

## **Catalysing Green Technologies for Sustainable Water Service Delivery**



### **D2: Report on Feasibility Study Framework**



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## Terms and Abbreviations

Term/Abbreviation	Meaning
ASALs	Arid and semi-arid areas
CTCN	Climate Technology Centre and Network
GoK	Government of Kenya
LAPSSET	Lamu Port Southern Sudan-Ethiopia Transport
MTP	Medium Term Plan of Vision 2030
RETS	Renewable Energy Technologies
RE	Renewable Energy
UDP	UNEP DTU Partnership
WAGs	Water Action Groups
WASH	Water supply and sanitation
WRUAs	Water resource users associations
WSTF	Water Services Trust Fund
SDGs	Sustainable Development Goals
INDCs	National Determined Contributions
COP	Conference of the Parties to the UN Framework Convention on Climate Change (UNFCCC),
SWTs	Small Wind Turbines
VIP	Ventilated Improved Latrines
WASREB	Water Services Regulatory Board

## 1. Overview

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### 1.1. Introduction

Water Services Trust Fund (WSTF), is a State Corporation established with a mandate to mobilise finance for the provision of water services to the underserved areas in Kenya. Despite the progress achieved, water coverage has been relatively slow increasing at an approximate rate of 1% between 2012 and 2015. Access to improved water services in urban and urbanizing areas stood at 55% and 49% for rural population by 2015 compared to the average national target of 80%. (Water Services Regulatory Board (WSRB) 2016)(WASREB 2014)

Water has variety of uses; agriculture, industry, livestock, hygiene etc. where most technological nexus are developed and applied. However, variety of technology applications are at their infancy and several barriers prevent solutions from reaching scale, including high cost of investments, limited awareness of benefits and technology supply chain. Moreover, the group experiencing lowest access to water services also have low access to basic services, they rely on unskilled jobs, have insecure income that is vulnerable to environmental shocks, low infrastructure coverage such as sanitation and transport and limited access to market for their produce and products. Being isolated and with little access to resources and important information, such people miss many opportunities to improve their lives.

These challenges cannot be addressed by a single entity but joining forces through new collaborative efforts in which motivated parties from different societal sectors pool to provide solutions to (perceived) common problems. Capacity development for sustainable and efficient water management need to focus on strategies to catalyse development of water–energy and food nexus including enhancing awareness on its benefits, access to affordable finance, management capabilities for delivery, policy incentives and improved codes and standards for the deployment of the green technologies.

Over the years, WSTF has financed a number of rehabilitation or non-functional water projects, which by itself is indication of need for designs requiring less operation and maintenance, and thereby release available finance to focus on new/undeveloped areas. WSTF is in the forefront of ensuring sustainable water sector investment which informs the need for this study.

Investment in green solutions for water can drive sustainable water management and multiples other benefits such as improved agricultural production, improved livestock production and improved livelihoods. In this context, green technologies for water apply broadly to technologies which enhance the use of renewable energy and efficiency, reduce reliance on fossil fuels, prevent pollution, increase climate resilience, and facilitate recycling of wastewater and its constituents' and/or raise productivity of freshwater.

Low cost green technologies investments are intended to provide services through the integration of either new or renewed facilities into already existing infrastructures. Partnership with the various stakeholders intervening in the system is thus a necessity. Also, sound economic policy, quality institutions and strong political commitment can help the implementation and management of the low cost green technology investments, and therefore resulting in achievement of larger benefits. In short, investments are easier to carry out where

the context is more favourable. For this reason, the specific context characteristics need to be taken into due consideration starting with feasibility phase. In some cases, improvements in the institutional set up might be needed to ensure an adequacy in low cost technologies performance.

The foregoing in mind, WSTF requested for technical assistance from the Climate Technology Centre and Network (CTCN) to catalyse low cost green technologies<sup>1</sup> for sustainable water service delivery in Northern Kenya and peri-urban areas. UNEP-DTU Partnership (UDP) was contracted by CTCN to provide technical assistance to (a) analyse the feasibility and sustainability of the deployment 3-specific low-cost green technologies for improved water services for household consumption, farming and/or irrigation, in underserved arid and semi-arid areas (ASALs) in Northern Kenya and in peri-urban areas and (b) to analyse private sector engagement potential in their deployment.

The main objectives of the CTCN technical assistance are:

- i. To determine the technical, economic and social feasibility of three water technologies for the targeted areas, through a pre-feasibility study entailing in-depth primary and secondary data collection and analysis.
- ii. To identify potential private sector actors and Public Private Partnerships (PPP) within the water sector for the deployment of green water technologies.
- iii. To develop a PPP business model in collaboration with relevant stakeholders model and build their capacity to engage in PPP.
- iv. To develop a concept note to trigger future funding i.e. to enable piloting of technologies, supporting implementation of PPP etc.).

### 1.2. Objective of Pre-Feasibility Study

The pre-feasibility study considers identifying the contextual features that allow use or limit the viability of selected technologies in areas (counties) with less developed infrastructure within the wider view of sustainable water supply. This includes people's attitudes and preferences, institutional and financial opportunities and barriers, as well as relevance of technologies in enhancing sustainable water supply. In addition, the study captures management issues such as operation and maintenance needs and infrastructure resilience against frequent climate impacts such as droughts, flooding, high infiltration and evapo-transpiration rates leading to high water losses from rain water harvesting systems.

The objective of the pre-feasibility study is thus to assess the technical, economic and social feasibility of three water technologies for the targeted areas, through an in-depth primary and secondary data collection and analysis.

Specifically, the pre-feasibility will include an analysis of:

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<sup>1</sup> *Green technology encompasses a continuously evolving group of methods, materials and systems for generating services while conserving the natural environment and resources and/or mitigate or reverses the effects of human activity on the environment:*

- i. Technical feasibility (types of technologies, durability, viability and materials required, skills and knowledge, potential providers).
- ii. Economic Feasibility (cost effectiveness, price of materials, operation and maintenance costs, current demand and supply, cost recovery, financing)
- iii. Social feasibility of the chosen technologies ( potential to create employment, social acceptability, awareness attitude and perception of the technology, land use patterns, gender and governance issues)
- iv. Risks, sustainability and reliability potential of these green technologies.

The pre-feasibility study and subsequent implementation of the CTCN technical assistance contributes to WSTF's strategic objective of "financing sustainable water and sanitation services in underserved rural and urban areas" (WSTF 2014) and contributes to national priorities and planned development programs in the water and environment sector in Kenya.

### **1.3. Structure of the report**

This report presents the study framework applied for conducting the pre-feasibility study of selected low-cost technologies in the context of water supply. It describes how the feasibility study goes about to identify both good design features and any shortcomings or disadvantages of the selected technology with a view to developing a modified and improved solutions with better performance and which better meet end-user requirements and deployment.

This document is organized in four (4) sections;

#### ***Section 1: Introduction***

Brief introduction to the study, definition of scope and objectives, project genesis and statement of constraints within which it will be conducted

#### ***Section 2: Description of Study areas***

This section outlines the areas where the study will be carried out

#### ***Section 3: Description of technology alternatives and selection***

Here the types of technologies addressed are listed, including salient features for the study areas and selected technology

#### ***Section 4: Description of the methodology***

The section presents an overview of the data collection and analysis, including study approach, study parameters and indicators, timeframe and main stakeholders. This section describes in greater detail particular activities that are critical in delivering outcomes.

### **1.4. Scope**

The focus of the pre-feasibility study framework outlined in this document is specific three (3) selected technologies namely water pans, solar and wind powered pumping system. The focus is on the extent to which they are employed to address challenges of water accessibility and availability (system capacity and reliability), affordability and acceptability, particularly in rural and peri-urban areas. The study will also include other types of water and energy sources for

control and comparison of costs, benefits and challenges that relate to the application of the identified technologies

#### **1.4.1. Inclusions**

The study depicts existing structures and conditions through primary and secondary data collection and identifies and analyses opportunities and gaps that can be addressed to achieve improved water services in target areas in Kenya.

#### **1.4.2. Exclusions**

The study is primarily intended to assess potential single technology to improve water supply services in specific contexts (county and/or ecological zone) and not as a selection tool which selects between various technologies, or to assess complex systems such as a piped supply with tanks, pipes and taps. The field visits will be used to verify the context and boundaries of study application.

#### **1.4.3. Constraints**

The following are some of the constraints identified in the feasibility study:

- Limited time for the data collection process
- Limited resources to conduct data collection process

#### **1.4.4. Assumptions**

- i. The data obtained shall be a true representation of the real time scenario in the field, meaning that the respondents are truthful and reveal the entire information about the situation on the ground
- ii. Technology performance, preferences and experience in particular locations is generally representative of what happens in the specific agro-ecological zone and lessons on its application can be generalised irrespective of social circumstances

## 2. Context and Description of Study Area

### 2.1. The challenge of Technology in Water and Sanitation

Water supply and sanitation in Kenya is characterised by low levels of access, particular in urban slums and in rural areas, as well as poor service quality in the form of intermittent water supply. Despite the technological leaps and enhanced financial investment to the water sector in the last decade, progress towards improved access to water and sanitation services is at a staggering low, particularly in many rural and peri-urban areas in Kenya.<sup>2</sup>



**Figure 1: ASAL Counties in Kenya**

The ASALs in Kenya make up 89% of the land surface and 36% of its population (14 million people by 2009), supports 70% of the livestock and generate 90% of the country tourism revenue. Yet, scarcity and poor management of water sources, environmental degradation and land pressure, insecurity, recurring cyclical droughts, unpredictable weather patterns and population growth remain some of the key challenges to livelihoods. These challenges have continued to mask the vast development potential in these areas over the past years. Despite the water sector reforms that were initiated in 2002, access to safe water, sanitation and hygiene for people and livestock still remains low.

It is estimated that 18.5 million or 41% of Kenyan population still lack access to improved water services. Seasonal and regional water scarcity exacerbates the difficulty to improved water supply and climate change and variability will generate more extreme events, such as floods and droughts. These phenomena are expected to have significant effects on water safety and security, altering patterns of availability and distribution, and increasing the risks of water contamination. Kenya has therefore, prioritized the water sector as a critical area of focus for climate change adaptation, alongside other sectors and highlights the crucial role of the technologies employed to ensure the effectiveness of adaptation (TEC 2014).

Ironically, regions that are characterised by low water service levels also have poor provision of structures and limited management skills to support water services (1). Functionality as well as the sustainability of rural and peri-urban water supplies is still a challenge because of high cost

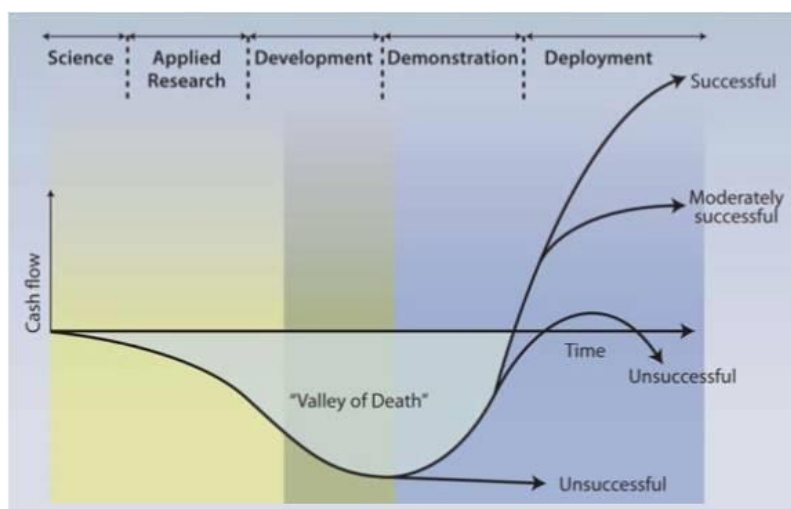
<sup>2</sup> The average access to improved water in five ASAL counties of Garissa, Isiolo, Marsabit, Wajir and Turkana is 37% compared to national average of 59% (Global et al. 2015)



of operations and maintenance. In particular, the cost of energy supply has a direct implication on the quality and prices of water services (2). Many experts have suggested that technologies such as solar, wind, and small-scale hydropower are not only economically viable source of energy for water supplies but also ideal for water supply in disadvantaged areas (Kamp & Vanheule 2015).

However, investments in water and energy technologies are often more than just cost-recovering over their lifetime cycle. Investment in technology makes up high proportion of the initial implementation costs, and subsequently that of operation and maintenance. While the standard model of economic theory would suggest that any cost-effective measure should be automatically implemented, investments in water and energy technology is often more than just cost-recovering over the project lifetime cycle.

Innovation and development of water supply and sanitation (WASH) technologies have the potential to facilitate a more dignified and humane way of life for all and especially for the poorest in the Kenya. However, many technologies which once showed promise for



**Figure 2: Technological Valley of Death (18)**

tackling the water supply problems faced in a particular region have often failed when the expectations of the users are not met and determining factors to sustain the technology are lacking (Hostettler & Hazboun 2015). Many great ideas fail to get to their full scale potential and disappear in the 'valley of death' between their piloting and full deployment. Typically, two main barriers hinder progress of innovation to full commercialisation: pervasive market barriers and unavailability of private sector financing to propel ideas to prototype and onwards to full commercial scale (Jenkins & Mansur 2011).

The lessons learned from Kenya relating to technologies such as the VIP latrine<sup>3</sup>, the India Mark II<sup>4</sup> and Afridev hand pumps<sup>5</sup>, kijito wind pumps<sup>6</sup> indicate that successful uptake needs an

<sup>3</sup> The ventilated improved pit (VIP) is a pit latrine provided with vent pipe and squat hole cover to control the problem of flies and unpleasant odours. <http://wedc.lboro.ac.uk/resources/booklets/G027-VIP-latrine-on-line.pdf>

<sup>4</sup> The India Mark II Pump is a robust human-powered, lever action hand pump designed to lift water from a depth of 50m or less. Typically intended for, serving communities of less than 300 persons. <http://www.rural-water-supply.net/en/implementation/public-domain-handpumps/india-mark-ii>

<sup>5</sup> The Afridev Pump is reciprocating type hand pump designed to lift water at less than depths 45m and meet the requirements for Village Level Operation and Maintenance. <https://www.dayliff.com/hand-pumps/category/289-afridev>

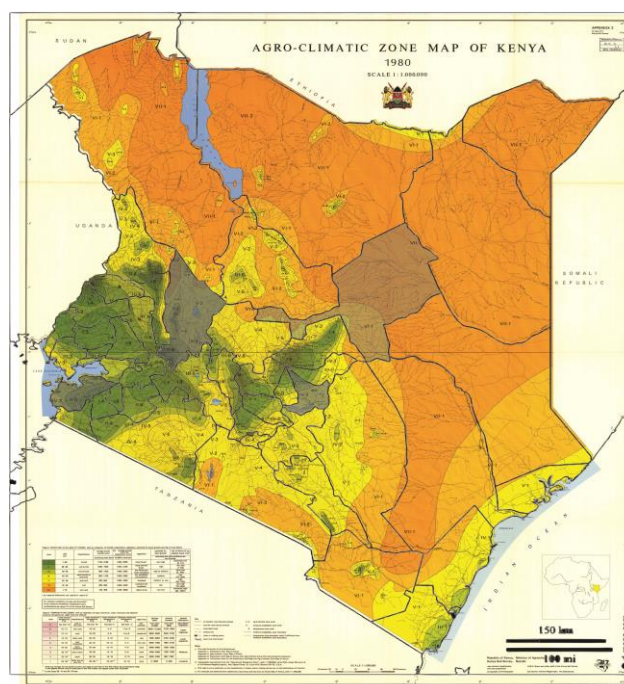
<sup>6</sup> A kijito is a multi-bladed rotor (3.65m - 7.9m) wind pump designed to operate in low wind speed regimes (from 2.5 m/s) <http://www.wot.utwente.nl/en/demonstration-site/wind/the-kijito>

introduction process based on a strong partnership with dynamic governance (WASHTech 2011). Furthermore, various aspects such as the acceptance of technologies, the ability of users to purchase the infrastructure and pay recurrent costs for operation and maintenance, the knowhow and skills available to operate and maintain the system, and the resources and capacity of local governments to support user communities all influence successful uptake and the provision of lasting services for sustainable water supply.

## 2.2. Description of study area

### 2.2.1. Country Profile

Kenya has climatic and ecological extremes with altitude varying from sea level to over 5000 m in the highlands. The mean annual rainfall ranges from < 250 mm in semi-arid and arid areas to > 2000 mm in high potential areas. Agriculture is the most important economic activity in Kenya and represents more than 26% of gross domestic product, with 75% of the country's population depending on agriculture for food and income generation. Approximately 1/3 of the country's land area is agriculturally productive which includes the lake, coastal and highland regions. The other 2/3 of the land area is semi-arid to arid which are largely characterized by low, unreliable and poorly distributed rainfall. The ASALS areas are normally used for livestock production with livestock production contributing to 26% of Kenya's agricultural production<sup>7</sup>.



**Figure 3: Target counties on the agro-ecological map of Kenya**

Kenya is divided into seven agro-climatic zones using moisture index (Sombroek et al. 1982) based on annual rainfall, which is expressed as a percentage of the potential evaporation. Areas that are categorised as zones I, II and III have a greater index than 50% and are considered to be good for cropping, accounting for 12% of the country land. Zones V, VI and VII are considered to be ASALS region which have an average rainfall of < 900mm, accounting for 83% of the land.

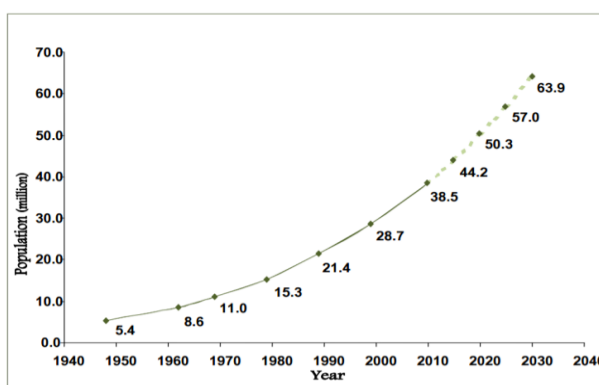
**Table 1: Classification of Agro-climatic zones, (3)**

Agro - Climatic Zone	Classification	Moisture Index	Annual Rainfall (mm)	Land Area
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<sup>7</sup> <http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Kenya.htm>

		(%)		(%)
I	Humid	>80	1100-2700	12
II	Sub-humid	65 - 80	1000-1600	
III	Semi-humid	50 - 65	800-1400	
IV	Semi-humid to semi-arid	40 - 50	600-1100	5
V	Semi-arid	25 - 40	450-900	15
VI	Arid	15 - 25	300-550	22
VII	Very arid	<15	150-350	46

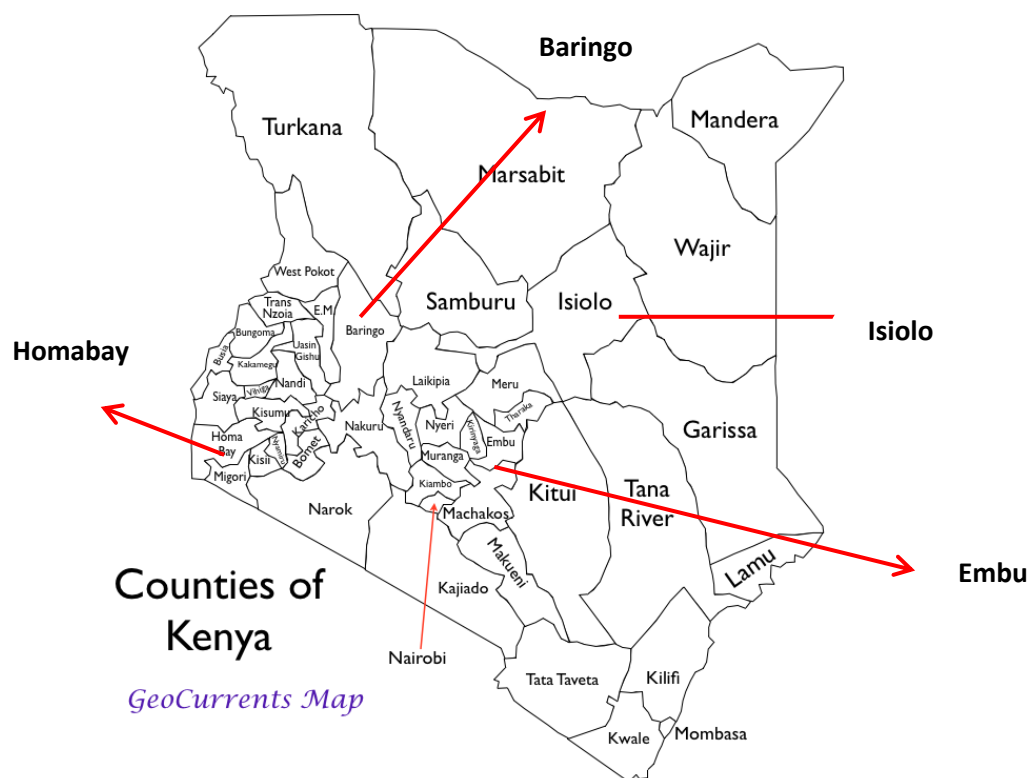
The population growth in Kenya is relatively high and continues to impact on access to safe water. Population increase in Kenya has been a great contributor to water scarcity with the increased population mounting demand and competition for water for domestic, agricultural, industrial and municipal uses. Rapid urbanization continues to expose more people to water shortages with negative implications to health, livelihoods and security.



**Figure 4: Kenya Population Growth 1948-2040, (Kenya National Bureau of Statistics (KNBS) 2012)**

### 2.3. Selected Study Areas

The study will be carried out in four (4) counties out of 47 counties in Kenya, namely Baringo, Embu, Homabay and Isiolo.



**Figure 5: Study Areas**

The counties are selected to represent the different agro-ecological zones in Kenya, with priority given to counties identified for WSTF investment programmes funded by the EU and Danida, as these are likely to benefit directly from the results of this study. The table below represents the target counties based on the various ecological zones, the technologies available and WSTF interventions.

**Table 2: Selected Counties for the field Survey**

Select County	Zones covered				Available technologies	WSTF Interventions
	Humid	Semi humid	semi - Arid	Arid		
Baringo					3 Technologies (Solar, Wind& Water pans)	European Union
Isiolo					3 Technologies (Solar, Wind& Water pans)	Green growth
Embu					3 Technologies (Solar, Wind& Water pans)	Peri urban experience
Homa bay					2 Technologies( Water pans & Solar)	Peri urban & PPP experience

### 2.3.1. Baringo County Profile

Baringo county is situated in the Rift valley and covers an area of 11, 015 Km<sup>2</sup>. The county's climate varies from humid in the highlands to arid in the lowlands areas. (County Government of Baringo, 2013). According to the 2009 Kenya Population and Housing Census (GoK, 2010) the county's population is 555,561 (279,081 males and 276,480 females). The county's intercensal growth rate is 3.3% per annum, which is above the national average of 3%. The major sources of employment are: agriculture, rural self-employed, urban self-employed and wage employment. Wage employment is the main source of employment in the county, generating about 34 per cent of the total employment. Out of the county total labour force 68% are unemployed.

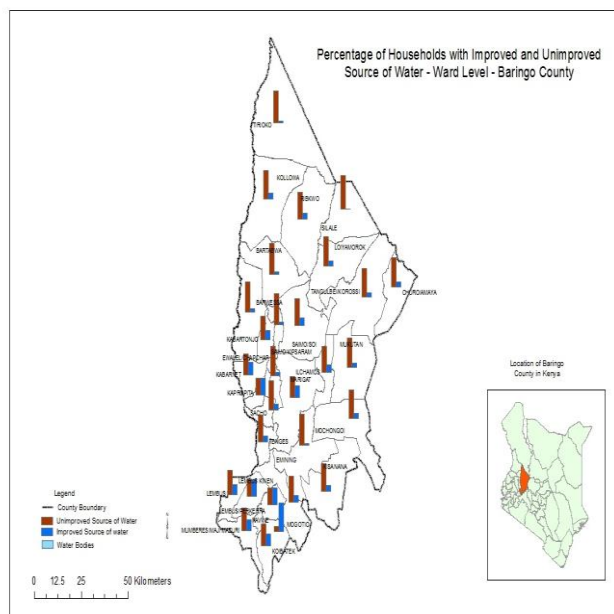


Figure 6: percentage of households with improved and unimproved water (KNBS, 2013)

24% of the county population uses improved sources of water with the rest largely relying on unimproved water sources. There is no significant gender differential as 24% of the male headed households and 23% of the female headed households use improved sources (KNBS, 2013)

Through the rural electrification programme by the GoK, the county has increase its electricity connectivity with 2,346 new connections observed between 2010 and 2011. The county has great potential of geothermal energy around Lake Bogoria and Silale.

Most of the land in the county is under trust and is largely owned by the community. About 30% of the land is demarcated with title deeds being used as land ownership document. There are few cases of landlessness in the county. Environmental degradation in the Baringo County is widespread with some areas lined up with deep gullies and without any vegetation making these areas unfit for development activities. Further, development of settlements in the County fragile ecosystem continues to impact on water resources therefore reducing the county potential for livestock and agricultural output. Climate change is largely characterised by increased warming and recurrent droughts. Effects of climate change continue to impact on the county ability to provide sustainable water supply to its urban and rural populations.

### 2.3.2. Embu County Profile

Embu County covers an area of 2,818 Km<sup>2</sup> with a population of 516,212, according to the 2009 population census. Embu County depicts the typical agro-ecological profile of the windward side of Mt. Kenya of cold and wet to hot and dry lower zones in the Tana River Basin. The average rainfall in the upper areas is 2000 mm and 600 mm in the lower areas.

The largest proportion of arable land in the county is used for agriculture with farms averaging 1.98 acres following land fragmentation over the years; large-scale farms average 7.4 acres. According to the KNBS (2005/06), 59.6% of land parcels in the county have title deeds. High population pressure in the upper region and lack of land adjudication in the lower region of the county has caused landlessness. The county plays a major role in the national energy sectors as it host the seven-folk project that contributes 80.2% of the country's electricity. Electricity coverage in the county is mostly confined in the urban as compared to the rural areas. The recent government rural electrification programme has contributed to increased rural electricity coverage in the recent past.

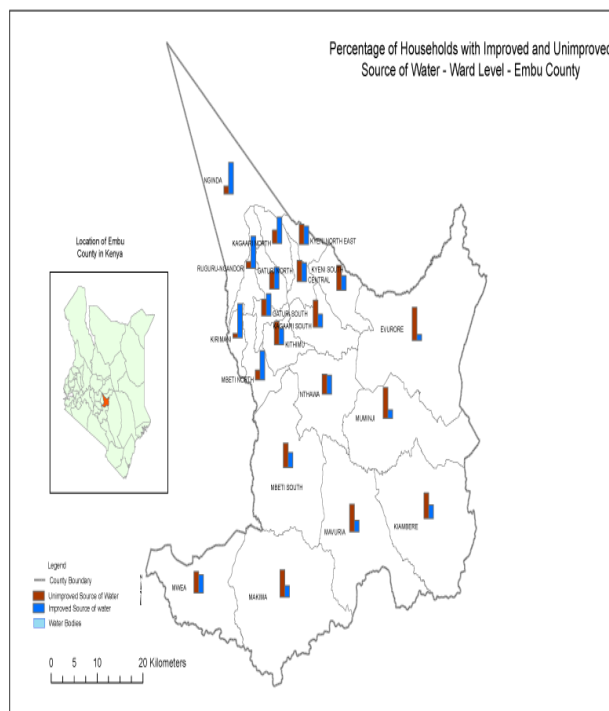


Figure 7: percentage of households with improved and unimproved water (KNBS, 2013)

Embu County is predominantly characterised by a rural settlement pattern in the upper part and a more scattered settlement pattern in the lower parts. Deforestation, logging and wet land encroachment are the main contributors to environmental degradation in the county. The county has experienced its share of climate change through increased drought periods, erratic weather patterns and increased temperature, especially on the lower areas of the county.

In Embu County, 49% of residents use improved sources of water, with the rest relying on unimproved sources. Use of improved sources is slightly higher in male headed households at 50% as compared with female headed households at 46%.

### 2.3.3. Homabay County Profile

Homabay County covers 3,183 km<sup>2</sup> with a population of 963,794 persons (462,454 males and 501,340 females) according to the 2009 population census. The county is divided into two ecological zones, namely the upper and lower midland with an equatorial type of climate. There are two rainy season namely long rainy season from 250-1000mm and short rains ranging from 500-700mm. The county average annual rainfall ranges from 700 to 8000 mm.

In Homabay County, 28% of residents use improved sources of water, with the rest

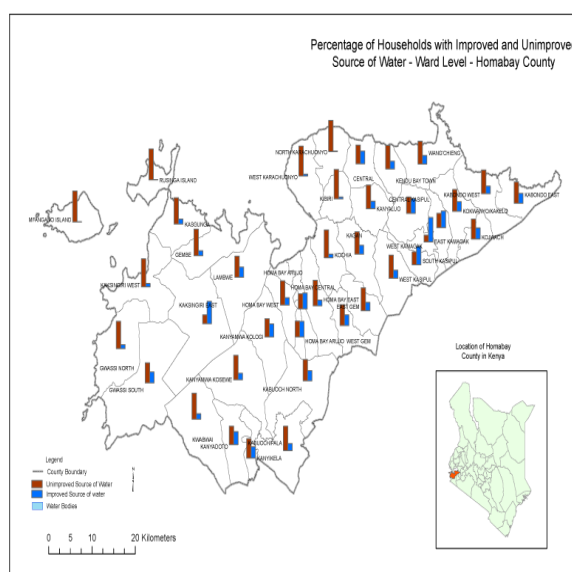


Figure 8: percentage of households with improved and unimproved water (KNBS, 2013)



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#### 2.3.4. Isiolo County profile

Over 80% of the land in Isiolo County is non-arable (22,000 km<sup>2</sup>) and is used for grazing by the pastoralists but in some wards such as Kinna, agro-pastoralism is practised. Only 1,497 hectares are under food crops production. Land is communally owned and held in trust by the county government.

70% of the county population uses wood fuel which has resulted to extensive land degradation due to over harvesting of tree primarily for charcoal. Of the 31, 326 households across the county, only 2500 have access to grid electricity.

Percentage of Households with Improved and Unimproved Source of Water - Ward Level - Isiolo County

Location of Isiolo County in Kenya

Legend

- County Boundary
- Unimproved Source of Water
- Improved Source of Water
- Water Bodies

0 12.5 25 50 Kilometers

**Figure 9:** percentage of households with improved and unimproved water (KNBS, 2013)

climate change are unpredictable rainfalls, floods, recurrent droughts, loss of forest and wetland ecosystems and scarcity of portable water.



### 3. Technology Alternatives Outline

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The interrelationship between the water sector and other key sectors such as agriculture, public health, energy and animal husbandry presents the sector as a complex sector. The effects of climate change further increases the complexity of the water sector, as various measures for climate adaptation and mitigation linked to these sectors are required. Therefore, it is imperative that technologies that enhance sustainable water supply are adopted to reduce vulnerability to climate change and enhance climate resilience.

The term adaptation technology has become common with the rise of climate change talk across the globe. Adaptation technology is defined as the application of technology to reduce vulnerability or enhance resilience of human or natural system to the impacts of climate change (UNFCCC, 2005). In the water sector, it is important that site specific solutions are considered within the integrated water management context<sup>8</sup>. Poor planning, over-emphasis on short term outcomes and failure to account for possible climate consequences have been attributed to maladaptation or adopting technologies that do not effectively vulnerability of climate change (TEC 2014).

#### 3.1. Prioritization and selection priority green water technologies

The green water technologies were selected from list of five (5) technologies identified by WSTF when submitting request for assistance.

- (1) Solar water pumping system
- (2) Wind powered pumping systems,
- (3) Sand dams ( sub surface rainwater water storage technology),
- (4) Djabias (Semi-underground tanks with water catchment systems),
- (5) Water pans (small surface rainwater storage)

In common, the technologies are all low-cost simple technologies involving either renewable energy or enhancing water storage and generally appropriate for underserved communities. The five technologies were evaluated and prioritised through a multi-criteria analysis using a combination weighted criteria based on the following criteria and which will be subject to an in-depth analysis:

- i. Cost of technology (initial investment, operations and Maintenance)
- ii. PPP potential for the selected technologies
- iii. Potential to improve livelihood and grow local economy
- iv. Availability of requisite skills for installation, operations and maintenance
- v. Potential deployment across the country, and

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<sup>8</sup> A process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystem (GWP, 2000).

- vi. Capacity to enhance water quality and quantity
- vii. Potential to reduce emission and increased resilience to climate change and variability

**Table 3: Relative technology score for the identified ranking factors**

	Costs		Benefits							
	O&M costs	Capital costs	PPP Potential	Livelihood improvement, employment and economic empowerment	Availability skills to supply installation, running and maintenance	Potential deployment across country	Capacity to enhance water quality	Capacity to enhance water quantity	Potential to reduce GHG emissions	Potential to increase resilience to climate change
<i>Technology 1: Solar water pumping system</i>	8	6	9	9	4	8.5	8	9	10	7
<i>Technology 2: Wind powered pumping systems or wind mill</i>	8	5	8	8.5	2	8	8	9	10	7
<i>Technology 3: Sand dams (run off water harvesting technology)</i>	9.5	8	4	7	8	5	8	5	5	8.5
<i>Technology 4: Djabias (Semi-underground tanks with water catchment systems)</i>	8.5	8	2	4.5	8	9	3	3	5	6
<i>Technology 5: Water pans (run off water harvesting technology)</i>	6	4	6	8	7	7	2	5	5	7

**Table 4: Weighted Score and Prioritised Technology**

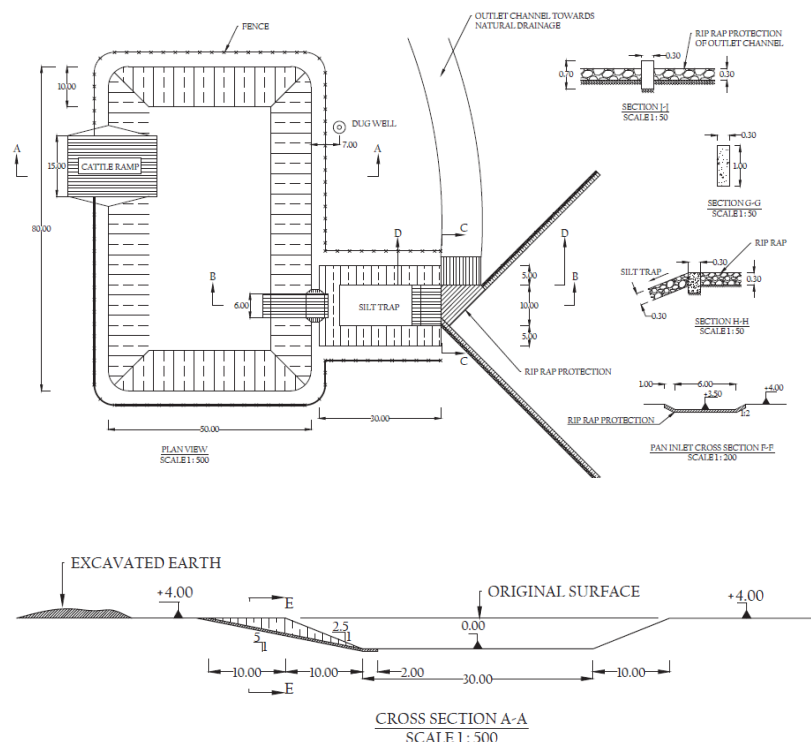
	Costs		Benefits								Total Score
	O& M costs	Capital costs	PPP Potential	Livelihood improvement, employment, economic empowerment	Availability skills to supply installation, running and maintenance	Potential deployment across country	Capacity to enhance water quality	Capacity to enhance water quantity	Potential to reduce GHG emissions	Potential to increase resilience to climate change	
<b>Technology 1: Solar water pumping system</b>	64	48	72	117	52	34	32	117	130	91	602
<b>Technology 2: Wind powered pumping systems or wind mill</b>	64	40	64	110.5	26	32	32	117	130	91	551.5
<b>Technology 3: Sand dams (run off water harvesting technology)</b>	76	64	32	91	104	20	32	65	65	110.5	473
<b>Technology 4: Djabias (Semi-underground tanks with water catchment systems)</b>	68	64	16	58.5	104	36	12	39	65	78	394.5
<b>Technology 5: Water pans (run off water harvesting technology)</b>	48	32	48	104	91	28	8	65	65	91	441

<i>Criterion weight</i>	13	8	8	13	13	4	4	13	13	13	
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## 3.2. Outline of Selected Technology

### 3.2.1. Water Pan

Water storage pans are excavated surface water storage facilities of limited capacity (generally not exceeding 20,000 m<sup>3</sup>) which are mainly constructed in locations where the topography does not allow the construction of a small dam and instead favours excavation. Excavation of larger pans (up to 150,000 m<sup>3</sup>) is possible and can be done, especially near populated centres, but the construction cost is generally high due to the 1 to 1 excavation to storage ratio.



**Figure 10: Typical plan and section drawing of a water pan,**  
(Government of Kenya 2015)

However, when a suitable inclined location can be identified for the construction of the pan a somewhat more favourable ratio can be obtained. Storage pans tend to be relatively expensive constructions when compared to small earth dams; where possible natural depressions can be enlarged to produce water pans with a slightly better storage to earthworks ratio. (Government of Kenya 2015)

Pans for the purpose of surface water storage can be constructed wherever a sufficient quantity of water can be intercepted to create a small reservoir. Pans are basically used in such locations where no topographically suitable site can be found for the construction of a small dam, or where no suitable construction materials for the construction of a dam can be found.

Water storage pans are subject to the same limitations regarding sedimentation and evaporation as small dams. Due to their shallow depths (usually 2.50 m to 5.00 m) water storage pans are usually not suitable as permanent water sources for high evaporation areas, while for catchment areas subject to erosion, silt traps will have to be included in the design (Government of Kenya 2015).

Apart from the two factors mentioned above (topography and availability of construction materials), basic principles for selection of appropriate locations include;

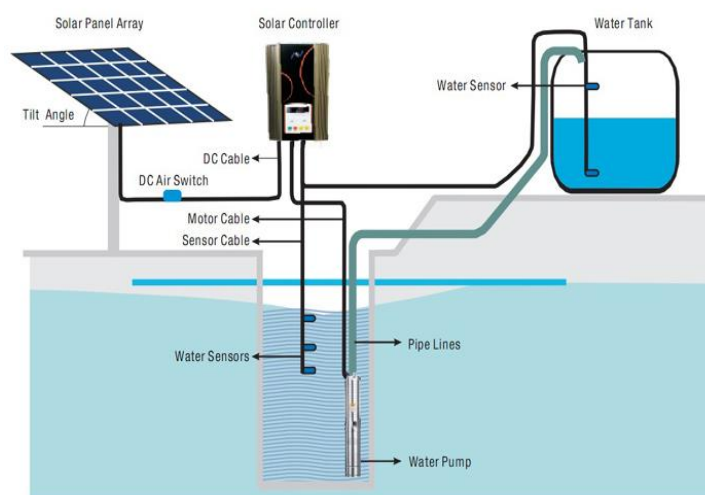
- i. The water-tightness of the reservoir in sandy areas but since pan dimensions are limited, lining of the reservoir with an impervious clay blanket can often present a solution for pans,
- ii. The natural drainage and flow pattern of the intercepted water and an overflow structure for any excess water towards the natural drainage
- iii. Silt trap which is often combined with the overflow structure.
- iv. Sedimentation, evaporation and ecological impact
- v. Specific alignment of the pan to minimize earthworks
- vi. Storage sizes considering the expected inflows, Length of the dry period, reliability level to be maintained during a given dry period and the expected water use and relative importance of the evaporation losses<sup>9</sup>.

Strength	Weaknesses
Easy to construct and maintain	Low, erratic rainfall and droughts may result to water pans drying
No energy is required to draw water	Elevation often restricts conveyance by gravity
Less susceptible to damage when overtopping and weak structural foundation	Seepage losses from the reservoir
Reduces impact of floods by storing initial floodwaters, controlling erosion.	Poor water quality owing to high turbidity and contamination of water in open reservoirs
Can be constructed on any soil type	High rate siltation by sediment during severe storms, and especially at the end of dry season
It has potential of raising water table downstream and in nearby wells.	The risk of people and livestock drowning in the pool
	High evaporation losses
	Expensive to construct relative to water volume stored

### 3.2.2. Solar energy

Solar energy is the best-known renewable energy technology in Kenya. Direct solar energy can be broadly categorized into solar photovoltaic (PV) technologies (converting the sun's energy into electrical energy) and solar thermal technologies (using the sun's energy directly for

<sup>9</sup> Generally pans in arid areas should be sized with emphasis on availability of grazing (i.e. the pan should dry out just as the available grazing is finished). Large pans may result in overgrazing in the area around the pan.



**Figure 11: Typical Solar water pumping system (20)**

heating, cooking and drying, etc.) (Kiplagat et al. 2011)(Philippa Marshall, Phil Wallace n.d.)

The building block of a PV system is a PV cell. Many PV cells are encapsulated together to form a PV panel or module. A PV array, which is the complete power generating unit, consists of any number of PV modules/panels. PV cells typically have a capacity between 5 and 300 W but systems may have a total installed capacity ranging from 10 W to 100 MW. The very modular nature of PV panels as building blocks to a PV system

gives the sizing of systems an important flexibility. The sizing of the solar water pumping system depends on the maximum flow rate ( $\text{m}^3/\text{hour}$ ), the head, the power requirements and the solar radiation of the area. Typical solar water pumping system is shown in Figure 14 and includes:-

- Source of energy-solar Photovoltaic system (panels, inverter)
- Pumps (submersible)
- Source of water
- Water storage facility
- Water level detector

**Table 5: Example of solar application and system type, (UNIDO 2010)**

Technology type (PV/solar thermal)	System	Application
PV (solar electric)	Grid connected	Supplementing mains supply
PV (solar electric)	Stand-alone	Small home systems for lighting, radio, TV, etc. Small commercial/community systems, including health care, schools, etc. Telecommunications Navigation aids Water pumping Commercial systems Remote settlements Mini-grid systems
Solar thermal	Connected to existing water and/or space heating system	Supplementing supply of hot water and/or space heating provided by the electricity grid or gas network
Solar thermal	Stand-alone	Water heating, i.e. for rural clinics Drying (often grain or other agricultural products) Cooking Distillation Cooling



The amount of energy that can be produced is directly dependent on the sunshine intensity. Thus, for example, PV devices are capable of producing electricity even in cloudy weather albeit at a reduced rate. Natural cycles in the context of PV systems thus have three dimensions; a seasonal variation in potential electricity production with the peak in hot season although in principle PV devices operating along the equator has an almost constant exploitable potential throughout the year. Secondly, electricity production varies on a diurnal basis from dawn to dusk peaking during mid-day. Finally, short-term fluctuation of weather conditions, including clouds and rainfall, impact on the inter-hourly amount of electricity that can be harvested. The strengths and weaknesses of this technology are presented in Table 6.

**Table 6: Strengths and weaknesses of PV energy systems, (UNIDO 2010)**

Strengths	Weaknesses
Technology is mature. It has high reliability and long lifetimes (power output warranties from PV panels now commonly for 25 years)	Performance is dependent on sunshine levels and local weather conditions
Automatic operation with very low maintenance requirements	Storage/back-up usually required due to fluctuating nature of sunshine levels/no power production at night.
No fuel required (no additional costs for fuel nor delivery logistics)	High capital/initial investment costs
Modular nature of PV allows for a complete range of system sizes as application dictates	Specific training and infrastructure needs
Environmental impact low compared with conventional energy sources	Energy intensity of silicon production for PV solar cells
The solar system is an easily visible sign of a high level of responsibility, environmental awareness and commitment	Provision for collection of batteries and facilities to recycle batteries are necessary
The user is less affected by rising prices for other energy sources	Use of toxic materials in some PV panels

### Challenges for solar PV on in rural and peri-urban Areas

The installed solar PV capacity in Kenya and Africa is low considering the solar radiation levels. It was initially speculated that the low uptake of solar technology was associated with unaffordability low awareness of and limitations in technical capacity. The limited diffusion of solar technology can be attributed to a wide range of factors associated with players on every level of the value chain from the end user through to the investors (6). Various factors affect choice and the penetration of PV lighting systems in rural Africa including access to finance, distribution challenges, consumer education, market spoilage due to substandard products, government policies and after sale support. The challenges affecting the growth of the solar energy industry in Africa can be grouped into the following four categories (6):

- a. Enabling environment: Kenya's applies the Least Cost Power Development Plan (LCPDP) i.e. lowest overall economic cost options - for development of new energy generation. On this basis solar energy sources are often relegated on previous assumptions that solar energy is too expensive. This policy stance and presumption limits growth of solar home solutions and other off-grid uses in rural areas. This standpoint is changing because of active donor support for solar energy.
- b. Access to finance/affordability: Access to finance is considered as the major challenge to the penetration of solar energy technology. The impacts of limited financing are felt on all levels of the supply value chain from the manufacturer through to the importers, distributors, dealers and finally the consumer. Lack of concrete information about the solar industry is a major barrier to investment. Further, limited awareness of market trends and rates of return alongside fears of political instability continue to raise the risk elements for investors. . Over reliance to foreign skills combined with high interest rates similarly affects the viability of solar energy projects.. With strategic negotiation between the various actors and well-structured financial models, solar projects can attract lower capital cost.
- c. Awareness: Lack of awareness by consumer has been considered as among the top three challenges facing the penetration of PV systems in Kenya and the rest of Africa (6). When there is high presence of products that are sub-standards in the market spoilage occurs. Cheap products that have poor quality results make market penetration difficult since the consumers no longer trust the technology. Therefore the target market awareness levels of the energy generation options available, quality and their benefits is important to overcome market spoilage. In a study carried out by the Lumina Project on LED torches in East Africa, it was found that 90% of the users experienced quality-related problems during the six-month study period (Tracy et al. 2010) In 2009, Lighting Africa undertook the quality testing of solar products in the African market; the study revealed that 13 out of the 14 Pico PV products<sup>10</sup> in circulation did not pass quality tests. A follow-up round of tests in 2012 returned results where 46 of the 120 products available in the market passed the quality tests. Consumer education is considered as an expensive hurdle that needs to be overcome for the solar products to develop a client base especially in the rural settings.
- d. Access to technical support services: Ensuring that there is technical assistance in the proximity of the technology consumer plays a major role in overcoming market spoilage. The availability of trusted technicians with the knowhow of trouble shooting, repair and maintenance of solar systems within the end user locality increases their trust. With the uniqueness of the most of the solar energy products, it is necessary to localise their maintenance capacity especially where these technologies are being marketed. However, due to the scattered nature of end-users in rural areas linked to their limited buying

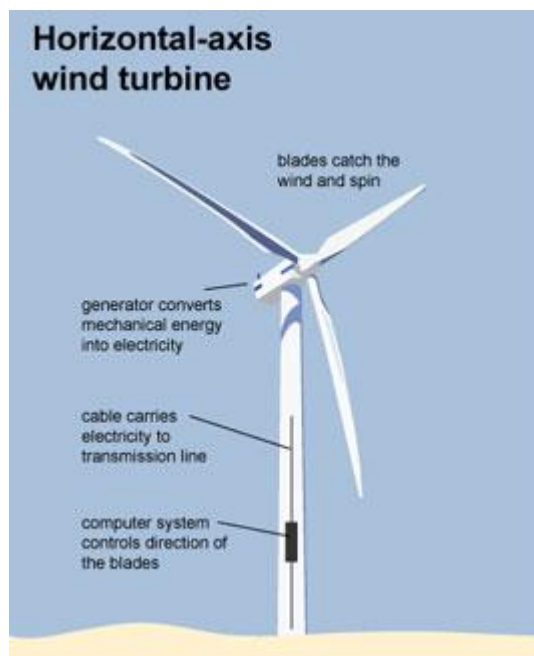
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<sup>10</sup> A Pico PV system is defined as a small PV-system with a power output of 1 to 10W, mainly used for lighting and thus able to replace unhealthy and inefficient sources such as kerosene lamps and candles

capability makes the concept of setting up maintenance centres in the distribution regions unattractive.

### 3.2.3. Wind energy

Wind turbines generating electricity several turbine types exist but presently the most common



**Figure 12: Horizontal axis three bladed wind turbine, (19)**

configuration has become the horizontal axis three bladed turbines (Figure 15). The rotor may be positioned up or downwind (although the former is probably the most common). Wind turbine produces power by converting the force of the wind (kinetic energy) acting on the rotor blades (rotational energy) into torque (turning force or mechanical energy). This rotational energy is used either within a generator to produce electricity or, perhaps less common only, it is used directly for driving equipment such as milling machines or water pumps (often via conversion to linear motion for piston pumps). Water pumping applications are more common in developing countries.

Modern wind turbines vary in size with two market ranges: small units rated at just a few hundred watts up to 50-80 kW in capacity, used mainly for rural and stand-alone power

systems; and large units, from 150 kW up to 5 MW in capacity, used for large-scale, grid-connected systems. The dissemination of wind pumps in selected African countries by 2008 is shown in Table 7 (2). Preliminary wind power potential (density) in the country is estimated to be around 350 W/m<sup>2</sup> in several isolated regions and would therefore considered to be suitable for wind power development. (AHK 2013)

**Table 7: Average wind speed potentials and number of wind pumps for selected countries in Africa, (Karekezi et al. 2003)**

Country	(Average) wind speed potential (m/s)	Number of wind pump
Botswana	2-3	200
Burundi	>6	1
Djibouti	4	7
Ethiopia	30.5-5.5	—
Eritrea	3-8	<10
Guinea	2.0-4.0	—
Kenya	3	272
Mauritius	8.0	—
Morocco	>10	—
Mozambique	0.7-2.6	50
Namibia	—	30,000
Rwanda	—	—
Seychelles	3.62-6.34	—
South Africa	7.29-9.7	300,000
Sudan	3	12
United Rep. of Tanzania	3	58
Uganda	4	7
Zambia	2.5	100
Zimbabwe	3-4	650

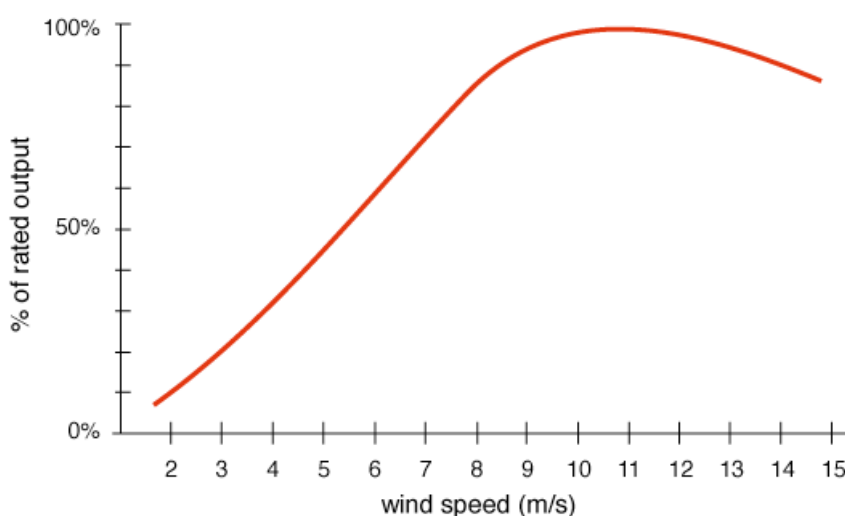
**Table 8: Strengths and weaknesses of wind energy systems, (UNIDO 2010)**

Strengths	Weaknesses
Technology is relatively simple and robust with lifetimes of over 15 years without major new investment	Site-specific technology (requires a suitable site)
Automatic operation with low maintenance requirements	Variable power produced therefore storage/back-up required.
No fuel required (no additional costs for fuel nor delivery logistics)	High capital/initial investment costs can impede development (especially in developing countries)
Environmental impact low compared with conventional energy sources	Potential market needs to be large enough to support expertise/equipment required for implementation
Mature, well developed, technology in developed countries	Cranage and transport access problems for installation of larger systems in remote areas
The technology can be adapted for complete or part manufacture (e.g. the tower) in developing countries	

Grid-connected wind turbines are mainly through large-scale installations either on land (on-shore) or in the sea on the continental shelf (off-shore). In addition, smaller machines are now being grid-connected. This principle can be used to contribute to a more decentralized grid network and/or to support a weak grid. Wind turbines do, however, generate electricity

intermittently in correlation to the underlying fluctuation of the wind. Because wind turbines do not produce power constantly and at their rated power (which is only achieved at higher wind speeds)

capacity factors (i.e. actual annual energy output divided by the theoretical maximum output) are typically between 20 per cent and 30 per cent. One of the principal areas of concerns of wind energy is its variable power output, which can create network problems as the share of intermittent generation on the grid rises.



**Figure 13: Power curve of small wind turbines, (Anon n.d.)**

The most common stand-alone wind turbines involve the use of a wind generator to maintain an adequate level of charge in an electrical storage battery. The battery in turn can provide electricity on demand for electrical applications such as lights, radios, refrigeration, telecommunications, etc., irrespective of whether or not the wind is blowing. A controller is also used to ensure that the batteries are not damaged by overcharging (when surplus energy is dissipated through a dump load) or excessive discharge, usually by sensing low voltage. Loads connected to the battery can either be DC or AC (via an inverter).

Small wind battery charging systems are most commonly rated at between 25-100 W for a 10m/s wind speed, and are quite small with a rotor diameter of 50 cm to 1 m. These systems are suitable for remote settlements. Larger stand-alone systems, incorporating larger wind electricity generators and correspondingly larger battery banks (at an increased cost) are also available, these may include other renewable energy technologies, such as PV, as well as diesel generators to ensure that the batteries are always charged and that power availability is high. Less common is the stand-alone system which does not incorporate a battery bank. This involves the use of a wind turbine with, at least, a diesel generator, which will automatically supply power when required. This has the advantage of not requiring a battery bank but the required control systems are complex.

Wind turbines for water pumping most common type is the wind pump which uses the wind's kinetic energy to lift water. Wind pumps are typically used for water supply (livestock or human settlements) or small-scale irrigation.

### 3.1.3 Challenges for small wind turbine in rural and peri-urban areas

**Cost of technology:** Cost remains to be the most influential factor for the deployment of small wind turbines (SWTs.) In Europe, the installed cost of a SWT ranges from 2.100 to 7.400 € per kW and the electricity production cost between 0,15 to 0,30 € per kWh. Within this spot, competitiveness of the sector is linked to the possibility of reducing the technology costs and be in such parity with the energy trading, so that the SWT technology is attractive to the targeted market. (7)

**Site selection:** Wind resource assessment stands a delicate drawback for SWT. Accurate prediction of the wind speed is essential to calculate the electricity output of a wind turbine, representing the basis for economic performance. Wind evaluation currently presents challenges for the small wind industry owing to the fact that assessments are site specific and time consuming. This means that wind energy development requires some initial investment for careful wind prospecting. Good equipment and quality work is needed, both being cost-intensive.

In urban areas, the shading and turbulence effect of surrounding obstacles produces inconsistent and unpredictable wind patterns below 30 m. As a result, the vast demand for inexpensive and efficient methods of predicting and collecting local wind data is another key driving factor that requires further innovation and cost reduction in the technology.

**Wind resource database:** The Ministry of Energy (MoE) has made some progress in this area but suppliers of wind turbines often rely on meteorological data and customers' observations to determine whether particular site is viable. Such information may not be available or misleading and could lead to installation of poorly performing or non-performing systems.

**Aesthetic, noise and vibration:** Noise emission is one of the major concerns of SWTs one, which are mostly erected into the urban areas. Tonal noise emitted from the wind turbine installations, such as gearboxes or electrical power transmission parts, vibration excitation mechanism is resonance of the dominant whirling mode of the turbine, aesthetic issues are key enablers for the social acceptance of these systems poses an environmental and social acceptance problem especially in urban environment.

**Low awareness:** Majority of people in the target areas have no previous experience or knowledge of wind system. There is generally low public awareness for wind energy.

**Local capacities:** Areas in the Northern Kenya that have the highest potential for wind energy generation have poorly developed local technical capacities for grid integration and system management due to the early stage of the market development for grid-connected systems. Activities for capacity development are necessary

## 4. Approach and Methodology of study

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### 4.1. Approach

The present study is based on the hypothesis that low-cost green technologies have potential to sustainably improve access to safe drinking water and sanitation services in Kenya.

The study follows a stepwise process on the applicability, scalability and sustainability of each selected technology to provide lasting services in a specific context and on the readiness for its introduction (Washtech and Skat Foundation 2013). The process entails the application of various methodologies to access (a) the technical (types of technologies and materials required, skills and knowledge required and potential technology providers), (b) the economic (cost effectiveness, price of materials, operation and maintenance costs, current demand and supply) and (c) the social feasibilities (potential to create employment, attitude and perception, land use patterns, gender and governance issues) of the selected low cost technologies.

The data and information needed will be collected through secondary data collection (e.g. extensive desk studies including scientific articles, reports etc.) and primary data collection through field visit in the target counties described in 2.3 and Annex V. The field visit will be conducted by the consultant who will be assisted by field assistants for the purposes of maximizing responses and translating the designed survey tools (users' questionnaire, water manager questionnaire, focus group discussion, observations and key informant semi-structured interviews). The use of the various survey tools will ensure triangulation of data, so as to allow validation of the data collected from different sources. All relevant actors will be involved in the collection of data and in the generation and discussion of results. This allows a wide range of actors to bring in their perspectives and views, including representatives from national and county government, private sector and technology users such as communities.

The study will use mixed-method and experimental design that creates a representative sample for the data collection. The team will ensure in-person site visits and data collection at all of the sample locations, and maximize the use of existing valid data resources to help assess the reality of the hypothesis.

Appreciation will be given to the following when undertaking the data collection and analysis:

- Integrity – being true to oneself is a personal core value of each of the consultants as well as being true to the assignment as a research ethic.
- Flexibility – maintaining a reflective review process is a crucial component of developing and implementing any consultancy assignment in order to capture unexpected risks or results.
- Informed – implying a thorough understanding of the principles of performance assessment and development of water supply sector in Kenya and differing enabling environments.
- Insightful – to ensure the approach is insightful the consultants have drawn on known methodologies for undertaking such an assignment.
- Objectivity – in order to minimise the risk of subjectivity a mixed method design is proposed where qualitative data will be used to triangulate quantitative data analysis.

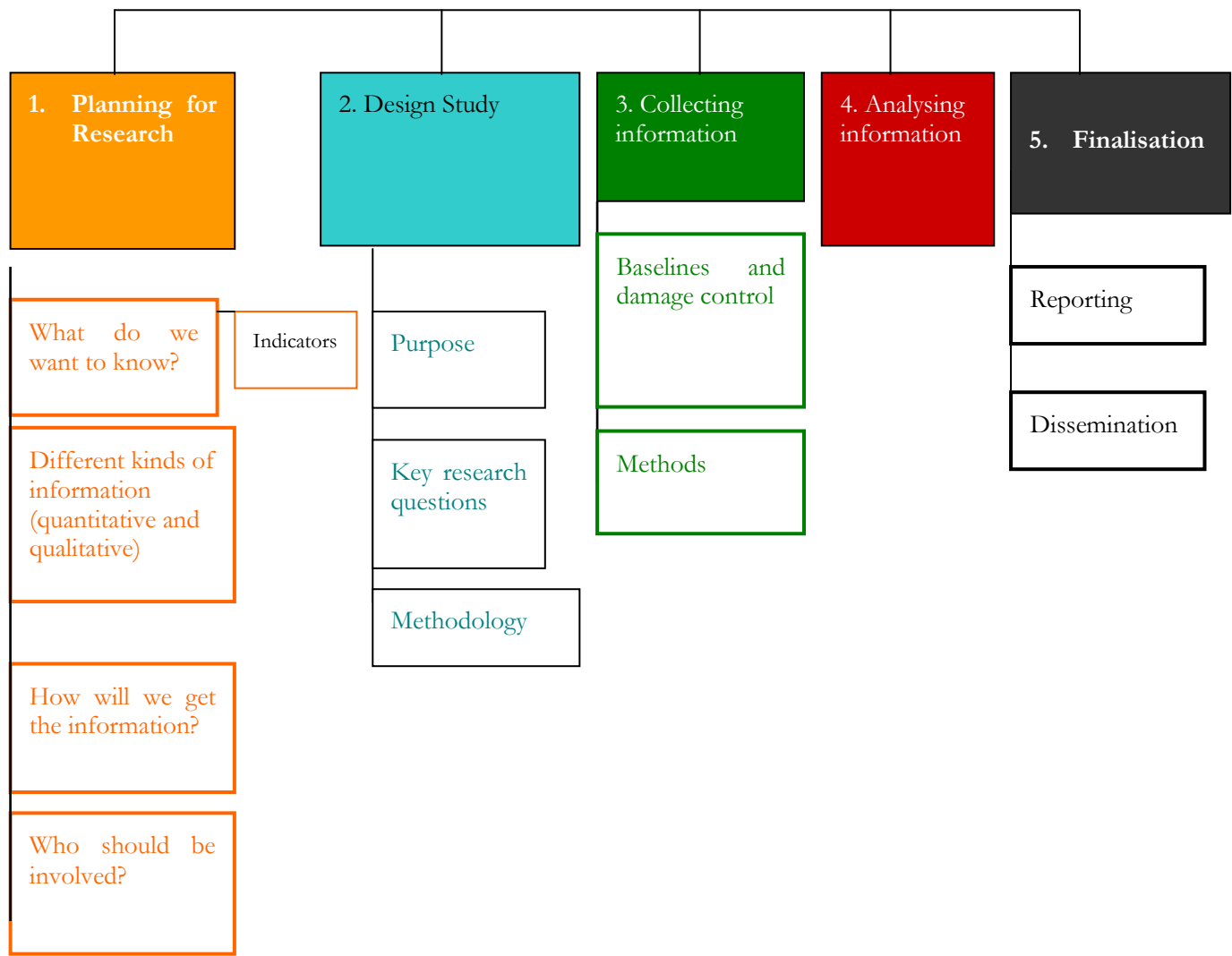


4.2. Overall study proces

The different stages followed in the study process are outlined in Table 9 below.

- Stage 1:** the objective is to understand fully the precise objectives of the technology assessment and to tailor the survey and reporting against these. The background situation and stakeholder involvement will help to gain a fuller understanding of the context and background.
- Stage 2:** aims to prepare and agree on well-defined research questions that need to be addressed and which will affect the choice of data collection tools to be used. Different quantitative and qualitative analysis methods will be used to provide strong evidence of achievement against the key research questions.
- Stage 3:** aims at collecting data that will enable to answer the identified research questions.
- Stage 4 & 5:** stage 4 and 5 involve data analysis and elaboration of report, based on the date gathered in stage 3.

Table 9: Study Process



### 4.3. Research Questions

To provide a better understanding of the study and its main objectives, it is necessary to set up the study result areas based on the key areas of assessments (technical, economic and social) and develop research question around these result areas. As mentioned, the main objective of the study is to analyse the technological viabilities of solar, wind pumping systems and water pans in term of their availability, accessibility, affordability and acceptability, as these factors are known to have influence on the successful uptake and sustainability of low cost technologies for sustainable water supply. A technology is therefore technically viable if it is durable, reliable at all times during various climate extremes and has the capacity to address users' needs. Based on the economic aspects, a technology is deemed viable if it is cost effective in terms of its' capital cost, operation and maintenance and whether these costs are sustainable. Finally, a technology is deemed viable if it is socially acceptable, transformative in term of job creation and improved livelihoods, and if it is inclusive in the sense that it allows an equitable access to water by both men and women. As a result the three key research questions that will be addressed in the feasibility study are the following:

1. Do the identified green technologies provide functional mechanism for climate proofed water supply?
2. Do the identified green technology cost effectively and sustainably increase water supply in the target areas.
3. What are the community's attitudes and perceptions of the specific technologies for water supply?'

The figure below summaries the rationale behind the study's key research questions;



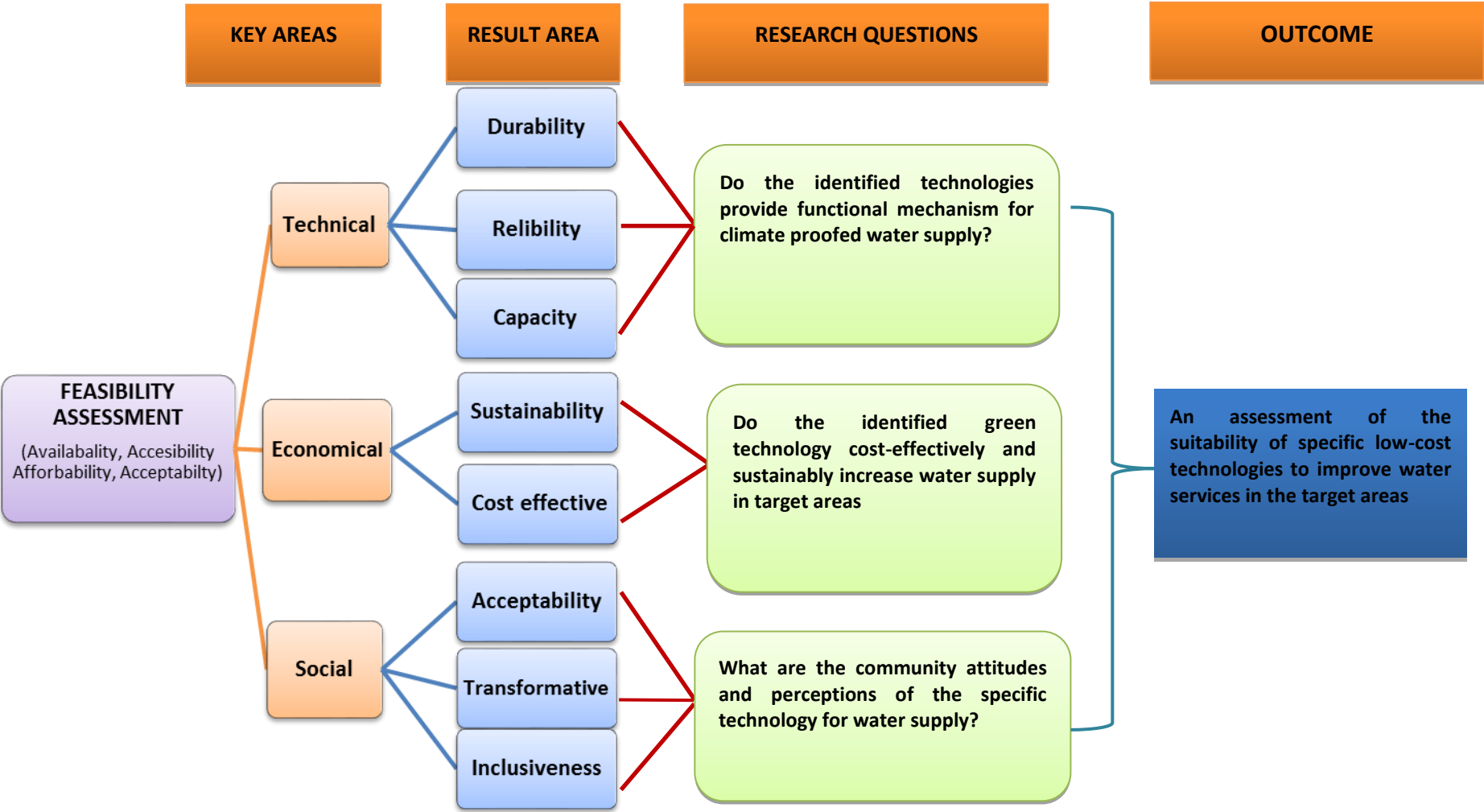


Figure 14: Key areas and Research Questions

Based on the research questions outlined above, in depth analysis will focus on sustainability indicators considering the functional conditions of the identified technologies, including the financial, social, institutional, legal, environmental, technical, and capacity-related aspects, from the perspectives of three key actor groups: (i) users/buyers, (ii) producers/providers, and (iii) regulators/investors/facilitators. For each match of dimension and perspective an indicator is selected. For each of the 18 indicators, questions are developed and answers will be collected from the identified key actors during the field visits.

		Perspectives of Key Actors		
		User/buyer	Producer/Provider	Regulator/ investor/ facilitator
Sustainability Dimensions	Social	1) Demand and preference of the technology	2) Technology uptake	3) social marketing and equitability
	Economics	4) Affordability / Price	5) Cost recovery/ Profitability	6) Public Benefit (priorities)
	Environmental	7) Water quality	8) Resilience of water supply	9) Reduce vulnerability, impact on health
	Legal and Institutions	10) Responsiveness, friendly	11) Model of delivery, access level	12) Alignment laws/policy/strategies
	Skill and Knowledge	13) Ease to use and manage	14) Skills for operation and maintenance	15) Capacity for monitoring, evaluation and technology validation
	Technological	16) Capacity, reliability to meet demand	17) durability , serviceability	18) Deployment/ up-scaling technology

**Table 10:** Technology adaptation indicators from the perspectives of different actors (adapted Hostettler & Hazboun 2015)

#### 4.4. Description of Methodology

The linkages between research questions and the choice of data collection tools and methods applied in the present study are presented in table 11 below. A detailed description of the specific data collection tools applied is presented below.

##### 4.4.1. Document Review/ Secondary research

This will include a comprehensive document and data archive review in order to establish an analytical base from which to conduct the data collection and analysis. The review will seek data from literature to provide background on issues where information cannot be collected verbally with key informant interviews or through questionnaires. The secondary data collection is based on the review of:

- Strategy documents
- Project and study reports
- County/district development plan
- GOK line ministry/department reports
- Scientific articles
- Other relevant reports or documents

#### 4.4.2. Key Informants Interviews (KII), semi-structured interviews (SSI): and Focus Group Discussions (FGD)

A mix of semi-structured interviews for the key informants and focus group discussions will be used to guide the qualitative data collection process. Interviews will be conducted with the line ministries staff, Implementation agencies staff, key community leaders, technology providers and other individuals deemed resourceful to gain more in depth understanding of the identified technologies, their technical economic and social aspects based on their experiences. Key guiding questions will be adapted for the different types of stakeholders. The flexibility of semi-structured interview for the key informants and focus group discussions bring a richness of discussion and allows the participants to talk freely around the subject, allowing also new insights on issues that were not necessarily expected beforehand. Interviews will be held through face-to-face interaction, telephone or Skype, or a combination. The focus group discussions will compose of a minimum of five people so as to allow the facilitator to coordinate the discussion and avoid biases of responses from one individual.

#### 4.4.3. Technology Survey Questionnaires

Survey questionnaires (60) have been developed with inputs from WSTF and will be used to gather relevant information on the selected technologies. Both quantitative and qualitative data will be collected using ODK mobile application Android smartphones and displayed online.

This enables a more accurate collection of data, which is also easier to gather and share. Data can be collected in areas where there is no mobile connection, as it is automatically transmitted once a connection is detected. Results are made available in real time, leading to better decisions.

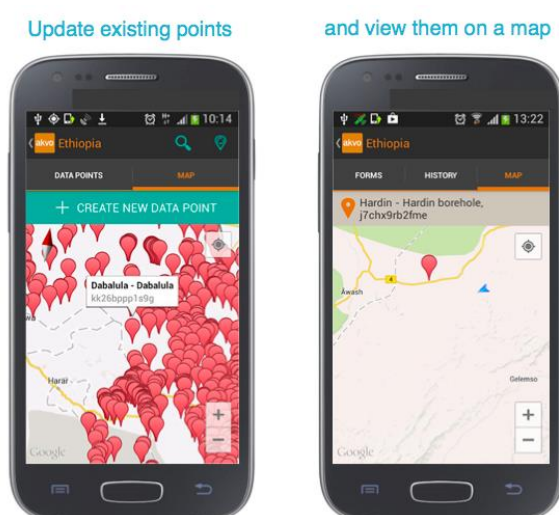
A minimum of 80 technology points will be sampled and distributed across four counties. Field survey will identify points by snowball sampling based on referral by stakeholders at the county level, field guides and community members in target areas. The field study will take 24 days in the targeted areas.

#### 4.4.4. Observation

It will be important to observe progress being made and adoption of technologies being promoted so as to get a picture of the situation on the ground.

Observations will be undertaken in the field by enumerators and summarised in the daily summary tool (74). This will be used to inform on the technology context, especially with regards to issues that may not be adequately captured in the questionnaires and interviews. Observations will be very useful especially in explaining the performance of a given technology point and will examine among others:

- Size, capacity and quality of technology and nonconformity



- State of technology e.g. the state of water pan, solar and wind installation
- Physical environment of the site e.g. the environmental hygiene and sanitation which will be captured through the use of photographs.
- Protection systems e.g. the fencing among others
- Other aspects that may be of interest to the team

The table below describes the type of respondent for each survey tool and the factor influencing the choice of the respondent.

**Table 11: Summary of the data collection tools**

Survey Tool	Respondent	Choice of respondent	Research question answered
Water Manager survey tool	Caretaker or a member of the community technology management committee	The choice of respondent was greatly influenced by the direct contact with the technology in terms of its; <ul style="list-style-type: none"> <li>- Technical operation</li> <li>- Cost of operation and maintenance,</li> <li>- Revenue collected,</li> <li>- Challenges in operation and maintenance of the technology</li> <li>- Skills and know-how of technology operation of a respondent.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Do the identified technologies provide functional mechanism for climate proofed water supply?</li> <li>▪ Do the identified green technology cost-effectively and sustainably increase water supply in target areas</li> <li>▪ What are the community attitudes and perceptions of the specific technology for water supply project?</li> </ul>
Water user survey tool	The water user	The choice of respondent was influenced by: <ul style="list-style-type: none"> <li>- A person daily interaction with the technology during obtaining water.</li> </ul>	<ul style="list-style-type: none"> <li>▪ What are the community attitudes and perceptions of the specific technology for water supply project?</li> </ul>
Semi Structured interview form/ Focus group Discussions	In line ministries in national and local government, Water Resources Management Authority, Water services boards, water services providers, civil society organizations and community management committee	The choice of respondent was; <ul style="list-style-type: none"> <li>- The ability to obtain first-hand knowledge on low cost technologies that enhances sustainable water supply in the study area</li> </ul>	<ul style="list-style-type: none"> <li>▪ Do the identified green technology cost-effectively and sustainably increase water supply in target areas</li> <li>▪ Do the identified green technology cost-effectively and sustainably increase water supply in target areas</li> </ul>
Field Observation	The field assistants	observation and examination on the technology sites to capture the technology condition	<ul style="list-style-type: none"> <li>▪ Observation will complement:</li> <li>▪ Do the identified technologies provide functional mechanism for climate proofed water</li> </ul>

			supply?
Case study tool	Field Assistants	Unique observations on the holistic operation of a technology based on its operation and maintenance, its development, its management and on its interaction with the larger community were captured through the use of the case study survey tool.	<ul style="list-style-type: none"> <li>Do the identified technologies provide functional mechanism for climate proofed water supply?</li> </ul>
Daily Report Tool	Field Assistant	The tool will give a summary of the day's activity	Complement all the research questions

#### 4.4.5. Methodological limitations and Mitigation of risks

The methodological limitations and risk mitigation measures of each of the tools used as part of this study are summarised in the table below.

**Table 12: Methodological Limitation and Mitigation measures**

Category	Methodological limitations	Risk mitigation measures
Literature review	Large number of documents to be collected from various sources	<ul style="list-style-type: none"> <li>- Conduct broad literature review and informative interviews and discussions with WSTF and relevant stakeholders to ensure access to relevant documents.</li> <li>- Researcher will focus on documents that specifically discuss selected of green technologies and climate change risk in water supply to low-income population segment</li> </ul>
Semi-structured interviews selection	<ul style="list-style-type: none"> <li>- Large number of people are involved with technology therefore making it difficult to select the key informant based on their extensive projects undertaken</li> <li>- Same template may not work for all interviews and conversation guidelines need adapted to the respondent's background / specific area of expertise which make analysis more complex</li> </ul>	<ul style="list-style-type: none"> <li>- Make careful selection of respondents taking to account the study objectives and WSTF mandate.</li> <li>- Develop different templates for different groups of stakeholders (Policy makers, implementers and management committee)</li> <li>- The evaluation team takes only recurrent topics into account in</li> </ul>



		the report.
Mobile Tools	<ul style="list-style-type: none"> <li>- Someone has to go through the questionnaire with respondent, which is time-consuming and may result in a limited number of respondents that can be reached</li> <li>- With questionnaire mobile tool it is not possible to explore what people are saying any further</li> </ul>	<ul style="list-style-type: none"> <li>- Recruit and train enumerators to support principal researcher</li> <li>- Complement with significant change stories and case studies in which the respondents tell the situation in their own words</li> </ul>
Focus groups	<ul style="list-style-type: none"> <li>- Risks of not capturing important information being discussed.</li> </ul>	Focus groups interviews should be recorded and then transcribed.
Participant observation	<ul style="list-style-type: none"> <li>- It may be difficult to observe and participate. The process is very time-consuming.</li> </ul>	Survey undertaken by team of 2 or 3 enumerators

#### 4.5. Key Stakeholder Selection

The main partners for this study are the Water Services Trust Fund being the primary beneficiary institution and originator of request for the CTCN technical assistance, Kenya Industrial Research and Development Institute (KIRDI) as the National Designated Entity (NDE), Ministry of Environment & Natural Resources, Ministry of Water and Irrigation and the Danish Embassy in Kenya who are supporting green growth water investment programme 2016-2020

Key stakeholders have been identified by purposive sampling in discussion with WSTF. These include the Water Resources Management Authority (WRMA), Water Services Regulatory Board (WASREB), Water Services Board, National Environment Management Authority (NEMA), Ministry of Energy Renewable Energy companies Local and International institutions of higher learning and County authorities and water services providers. The latter two carry legal mandate and investment in water supply. Other stakeholders involved in the study include communities and implementing partners, technology providers (e.g. Davis and Shirtliff<sup>11</sup>, Gosolar<sup>12</sup>, and Kenital<sup>13</sup>), practitioner associations (Kenya Renewable Energy Association<sup>14</sup> and Kenya Water Industry Association<sup>15</sup>, Institution of Engineers of Kenya<sup>16</sup>) and NGOs implementing water solutions (53).

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<sup>11</sup> <https://www.davisandshirtliff.com/>

<sup>12</sup> <http://www.gosolarltd.com/>

<sup>13</sup> <http://www.kenital.com/>

<sup>14</sup> <http://kerea.org/>

<sup>15</sup> <http://www.kwia.org/>

<sup>16</sup> <http://www.iekenya.org/>

Pre-field stakeholder meetings will be held with WSTF and county official before starting field activities in each target area. The objective of the meetings is to get a wider understanding of the water supply and technology status in each county, refine research questions and data collection instruments and review available data sources from related project by other players. The meetings will also be used to discuss study logistics and the study processes.

Other key stakeholders will also be consulted throughout the data collection process to ensure inclusivity, focus and alignment with the broader study objectives. Participating in obtaining divergent data from various sources will also provide a means to test and gather ideas, fill in possible data gaps and allow feedback by key stakeholders for the dual purpose of validating key assumptions and findings and to trigger discussion around previously un-captured ideas.

#### **4.6. Ethical Considerations**

The study will be undertaken with a strong understanding of ethical considerations. Focus will be placed on establishing good relations between the enumerator and the respondents on the one hand, and between the team and the community on the other hand. Informed consent of the respondent will be sought, and the source of information collected during this study will not be disclosed without the consent of the respondents. Unrealistic promises are avoided in the entire study period by properly explaining to the consenting respondents that participation in the research is voluntary and that they should not expect any reward in return. The time for FGD administration will be negotiated with the participants to guarantee their active participation without compromising their major daily livelihood activities.

#### **4.7. Preparation of tools and ‘training’**

Before embarking on the field study various preparation on the survey tool and field assistant training will take place to ensure that all the assistants has a complete understanding of the purpose and procedures of the feasibility study. The consultant will conduct a familiarisation session to review the research questions and the data collection instruments. By the end of the training it is expected that there will be a good common understanding of the study indicators and how to respond to the questionnaires.

During the training, the following areas will be highlighted:

- Explanation of the survey justification and objectives
- Courtesy and ethical aspects of research
- Taking participants through the questionnaire and explaining how they should fill it.
- Simulation on questionnaire administration.

#### 4.8. Sampling Plan - Cluster Selection and Sample Size

In designing this study, the four selected counties were drawn upon the nationally representative sample within the seven ecological zones in Kenya mainly humid, sub-humid, semi-humid, semi-humid to semi-arid, semi-arid, arid and very arid and the peri-urban areas in these counties. Further, study areas within these counties will be identified through cluster sampling through the use of electoral administrative and electoral boundaries. The electoral wards within each county will be listed and used as the basic clusters. The study clusters will then be randomly selected from the list of electoral wards. Exact technology points will be identified by snowball or referral sampling by stakeholders and community members at the county level, field guides and survey participants in target areas.

**Table 13: Sampling process template**

County		District		Location	Technology	
	Sub-County	Total Ward	Population size	Sampled Ward	Sampled Technology	Total nos (if known)
County A	A1	xx	xx	A11	A	xx
					B	xx
					C	
				A12	D	xx
					E	xx
					F	xx
					G	xx
				Sub Total		
	Sub-County A1 Subtotal		xx			
	A2	xx	xx	A21	H	xx
J					xx	
K					xx	
Sub Total						
Sub-County A2 Subtotal		xx				
County A Total		xx	xx (xx %)			
County B	B1	xx	xx	B11	L	xx
					M	xx
					N	xx
					Sub Total	
	Sub-County B1 Sub Total		xx			
	B2	xx	xx	B21	O	xx
					P	xx
					Q	
	Sub-County B2 Sub Total		xx			
	B3	xx	xx	B31	R	xx
S					xx	
T					xx	
Sub Total						
Sub-County B3 Sub Total		xx				
GRAND TOTAL		xx	xx (xx %)			
(National)						

## 4.9. Risks in the field

### a. Security

The security situation in Isiolo and Baringo is very unpredictable due to presence of various groups of bandits, hence a contingency plan to revise planned study area as determined by security situation on the ground.

### b. Language

Language barriers will be managed by recruiting enumerators from the area. While translation of the tools into local language may not be necessary, the tools will be thoroughly discussed and a common understanding of the questions developed. Pre-testing of the questionnaire during the training of the enumerators will help clarify potential language difficulties.

### c. Sites Accessibility

Long distance to sites constitutes a challenge to access the sites and start field work early, both for research team and respondents. This challenge will be tackled by enumerators working late to complete the day-to-day's assignments.

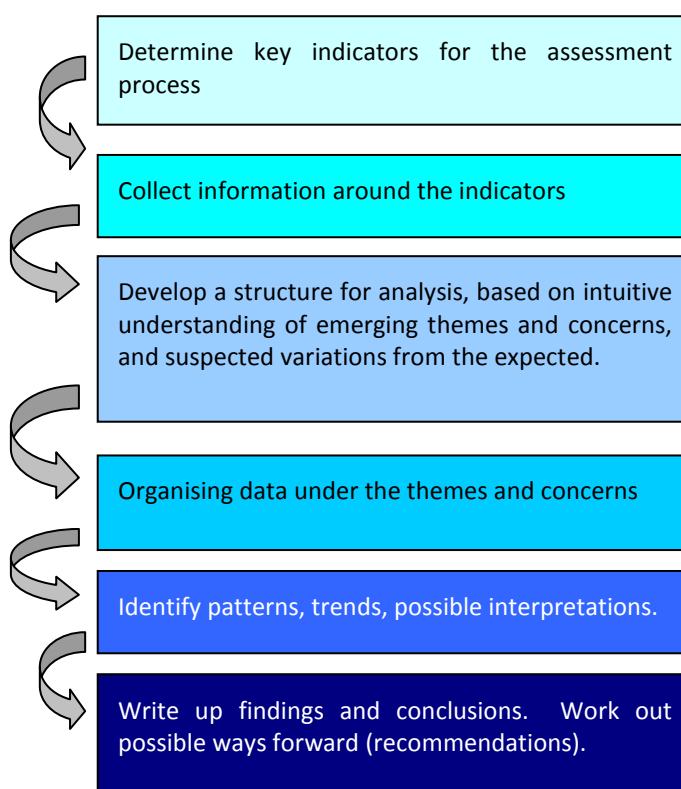
The data collection will take place during the rainy season in Kenya and it is therefore possible that some parts of the target areas will be inaccessible or difficult to access. It is anticipated that the use of four wheeled vehicles will minimise this risk.

## 4.10. Analysing of data and information

The analysis will turn the detailed information into an understanding of patterns, spatial distribution of technology, trends and interpretations.

The starting point for the analysis will be the intuitive understanding of qualitative data coming out of information gathering process, and in this way establish links between the study objectives and the summary findings derived from the raw data.

Analytical or methodical treatment of data combining graphical analysis<sup>17</sup>, contingency tables or cross tabulation<sup>18</sup> and statistical summaries will be adopted for all



**Figure 15: The process of data and information analysis**

<sup>17</sup> Graphical depiction of data using charts, figures and graphs

<sup>18</sup> Matrix format table that displays frequency distribution of variables

collected data types.

#### 4.10.1. Data processing, reduction and cleaning

Data reduction<sup>19</sup> will be incorporated before analysis of data. Data reduction entails transforming responses into a clustered and simplified form around key variables. Data reduction will allow reduction of multitudinous amounts of data into simpler and meaningful form.

#### 4.10.2. Data analysis and presentation

SPSS DE version 13 will be used to analyse quantitative data obtained from the field activity whereas qualitative data will be analysed through the inductive approach which will entail grouping the data and looking for relationships.

The results will be presented in tabulations, charts and blending of narratives collected from the semi structured interviews from key informants and focus group discussions with the statistical findings. Notes generated from the Focus Group Discussions, key informants interviews and documents reviews will be summarized to key points.

The Key points are then be used to validate the statistics and information generated from the water manager survey tool. To ensure data security, passwords for computers and databases, lockable cabinets and other security measures will be employed.

#### 4.10.3. Data quality

Data quality will be assured by way of triangulating the data. This will be achieved by collection of data from various methods described above as well as the use of divergent methodologies. Triangulation of data is expected to strengthen the feasibility report due to increased credibility and validity of the data collected through:

- a. Data source triangulation— Achieved through using evidence from different types of data sources, such as primary and secondary research or interviews, documents, , photographs and observations
- b. Methodology triangulation—achieved by way of combining multiple methods to gather data, such as documents, interviews, observations, questionnaires or surveys.



<sup>19</sup> Miles, M. B and Huberman, A. M (1994), qualitative data analysis: an expanded source. ed, Sage

**Figure 16: Aspects of data quality**

The following data quality dimensions defined the threshold for the weighting and ensuring the obtained data is an accurate measure.

The aspects are defined below on how their significantly contributed to the data quality as whole.

- ✓ Validity: Are all the data values within the value domains specified by the research questions?
- ✓ Accuracy: Does the data reflect the real world observations?
- ✓ Consistency: is data consistence between the various survey tools?
- ✓ Integrity: are the relations between entities and attributes consistent?
- ✓ Timeliness: is the data available in the time needed
- ✓ Completeness: is all necessary data present

#### **4.11. Summary of the research design**

The table below outlines the various sources of data to be obtained to answer the outlined research questions, the best suited data collection method for each identified source and the type of analysis suited for each collected type of data.

**Table 14: Summary of Research design**

Research question	Specific Result Area	Source of Data	Data collection techniques/tools	Data Analysis	Interviewees
Do the identified technologies provide functional mechanism for climate proofed water supply?	Assessing Technology Durability	<ul style="list-style-type: none"> <li>- Water sector stakeholders (MoWI, county Governments, WSPs)/partners(NGOs, CBOs, donors)/ beneficiaries</li> <li>- WSTF and other Water sector institutions</li> <li>- Documents</li> </ul>	Literature review, Survey questionnaire, Key Informant Interviews (KIIs), SSI, Focus Group Discussions (FGDs), observation	- Frequencies for quantitative data	Selected stakeholders (County Government, WSPs, MoWI, MENR, NGOS, CBOs, WRMA, WASREB, WRUAs)
	Assessing Technology reliability	<ul style="list-style-type: none"> <li>- Water sector stakeholders/partners/ beneficiaries</li> <li>- WSTF and other Water sector institutions country programs document</li> </ul>		- thematically for qualitative data	
	Assessing Technology capacity	<ul style="list-style-type: none"> <li>- Water sector stakeholders/partners/ beneficiaries</li> <li>- WSTF and other Water sector institutions country programs document</li> </ul>		- graphical and contingency table for Categorical, ordinal and interval data	
Do the identified green technology cost effectively and sustainably increase water supply in the target areas?	Assessing Technology cost effectiveness	<ul style="list-style-type: none"> <li>- Water sector stakeholders (technology supplies for waterpans, wind and solar pumps/partners/ beneficiaries</li> <li>- Capital cost O&amp;M plans (if available) services</li> </ul>	Literature review, survey questionnaire, KIIs, SSI, FGDs	<ul style="list-style-type: none"> <li>- SPSS for quantitative data</li> <li>- graphical and contingency table for Categorical, ordinal and interval data</li> </ul>	Water Committee and technology caretakers, technology suppliers, technology financiers
	Assessing Technology sustainability	<ul style="list-style-type: none"> <li>- Water sector stakeholders/partners/ beneficiaries</li> </ul>	Literature review, survey questionnaire, KIIs, SSI, FGDs	<ul style="list-style-type: none"> <li>- chi-square and t-test for quantitative data</li> <li>- graphical and contingency table for Categorical, ordinal and interval data</li> </ul>	
What are the community attitudes and perceptions of specific technology for water supply?	Assessing Technology acceptability	<ul style="list-style-type: none"> <li>- Community water committees, beneficiary community</li> </ul>	User survey questionnaire, KIIs, FGDs, observation, KIIs, FGDs, observation	<ul style="list-style-type: none"> <li>- Graphical and contingency table for Categorical, ordinal and interval data</li> <li>- thematically for qualitative data</li> </ul>	Technology beneficiaries, technology user
	Assessing Technology outcomes and emerging impact (transformative)	<ul style="list-style-type: none"> <li>- Community water committees, beneficiary community</li> </ul>		<ul style="list-style-type: none"> <li>- chi-square and t-test for quantitative data</li> <li>- graphical and contingency table for Categorical, ordinal and interval data</li> </ul>	
	Assessing the technology ability to influence community inclusiveness	<ul style="list-style-type: none"> <li>- Community water committees, beneficiary community</li> </ul>		- thematically for qualitative data	

#### 4.10.4. Gender Factor in Analysis

The data collected will be sex-disaggregated data to allow for the measurement of gender differences on various social and economic dimensions related to the identified technologies. Including a gender analysis in this assessment is essential, since both women and men are affected by the technology and their impacts on sustainable water supply in various different ways.

Enumerators shall include men and women, and deliberate effort to encourage gender diversity and excluded groups will be made.

#### 4.11. Reporting

The table tabulates different reporting and communication mechanisms appropriate for different stakeholders and at different times during the study.

Target group	Appropriate format
Study Team, WSTF, NDE and Key stakeholders	Written Draft and Final reports, presented verbally at the Inception, after field mission and Feasibility study
Donors, CTCN	Full written report with executive summary or a special version, focused on donor/financier concerns and interests.
Wider development community	Journal articles, dissemination workshop websites.

##### 4.11.1. Writing and quality assurance

The writing of the reports (draft and final) will be subject to review by UNEP DTU Partnership, WSTF contact person(s) and NDE focal person before submission as draft and final reports.



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## I. FINAL REPORT OUTLINE

### **Executive Summary**

#### **1. Introduction**

#### **2. Approach to study**

- 2.1. Objectives
- 2.2. Selection of technologies – Technical, social, economic and environmental parameters
- 2.3. Potential of Selected low-cost technologies for water services
- 2.4. Description of assessment methods

#### **3. Green infrastructure and Renewable Energy Developments Potential for adaptation and resilience in Kenya**

##### **Context Analysis**

- 3.1. Institutional and Policy Framework for water, energy and climate
  - 3.1.1. International
  - 3.1.2. National
- 3.2. Demographic studies (Target Counties)
- 3.3. Water resources availability and services coverage

##### **Technology Analysis**

- 3.4. Solar Energy Resources Potential
- 3.5. Wind Energy Resources Potential
- 3.6. Water Storage potential

#### **4. Embedding Low cost green technology in water services for climate adaptation and resilience**

- 4.1. Existing infrastructure
- 4.2. New infrastructure

#### **5. Analysis of Findings**

- 5.1. Governance, organizational, and enabling environment
- 5.2. Technical Analysis (capacity, reliability, durability)
- 5.3. Social Assessment (acceptability, inclusion, transformative)
- 5.4. Economics Analysis (cost effectiveness, benefits)
- 5.5. Environmental and climate risk assessment (risk mitigation, resilience, adaptation capacity)
- 5.6. Financial Mechanisms and financing opportunities
- 5.7. Technology risk and sustainability analysis

- 5.8. Suitability, replicability and up-scaling
- 5.9. Potential for Private sector engagement (PPPs)

## **6. Key messages/recommendations**

### Annexes

- County profile
- List of Participants and consultation
- Survey tools
- Drawings

## II. LIST ALL KEY PARTNERS AND STAKEHOLDERS

CATEGORY	ORGANIZATIONS	ROLE	STUDY RESPONSIBILITY	CONTACT
NATIONAL GOVERNMENT	Ministry of Water and Irrigation (MoWI)	Policy formulator	Provide insight on the country water status	Prof. Fred H. K. Segor P.O.BOX 49720-00100, Maji House, 6th Floor, Ngong Road, Tel: (25420) 271-6103 fksegor@yahoo.com  Eng. Lawrence N. Simitu, <a href="mailto:watersecretary@water.go.ke">watersecretary@water.go.ke</a> Eng. Kimathi Kyengo
	Water Services Trust Fund (WSTF)	Assist in financing the provision of water services to areas of Kenya which are without adequate water services	Assists in provision of data on the various project it has handled in the study areas Offer guidance and support during the study	Ismail Fahmy M. Shaiye P.O.BOX 49699-00100, CIC Plaza, Mara Road Tel : (25420) 272-0696 ismail.shaiye@waterfund.go.ke  Willis Ombai willis.ombai@waterfund.go.ke
	Water Resources Management Authority (WRMA)	Lead agency in the management of water resources in the country.	Provision of water points data Provision of information on ground water table in the selected area	
	Water Services Regulatory Board (WASREB)	Oversee the implementation of policies and strategies relating to provision of water and sewerage services	Advise of water tariffs which is critical in the study economic feasibility	
	Energy Regulatory Commission (ERC)	Regulate the electrical energy, petroleum and related products, renewable energy and other forms of energy.	Provide information on the renewable energy potential in the country	
				Dr Pacifica F. Achieng Ogola   Director Climate Change

				<p>Programmes Coordination Directorate of Climate Change  State Department of Environment Ministry of Environment and Natural Resources NHIF Building, 12th Floor, Ragati Road P. O. Box 30126 -00100 NAIROBI</p> <p>Cell Phone:+254 722 296396 Email: <a href="mailto:pacie04@yahoo.co.uk">pacie04@yahoo.co.uk</a> Skype: pacie03</p>
	National Environmental Management Authority (NEMA)	Oversee the implementation of all policies relating to environment	Currently working on the Green Climate Fund and will assist in provision of information and guidance to the technical aspects of the identified technology in respect to the study	Prof. Geoffrey M. Wahungu P.O.BOX 67839-00200, Eland House, Pepo Road off Mombasa Road Tel: (254206) 000-5522 <a href="mailto:gwahungu@nema.go.ke">gwahungu@nema.go.ke</a>
	National Drought Management Authority (NDMA)	Establish mechanisms which ensure that drought does not result in emergencies and that the impacts of climate change are sufficiently mitigated	Water plays a critical role in management of drought. NDMA will provide information on how accessibility of water can cushion against negative impacts of drought. Share on some of the projects is working on	Paul Kimeu <a href="mailto:paul.kimeu@ndma.go.ke">paul.kimeu@ndma.go.ke</a>
RESEARCH ENTITIES	Kenya Industrial Research and Development Institute (KIRDI)	Mandated to Carry out research and development in various fields	Play a critical role in research and development in the energy sector and therefore provide insight on renewable energy in regards to this study	Dr. Arthur S. Onyuka P.O.BOX 30650-00100, Popo Road off Mombasa Road, South C Tel: (25471) 930-0962 (25420) 600-3884 <a href="mailto:arthuronyuka@hotmail.com">arthuronyuka@hotmail.com</a>
	Africa Centre for Technological Studies (ACTs)	Pioneering in development research think tank on harnessing	Provide insights on the various technology and innovation for	Joan Kariuki +254 711 494832

		applications of science, technology and innovation policies for sustainable development in Africa	sustainable water services	
COUNTY GOVERNMENT	County Department for Water	County oversight on water services	Provision of insight on county water status	
	Water Services Providers	Provide clean water and sewerage services	Provide information on water tariff and coverage especially in peri-urban setting	
PROFESSIONAL ASSOCIATIONS	Water Service Providers Association (WASPA)	WASPA is an association of Water Services Providers in the country and it provide to provide a forum for the various companies to learn from each other.	WASPA & KWIA will provide relevant information regarding water services coverage in the country	Maji House 5th Floor, Room 561 P.O. Box 25642-00100, Nairobi, Kenya
	Kenya Water Industry Association (KWIA)	Kenya Water Industry Association (KWIA) is a private sector Business Member Organization aimed at improving access to water in order to spur socio-economic development and impact lives and livelihoods positively.		kwiawater@gmail.com info@kwia.co.ke
	Kenya Association of Manufacturers (KAM)	Kenya Association of Manufacturers is the representative organisation for manufacturing value-add industries in Kenya	Manufacturers are the biggest consumers of water, there are a main stakeholder in this study	15 Mwanzi Road opp Westgate P.O Box 30225 – 00100 Nairobi Mobile: +254(0)722201368, +254(0)734646004/5 Tel: +254 (020) 232481
PRIVATE SECTOR	Davis and Shirliff	Supplier of water related equipment/ technology in East African Region	Provision of information on available low cost green technology to assist in answering up the technical and economic questions	Industrial Area, Dundori Road Nairobi P.O. Box: 41762-00100 Kenya Tel : +254-733 610085



	Epi-Centre Africa	Supply and Installation of Water Pumps, Power Generator sets, Solar Power Systems, Water Treatment Equipment's and associated items.		Timothy Mutwii Sales engineer Tel;+254 729 851 106 sales@epicenterafrica.com
DEVELOPMENT ORGANIZATIONS	Kenya Climate and Innovation Centre (KCIC)	Provides holistic, country-driven support to accelerate the development, deployment and transfer of locally relevant climate and clean energy technologies.	KCIC will provide useful information on the deployment capability of the identified technologies based on its previous experiences	Edwards Mungai CEO Tel +254 722 733 324
	SNV	Provide advisory services, promote the development and brokering of knowledge, and support policy dialogue at the national level	SNV has been keen in WASH services in Kenya and therefore its programmes will provide insights on the possibility of deployment of the identified technologies	
	Millennium Water Alliance (MWA)	Offering sustainable solutions through advocacy, shared knowledge, and collaborative programming	MWA is engaged in various programme in the water sector	
	Agile Harmonized Assistance for Devolved Institutions (AHADI)	USAID programme aimed at Strengthen the capacity of counties through training, mentoring and technical assistance for key leaders – building skills and accountability in governance and service delivery	AHADI is a key stakeholder in this study as it has engaged in developing a water policy for Isiolo county which is one county in this study	Waceke Wachira, Chief of Party AHADI Project Email: waceke@ahadi-devolution.org
	Cordiad	Drought risk reduction	Have various projects on drought risk reduction and therefore plays an important role in sharing lessons learnt	Mohamed Dida P.O.BOX 40278-00100 , 5th Floor, New Rehama House Rhapta Road,

				Westlands Tel: (25472) 188-4397 (25472) 220-3095 mohamed.dida@cordaid.net
	DANIDA	It has a thematic Programme on Green Growth and Employment	Provision of insight on its various project under green growth in relation to sustainable water provision	Anne N. Angwenyi P.O.BOX 40412 - 00100 Embassy of Denmark 13 Runda Drive Tel: (25420) 425-3000 annean@um.dk
	Adaptation Consortium	Strengthening Adaptation and Resilience to Climate Change	The consortium has worked closely with county governments on climate finance fund and therefore it will give critical information on climate adaptation through sustainable water services	Yazan A. Elhadi P.O.BOX 74247 - 00200, Bazaar Plaza, Biashara Strret, 2nd Floor Tel: (254737) 777-6276 yelhadi@adaconsortium.org

### III. TIMEFRAMES

[illegible]

#### IV. SURVEY TOOLS

##### Technology point manager/caretaker survey questionnaire

###### Section 1: General Information

1. Collect GPS coordinates (*automatic using mobile application*)
2. Name of the interviewer
3. County:
4. Sub-county:
5. Administrative Location, Ecological Zone:
6. Photograph of the technology:
7. Year of installation /construction:
8. Weather conditions during survey
9. Period since last rainfall

###### Section 2: Administrative Information

10. Specific technology point
  - a. Water Point (go to 11)
  - b. Others (specify) (go to 13)
11. Type of water sources of water? (*select all which applies*)
  - a. Borehole, depth (if known)
  - b. Shallow wells, depth (if known)
  - c. Water Pan
  - d. Small dam
  - e. River
  - f. Others.....
12. How many months in the year is water available
  - a. Never
  - b. 1 month
  - c. 2 months
  - d. 3 months
  - e. 3-6 months
  - f. 6-9 months
  - g. 9-12 months
  - h. Throughout

If not available throughout the year, why
13. Please specify energy source and application:
  - c. Solar powered (go to 14)
  - d. Wind powered (go to 15)
  - e. Diesel
  - f. Hand pump (go to 1817)

- g. Grid electricity (go to 1817)
  - h. Gravity (go to 1817)
14. How many cells are used for the solar system?
15. Specify the wind energy?
- a. Wind-electrical
  - b. Wind- mechanical
16. What is the height of the installed windmill? (metres)
17. Is water placed in a storage tank before distribution?
- a. Yes
  - b. No
  - c. If yes, what is the size of storage, (m<sup>3</sup>)
18. Who owns the technology?
- a. Community
  - b. Government
  - c. CSO
  - d. Private Company
  - e. Individual
  - f. Others.....
19. Who owns the land on which the technology stands?
- i. Community
  - ii. Individual
  - iii. Private Institution.....
  - iv. Public institution.....
  - v. Others.....
20. Type of uses (Select all that applies)
- a. Domestic (go to 21)
  - b. Institutional (go to 21 [ii] )
  - c. Livestock ( go to 22 23)
  - d. Farming (go to 24)
  - e. Industries
  - f. Others.....
- 21.
- i. How many households are served by this technology point?
    - a. 0-50
    - b. 50-100
    - c. 100-150
    - d. 150-200

- e. > 200; specify
  - ii. How many users are there in the institution?
22. What is the average number of individuals in a household? .....
23. How many animal are served by this technology point?
- a. Cattle.....
  - b. Sheep & Goat.....
  - c. Donkey.....
  - d. Camel.....
24. How many farmers are serviced by this technology point?
- a. 0-50
  - b. 50-100
  - c. 100-150
  - d. 150-200
  - e. > 200; specify
25. What is the average size of irrigated land for each farmer?
- Section 2: Financial Analysis
26. What is the source of construction finance? (Select all that applies and percentage Contributed)
- a. Donor
  - b. Government
  - c. Community
  - d. Private
  - e. Others.....
27. What is the approximate construction cost?
28. What is the source of operating and maintenance finance? (Select all that applies and percentage Contributed)
- a. Donor
  - b. Government
  - c. Community
  - d. Private
  - e. Revenue
  - f. Others.....
29. What are the main challenges experienced while using this technology? (Select all that applies)
- a. Equipment breakdown
  - b. Complex/difficult to operate

- c. Lack of spare parts
- d. Low revenues collection
- e. others (specify)

30. Who operates the technology?

31. Is the caretaker/ operator skilled?

- a. Yes
- b. No
- c. *If Yes*, What is his qualification?

32. Is there anyone who provides training to caretaker/ operator?

- a. Government
- b. technology supplier
- c. NGO
- d. Others (specify)

33. What are the normal operation costs of the technology?

- a. Fuel cost.....
- b. Operator salary.....
- c. Others (specify)....

34. How often is does the system undergo maintenance?

- i. Bi yearly
- ii. Quarterly
- iii. Yearly
- iv. > Year (specify).....

35. How long does it take for repairs to be addressed?

- i. 1-3 days
- ii. 4-6 days
- iii. 1 week
- iv. 2 Month
- v. > 2 month specify.....

36. Which components of the technology fails most often?

37. What is the approximate cost of maintenance per month.....

38. is any improvement that's needed to improve performance of technology

39. Who does the maintenance?

- a. County government
- b. Local technician
- c. External technician

- d. Technology supplier
- e. Others.....

40. Does the technology have
- a. Operation plan (Y/N)
  - b. Maintenance plan (Y/N)

41. How much is charged for the water?
- e. Domestic (per m<sup>3</sup>).....
  - f. Cattle.....
  - g. Sheep & Goat.....
  - h. Donkey.....
  - i. Camel.....

42. What is average amount collected in a month.....

### Section 3: Technical Analysis

43. Does the technology have the capacity to handle the water needs in the community?
- a. Yes
  - b. No
- If no, what is the problem?

44. What is the capacity / size of the technology
- a. If water storage.....m<sup>3</sup>
  - b. if borehole, yield .....m<sup>3</sup>/hour
  - c. If powered ..... ☐ watts ☐ kVA

45. On average, how many hours does it work in a day?.....

46. Does it work differently during different times of the day ?
- a. Yes
  - b. No

If yes, explain.....

47. Does it work differently during different times/seasons of the year?
- c. Yes
  - d. No

If yes, explain.....

48. Do you think the technology is reliable?
- a. Yes
  - b. No

If no, why.....

49. Consumer distance to this water technology point?



- a. What is the distance covered by the furthest consumer of this water Technology? (km)
- b. How much time does it take the furthest user to reach this technology point (Minutes)

50. Average distance to alternative water sources?

- c. How far is the alternative water sources from the nearest source (km)
- d. How much time does it take to reach the alternative water source (minutes)

#### Section 4: Social Analysis

51. Which technology do you think is best to enhance water supply in the area? (max three)

52. Are the users satisfied with the technology?

- a) Very satisfied b) Satisfied c) Not satisfied d) Very Dissatisfied (if not, why?)

53. What are some of the benefits accrued by the users of this technology

54. In your perception, what are the most important water related issues in this area?

55. Are you aware if there are water uses constrained by the amount of water available from this technology?

#### Section 5: Water Quality

56. Is the water good for purposes (drinking, livestock, irrigation)

57. Related to 56, what is the impact of the water quality on users?

## User interview questionnaire

### Instructions to participants:

*The Water Services Trust Fund is undertaking field survey on the potential of water pan, solar and wind energy to improve water service level in the underserved urban and rural areas across the country.*

*The survey will determine among others;*

- i. Prevalence of selected technology in different parts of the country,*
- ii. If technologies currently in use provide adequate water supply in different climate zones and seasons, otherwise the potential of the selected technology to overcome critical challenges facing water supply*
- iii. Arrangement that's best placed to make selected technology easily available and minimise operation failures.*

*Feedback from this study will greatly contribute to the social aspect of this assessment. Your participation will be appreciated and confidentiality will be observed with respect to your feedback.*

---

### **Part I Personal and General Data**

1. Date and time interview (automatic)
2. GPS coordinate (Automatic)
3. County, Ward and administrative location, Ecological zone
4. Name of the interviewer
5. What is your name? (Optional)\_\_\_\_\_
6. What is your telephone number and email address (if available)? .....
7. What is your gender? M ☐ ☐
8. What is your occupation?
9. How many members are there in your household?

### **Part II Existence of water sources and functionality**

10. Which is the common source(s) of your water supply:
  - i. Wet season
  - ii. Dry season

*(Provide selection list - tick more than one source where necessary)*

  - a) Piped network
  - b) Borehole
  - c) Water Pan
  - d) Sand Dams

- e) Shallow well
- f) Rivers
- g) Private rainwater tank , specfy construction material
- h) Others (Specify).....)

11. From the answer above, what method is used for abstracting water in your nearest source of water supply?

- a. Solar water pumping system
- b. wind pumping system
- c. Diesel pump
- d. Hand Pump
- e. Grid electricity
- f. Gravity
- g. None
- h. Others.....(specify)

12. How is water obtained from this technology used? (Select all that applies)

- g. Domestic
- h. Livestock
- i. Poultry and fishing rearing
- j. Farming
- k. Commercial (specify)
- l. Others.....

13. What is the current status of your main water sources in terms of functionality?

- a.) Functional (go to 19)
- b.) Non functional
- c.) Temporarily down
- d.) Don't know

If not functional or temporarily down, explain

14. How many months in the year is water available at the nearest water technology point

- a. Never
- b. 1 month
- c. 2 months
- d. 3 months
- e. 3-6 months
- f. 6-9 months
- g. 9-12 months
- h. Throughout

15. On average, how many hours in a day is technology at your nearest water source working?

16. Does the technology at your nearest point work differently in different time of day?

- e. Yes
- f. No

If yes, explain.....

17. Does the technology work differently in different times/seasons of the year?

g. Yes

h. No

If yes, explain.....

18. Do you think the technology is use at your nearest water source is reliable?

• Yes

• No

If no, why.....

19. In your own opinion, what are the main challenges observed in provision of water using this technology.....

### Part III Technology Point Operation and Management

20. Who is responsible for managing this technology?

a) County Government

b) NGOs/CBOs

c) Individual

d) private

e) None

f) Others..... (Specify)

21. If yes, how many times in a week are they present at the water sources?

a) Once a week ☐ b) Twice a week ☐ c) Three times and above ☐

d) Never present ☐ e) Do not know ☐

22. Is there water manager/caretaker resident in this community?

a) Yes ☐

b) No ☐

23. Usually, what is the gender of the water manager/caretaker?

a) Mostly males ☐

b) Mostly females ☐

24. Have conflicts over water arisen within the community since the technology was implemented?

If yes which ones and how was it resolved?

25. From the above mentioned technologies, in your opinion what improvement should be introduced to ensure water supply?

### Part IV Level Community Contribution towards O&M

26. How much do you pay for the water fetched?

27. Do people in your community contribute towards the following water services?

*You may tick more than one where necessary*

- |                              |     |                          |    |                          |
|------------------------------|-----|--------------------------|----|--------------------------|
| a) Initial investment cost   | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| b) Operation and maintenance | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| c) Do not contribute at all  |     | <input type="checkbox"/> |    |                          |
| d) Do not know               |     | <input type="checkbox"/> |    |                          |

28. Are you satisfied with how the caretakers respond to water and technology problems?

*Please indicate by ticking, whether you are; 1 = extremely satisfied, 2 = satisfied, 3 = dissatisfied or 4 = extremely dissatisfied, using a scale given between 1-4, with 4 being the highest score*

1 ☐      2 ☐      3 ☐      4 ☐

If not satisfied, why

#### Part V Level of support by government/NGO agencies

29. Is there any kind of support offered to your community or water management committee by the following agencies?

- |                                 |     |                          |    |                          |
|---------------------------------|-----|--------------------------|----|--------------------------|
| a) National Government agencies | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| b) County government            | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| c) CDF                          | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| d) NGO                          | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| e) Private contractors          | Yes | <input type="checkbox"/> | No | <input type="checkbox"/> |
| f) Others (Specify).....        |     |                          |    |                          |

30. Do you know what kind of support is provided by the above organizations?

31. If yes, how satisfied are you with the level of support to ensure provision and sustainability of water supply by these agencies?

*Please indicate by ticking, whether you are; 1 = extremely satisfied, 2 = satisfied, 3 = dissatisfied or 4 = extremely dissatisfied, using a scale given between 1-4, with 4 being the highest score*

- |                                 |                            |                            |                            |                            |
|---------------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| a). County government           | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input type="checkbox"/> |
| b). Sub County Local government | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input type="checkbox"/> |
| c). NGOs                        | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input type="checkbox"/> |
| d). Private contractors         | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input type="checkbox"/> |
| e). Others (Specify).....       | 1 <input type="checkbox"/> | 2 <input type="checkbox"/> | 3 <input type="checkbox"/> | 4 <input type="checkbox"/> |

#### Part VI Impact of Technology To the user

32. Are you satisfied with the technology being used

Yes ☐      No ☐

33. If no, why?.....

34. How can you rate the water technology easiness in use?

*Please indicate by ticking, whether you are; 1 = extremely satisfied, 2 = satisfied, 3 = dissatisfied or 4 = extremely dissatisfied, using a scale given between 1-4, with 4 being the highest score*

1 ☐ 2 ☐ 3 ☐ 4 ☐

35. Average distance/time to the nearest water point?

e. How far is nearest water source from your home (km)

f. How much time does it take to reach the nearest water source (minutes)

36. Average distance/time to the alternative water sources?

g. How far is the nearest alternative water sources (km)

h. How much time does it take to reach the nearest alternative water source (minutes)

37. How much time do you spend daily to fetch water?

38. Who in your household is typically responsible for fetching water.

~~What is the distance between the water technology from your home?.....~~

39. Has the technology assisted you to obtain water easily?

Yes ☐ No ☐

If no, how so?.....

40. In your opinion, what could be done to improve water supply in this area?

a).....

b).....

c).....

41. Is the water good for consumption?

a. Yes

b. No

42. Is the water obtained from this technology enough for your needs?

a. Yes

b. No

43.

a. How much water do you collect everyday?

b. How much water do you require for all your daily needs?

#### Part VI: Interviewer Observation Remarks

1. The technology point e.g. the state of water pan. solar and wind installation (please allow for space to type in)

2. The physical environment of the site e.g. the environmental hygiene and sanitation (please allow for space to type in)

3. The protection systems e.g. the fencing among others (please allow for space to type in)

4. Any other thing that will be of interest to the team (please allow for space to type in)

## Questions guide for semi-structured interview

### (Key Informants & Focus Group Discussions)

Organization:

Name of interviewee or group:

Level of responsibility:

Place of interview

Date:

---

### A. Policy and Top Management

*(Line ministries, County Executives, National Agencies)*

1. Which technologies are commonly used for storage and pumping water supplies and which factors mostly influence technology choice?

*(Guide to interviewer: How important are these factors, are water pan, solar and wind energy ranked among the most prevalent technologies? How many have been constructed in the last 1-year and by who?)*

2. Do the common technologies adequately address water demand and development priorities

*(Guide to interviewer: Which are the priority water needs, are benefits equitably distributed, what quality is required for priority water uses, what is the pattern of water demand)*

3. What is the performance of common water technologies (and water pans, solar and small wind turbines, if any) in different seasons and climate extremes

*(Guide to interviewer: do the current technologies [and selected low-cost technologies, if available] adequately meet water demand, throughout the year, is the quality adequate for priority water uses, what is the pattern of water demand vis-à-vis the technology capacity)*

4. What is the potential contribution of green technologies, specifically water pans, solar and wind energy in addressing water supply challenges

*(Guide to interviewer: Is there a systematic effort to incorporate green technologies in water supplies or it happens at random, who are the key actors; suppliers, standard and regulation, capacity building, O&M)*

5. How do you engage private sector in the improvement of water supply?

*(Guide to interviewer: Is there a strategy to engage private sector participation in development and management of water supplies?)*

## B. Implementation and Middle Level Management

*(Project and Water Service Managers, Technology suppliers, civil society)*

1. Which are the main challenges towards ensuring water supply is adequate, reliable and affordable across the year in the county/country?

*(Guide to interviewer: Are efficiency gap known and articulated in the management plans? is there potential for water pans, solar and wind energy to address these challenges?)*

2. What is the main source finances for construction, operation and maintenance of water supply?

*(Guide to interviewer: How is the cost infrastructure development met? Is cost recovery mechanism in place? Is revenue collected sufficient to maintain water supplies? Is the cost affordable to the users?)*

3. What is the potential contribution of water pans, solar and wind energy in addressing cost and technical challenges

*(Guide to interviewer: Is there a strategy for greening water supply? if green technology has been implemented what is the experience, are water pan, solar and wind energy sources among the preferred technologies)*

4. Which management model and capacity will support adoption and deployment of water pans, solar and small wind energy technologies for sustainable water supplies?

*(Guide to interviewer: What knowledge, technology management and capacity gaps require attention for deployment of water pans, wind and solar energy?)*

5. Do the current beneficiaries match up the initial plan?

*(Guide to interviewer: in cases where water pan, solar and wind technology is implemented, what were the envisaged benefits at the beginning, were the target benefits achieved, if exceed or less than expected, why?)*

## Focus Group Discussion Guide

1. Has this technology improved the amount and quality of water available round the year?



*(Guide to interviewer: How is water availability situation before the technology and now?)*

2. What are the impacts brought about by the implementation of this technology? Who has benefited the most?

*(Guide to interviewer: What difference has the technology made in the way people relate, derive income, spend time and money and educate, is there change in priorities activities, are there any businesses that have emerged since the technology was installed?, does the project benefits men and women in different ways? if yes how, are benefits the same for different income and age group if yes how and why?)*

3. Is the technology easy to manage and do you think the benefits will continue for long time? If no, why not?

*(Guide to interviewer: Who operates the technology, has any modification been made to ease operations, what happens when technology breakdown? Do the beneficiaries consider this is best technology for the situation?)*

4. Have conflicts arisen in the community over water since the technology was implemented? If yes which one and how are they being resolved?

*(Guide to interviewer: is there section of community dissatisfied with the technology? could this be as result siting, cost of water, exclusion of important water needs, inadequate water supplied by the technology or management model?)*

### Daily Field Survey Report

- i. Short description what you observed today, your general impressions of the water situation, technologies and deployed and in particular target technologies of this study i.e. water pans, solar and wind energy?
- ii. Provide background information that help contextualize the observation, description specific areas where the observation was made. Example – organization of water supply, on-going or recent projects, significant historical happening etc.
- iii. Demographic information about people who responded to survey. Example; age, gender, ethnicity, occupation, prevalent behaviors or belief, social harmony, exclusion and/or any other variables you consider relevant to this study - Who is doing what and saying what, as well as, who is not doing or saying what.
- iv. Any incidence, event or situation when observation, that (potentially) interfered with record of factual data. Example, time of day, ability engage respondents, weather, in ability to access technology site, demonstration etc.
- v. Did you make unique observation – an aspect of technology or water supply and/or their management that is particularly remarkable or overlooked/missing? Any possible explanation for this observation?

## V. TARGET SURVEY AREAS

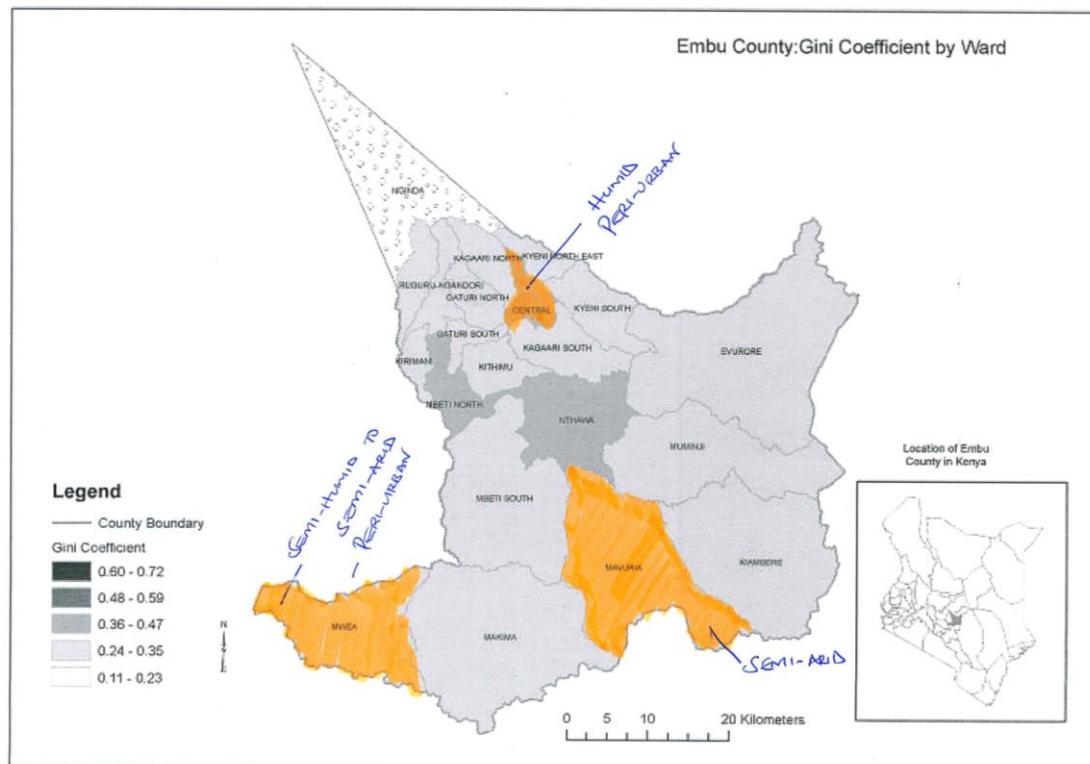


Figure 17: Target Survey areas in Embu County

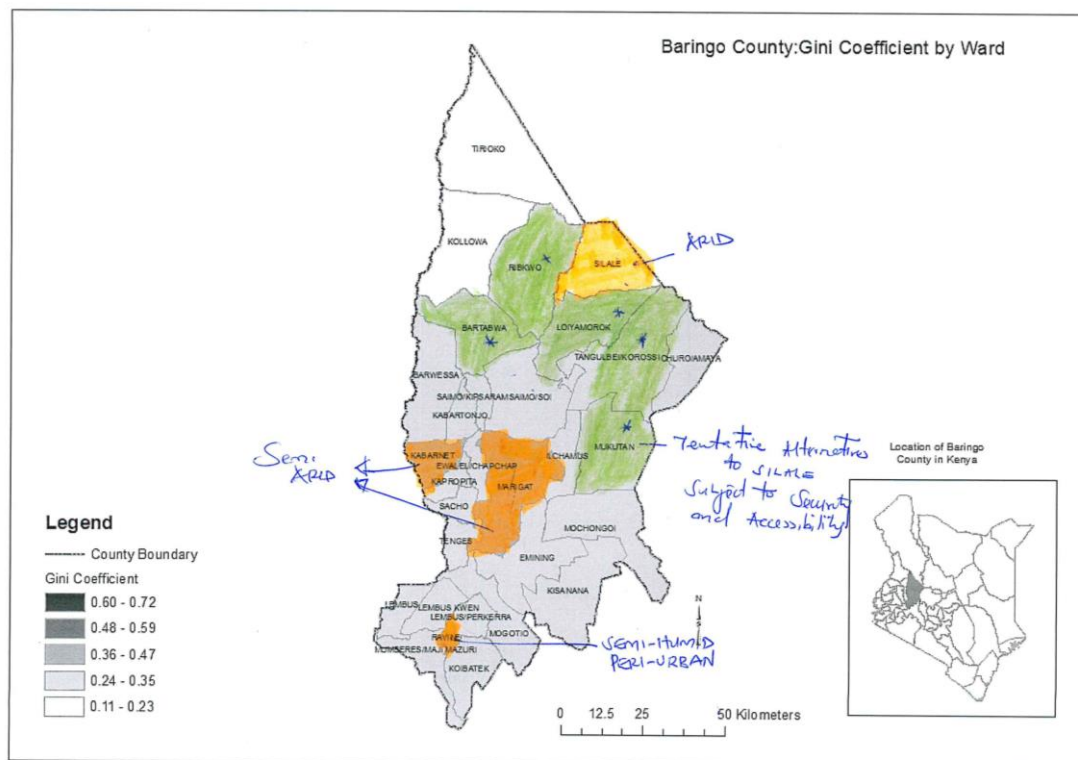


Figure 18: Target Survey areas in Baringo County

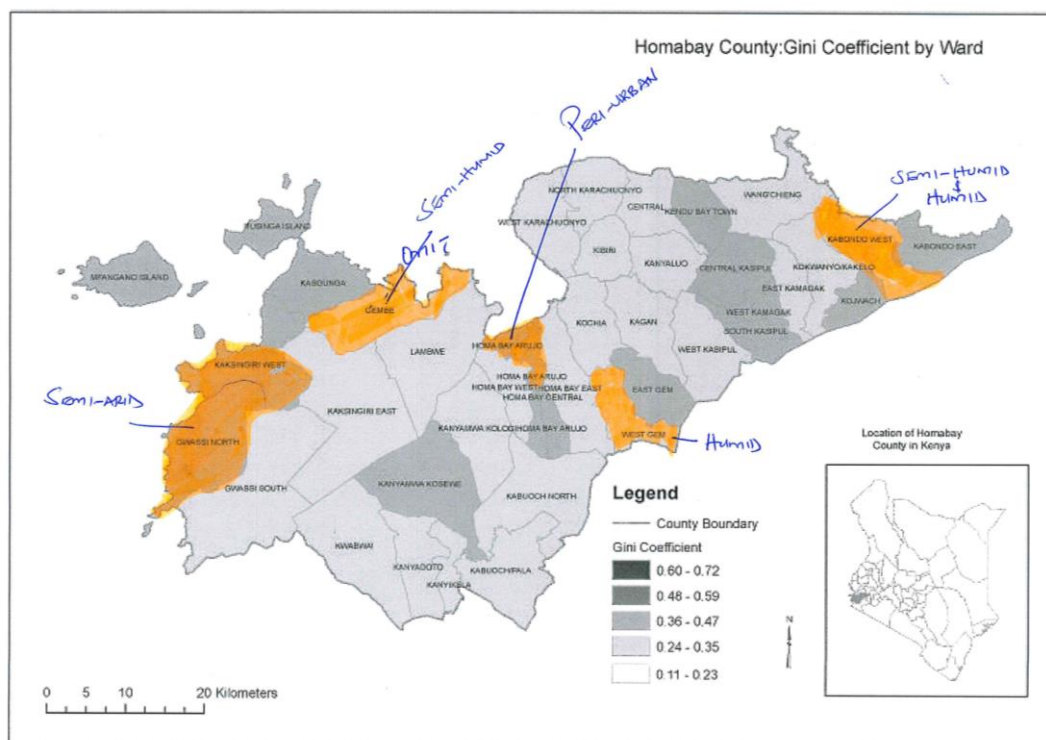


Figure 19: Target Survey areas in Homabay County

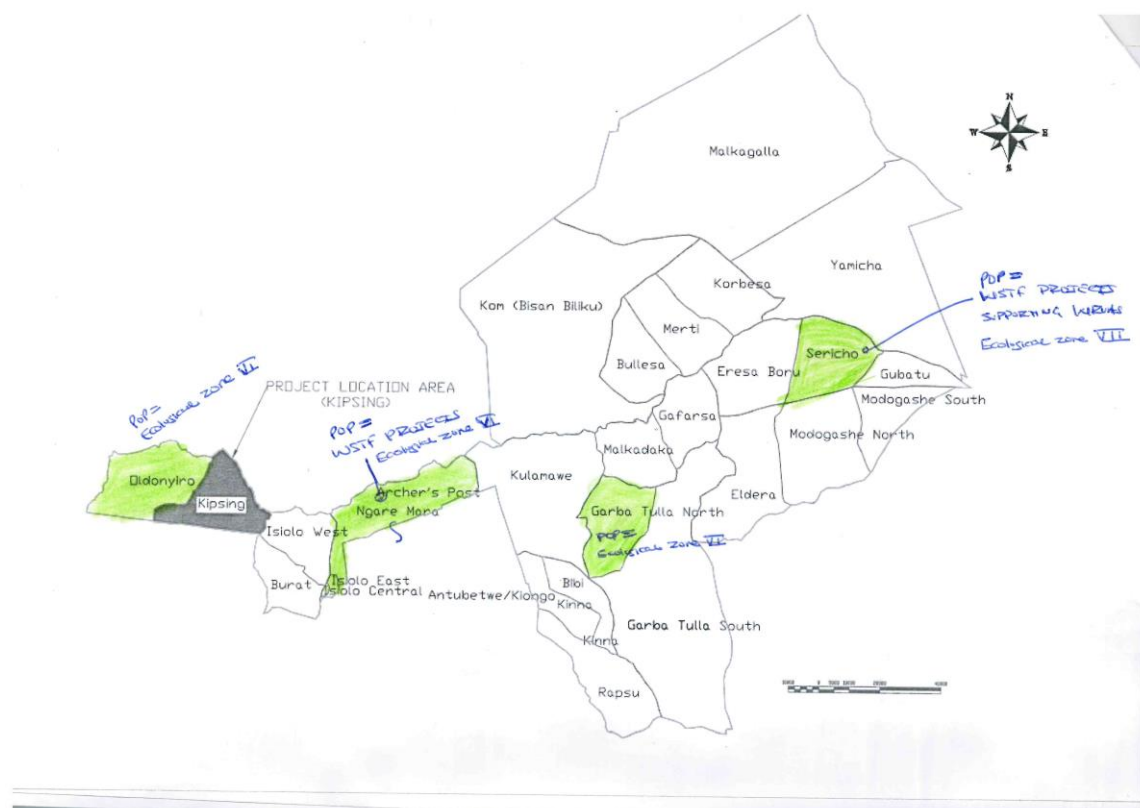
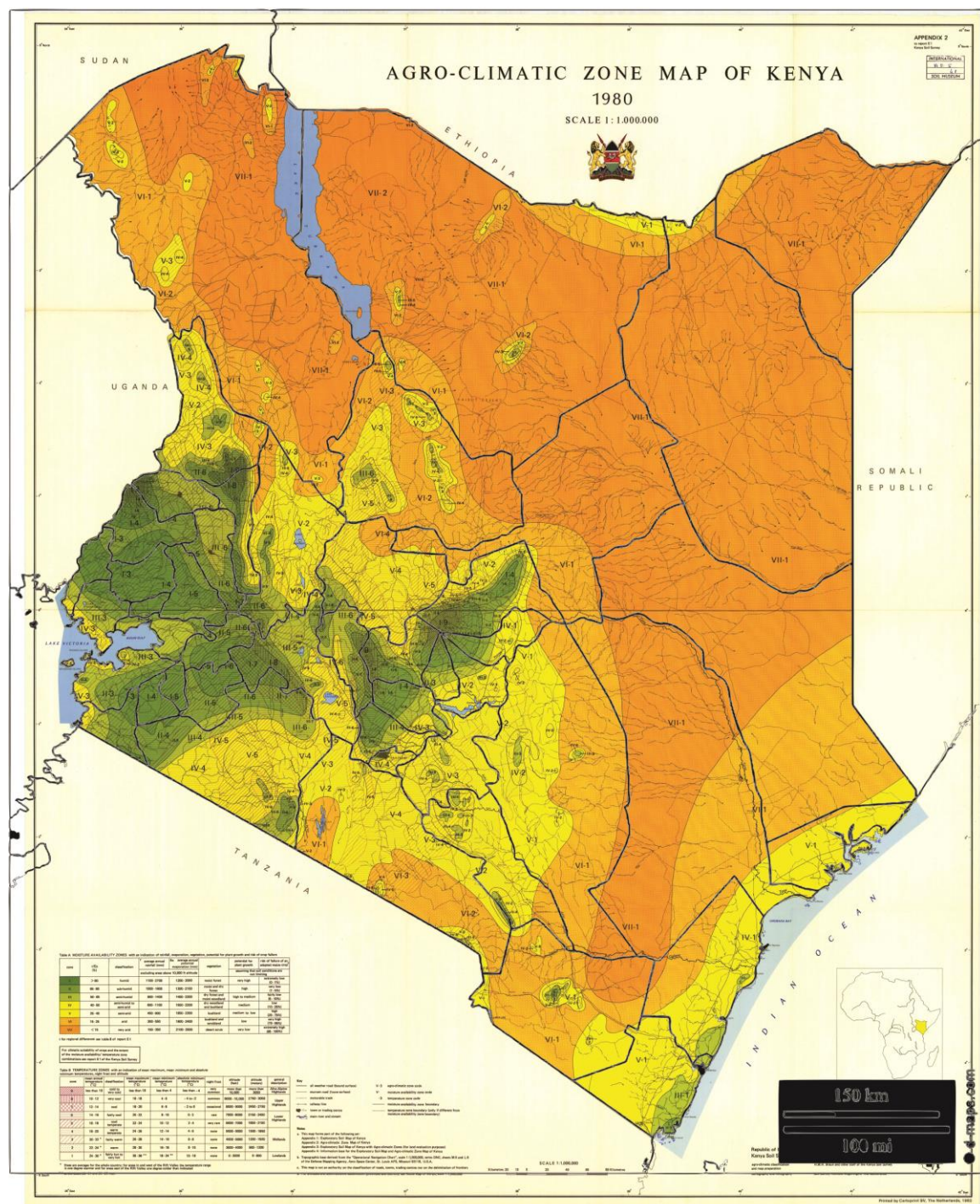


Figure 20: Target Survey area in Isiolo County

## VI. MAPS





**Figure 21: Agro climatic Zone map of Kenya**

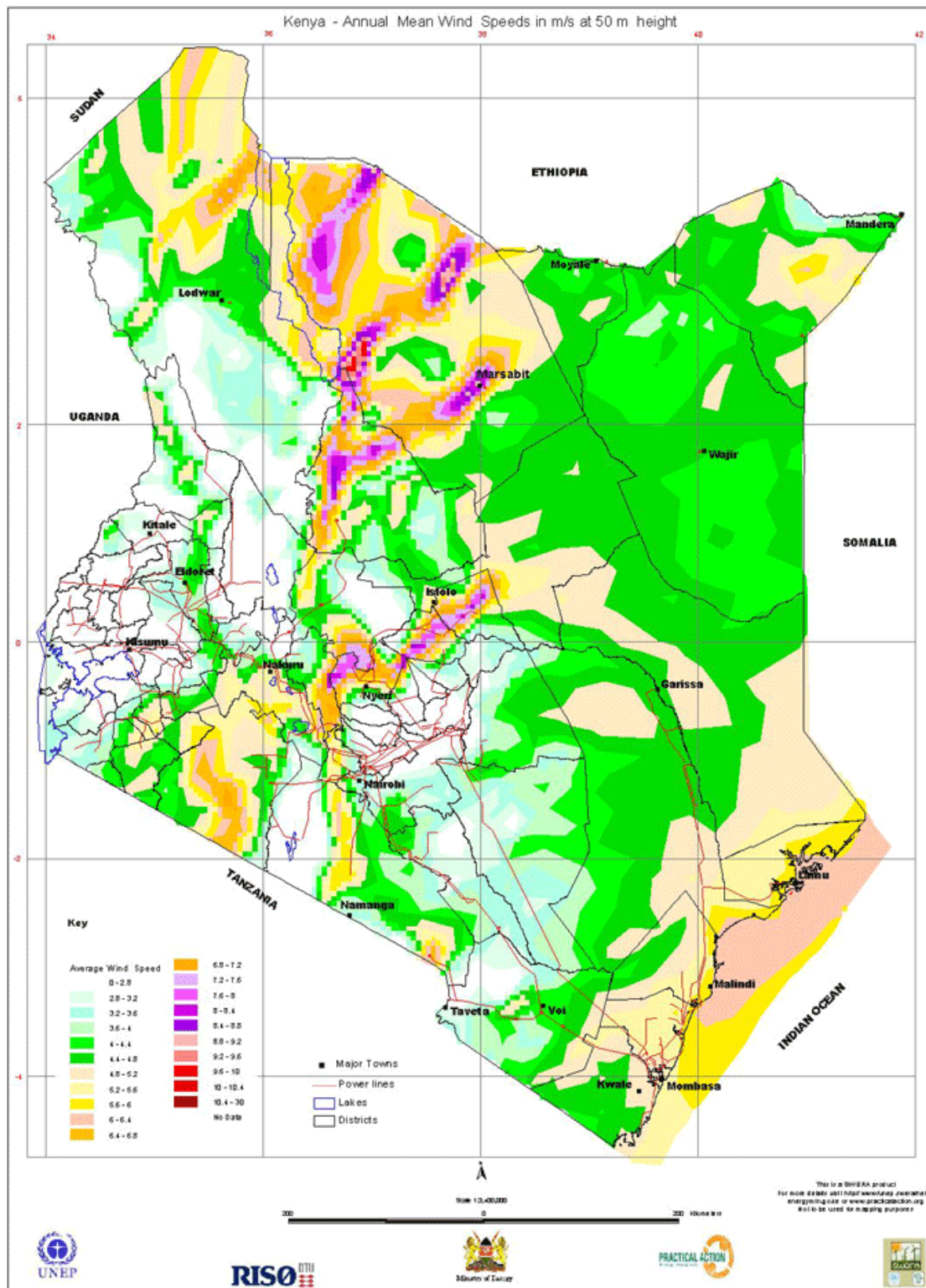


Figure 22: Annual Mean wind speed at 50m



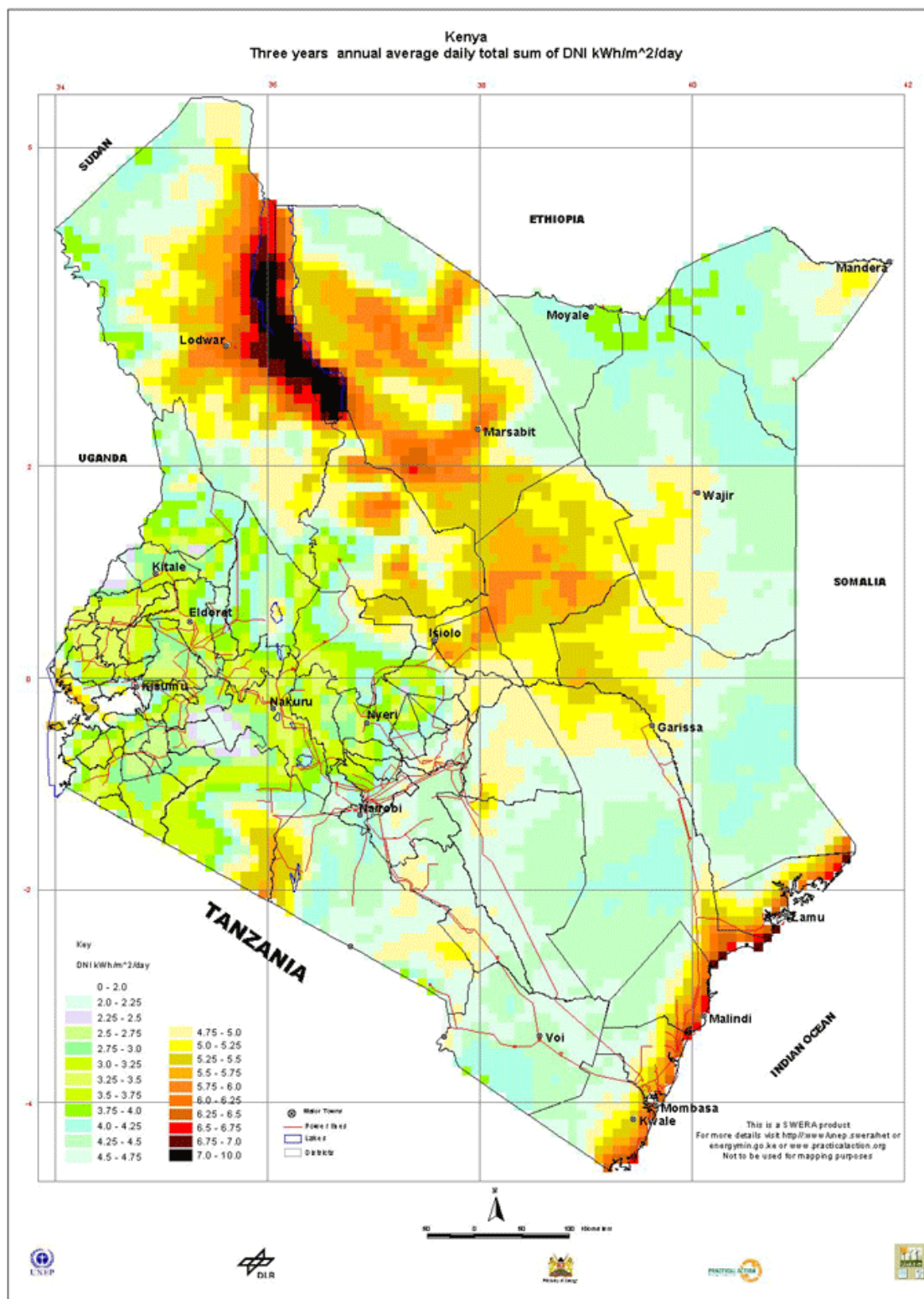


Figure 23: Three years daily mean Radiation





The Climate Technology Centre and Network (CTCN) fosters technology transfer and deployment at the request of developing countries through three core services: technical assistance, capacity building and scaling up international collaboration. The Centre is the operational arm of the UNFCCC Technology Mechanism, it is hosted and managed by the United Nations Environment and the United Nations Industrial Development Organization (UNIDO), and supported by more than 260 network partners around the world.

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