THE KINGDOM OF SWAZILAND

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE MITIGATION REPORT

June 2016

Technology Needs Assessment for Climate Change Mitigation Report

The Kingdom of Swaziland

Wunder Sight Investments' grid connected solar PV power plant in Siteki, Swaziland

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
tCO2e	Tones Carbon Dioxide Equivalent
CSO	Central Statistics Office
CTCN	Climate Technology Centre and Network
DTU	Technical University of Denmark
ESKOM	Electricity Supply Commission of South Africa
EIA	Environmental Impact Assessment
ERC	Energy Research Centre
EST	Environmentally Sustainable Technology
Ha	Hectare (10000 square metres)
HFCs	Hydrofluorocarbons
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOS	Government of Swaziland
IPCC	Intergovernmental Panel on Climate Change
kW	Kilowatt (10^3 watts)
HFO	Heavy Furnace Oil
IPP	Independent Power Producer
INDC	Intended Nationally Determined Contributions
IRENA	International Renewable Agency
LPG	Liquefied Petroleum Gas
LULUCF	Land Use Change and Land Use Change and Forestry
MNRE	Ministry of natural Resources and Energy
MEPD	Ministry of Economic Planning and Development
MET	Swaziland Meteorological Services
MTEA	Ministry of Tourism and Environmental Affairs
MOA	Ministry of Agriculture
MCDA	Multi Criteria Decision Analysis
MW	Megawatt (10^6 watts)
NCCSAP	National Climate Change Strategy and Action Plan
NEPIS	National Energy Policy Implementation Strategy
NDS	National Development Strategy
N2O	Nitrous Oxide
PFCs	Perfluorocarbons
NMOVC	Non-Methane Organic Volatile Compounds
PPP	Public Private Partnership
PV	Photovoltaic
RSSC	Royal Swaziland Sugar Corporation
RRA	Renewables Readiness Assessment
RE	Renewable Energy
RETs	Renewable Energy Technologies
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SEA	Swaziland Environment Authority
SE4ALL	Sustainable Energy For All

SEC	Swaziland Electricity Company
SERA	Swaziland Energy Regulatory Authority
SIPA	Swaziland Investment Promotion Authority
SNL	Swazi Nation Land
SWASA	Swaziland Standards Authority
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TDL	Tittle Deed Land
TJ	Terra-Joule (10^{12} Joules)
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USL	Ubombo Sugar Limited

Executive Summary

This project report is on "*Mitigation Technology Needs Assessment for Swaziland*." The Technology Needs Assessment (TNA) project is conducted by the Department of Meteorological Services under the Ministry of Tourism and Environmental Affairs (through the Principal Secretary), and supported by the United Nations Environment Programme (UNEP) through the UNEP partnership with the Technical University of Denmark (DTU). The regional technical support for the project is provided by the Energy Research Centre of the University of Cape Town. A National Climate Change Committee (NCCC), with representatives from the private and public sectors and civic society, even though it has a broader mandate took the role of the steering committee for the TNA exercise. The administration of the project is under a TNA Coordinator who is the National Climate Change Coordinator in the Department of Meteorological Services and a Technology Needs Assessment Project Administrator. A consultant was appointed to carry out the work, and lead various stakeholders in the process, since the exercise is stakeholder driven.

The project involved the identification of technologies for climate change mitigation in Swaziland that are in line with national development priorities. The technology options were identified through analyzing the activities in the economic sectors in the country and identifying possibilities for mitigation. The prioritisation of the identified technologies was carried out using Multi Criteria Decision Analysis (MCDA). They were prioritized according to criteria that were selected on the basis of their social, economic and environmental impacts and benefits. Barriers to the implementation of these technologies will be identified and analysed at a later stage. An enabling framework to overcome these barriers will also be developed. Finally, a mitigation Technology Action Plan (TAP) will be produced. Barrier analysis, enabling framework and the TAP are not part of this initial technology prioritisation phase. The technologies selected were grouped according to the relevant economic sectors under the 1996 International Governmental Panel on Climate Change guidelines. For Swaziland these are energy, industrial processes, agriculture, waste and land-use change and land-use change and forestry. The emissions from these sectors are found in Swaziland Second National Communication.

From the Second National Communication the total greenhouse gas emissions for the year 2000, not considering uptake by sinks, amounted to 18,658 Gg CO_2 equivalent. When considering the GHG emissions by sectors, industrial processes accounted for 45.8% (mostly hydro fluorocarbons from refrigeration and air conditioning) followed by waste 33.7%, agriculture 8.2%, energy 6.7% and land-use change and land-use change and forestry 5.6%.

The technology identification and prioritization was done for three economic sectors, which are energy, waste and land use change and land use change and forestry (LULUCF) through extensive stakeholder consultation. The industry sector was left out since in Swaziland the bulk of greenhouse gas emissions are from hydro fluorocarbons emitted from a refrigerator assembly plant and servicing of air conditioners and other cooling appliances, and international programmes are underway to have them phased out by 2030. The waste sector is the second largest contributor and could be the largest if the greenhouse gas emissions in the industrial sector are addressed. The agriculture sector was not considered for mitigation since it is of high priority in adaptation. The stakeholders felt that including agriculture in mitigation may lead to more technical support being given to agriculture over all the other sectors. There is also a prioritized technology in the agriculture sector on grazing land management which could result in mitigation if properly implemented. The energy even though at the time has the second lowest emissions by sector is considered very important as this could change because there is strong political pressure for the construction of a coal power plant in Swaziland. Also, the energy sector has better quality data and can result in the implementation of technology options with better quantifiable emissions reductions that can be exemplary to the implementation of technologies in other sectors.

Results

Energy: The energy sector was divided into three subsectors, which are power generation, household energy and energy efficiency/energy conservation. Because of time constraints household energy was combined with energy efficiency/conservation for the purpose of the prioritization. This sector is very important in the country as it contributes to economic development and the wellbeing of the country's citizens. In 2010, energy needs for Swaziland were met by traditional biomass (39.7%) derived unsustainably from indigenous forests, industrial biomass (10.5%) (in the form of bagasse and wood chips), petroleum products(19.4%) (petrol, diesel, paraffin, liquefied petroleum gas and heavy fuel oil), electricity (11%) (of this electricity 20% is from local hydro production and 80% imports mainly from coal fired power plants in South Africa), coal (17.6%) and to a small extent solar PV, solar thermal and others.

Stakeholders observed that electricity imports were too high and that the country had placed power generation as one of its priority areas. In these discussions the expansion of hydropower was prioritized followed by power production from biomass, and solar photovoltaic was third. The renewable biomass resource available in Swaziland is in the form of bagasse from the sugar industry and wood chips from the plantation forest.

On household energy and energy efficiency/conservation, the top two prioritized technologies were energy efficient buildings and efficient public transport and solar PV. During the validation workshop stakeholders felt that without proper planning of how peopled are settled in the country it would be difficult to develop an action plan for efficient public transport. It was also observed that the energy efficient building option would also be difficult to develop action plans for unless this is done for specific structures or a rollout of specific building designs. However, the stakeholders strongly felt that Swaziland needed to be capacitated in the design and construction of energy efficient buildings, and that such capacity was long overdue. In addition, stakeholders noted that current building plans are not deliberately designed to benefit solar PV systems and solar water heaters.

Waste: The waste sector was also considered very important, in particular municipal waste. It was noted that current common method of handling waste was disposal in dumpsites. The organic waste in these dumpsites decompose and in the process releases methane into the atmosphere. Also, smaller towns still use open burning as a waste disposal method resulting in carbon dioxide emissions amongst other greenhouse gases. It was also pointed out that municipalities are running out of landfill space and are finding it difficult and costly to get new landfill sites.

LULUCF: The LULUCF sector is

In Swaziland, about 50% of the land is used for grazing ruminants that are mainly cattle and goats and are responsible for emitting some greenhouse gases mainly methane, under the agriculture sector. About 12% of the land is used for subsistence agriculture, and 6% used for large scale farming in Tittle Deed Land. Indigenous woodland and plantation forest covers the rest of the area. Emissions from the LULUCF sector arise mainly from uncontrolled wild fires, onsite burning after harvesting of timber, and the removal of biomass for firewood. On its own the LULUCF sector is a net sink of GHG emissions. However when combined with other national emissions Swaziland becomes a net emitter. The role of LULUCF in mitigation is to reduce the overall national emissions.

A brief description of the selected technologies under this TNA follows. They are listed in summary in the table below.

***Hydropower* –** This is the technology where running water is directed to a turbine to generate electricity. *Swaziland* has been generating electricity from hydropower for decades and has a current installed capacity of 62 MW. There are potential sites for its expansion to above 120 MW.

Biomass Combined Heat and Power – This technology is used to generate both heat and electricity. Swaziland has experience in this method of power generation from the pulp, timber and sugar industries. There could be additional supply of biomass from forestry residues and waste from the harvesting of timber that are currently burnt on site and the tops and trash that is currently burnt in the field prior to harvesting by using the green harvesting of sugar cane.

Solar PV – Swaziland uses solar PV systems but not to its full potential. There are limited household and institutional installations that use solar PV without feeding into the grid or a mini grid. There is one company that has a pilot installation of close to 100 MW that feeds into the national grid. There is therefore a lot of capacitation needed to expand solar PV technology in Swaziland.

Energy Efficient Buildings – This technology involves the design and construction of buildings so that they can use minimal energy for indoor comfort of occupants. It also extends to constructing buildings suitable for the installation of energy generation such as solar PV and water heating. At an advanced level it includes the installation of Building Energy Management Systems that automatically control the energy consumption of a building. This technology was suggested by stakeholders who felt that there was need for the improvement of comfort inside buildings while saving energy and also mitigating climate change. The skills for design and construction of energy efficient buildings are very limited in Swaziland and stakeholders wanted Swaziland to be capacitated in this area.

Separate/Reuse/Recycle – For this technology waste is separated at source and that which is not separable at the production location is separated at central locations. Reusable items are separated for reuse and recyclable material is put in appropriate bins for recycling. This technology is to mitigate climate change by reducing the waste that final ends up rotting in a landfill emitting greenhouse gases such as methane.

Composting – Is the degrading of organic waste by aerobic bacteria, fungi and other microorganisms to make a plant nutrient rich mixture used as a fertiliser. This technology is practiced informally in Swaziland and has to be systematically adopted to help municipalities manage their waste and mitigate climate change.

Semi-aerobic landfill- This is a system of treating waste where the waste has to be turned around and mixed from time to time while letting air in from the bottom. It results in faster waste degradation with a leachate that is economical to treat.

Agroforestry – This technology involves the integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. It is practiced in some small farms informally.

Urban forestry – This is the growing of trees in urban areas for aesthetic, environmental, and economic benefits to city residents and visitors by preserving, managing, and enhancing existing trees and other vegetation and promoting the reforestation of the urban area, through an active integrated program with community support and participation.

Grazing land management - This is managing livestock numbers and types to make the most of your pastures while maintaining or improving land condition and biodiversity.

	Sector	**Prioritised technologies**
1	Energy – Power generation subsector	Hydro power
		Biomass Combined Heat and Power
		Solar PV
		Energy Efficient Buildings
3	Waste	Separate/Reuse/Recycle
		Composting
		Semi-aerobic landfill
4	LULUCF	Agroforestry
		Urban Forestry
		Grazing land management

1: INTRODUCTION

1.1 Background

The Technology Needs Assessment (TNA) for Swaziland emanates from the obligations and commitments that the country has as a signatory to both the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. As outlined by Article 4 of the Convention, Swaziland has an obligation to contribute towards the ultimate objective of the UNFCCC by undertaking both mitigation and adaptation actions aimed at reducing greenhouse gas emissions and increasing resilience to climate change for key sectors of the economy, respectively. Technology is necessary and plays a critical role in mitigation, hence the need for a proper assessment informed by the national circumstances and best available research on relevant technologies that would assist the country reduce its greenhouse gas emissions or enable the country to avoid future emission through embarking on a low carbon emission development pathway. This TNA exercise for Swaziland identifies and prioritises relevant technologies that can help reduce greenhouse gas emissions as compared to a growth as usual scenario. It is a follow up to an assessment made in 2010 (GOS MTEA, 2010) which was part of the country's second National Communication to the UNFCCC. The first TNA exercise evaluated several technologies some of which are also considered in the current exercise. It however was limited to technology identification and did not carry out a barrier analysis and evaluate potential enabling frameworks, nor did it develop technology action plans (TAPs) for any of the prioritised technologies.

The primary goal of the TNA project is to identify technological needs for achieving Swaziland's sustainable development priorities as outlined in the Revised National Development Strategy (NDS) (2015). The report identifies, assesses and prioritizes critical sectors and priority environmentally sound technologies (ESTs), which can help achieve desired national development goals and at the same time reduce Greenhouse gas (GHG) emissions. This TNA is part of activities in the country that address climate change which include amongst others the reviewed National Development Strategy (NDS) the Third National Communication (TNC) and the Intended Nationally Determined Contributions (INDC). The TNA has potential to contribute to enhanced capacity in the different economic sectors to acquire environmentally sustainable technologies, developing important links among stakeholders to mainstream climate change issues.

Specific objectives of the TNA are to:

a) Identify priority sectors and suitable technologies that contribute to climate change mitigation in the relevant sectors.
b) Prioritize identified technologies, their cost-effectiveness, and barriers hindering their acquisition, deployment and diffusion.
c) Develop an enabling framework for the deployment and diffusion of the prioritized technologies.
d) Develop a Technology Action Plan (TAP) that specify activities and enabling framework necessary to overcome the barriers and facilitate the transfer, adoption and diffusion of the prioritized technologies in Swaziland
e) Develop project ideas for priority technologies, and to enable and facilitate resource mobilization for their implementation.

1.2 Existing national policies on climate change mitigation and development priorities

Climate change mitigation is linked closely to national development in Swaziland. Some of the national priorities include increasing local power generation, reducing imported petroleum liquid fuels, expanding industrial production, improving the standard of living, etc., all of which have a bearing on climate change through emission greenhouse gasses emissions responsible for climate change. The National Development Strategy (NDS) as reviewed in 2014 provides the overall guidance on climate change mitigation and the path that the country would take to foster economic growth. Any climate action should therefore contribute towards sustainable development and should be compatible with the NDS. Key strategic developmental priorities relevant to climate change mitigation identified by the NDS mainly focus on sustainable energy and include research and development for energy systems, promotion of renewable energy technologies and afforestation/ reforestation. In Swaziland, energy issues are intricately linked to the forestry sector as traditional biomass is widely used for household cooking and heating especially in rural areas and account for 90% of the energy needs (MNRE & IRENA, 2014).

The draft National Climate Change Policy (NCCP) and the draft National Climate Change Strategy and Action Plan (NCCSAP) also prioritizes several sectors for climate change mitigation. The second strategic objective of the draft NCCSAP aims at "promoting development and implementation of adaptation and mitigation actions that contribute to achievement of sustainable development, eradication of poverty and enhances adaptive capacity". This highlights that although the country aims at accelerating economic development as enshrined in the NDS it wishes to do it in a sustainable way. Technology would therefore play a major role in attaining such development and the current TNA exercise is carried out in good timing when the country has just reviewed and updated its NDS and has also finalised both the NCCP and the NCCSAP. The NCCSAP prioritised the following sectors for mitigation: Industry, Waste Management, Agriculture, Energy, Land Use, Land Use Change and Forestry and Transport. Since mitigation is based on greenhouse gas emissions which are in turn estimated based on certain methodologies, the selection of mitigation sectors for this exercise is based on the six emissions categories defined by the Intergovernmental Panel on Climate Change (IPCC): (i) Energy, (ii) Industrial Processes, (iii) Solvents, (iv) Agriculture (v) Land Use Change and Land Use Change Forestry, and (vi) Waste.

Swaziland has implemented several climate change mitigation activities under the UNFCCC. The diagram below highlights the key policies, strategies and action plans that provide the necessary implementation framework for mitigation. Some of the listed polices and strategies will be highlighted as appropriate in the document. These policies and strategies tend to set targets without concrete action plans. The TNA will add value in some of these by producing concrete action plans that can be submitted for funding. Its success shall provide an example for the other sectors to follow suit.

Figure 1: Policies, strategies and projects aimed at mitigating climate change.

1.3 Sector selection

1.3.1 An overview of sectors, projected climate change, and GHG emissions status and trends of the different sectors

The country's developmental priorities as outlined in the NDS have influence on the greenhouse gas emissions as priority developments and production activities will be a source of emissions. The NDS highlights seven (7) micro strategic areas that will assist the country to achieve its vision of attaining a level of development akin to that of developed countries by 2022. The seven strategic areas are: (i) governance and sound economic management, (ii) economic acceleration, industrialization and diversification, (iii) agricultural development, (iv) research and development, (iv) human capital development, (vi) strategic infrastructural development and (vii) environmental management.

1.3.1.1 Energy Sector

Like in any other country the energy sector plays a key role in all economic sectors in Swaziland such as agriculture, commerce, household, industry, mining and, transport. The main energy carriers consumed in these sectors include industrial biomass (bagasse and wood chips), coal, electricity, petroleum fuels (gasoline, diesel, heavy fuel oil, liquefied petroleum gas and kerosene), and traditional wood fuel. With the exception of industrial biomass and about 20% of electricity from hydro, these energy carriers are from non-renewable resources and therefore produce net emissions of GHGs. As a country Swaziland is a comparatively low emitter of greenhouse gases, but being party to the UNFCCC it is required to mitigate the emission of these gases. The energy sector is not the highest emitter of greenhouse gases in the country, but it has more complete information in the form of fuel quantities consumed, technologies used, emission factors, and available mitigation technology options. Therefore mitigation potential can be more accurately determined in this sector. Also, the country is embarking on a 300 MW coal power plant and there are unconfirmed reports that it may increase to 1,000 MW. With the phasing out of greenhouse gas emissions from the air conditioning and refrigeration sectors, and the introduction of new coal based power plant the energy sector may become one of the top emitters of GHGs in Swaziland. It therefore makes sense to start the implementation of greenhouse gas mitigation options in Swaziland to fulfill the obligations of the UNFCCC and to reduce the carbon foot print of local products. Renewable energy technologies can also reduce the dependence on centralized energy sources whose failure could have national catastrophic consequences. They can also result in an increase in the diversity of skills in the country, which can enhance national development.

Renewable energy technologies are already implemented in the country. These include the generation of power from bagasse for selling to the national grid, installation of solar PV systems and installation of solar water heaters. These can be scaled up so that they can make a significant impact in GHG reduction and the energy supply.

1.3.1.2 Industrial Processes

Greenhouse gas emissions are produced from a wide variety of industrial activities. The main emission sources are from industrial processes that chemically or physically transform materials. In Swaziland these include the use of asphalt in roofing and road paving, propellants in the food and beverage industry, foam blowing, fire extinguishers, aerosols and solvents and most of all in the repair and assembly of refrigerators. The Second National Communication indicates that industrial sector had the highest emissions of greenhouse gases at 9,053 Gg CO_2 equivalent. This was a result of the high emission factors for refrigerants from the fridge assembly plant. The global warming potential for these gases rage from 140 to 11,700 as compared to CO_2. The gases involved which are hydrofluorocarbons (HFCs) are, however, due to be phased out globally by 2030, and they are therefore of no concern to this TNA exercise.

1.3.1.3 Agriculture

Agriculture plays a significant role in the national economy of the Kingdom of Swaziland, contributing 8.4% to the GDP in 2009, and plays a great role in income generation particularly for the rural community, provision of raw materials for the manufacturing industries, and generation of export products for foreign exchange. The major export products derived from agricultural production are: Sugar, citrus fruits, beef, live animals, and soft drink concentrates (SADC, 2005).

From the SNC the major contributor of GHG emissions in agriculture were agricultural soils at 629 Gg CO_2-eq. The ruminants, cattle and goats contributed 435 Gg CO_2–eq. Prescribed burning of savannas and field burning of crop residues contributed 276 and 248 Gg CO_2–eq, respectively. Manure management and rice cultivation contributed small amounts.

1.3.1.4 Land-Use-Change and Land-Use-Change and Forestry

The land in Swaziland has two classifications namely Swazi Nation Land (SNL) and Tittle Deed Land (TDL). SNL land which accounts for about 63% of the area of the country is a communal land under chiefs, administered by chiefs under Swazi Law and Custom, which is not documented, but enforced through traditional structures. TDL accounts for about 37 percent of the land area. In TDL, land the owner which could be a corporate or individual has exclusive rights to the land. The main land use is communal grazing, which covers about 50% of the total land area. About 12% of the total area is used for small-scale crop production. Large-scale agriculture is practised in 6% of the total area, and it is found in Title Deed Land (TDL) where about 70 000 ha are irrigated, with the dominant crop under irrigation being sugarcane.

The country is endowed with extensive cultivated plantation and natural forests and woodlands covering about 45% of the total land area. Forests account for 563 325 ha, and 427 034 ha is other wooded land. The country does not have a primary forest, and the present forest is a naturally regenerated forest where there are visible indications of human activities. Some are a result of poor management practices. The area under natural forest has been increasing from 312 000 ha in 1990 to 423 000 ha in 2010, showing forest regeneration rate of about 1.5% in 2010 (FRA, 2015). On the other hand the area under plantations has decreased from a peak of 160 000 ha in 1990 to 140 000 ha in 2010.

Forest plantations cover about 8% of the total area. The dominant species in the plantation forest is the pine which was used to produce wood pulp and timber and since 2004 is now only used for timber in the form of planks. The other species are wattle and eucalyptus. Wattle is used as timber logs and is growingly being used for household firewood in the higher regions of the country. Previously wattle bark was exported to leather tanning industries. Eucalyptus is mainly grown for its timber poles for sale locally and also for export.

The LULUCF sector contributed gross emissions of 1,105 CO_2–eq according to the SNC but was not disaggregated according to source. This gross emission from LULUCF does not take into account the absorption by sinks. The main sources of GHG emissions from the LULUCF sector in Swaziland are burning of forest by wildfires, unstainable fuel gathering for domestic use, and commercial felling. Commercial felling is however done on forest plantations that are well managed. The other significant source of emissions is the reduction in carbon stocks in living biomass. The main removals of GHG are annual increases in biomass increment due to forest growth and annual change in carbon stocks in living biomass due to growth in trees in the country’s grasslands.

1.3.2 Overall Greenhouse gas emissions

Presented here are the GHG emissions using Year 2000 as base year as assessed in the Second National Communication. In the year 2000, total GHG emissions were estimated at 19.8 million tonnes of CO_2

equivalent. Results of this inventory indicate that Swaziland is a net source of GHGs, a change from the 1994 GHG Emission, where Swaziland was a net sink. The highest emitted GHGs in Swaziland are HFCs which contributed 45.8% to total national GHG emissions expressed in CO_2 equivalent in 2000, followed by N_2O, 33.1% and, CO_2, 14.3%. CH_4 contributed 6.8% which is insignificant in comparison to the overall GHG emissions in the country.

When considering the GHG emissions by sectors, Industrial processes accounted for 45.8% (mostly HFCs) followed by Waste 33.7%, Agriculture 8.2%, Energy 6.7% and land use change 5.6%. Total GHG emissions in 2000, excluding uptake by sinks, amounted to 18,658 Gg CO_2 equivalent as shown in Table ****.

Table 1. Summary of national greenhouse gas emissions for the year 2000

Source	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
	CO_2 equivalent (Gg)						
Energy	1,172	121	40				1,333
Industrial Processes				9,053		10	9,063
Agriculture		849	753				1,602
Land Use, Land Use Change and Forestry	1,102	3					1,105
Waste	5596	3662	5,7310				6,6578
Total	**2,833**	**1,340**	**6,5250**	**9,053**	**0.00**	**10.30**	**19,763**

.

1.3.3 Process and results of sector selection

Swaziland favours mitigation options that are in line with its national development objectives which prioritizes sectors that yield the highest possible development benefits for its people. The sectors were prioritized by stakeholders based on both their mitigation potential and the expected economic and social benefits. For the sake of prioritizing the sectors, a national sector prioritization workshop was held on the 13 of July 2015 at Royal Villas Hotel, Ezulwini. This workshop was aimed at selecting three priority sectors for both mitigation and adaptation.

For mitigation, a set of criterion was prepared by the consultant and presented to the stakeholders after the entire methodology was presented to them. The criteria included:

1. Economic importance of the sector and its overall contribution to the country's GDP,
2. Social value of the sector and how it contributes to the social wellbeing of the people including job creation, and
3. Environmental relevance of the sector and how it impact on the quality of the environment.
4. GHG reduction potential and feasibility of the sector including its current GHG emissions and feasibility of abatement interventions.

Using the criteria, the stakeholders prioritized 3 sectors. Results of the sector prioritization are shown in table 2 below. From the results, the energy sector ranked highest followed by the agriculture sector then the waste, industry and lastly the LULUCF sector. The adaptation part prioritised grazing land management, which would either stabilise or increase carbon stocks compared to business as usual. Also, increasing energy production from bagasse in the energy sector would call for green harvesting of sugar cane which would eliminate field burning. This would result in lower demand for coal generated electricity, thus reducing greenhouse gas emissions.

Table 2. Criteria and results of the sector prioritization exercise.

Sectors	Economic	Social	Environmental	GHG reduction	Total benefit	Rank
Energy	5	5	3.5	5	18.5	1
Industry	4	4	3.5	1	12.5	3
Agriculture	4	4	3.5	2	13.5	2
LULUCF	3.5	2.5	3.5	2	11.5	4
Waste	2	3.5	3.5	3.5	12.5	3

Based on the national communications to the UNFCCC, it was clear that the industry sector is the major contributor to the country's greenhouse gas emissions and one would expect that the industry sector be prioritized. However the emissions from this sector are mainly HFCs from manufacturing of refrigerators. The stakeholders decided that since there is already a project aimed at phasing out HFCs by 2030 in the country from the refrigeration industry, there was no need for prioritizing this sector but instead focused on other sectors where there is greater potential for interventions. The waste sector and the LULUCF sector were therefore prioritized as the second and third sectors after the energy sector

PRIORITIZED SECTORS FOR MITIGATION

1. *Energy sector*
2. *Waste sector*
3. *LULUCF sector*

2: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THE STAKEHOLDER INVOLVEMENT

The current TNA project is part of a global project that comprises of 26 countries. The country is implementing the project with assistance from UNEP/UDP and the Energy Research Centre of the Universiy of Cape Town as the regional Centre. UDP is responsible for providing technical support for the project while the ERC operates as a help desk for the country providing support and assistance where necessary and also reviews reports for the project. Figure 1 below provides a schematic representation of the organisations responsible for implementimg the project.

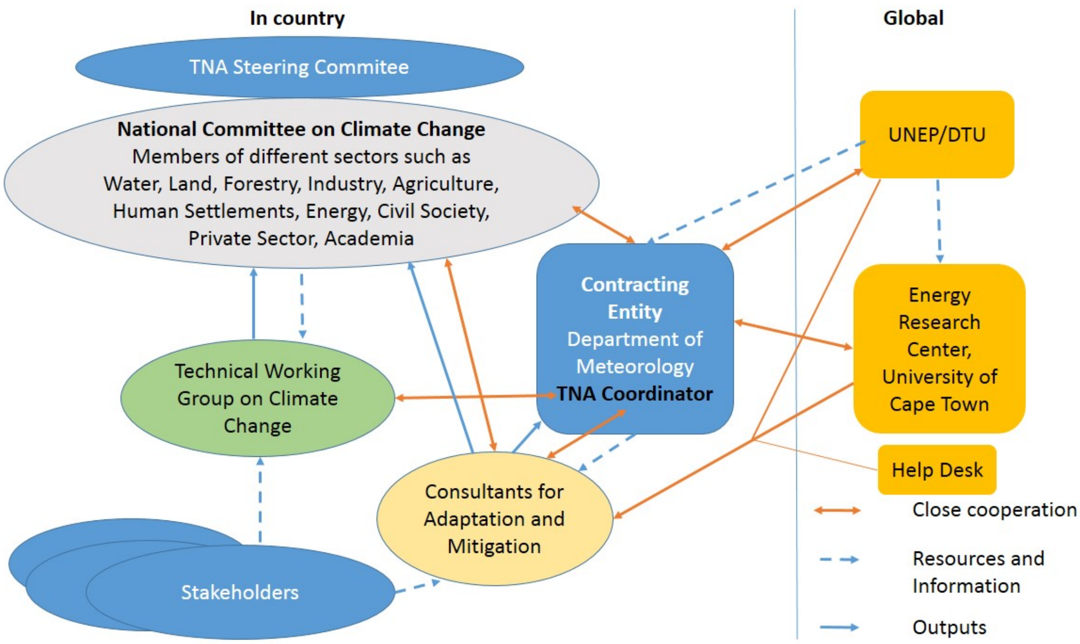

Figure 2. Institutional structure for the TNA

2.1 Project Management Team

The "*Technology Needs Assessment for Swaziland*" is coordinated by the Department of Meteorological Services under the Ministry of Tourism and Environmental Affairs in its capacity as the national focal institution for climate change activities in the country. The management structure of the project is summarised by fig 2.1 below.

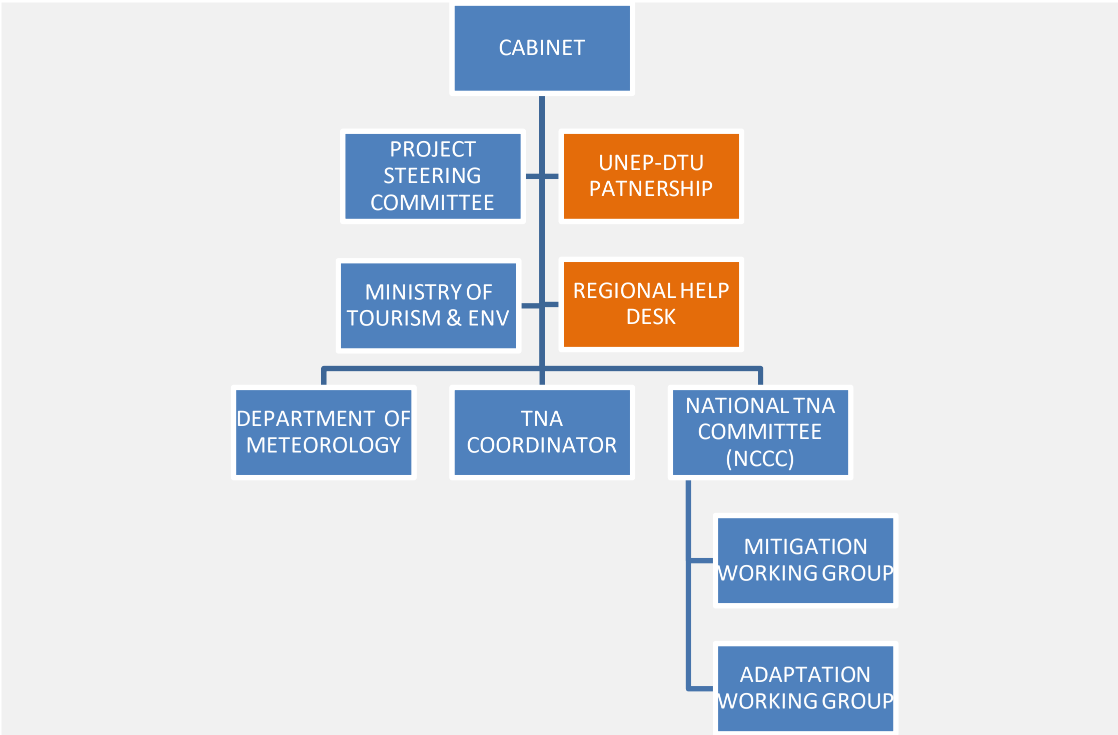

Figure 3: Management structure for the TNA project. The orange colour indicates organisations or structures outside the Ministry's jurisdiction.

A steering committee was constituted during the inception phase of the project. It comprises of high ranking government officials including the office of the Accountant General, the Executive Director of Swaziland Environment Authority (also the GEF focal point), the UNFCCC focal point, the Ministry of Information, Communication and Technology, the Ministry of Health and the Director of Agriculture. The role of this committee is to provide high-level guidance and endorsement to the national TNA team and help secure political acceptance for the TNA process. Furthermore, the steering committee supervises the TNA work and provides advice to the National TNA team whenever requested.

Under the guidance of the Steering Committee, a National TNA Team mainly comprising members of the National Climate Change Committee (NCCC), with representatives from the private and public sectors and civil society, functions as the supreme climate change committee in the country and also responsible for the TNA process. It is the core driving group and is a standing national technical committee that was established in 2010 by a Cabinet decision. Its main aim is to provide technical guidance on issues of climate change in the country and for the process of the TNA process it is to provide an overall co-ordination of the development and implementation of the National Climate Programme and Climate Change Research. Specific responsibilities include:

1. Identifying national development priorities, and priority sectors for technology needs.
2. Deciding on the constitution of sectoral / technological workgroups
3. Approving the technologies and strategies for mitigation and adaptation recommended by sectoral workgroups.
4. Approving the Sectoral Technology Action Plan and developing a cross-cutting National Technology Action Plan (TAP) for mitigation and adaptation.

Two independent consultants were hired during the inception phase of the project, one for mitigation and another for adaptation. As experts in their fields, they are tasked with undertaking the work and supporting the entire TNA process. They are responsible for carrying out research, analysis and synthesis of the entire process.

The TNA Coordinator is responsible for leading the TNA process within the Department of Meteorological Services. The coordinator is assisted by a project administrator who is responsible for the day to day administration of the project, including financial administration.

Two technical working groups have been constituted under the guidance of the National TNA Committee. These are the Mitigation Working Group which is responsible for providing assistance to the mitigation consultant and provide input to the TNA process and the Adaptation Working Group which is responsible for providing assistance and evaluate the work of the adaptation consultant.

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

Stakeholder engagement is critical for inclusive decision making and for bringing in more ideas as each stakeholder is different and brings unique value to the process. Each stakeholder represents a different interest group from public sector, private sector, civil society and traditional leaders. In this case, the stakeholders have different roles along the various steps of the implementation of the TNA project hence it was important to identify them at an early stage of the TNA process and make the decision as to which stage of the TNA process such stakeholders would be more crucial. A step by step approach was followed when deciding on the selection of stakeholders and the steps followed were:

1. **Stakeholder mapping and sectoral representation**

   The team of consultants, TNA coordinator and the TNA administrator had brainstorming meeting on identifying the relevant stakeholders. First, a broad list of relevant stakeholders was drawn up by the team. This was not a difficult task as the selection process benefited from using existing structures from projects implemented by the MET Department. The stakeholders were carefully selected, targeting those that would bring most value to the exercise.

2. Scheduling engagement stage

The team in 1 above prepared matrices for each sector to indicate the stage where each stakeholder would be required. Some stakeholder were required for the prioritisation process while others would be required at later stages for barrier analysis and enabling framework and for the development of the TAPs.

3. Keeping the stakeholders engaged

The TNA project benefited significantly from on-going projects and learnt from them with regard to challenges and good practices in stakeholder engagement in the case of Swaziland. The team had to schedule the workshops and to space them at convenient periods to take into account other climate change activities in the country. There was one case where all the stakeholders met at a retreat for both the INDC and the TNA projects. This proved to be very successful because of the synergies between the two projects.

For this stage of the TNA process, several consultation tools and techniques were built into the national TNA methodology for stakeholder consultation. These were:

a. **Workshops and focused group discussions** were used during the planning phase for informing stakeholders about the project, for prioritizing sectors and technologies and for reviewing documents prepared by consultants.
b. **Field observations** were used for collecting data for generation of fact sheets and since some technologies were already implemented in the country but at a low scale and stakeholders were not aware of them.
c. **Brainstorming sessions** were used mostly by the Steering Committee and the TNA team for tracking progress, sharing ideas and providing guidance to the consultants.

A summary of the stakeholder consultation events is shown in Table 3 below.

Table 3. Stakeholder consultation meetings for the TNA

EVENT	DATE	NUMBER OF PARTICIPANTS	KEY FOCUS
TNA Project Introduction	Pigg's Peak Hotel		Introduction meeting aimed at introducing the entire project to stakeholders. The minister opened the meeting, therefore demonstrating the political support.
Inception workshop	24 March 2015 Mountain Inn Hotel, Mbabane		The workshop was during the UNEP and ERC mission to the country as part of the global programme and aimed at highlighting the methodology to be used in carrying out the TNA process.
Sector prioritization workshop	13 July 2015 Royal Villas, Ezulwini	22	Workshop aimed at collecting sectoral data and prioritizing 3 sectors for both mitigation and adaptation based on criteria identified by the consultant.
Technology Prioritization workshop	20 – 21 August 2015, Simunye	43	Joint technology identification and prioritization workshops for both mitigation and adaptation.
Mitigation Technologies Prioritization	04 February 2016, Royal Swazi Hotel, Ezulwini.	31	Technology Prioritization workshop for mitigation where stakeholders prioritized mitigation technologies.

3: TECHNOLOGY PRIORITISATION FOR ENERGY SECTOR

The energy sector is one of the sectors that have potential for climate change mitigation in the country. There are various national programmes and projects aimed at promoting and facilitating clean energy options and also creating the necessary policy framework for the implementation of such programmes. For the purpose of this exercise, the sector technologies have been categorized into the following subsectors/categories;

i. Power generation,
ii. Household energy, and
iii. Energy conservation and energy efficiency.

The Sustainable Energy for all rapid assessment and gap analysis report of 2014 prioritized universal access to modern energy services as a key objective. Such an objective requires the country to diversity to other affordable modern lighting and cooking technologies to meet the demand. Thus stakeholders prioritized power generation in order to reduce the country's dependency on imported electricity from South Africa and Mozambique while addressing the issue of universal access to modern energy.

3.1 GHG emissions and existing technologies of Energy sector

The Second National Communication showed that energy – related activities have a limited contribution to GHG emissions in Swaziland, estimated at 6.7% of total GHG emissions. Almost all the emissions from this sector are from fuel combustion. A very small percentage constitutes of fugitive emissions (0.3%) arising from coal mining activities. In terms of CO2 emissions, the most dominant greenhouse gas in combustion processes, the largest contribution in the energy sector was transport (48%), followed by manufacturing (40%), and residential (11%) and others including agriculture commercial etc., accounted for less than 1%.

3.2 Decision context

The country's energy policy environment is governed by the NEP, the National Forestry Policy, the National Energy Policy Implementation Strategy (NEPIS) and the National Biofuels Development Strategy. The NEPIS is the most important since it was devised solely for the energy sector. The NEPIS outlines five main objectives which the country wishes to pursue. These are:

1. Ensuring access to energy for all;
2. Enhancing employment creation;
3. Ensuring security of energy supply;

4. Stimulating energy growth and development; and
5. Ensuring environmental and health sustainability.

Since the adoption of NEPIS in 2009, there has been some developments on the ground. These include the installation of a 95 kW solar pV station feeding into the national grid. This is due to be increased to 21 MW. The MNRE has facilitated the installation of several small solar PV systems in government and parastatal establishments. The MNRE is also facilitating the bioethanol petrol and diesel blends. Even though not as a result of the NEPIS, there are some developments that could assist in the development of a low carbon path. One of these is Public Private Partnership Policy of 2013 by the Ministry of Finance whose aim is to mobilise private sector resources to improve and develop energy infrastructure and service delivery. This policy provides government departments and state enterprises with a means of cooperation with the private sector. The specific aim is to speed up efficient and cost-effective implementation and management of energy investments and better services to customers, in energy service delivery, while allowing the public sector to concentrate on its core function. Another supporting activity for the NEPIS is the Swaziland Sustainable Energy For All (SE4ALL) assessment of 2014 which was a study aimed at determining the country's requirements to achieve sustainable energy for all.

As South Africa is moving towards cost-reflective tariffs, Eskom in 2012 was targeting tariff increases of 16% over five years (Multi-year Price Determination (MYPD3)), but was granted 8%, 8%, 12.7%, and 9.4% in 2013/14, 2014/15, 2015/16 and 2016/17, respectively, according to the National Energy Regulator of South Africa. The purpose is to prompt more investment in its generation capacity and upgrade its transmission infrastructure. However, it was only granted a 10.1% increase in 2015 and 9.4% in 2016. Swaziland is already feeling the impact of these changes, as power import costs from South Africa have risen. Swaziland imports about 80% of her electricity from that country. Thus there is growing concern about Swaziland electricity sector's dependence on external factors. The country's available renewable energy resources, like biomass and solar, could complement hydropower generation and shift the current scenario. The higher share of the electricity supply mix would reduce dependence on imports from neighbouring countries, mainly generated from coal. Due to this drive, the stakeholders initially wanted the TNA exercise to focus on technologies that aim at increasing power generation technologies. Swaziland is well endowed with renewable resources suitable for power generation. In addition to hydro, these include solar, bagasse from the sugar industry and wood chips from the timber industry.

3.3 An overview of possible mitigation technology options in the Energy Sector and their mitigation potential and other co-benefits

The energy sector is one of the most important sectors when it comes to climate change mitigation since it comes with other key co-benefits other than emission reduction like health benefits, job creation, increased access to energy for income generation, and increased energy access for social upliftment as outlined in the SE4ALL. In the face of climate change the country also realises the need for energy efficiency and the development of alternative energy sources to polluting fossil fuels. This section outlines the energy context of Swaziland under which mitigation options were identified.

The greenhouse gas emissions from the energy sector are a result of the nature of the national energy supply. The Total Primary Energy Supply (TPES) in Swaziland is mainly composed of traditional biomass (firewood) 39.7%, industrial biomass (bagasse and wood chips) 11.6%, petroleum products 20.0%, coal and electricity 11.0%, coal 17.6%, and other (solar PV, solar thermal etc.) less that 1%. (MNRE Energy balance, 2010).

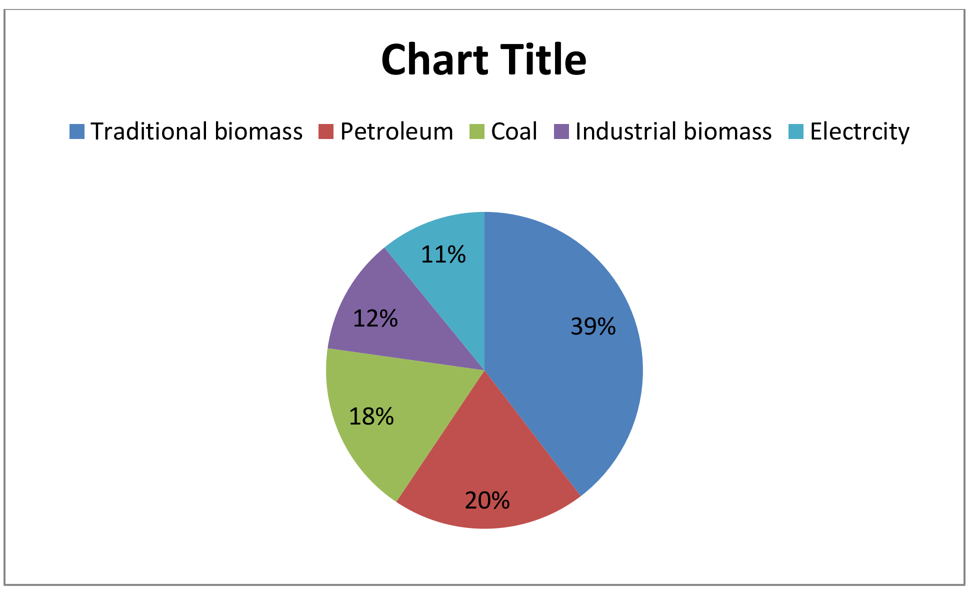

Figure 4. Current Energy Mix of swaziland in 2010

All petroleum products are imported from South Africa. Although semi anthracite coal is mined in Swaziland, it is all exported, while bituminous coal is imported from South Africa. The reason for this is that the anthracite coal brings much needed foreign exchange because of its high value and the coal boilers used locally were designed to burn bituminous coal. Local electricity production is from hydropower as well as biomass from local agriculture and forestry sectors.

Swaziland's energy consumption was estimated at 5,976,052 barrels of oil equivalent in 2010 and shows that petroleum products (56%) had the largest share in Swaziland's energy mix in 2010, followed by electricity (20%). Renewable energy and coal contributed 12% each. GHG emissions in the energy sector result from fuel combustion in the manufacturing industries and construction, transport, residential, and others to include commercial/institutional, and agricultural/forestry/fishing. Fugitive emissions are from coal operations.

3.3.1 Bio-liquid fuels

Swaziland currently produces ethanol for export from the fermentation of molasses. Some of the molasses are also exported to South Africa to produce animal feed. Swaziland has the potential to produce more anhydrous ethanol specifically for biofuels. The sugar industry has shown interest in this revenue stream. The MNRE successfully collaborated with Royal Swaziland Sugar Corporation for trials of a fuel of 10% anhydrous ethanol with 90% ethanol. Now the MNRE is working with the oil the relevant stakeholders on a roll out for the 10% ethanol and 90% petrol (E10) blend. Further to that, the MNRE is also considering a 5% ethanol and 95% diesel (E5 fuel). In this exercise the MNRE is working with the locally represented petroleum companies, USA Distilleries, the sugar industry and some international consultants including some from Brazil - which is advanced in the bioethanol blending industry. There is both political endorsement and technical support available for biofuels based on ethanol.

3.3.2 Power generation technologies

The technologies identified for the power generation subsector are shown in Table 4.

Table 4: List of technologies for power generation category.

	Technology	**Usage in Swaziland**	**Brief description**
1	Combined Heat and Power Generation	Swaziland has experience in the CHP technology from the sugar, pulp and timber industries, although the pulp industry has been closed	Industrial use of biomass energy is for combined heat and power (CHP) generation. The technologies used include the burning of biomass in standalone boilers and the co-firing of the biomass with coal.

2	Solar Photovoltaic Power systems	The average daily solar insolation for Swaziland is 4.77 kWh/m2. Swaziland is gaining experience in medium scale solar PV systems. 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. The local power company SEC is now embarking on some grid-connected solar PV systems in partnership with the private sector.	Solar photovoltaic (PV), refers to the technology of using solar cells to convert solar radiation directly into electricity
3	Hydropower	Swaziland has a long experience with hydropower and several sites have been identified in Swaziland to expand hydro power. Potential sites for expanding hydropower include: Lower Usutu Small Holder Irrigation Project (LUSIP) – approximately 3-7 MW (dam has been built for irrigation); Mnjoli – approximately 3-5 MW; Lower Maguduza – approximately 10 MW and Ngwempisi – approximately 120 MW	Hydro power plants capture the energy released by water falling over a head through a turbine that converts this into mechanical power, which drives generators to produce electricity
4	Pulverised coal with high efficiency	Swaziland has huge coal reserves for the size of the country. The local power company SEC is considering producing its base load from thermal coal fired power station. The initial target is 300 MW and it is expected that the plant will be modern with high efficiency to reduce emissions	The technology can combust pulverized coal and produce steam at higher temperatures and under a higher pressure, so that a higher efficiency level is reached.
5	Natural gas power generation	Mozambique has discovered huge reserves of natural gas and it is feasible that the gas could be piped to Swaziland for electricity generation.	To produce electricity, natural gas is burned in a turbine similar to a jet engine, and the turbine runs a generator.

6	Wind Power	The wind speeds in Swaziland are relatively low around 4 m/s which makes it not cost effective to embark on wind power systems.	In wind power, moving air particles strike (wind) strikes the blades of the wind turbine causing rotation of the generator unit, which results in the generation of electricity.

3.3.3 Household and Energy Efficiency technologies

Table 5: List of Household and Efficiency technologies.

	Technology	**Brief description**
1	Natural gas for household use	Natural gas can be piped from Mozambique for household use to replace wood fuel, paraffin and in some cases electricity for cooking and space heating
2	Ethanol Cook stoves	Ethanol cook stoves have a good potential to replace paraffin and wood fuel particularly in areas of wood scarcity. The ethanol stoves and the fuel can be produced locally.
3	Efficient cook stoves	Efficient solid biomass cook stoves have been promoted over the years but the uptake is relatively slow. The MNRE is now investigating the reason for this.
4	Energy Efficient buildings	With climate change the temperatures are expected to rise and causing discomfort, not only during the day where it reduces productivity and increases air conditioning costs where they are available, but also at night where they make it difficult to sleep. Swaziland does not have a lot of experience in energy efficient built environment. It is difficult to quantify how much mitigation potential is there in this option but issues of energy efficient buildings are a common concern in the country.
5	Biogas for cooking	There is low biogas experience in Swaziland. However, the Swaziland Water and Agricultural Development Enterprise has installed biogas digesters for households as a mitigation exercise after displacing people for dam construction. Also a big company USA Distilleries is embarking on installation of biogas plants to produce gas from its liquid waste.

6	Efficient public transport	Swaziland does not have heavy traffic congestion yet but the number of cars in the road is increasing rapidly annually. It is therefore important to develop plans for efficient transport systems to reduce the urge for people to use their individual cars. Right now even people who do not want to drive are forced to drive because of the inconveniences experienced in the current public transport system. An efficient public transport system could decrease the number of cars in the road thus reducing emissions from road transport which is the major contributor of greenhouse gases in the energy sector.
7	Solar water pumping	Solar water pumping is done in Swaziland but rather at a low scale. It is a mature technology in the country that needs upscaling.
8	Power factor correction	There are situations where equipment in a facility draws more electrical power from the supply than it actually consumes. This excess power results in higher energy losses in the transmission lines and equipment in the form of heat. It also forces the supplier to provide more capacity than actually needed. The steps done for ensuring that the equipment only draws the power it needs is called power factor correction.
9	Solar PV	Swaziland receives a daily average of 4.77 kWh/m^2 of solar insolation. The potential for solar PV systems is high both for households, establishments, the power utility and independent power producers. The drawback to the adoption of solar PV systems is the high upfront costs solar panels and that of batteries that have to be replaced every 10 years if well taken care of.
10	Smart meters	Smart meters can facilitate electricity savings. They provide with daily information on electricity usage so that consumers are able to determine what each appliance consumes. They can be programmed to limit power usage by cutting power when the usage is excessive above a specific value.
11	Solar geysers	With the high solar insolation in Swaziland, solar geysers can help reduce water heating costs. There is currently a very slow uptake of solar water heaters in Swaziland. They have high upfront costs

		and there is need to find methods to increase their uptake especially in institutions and government buildings.

3.4 Criteria and process of technology prioritisation for Energy sector

Multi criteria analysis was used as a tool to prioritize the suggested technologies. This was done using the Multi Criteria Decision Analysis (MCDA) Excel spreadsheet. Since the sector was divided into two categories; power generation, household energy and energy savings and efficiency, different MCDA analysis were made for each one of them. It was difficult to come with unified prioritization criteria for both since the power generation one had different metrics and different indicators. For example, power generation is large scale investment, while household interventions and energy efficiency/conservation can be done at a lower scale. For that reason a separate set of criterion was established for the power generation category.

The prioritization process for the energy sector followed the following steps:

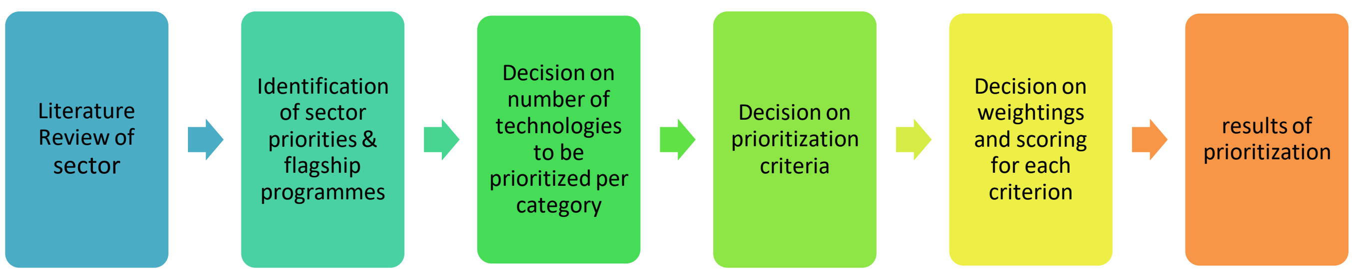

Figure 5. Steps followed in the prioritisation of options.

The process began with a literature review. This was used to identify the sectors developmental priorities and flagship programmes and projects which have a mitigation potential. During the prioritization meeting, stakeholders decided that power generation technologies are the most important ones for the country therefore two technologies should be prioritised from this category and the other two will come from the household and efficiency category.

3.4.1 Prioritization Criteria for power generation Category

In a round table setting, the mitigation team discussed the possible technologies for the power generation category and agreed on a set of criteria for prioritization highlighted in table 6 below.

Table 6 Criteria for prioritization for the power generation category in the energy sector.

	CRITERION	CRITERIA CATEGORY	UNIT CHOSEN	VALUE PREFERRED (HIGH, LOW)
Criterion 1	CO_2 reduction potential	Environment	CO_2eq/kWh	High
Criterion 2	Low abatement cost	Economic	E/tCO_2eq	High
Criterion 3	Job creation	Social	Number of jobs	High
Criterion 4	Foreign exchange savings	Economic	Emalangeni	High
Criterion 5	Low investment cost	Economic	Emalangeni	High
Criterion 6	Resource availability (primary energy carrier)		Level	High
Criterion 7	Environmental (low GHG emissions)	Environment	Level	High
Criterion 8	Local skills capacity	Social	Level	High
Criterion 9	Technology sustainability (primary energy carrier always there)		Level	High
Criterion 10	Security of supply	Social	Level	High

Here is a brief description of the meaning of each criteria, and the rationale for their assigned weights.

CO_2 reduction potential refers to the total GHG emissions reduction potential of the particular technology option. **Mitigation** was the target and therefore given a weighting of 20%.

Low abatement cost refers to the cost per tonne of CO_2 eq. saved The mitigation has to be done in a cost effective way therefore low abatement cost which is the cost per tonne of carbon dioxide equivalent saved was also given the same weight of 20% as the mitigation.

Job creation refers to the absolute number of jobs likely to be created by the adoption of the technology option. Due to national circumstances of high unemployment **job creation** was considered to be important and was given a weight of 10%.

Foreign exchange savings refers to the extent to which the technology can result in the country getting savings from reduced imports. **Environmental frendliness** refers to all other environmental pollution into for example surface water, ground water, and air. **Technology sustainability** refers to whether the technology has a long or short future with respect to the primary energy resources availability and the competing technologies. **Security of supply** refers to whether the energy source can be affected by external factors such as foreign relations climate change etc. **Foreign Exchange Savings**, **Environmental Friendliness, Technology Sustainability, and Security of Supply** were all assigned the same weighting of 5% as they are also important. **Low investment** cost refers to the cost per KWh of electricity generated.

Low investment cost was considered also important since if the country could not afford the initial capital investment it would be pointless to recommend that technology, low investment cost was give 10%.

Resource availability refers to how readily the primary energy carrier is, like the amount of bagasse, river flow, wind resource/speed, solar insolation, etc. There would be no point in prioritising a technology if the primary energy resource such as bagasse, wood chips, river levels, solar insolation were inadequate and therefore **resource availability** was assigned 10%.

Local skills capacity refers to the extent to which there is local capacity to operate and maintain the technology. There would be problems implementing a technology without capacity of local skills. This criterion was given a weighting of 10%.

The identified criteria were then used in the Multi Criteria Decision Analysis (MCDA) using a score range of 1 to 5 for all each criterion. Table 7 extracted from the Excel spread sheet shows the weightings of the criteria.

The rationale for assigning the weights is given below.

Table 7. Weights of criteria for power generation technologies.

	Criterion	Allocation of budget (total = 100)	Weight, %
Criterion 1	CO2 Reduction Potential	20	20%
Criterion 2	Abatement Cost	20	20%
Criterion 3	Job Creation	10	10%
Criterion 4	Foreign Exchange Savings	5	5%
Criterion 5	Low Investment Cost	10	10%
Criterion 6	Resource Availability	10	10%
Criterion 7	Environmental Friendliness	5	5%
Criterion 8	Local Capacity	10	10%
Criterion 9	Technology Sustainability	5	5%
Criterion 10	Security of Supply	5	5%

Table 8. Stakeholder input data for the different criteria for power generation under each technology from Excel Spreadsheet.

Option/Criterion	CO2 Reduction Potential	Abatement Cost	Job Creation	Freign Exchange Savings	Capital Investmetn Cost	Resource Availability	Environmental Friendliness

Units	tCO2e	E/tCO2	Number of jobs	Emalangeni	Emalangeni	Level	Level
Preferred value	High	High	High	High	High	High	High
Hydropower	5	5	2.5	4	2.5	3	4
Pulverised Coal	2.5	3	4	5	1	5	2
Combinend Heat & Power Bagasse	5	4	2	3	3	3	3
Combined Heat & power Wood	5	4	3	3	3	4	4
Solar Photovoltaic	5	2	2	1	2	4	5
Natural Gas (thermal)	3	4	2	1	2	1	3
Wind Power	5	1	1	1	1	2	4

3.4.2 Prioritization Criteria for Household and Energy Efficiency Category

With the assistance of the consultant, stakeholders discussed the possible criteria for household and energy efficiency category under the energy sector and came up with the criteria in the table below.

Table 9: Prioritization criteria for the household and energy efficiency category

Criteria	Units	Weighting	Preferred value
Mitigation potential	Scale 1 – 5	20 %	High
Maturity	Scale 1 – 5	10 %	High
Sustainability	Scale 1 – 5	15 %	High
Job Creation	Scale 1 – 5	10 %	High
Cost effectiveness	Scale 1 – 5	20 %	High
Income generation potential	Scale 1 – 5	20 %	High
Gender	Scale 1 – 5	25 %	High

Here is a brief description of the meaning of each criteria and the rationale for the weighting are given below.

Mitigation potential refers to the total GHG emissions reduction potential of the particular technology option. This criterion was considered to be the most important for this exercise and was assigned a weighting of 20%.

Maturity refers to the extent to which the technology has been adopted around the world and the existing capacity for local adoption. It can ensure success the success of the deployment of a technology and was given a weighting of 15%.

Sustainability refers to the primary energy resource e.g. bagasse, water levels in rivers, etc. It was considered important since failure in a project in a sector leads scepticism of future projects, and was given 15%.

Job creation refers to the absolute number of jobs likely to be created by the adoption of the technology option. In view of the high unemployment rate in the country job creation was considered important and given a weighting of 15%.

Cost-effectiveness meant the value for money of the technology. It was given a weighting of 20% since some of the technology options are targeted at households some of which are at low income levels.

Income generation indicates the potential of that technology to be used to provide income for the user. This was again included since some of the technologies could be used by low income groups for income generation purposes and due to this importance was assigned a weighting of 20%.

Gender refers to whether or not this technology has a positive effect on gender e.g. less time or distance to collect firewood. Stakeholders noted that some of these technologies are likely to be used mostly by women and therefore there must be something to address gender issues in these technologies. Therefore gender was included and given a weighting of 5%.

The energy sector has many subsectors, but the stakeholders decided that in the interest of time the options related to household energy, energy efficiency and conservation be grouped together in the prioritisation exercise. The technologies and stake holder input data are shown in Table 10.

Table 10. Stakeholder input data for the different criteria under each household energy and energy efficiency/conservation technology extracted from Excel Spreadsheet.

Option/Criterion	Mitigation potential	Maturity	Sustainability	Job creation	Cost effectiveness	Income generation/savings	Gender
Units	level	level	level	level	level	level	level
Preferred value	High	High	High	High	High	High	High
Ethanol Cook Stoves	3	3	4	2	4	3	5
Biogas	5	3	2	1	3	3	3
Solar Geyser	5	5	5	3	2	3	5
Solar PV Home Systems	5	5	4	3	2	3	5
Efficient Solid Biomass Stoves	3	5	4	3	2	3	5
Household Natural gas	3	2	1	4	2	3	5
Power Factor Correction	5	4	5	4	2	3	5
Efficient Public Transport	4	3	5	4	3	4	3
Solar Water Pumping	5	3	4	3	2	4	3
Smart Meters	2	3	4	3	2	3	5
Energy Effcient Buildings	5	2	5	3	3	4	5

3.5 Results of technology prioritisation for Energy sector

3.5.1 Power Generation

Table 11: Prioritization results for power generation category.

RANK	OPTION	WEIGHTED SCORE
1	**Hydropower**	**80.6**
2	**Combined Heat & Power (Bagasse/wood chips)**	**73.1**
3	**Solar Photovoltaic**	**58.5**
4	Pulverised Coal	49.3
5	Natural Gas (thermal)	45.5
6	Wind Power	23.9

Table 12: Prioritization results for the household and energy efficiency category.

RANK	OPTION	WEIGHTED SCORE
1	**Energy Efficiency in Buildings**	**76.7 %**
2	**Efficient public transport**	**68.3 %**
3	**Solar PV water pumping**	**61.3 %**
4	Solar Geyser	56.7 %
5	Power factor correction	56.7 %
6	Ethanol cook stoves	42.9 %
7	Biogas for cooking	37.1 %
8	Efficient wood stoves	32.9 %
9	Smart meters	16.3 %
10	Natural gas	15.0 %

The stakeholders further deliberated on the priorities in the energy sector. It was noted that the efficient public transport option would be impossible to implement unless only between the two cities Mbabane and Manzini, the reason being that there is no planning on how people are settled. People settle throughout the country randomly making it impossible for properly planned transportation services. The plans may also meet with resistance from incumbent transport operators who may feel the new system may threaten their businesses. The efficient public transport option although prioritised and the fact that it would be good if circumstances were different was removed by the stakeholders.

The technology options, solar PV power generation, solar PV home systems and solar PV water pumping were all combined into solar photovoltaic and remained a priority.

The stakeholders observed that energy efficient buildings were very important for Swaziland in view of a warming climate. It was noted that buildings are constructed primarily guided by the terrain without integrating planning for the buildings to lower heating and cooling requirements in winter and summer, respectively. The building designs also do not include the possibility of adding solar water heaters or solar PV systems either as part of the initial construction or at a later stage. Stakeholders noted that there is great interest in energy efficient buildings in the country but there was a low level of skills for designing and constructing such. The stakeholders wanted this technology option to be prioritised.

It was, however, noted that it would be difficult to develop a TAP for this technology unless it was targeting a particular structure or a rollout of certain structures whose costs and greenhouse gas emissions reduction could be determined. Regardless of this the stakeholders wanted this technology option to be prioritised at the very least to capacitate the local construction industry. This technology option therefore remained in the priority list. The final priority list for the energy sector is given in the Table 13 below.

Table 13 Prioritised options in the energy sector.

RANK	OPTION	WEIGHTED SCORE
1	**Hydropower**	**80.6%**
2	**Combined Heat & Power (bagasse/wood chips)**	**73.1%**
3	**Solar Photovoltaic**	**61.3 %**
4	**Energy Efficiency in Buildings**	56.7 %

4: TECHNOLOGY PRIORITISATION FOR WASTE

In Swaziland, the waste sector is categorised into solid waste dumping in landfills, semi-aerobic ponds water treatment (used by the Swaziland Water Services Corporation), open burning and incineration (usually for some medical waste). The cities and major towns dispose their solid waste in dumpsites, while smaller towns burn their solid waste in the open. As Swaziland's population increases and as the country continues to develop, waste management poses an ever increasing challenge to both the environment and humans (State of the Environment Report, 2012). Various types of wastes are generated in the country's cities, which, if not properly managed, could negatively affect the environment in different ways including the emission of greenhouse gases.

Solid waste disposal takes on various forms in Swaziland. Municipalities have all along practiced waste dumping where a dumpsite was dug up in the ground and the waste dumped in the pit. When the waste reached a certain level it would be flattened by tractors and covered with soil. More waste would be dumped and the process repeated until the dumpsite was full. At that stage another dumpsite would be dug up. Smaller towns in the country still use open burning of municipal waste and some dense settlements especially peri-urban settlements lack any waste disposal system. This is the main reason why open burning and littering is still a challenge in the country as people burn and throw waste anywhere to get it out of their immediate space.

Municipalities in the country are currently attempting to follow modern waste management practices. Previously the waste was not weighed nor separated to facilitate recovery of recyclable material. Now bigger municipalities like Mbabane, Matsapha and Manzini are exploring proper waste management practices and also constructing proper landfills (Ramboll 2000, Times of Swaziland 27 June 2010). This is mainly because waste production has increased with increasing population, while available land for more dumpsites has become more expensive and difficult to get.

Waste water and sewage from municipalities is collected through a network of pipes by the Swaziland Water Services Corporation (SWSC) for treatment. Industrial waste water and sewage are mixed and treated together. Most rural households use pit latrines for human waste disposal while some especially those with adequate water resources use septic tanks. There are only two waste water treatment plants in the country; one in Nhlambeni and another in Ezulwini. After treatment, the biogas produced from the treatment plants is flared.

4.1 GHG emissions in the waste sector

The main sources of methane (CH4) and nitrous oxide (N2O) emissions from the waste sector emanates from the following categories: Waste disposal on land (managed and unmanaged) and Wastewater handling (industrial, domestic and commercial, other wastewater), and waste incineration and open burning. The second national communication showed that the waste sector is the second largest emitter in the year 2000 with emissions estimated at 6,658 Gg CO_2 eq. (about 33.7 percent of the total GHG emissions for the country). The largest contribution to the sector came from predominantly open burning of waste with a share of 89%, followed by indirect emissions from mainly N_2O, solid waste (3%), and waste water treatment, primarily from sewage that leads to some methane emissions (2%).

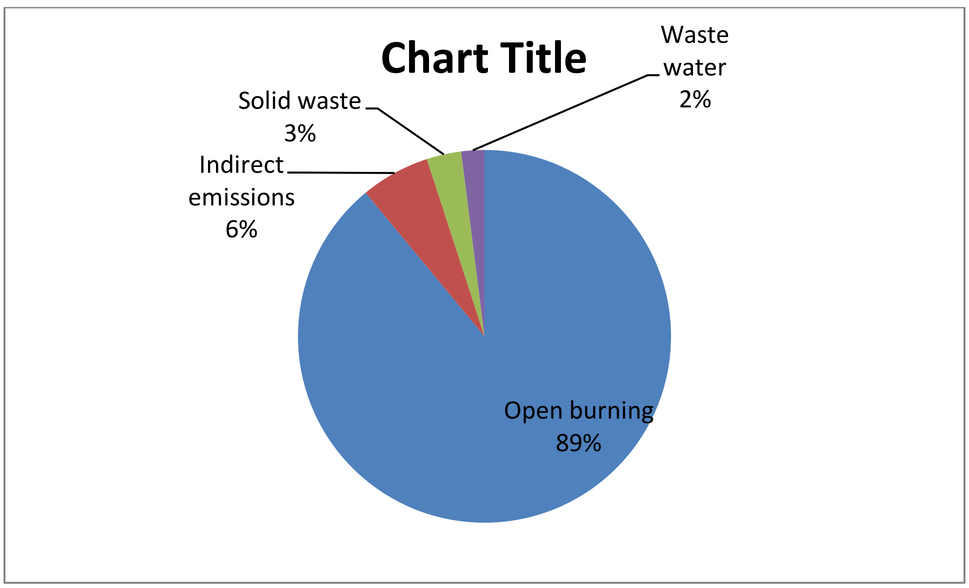

Figure 6. Share of greenhouse gas emissions from the waste sector

4.2 Decision context

Waste management is a significant challenge in Swaziland and is one of the prioritised areas for action. It noted that it is a symptom of many factors; industrialization, consumer patterns, urbanization and population growth as well as the lack of access to waste management information. The State of the Environment Report recommends that, remedial actions that can address this problem include changes in behavioural patterns; establishment of waste infrastructure and the development of required legislation in order to prevent accumulation of waste and promote recycling of waste material. Currently waste management is governed by the Swaziland Waste Regulations of 2000, the National Environmental Policy and the National environment Act. A National Solid Waste Management Strategy was formulated which aimed at “developing, implementing and maintaining an integrated waste management system that will reduce the adverse impact of all forms of solid waste, so that social and economic development in Swaziland, the health of its people and the quality of its environment and its resources benefit”.

4.3 An overview of possible mitigation technology options in Sector and their mitigation potential and other co-benefits

The consultant prepared fact sheets for the waste sector and stakeholders were requested to make their inputs on the fact sheets. This was mainly because some information especially on the maturity of the technology and on the institutional arrangements was not readily available. A total of 8 technologies were identified and fact sheets were prepared for the respective technologies. Two of them were disqualified by the stakeholders before the prioritization process. These were: biogas for mitigation which stakeholders said should be dealt with under the energy sector and advanced paper recycling which stakeholders said recycling is still not matured in Swaziland therefore the country should focus on basic recycling technologies which still have a huge potential before considering advanced recycling technologies.

Table 14: List of possible technologies for the waste sector.

	Technology	**Brief description**
1	Recycling/reuse/separation at facility	This refers to procedures following the waste hierarchy aimed at minimising land filled waste. Recycle means the breaking down of a product to make it a raw material for making new products. This is contrasted from reuse which is using the product again after it has been used or using the product for a different function. Both recycle and reuse require the separation of the waste into different categories.
2	Municipal Solid Waste Composting	Treatment of organic waste through biological decomposition under controlled conditions for conversion to fertilizer.
3	Municipal & Clinical Solid Waste Incineration	Burning of solid waste at high temperatures to reduce the amount in terms of mass and volume.

4	Semi-aerobic landfill	Utilizes a water barrier to line the sides and bottom of the landfill to avoid leachate towards the bottom with a slope to allow leachate flow towards collecting pipes.
5	Aerobic ponds	A pond containing bacteria and algae in suspension; aerobic conditions prevail throughout its depth with no mechanical aeration hence less maintenance and no energy requirements.
6	Advanced paper recycling	Process of recovering waste paper and remaking it into new products.
7	Biogas for cooking from waste	Collection and usage of biogas generated during anaerobic digestion of solid waste and waste water.
8	Activated sludge	Biological waste water treatment process which cultivates microorganisms of many different types

4.4 Criteria and process of technology prioritisation for waste sector

The criteria selected by the stakeholders for prioritizing technologies in the waste sector are shown in Table 15.

Table 15: Prioritization criteria for the waste sector.

Criterion	Units	Weighting	Preferred value
Environmental Pollution	Scale 1 – 5	20 %	Low
Job Creation	Scale 1 – 5	15 %	High
Mitigation potential	Scale 1 – 5	10 %	High
Capital costs	Scale 1 – 5	15 %	Low
Technology viability	Scale 1 – 5	10 %	high
Operational costs	Scale 1 – 5	5 %	Low
Public perception	Scale 1 – 5	25 %	Low

The rationale for the weightings is given below.

Public opinion in the establishment of a waste treatment facility was considered to be one of the biggest barriers. If the public is not convinced on the safety of a waste treatment facility, there is no way it can be constructed. Ignoring public opionion could lead to civil unrest with negative consequences for the technology and project. Overcoming the **negative public perception** was therefore given the highest weight of 25%.

The waste sector in general results in different types of **environmental pollution** that need to be addressed. The stakeholders considered the addressing of environmental pollution important and gave it a weighting of 20 %.

Job creation and **low capital costs** were found to be important and weighted at 15% each.

Mitigation potential which is important in the TNA exercise was given a weighting of 10 %. The stakeholders stated that waste has to be addressed whether or not climate change considerations are taken into account. They noted that while addressing waste climate change mitigation should also be considered.

Table 16. Stakeholder input data for the different criteria under each waste technology extracted from Excel Spreadsheet.

Option/Criterion	Environmental pollution	Job creation	Mitigation potential	Capital cost	Technology viability	Operating costs	Public perceptio
Units	Level	Level	Level	Level	Level	Level	Lev
Preferred value	Low	High	High	Low	High	Low	Lo
Recycle/Reuse/Separate Facility	1	5	5	2	5	2	
Composting	2	3	3	1	4	1	
Incineration	4	3	2	5	5	4	
Semi-aerobic Landfill	3	4	3	5	5	5	
Aerobic ponds	4	3	3	3	5	5	
Activated sludge	3	3	4	5	4	4	

Table 17: Prioritization results for the waste sector.

	Technology	Weighted scores
1	**Separate/reuse/recycle**	**85.0 %**

2	**Composting**	**52.1 %**
3	**Semi –aerobic Landfill**	**24.2 %**
4	Aerobic ponds	17.5 %
5	Incineration	17.5 %
6	Activated sludge	7.9 %

The technologies that were prioritised in the waste sector are listed in Table 17. They are separate /reuse/recycle, composting and semi-aerobic landfill. The semi-aerobic land fill was lowly rated because it is basically an unknown technology locally. Stakeholders decided to have it included since there was something to learn of a possibly good mitigation technology.

5 TECHNOLOGY PRIORITISATION FOR LAND USE, LAND USE CHANGE AND FORESTRY (LULUCF) SECTOR

5.1 GHG emissions and existing technologies of Sector A

The Land Use, Land Use Change and Forestry sector was a net source of CO_2 by 1105.2 Gg equivalent in 2000. The highest contribution of CO_2 emissions came from commercial harvest estimated at 3508.3 Gg equivalent representing 92% of total CO_2 emissions from the sector, followed by onsite decay, and carbon loss from organic soils, each representing around 2.6%. The minimum contribution came from offsite burning, change in soil carbon in mineral soils and liming of soils all estimated at 85.3 Gg equivalent representing 2.2% of total CO_2 emissions. The largest contribution of carbon uptake comes from trees including commercial plantations representing 95% of total CO_2 uptake and remaining 5% is attributed to carbon uptake in abandoned areas.

5.2 Decision context

According to the State of the Environment Report, pressures on the environment as a result of the driving forces from the increasing population have led to land use changes through clearing of indigenous forest storing carbon. These occur in different ways, from subtle modification of ecosystems as a result of increased extraction of goods to more drastic changes on the land through clearing of natural land and converting to crop, animal and other production use. Land use changes in Swaziland are not recorded in a systematic or comprehensive manner. Limited and specific statistical data are recorded annually within certain sectors such as agriculture. In other sectors such as forestry only few ad hoc inventories have been made. Only one comprehensive national land use inventory has been conducted, in 1994 (MOA 1994). A few land cover inventories have been made, as part of Southern African exercises, also on an ad hoc basis. The National Trust Commission does monitor ground developments through satellite imaging. One of their interests is to monitor the prevalence of forest fires.

The systemic and institutional response to the impacts of land use change has been rather limited in recent years. A draft land policy was compiled in 1999 but has not been debated in Parliament because of opposition from some prominent stakeholders. The Land Planning Section (Ministry of Agriculture) was established in 1968 and has a mandate to guide the utilisation of land and water resources. Its mission is to rationalise land resource utilisation for sustainability of future generations. The main objectives of this department is to ensure that land is utilised optimally and sustainably for its most suitable use. However, without the land policy its efforts are compromised.

5.3 An overview of possible mitigation technology options in the LULUCF and their mitigation potential and other co-benefits

The consultant prepared fact sheets for the LULUCF sector and stakeholders were requested to make their inputs on the fact sheets. As discussed earlier, the LULUCF sector lacks a policy and this makes it difficult to get permission for sites at which mitigation options can be implemented. In Title Deed Land the owners have rights to use the land in any manner they wish. On Swazi Nation Land, the land is used arbitrarily by traditional administrators, and control of land allocated for specific projects usually prove difficult in the absence of a land policy. According to the TNA Handbook mitigation in the LULUCF must be site specific. The National Land Policy drafted in 1999 provided guidance on land use, rural development, gender issues etc. on national land but could not be debated in Parliament due to lobbying by interest groups. Even with this constraint, stakeholders in the TNA process were encouraged to identify places in Swaziland where mitigation projects could be carried out. One Stakeholder suggested that there could be a possibility of a site for carbon sequestration on land owned by one of the timber industries. That site will be pursued at a later stage. The mitigation technology options considered in the LULUCF include substitution, sequestration and conservation. These technologies are briefly discussed in the next table.

Table 18: List of technologies in the LULUCF sector.

	Technology	Brief description
1	Agroforestry	Agroforestry is an activity that combines production on the same plot of land, agricultural activities such as crops, pasture and trees. This can be done by planting trees in cropland or pastureland to increase the carbon stocks where the trees could have other benefits such as fruits, nuts, timber etc.
2	Urban Forestry	Urban forestry is a form of carbon sequestration in that the trees in an urban environment are deliberately planted and properly managed. Its purpose is usually for contribution to the physiological, sociological, and economic well-being of urban society, but at the same time the trees sink and store carbon.
3	Grazing land management	This is a conservation technology. Conservation involves the protection of existing terrestrial carbon stocks. This is by forest conservation, which prevents further deforestation. It could also include improvement of the quantity of existing carbon stocks.

Four options were identified for mitigation under LULUCF, and they were all related to sequestration and conservation. These are options are listed here.

1. Sequestration: Agro-forestry in the Lowveld: A dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels.
2. Sequestration: Urban forestry in Manzini, Matsapha, Lavumisa, Buhleni and Siphofaneni: Urban forestry is the care and management of tree populations in urban settings for the purpose of improving the urban environment
3. Sequestration: Species introduction in the Lowveld region: Entails sowing introduced pasture species where native species have been overtaken by undesirable species such as wiregrass, or exotic weedy grasses.
4. Conservation: Grazing land management in the Middleveld: Managing grazing land through controlling of grazing intensity and timing

5.4 Criteria and process of technology prioritisation for LULUCF sector.

Table 19: Prioritization criteria for the LULUCF sector.

Criterion	Units	Weighting	Preferred value
Environmental Protection potential	Scale 1 – 5	25 %	High
Feasibility	Scale 1 – 5	20 %	High
Carbon storage	Scale 1 – 5	25 %	High
Sustainability	Scale 1 – 5	20 %	High
Income generation	Scale 1 – 5	10 %	high

The criteria selected by the stakeholders for prioritizing technologies in the LULUCF sector and the rationale for the weighting follows.

Environmental protection refers to the elimination or reduction of the rate of soil erosion and the protecting the carbon stocks in an area. It was considered to be very important and given a weight of 25%.

Carbon storage was considered to be the key part of mitigation in LULUCF and was assigned a weighting of 25%.

Feasibility refers to the extent of how possible it is to implement that option in Swaziland and was considered to be important and assigned a weighting of 20%.

Also considered important was the **sustainabilit**y of the option. There have been cases in Swaziland where land was allocated for one purpose and the subsequently used for another without much justification. The sustainability criterion was therefore assigned a weighting of 20%.

Income generation was seen to support sustainability in the way that if the community benefitted from the option implementation, they were likely to support it. It was therefore assigned a weighting of 10%.

Table 20. Table 21. Stakeholder input data for the different criteria under each LULUCF technology extracted from Excel Spreadsheet.

Option/Criterion	Environment pretection	Feasibility	Carbon storage	Sustainability	Income generation
Units	Level	Level	Level	Level	Level
Preferred value	High	High	High	High	High
Agrofrestry	5	4	5	3	4
Grazing integrity management	5	3	3	4	4
Species introduction	5	3	3	3	3
Urban forestry	5	4	4	4	2

5.5 Results of Technology Prioritization

Table 22: Prioritization results for LULUCF sector.

	Technology	Weighted scores
1	**Agroforestry**	**55 %**
2	**Urban forestry**	**52.5 %**
3	**Grazing land management**	**30.0 %**
4	Species introduction	5.0 %

Afforestation is currently undertaken by the timber industry in Swaziland. Some grasslands have been converted to forest through the plantation of exotic species such as eucalyptus, pine, and wattle. This can be increased especially in marginalized land. Urban forestry on the other hand was prioritized by the stakeholders but its impact may be relatively small in terms of mitigation potential. Grazing land management has obstacles in terms on the lack of a land policy. It would be difficult to control the spreading of settlement that reduces the grazing land leading to degradation. Forest protection is only possible in the areas reserved for game where game rangers protect the place with firearms from trespassers. Increasing these land areas would require legislation enacted through a policy. There were recommendation in the SNC for mitigation in the forestry sector that included forest protection, reforestation through forest regeneration, reforestation through rotation and provision of alternative energy sources like bioenergy and encouragement of active participation of communities in forest conservation and in the implementation of reforestation programmes. These are however not practical in Swazi Nation Land unless there is a change in policy that is being stagnated by traditional structures that are very powerful in the country. The efforts by the team iunder LUCLUCF were acts of desperation.

6 SUMMARY

The TNA was a stakeholder driven exercise. The stakeholders were coming from different economic sectors and had varied backgrounds and interests. They identified technologies on the basis of information available at the time. The technologies identified for prioritisation were 18 in energy, 6 in waste and 4 in LULUCF.

In the energy sector the top 5 ranked technologies were hydropower, combined heat and power using biomass (bagasse and wood chips), solar PV, energy efficient buildings, and efficient public transport. The energy sector even though it is not the highest in emissions in Swaziland has a lot of technologies for mitigation, the reason being that it has a large variety of subsectors. Also the energy sector has more accurate data in terms of quantities of the various energy sources consumed. Swaziland is also planning to add fossil fuel based power plants by establishing a 300 MW coal power plant. This could increase the CO_2eq. emissions drastically making the energy sector one of the highest emitters. This is also in view of that the greenhouse gases that make the industrial processes sector the largest contributor are likely to be phased out by 2030. There is therefore need to be prepared for the implementation of a larger number of mitigation technologies in the energy sector. Swaziland has experience in technologies like hydropower, combined heat and power, and limited experience in solar PV. Efficient public transport and energy efficient buildings are all new technologies to Swaziland.

The four technologies prioritised in the waste were separate/reuse/recycle, composting and semi-aerobic landfill. It is important to note that the separation of waste is key to reuse, recycle, composting and semi-aerobic landfill technologies. The separation of waste is therefore the most important of all the technologies. Composting is a familiar technology but to undertake it at large scale for municipal waste would need technical assistance. Semi-aerobic landfill is an invention from Japan that is now applied in several countries in Asia. Swaziland will also need assistance in implementing this technology.

The technologies prioritised in the LULUCF sector were agroforestry, urban forestry and grazing land management. It was noted that agroforestry is being practised by farmers but informally. Grazing land management is needed mostly in Swazi Nation Land where signs of land degradation have been observed. This technology has some barriers but they will be attended to in the barrier analysis and enabling framework. Urban forestry will have the challenge of space but there are niche areas of an urban environment where this technology in needed.

Based on the discussions above, the prioritised technologies are listed in Table 16. Consideration for TAP development will be for these technologies.

Table 23: Final list of prioritized mitigation technologies for Swaziland.

	Sector	Prioritised technologies
1	Energy – Power generation subsector	Hydro power
		Biomass Combined Heat and Power
		Solar PV
		Energy Efficient Buildings
3	Waste	Separate/Reuse/Recycle
		Composting
		Semi-aerobic landfill
4	LULUCF	Agro-forestry
		Urban Forestry
		Grazing land management

REFERENCES

1. Evans, J. and Masson, P. (2008), Sustainable Plantation Forestry: A Case Study of Wood Production and Environmental Management Strategies in the Usutu Forest, Swaziland. In The Forests Handbook, Volume 2: Applying Forest Science for Sustainable Management
2. IRENA (2011) Swaziland - Renewable Energy Country Profile
3. IRENA (2014) Swaziland Renewables Readiness Assessment
4. GOS- MEPD (2014), National Development Strategy (NDS) Review
5. GOS-MEDP (2012), Public Private Partnership Policy
6. GOS-MJCA(2007), Energy Regulatory Act
7. GOS-MJCA(2007), Electricity Act
8. GOS-MJCA (2002), Swaziland Environment Management Act
9. GOS-MJCA (2000), Swaziland Waste Regulation Act
10. GOS-MNRE (2009), National Energy Policy Implementation Strategy
11. GOS-MNRE (2008), National Biofuels Development Strategy
12. GOS-MNRE(2014), Swaziland Household Energy Access Report
13. GOS-MNRE (2014), Sustainable Energy for All (SE4ALL) Action Plan
14. GOS-MNRE (2010) Energy Balance 2010 (Internal document).
15. GOS-MNRE (2009), National Energy Policy Implementation Strategy
16. GOS-MTEA (2012) Swaziland's Second National Communication to the UNFCCC
17. GOS-MTEA (2010), Technology Needs Assessment for Climate Change for Swaziland
18. GOS-MTEA (2015), Draft National Climate Change Policy (NCCP)
19. SEA (2002), National Solid Waste Management Strategy for Swaziland
20. Swaziland Rural Electrification Project, Authors, year??
21. GOS-MTEA (2014), Draft National Climate Change Strategy and Action Plan (NCCSAP)
22. UNDP (2010), Swaziland Household Income and Expenditure Survey 2010
23. SEC (2015), Annual Report 2014/15
24. GFA Envest (2009), Assessment of Renewable Energy and Energy Efficiency Options in the Swazi Sugar Industry and an Analysis of Co-financing Options via Carbon Certificates.
25. GOS-CSO (2011), Poverty in a Decade of low economic growth: Swaziland in the 2000's
26. UN (1992), United Nations Framework Convention On Climate Change
27. UN (1998), Kyoto Protocol To The United Nations Framework Convention On Climate Change.

ANNEX I: TECHNOLOGY FACTSHEETS FOR SELECTED TECHNOLOGIES

A1 Energy Sector

A1.1: Solar Photovoltaic Fact Sheet

Sector	**Energy**
Sub-sector	**On Grid Power Generation**
Technology name	**Solar Photovoltaic Power**
Availability	**Available**
Scale	**Small to medium**
Technology Information	
Technology description Solar photovoltaic, or simply photovoltaic (SPV or PV), refers to the technology of using solar cells to convert solar radiation (light) directly into electricity. Solar panels are limited to only produce electricity in periods of sunlight, either direct or diffuse sunlight on overcast days. During the night they will not produce power. This means that solar cells, if used for remote/off-grid generation purposes, need to be implemented in conjunction with some kind of storage system such as a battery or as a hybrid system with some other type of generator. The maximum recorded efficiency of common SPV cells is 20%. In the capital city Mbabane, Swaziland receives 3.62 to 5.96 kWh/m^2 per day of sunlight, with an average of 4.77 kWh/m^2 [1]. The device that converts the sun's radiation into electricity is in the form of flat panels. The maximum amount of electricity produced per m^2 of modern solar panels in Mbabane is 0.954 kWh per day. For example, the maximum power that can be generated from a soccer field of size 105 m x 68 (7140 m^2) m (size of the FNB soccer field in Johannesburg) in Mbabane is 6811 kWh of electricity, assuming 20% efficiency panels. Such an amount of electricity can power up four light bulbs (15 watt compact fluorescent light (CFL)) for four hours in 28400 households. In spite of significant decreases in the cost of solar PV systems, the majority of PV deployment is still driven by donations and substantial subsidy schemes, particularly feed-in tariffs.	
Technology feasibility Technology is mature, with continuous improvements and Swaziland is relatively sunny especially the middle and lower regions. There are already sizable solar PV grid tie systems in Swaziland. The current systems in Swaziland are connected after the utility meter and they do not feed power to the grid. Their power is not directly monitored by the grid system. The systems include a 31.2 kW at the Blood Bank, 60 kW at the Luyengo Campus of the University of Swaziland, a 31.2 kW at Mhlumeni border gate and a planned 31.2 kW at Nhlangano Health Centre [2]. There is also a 25 kW installation at Bulembu village which has no batteries and is used to reduce the electricity demand during the day. [3]	
Market potential In the last two decades the global solar PV market has experienced rapid expansion, with an average annual growth rate of 40%. An annual growth rate of 17% is forecast over the next decades [4]. There is a high potential for grid connected solar photovoltaic systems in Swaziland. The main barrier is that	

many organisations are not well informed and some are waiting for the prices to further go down or grid electricity prices to go up.

Currently, there are two companies that are seriously considering installing on-grid solar PV systems. One aims at producing 10 MW and the other 100 MW. One of the Companies has started by installing a 100 kW plant in Siteki, a picture of which is in the page before the table of contents. There is also a growing middle class in Swaziland that can take advantage of the technology.

Climate and other environmental benefits

The main environmental impacts of solar cells are related to their production and decommissioning. Solar PV has a very low lifecycle cost of pollution per kilowatt-hour compared to other technologies. Furthermore they predict that upwards of 80% of the bulk material in solar panels will be recyclable, and recycling of solar panels is already economically viable [5]. In terms of land use, the area required by PV is less than that of traditional fossil fuel cycles and does not involve any disturbance of the ground, fuel transport, or water contamination.

Solar PV has energy payback periods ranging from 2 to 5 years for good to moderate locations and lifecycle GHG emissions in the order of 30 to 70 gCO2eq./kWh depending on panel type, solar resource, manufacturing method and installation size [6]. This compares to emission factors for coal fired plants of more than 0.957t CO2eq./MWh for South African grid power [7]. There is therefore a large potential for solar PV to contribute to reductions in carbon emissions from the power generation subsector. The carbon emission factor for solar PV is 46 gCO2eq./kWh [8].

Financial requirements and costs

The cost of PV electricity generation in the region is just below E1.00 per kWh. The payback period for solar system is 2 to 5 years, while the lifetime of solar PV systems is about 25 years, and O&M cost are estimated at 1.5% of capital cost per year [9].

Pros

- Reduces electricity costs and can be income generating if excess power is produced.
- The price of electricity in the region is likely to continue increasing until the power supply in the Southern African Power pool meets demand. These price increases could make solar PV power more affordable..
- Maintenance is minimal and mainly requires the cleaning of the solar panels to ensure efficiencies are maintained.
- Has low lifetime carbon emissions
- Could last up to 30 years.

Cons

- Initial cost is still high.
- Power production is dependent on weather conditions.
- There is still no mechanism in Swaziland for low power solar PV grid connection.

A1.2: Hydro Power expansion fact sheet

Sector	**Energy**
Sub-sector	**Grid Power Generation**
Technology Name	**Hydro Power Expansion**
Availability	**Available**
Scale	**Small to Medium**
Technology Information	

Technology description

Hydropower systems exploit the energy of moving water. By falling water through a turbine and converts it into mechanical power which drives generators to produce electricity. The water strikes the blades of a turbine which rotates the generating unit resulting in the kinetic energy of the water converted to electricity. Modern hydro turbines can convert up to 90% of the water energy into electricity. This very efficient compared to fossil fuel power plants where the best ones have a performance of up to 60% [9]. It is the second most used renewable energy source in the world after solid biomass. Hydropower is currently the main method by which the Swaziland Electricity Company (SEC) generates electricity.

What determines the amount of electricity produced by a hydro turbine is the operating head which is the distance over which the water falls and the amount of water going through per unit time (flow rate). SEC uses an impoundment facility where the head is created by storing the water at a dam higher up from the turbine. If the dam is large enough, it can store water for power generation even during the dry season. Hydropower is also very easy to bring on line and adjustable to provide the necessary amount of electricity.

Hydropower is classified into small and large hydro [10]. Small hydropower here refers to hydroelectric power plants below 10MW installed capacity. It is divided into further categories depending on its size, such as mini - (less than 1000kW), micro-hydro (less than 100kW) and pico-hydro (less than 5kW), and the definitions may vary according to manufacturers and countries, as there is no internationally accepted definition of small hydropower. For example, in China, small hydropower refers to capacities of up to 25 MW, in India of up to 15 MW and in Sweden 'small' refers to up to 1.5 MW. Large hydropower usually referes to more than 100 MW installed capacity. In Swaziland small means below 1 MW.

Technology feasibility

Large scale hydropower stations require large dams or a series of dams to store large quantities of water. The dams can also be used for other purposes like irrigation. In recent years a lot of improvement in terms of efficiency, performance, operations, maintenance and advanced turbine development has occurred rendering this technology more feasible globally. There is therefore a larger potential for further deployment of this technology in Swaziland. Existing regulations and expertise on hydropower is sufficient to expand this technology. Swaziland has put in place several policies that promote clean energy including hydropower. In 2007 the country undertook energy reforms which reduced the utility (SECs) monopoly therefore establishing a regulatory body called the Swaziland Energy Regulatory Authority (SERA). The country is also a party to several regional integration agreements like the Southern African Power Pool (SAPP) which aims at ensuring access to cost effective electricity.

Swaziland has been using hydropower technology in many ranges and have experience with both small and medium hydro stations. This means that the technology is economically and technically mature in the country. The current installed capacity of hydro power in the country totals to 60.4 MW in five sites; Ezulwini (20 MW), Maguga (19.8 MW), Dwaleni (15 MW), and Maguduza (5.6).

Since hydropower is also dependent on the geographical conditions of the country or the terrain, the mountainous landscapes of the country provides for several areas for hydro power expansion. The main challenge for hydro in Swaziland is its dependence on water resources, a resource that is gradually becoming scarce in the country. During dry seasons or drought, SEC is required to cease power generation and water in dams is prioritized for domestic use and agricultural production. This introduces a non-constant production although it is not common and only happens during severe drought years.

Market potential

Due to its lower cost and its high efficiency, the technology has a potential in the market. In Swaziland several sites have been identified for the installation of hydropower systems. These range from pico hydro to small hydro.

These sites include the following:

- Lower Usutu Small Holder Irrigation Project (LUSIP) – approximately 3-7 MW (dam has been built for irrigation)
- Mnjoli – approximately 3-5 MW (from dam constructed for sugar irrigation)
- Lower Maguduza – approximately 10 MW
- Ngwempisi – approximately 120 MW

Climate and other environmental benefits

Hydropower can achieve significant GHG reductions as it reduces the fossil fuel based electricity import from South Africa. The largest source of greenhouse gases for hydropower is the construction of the facilities and biomass decomposition from reservoir flooding [11]. However, on overall, the life cycle of GHG emissions per unit of electricity generated is lower for hydropower than for fossil fuels. Steinhurst et al, 2012 estimates that in the tropical regions, for an equal electric energy output, hydropower plants emit about 1/3 of the least emitting oil and coal power plants. For an example, for a dam which is anticipated to produce 2,700 GWh/year, the estimates shows a lifecycle average emission rate ranging from 160 to 250 kg CO_2 eq./MWh. The average carbon intensity is 4 gCO2eq./kWh.

In addition to methane emissions from flooded biomass, the dam water is stagnant compared to free flowing water therefore can cause water-borne sediments and nutrients to be trapped, resulting in undesirable growth and spread of algae and aquatic weeds.

A hydropower turbine is made mainly of metal parts, which means that its parts are almost 100% recyclable.

Financial requirements and costs

Hydro power produces electricity with low cost compared with other known ways of producing electricity, but the opportunities for investment are in fact limited by the high cost of the construction and possibilities for investment. The capital costs of hydropower projects are dominated by the civil works and equipment costs. Such infrastructure costs can account for up to half of total costs for a project in remote areas. Proper site selection can however reduce costs as hydropower is a highly site specific technology. The total installed cost for large scale hydropower stations typically ranges from as low as 1000 US $ per kW to around US $ 3500 per kW if the civil works is not in place. However, if existing dams built for other purposes like irrigation hydropower installations may cost as low as US $ 450 per kW [12].

Hydropower typically have low operations and maintenance costs over their lifetime and such costs are similar to those of wind but not as low as for solar PV. When a series of plants are installed along a river, centralized control, remote management and a dedicated operations team to manage the chain of stations can reduce O&M Costs to very low levels. Annual O&M costs are often quoted as percentage of the investment cost per kW per year. Typical values range from 1% to 4% of investment capital. The IRENA assumes 3 % for smaller hydropower projects with larger plants having significantly lower costs [13].

Pros

In addition to providing access to energy, hydropower dams have other multiple benefits, including supplying water for irrigation, industrial production and residential use as well as flood prevention and habitat maintenance. With the demand for water increasing in the country and drought expected to worsen, competition for water resources is expected to increase and hydropower dams will provide dual use. Other advantages include:

- Relatively low operational costs.
- High efficient with turbines capable of converting more than 90 % of available energy.
- It is climate friendly and does not produce air pollution or toxic by-products.
- It has robust and long lasting technology with turbine having a lifetime of more 40 years which could be lengthened with proper management.
- Hydro-electric technology is a proven technology that offers reliable and flexible operation and can respond within seconds to changes in load demand.
- Dam can be used for leisure purposes such as fishing, boating, irrigation, etc.

Cons

The process of daming a river and creating a reservoir have several disadvantages and can pose its own environmental, economic, health and social problems. These disadvantages are:

- It could result in the displacement of people from their familiar land.
- Loss of fertile and most useful land to reservoirs.
- The rotting organic matter reservoirs can lead to significant methane emissions
- There could be infestation of algae and water weeds due to the rich nutrients in the stagnant water.

A1.3: Biomass Combined Heat and Power

Sector	**Energy**
Sub-sector	**Grid Power Generation**
Technology name	**Biomass Combined Heat and Power**
Availability	**Available**
Scale	**Medium**

Technology Information

Technology description

This technology utilises biomass of different forms to produce power and heat. It can be a small plant or large industrial scale electricity generation unit. Two technologically mature and cost effective options exist and these are**:** The burning of biomass in **standalone boilers** and the **co-firing** of the biomass with coal to produce steam. The steam is directed to a steam turbine which rotates a generator to produce electricity. In standalone boilers, the biomass is the only fuel used to produce electricity and heat while in co-firing or co-combustion involves supplementing existing coal with biomass. Several feed stocks can be used to power the boilers. These include bagasse and wood chips in the case of Swaziland and other biomass.

- Swaziland has experience in the CHP technology from the sugar, pulp and timber industries, although the pulp company has been closed. Solid biomass resources available in Swaziland include bagasse, sugarcane tops and trash from the sugar industry and wood chips and wood waste from the timber industry. The sugar is planted and harvested annually hence cycling the carbon in the atmosphere. The trees are planted and raised for several years prior to harvesting. For the timber industry logs are harvested after fifteen years or more, but could be harvested as early as eight years if solely used for power application. They also act as carbon sinks when growing and release some of the carbon dioxide when burnt as fuel and overall are assumed to have minimal net greenhouse gas emissions.

Technology feasibility

Swaziland has experience in this technology from the sugar, pulp and timber industries.

Market potential

Swaziland has three sugar mills and a total harvested area of close to 60 000 hectares. Green harvesting of the sugar cane could yield bagasse, trash and tops that could lead to massive increase in the amount of biomass for combustion in the boilers for CHP. Currently green harvesting that also lead to the collection of the trash and tops is only done at a limited extent as a pilot project. The plantation forest covers about 114 000 hectares, again providing a large source of solid biomass resource. The plantation forest was mainly planted for pulp and timber. The pulp company closed leading to the availability of excess timber. Also the branches were burnt on site and they can be taken to the mill for the production of wood chips. Ubombo Sugar limited is already selling electrical power to the national utility company SEC through a power purchase agreement. The Royal Swaziland Sugar Corporation (RSSC) is also planning to follow suit.

Climate and other environmental benefits

Carbon emission intensity is 18 gCO2eq./kWh as compared to coal which is 957 kg CO2eq./kWh

Financial requirements and costs

Here is something on costs taken verbatim from Climatetechwiki [10].

Investment costs: dedicated Biomass power plants cost approximately $760-900/kW (IPCC, 2011) whereas the cost of retrofitting an existing coal-fired power plant ranges from $300-700/kW for direct

co-firing (IPCC 2011; IEA 2012; IRENA 2012). Indirect co-firing investment costs are approximately 10 times greater at around $3000-4000/kW (ECN, 2012b). Operation and maintenance costs: for co-firing O&M costs are similar to coal-fired plants. For direct co-firing they typically average 2.5-3.5% of capital costs (IRENA, 2012) and approximately 5% for indirect co-firing (ECN, 2012b). As the biomass-to-coal ration increase or the quality of the biomass used decreases, the O&M costs rise.
Pros • Feed stock is localized and less prone to international price fluctuations. • Some of the feedstock is a waste product, and therefore of low cost. • It has low carbon emissions and cleaner than fossil fuels • The feedstock can be sustainable
Cons • Requires a lot of land and can lead to deforestation. • Requires water to grow. • Need to manage ash and control the emissions of NOx, soot, and CO. • May compete directly with food production (e.g. corn, soy). • Crops like sugarcane are seasonal. • Transportation of low calorific fuel could be costly. • Some methane and CO2 are emitted during the growing of feedstock.

A1.4: Efficient Energy Buildings

Sector	**Energy**
Sub-sector	**Energy efficiency and conservation**
Technology name	**Energy efficient buildings**
Availability	**Available internationally but limited locally**
Scale	**Medium**

Technology Information

Technology description

The built environment can be designed to consume minimal energy and also increase the potential for the building to generate energy through the installation of energy generating technologies such as solar PV systems. Currently, most structures in Swaziland are constructed without consideration of minimising energy consumption. This ends up increasing heating, lighting and cooling costs for the built environment. Many people are aware that there are some interventions that can be done in the design and construction of structures that could reduce energy consumption throughout the life of the structure. Related to this is a system that intelligently manages the energy and other needs in buildings and which can have considerable benefits. Such a system is called building energy management system (BEMS).

BEMS is a sophisticated method to monitor and control the building's energy needs. Next to energy management, the system can control and monitor a large variety of other aspects of the building regardless of whether it is residential or commercial. Examples of these functions are heating, ventilation and air conditioning (HVAC), lighting or security measures. BEMS technology can be applied in both residential and commercial buildings.

Technology feasibility

Swaziland has limited experience in this technology but the interest is very high.

With BEMS, while the operation of the technology might be relatively straightforward due to a sophisticated interface, there is still a need for skilled operators of the technology. In addition, the installation of the technology requires training of the installation personnel.

Market potential

There is interest in this technology. The problem is lack of demonstration and promotion. Some people who have already built their houses realize now that the orientation of their roofs does not enable them to fully benefit from sunlight, shading, and installation of solar PV and solar geyser.

Climate and other environmental benefits

Savings in energy consumption could lead to direct reduction in greenhouse gases, since a lot of energy production leads to these emissions.

Financial requirements and costs

The costs for building energy efficient buildings should not be much different from standard building methods. The extra costs involved could be offset by reduction in energy costs. There is a lot to learn with exposure to this technology option.

The IPCC (2007) [14] concludes that the BEMS technology can reduce energy usage and but costs depending on a variety of conditions including weather conditions, energy used for heating and/or cooling, size of the establishment etc. Estimates provided on the technology energy savings differ considerably and therefore the technology requires more research and development to determine the financial requirements and costs. For example, Birtles and John (1984) estimate energy savings up to

27 % compared to no BEMS installed, while the IPCC notes estimates between 5 % and 40 % (IPCC, 2007). Additionally Roth et al. (2005) estimate energy savings up to 20 % in space heating energy consumption and 10 % for lighting and ventilation, combining to a 5 % to 20 % overall energy savings range.
Pros • Increased energy efficiency • Improved indoor environmental conditions and hence productivity • Reducing overall cost of energy • Improved fire, security and other emergency procedures • Improved standards of plant/building function • Improved management of the building
Cons • Higher initial costs for design and installation • Operation and maintenance costs for BEMS might be higher compared to simpler management systems, but could be offset by lower utility bills. • Need for skilled operators • Requires commitment at all levels.

A2 Waste Sector

A2.1: Municipal Waste Separation/Reuse/Recycle facility Fact Sheet

Sector	Waste
Sub-sector	Municipal Waste Management
Technology name	Municipal Waste Recycling/Reuse/Separation Facility
Availability	Available
Scale	Large
Technology Background Information	

Technology description

Municipal solid waste consist of mainly paper, cardboard, textiles, glass, cans, scrap metal, tools, wood, garden waste, plastic bottles, batteries, other general household waste, and household electrical products such as fridges/freezers, stoves, irons, personal computers, printers. Some of these items are recyclable or contain materials that are reusable. This is evidenced by the number of people making a living solely by recovering materials at the dump sites. If this would be formalized, those people could be employed formerly to separate waste or an attractive system could be developed to compensate them for waste separation. That way the municipality could maximize the recovery of resources in the waste stream which could pay for itself in the way of space saved and selling or using some of the recovered material and items. Recyclable and/or reusable items and materials could be recovered thus avoiding their deposition into the landfill. This way the landfill could be used as a last resort place for the waste generated, and hence would lead to less contribution to global warming and other detrimental environmental effects.

It is always advisable to follow the so called waste hierarchy when managing waste. This minimises land filled waste by encouraging people to consider several steps before disposing of waste to landfills. These steps are:

a) prevention; the formulation of a product eco-design policy addressing both the generation of waste and the presence of hazardous substances in waste, with a view to promoting technologies focusing on durable, re-usable and recyclable products;

(b) preparing for re-use; to promote the re-use of products and preparing for re-use activities, notably by encouraging the establishment and support of re-use and repair networks,

(c) recycling; to promote high quality recycling and, to this end, shall set up separate collections of waste where technically, environmentally and economically practicable and appropriate to meet the necessary quality standards for the relevant recycling sectors. Separate collection shall be set up for at least the following: paper, metal, plastic and glass

(d) other recovery; waste incineration, and other energy recovery techniques, such as pyrolysis, combined with energy recovery;

(e) disposal; where recovery in is not undertaken, waste undergoes safe disposal operations which safeguards the protection of human health and the environment.

Technology feasibility

There are people in Swaziland who make a living by recovering useful items from municipal waste. In effect they are informally promoting reuse and recycling. For bottles, the Swaziland Breweries have put a price on soft drink and beer bottles and people collect them for the money. If reusing and recycling could be formalized it can be done at a larger scale and the recovered items can attract more value. The reuse/recycling facilities can also serve as a waste separation centre so that from this stage the different types of waste can be directed to appropriate treatment facilities. Currently there is no recycling plant in Swaziland. However in Mbabane, there is a waste recycling centre situated in the industrial area which buys paper, newspapers, plastic and metal from the public. The centre only packages the separated waste and sends it to South Africa. The challenge that this facility faces is the fact that people's attitudes are still not geared for recycling and would dispose the recyclable materials together with land filled waste. People are also not comfortable in carrying the waste to the recycling centre but can do it if the facilities could be provided in the form of the general waste collection procedures.

There are also several handicraft centres in the country that uses waste materials like plastic bags for making their handicrafts. This provides a market for waste collected from the dump sites. The waste materials are crafted to their useful products like mats, bags and toys.

Market potential

Waste management is a challenge in the country. Although there are waste management policies and legislations, these are hardly enforced. The country is currently trying to pass a plastic bill which is expected to assist in promoting re-use of plastic bags and to also assign a price to plastic bags. Such a bill and other national waste management legislation provide a good opportunity for proper waste management. However, for such to be successful, a strong public awareness campaign should be implemented to instill behavioral change and to assign value to recyclable materials.

Climate and other environmental benefits

- Reduce organic matter going to landfills that could decompose releasing methane, carbon dioxide and other greenhouse gases.
- More efficient use of scarce (natural) resources such as metals and minerals
- Lower air and water pollution impact due to avoidance of primary production processes, such as mining, quarrying, processing, etc and avoid littering.,
- A reduction of energy use in the material/product production process (e.g. the copper recycling process results in energy savings of up to 85% compared to primary production; ECI 2008) [15],
- A lower level of GHG emissions (associated with lower energy use) of recycled materials (i.e. secondary market) compared to the primary market,
- Increased employment associated with handling and processing of waste streams, additional employment could be in waste collection, waste handling and processing, secondary material/product trade (e.g. second-hand store); the exact employment effect depends on the recycling technology/process chosen related to current existing waste management practices in the area, etc.

Financial requirements and costs

Investment costs in obtaining the site, construction and equipment may tend to be relatively high. For example, if a refrigerator is brought to the site it has to be broken into pieces, and different metals, plastic, glass and rubber have to be separated from this one unit for recycling, and equipment would be needed. But there could be a payback in the way that it would reduce the required land space for a land fill, and can also feed to either the composting and semi-aerobic landfill.

Pros

- Saves space in landfills.
- May generate revenue by selling the material.

• Saves resources and energy from the processing of raw materials.
Cons • May require decontamination first to ensure safe reusability. • In some cases there could be need for sampling to verify if recyclable material is not contaminated.. • May increase risk to public. • Public perception may be negative regarding usability of product.

A2.2: Semi-aerobic Landfill Fact Sheet

Sector	Waste
Sub-sector	Waste Management
Technology name	Semi-aerobic landfill
Availability	Available
Scale	Large scale

Technology Background Information

Technology description

The semi-aerobic landfill system is quick to stabilize the filled landfill so that the site at which it is located can be available for other uses. It was developed in Fukuowa University in Japan [16]. A water barrier is used to line the sides and bottom of the landfill to avoid leachate from seeping into the ground. The landfill should be structured such that it allows leachate towards the bottom, and the bottom should have a slope to allow ease of leachate flow. At the bottom above the water barrier leachate collecting pipes are set up to remove the leachate. Waste is deposited in layers of thicknesses of 1 m or less and then covered with at least 15 cm of soil to limit bad smell, the spread of vermin and pests and stop the scattering of light waste by wind. The final soil layer should be about 50 cm. The final layer should be 30 cm of compacted clay to stop rainwater from seeping into the decomposing waste. The top surface of the landfill should slope to allow rainwater flow away from the landfill. Air is forced from the open end of the leachate pipe to provide oxygen to the waste above to enhance aerobic decomposition of the waste. Respiring bacteria in the presence of oxygen changes the biodegradable material to carbon dioxide and water leaving a residue of humus. The decomposition activity releases thermal energy resulting in temperatures of about 50 to 70°C. In aerobic decomposition about a third of the carbon is used to build the structure of the organism, while two thirds is released as carbon dioxide. The oxygen also promotes simultaneous nitrification-denitrification of ammonium produced to nitrogen gas and the conversion of sulfur to sulfur ion thus reducing the foul odor of rotting waste. This reduces the amount of methane emitted. The result is less methane and other greenhouse gases produced and instead carbon dioxide emitted which is less potent as a greenhouse gas. This technology therefore mitigates global warming by reducing the global warming potential of the landfill.

Technology feasibility

This technology was first used in Japan, and now it is used in a number of countries in Asia, with severe waste problems.

Market potential

All the cities and towns in Swaziland have waste disposal challenges. Some towns even use open waste burning which is against the aspirations of both the UNFCCC and the Stockholm Convention to which Swaziland is party to. Adoption of waste management strategies would be beneficial to all of them.

Climate and other environmental benefits

It reduces methane emissions

Financial requirements and costs

The literature states that the semi-aerobic landfills treat waste economically than anaerobic landfills [17,18, 19, 20].

Pros

- Relatively lower cost than anaerobic landfill
- Leachate is discharged as soon as it is collected - reduce the seepage of leachate
- Fresh air is brought in from the pipes - enhance waste stabilization, improve leachate quality and reduce the cost of final treatment of leachate
- Release gas from gas ventilation pipes - reduce gas pressure and the chance of gas explosion
- Compaction of waste - reduce land demand

• Enhance waste stabilization - less time requires for the reuse of completed landfills (for vegetation, open space, parks, recreation, school, etc.) • Reduction of CH_4 and increase of CO_2 - global warming potential of CH_4 is about 21 times more than that of CO_2 - helps preventing the global warming • Cost-effective as initial investment and maintenance cost of Semi-aerobic is lower than that of Aerobic type of landfill
Cons • Rain water could seep into the landfill destabilizing the process. • The could be a production of unknown gases by the introduction of air. • The introduction of air could produce flammable or explosive gases

A2.3 Municipal Solid Waste Composting Fact Sheet

Sector	**Waste**
Sub-sector	**Waste Management**
Technology name	**Municipal solid waste composting**
Availability	**Available**
Scale	**Large scale**

Technology Background Information

Technology description

Organic waste such as paper cardboard, garden waste, tree and shrub trimmings etc., found in municipal waste could be converted into a compost fertilizer. Compost contains nutrients essential to plants and has the property to keep water like a sponge. Composting of municipal solid waste has to be done under controlled conditions to enhance the biological conditions suitable for the decomposition of biodegradable organic waste. Microorganisms including bacteria and fungi are responsible for the decomposition of the organic matter. They break down the matter into its constituent nutrients good for plants. The resulting product is a rich fertilizer that is odor and pathogen free. The microorganisms require the right conditions of organic matter of the right size, regular mixing, enough oxygen, the right oxygen to nitrogen ratio, temperature, amount of moisture, populations of the microorganisms. To achieve the desired conditions the biomass have to be worked on through some mechanical means and aeration. Compostable materials include plant waste, paper, wood, food waste, etc. Such materials are abundant in municipal waste. The main gas emitted from composting is carbon dioxide as compared to methane and carbon dioxide in the case of aerobic decomposition, and therefore reduces contribution to global warming.

Technology feasibility

Technology is mature and used worldwide. Some of the waste produced like garden waste and tree cuttings and trimmings are obviously compostable material and can be taken directly from source to the composting site. Other waste can be separated by the existing dumpsite scavengers.

Market potential

The municipalities in Swaziland have limited available space for dump sites and are compelled to develop sound waste management practices. All the cities and towns in Swaziland have waste disposal challenges. Some towns even use open waste burning which is against the aspirations of both the UNFCCC and the Stockholm Convention to which Swaziland is party to. Adoption of waste management strategies would be beneficial to all of them.

Climate and other environmental benefits

Composting reduces the emission of methane a more potent greenhouse gas. It also saves landfill space.

Financial requirements and costs

This technology can be economical since if end product is not contaminated can be sold as a fertilizer. In addition, the land fill is reusable reducing the need cost for the purchase of a new site.

Pros

- Relatively low cost
- If done correctly the product could be valuable
- Saves space in landfills
- Space can be reused
- May minimize spread of pathogens
- Growing acceptance by states and industry

Cons

- Have to be constantly worked on and monitored

- There could be odors and seepage of water
- Requires control of vermin and other vectors
- Product could be contaminated with heavy metals.
- Requires dedicated space for a period of time.
- Requires maintenance or monitoring.
- Possible odors and runoff.
- Public perception regarding usability of product may be negative.

A3: LULUCF Fact Sheets

A3.1 Grazing-land Management

Sector	**LULUCF**
Sub-sector	**Land and Forestry**
Technology name	**Grazing-land Management**
Availability	**Available**
Scale	**Large scale**
Technology Background Information	
Technology description In Swaziland grazing land occupy a much larger area than cropland and is generally not managed. The farmers on Swazi Nation Land do not consider issues of grazing intensity or percent utilization. Grazing intensity and percent utilization are often used interchangeably but actually differ in what they describe, which are methods of determining the sustainability of grazing land. Grazing intensity is the cumulative effects grazing animals have on rangelands during a particular time period. In contrast utilization is the percentage of the current year's herbage production consumed or destroyed by herbivores. Percent herbage use provides only one measure of grazing intensity. Others include amount of forage standing crop remaining at the end of the grazing cycle, percentages of grazed and ungrazed plants, plant stubble heights, litter, or carry over vegetation from previous years and visual appearance. The intensity and timing of grazing can influence the removal, growth, carbon allocation, and flora of grasslands, thereby affecting the amount of carbon accrual in soils [21, 22, 23, 24]. The influence of grazing intensity on emission of non-CO2 gases is not well-established, apart from the direct effects on emissions from adjustments in livestock numbers.	
Technology feasibility Technology is mature and used worldwide. Some of the waste produced like garden waste and tree cuttings and trimmings are obviously compostable material and can be taken directly from source to the composting site. Other waste can be separated by the existing dumpsite scavengers.	
Market potential There are a lot of areas in Swaziland where overgrazing manifest itself. These areas need to be properly managed before they lose too much vegetation. There are, however, some problems in tackling land issues in Swaziland. Anything done on Swazi Nation Land has to be approved by traditional structures. Reducing livestock densities may not be accepted by the community leaders and their subjects. The farmers were told last season (2015/16) to reduce their livestock due to an anticipated drought but they did not and many cattle died.	
Climate and other environmental benefits The management of grazing land can help in maintaining the quantities of above and below ground carbon stocks by preventing soil erosion and the destruction of vegetation.	
Financial requirements and costs There could be costs associated with the fencing of some potions of land, and the studies to be carried out to monitor and evaluate the implementation of the option.	
Pros • Reduces soil degradation • Improves vegetation • Avoids degradation of pasture through trampling, introducing weeds (eg. in feeds). • Avoids destruction of habitats. • Minimizes competition of forage material between domesticated animals and wild animals.	

• Decreases loss of biodiversity.
Cons • Requires some studies of the behavior of the vegetation under different grazing conditions. • Requires the education of farmers which may prove difficult as they may not have time for the lessons. • Traditional leaders may not agree with allocating land for studies. • Local farmers may not agree to reduce their livestock because they highly value them. •

A3.2: Agro-forestry for Mitigation for Swaziland

Sector	**LULUCF**
Sub-sector	**Forestry**
Technology name	**Agroforestry**
Availability	**Available**
Scale	**Medium to large**
Technology Information	
Technology description Agro-forestry, as defined by the World Agro-forestry Centre [25], is "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels". On the other hand, the Association for Temperate Agro-forestry [26] describes it as "an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock". Agro-forestry offers great potential for carbon sequestration. In addition to mitigation benefits, agro-forestry can also address the need for improved food security and increased energy resources, as well as the need to sustainably manage agricultural landscapes. Agro-forestry is one of the important terrestrial carbon sequestration systems. It involves a mixture of trees, agricultural crops, and pastures to exploit the ecological and economic interaction of an agro-ecosystem. Agro-ecosystems play a central role in the global carbon cycle and contain approximately 12% of world terrestrial carbon [10]. Increased sequestration by agro-forests is an important element of a comprehensive strategy to reduce GHG emissions. The system of planting trees in strategic locations on farms to compensate for the lost carbon due to cutting of trees for agriculture is called agro-forestry. It has the biggest potential for increasing agricultural carbon sequestration in tropical countries. Terrestrial sequestration is based on the fact that plants take CO2 out of the atmosphere through photosynthesis and store it as organic carbon in above-ground biomass (trees and other plants) and in the soil through root growth and the incorporation of organic matter. Thus, the process of carbon loss through land use change can be reversed, at least partially, through improved land use and management practices. In addition to afforestation, changes in agricultural land management, such as the adoption of tillage practices that reduce soil disturbance and incorporate crop residues into the soil, can remove carbon from the atmosphere and store it in the soil as long as those land use and management practices are maintained. Agro-forestry systems will vary by region. However, crops and forests together will elevate the carbon conserving capacity of the agro-ecosystem of a region.	
Technology feasibility There is an opportunity to include agroforestry practices in subsistence and smallholder farming. This practice is aligned to traditional farming methods where farmers would have fruit trees and crops in the same land therefore can be easily accepted.	
Market potential This technology is already practiced by individuals and in small farms, but not formally. Education could help increase its benefits and adoption.	
Climate and other environmental benefits The benefits of this technology are carbon sequestration and storage in below ground and above ground carbon.	
Financial requirements and costs Financial requirements are in the form of seedlings, labour and chemical inputs. The labour can be provided by the people who already work the land, when the demand from other activities is low. Less exotic plant species tend to grow with minimum chemical needs. Seedlings are usually very affordable and there are also activities where they are provided for free. The Forestry Department	

under the Ministry of Tourism and Environmental Affairs is responsible for promoting agro-forestry and for providing farmers with seedlings.
Pros • Products from trees such as fruits, timber, fodder and medicinal products. • Trees act as a buffer against storms to prevent crop destruction. • Trees send their roots considerably deeper than crops, thereby placing organic matter at deeper depths in the soil where tillage won't accelerate its decomposition and the release of CO2. • Leaf litter generates compost and serves as mulch that reduces runoff from rainfall. It also slows soil water loss from evaporation into the atmosphere. • Agro-forestry trees also improve land cover and reduce soil erosion, which is a crucial process in soil carbon dynamics. • Carbon storage continues beyond harvest if boles, stems, or branches are processed into durable products that do not decompose and release CO2. • An agro-forestry could induce a conducive micro-climate that can improve the quality and yield quantity of some crops.
Cons • Increasing agroforestry may involve practices that increase emissions of GHGs making the net carbon mitigation to be marginal. • This technology is a very slow process of carbon sequestration and storage. • Some species of trees may be breeding habitats for insect pests.

A3.3: Urban Forestry

Sector	**LULUCF**
Sub-sector	**Forestry**
Technology name	**Urban Forestry**
Availability	**Available**
Scale	**Small to medium**
Technology Information	

Technology description

Urban forestry is the care and management of tree populations in urban settings for the purpose of improving the urban environment. The concept of urban forestry, which advocates the role of trees as a critical part of the urban structure, was developed to address the issue of impact on forestry by urbanization. The urban forestry comprises all green elements under the control of the urban area administration.

Changes in structure of society have accelerated the urbanization. Urbanization is considered as the main driver for eco system change [10]. According to the WHO in 2014, 54 % of the world's population lives in cities [27]. Developing countries in particular are urbanizing rapidly thus emitting more greenhouse gases (GHG). Urbanization generally has adverse effects on eco system like destruction in habitat and watershed, change in forest structure, etc.

Urban forestry is the care and management of tree populations in urban settings for the purpose of improving the urban environment. The concept of urban forestry, which advocates the role of trees as a critical part of the urban structure, was developed to address the issue of impact on forestry by urbanization. The urban forestry comprises all green elements under urban influence, (FAO, 2001), such as:

- Street trees and road plantations
- Public green areas, such as parks, gardens, cemeteries,
- Semi-private space, such as green space in residential areas and in industrial or specially designated parks
- Public and private tree plantations on vacant lots, green belts, woodlands, rangelands, and forests close to urban areas
- Natural forests under urban influence, such as nature reserves, national parks and forests for eco-tourism.

Urban agricultural land, such as orchards, allotments etc

Technology feasibility

Technology is mature, with continuous improvements and Swaziland is relatively sunny especially the middle and lower regions. There are already sizable solar PV grid tie systems in Swaziland. The current systems in Swaziland are connected after the utility meter and they do not feed power to the grid. Their power is not directly monitored by the grid system. The systems include a 31.2 kW at the Blood Bank, 60 kW at the Luyengo Campus of the University of Swaziland, a 31.2 kW at Mhlumeni border gate and a planned 31.2 kW at Nhlangano Health Centre [2]. There is also a 25 kW installation at Bulembu village which has no batteries and is used to reduce the electricity demand during the day. [3]

Market potential

In the last two decades the global solar PV market has experienced rapid expansion, with an average annual growth rate of 40%. An annual growth rate of 17% is forecast over the next decades [4]. There is a high potential for grid connected solar photovoltaic systems in Swaziland. The main barrier is that many organisations are not well informed and some are waiting for the prices to further go down or grid electricity prices to go up.

Currently, there are two companies that are seriously considering installing on-grid solar PV systems. One aims at producing 10 MW and the other 100 MW. One of the Companies has started

by installing a 100 kW plant in Siteki, a picture of which is in the front cover page of this document. There is also a growing middle class in Swaziland that can take advantage of the technology.
Climate and other environmental benefits   Urban forests have several environmental benefits including the following.   • Sequestrate carbon below and above ground.   • Trees can reduce air pollution through trapping and holding particulate pollutants such as ash, smoke and dust.   • Trees can help reduce soil erosion in sloppy areas of the urban area.   • Trees helps conserve cooling energy by providing shade.   • Trees can act as a sound absorber and muffle the sound in the urban areas.   • Trees can reduce the heat absorbed by urban structures therefore resulting an overall lower temperature compared to when there were no trees.
Financial requirements and costs   The financial requirements will include obtaining the seedlings, planting, protection, cleaning fallen leaves and managing the tree growth by pruning etc.
Pros   • Urban forests acts as a carbon sink and sequestrate carbon dioxide   • Urban forests can also help improve the quality of urban life by providing a scenic view.   • Some plants can provide fruits and may have some medicinal benefits.   • They can be used for recreational purposes.   • They can also provide shade and act as a cooling effect to nearby areas.
Cons   • A key challenge with urban forestry is the competition for space with other infrastructure like houses, shops etc.   • In urban areas, land is usually expensive and each square metre is used efficiently for development purposes.   • There is a limitation on possible plant species that can be grown because of restricted root space and abnormal exposures to sunlight.

REFERENCES FOR FACT SHEETS

1. Gaismaq, http://www.gaisma.com/en/location/mbabane.html
2. MNRE Energy officers
3. Bulembu Ministries Swaziland, "Power to the People," October 20 2011
4. https://en.wikipedia.org/wiki/Solar_power_in_the_United_States
5. http://www.solarwaste.eu/collection-and-recycling/
6. http://www.climatetechwiki.org/technology/pv
7. Randall Spalding-Fecher, Pöyry Management Consulting (Sweden) AB,What is the carbon emission factor for the South African electricity grid? Journal of Energy in Southern Africa • Vol 22 No 4 • November 2011
8. IPCC 2011 Agregated Results of the Available Literature
9. J Wisconsin Valley Improvement Company, "Facts About Hydropower," http://www.wvic.com/Content/Facts_About_Hydropower.cfm
10. Climate Tech Wiki
11. Steinhurst et al, "Hydropower Greenhouse Gas Emissions", Synaps Energy Economics Inc., February 14 2012
12. International Energy Agency: Hydropower Essentials 2013
13. International Renewable Agency, "Hydropower Technology Brief", February 2015
14. IPCC (2007) BEMS
15. ECI 2008) [15]
16. It was developed in Fukuowa University in Japan [16].
17. Chong TL[1], Matsufuji Y, Hassan MN., Implementation of the semi-aerobic landfill system (Fukuoka method) in developing countries: a Malaysia cost analysis, NCBI 25 July 2005
18. Pattharathanon et al., "Greenhouse Gas Emission and Economic Evaluation from Municipal Solid Waste Landfill in Thailand" IPCBEE vol.42 (2012)
19. Bilgili et. Al. "Aerobic Landfill Application in Developing Countries: A Case Study" Yildiz Technical University, Istanbul, Turkey October 7 2000,
20. Global Environment Centre foundation, http://nett21.gec.jp/waste/data/waste_l-1.html
21. Conant, R.T., K. Paustian, and E.T. Elliott, 2001: Grassland management and conversion into grassland: Effects on soil carbon. Ecological Applications, 11, pp. 343-355.
22. Freibauer, A., M. Rounsevell, P. Smith, and A. Verhagen, 2004: Carbon sequestration in the agricultural soils of Europe. Geoderma, 122, pp. 1-23.
23. Conant, R.T. and K. Paustian, 2002: Potential soil carbon sequestration in overgrazed grassland ecosystems. Global Biogeochemical Cycles, 16 (4), 1143 pp., doi:10.1029/2001GB001661.
24. Reeder, J.D., G.E. Schuman, J.A. Morgan, and D.R. Lecain, 2004: Response of organic and inorganic carbon and nitrogen to long-term grazing of the shortgrass steppe. Environmental Management, 33, pp. 485-495.
25. World Agro-forestry Centre [25]
26. Association for Temperate Agro-forestry [26]
27. http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/