THE KINGDOM OF SWAZILAND

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE TNA MITIGATION BARRIER AND ENABLING FRAMEWORK REPORT FOR SWAZILAND

May 2017

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Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
BAEF	Barrier Analysis and Enabling Framework
CHP	Combined Heat and Power
CIC	Construction Industry Council
FSE&CC	Federation of Swaziland Employers and Chamber of Commerce
IETC	International Environmental Technology Centre
LED	Light Emitting Diode
MCIAT	Ministry of Commerce, Industry and Trade
MCIT	Ministry of Commerce and Industry
MED	Ministry of Education
MEPD	Ministry of Economic Planning and Development
MFA	Ministry of Foreign Affairs
MHUD	Ministry of Housing and Urban Development
MICT	Ministry of Information and Communication Technology
MITC	Manzini Industrial Training Centre
MNRE	Ministry of Natural Resources and Energy
MOJ	Ministry of Justice
MPWT	Ministry of Public Works and Transport
MTEA	Ministry of Tourism and Environmental Affairs
PV	Photovoltaic
REP	Rural Electrification Programme
SACREE	Sothern African Centre for Renewable Energy and Energy Efficiency
SADC	Southern African Development Community
SCOT	Swaziland College of Technology
SEA	Swaziland Environment Authority
SEDCO	Swaziland Enterprise Development Corporation
SIPA	Swaziland Industrial Development Corporation
SWASA	Swaziland Standards Authority
TAP	Technology Action Plan
tCO2eq	Tonnes carbon dioxide equivalent
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNISWA	University of Swaziland
VOCTIM	Vocational Training Institute in Matsapha

Units

Abbreviation	Meaning
kg	Kilogram (1 000 g)
t	Ton (1 000 kg)
Mt	Mega ton (1 million ton)
Gt	Giga ton (1 billion ton)
CO_2e	Carbon dioxide equivalent
W	Watt
kW	Kilowatt (1 000 W)

kWh	Kilowatt-hour
MWh	Megawatt-hour
GWh	Gigawatt-hour

Executive Summary

This report outlines the barriers that could hinder the adoption, development and deployment of the prioritised mitigation technologies in the TNA exercise in Swaziland. It also discusses measures to overcome these barriers. And finally provides a framework to overcome the barriers.

The TNA prioritised technologies in Energy, waste, and Land use, land-use change and forestry. The top three technologies in the energy sector and two in waste and land-use change and forestry were further developed for the identification of barriers and development of the enabling framework. These seven technologies are to be further developed to technology action plans.

The technologies selected for further analysis and development to technology action plans in the energy sector, are energy efficient buildings, combined heat and power using biomass fuel in the form of bagasse, sugar cane trash and wood chips, and solar PV. The energy efficient building addresses the building envelope and an ad hoc manner includes solar water heaters. The solar water heaters were not included in the original selection of technologies but with further discussion with stakeholders it was found that they were actually important. Only the cost benefit analysis of the solar water heaters is included.

In the waste sector the technologies selected include waste sorting and composting technologies, and in the land use change and land use change and forestry, agroforestry and urban forestry were considered.

1. **Root causes for low deployment of the technologies**

   The consultant was able to identify the root causes of the low deployment of the technologies, through discussions with stakeholders after the workshops were conducted and these are listed below. They stand to be validated by the stakeholders together in one room.

Energy efficient buildings: Technology is not familiar to many and needs to be widely publicised, and architects, builders and building material suppliers upskilled.

Combined heat and power: There is market uncertainty for the energy produced and therefore the companies are not ready to fully invest as they are not sure of future prices and markets.

Solar PV: The use of the electricity produced from solar PV is limited without net metering.

Waste sorting: There are limited opportunities for recyclable materials in Swaziland.

Composting: The economic benefits of the technology are not well understood in Swaziland.

Agroforestry: The benefits of the technology are not well understood.

Urban forestry: The overall benefits are not well appreciated by the administrators and urban dwellers

2. Barriers to the deployment and diffusion of the technologies

The barriers and measures for the selected technologies are shown in Tables 1to 3, and the enabling framework is shown in Table 4.

Table1: Barriers and Measures for energy efficient buildings

Financial Barriers	Measure(s)
Perceived high cost of building materials	• Do cost analysis of energy efficient buildings to determine the actual costs of materials and construction. • Develop local materials to build energy efficient buildings.
Nonfinancial barriers	**Measure(s)**
Low awareness of the benefits of energy efficient buildings	• Conduct workshops and road shows for the industry and the public for education and dissemination of the information obtained from the studies conducted for the first barrier.
Limited skills for architects, builders and building material suppliers	• Capacitate architects and builders with necessary information and skills to design and construct energy efficient buildings. • Help building material suppliers with the know how to acquire building materials for energy efficient buildings.
Poor enforcement of the building code and municipality by laws	• The Housing Act is silent on energy efficient buildings. The building code and municipal bylaws were enacted without amending the Act and therefore render them unenforceable. The Housing Act must be amended to enable the enforcement of the existing building code and municipal bylaws.
Poor regulatory framework	• Formulate an appropriate regulatory framework for energy efficiency in particular energy efficiency buildings.

Table 2: Barriers and measures for combined heat and power technology

Financial Barriers	Measure(s)
High capital cost of technology	• Use the public private partnership policy to provide government guarantees for CHP power plants. The private power

	producers can therefore have access to low interest loans. • Develop capacity to access low interest funding and grants through climate change mechanisms such as the Green Carbon Fund and others.
Uncertainty in the power market or perception of it (this can be due to unavailability of the power market, lower prices of import power or establishment local coal thermal power plant)	• The Government could submit a commitment to the Southern African Power Pool of the potential future power production capacity of the country to secure future power markets for local companies. That way it can secure markets in the SAPP for biomass generated electrical power. The power producers should in turn make binding commitments to governments on the intended power production. • The Government could guarantee that power produced locally at a reasonable price would have a ready market locally, to reduce the risk of the dependence on foreign electricity supply where the supplier government may have a change of policy that can negatively affect the supply. • Develop capacity for the certification of carbon credits for local green power technologies in order to access carbon markets that can improve the cost competitiveness of such power production.
Nonfinancial barriers	**Measures**
Absence of an integrated power generation resource plan	• Develop a national power generation resource plan. This plan can set clear targets for the different power generating technologies so that players in the market can identify opportunities for investing.
Uncertainty of biomass resource availability (biomass shortages can be caused by severe drought and forest fires)	• Grow wattle and bamboo on marginalised lad to be used in times of biomass shortages. • Prepare boilers for co-firing with coal. • Establish stand-by natural gas power plants. There is plenty natural gas reserves in neighbouring Mozambique.

Table 3: Barriers and measures for solar PV technology

Financial barriers	Measure(s)
High cost of solar PV equipment	• Provide support for local or regional production of components. Components could be purchased in bulk as basic parts and assembled locally or regionally, which ever could be most cost effective price could possibly come down. Reduction in price could come from bulk discount prices, lower shipping costs per unit and lower labour costs • Provide regional coordination for the technology to enable bulk purchasing of parts and harmonization of solar PV standards and training which can overall result in lower prices. This coordination can be done through SACREE and the SADC • Demonstrate to property financers that solar PV systems add value to property. If property financing institutions could be satisfied that solar PV systems add value to property, and that the technology is mature and reliable, they can be financed through regular property financing. Property finance interest rates are always lower than normal bank loan interest. That can reduce the system costs. • Subsidise the cost of solar PV equipment through carbon credits. Solar PV CO_2e savings are relatively easy to determine once the system has been installed.
High cost of lad for solar PV installations	• Develop a land-use policy that would ensure that land is used efficiently for communal and national benefit to win support from traditional structures who are somewhat opposed to the full Land Policy 1999. Efficient land allocation and settlement would have many benefits some of which include the better provision of essential services, increased land availability for grazing and crop production, and other development projects such as solar PV installations. • Find creative sites for solar PV installations. Such sites include parking lot roof tops, building walls, recreation areas, space between runways at airports. Etc.
Low price of domestic electricity	• A cost reflective tariff must be applied for domestic electricity users to encourage electricity saving and adopting solar PV technology so save on the electricity bill. Currently in Swaziland, businesses pay higher electricity tariffs in order to subsidise domestic users even the wealthy. A lifeline tariff exists for the poor in Swaziland, that should be maintained
Potential low price of imports electricity	• This could be a perceived barrier in the sense that in neighbouring South Africa companies have been bidding to ESKOM, the state owned enterprise mandated to produce and distribute power, at \$0.05 per kWh. The prices of solar PV power are already low and coming down. • Swaziland must prioritise energy security over price, and then address generation cost reduction once secured.

Nonfinancial Barriers	Measure(s)
Solar PV has limited use with expensive storage	• Provide net metering. Net metering can enable solar PV installers to realise the full benefit of solar PV which will be a reduction in their electricity bills.
No regulatory framework to directly support the uptake of solar PV	• Develop a regulatory framework to enable net metering. Provision of net metering can definitely increase the uptake of solar PV technology. There companies already that are generating excess power like Ngwenya Glass that are trying to lobby for the net metering policy. Net metering is a billing mechanism that allows electricity customers who also generate their own electricity to feed their excess power to the public grid. It measures the difference between power consumed from the grid and the power fed to the grid by the customer. The customer is then charged for the net electricity consumed. Net metering rules, credit and rates vary from one country to another and could vary even between different regions in the country. Net metering programs can be voluntarily offered by a utility company through regulatory legislation. The energy regulator should consider the establishment of the net metering policy as means to support for national energy security.
Poor supply chain	• Provide business models for the solar PV business. Use existing institutions like UNISWA, SEDCO and SCOT to develop business models suitable for starting and running solar PV businesses. These business models could cover sourcing of products, local assembly, sizing systems and installation and maintenance of solar PV systems. Outstanding graduates from tertiary institutions or entrepreneurs can be selected to be exposed to these business models for further implementation.
Limited local technical skill for installation and maintenance	• Provide training and accreditation of solar PV installers Tertiary institutions should develop curriculum on the installation and maintenance of solar PV systems. Organisations and individuals who undergo such training could apply for accreditation and undergo tests for certification.
Limited research and development on solar PV systems	• Increase solar PV research and development at tertiary institutions • Increase solar PV research and development at tertiary institutions • Tertiary institutions should be supported through research grants to take on their leading role of conducting research and development on solar PV and provide information in order to bring solar PV technology to the fore.
Inadequate public knowledge on solar PV systems	• Conduct workshops and road shows on solar PV technology demonstrating realistic capabilities of solar PV. The Energy Department of the Ministry of natural Resources and Energy

	could hold workshops and road shows to increase the knowledge of the people on solar PV technology. The demonstration must be designed to bring awareness on the functionality, misconceptions and limitations of the solar PV technology.
Non uniform quality of products and inconsistent quality of installation	• Develop standards for solar PV equipment and installation. There is need to establish standards for all aspects of solar PV technology. The standards should cover the components and the installation of the systems. • Establish training, testing and accreditation institutions for solar PV components and installation and maintenance.
Security problems from theft and vandalism	• Adequately support the panels to require effort and time to remove them. • Provide adequate lighting to ensure that people who try to vandalise the panels can be easily visible. • Elevation can also be a deterrent to vandalism and theft.
Limited knowledge of grid compatibility of solar PV systems	• Improve knowledge on solar PV grid compatibility. Grid-tie solar PV is practiced in many countries (e.g. North America, Europe, Japan Australia etc.) for commercial entities, institutions and domestic solar PV systems. Train engineers and technicians to acquire the appropriate knowledge to properly select and install equipment to interface solar PV systems with the national grid.
Solar PV power generation is intermittent	• Measure: Learn from best practices from around the world. Solar PV is now used worldwide, and everywhere it is an intermittent power source. Methods of coping with high supply during the day, low supply on rainy and cloudy days and no supply at night should be obtained from countries like the USA, Australia and Germany where solar PV is widely used.
Solar PV is vulnerable to extreme weather conditions	• Train installers on best practices for minimising extreme weather effects on solar PV. The installers should be properly trained on mounting panels to withstand local storm conditions. The adverse weather conditions are wind storms and hail. Proper training of installers can help minimise the effects of these. • Where the risk is high use appropriate technology. There are some solar panels that are less likely to be damaged by hail such as thin film and amorphous silicon cells. Also, solar cells covered with tempered glass that can reduce the effect of hail.

Table 4: Barriers and measures for waste sorting technology

Financial Barriers	Measures
High capital costs of waste sorting equipment	• Develop capacity to source funding from available local, regional and international sources. The total cost of the

	operation including maintenance will be around 4 million US dollars over the life of 20 years of the equipment. Such an amount can be sourced from carbon funding mechanisms under the UNFCCC and the SC. The country can provide the land. Employees of the sorting unit can be paid from sold recyclables.
• ***Low demand for some recyclable materials***	• Develop a waste-to-energy project for combustible waste. If the waste is combustible considerations can be made for a waste-to-energy project where such waste can be burnt in a boiler system to generate electricity. Even if not profitable such a system can be subsidised by the amount equivalent of saved landfill space and the price of carbon credits generated. • Develop local recycling facilities. If the local waste is collected for recycling in neighbouring countries like South Africa, it may be worthwhile to invest in a local recycling plant. Such a waste will not be subjected to high transportation and export costs, and therefore could be viable. If not profitable such a plant can be subsidised by the equivalent amount of landfill space saved and carbon credits generated.
Low landfill gate prices	• Sensibly increase landfill space charges. In one engineered landfill, the price was found to be $7.79 per tonne of waste. Such low prices may reduce the incentive to reduce waste by companies and other organisations. A higher tariff may increase recycling, reusing and upcycling and thereby reducing the amount of waste to the landfill. On the other hand, sorted clean waste can be made to attract a rebate to reduce high landfill charges if instituted. The price increases should not be prohibitively high to encourage secret dumping in undesignated sites.
Nonfinancial Barriers	**Measures**
Inadequate skills for Operation and maintenance of automatic waste sorting equipment	• Provide training to relevant personnel. To address the issue of relevant skills, the suppliers of the said equipment will have to come to train the personnel on site on how to maintain such equipment. People with the right background and aptitude must be selected for the training on all the aspects of the equipment.
Inadequate knowledge about recycling opportunities	• Provide national education and raising awareness on waste management at different levels. There will be need for national campaigns on the handling of waste. This will be done in all government agencies, industries, municipalities, schools, institutions and communities. Funding for such shall be sourced from funding mechanisms of relevant international conventions.
Bad habits	• Increase sensitisation campaigns on environmental and health effects of waste. Bad habits are primarily due to

	lack of sensitisation. The national campaigns can go a long way in addressing people attitudes towards the handling of waste.
Inadequate variety of facilities for recycling	• Train personnel on recycling technologies. Train people on recycling technologies. Provide these people with knowledge on best available techniques (BAT) and best environmental practices (BEP) to address different waste streams around the world. Information gathered can reveal possibilities to handle such waste and stimulate entrepreneurship in the waste management sector.
No strategies for waste separation for reuse, recycling and upcycling	• Develop strategies to enable small communities to benefit from reusing, recycling and upcycling of waste. Small communities do not at all have means to recycle waste except returnable soft drink and alcohol bottles. Small communities could be encouraged to stockpile recyclable waste for collection at determined intervals. Money collected from such efforts could be used to fund community projects.
Inadequate regulatory framework to encourage waste separation for reuse, recycling and upcycling	• Develop a regulatory framework on sorting, reusing, recycle and upcycling of waste. The government must develop a regulatory framework to drive the sorting, reuse, recycling and upcycling of waste. Such a regulatory framework must include incentives for doing such.

Table 5: Barriers and measures for composting technology

Financial Barriers	Measures
High cost and difficulty accessing finance	• Develop capacity to source funding from available local, regional and international sources. • Means to attract donor funding for pilot projects must be put in place. • Government could provide guarantee schemes for low interest loans for composting technology through funds from donor organisations or climate change mechanisms.
Fear that feasibility studies are overly optimistic	• Develop capacity within existing institutions to conduct feasibility studies with stringent requirements.
Nonfinancial Barriers	**Measures**
Low adoption of waste separation (leads to possible contamination of organic waste)	• Simultaneously promote the waste sorting technology and encourage the separation of waste at source to increase the availability of clean compostable waste
Scepticism on the quality of the compost product (product could be suspect to heavy metal contamination and not	• Introduce quality management systems. There has to be a quality control system for composting. The first step should be the selection of uncontaminated organic matter from source and ensure that this

comparable to standard commercial fertiliser)	matter is not mixed with municipal general waste. • Atomic and molecular spectroscopy can be used to monitor the level of heavy metals and pesticides in the final product. Microbiologists can be engaged to monitor the presence of pathogens. • The quality of the fertiliser can be analysed in existing institutions.
Low awareness of the composting technology	• Conduct campaigns to promote organic waste composting. Some incentives can be made to encourage the separation of waste at source to promote composting both in the home and at a large scale, and may be offer money for clean organic waste.
Inadequate skills on the composting technology	• Educate and train people on composting technologies. People and organisations must be educated on the composting technologies both at the domestic level to commercial scale.
Difficulty obtaining composting sites (Residents may suspect that the composting site will attract animals, pests, cause odours and lower property values.)	• Involve stakeholders at all levels. When promoting composting, communities must be involved from the policy level, strategy formulation level all the way to the regulatory framework development. Measures to deal with the perceived and real fears must be put in place. Pilot composting facilities must be established at farms to demonstrate the adoption of the identified measure to deal with the fears. Government farms could be the ideal places to start with.
Ignorance about the importance of composting (as a climate change mitigation technology and the value of the compost material)	• Make households, entrepreneur and institutions aware of the benefits of composting. The general public needs to be educated about the benefits of composting which includes savings in landfill space, greenhouse gas emission avoidance and availability of a cheap fertiliser.

Table 6: Barriers and measures for agroforestry technology

Financial Barriers	Measures
Insufficient capital and low access to finance	• Donation campaign for tree seedlings. A local donation campaign can be organised for seedlings. There has been tree planting campaigns in Swaziland where free tree seedlings have been provided to people before. Enhancing such activities can solve the issue of availability of tree seedlings. • Solicit for funding from donors, grants, government support, and climate change mechanisms for fencing

	materials, protective gear for local labour, borehole or earth dam if necessary, and pest control measures.
Long time before realising benefits (communities could see the engagement of several years without returns to be a financial burden – for watering, weeding, pruning and pest and disease control)	• Engage the organised community labour force. Fruit trees need the most care in the first year and first two winters. After one and a half years the trees will not need to be watered all the time as their roots will be long enough to get water from the ground. The requirement for weeding will also be minimised once the trees are taller than the weeds. Pruning is only done once in a while. The existence of a community labour force will be important to encourage farmers to engage the agroforestry technology.
Nonfinancial Barriers	**Measures**
Low interest in implementing agroforestry for climate change mitigation	• Emphasise the tangible benefits to the community and make climate change mitigation to be a bonus. The tangible benefits to be emphasised could include availability of fruits or timber and income generating opportunities. Other benefits include shade soil fertilisation from falling leaves and others. Also instil in their minds that their efforts result in climate change mitigation.
Low water resources	• Ensure water availability prior to inception of the project. Before a place is earmarked for agroforestry, the issue of water availability have to be solved. Either the water is available naturally or some means to me the water available must be made. One way would be include boreholes in the project or to build earth dams to catch rain water that can have enough capacity to last till the next rain season. There will of course be problems if the community will want to use the borehole or earth dam water for other purposes than what it is intended for. If such problems are perceived the agroforestry should not be implemented in that community unless a solution is found.
Low availability of land	• Maximise the use available land resources. The literature shows that the average available land for small holder farmers on SNL is 1.5 ha. Taking only 1.5% of that land and growing the trees in the periphery may solve the problem of low land availability. Trees can also be scattered inside the fields.
Low awareness of the benefits of agroforestry	• Conduct awareness raising and training on agroforestry. The awareness raising and training on the agroforestry technology may reduce the scepticism amongst the farmers. Information on the raising exotic fruit trees must be sourced and disseminated to the farmers. When it comes to indigenous trees this could be a challenge. Extension workers can advise through observations of areas where the trees grow naturally.

Infertile soils for agroforestry	• Use local fertilising resources. Use locally available resources such as cattle and chicken manure, compost and nay available biodegradable carbon source.

Table 7: barriers and measures for urban forestry

Financial Barriers	Measures
Unattractive for carbon markets	• Emphasize local benefits over international benefits in order to get approval for a local budget for funding the technology. By emphasizing local benefits of urban forestry residents may be motivated to adopt this technology and there would be no need to look for carbon markets to fund the technology. The benefits for the residents include aesthetic appeal, providing shade and acting as wind breaks thus reducing the energy needed for heating and cooling, having economic value when matured, and providing oxygen for better health, providing recreation and food, dampen noise levels, reduce air pollution locally, clean the urban air by settling out, trapping and holding particulate pollutants like ash, smoke and dust, protects areas prone to soil erosion and reduce water runoff and increasing ground water recharge.
High cost of planting and maintaining trees	• Establish a fund to pay for the urban forestry. Have open forums with the residents on how the city would be without the trees and ask for donations to keep the city green. Occasionally ask for donor funding using documentation that shows that the carbon sequestration capacity of the city increases from year to year.
Nonfinancial Barriers	**Measures**
Inadequate knowledge about urban forestry technology by administrators and community	• Provide education and training on the technology. Provide education and training emphasizing the local benefits of this technology, while making climate change mitigation a bonus. Challenge the myths commonly held to be true about the difficulties of planting trees in urban areas and publicize best practice about how to overcome them.
Inadequate support for technology – little or no resource allocation	• Conduct education and outreach on the urban forestry technology. Source donor funding to conduct education and raising awareness on the benefits of urban forestry. This education and awareness raising may not be stand-alone but could include other programmes in the UNFCCC and other conventions where synergy exists.
Conflict between the land owner and municipalities in	• Involve the stakeholders at all levels. Stakeholders must be involved from policy formulation through

the implementation of urban forestry	development of the regulatory framework to the implementation strategy. That way the residents can take the entire project of urban forestry as theirs. The trees have to be seen by residents as part of the urban infrastructure. Trees must be planted in areas where they are unlikely to contribute to building damage by their roots, falling on buildings or leaves, flowers and fruits falling on undesired areas. More effort is needed on the part of urban forestry managers and professionals to collect information and generate relatable messages about the urban forest specific to different audiences including elected officials and the public. Taking care to target messages will ensure that urban forestry information is understood and applicable to these different audiences and hopefully gain the attention and interest of leaders and the public.
Risk of urban tree mortality and poor health due to stressful conditions of the urban environment	• Engage professional in selecting the type of trees for specific areas. Professional must be engaged to determine the right trees for each specific area. Some trees are very resilient and can thrive under difficult conditions such as limited root space, shading, partially contaminated soil etc.

3. Enabling framework for to overcome the barriers

The enabling framework to overcome the barriers is given inn Tables 8 to 13.

Table 8: Enabling framework to address common barriers in the energy sector

Barrier	Enabling framework	Role players
High capital cost • ***Energy efficient building: high cost of building;*** • ***CHP: High cost of technology;*** • ***Sola PV: high cost of equipment***	1. Develop business models to demonstrate to local financial institutions the viability of mitigation technologies for financing	MTEA, DOM, MEDP, SEDCO, SIPA and UNISWA
	2. Develop skills to access low interest capital from climate change mechanisms	MTEA, DOM, MEDP and UNISWA
Low awareness of benefits of technologies	1. Develop awareness material addressing each stakeholder segment in the country 2. Conduct education and training on the climate change mitigation technologies stressing their tangible and climate	MTEA, DOM, MEDP, UNISWA, MED, CIC and SEA

	change benefits 3. Use available platforms such as organised games, community meetings, print and electronic media, trade shows etc. to disseminate information	
Inadequate level of skills in the country	1. Conduct climate change skills audits to determine the needed skills in the country 2. Conduct climate change skills development and capacitation of low skilled qualified personnel for prioritised technologies	MTEA, DOM, MEDP, SCOT and UNISWA
Inadequate regulatory framework	1. Develop policies and regulatory framework to address local needs while benefitting climate change mitigation for each of the technologies 2. Develop enforcement mechanisms for the regulatory framework through incentives, penalties or both for each of the technologies	MTEA, DOM and MOJ, CIC, FSE&CC and MHUD

Table 9: Enabling framework for barriers specific to energy efficient building technology

Barrier	Enabling framework	Role players
High cost of building material	1. Conduct research and development for locally produced energy efficient building materials 2. Develop a different tax regime for products according to their energy efficiency ranking	MTEA, DOM, CIC, UNISWA and SCOT

Table 10: Enabling framework for barriers specific to CHP technology

Barrier	***Enabling framework***	***Role players***
Market uncertainty or perception of it	1. Government guarantees the purchase reasonably priced locally produced power for energy security 2. Government commits locally produced extra power to the Southern African Power Pool	MTEA, DOM, MNRE, FSE&CC, and UNISWA
Uncertainty of biomass resource availability because of forest fire risks and drought	1. Plan for contingencies for periods of low biomass availability, like for instance a stand-by natural gas power plant	MTEA, DOM, MNRE, DOF, FSE&CC and UNISWA

Table 11: Enabling framework to barriers specific to Solar PV technology

Barrier	Enabling framework	Role players
High cost of equipment and Solar PV has limited use	1. Provide support for regional standards to allow high volume of components at low prices. 2. Encourage local assembly of components. 3. Implement net metering and this will be a sufficient motivation for solar PV and directly addresses the barrier of limited use.	MTEA, DOM, MNRE SIPA, FSE&CC, SEC, SERA and SWASA,
High cost of land	1. Find creative sites for solar PV installations	MTEA, DOM, MNRE and UNISWA
Poor supply chain; weak entrepreneurial skills; limited local technical skill for installation and maintenance; and limited research and development on solar PV systems	These barriers are all linked. The poor supply chain is due to limited local technical skills for installation and maintenance which results from limited research and development which comes with education and training on solar PV. 1. There must be increased research and development in solar PV coupled with education and training, and information dissemination to boost technical skills. 2. Business models must be developed for systems of different sizes must be developed and provided to individuals and businesses that meet certain criteria to boost the entrepreneurial skills and improve the supply chain.	MTEA, DOM, MNRE, SIPA, UNISWA, SEDCO and MEDP
Limited knowledge of grid compatibility of solar PV systems	1. Train engineers and artisans on dealing with compatibility issues for grid-connected solar PV systems	MTEA, DOM, MNRE, SEC and MEDP
Solar PV is vulnerable to extreme weather conditions	1. Adequately train installers on best practices for minimising extreme weather effects on solar PV. 2. Where the risk is high use appropriate technology in high risk of impacts use thin film solar PV technology.	MTEA, DOM, MED, UNISWA, and SCOT

Solar PV power is intermittent	1. Engineers and artisans have to be trained on handling intermittent power. The California in the USA, Germany and Australia are countries to learn from since they have large solar PV installations.	

Table 12: Enabling framework to overcome common barriers in the waste sector

Barrier	Enabling framework	Responsibility
Related to high costs, limited access to finance, and fear that feasibility studies are overly optimistic	1. Conduct proper feasibility studies that are very close to reality. 2. From the feasibility studies develop pilot projects to demonstrate the viability of climate change mitigation businesses in the waste sector. 3. Capacitate relevant local organisations and individuals on how to access local, regional, continental and international climate change funds.	MTEA, DOM, SEA, MEDP, DOF, SEDCO MOA and UNISWA
Related to inadequate knowledge, low awareness, ignorance, low adoption of technologies and bad habits	1. Provide education and conduct outreach programmes that can help capacitate people to be more knowledgeable on bad effects of improper waste management, means to properly manage different waste streams, benefits of proper waste management.	MTEA, DOM, SEA, MEDP, DOF and MOA, UNISWA
Low demand for recyclable materials	1. Have a technology expert group on waste issues. This group could conduct studies on waste treatment in the region and internationally to identify recycling and upcycling opportunities that are relevant for the local market. This expert group could constitute of people in the waste sectors of municipalities, company towns, the SEA and UNISWA. 2. Expose potential entrepreneurs in business opportunities that require some waste products as raw material inputs. 3. Develop strategies for accumulating specific waste resources in remote communities to quantities large enough to justify	MTEA, DOM, SEA, MHUD, MEDP, SEDCO and UNISWA

	transportation to recycling facilities. 4. Develop training programmes of waste upcycling. 5. Collect accurate statistics on different waste streams produced nationally in order to assist local entrepreneurs or international investors to determine the viability of waste minimisation businesses.	
Related to inadequate policy, regulatory framework and strategies	Develop appropriate policies, regulatory framework and strategies to address all aspects waste including waste sorting at source, reusing, recycling, upcycling and other waste treatment methods to be holistic.	MTEA, DOM, SEA, MEDP, MHUD, SEDCO, UNISWA and MOJ.

Table 13: Enabling framework to overcome the common barriers in the LULUCF sector

Barrier	Enabling framework	Responsibility
Insufficient capital or low access to funding	Capacitate relevant local organisations on how to accessing local, regional, continental and international climate change funds. There are numerous sources of funds for climate change activities such as the global fund, crowd funding, African Development Bank etc. Most people are not aware of these and how to access the respective funds. As much effort as possible must be applied to cushion the smallholder farmer to implement the technology.	MTEA, DOM, SEA, MEDP, DOF and MOA
Low awareness of the benefits of agroforestry and long time before realising benefits	1. There is need to educate and train agricultural extension officers on agroforestry 2. Conduct campaigns on the agroforestry technology 3. Develop demonstration sites for agroforestry 4. Conduct research on growing indigenous fruit trees 5. Raise awareness of the tangible benefits of agroforestry and make climate change benefits a bonus one	MTEA, DOM, SEA, MEDP, DOF, MOA, MOE, NGOs, UNISWA
Low water	1. Build earth dams in identified areas	

resources	2. Obtain funding for a boreholes and water storage facilities	
Low availability of labour to care for trees	Organise communal labour forces to help the community on various activities. Means to motivate these groups must be developed.	MTEA, DOM, SEA, MEDP, DOF, MOA, MOE, MNRE, NGOs, UNISWA, MOTA

Chapter 1 Background on Prioritised Technologies and Methodology for Barrier Analysis and Enabling Framework

1.1 Prioritisation of technologies

This report is on the second phase of the mitigation technology needs assessment (TNA) exercise for Swaziland that began in 2015. The first phase was an extensive stakeholder consultation to identify and prioritise relevant climate change mitigation technologies for Swaziland. The identified technologies had to be in line with national priorities for the country. The country's priorities are around poverty alleviation, job creation and social and economic development. The economic sectors selected for mitigation technologies are energy, waste and land use change and land use change and forestry (LULUCF). The prioritized technologies in each sector are shown in Table 1.1.

Table 1.1: Prioritised mitigation technologies for Swaziland.

	Sector	Prioritised technologies
1	Energy	Hydro power
		Energy efficient buildings
		Biomass combined heat and power
		Solar water heaters
		Solar photovoltaic
3	Waste	Waste sorting
		Composting
		Semi-aerobic landfill
4	LULUCF	Agro-forestry
		Urban Forestry
		Grazing land management

1.2 Selection of technologies for barrier analysis and enabling framework

After the TNA exercise two workshops were held for the barrier analysis and enabling framework (BAEF) in the energy sector. The first was on 31 August to 2 September 2016 to identify the technology barriers, and the second was on 29 to 31 March 2017 to develop the enabling framework. Both workshops were held at the Piggs Peak Protea Hotel and Casino. The problem tree and solution tree method was used to develop the enabling framework. In each workshop, the stakeholders were divided into groups for discussions and there were plenary sessions where the groups made the presentations. The stakeholders were also very instrumental in bringing about information that the consultant was not aware off.

For power generation, hydropower was highly prioritised during the TNA exercise. However, during the BAEF it was noted that Swaziland had been building dams and using hydropower for decades and therefore the technology was mature and did not need much in terms of technology transfer. In addition, the severe drought of 2015/2016 made the stakeholder to be uncomfortable with huge investments on hydro without convincing positive modelling results of the possible river flow scenarios under climate change. It was also mentioned by some stakeholders that funding for hydropower was also considered to be more easily available from various sources as compared to coal power generation. It was decided that hydropower be not considered further for BAEF and development into a TAP.

The BAEF for Waste and LULUCF was done after the two workshops. For waste, the stakeholders had initially felt that there were a number of Conventions that addressed waste issues in synergy with the UNFCCC and therefore there was no need to include it in the BAEF. For LULUCF it was noted that it was difficult to maintain carbon stocks in agroforestry, urban forestry and grazing land in Swaziland unless the Land Policy 1999 was passed. One participant also went to the extent to state that the Department of Forestry had a project of giving away free tree seedlings to small holder farmers anf their experience was that only 20% of the trees survived the first year. However, the team at the ERC in Cape Town felt that these two sectors had to be included. They were then included through consultation with the same stakeholders as were present in the workshops through communications by emails and the phone. No problem and solution trees were prepared for them and neither the market maps. The reason not to widen the scope of stakeholders during the subsequent consultation was to avoid having the need to capacitate the new stakeholders, and also to explain what had happened in the previous workshops. What would happen in the workshops was that new people always brought new ideas in most cases conflicting with what was resolved in the previous workshop(s). There were seven finally selected technologies to be taken to the next step of barrier analysis and enabling framework and eventually be developed into technology action plans (TAPs) a listed below:

Energy Sector

- ***Energy efficient buildings:*** This technology addresses the building envelope. The consultant on-his-own decided to do a cost benefit analysis for solar water heaters under energy efficient buildings because in subsequent discussions to the workshops solar water heaters kept being mentioned by stakeholders. Light emitting diode (LED) lighting had been included by the stakeholders, but subsequent calculations showed that their energy savings compared to fluorescent lights, which have now been universally adopted in Swaziland, was minimal. The fixtures used for LEDs are the same as those for fluorescent lights and therefore there would be no extra cost to using them except for the cost of the lamp. LED prices are coming down and will soon be generally available and affordable. The consultant therefore decided not to further do a BAEF for LED lights as part of the energy efficient buildings technology.

- ***Solar photovoltaic:*** This addresses domestic and institutional grid-tie solar PV systems to save power during the day or to feed into the grid when a feed-in policy is put in place. Stand-alone solar PV systems were not considered because they have limited use as a result of the high cost of storage. There is need to develop models for the best use of standalone solar PV systems without storage. Of course they work for small battery charging for cell phones and solar lanterns. But as a mitigation project such has a low potential impact, and would be more relevant to social upliftment.
- ***Combined heat and power (CHP):*** This technology involves power generation from steam turbines using biomass fuel in the form of bagasse, sugar cane trash, and wood chips. Such is already being practiced in Swaziland and needs to be scaled up.

Waste sector

- ***Waste sorting:*** This technology was earmarked for the proposed waste facility at Mafutseni to accept waste from Manzini, Matsapha, Siteki and Sikhuphe. The facility shall sort waste into the different categories of metal, plastic, paper, glass and organic matter to be sold for reuse, recycling and upcycling.
- ***Composting:*** This technology shall be for composting clean organic waste to produce a valuable marketable fertiliser. This waste shall be tested for pesticides and heavy metals occasionally to warrant its safety.

LULUCF Sector

- ***Agroforestry:*** This technology is where a mixture of agricultural and forestry activities are carried out on the same piece of land. This technology shall be promoted nationally but direct support shall be given to small holder farmers.
- ***Urban forestry:*** This technology shall target new developments around towns and cities to incorporate urban forestry in development.

1.3 Barrier Analysis and Possible Enabling Measures Methodology

The BAEF outlines the barriers that could hinder the adoption, development and deployment of the prioritised technologies. It also outlines a framework to overcome these barriers for the successful deployment and diffusion of these technologies. The Barrier analysis and development of corresponding enabling framework was done in two stakeholder workshops as mentioned in Section 1.2. Stakeholders were taken through the Logical Problem Analysis (LPA) tool for analysing causal relations as provided in the Guide Book on Overcoming Barriers to the Transfer and Diffusion of Climate Technologies.[1] The LPA tool was used in identification of barriers and measures to isolate the starter problem in the context of technology diffusion. Problem trees were developed and in turn solution trees were formulated to tackle the problems. The problem trees identified for the different technologies together with their counterpart solution trees are given in the Annexes. Market maps were used to identify the role players in enabling the technology deployment and diffusion.

Chapter 2 Energy Sector

Swaziland's energy consumption was estimated at 41 000 TJ in 2010. The highest contributor was biomass in the form of traditional biomass as wood fuel 39.6%, industrial biomass bagasse 10.6% and industrial biomass wood chips 1.1%. Petroleum products accounted for 19.4 % in the form of diesel at 11.0%, petrol at 7.8%, paraffin 0.7%, liquefied petroleum gas (LPG) at 0.6% and Heavy Furnace Oil (HFO) at 0.03%. Coal contributed 17.7%, while electricity added 10.6% to the total energy consumed.[2] The coal consumption is decreasing in Swaziland as drycleaners and the textile industries are now primarily using paraffin boilers and the sugar industry is increasingly using bagasse, sugar cane trash and wood chips for their boilers. Energy GHG emissions in the energy sector result from fuel combustion in the manufacturing and construction industries, transport, residential, and others to include commercial/institutional, and agricultural sectors. Fugitive emissions are from coal mining operations. The energy applications in Swaziland and their respective sources are shown in Table 2.1.

Table 2.1: Energy applications and their respective energy resources in Swaziland.

	Application	Energy Resource Options
Residential	Lighting	Electricity, paraffin, LPG, candles and solar PV
	Cooking	Electricity, LPG, wood fuel, paraffin and coal
	Water heating	Electricity, wood fuel, paraffin, coal and solar
	Space heating/cooling	Electricity, wood fuel, paraffin, coal and LPG
	Refrigeration	Electricity and LPG
	Water pumping	Electricity, wind and solar and human (hand pumps)
Transport	Vehicle motive power	Diesel and petrol
Industry	Motive Power	Electricity
	Lighting	Electricity
	Refrigeration	Electricity
	Process heat	Bagasse, coal , HFO, LPG and wood residue
	Cooking	Electricity, coal, paraffin, wood fuel and LPG
Commercial	Lighting	Electricity
	Water heating	Electricity and paraffin
	Air conditioning	Electricity
Agriculture	Water pumping	Electricity and solar

2.1 Preliminary targets for Technology Transfer and Diffusion

The technologies selected for BAEF for the energy sector are listed in Table 2.1

Table 2.2: Selected technologies for the energy sector

#	Prioritises technology	Sub technology	Category
1	Built environment	(a) Energy efficient building envelope	Capital and Consumer
		(b) Solar water heater	Consumer
2	Combined heat and power	(a) Bagasse/sugar cane trash boiler	Capital
		(b) Wood chip boiler	Capital
3	Solar PV	(a) Domestic solar PV	Consumer
		(b) Institutional solar PV	Capital

1. (a) Efficient building envelope targets

The building envelope is chosen since it is the key factor in the energy transmission between the inside and the outside environment. The target for energy efficient building envelope is the basic insulation of the commercial and residential sectors. Commercial space can consume 236 kWh per m^2 per year. Basic insulation can save 14% of the energy for cooling and heating office space. The cost of basic insulation is $53.82 per square metre[3]. The commercial sector in Swaziland consumed 106.3 GWh of electricity in 2016.[4] Targeting 10% of the commercial sector would result in retrofitting 44 million m^2 of buildings at a cost of 2.4 billion dollars. The savings in ghg emissions shall be 34 Mt CO_2e. The targeted number for the residential sector is the 5% of households that use more than 400 kWh of electricity per month. This is about 13 000 of households. The investment required shall be $1.1 million and the GHG avoided emissions shall be 81 thousand t CO_2e. Table 2.2 summarises the preliminary targets for this technology.

Table 2.3: targets for energy efficient building technology – basic insulation

Technology	Energy efficient buildings - building envelope
Primary target	44 million m^2 of commercial space 13 000 residential households
Required investment	Price for basic insulation: $53.82 per metre squared[3] Total investment: $2.4 billion for the commercial and $1.1 million for the residential sector.

Expected lifetime	30 years
Expected economic benefits	Total energy savings (14% of 236 kwh per m2): 1.24 GWh The net present value of the electricity saved is: $868 million
Cilmate change mitigation benefits	The energy saved shall be: 1.45 GWh per year This is equivalent to: 33.5 Mt Co2e over 30years

1. (b) Preliminary targets for the Solar water heater technology

The target shall be 10% of the number of households with indoor plumbing and consume more than 300 kWh of electricity per month.[5] That is about 13 000 households. This number can be scaled up as the technology gets more familiar and appreciated. The cost of water heating for a 100 litre tank from 20^o to 60^o, once a day is mass of the water multiplied by the heat capacity multiplied by the temperature difference which is 4.65 kWh per day which is 140 kWh per month. That is about 47% of 300 kWh, which is between the 40 and 60% reported by CSIR. If the average consumption is 350 kWh per month, then 40% savings is equivalent to 140 kWh savings per month.

Table 2.4: Targets for energy efficient buildings – solar water heaters

Technology	Energy efficient buildings – solar water heaters
Primary target	13 000 households consuming more than 300 kWh of electricity.
Required investment	Price for solar water heater including installation: $615.38 per unit[6] Total investment: $8 million
Expected lifetime	20 years
Expected economic benefits	Energy savings per household: 1697.66 kwh per year Total energy savings: 22 GWh Net present value of the electricity saved is: $28.6 million
Climate change mitigation benefits	The energy saved shall be: 22.1 GWh per year This is equivalent to: 1.70 kt Co2e over 20years

2. Preliminary targets for diffusion of the CHP technology (bagasse, sugarcane trash and wood chips fuel)

The Ministry of Natural Resources and energy is targeting to increase the renewable energy contribution to power generation from 28% to 50% by the year 2018.[7] This would be equivalent to 50 MW renewable energy power generation capacity. One of the options for renewable energy power generation is biomass thermal power. Two companies in the timber industry have also shown interest in producing power using wood chips. In this TNA project, a minimum target of 65 MW from CHP will be considered within the next two years and additional 60 MW. For the TNA exercise the target is to promote the installation of 65 MW biomass CHP units in the country using bagasse and wood chips as fuel. It is envisaged that more CHP plants shall follow after these. The energy is assumed to be priced at a wholesale price of $0.07692 per kWh to compete with the coal power wholesale price.[8]

Table 2.5: Targets for CHP technology using bagasse, sugar cane trash and wood chips

Technology	Combined heat and power using bagasse and wood chips as fuel
Primary target	44 million m^2 of commercial space 13 000 residential households
Required investment	Investment for $308 million Operation and maintenance including fuel, spare parts and human resources: 4.5% of investment
Expected lifetime	30 years
Expected economic benefits	Total energy savings: 14.2 GWh Whole sale price of electricity: $0.07692/kWh[8] The net present value of the electricity saved is: $304 million
Climate change mitigation benefits	The energy generated is equivalent to is equivalent to: 10.9 Gt CO2e over 30years

3. Preliminary targets for the Solar PV technology transfer and diffusion

The preliminary targets for this technology are based on the number of users currently connected to the grid. According to the SEC Annual Report 2015/2016 there were 149,700 domestic customers and 14,400 nondomestic customers.[4] Of the domestic users 10% use more than 300 kWh of electricity per month.[9] That is about 15 000 households. These households are targeted because they are likely to afford a 1.5 kW grid-tie solar PV system that costs $2 723. This system is the smallest that is available for grid-tie connection. The target for nondomestic users is initially 10% of those who use electricity. A system that would fit on a small roof top like at the Blood Bank in Mbabane is around 50 KW. The insolation for Swaziland is 4.77 kWh/m^2/day.[10] The solar panels are assumed to be rated at 200 W each with an area of 1.64 m^2, and an efficiency of 15%. The CO_2e avoided emissions are calculated with respect to a clean cola power system with emissions 0.77t per MWh.[11]

Table 2.6: Targets for Solar PV technology using bagasse and wood chips

Technology	Solar PV
Primary target	1. 15 00 households 2. 4 000 institutional
Required investment	Investment for domestic: $45.1 million Investment for institutional: $592 million

Expected lifetime	25 years
Expected economic benefits	Total energy savings for: 12950 GWh The net present value of the electricity saved: $662 million
Climate change mitigation benefits	The energy generated is equivalent to is equivalent to: 9971 Gt CO2e over 25 years

There is also interest in the private to establish more solar PV power plants to feed into the national grid in addition to the 21 MW planned by Wundersight.[12] This could result in more electricity being generated than the country currently consumes. However, there is a growing electricity demand in the Southern Africa Power pool. If the country can commit early enough it would be able to feed the excess electricity into the SAPP. In addition to this target the private sector has shown interest in installing large solar PV plants both for the local and regional market. Funding for this investment has already been secured from local financial institutions. The main local electricity utility, which owns the transmission network has so far committed to source up to 20% of its power from intermittent producers

2.2 Barrier Analysis and Possible Enabling Measures for Technology 1: Energy Efficient Buildings

2.2.1 General description of the technology

1. Energy efficient building envelope

Energy efficient buildings are designed such that the building envelope reduces heat transfer between the interior and the outside environment. This leads to lower heating costs during the winter and lower cooling costs in summer. In addition, they are constructed such that they maximise the use of sunlight during the day to reduce lighting costs. The cost of energy efficient building materials such as additional insulation and specially glazed windows could increase cost, but this can result in a payback from lower heating, ventilation, air conditioning costs.[13] These buildings are also fitted with energy efficient lights, appliances and heating and cooling systems. Such buildings therefore reduce energy consumption and hence the corresponding emission of greenhouse gases.

In the design of energy efficient building, the building envelope is usually the first consideration. This consists of the walls, floors, roofs, doors, windows, skylights, and clerestories. The building designer must not only understand the structural integrity of building materials but also their fundamentals such as expansion coefficients and heat transfer and reflection characteristics. The designer must also have knowledge of the current and predicted future climatic conditions. Swaziland needs people with such expertise in order to design and construct energy efficient buildings.

In addition to the building envelop the appliances used in the building have to be energy efficient if overall building energy use is to be minimised. That means efficient devices should be used such as LED lighting, efficient stoves and refrigerators, efficient heating and cooling systems, energy saving means of water heating etc. More sophisticated buildings employ building management systems (BMS), which controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems by means of computerised systems.

2. Solar water heaters

One of the means to save energy in buildings is to use solar water heaters. Solar water heaters absorb radiant heat from the sun to heat up water. There are two main types of solar water heaters, direct and indirect. Direct solar water heaters consist of solar collectors that absorb heat from the sun. Water runs through channels in the collector and absorbs the heat and returns to the tank as hot water. Direct solar water heaters can be thermosyphon or active closed loop. Thermosyphon water heaters have a heat collector at the bottom and a tank at the top. The heated water at the collector rises by convection and the cooler water at the top flows downward to collect heat forming a cycle. There are no pumps controllers or wiring. Active solar water heaters require a pump to circulate the water.

Indirect solar water heaters use a working fluid which is an antifreeze to run thorough the collector to absorb the heat. It is then pumped through the tank of hot water where a heat exchanger releases the heat from the fluid into the water. Such a system is suitable for places that get below freezing to avoid the freezing of water in the collector and pipes.

The collector can be a box with a glass upper window that is painted black with tubes or channels for water flow or evacuated tube solar collector. The evacuated tube solar collector features parallel rows of transparent glass tubes. These tubes contain a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiant heat loss. These collectors are used mainly on commercial applications.

According to UNEP the use of thermal energy including water heating has been rising steadily since 2000. In developed countries water heating accounts for up to 25% of the energy used in a household.[14] Water heating consumes between 40 and 50% of electrical energy in a household.[15] While data on water heating demand is not readily available in Swaziland, it is sensible to assume (based on experiences from other countries) that reducing water heating costs could significantly reduce the overall heat consumption in a building even in developing countries. Another motivating factor to include solar water heaters is the fact that the uptake of these systems is very low in Swaziland while there is plenty of sunshine. Including solar water heating in the BAEF and TAP can help bring solar water heating to the fore.

As mentioned above, it is said in the literature that water heating can consume up to 25% of the energy consumption in a household or 40 to 60% of the electrical energy. There are two main types of solar water heaters, the active types with pumps and controllers and the passive ones that circulate the water by the natural principle of convection. The active types are more popular in Swaziland since they are targeted for the higher income people. These are people with indoor plumbing. The CSO 2010 indicated that 21.4% of households had indoor plumbing.[5] These households would constitute the target for solar water heaters since they have adequate income to purchase such. For the lower income households, passive solar water heaters are more suitable. These heaters eliminate the cost of the pump, controller and more expensive collector making them more affordable. However, these will not be considered for the BAEF since they require further studies to determine the baseline emissions from water heating from sources other than electricity.

2.2.2 Identification of barriers for technology

The stakeholders at the workshop identified one economic/financial barrier and four nonfinancial barriers for energy efficient buildings technology. These are discussed in section 2.3.1.1 and 2.3.2.2.

2.3.1.1 Economic and financial barriers

(a) ***Perceived high cost of building***
Low awareness of the long term benefits of energy efficient buildings (compared to high upfront costs) and products result in the low interest and demand. As a result such building materials have to be acquired through special order purchases which render them to be more expensive. If the products could be purchased in the same quantities as the standard products their cost could be significantly reduced. The use of locally available materials to build energy efficient buildings is also not being explored.

2.3.1.2 Nonfinancial barriers

(a) ***Low awareness of technology and associated benefits***
Designing and building energy efficient buildings is relatively new in Swaziland. Major structures that are built this way are the American Embassy at Ezulwini Valley and the Motor Vehicle Accident fund building in Mbabane. This technology is not only new to Swaziland but also to the region. In the local newspapers the idea of green buildings is discussed from time to time but has not systematically filtered down to the general public. It still remains a theoretical concept to most. There is, however, a growing community interested in energy efficient buildings as was witnessed at the TNA stakeholder workshops.

(b) ***Low skills of architects and builders***
The idea of energy efficient buildings has not considered important in Swaziland. People built houses based on what the architect could provide and the available building materials for structural integrity without considerations of the energy efficiency of the building envelope. With issues of climate change taking too long to be mainstreamed a lot of local architects and building contractors were not properly trained on the design and construction of energy efficient buildings. The suppliers of

building materials also do not advise customers on suitable building materials for energy efficiency.

(c) ***Poor enforcement of the building code and bylaws***
There is hardly any enforcement of the building code. The reason is that the structural integrity and electrical wiring tend to be the most important things considered by the inspectors. Some municipalities now have bylaws that directly address issues of building energy efficiency. An example is the municipal Council of Mbabane that has updated the Urban Government Act 1969, to include that commercial and industrial buildings should be equipped with at least 70% energy saving technologies, residential buildings use energy savings technologies, green technologies must have proven climate change mitigation impact, and encourage the use of natural lighting in buildings. The interest in energy efficient buildings has been brought about by the need to cool buildings during hot times (due to increase in average temperatures) and to heat them on cold days using electricity and the desire for higher levels of comfort. Municipalities are now to some extent of the need to be climate change conscious.

2.2.3 Identification of measures for the technology

The measures to overcome the barriers for energy efficient buildings technology are given below.

2.2.2.1 Measures for financial barriers

(a) Perceived high cost of building

Measures:

1. *Undertake cost analysis of energy efficient buildings*
The high cost of energy efficient buildings could be real or perceived. A cost analysis of the design, materials and construction of energy efficient buildings must be carried out. Information from such should be disseminated adequately. If the results are favourable they could lead to higher adoption of the technology, thus enabling suppliers to buy in bulk and thus reducing the costs. Also if financial institutions are convinced that the value of energy efficient buildings is higher than that of the current normal type buildings, they can provide the financing for such construction. This is important since the technology has to be adopted first by the higher income groups so that the prices can be lowered for the lower income households. Subsidies for energy efficient buildings and tax exemptions for the consumer market are unlikely in a country like Swaziland at the present time. Government has a cash shortfall and the tax collecting unit of Swaziland the Swaziland Revenue Authority (SRA) is trying to find new revenue streams to collect money for the government.

2. *Use of local materials to build energy efficient buildings*
There must be research and development of local building materials for energy efficient buildings. Some of the resources like wood and wood waste suitable for

manufacturing building insulation are readily available in Swaziland. These can be impregnated with noncombustible resins reduce fire hazards.

2.2.2.2 Measures for nonfinancial barriers

(a) **Low awareness of efficient buildings technology**

Measure: *Conduct workshops and road shows for the industry and the public*
Workshops and road shows for architects, construction companies and the public must be conducted to raise awareness on energy efficient buildings. The results from the cost analysis of energy efficient buildings conducted under the first barrier must be disseminated to these stakeholders.

(b) **Low skills of architects, builders and building material retailers**

Measures:

1. *Empower architects and builders with necessary skills and knowledge*
   Provide short-term education and training courses for architects and builders. These people already have the building skills, they just have to be shown the new ways or directed to information resources on energy efficient buildings.
2. *Capacitate building material suppliers on how to acquire such materials for energy efficient buildings.*
   Help building material suppliers to obtain knowledge on sourcing energy efficient building materials. They have to be made to be aware of quality and warranty issues for such materials.

(c) **Poor enforcement of the building code and bylaws**

Measure: *Develop procedures to enforce building codes and bylaws related to energy efficient buildings*
Currently the building approval and inspection addresses structural integrity, fire safety, health, and electrical safety of buildings. The building code and bylaws were enacted without an act that addresses energy efficiency in buildings. This renders this part of the building code and bylaws not enforceable. They must also be equipped to address issues of energy efficiency in buildings. Energy efficiency and conservation is a national issue because if wasted energy is imported, foreign exchange is also wasted, while if it is sourced locally indigenous energy resources are wasted. Amending the Housing Act to include energy efficiency can result in an enforceable regulatory framework for energy efficiency inn buildings.

2.2.4 Cost benefit analysis for technology

The cost benefit for energy efficient buildings was done for basic insulation for commercial and residential buildings and the installation of solar water heaters for the domestic sector. The cost benefit analysis was done using the net present value equation.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0,$$

Where NPV= net present value

C_0 = initial investment
C_t = net cash flow in period t
r = discount rate
t = number of time periods
The value of energy savings were taken to increase by the inflation average rate of 7.6%. This is the average inflation rate over the last 12 months. Over the last twelve months the average discount rate was 8.3% and this figure was used. The results for this are shown in Table 1.2

Table 2.7: Cost benefit analysis for the built environment

		Basic insulation		Solar water heater
	Year	Commercial	Residential	
	0	-2362588134	-104948172	-8000000
	1	166272150	64011568	2530024
	2	165197445	63597827	2513671
	3	164129687	63186761	2497424
	4	163068830	62778352	2481281
	5	162014831	62372582	2465244
	6	160967643	61969435	2449309
	7	159927225	61568894	2433478
	8	158893531	61170942	2417749
	9	157866518	60775562	2402122
	10	156846143	60382737	2386596
	11	155832364	59992452	2371170
	12	154825137	59604689	2355844
	13	153824421	59219432	2340617
	14	152830173	58836666	2325488
	15	151842351	58456374	2310458
	16	150860913	58078539	2295524
	17	149885820	57703147	2280687
	18	148917029	57330181	2265945
	19	147954499	56959626	2251299
	20	146998191	56591466	2236748
	21	146048065	56225685	
	22	145104079	55862269	
	23	144166195	55501202	
	24	143234373	55142468	
	25	142308573	54786054	
	26	141388758	54431942	
	27	140474888	54080120	
	28	139566925	53730572	
	29	138664830	53383283	

	30	137768566	53038238	
Net present value		**2185092018**	**1645820895**	**39610678**

2.3 Barrier Analysis and Possible Measures for Technology 2: Combined Heat and Power

2.3.1 General description Technology

Combined heat and power (CHP) systems are used to generate electricity and the heat that would otherwise be lost in cooling and condensing the exhaust steam is used as process heat for other activities in the plant and elsewhere. This combination of heat and power generation is usually called cogeneration. These systems are more efficient than separate systems that generate electricity or heat. In Swaziland there has been experience in cogeneration in the pulp, timber and sugar industries. The fuel feedstock in the pulp industry was wood chips and coal. In the timber industry it was purely wood chips while in the sugar industry there bagasse/coal and bagasse only boilers have been used.

In the biomass CHP system the biomass fuel is burnt in a boiler to generate high temperature and pressure steam. The resultant steam at a high temperature and pressure is then directed to a steam turbine to generate electricity. The low pressure steam after the turbine can be used as process heat.

The resources for combined heat and power are available in Swaziland. These include wood chips from the timber industry and bagasse from the sugar industry. There is also a company called SUXE International with an interest in teaching smallholder farmers and some sugarcane farmers to grow bamboo as biomass feedstock for CHP plants. They have 3, 10, 50, 100 and 200 megawatt equivalent power plants. Montingy the largest timber company in Swaziland is considering a 35 MW plant[16] while the Royal Swaziland Sugar Association is planning to increase its capacity by 30 MW.[17] Montigny has a potential of assisting neighbouring communities in converting the invasive wattle trees into a feed stock for their boilers which can increase the capacity to 60 MW. There is a second timber company that has also indicated that it may be interested in producing power from its wood waste. Ubombo Sugar Limited is already supplying the main electricity utility SEC with power through a privately negotiated power purchase agreement. This power is produced through the burning of bagasse, a renewable resource. In 2016/17 financial year the company supplied 55 GWh to the national grid from its 25 MW co-generation plant.[4] The Royal Swaziland Sugar Corporation has on the other hand indicated that it could install up to 30 MW extra power using bagasse to sell to the national grid if the market can be conducive.[17]

2.3.2 Identification of barriers for the technology

The stakeholders at the BAEF workshop identified two economic/financial barriers and three nonfinancial barriers for combined heat and power technology. These are discussed in section 3.3.1.1 and 3.3.2.2. There are of course other barriers related to power purchase agreements, public private partnerships, tariff issues and regulatory issues. Two successful power purchase agreements have been successfully negotiated between the Swaziland Electricity Company and Ubombo Sugar Limited Wundersight Investments for purchasing power produced from bagasse and solar PV, respectively. There could be improvements negotiated in these agreements but now it has been determined that they are workable. The public private partnership policy is already in place and it is being used in projects like road construction therefore it was not further discussed by stakeholders. There is the Electricity Act 2007 which governs the electricity sector in the country. There is also the Swaziland Energy Regulator (SERA) which is responsible for setting up regulations in the electricity industry together with government, independent power producers, the SEC and consumers[18]. The stakeholders assumed that mechanisms for transparent regulation can now be dealt with adequately in Swaziland.

2.3.1.1 Economic and financial barriers

(a) ***High capital cost of technology***
Swaziland does not manufacture any equipment for the combined heat and power systems and therefore has to import all the necessary equipment. The importation of such large pieces of equipment raises the cost as compared to their countries of origin. In addition to the cost, the construction of such systems require the services of international experts which results in additional costs for stetting-up the plant. Swaziland does have a Public Private Partnership Policy but the investment responsibility for power generation still lies on the private investor. Without the final approval of a power generation resource plan and commitment to energy security by policy makers, there is still a high risk in investing in power generation which also leads to the high capital costs.

(b) ***Uncertainty in the power market of or perception of it***
The market uncertainty stems from that the country is embarking on the construction of a coal thermal power station that will meet the power demands of the country. The price of this electricity is not yet known. Some renewable energy power generation companies feel threatened by this situation.

The country also imports power from South Africa's ESKOM. ESKOM is a major supplier of power on the African continent. Due to economies of scale, Eskom is the largest and cheapest power supplier and can make local generation uncompetitive. There is also potential for cheap power supplies in other countries such as the DRC with large rivers, which could generate huge amounts of cheap hydro power. However, there are also risks due to instability in some of the countries and possibility of regime changes that may bring to power governments that may be hostile to Swaziland leading to power disruptions.

2.3.1.2 Nonfinancial barriers

(a) ***Absence of integrated power generation resource plan***

There is need for an integrated power generation resource plan. This plan can look at the available resources and determine their deployment at different times to meet the ever changing power demand.

(b) ***Uncertainty of biomass resource availability***
There is uncertainty on the amount of biomass available at any one time for power generation. The sugar industry depends on irrigation and therefore susceptible to drought conditions, or years with less than normal rainfall. The timber industry even though less affected by drought at the current times is very susceptible to wild fires. Between 2007 and 2008 the country experienced the worst plantation fires in history, where about 40% of the timber resources for a Usutu Pulp Mill were destroyed, partly leading to the closure of the company. At the same period Peak Timbers lost about 80% of their forest area leading them to stop producing biomass electricity.[19]

(c) ***Inadequate level of skills***
The country has been involved in cogeneration for decades using coal, coal and wood chips, coal and bagasse, bagasse and wood chips. The artisans and some operations engineers are available in the country. The skills that are mainly in shortage are for the construction and some higher level engineering skills which are sourced from outside on an on-demand basis. With increased cogeneration, there will be need for these higher level technical skills.

2.3.3 Identification of measures for technology

The measures to overcome the barriers for combined heat and power technology are given discussed here.

2.3.2.1 Measures for economic and financial barriers

(a) **High capital cost of technology**
Measure: *Provide government support in procurement*
Use the public private partnership policy to provide government guarantees for CHP power plants. Develop capacity to access funding through climate change mechanisms such as the Green Carbon Fund and others.

(b) **Uncertainty in the power market or perception of it**
Measures:

1. *Government must ensure national energy security and commit to supply power to the Southern African Power Pool*

The government could submit a commitment to the Southern African Power Pool of the potential future power production capacity of the country. That way it can secure markets in the SAPP for biomass generated electrical power.

2. Government commits to provides guarantees to local producers

The government could address this issue on the basis of energy security. Government could guarantee that power produced locally at a reasonable price would have a ready market locally. This could reduce the risk of the dependence on foreign electricity supply where the supplier government may have a change of policy that can negatively affect the supply.

3. Develop capacity for carbon credit certification for green technologies
Certification of carbon credits for local green power technologies can result in sellable avoided carbon emissions, which can subsidise the price of the power generated making it more price competitive.

2.3.2.2 Measures for nonfinancial barriers

(a) **Lack of integrated power generation resource plan**
Measures: Develop an integrated power generation resource plan
Government must develop a national power generation resources plan. This plan should address the possible scenarios in power generation to get the appropriate energy mix balancing cost, security and environmental impacts.

(b) **Uncertainty of biomass resource availability**
Measures: *Plan for contingencies in the periods of drought or extensive forest fires where the biomass resources can be drastically reduced*
There must be plans for co-firing with coal or the planting of biomass feed stocks like bamboo and wattle on degraded land to supplement biomass shortages. There could also be stand-by natural gas power plants. There are huge natural gas reserves in neighbouring Mozambique.

(d) ***Inadequate level of skills***
Measure: *Provide the necessary high level skills training to engineers and artisans to assemble and run efficient boilers and turbines for CHP technology.*
The country must invest in the high level technical skills training to run efficient boilers and turbines for the CHP technology. These skilled personnel may not be necessarily attached to the same company but may service all the CHP companies in the country and also take on jobs outside the country.

2.3.4 Cost benefit analysis

CHP assumes that the installed power generation capacity shall be 65 MW, where 30 MW shall be from using bagasse and 35 MW from using wood chips. A scheduled shut-down period is estimated at two months per year resulting in the availability of 83%. The inflation and discount rates are assumed to be 7.6 and 8.3%, respectively. The cost of wood chips is comparable to that of bagasse at $30.76 per ton.[20]

Table 2.8: Cost benefit analysis for combined heat and power using bagasse and wood chips fuel

Year	Earnings (10^6 $)	Year	Earnings (10^6 $)	Year	Earnings (10^6 $)
0	-307.692				
1	22.4	11	21.0	21	19.6
2	22.2	12	20.8	22	19.5
3	22.1	13	20.7	23	19.4
4	21.9	14	20.6	24	19.3
5	21.8	15	20.4	25	19.1
6	21.6	16	20.3	26	19.0
7	21.5	17	20.2	27	18.9
8	21.4	18	20.0	28	18.8
9	21.2	19	19.9	29	18.6
10	21.1	20	19.8	30	18.5
Net present value					303.9

2.4 Barrier Analysis and Possible Measures for technology 3: Solar PV

2.4. 1 General description of solar PV technology

Solar Photovoltaic (Solar PV) is a technology in which light is directly converted into electricity. This electrical power is produced in solar panels. Each solar panel typically consists of 6 to 10 solar cells where the actual photovoltaic effect takes place. Most solar PV panels are designed to be fitted in existing rooftops. The power generated by solar panels is usually small and not in the form required for operating most domestic appliances and industrial equipment. Therefore several panels may be required to increase the power and an inverter required to condition the power to that required by appliances and equipment. For use when there is no direct sunlight storage systems in the form of batteries are required. The solar panels that produce the electricity from the sunlight account for a small fraction of the total cost of a solar PV system. For systems with batteries it can be as low as 10% and for systems without batteries it can be about 20%.

Solar PV systems are improving all the time. The efficiencies are increasing while the prices are going down. The prices have gone down on by 90% over 25 years, while the efficiencies and over the last 10 years, the efficiency of average commercial wafer-based silicon modules increased from about 12% to 17%, while at the same time, CdTe module efficiency increased from 9% to 16%.[21]

Swaziland is gaining experience in small to medium scale solar PV systems. There are installed individual households standalone systems and institutional systems with inverters. These include a 31.2 kW at the Blood Bank, 60 kW at the Luyengo Campus of the University of Swaziland, 31.2 kW at Mhlumeni border gate and a planned 31.2 kW at Nhlangano Health Centre, as well as a 25 kW at Bulembu village.[22] Wundersight investments have installed a 100 W solar PV system that feeds into the national grid. This company is planning in installing a 22 MW grid connected solar PV plant.[12] The local power company SEC is also planning on its own solar PV plant that will be connected to the national grid.

2.4.2 Identification of barriers

The stakeholders at the BAEF workshop identified three economic/financial barriers and five nonfinancial barriers for solar PV technology. These are discussed below.

2.4.2.1 Economic and financial barriers

(a) ***High cost of equipment***
Solar PV components are all imported into Swaziland. The cost to convert the power to the usable AC is much higher that the panels especially if it has to be a pure sine required by some household appliances. The cost of storage is very high and unaffordable for the poor. The costs comprise of the purchase price, shipping and handling, taxes and mark-up for the suppliers. These costs also apply to the replacement and maintenance parts such as inverters, regulators and batteries. Another complication arises from the volatility in recent years of the local currency with respect to the international currencies used to purchase solar PV hardware. The country therefore has little control over the prices of the components.

(b) ***High cost of land***
Accessing land for large solar PV systems is rather difficult because of the land scarcity in Swaziland. The country is small with increasing unplanned settlements even making it difficult to get space for ground based solar PV systems.

(c) ***Low price of domestic electricity***
Domestic electricity is to some extent subsidised by commercial users. The price of electricity for domestic consumption is not price reflective of the production and distribution costs. This results low interest in investing generating electricity cheaply for self-use.

(e) ***Potential low price of imports electricity***
The country imports power from South Africa's ESKOM. ESKOM is trying to reduce its generation costs capitalising on its enormous size. If successful, it could have low enough prices that could make electricity production from solar PV higher than just buying from the grid.

2.4.2.2 Nonfinancial barriers

(a) ***Solar PV has limited use with expensive storage***
Consumers tend to compare solar PV with grid electricity or electricity from a generator. They get frustrated when they find that they cannot use solar PV for ironing, boiling water with an electric kettle etc. The solar electricity in the absence of storage and net metering is only available during the day when many households have little use for electricity. The things mentioned above make solar PV to be not attractive to a lot of people even those who can afford it.

(b) ***No regulatory framework to directly support the uptake of solar PV***
Solar PV power is produced only during the day and without storage, which is very expensive, it is not available at night. Net metering would allow solar PV power producers to feed the excess produced electrical energy to be fed into the grid,

reversing the units in the meter thus providing credit to the customer. When night falls or on cloudy/rainy days the credit power can be consumed by the user. Net metering therefore is very attractive because it does not have the burden of the cost of storage and is suitable households as their power consumption may be less during the day and high in the evenings and mornings. Provision for net metering can obviously lead to a high uptake of the solar PV technology.

(c) ***Poor supply chain***

People are now familiar with solar PV technology. However, when it comes to accessing the technology people are still limited to the few suppliers that are available, some of whom are just retailers and not well-versed with the technology. The sellers tend to control the price without alternatives for the consumers. This results in high costs and poor service thereby giving solar a bad reputation of being expensive and unreliable.

(d) ***Weak entrepreneurial skills***

The education and training regime in Swaziland tends to focus in preparing people for the job market rather than entrepreneurship. There are hardly any local individuals who are exploiting the opportunities offered by the solar PV industry. A lot of the suppliers of solar PV systems are not specialised but are either electricity product retail shops or outright merchants.

(e) ***Limited local technical skill for installation and maintenance***

There is still relatively low level of local skills in solar PV installation and maintenance. Some bigger installations even by government have been installed by foreign vendors because of the relatively limited local technical skills. There have been cases where such installations did not meet expectations.

(f) ***Low research and development on solar PV systems***

There is very low activity is the solar PV research and development in the country. This results in the lack of ownership in the technology leading to low adoption. It makes the people believe that solar PV is a foreign exotic technology, not really one that is readily accessible and can better their lives.

(g) ***Inadequate public knowledge on solar PV systems***

The public is aware of the existence of the solar PV technology for the generation of electricity. However, people do not understand its capabilities and where it can be of benefit. Some people install poor quality systems that do not work as expected and this results in negative perceptions about the technology.

(h) ***Non uniform quality of products and inconsistent quality of installation***

There is a lack of standards for the importation of solar PV components and their installation. The products available in the market vary widely in terms of value and performance. The connectors that terminate cables also vary leading to frustrations in interconnections.

(i) ***Security problems from theft and vandalism***

Solar panels are mounted outside and are therefore prone to both theft and vandalism. There are no proper statistics on solar PV theft and vandalism but cases have been reported. One case was stones where used to damage solar street lights along the Mbabane Manzini freeway at Ezulwini. The motive for this act was never ascertained. There have been cases of solar PV panel theft and in one case the stolen panels were made into coffee tables.

(j) ***Limited knowledge of grid compatibility of solar PV systems***

There is need to determine the right specification for inverters for compatibility with the local national grid.

(k) ***Solar PV power generation is intermittent***
Power from solar PV is generated mostly on sunny days and less so on cloudy days, and none at night. This poses a problem for grid power management and for off-grid users.

(l) ***Solar PV is vulnerable to extreme weather conditions***
Solar panels can be susceptible to being stripped off mountings by wind storms and physical damage from hail storms.

2.4.3 Identification of measures

The measures to overcome the barriers for solar PV technology given in this section.

2.4.3.1 Measures for Economic and financial

(a) **High cost of solar PV equipment**
Measures:

1. *Provide support for local production of components*
   The high cost of solar PV is also due to the lack of local production of some of the components. If say some of the components could be purchased in more basic forms and assembled locally the prices could be lower. This reduction in price would come from lower shipping costs of bulk components and lower labour costs.
2. *Provide regional coordination for the technology*
   Regional coordination of the solar PV technology could facilitate high adoption of this technology. Basic components could be imported in bulk and assembled at regional production locations leading to lower prices. This can be supported by harmonised standards and training on solar PV within the region.
3. *Demonstrate to property financers that solar PV systems add value to property*
   If property financing institution could be convinced that solar PV systems add value to property, and that the technology is mature and reliable, they can be financed through regular property financing. Property finance interest rates are always lower than normal bank loan interest. That can reduce the system costs.
4. *Develop capacity to certify carbon credits for solar PV system and use the credits to subsidise solar PV equipment*
   Solar PV carbon credits should be relatively easy to determine once the solar PV system has been installed. It should be easy to develop local capacity to do solar PV carbon credit audits. Future carbon savings can be used to leverage subsidies for solar PV equipment.

(b) **High cost of land**
Measures:

1. *Develop a land-use policy*

   The land-use policy would be somewhat different from the Land Policy whose draft was completed in 1999 but has never been debated. This would address the use of land for communal and national benefit to win support from traditional structures who are somewhat opposed to the full Land Policy. Such a policy would look at how to best use available land, which could mean relocating some residents in order to free up inefficiently allocated land settlements. Efficient land allocation and settlement would have many benefits some of which include the better provision of essential services, increased land availability for grazing and crop production, and other development projects such as solar PV installations.

2. *Find creative solar PV installation sites*

   This will involve identifying possible sites in addition to roof tops, for solar PV systems. There are already examples of such systems where solar PV installations provide shades such as parking lots and recreational space, area between aircraft runways, building walls etc. In addition as the prices of solar PV panels come down, the panels can be mounted so that more are mounted in a given area even if the angle towards the sun is not optimised for all of them if the result will be more power produced at a lower cost that current grid power.

(c) ***Low price of domestic electricity***

Measure: *Apply cost reflective electricity tariffs*

The prevailing situation in Swaziland is that industrial consumers pay higher tariffs for electricity than other consumers. This is done to subsidise domestic users. All domestic users are subsidised, irrespective of income levels. If cost reflective tariffs were to be implemented, domestic users would be motivated to save electricity or switch to solar PV. This measure is already being implemented by the local electricity utility and the energy regulator, where when a price increase is instituted a higher percentage is applied to the domestic users as compared to the industrial users until the prices are cost reflective. This can be done such that it targets the large consumers. With prepaid metering now universally adopted in Swaziland the computer can detect the purchase amount ad apply a higher tariff to those who purchase higher amounts. Once the price is high enough the consumers would consider energy efficiency, conservation and alternatives such as solar PV.

(d) ***Potential low price of imports electricity***

Measure: *Prioritise energy security over price*

Incentivise local solar PV power generators to increase production in order to achieve national energy security. Provide support for research on the cost effective production of power from solar PV. Also this may soon be a myth that solar PV power is more expensive than grid power. In nearby South Africa solar PV was bided at $0.05 per kWh.[8]

2.4.3.2 Measures for nonfinancial barriers

(a) ***Solar PV has limited use with expensive storage***
Measure: *Provide net metering*
Net metering would allow solar PV power to be fed into the grid and accessed back in the more useable form for all electrical uses in the house or facility.

(b) ***No regulatory framework to directly support the uptake of solar PV***
Measure: *Develop a regulatory framework to enable net metering*
Provision of net metering can definitely increase the uptake of solar PV technology. There companies already that are generating excess power like Ngwenya Glass that are trying to lobby for the net metering policy. Net metering is a billing mechanism that allows electricity customers who also generate their own electricity to feed their excess power to the public grid. It measures the difference between power consumed from the grid and the power fed to the grid by the customer. The customer is then charged for the net electricity consumed. Net metering rules, credit and rates vary from one country to another and could vary even between different regions in the country. Net metering programs can be voluntarily offered by a utility company through regulatory legislation. The energy regulator should consider the establishment of the net metering policy for national energy security.

(c) ***Poor supply chain***
Measure: Provide business models for the solar PV business
Use existing institutions like UNISWA, SEDCO and SCOT to develop business models suitable for starting and running solar PV businesses. These business models could cover sourcing of products, local assembly, sizing systems and installation and maintenance of solar PV systems. Outstanding graduates from tertiary institutions or entrepreneurs can be selected to be exposed to these business models.

(d) ***Weak entrepreneurial skills***
Measure: Provide business models for the solar PV business
Use existing institutions like UNISWA, SEDCO and SCOT to develop business models suitable for starting and running solar PV businesses. These business models could cover sourcing of products, local assembly, sizing of systems, and installation and maintenance of solar PV systems. Outstanding graduates from tertiary institutions or entrepreneurs can be selected to be exposed to these business models for further implementation.

(e) **Limited local technical skill for installation and maintenance**
Measure: *Provide training and accreditation of solar PV installers*
Tertiary institutions should develop curriculum on the installation and maintenance of solar PV systems. Organisations and individuals who undergo such training could apply for accreditation and undergo tests for certification.

(f) ***Limited research and development on solar PV systems***
Measure: *Increase solar PV research and development at tertiary institutions*
Increase solar PV research and development at tertiary institutions

Tertiary institutions should be supported through research grants to take on their leading role of conducting research and development on solar PV and provide information in order to bring solar PV technology to the fore.

(g) ***Inadequate public knowledge on solar PV systems***

Measure: *Conduct workshops and road shows on solar PV technology demonstrating realistic capabilities of solar PV*

The Energy Department of the Ministry of natural Resources and Energy could hold workshops and road shows to increase the knowledge of the people on solar PV technology. The demonstration must be designed to bring awareness on the functionality, misconceptions and limitations of the solar PV technology.

(h) ***Non uniform quality of products and inconsistent quality of installation***

Measure: *Develop standards for solar PV equipment and installation*

There is need to establish standards for all aspects of solar PV technology. The standards should cover the components and the installation of the systems.

(i) ***Security problems from theft and vandalism***

Measures:

1. *Adequately support the panels*

Adequately support the panels to require effort and time to remove them.

2. *Provide adequate lighting*

Provide adequate lighting to ensure that people who try to vandalise the panels can be easily visible.

3. Support the panels on strong high supports

Elevation can also be a deterrent to vandalism and theft.

(j) ***Limited knowledge of grid compatibility of solar PV systems***

Measure: *Improve knowledge on solar PV grid compatibility*

Grid-tie solar PV is practiced in many countries (e.g. North America, Europe, Japan Australia etc.) for commercial entities, institutions and domestic solar PV systems. Train engineers and technicians to acquire the appropriate knowledge to properly select and install equipment to interface solar PV systems with the national grid.

(k) ***Solar PV power generation is intermittent***

Measure: *Learn from best practices from around the world*

Solar PV is now used worldwide, and everywhere it is an intermittent power source. Methods of coping with high supply during the day, low supply on rainy and cloudy days and no supply at night should be obtained from countries like the USA, Australia and Germany where solar PV is widely used.

(l) ***Solar PV is vulnerable to extreme weather conditions***

Measures:

1. *Train installers on best practices for minimising extreme weather effects on solar PV*

   The installers should be properly trained on mounting panels to withstand local storm conditions. The adverse weather conditions are wind storms and hail. Proper training of installers can help minimise the effects of these.

2. *Where the risk is high use appropriate technology*

There are some solar panels that are less likely to be damaged by hail such as thin film and amorphous silicon cells. Also, solar cells covered with tempered glass that can reduce the effect of hail.

2.4.4 Cost benefit analysis

The cost benefit analysis was done for the installation of 1.5 kW solar PV systems for 15 000 domestic users and 50 kW in 15 000 institutions. The net present value equation was used for the analysis. The electricity price was assumed to increase at average inflation of about 7.6% and the efficiency of the systems was assumed to degrade by 0.5% per year. The discount rate used is 8.3%.

Table 2.9: Cost benefit analysis for solar PV technology

		Domestic installations	Institutional installations
	0	-45140100	-591660000
	1	4159174	55509409.1
	2	4110448	54859392.4
	3	4062288	54216906.3
	4	4014685	53581863.9
	5	3967635	52954179.6
	6	3921129	52333768.6
	7	3875163	51720547.1
	8	3829729	51114432.4
	9	3784822	50515342.4
	10	3740436	49923196.4
	11	3696565	49337914.3
	12	3653202	48759417.1
	13	3610342	48187626.5
	14	3567979	47622465.4
	15	3526107	47063857.2
	16	3484721	46511726.6
	17	3443815	45965998.8
	18	3403384	45426600.2
	19	3363421	44893457.7
	20	3323923	44366499.3
	21	3284882	43845653.6
	22	3246295	43330850.3
	23	3208155	42822019.7
	24	3170459	42319092.9
	25	3133199	41822001.9
Net present value		45441859	617344220

2.5 Linkages of the barriers identified

2.5.1 High cost of technology and technology awareness of financial institutions

The barrier of high cost is common in all technologies. In Swaziland this high cost mainly applies to the cost of the equipment required to implement the technology. Financial institutions are willing to provide finance if they are convinced that there shall be returns on investment. For example, in the case of buildings, if the technology adds value to the building, local financers have stated that they would finance the implementation of the technology as part of the mortgage. This barrier is linked to that of awareness. The low knowledge by financial institutions of the financial benefits of climate change mitigation technologies result in their reluctance to fund such. The barriers of high cost and knowledge of the financial benefits of the technology are therefore linked. The Public Pension Service Fund stated in one workshop that they had enough money to give minimum loans of $2.5 million in order to not directly compete with the banks. There is a need to do nation-wide awareness of the climate change mitigation technologies where disseminated information tailored for each stakeholder group. Reducing tax is not an option in Swaziland at the time as the government is trying to widen its tax base in order to service its huge wage bill and to fund its current commitments.

2.5.2 Low awareness of benefits of technology

This barrier is common to the energy efficient buildings and solar PV. Some people and organisations who can afford to invest in energy efficient buildings and solar PV are not really aware of the significance of the benefits of such. They do not have access to methods of quick calculations of the benefits they can get from investing in these technologies. This calls for national investment in awareness and education in the benefits of these technologies for both self and the environment.

2.5.3 Inadequate level of appropriate skills

The low skills base barrier is also common in all the technologies. The country needs to develop a comprehensive manpower needs assessments. The country is losing opportunities to implement various climate change technologies because there is a low level of specialists that can implement them. There are also low level skills in preparing bankable proposals to attract foreign investments in climate change mitigation technologies. The country needs to develop skills to implement the technologies and skills to source international available climate change funds. For the energy efficient building technology, the architects, building material supplier and builders need to be capacitated with the appropriate skills. For the combined heat and power, the engineers need to be up-skilled to handle the challenges of advanced boilers and turbines for power generation. For solar PV there is need for skills for proper sizing and installation of solar PV systems. Currently, most solar PV installers come from outside the country.

2.5.4 Regulatory framework

There is a Climate Change Policy and fragmented regulatory framework in the country that address climate change. However, there seem to be no appropriate structures to either strengthen the existing regulations or develop the implementation strategy for the policy. A sustainable energy integrated resource plan can help direct the country to investing in the relevant technologies for climate change mitigation. Regulatory frameworks could promote investment in climate friendly technologies. Net metering regulations can promote investment is solar PV. Energy security strategies can encourage CHP power generation. The energy efficiency policy and associated regulations and strategies can promote the conservation of energy resources. The regulatory framework does not only promote the adoption of clean technologies but also covers standards of the implementation of their implementation. The standards enhance the credibility of the technologies leading to their higher adoption by ensuring that they deliver as specified.

2.6 Enabling Framework for Overcoming Barriers in the Energy Sector

2.6.1 Enabling framework top overcome common barriers for in the energy sector

The enabling framework developed for the energy sector is presented in Tables 2.10 to 2.13 below.

Table 2.10: Enabling framework to address common barriers in the energy sector

Barrier	Enabling framework	Role players
High capital cost • ***Energy efficient building: high cost of building;*** • ***CHP: High cost of technology;*** • ***Sola PV: high cost of equipment***	3. Develop business models to demonstrate to local financial institutions the viability of mitigation technologies for financing	MTEA, DOM, MEDP, SEDCO, SIPA and UNISWA
	4. Develop skills to access low interest capital from climate change mechanisms	MTEA, DOM, MEDP and UNISWA
Low awareness of benefits of technologies	4. Develop awareness material addressing each stakeholder segment in the country 5. Conduct education and training on the climate change mitigation technologies stressing their tangible and climate change benefits 6. Use available platforms such as organised games, community meetings, print and electronic media, trade shows etc. to	MTEA, DOM, MEDP, UNISWA, MED, CIC and SEA

	disseminate information	
Inadequate level of skills in the country	3. Conduct climate change skills audits to determine the needed skills in the country 4. Conduct climate change skills development and capacitation of low skilled qualified personnel for prioritised technologies	MTEA, DOM, MEDP, SCOT and UNISWA
Inadequate regulatory framework	3. Develop policies and regulatory framework to address local needs while benefitting climate change mitigation for each of the technologies 4. Develop enforcement mechanisms for the regulatory framework through incentives, penalties or both for each of the technologies	MTEA, DOM and MOJ, CIC, FSE&CC and MHUD

3.6.2 Enabling framework for barriers specific to energy efficient building technology

Table 2.11: Enabling framework for barriers specific to energy efficient building technology

Barrier	Enabling framework	Role players
High cost of building material	3. Conduct research and development for locally produced energy efficient building materials 4. Develop a different tax regime for products according to their energy efficiency ranking	MTEA, DOM, CIC, UNISWA and SCOT

2.6.3.2 Enabling framework specific to CHP technology

Table 2.12: Enabling framework for barriers specific to CHP technology

Barrier	***Enabling framework***	***Role players***
Market uncertainty or perception of it	3. Government guarantees the purchase reasonably priced locally produced power for energy security 4. Government commits locally produced extra power to the Southern African Power Pool	MTEA, DOM, MNRE, FSE&CC, and UNISWA
Uncertainty of biomass resource availability because of forest fire risks	2. Plan for contingencies for periods of low biomass availability, like for instance a	MTEA, DOM, MNRE, DOF, FSE&CC and UNISWA

and drought	stand-by natural gas power plant	

2.6.4 Enabling framework for barriers specific to solar PV technology

Table 2.13: Enabling framework to barriers specific to Solar PV technology

Barrier	Enabling framework	Role players
High cost of equipment and Solar PV has limited use	4. Provide support for regional standards to allow high volume of components at low prices. 5. Encourage local assembly of components. 6. Implement net metering and this will be a sufficient motivation for solar PV and directly addresses the barrier of limited use.	MTEA, DOM, MNRE SIPA, FSE&CC, SEC, SERA and SWASA,
High cost of land	2. Find creative sites for solar PV installations	MTEA, DOM, MNRE and UNISWA
Poor supply chain; weak entrepreneurial skills; limited local technical skill for installation and maintenance; and limited research and development on solar PV systems	These barriers are all linked. The poor supply chain is due to limited local technical skills for installation and maintenance which results from limited research and development which comes with education and training on solar PV. 3. There must be increased research and development in solar PV coupled with education and training, and information dissemination to boost technical skills. 4. Business models must be developed for systems of different sizes must be developed and provided to individuals and businesses that meet certain criteria to boost the entrepreneurial skills and improve the supply chain.	MTEA, DOM, MNRE, SIPA, UNISWA, SEDCO and MEDP
Limited knowledge of grid compatibility of solar PV systems	2. Train engineers and artisans on dealing with compatibility issues for grid-connected solar PV systems	MTEA, DOM, MNRE, SEC and MEDP
Solar PV is vulnerable to extreme weather conditions	3. Adequately train installers on best practices for minimising extreme weather effects on solar	MTEA, DOM, MED, UNISWA, and SCOT

	PV. 4. Where the risk is high use appropriate technology in high risk of impacts use thin film solar PV technology.	
Solar PV power is intermittent	2. Engineers and artisans have to be trained on handling intermittent power. The California in the USA, Germany and Australia are countries to learn from since they have large solar PV installations.	

Chapter 3 Waste Sector

Waste issues in the country fall under the Swaziland Environment Authority (SEA) which is parastatal tasked with addressing all environmental issues in the country. The SEA was established by the Swaziland Environment Act 2002.[23] Part IV of the Act is a very comprehensive document on waste. It addresses issues on the general prohibition and duty of care on waste, waste licences, import, export and trade in waste, waste management functions of the Swaziland Environment Authority, the role of local authorities, site restoration orders, waste regulations and the designation of waste control areas. Other national documents on waste include the National Environmental Policy and the Waste Regulations 2000. The SEA developed the National Solid Waste Management Strategy to use information in the previously mentioned documents to implement waste management practices in line with international practices. Due to a number of constraints a lot of the objectives in the strategy have not been universally met in the country. The bigger municipalities in the country are, however, trying to align themselves with this strategy.

Waste in Swaziland is currently handled in different ways by different stakeholders. Big municipalities are trying to follow the line of sorting waste for the purpose of recycling, reusing, upcycling and dumping the rest of the waste in engineered landfills. Some of the landfills are constructed such that they collect the leachate and vent out methane into the atmosphere. Others are controlled dumpsite. In some smaller towns and communities waste is simply burnt right in the open or in pits with little or no recycling, reusing or upcycling. The separate/reuse/recycle technology was ranked very high by the stakeholders in the technology needs assessment prioritisation. It got score of 85%. In the BAEF it is renamed waste sorting.

3.1 Preliminary targets for the transfer and diffusion of the Sector

1. Waste sorting technology

All sectors of the economy are targeted for the waste sorting technology. It would not be effective to be selective as the issue of waste disposal is a national one. Communities must be sensitised waste management practices. The awareness raising must also use the synergy between the UNFCCC and the Stockholm Convention on Persistent organic pollutants, as both conventions are against the open burning of waste.

The targets for sensitisation on waste sorting will be national. That way a huge impact can be made in mitigating climate change. It is suggested that a municipal solid waste sorting plant be constructed at the new waste management site to be located in Mafutseni in central Swaziland. This site will serve Manzini City and Matsapha, Malkerns, Ezulwini, Sikhuphe and Siteki towns. This site will therefore have a lot of waste to process each day. When calculating the emissions saved, transportation of the waste to the site has not been included as the waste will be transported there by the municipalities, industries, individuals and other stakeholders. The workers at the sorting facility will be paid from funds obtained through the selling the valuable sorted waste. Recyclers will collect the waste from site. Table 3.1 gives the preliminary targets for the technology

Table 3.1: Preliminary Targets Transfer and Diffusion of the waste sorting Technology

Technology	Waste sorting
Primary target	Awareness raising, education and training: National Waste sorting facility: to cater for waste from Manzini, Matsapah, Siteki and Sikhuphe.
Required investment	National awareness raising and training costs = $154 000 Waste sorting equipment = $1 200 000 Shelter for sorters = $15 400 **Total: $1.37 million**
Expected lifetime	30 years
Expected economic benefits	1. Savings in landfill space:$1.60 million 2. Sales of recyclable materials: $975 thousand
Climate change mitigation benefits	Avoided GHG emissions 174 680 tCO2e Cost per tonne of CO2e emissions avoided = $18.3

2. Composting technology

Compostable matter consists of biodegradable organic matter. Such matter includes food waste, garden waste, leaves, paper, cardboard, grass clippings, manure, etc. Municipal general, domestic, some industrial and agricultural wastes are usually rich in biodegradable organic waste. Of preliminary interest in this barrier and enabling framework development is municipal and domestic waste. Ideas coming out of this work can be adopted by companies and farms. The preliminary target is the waste treatment site to be located at Mafutseni at the centre of Swaziland. This site will receive waste from Matsapha, Manzini, Siteki and Sikhuphe. Currently the total annual municipal waste from the first three municipalities amount to about 13 000 tons per year. Sikhuphe is yet to be a municipality. The amount of compostable organic matter generated is 61913 tons.

A plant capable of sorting waste between 2.5 to 6 t/h cost around one million euro (€1 000 000) or one point two million dollars ($1 200 000), and can be staffed by 8 to 20 people.

Table 3.2: Preliminary targets for transfer and diffusion of the composting technology

Technology	Composting
Primary targets	National awareness raising and training where necessary • Municipalities • Company Towns • Farmers • Households
Required Investment Cost	**Awareness raising and training costs = $77 000** Total cost of required 1 ha land = $62 000 Site Prep. Asphalt/Concrete Pad ($27/square yard): 135 000 Grinder/Shredder : $3,500 Tractor/Front End Loader : $150 000 Windrow Turner : $200 000 Screeners : $180 000 **Total cost = 811 300**
Expected life time	20 years
Expected economic benefits	3. Savings in landfill space:$1.60 million 4. Sales of recyclable materials: $975 thousand 5. Reduction or elimination of the need for chemical fertilizers 6. Increases crop yields 7. Can revitalise habitats by amending contaminated and marginal soils 8. Decreased need for water 9. Is a marketable commodity and can be low-cost alternative to standard landfill cover 10. Can extend the life of a municipal landfill
Climate Change Mitigation Impacts	Avoided CO2e per tonne = 28.33 tonnes Total avoided ghg emissions= 1 270 t CO2e **Cost per tonne of CO2e emissions avoided = $128**

3.2 Barrier analysis and possible enabling measures for Technology 1: Waste Sorting

3.2.1 General description technology

Waste sorting separates the waste into different categories according to type. This can be done preferably at source or at the receiving side. The benefit of waste sorting in climate change mitigation is the removal of biodegradable material that can end up in a landfill where it can biodegrade to produce and emit methane, a gas that is 21 times more potent as a greenhouse gas than carbon dioxide. An added benefit of waste sorting is that some of the waste can be reused, recycled and upcycled reducing the amount of waste that ends up in the landfills as landfill space is becoming scarce and expensive. Some of the waste products can be reusable while some can be recyclable into new useful products, in both cases avoiding them getting to the landfill. Biodegradable waste can also be directed to composting sites or semi-aerobic landfills for further decomposition that can reduce methane emissions. Waste sorting can also be an income generating activity where reusable and recyclable materials can be sold for cash to reward the effort. The waste sorting system has to be designed to suit local needs.

The categories of waste can be classified as biodegradable, recyclable, inert, electrical and electronic, composite, hazardous toxic and biomedical.

Biodegradable waste: This is waste that can be decomposed by bacteria, fungi and or any other biological means. Such waste contains nutrients that are needed by the microorganisms responsible for the biodegradation. Examples of biodegradable waste include food, paper, cardboard, plant material, etc. Such waste can be recycled, composted, diverted to a biogas digester to produce biogas energy, or burnt in an incinerator to produce energy in a waste-to-energy project.

Recyclable materials: These are waste materials that can be converted to other useful materials and products. These include metals, plastics, paper, cardboard, glass, car batteries etc.

Reusable waste: Reusable waste can be reused without necessarily being transformed to another form. Such waste would include clothes, shoes, furniture, planks, containers, etc.

Unpcyclable Waste: This the type of waste that can be made into a better product of higher value than when considered a waste product.

 

(a) (b)

Figure: (a) Upcycled tyres at Matsapha Town Board Engineered landfill. (b) Uncycled plastic from plastic bags at Lavumisa Town Board

Inert waste: Inert waste constitutes of materials that are hardly react both biologically and chemically. Such waste takes a very long time to decompose and is not a threat to the environment except for taking up landfill space without giving up any as a result of decomposition. Examples of such waste include demolition materials from manmade structures, dugout dirt and rocks etc.

Electrical and Electronic Waste: Change in lifestyles of people everywhere around the world is leading to the rapid increase in the use of electrical and electronic equipment. This of course lead to an increase related waste due to product end of life, irreparable failure and obsolescence. Waste electric and electronic equipment (WEEE) can be a source of hazardous waste that can harm the environment and humans. Products like fridges can consume large landfill spaces. Most WEEE does not necessarily contribute directly to climate change, but separating this waste from municipal waste can help improve opportunities for biodegradable waste composting or treatment in semi-aerobic landfills. Electrical and electronic waste includes, household industrial and domestic appliances, TVs, computers, cameras, fluorescent lamps, motors, transformers, specialty batteries, etc.

Hazardous waste: Hazardous waste poses a threat to the public and the environment. Such waste has a potential to be ignited easily, highly reactive or corrosive, etc. Such waste includes most paints and solvents, chemicals, batteries, fluorescent lamps, aerosol sprays and fertilisers, used motor oil, antifreeze, ammunition, radioactive waste in devices like smoke detectors, etc.

Toxic waste: Toxic waste is any chemical compound in liquid, solid, or gaseous form that can cause physiological damage if inhaled, swallowed, or absorbed through the skin. Common toxic chemicals include pesticides, herbicides, fungicides, and can also be found in some everyday electronic gadgets including batteries.

Biomedical waste: Biomedical waste is produced in the health sector. They include expired pharmaceutical drugs, human tissue, sharps which are objects used to puncture or lacerate skin the include hypodermic needles, disposable scalpels and blades, contaminated glass and some plastics, and other material.

Waste in Swaziland is currently treated in the following ways:

- Disposal in engineered landfill
- Disposal in a controlled dumpsite
- Disposal at a dumpsite
- Disposal by incineration
- Disposal by open burning

In engineered and controlled landfills a lot of recyclable, reusable, and upcyclable materials are recovered before dumping into the landfill. This reduces the amount of dumped waste and saves space. At engineered landfills dangerous waste arrive after separation at source. Controlled dumpsites do not accept dangerous waste since they do not have the proper means to handle it. In addition, engineered landfills also have programmes for composting biodegradable waste, and upcycling some waste. Hazardous waste is mainly disposed of by burning in incinerators. The country is party to the Bezel Convention and can transport other hazardous waste across borders for disposal in other countries. The country has several incinerators that burn biomedical waste at temperatures above 800^{o}C.

At dumpsites there is absolutely no control what goes there and sometimes the waste can pile up such that it poses a fire risk that can generate greenhouse gases. Also, the buried biodegradable waste can also decompose by anaerobic means thereby producing methane a more potent greenhouse gas than CO_2. Even though engineered landfills try to reduce biodegradable waste by diverting some of it to recycling and reusing, some of is deliberately disposed into the landfill and a ventilation system is constructed to vent of the methane produced.

(a) (b)

Figure : (a) Waste piled up at a dumpsite. (b) Open burning of waste at a dumpsite.

Open burning of domestic waste is common practice in small towns and settlements in Swaziland. In rural and peri-urban areas the open burning of domestic waste is the method of choice for waste disposal historically promoted by the Ministry of Health in an effort to control the spread of diseases. The open burning of domestic waste directly contributes to the emission of greenhouse gases. Open burning of waste as also been observed to be a problem under the Stockholm Convention on Persistent Organic Compound is Swaziland.

The above two paragraphs reveal that waste disposal directly contributes to greenhouse gas emissions in Swaziland. There is need to address this issue. The separate/reuse/recycle technology can help mitigate climate change in the solid waste sector.

3.2.2 Identification of barriers for the technology

3.2.2.1 *Economic and financial barriers*

(a) ***High capital costs of waste sorting equipment***
Waste sorting equipment suitable for Swaziland can be expensive at around 0.5 million to 1 million euro for systems that can sort from 2.5 to 6 tonnes per hour employing up to 20 people.

(b) ***Low demand for some recyclable materials***
It could be possible that in the country there is a low demand for recyclable waste and that shipping to other countries could prove to be prohibitively expensive.

3.2.2.2 *Non financial barriers*

(a) ***Inadequate skills for O&M***
There are inadequate skills to operate and maintain sophisticated waste sorting equipment. Such equipment separate the waste using a drum screen, a ballistic separator, air separators, storage conveyors, non-ferrous separators, optic separators, balers, etc., technologies not familiar with local maintenance personnel.

(b) ***Inadequate knowledge about recycling opportunities***
Waste gets mixed at source due to that recyclable materials are not well understood. This can result in the contamination of recyclables that can render them non-recyclable. Such waste include glass bottles, paper, cardboard, and plastics that are soiled, exposed to oil, food stuffs etc.

(c) ***Bad habits***
Some people have a “don’t” care attitude about waste. This is primarily due to lack of sensitisation about waste effects to the environment, health and of it being an eyesore.

(d) ***Inadequate variety of facilities for recycling***
There are inadequate facilities for recycling. There are some waste products that a recyclable in other countries that are not in Swaziland. The recycling facilities are also very far from other communities making recycling not worth it without a proper strategy.

(e) ***Low landfill gate prices***
Low landfill gate prices discourages the separation of waste resulting in all the waste going to the landfill, rather than the removal of recyclable waste prior to dumping.

(f) ***Inadequate regulatory framework to encourage waste separation for reuse, recycling and upcycling***
Government does have policies on waste but does not have a regulatory framework to directly drive reuse, recycling and upcycling.

(g) ***No strategies for waste separation for reuse, recycling and upcycling***
There are no strategies for waste sorting for reuse, recycling and upcycling. Small communities far from recycling facilities are not provided options on how to reuse, recycle and upcycling their waste.

3.2.3 Identification of measures for the technology

This section outlines the identified measures for addressing the identified barriers for this technology.

3.2.3.1 *Economic and financial measures*

(a) ***High capital costs and difficulty accessing finance***
Measure: *Develop capacity to source funding from available local, regional and international sources*
The total cost of the operation including maintenance will be around 4 million US dollars over the life of 20 years of the equipment. Such an amount can be sourced from carbon funding mechanisms under the UNFCCC and the SC. The country can provide the land. Employees of the sorting unit can be paid from sold recyclables.

(b) ***Low demand for some recyclable materials***
Measures:

1. *Develop a waste-to-energy project for combustible waste*
   If the waste is combustible considerations can be made for a waste-to-energy project where such waste can be burnt in a boiler system to generate electricity. Even if not profitable such a system can be subsidised by the amount equivalent of saved landfill space and the price of carbon credits generated.
2. *Develop local recycling facilities*
   If the local waste is collected for recycling in neighbouring countries like South Africa, it may be worthwhile to invest in a local recycling plant. Such a waste will not be subjected to high transportation and export costs, and therefore could be viable. If not profitable such a plant can be subsidised by the equivalent amount of landfill space saved and carbon credits generated.

(c) ***Low landfill gate prices***
Measure: *Sensibly increase landfill space charges*
In one engineered landfill, the price was found to be $7.79 per tonne of waste. Such low prices may reduce the incentive to reduce waste by companies and other organisations. A higher tariff may increase recycling, reusing and upcycling and thereby reducing the amount of waste to the landfill. On the other hand, sorted clean waste can be made to attract a rebate to reduce high landfill charges if instituted. The price increases should not be prohibitively high to encourage secret dumping in undesignated sites.

2.2.3.2 Non financial measures

(a) ***Inadequate skills for O&M***
Measure: *Provide training to relevant personnel*
To address the issue of relevant skills, the suppliers of the said equipment will have to come to train the personnel on site on how to maintain such equipment. People

with the right background and aptitude must be selected for the training on all the aspects of the equipment.

(b) ***Inadequate knowledge about recycling opportunities***
Measure: *Provide national education and awareness raising on waste management at different levels*
There will be need for national campaigns on the handling of waste. This will be done in all government agencies, industries, municipalities, schools, institutions and communities. Funding for such shall be sourced from funding mechanisms of relevant international conventions.

(c) ***Bad habits***
Measure: *Increase sensitisation campaigns on environmental and health effects of waste*
Bad habits are primarily due to lack of sensitisation. The national campaigns can go a long way in addressing people attitudes towards the handling of waste.

(d) ***Inadequate variety of facilities for recycling***
Measure: *Train personnel on recycling technologies*
Train people on recycling technologies. Provide these people with knowledge on best available techniques (BAT) and best environmental practices (BEP) to address different waste streams around the world. Information gathered can reveal possibilities to handle such waste and stimulate entrepreneurship in the waste management sector.

(e) ***Inadequate regulatory framework to encourage waste separation for reuse, recycling and upcycling***
Measure: *Develop a regulatory framework on the reuse, recycle and upcycling of waste*
The government must develop a regulatory framework to drive the reuse, recycling and upcycling of waste. Such a regulatory framework must include incentives for doing such.

(f) ***No strategies for waste separation for reuse, recycling and upcycling***
Measure: *Develop strategies to enable small communities to benefit from reusing, recycling and upcycling of waste*
Small communities do not at all have means to recycle waste except returnable soft drink and alcohol bottles. Small communities could be encouraged to stockpile recyclable waste for collection at determined intervals. Money collected from such efforts could be used to fund community projects.

3.2.4 Cost-benefits analysis of the sort reuse recycle and upcycle technology

It was mentioned earlier that the Government of Swaziland is planning a waste disposal site in Mafutseni to cater fort the waste from Manzini, Matsapha, Siteki and Sikhuphe. From data obtained from Manzini, Manzini and Siteki the amount of waste collected totals 13 009.18 tonnes per year for 2016/17. This is equivalent to 1084 tons of waste per month or 48 tons of waste per day taking a month to have 22.5 working days or 6 tonnes of waste per hour for an eight hour shift. An automatic waste sorting machine for such an amount of waste would cost around one and a half million dollars ($1 500 000). Such a machine can be operated by about 8 to 20 people.[24] The waste is assumed to increase at the same rate as urbanisation which is currently 1.23%.[25] The recyclable waste is assumed to be resalable at market value as shown in table 3.3.[26] The targets for this technology are summarised in Table 3.4.

Table 3.3: Market values of recyclable materials

Recyclable material	Price per tonne ($)
Metals	174.62
Glass	37.69
Paper	57.23
Plastics	240.00
Organic component of MSW	14.54

Table 3.4: Cost benefit analysis of the technology

Year	Costs	Metals	Plastics	Paper	Glass	organic
0	-1650000					
1	-154229	345038	218879	69592	22917	28728
2	-144160	322513	204590	65049	21421	26852
3	-134749	301459	191234	60803	20022	25099
4	-125953	281779	178750	56833	18715	23461
5	-117730	263384	167081	53123	17493	21929
6	-110045	246190	156173	49655	16351	20498
7	-102861	230118	145978	46414	15284	19160
8	-96146	215096	136448	43384	14286	17909
9	-89869	201054	127541	40551	13354	16740
10	-84002	187929	119215	37904	12482	15647
11	-78519	175661	111432	35430	11667	14625
12	-73393	164193	104158	33117	10905	13671
13	-68602	153474	97358	30955	10193	12778
14	-64123	143455	91003	28934	9528	11944

15	-59937	134090	85062	27045	8906	11164
16	-56024	125337	79509	25280	8325	10436
17	-52367	117155	74318	23629	7781	9754
18	-48948	109506	69467	22087	7273	9118
19	-45753	102358	64932	20645	6798	8522
20	-42766	95676	60693	19297	6355	7966
	-3400175	3915465	2483819	789727	260058	326001
						974721

3.3 Barrier analysis and possible enabling measures for Technology 2: Composting

3.3.1 General Description of Technology

The waste composting technology was the second rated technology in the waste sector at 52.1%. Compostable waste contains biodegradable carbon. This type of waste comes mainly in the form of food waste, cardboard, paper, garden-waste and tree trimmings. The same waste if it ends in a landfill can produce methane a more potent greenhouse gas than carbon dioxide. Therefore preventing biodegradable carbon materials from reaching the landfill can mitigate climate change through global warming. Composting can therefore be a technology mitigating climate change.

Composting is the aerobic decomposition of organic materials by micro-organisms under controlled conditions into a soil-like substance called compost. During composting, microorganisms such as bacteria and fungi break down complex organic compounds into simpler substances and produce carbon dioxide, water, minerals, and stabilized organic matter (compost). This bulk-reduced stabilised humus residue of compost of can be of sufficient quality to be marketed as a soil conditioner or growing medium in agriculture or horticulture.

Composting can be done at a small scale at household level or in a large scale. There are different types of composting methods suitable for different quantities of inputs. Composting facilities can be aerated or unaerated and covered or not covered. The methods include passive piles, windrows, static piles, and in-vessel composting (in bins, beds, silos, transportable containers, and rotating drums). The basic aspect of the composting technology involves the piling up of carbon-rich matter or browns (e.g. dead leaves, paper, cardboard, hay, ash), with nitrogen-rich organics or greens like (e.g. vegetable peelings, grass clippings, weeds without mature seeds and fresh manure) in the right ratio (about 1:2) and nature will start to break down your organic waste. The materials for composting must be reduced in size so that they evenly mix. Garden soil is either added in layers or mixed right away with the greens and browns. The mixture is the covered with another layer of garden soil. Every so often the mixture is turned around so that the outside material is taken into the inside while the inside material is taken to the outside. In cases compost worms are added to enhance the process. The resulting compost makes a good organic fertilizer that can be used on plants and lawns, or sold for agriculture or horticulture uses. The process produces heat, which can destroy some pathogens (disease-causing microorganisms) and weed seeds. Good-quality compost provides nutrients in a form that plants can use. It enriches the soil health and enhances the soil food. It builds soil structure and improves drainage. It also creates more water-holding ability in soil, which means less watering and acts as a buffer to toxins. Not to mention, it's free plant food.

The selected composting method for municipal waste is turned windrow or aerated composting. This type of composting involves forming organic waste into rows of long piles called "windrows" and aerating them periodically by either manually or mechanically turning the piles. The ideal pile height is between 1.2 and 2.7 m with a width of 4.2 to 5 m. This size pile is large enough to generate enough heat and maintain temperatures. It is small enough to allow oxygen flow to the windrow's core. Large volumes of diverse wastes such as yard trimmings, grease, liquids, and animal by-products (such as fish and poultry wastes) can be composted through this method. This composting technology requires continuous labour and equipment for turning the mixture from time to time. The piles may have to be covered in warm arid climates to prevent moisture loss. In rainy areas the piles should constructed such that water does not drench the mixture. Leachate should be collected and treated properly to avoid contamination of surface and ground water. There should also be a system to control odours.

3.3.2 Identification of barriers for the technology

3.3.2.1 *Economic and financial barriers*

(a) ***High cost and difficulty accessing finance***

The equipment and land for large scale composting is relatively high.

(a) ***Fear that feasibility studies are overly optimistic***

There could be fear that feasibility studies could be overly optimistic and therefor pose a high risk to investors.

2.3.2.2 Nonfinancial barriers

(a) ***Low adoption of waste separation***

There is likely to be a low adoption of separation of waste at source particularly at domestic level. Industry and institutions may not have an incentive to separate waste if the landfill gate costs too low. Otherwise clean organic waste may be contaminated by the time it gets to the landfill.

(b) ***Scepticism on the quality of the compost product***
There could be scepticism on the quality of the compost product which may render the product unsalable. It may be suspected to be contaminated with pesticide residues from fruit peelings, heavy metals from contact with general waste and pathogens. It may be difficult to compare the value of compost to commercial fertiliser.

(b) ***Low awareness of the composting technology***
There is limited awareness of the benefits of the composting technology, particularly in small towns. Bigger city officials are aware of the technology but its implementation is still limited.

(c) ***Difficulty obtaining composting sites***
There could be difficulty in obtaining sites for composting. Residents may suspect that the composting site will attract animals, pests, cause odours and lower property values.

(d) ***Ignorance about the importance of composting***
The general public is not aware of the huge benefits of composting which includes savings in landfill space, greenhouse gas emission avoidance, and availability of a cheap fertiliser.

3.3.3 Identified measures for the technology

3.3.3.1 Economic and financial measures

(a) ***High cost and difficulty accessing finance***
Measures: *Develop capacity to source funding from available local, regional and international sources*
Means to attract donor funding must be put in place. Government could provide guarantee schemes for low interest loans for composting technology through funds from donor organisations.

(c) ***Fear that feasibility studies are overly optimistic***
Measure: *Conduct feasibility studies with stringent requirements*

There could be fear that feasibility studies could be overly optimistic and therefor pose a high risk to investors

3.3.3.2 Nonfinancial measures

(a) ***Low adoption of waste separation***

Measure: *Conduct campaigns to promote composting*

Campaigns should be made to encourage the separation of waste at source. Some incentives can be made to encourage the separation of waste at source to promote composting both in the home and at a large scale. Also, a programme of the provision of affordable waste bins for the different waste streams must be put in place.

(b) ***Scepticism on the quality of the compost product***

Measure: *Introduce quality management systems*

There has to be a quality control system for composting. The first step should be the selection of uncontaminated organic matter from source and ensure that this matter is not mixed with municipal general waste. Atomic and molecular spectroscopy can be used to monitor the level of heavy metals and pesticides in the final product. Microbiologists can be engaged to monitor the presence of pathogens.

(b) ***Inadequate skills on the composting technology***

Measure: *Educate and train people on composting technologies*

People must be educated on the composting technologies both at the domestic level to commercial scale.

(c) ***Difficulty obtaining composting sites***

Measure: *Involve stakeholders at all levels*

When promoting composting, communities must be involved from the policy level, strategy formulation level all the way to the regulatory framework development. Measures to deal with the perceived and real fears must be put in place. Pilot composting facilities must be established at farms to demonstrate the adoption of the identified measure to deal with the fears. Government farms could be the ideal places to start with.

(d) ***Ignorance about the importance of composting***

Measure: *Make people aware of the benefits of composting*

The general public needs to be educated about the benefits of composting which includes savings in landfill space, greenhouse gas emission avoidance and availability of a cheap fertiliser.

3.3.4 Cost benefit analysis for the technology

The data collected revealed that there was a total of 61912.86 tonnes of biodegradable waste in the form of garden waste, tree trimmings, kitchen waste and cardboard produced in the city of Manzini and Matsapha and Siteki towns. Such waste is suitable for composting. The target is to compost in 1 ha of land. In such a pace 1045.223tonnes of waste can be composted. The costs for the technology are shown in Table 3.5.

Table 3.5: Cost for the technology

	Item		Cost ($)
	Awareness raising, education and training		200 000
	Cost of 1 ha land		61 600
	Cost to pave 5 000 m^2		16 200
	Equipment		
	Grinder/Shredder	3 500	3 500
	Tractor/Front End Loader	150 000	150 000
	Windrow Turner	200 000	200 000
	Screeners	180 000	180 000
	Total costs		**811 300**

Table 3.6: Cost benefit analysis for the technology

Year	Earnings (10^3 $)	Year	Earnings (10^3 $)
0	-811		
1	279	11	262
2	278	12	260
3	276	13	258
4	274	14	257
5	272	15	255
6	270	16	254
7	269	17	252
8	267	18	250
9	265	19	249
10	264	20	247

			4 447

3.4 Linkages of the barriers identified

3.4.1 Barriers related to high cost and low access to finance

High cost is common amongst both technologies. Banks in Swaziland are very conservative. They do not want to lend to support unproven technologies. There is need to try to solicit international finance for such projects, at least pilot projects. Local banks can then learn from the success of these projects and then support the further development of these technologies.

There is relatively low skill in Swaziland to access funds available from the international climate change mechanisms. There are numerous sources of funds for climate change activities such as the global fund, crowd funding, African Development Bank etc. Most people are not aware of these and how to access their respective funds. A team must be assembled to capacitate local on accessing these funds. The country can learn from East and West Africa, Latin America and Asia where accessing international finance has been very successful. There is need to train locals on developing bankable proposals for climate change projects.

3.4.2 Barriers related to manpower capacitation

Low demand for recyclable materials, scepticism on the quality of the compost product, and fear that feasibility studies are overly optimistic are barriers that can be addressed by developing appropriate manpower capacities. With the right manpower capacitation new recycling and up-cycling opportunities can be developed, quality systems can be put in place and realistic feasibility studies can be conducted.

3.4.3 Barriers related to lack of knowledge and awareness

Bad habits, low awareness and adoption, and ignorance are all barriers related to knowledge. Education and outreach programmes can help address these barriers. There is a lot of knowledge amongst special groups that does not filter down to public sector institutions, the private sector and individuals.

3.4.4 Barriers related to administrative issues

Policies, strategies and regulatory framework barriers have to be solved by administrators through extensive stakeholder consultation with a bottom up approach. The people to eventually implement the technologies need to own the projects from as early as their development stages to the implementation phase.

3.5 Enabling Framework for Overcoming Barriers in the Waste Sector

The enabling framework for technologies in the waste sector is partially in place. The SEA is updating its waste management strategy and is already providing assistance to communities with skip bins and tractors to collect waste. The Ministry of Housing and Urban Development is also providing municipalities and some communities with waste collection trucks. All municipalities and company towns are knowledgeable on waste management requirements in Swaziland. Some organisations in Swaziland are implementing the ISO14001 Environment Management System. Some of these include the Swaziland Meteorological Services,[27] Royal Swaziland Sugar Corporation (RSSC),[17] Swaziland Electricity Company[4] and Ubombo Sugar Limited.

A good example that illustrates that some aspects of the enabling framework for waste management exist in Swaziland is the case of RSSC. RSSC is a company that grows irrigated sugar cane and manufactures sugar and ethanol, and has company villages. This company is aware of the environmental impacts of its operations and is implementing the ISO 14001 throughout its operations. The waste is treated as follows:[17]

- General solid waste is disposed at its engineered landfill constructed to prevent leachate pollutants from escaping into the environment.
- Effluent from the distillery goes through several treatment stages such that almost zero pollution reaches natural water bodies. The remaining liquid after distillation is concentrated to produce a potassium fertiliser that is returned to the fields.
- The company is planning to install a 30 Megawatts power plant to generate power through co-generation using sugarcane fibre and wood chips to make it (including factories, irrigation systems and its villages) self-sufficient with its renewable power source. The ash from the boilers is returned to the fields to replenish the minerals.
- The factory smoke stacks at the factories are fitted with wet scrubbers to clean the emissions to the atmosphere.
- A large quantity of the CO_2 produced during the fermentation process at the distillery is harnessed and sold for use in soft drink production.

The enabling framework to overcome the barriers in the waste sector is outlined in Table 3.7.

Table 3.7: Enabling framework to overcome common barriers in the waste sector

Barrier	Enabling framework	Responsibility
Related to high costs,	4. Conduct proper feasibility studies that are very close to reality.	MTEA, DOM, SEA, MEDP, DOF, SEDCO

limited access to finance, and fear that feasibility studies are overly optimistic	5. From the feasibility studies develop pilot projects to demonstrate the viability of climate change mitigation businesses in the waste sector. 6. Capacitate relevant local organisations and individuals on how to access local, regional, continental and international climate change funds.	MOA and UNISWA
Related to inadequate knowledge, low awareness, ignorance, low adoption of technologies and bad habits	2. Provide education and conduct outreach programmes that can help capacitate people to be more knowledgeable on bad effects of improper waste management, means to properly manage different waste streams, benefits of proper waste management.	MTEA, DOM, SEA, MEDP, DOF and MOA, UNISWA
Low demand for recyclable materials	6. Have a technology expert group on waste issues. This group could conduct studies on waste treatment in the region and internationally to identify recycling and upcycling opportunities that are relevant for the local market. This expert group could constitute of people in the waste sectors of municipalities, company towns, the SEA and UNISWA. 7. Expose potential entrepreneurs in business opportunities that require some waste products as raw material inputs. 8. Develop strategies for accumulating specific waste resources in remote communities to quantities large enough to justify transportation to recycling facilities. 9. Develop training programmes of waste upcycling. 10. Collect accurate statistics on different waste streams produced nationally in order to assist local entrepreneurs or international investors to determine the viability of waste minimisation businesses.	MTEA, DOM, SEA, MHUD, MEDP, SEDCO and UNISWA

Related to inadequate policy, regulatory framework and strategies	Develop appropriate policies, regulatory framework and strategies to address all aspects waste including waste sorting at source, reusing, recycling, upcycling and other waste treatment methods to be holistic.	MTEA, DOM, SEA, MEDP, MHUD, SEDCO, UNISWA and MOJ.

Chapter 4 Land Use Land Use Change and Forestry

4.1 Preliminary targets for technology transfer and diffusion under LULUCF

Two technologies were considered for LULUCF and they are agroforestry and urban forestry. The targets for technology transfer and diffusion for these are discussed in this section.

1 Agroforestry

Agroforestry forestry technology will target all farmers in crop agricultural lands including small holder farmers. The land is Swaziland comprises two types. The first is Swazi Nation Land (SNL) held in trust by His Majesty the King. It constitutes 54% of the land area. Land for homesteads and fields is allocated by traditional authorities and grazing is land is communal. The average size of crop farmland in SNL is 1.5 ha. The other type is Title Deed Land (TDL) which constituting about 46% of total land area and is private land.[28] The agroforestry technology awareness raising and training will target both SNL and TDL farmers. Agroforestry has synergy with the efforts of the Government of Swaziland and Food and Agriculture Organisation (FAO) of the United Nations through the Ministry of Agriculture and funded by the European Union to develop improved smallholder production and marketing systems which lead to sustainable food security and an improved quality of life for rural households in Swaziland," whose mid-term report came out in 2011. The European Union budgeted fourteen point two million euro on the project (€14.2). This exercise had some success in achieving teambuilding for the implementation of the project. It developed guidelines for Good Agricultural Practices (GAP) and Established more than 1 000 demonstrations plots, trained over 2 000 farmers and carried out 20 on-farm trials of appropriate technologies, and initiated backyard garden production of vegetables, which often benefit small-scale female-headed farm households. A lot can be learnt from this project in diffusing the agroforestry technology.[29]

The agroforestry technology option shall be targeted to 2 000 small holder farmers on SNL who shall be assisted both financially and technically. Farms of TDL shall also be targeted and provided mainly with technical assistance. The average land available for small holder farms in 1.5 ha.[30] Since these farmers do not have a lot of land only 20 trees shall be targeted per household. Most of the trees shall be planted at the periphery. The selection of 20 trees is aimed at reducing the labour requirements. The targeting of 2 000 farmers is to make the project manageable at inception. The total number of plants required shall be 40 000. Grafter trees shall be acquired as they are expected to start producing fruit after 3 years. Table 4.1 below outlines the preliminary targets for this technology.

Table 4.1: Preliminary targets for agroforestry

Technology	Agroforestry
Primary targets	Awareness raising, education and training: National (all four regions of the country catering for both small holder farmers on SNL and TDL) Implementation: 2000 farmers on SNL each with 20 trees
Required Investment Cost	Awareness raising, training and education costs: $1.84 million Fencing: $24.6 million Fruit tree seedlings: $1328 thousand Total initial investment cost: $26.75 million
Expected life time	50 years
Expected economic benefits	Net present value of mangoes sold: $11 billion
Climate Change Mitigation Impacts	Carbon sequestrated per tree: 47.2 tons Total CO_2e sequestrated for 40 000 trees: 69.2 Gt CO_2

http://swaziland.opendataforafrica.org/urpsusd/swaziland-agriculture-sheet

The idea in urn 000 demonstrations plots, trained over 2 000 farmers and Carried out 20 on-farm trials of appropriate technologies, and initiated backyard garden production of vegetables, which often benefit small-scale female-headed farm households. A lot can be learned from this project in diffusing the agroforestry technology.

This technology option will target 2 000 small holder farmers on SNL. Only 1.5 % of the land will be used for agroforestry. That is an equivalent to 0.0225 ha. If the trees are spaced 4 m by 4 m, then there will be 625 trees per ha, which means 20 trees per household. The selection of 20 trees is aimed at reducing the labour requirements. Table 1 below outlines the preliminary targets for this technology.

2. Preliminary targets for Urban Forestry

There are 12 recognised municipalities in Swaziland. These can be initially targeted for urban forestry development. In particular preliminary targets for urban technology are small towns and new suburbs around larger towns and cities. The number of trees to be planted in the different municipalities are indicated in brackets next to each municipality name: Mbabane (17500); Manzini (17500); Piggs Peak (17500); Mankayane (1750); Matsapha (7 000); Siteki (3 500); Lavumisa (1 750); Vuvulane (1 750); Hlathikhulu (1 750); Nhlangano (3 500); Ngwenya (1 750) and Ezulwini (3 500). This shall make a total of 63 000 trees.

Table 4.2: Preliminary targets for technology transfer and diffusion

Technology	Agroforestry
Primary targets	Awareness raising, education and training: All twelve municipalities to plant a total of 63 000 trees

Required Investment Cost	Awareness raising, training and education costs: $25 000 Tree seedlings: $1328 thousand Total initial investment cost: $26.75 million
Expected life time	50 years
Expected economic benefits	Net present value of investment: $ -237 thousand (a monetary loss is made) ***Other benefits:*** 1. Aesthetic appeal that adds market value to residential neighbourhoods. 2. Shade and wind blocking - that reduces building energy costs. 3. Reduced soil erosion from storm water runoff that.
Climate Change Mitigation Impacts	Carbon stored per ha = 28.33 tons Total carbon stored = 1 785 Cost per tonne of CO2e emissions avoided = $133 per tonne

4.2 Barrier analysis and possible enabling measures for Technology 1: Agroforestry

4.2.1 General Description of the technology

Agroforestry was the highest prioritised technologies in LULUCF with a score of 55.0%. Agroforestry includes using the land for agricultural activities such as crop or postural plants production and the growing of trees for timber, fruits, nuts etc. This is could be done by either planting trees on agricultural land or by cropping forested land after thinning. In a lot of cases agroforestry is used a as an adaptation measure. For adaptation purposes the trees help to reduce soil erosion, improve water and soil quality, and provide useful yields of other necessities in addition to the usual agricultural products. For mitigation agroforestry can be used to either to maintain or increase carbon stocks on the land. The woody biomass could provide for a measurable increase in carbon stocks per land area which can be a contribution to climate change mitigation. Trees store carbon both above and below ground, and increase the organic matter in the soil supporting the activity of microorganisms that can enrich the soil. Falling leaves also enrich the soil with They also absorb nutrients from deed in the soil and bring them to the topsoil and therefore enriching the soil for the crops. Organic matter also tends to keep moisture for longer periods and which can be of benefit to the crops even in time of relatively low precipitation.

To be attractive, agroforestry should be developed so that there is a complimentary between trees and crops to enable the best use of the land resources. It is also best if the yields from the crops come at different times from the yields from the trees. That way they system provides on going benefit. Agroforestry could also provide benefits during weather changes as when crops fail there could still be livelihood from the trees. The trees can be better cared for since the land around them is always worked on and monitored. This would reduce the risk of fires and nonconforming trees can be removed and replanting done for a better yield.

Agroforestry also supports biodiversity in different ways. The trees could provide habitats for birds and useful insects. Different plans and animal life could be supported between the trees. Raised animals could shelter from wind, rain and the sun under the trees. The trees could also improve the aesthetics of the landscape. There could also be better control alien and invasive plant species which ten to flourish in forests that are not closely monitored. Table 4.3 shows the amount of biomass carbon on agricultural land around the world.

Table 4.3: Amount of biomass carbon on agricultural land around the world[31]

Biomass Carbon on Agricultural Land								
	Total Biomass Carbon				Average Biomass Carbon			
	Pg C			Increase as % of Total C	t C/ha			Total Agricultural Area (km^2)
Region	**2000**	**2010**	**Change**		**2000**	**2010**	**Change**	
Australia/Pacific	2.11	2.28	0.17	8.06	26.7	28.9	2.2	790,658
Central America	1.42	1.52	0.09	6.45	52.9	56.3	3.4	269,235
Central Asia	0.48	0.47	0.00	−1.04	5.7	5.7	−0.1	830,949
East Asia	2.37	2.53	0.16	6.95	13.2	14.1	0.9	1,795,893
Eastern and Southern Africa	2.31	2.30	0.00	−0.17	14.7	14.6	−0.0	1,573,527
Europe	2.13	2.15	0.02	0.96	9.3	9.4	0.1	2,299,766
North Africa	0.11	0.11	0.00	−0.01	7.3	7.3	−0.0	155,948
North America	3.31	3.40	0.09	2.68	16.0	16.4	0.4	2,073,033
Russia	1.07	1.07	0.00	0.02	6.4	6.4	0.0	1,669,166
South America	11.34	12.13	0.79	6.95	29.2	31.2	2.0	3,888,792
South Asia	2.30	2.48	0.18	7.85	12.6	13.6	1.0	1,827,025
South East Asia	10.03	10.69	0.66	6.59	60.8	64.8	4.0	1,648,268
West and Central Africa	5.57	5.45	−0.12	−2.18	23.3	22.8	−0.5	2,390,980
Western Asia	0.75	0.79	0.04	4.72	7.9	8.2	0.4	955,689
Global	**45.30**	**47.37**	**2.07**	**4.57**	**28.0**	**29.0**	**0.95**	**22,168,929**
Agricultural Baseline	11.08	11.08			5.0	5.0		
Contribution by Trees	**34.22**	**36.29**	**2.07**	**4.57**	**23.03**	**23.97**	**0.95**	

There has been a substantial increase (>2 PgC) in total biomass carbon being stored on agricultural land globally, with a corresponding increase in average biomass carbon hectare (from 20.4 to 21.4 tC ha^{-1}). More than 75% of that was contributed by the tree component. South America and Southeast Asia have by far the largest carbon stocks on agricultural land.

4.2.2 Identification of barriers for the technology

4.2.2.1 Economic and financial barriers

(a) ***Insufficient capital and low access to finance***

Some small farmers may not have the money to purchase the seeds or seedlings of the suitable trees for their area. For some smallholder farmers on national land the cost to protect the plants from animals and possibly from theft can be too high for some families, such that even if the seedlings are provided free the trees cannot be raised to fruition. For some trees in some areas there may also be need for pest control measures which the farmer may not have access to. Capital can also be needed to study the type of soil to determine its suitability for certain trees or the purchase of other inputs such as fertilisers to enrich the soil for that particular tree species.

(b) ***Long time before realising benefits***

The time before benefits are realised for fruit trees could be 4 to 5 years and 8 to 25 years for timber products. This may make agroforestry not appeal to some farmers. The trees shall need financial inputs for weeding, watering, pruning, pest and disease control which will require financing in the form of labour, tools and materials, for return after some years. However, the planting of fruit trees around homesteads, even though not systematic, is a common thing in Swaziland.

4.2.2.2 Nonfinancial barriers

(a) ***Low interest in implementing agroforestry for climate change mitigation***

Small farmers are not interested in adopting agroforestry for climate change. This is partially due to lack of knowledge on the link between agroforestry and climate change. The main cause could be that people are more concerned about their daily existence than to try to change the world. Also, the benefits are realised after some years of taking care of the trees. Usually a few trees grown around the tree household are usually seen to be sufficient as they need the least amount of care. According to officers of the forestry Department, only 20% trees given for free to households survive the first year.

(b) ***Low water resources***

Some areas have relatively low water resources particularly during the winter season and drought years.

(c) ***Low availability of labour to care for trees***

Young trees will need regular watering particularly during the first year of planting and the dry season. Some smallholder farmers may not have adequate personnel to carry-out such activities.

(d) ***Low availability of land***

Low availability of land could be a barrier for a smallholder to engage in agroforestry for timber products. For timber trees the number of trees must be high enough to justify harvesting and transportation costs.

(e) ***Low awareness of the benefits of agroforestry***
Some farmers may not be aware of the benefits of agroforestry. This can lead to scepticism and low adoption of the technology.

(f) ***Infertile soils for agroforestry***
Some soils may not be suitable for some trees.

4.2.3 Identification of measures for the technology

4.2.3.1 Economic and financial Measures

(a) ***Insufficient capital and low access to finance***
Measures:

1. *Donation campaign for tree seedlings*
   A local donation campaign can be organised for seedlings. There has been tree planting campaigns in Swaziland where free tree seedlings have been provided to people before. Enhancing such activities can solve the issue of availability of tree seedlings.

2. Mobilise funding
   Solicit for funding from donors, grants, government support, and climate change mechanisms for fencing materials, protective gear for local labour, borehole or earth dam if necessary, and pest control measures.

(b) **Long time before realising benefits**
Measure: *Engage the organised community labour force*
Fruit trees need the most care in the first year and first two winters. After one and a half years the trees will not need to be watered all the time as their roots will be long enough to get water from the ground. The requirement for weeding will also be minimised once the trees are taller than the weeds. Pruning is only done once in a while. The existence of a community labour force will be key to encourage farmers to engage the agroforestry technology.

4.2.3.2 Nonfinancial measures

(a) ***Low interest in implementing agroforestry for climate change mitigation***

Measure: Emphasise the tangible benefits to the community and make climate change mitigation to be a bonus. The tangible benefits to be emphasised could include availability of fruits or timber and income generating opportunities. Other benefits include shade soil fertilisation from falling leaves and others. Also instil in their minds that their efforts result in climate change mitigation.

(b) ***Low water resources***

Measure: *Ensure water availability prior to inception of the project*

Before a place is earmarked for agroforestry, the issue of water availability have to be solved. Either the water is available naturally or some means to me the water available must be made. One way would be include boreholes in the project or to build earth dams to catch rain water that can have enough capacity to last till the next rain season. There will of course be problems if the community will want to use the borehole or earth dam water for other purposes than what it is intended for. If such problems are perceived the agroforestry should not be implemented in that community unless a solution is found.

(c) ***Low availability of labour to care for trees***

Measure: *Establishment a communal labour force*

This communal labour force can plant the trees, erect the fences, do the weeding and pruning and manage pest control. When properly sensitised, communities in Swaziland, especially the youth, have been seen to commit themselves to community projects.

(d) ***Insufficient land***

Measure: *Maximise the use available land resources*

The literature shows that the average available land for small holder farmers on SNL is 1.5 ha [1]. Taking only 1.5% of that land and growing the trees in the periphery may solve the problem of low land availability. Trees can also be scattered inside the fields.

(e) ***Low awareness of the benefits of agroforestry***

Measure: *Conduct awareness raising and training on agroforestry*

The awareness raising and training on the agroforestry technology may reduce the scepticism amongst the farmers. Information on the raising exotic fruit trees must be sourced and disseminated to the farmers. When it comes to indigenous trees this could be a challenge. Extension workers can advise through observations of areas where the trees grow naturally.

(g) ***Infertile soils for agroforestry***

Measure: *Use local fertilising resources*

Use locally available resources such as cattle and chicken manure, compost and any available biodegradable carbon source.

4.2.4 Cost benefit analysis of the technology

As mentioned earlier the available land for 2 000 farmers for agroforestry is 45 ha and 31 000 trees will be required. The cost of raising fruit trees to fruition is $11 538 per ha. The price per plant shall be around $6.4. These are plants that have grown strong enough to be quickly independent after planting. Seedlings require a lot of care and their survival rate is low inn homesteads. The Department of Forestry distributed seedlings to farmers on SNL. Personnel in the Department say that the survival rate of the seedlings within the first year is about 20%. It is therefore better to plant trees that are already strong enough to survive. The costs benefit analysis of the initial implementation of the technology is shown in Table 4.4.

Table 4.4: Cost benefit analysis of the technology

Year	Earnings (10^6 $)	Year	Earnings (10^6 $)	Year	Earnings (10^6 $)	Year	Earnings (10^6 $)	Yea r	Earnings (10^6 $)
0	-26.8								
1	-0.54	11	207.30	21	291.46	31	273.16	41	256.01
2	-0.52	12	231.71	22	289.58	32	271.40	42	254.36
3	-0.50	13	255.80	23	287.71	33	269.64	43	252.71
4	-0.49	14	279.57	24	285.85	34	267.90	44	251.08
5	-0.47	15	303.02	25	284.00	35	266.17	45	249.45
6	66.86	16	301.07	26	282.16	36	264.45	46	247.84
7	93.03	17	299.12	27	280.34	37	262.74	47	246.24
8	132.08	18	297.19	28	278.53	38	261.04	48	244.65
9	157.49	19	295.27	29	276.73	39	259.35	49	243.07
10	182.56	20	293.36	30	274.94	40	257.68	50	241.50
Net present value									11337.87

4.3 Barrier analysis and possible enabling measures for Technology 2: Urban Forestry

4.3.1 General description of the Technology

During the TNA process urban forestry was the second prioritised LULUCF technology at 52.5% following Agroforestry at 55%. According to Climatetechwiki, "Urban forestry is the care and management of tree populations in urban settings for the purpose of improving the urban environment."[32] According to the CIA Fact Book [2], Swaziland is urbanising at an annual rate of 1.23%.[25] Urbanisation results in the in land-use-change destruction where areas with vegetation are transformed into settlements, formal and informal. This results in ghg emissions and reduces the carbon sequestration capacity of the transformed land. The urban forestry technology can help compensate for this negative impact on the environment sequestrating carbon-dioxide generated around the urban dwelling. The urban forestry technology has to be made an integral part urban development. The trees can be planted in a variety of places to serve different purposes of urban life. All green elements under urban influence comprise the urban forestry Examples include the following:

1. Street trees and road plantations
2. Public green areas, such as parks, gardens, cemeteries,
3. Semi-private space, such as green space in residential areas and in industrial or specially designated parks
4. Public and private tree plantations on vacant lots, green belts, woodlands, rangelands, and forests close to urban areas
5. Natural forests under urban influence, such as nature reserves, national parks and forests for eco-tourism.
6. Urban agricultural land, such as orchards, allotments etc.

The urban forestry has many benefits that include environmental and human benefits. These include mitigation against climate change by partially offsetting carbon dioxide emissions from urban activities such as industrial activity and vehicle transportation, providing aesthetic appeal, providing shade and acting as wind breaks thus reducing the energy needed for heating and cooling, having economic value when matured, and providing oxygen. Some trees in the urban setting can also provide recreation and food. Others can also have positive psychological effects on people leading to health benefits. Trees are also noise dampers. They can reduce the noise around the urban area. Trees also reduce air pollution around the urban area. They clean the urban air by settling out, trapping and holding particulate pollutants like ash, smoke and dust. Such particulates are a major cause of damages human lungs. Trees can also be planted in areas prone to soil erosion around the urban dwelling thus reducing water runoff and increasing ground water recharge.

There are many urban dwellings in Swaziland that provide opportunities for urban forestry. The highest opportunities exist in company towns and towns under development. Company towns in Swaziland tend to have trees both indigenous that were there prior to the establishment of the townships and exotic tree species that were planted after their establishment. There are also small towns that are currently being under development in Swaziland. These towns can be developed in a way that they accommodate urban forestry. In addition the bigger towns are developing new suburbs that can also benefit from incorporating the urban forestry technology in their development. The company towns which already have significant numbers of trees can be encouraged to increase their carbon forestry resources. The company towns in Swaziland include those owned by the timer company Montigny which are Bhunya and Mhlambanyatsi, the sugar, citrus and banana growers which include Big Bend, Simunye, Mhlume, Tshaneni, Thabankulu, Thambuthi, Ngoni and the Swaziland Railways that Mpaka and Sidvokodvo. Upcoming urban areas include Buhleni, Sikhuphe, Vuvulane, Ngwenya, Siphofaneni, Lavumisa, and Lomahasha. The number of these areas clearly shows the great potential for urban forestry in Swaziland.

Figure: A company town with a lot of trees in Swaziland.

To increase the number of trees in an urban setting requires an urban forestry policy, an implementation strategy and regulatory framework. The objective of this policy would be to ensure that new urban developments or expansion of existing ones incorporate urban forestry. The policy must involve stakeholders at every level to avoid conflicts in its implementation. Urban forestry needs good planning and buy-in from the residents for its successful introduction. Also, proper selection of suitable trees must be done because trees in the urban area may be subjected to limited root and crown space, shading from sunlight, and soil and air pollution. Some trees depending on their location may need annual pruning which could be stressful to some species that they may not cope.

Even though the maintenance of urban trees results in the emission of greenhouse gases, this amounts to 2 to 5% of the amount reduced.[33] Maintenance emissions arise from the use of gasoline and diesel fuels by vehicle fleets, and by petrol-powered equipment such as chainsaws, chippers, stump removers, and leaf blowers. Trees in the tropics can sequestrate 22 kg of CO_2 per year from the atmosphere. Outside the tropics they sequestrate less. However, it said that urban forestry can offset up-to 18% of industrial carbon emissions and can store an equivalent of 1.75 times the emissions from the urban area energy supply.[34] According to Liu and Li, urban forestry in Shenyang, China helped store 337 000 t carbon at a rate of 29 000 t per year.[35]

As mentioned earlier, there are costs associated with urban forestry. The US Forestry Service conducted a study of the costs and benefits of urban forestry in several cities in the United States. They found that the cities spent $13– 65 annually per tree while the benefits ranged from $31 to $89 per tree. That means that for every dollar invested in management, benefits returned annually ranged from $1.37 to $3.09.[36] In Swaziland the management of urban forest per tree can be expected to be less that and the same applies to the benefits since labour costs are much lower and the trees are also not expected to be equally valuable as those in the USA.

4.3.2 Identification of barriers for the technology

Few barriers and limitations faced in promoting urban forestry are listed below:

4.3.2.1 Economic and financial barriers

(a) ***Unattractive for carbon markets***

Because of the small number of trees and possible unpredictable permanence of the urban forestry driven by many factors including new pressing development, this technology may not find attractive carbon markets. The costs of project development, verification, monitoring & concerns about methodologies may also make urban forestry to be unattractive to carbon markets.

(b) ***High cost of planting and maintaining trees***

Urban forestry can come at a high cost for municipalities. First the tree planting cost can be high since a few trees per site around an urban are planted. The panted trees have to be taken care of by watering, weeding, trimming and take the trimmings to a disposal site all of which costs money. There are also costs associated to pest control and cleaning leaves when they fall.

4.3.2.2 Noneconomic barriers

(c) ***Inadequate knowledge about urban forestry***

In Swaziland, there is very little knowledge of urban forestry and its benefits.

(d) ***Inadequate support for technology***

Because of low knowledge of the technology, there is basically no support for the technology both financially and technically. The technology may not be supported by the administrators and the community because of the lack of appreciation of its value. There may not be adequate resource allocation by a municipality to the technology.

(e) ***Conflict between the land owner and municipalities in the implementation of urban forestry***

If instituted as a policy to have people planting trees in their premises there may be conflict with the authorities. Some people may not want to be forced to plant and take care of trees.

(f) ***Risk of urban tree mortality and poor health due to the stressful conditions of the urban environment***

The overall project may fail because trees may die after planting and some may not be able to take the urban stress of contaminated soil and air, limited root and crown space, and limited exposure to sunshine.

4.3.3 Identification of measures the technology

4.3.3.1 Economic and financial barriers

(a) ***Unattractive for carbon markets***

Measure: *Emphasize local benefits over international benefits*

By emphasizing local benefits of urban forestry residents may be motivated to adopt this technology. The benefits for the residents include aesthetic appeal, providing shade and acting as wind breaks thus reducing the energy needed for heating and cooling, having economic value when matured, and providing oxygen for better health, providing recreation and food, dampen noise levels, reduce air pollution locally, clean the urban air by settling out, trapping and holding particulate pollutants like ash, smoke and dust, protects areas prone to soil erosion and reduce water runoff and increasing ground water recharge.

(b) ***High cost***

Measure: *Establish a fund to pay for the urban forestry*

Have open forums with the residents on how the city would be without the trees and ask for donations to keep the city green. Occasionally ask for donor funding using documentation that shows that the carbon sequestration capacity of the city increases from year to year.

3.3.3.2 Noneconomic barriers

(a) ***Inadequate knowledge about urban forestry***

Measure: *Provide education and training on the technology*

Provide education and training emphasizing the local benefits of this technology, while making climate change mitigation a bonus. Challenge the myths commonly held to be true about the difficulties of planting trees in urban areas and publicize best practice about how to overcome them.

(b) ***Inadequate support for technology***

Measure: *Conduct education and outreach on the urban forestry technology*

Source donor funding to conduct education and awareness raising on the benefits of urban forestry. This education and awareness raising may not be stand-alone but could include other programmes in the UNFCCC and other conventions where synergy exists.

(c) ***Conflict between the land owner and municipalities***

Measure: *Involve the stakeholders at all levels*

Stakeholders must be involved from policy formulation through development of the regulatory framework to the implementation strategy. That way the residents can take the entire project of urban forestry as theirs. The trees have to be seen by residents as part of the urban infrastructure. Trees must be planted in areas where they are unlikely to contribute to building damage by their roots, falling on buildings or leaves, flowers and fruits falling on undesired areas. More effort is needed on the part of urban forestry managers and professionals to collect information and generate relatable messages about the urban forest specific to different audiences including elected officials and the public. Taking care to target messages will ensure that urban forestry information is understood and applicable to these different audiences and hopefully gain the attention and interest of leaders and the public.

(d) ***Risk of urban tree mortality and poor health***

Measure: *Engage professional in selecting the type of trees for specific areas*

Professional must be engaged to determine the right trees for each specific area. Some trees are very resilient and can thrive under difficult environmental situations.

4.3.4 Cost benefit analysis

A total 63 000 trees are to be planted in the 12 municipalities of Swaziland. The trees shall be thinned by 25% and pruned at 5 years. This thinning shall have no commercial value. They shall also be pruned at 7 and 9 years. They shall also be thinned at 13 years by 53% of the density from the 5 year thinning, for poles of commercial value for posts and pallet material. At 23 years, they shall be thinned once again at by 62.5 % of the density from the 13 year thinning, for saw log for thicker trees and poles for thinner ones. The timer at 30 years shall be sold as saw logs. The net present value of the investment was found to be $-237 000, which is a loss leading to carbon cost of $133 per ton CO_2e. The cost benefit analysis for this technology is shown in Table 5.5.

Table 4.5: Cost benefit analysis for the technology

	Net present value	Income	Costs
0	-333500		
5	-39339	18514.99	40635
7	-22577	22403.14	23625
9	-29714	24643.45	31500
13	-14477	64449	15750
23	-8140	108360	9450
30	-237375	867195	28350

4.4 Linkages of the barriers identified

4.4.1 Insufficient capital, high cost, low access to finance and unattractive carbon markets

High costs and low access to finance seems to be common to all technologies. High costs tend to be due to external exposure, like instability of the local currency and the need to import almost every piece of equipment that is required to implement the technologies.

Access to finance in some cases is due to the lack of understanding by local banks of the technologies. Banks do not want to take risks in technologies they do not understand. It is difficult to develop bankable projects on agroforestry in in SNL and urban forestry. Such projects can rely on donor funding or government guarantees. There is, however, low expertise in Swaziland to develop bankable projects for climate change projects. There is still low knowledge on the regional and international climate change funding mechanisms. There is therefore need to develop and strengthen proposal development for bankable projects in the country. The low expertise in finding funding sources also extends to the inability to find niche carbon markets for urban forestry.

4.4.2 Inadequate knowledge and low of awareness

In Swaziland the existence of agroforestry and urban forestry technologies is known by an elite group. These technologies are not generally known by the public. There is some non-systematic agroforestry practised in Swaziland and there are trees grown in urban areas but not necessarily in coordinated manner. Without the knowledge of these technologies and their benefits the result is the inadequate support and low adoption of the technologies.

4.4.3 Barriers related to resources

Barriers such as low water resources, low availability of land, low availability of labour to care for trees, infertile soils for agroforestry and considerations of the long time before realising benefits, are also linked to poverty. Most rural households are relatively poor and cannot afford to overcome such barriers without external assistance. Households who are well off cannot see all these as barriers.

4.5 Enabling Framework for overcoming the barriers in LULUCF sector

It is important to note that systematic agroforestry is a rather new technology to Swaziland. Its relation to climate change is not generally considered by local farmers. The enabling framework should address the root cause of the lack of adoption of this technology. Some households in Swaziland grow trees primarily for fruits, shade, wind break and firewood. Trees are not ordinarily grown for timber by households. The idea that planting trees is good for the environment is not yet instilled in the general population. It is commercial entities that venture into plating trees for timber. Also households have more immediate pressing issues to make efforts to combat climate change. The barriers in agroforestry include low knowledge of the technology, low knowledge of its benefits, lack of short-term benefits, high initial cost, low water resources for some areas, and expertise on suitable tree species. The adoption of this technology cannot be a regulatory issue as that would appear like over regulation of the people if forced to grow a certain number of trees per homestead. The approach should be to educate, motivate and emphasize the benefits of the technology to the farmers. The costs of the technology must be made to be least burdening to the farmers.

The enabling framework for overcoming the common barriers in the LULUCF sector is shown in Table 5.6 below.

Table 4.6: Enabling framework to overcome the common barriers in the LULUCF sector

Barrier	Enabling framework	Responsibility
Insufficient capital or low access to funding	Capacitate relevant local organisations on how to accessing local, regional, continental and international climate change funds. There are numerous sources of funds for climate change activities such as the global fund, crowd funding, African Development Bank etc. Most people are not aware of these and how to access the respective funds. As much effort as possible must be applied to cushion the smallholder farmer to implement the technology.	MTEA, DOM, SEA, MEDP, DOF and MOA
Low awareness of the benefits of agroforestry and long time before realising benefits	6. There is need to educate and train agricultural extension officers on agroforestry 7. Conduct campaigns on the agroforestry technology 8. Develop demonstration sites for agroforestry 9. Conduct research on growing indigenous fruit trees 10. Raise awareness of the tangible benefits of agroforestry and make climate change benefits a bonus one	MTEA, DOM, SEA, MEDP, DOF, MOA, MOE, NGOs, UNISWA
Low water resources	3. Build earth dams in identified areas 4. Obtain funding for a boreholes and water storage facilities	
Low availability of labour to care for trees	Organise communal labour forces to help the community on various activities. Means to motivate these groups must be developed.	MTEA, DOM, SEA, MEDP, DOF, MOA, MOE, MNRE, NGOs, UNISWA, MOTA

6 Enabling framework for overcoming the barriers

In conducting the TNA exercise, it was stipulated that technologies have to be in line with national development priorities. The development priorities of Swaziland are outlined in His Majesty's Programme of Action 2013 to 2018, where the focal areas are stated "economic prosperity, agriculture and environmental sustainability, education, health, service delivery, infrastructure, governance and corruption."[37] Right there climate change issues have direct impact on agriculture, economic prosperity, environmental sustainability, health and service delivery. This means that climate change issues are cross cutting in Swaziland and must be mainstreamed into all national activities.

The economy depends a lot on agriculture and forestry, but also on tourism, energy, water resources and the commercial sector all of which are affected by climate change directly and indirectly. The country can benefit from the creation of strategic institutions and centres of innovation where knowledge can be developed and disseminated to increase the awareness and knowledge amongst the population. UNDP and other donor organisation could be approached to help in the establishment of these institutions that could "stir up" national activities to address issues in the Programme of Action to 2022 and beyond as outlined in the Swaziland National Development Strategy.[38] This could include partnering with the Small Enterprise Development Company of Swaziland to nature clean energy entrepreneurs to take advantage of the different technologies with a bearing on climate change. The enabling framework is show in Table 25.

Enabling framework for the technologies

Issue	Enabling framework	Responsibility
Civic engagement in development	Create institutions that can do research and provide up-to-date information on available, new and upcoming technologies that can address climate change in the different sectors.	MET, UNDP, MEPD.
Research, development and information dissemination	Create mechanisms to stimulate research, development and information dissemination. Target research could be on solar PV, building materials, energy efficient equipment, energy conservation and energy efficiency.	UNISWA, SCOT, VOCTIM MITC, MEPD
Technology information centres	Develop information data bases on relevant technologies. For what??	MET, MNRE, UNISWA, UNDP, MEPD
Skills capacity	All the technologies require some level of skill for their implementation. Tertiary institutions have to identify the required skills for the implementation of the various technologies in the different sectors. Short-term courses not necessarily leading to qualifications but for upskilling personnel	UNISWA, SCOT, VOCTIM, MITC

	must be developed by tertiary institutions with the support from government.	
Local support for production of components	Support the development of local industry to assemble Solar PV components locally. Also, new building materials using local resources could also be manufactured locally.	SIPA, EDCO, MEPD, MOCIT
Training and accreditation	Provide training and accreditation of solar PV installers, efficient building technicians and artisans and power generation artisans and engineers.	UNISWA, SWASA, external institutions
Development of testing and certification	Provide testing facilities for solar PV systems, building materials, appliances etc. In addition performance testing and certification for installed systems.	UNISWA, SCOT, VOCTIM, MITC, SWASA
Engagement of national human resources in implementing government policies	Utilise all local human resources when implementing government policies. Industry, the commercials sector, parastals, NGOs and the public must be roped in implemented. For example the people in the street tend not to know about things like the Sustainable Development Goals, NDS-Vision 2022, etc. There is need to use a bottom-up approach in the development of polices and their implementation strategies.	MEPD
Land-use	Develop a land-use policy. The entire country must be zoned to limit the haphazard settlements of people. This could save land that can be used for development projects including those for climate change mitigation such as solar PV, afforestation, etc.	MOJ, MOTA
Regional coordination	Exploit regional coordination to gain opportunities for Swaziland. The country is a member of the Southern African Development Community (SADC), an organisation meant to enhance the development of member states. This organisation must be used to provide regional coordination in the tackling of climate change issues thus share knowledge and experiences amongst member states.	MOFA, MNRE
Regulation and enforcement	Develop appropriate regulatory framework that supports the diffusion of selected technologies, like net metering, up to date building code, and enforce the relevant regulations.	MOJ, MHUD
Workshops and road shows	Develop efficient ways to educate and disseminate information to professionals and	MET, MNRE, SIPA, MEPD

	consumers.	
Standards development	Develop standards for the import of components and solar PV installation. Also, standards for energy efficient materials and building should be developed.	SWASA, MNRE,, UNISWA

References

[1] Nyagaard I and Ulrich E H. Overcoming Barriers to the Transfer and Diffusion of Climate Technologies, New Delhi: Magnum Custom Publishing,2015
[2] MNRE. *Internal Document – Energy Balance*. Mbabane: GoS, 2010
[3] Clint A et al. Costs And Benefits of Residential Energy Efficiency Investments. New Brunswick: The State University of New Jersey, July 2011
[4] SEC. Annual Report. Mbabane: SEC, 2015/16
[5] CSO. *Poverty in a Decade of slow Economic Growth: Swaziland in the 2000's*. Mbabane: GoS 2010
[6] Solar Advice. *Solar Geyser Price Comparisons for the South African Market*. Retrieved April 20, 2017 from https://solaradvice.co.za/solar-geyser-price-comparisons/
[7] MNRE. *Draft National Energy Policy*. Mabane: GoS 2-17
[8] fin24. *Cost of new power generation in South Africa* CSIR Retrieved March 24 2017 from https://www.fin24.com/Economy/Eskom/cost-of-new-power-generation-in-south-africa-20161017
[9] MNRE. *Swaziland Household Energy Access Survey*. Mbabane: GoS 2014
[10] GAISMA. *Solar Energy and Surface Meteorology*. Retrieved March 25 2017, https://www.gaisma.com/en/location/mbabane.html.
[11] ClimateTechwiki. *Pulverised Coal Combustion With Higher Efficiency*. Retrieved April 30 from http://www.climatetechwiki.org/technology/sup_crit_coal
[12]Solarwood. *Wundersight Green Energy to Cover Over 4% of Electricity in Swaziland*. Retrieved May 5 2017 from http://solarwood.pt/2017/03/22/wundersight-green-energy-cover-4-electricity-swaziland/
[13] Whole Building Design Guide. *Windows and Glazing, Retrieved.* May 6, 2017 from https://www.wbdg.org/resources/windows-and-glazing
[14] Veilleux N et al. *Solar Water Heating a Strategic Planning Guide for Cities in Developing Countries*. UNEP 2015
[15] Meyer J P. *A Review of Domestic Hot-Water Consumption in South Africa*. R&D Journal 2000 16(3)
[16] Munyaradzi Makoni. *Swaziland Plans 35 MW Biomass Pant*. Renewable Energy World July 20 2016, Retrieved April 21 2017 from http://www.renewableenergyworld.com/articles/2016/07/swaziland-plans-35-mw-biomass-plant.html
[17] RSSC. *Environmental*. Retrieved April 21 2017 from http://www.rssc.co.sz/csi/environmental/
[18] MNRE. *Electricity Act 2007*. Mbabane: GoS 2007
[19] Jha, Madam K, Google Books,Natural and Anthropogenic Disasters: Vulnerability, Preparedness and Mitigation p373, Springer 2010
[20] IOL. *Swazi Sugar to Power its Mills Using Biomass*. Retrieved May 31 from https://www.iol.co.za/business-report/economy/swazi-sugar-to-power-its-mills-using-biomass-692671
[21] Fraunhofer Institute for Solar Energy Systems. *Photovoltaics Report*. Retrieved May 3 2017 from https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf
[22] MNRE. *Sustainable Energy for All Country Action Plan*. Mbabane: GoS May 2014
[23] MOJ. *The Environment Management Act*. Mbabane : GoS, 2002.
[24] Parini. *Automatic waste sorting plant*. Retrieved march 23 2017 from http://www.parinisrl.it/en/portfolio/waste-sorting-plants/
[25] CIA. *The World Fact Book*. Retrieved May 24 2017 from https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html
[26] GreenCape. *Waste Economy – 2015*. Retrieved May 24 2017 from Market Intelligencehttps://www.greencape.co.za/assets/MIRs-2015/GreenCape-Market-Intelligence-Report-2015-Waste.pdf
[27] Swaziland Meteorological Services. *Swaziland Meteorological Services*. Retrieved March 25 2017 from http://www.swazimet.gov.sz/index.php?page=about
[28] IFAD. Land and Natural Resources in Swaziland. Retrieved May 13 2017 from https://www.ifad.org/documents/10180/19c94d55-7d78-4fdc-a494-3a6702e9f8b6
[29] FAO. *Swaziland Agricultural Development Project*. Retrieved March 14 2017 from http://www.fao.org/docrep/016/ap602e/ap602e.pdf
[30]

[31] Zomer et al., Climate Change Mitigation from Agroforestry Estimated. Retrieved 20 March 2017 from https://ccafs.cgiar.org/news/climate-change-mitigation-agroforestry-quantified#.Wrpp32dWWZQ

[32] Climatetechwiki. *Urban Forestry*. Retrieved 15 March 2017 from http://www.climatetechwiki.org/technology/urban-forestry

[33] McPherson, E.G., J.R. Simpson, P.J. Peper, and E. Aguaron. 2008. *Urban Forestry and Climate Change*. Albany, CA: USDA Forest Service, Pacific Southwest Research Station.

[34] Zhao, M., Kong, Z., Escobedo and F. J., Gao, J. (2010). *Impacts of Urban Forests on Offsetting Carbon Emissions from Industrial Energy use in Hangzhou, China*. Journal of Environmental Management, 91 (4), 806-813.

[35] Liu, C. and Li, X., (2011). *Carbon storage and sequestration by urban forests in Shenyang, China.* Urban Forestry and urban Greening, 11(2), 121-128.

[36] McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., Xiao, Q. (2005). *Municipal forest benefits and costs in Five U.S. Cities*. Journal o f Forestry. 103(8): 411-416

[37] MEDP. *His Majesty's Programme of Action 2013 – 2018*. Mbabane: GoS 2012

[38] MEDP. *Revised National Development Strategy – Vision 2022*. Mbabane: GoS 2014

Annexe 1: Problem and Solution Trees for Technologies

A1.1 Built Environment Problem Tree

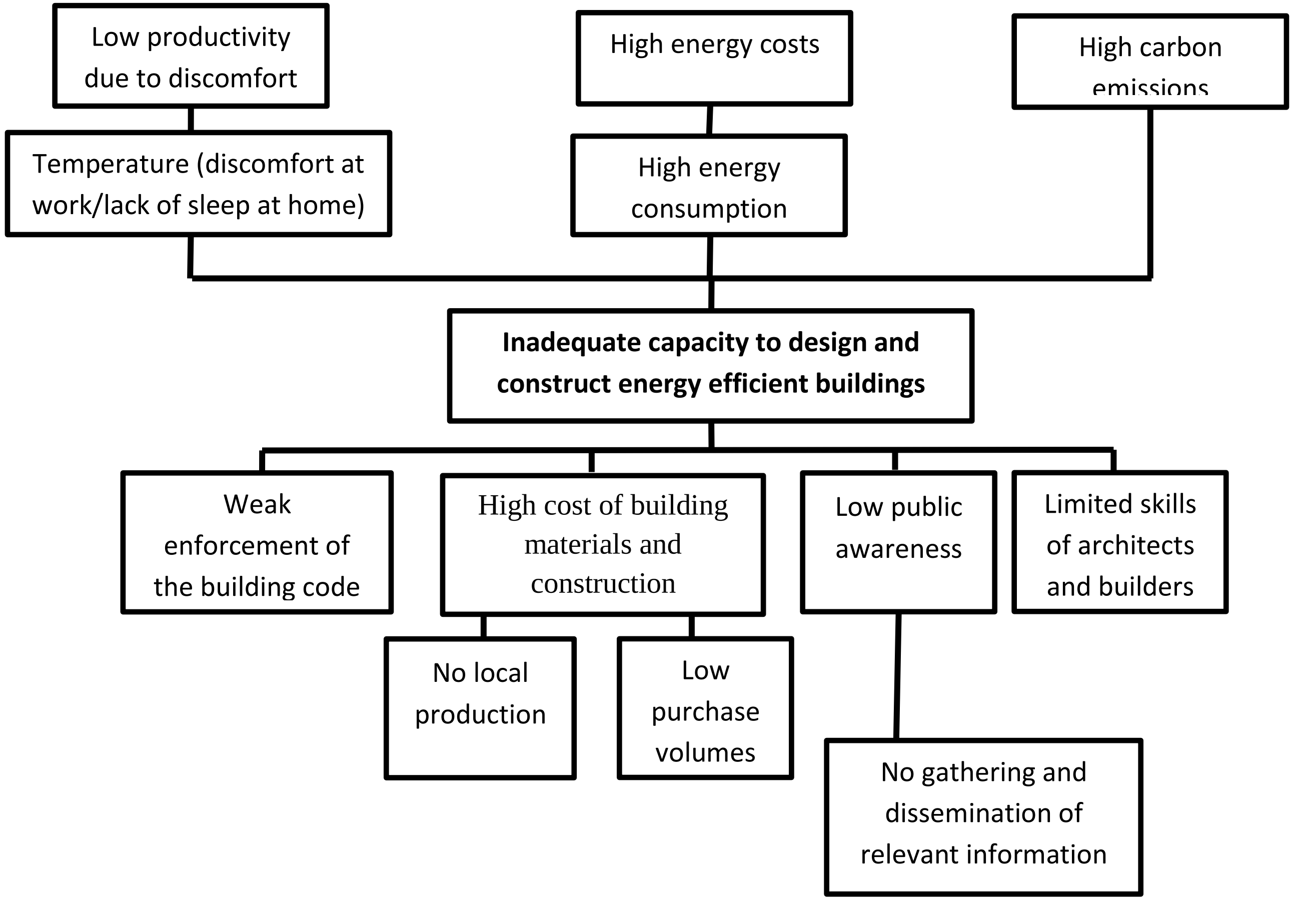

Figure 1. Problem tree for the Built Environment Technology

A1.2: Built Environment Solution Tree

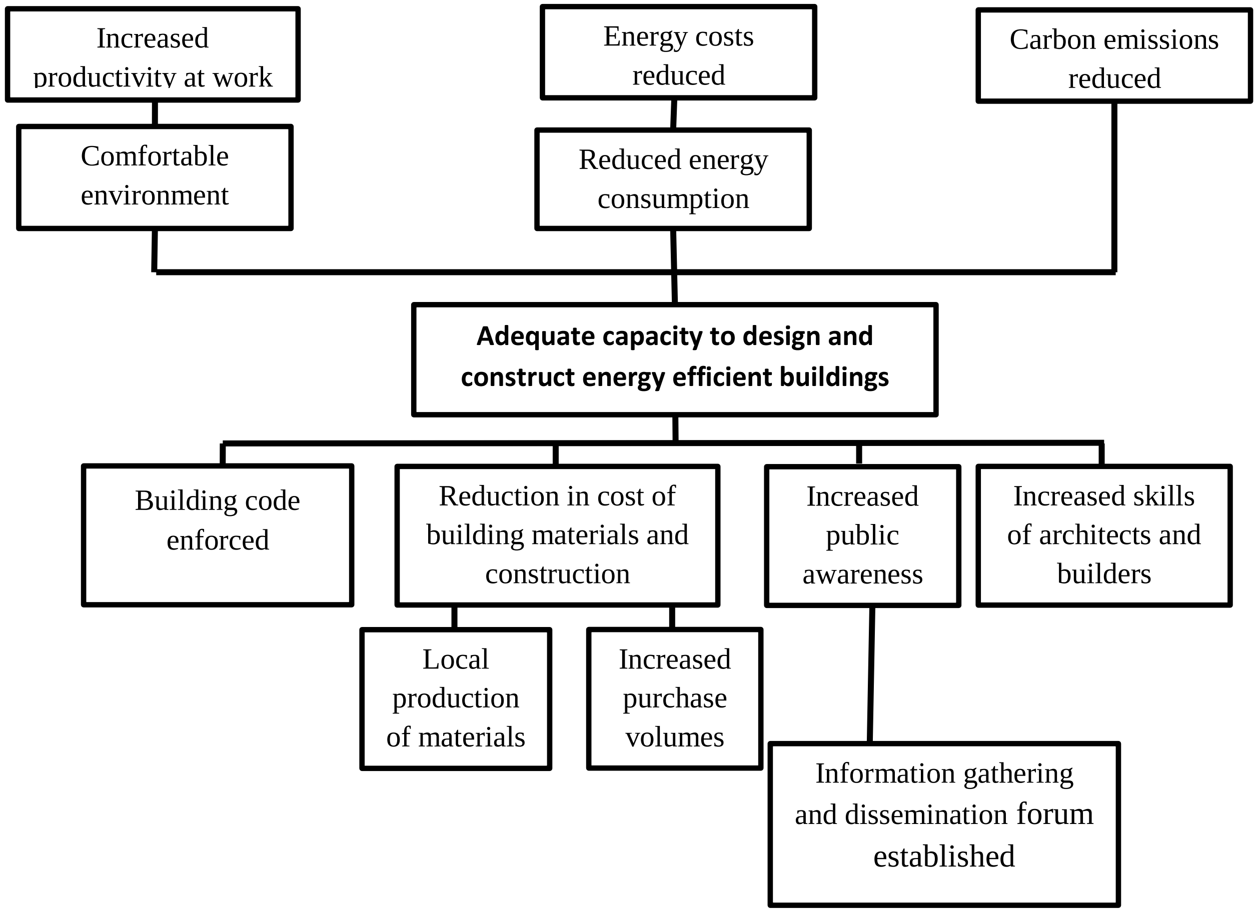

Figure 2. Solution tree for the Built Environment Technology

A1.3: Combined Heat and Power Problem Tree

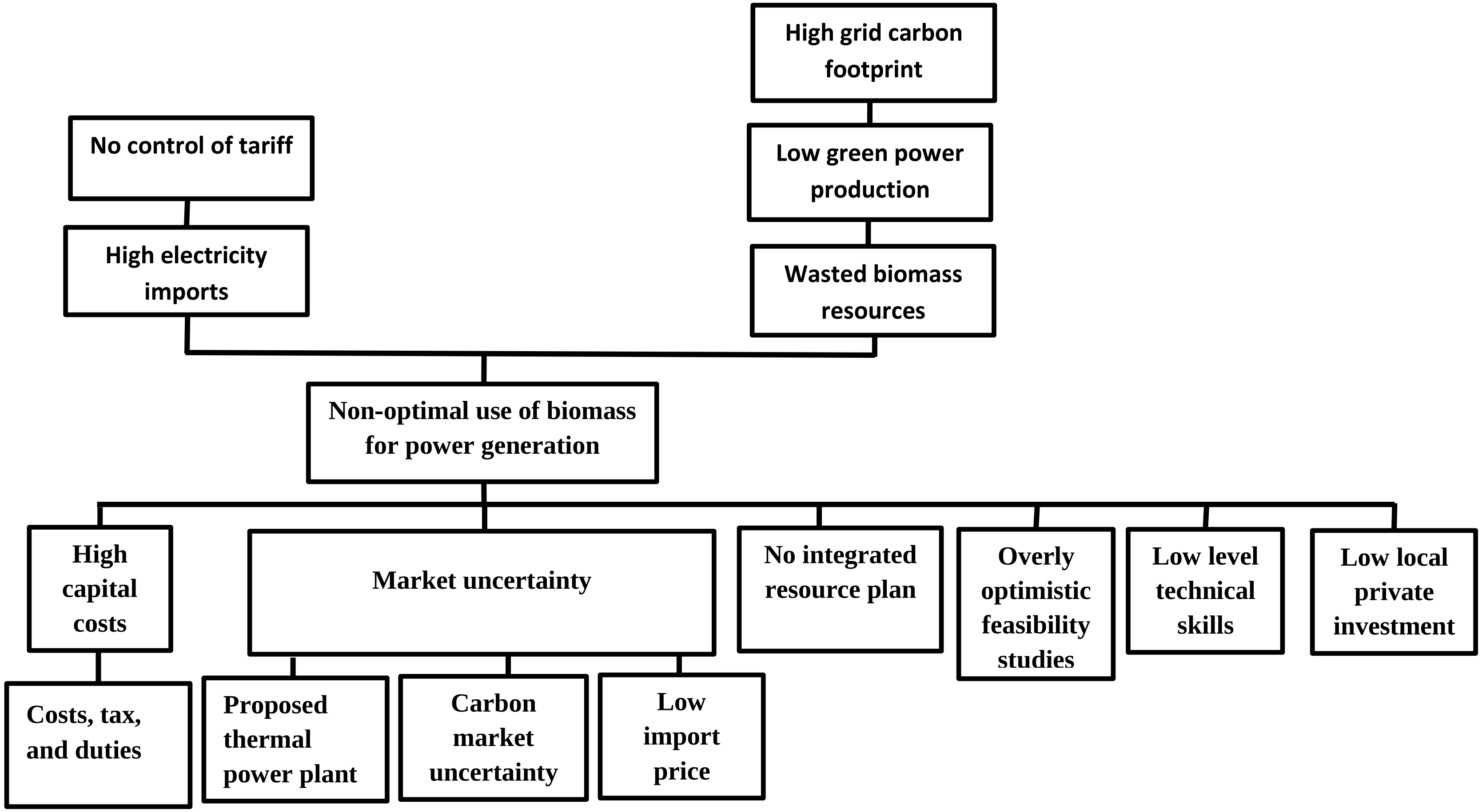

Figure 3. Problem tree for Combined Heat and Power Technology

A1.4: Combined Heat and Power Solution Tree

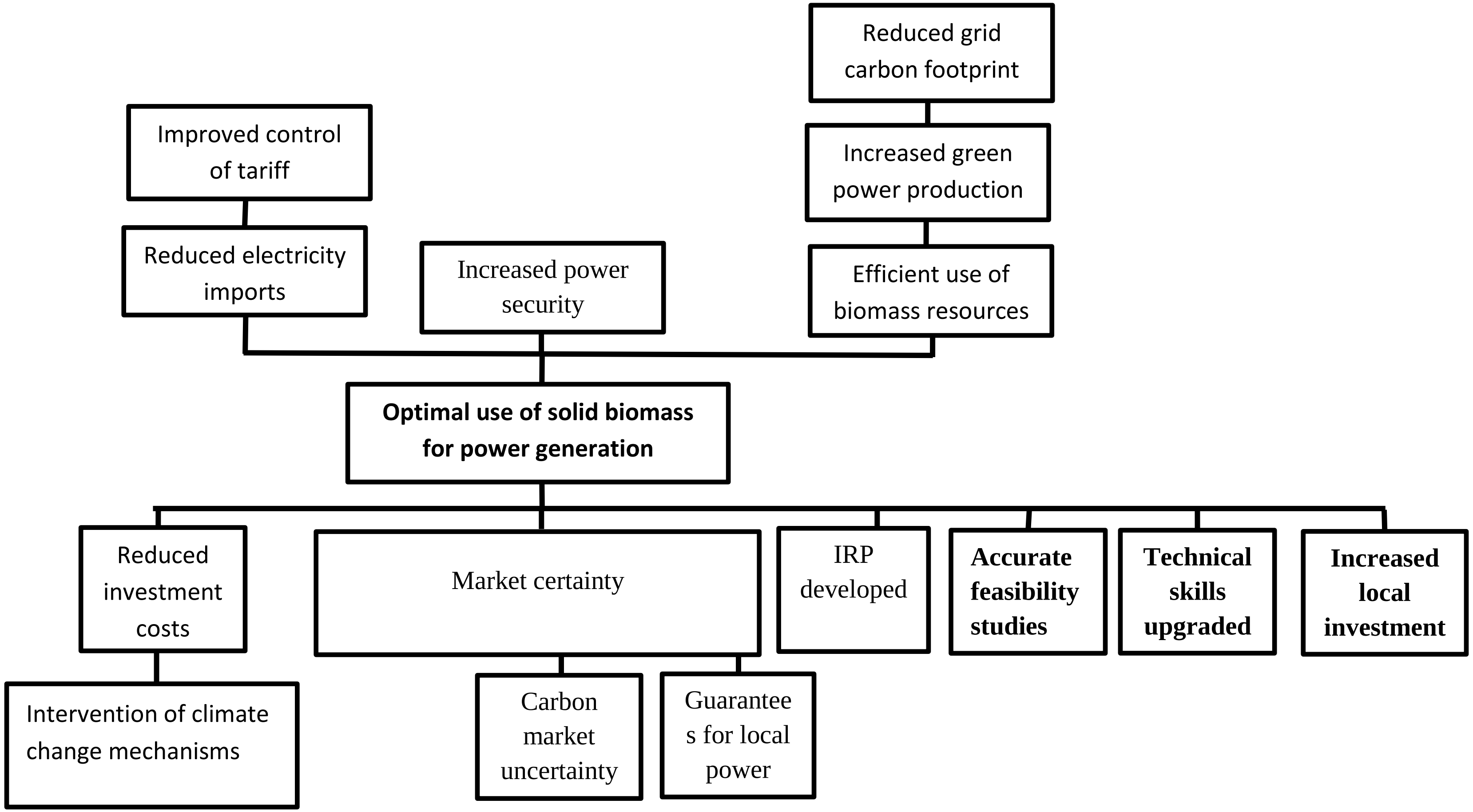

Figure 4. Solution tree for Combined Heat and Power technology

A1.5: Solar PV Problem Tree

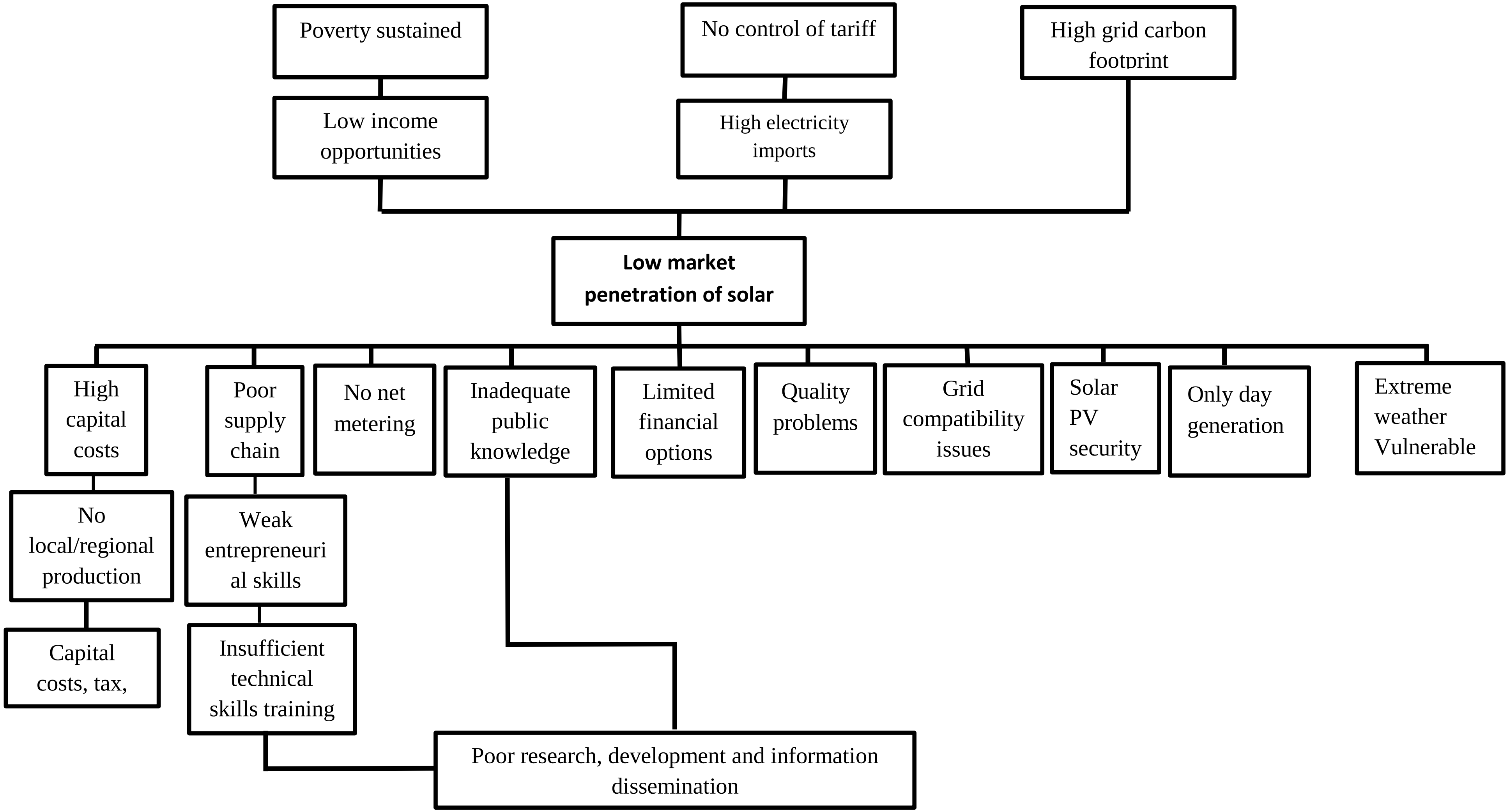

Figure 5. Problem tree for Solar PV Technology

A1.6: Solar PV Solution Tree

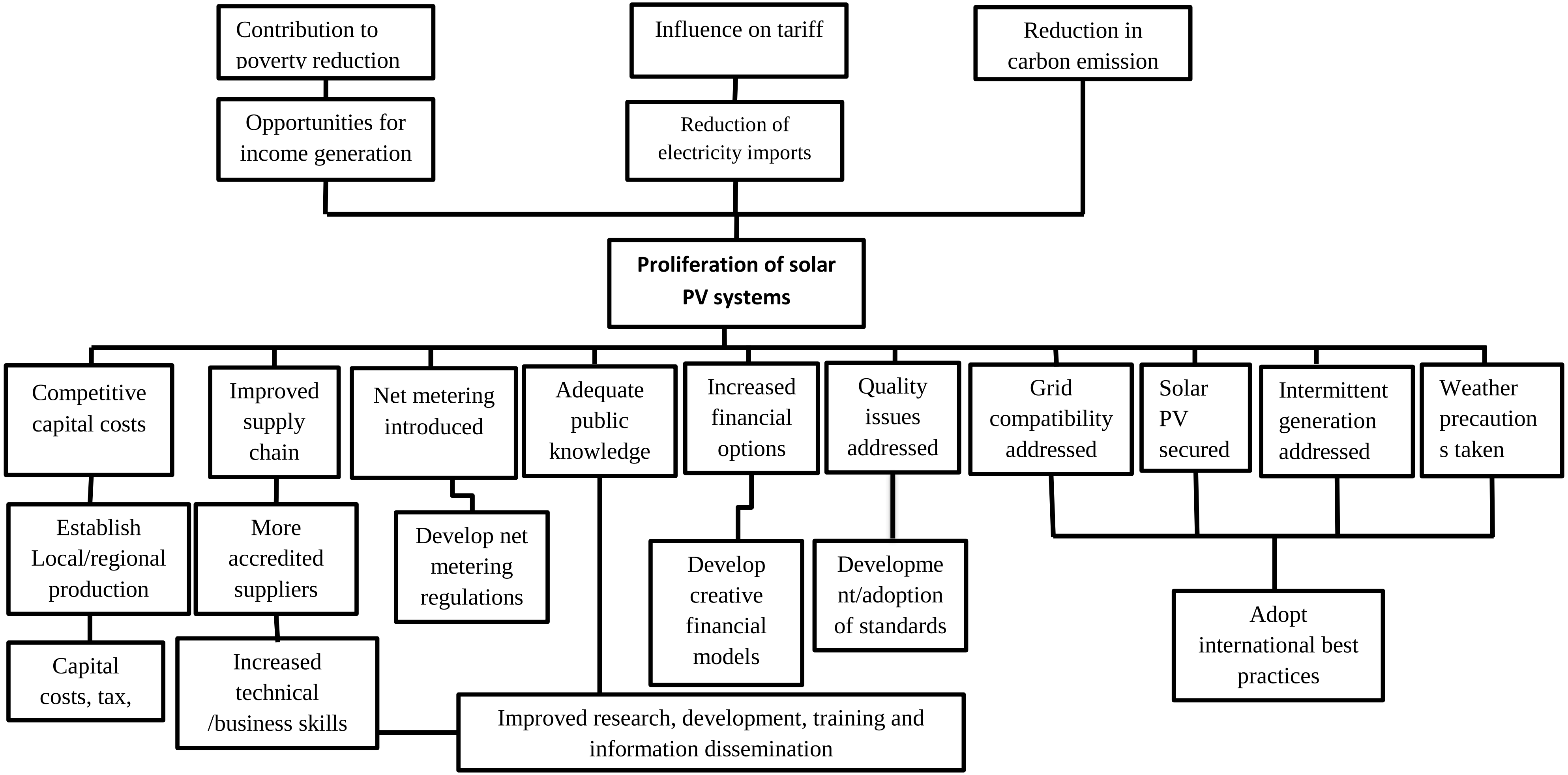

Figure 6. Solution tree for Solar PV Technology

Annexe 2: Market Maps

A2.1 Built Environment Market Map

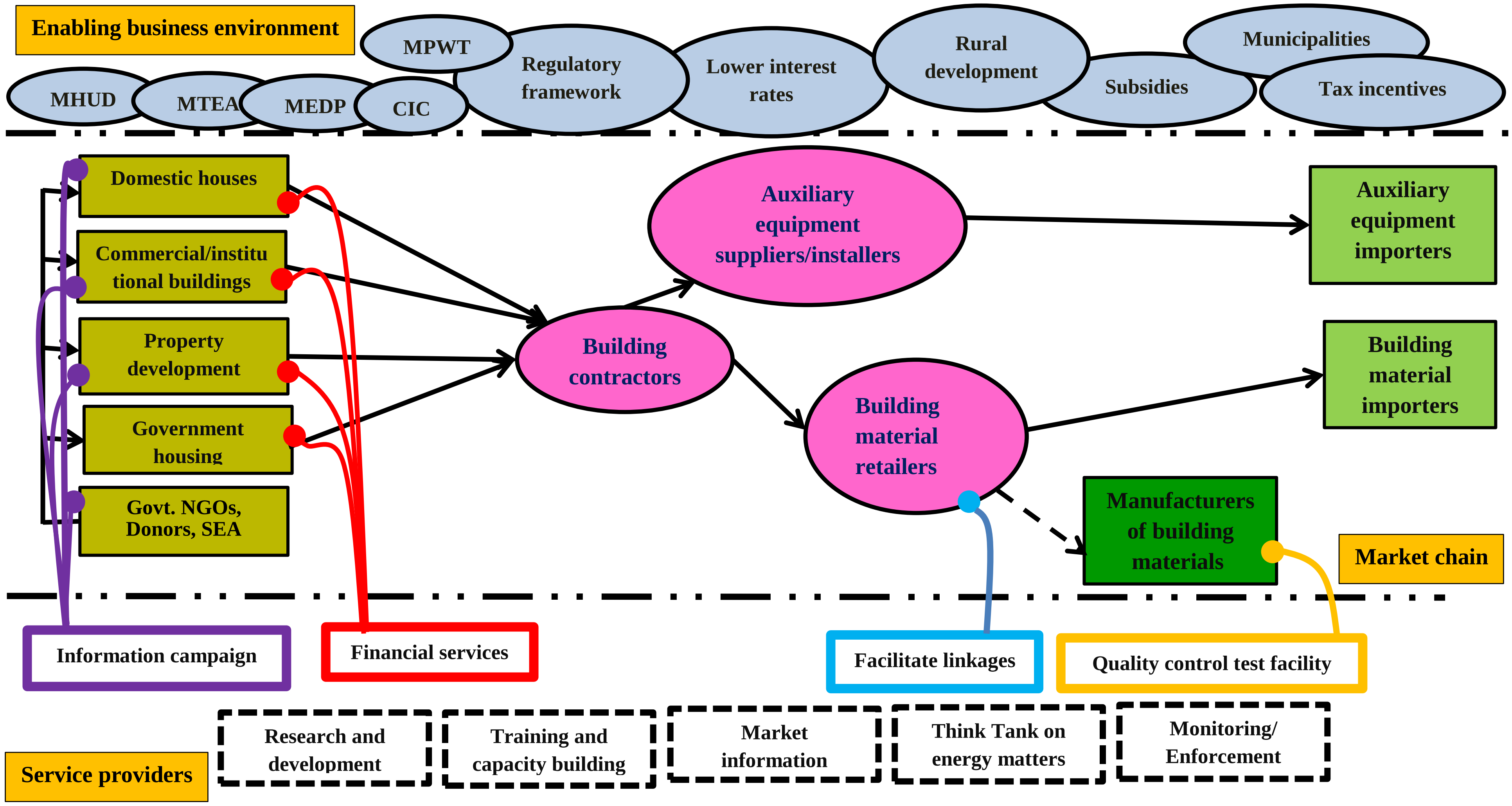

Figure 7. Market map for Built Environment Technology

A2.2 Combined Heat and Power Market Map

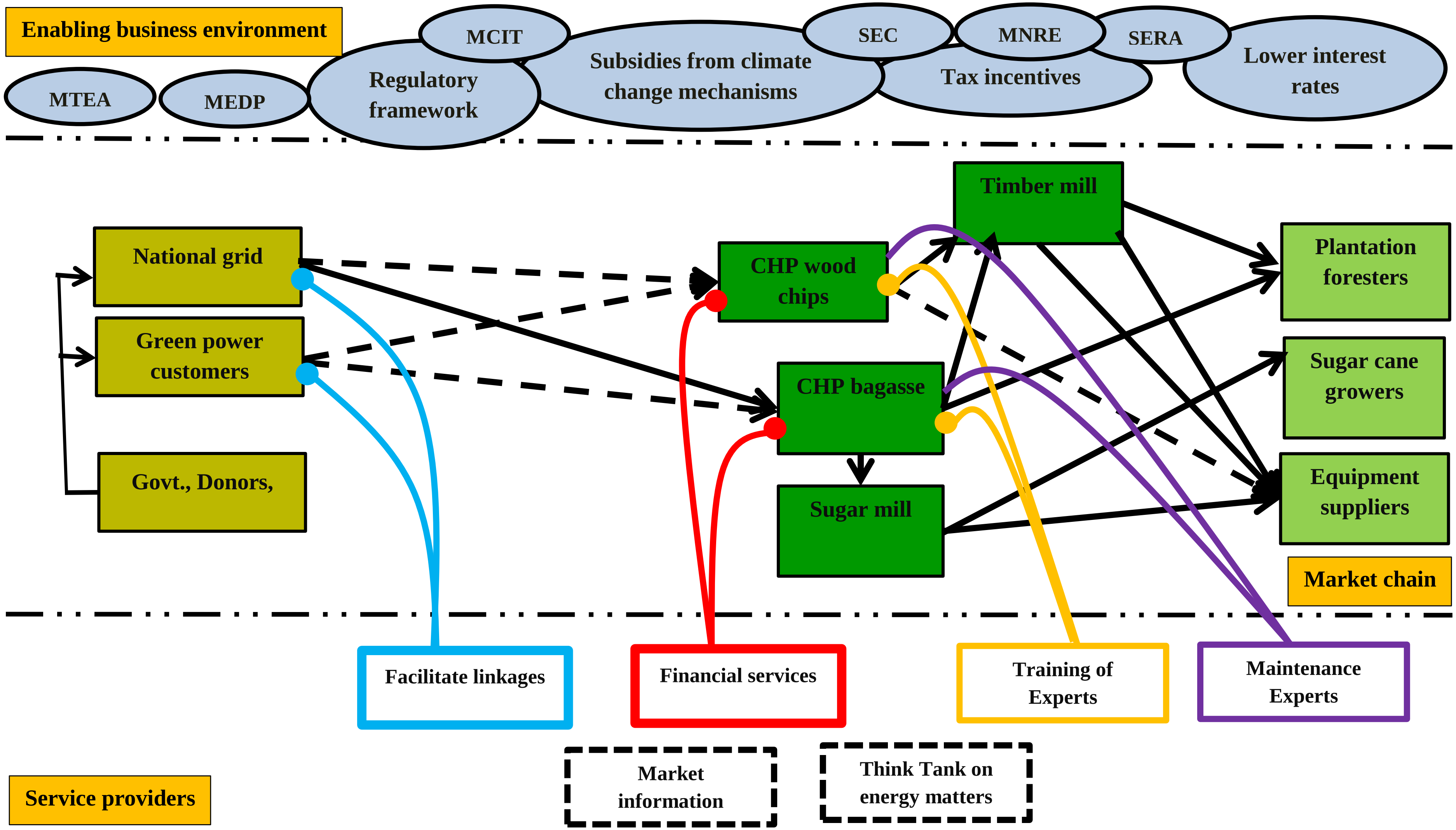

Figure 8. Market map for Combined Heat and Power

A2.3 Solar PV Market Map

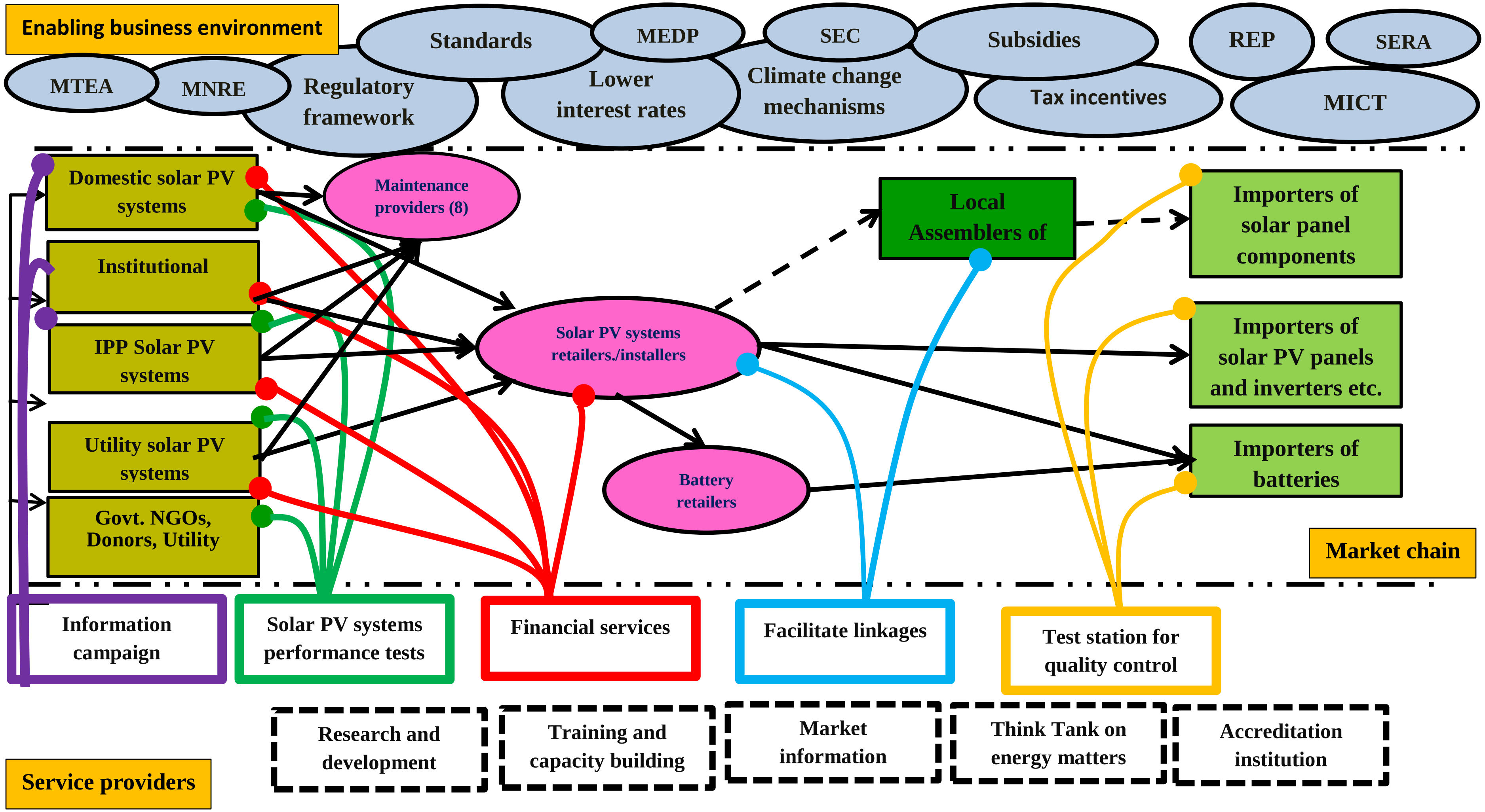

Figure 9. Market map for Solar PV Technology