Funding for R&D activities should be provided by either the government and private sector through Public Private Partnership or donor agencies through International Non-Government Organizations. Moreover, the government should also consider encouraging institutional based research activities and incorporating energy efficiency technologies into the technical institution programs.

Measures for Information and Awareness

- **Barrier**: Insufficient Awareness about the technology
- **Measures:** Information and awareness campaigns

This technology potential should be provided with relevant information such as benefits, costs, sources of financing or subsidy programs, market potential. Such information could be shared by conducting adequate information and awareness campaigns through print, demonstration activities, case studies and demonstration sites. Also, the motivation of media including electronic media, social media could be sought to develop an interest in sharing information about technology.

1.2.4 COST-BENEFIT ANALYSIS OF EFFICIENT WOOD STOVE

Lately, institutional research at both local and international levels have served to enrich the information available for studies such as this. Such works have created data pools on the technical characteristics of stoves ranging from their efficiency to emissions levels as presented in the Global Alliance for Clean Cook stoves catalogue (Clean Cooking Alliance, 2020) .They have also exposed the usage behaviors that serve to back or undermine gains from clean cooking interventions. Even so, there remain a number of parameters that are difficult to find data on.

The costs considered are the capital costs of acquiring new technologies and all accompanying set up (Capex), operation and maintenance costs (including time) spent on technology (Opex), distribution and marketing costs associated with making the technology accessible and learning costs associated with adopting new technology. Learning costs comprises both the time spent and the reduction in the quality of food prepared. Total cost is estimated as simple aggregation of all the individual components listed above. All estimated time costs assume a fraction of the market wage for unskilled labor including time benefits.

The benefits to be considered include; health improvements arising from cleaner indoor air quality, improved time management from efficient cooking; and environmental benefits resulting from reduced emissions and reduced forest loss/degradation.

To address the complexities associated with the different gasses as their impact over time differs, the present value of radiative forcing from the various gasses is adopted. With the advancement of literature and availability of data, it is now possible to undertake a complete estimation of radiative forcing from a cocktail of emissions linked to each stove type, over time. In fact, emissions such as black carbon and organic carbon that hitherto were not completely understood, are now well explained; allowing for distinct treatment of their unique characteristics. As such, carbon costs are discounted to improve the consistency of valuation.

1.3 BARRIER ANALYSIS AND POSSIBLE ENABLING MEASURES FOR THE BATTERY ELECTRIC VEHICLE

1.3.1 GENERAL DESCRIPTION OF BATTERY ELECTRIC VEHICLE

Most electric vehicles today use an electric battery, consisting of electrochemical cells with external connections in order to provide power to the vehicle (Crompton, 2000).

Battery technology for Electric Vehicles (EVs) has developed from early lead-acid batteries used in the late 19th century to the 2010s, to lithium-ion batteries which are found in most EVs today (Hiroyuki, Ryuichi, Yutaka, Takenori, & Taizou, 2018) . The overall battery is referred to as a battery pack, which is a group of multiple battery modules and cells. For example, the Tesla Model S battery pack has up to 7,104 cells, split into 16 modules with 6 groups of 74 cells in each. Each cell has a nominal voltage of 3-4 volts, depending on its chemical composition.

Electric cars have traditionally used series wound Direct Current (DC) motors, a form of brushed DC electric motor. Separately excited and permanent magnet are just two of the types of DC motors available. More recent electric vehicles have made use of a variety of Alternate Current (AC) motor types, as these are simpler to build and have no brushes that can wear out. These are usually induction motors or brushless AC electric motors which use permanent magnets. There are several variations of the permanent magnet motor which offer simpler drive schemes and/or lower cost including the brushless DC electric motor.

Once electric power is supplied to the motor (from the controller), the magnetic field interaction inside the motor will turn the drive shaft and ultimately the vehicle's wheels (Tristan, 2018).

EV battery storage is a key element for the global energy transition which is dependent on more electricity storage right now. As energy availability is the most important factor for the vitality of an economy the mobile storage infrastructure of EV batteries can be seen as one of the most meaningful infrastructure projects facilitating the energy transition to a fully sustainable economy based on renewables. A meta-study graphically showing the importance of electricity storage depicts the technology in context (Berdelle, 2020).

Electric vehicles produce no greenhouse gas emissions in operation, but the electricity used to power them may do so in its generation (Nealar, Reichmuth, & Anair, 2015). The two factors driving the emissions of battery electric vehicles are the carbon intensity of the electricity used to recharge the Electric Vehicle (commonly expressed in grams of CO_2 per kWh) and the specific electricity consumption (in kilometers/kWh).

The carbon intensity of electricity varies depending on the source of electricity where it is consumed. A country with a high share of renewable energy in its electricity mix will have a low C.I. In the European Union, in 2013, the carbon intensity had a strong geographic variability but in most of the member states, electric vehicles were "greener" than conventional ones. On average, electric cars saved 50%–60% of CO_2 emissions compared to diesel and gasoline fueled engines.

Moreover, the de-carbonization process underway in electricity production is constantly reducing the GHG emissions due to the use of electric vehicles. In the European Union, on average, between 2009 and 2013 there was a reduction in the electricity carbon intensity of 17% (Moro & Lonza, 2018). In a life-cycle assessment perspective, considering the GHG necessary to build the battery and its end-of-life, the GHG savings are 10-13% lower (Moro & Helmers, 2015).

GHGs are also emitted when the electric vehicle is being manufactured. The lithium-ion batteries used in the vehicle take more materials and energy to produce because of the extraction process of the lithium and cobalt essential to the battery (Nealar, Reichmuth, & Anair, 2015). This means the bigger the electric vehicle, the more carbon dioxide emitted.

The mines that are used to produce the lithium and cobalt used in the battery are also creating problems for the environment, as fish are dying up to 150 miles (240 km) downstream from mining operations due to chemical leaks and the chemicals also leak into the water sources the people that live near the mines use, creating health problems for the animals and people that live nearby (Katwala, 2018).

1.4 Identification of barriers for Battery Electric Vehicles

The dillusion of BEVs in the region depends on several real and perceived barriers. These barriers were identified through a thorough literature review, including an analysis of relevant online content, previously published studies and related institutions.

The approach resulted in 17 barriers relevant to BEV diffusion. The major barriers in the wide diffusion of Battery Electric Vehicles technology are categorized under economic and financial and non-financial barriers.

Table 4. Identified Barriers for Battery Electric Vehicle Technology

Category	Barrier Dimension	Main Barriers
Economic and Financial barriers	Cost	a. Higher purchase price b. Battery replacement cost c. Higher electricity price for charging d. Lack of credit access for BEVs
Non-financial barriers	Policy, legal and regulatory	e. Lack of long-term planning and goals on the government's part f. Absence of an annual tax exemption
	Technical	g. Limited range (one-time travel distance at full charge) h. Lack of evidence on reliability and performance i. Limited battery life j. Fewer BEV models
	Social	k. Lack of knowledge on BEVs l. Lack of environmental awareness regarding BEVs m. Consumer's limited understanding of the product quality of BEVs
	Infrastructure	n. Lack of charging stations o. Lack of repair and maintenance workshops
	Information and awareness	p. Absence of awareness raising about BEVs

1.4.1 ECONOMIC AND FINANCIAL BARRIERS FOR THE BATTERY ELECTRIC VEHICLE TECHNOLOGY

Cost Barrier

Higher Purchase Price: Consumers view the higher purchase price of BEVs as a major concern. The consumers spent USD 120 billion on electric car purchase in 2022, a 50% increase from 2019, which breaks down to a 41% increase in sales and a 6% rise in average prices. The rise in average prices reflects that Europe. Where prices are higher on average than in Asia, accounted for a bigger proportion of new electric car registrations. In 2020, the global average BEV price was around USD 40 000 (IEA, 2021).Manufacturing costs are higher, hence, BEVs have a higher market price than those of combustion engine vehicles (Cherchie, 2017). Subsidizing BEV purchase is becoming a popular tool in many countries to promote their di usion.

Battery Replacement Cost: The battery life of a BEV is limited to eight to ten years (Sanya, Krause, Lane, & Graham, 2013) , and the consumer must bear the cost burden of its replacement. This aspect serves as a key barrier against BEV uptake (Rogers E. , 1983). Previous research has also pointed out that the cost of the battery accounts for a significant proportion of a BEV's total purchase price (Egbue & Long, 2012) (Council, 2013).

Higher Electricity Price for Charging: BEVs utilize electrical energy to run compared to combustion engine vehicles, which use petrol or diesel. Consumers are sensitive to the cost of fuel and, thus, a higher electricity price reduces the demand for BEVs (Kim, Jeesun & Park, & Joo, 2018) (Kevin & Enrich, 2011) (Olivier, Cathy, Kenneth, & Laurence, 2012). The daily operation cost of a BEV is mainly dependent on the electricity price for charging the BEV and, thus, lower electricity prices could persuade potential BEV users to purchase a BEV.

Lack of Credit Access for BEVs: Consumers are hesitant to invest in new technologies as they typically pose some measure of risk such as property fire, charger management, charger location, cyber risks, vehicles repair, etc., and, therefore, policy makers can play a vital role by facilitating the purchase of BEVs by providing users with subsidized interest rate credit mechanisms (Wikstrom, Hansson, & Alvfors, 2016). Di culty in obtaining credit access due to a weak or absent credit mechanism serves as another barrier against the di usion of BEVs (Gan, 2003).

1.4.2 NON - FINANCIAL BARRIERS FOR THE BATTERY ELECTRIC VEHICLE TECHNOLOGY

Policy, Legal and Regulatory Barrier

Lack of long-term planning and goals on the government's part: Governments should connect the introduction in BEV usage at the national level to their respective sustainable development visions (Nykvist & Nilsson, 2015). Long-term planning and goal development by the government could foster faster BEV di usion. Appropriate legislation, geared toward the provision of a su cient number of charging networks, government procurement strategies, environmental awareness, subsidized purchasing, among other policies, should be included in long-term plans and goals for accelerated BEV uptake (Gail, Danielle, & Graciela, 2018). Given that BEV di usion is still in its proposal stage in Vanuatu, the lack of long-term planning and goal setting by the government is an important policy barrier.

Absence of an Annual Tax Exemption: Vehicle owners pay mandatory annual vehicle, road, and route permit taxes. Providing tax benefits to BEV users could help the di usion of BEVs over their conventional counterparts (Steenberghen & Lopez, 2008) (Farla, Alkemade, & Suurs, 2010) (Lemoine, Kammen, & Farrell, 2008) (Tanaka, Ida, Murakami, & Friedman, 2014).

Technical Barrier

Limited range: BEV batteries must be charged for the vehicle to run and their storage capacities determine the distance that can be traveled on a single charge. One of the major user concerns for BEVs is range anxiety (Jensen, Cherchi, & Mabit, 2013) (Bonges & Lusk, 2016) (Zhang, Yu, & Zou, 2011). Users who do not need to travel long distances for their daily routines are likely to show more interest in BEVs (Quak, Nesterova, & van Rooijen, 2016). Thus, limited range can be considered as an important technical barrier.

Lack of Evidence on Reliability and Performance: BEVs are a relatively new technology compared with CVs, and potential users tend to be concerned about their technological performance, which increases their unwillingness to use BEVs (Quak, Nesterova, & van Rooijen, 2016). Lack of performance is known to a ect user perceptions of BEVs (Franke, Neumann, Bühler, Cocron, & Krems, 2012), whereas system stability is an important detrimental factor against the increased deployment of BEVs (Xue, You, & Shao, 2014). Thus, a lack of evidence regarding reliability and performance can be considered as another technical barrier.

Limited battery life: BEVs run on the power provided by charged batteries. However, the typical warranty for an BEV battery, improved more recently, lasts between eight and ten years. After this battery life period, battery replacement should be borne by the user. The batteries are also sensitive to overcharging, which poses a problem for BEV users (Carley, Krause, Lane, & Graham, 2013). Limited battery life requires frequent replacements, which is a major burden on BEV users (Haddadian, Khodayar, & Shahidehpour, 2015) (Pelletier, Jabali, & Laporte, 2014). Given that the batteries are also not environmentally friendly it is necessary for a proper disposal of them.

Fewer BEV Models: BEV uptake is a ected by the limited number of design models. A wider range of car models can appeal to a broader consumer segment (Cairns & Albertus, 2010) (Linzenich, Arning, Bongartz, Mitsos, & Ziefle, 2019). Thus, limited BEV model availability poses another challenge in that it narrows down choices for users (Quak, Nesterova, & van Rooijen, 2016) (Haddadian, Khodayar, & Shahidehpour, 2015). The BEV manufacturing industry is responsible for the research, development, and production of BEVs. However, the production of di erent BEV models is typically limited (Xue, You, & Shao, 2014).

Social Barrier

Lack of knowledge on BEVs: Market failures can occur when users have incomplete information about a product. Thus, correct information provision is crucial to aid the transition towards products such as BEVs (Broadbent, Drozdzewski, & Metternicht, 2018) (Lutsey, Searle, Chambliss, & Bandivadekar, 2015). Potential users' awareness of the benefits of an BEV, financial incentives, infrastructure availability, and potential fuel-related savings are likely to be essential factors a ecting the uptake of BEV

(Ninh, Bentzen, & Laugesen, 2014). Notably, this barrier is limited to the provision of general information about BEVs for potential users. It does not consider the users' understanding of the product quality of BEVs.

Lack of environmental awareness regarding BEVs: Emission reduction is one of the key advantages of using BEVs. In total, 21.2% of electricity is generated from renewable energy sources in Vanuatu, which is emission-free. However, consumers are often uncertain about possible emission reductions due to BEVs and, at times, they are environmentally unaware about the harm caused by greenhouse gas emissions due to the use of CVs (Haddadian, Khodayar, & Shahidehpour, 2015). Environmental awareness regarding BEVs enhances the adaptation rate of BEVs (Sierzchula, Bakker, Maat, & VanWee, 2014).

Consumer's limited understanding of the product quality of BEVs: Consumers' perceptions of the quality of BEVs as a product may influence their decision to purchase BEVs. Uninformed or wrongly informed consumers are likely to be unwilling to purchase BEVs (Franke, Neumann, Bühler, Cocron, & Krems, 2012). Actual versus perceived product quality limitations, such as those related to performance and reliability, range capacity, and other technical issues, may create a perception gap among potential BEV users (Haddadian, Khodayar, & Shahidehpour, 2015). Thus, it appears that consumers must be informed about the quality of BEVs, as this particular social factor serves as a prerequisite for their acceptance. Notably, this barrier is limited to product quality concerns about BEVs, as this technology will be relatively new in the Vanuatu market.

Infrastructure Barrier

Lack of charging stations: A su cient number of charging stations is a prerequisite for BEV di usion. The lower number of charging networks has been recognized as a limiting factor for consumers to buy BEVs (Egbue & Long, 2012) (Mock & Yang, 2014) (Sierzchula, Bakker, Maat, & VanWee, 2014). The public and private sectors are reluctant to invest in charging stations as the number of BEV users is still insu cient and, conversely, potential BEV users hesitate from purchasing BEVs due to the insu cient number of charging stations (Haddadian, Khodayar, & Shahidehpour, 2015) (Bonges & Lusk, 2016).

Lack of repair and maintenance workshops: Current BEV owners are disappointed about the low number of support centres or workshops for BEV repair and maintenance in comparison to those for CVs (Quak, Nesterova, & van Rooijen, 2016). Further, BEV-related repair and maintenance procedures can be complicated, and only a few trained mechanics are available to fix such issues when they arise (Weiller & Neely, 2014). BEV cars are predominantly an electronically machine and not a mechanical one. Within the Pacific Island States, we have fostered a good mechanical understanding of vehicles but are still lacking on modern electronic vehicles (especially BEVs)

Information and Awareness Barrier

Absence of awareness raising about BEVs: According to Rogers (Rogers E. , 1983), the di usion of any new technology can be accelerated by providing potential users with the necessary information about the technology. Educational programs, advertisements, and media communications can play a crucial role in the di usion of BEVs (Broadbent, Drozdzewski, & Metternicht, 2018). Thus, designing and implementing awareness-raising campaigns is crucial to foster the di usion of BEVs in Vanuatu. Such campaigns are likely to reduce consumers' hesitation about purchasing BEVs. As BEVs will be new to Vanuatu, this study considered the absence of awareness raising as a policy barrier against the di usion of BEVs in the country.

1.5 Identified measures for Battery Electric Vehicles

The following step-by-step process is applied to identify measures for battery electric vehicle technology.

i. Literature review
ii. Bilateral meeting
iii. Guidance from TNA Guidebook
iv. Stakeholder consultation meeting

During the stakeholder consultation meeting, market map and problem tree are presented to discuss to change from problems to the solution, then the measures are classified and evaluated. To have comprehensive measures, stakeholders from the technical working group are requested to give more comments and feedbacks by reviewing the report.

1.6 Economic and financial measures for Battery Electric Vehicles Technology

Measures for cost barriers

- **Barrier:** Higher Purchase Price
- **Measures:** Introduce subsidy through the government or project

Subsidizing BEV purchase is becoming a popular tool in many countries to promote their di usion. The introduction of 20%-25% subsidy will encourage the uptake and change-over fleet vehicles to BEVs.

- **Barrier:** Battery replacement costs
- **Measures:** Exploring cost-reduction strategy

Cell manufacturing and improving the availability of critical cell components are the most prioritized strategies followed by standardization and development of ancillary industries. These results agree with general intuition that domestic manufacturing of cells will reduce the cost of batteries and thus, three out of top four are about promoting cell manufacturing and battery packaging in the country. Standardization is a relatively inexpensive policy instrument that can play an important role in preventing the entry of sub-standard batteries in the market. It will act as a barrier to entry in the market and will encourage investments by providing a fair and competitive market for everyone. Standards will also help end-users in decision making and will address anxieties over the safety of batteries and electric vehicles. Most of the other options were found to have similar rank and priority. However, assurance of demand and creation of market will play an essential role in encouraging investments. Hence, financial assistance to end-users, mass procurement, charging infrastructure and awareness about BEVs are important and must be pursued simultaneously as these will play a crucial role in creating demand.

- **Barrier:** Higher electricity price for charging
- **Measures:** Levelized cost of charging BEVs

Considering when, where, and how EVs are charged. The levelized cost of charging includes costs associated with the purchase and installation of charging equipment and retail electricity prices, derived from real-world utility tariffs. To contextualize the levelized cost of charging, we estimate lifetime fuel cost savings, comparing refueling costs for BEVs with those for conventional gasoline vehicles over a 15-year vehicle life.

- **Barrier:** Lack of credit access for BEVs
- **Measures:** Policies to promote BEVs deployment

Policy makers can play a vital role by facilitating the purchase of BEVs by providing users with subsidized interest rate credit mechanisms. Consequently, policy should address car drivers' purchase decision by incentives to convince them to voluntary switch to less polluting vehicles That is with the introduction of such instruments and includes tax waivers for fully electric vehicles, and sale of carbon surplus arising from EV adoption on carbon market platform.

1.7 Non-Financial measures for Battery Electric Vehicles

Measures for Policy, Legal and Regulatory Barriers

- **Barrier:** Lack of long-term planning and goals on the government's part
- **Measures:** Long term planning and development goals

Long-term planning and goal development by the government could foster faster BEV di usion. Appropriate legislation, geared toward the provision of a su cient number of charging networks, government procurement strategies, environmental awareness, subsidized purchasing, among other policies, should be included in long-term plans but be reflected in the mid-term plans such as in the NDCs particularly in the transport sector and includes Electric Vehicles (e-mobility): by 2030, (a) Introduce e-buses for public transportation (10% of total public buses); (b) Introduce e-cars in Vanuatu (10% of government fleet); and (c) 1000 electric two wheelers (e-bikes)/three wheelers (e-rickshaw) to re-assure the goals for accelerated BEV uptake.

- **Barrier:** Absence of an Annual Tax Exemption
- **Measures**: Provide Tax Benefits

Vehicle owners pay mandatory annual vehicle, road, and route permit taxes. Providing tax benefits to BEV users could help the di usion of BEVs over their conventional counterparts.

Many officials within government, farmers and other private sector organizations who qualify are granted tax cuts on the import duty for vehicles. These cuts range from 50% to 100%. As a means to encourage the diffusion of BEVs, these exemptions can be expanded to include the individuals within the wider population who may wish to invest in a BEV. For example, someone who feels that the BEV will be best suited for their circumstance will be offered this cut as an incentive. This tax break can be seen as 'non-carbon tax' that encourages individuals to reduce on their carbon footprint and to make a positive contribution to mitigating climate change. However, this measure must be integrated with electricity supplied by renewable energy sources.

Measures for Technical Barrier

- **Barrier:** Limited range (one-time travel distance at full charge)
- **Measures:** Have multiple charging stations

The need for charging infrastructure using renewable energy sources has to be addressed. This includes the use of PV technology to charge the vehicles. However, on the national level, a pilot project to introduce this can be done. The government owns and operates a large fleet of vehicles and also owns many building in strategic locations all over the country. The government may also wish to partner with private entities, for example, supermarkets which have large parking lots to install such systems. In the future and when the diffusion becomes entrenched, areas such as the fuel stations can also be solarized, with charging station attached.

EVs require access to charging points, but the type and location of chargers are not exclusively the choice of EV owners. Technological change, government policy, city planning and power utilities all play a role in EV charging infrastructure. The location, distribution and types of electric vehicle supply equipment depend on EV stocks, travel patterns, transport modes and urbanization trends. These and other factors vary across regions and time and includes:

- Home charging is most readily available for EV owners residing in detached or semi-detached housing, or with access to a garage or a parking structure.
- Workplaces can partially accommodate the demand for EV charging. Its availability depends on a combination of employer-based initiatives and regional or national policies.
- Publicly accessible chargers are needed where home and workplace charging are unavailable or insufficient to meet needs (such as for long-distance travel). The split between fast and slow charging points is determined by a variety of factors that are interconnected and dynamic, such as charging behavior, battery capacity, population and housing densities, and national and local government policies.
- **Barrier:** Lack of Evidence on Reliability and Performance
- **Measures:** Reliability and Performance of the BEVs

Reliability and performance depend greatly on the battery functional parameters such as the energy provided, the capacity of the battery, the power and internal resistance, the storage or charge retention and the battery durability.

- **Barrier:** Limited Battery Life
- **Measures:** Do not overcharge the battery

Overcharging a battery can shorten the battery life that may possess a problem for BEV users, and thus result in more frequent replacement of the battery.

At high rates of overcharge a battery will progressively heat up. As it gets hotter it will accept more current, heating up even further. This is called thermal runaway and it can destroy a battery in as little as a few hours.

- **Barrier**: Fewer BEV Models
- **Measures:** More research, development and production of BEV Models

The BEV manufacturing industry is responsible for the research, development, and production of BEVs. However, local assembly of different BEV models might be typically for Vanuatu.

Measures for Social Barriers

- **Barrier:** Lack of knowledge on BEVs
- **Measures:** Knowledge on BEVs

Having the correct information provision is crucial to aid the transition towards products such as BEVs. Potential users' awareness of the benefits of the BEV, financial

Table 5. Common barriers and proposed enabling framework for Energy Sector

No	Common barriers	Enabling framework	Technology
1	High capital cost	a. Facilitate tax reduction or tax removing scheme on importation of technologies in respect of Energy Efficiency Projects	Efficient Wood Stove, BEV
2	Lack of/Insufficient financial support and subsidy	b. Engage with international funding agencies c. Create subsidy program for Energy Efficiency in residential sector	Efficient Wood Stove, BEV
3	Lack of / Insufficient policy, legal and regulatory framework	d. Develop appropriate policy and regulation framework to promote mitigation technologies	Efficient Wood Stove, BEV
4	Limited market information	e. Create awareness campaign through various media	Efficient Wood Stove, BEV

incentives, infrastructure availability, and potential fuel-related savings are likely to be essential factors affecting the uptake of BEV.

- **Barrier**: Lack of environmental awareness regarding BEVs
- **Measures:** Environmental awareness regarding BEVs

Environmental awareness regarding BEVs enhances the adaptation rate of BEVs. And includes the reduction in GHG emission and at times, they are environmentally unaware about the harm caused by greenhouse gas emissions due to the use of CVs.

Noise is irritating and can have adverse health effects. The benefits are even greater for utility vehicles such as buses or refuse collection vehicles. Electric versions of such vehicles are significantly quieter – across the entire spectrum of speeds driven in urban traffic. The same applies to mopeds and motorbikes. In motorized two-wheelers, the internal combustion engine and associated processes and components are usually so noisy that electric versions are quieter at all speeds.

- **Barrier:** Consumer's limited understanding of the product quality of BEVs
- **Measures:** Consumers' perceptions of the quality of BEVs

Consumers' perceptions of the quality of BEVs as a product may influence their decision to purchase BEVs. Uninformed or wrongly informed consumers are likely to be unwilling to purchase BEVs.

Measure for Infrastructure Barriers

- **Barrier:** Lack of charging stations
- **Measures:** Sufficient charging stations

A sufficient number of charging stations is a prerequisite for BEV diffusion. The need for charging infrastructure using renewable energy sources has to be addressed once the BEV is introduced into the country. However, on a national level, a pilot project to introduce this can be done.

- **Barrier:** Lack of repair and maintenance workshop
- **Measures:** Develop institutional and individual capacity to provide training to technicians

Both institutional and personnel capacity building can be addressed by first upgrading and updating the automotive technology program at the existing institutions and training facilities. This will require the collaboration between the institutions, vehicle importers and other key stakeholders to review and design the training, agree on training materials required and re-train current faculty present to deliver the training. Additionally, vehicle importers who agree to import EVs may also be assisted to upgrade their facilities to provide appropriate service for these types of vehicles.

Measures for Information and Awareness Barrier

- **Barrier:** Absence of awareness raising about BEVs
- **Measures:** Deliberating information on BEV

The di usion of any new technology can be accelerated by providing potential users with the necessary information about the technology. Educational programs, advertisements, and media communications can play a crucial role in the di usion of BEVs.

1.8 Linkages of the barriers identified

Few of the barriers are similar to each other even though technologies' nature is different from one another. These barriers are specified as common barriers. These linked barriers are mentioned below.

High Capital Cost: High capital cost due to import tax and lack of or insufficient financial support and subsidy are the most significant common barrier to all technologies in the Energy Sector. Since most of the equipment is imported, custom duty is levied on every equipment and the rate of customs duty is varies based on the countries of origin. Apart from custom duty, a 0- 50% commercial tax is levied on every technology as well.

Lack of/ Insufficient financial support and subsidy: The insufficient subsidy is mainly concerning both the technologies because the country has a big financial gap to achieve NERM's target in 2030. In the case of Energy Efficiency Wood Stove, the country has no subsidy program to promote the diffusion of these technologies. Due to lack of subsidy, consumers need to invest their own money to apply these technologies at home.

Lack of / Insufficient policy, legal and regulatory framework: This is another common barrier for all technologies although the nature of the policy framework is varying from one another. Since the country does not have sufficient GHG Emission Policy and long-term planning goals, the pathway of more diffusion of these technologies are in the bottleneck. For example, investors are generally reluctant to invest more in BEVs due to lack of legislation, geared toward the provision of a su cient number of charging networks, government procurement strategies, environmental awareness, subsidized purchasing, among other policies, should be included in long-term plans and goals for accelerated BEV uptake.

Limited market information: This barrier is hindering penetrating the local market especially outside of the main city areas of Vanuatu. Since Energy Efficiency Wood Stove and BEV technology are capital goods, public awareness is very essential to diffuse these technologies well. However, the market information of these technologies cannot be accessed by people easily because people cannot be able to see this information in the public domain. Currently, the advertisement of these technologies cannot be able to see widely even in the city area although people from city areas can access information from supermarkets and some retail shops. Therefore, people who are living outside of the city area are far away to access the latest information about these technologies.

1.9 Enabling framework for overcoming the barriers in the Energy Sector

The common barriers are already identified in the previous section. These common barriers are broad categories into (1) High capital cost due to import tax, (2) Lack of/ Insufficient financial support and subsidy, (3) Lack of sufficient policy, legal and regulatory framework and (4) Limited market information. The table 5 proposes an enabling framework for common barriers.

Enabling framework for common barriers in detail:

1. ***Facilitate tax reduction or tax removing scheme on the importation of technologies in respect of Energy Efficiency Projects***

   Providing enabling financial framework and import tax reduction will be an effective measure to overcome the barrier of high capital cost due to import tax. Efficient Wood Stove and BEV technology suppliers can be provided either a tax holiday or tax reduction plan for a limited period during the technology promotion time of applying energy-efficient products in the household. Any revenue loss will be compensated to the government by indirect saving through national-level energy saving and energy security improvement. Moreover, GHG emissions from energy consumption can be reduced.

2. ***Engage with international funding agencies***

   The government should provide subsidies by seeking support from international funding agencies that already have such initiatives. The government can take a current experience with the World Bank to provide a certain amount of subsidy to implement a mini-grid project in the off-grid area. By using the experience of the current rural electrification project, the government should negotiate quickly and efficiently with international funding agencies to take concession loans to support the deployment of Efficient Wood Stove and BEV. This lead to secure the loan for the country. At the same time, the government should consider maintaining the current amount of subsidy rate of 30%.

3. ***Develop appropriate policy and regulatory framework to promote mitigation technologies***

(i) Develop BEV regulation:
Government policy, shareholder activism and consumer demand, fueled by the climate crisis, are accelerating the shift from mobility to eMobility – driving forward one of the most radical transformations since the introduction of the internal combustion engine.As infrastructure is electrified and supply chains are reimagined, the challenges are too big for one sector to solve alone. Only through collaboration can organizations thrive in the emerging eMobility ecosystem, win customers, and drive returns while advancing sustainability in transport.

We believe that organizations must define their role in the emerging eMobility ecosystem, maintain a total focus on the customer experience and partner intelligently across the value chain to access greater opportunities for growth. Developing this new regulation and framework can take time but more financing can be secured if this can develop at the soonest.

(ii) Establish an appropriate regulatory mechanism for Efficient Wood Stove to promote mitigation technologies for household-level energy efficiency improvement

The existing regulatory mechanism for building the support to rural communities in Vanuatu, especially in terms of energy access, sustainable energy and green growth targets is represented in the updated National Energy Road Map, 2016 to 2030. With some limited efforts been initiated to promote Efficient Wood Stoves a more specific regulatory framework is expected to increase and substantiate the efficacy of the local production at lower price and reach wider end-user, hence leading to environmental, social, health and economic benefits.

Establishing an appropriate regulatory framework together with an effective implementation mechanism will be an effective instrument to promote mitigation technologies. Moreover, that legal and regulatory framework should ensure to be continuous improvement of Efficient Wood Stove. Therefore, it is suggested that entry requirements, registration schemes, verification programs, and enforcement frameworks for Efficient Wood Stove should be developed as soon as possible. Moreover, the community will have overall guidance to promote this mitigation technology.

4. ***Create an awareness campaign through various media***

As Efficient Wood Stove and BEV technologies are market-driven products, public awareness is important to diffuse technologies well. To promote public awareness, a promotion campaign should be considered to do in a crowded area such as a supermarket, local market. Moreover, the media campaign is also an effective way of product marketing and promotion by using radio, TV, social network, etc. Additionally, the public event can be facilitated in some days like World Environment Day, the Energy Open Day, etc. Also, the information on the technology can be spread through awareness-raising materials like posters, pamphlets, brochures, billboards, etc. These activates could be done through during the energy efficiency program for Efficient Wood Stove and BEV with private sectors to promote technologies.

CHAPTER 2

Waste-to-Energy Sector

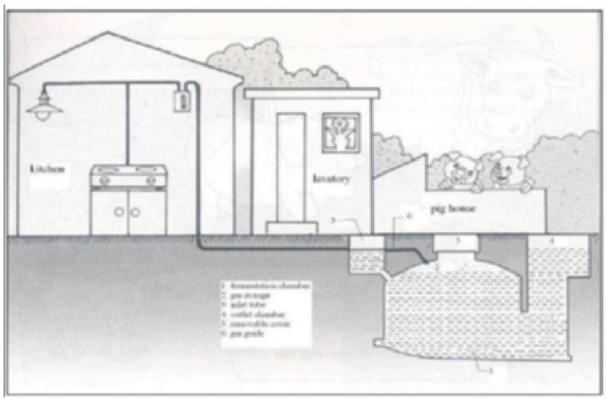
2.1 Barrier analysis and possible enabling measures for manure based biogas digester technology

2.1.1 General description

Manure-based biogas digesters are animal manure treatment and fermentation system which includes fermentation tanks, manure input and fermentation via anaerobic environment. The methane concentration of biogas is around 60%, so the recovery and utilization of biogas from digested slurry in a biogas digester will reduce CH_4 emissions from the manure. In addition, the biogas can be used to provide electricity, energy and reduce CO_2 emissions from fossil fuel (coal) displaced by biogas.

A biogas digester is usually composed of six parts: fermentation chamber, gas storage, inlet tube, outlet chamber, removable or sealed cover, and a gas pipeline (see in Figure 1).

Figure 1. Example of a schematic of 'Three in One' combination of household biogas digesters[3]



The mechanics of biogas generation is similar to practice elsewhere which can be described as follows:

- The captured gas is stored in the upper part of the digester tank (gas storage area), which is constructed as an arc ship. The generation of biogas will gradually increase the pressure in the stored area. When the volume of the captured gas is larger than the amount consumed, the pressure in the gas storage will increase and slurry will be pushed into the outlet chamber. If the gas consumed exceeds gas availability, the slurry level drops and the fermented slurry flows back into fermentation chamber.
- The placement of the digester tank (underground fermentation) keeps the temperature in the tank relatively stable ensuring that the slurry can be fermented at adequate temperatures throughout the year without requiring additional heating.
- The bottom of the digester inclines from the material-feeding inlet to the material-outlet, allowing free flow of the slurry.
- The digester has been designed to allow the effluent

[3] Improved Design of Anaerobic Digesters for Household Biogas Production in Indonesia: One Cow, One Digester, and One Hour of Cooking per Day, 2014

to be removed without breaking the gas seal, taking the effluent liquid out through the outlet chamber. As pointed out in technology definition biogas fermentation is a process in which certain bacteria decompose organic matter to produce methane. In order to obtain normal biogas fermentation and a fairly high gas yield, it is necessary to ensure the basic conditions required by the methane bacteria are met for them to carry out normal vital activity (including growth, development, multiplication, catabolism etc.).

Microbes that play a major role in biogas fermentation are all strict anaerobes. In an aerobic environment, the decomposition of organic matter produces CO_2, however, in an anaerobic environment, it results in CH_4. A strict anaerobic environment is a vital factor in biogas fermentation. Therefore, it is essential to build a well-sealed, air-tight biogas digester (anaerobic digester) to ensure a strictly anaerobic environment for artificial biogas production and effective storage of the gas to prevent leakage or escape

Sufficient raw materials for biogas fermentation constitute the material basis for biogas production. The nutrients that methane bacteria draw from the raw materials are carbon (in the form of carbohydrates), nitrogen (such as found in protein, nitrite, and ammonium), inorganic salts, etc. Carbon provides energy, and nitrogen is used in the formation of cells. Biogas bacteria require a suitable carbon-nitrogen ratio (C: N). The suitable carbon-nitrogen ratio for rural biogas digesters should be 25~30:1. The carbon-nitrogen ratio changes with different raw materials, and one must bear that fact in mind when choosing a mix of raw materials for the digester.

The appropriate dry matter concentration in the raw materials for biogas fermentation in rural areas should be 7%~9%. Within this range, a low concentration of raw materials may be selected in summer, while in winter a higher value is preferred.

Biogas fermentation rates depend greatly on the temperature of the fermenting liquid in the digester. Temperature directly affects the digestion rate of the raw materials and gas yield. Biogas fermentation takes place within a wide temperature range (XuZengfu, 1981). The higher the temperature, the quicker the digestion of the raw materials will be, and the gas production rate will also become higher. Based on real fermentation conditions, we have identified the following three temperature ranges for fermentation:

- High temperature fermentation: 47°C~55°C
- Medium temperature fermentation: 35°C ~38°C
- Normal temperature fermentation: ambient air temperature of the four seasons. Selecting the temperature range for biogas fermentation depends on the type, sources, and quantities of raw materials; the purposes and requirements of processing organic wastes; and their economic value. Most household biogas digesters are normal temperature fermentation.

The pH value of the fermenting liquid has an important impact on the biological activity of biogas bacteria. Normal biogas fermentation requires the pH value to be between 7 and 8. During the normal process of biogas fermentation in a rural digester, the pH value undergoes a naturally balanced process, in which it first drops from a high value to a low value, then rises again until it almost becomes a constant. This process is closely related to the dynamic balance of three periods of biogas fermentation. After feeding the biogas digester, the time that the pH value takes to reach its normal level depends on the temperature and the kinds and amounts of raw materials that are fed in.

2.1.2 IDENTIFICATION OF BARRIERS TO MANURE BASED BIOGAS DIGESTER TECHNOLOGY

The key barriers to biogas system uptake, especially for institutions are identified through a current project sponsored by the EU-GIZ ACSE. The project sought to determine the market factors that will be necessary for the wide diffusion of biogas as an alternative source of energy for use on kitchen waste. In this regard, many barriers were discussed and the main barrier identified was that of economic and financial. There were other non-financial barriers however that will need urgent attention if the financial barriers are eventually overcome. The market mapping exercise was also use to visualize key barriers and potential measures to overcome them. The barriers are shown in table 6.

Table 6. Barriers to the diffusion of manure based biogas digester

Category	Barrier Dimension	Main Barrier
Economic and financial barriers	Cost	a. High up-front cost of commercial type systems b. High operational and maintenance cost due to the labor intensive nature of operations
Non-economic and financial barriers	Technical	c. Taboo about nature of the gas generated from waste of animals d. Small size of waste input to make some systems viable e. Labor intensive nature of the system requiring commitment to provide feed stock to the system
	Information and Awareness	f. Lack of awareness on the commercial viability of biogas systems

2.1.2.1 ECONOMIC AND FINANCIAL BARRIERS

Cost Barriers

High upfront cost of commercial type system: All equipment and machinery required for the conversion of waste to energy need to be imported on commercial terms. As large sums of money are expected to get involved in the implementation of this technology, required finances have to be raised through commercial lending institutions at commercial rates. Moreover, Vanuatu has no elaborate policy to support initiatives that are aiming at mitigating climate change and relieve the energy cost burden. Whereas fossil fuel based energy conversion projects, such as petroleum power projects, are implemented by government institutions or private sector with very concessionary terms with guarantees provided by the government.

The feasibility study conducted indicates that a brick made only of fixed dome digester costs between USD 3193.99 and USD 4471.59 (K.Obileke, G.Makaka, N.Nwokolo, E.L.Meyer, & P.Mukumba, 2022). This high cost is attributed to the construction material, thus prompting the need to use materials of lower cost for affordability and sustainability.

From the economic analysis conducted, the total initial investment cost of the biogas digester was reported to be USD 1623.41 with an internal rate of return of 8.5%, discount payback period of 2 years and net present value of USD 1783.10. The findings equally revealed that the estimated quantity of biogas could replace 33.2% of liquefied petroleum gas (LPG) cooking gas and a savings of USD119 at USD3.60/kg[4] . With biogas, you can reduce your cooking fuel expenses by as much as 80% (KeChrist Obileke, 2022).

High operational and maintenance costs: Additionally, biogas production can be labor extensive and as such can be a relatively costly endeavor. These systems require regular feeding of the system and stirring; regular withdrawal of the digestate from the system and other regular maintenance issues to ensure the most efficient production of the biogas. In this regard, the labor cost associated with the system can be higher than compared to the use of LPG or even using biomass, such as wood especially for poultry and meat production for which the biogas use is intended. This cost can also serve as a barrier that needs consideration when a biogas system is contemplated (KeChrist Obileke, 2022).

2.1.2.2 NON-FINANCIAL BARRIERS

Technical Barriers

The nature of gas generated: There are some key non-financial barriers that need to be considered if biogas will be diffused effectively in the market. Firstly, there is a taboo about biogas as its production is linked to the source of the waste that is used to generate it. For example, some people are of the opinion that the gas produced from say pig waste is unhealthy and unsafe for use in the kitchen. This is a very critical barrier as it can hinder the uptake of an affordable source of energy for communities and individuals who may be energy impoverished.

Small size of waste input: The limited quantities of the waste stock may also be a barrier, in that this can affect the efficient functioning of the system. In this regard, the

[4] USD119 is equivalent to 14,180 vatu and at 427 vatu/kg

small quantities of waste stock and the possible infrequent generation of this stock can adversely affect the production of biogas. This may not be favorable with stakeholders as lack of consistency in biogas will hinder the work flow of cooking and other activities that the gas is used for.

Labor intensive: There is an opinion that biogas systems require constant attention to endure that they function. In the case of LPG, end-users simply attach a cylinder to the stove or other equipment and the cylinder only needs to be changed when the LPG has been used up. In the case of biogas production, waste has to be fed often, the system needs to be agitated to increase gas production, the waste has to be collected and stored and from time-to-time the system needs to be cleaned of the solid particles. This may contribute to making biogas production less attractive for conventional end-use such as cooking, since it appears to be more labor intensive.

Information and Awareness Barrier

Lack of awareness: The final barrier identified is one of lack of awareness on the commercial viability of biogas. In this regard, stakeholders and end-users are not adequately informed on the benefits of using biogas as opposed to the LPG that is very well known. Thus stakeholders may be hesitant to invest in this technology as it appears to be commercially unattractive.

2.2 Barrier analysis for compact biogas digester for urban household technology

This section describes the barriers analysis and enabling framework that was conducted for the compact biogas digester for urban household technologies. The market mapping technique was used to assist with the selection of barriers and measures. The two-day workshops held on the 01st and 2nd of February 2021, that was held to finalize the selection process, a number of stakeholders were involved. The barriers selection process is fully described in section

2.2.1 GENERAL DESCRIPTION OF THE TECHNOLOGY

Appropriate Rural Technology Institute of Pune, Maharashtra, India (www.arti-india.org) has developed a "Compact Bio-Gas Digester" to resolve technical as well as operational challenges of the conventional biogas digester." The volume of this digester is 0.75 m3. It essentially consists of two plastic tanks. Through this technology, an average household could generate adequate biogas to meet the household requirements for cooking.

The ARTI compact biogas system is made from two cut-down standard high-density polyethylene water tanks and standard plumber piping. The larger tank acts as the container containing the waste material while the smaller one is inverted and telescoped into this larger one. This smaller inverted tank is the floating gas chamber, whose rise is proportional to the produced gas and acts as a storage space for the gas.

The gas can then be used directly for cooking on an adjustable gas stove and the liquid effluent from the digester can be applied as fertilizer in gardens or agriculture.

By specification of ARTI, the CBS of approximate 1 m3 capacity is designed for treating 1-2 Kg (dry weight) of kitchen waste per day (www.howtopedia.org).

The usable gas volume of the 750 L-gasholder is 400 L. The hydraulic retention time suggested by ARTI-TZ, which is the ratio of the reactor volume (0.85 m3) to the flow rate of the inflow substrate (0.02 m3/day), is 42.5 days. The rather long hydraulic retention time is designed to compensate for incomplete mixing.

2.3 Identification of barriers for compact biogas digester for urban household technology

A total number of 5 key barriers have been identified through stakeholder consultations by analyzing causal relations using root cause analysis and market mapping for the technology. Conversion of biomass / waste to energy, and supported by review of literature and personal inputs.

Table 7. Barriers to the diffusion of compact biogas digester

Category	Barrier Dimension	Main Barrier
Economic and financial barriers	Cost	a. High capital cost b. Difficulty to access finance
Non-economic and financial barriers	Technical	c. Technology not fully developed
	Social	d. Convenience to and acceptability by consumers not evaluated
	Information and Awareness	e. Private sector not informed of business viability

2.3.1 ECONOMIC AND FINANCIAL BARRIERS

Cost Barriers

High capital cost: All equipment and machinery required for the conversion of waste to energy need to be imported on commercial terms. As large sums of money are expected to get involved in the implementation of this technology, required finances have to be raised through commercial lending institutions at commercial rates. Moreover, the GoV has no elaborate policy to support initiatives that are aiming at mitigating climate change and relieve the energy cost burden. Whereas fossil fuel based energy conversion projects, such as petroleum power projects, are implemented by government institutions or private sector with very concessionary terms with guarantees provided by the government.

Difficulty to access finance: As indicated in (a) above, the contribution of waste to electricity is not a common practice, as such commercial banks in Vanuatu may not be easily attracted to finance them. In respect of hydropower and diesel generation, already there are many existing plants, which provides needed comfort for the lenders. Moreover, most of the wastes are generated as waste as such it is not yet common to many to regard waste as a resource. The waste management is very sporadic as such there is no guarantee of continuous supply of residual derived fuel to the project developers. Furthermore, the current bank lending rates are exorbitantly high on average 23%, which are not user friendly to private lenders. For these reasons, the commercial banks do not have a great enthusiasm in providing required finances for biomass or waste based energy conversion projects and the lenders are not willing to borrow money at such high borrowing rates for the projects that may prove burdensome to sustain.

2.3.2 NON-ECONOMIC AND FINANCIAL BARRIERS

Technical Barrier

Technology not fully developed (RDF): Similarly, the use of municipal solid wastes to manufacture and use residue derived fuel are also not a commonly used in Vanuatu, due to these technologies requiring a scale of operation that needs high investment. Potential investors may need to be exposed to such facilities operating in other countries in order to garner confidence.

Social Barrier

Convenience to and acceptability by consumers not evaluated: The compact biogas digester is made up of a pair of plastic vessels to be used at household level by utilizing food residues. Although kitchen wastes such as vegetable peelings also can be used as feed material, the use of such materials causes two difficulties. (a) Need to be first macerated using a device such as hand-operated meat mincer prior to feeding the digester. (b) Fibrous materials are slow to digest and take a longer resident time in the digester slowing down the digestion process and resulting in inadequate gas generation. For the above two reasons, the uptake of this technology is expected to be low if measures to address these barriers are not put in place.

Information and awareness barrier

Private sector not informed of business viability: In respect of Micro hydro, solar wind, small biomass based power generation, the Energy and Water Utility Regulatory Authority (URA) has formulated and published specific Standardized Power Purchase Tariffs for each of these technologies. However, in respect of the waste to energy, tariffs have to be obtained through competitive bidding. Competitive bidding in this technology will take some time to come by as there is no adequate baseline data to support the business viability.

2.4 Identified Measures

The measures identified to overcome the suggested barriers for both the waste-to-energy technologies were simultaneously selected and debated at the workshop with the stakeholder. The market mapping process also assisted with the process. The identified measures are given below.

2.4.1 ECONOMIC AND FINANCIAL MEASURES FOR MANURE BASED BIOGAS DIGESTER

Measures for cost barriers

- **Barrier**: High up-front cost of commercial type systems
- **Measures**: Create soft loan for user's access

Soft loans will be an important measure to assist with the diffusion of biogas technologies. These technologies will be generally small scale and can be locally constructed or small scale commercial systems imported. One project report suggests that investment required for the importation of a small unit can range between USD 1,700.00[5] to USD1,900.00, with a further USD370 required. Therefore, an installed cost may range between, USD 2,035.00 to USD2,220.00. Such an investment and up to about USD 3,700.00 can be considered to be a soft loan and the intent of such a loan should lend itself to lowered interest rates. The financial incentive of accelerated depreciation and interest rate drawdown can be applied (GRENADA, 2018).

- **Barrier**: High operational and maintenance cost due to the labor intensive nature of operations
- **Measures:** Conduct productivity study to analyze how labor intensity can be reduced

Workers on the farm see the process of feeding a biogas system with waste as extra work that needs extra compensation. This can be addressed through effective productivity surveys to see where savings in time and effort by workers can be reduced. In other words, the gathering of waste feedstock and the eventual feeding can be done more efficiently and effectively. On small farms where the feedstock is minimal, then this work will not significantly increase costs. In many cases it is now about changing what is done with the waste after pens and plots are cleaned.

2.4.2 NON-ECONOMIC AND FINANCIAL MEASURES FOR THE MANURE BASED DIGESTER

Measures for technical barriers

- **Barrier:** The nature of gas generated
- **Measures:** Build awareness on the nature of gas generated from waste of animals among workers

The non-financial measures associated with biogas range from societal misconceptions on the nature of the gas to that of the awareness on the economic benefits that can be obtained from investing in biogas. Firstly, many stakeholders feel that biogas is a messy gas that should not be used for cooking and other activities associated with food. This misconception can be allayed through careful and convincing information sharing and through visits to existing sites where the gas is actually being used. The evidence is real on such sites as the natural gas produced reveals no such smell. On the other hand, though, workers on the farm have a taboo of dealing with such a system where waste has to be fed into the system almost daily.

- **Barrier:** Small size of waste input
- **Measures:** Appropriately size systems for waste feed stock

It is now possible to invest in appropriately sized commercial grade biogas systems or to construct custom made systems. By so doing, systems can be optimized for the size for the farm, thus providing efficient use of the system. This will also ensure that the load or end-use of the gas can closely match the quantity of the gas produced. The sizing and eventually close matching of supply to end-use will be critical to the success and economic viability of investments in small biogas systems.

- **Barrier**: Labor intensive
- **Measures:** Conduct productivity study to analyze how labor intensity can be reduced

Workers on the farm see the process of feeding a biogas system with waste as extra work that needs extra compensation. This can be addressed through effective productivity surveys to see where savings in time and effort by workers can be reduced. In other words, the gathering of waste feedstock and the eventual feeding can be done more efficiently and effectively. On small farms where the feedstock is minimal, then this work will not significantly increase costs. In many cases it is now about changing what is done with the waste after pens and plots are cleaned.

Measures for information and awareness barriers

- **Barrier**: Lack of awareness
- **Measures:** Publish results of current project and use of training future investors

There are a number of demonstration projects occurring in the market. However, the results of these projects are not widely known or disseminated. In this regard, measures

[5] USD 1,700 is equivalent to 203,000 vatu

can be put in place that project results be published in user friendly formats, such as information brochures to be used for marketing processes. Additionally, workshops and seminars should also be held to impart the knowledge and skills gained from these projects. Moreover, visits and hands-on training and demonstration of these projects should take place regularly to ensure that potential investors have a comprehensive understanding of the nature of biogas systems.

2.4.3 ECONOMIC AND FINANCIAL MEASURES FOR COMPACT BIOGAS DIGESTER FOR URBAN HOUSEHOLDS

Measures for Cost barriers

- **Barrier**: High Capital Costs
- **Measures**:
    - Reduce or eliminate Government taxes on imports and local fabrications and constructions. The government imposes tax on all local fabrications and constructions. Concessions in the form of tax reduction or waivers would be an incentive for easy diffusion of the compact biogas technology. The national economic benefits of introduction and propagation of these technologies offset any government revenue loss due to such concessions.
    - Availability of donor funds on concessionary terms for these sectors. Donor agencies having a mandate to promote these technologies in the developing countries need to consider providing funds to private sector institutions on concessionary terms to access these technologies. For example, UNDP has been in fore front to promote renewable energy in Vanuatu. Such funding, if necessary, may be channeled through the government treasury and through commercial banks.
    - Adoption of financial mechanism Soft loans will be an important measure to assist with the diffusion of biogas technologies. These technologies will be generally small scale and can be locally constructed or small scale commercial systems imported. One project report suggests that investment required for the importation of a small unit can range between USD1,700[6] to USD1,900, with a further USD 370 required. Therefore, an installed cost may range between, USD2,000 to USD2,200. Such an investment and up to about USD3,700 can be considered to be a soft loan and the intent of such a loan should lend itself to lowered interest rates. The financial incentive of accelerated depreciation and interest rate drawdown can be applied.
- **Barrier**: Difficulties to access finance
- **Measure**:
    - MCCA should establish a levy on fossil fuels or used existing levies (e.g. Rural Electrification levy, Road Toll levy) and use such proceeds to establish a Fund to provide low interest finance for Renewable Energy and Energy Efficiency projects.
    - Establish specific renewable energy Act to promote renewable

Currently renewable energies are not mentioned in the Electricity Act No. 13 of 2010. Provisions of renewable energy are not strong enough to provide the needed impetus to promote renewable energy. Therefore, it is recommended that the MCCA should consider establishing a dedicated law that may promote use of renewable technologies including biogas digesters.

2.4.4 NON-FINANCIAL MEASURES FOR COMPACT BIOGAS DIGESTER FOR URBAN HOUSEHOLDS

Measures for technical barriers

- **Barrier:** Technology not fully developed
- **Measures**: Relevant government institutions to develop and resolve all technical issues related to compact biogas digester. These may include, inadequate of mixing, optimum resident time, proper sealing of the bio digester, optimum amount of water to be used, pressure regulation etc.

The technology to generate biogas from easily biodegradable biomass is a new technology for Vanuatu. Biogas digesters comes in various sizes and shapes. It is proposed to introduce a compact biogas digester to be used in urban households with suitable feed material to generate

[6] USD 1,700 is equivalent to 203,000 vatu

adequate biogas to enable meeting the daily energy demand of an average family for cooking. ARI digester has already been tested at Ardhi University and found that it is a viable for using food leftover in households. But the amount of food left over in an average household is inadequate to generate the required amount of gas. Research is required to identify additional raw materials to supplement the household leftovers.

Measures for Social Barrier

- **Barrier**: Convenience to and acceptability by consumers not evaluated
- **Measures**: Relevant government institutions should develop communication strategy, awareness materials and promotional strategies to ensure public acceptance of compact biogas digesters

The use of biogas to cook meals is not different to the use of LPG for the same purpose. The pressure of the gas in biogas generated in a digester is very much lower than the pressure of LPG. A simple adjustment at the burner would solve this problem. Biogas generated from Compact Bio digester does not give any unpleasant smell. Hence there will be no resistance from the users on these two issues. However, urban dwellers may be reluctant to feed 2 kg of leftovers daily into a digester, particularly, if the digester is kept outside the kitchen. As the price of LPG is continuously increasing, it is very likely that unban community would accept the little hassle of feeding the digester than buying LPG. This aspect need to be evaluated and appropriate action be taken to ensure that this technology is acceptable to the masses.

Measures for Information and awareness barrier

- **Barrier**: Private sector not informed of business viability
- **Measures**: Biogas digester technology has been promoted by public institution. The success of it will be limited as there are still work to fix large designs targeting institutions. For this technology to succeed, involvement of private sector is essential.

In order to address the above barrier, it is recommended that the relevant state institutions such as the DoE and other relevant institutions conduct economic and financial feasibility studies of these technologies and make the study results available to the private sector.

2.5 Linkage of the Barriers Identified

Two of the barriers identified for the two technologies are linked and this section provides a comprehensive overview of these linkages. In considering these linkages, the nature of the market and especially the small market size with few or no opportunities for economies of scale must be considered. Therefore, and as the technologies are market or consumer goods, the barriers may be similar in nature. In other words, the materials for the construction are imported, but with the compact biogas digester, local materials can be used to construct a system.

1. High Capital Cost

From this point of departure, the economic and financial barriers are intricately linked, and workshop participants agreed that for both biogas technologies these barriers were the most significant. Although this discussion can apply to both the systems, workshop participant agreed that the 'costing' issues were more significant for both technologies and this will be addressed subsequently.

A review of the barriers for the technologies in question shows that: 'high upfront cost' and 'insufficient/inadequate incentives' were the two main economic barriers. These barriers are linked from the perspective that lack of tax based incentives can contribute to the high cost of the technologies in question. In other words, the price of a biogas component comprises the cost of the items at the source market insurance and freight and other relevant taxes: VAT, General consumption tax and charges at the port. The importer and retailer will then have a mark-up, which is based on the business model of the importer and retailer. The importer and the retailer pass on all costs to the end user, however, they only have control of the mark-up and profits that they intend to accrue from the sale of the product.

Therefore, retailers and importers may have limited control over the final price to the end-user. The retailer/importer pricing will be done in such a manner that they maintain a viable, successful and competitive business. Secondly, importers may also source more affordable technologies on the global market. Biogas systems are also imported from China and Germany. Prices on the local market can also be controlled through importers finding discounts for bulk purchases and other market mechanisms to reduce the cost of technologies. However, this is limited as the market is small and bulk buys in the true sense may be still relatively small quantities. But taxes and other charges are fixed.

The other option for controlling or even lowering the 'high upfront cost' identified can be achieved through government interventions. This will address the issue of incentives to encourage the uptake of these technologies. However, it was suggested that government may not be in a position to afford tax incentives through tax exemptions.

2. Information and Awareness

Therefore, the non-financial barriers and especially the ones associated with 'information and Awareness' are also linked to the two economic barriers discussed above. This barrier is hindering penetrating the local market especially outside of the main city areas of Vanuatu. Since the biogas technologies are capital goods, public awareness is very essential to diffuse these technologies well. However, the market information of these technologies cannot be accessed by people easily because people cannot be able to see this information in the public domain. Currently, the advertisement of these technologies cannot be able to see widely even in the city area although people from city areas can access information from supermarkets and some retail shops. Therefore, people who are living outside of the city area are far away to access the latest information about these technologies.

2.6 Enabling framework for overcoming the barriers in the waste-to-energy sector

The common barriers are already identified in the previous section. These common barriers are broad categories into (1) High capital cost due to import tax, and (2) Limited market information. The table 9 proposes an enabling framework for the common barriers.

Table 8. Common barriers and proposed enabling framework for Waste-to-Energy Sector

No	Barrier Dimension	Enabling framework	Technology
1	High capital cost	a. Facilitate tax reduction or tax removing scheme on importation of technologies in respect of Biogas Projects b. Provide incentives schemes to developers	Manure based digester, Compact biogas digester
2	Limited market information	c. Create promotional awareness campaign through various media	Manure based digester, Compact biogas digester

Enabling framework for common barriers in detail:

1. Facilitate tax reduction or tax removing scheme on the importation of technologies in respect of Biogas Projects

Providing enabling financial framework and import tax reduction will be an effective measure to overcome the barrier of high capital cost due to import tax. Biogas technology suppliers can be provided either a tax holiday or tax reduction plan for a limited period during the technology promotion time of applying energy-efficient products in the household. Any revenue loss will be compensated to the government by indirect saving through national-level energy saving and energy security improvement. Moreover, GHG emissions from energy consumption can be reduced.

2. Provide incentives schemes to developers

Further incentive schemes that may be employed to provide affordable finance for the biogas system investments. These include the accelerated depreciation and interest rate drawdown. The first incentive is intended to reduce on the taxes paid early in an investment. This reduction should accrue to more savings for the investor, especially commercial investor in for example the retailer sector. The second option: interest rate drawdown may be attractive to the individual household. In this regard, someone wishing to investment in a small scale biogas system will only pay interest on the portion of loans approved for the project. This should accrue to savings for the individual as they may only be required to finance the portion of the loan that they actual use for the project.

3. Create promotional awareness campaign through various media

As both Manure based digester and compact biogas digester technologies are market-driven products, public awareness is important to diffuse technologies well. To promote public awareness, a promotion campaign should be considered to do in a crowded area such as a supermarket, local market. Moreover, the media campaign is also an effective way of product marketing and promotion by using radio, TV, social network, etc.

Additionally, the public event can be facilitated in some days like World Environment Day, the Energy Open Day, etc. Also, the information on the technology can be spread through awareness-raising materials like posters, pamphlets, brochures, billboards, etc. These activities could be done during the energy program for biogas technology with private sectors to promote technologies.

General comment: it will be helpful to clearly describe the stakeholder consultation process and how to came with the results.

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67 Physical Planning and Development Control Act (1986)

68 Land Acquisition and Compensation Act (2006)

69 Local Government Act (2002)

70 Environmental Management and Conservation Act (2002)

71 Waste Management Act (2014)

National Regulations

72 EIA Regulation (2002)

73 Public Health Regulations (1975)

National Policies

74 Vanuatu National Energy Framework Policy (2015)

75 Vanuatu Climate Change and Disaster Risk Reduction Policy (2015)

International Treaties and Conventions

76 United Nations Framework Convention on Climate Change, UNFCCC (2018)

Annex I: Market mapping results

Figure 2. Efficiency Wood Stove market map

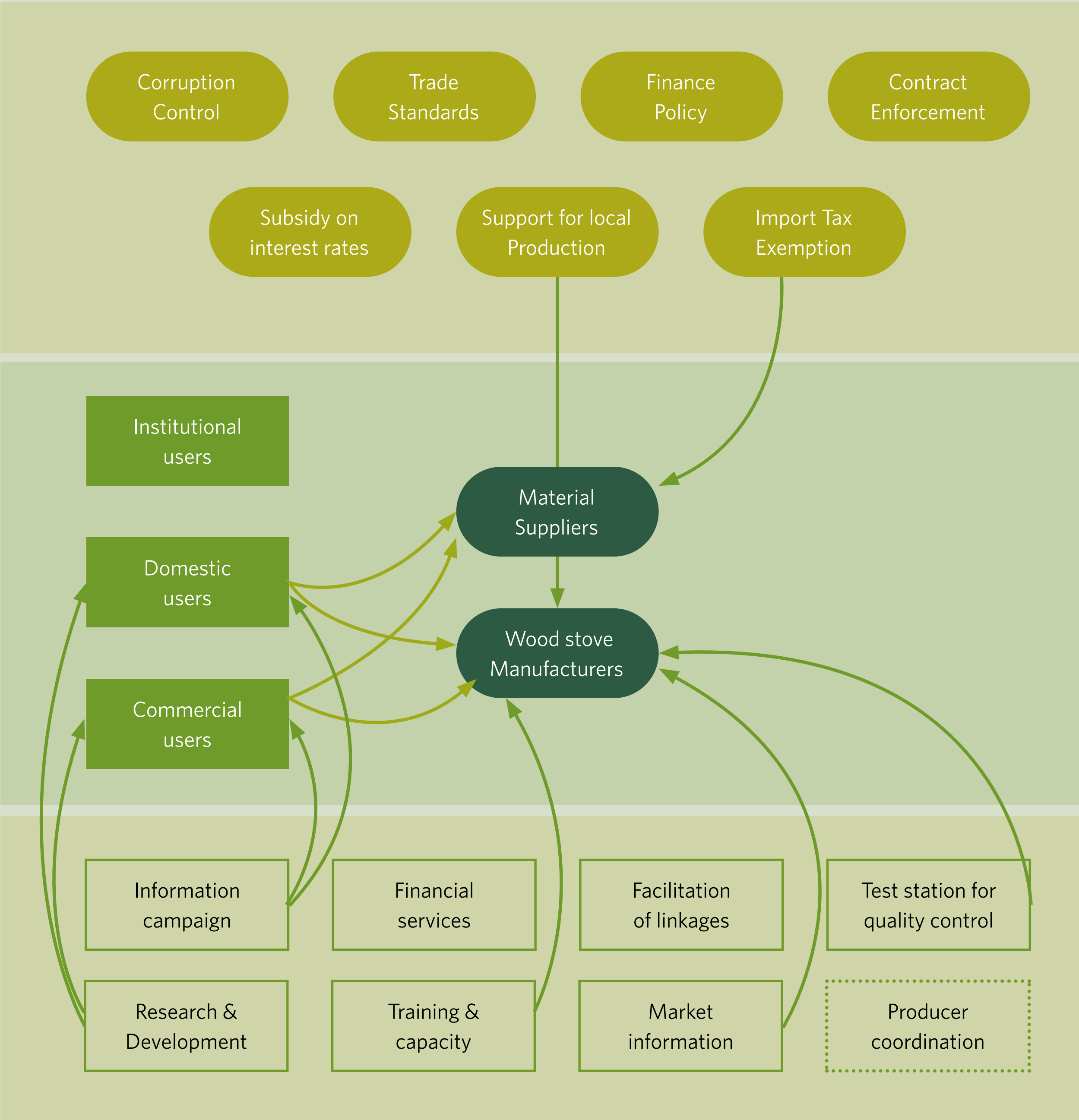


Figure 3. Battery Electric Vehicle market map

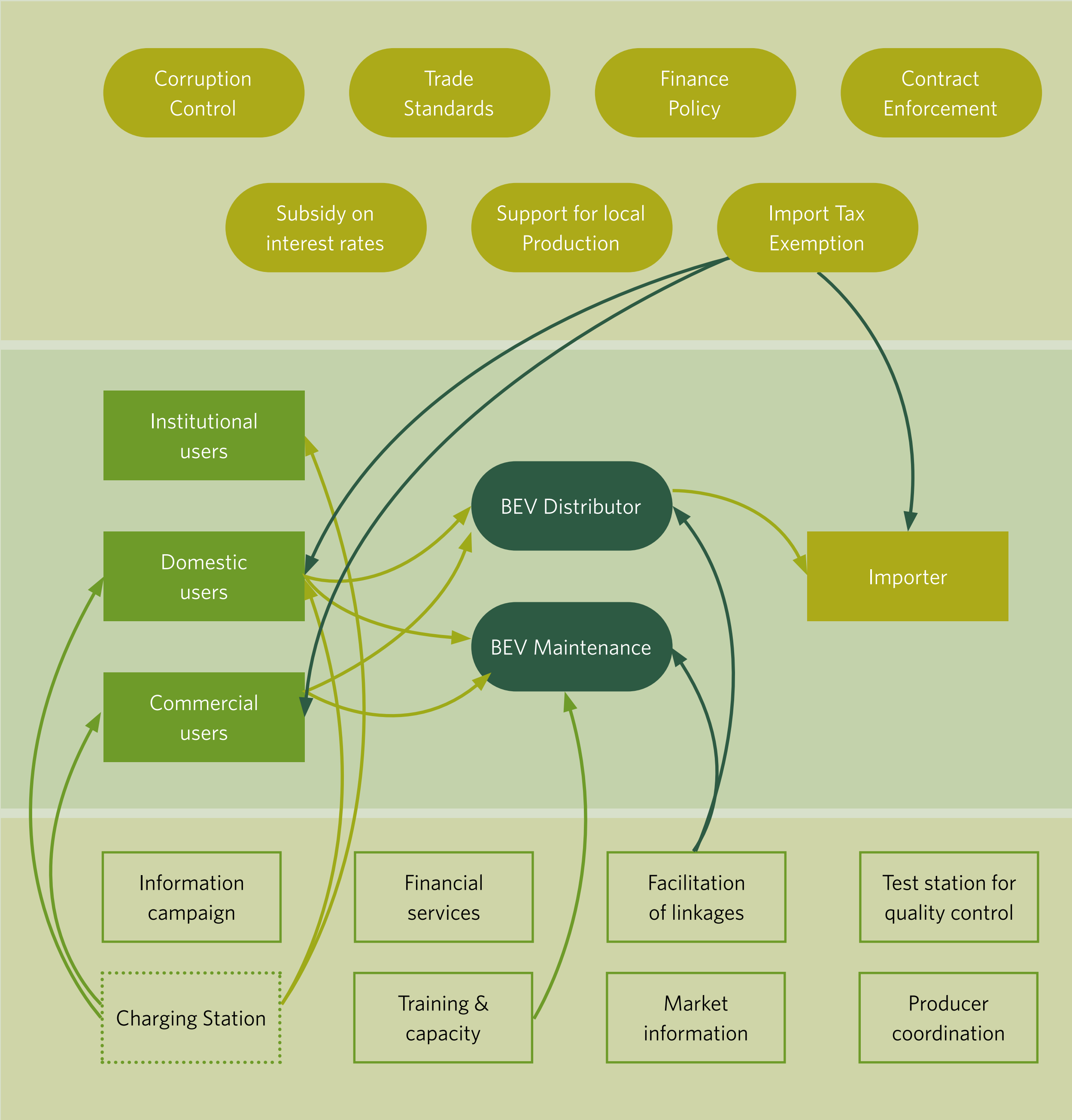


Figure 4. Manure based digester market map

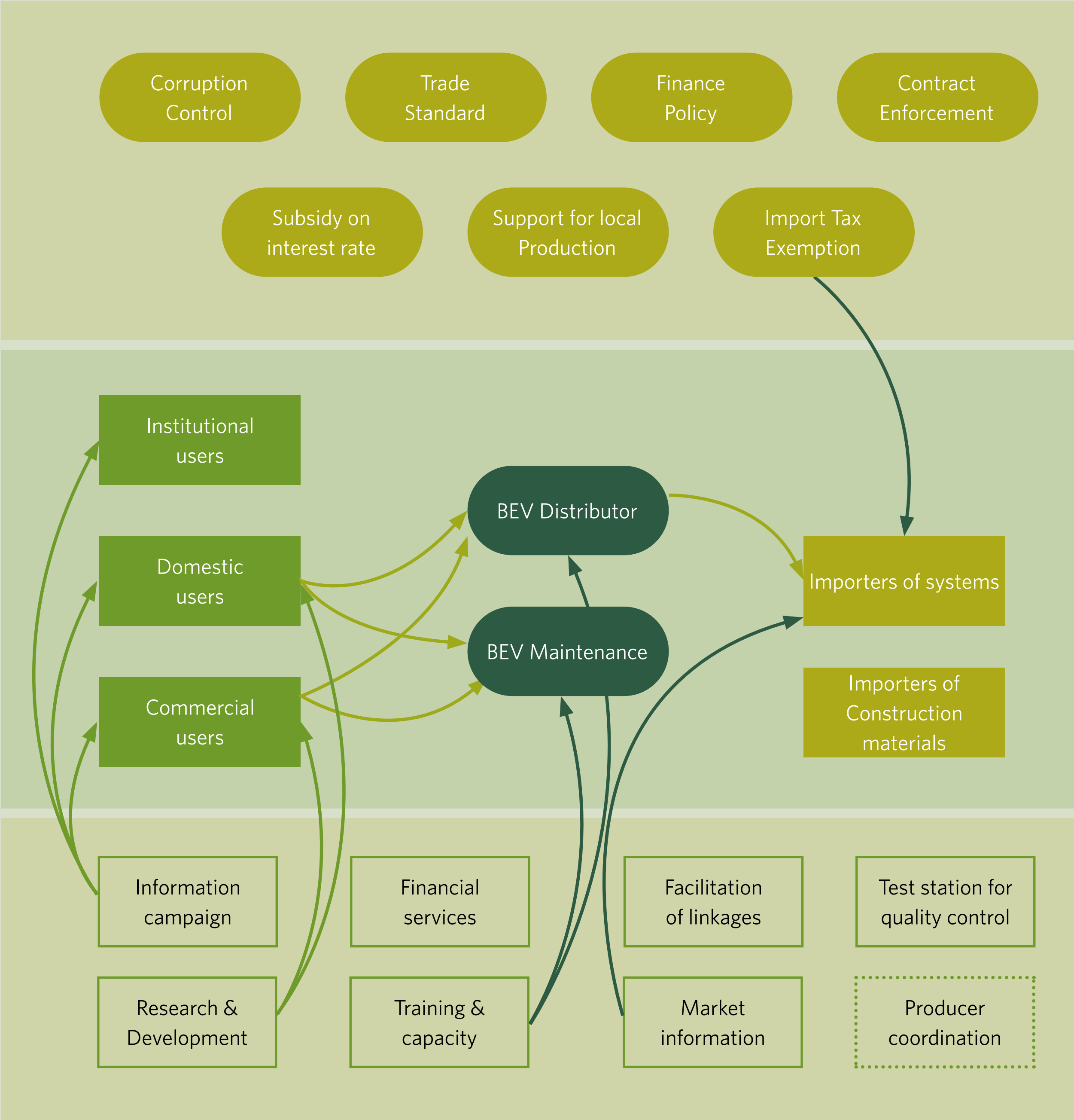
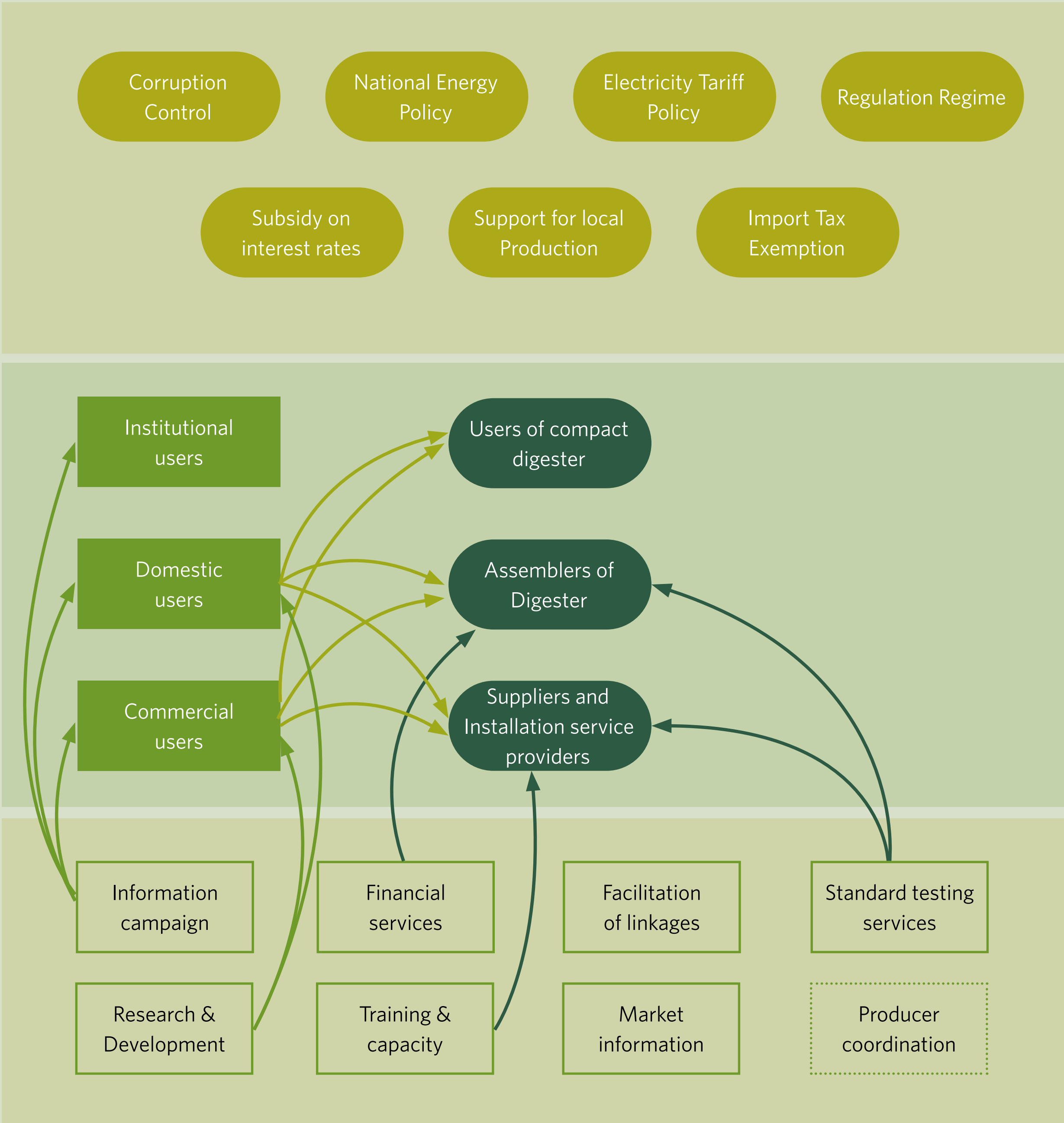


Figure 5. Compact biogas digester market map



Annex II: List of stakeholders

Table 9. Common barriers and proposed enabling framework for Waste-to-Energy Sector

Name	Affiliation	Designation	Email
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