CLEAN ENERGY AND WATER: AN ASSESSMENT FOR SERVICES FOR ADAPTATION TO CLIMATE CHANGE

FINAL ASSESSMENT REPORT

By

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Executive Summary

This regional study of East Africa is one of the four assessment reports under the exploratory project of the International Development Research Centre (IDRC) with an overall objective of assessing renewable energy use in water services in East Africa and its implication on adaptation to climate change impacts. The report further assess the challenges facing the wider use of renewable energy technologies in water services as an option for addressing the adverse impact of climate change on water services.

The energy sector in the Eastern African region is characterized by an over-reliance on traditional biomass energy resources which accounts for over 70% in all countries. The region is characterized by low levels of electricity consumption and inadequate access to grid electricity.. A similar situation is experienced in the water sector which is also characterized by low levels of access to piped water and limited access to improved water resources particularly in the rural areas. Like the energy sector, the water sector is facing significant pressure from rapid population growth that is on the upward trend in the region and has led to higher demand for water services.

Eastern Africa has recently experienced extreme weather events that provide growing evidence of the adverse impacts of climate change notably in terms of rising temperatures, shorter rainy seasons, floods, drought and famine. These events highlight the need to investigate mitigation options – a key a objective of this study with respect to renewables-based water systems.

In cases where renewable energy technologies have been adopted to meet water services for communities, they have registered positive impacts. The technologies have enabled women reduce water collection distances. Treadle pumps have successfully raised food security and increased household incomes arising from increased productive of irrigated market gardens.

The dissemination of treadle pumps is higher compared to other water pumping renewable energy technologies. This is partly attributed to the low cost of treadle pumps. At under US$200, low income households can purchase treadle pumps from savings or retirement benefits. However, the lifetime use of the pumps is six years which is low compared to ram pumps – 40 years and wind pumps - 20 years.

The study's findings indicate that there are no clear-cut policies that support the dissemination of renewable energy technologies for water services as an adaptation strategy to climate change. Most of the national policies and strategies focus of large-scale conventional power generation technologies and national electrification projects through the national grid.

The study's findings confirmed that there is limited support by governments for renewable energy technologies and water services to promote the dissemination of treadle pumps, wind pumps and ram pumps. This is demonstrated by the fact that the budgetary allocation on renewable energy technologies development projects in Kenya and Tanzania is less than 2.5% of each country energy sector development budget.

In addition to low budgetary allocations to renewables and water services in general, the policy architecture in East African countries is not conducive to many of the aforementioned renewable energy water pumping technologies. Promotion of pro-poor renewable-based water pumping options such as treadle pumps, wind pumps and ram pumps (examined in this report), require collaboration between the mnistries in charge of the energy with those in charge of water and possibly agriculture. This is difficult in institutional settings where ministries are essentially impervious silos that allow very limited horizontal communication. This clearly an important policy design issue that needs further research and investigation in the next phase of this study.

The study states that there has been little research carried out to date on how climate change may affect performance of renewable energy technologies for water supply – an important avenue for follow-up research.

Collaborative research through existing network of IDRC international researchers, further studies can be commissioned to provide useful documentation on large-scale dissemination of renewables-based water pumping systems earlier used in middle and high income countries to provide important lessons learned for Eastern African countries.

Another important research question that needs to be addressed is to determine, to the extent possible, the roles that information and communication technologies (ICTs) are playing or could potentially play in supporting water and energy distribution and availability of services.

A clear and practical entry point for further investment and research support by the CCW program is the substantial amount of studies and research undertaken by AFREPREN/FWD and its members in region on the subject of renewables for water services in East Africa. This will better leverage AFREPREN/FWD's intellectual and skills assets as well as past and ongoing relevant projects and network of experts and policy contacts at national level.

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- Abbreviations

AFREPREN/FWD	Energy Environment and Development Network for Africa
ApproTEC	Appropriate Technologies for Enterprise Creation
BHEL	Bob Harries Engineering Limited
CCW	Climate Change and Water
COWAPA	Community Water for Poverty
EACCCP	East African Community Climate Change Policy
ERB	Energy Regulation Board
ERC	Energy Regulation Commission
EWURA	Energy and Water Utilities Regulatory Authority
FAO	Food and Agricultural Organization
GDC	Geothermal Development Company
GDG	Gatongora Development Group
GDP	Gross domestic product
GEF	Global Environment Fund
ICTs	Information and Communication Technologies
IDRC	International Development Research Centre
IGAD	Intergovernmental Authority on Development
KETRACO	Kenya Transmission Company Limited
KP	Kenya Power
LVIA	Lay Volunteer International Association
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MWE	Ministry of Water and Environment
NAMAs	Nationally Appropriate Mitigation Measures

NAPAs	National Adaptation Programmes of Action
NCCRS	National Climate Change Response Strategy
PV	Photovoltaic
REA	Rural Electrification Authority
RETs	Renewable Energy Technologies
TANESCO	Tanzania Electricity Supply Company
UEB	Uganda Electricity Board
UEDCL	Uganda Electricity Distribution Company
UEGCL	Uganda Electricity Generation Company
UETCL	Uganda Electricity Transmission Company
UNDEWA	United Nations Department for Early Warning Assessment
UNDP	United Nations Development Programmes
UNEP	United Nations Environment Programme -
UNFCCC	United Nations Framework Convention on Climate Change
WAB	Water Appeals Board
WFP	World Food Programme
WSRB	Water Services Regulatory Board
WSS	Water and Sewerage Services
WSTF	Water Services Trust Funds

List of Units

%	percent
BC	Before Christ
hrs	hours
km	kilometer
Kshs	Kenya Shillings
kWh	kilowatt hours
kWp	kilowatt peak
m/s	metres per second
m^2	square metres
m^3	cubic metres
^oF	Fahrenheit
Tshs	Tanzania Shillings
US$	United States Dollar

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1. INTRODUCTION

Overall Objective of the Proposed Study

The overall objective of this study is to gain a better understanding of renewable energy use in water services in East Africa in the context of adaptation to climate change, thus setting the stage for a high impact research program on the nexus of renewables, water and adaptation to climate change.

Specific Objectives of the Proposed Study

- Gain a better understanding of the extent to which renewable energy technologies are used for water services in East Africa and implications for enhancing quality and coverage of water services.
- Assess the challenges facing the wider use of renewable energy technologies in water services as an option for addressing the adverse impact of climate change on water services.
- Review the opportunities for scaling up the application of renewable energy technologies in water services through wider dissemination of renewables.
- Identify key questions for further research aimed at energy policy change and initiatives to enhance adaptation capacity to climate change for populations in areas under climate-related water stress.
- Propose clear and practical entry points for further investment and research support by the CCW program based on the proposed study as well as the field experience of AFREPREN/FWD.

Rationale and Justification for the Choice of the Countries/Geographical Region of Focus

Based on preliminary assessment of available data and information as well as the extent to which relevant renewable energy technologies for water services have been installed, the East African study will focus on Kenya and Tanzania. There are several other factors that have been taken into consideration while choosing the two countries as the focus of the research. For example, East African countries (Kenya, Uganda, Tanzania, Ethiopia, Eritrea, Rwanda and Burundi) have relatively comparable socio-political and climatic features. These include, but are not limited, to similar energy, climate change and policy challenges. Consequently, the findings based on case studies in Kenya and Tanzania will , to some extent, be representative of the East African region, implying that the lessons learnt from the two countries could be replicated, to some degree, in the other countries in the region.

AFREPREN/FWD has previously conducted similar studies in the two countries which will allow this study to identify relevant case studies as well as start from a more advanced research level. In addition, the two countries appear to register relatively higher installations of the selected case study renewable energy water pumping technologies (e.g. wind pumps and treadle pumps that can enhance adaptation to climate change) than other countries in the region.

The extensive and growing sub-regional policy and research linkages (plus common research language – primarily English except in Burundi - and better communication links) as well as formal regional agencies (such as East African Community, IGAD – Intergovernmental Authority on Development and Lake Victoria Basin Commission and Nile Basin Initiative) in the East African region will allow for more effective dissemination of any research findings arising from the two country case studies of Kenya and Tanzania as well as from any follow up research work. The growing level of policy coordination is another important reason why research findings from one eastern African country would be of relevance to other countries in the region. Increased coordination of national policies is driven by the growing trade among them as well as joint membership in economic trade blocs such as the East African Community and the Common Market for East and Southern Africa (COMESA). In addition, the countries' senior policy makers regularly meet to coordinate policies and undertake joint investment initiatives. For example, Ministers of Finance in East Africa coordinate to ensure that they read their annual budget speeches on the same day which reduces short-term speculative trade arbitrages but also demonstrate how closely Ministers of Finance are beginning to work together. . Policies that prove successful in one country are usually rapidly copied by other countries in the region.

Lastly, this study selected renewable energy technologies for water pumping and irrigation (wind, ram, solar PV and treadle pumps), that have significant potential for enhancing food security among the poor and protecting them from the predicted adverse impact of climate change such as increased incidences of drought. More importantly, these technologies are already being used by the rural poor in parts of Kenya and Tanzania, making it possible to undertake an empirical assessment of the relevance of renewables to water services and adaptation to climate change.

2. METHODOLOGY

During the study, the research team relied on the following resources:

- Available literature, official documentation and past/ongoing studies on water and energy services as well as on environment and climate change.
- Published reports of Nationally Appropriate Mitigation Measures (NAMAs) and National Adaptation Programmes of Action (NAPAs)
- Regional and National climate change adaptation, energy and renewable energy policies and strategies
- Past and ongoing studies undertaken by AFREPREN/FWD on energy services in the eastern Africa region.
- Available data and statistics from databases, surveys, research studies and reports published by key stakeholders such as ministries of environment, energy, finance and water.
- Data compiled from surveys conducted in previous studies
- Data compiled from field visits/case studies
- Past field experiences of the AFREPREN/FWD research team

The methods used to achieve the study objectives involved the following:

- *Data and statistics compilation*: Bringing together existing data and statistics on the water and energy services as well as climate change. Where possible, the study compiled time-series statistics which provided insights on prevailing trends.
- *Literature review*: Based on available documents, data and statistics from government ministries of energy, planning, water and irrigation, agriculture; water services boards; utility agencies; and, other Government agencies and independent research institutions.
- *Review of Energy Policies*: Analytical review of current policies governing the energy sector, water, climate change and other relevant sectors. In addition, the aforementioned review included associated legislature and strategic plans.

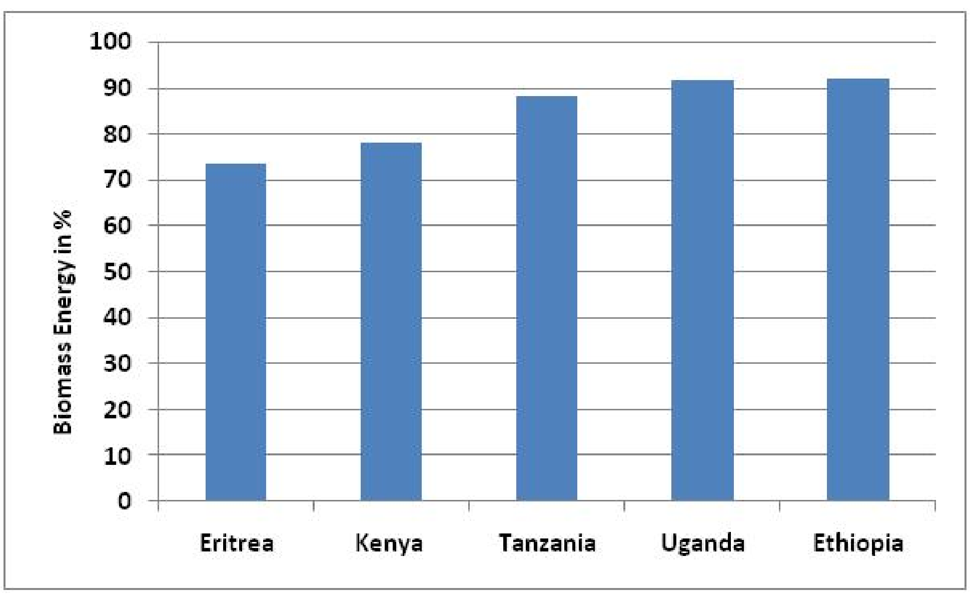
This report is sub-divided into seven chapters. The first chapter presents the overall and specific objectives of the study on renewables, water and adaptation to climate change and explains the rationale and motivation of the study. Chapter two briefly discusses key methodologies used by the research team. The third chapter provides a brief background review of the energy sector and water services in Eastern Africa and highlighs evidence of climate change impacts. Chapter four provides a short review of key renewables (i.e. treadle, ram, solar PV and wind pumps) that can play a major role in water services delivery. Chapter five presents case examples of renewable energy application in water services with a special emphasis on two key renewable energy options, namely: treadle and wind pumps. Chapter six presents an initial assessment of decentralized renewable energy technologies (RETs) for water services in Eastern Africa and discusses how the two selected renewables can play an important role in enhancing the resilience of water and water-related issues to adverse impacts of climate change.. It then reviews regional and national climate change adaptation strategies and examines the key factors driving use of renweables in the region. The seventh and final chapter summarizes the findings of the study, recommends areas of further research studies, and proposes practical entry points for further investment and research support by the CCW Program.

3. SECTION I – BACKGROUND REVIEW OF THE ENERGY SECTOR AND WATER SERVICES IN EASTERN AFRICA

The Energy Sector in Eastern Africa

The energy sector in the Eastern African region is characterized by three key factors - an over-reliance on traditional biomass energy resources (to meet the energy needs of most rural households); low penetration levels of renewable energy technologies (see Section II); and, a heavy dependence on imported petroleum (which meets the demand of the modern economy). For example, in Kenya where the biomass consumption is the second lowest in the region, biomass energy supply accounts for up to 78% of the total energy consumed (IEA, 2010). Much higher consumption levels of biomass are registered in the other Eastern African countries as shown in the Figure 1.

Figure 1: Biomass Energy as a Percentage of Total Energy for Selected Eastern and Horn of African Countries (2008)



Source: IEA 2010; MoEDU, 2009

Although the economies of East African countries are experiencing substantial growth, the per capita consumption of modern energy in the region is still very low. The region is characterized by low levels of electricity consumption and inadequate access to grid electricity. For example, the per capita consumption of electricity in Tanzania stands at 84 kWh (IEA, 2011a), close to 2 ordesr of magnitude lower than the world average. The picture looks even more serious in the case of Uganda where only 9% of the population has access to electricity and the per capita electricity consumption stands at 68 kWh (Andrew and Barry, 2010; NationMaster.com, 2011). Kenya's per capita electricity consumption is estimated at 156 kWh per capita (IEA, 2011b) which is the highest in the region but still very low compared to the global average of 2,825 kWh (World Bank, 2011a). Table 1 shows the electricity access levels and the per capita electricity consumption in the region, which confirms that a large portion of the population (particularly in rural areas) has no access to electricity.

Table 2: Electrification Levels and per capita Electricity Consumption in East Africa and Horn of Africa Countries (2008)

Countries	Electrification Levels (%)			Population without access (millions)	Per capita electricity consumption (kWh)
	Total	Urban	Rural		
Eritrea	32.0	86.0	5.0	3.4	48
Ethiopia	15.3	80.0	2.0	68.7	42
Kenya	18.1*	51.3	5.0	33.2*	156
Tanzania	11.5	39.0	2.0	36.8	84
Uganda	9.0	42.5	4.0	29.1	68

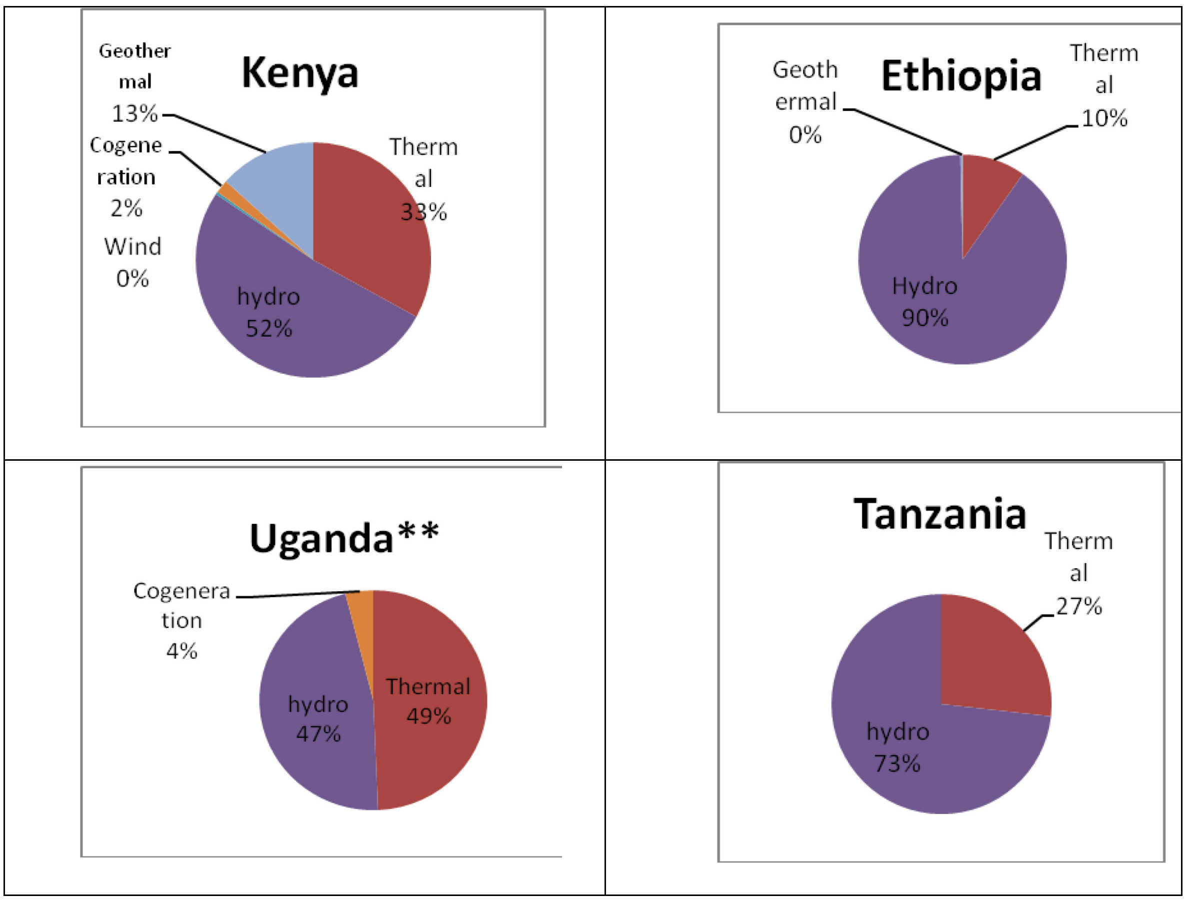
Note * Data for 2010

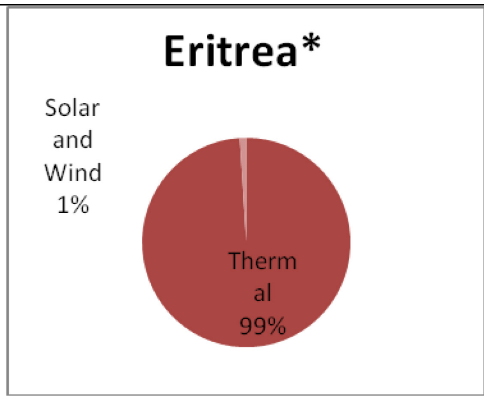
Source: IEA, 2011a; 2011b; 2011c; 2011d; 2011e; 2011f; KPLC, 2010; World Bank, 2011a

With limited rural access to electricity and other modern forms of energy, use of cleaner energy options in rural areas, and specifically, in the water sector is limited as demonstrated by very low levels of modern-energy powered irrigation. Without access to modern energy for water pumping/irrigation, the region still relies on a few and inefficient labour-intensive approaches (e.g. hand-dug water wells, bucket irrigation, etc) as key options for adapting to any adverse impact of climate change on water services.

The main source of electricity in the Eastern African region is hydro. With the exception of Eritrea, all the countries record over 50% dependency on hydro power generation. Ethiopia's power sector is the most dependent with 90% of total electricity generation coming from large hydro sources. Figure 2 presents the contribution of hydro electricity generation in the respective East African countries:

Figure 2: Electricity generation in East and Horn of Africa for the year 2010

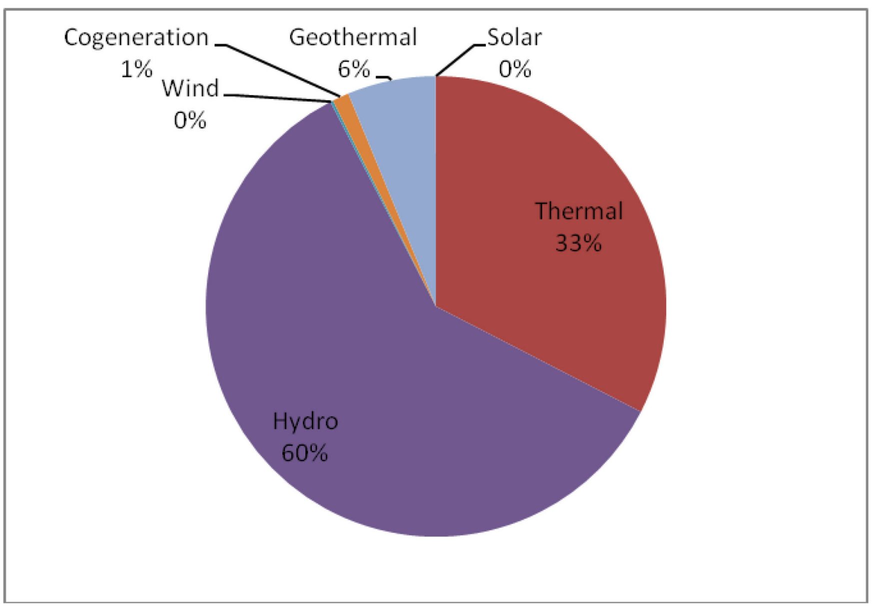




Note *Data is for 2008 ** Data is for 2009
Source: TANESCO, 2011; IEA 2011g; EEPCo, 2011; UETCL, 2010; KPLC, 2010; MeM, 2009

With the exception of Eritrea, this high level of dependency on hydro electric power generation is also replicated at regional level. Figure 3 shows the different sources used for electricity generation in the region, demonstrating the extent to which the region's power sector is dependent on hydro-electric power generation[1] – exposing the region's power sector to the negative impacts of climate change especially prolonged spells of drought.

Figure 3: Electricity Generation in East Africa for the year 2010*



[1] Hydropower has a number of drawbacks. Hydro projects in Africa have generally been large-scale and require relatively large loans, contributing to high external debt levels.. Large hydro projects directly benefit only a small section of the population i.e. the middle and upper class with access to electricity, which means large-scale hydropower, is, in many respects, fundamentially inequitable as both low and middle/high incomes contribute to the repayment of the hydropower-related national debts. In addition, the large amounts of capital involved have attracted allegations of corruption. This has often led to the stalling or lengthy delays in many hydro power projects.

Note - *Eritrea data is for 2008 and Uganda is for 2009

Source: TANESCO, 2011; IEA 2011; EEPCo, 2011; UTLC, 2010; KPLC, 2010; MeM, 2009

This section provided a brief review of the energy sector in Eastern Africa. The next section will now turn to the water services sector which is vulnerable to the adverse impacts of climate change and could enhance its resilience through better access to modern energy options.

Water Services in Eastern Africa

Water services in Eastern Africa are characterized by inequitable levels of access to improved water sources (i.e. utility piped water, standpipes and protected wells and springs) with large differences between rural and urban access levels. As shown in the following table, urban areas tend to have better levels of access to improved water sources than in rural areas.

Table 3: Access to Improved Water Sources in % (2008)

Country	Urban	Rural
Eritrea	74	57
Ethiopia	98	26
Kenya	83	52
Tanzania	80	45
Uganda	91	64
Other Developing Countries		
Nicaragua	98	68
Paraguay	99	66
Honduras	95	77
Brazil	99	84
Chile	99	75
Mexico	96	87
Bangladesh	85	78
India	96	84
Nepal	93	87
Sri Lanka	98	88

Source: World Bank, 2011a

Close to 50% of the rural population (Ethiopia and Tanzania register even lower percentage – see table 2 above) having no access to improved water services. A closer examination of improved water sources, however, indicates that access to piped water is very low and often largely limited to urban areas – in part, a result of low access to modern energy as piped water services frequently require some form of modern energy-powered equipment to pump water except in entirely gravity driven water systems. Table 3 shows in Uganda and Tanzania, the population served by piped water is extremely low at 3% and 7.4%, respectively (Allgood, et al, 2004).

Kenya and Ethiopia register higher access levels but which are still relatively low at 35% and 20%, respectively (Kenya Open Data, 2011;UNICEF, 2010).

Table 4: Access to Piped Water

Country	% of total population	Year
Kenya	**35**	**2009**
Ethiopia	**20**	**2007**
Tanzania	**7.4**	**2007**
Uganda	**3**	**2004**
Other regions		
India	74	2006
Nepal	73	2003
Sri-Lanka	29	2004
Brazil	77	2010
Egypt	98	2008
Morocco	65.5	2004

Source: AICD, 2010 ; Allgood, et al, 2004; Kenya Open Data, 2011; UNICEF, 2010 ; Source: WSP, 2009; Regmi, 2003; UNESCAP, 2004; Easyexpat, 2010, IRIN, 2008; Arizona, 2004

Most of the urban water supply systems and infrastructure in the region are aged and in poor condition. This has led to water losses arising from unrepaired leakages along the water supply piping network compounded by unreliable electricy supply resulting non-function water pumps leading to frequent water supply shortages.

Like in the energy sector, the water sector has been facing significant pressure from rapid population growth and urbanization. As shown in the table 4, the growth in urban population has been on an upward trend in virtually all East African countries and has led to higher demand for water services.

Table 5: Urban Population Growth (% annual)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Eritrea	4.90	5.66	5.90	5.95	5.78	5.48	5.74	5.43	5.20	5.10	5.07
Ethiopia	3.99	4.20	4.12	4.04	3.96	3.87	4.15	4.06	3.98	3.92	3.87
Kenya	3.28	3.61	3.62	3.62	3.60	3.57	4.01	3.97	3.95	3.96	3.99
Tanzania	4.13	4.24	4.25	4.27	4.29	4.31	4.58	4.60	4.62	4.64	4.66
Uganda	3.73	3.79	3.85	3.88	3.90	3.89	4.52	4.50	4.48	4.45	4.42

Source: World Bank, 2011a

Both rural and urban water systems have, in recent years, been adversely affected by frequent and prolonged droughts as well as shorter rainfall periods which are believed to be, in some respects, an indication of climate change. Frequent and longer drought periods have contributed to lower volumes of water storage due to lower volumes of rain water being collected in rivers. Consequently, almost every year, major cities in the region periodically implement water rationing programmes in a bid to equitably distribute the limited and diminishing supplies of available water.

In terms of water services for irrigation, the region is far behind other parts of the developing world as demonstrated by continued reliance on rain-fed agriculture. According to the FAO-AQUASTAT survey, irrigated land accounts for less than 4% of total arable land in Tanzania and Kenya while countries which are equally poor such as Nepal manage to irrigate close to 30% of their land. Mauritius, a neighbouring island, irrigates 20% of its land. The very limited amount of agricultural land in the eastern African region (compared to other parts of Africa – notably North Africa) that is irrigated in comparison to countries in other regions of the world is shown in the following table:

(Steve Comment – add other countries from outside Africa and delete North Africa and Mauritius)

Table 6: Irrigated Land in the Selected Eastern African Region Countries(2007)

Country	('000 ha)	% of cultivated land
Nepal	1 168	30
Eritrea	21	4.3
Tanzania	184	3.6
Ethiopia	290	2.5
Kenya	103	2
Uganda	9	0.1

Source: FAO-AQUASTAT, 2005; FAO, 2009

Impact of Climate Change on Water Services in Eastern Africa. (Steve - no need to mention none water related impacts plus mention any link to renewables)

According to a wide variety of published sources in scientific documents and public media (quoted in the following section), the impacts of climate change on the water sector of Africa and other developing countries appear to be predominantly negative and include the following:

(i) "Water pressures may be intensified as rainfall becomes more erratic, glaciers retreat and rivers dry up. While there is much uncertainty about flow of the Nile (which links river basins of several eastern African countries, namely: Tanzania, Kenya, Uganda, Rwanda, Ethiopia and Sudan), several models suggest a decrease in river flow. Nine recent climate scenarios show impacts ranging from no change to more than 75% reduction in the Nile's flow by 2100" (IPCC, 2001).

(ii) "With the increased incidences of global warming, there is prediction of the re-emergence of the "mega-droughts" in Africa. Droughts, some of which can last for centuries, have become the norm in many parts of sub-Saharan Africa. Coupled with the added stress of a continuous global warming, it is predicted that dry spells more severe than those already experienced would continuously recur making it more difficult for the people who live in these drought prone areas" (Monitor Publications, 2009).

(iii) "Between 250–550 million additional people in the developing world may be at risk of hunger with a temperature increase of 3°C (resulting in increased droughts), with more than half of these people concentrated in Africa and Western Asia. Climate change is also predicted to decrease - and/or shift - the areas of suitable climate for 81% to 97% of Africa's plant species. By 2085, 25% - 42% of plant species in Africa could find they no longer have any suitable habitat" (Stern Review, 2007).

(iv) Land degeneration as a result of continuous heavy rains could lead to the weakening of the region's earth's surface due to absorption of excess water. This is likely to lead to increased incidents of landslides or could lead to large volumes of surface run-off water, which contributes to soil erosion.

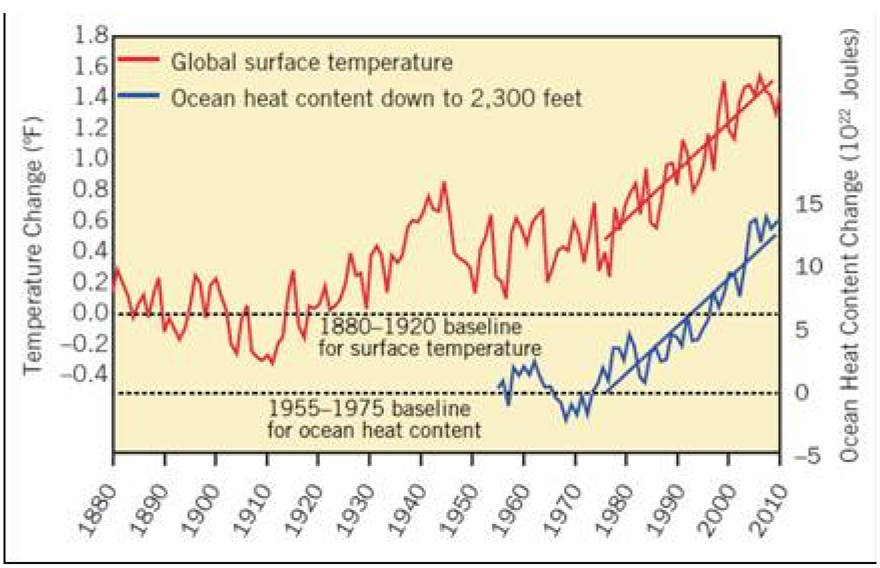
Evidence of Occurrence of Climate Change in Eastern Africa

Like many parts of Africa, Eastern Africa has recently experienced events that provide growing evidence of the adverse impacts of climate change notably the effects of rising temperatures.

3.1.1 Increased Temperatures

The global temperature has been on steady increase and scientific records indicate that for over a century the surface temperatures have gradually increased by nearly 1.5^{o}F (See Figure 4**).**

Figure 4: Global Surface Temperature



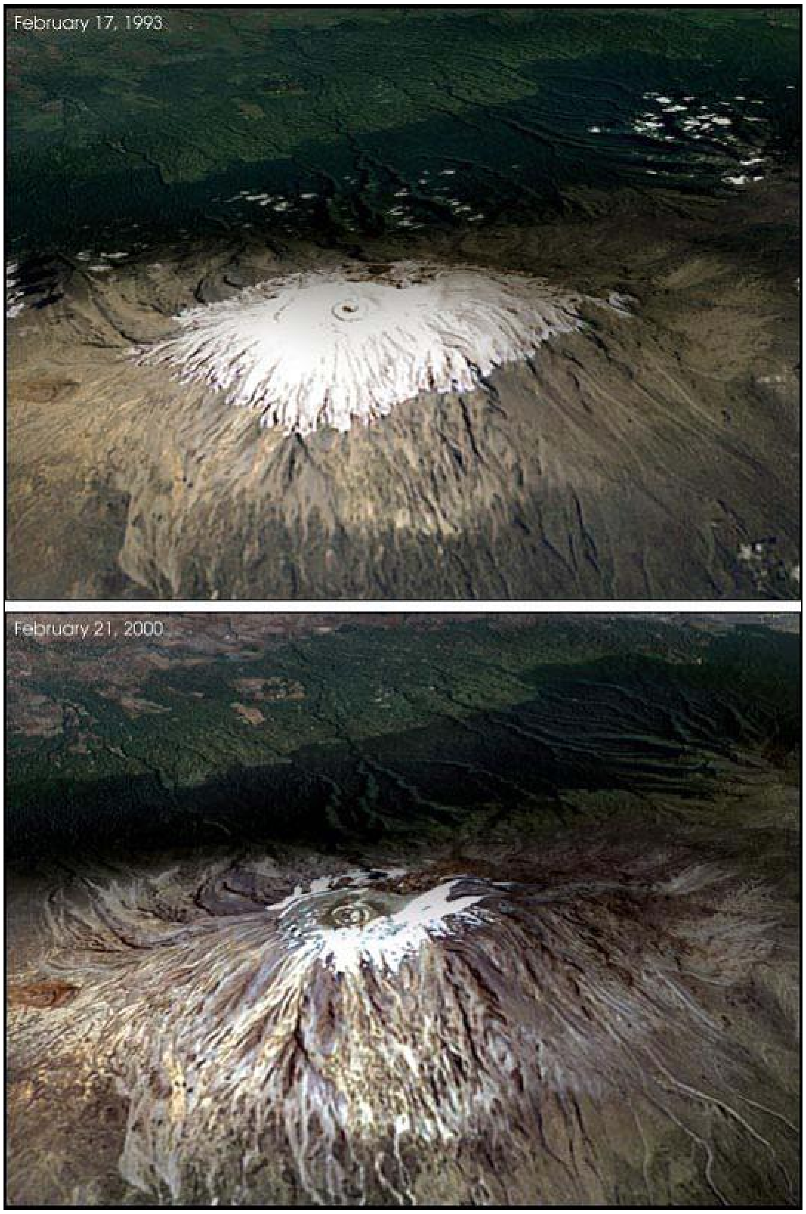
Source: Pew Center, 2011

At local regional level, a clear sign of increased temperatures in the region is the loss of glaciers on top of Mounts Kilimanjaro and Kenya. Glacial retreat in Mount Kilimanjaro is better documented and it is reported that its glacial area has decreased by 80% since the early 20^{th} century (URT, 2007). Figure 5 demonstrates the dramatic glacial retreat between 1993 and 2000. Meanwhile, studies of nearby rivers and streams that drain Mount Kilimanjaro indicate adverse impacts of climate change on water resources. A situation analysis of water and environmental issues on Pangani basin in Tanzania, lasting for almost a decade, predicts that due to climate change, the river water levels will reduce (PBWB/IUCN, 2011).

Climate change impacts also have been witnessed on Mount Kenya, which is one of the five water towers of Kenya and the source of Tana River, as well as other numerous streams that support commercial and subsistence farming around the slopes of the mountain. It is reported that in 1960s to 1990s, the increase in human settlements around the slopes of Mt. Kenya has contributed to clearing of forests thus reducing the forest cover (UNEP, 2009) and contributed to the disappearance of several glaciers which now total seven down from the eleven that covered the mountain peaks in early 1900s (UNEP, 2009). This has resulted in decrease of ice cover on Mount Kenya to one third of the initial cover (UNEP, 2009).

Increased temperatures have broad and far-reaching impacts on the region. In addition to causing water loss due to increased evaporation, high temperatures at the wrong time of the crop cycle inhibits yields of crops such as wheat, rice, maize, potatoes and soy beans, especially during the key development stages. Livestock such as rabbits, pigs and poultry also suffer from extreme heat. In addition, increased temperatures reduce milk production and cattle reproduction.

Figure 5: Glacial Retreat on Mt. Kilimanjaro, Tanzania



Source: URT, 2007

3.1.2 Shorter Rainy Seasons

The economies of Eastern Africa are dependent on rain-fed agriculture. In recent years, the rainy seasons in some of the countries have become shorter than usual impacting negatively on food production in the region. For example, in Uganda, a large proportion of the population depends on streams, which have tended to dry up fast due to the shorter rainy seasons which do not produce enough water to regenerate the streams and rivers. This appears to have caused crop failures (GoU, 2007) and serious water stress for a substantial proportion of rural communities leading to migrations into neighboring districts. In addition, reduced income levels due to a decline in harvest volumes has triggered job losses among casual farm workers and subsequent loss of income for a large number of casual farm laborers. Figure 6 shows the impact of shorter rainy seasons on a maize farm in Uganda.

Figure 6: Maize Crop Failure Due to Shorter Rainy Seasons

Source: GoU, 2007

In 2009, extreme drought hit Kenya's bread-basket, the source of most of the maize (a key staple food in the country) consumed in the country.. Crop failure led to shortages of maize in the country and contributed to a steep increase in the cost of maize and maize meal – this had devastating effects on the poor.

The eastern and horn of Africa region was, in 2011/early 2012, once again, the epicenter of drought-related food shortages which have led, in some parts of the region, to famine-type situations, with several countries and international organizations declaring emergencies. The combination of drought and insecurity has, in some parts of the horn of Africa, resulted in outright famine with a growing toll of casualties particularly among the vulnerable, children, women and the aged.

3.1.3 Drought and Famine

Scientists and researchers partly attribute the recent increased incidences and intensity of drought in the region to changes in rainfall patterns arising from climate change (Stern Review, 2007). Increased evaporation has increased the risk of droughts in areas already at risk.

Because of the continent's low adaptive capacity, drought tends to have a disproportionate negative impact on Africa. Some of the largest catchment basins of Niger, Lake Chad, and Senegal, are said to have been affected by climate change and currently, the total available water is said to have decreased by 40 to 60 percent, in part, due to climate change and partially due to high demand for agricultural water (UNEP, 2007).

In Eastern Africa, frequent and recurrent episodes of drought in the past have resulted in huge losses of life and property, migration of people, loss of crops and livestock, decline in hydroelectric power generation and displacement of wildlife (RoE, 2007; IPCC, 2007; Stern Review, 2007, RoE, 2007; RoR 2006; GoU 2007; URT 2007). For example, prolonged and severe droughts have lead to low water levels in rivers, underground aquifers and reservoirs thereby affecting the hydrology, biodiversity and water supply. The most severe impacts of drought were felt during the drought of 2004/05, which led to a reduction of water levels in Lake Victoria and Nile River, leading to serious impacts on the Ugandan economy (GoU, 2007). As mentioned earlier, the dark spectre of drought, food shortages and episodes of famine are now being experienced in the eastern and horn of Africa region again in 2011/early 2012.

Even in areas where outright drought is not on the cards, traditional methods of irrigation are proving to be inadequate to ensure food security and increased food production. Farmers using traditional furrow or bucket irrigation method face a number of challenges in their farming. During dry spells, water level in river sources reduces thus limiting drawing by farmers. This particular true in water catchment areas where furrows are widely used to irrigated land. It becomes cumbersome to draw water from very far sources to irrigate land vis-à-vis domestic needs e.g. cooking. For some areas women walk a distance of 15kms to fetch water or spent almost 8 – 10 hours a daily in search of water. This has adversely affected irrigated agriculture in these areas for food production.

The following case examples provide a brief assessment of challenges faced by communities using traditional irrigation methods or depend on rain-fed agriculture – highlighting the need for more energy efficient options for water pumping.

3.1.4 The Traditional Irrigation System of the Chagga of Kilimanjaro - Tanzania

The traditional irrigation system of the Chagga of Kilimanjaro in Tanzania has been there since time immemorial. Early Europeans who visited the community area were vastly impressed by the complicated network of irrigation furrows which collect water from the mountain's streams and irrigated the fields below.

Unfortunately, as with so many tribal societies today, the traditional Chagga way of life – and with it, the survival of their irrigation system – is threatened by what appears to be the adverse impacts of climate change. Trees required for preserving the catchment area have been cut down and, as a result, some feeder springs have dried up and rivers have ceased to flow.

The Chagga with their irrigation system are highly dependent on a steady river discharge.

Changes to the water balance present a serious threat to their existence. During the dry seasons water shortages especially on the lower foothills become increasingly common. Women and children have to spend a big part of the day fetching water. Yet, the water demand grows rapidly.

That trend will undoubtedly get worse unless action is taken soon. If it is not, there will be less water available for the furrows and their maintenance will quickly become uneconomic. When that happens, the Chagga's highly efficient irrigation system will sadly, but inevitably, fall into disuse.

Source: Agrawala et al, 2003; Goldsmith and Hildyard, 1984

Increased incidents of drought (which are thought to be climate related) have had negative impacts on the region's power sector. Drought severely affects the power sector leading to massive load shedding programmes and massive losses on the region's economies (see appendix for more details).

The semi-arid and arid areas of Kenya and Tanzania are more susceptible to impacts of climate change due to high precipitation that exacerbates water scarcity. This has led to loss of livestock among pastoralist communities as well as poor agricultural yields by traditional farming communities. It has forced some communities to invest in boreholes to supply water. The few who pump water are using engines that rely on high cost fossil fuel to pump and experience a wide range of challenges as explained in the following case studies.

3.1.5 Makanya Catchment in Tanzania (Steve comment – to section 3)

The Makanya catchment is located in the South Pare Mountains, Same District, Kilimanjaro region, Tanzania. The catchment is similar to other rural areas in semiarid East Africa in that it has experienced a series of dramatic changes over the past decades.

The catchment covers 320 km^2 and hosts some 15 rural villages. The climate is semiarid to dry subhumid, and the rainfall pattern bimodal. Annual average precipitation ranges from 500 mm in the lowlands to about 1,000 mm in the highlands, but the rainfall is highly variable both between and within years and the variability has increased over the past decades.

Small-scale farming, that is non-mechanized and involves few external inputs, is the principal food and income source. Farmers grow maize for subsistence, with harvests averaging just above 1 ton/ha and vegetables as cash crops. Downstream in the catchment, rainfall is too low for crop production and farming is supported by a local spate-irrigation (flood irrigation) system. Livestock keeping constitutes an important additional livelihood source here. Farmers in all parts of the catchment perceive lack of water as a major constraint to crop production due to reliance on the inefficient spate-iirrigation system..

Source: Adapted from Enfors et al, 2008

Table 6 shows the years of droughts/significant rain shortages in agriculturally productive areas in the region and demonstrates the growing frequency of drought/rain shortages in the region.

Table 7: Incidence of Drought/Rain Shortages in Selected Eastern African Countries

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Eritrea	√		√	√	√	√	√	√	√	√	√	√	√	√
Ethiopia	√		√	√	√	√	√	√	√	√	√	√	√	√
Kenya	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Tanzania	√	√	√	√		√	√	√	√	√			√	
Uganda	√		√	√	√	√	√		√		√	√	√	

√=Significant shortage of rain/Drought

Source: CRED, 2011: Practical Action Consulting, 2011; Water Rhapsody, 2011; Guardian, 2009; WFP, 2009: WFP, 2008; World Bank, 2004; Qureshi and Smakhtin, undated; REMA, 2009; Dixit, undated; IFAD, undated

3.1.6 Floods

An increase in flooding incidences as a result of sporadic and excess rainfall have been reported in recent times in Eastern Africa (GoU, 2007) and linked, by some analysts, to climate change. In addition to displacing people, floods also lead to waterlogged fields and washing away of crops causing a shortfall in food production. Heavy and unpredicted rainfall in the region has led to increased incidences of flash floods that have resulted in outbreaks of waterborne diseases such as diarrhea and cholera. Flooding has also damaged critical infrastructure such roads, bridges and communication.

Figure 7: Flooding in a Remote Village in Uganda

Source: GoU, 2007

Most countries in Eastern Africa are dependent on hydropower generation. Floods have a negative impact on hydropower generation due to the rapid buildup of siltation in hydropower dams (Karekezi and Kithyoma, 2005).

In Kenya, in early 2010, floods led to the loss of 94 lives as well as destruction of about 40 bridges and 11 schools. In addition, over 141,000 people were affected by the floods. Also affected were farm lands and livestock thereby posing a threat to food security among the affected populations (IFRC, 2010). Similarly, floods in Tanzania left 94 people dead and about 50,000 homeless (SOS Children's Village, 2010).

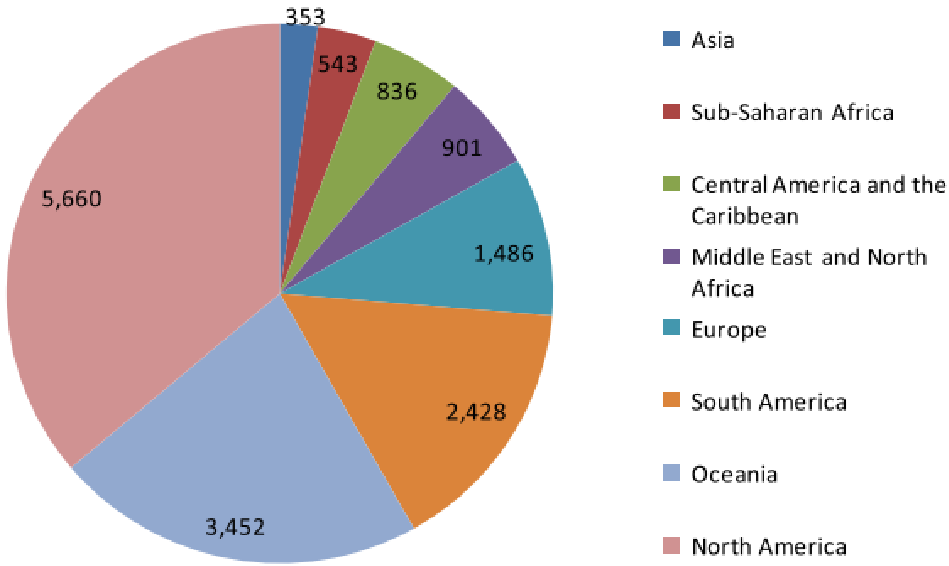
Review of Key Water-Related Climate Change Challenges facing the Rural Poor in Eastern Africa

The adverse portrait of the impacts of climate change in East Africa, as discussed in the earlier sections of the report, underscores the need for the continent to be well prepared to deal with the negative results of water-related climate change in the region. Eastern Africa is vulnerable to climate change due to its already fragile environment, an economic structure that is dependent on rain-fed agro-based economic activites that are highly sensitive to an adverse and changing climate compounded by low incomes that constrain the region's ability to adapt.

Food security: All countries in the region are dependent on rain-fed agriculture which contributes substantially to the GDP of the individual countries. For example, for a very long time, Kenya's number one foreign exchange earner was the agricultural sector which accounted for about 23% of total GDP in 2010 (GoK, 2008). The main limitation in the agricultural sector is the dependence on rain-fed agriculture. The absence of advanced farming practices such as irrigation (which, in turns, requires access to modern energy services), exposes the rural poor to massive crop failure and poor harvests due to growing episodes of drought and shorter rainy seasons. This can have a catastrophic impact on the region's economy as agriculture and agro-industries provide employment for up to 80% of the population.

Adequate potable water supply: With the rapid population growth in East Africa, there is increasing pressure on the available surface and ground water sources. East Africa has made very limited investment in artificial water storage (including irrigation systems, dams, and ground water). For example, Ethiopia has less than 1% of the artificial water storage capacity per capita of North America. Available data suggests that most East African countries do not have enough water storage to manage annual water demand based on the current average seasonal rainfall cycle nor is the level of investment adequate, as illustrated in Figure 8. Adequate water storage is expected to be critical to the survival of the region's population should the adverse climate change predictions occur.

Figure 8: Water Storage Investment (USDUS$ Billion) (Steve comment – need comparative figures from other regions plus generate per capita data as high numbers for Nigeria may be misleading – see table 7)



Source: McCartney and Smakhtin,2010

Renewable Energy Technologies (RETs) and Water Services in Eastern Africa

A large proportion of the poor in rural and peri-urban areas of eastern African countries rely on rain-fed subsistence farming for their food supply. Consequently, drought can directly threaten the food security of the poor. As mentioned earlier, the incidence of drought in the Eastern African region appears to be increasing (which is said to be, in part, due to climate change), with some countries experiencing drought almost every year. The impact of repeated drought is bound to be very severe, and is likely to lead to serious shortages in food production.

Renewable energy can power irrigation equipment and assist in ensuring food security during drought periods especially among the poor. While irrigation is still an embryonic practice in most of Sub-Saharan Africa (including Eastern Africa), it is widely practiced in Asia (see following table).

Table 8: Proportion of Food Produced in Irrigated Land

Region	Food produced from irrigated land (%)
Asia	60
Middle east and north Africa	33
Latin America	10
Sub-Saharan Africa	9

Source: Lipton e*t al*, 2003, FAO, 2001

Renewable energy can play an important role in enhancing food security among the poor through technologies that can be used for irrigation and water pumping. Water lifting devices can be driven by renewable energy technologies such as wind pumps, solar PV pumps, treadle pumps and ram pumps. Renewable energy-based pumping technologies can ensure food supply throughout the year but also generate additional income for households.

Renewable energy-based water services can contribute to meeting potable water supply and irrigation constraints facing East Africa, especially in rural areas. In addition, as shown in the following table, renewable energy-based water services can assist in meeting several of the Millennium Development Goals.

Table 9: Matrix of Renewable Energy-based Water Services and the Millennium Development Goals

RELEVANT MILLENNIUM DEVELOPMENT GOALS	POTENTIAL ROLE OF RENEWABLE ENERGY-BASED WATER SERVICES Some Direct and Indirect Contributions	ADAPTATION ISSUES
1. Extreme poverty and hunger • To halve, between 1990 and 2015, the proportion of people who	• The bulk of (95 percent) staple foods need cooking before they can be eaten and need water for cooking. Provision of clean water for cooking	• Communities living in drought-prone areas can use wind or solar PV for

RELEVANT MILLENNIUM DEVELOPMENT GOALS	POTENTIAL ROLE OF RENEWABLE ENERGY-BASED WATER SERVICES Some Direct and Indirect Contributions	ADAPTATION ISSUES
suffer from hunger.	often requires energy. • Renewable energy technologies such as wind pumps and treadle pumps can be used for irrigation in order to increase food production and improves nutrition.	pumping water for domestic, irrigation and livestock uses thus improving agricultural productivity thus enhancing food security. In addition surplus agricultural produce can be sold to areas with food shortage generating additional income which can be used to invest in options that enhances resiliences to future drought periods such as small scale dams.
2. Universal primary education • To ensure that, by 2015, children everywhere will be able to complete a full course of primary schooling.	• Renewable energy can help create more child friendly environment. For example, access to clean water improves sanitation in schools thereby enhancing the health of children, thus improving attendance at school and reducing drop out rates.	• By contributing to better educational services, renewable energy-based water services can indirectly enhance local communities resilience to adverse climate change impacts. Better educated people can develop and deploy low-cost options for addressing the adverse impacts of climate change.

RELEVANT MILLENNIUM DEVELOPMENT GOALS	POTENTIAL ROLE OF RENEWABLE ENERGY-BASED WATER SERVICES Some Direct and Indirect Contributions	ADAPTATION ISSUES
3. Gender equality and women's empowerment • Ensuring that girls and boys have equal access to primary and secondary education, preferably by 2005, and to all levels of education no later than 2015.	• Availability of renewable energy options can free girls' and young women's time from survival activities such as walking long distances to fetch water. The freed time can be productively used to generate more income or acquire education	• Increased incomes arising from renewable energy-based water services, can be invested in alternative income generating activities that employ women and protect their incomes. Increased education for girls arising from renewable energy based water services, would strengthen the intellectual capacity of local communities and enhance their ability to adopt and deploy innovative climate adaptation measures.
7) Environmental sustainability • To stop the unsustainable exploitation of natural resources; and • To halve, between 1990 and 2015, the proportion of people who are unable to	• Increased agricultural productivity can be facilitated by the greater use of renewable energy-based irrigation, which in turn reduces the need to expand quantity of land under cultivation thus reducing pressure on ecosystem conversion. • Renewable energy can be used to purify water or pump clean ground water locally; reducing time spent	• Renewable-based irrigation systems can facilitate the establishement of tree belts that creates beneficial local micro-climates and enhances local communities resilience to climate-change related incidences of drought • Renewable-based water services would increase

RELEVANT MILLENNIUM DEVELOPMENT GOALS	POTENTIAL ROLE OF RENEWABLE ENERGY-BASED WATER SERVICES Some Direct and Indirect Contributions	ADAPTATION ISSUES
reach or to afford safe drinking water and sanitation.	collecting it and reducing drudgery.	the availability of potable water, reduce disease burdens and ensure the availability of able bodied men and women who are able to invest labor in constructing water dams which constitute an important adaptation response measure.

Source: Adapted from DFID, 2002; Modi et al, 2005

This section has discussed how renewables can be an important option for enhancing the resilience of the water sector in Eastern African to the adverse impacts of climate change with a special emphasis on drought. The next section will now examine in greater depth some of the more promising renewables that could be important climate adaptation measures for the rural poor of East Africa.

- **4. SECTION II – REVIEW OF RELEVANT RENEWABLE ENERGY TECHNOLOGIES FOR WATER SERVICES DELIVERY (Steve comment – need preceding paragraph providing link and avoiding abrupt change)**

Renewable Energy Technologies

The dissemination of renewable energy technologies in rural areas continue to be confined to small-scale projects with the only notable dissemination of renewables recorded in improved biomass cookstoves and use of PVs for lighting. Both of these options are unlikely to have a significant impact on enhancing resilience to the adverse impacts of climate change on water services.

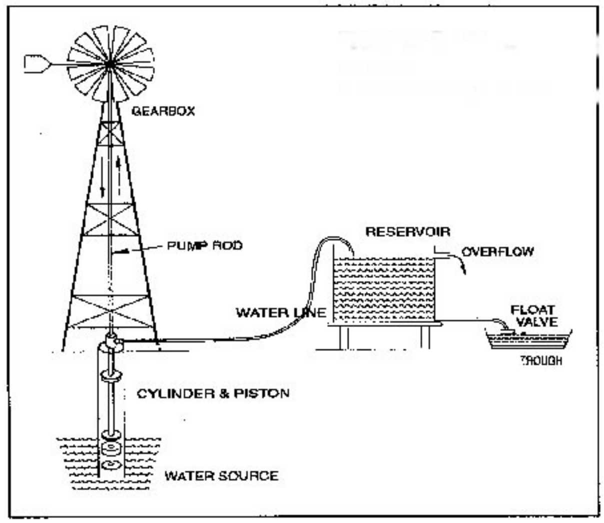
There are, however, a number of renewable energy options that are showing some embryonic signs of success and that could potentially enhance the resilience of the water sector and poor rural communities to adverse impacts of climate change. Examples include windpumps, treadle pumps, ram pumps and solar PV-powered pumps that are discussed in greater detail in the next sections.

4.1.1 Wind Pumps (Steve comment – useful to mention the high numbers of windpumps in South Africa and Namibia to demonstrate potential0

Wind pumping technologies (see following illustration) can supply water for irrigation as well as for household use and livestock (Harries, 2002).

The following diagram below shows a photo and a technical illustration of the technology.

Photo of Technology	Technical Illustration(s)

Photo of Technology	Technical Illustration(s)
	

Source: Government of New Brunswick, undated; Karekezi et al, 2010; Karekezi et al, 2005

Wind pumps have a number of uses, some of them include:

- Pumping water for livestock,
- Irrigation
- Supply of potable water for domestic purposes.
- Industrial water supply

Usage of wind pumps have a number of benefits including the following:

- The technology required for wind power for water pumping is simpler and thus more accessible than that for electricity generation
- In remote areas where diesel fuel costs are high, wind pumps can be economically viable at even lower speeds, so long as the water level is high.
- Wind pumps are, often, economical viable for remote cattle ranches where small dispersed water supplies are needed for livestock.
-

Often though some problems are encountered such as:

1. Wind pumps can be unreliable due prevailing wind-regimes not being well assessed. Since wind pumps only work when the wind is blowing at sufficient wind speeds (usually

3 m/s and above), it is necessary to have adequate water reservoirs to provide water during periods of no or low windspeeds.

2. If wind patterns change as a result of climate change, well-designed wind pumps can adapt to changing wind directions as the tower can rotate for the blades to face the direction from which the wind is coming from. Water storage capacity can greatly enhance wind pumps ability to adapt to changing wind regimes and enhance the resilience of the water sector.
3. Boreholes can sometimes be too deep for wind pumps to perform optimally which underlines the need for appropriately sizing at the project design stage.
4. Preventive maintenance-related breakdowns can occur if proper care of wind pumps is not taken. However, this can be easily solved by having a local technician trained – the technician need not be specialized in wind pumps i.e. a motor vehicle mechanic or a bicycle repairman can be easily trained to maintain wind pumps.

Wind driven mechanical power for water pumping, both irrigation and drinking water, are gaining widespread acceptance, and many more projects and investments are occurring. In the order of one million mechanical wind pumps are in use for water pumping, primarily in Argentina, following decades of development. Large numbers of wind pumps are also used in Africa as shown in table 9 below.

Table 10: Number of wind pumps in use in the Southern Africa countries

Table 9:

Country	Number of wind pumps
South Africa	400,000
Namibia	30,000
Zimbabwe	650
Cape Verde	800

Source: (Karekezi and Ranja, 1997; Karekezi and Kithyoma, 2005)

East African countries can learn from South Africa and Namibia which possess large numbers of wind pumps in sub-Saharan Africa (Karekezi and Kithyoma, 2005). The estimated 400,000 wind pumps that are in operation in South Africa, are believed to have, in the past, played a major role in supporting irrigated agriculture in the country and transforming South Africa from a drought-prone country with chronic food shortages country into a food surplus country that exports food to countries in the region with better rain regimes. In this respect, windpumps proved to be a viable climate adaptation measure for South Africa and could potential play a similar role for the rest of sub-Saharan Africa.

Wind pumps are in use in the Eastern African region. The potential for wider use of wind pumping is significant as the average wind speeds of about 3 m/s in Kenya and Tanzania are sufficient for water pumping (Karekezi et al, 2005).

Although the number of windpumps in the region are low (see following table), there is now a small but viable windpump industry that could provide the basis for accelerating the dissemination of windpumps to the 50,000+ levels that are seen in South African and Namibia.

Table 11: Wind Pump Installations in Eastern Africa

Region	Number of Wind Pumps Installed
Kenya	300-350
Tanzania	106
Eritrea	<10
Uganda	18*

* Bob Harries installation
Source: BHEL, 2008; Karekezi et al, 2009; Nzali and Mushi, 2006

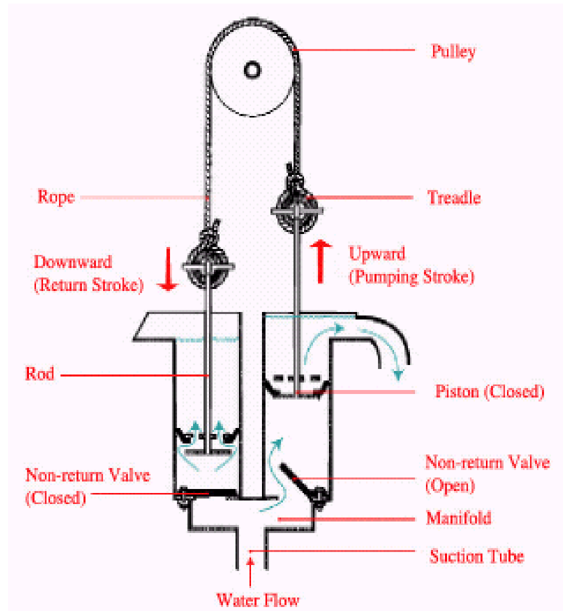
4.1.2 Treadle Pumps

Treadle pumps (see following illustration) have primarily been developed for pumping water for irrigation. However, other uses include pumping potable water for domestic and livestock consumption.

Treadle pumps can improve the resilience of water sector to climate change. For example, they help farmers to minimize dependence on erratic rainfall by giving them the capacity to grow crops all round the year. In addition, treadle pumps are low-cost and help farmers maximize return on their small plots of land. Treadle pumps cost under US$ 200 depending on the different costs of labour and materials in each country.

The following diagram shows a picture of a treadle pump as well as its technical illustration:

Photo of Technology	Technical Illustration(s)



Source: FAO/IPRTID, 2000; Karekezi et al, 2005

<u>Common Problems and Response Options</u>

- The cost of treadle pumps is still beyond the reach of very low-income communal farmers who may require some form of credit scheme to overcome the high-up-front cost.
- Pumps are mostly managed by women. However, operating a treadle pump requires elevation of operator above the ground. In certain parts of the developing world, women do not feel comfortable standing on the pumps for long periods. They feel exposed and consider it indignified. However, with additional income from increased productivity, women can employ young men to carryout pumping. Treadle pumps can also be re-designed to reduce the required elevation.
- Unlike other pumps (e.g. wind pumps), treadle pumps appear to have a limited suction head of up to 7 meters and are best used in places with high underground water tables.

Some 186,804[2] treadle pumps are reported to have been sold in the region since 1991 (including exports to West and southern Africa (Kickstart, 2011). The provision of these pumps has enabled many families to be lifted out of poverty. More households in the region have continued to embrace the technology and more pumps are expected to be in use. The following table provides a breakdown of treadle pumps (includes hip pumps) sold in some of East Africa countries since 1991:

[2] This number includes new type of pump – the hip pump, a different technology from treadle pump sold by Kickstart International and not accounted for separately.

Table 12: Treadle Pumps Sold in East African Countries

Country	Number of Treadle Pumps**
Kenya	77,469
Tanzania	46,769
Uganda	3,733*
Ethiopia	n.a
Eritrea	n.a

* Number of treadle pumps sold up to November 2009

** These are treadle pumps sold by Kickstart International

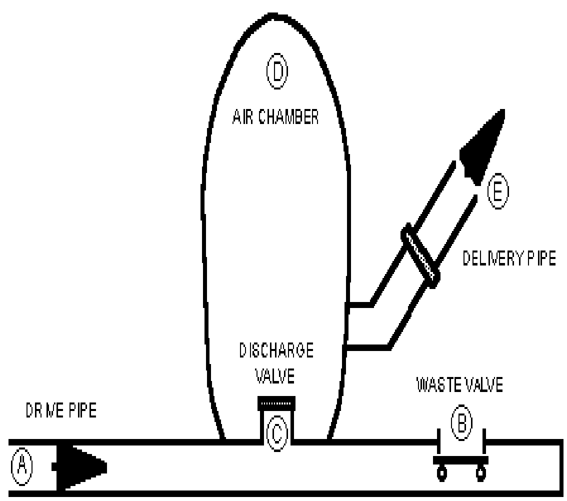
n.a – data not available

Source: Kickstart, 2011; World Bank 2011b

4.1.3 Ram Pumps

There is a limited use of ram pumps in the East Africa (see following illustration of ram pump and appendix for more technical details) but experience from Tanzania indicates that hydraulic rams pumps are durable and reliable for domestic water application and even for irrigation, if installed and operated in an optimal fashion.

Provided below is a picture showing a ram pump and the technical illustration:

Photo of Technology	Technical Illustration(s)
	

Source: GlobalSpec, 2011; Karekezi et al, 2005

Ram pumps can only be used in situations where falling water is available. These devices are mostly intended for domestic and livestock supplies in hilly and mountainous areas requiring small flow rates delivered to high heads. Ram pumps are rarely used for overhead irrigation purposes since they require high flow rates that will entail the use of larger sizes of ram pumps with 4 to 6 inch drive pipes, which would dramatically increase costs. However, ram pumps are suitable for drip irrigation which is characterized by low water flow rates.

Ram pumps can improve resilience of the water sector to climate change as water can be pumped when the river flow is high for storage for use during times when river flow rates are low e.g. during dry spells. In addition, ram pumps can be adjusted to cope with varying river flow rates, for instance, allowing more rapid pumping cycles when water availability is high and vice versa.

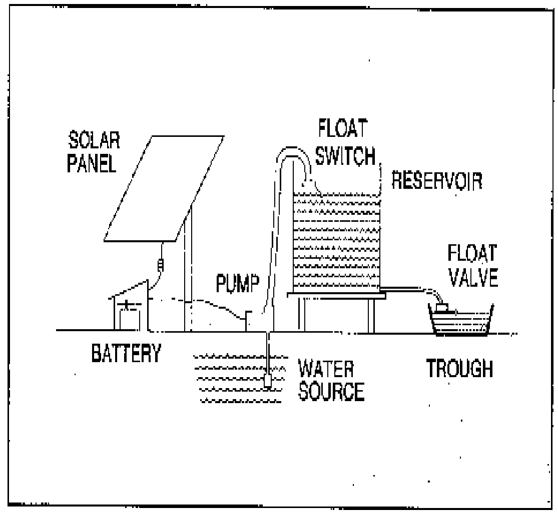
Ram pumps can be locally manufactured as demonstrated by Jandu Plumbers of Arusha in Tanzania who manufacture ram pumps for distribution in the north-Eastern region of Tanzania. There is only anecdote evidence on installed number of ram pumps in the region. A research project on hydraulic ram pump, estimates that by 1990, there were only five (5) pumps in Uganda (IDRC, 1992). For Kenya, by 2010, there were more than 60 working ram pumps within Githunguri area which is about 20km from Nairobi (ICAT, 2010). In Tanzania one of the ram pumps fabricators is Jandu Plumbers. In Kenya, Clean Air Energy Solutions Kenya is another manufacture of ram pumps. It has been in operation since 1999 and has installed a total 32 ram pumps (ICAT, 2010).

4.1.4 Solar PV Pumps

Solar PV pumps (see following illustration and appendices for additional technical details) have been in use all over the world since the late 1970s.

The following diagram shows a photo of a solar pump and a technical illustration of the pump:

Photo of Technology	Technical Illustration(s)



Source: Government of New Brunswick, undated

Common uses of solar PV pumps is in potable water supply and livestock watering particularly in arid and semi-arid areas which often have very high levels of insolation year round. With much of the region in and around the solar rich zone of the Equator, this is, also, true of most of the East Africa region which in general experience few fully cloudy days. The ability of solar PV pumps to work throughout the year can improve the resilience of the water sector to climate change.

The following table presents estimated solar insolation intensities for the Eastern Africa countries:

Table 13: Solar Insolation in Eastern African Countries

Country	**(kWh/m^2)**
Eritrea	4.0-7.0
Ethiopia	5.0-6.0
Kenya	4.0-6.0
Tanzania	4.5-6.5
Uganda	4.0-6.0

Source: Karekezi *et al*, 2009; MEMD, 2007

There is limited information on dissemination of solar PV pumps in Eastern African countries. However, based on total number of systems installed, the authors estimated that solar PV pump systems would account for a very small proportion of the total PV installations, as shown in table 11.

Table 14: Dissemination of Solar PV pumps in Eastern African Countries

Country	Estimated number of systems	Estimated capacity (kWp)*
Eritrea	2,000	36
Ethiopia	5,000	90
Tanzania	>10,000	>180
Uganda	5,000**	90
Kenya	>500,000	>9,000

* Installed capacity based on an average module size of 18 Wp
** Estimated number of systems installed from 2002
Source: GTZ, 2009; Karekezi et al, 2009

Key Selected Renewable Energy Technologies for Enhancing Resilience of Water Services to Climate Change

Based on the level of dissemination of different renewable energy technologies as well as availability of case studies, the following table presents two key selected renewable energy technologies – treadle pumps and windpumps - that will be examined in greater depth in the next chapter (as well as in next phase of this study where more detailed field work is expected to be undertaken) to provide a comprehensive assessment of the role/potential of selected renewable energy technologies in enhancing resilience of water services to climate change.

Table 15: RETs Matrix

Category	Requirement	Energy req.	Technology	Target group	Case study context

Category	Requirement	Energy req.	Technology	Target group	Case study context
Residential/Social/Community Services	Portable water	- Wind energy (3 m/s)	Wind pump	Communities/Rural households	Kenya - Gatongora Development Group - Mwiyoyo Community Water Project - Maji Moto Community Water Project - Nearby communities to the above projects without wind pumps - Additional case studies from the former North Eastern and Eastern provinces to be identified Tanzania - Kisigisa Village Community Water Project - Nearby communities to the above project without wind pumps
Productive (Agriculture)	Crop irrigation	- Animate power	Treadle pump	Rural peasant farmers	Kenya and Tanzania - Obtain from KickStart areas of high concentration of treadle pumps use and nearby farming communities without treadle pumps

5. SECTION III – ROLE OF DECENTRALIZED RENEWABLE ENERGY TECHNOLOGIES IN CLIMATE CHANGE ADAPTATION

Treadle Pump Case Studies - Role of Decentralized RETs in Climate Change Adaptation to Enhance Food Security

Many sub-Saharan African farmers are still irrigating very small plots of land using bucket-lifting technologies, which are slow, cumbersome and labor intensive, for women in particular. As a more efficient alternative, treadle pump-based small-scale irrigation has registered encouraging results in many parts of the world including East Africa, at a time when large-scale irrigation schemes have largely failed.

Case studies from East Africa (Kenya and Tanzania) and other parts of Sub-Saharan Africa (Niger, Zambia and Zimbabwe) show that, by using animate energy-driven treadle pumps instead of bucket irrigation, farmers can increase irrigated land, reduce work time, improve crop quality, grow new crops and increase the number of cropping cycles. Treadle pump technology has enabled poor rural farmers, especially women, to increase their incomes by selling surplus produce in the local market. Treadle pumps make it easier for farmers, especially women, to irrigate their fields or vegetable gardens.

The increased incomes associated with treadle pumps is critical to adaptation to climate change as it provides poor household with cash that broadens the range of adaptation measures that they can afford to take on board.

Treadle pumps are affordable and easy to handle. If pumps are produced locally, they can also create jobs and income – the pumps cost under US$ 200 and can be built with ordinary workshop equipment. . Most low income owners of the treadle pumps in Kenya purchased them mainly through savings made by users as well as from the sale of crops and livestock and use of retirement benefits. Currently, there is growing reliance on local banks and micro-finance institutions to provide financing to small-scale farmers to procure treadle pumps.

As treadle pumps usually reach water only within seven meters, they do not, in most cases, deplete valuable groundwater resources. The local water table would drop only if a large number of farmers were operating in the same area. However, the treadles are best used in areas with high groundwater levels due to limited suction head. This implies the technology is vulnerable to climate change especially impacts of prolonged droughts where groundwater tables level drop beyond 7 meters above the ground.

However, even in the event of dropping water tables, the increased past incomes that treadle pumps generate when they were in use would provide the poor with the flexibility and ability to pursue other adaptation measures which may include testing and switching to alternative renewable energy water pumping technologies and investing in water conservation measures such as small scale dams.

Some 186,804 treadle pumps (including exports to West and southern Africa) are reported to have been sold in the region since 1991 (Kickstart, 2011). Of which a total of 127,971 pumps are estimated to have been sold in Kenya, Uganda and Tanzania since 1991.

The higher numbers recorded in the region is attributed to the efforts of Kickstart International, a private social-enterprise that has been involved in promotion of treadle pump technology that creates employment and is profitable to small-scale enterprises. Kickstart has adopted a business approach that is focused on research, development and marketing treadle pumps. It identifies local large-scale manufacturer of pumps and uses existing market chains to reach remote rural farmers. It uses a few giveaways (free treadle pumps) to created awareness of the benefits of using treadle pumps.

The early adopters of the treadle pump have recorded impressive benefits such as doubling of agricultural yields (KickStart, 2011). The impressive benefits encourages other farmers to buy treadle pumps.

The following case studies on treadle pumps provide useful insights on the positive benefits of treadle pumps.

5.1.1 Case Study of ApproTEC Treadle Pumps, Kenya

Treadle pumps have been in use in Kenya since 1991 when the first version was introduced in both rural and urban areas and generated a wide range of benefits to users, manufacturers, promoters and retailers. The experience in Kenya shows that treadle pumps are purchased mainly through savings made by users. Other important sources of capital include selling of crops, livestock and retirement benefits. The majority of the treadle pump owners came to learn of these pumps by word of mouth and through live demonstrations of the technology and this attracted most of the people to purchase pumps. While males own 84% of the treadle pumps, women manage nearly three quarters of these pumps, which are mainly used for irrigating crops and to some extent in supplying water for household use and animals.

A reliable source of water to run the pump is a pre-requisite for a successful use of the pumps. During the 1999 survey by the monitoring department of ApproTEC, most of the pumps had been in use for over 8 months drawing water mainly from streams and wells of average depth of 14 feet. In rural areas, digging a well cost Kshs 130 per feet and thus some farmers spent more on irrigation despite having purchased water pumps. There are those farmers who use water dams and swamps for irrigation. At the time of survey, 91% of the pumps had been active and had been used at least once. The reason for inactive pumps was attributed to increased depth of the water level in the well making the use of pumps impossible.

Most of the pumps are used on an average of approximately 3 hours per day with more time (4hrs) being spent to irrigate farms in Western Kenya than Central province. Areas under irrigation increased amongst users by 700% from an average of 0.03ha to 0.24ha in 1999 to 0.59 ha in 2004. Each pump sold is used by approximately 2 households as a third of the pumps are lent out to neighbours for use at no cost.

Farmers are engaged in producing high value crops such as tomatoes, kales and cabbages. There are those who plant french beans, cut flowers, passion fruits, green maize and onions. Potatoes, cowpeas, carrots, tea nursery, coffee, coriander, watermelon, spinach, sugar snaps and okra are also irrigated by a number of farmers. The increased crop intensity means that pump users are moving away from traditional crops that were mainly for subsistence and increasing the volume of cash crops. The number of crop cycles has also increased as a result of irrigation from 1.2-crop cycle before irrigation to an average of 2.3 crop cycles. One advantage associated with increased number of crop cycles was timing of cropping so as to have the crops when they fetch higher prices from the market.

Each pump sold allows for crop cycle sales income of Kshs 46,031 (US$ 590). Out of this, Kshs 5,943 (US$76) is spent on production costs leading to profits per crop cycle of Kshs 40,088 (US$ 514). Thus, treadle pumps have increased incomes for poor families, created employment for operators and owners, made irrigation easy, provided food for poor families and created opportunities to invest in other income generating activities.

However, poor farmers face several challenges in the day-to-day operation with the pumps. These include mechanical problems, seasonal water sources for those using dams and wells, limited suction head of many wells whose depth is beyond reach of many pumps, pests and diseases and market glut for crops. In some areas, especially Machakos, Makueni and Kitui, there is a major problem of salty water that corrodes pumps. Sloppy lands in Central part of Kenya inhibit use of pumps. Farmers also complained of lack of knowledge of appropriate irrigation methods and were concerned that the tread pumps irrigate limited areas compared to the motorized ones.

Source: www.kickstart.org; ApproTEC, 1999

5.1.2 Case Example of the Impact of Treadle Pumps in Transforming the Rural Poor

Not long ago Mr Moses Chumo and his family were living on his father-in law's farm trying to grow maize and using a bucket to irrigate less than $1/8^{th}$ of an acre of kales from a local stream. Mr Chumo and his wife could not afford to keep their children in school and the family was barely getting by. Then he saw a treadle pump being demonstrated at a local store. He liked what he saw and saved US$ 75 to buy a pump. The new pump allowed him to grow almost 1 acre of kales and enough good quality napier grass to feed his cows. This led to increased milk production and a greatly increased income allowing him to buy more and better cows, a chaff cutter to better feed them and eventually his new 7 acres piece of land. Mr. Chumo now plants tomatoes, french beans, kales & fruits and will have plenty of space left to grow Napier grass for his 5 cows. Already he and his wife are saving to send the first of their 5 children to a good secondary school.

Mrs. Janet Ondiek, a small-scale farmer in Kajulu, Kisumu, is a widow who manages her farm following the death of her husband in 1997. Janet's farm is next to a perennial stream. Using bucket irrigation she used to make a profit of just Kshs 7,000 (US$ 93) per season. In early 1999 Janet saw the treadle pump being demonstrated at Gita, a local market and liked it so much that she bought one on the spot. She has used it to transform her horticultural business. She now irrigates 2.5 acres, growing high value crops like bulb onions, tomatoes, and sweet peppers as well as kale and spinach, which she sells in Kisumu. In 1999, her profits topped Kshs 240,000 (US$ 3,200), and she now employs 5 workers. After the death of her husband, Janet's 6 children almost dropped out of school due to lack of school fees, but now with irrigation she makes enough money to send them to college.

Source: www.kickstart.org

5.1.3 Case Study of ApproTEC Treadle Pumps, Tanzania

Catherine Gwambie and her husband, Hawzi Mwami, are an entrepreneurial couple from Tanzania. They had dreams of being successful shop owners in Dar es Salaam. They farmed in their native Kigoma, growing and selling maize and beans to save enough to open a shop selling household supplies.

The shop was reasonably successful, but it did not generate as much income as they needed to support their family. Mr. Mwami decided to buy land to raise chickens and for Mrs. Mwami to start growing and selling vegetables. It was a good business but difficult because irrigation with a bucket took a lot of effort and time than using renewables for irrigation.

Early 2007 Mrs. Mwami heard an advertisement for the Super MoneyMaker on the radio. She excitedly told her husband about this new pump that was affordable and made irrigation easier and quicker. Mr. Mwami was not convinced. Mrs. Mwami insisted and since she was using her own money she would make the decision. Together they went to the Kariakoo market in Dar es Salaam to buy a Super MoneyMaker at the shop owned by Mama Songa (another KickStart Success Story).

The pump worked so well and has increased Mrs. Mwami's productivity. She has expanded with another plot to increase her business. She currently employs her daughter and young sister. They have three young children and they plan to send them to good secondary schools now that they have money. The Mwamis have plans to build a nicer house for their family. Mr. Mwami freely admits that his wife was right about the pump, and between their two businesses, they see a bright future for their family.

Source: www.kickstart.org

Wind Pump Case Studies - Role of Decentralized RETs in Climate Change Adaptation to Enhance Potable Water Supply

In the region, the level of dissemination of wind pumps is low, however, due to limited information available there could be unaccounted for wind pumps. On the other hand, low levels of dissemination of wind pumps could be attributed by high upfront cost, lack of awareness on locally manufactured wind pumps, inadequate support from policy makers and lack of financing to support development of local manufacturers. Cost of wind pumps is a factor not to be ignored, as compared to costs of treadle and ram pumps, at less than US$200 and US$ 300 respectively. The high cost of wind pumps of about US$ 3,000, is beyond the reach of many individuals unless community members opt to raise funds a scenario witnessed to be a more practical approach to share high-upfront costs.

Another factor is on the approach used to disseminate wind pumps. Unlike treadle pumps, there is no local-based organization known to be involved in the marketing of wind pumps. For treadle pump, Kickstart International, as a private social-enterprise uses two model approaches to disseminate the pump. The giveaway and selling models, through these approaches it has been able reach a wider market segment. Giveaway pumps are financed by donor funds while the ones sold are used as source of revenue for the organization. This dissemination approach creates awareness on the benefits of using treadle pump in farming while selling approach by Kickstart International, ensures its profitability and sustainability. It also enables the organization support its activities on research and development of the treadle pump technology thus meeting users' demands.

The small numbers of wind pumps that have been installed to date are by private businesses/farms/ranches or missionary-faith based institutions. Some of the installations of wind pumps have been through financing by donors and private developers and has resulted in several benefits to households within the locality of the pumps.

The following case studies provide useful assessment wind pumps initiatives in Kenya and Tanzania.

5.1.4 Case Studies on Use of Wind Pumps in Kenya

Gatongora Development Group, Ruiru

One of the most successful self-help groups in the utilization of wind pumps has been Gatongora Development Group (GDG) located in Ruiru, Kenya, with a total of 40 members. The group recognized the high cost of electricity driven water pumps and opted for wind pump that was installed by BHEL in 1999. The group members solicited for funds through a loan from a micro- financing institution. Once the project was completed, a committee was appointed by members of the community to oversee the project. Water is sold to the community with proceeds being used to repay the loan.

Currently, community members have to come to the water pump to collect their water. However, it is envisaged that in the future, when more funds become available, water will be connected to each household. In the past, funds collected for repairs and loan repayments from community projects were mismanaged. However, in this case, with the community directly benefiting from the project, funds are well managed, since everyone has a stake and values the windpump as an important community asset.

Small Grant Wind Pump Initiatives

Other recent examples of use of wind pumps are the initiatives supported by UNDP GEF Small Grants Programme[3] to supply communities with water for irrigation and domestic use. One of the projects is in Mwiyoyo sub-location of Kieni west division in Nyeri District. Through a grant of US$ 38,000 to augment community contributions of US$10,000, a wind pump was installed to draw water from Labura dam and serve 200 homes. The water is mainly used for domestic purposes and watering livestock. Each household pays a monthly fee of Kshs 50 (US$ 0.6) for pump maintenance.

Several livelihood benefits have been noted since inception of the project. Farmers have started kitchen gardens to enhance food security. A total of 200 women save an average of 2 hours per day previously used in the collection of water. The beneficiaries have also

[3] www.ke.undp.org/GEF-SGP/ for projects on maji moto and mwiyoyo. Assessed 20th June 2004

developed a tree nursery of 30,000 seedlings ready for sale.

Through another grant of US$ 20,000, GEF has supported Community Water for Poverty reduction (COWAPA) to revive a windmill near Maasai Girls School in Narok District. A wind mill was installed in the early 1990s at the spring and a pipeline laid for two kilometres to Maji Moto town and had been neglected due to lack of maintenance. The windmill is to provide water for the Maasai community living near the spring which is the community's major source of water.

Mugie Ranch, Rumuruti

Mugie Ranch located in the remote dry areas North of Rumuruti exhibits another successful example of application of wind pumping technology in hybrid systems involving diesel pumps. Rumuruti is a very dry area, and a long way from any major town. The ranch rears more than 15,000 heads of sheep and using diesel pumps alone would be an expensive option to supply livestock water needs. BoB Harries Engineering Ltd (BHEL) - manufacturers of the Kijito windpump - installed the first wind pump on the site more than 15 years ago. BHEL developed a combination valve (hybrid model), which enables a submersible pump to be installed below the wind pump cylinder, and is therefore able to be used by the diesel generator. Most of the time, the wind pump is in use, even though there is the option to use the generator if necessary. With wind energy, the installation is providing a constant supply of water, at a fraction of the cost of only using a diesel or electrical installation.

Currently, three more wind pumps were installed on the site in year 2000 to supply livestock water needs. This was mainly due to the exceptional performance of the first wind pump, which ran for twelve years without a leather washer being changed in the cylinder. This was as a result of a well-drilled borehole, sound installation and consistent maintenance. In most cases, wind pump breakdown is usually due to worn out washers.

Source: Adapted from BHEL, 2004a, b

5.1.5 Case Study on Kisigisa Village Community Water Project, Tanzania

In Tanzania, Water Aid installed wind pump in Kisigisa Village, Kongwa district, in Dodoma, central Tanzania, more than 10 years ago with financial support from Lay Volunteer International Association (LVIA) at an estimated cost of Tshs 7million. The wind pump provides an average of 4,000 litres per day, mainly for domestic, institutional and livestock use. Before installation, women and children walked for more than 15km to the nearest water supply in Msagara village. Though the water scheme is managed by Village Water Committee, who collects tariffs of between Tshs 20 –30 per 20 litres for domestic and livestock respectively, the LVIA/Water Aid is still responsible for maintenance whenever the wind pump breaks down at an average cost of cost between Tshs 20,000 – 40,000. One of the major problems affecting optimum operation of the wind pump is the intermittent wind regime that affects water supply.

The problem of intermittent windspeed also affects other parts of Dodoma and Singida regions, where low wind speeds and borehole/well water delivery is not adequate for village domestic requirements. Furthermore, the cost of 20 litres of water at Tshs 20 was considered too expensive for people in the area to use the water for irrigation.

Impact of Diffusion of Decentralized RETs for Water Services

There is limited information on the potential impact of wider dissemination of renewable energy technologies on water services in East Africa and even less information and data on the extent to which renewable energy technologies could assist in enhancing the resilience of water services to climate change. This is clearly an important area that needs further assessment and careful research.

What is available consist of anecdotal evidence and results from a few pilot initiatives. What is clearly missing is a comparative assessment that unequivocally demonstrates the extent to which renewables can be an important climate adaptation measure in East Africa's water sector.

A comparative assessment of two similar areas that have gone through drought period and/or flooding experience with one area having renewable energy installations for water services and the other not having any renewable energy technologies could, ideally, provide strong evidence of the positive impact of renewables on adaptation. It would also indicate the benefits and drawbacks of each water service-related renewable energy technology and provide a sound empirical basis for recommending different types of renewable for different socio-climatic zones.

Identifying such areas would not be difficult. It would only require finding a site in a drought-prone area which has a renewable energy installation such as wind pump, ram pump or treadle pump and compare various key indicators with adjacent areas that have no renewable energy technology. Similarly, flood prone areas can also be assessed in a similar comparative fashion.

What would be more difficult would be to agree on indicators that would clearly demonstrate that a particular renewable energy option could indeed enhance water services resilience to climate change. The indicator might be water availability over periods of time but that could prove difficult if no consistent documentation of water supply and/or use is in place. It would also require long-term data which is difficult to find in sub-Saharan Africa.

Wind pumps distributed by Bob Harries Engineering Ltd (BHEL) are likely to provide long-term data as well as have comprehensive records. This is especially true of wind pumps installed in missionary-faith based institutions. Long-term data on treadle pumps and ram pumps would be more difficult to obtain.

The comparative field study could also yield valuable information on the comparative technical performance and cost-effectiveness of various renewable energy technologies for water services which could be used to verify theoretical assessments of the comparative costs of various renewable energy technologies as shown in the following table:

Table 16: Technical Summary of Key Non-Electrical Irrigation Technologies

	Model / Type	**Rate of discharge (m^3/hour)**	**Suction depth H_S (m)**	**Total head H_T (m)**
Treadle Pump - ApproTEC	Kickstart MoneyMaker	6.00	7	6.50
	Kickstart Super-MoneyMaker	5.40	7	20.50
	Swiss concrete	6.00	7	8.00
Hydraulic Water Rams 2"	Fleming / B&L / Vulkan	4.50	12.19	15.24
Wind Pump – Kijito	Kijito Wind pump	7.50	6.00	42.00

Source: Andreas, 2007; BHEL, 2002; Karekezi et al, 2005; Kickstart, 2009; Musa, 1993

Table 17: Initial Investment and Specific Cost of Irrigation Water for Different Renewable Energy Technologies

Component	**Treadle Pumps**	**Hydrams (Hydraulic Ram pumps)**	**Wind Pump**
Cost + installation (US$)	171.00	295.08	2,980.83
Annual Lubrication, Maintenance, Spare parts & repairs cost (US$)	6.42	5.62	58.09
Total costs (US$)	177.42	300.7	3,038.92

Component	Treadle Pumps	Hydrams (Hydraulic Ram pumps)	Wind Pump
Lifetime (years)	6.00	40.00	20.00
Rate of discharge (m^3/hour)	4.32	4.50	7.50
Specific Cost of Water (US$/$m^3$/annum)	0.03	0.05	0.29
Salvage costs after lifetime of pump (US$)	133.56	148.52	1,240.53

Source: Karekezi, et al, 2005

From table 15, it is clear that the treadle pump has the lowest cost of the three renewables-based water pumping technology options in terms of initial installation, lubrication and maintenance costs and specific costs of water. The wind pump option is the highest cost option registering the highest specific cost of pumped water. However, it has a high rate of discharge and a high salvaged cost after its lifetime (20 years) of operation, Its high rate of discharge can allow it to meet the needs of a large number of households or a community.

Impact of Climate Change on Performance of Selected Key Renewables for Water Services

There is virtually no known widely acclaimed expert study or major reliable regional studies focusing on the linkage between climate change, renewable energy and water services. However, a key energy security-related climate change impact that has been reviewed but not investigated in detail, especially in East and Horn of Africa, is drought-related hydro-power generation power crises (IPCC, 2001; Magadza, 2000; UNEP, 2005). In addition, there are recent studies that place Africa's adaptation to climate change through renewable energy at the forefront. These studies include AFREPREN/FWD work on renewables within the context of the African Climate Appeal initiative led by Heinrich Boll Foundation as well as the United Nations Department for Early Warning Assessment (UNDEWA), Global Environment Outlook 2007 report that briefly examines the impacts of climate change in Africa and proposes appropriate adaptation measures.

With the exception of large-scale hydropower, the implications of climate change on renewable energy technologies and water services in East Africa is not fully understood nor extensively studied. The impacts of climate change on renewable energy technologies dissemination and water services will not only depend on climatic factors, but also on patterns of economic growth, land use, population growth, distribution, technological change and social and cultural trends that shape individual and institutional actions. For example, extreme changes in temperature or rainfall due to climate change could affect dissemination of renewable energy technologies either adversely or positively.

There has been also little research carried out to date on how climate change may affect performance of renewable energy technologies for water supply. Some of the better known impacts that need further investigations include:

- The possibility that climate change induced drought could adversely affect the performance of renewable energy water pumping technologies such wind pumps, ram pumps and treadle pumps due to dropping underground water levels.

- Increased incidences of floods could damage the infrastructure for renewable energy technologies (for example, flooding can affect water pumping and supply system.

Having delve to some degree on the technical and financial aspects of renewables for water services, the next section will review the policy dimension of adaptation to climate change, renewables and water services.

6. SECTION IV – ASSESSMENT OF DECENTRALIZED RENEWABLE ENERGY TECHNOLOGIES (RETs) FOR WATER SERVICES IN EASTERN AFRICA

Review of Climate Change Adaptation Strategies for Water Services in Eastern Africa and Potential Role of Renewables

East Africa states are signatories to various international treaties such as the United Nations Framework Convention on Climate Change and the Kyoto protocol. In addition, they have consistent and active participants in international climate change forums and acceded to international pacts that are adopted in their national legislations addressing climate change.

At regional level, in 2009 the head of states of East African countries agreed to have an East African Community Climate Change Policy (EACCCP) and by 2011 the document was in place. The EACCCP was formulated to address challenges of climate change through integrated, harmonized and multi-sectoral strategies that provided the vital framework for action. It proposes options for combating the adverse impacts of climate change in realization of sustainable development. The key focus of this policy is to guide its members on collective measures of economic development vis-a-vis climate change impacts.

The EACCCP gives priority to three areas of measures that focus on adaptation, mitigation and climate change research. Adaptation measures are drawn from priorities identified by member countries' National Adaptation Programmes of Action, National Adaptation Plans and Climate Change strategies.

The EACCP adaptation chapter focuses on reducing vulnerability and building resilience to adverse climate change impacts that could affect ecosystems, livelihoods as well as threatened socio-economic development. It outlines approaches to realize adaptation by partner states through key sectors such as water, energy, agriculture, environment, tourism, industry, education, transport and infrastructure. It provides sectors objectives, highlighting challenges to implementation by member countries.. With regard to the water sector which is facing changing rainfall patterns and prolonged droughts, it appeals to member countries to conserve and efficiently as well as sustainably use water resources..

For the energy sector, the EACCP highlights challenges arising from East Africa countries reliance on hydro-electric power that is susceptible to climate change. It points out the low investment in affordable cleaner energy in the rural areas. The EACCP encourages member countries to promote renewable energy technologies such as solar, wind and geothermal. The EACCP does, not however, address the envisaged use of renewable energy as an important adaptation measure for the water services sector, agriculture and food security.

At national level, each of the East African countries have, in place, national adaptation strategies/documents.

Kenya is making progress in addressing the environmental challenge and by 2010 it set up the National Climate Change Response Strategy (NCCRS). The government considers this strategy as the basis for the formulation of National Climate Change Policy. The strategy provides multi-sectoral interventions to address climate change. Its main purpose is to strengthen the nationwide actions for climate change adaptation and mitigation of greenhouse gas emission.

In detail, the NCCRS provides an action plan with specific sectors' actions, implementation timeframe and agencies involved. In the action plan it highlights on-going interventions and briefly describes successful case examples within the country.

With respect to water sector interventions, the strategy highlight Kenya as a water scarce country whose annual per capita renewable water source is less than the conventional universal minimum of a thousand cubic meters (1,000 m^3). The NCCRS proposes interventions that would channel water to deficit areas from where it is in excess through construction of intra and inter basins water transfers. Limited attention is given to the renewable energy option for water services (GoK, 2010a).

Some attention is given to energy, particularly the risk of relying on large hydropower which is vulnerable ot climate change. Similar to the regional policy, Kenya's strategy falls short of addressing on how to deploy renewable energy technologies to reduce the impacts of climate change. Instead the energy sector mitigation interventions focus on reducing greenhouse gas emissions. It recommends on accelerated development of renewable energy to bring a low-carbon economy closer to reality

In 2006, Tanzania formulated a National Adaptation Programme of Action (NAPA) to address climate change impacts on its agriculture and other economic sectors. The main objective of the NAPA was to identify climate change adaptation actions that could lead to long-term sustainable economic development. It highlights issues raised in Tanzania's Disaster Vulnerability Assessment report that are linked to climate change such as increase in temperature, change in rainfall patterns and drought. In addition, it provides a descriptive discussion of the key sectors such as agriculture, water, energy, tourism and health that are vulnerable to climate change.

Regarding water sector, Tanzania's NAPA explains that a large numbers of households depend on natural water sources such as lakes, rivers and streams as well as rain-water harvesting. These water sources are vulnerable to climate change impacts which include drought, increased precipitation due to high temperatures and decrease in rainfall amount. For the energy sector, the NAPA, also highlights inadequate energy supply for Tanzania with majority of households using biomass, and at commercial level reliance on fossil fuel and hydro-electric energy sources.

In the last chapter of the NAPA, it outlines a matrix table on adaptation strategies and priority sectors. In addition, it takes into account existing interventions as well as proposes potential adaptation activities. In the matrix, water and energy sectors are ranked the top three sectors alongside agriculture as urgent priority areas that would face adverse effects arising from climate change impacts. As with other East African ountries NAPAs, Tanzania's NAPA, does not address the potential role of renewables in increasing the resilience of the country's water sector.

Uganda's NAPA preparation was guided by two considerations: the need for Uganda to achieve the Millennium Development Goals (MDGs) and the country's development objectives as enshrined in Poverty Eradication Action Plan (PEAP). The NAPA focus areas include eradication of extreme poverty and hunger, ensuring environmental sustainability among other issues.

The NAPA explores the climate change problem by highliting the increased frequency and intensity of extreme weather events such as droughts, floods, landslides and heat waves. The events of the past few years have demonstrated the magnitude of the problem. Frequent droughts have lowered water table levels, leading to drying of boreholes.

The NAPA establishes that although Uganda has abundant water resources, its distribution is uneven. Prolonged and severe droughts lead to low water levels in rivers, underground aquifers and reservoirs, affecting the hydrology, biodiversity and water supply. The severe drought contributed to the water reduction of the Lake and Nile River level, which had adverse impacts on power generation. The resultant power rationing in the domestic and commercial sectors greatly disrupted economic activities and triggered a decline in manufacturing output. aptation activities.

The NAPA concludes by presenting a set of prioritized interventions and an implementation framework proposing various projects for each action point. Some of the proposed projects will have specific outputs which include; building strategic irrigation demonstration units, promoting simple and low cost irrigation technologies, promoting energy-saving technologies and alternative energy sources, among other outputs

In conclusion, the East African adaptation policy, Kenya's strategy Tanzania's NAPA and Uganda NAPA, do address renewables as an important option for enhancing national resilience to climate change. The research team, however, was not able to find a substantive and widely acknowledged official policy document or strategy that supports the utilization of renewable energy technologies for water pumping to mitigate the impacts of climate change.

Factors Driving Use of Decentralized RETs for Climate Change Adaptation in Water Services

6.1.1 Assessment of Government Investments in Decentralized Energy Options

In this study, one of the key factors that was partially assessed is Government investment in decentralized energy options that are often suitable for water services and water pumping. The assessment assists in partly testing the following hypothesis: *Lack of investment in small scale decentralized energy options by Governments in East Africa has been a major contributor to the widespread inability to scale up decentralized energy use for water services in the region.*

This study partly tests this hypothesis by reviewing available budgetary allocations of selected East African Governments to the energy sector. Specifically, the study attempts to establish the proportion of budgets of region's ministries of energy that is allocated to renewable energy development in comparison to the allocation for conventional energy options. Large allocations to small scale renewable energy options would imply the availability of substantial resources which could be used to financed small scale renewable energy options that are suitable for rural water services.

The review of budgetary allocations for water sector also assists in testing the following hypothesis: *Lack of significant budgetary allocation towards water supply and irrigation development has resulted in low levels of access to improved water sources especially in rural areas in the region*. This hypothesis is partially tested by comparing the allocation for water development with other sectors.

The budgetary allocation to the energy sector in Kenya and Tanzania has been on the upward trend. Table 16 shows the trend in budgetary allocation for Tanzania's energy development. In the financial year 2009/2010, the Government of Tanzania allocated Tshs 2,825,431.4 million compared to Tshs 2,201,095.5 million for fiscal year 2007/2008, an increase of slightly over 27%.

Table 18: Trends in the Allocation to Energy Sector in the Total Development Budget - Tanzania

Fiscal Year	Total Development Budget (TShs in millions)			Percentage (%) Allocated to Energy Sector		
	Domestic	Foreign	Total	Domestic	Foreign	Total
2005/06	297,469	1,060,721	1,358,190	0.5	2.5	2.0
2006/07	520,400	1,214,126	1,734,526	42.6	16.8	24.6
2007/08	739,203.5	1,461,892.4	2,201,095.5	26.2	7.7	13.9
2008/09	940,380	1,551,100	2,491,480	9.9	14.2	12.6
2009/10	960,028.4	1,857,403	2,825,431.4	9.5	3.3	5.4

Source: Mwakapugi et al 2010

During the same fiscal period, as indicated in table 17, the Government of Kenya allocated Kshs 33,118 million for 2009/2010 compared to Kshs 21,075 million for 2007/2008 translating to a 50%+ increase (GoK, 2011).

Table 19: Trends of Development Expenditures (Kshs. Millions) - Kenya

Sub Sectors	Approved Estimates	Actual Expenditures

	2007/2008	2008/09	2009/10	2007/2008	2008/09	2009/10
Roads	33,682	46,437	58,491	24,597	36,279	36,577
Transport	4,789	2,482	5,792	3,324	2,013	3,548
Public Works	1,705	2,287	3,971	1,454	2,137	3,007
Housing	1,364	2,066	2,074	1,284	1,900	2063
Energy	21,075	31,260	33,118	17,704	30,560	32,513
Local Government	2,973	2,375	4,556	2,796	2,057	1,988
Nairobi Metropolitan Development	0	1,650	1,420	0	1,150	1,144
TOTAL	**65,588**	**88,557**	**109,422**	**51,159**	**76,096**	**80,840**

Source: GoK, 2011

Although the budgetary allocation for energy in both countries is increasing on annual basis, it is important to gain a more detailed understanding of allocations within the energy budget line time to obtain a better appreciation of budgetary support for renewable energy use in the water sector. A closer examination on Kenya's budget reveals that in fiscal year 2010/2011, more funds were channeled towards national electrification programmes. This amounted to Kshs 34,571.6 million compared to renewable energy technology initiatives which were allocated only Kshs 605.46 million (GoK, 2011). Similarly, in 2009/2010, the Tanzania Government allocated Tshs 1,200 million compared to utility and electrification projects which add up to Tshs 76,646.2 million. A quick back-of-the envelop calculation indicates that budgetary allocation to small-scale renewable energy use in water sector of both governments amounts to less than 2.5% of energy development funds.

The pattern of tiny budgetary allocations to small scale renewables appears to hold for other countries in the region. As indicated in table 18, Tanzania, Uganda and Ethiopia have even smaller budgetary allocations to renewables.

Table 19: Energy Budget Allocation to Renewable Energy Development (%)

Country	Fiscal Year				
	2006/07	2007/08	2008/09	2009/10	2010/11
Tanzania	1.41	0.87	1.21	2.16	-
Kenya*	-	1.11	2.23	1.96	1.67
Uganda	-	-	0.5	0.04	0.05

*Kenya * - small-scale renewable development*

Source: GoK, 2010b ; 2011; GoU, 2009; 2010: Karekezi et al, 2009; Kiva, 2008 ; Mwakapugi et al, 2010

In the financial year 2007/2008, sectoral budgetary allocation for the water sector in Tanzania was 6.5%. However, the actual expenditure on water was 3.6% of the Tanzania's budget (Berg, 2009).

Meanwhile, Kenya's budgetary allocation for water and irrigation in 2007/2008 was Kshs 3,609 million (GoK, 2011). This is approximately 17% of the budgetary allocation to energy sector in the same fiscal year. It indicates overall budgetary allocation for water sector is less compared to other key sectors and does not reflect the need for water. Most of the budgetary support for water sector has been used to finance operations support, maintenance and rehabilitation of worn out infrastructure thus limiting financing of new investments in the water sector. For example, in Kenya's rural areas where major farming takes place, the investment in water sector falls short by a whopping 54-57%. While the urban areas, the investment in the water sector that is required is 10-19% higher than actual outlays (Uwazi, 2010). Even the Water Services Trust Fund receives less than 1% from Ministry of Water and Irrigation budgetary allocation (Uwazi, 2010).

6.1.2 Drivers and Barriers to Use of Decentralized RETs for Climate Change Adaptation for Water Services

There are a number of key issues and barriers which impede scaling up of decentralized RETs for water services. These can be categorized into two: technical and non-technical issues.

6.1.2.1 Technical issues

a) Design and installation skills

For renewables-based water pumping systems, a key challenge is obtaining reliable and long-term resource data. Few countries have reliable data on water tables at micro-level nor can one find long-term data on local windspeeds. This lacuna can lead to poor design and inappropriate installations of renewables-based water pumping systems.

Water pumping systems which have not been designed and installed correctly are unlikely to operate satisfactorily. Design may not be a problem if the system is in simple kit form, or designed by experts, although this does pose the problem of ensuring that it is understood at the local level.

The main obstacle in developing countries comes in the area of installation and maintenance skills at the local-level. Although installing some small-scale renewable energy systems, such as wind or PV water pumping systems, may not usually pose serious problems in some countries (especially when they are sold in kits which contain all the necessary components, along with instructions in the appropriate language), there are definite skills shortages in many countries and unevenness in skills capacity across a country. For example, there is a much higher concentration of installation and maintenance skills in urban areas than there is in rural areas.

Installations of small-scale water pumping systems may, in some cases, be completed by the owner/user (if provided with a good instructions manual). However, a skilled technician is usually still needed in the area for maintenance and technical problem solving. In addition, for larger installations, e.g. for a community hospital, the installation should be carried out by qualified technicians with the same thoroughness that conventional energy supply systems require. This can be a problem if there is a shortage of skilled people in the country.

b) *Quality control and warranties*

It is important to select good quality renewables-based water pumping systems, preferably approved systems (i.e. following a defined standard). Systems should be well-designed and properly sized for the specific need. They also need to be long-lasting, user-friendly and repairable by local technicians. The warranty of the renewable energy system and its constituent components also needs to be considered.

Standards do not always exist for system components. This has led to the situation where the quality can vary significantly between several apparently similar devices, or between the various components within a single renewables-based water pumping system. To avoid purchasing inadequate systems or components, it is advisable to prepare a set of technical specifications to define the standard required for a given application.

c) *Maintenance and after-sales service*

Some renewable energy-based water pumping systems require little more than occasional checking of apparatus and components whilst others will require a full maintenance schedule. Preventative maintenance should be planned in full, including the arrangement of the finance necessary to complete this and to cover the costs of repairs and replacements. Maintenance can often be a problem for dispersed small scale renewable energy systems such as wind pumps in rural and remote areas. It is often advisable to cluster renewable energy installations to reduce maintenance costs and ensure proper back-up.

d) *Training*

Training local people to install, maintain and repair renewables-based water pumping systems is essential. Users can also be educated about the renewable energy system in terms of: what it does; how it works; and, how to look after it. A user-manual should always be given to the end-user along with the renewable energy system. Information dissemination can also play an important role. First, it gives accurate information about what a system can or cannot do. If dissemination of information is undertaken before any system is installed, then there is less likelihood that there will be over-optimistic expectations. At the same time, raising awareness of renewables-based water pumping systems can stimulate local markets.

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6.1.2.2 Non-technical issues

a) *Awareness*

Most renewables-based water pumping systems are now technically mature and proven but they are sometimes still regarded as risky, complicated, expensive and, often thought, that they do not work effectively. This view prevails from the early days of development when there were indeed sometimes such problems.

Consumer awareness campaigns focusing on successful renewables-based water pumping systems use in the region should be an integral part of any major initiative.

b) *Policy/regulatory issues*

In contrast to convention energy options, the limited Government budgetary support (although there are signs that this is beginning to change) as well as regulator support for small and medium renewable energy options suitable for water services continues to be a major constraint. The continued poor performance of conventional energy options has, however, seen slow but sure enactment of policies that support renewable energy technologies across the East African region. . For example, Kenya formulated in 2008 feed-in-tariffs policy. In 2009, Tanzania enacted its own sets of feed-in-tariffs.

c) *Institutional capacity-building for micro-finance*

The high up-front cost of renewables-based water service options continues to be a major barrier. There are, however, a number of successful financial models from different parts of Africa nad from around the world which utilize microenterprise credit to finance small purchases in rural areas. Although micro-credit systems are often focused on the agriculture sector, there are a number of revolving funds which are providing credit in rural areas of Africa and other developing countries for renewable energy options. Simiarl micro-credit options could play a major role in expanding the application of renewables-based water pumping options.

d) Community involvement

Community involvement is often critical to the success of a local renewables-based water pumping project. Many such projects in developing countries have failed because the needs and preferences of the local community were not considered before the project went ahead and systems installed. If there is limited community participation, the failure rate of renawbles equipment and theft are likely to be high.

Where a technology, such as a windpump pump, is designed to benefit an entire community, a local organization needs to take responsibility for ensuring that the technology is managed and utilized according to the needs and preferences of the entire community. Such an organization should, preferably, be representative of the entire community so that all community members have the right to use the system. The organization may need to define the hours of operation of the system, the tariffs per liter of water that might be levied, the maintenance to be carried out and by whom. The presence of such an organization can help to ensure that the system, and any revenue it generates, will benefit the entire community, not just a privileged few. Such a community will need to be set up, well in advance of system installation

e) Women in development

The vital role which women play in development is often underestimated or ignored. However, it is often women who benefit most from renewables-based water pumping systems. For example, local water pumps powered by wind or solar can reduce travel distanced to collect water. Such systems can be used by the women to provide potable water as well as to irrigate their market gardens, thus providing fresh vegetables for their families, with the excess sold and bringing in additional revenue for the family.

As mentioned earlier, about 70% of treadle pump users are women (Karekezi et al, 2005)..Training should be targeted at women to help them develop simple skills that would allow them to undertake routine maintenance as well as deal with simple breakdowns of treadle pumps.

Other key issues that affect the use of decentralized renewable-based options for water services in East Africa include the following:

i. Increased frequency and duration of droughts - The frequency and duration of droughts in the region has increased over the past couple of decades. Renewables-based water pumping systems may be designed to operate in short-term drought periods and may not be able to cope with lengthier drought periods. Although renewables are an important adaptation option to climate change, it is important to realize that renewables may need to be redesigned to cope with the adverse impacts of climate change.
ii. Increasing cost of fossil fuels - The world oil price for recent years has been on an increase, with a steep rise in oil prices in mid 2007 as shown in figure 9. Coincidentally,

this happened to be the period of drought in East Africa. The periods when high oil prices coincide with drought periods can be stressful to the region's economies but may also represent important windows of opportunities for promoting drought-resistant renewables-based water pumping options such as windpumps. .

Figure 9: World price of oil, November 2006 – November 2011

Source: www.oil-price.net/

iii. Decreasing cost of renewables - there is limited information on cost of renewable-based water pumping systems especially at retail level but the general trend globally and the region is that of decreasing costs arising from more cost-effective designs and economies of scale. Local manufacture using lower cost materials could be an important option for reducing the up-front costs of renewables-based water pumping systems.

iv. Growing interest in decentralized development/governance in the region – especially in Kenya which enacted a new constitution that focuses on decentralized development and decentralized governemnt structures and decentralized allocations of national budgets. This means that, in addition, to national budgets, it may be possible to secure additional financing for renewables-based water pumping systems from local government budgets.

6.1.3 Assessment of Prevailing Policies/Strategies for Climate Change Adaptation in the Energy and Water Sectors

As mentioned earlier, there are no explicit policies promoting renewable for water pumping in the region. Most of the available national regulatory documents focus on key sectors of water and energy with objectives of meeting the citizens' demand alongside improving the supply. These include, in Kenya: the Energy Act (2006); and Water Act (2002), while in Tanzania: the Rural Energy Act (2005); the Atomic Energy Act (2002); and the Water Resources Management Act (2009). The following brief overview of energy and water policies and regulations provides a clear need for legislation and/or policies that promote renewables for water pumping.

6.1.3.1 Energy Policies, Legislations and Regulations

Kenya's Energy Act of 2006 stipulates that development and use of renewable energy technologies shall be promoted. These includes but not limited to solar, wind, hydropower and biogas. It further stipulates areas where use and development of renewable energy may be promoted. Under section 103, part 2 (h), it calls for utilization of renewable energy sources for either power generation or transportation. It excludes the utilization of renewable energy sources for agricultural development such as in irrigation to enhance agricultural productivity and increase food security.

Tanzania has the Atomic energy Act (2002) and the Rural Energy Act (2005). For the Atomic Energy Act, is basically intended to govern on atomic energy and nuclear technology in Tanzania and has no guidelines for other renewable energy technologies. The Rural Energy Act (2005) stipulates on establishment of rural energy board which is mandated to support, provide technical assistance and allocate grants to modern energy projects. The overall focus of the rural energy act is on modern energy and does not specifically highlight renewabl-based water services solutions.

One of the specific objectives of the Tanzania's National Energy Policy of 2003 is to enhance the development and utilization of indigenous and renewable energy sources and technologies. The policy highlights Tanzania's over dependence on imported fossil fuel and hydro-electric power. The policy is cognizant of limited technical capacity in the country to develop renewable energy technologies which contributes to slow adoption of renewables. It calls for pro-active promotion of renewable energy technologies and proposes an institutional framework to promote the development of renewables but makes not specific reference to the institutional responsibility for promoting renewables-based water pumping options.

In spite of the plethora of energy institutions in both countries (Ministries, regulatory agencies, rural electrification authorities, utilities, regional water boards, etc) there is no designated agency that oversees the role of disseminating renewables in the country nor is there an institutional responsibility for promoting renewables-based water pumping.

6.1.3.2 Water Policies, Legislations and Regulations

Kenya's water reforms contributed to the formulation of Water Act (2002) that paved way for separation of water resource management and institutional functions on policy; regulation; and, assets holding and operations. The Act was enacted in 2003 to ensure guidelines on water resources allocation are developed. It led to establishment of Water Resource Management Authority as a regulatory board for water resources in Kenya. In addition, it stipulated licensing of water services boards and water service providers to ensure water supply to citizens.

Under this water act, the regulatory board is charged with various duties, one being to regulate and protect water resources quality against adverse impacts. Although, progress has been made since the enactement of the Water Act, the question of establishing institutional responsibility for promoting, supporting and developing renewables-based water services remains unanswered.

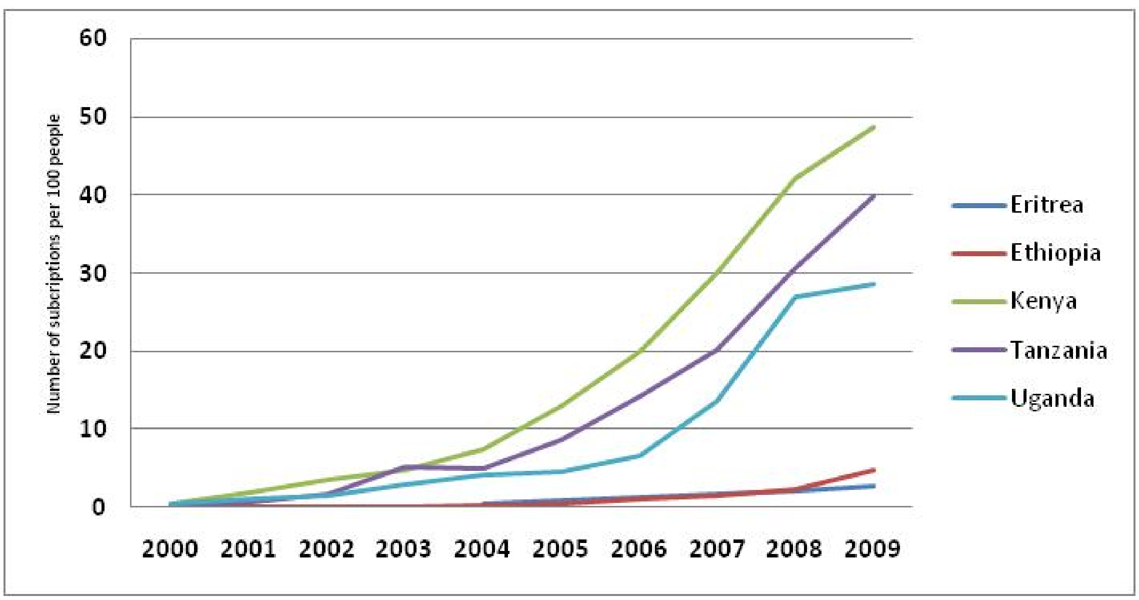
In Tanzania, the Water Resources Management Act (2009) provides guidelines on water management and protection, relevant authorities, regulatory and permits to abstraction of water. The main purposes of the Act is ensure that Tanzania's water resources are managed, conserved, protected, used, developed and controlled in ways that are sustainable and facilitate social economic development. As with the Kenya's Water Act, there is not specific institutional responsibility for promoting renewables-based water pumping systems.

6.1.4 Role of Communication Technologies in Enhancing Climate Change Adaptation in Water Services

Due to limited time and resources, this study was not able to comprehensive address the question of how communication technologies can enhance climate change adaptation in water services. It is hoped that a follow-up study will assess the role of communication technologies in improving the efficiency and equity of water services.

Data on penetration of mobile telecommunication could be used to partially test the following hypothesis: *The high penetration of mobile telephones in the region can contribute to improving efficiency of water services delivery, especially in rural areas*. The following figure shows the growth of mobile telephones in the region:

Figure 10: Mobile cellular subscriptions (per 100 people)



Source: World Bank, 2011a

It is proposed that the follow-up study assesses the current uses of mobile telecommunication in the following :

- Water services mapping and monitoring in the region.

- Water Points Mapping in East Africa (Kenya, Uganda, Tanzania and Ethiopia)

- Raising the Water Pressure initiative in Tanzania

- Mobile phone based billing query and payment system in Kenya

The assessment of above initiatives could provide useful insights on how the new mobile technologies could be used to expand the use of renewable-based water pumping systems. The above assessment will assist in responding to the following key research question: *Which roles are information and communication technologies (ICTs) playing or could potentially play in supporting water and energy distribution and availability of services, for instance facilitating the organization of data from communities to institutions and among institutions?*

7.

SECTION V – CONCLUSIONS AND RECOMMENDATIONS

Key Findings of the Study

This study seeks to assess renewable energy use in water services in East Africa and its implication on adaptation to climate change impacts. The key limitation of this study is lack of long-term series data and information. The available data, case studies and analysis are not sufficient to undertake a conclusive assessment of the potential of key renewable-based options of treadle pump, rampum, solar PV pump and wind pumps in adaptation to climate change. However, the available information and data revealed the following:

a) There is limited support by governments in the region for renewable energy technologies and water services to promote the dissemination of treadle pumps, wind pumps and ram pumps. The budgetary allocation for renewable energy technologies development projects for Kenya and Tanzania is less than 2.5% of each country energy sector development budget.

b) In cases where renewable energy technologies have been adopted to meet water services for communities, they have registered positive impacts. The technologies have enabled women reduce water collection distances. Treadle pumps have successfully raised food security and increased household incomes arising from increased productive of irrigated market gardens.

c) The dissemination of treadle pumps is higher compared to other water pumping renewable energy technologies. This is partly attributed to the low cost of treadle pumps. At under US$200, low income households can purchase treadle pumps from savings or retirement benefits. However, the lifetime use of the pumps is six years which is low compared to ram pumps – 40 years and wind pumps - 20 years.

d) There are no clear-cut policies that support the dissemination of renewable energy technologies for water services as an adaptation strategy to climate change. Most of the national policies and strategies focus of large-scale conventional power generation technologies and national electrification projects through the national grid.

Key Questions and Opportunity Windows for Further Research

a) **Government Involvement and Policies in Decentralized Renewable Energy Technologies for Water Services**

In addition to low budgetary allocations to renewables and water services in general, the policy architecture in East African countries is not conducive to many of the aforementioned renewable energy water pumping technologies. The treadle pumps, wind pumps and ram pumps that have been discussed in previous sections of this report require collaboration between the mnistries in charge of the energy with those in charge of water. This is difficult in institutional settings where ministries are essentially impervious silos that allow very limited horizontal communication. This clearly an important policy design issue that needs further research and investigation in the next phase of this study.

b) **Renewable Energy Technologies for Water Services**

There is limited information on large-scale dissemination of small scale renewable energy-based water pumping technologies. Most of the successful case studies occurred in the past in more developed economies whose current pre-occupation is to promote large scale energy projects. With time, information on successful case studies will disappear from records with a few documents archived in a few museums on the history of technology.

This is an area where through collaborative networks of international researchers, further studies can be commissioned to provide useful documentation on renewables earlier used in middle and high income countries for water pumping and thus provide important lessons learned for Eastern African countries.

As mentioned earlier, a comparative assessment of two similar areas that have gone through drought period experience with one area having renewable energy installations for water services and the other not having any renewable energy technologies could, ideally, provide strong empirical evidence of the positive impact of renewables on adaptation. It would also indicate the benefits and drawbacks of each water service-related renewable energy technology and provide a sound empirical basis for recommending different types of renewable for different socio-climatic zones.

Identifying such areas would not be difficult. It would only require finding a site in a drought-prone area which has a renewable energy installation such as wind pump, ram pump or treadle pump and compare various key indicators with adjacent areas that have no renewable energy technology. Similarly, flood prone areas can also be assessed in a similar comparative fashion.

What would be more difficult would be to agree on indicators that would clearly demonstrate that a particular renewable energy option could indeed enhance water services resilience to climate change. The indicator might be water availability over periods of time but that could prove difficult if no consistent system of documenting water supply and/or use is in place. It would also require long-term data which is difficult to find in sub-Saharan Africa.

Wind pumps distributed by Bob Harries Engineering are likely to provide long-term data as well as have comprehensive records. This is especially true of wind pumps installed in missionary-faith based institutions. Long-term data on treadle pumps and ram pumps would be more difficult to obtain.

The comparative field study could also yield valuable information on the comparative cost-effectiveness of various renewable energy technologies for water services which could be used to verify theoretical assessments of the comparative costs of various renewable energy technologies as shown in the previous Table 14.

c) Renewable Energy Technologies for Water Services Resilience to Climate Change

There has been little research carried out to date on how climate change may affect performance of renewable energy technologies for water supply. Some of the better known impacts that need to be better understood and could constitute focal areas of further research include:
- The possibility that climate change induced drought could adversely affect the performance of renewable energy water pumping technologies such wind pumps, ram pumps and treadle pumps due to dropping underground water levels.

- Increased incidences of floods could damage the infrastructure for renewable energy technologies (for example, flooding Solar PV battery storage sites) as well as water pumping and supply system.

- Climate change that leads to increased cloudiness could reduce solar radiation thus affecting the effectiveness of solar PV for water pumping. Similarly, water pumping would be adversely affected if wind speeds increase above or fall below the acceptable operating range of the technology.

d) The Role of ICTs in Dissemination of Renewable Energy Technologies for Water Services

Another important research question that needs to be addressed is to determine, to the extent possible, the roles that information and communication technologies (ICTs) are playing or could potentially play in supporting water and energy distribution and availability of services.

Proposal of Clear and Practical Entry Points for Further Investment and Research Support by the CCW Program

A clear and practical entry point for further investment and research support by the CCW program is the substantial amount of studies and research undertaken by AFREPREN/FWD and its members in region on the subject of renewables for water services in East Africa. This will better leverage AFREPREN/FWD's intellectual and skills assets as well as past and ongoing relevant projects and network of experts and policy contacts at national level.

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- **Appendices**

Appendix 1: Names and Contacts of 3 Researchers Working on Related Issues in the Region Under Assessment

Ayago Wambile

Mr. Wambile is a graduate in agriculture and rural development with 8 years of experience in energy, land resource management, food security, livelihoods and poverty issues among pastoral communities in arid areas of Kenya and southern Ethiopia. Mr. Wambile's contribution to the study will be to carry out a survey of wind pumps in arid and semi-arid parts of Kenya (former North Eastern and Eastern provinces). The survey will include communities using wind pumps for portable water as well as nearby communities without wind pumps. The findings of Mr. Wambile's survey will be valuable as they will provide informed data and information for Sections IV and V of the study report. Mr. Wambile's contacts are provided below:

Tel: +254 720 377 530

Email: awambille@gmail.com

Benedict Muyale

Mr. Muyale is an Environment Expert with 2 years experience in the energy sector. His contribution to the study will be to compile a qualitative assessment on climate change in Kenya. Mr. Muyale's case study will focus on using secondary data on climate and water services in order to draw emerging patterns and linkages. Subject to data availability, Mr. Muyale's case study will compile time series data from which trend analysis will be undertaken. Mr. Muyale's contacts are provided below:

Tel: +254 20 3866032/3871467/3872144/383714

Fax: +254 20 3861464/3876470/3740524

Email: afrepren@africaonline.co.ke

Buti Mogotsi

Mr. Mogotsi is currently a Principal Energy Officer at the Energy Affairs Division of the Ministry of Minerals, Energy and Water Affairs of Botswana. He is in charge of the New and Renewables Sources of Energy (NRSE) section of the Division. He has extensive experience in project design, implementation and evaluation, management of the NRSE sub-sector and technology assessment. Mr. Mogotsi has authored numerous reports and papers on energy that have been instrumental in shaping Botswana's energy and environmental policies. Mr. Mogotsi experience in the Renewables and Energy for Rural Development research will be useful to this study. **Tel:** +267 314 221 ext 215

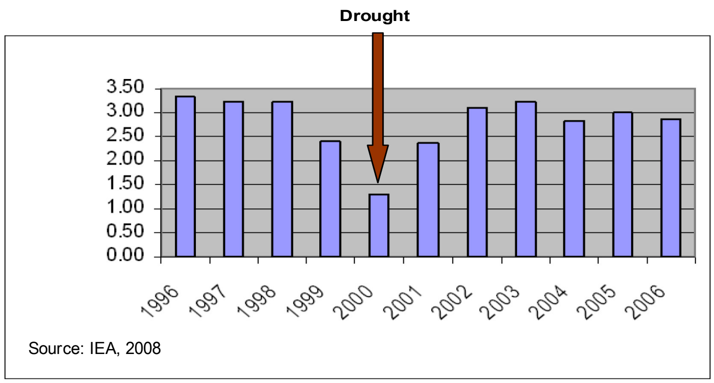
Fax: +267 314 201/391 455

Email: butim@mega.bw or bomogotsi@gov.bw

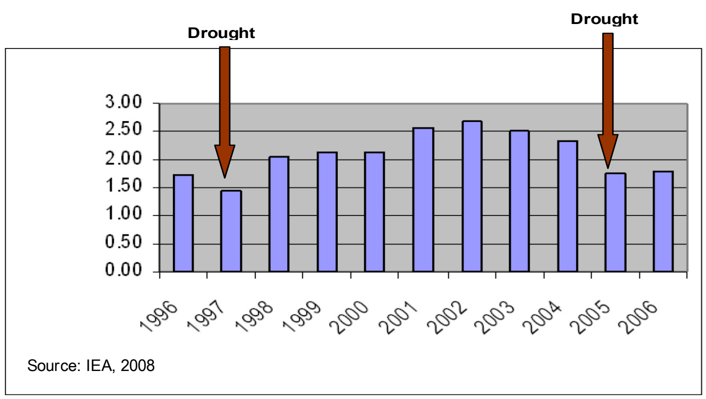
Appendix 2: Impact of Drought on Hydropower in East Africa

Figure xx: Hydroelectric Power Generation in East Africa (1996-2006 in Billion kWh)

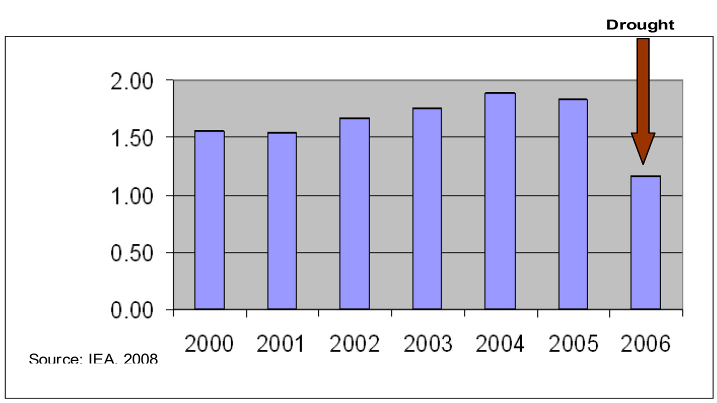
Kenya



Tanzania



Uganda



Source: IEA, 2008

As has already been mentioned, the region is heavily dependent on hydropower electricity generation – accounting for 79% of total electricity generated in East Africa. In spite of despite the past experiences and warnings of foreseeable reduction in precipitation, several countries in the region continue investing heavily in ambitious hydropower projects. Notable examples are in Uganda with the 250 MW Bujagali hydropower plant and, more recently, Ethiopia's ambitious 2,000 MW Mendeya large hydropower plant that is to be located at the junction of the Abay and Dedessa (Xinhua News Agency, 2009).

With most of the countries in the region lacking a diversified power sector, a combination of increased drought and shortened rainy season is likely to cripple the power sector. This could lead to sharp drops in their respective GDPs. In addition, the prevailing encroachment of water catchment areas for agricultural use appears to make hydropower development more vulnerable

Appendix 3: Wind pumps

Fundamentals/Principles of Operation

Wind is moving air and therefore contains kinetic energy. Wind energy technologies convert this energy into rotating shaft power which can be used for water lifting (wind pumps), electricity generation (wind turbines) and machine turning. The development of wind machines dates back to 2000 BC, when wind energy technologies were used for grinding grain in Persia, the Middle East and Babylon. Ancient ship designs utilized a sail to trap wind energy, thereby moving the ship. On the Isle of Crete, farmers have traditionally used a sail in wind pumps. In the twelfth century, the Dutch developed large horizontal shaft windmills for pumping water, grinding grain, and running saw mills and other machines.

The basic components of the wind pump include the rotor, the tail, tower, pump rods, the transmission, the rising main, the pump and borehole as source of water. Most wind pumps are connected to a tank for water storage. The rotor is the essential part that converts the power of wind (Kinetic energy) into useful shaft power. The rotor is fixed to steel shaft by means of one or two hub plates. The shaft is supported by steel sleeve of roller bearings or by hardwood sleeve bearings. Rotors for water pumping range from 1.5 to 8 metres in diameter.

The tower is what supports the head assembly and raises it over any obstructions into the path of the wind. It also serves as a rig during installation of the pipes of deep wells pumps. Tower heights range from six metres for small windmills to 18 metres for large ones. The most common height is around ten metres.

The power is transmitted from the rotor to the pump rods via a gearing system or via direct drive mechanism. The movements of pump rods cause the pump to lift water to the tank. Water can then be fed into the distribution network from the tank. The function of the tail vane is to keep the rotor oriented into wind. Most wind pumps have a tail vane that is designed for automatic furling (turning of the machine out of the wind) at high speed to prevent damage.

To install a small wind pump some pre-conditions need to be considered i.e

- Ascertain wind speed of at least 2-3m/s for most part of the year. The successful exploitation of wind energy is highly site-specific and largely depends on the wind resources of the area being exploited. Assessment of the wind regime in the area to ascertain that it is high enough to run a wind pump and available during most of the year is an essential exercise.
- Carry out an assessment of the minimum water requirement per day to enable sizing of the wind pump to suit the wind regime and water requirements.
- If water is drawn from a borehole, drill and encase it properly to prevent damage to the wind pump.
- Consider potential obstructions of wind towards the wind pump such as trees, tall buildings, etc. Locate the wind pump away from any obstructions such as trees, tall buildings, etc and do not locate too far away from where the water is required.

- Contact the local authority on planning and permission to install a wind pump.
- Consider how much the wind pump will cost to install and maintain, establish the size of wind pump which will be effective on the kind of project implemented.
- Consider who would be trained to provide preventive maintenance to the wind pump – usually greasing moving parts and inspection for wear-and-tear.
- To ensuring proper commissioning of wind pump and early resolution of installation-related problems ensure that the installer/manufacturer provide at least 1 year labour and parts warranty.

Appendix 4: Treadle Pumps

Fundamentals/Principles of Operation

A treadle pump is a human-powered pump designed to lift water from a depth of seven meters or less, it sits on top of the water source. Pumping is activated by stepping up and down on treadles which drive pistons, creating cylinder suction that draws groundwater to the surface.

The most important innovation of the treadle pump is the change from using arms and hands for pumping to feet and legs. This is because the most powerful muscles are the legs and back muscles compared to muscles in the arms (Fraenkel, 1995).

A treadle pump comprises of a cylinder fitted with a piston and some means of pushing the piston up and down. A pipe connects the pump to the water source and at the end of this pipe is a non-return valve that allows water to enter the pipe and stops it from flowing back to the source.

The piston and cylinder must have a close fit so that when the piston is raised, it creates a vacuum in the cylinder and water is sucked into the pump. When the piston is pushed down, the water is pushed through a small valve in the piston to fill up the space above it. When the piston is raised again, it lifts this water until it pours out over the rim of the cylinder and into the irrigation channel or tank. At the same time, more water is drawn into the space below the piston. The downward stroke of the piston once again pushes water through the small valve into the space above the piston and the process is repeated all over again.

Two cylinders are used positioned side by side and a chain or rope, which passes over a pulley or a rocker bar, connects the two pistons so that when one piston is being pushed down, the other is coming up. Each piston is connected to a treadle. The operator stands on the treadle and presses them up and down in a rhythmic motion; just the same way you cycle a bicycle. This rhythmic method of driving the pump has gained wide acceptance among poor farmers and seems to be preferable to any mechanism that requires only one foot or arms and hands. (Balla, 2004).

Two pumps have been developed from this concept. The first was the suction pump to lift water from a shallow well and discharge it over a spout into a canal for gravity irrigation. This was developed in Bangladesh where farmers needed to lift large quantities of water through shallow lifts of 1-2 metres (Balla, 2004). The second development was the pressure pump. This works on exactly the same principles as the suction pump but the delivery end was modified so that water could be fed into a pipe under pressure for sprinklers or horse pipes. The pressure pumps are used when water sources are deep (more than 4 metres) and there is need to deliver water under pressure to sprinklers, drippers or to a head tank. This requirement may also be the result of irrigating undulating or steeply slopping land.

<u>What to Consider When Installing these Technologies on a Small Scale</u>

- Carry out an assessment of the minimum water requirement per day and depth of the well (if applicable) to determine the size of the wind pump to suit the water requirements and ensure a reliable and source of water (>1 litre/second per pump)

- Make sure that there is water source within 6metres from the ground surface or locate the pump in locations where the source of water (well or stream) is close to the area to be irrigated.
- Ensure that adequate land available for garden expansion and that there is a market for the increased production arising from irrigation by treadle pump.
- Since the pump utilizes human energy, ready availability of labour is crucial.

Appendix 5: Ram Pumps

Fundamentals/Principles of Operation

Ram pumps (also referred to as hydraulic ram or hydram) are water-pumping devices that are powered by falling water. The pump works by using the energy of a large amount of water dropping a small height to lift a small amount of water to a much greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. Wherever a fall of water can be obtained, the ram pump can be used as comparatively cheap, simple and reliable means of raising water to considerable heights (Jeffery et al 1992).

The pump requires no external power source apart from the force exerted by water and runs automatically for 24 hours a day with minimum maintenance. The pump utilizes the pressure surge (water hammering effect) which develops when a moving water mass meets an obstruction, to produce power for water lift.

A ram pump consists of a drive pipe, which leads from the water source to the ram body. The ram body incorporates three valves: the impulse valve, which is equipped with a return spring; an air feeder valve; and, a delivery valve. As shown in the following figure, water flows through the drive pipe to let water into the ram body; increased pressure on the underside of the impulse valve overcomes the return spring pushing it upwards thereby creating pressure on the delivery valve, which opens the delivery valve allowing water into the air chamber. Water through the delivery valve compress the air inside the air chamber at the same time discharging water through the delivery pipe. As momentum of water in the ram decreases, delivery valve drops down closing the opening and the water rebounds. This creates a sudden drop of pressure in the ram body allowing air to enter it through air feeder valve causing impulse valve to drop down and open quickly and the cycle continues.

Adjusting the spring regulates the frequency at which the cycle is repeated. Once the spring is adjusted the ram pump needs no attention, provided water flow is continuous and no foreign materials get into the pump to block the valves.

Appendix 6: Solar Pumps

Fundamentals/Principles of Operation

Solar photovoltaic (PV) pumps use solar PV arrays to convert sun light rays directly into electrical energy. The amount of energy produced is directly depends directly on the sun rays. Solar PV pumps have a capability to operate even during winter seasons and even during cloudy weather albeit at a reduced rate. As with many other renewable energy technologies, PV has a seasonal variation in potential electricity production with the peak in summer. However, due to the Eastern Africa's position along the equator, solar PV pumps have an almost constant exploitable potential throughout the year. However, electricity production varies on a diurnal basis from dawn to evening.

Along the usage of solar pumps considerable research and development, coupled with some field-testing efforts, have resulted in invention of cheaper water pumping equipment and efficient controls. A typical solar PV pumping system consists of the following components:

- An electric pump
- A controller used for adjusting speed and output power according to input from solar panels
- Solar panel(s) for converting sunlight into electrical energy