University of Nairobi

MANAGING APPLICATION OF DOMESTIC WATER HEATING SYSTEMS IN URBAN AREAS IN KENYA, CASE STUDY OF SYOKIMAU, MACHAKOS.

By

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Declaration

This research is my original work and has not been presented for the award of a degree in any other institution or university.

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Dedication

To my family.

Acknowledgements

It has been a long journey towards completion of this study, a journey that was made bearable by the support which was graciously given to me by special individuals and organizations that the Almighty God strategically placed on my path**.**

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ABBREVIATIONS AND ACRONYMS

AC	Alternating Current
API	African Policy Institute
BIPV	Building Integrated Photovoltaic
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
CSH	Concentrated Solar Heat
DC	Direct Current
DME	Department of Mineral & Energy (South Africa)
EE	Energy Efficiency
ERB	Energy Regulatory Board
ERC	Energy Regulatory Commission
EU	European Union
GEF	Global Environmental Facility
GOK	Government of Kenya
GW	Gigawatt
IEA	International Energy Agency
IIEC	International Institute for Energy Conservation
ISES	International Solar Energy Society
ISO	International Standards Organization
K	Kelvin
KPLC	Kenya Power and Lighting Company
KwH	Kilowatt Hour
LED	Light Emitting Diode
MW	Megawatts
NCA	National Construction Authority
NGO	Non-Governmental Organizations
NREL	National Renewable Energy Laboratory (USA)
PV	Photovoltaic
QC	Quality Control
R & D	Research and Development

RE	Renewable Energy
RET	Renewable Energy Technology
RPS	Renewable Portfolio Standard
SHS	Solar Home Systems
SRA	Syokimau Resident Association
SWH	Solar Water Heating
UK	United Kingdom
UNCFCC	United Nations Convention for Climate Change
UNDP	United Nations Development Program
US	United States
VAT	Value Added Tax
WBGU	German Advisory Council on Global Change

ABSTRACT

Utilization of solar energy in heating water is just but one way in which solar energy that forms a part of renewable energy is used and the World Governments have been deliberately investing and encouraging the use of this category of energy since is more sustainable and environmentally friendly. The Kenya Government went ahead and introduced laws that would ensure its adoption, one of them being the solar water heating regulations of 2012 which made it mandatory for home owners to integrate solar water heating systems in their developments. This law was enacted in May 2012 and provided a five year window within which all older and new developments ought to have complied. Despite of a high penalty prescribed by this regulation for non-compliance however, a huge proportion of new and old homes still have not complied and four main reasons have been cited as leading to this which includes high installation cost, lack of adequate information on the system, lack of technical capacity and weak enforcement mechanisms. The study aimed at establishing how these factors influenced or affected compliance to the law. The methodology used included development of a theoretical background from reflecting on various literature appropriate to the study, policies developed and regulations as well. This also included case studies from various countries of the world where application of solar water heating has been adopted. Syokimau estate which is located in Machakos County, a typical middle income neighborhood was chosen as the basis for the study, and a target population purposively selected to which a questionnaire administered. The study established that the four factors contributed to the noncompliance in various proportions, with the high cost of installation leading at 74% of those who had not installed the system. Lack of adequate information comes second with 39% of those who are non-compliant citing it as a reason. None of the respondents cited lack of technology, and 15% were non-committal, implying total lack of interest. This is the group which only appropriate enforcement can make them comply with the regulations. Key recommendations from the study include a more coordinated enforcement mechanism which will involve all the key stake holders including the ERC, Local authorities, consultants, Power distribution companies and even users. Ensuring that SWH system was an integral part of the building design and process, the Government developing policies that would ensure local manufacturers together with suitable fiscal policies would ensure both accessibility and affordability of SWH systems to classes of people. Strategies aimed at enhancing publicity would also ensure that the people are more

informed about SWH systems, which would enable them to make the choice. An implementation matrix that would ensure compliance was also develope

CHAPTER 1

INTRODUCTION

1.1 Background

The sun's energy forms a part of renewable energy concept often termed as "green" due to its nonpolluting nature. Renewable energy can be defined as energy that is obtained from the continuous or repetitive currents of energy occurring in the natural environment. For solar energy the cycle is the 24 hours it takes between two sunrises. This is as opposed to non-renewable energy which is obtained from static stores of energy that remains bound unless released by human intervention. (Weir, 1986)

Harnessing solar energy has been man's preoccupation for a long time and innovations have been made over time, mostly in the areas of heating and generation of electricity. Heating applications have widely been in domestic water heating whose systems have evolved overtime with new and more efficient ones being developed by the day (Perlin, 2013).

Kenya with an area of 580,367 square kilometers, and sitting astride the equator, experiences huge quantities of solar radiation throughout the country, which is also fairy consistent all the year round (Hankins, 2010). This can be utilized either directly as thermal energy or after conversion into other forms, especially electric energy through PV modules for other applications. Table 1.1 shows the annual average maximum and minimum temperatures experienced in various regions of Kenya.

Table 1.1 Average annual temperatures in selected towns in Kenya.

City/ Town	Location in the Country	Elevation Meters	Average annual Max Temp	Average annual Min Temp
Mombasa	Coast region	17	30.3	22.4
Nairobi	Central- Capital city	1661	25.3	13.6
Eldoret	Highlands- Rift valley	2085	23.6	9.5
Lodwar	Arid North	506	34.8	23.7
Mandera	Arid North	506	34.8	25.7

Source: *Diana (SPoD), 2006*

Solar energy have been thought of as a viable energy solution to Africa's ever growing energy needs for the future if it can be efficiently and extensively harnessed. There are calls from the world's Governments to reduce their carbon footprints, and they are encouraged to direct significant investments towards processes that are non-polluting, and those with minimal negative impact to the environment. Currently the bulk of the world's energy is generated from nuclear reactors, fossil fuels like oil and coal, and hydroelectricity. While the first two ends up polluting the environment, the later disturbs the ecological balance through creation of huge man made dams that also causes undesirable human displacements.

Renewable energy sources therefore ends up being a more desirable option because of their advantages over nonrenewable sources which includes minimal impact to the environment and their limitless nature. Utilization of solar energy is among the central strategies applied in greening the world though this is yet to reach the extent to which the other sources has been utilized (Ulgen ,1985). Solar energy has also been thought as being key to the eventual solution of world's growing energy requirements because of its wide availability throughout the world, though it is more concentrated in the tropics.

World Governments are therefore not only inclining towards subsidizing these areas of energy production, but also encouraging research and advancement of new energy technologies that will eventually make it possible to fully exploit renewable energy sources, like in the case of Germany (WBGU, 2003) . Focused initiatives and significant investment towards improving the solar energy conversion technologies and also aiming at raising awareness on the need to adopt renewable energy has resulted in Significant achievements being made towards this direction, and which have slowly been gaining momentum in both the developed and developing countries. (Kalogirou, 2009)

Such initiatives have included numerous global forums that addressed renewable energy and the current air pollution levels amongst other environmental concerns, and also resulted in important agreements like the Kyoto protocol discussed in chapter 2 section 2.10.(i), which have encouraged investment in renewable energies by awarding carbon points which can be converted into economic benefits by member nations.

1.2 Problem statement

Kenya like many other developing economies falls short in meeting its energy demands and one of the strategy that the Government of Kenya has adopted as it endeavors to meet this deficit has been to embrace renewable energy technology. It has particularly encourage its use in residential homes , and more so in the heating of water for domestic purposes due to the realization that considerable quantities energy in the residential sector is consumed on hot water production (Ngui, 2011) .This therefore makes the utilization of solar energy have enormous potential to assist in the reduction of energy drawn from the power supply grid by residential houses, and the energy saved can be directed to meet demand of electricity in other key sectors of the economy like manufacturing (Diakoulaki , 2001)

This has consequently led to the enactment of the solar water heating act which is supposed to ensure that most of the hot water that is consumed in domestic homes and institutions as well is heated through solar means. The law took cognizance of the fact that most of the country experiences extensive exposure to solar radiation that is largely under-utilized, which can effectively be harnessed through the use of by SWH systems.

The gazzetment of the solar water heating Act by the Kenya Government made its application mandatory in all residential development, and it covers all new & existing buildings, Extensions or alterations – residential and commercial within jurisdiction of a local authority that have a hot water requirement of more than 100 litres per day. It demands that sixty percent of all domestic hot water requirements is to be heated through SWH systems. The populace was also to understand that this form of energy was both cheap and reliable despite of the initial capital investment.

The only exemptions to the requirement included houses with technical limitations, such as high-rise buildings, premises that are supplied by co-generation, or buildings that cover hot water demand by renewable or green electricity.

However, despite of the act being in force in the last five years, its application has remained quite limited in urban households where it was supposed to apply. Indeed it stated that those households developed earlier and had not installed it had a period of five years from the date of enactment within which they are required to comply by May 2017.

The regulations further stipulate that as a way of ensuring compliance, no household should be connected to the main grid supply unless SWH has been installed. This was to be ensured by Kenya power and lighting company which is the only power distribution Company in Kenya, and this further reveals a problem in enforcing compliance. The problem in enforcement is laid bare by the fact that many housing units have been built since enactment of the law, and which have been connected to the grid power despite their not having installed SWH.

If the regulations are complied with, the SWH systems would be an easily identifiable feature in all residential developments on roof tops or other position easily visible since it requires exposure to the sun**.** Compliance would also mean that the national power deficit would be much less since solar energy would supplement grid supply.

In residential buildings, hot water is used in many crucial activities, like dish washing, laundry and bathing, though the most predominant usage is in bathing. During use it is often mixed with cold water in a *mixer* to the desired temperature before use. In the traditional hot water house plumbing systems, the hot water was supplied to the point of use through well insulated pipes which connected it to the hot water storage tank. This tank was usually well insulated with a suitable material and consisted of either an electric heating element near the bottom which heats up the water or an LPG burner. Some buildings today still employ this method especially where the quantities of hot water required is substantial at certain peak moments.

In this system water is heated in a boiler with the source of heat which could be either an electric element or a gas burner located at the bottom. As it heats up it moves towards the top part and is replaced by cooler water from a supply pipe at the bottom that gets heated as well. The temperature is usually controlled by means of a thermostat in the case of electric heater, and hot water supply to the house is tapped from the top of the boiler tank. This system is however quite wasteful because it heats up the water in bulk even when much less is required (Wilfried , 1985).

Heating water by electricity has always been expensive and was traditionally considered as a luxury in Kenya. The power supplied for this purpose in the old electricity meters was supplied through a ripple unit which ensured that only the surplus power was used for this purpose. A different billing rate was also used which was higher than that applied for the electric power used for the other purposes.

This made the water heating bill contribute a very significant portion to the residential house electricity bill**,** and this has eventually led to extensive usage of Instant shower heaters which are not metered in isolation. These heaters have continued to be popular because they also heat up the water that is required at the time, but cumulatively however, they still add significantly to the cost of electricity. This is because to heat up water that fast, a lot of electric power has to be consumed, and most of them therefore are rated upwards of 2000watts. They also come with increased the risk of electrocution when they either become faulty or if they are of poor quality, a category in which the majority of those which are in use in Kenya belongs.

Instant heaters are also preferred not only due to the convenience that they provide during the bathing process since no preparation of water is required, but they also requires no additional plumbing to the house in the form of separate piping for the hot water supply. The only requirement that they need is an electricity connection point near the water outlet for connection purposes.

In the light of the above, a lot of electricity is still being consumed in the households to heat up water but the cost is normally hidden in the total house bill. The customers ends up paying much less than what they would have paid in the event that a different higher rate was applied. This relative "cheapness" has resulted in increased usage of electricity for this purpose, with KPLC not collecting revenue equivalent to the usage.

Despite of the gazettment of the law making application of SWH system mandatory, there has only been a limited increase in the uptake, and no change in the amount of power consumed by the residential houses has been observed. This points out to the existence of a problem in compliance.

GOK realizing that a significant amount of electricity that is supplied to residential houses is still being used for this purpose which implies that despite of a limited increase in the uptake of the solar heating systems following the gazettement, of the regulations, a great problem in compliance exists.

According to ERC, the reason as to why Kenya's solar water heater market has so far shown only little growth probably because of three factors namely, (ERC, 2015)

i) The high cost of installation
ii) Little awareness of the regulation and system in general
iii) Lack of technical capacity to both install and maintain the system.

Lack of enforcement through the power distribution company (KPLC) as anticipated by the act has contributed to less compliance by home developers.

The study aims at investigating how the Four mentioned factors namely, High Installation cost, Lack of awareness, lack of technical capacity and lack of enforcement by KPLC has as influenced the current limited usage and non-compliance to the law.

1.3. Research Question

The research questions are:

i) What is the extent to which the solar water heating system has been implemented by individual urban home developers?

ii) What are the implementation factors that determine the choice to install solar water heaters?

iii) What extent does the factors determine solar water heaters implementation by individual urban home developers?

iv) What appropriate mechanisms can be put in place to ensure compliance in implementation of SWH systems by individual urban home developers?

1.4. Objectives of the study

The objectives of study are:

i) Establish the extent to which solar water heating systems has been integrated in urban residential homes developed by individuals

ii) Establish the factors that contribute towards the choice by individual urban home developers to install solar water heaters

iii) Establish the extent to which the factors have contributed towards the implementation of SWH by individual urban home developers

iv) Formulate a model/ framework for enforcement mechanism for ensuring effective application of solar water heating in urban homes.

1.5.Justification of the study

Kenya faces a huge energy deficit, and the energy infrastructure is not growing fast enough to enable it meet this demand. It has been realized that if renewable energy and in particular solar energy is appropriately harnessed, it can go a long way in assisting to meet the high energy demand.

Figure 1.2 shows the peak demand against the installed capacity and brings out the extent of the power deficit that exists, and how it has been changing in from 2013, and also the projected demand to 2030.

Table: 1.2 Electricity Peak Demand Projection

Year	Peak Demand	Installed Capacity
2013	1,500 MW	1,200 MW
2016	1,600 MW	1429 MW
2020	3600 MW	-
2030	15,000 MW	-

Source ERC, 2012

The law that was passed to ensure that the huge amount of energy currently being used in heating up domestic water was channeled to other uses through obliging home developers to install SWH systems is not being complied with, and the study intends to not only establish why compliance has been and continue being resisted, but also recommend ways through which it can be guaranteed for the national good.

Its importance cannot be overemphasized since energy is a key driver towards industrialization, on which Kenya's vision 2030 is anchored amongst other key pillars (Kenya Vision 2030, 2008)

A study by Stockholm Environment Institute (SEL) in 2009 on the economic impact of climate change in Kenya found out that its greenhouse emissions are rapidly increasing. Kenya's climate change response strategy proposes to reduce this impact through various methods including adoption of and promotion of use of environmentally friendly energy sources. The energy sector in particular was found to have increased its emission by more than 50%, and it became prudent for the Government to encourage development and investment in relatively non-polluting processes of energy production.

1.6 Significance of the study

The findings of this study will benefit all stakeholders including the Kenya Government, which will better understand why its objective of ensuring the installation of SWH's in homes is still yet to be achieved despite of the law and similarly the ERC will understand where it fails in the enforcement of the regulations. The professionals and Local authorities will also appreciate the key roles that they need to play if the implementation as anticipated by the law is to be achieved. All the stakeholders will also get to understand the current extent of installation, and the challenges faced by developers or individuals who build their homes in installing SWH's.

1.7 Scope and Limitations

Despite of there probably being many more factors as to why SWH systems are not in wide use, the study was limited to only finding out how the above cited factors affected the implementation. It was also be limited to the social and income group found in Syokimau, which is middle income neighborhood, while taking cognizance that the same factors could affect another category quite differently, and even other unlisted factors could even become significant depending on the target group.

The study therefore addressed a scenario where Electricity grid supply was available, which therefore made inclusion of SWH a matter of choice and or submission to law.

1.8 Definition of terms

Concept	An abstract idea
Enforce	Ensure observance of or obedience to law
Global	Relating to the whole world
Install	To place in position and connect for use
Installation	The act of installing
Kilowatt	1000 watts
Kilowatt-hour	Unit of energy equal to work done by a power of 1000 watts in one hour
Proposition	Content of a sentence that affirms or denies something and can be true or false
Regulations	As required by official rules or procedures which are laid down and gazetted
Renewable	Alternative source of energy that restores itself from nature once depleted
Research	Systematic investigation to establish facts or principles on a subject
Solar	Relating to the sun, operating by utilizing the energy of the sun
Standards	Accepted and approved level of excellence of quality
Study	An investigation and analysis of a subject
System	A group or combination of interacting elements forming a collective entity

Tropic Part of the earth's surface lying between the tropic of Cancer and Capricorn.

Watt The power dissipated by a current of 1 ampere flowing across a potential difference

Of one volt

1.9 Organization of study

Chapter one introduces the study from a broad perspective, highlighting the great potential of solar energy in alleviating the energy shortfalls, and also as a clean energy source. It further on describes Kenya's great potential due to its strategic location, and also the general inclination by the entire world towards adoption of renewable energy sources in which category solar energy falls. The chapter goes on to describe the problem which further leads to the research questions, objectives, justification and the significance of the study, including its scope and limitations.

Chapter two is a review of literature on the subject and delves into the science of sunlight, how technological interventions have been used to harness solar energy, the global trend and the extent to which this has been done, and also looks at the Kenyan situation. It explores the factors that have affected the implementation of SWH and how they have done so, together with possible interventions. It also review the existing policies and more importantly the solar water heating regulations of 2012, which was the main tool through which the implementation was to be ensured.

Chapter three details the research methods adopted, flow of research activities and data sources for both primary and secondary data. It also describes the sampling design including details of the study area and the unit of analysis. Population frame, research tools and data collection and analysis methods, and mode of presentation are also described.

Chapter four describes the findings of the study as guided by the respondents' answers to the questionnaire which is based on the research questions. It looks at how the four key aspects under study namely the cost of installation, lack of information, technical competence and inadequate enforcement mechanisms influence the extent of solar water heaters uptake.

Chapter five is a discussion of the effect of the factors highlighted based on the findings, but goes further to point out the possible interventions that can be adopted so as to mitigate the poor uptake of SWH systems and increase implementation.

Chapter six gives a summary statement on the conclusions and recommendations of the study, states the measures that would need to be taken to improve the uptake, and this is synthesized in an implementation matrix which if used would ensure that all households comply as anticipated by the law. In this matrix key stakeholders and the roles that they need to play are brought out. Further research areas have also been proposed in this chapter.

Chapter 2

LITERATURE REVIEW

2.1 Solar Energy as a renewable source.

Solar Energy falls under the category referred to as renewable which by nature is that energy whose supply is not affected by the rate of consumption. This kind of energy keeps renewing itself through a natural process (without human input) and is therefore deemed to be limitless (Hofierka, 2009). The distribution of this kind of energy follows natural or geographic processes and man only learns how best to tap or access it through technological means. The effectiveness of how this is done or the amount of energy accessed is dependent on the efficiency of the technology, and overtime man has continually improved on technological systems in terms of design so as to continually improve on this efficiency.

One other key attributes of this kind of energy is that its generation often involves non-polluting processes and for this reason it is also referred to as “clean energy”. Certain attributes have been observed about renewable energy other than its limitless nature, with one being that it comes in some cycles also referred to as energy currents occurring over a period of time. Each cycle or current brings in a renewed wave and hence the term “renewable” (Weir, 1986)

These energy cycles are normally tied to natural and geographical processes which man have no control of and so also vary at different points on the earth’s surface or area.

This attribute implies that any kind of renewable energy cannot be assumed to be exploitable everywhere, but rather it must be proceeded by a process of study of the particular area so as to determine its suitability for any particular type to be exploited. For example, for solar energy to be fully and more efficiently exploited, the area must meet certain conditions for its suitability to be ascertained including long hours of sunshine over the day, month and year. Others determining factors could include the degree of cloud cover, dust in the air and position from the equator. For wind energy it would be the predominant wind speeds for the area.

Because the localized factors which determines suitability also varies constantly, renewable energy has been observed to be very dynamic in terms of magnitudes (Kalogirou, 2004). This is in contrast to say the energy derived from finite sources like oil which on extraction is possible to control the energy amounts being extracted, and even can be stopped at will. Example, fuel consumption can be stopped when an engine is put off.

For renewable energy like the Sun, stopping or diminishing the conversion does not stop the energy from flowing. It also cannot be adjusted so as to peak when the energy demands are high, and indeed most of the time it peaks when the demand is less. Coordinating the energy conversion with demand becomes a challenge for most of the renewable sources of energy and the most suitable intervention for this situation has been to store up this energy until when it is required. For solar PV systems that converts the sun's energy into electricity this takes the form of batteries, but for solar water heating system this are well insulated hot water storage tanks that are able to keep the water hot until when it is required.

Renewable energy has also been termed to be dispersed, which implies that it comes in relatively small quantities over a large area (low energy flux densities) as opposed finite sources like to say fossil fuels where the energy is more concentrated and hence more easily harnessed. Renewable energy therefore can only be harnessed in dispersed locations which make it relatively more expensive to install. It also requires much larger installations for reasonable amounts to be converted which are normally quite expensive, but the processes are less polluting to the environment and regardless of how much energy is converted, it does not affect the quantity in the source.

Renewable energy is often converted and used locally as opposed to that from finite sources that is more concentrated in generation but distributed widely. The major cost in this type of energy (from finite sources) is in the distribution system to various locations of usage.

Like in all situations where man endeavors to utilize renewable energy, important principles to observe includes maximizing efficiency through minimization of losses and maximization of both economic and social benefits. The application of any renewable energy would also demand an understanding of its underlying principles so that the above mentioned can be realized.

It is therefore of outmost importance to work out the cost benefit analysis, but more often than not, it is almost always worthy to invest in this area due to the inexhaustible nature of renewable energy, and its low environmental cost. This inexhaustible nature implies that if well harnessed it has the potential of greatly improving the quality of life since it can be a huge source of easily accessible and affordable energy.

There exists a direct relationship between the yearly requirements of energy (R) for a given population (N), and the standard of living, as follows:

$$R = SN/f$$

Where S is per caput gross natural product (a measure of the standard of living) and f is a complex and a nonlinear coefficient that is a function of many factors which can be considered as a coefficient for transforming energy into wealth. (Goldemberg, 1985)

2.2 Science of Solar Energy

The source of energy from the sun comes from the burning gases and from the atomic fusion processes that takes place on its surface, and arrives on the earth's surface at a flux density of between 2- 7 kWh/ M Sq per day, in wavelength bands of between 0.3 and 2.5 Micrometer (Planck, 1900).

The variation of the total energy received on any particular day depends on the place, time and weather. Figure 2.1 below shows the various wavelengths in which solar energy reaches the earth.

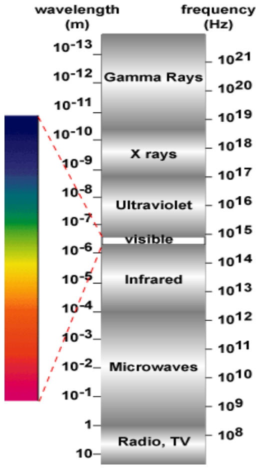

Figure 2.1: Electromagnetic Spectrum showing the various wavelengths of the energy.
Source: Planck (1900), 1967

The energy reaches the earth in different wavelengths categorized in four clusters, namely the Ultra Violet radiation, White light, Infra-Red and Cosmic rays, each category being bound within certain wavelengths of the radiation (Planck, 1967).

The part solar energy manifested by heat is normally found in the Infra-Red part of the Spectrum which consist of long wavelengths in relation to the rest. This energy which is expressed as heat is what is utilized in SWH equipment to heat up water to be used in the households.

The character of Light from the sun has been scientifically determined as to be dual in nature that is to both be wavelike and also particulate at the same time. These light particles are referred to as photons and are responsible for the photovoltaic effect that causes sunlight to generate electricity when certain materials are exposed to it. Such materials are termed as being photosensitive (Einstein, 1905).

Some key characteristics of incident solar energy which are critical in determining its effectiveness when it interacts with a photovoltaic converter or solar heating component includes the following:

i) The spectral content of the incident light

ii) The radiant power density from the sun

iii) The angle at which the incident energy strikes the solar converter

iv) The overall energy from the sun over a period of time e.g daily, monthly or yearly.

Current Components makes use of solar energy in two ways:

i) Those that makes use of direct solar radiation, especially the infra-red component of solar radiation that is responsible for the heating effect (Thermal collectors)

ii) Those which converts the sunlight into electricity, hence the term Photovoltaic simply abbreviated as PV. (Photovoltaic cells)

Efforts to harness the suns energy in concentrated form and direct it towards suitable man's ends have long been a human pursuit.

2.3. How Solar Water Heater Works

Solar water system is an equipment that simply captures the heat from the sun and uses it to heat up water to be used wherever it is required. At its very basic, it would just consist of a container with water which is exposed to sunlight. The efficiency of how it works can be determined by the extent of temperature change of the water, and also the length of time the water will remain hot till it is conveyed to the point of use.

The efficiency in this basic form would be wanting due to multiple heat losses beside the inefficiency of the heat exchange process that would take place between the sun's rays and the water surface which is also quite reflective. Improvements have taken place from this basic concept of heating water in a container, first by containing water in sealed tubes which besides increasing the contact surface of the water being heated and the media through which the heat is transferred to the water, it also drastically reduces heat loss from the process of convection that would otherwise take place when the water surface is exposed. New and better absorptive materials keeps being developed to improve performance (Kennedy, 2002).

Conducting steel tubes coated with a better heat absorbing material with minimal losses (thin layer of semiconductors have been used) and enclosed in a glass covered panel have proved to be effective. Creating a vacuum further improves the performance of this component referred as the collector since it is at this point that heat energy is collected.

Sunlight is absorbed by one or more solar collectors, which transfer the absorbed solar heat to water circulated through the collector(s), and as it has been observed earlier as pertains to renewable energy, the energy have to be stored for usage when it is required, and this is done through a well-insulated hot water storage tank.

The amount of energy absorbed is dependent on the amount of sunshine hours experienced during the day, orientation of the collector in relation to the sun, the collector's area exposed to the sun and also its efficiency determined by its technical specifications.

The mass of the water is also important since the greater the mass the more heat energy it can store.

2.3.1 Basic kinds of SWH Systems

There are two basic categories or types of solar water heater systems namely:

i) Active (forced circulation) systems that use pumps to circulate the water

ii) Passive (thermosiphon) systems that rely on natural convection for water circulation.

Both types of systems include solar thermal collectors and storage tanks. The collectors can range in size from 900mm. x 2100mm up to 1200mm. x 3600mm. and are often used in groups.

The storage tanks are usually larger than those used in the traditional domestic boiler type water heaters and generally hold from 100 litres upwards. These tanks may be connected together to form a battery which increase the storage capacity.

The active system (forced circulation) uses an electrical pump to circulate water between the solar collectors and the storage tank, and the pump may be either a 120V AC pump or a DC pump. An AC pump is plugged into regular house current and relies on temperature sensors and a differential controller to turn the pump on and off.

The passive (thermosiphon) system in turn relies on natural convection to circulate the hot water. Hot water naturally rises so no mechanical pump is needed. It is essential, however, that in a passive system the storage tank be higher than the collectors. As long as the sun shines, water in the collector will heat and move slowly upward into the tank with the colder water descending to replace it. (Kim, 2007)

As shown in figure 2.2 below, the storage tank is usually mounted horizontally above the collectors on the roof, the added weight should be a consideration in the building's structural design

Figure 2.2 Roof mounted Solar Water heating System

Source: Belina multi industries, solar@belina.biz 2016

Figure 2.3 shows a schematic diagram of a forced circulation solar hot water system.

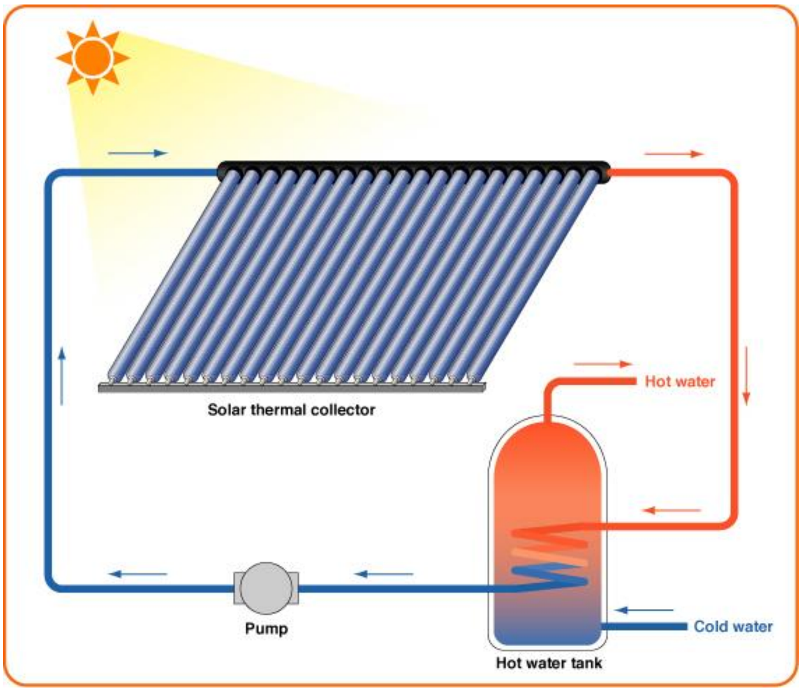

Figure 2.3. Forced circulation solar hot water system

Source: Mauthner 2012

2.4. Challenges faced in SWH Application

Application of solar water heating systems comes with various challenges which needs to be understood and taken into account as decisions to apply, mount and use them are made. These includes the following:

2.4.1 Variation of Solar Energy varies with changing atmospheric conditions (clouds and dust)

The Intensity of the sun is dependent on the atmospheric conditions, in that the energy comes from the sun which is located a great distance from the earth's surface. This means that it travels through space (generally a vacuum), before entering the earth's atmosphere where it encounters obstacles in the form of clouds, dust and other atmospheric elements and impurities (Planck 1900). All these tends to block, filter or deflect it with the result of reducing its intensity periodically at any given point of the earth's surface.

This variation tends to make the energy supply irregular of even at times cuts it off completely like in a case of intense cloud cover. This in turn affects its reliability in the application.

Intervention

Unlike the old SWH systems, the current ones comes with a backup electric heat element that can be operated either automatically or manually. This element is used to heat up the water when the atmospheric conditions become unfavorable, so as to maintain consistent flow of hot water.

2.4.2 The changing position of the earth relative to the sun (day and night)

The rotation of earth around the sun creates day and night, interpreted as day time when the sun's energy can be utilized, and night time when it is nil. This brings in the challenge of limiting its harvesting to daytime only, with peak time being right in the middle of the day when the utilization of hot water is low.

Intervention

This challenge is mitigated by the provision of effectively insulated hot water storage tank which maintains the high water temperature until when needed despite of the sun having set. Such a storage tank can also be equipped with a thermostat operated electric element which simple maintains the hot temperature at a steady point.

2.4.3. High initial cost of installation

Application of Solar water heating systems widely has presumably been hampered by their high initial installation cost. This has supposedly arisen because most these equipment are not manufactured locally meaning that they have to be imported, and since their consumption has been quite low in the past this had to be done on demand.

The issue of cost can however be considered in the perspective of the total cost of putting up a house. As shall be demonstrated, this is simply a misconception because if the system is regarded as a prime consideration in the planning and implementation of the building project, its cost would then just be a small factor and can easily been absorbed.

The argument would not make economic sense when applied in a case of a simple bungalow whose construction cost is probably in the range of Three Million because with a combined purchase and installation cost of say an average of Kenya Shillings 150,000 it would account for only 5% and as the house becomes larger the proportion becomes even smaller. This amount can easily been absorbed in any housing financing arrangement, as it would appear as a component of the mechanical works of the house.

The perception that it is expensive probably comes from the situation where it is always added in as an afterthought, meaning that the SWH system is implemented long after the house has been completed. In such cases it comes with a new set of piping and connectors that does not help in making it any cheaper. The perception is further enhanced psychologically in the developer or owner of the premise ‘s mind because he has just come out of the building process, hence financially fatigued and is probably even already paying up the mortgage.

2.4.4. Lack of awareness

Lack of the relevant information has made the general populace less aware and largely ignorant of these systems. This has caused some significant inertia in its application since people generally are skeptical of what they do not understand. They are not in a position to make the decision to install since they are not aware of its advantages, system’s cost or even the mandatory requirement that they should install it.

2.4.5. Enforcement

There seem to be a great weakness in the enforcement of the law that requires that the Solar Water Heating systems be installed in all houses with hot water consumption capacity of more than 100 litres. Enforcement instruments would require to be reviewing for maximum effect and a multi agencies approach for enforcement adopted.

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2.5. The role of Policy in enhancing uptake of SWH

2.5.1. Policy Interventions

The Governments through their various agents plays a key role in determining the application of renewable energy components through designing suitable policies. These interventions however should not only be confined in the formulation of the policies and enactment of regulations followed by putting in place policing measures, but also through creating suitable investment environment and some incentives as well.

A substantial body of knowledge on how this can be done has been accumulated from various countries and their experiences, which Kenya and indeed the entire developing world can learn from.

The approach through policies should include but not limited to the following:

i) Long-term commitment, targets and consistency

The renewable energy transition does not happen automatically once a policy has been formulated. Experience has shown that considerable, consistent interventions of all types into energy markets are needed before meaningful renewable energy results starts to be achieved.

In India, conflicting and inconsistent state policies, aggravated by state electricity board regulations, delayed renewable development while Germany developed more consistent policies which ensured a remarkable market development. Consistent policies are also cheaper to administer.

This means that the Kenya Government needs to maintain pressure on SWH applications with concerted efforts, frequently conducting market surveys so as to determine how adoption is taking place. Reviews of the policies would need to take place frequently in response to the surveys, but most importantly there should be clear targets within a time frame on how these systems are to be rolled out incrementally so as to achieve the power saving through ensuring the use of this systems.

ii) Good laws and consistent enforcement

The effectiveness of positive interventions depends on whether they are taken seriously and followed through. If a nation does not have the political will and capacity to implement them, then the best policy models are of no value. Therefore, renewable energy policies should be easy to understand and also to implement, otherwise they will harm more than help. The

Government should devise a follow up mechanism on the implementation strategy, and not leave this to the discretion of the developer.

Enforcement should also be consistent, and tied to other existing policies and regulations so that this can be done collectively by different agencies of Government that controls various aspects of development. Enforcement should be carried out by using the local authorities as they approve the development plans, and also ensure implementation.

Since the law requires that the SWH system be put in place before grid power is connected, the Kenya power and lighting company should be compelled to ensure this, and this should also be included in their mandate (KPLC act) so that they can be held liable.

iii) Develop reliable, predictable market conditions

It has been proven that in order to achieve a steady and meaningful renewable energy price reduction, it is important to create a transparent and steady markets. Under such conditions, small and medium enterprises that is typical of Kenya and other developing economies can afford to enter this energy segment.

These enterprises provide the core of employment, and can collectively invest significantly towards the development of the sub sector. This has been the case in Denmark, Germany, Japan, Spain, and Brazil.

With a wide roll out of SWH systems, a predictable market will be created which will give rise to many dealers in the equipment, installation contractors, maintenance companies which will all have the net effect of making the running of the system cheap and affordable due to the economics of scale.

iv) Redress market failures

The energy market in Kenya has been characterized by monopoly from generation to distribution. Even though of late there have emerged small scale power generators/ distributors often localized at community level, due to a change in the law.

This monopoly has possibly hurt the market because the power pricing decisions are controlled by a single entity without any competition which has made electrical power relatively expensive. On a larger scale, this has caused some companies to relocate their factories from Kenya to neighboring countries whose power is more lowly priced. Even though energy markets have never been fully open or competitive, liberalizing the national energy market, is a sure way of correcting this price distortion.

If the market conditions mentioned above are ideal, it is not far-fetched to imagine a company that supplies and maintains solar water heating equipment and other renewable energy aspects and simply charges a fixed amount for equipment usage, which can free the developer/ owner from the installation and maintenance costs.

Renewable energy supportive policies are not only justified because of social and environmental benefits, but also to redress market distortions that have been favoring fossils and nuclear in the past.

v) Renewable Energy Feed-in (pricing) systems most successful

This is a system where renewable energy systems are installed alongside the grid distribution system and the two complements each other. This makes it possible for any surplus attained in the renewable energy system to be fed into the grid while any deficiency can be pulled from the grid.

The net surplus can be paid out in monetary terms or through the awarding of power credit to be used up in future.

To date, feed-in policies have achieved the greatest effect in terms of market penetrations of renewable energy and produced the most cost-effective renewable energy installations. They have also helped in the establishment of local industries, built domestic markets for renewable energy related components, created work opportunities, and attracted small and big private investors as well as bankers in much developed countries. This is mainly because the system also becomes an investment that brings in some returns.

By contrast, quota system is where a developer or establishment is given a certain energy quota that must be met using renewable energy means as a way of ensuring implementation. Quota systems benefits the owner directly without the possibility of selling the surplus and so is therefore not as attractive as the feed in system where it also becomes an investment.

Feed-in systems are therefore most suitable for developing countries since they tend to attract more investments (Private capital) and cause faster growth. This may however be difficult to apply in the case of solar water heating systems as opposed to photovoltaic systems (PV) which are used for generation of electricity. It is worthwhile to note however that certain manufacturers are already working to develop systems that can perform the dual functions of water heating and electricity generation.

2.5.2 Categories of Policy Mechanisms

For wide application to be witnessed, the policy mechanisms developed must both encourage and effectively help to enforce application of SWH systems. The following are five categories of policy mechanisms that determines renewable energy applications.

i) Regulations governing market/electric grid access and quotas mandating capacity/generation

ii) Financial interventions and Incentives

iii) Industry standards, planning permits and building regulations (codes)

iv) Education and information Dissemination

v) Public ownership and stakeholder involvement

2.5.2.1. Regulations governing market/ electric grid access and quotas mandating capacity/generation

Preferential access to the grid is as important as initial incentives to the introduction of renewable energy systems. There are two general types of regulatory policies for grid access that are used, one mandates the price while the other mandates quotas.

i) Feed-in tariffs or pricing systems

The best renewable energy market successes have been achieved where pricing systems are in place. Net metering" or "reverse metering" is a variant of the above, whereby excess renewable power (in the case of PV system) is fed into the grid at the going retail price.

In some cases, producers receive payment for each kilowatt-hour (for electricity generating systems) that is fed into the grid while in others they are only paid up to the point where their production equals consumption. Understandably, the net metering system without other financial incentives, does not suffice for significant market penetration, and could be considered a transitional phase to the full grid-feeder pricing system.

In other renewable systems like solar water systems, special pricing (discounted) can be applied to an equivalent amount of energy drawn from the grid matching that saved through the system. This would encourage people to install the system.

ii) Quotas - mandating capacity/ generation

This is a situation where the Government fixes the target and it may mandate a minimum share (quota) of capacity or energy to come from renewables. This mandate can be placed on producers, distributors or end consumers. Quotas can be applied to grid-connected and off-grid electricity, as well as other renewable energies like biofuels or solar thermal energy. In addition, policies can be adjusted if governments wish to adjust the pace of renewable energy market transformation through the application of a suitable pricing system.

2.5.2.2. Financial Incentives

Financial incentives provides an effective way in which governments can address the energy market failures and also encourage the use of renewable energy, thereby attempting to level the playing field. These incentives may take the form of tax credits, rebates, investment or production support as implemented in most developed countries. The following are some of the financial incentives that can be adopted.

i) Investment and production tax credits

These can cover either the total installed costs or the plant costs only. They are designed to encourage investment in renewable energy technologies. The tax cycle and not the renewable energy market demand tends to influence the flow of investments in renewable energy.

ii) Other forms of tax relief

Relief of environmental taxes or carbon taxes is a more impact related incentive. Import duties can also be reduced on renewable energy technologies until domestic industries are sufficiently established.

iii) Rebates and Payments

Government can provide rebates on the price of a renewable energy system depending on capacity installed, combined with low interest loans and public education. These must be tied to technology standards. (Japan a case). Payments and rebates are preferable to tax breaks because they accrue to all income levels and therefore produce a more even growth than the sudden income tax reduction. Rebates and payments on their own do not suffice to stimulate the market (Haas,2004), and should also be output related.

iv) Low-interest loans and guarantees

It has been argued that finance, rather than technology innovation drives down the renewable energy cost curve. Having observed this, the Federal Government of Germany refinances long term low interest bank loans to those who chose to invest in renewable energy.
In the developing world, many more poor people could have access to renewable energies if they had access to reasonable loans. Renewable energy loans are feasible if the monthly loan repayments are comparable to the current monthly expenditure on candles, paraffin (kerosene) and appliances.

v) Addressing subsidies and prices of conventional energy

Even current global subsidies for conventional energies remain many magnitudes higher than those for renewable energies (Geller, 2003). Surprisingly, about 80 to 90 percent of these global subsidies to the fossil fuel and nuclear industries are paid out by the developing world (Sawin, 2004). These countries that can least afford it and therefore keep their energy price unrealistically below the true costs of production and delivery.

Even small subsidies for petroleum products in developing countries can send out the wrong signals and direct nations down unsustainable energy paths, eventually trapping them into endless cycles of poverty. Subsidies, if at all granted, should have sunset clauses and should enable the recipients to transit to renewable energies.

Observations point out that it would be a better policy to channel significant resources towards energy efficiency, energy conservation and renewable energies. Instead of trying to find new money streams to subsidize established sunset technologies, the existing streams should be reallocated to renewables.

Governments in developing countries are large energy consumers through their energy inefficient buildings, vehicles, transport systems, military and infrastructure and they should therefore explore such measures.

2.5.2.3 Industry standards, planning permits and building codes

Developing nations most of which happens to be within the tropics have sufficient reasons for adopting renewable energy technologies. They however require to develop essential technological standards through certification, permit standards, grid connection standards, and the building regulations (codes). They also need to develop strategies for promoting renewable energies.

For the purpose of reliability, new technologies like SWH, PV and wind turbines demand new standards of performance, durability, safety and compatibility with existing systems and also suitable quality controls should be developed and enhanced.

Application of renewable energy can also be enhanced through policy demand on its integration in development plans before implementation permits are issued. This can be at various scales from mega to small developments. The Building codes (1976)**,** which sets the building standards in Kenya**,** should therefore promote energy efficiency and the use of renewable energy, especially for water heating and should be supported by complementary policies, research, training and regulations.

In developing countries like Kenya, domestic water heating consumes a significant proportion of the total energy usage and the building regulations should be prescriptive of the need to integrate a solar water heating system. This should be over and above any other existing regulation that prescribes it since the code is much easier to monitor implementation because it is enforced by the local authority whose presence is widespread over all municipalities.

Barcelona, Spain instituted an ordinance requiring that all new or to be altered buildings satisfy 60 % of their hot water consumption by SWH, or alternatively they were to be wired for PV installations, and the effects of this law was dramatic and carried no costs to the Authority.

Buildings represent investments with a longer lifetime than most power stations and can therefore be regarded as distributed energy generators in their own right instead of being consumers if energy generation or conversion systems are integrated. For this purpose, it is necessary to develop solar access regulations that would determine and protects any development's right to access solar radiation. Under these regulations, buildings, neighborhood and even large scale developments should be guaranteed of solar access through enactment of suitable legislation. This should be particularly so because the inclusion of solar water heating system is prescribed by law. Exposure to the sun should therefore also be protected and this can most effectively be done by the local Authority's development control section since it has to do with the building's orientation, neighborhood's design, building heights, amongst other factors which are all aspects of planning.

Development free solar corridors, maximum heights of buildings, controlled distances between buildings, control of vegetation and tree heights, roof gradients, solar terraces can all then become factors that would require to be predetermined and controlled.

The Sun would therefore be considered as a prime resource and would consequently be a major aspect in planning of human settlements.

2.5.2.4. Education and information dissemination

The mere availability of renewable energy resources, incentives, technology, capital, expertise and government policy does not suffice if there is insufficient end-user awareness. Knowledge plays a key role in determining the choices that people make and this is more so in the renewable energy arena. This is even more critical where there is already a well-established and apparently reliable conventional energy supply system.

For the uptake to increase, people must be made aware of the benefits, cost, energy nature, statutory regulations and obligations, and everything else that pertains to every aspect of renewable energy being advocated for. It is quite obvious that even with the law requiring that the system be implemented in homes and with the source being abundant; the inertia is bound to be higher if the populace is largely ignorant especially of the benefits of such systems.

Germany has less sunshine than France, and less wind resource than the UK. But its application of renewable energies is so much more because of the general awareness of the German population. Initial implementation of renewable energy systems face certain degrees of failures which have created negative perceptions in some countries. These can be overcome by the Governments, NGOs and the industry maintaining concerted efforts to disseminate the relevant information.

Educational institutions also have a responsibility of educating and enlightening the new generation and general populace about energy's role in socio-economic development and the environment. Other stakeholders that can play a crucial educating role includes concerned Government Ministries, Local Authorities, Non-Governmental Organizations, Special interest groups, Professional Societies/ associations and global bodies. The International Solar Energy Society for example, contributes to knowledge dissemination through conferences, workshops, publications, and summer schools. It also maintains international electronic networks for the dissemination of information, recognizes and awards exceptional achievers in furthering the science and application of renewable energies which goes along way into raising the awareness level.

5.2.5. Public ownership, cooperatives and stakeholders

Many developing nations have a strong tradition of communal public ownership and cooperative initiatives. This as yet seems not to be the general trend in the case of renewable energy generation and usage. Communal participation not only engenders public pride and avoids obstruction or vandalism, but also supports government renewable energy policies when these periodically come under pressure from vested less environmentally friendly energy lobbies.

Communities all over the world, and in many forms e.g. Women's groups, property owners, neighborhoods, Institutions etc. have joined together in developing renewable energy projects jointly and reaped enormous benefits which includes pushing for enactment of suitable policies and laws by Governments. Such organized groups that are contained within concentrated zone can also attract funding for renewable energy projects due to the suitable economics of scale. The fact that the benefits would be shared within a community makes it even more attractive as opposed to sparsely distributed people or groups with similar interests that poses spatial challenge which would call for many small localized systems.

The Table 2.1 shows various stakeholders and their probable roles in promoting the use of renewable energy:

Table 2.1 Key Stakeholders:

	Stakeholder	**Function**
1	Legislative authorities/ elected officials	Set national political priorities; social, economic, and environmental goals; legal framework conditions.
2	Government macroeconomic and development planners	Define development goals and macro policy; general economic policies; crosscutting issues; subsidies and trade policy; sustainable development goals, and frameworks.
3	Government energy authority or ministry	Set sector goals; technology priorities; policymaking and standard setting functions; legal and regulatory framework; incentive systems; federal, state, and local level jurisdiction.
4	Energy regulatory bodies	Have monitoring and oversight functions; implement the regulatory framework; administer fees and incentives.
5	Market coordination agencies	Dispatch entities; have operational coordination functions, interface with industry investors; information brokers.
6	Non-energy governmental authorities/ ministries	Sector policies; crosscutting issues; interrelation with energy policies; public sector energy consumers; require energy inputs for social services provision.
7	Energy supply industry	Private companies and public utilities; manage energy supply, electricity generation; fuels management and transport; finance some R&D.
8	Entrepreneurs and productive industries	Business development; economic value added; employment Generation; private sector energy consumers.
9	Energy equipment and endues equipment manufactures	Supply equipment for the energy industry and other industries, including vehicles and appliances; impact energy end-use efficiency; adapt/disseminate technology;

		finance some R&D.
10	Lending institutions	Financing options for large- and small-scale energy generation; capital provision for energy using enterprises; financing options for household energy consumers.
11	Civil society/ non-governmental organizations	Consumer participation and awareness; oversight and monitoring; environmental and social advocacy; equity considerations.
12	Energy specialists and consultants	Strategic advice, problem definition and analysis; systems development; specialist services delivery; options analysis; information sharing.
13	Academia and research organizations	R&D, knowledge generation, and sharing; formal and informal education; technical training; technology adaptation, application, and innovation.
14	Media	Awareness raising, advocacy; information sharing; journalistic inquiry, watchdog functions; monitoring, public transparency.

Source: Author 2017

2.6 Advantages and Disadvantages of Solar System Application, USA Case study.

2.6.1 Advantages

Figure 2.4 indicates the results of a survey conducted in the United States of America to determine what people thought were the main advantages or motivation when choosing to install a solar water heating system, and it was demonstrated that the savings realized was the main attraction, followed by realizing a better environment.

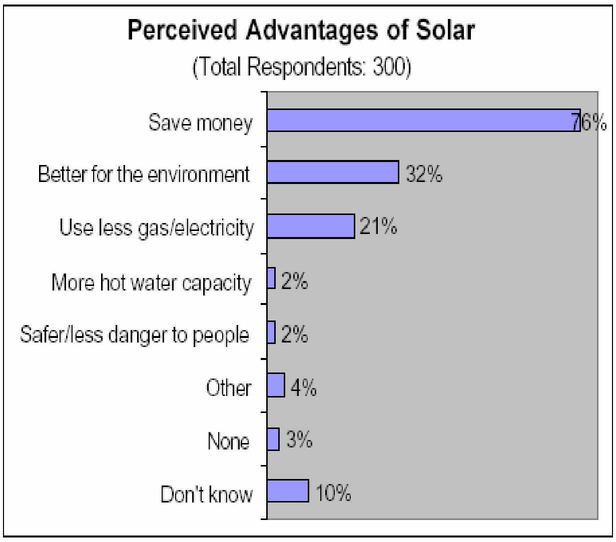

Figure 2.4. Perceived advantages of solar water heating

Source: Keller, 1999

This would not be much different in Kenya since this is similarly the main reason as to why the Government encourages its use. It also needs to be observed that as much as the policy and regulations demands that the SWH system be installed, it is of great importance that it gains acceptability from the people, and this can only be so once they get to understand and appreciate the benefits of the system. This could be real or maybe even perceptive but then, that is the point where the installation inertia can be overcome.

These benefits can therefore be summarized as follows:

i) Solar Energy offers cheap and reliable energy once installation has been done, and the system has a low maintenance cost.

ii) Application of Solar Energy is inclined towards the Government's policy of encouraging the use of renewable (green) energy and the trend in the world. Kenya is a signatory to various global pacts like the Kyoto protocol that strives to protect the environment, which are translated into Government policy documents, and usage of solar energy extends to wider global objectives.

iii) The Kenya Government has put in place incentives like tax exemption in the solar equipment purchase and also parts for maintenance, which one can take advantage of. This is in order to make these equipment more affordable to the general public.

iv) Solar water heating system being independent from grid electricity supply guarantees enjoyment of black-out free energy supply which is characteristic of many places in Kenya.

v) There is enhanced safety in using solar water heaters due to minimized possibilities of electrocution as it happens at times with instant water heaters which have gained popularity in Kenya in recent times.

vi) Low or zero power bills especially in sunny weathers releases finances that can be invested in other areas for personal development.

2.6.2 Disadvantages

In the same study at the United States of America, the perceived disadvantages were as in the graphical representation in figure 2.5:

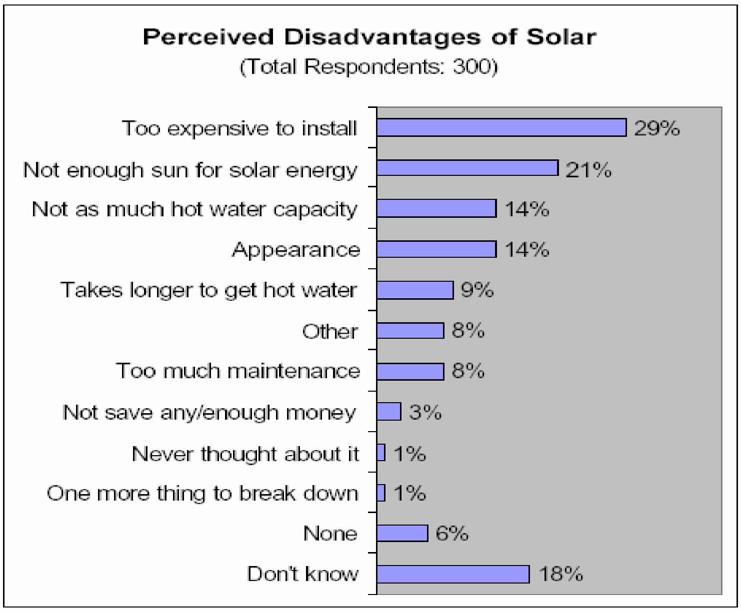

Figure 2.5 Perceived disadvantages of solar water heating

Source: Keller, 1999

As it can be observed, the greatest perceived disadvantage was the cost of installation, with 29% of the respondents citing it as the reason, followed by those who thought that the sun was inadequate at 21%. 14% doubted the ability of the system to provide adequate hot water while another 14% cared about the aesthetics of the system. Of interest are the 18% who pledged ignorance, meaning that they lacked sufficient knowledge on the system.

A similar survey in Kenya would most likely give more or less similar results, although the aspect on the adequacy of the sun would most likely vary depending on the local climatic conditions of the different locations of the respondents.

2.7. Cost Benefit Analysis

Extensive application of any system should be proceeded by a thorough study of both the benefits and associated costs. The study on impacts from local to National levels should include Economic, Environmental, Social and Technological considerations which should in turn inform the development of effective policies.

i) Economic Benefits

This is a more direct benefit since it can be determined by simply calculating the amount of energy saved as an opportunity cost and compared with the costs associated with system's maintenance over its working life time. Hot water demands can be determined from the second schedule Part A of the Energy regulations (ERC 2015), from which the amount of energy required to heat up water can be determined. This energy can be priced using the prevailing rates charged by KPLC and this would amount to the opportunity cost

ii) Environmental Benefits

Solar Energy has enormous environmental benefits in that it helps in the reduction of Environmental pollution that result from carbon emission which is caused when the power used is generated by an alternative means especially using coal and fossil fuels. It also saves on the pollution from nuclear waste if the same power was generated using nuclear means. Solar energy utilization also enhances environmental safety since it is localized in nature. This reduces the need for much higher current transmission through the grid that often poses some risks along the transmission lines which have been known to cause fire to vegetation and built environments as well.

iii) Social Benefits

Application of Solar energy for water heating will come with a host of social benefits inclusive of the following:

a) The technology if extensively used and even at the current extent has opened up a new area of competence that would become a necessity.

b) Extensive use of solar application will create new employment opportunities at various technical cadres, from design consultants, to installation and maintenance technicians.

c) Incorporation of solar heating system at a grand scale has the potential of introducing new design element in the building's aesthetics/ Architecture that would solidly identify with our position within the tropics (Identity from environmental response). The SWH system presently at times has aesthetical challenges when mounted on buildings because it is never an integral aspect of design and always comes in as an afterthought. If incorporated from the onset of the design process it would "belong" and hence introduce a natural link between the built form and the environment. The possibilities would be limitless including probably having a whole roof surface as a hot water heating system.

d) Since the energy is cheap, it potentially can elongate bathing time and this can encourage use of bathtubs or communal bathing facilities (Luxury). A closer look at most residences today reveals that people have been shying g away from including and making use of bathtubs mainly due to the large volume of water that would require to be heated. Availability of the relatively cheap solar energy can easily cause a reintroduction of their use including other communal solar heated baths (Indoors and outdoors), which would have a lot of social benefits.

iv) Technological Benefits

Kenya is yet to be able to meet its requirements for energy and making use of the solar water heating technology can be quite key towards attainment of energy sufficiency status. Other technological benefits would include the following:

a) Since the system is localized, it makes it possible for houses which are off the distribution grid to benefit from this technology.

b) It's being localized also reduces the electrical power load that would otherwise be conveyed using the distribution grid which has some technical advantage.

c) The new technology opens up another area of competence that creates employment opportunity

d) The technology requires little maintenance and hence makes it economical to run and reliable

2.8 Global Solar Thermal Harnessing Trend

It is estimated that only about half of the incoming solar energy from the sum actually finds its way to the earth's surface, with about 30% being reflected back and the rest being absorbed by the clouds and dust in the atmosphere. The earth receives approximately 174,000 terawatts (TW) of solar energy, with most area of its surface having insolation levels of 150-300 watts per square meter which translates to 3.5-7 kWh/ M Sq. per day.

In UNDP Publication on the potential of solar energy in 2000 in the world energy assessment, it estimated that the annual potential would be between 1,575 – 49,837 Exajoules (EJ) which was noted to be several times larger than the total world energy consumption of 559.8 EJ for the year 2012. The quantity of solar energy reaching the earth's surface is so much that the amount in one year is about twice that which will ever be obtained from all of the earth's nonrenewable sources of coal, oil , natural gas and mined Uranium.

UNDP observed that the potential of solar Energy per region was as per the Table 2.2.

Table 2.2. Solar Energy potential for various regions of the world.

Region	**N/A**	**LA & C**	**W/E**	**C& EE**	**S/U**	**M/E & N/Af**	**S/Af**	**P/A**	**S/A**	**C/A**	**P/ OECD**
Min	181.1	112.6	25.1	4.5	199.3	412.4	371.9	41.0	38.8	115.5	72.6
Max	7,410	3,385	914	154	8,655	11,060	9,528	994	1,339	4,135	2,263

Source: Michael (UNDP), 2000

Key
N/A - North America LA & C - Latin America & Caribbean S/U - Former Soviet Union
M/E & N/Af - Middle East & North Africa S/Af – Sub-Saharan Africa P/A – Pacific Asia
S/A - Southern Asia C/A - Centrally Planned Asia P/ OECD - Pacific OECD

Harnessing of Solar thermal Energy has contributed significantly the world over in terms of meeting the energy demands, and as the technology keeps on being improved over time this contribution has been on an upwards trend. In 2011 the global installed solar thermal capacity stood at 245 GW and exceeded wind power capacity that stood at 239 GW. Geothermal energy was at 12 GW while PV systems capacity stood at 67 GW. From this it is rather obvious that SWH systems are continually playing an immense role in the provision of clean and affordable energy. Global leaders in this area includes Cyprus, Israel, Austria, Barbados and Greece. Table 2.3 lists the leading countries and their collector capacity per 1000 inhabitants in 2011.

Table 2.3. Installed capacities in different countries of the world.

Rank	Country	Collector capacity per 1000 inhabitants (KWh)
1	Cyprus	574.8
2	Israel	393.9
3	Austria	337.4
4	Barbados	322.7
5	Greece	266.1
6	Turkey	119.8
7	Germany	112.2
8	Jordan	107.9
9	Australia	94.9
10	China	88.4

Source; Weiss and Maunthner, 2012

For significant growth of the SWH systems uptake to take place in some of these countries especially in Israel and China, certain deliberate interventions had to be adopted. In 1980, Israel's legislature passed a law requiring the installation of SWHs in all new homes (except those with limited roof areas). It is estimated that 85% of all homes in Israel have SWHs. Due to this success story, other countries also passed similar laws including Spain that passed it in 2006.

Solar water heating systems has had significant penetration in China from different reasons however which includes local manufacturing of low cost SWHs and lack of electricity and gas supply in rural China. Both of these have seen the uptake increase. Other than regulations, other important factors that have seen growth in uptake in especially Europe and Australia/ New Zealand have been:

i) Long term policy support of solar thermal incentives which enables the industry to plan long term and therefore invest in the market growth. This results in an Industry driven campaign to implement the same.

ii) Public education campaigns that raise consumer awareness to the benefits of the system, and in turn helps in creating demand.

In the United States of America, The uptake has been relatively low the reason being that SWHs cost relatively more that in Europe, Middle east and Australia/ New Zealand. In comparison to Israel and China, factors that have contributed to the higher cost in the USA are as shown in Table 2.4

Table 2.4: Factors resulting in high installation cost of SWH's in the United States of America.

	Cost Factor	**Impact**	**Explanation for higher cost in the US**
1	Technology Choice	High	Most common type in the US is the indirect system which is more expensive unlike in both China and Israel where the much cheaper thermosiphon type is widely used.
2	Design	High	Demand for more complex systems with higher quality materials and additional features in the US drive up the cost
3	Building SWH Preparation	High	Buildings particularly in Israel are designed to be SWH ready which significantly reduces the labor and material costs
4	Installer Cost	High	Inexperience, higher marketing/ overhead costs, less standardization and less competition contributes to higher costs
5	System Capacity	Medium	US systems use double collector areas and storage hence more expensive
6	Labor rates	Low/ Medium	Higher labor rates increase total installation cost in the US though relative to Israel they are comparable
7	Quality Demands	Low/ Medium	Chinese quality is inferior to the US though Israel's is certified in the US Market.
8	Manufacturing Volume	Medium/Low	US has low manufacturing volumes due to much less demand unlike Israel & China

			hence systems are more expensive
9	Pressure requirements	Low	End users expect water at higher and consistent pressures hence necessitating more expensive pressurized systems unlike in China & Israel
10	Incentives/ Rebates	N/A	Incentives more generous than in China & Israel

Source: National Laboratory of the US Department of Energy, office of Energy efficiency & Renewable Energy Technical Report NREL/TP-5500-54793 of August 2012

Presently, solar energy conversion is widely used to generate heat and produce electricity. A comparative study on the world energy consumption released by International Energy Agency (IEA) shows that in 2050, solar array installations will supply around 45% of energy demand in the world.

The cited global trends show that certain aspects pertaining to SWH systems are as follows:

i) The energy trend the world over is clearly gyrating towards renewable sources, and solar water heating (thermal) is clearly leading in this direction.

ii) Africa is lagging behind this world trend, and only a few of its countries have done enough as to achieve global recognition

iii) The countries that are successfully implementing SWHs have been very deliberate and the most important interventions that they have done includes:

   a) Enacting Laws that makes it mandatory to install SWH s in buildings
   b) Making the SWHs more affordable to people
   c) Creating long term policy support that acts as incentive to the industry which could include tax rebates amongst others and this would guarantee sustainability of the industry and market.
   d) Raising public awareness on the benefits of SWHs, which would increase demand and in turn lower the cost.
   e) Technology choice and consumer preference can influence the cost
   f) Technical support that is affordable also lowers the cost and especially in the installation, operation and maintenance of the system.
   g) Designing buildings that are SWHs responsive lowers the cost of installation and maximizes the benefits.

2.9 Utilization of solar energy in Kenya.

2.9.1 Background of Solar Energy use in Kenya

The geographic position of Kenya as a country where it sits astride the Equator as shown in Figure 2.6, favors the exploitation of Solar Energy due to the abundance of sunshine unlike countries in the far north and south of the Equator. Due to this abundance, it has become a natural option as it is not only cheap, but also reliable and would also cause some saving of energy obtained from other sources, which can then be used in the other economic sectors.

With such natural endowment of sunshine where the country enjoys an average daily insolation of 4-6 Kwh/Square Meter (ERC, 2015), coupled with ever increasing need for energy to fuel Kenya's Industrialization, it has become prudent for the Kenya Government to put in place Instruments that will ensure that Solar energy is being utilized effectively, if only to ease the energy burden. ERC has pointed out that the total area capable of delivering 6.0 Kwh/SqM per day in Kenya is approximately 106,000 Km Sq whose potential is 638,790 Terra watts hour (ERC, 2015)

Figure 2.6: Map of Kenya showing the latitudes and longitudes

Source: Wikipedia, 2017

Kenya has notably invested significantly in other forms of renewable energy and especially geothermal and wind also due to their enormous natural potential (Odrazek, 2011). It is estimated however that there are over 65,000 solar water heaters in use in Kenya and Nairobi is actually ranked first among the cities of Eastern Africa region in the use of SWH systems. It has been projected that the usage in Kenya is set to grow to more than 800,000 units by year 2020 (KIPPRA, 2016)

The Kenya Government's commitment to investing in the development of solar energy systems can be seen from its intention to develop solar generators in 74 public institutions as stated in its developmental blue print the Vision 2030, where this investment alone will to eventually cost the GOK in the tune of billions.

In the past, most of the aspects of renewable energy and more so the solar generation has been associated with remote areas which were outside the power distribution grid as an alternative energy source. This has mainly been in the area of electric power generation, through solar panels.

Solar water heating systems established themselves earlier since they provided a much cheaper alternative to the more expensive grid distributed power when used for heating water, but this however was often regarded as an un necessary costly element and a preserve of the affluent members of the community- an elite culture. In the nineteen seventies and eighties, the prevalence of SWH systems was so insignificant as to be noticeable but they began to appear in a noticeable way in the main urban centers from the Nineties. This easily corresponds with the time when energy started to become significantly expensive at the domestic front.

Over the years however, the perception has changed mainly due to two reasons, one of which is the high cost of energy and second its scarcity. Electricity cost has not only been taking an ever increasing proportion of the home budget as time goes by, but it is also becoming quite unreliable with many urban neighborhoods experiencing frequent blackouts due to either maintenance or power shortages. At certain times the country experiences some power rationing from KPLC, due to these shortages especially during the dry spells when the water levels in the dams used for electricity generation falls below certain levels.

2.9.2 Use of solar water heaters in Kenya

Water heating has been said to be responsible for approximately between 40 and 50% of domestic power bills, and any other system that can substitute direct heating by the grid supply would therefore be regarded as the easiest and fastest way of saving on electricity without necessarily incurring major investments.

On average, the residential sector in Kenya consumes about 820 GWh of electricity annually which keeps increasing by the day. This has been putting significant strain on the power infrastructure, especially at peak hours in the morning and in the evening when the utility is at its peak, and this has been a matter of concern for the Kenya Government because this energy can be utilized in other sectors of the economy for wealth creation. Encouraging and enforcing the use of solar water heaters in the domestic sector and by institutional and commercial users would reduce the power demand which will mean that the balance of energy can be directed to these other sectors.

This is what motivated the Kenya Government to develop and gazette the solar water Heating Regulations of 2012, meant to offer both the guidelines towards implementation and mechanism for enforcement and monitoring this application. Kenya leads in the east and central Africa region in the uptake and installation of solar equipment and It was established in 2013 that more than 320,000 solar home systems (SHS) were installed (water heating and electricity generation combined), which was quite high as compared to say Tanzania that had some 40,000 SHS installed. Kenya is actually regarded as a world leader when it comes to off grid solar uses.

In Kenya, it is typical to find a significant number of isolated solar systems in rural institutions other than homes, like schools, health facilities, places of worship and other social places. The number of institutions equipped with solar equipment through NGO agencies and also through donor assistance is even much higher.

2.9.3 Hot water demand Calculation (ERC regulations second schedule part A.)

According to ERC, demand for hot water should be calculated as per Table 2.5.

Table 2.5. Schedule for hot water demand

Type of Building/ Premises	**Specific Daily Hot Water Demand** **In Litres/ Day at 60 Degrees centigrade**
Domestic residential houses	30 per person

Educational institutions such as colleges and boarding schools	5 per student
Hotels, Hostels, Lodges and similar premises providing boarding services	40 per bed
Restaurants, Cafeterias and similar eating places	5 per meal
Laundries	5 per kilo of clothes

Source: ERC Regulations, 2012

The following should be noted when calculating the hot water demand:

Hot water demand calculations at other temperatures (T) shall be adjusted for the 60 ºC reference temperature and for the purposes of making this adjustment, the following assumptions and observations should be made;

i)) The equation assumes that the cold water temperature (inlet water temperature) is 15 ºC and a linear relationship. 45 º C is the difference between 60 º C and 15 º C.

ii) For buildings with seasonal variations in hot water demand such as Hotels, game Lodges. And similar premises, the demand may be adjusted by an annual occupancy rate of factor of not less than 70%.

iii)In calculating demand, it shall be assumed that the daily hot water demand is constant, throughout the year.

iiv) In calculating demand for domestic residential houses, the number of persons shall be taken to be equal to the number of bedrooms x 1.5.

v) In calculating the heat load of solar water heating system, heat losses in the hot water distribution system shall be taken into account.

Example of hot water demand calculation for a three bedroom house would be as follows:

From the table on hot water demand and subsequent part “c”, it follows that:

Amount of hot water demand on a typical three bedroom house with typically five occupants would be:

Persons = 1.5 x3 = 4.5

Litres of hot water required = 4.5 x 30 = 135 Litres

This implies that any house with three bedrooms and above should incorporate a solar hot water heating system since the demand is above the 100 litres threshold.

Amount of Energy saved by using SWH like in the case above would be as follows:

For the three bedroom house the energy saved would be that which would otherwise be used to heat up 135 litres of water up to 60 degrees centigrade.

Calculations: Thermal energy is calculated using the formula below:

E= MC(Final temperature – Initial Temperature)

Where:

E = Energy in Joules

M = Mass of water in Kilograms

C = Specific heat capacity (Amount of energy required to raise 1 gram of water temperature by one degree centigrade and this is 4.184 Joules)

Assuming that the water's temperature is being raise from room temperature (approximately 20 degrees Celsius to 60 degree Celsius, the solar energy used therefore would be as follows:

Weight of 135 Litres of water = 135 Kgs = 135,000 grams

E = 135,000 x 4.184x 40 = 22,593,600 joules

If it takes on average 7 hours to raise the temperature from 20 to 60 degrees Celsius, this translates to 896 Joules/ second, equivalent to 0.896 Kilowatts.

Assuming that only a quarter of the current 5 Million homes connected qualify and install the system, which is 1.25 Million, this will translate to 1.12 MW for every seven hours per day which is quite significant.

The investment is therefore certainly worth it at the national scale.

2.10 Policy Framework for management of SWH in Kenya

Management of energy and encouragement of the adoption of new technology must start from the highest level with the policy makers who must understand the need for this adoption and also the larger picture of possibilities and opportunities it affords.

A favorable policy that tends to “legitimize “the technology also helps to shape peoples’ attitudes towards creating acceptance and influences the economic environment which addresses amongst other issues the aspect of affordability.

People’s attitudes and perceptions must be favorable despite of enactment of any policy or regulations, otherwise it encounters a high degree of inertia or even resistance. If this is however achieved, then sustainability is guaranteed.

According to the Energy Regulatory Board (ERB), there are three factors that at the moment slows the acceptance and subsequent installation renewable energy systems including the solar water heaters in Kenya, and these includes the following:

i) The high capital required to install the gear required for generation inclusive of direct cost of equipment and cost of land.

ii) Limited information/ awareness on the potential opportunities and economic benefits offered by especially Solar Technology

iii) Lack of adherence to system standards by suppliers.

Some of the existing Policies and Regulatory Framework in Kenya that have encouraged investment in the renewable energy sector includes the following.

i) Kyoto Protocol

The Kyoto Protocol was created through UN Framework Convention for Climate Change (UNCFCC) and is described as “An enhancement of energy efficiency and an increase in the production and use of new and renewable energy, as well as institute measures to limit or reduce emissions of GHGs”

This protocol was created from realization that extensive use of fossil based energy sources released GHGs, (carbon based) which in turn led to global warming and caused negative climate change. The main contributors of these gases were the developed countries, whose energy needs were on an ever increasing trend due to rapidly expanding industrial activities.

The protocol was therefore intended to intervene and reverse this trend, and many of the industrialized and industrializing nations signed and ratified the protocol. They were required to adopt technologies of energy generation that limited or reduced this emissions, and it was believed that the use of renewable energies and adoption of energy efficiency measures to replace traditional power sources that generate GHGs would help to achieve this.

Kenya being a signatory of the Kyoto Protocol is obligated to ensure fulfillment of certain conditions aimed at reducing the world's pollution levels, most notably through the adoption of green approach, especially in energy production.

Some of the measures recommended that can influence the implementation of renewable energy includes the following:

a) Establish a Designated National Authority with dedicated, well-trained staff and powerful linkages to the ministries of energy and environment
b) Establish the Carbon Emission Baseline and disseminate to stakeholders
c) Establish the National Development Criteria, avoiding political opportunism, and disseminate to stakeholders

By encouraging the utilization of solar energy in water heating as a substitute of other alternatives, it aligns itself with the intentions of the protocol, and cuts down on gases which would have otherwise been emitted in the generation of the same amount of energy through fossil based fuels.

ii) Vision 2030

Vision 2030 observes that there will be a significant increase in Kenya's energy demand, and that currently the energy cost in the country is much higher than in her competitors. It states further that there is need for Kenya not only to generate more energy at a lower cost, but also increase efficiency in the consumption.

The strategies highlighted for achieving this includes the following:

a) Institutional reforms in the energy sector
b) Strong regulatory framework
c) Encouraging private power generators & separating generation from distribution
d) Exploring new sources of energy, one of which is exploitation of renewable energy sources including solar energy.

The document further on singles out establishment of Solar Generators to 74 public Institutions as a flagship project.

It is within this background that the solar water heating regulations of 2012 were enacted so as to bring in efficiency in the consumption of the power generated through other means, and also exploit solar energy in itself being renewable.
As shown in a different section, what may need to be done now is to strengthen the regulations and make them enforceable for the intention to be achieved.

iii) Tax Incentives

To encourage investment in this area, the Kenya Government further zero-rated the import duty and removed Value added Tax (VAT) on renewable energy equipment and accessories.

This effectively addressed the issue of affordability and consequently has contributed enormously towards creating a vibrant solar energy market in Kenya over the years.

It is estimated that the annual demand for solar energy systems has been growing at over 15% annually since 2005.

iv) Energy (Solar water heating) regulations 2012- Review

This Act of Parliament is meant to provide the legal framework that governs the application of solar water heating systems and some of the key areas of this regulation are discussed and reviewed below;

a) Installation and usage

The premises that must implement SWH’s and the window period for existing ones are clearly defined and the penalty for non-compliance and extent of hot water demand that must be covered by SWH system are also spelt out as below.

1) All premises within the jurisdiction of a local authority with hot water requirements of a capacity exceeding one hundred litres per day shall install and use solar heating systems.

2) Within a period of five years from the date of coming into force of these Regulations,(2012), all existing premises with hot water requirements of a capacity exceeding one hundred litres per day shall install and use solar heating systems.
3) A person who contravenes the provisions of this regulation commits an offence and shall, on conviction, be liable to a fine not exceeding one million shillings, or to imprisonment for a term not exceeding one year, or to both.
4) All premises shall have a minimum annual solar contribution of sixty per cent to the premises' hot water demand.
5) The regulations makes exemption to certain situations where implementing the law would be difficult and in particular mentions the following:
    i) Premises with technical limitations;
    ii) Premises incapable of incorporating solar heating systems due to their special circumstances;
    iii) Premises supplied with hot water from a cogeneration plant in or proximate to the premises;
    iv) Premises utilizing electricity generated from renewable energy and the excess is used to heat water as a dump load; or
    v) Such other premises as the Commission may determine.

b) Review of the implementation clause of ERC regulation.

From the above aspects of the regulations, several facts becomes obvious:

i) As indicated earlier in this study, every domestic house with two bedroom and above which is located in an urban area (within the jurisdiction of a local authority) qualifies under this regulation to install a solar hot water system.
ii) By the mid-2017, all houses falling under aspect "1" would be required to have installed a solar water heating system, in which case the deadline being almost past, there should be intense activities geared towards fulfilling this condition. It can therefore be observed that, the lack of any activity would mean that the people are not conscious at all of the deadline for installation.
iii) The assumption could be that most people are likely to be ignorant of this requirement due to not being informed of the requirement, and this opens up certain questions including the following:

1) How effective is the mechanism of communicating Government policies to the people
2) When and if the information is communicated, how effective is the packaging towards people understanding its significance
3) If the objective of the law will not have been achieved before the deadline, would the people who would not be compliant punished and yet no much effort has gone towards disseminating the information , noting that the scale of non-compliance is quite significant.
4) Lack of installation could also imply poor enforcement mechanisms, which leads to several queries including the following:
    - Does the anticipated enforcing Authority have the capacity to do so
    - How effective is the chosen mechanism of enforcement
    - What requires to be done to enhance compliance

c) Responsibility for Compliance

The Act bestows the responsibility of ensuring compliance to the developer, owner of the premise or occupier and the electric power distribution company as follows:

i) A developer of a housing estate, a promoter of the construction, an owner of the premises or an Architect or an Engineer engaged in the design or construction of premises is expected to comply with these Regulations.

ii) An owner of premises, Architect and an Engineer engaged in the design, construction, extension or alteration of premises is expected to incorporate solar water heating systems in all new premises designs and extensions or alterations to existing premises.

iii) An owner or occupier of premises that has a solar water heating system is expected to use and carry out the necessary operational maintenance and repairs required to keep the installation in good and efficient working condition.

iv) An electric power distributor or supplier is not expected to provide electricity supply to premises where a solar water heating system has not been installed.

d) Incentive

An owner or occupier to whom these Regulations apply may investigate the inclusion of the relevant solar water heating system into a project to be registered under any carbon finance mechanism (CFM) that may be established from time to time including the Clean Development Mechanism (CDM).

e) Punishment for Non-compliance

A person who contravenes the provisions of this regulation commits an offence and shall be liable, on conviction, to a fine not exceeding one million shillings, or imprisonment for a term not exceeding one year, or to both.

f) Power of Inspection

The Act gives overall responsibility of ensuring compliance to the energy regulatory commission (ERC), and stated as follows:

i) The Commission or its agent may inspect premises, to investigate matters relating to the installation of solar water heating systems in premises, in accordance with section 24 of the Act.
ii) The Commission shall issue a compliance certificate, upon request, where a solar water heating system has been installed in compliance with these Regulations.
iii) Where the Commission finds that the provisions of these Regulations have been contravened by the owner or an occupier of the premises or that a condition that may lead to the contravention of these Regulations has arisen, the Commission or its agent may issue a compliance notice to the owner or occupier of the premises.
iv) A notice issued under this Regulation shall specify-
    1) The regulation that have been contravened;
    2) The measures that should be undertaken to rectify the contravention; and
    3) The period within which the notice shall be complied with.
v) A person who does not comply with a notice issued under paragraph (4) within the specified period commits an offence and shall, on conviction, be liable to a fine not exceeding ten thousand shillings for residential premises and thirty thousand shillings for all other premises for each day or part thereof that the contravention continues.

This statement of inspection can easily be the weakest link towards enforcement because it bestows the inspection role to the ERC which has serious challenge of having enough reach and an inspection mechanism as would be required. It however empowers it to engage agents who would in turn ensure compliance, which has not happened, probably due to resource limitation. Like it has been stated, liaising with the local authority can go along way into providing the necessary network required for enforcement.

g) Standardization (Quality Control)

This section states the specifications and standards of the SWH system that must be used in the country in an attempt to regulate the standard of equipment through clauses stated as follows:

i) A person shall not use or employ for the purposes of or in connection with a solar heating system, any mode, material or apparatus other than that which complies with the Kenya bureau of Standards.

ii) A Solar collector shall, for the purposes of these Regulations, be of the unglazed flat plate, glazed flat plate or evacuated tube collector technologies or any other type that meets the Kenya Standards for solar collectors.

iii) A glazed, evacuated tube collector or any other type that meets the Kenya Standards for collectors shall be used in all installations except in installations for heating swimming pools where unglazed collectors may be used.

iv) Solar collector panels shall be insulated to improve their thermal efficiency performance.

v) The storage capacity of a solar water heating system shall not be less than one and a half times the daily hot water demand of the installation.

vi) The hot water storage tanks shall be insulated.

vii) All components selected for use in the installation of a solar water heating system shall be corrosion resistant.

viii) Selection of components for plumbing works in a Solar Water Heating System shall be in accordance with the planning and building code made under the Local Government Act, Cap. 265.

The Regulation on standardization would appear to be vague since it adopts assumed standards in reference to other bodies/ Acts. The Kenya bureau of standards should obtain the desired specifications and standards from the Energy regulatory body and simply enforce/ mark those which comply.

Also by referring to the Local Authorities Act, it exposes this sector to any shortcomings that the said act might have. For example, it is a widely known fact that the building code enforced by the local authorities has long been due for review, and it does not addresses the issue of Solar water heating systems, a relatively new phenomena in the industry is uncertain.

One necessary direction that it might have taken would be to require the Kenya bureau of standards to recommend approved manufacturers whose components have been or would be subjected to a thorough standard's checks with the possibility of de-registration in the event of dropping of standards and demand the usage of their equipment in Kenya.

The specifications for the standards would have been thoroughly specified.

h) Licensing of Solar Water Heating System installation work.

This part is intended to ensure that only qualified persons are engaged in the Installation of SWH. It also expects the commission to keep track of all the works, which in itself is quite a tall order. The law states as follows:

i) A person shall not undertake any solar water heating system installation work unless the person is licensed by the Commission as a solar water heating system technician or a contractor.

ii) The Commission shall not license a person as a solar water heating system technician unless the person has-

1) Qualifications and experience specified in Part C of the Second Schedule; and

2) Certification recognized by the Commission.

iii) The Commission shall not license a person to be a solar water heating system contractor, unless the person has in his or her employment, a licensed solar water heating system technician.

iv) A person who wishes to be licensed as a solar water heating system technician or a contractor shall make an application in Form set out in the Third Schedule.

v) The Commission may require and cause such applicant, for the purpose of ascertaining his ability to undertake, engage in or perform any work that is related to solar water heating system installation, to be examined, in such manner at it may determine, upon any matter or thing in connection with his application.

vi) The Commission shall process all applications within ninety days from the date of receipt of the application.

vii) The Commission may, after considering an application made under paragraph (4)

1) Grant the license applied for unconditionally or with such conditions as it may consider Fit; or

2) Refuse to grant the license applied for, giving reasons thereof.

viii) A license issued under this regulation shall be valid for a period of two years from the date of issue.

The licensing of works clause anticipated that all technicians be licensed, solar water heater works documented, and registers kept which would seem to be quite an ambitious task. It may be more effective if the task was delegated to a third party/ agent to do it on behalf. The agent would require to have a national reach through an elaborate network.

An authority and especially the National Construction Authority (NCA) which already has the mandate of accrediting construction workers in all areas would be most suited to maintain such a register, since it is also a requirement that all construction project must be registered with the authority before commencement it can easily keep records of the works on behalf of ERC.

NCA also have an effective monitoring network, with all regions in the country falling under a regional manager who has the required personnel to monitor and enforce regulations.

i) Installation Standards

This section is meant to guide the actual installation and highlights the following:

i) Solar collectors shall be installed at an angle between 10º and 20 º from horizontal plane and/or facing the equator:

ii) Provided that the solar collector area shall be increased by 10% for tilt angles of up to 30 º and 20% for tilt angles of up to 40 º for technical or aesthetic reasons and/or increased by 10% if the deviation from the direction of the equator is above 25 º.

The clause on installation standards can only be effective if it is integrated with the building code where the design team would be obligated to comply. This may also affect the aesthetics of the building which is a question that the design teams would require to consider.

The validity of this section can be challenged in that it makes an assumption that facing the equator maximizes the solar Insolation. While this may be true for those countries in the Northern and Southern hemispheres it cannot hold true as one approaches the equator. Taking for instance a house located just slightly north or south of the equator, it might end up facing North or South in totality and this would not maximize the solar exposure.

As advanced in the literature review, before the system is installed there should be a proceeding site study and audit which will lead in the determination of the best orientation for maximum exposure. This should not only be based on the daily movement of the sun from east to west, but also the north or south shift throughout the year.

The ideal angle would also be determined by a number of factors including the nature of the horizon and obstacles and the building’s aesthetics among others. The building code points out the roof angles as relating to the roofing materials, for example it prescribes the minimum roof angle for iron sheet, clay tiles, etc. This implies that the roof angle cannot be determined by one factor only, and therefore inclusion of solar water heating system should be conceptualized with the building during design so that they are a part of the thought process and all the factors can be considered together.

Including SWH,s in the code, together with the specifications for installation would also have the benefit of making them enforceable by the local authorities who are the enforcers of the code.

2.11 Conceptual Model

From the above sections, It is quite clear as to why the Kenya Government and indeed the whole globe is deliberately steering towards renewable energy and especially solar energy in alleviating its energy demands.

Solar water heating in particular has been a key target since a large proportion of energy consumed in domestic houses goes towards water heating and it is due to this that the Government of Kenya has enacted the energy regulations for solar water heating with the intention of not only encouraging its application, but also to enforce the same.

The regulations were gazetted in 2012 and the Government of Kenya provided a five year window within which all domestic houses that had not been installed with SWH system were to incorporate it, while all new developments were from henceforth required to include it. If this was to take place as anticipated by the regulation, all residential developments other that those included in the exemption clause were to have a solar water heating system by May 2017.

A general observation of residential sector of Kenya's urban development, which would fall under jurisdiction of an urban authority and hence required by law to install a SWH system, reveals that this has not happened which is indicative that the regulations has largely not been observed.

The Energy regulatory commission in its report cites the reasons for the low compliance as due to the High cost of SWH systems, Lack of awareness of the regulation and the system, and also lack of technical capacity for maintenance and installation of SWH system.

This would however appear to be quite simplistic since other crucial areas that can influence application fails to be considered in their analysis which has not been based on any actual research. Factors like the role of the existing policy mechanisms in encouraging the uptake has been ignored, which would address areas such as financial incentives, tax reliefs, market conditions, affordable loans to mitigate against the high cost, building regulations and dissemination of information amongst others.

The Solar water heating regulation in itself also has certain in adequacies as brought out that makes it difficult to enforce that ranges from its being vague in some sections, while also not synergizing itself with other existing regulations and laws that affects the building industry . If this is done, enforcement would not necessarily be done by the ERC only, but others as well, and more so the local authorities who have a more solid presence on the ground.

The likely factors therefore that has made compliance with this regulation by developers or home owners difficult to implement despite of the existence of the law includes the following:

a) High cost of Solar water heating system
b) Lack of adequate information on the system
c) Lack of technical capacity to install and maintain SWH systems in Kenya.
d) Weak enforcement mechanism of the law requiring all individuals whose household requirements for hot water exceeds 100 litres should integrate SWH system in the building.

In an ideal scenario, the home developers should install the system without having to be forced to do so from their understanding of the inherent benefits from a global to individual level and so in this study, only the first three factors which influence voluntary implementation would be considered. The fact that enforcement mechanisms have been evidently weak rather makes it an obvious factor but the importance of enforcement shall however be included in the model because it would still plays a key role in ensuring compliance if streamlined.

As has been observed earlier, no research has been done in Kenya to either confirm or refute the factors, unlike in the case of the United States where the high cost featured amongst other reasons. The High cost could however be a question of perception as indicated elsewhere in this study arising from lack of adequate information. The general population could also not be aware of the mandatory requirement for them to implement SWH, which in itself results from lack of information.

Figure 2.7 indicates the relationships between general objectives of the Government of Kenya as defined by the development policies and various protocols it is a signatory to that leads to the formulation of regulations and other enforcing mechanisms and their relationship to the factors that affects implementation.

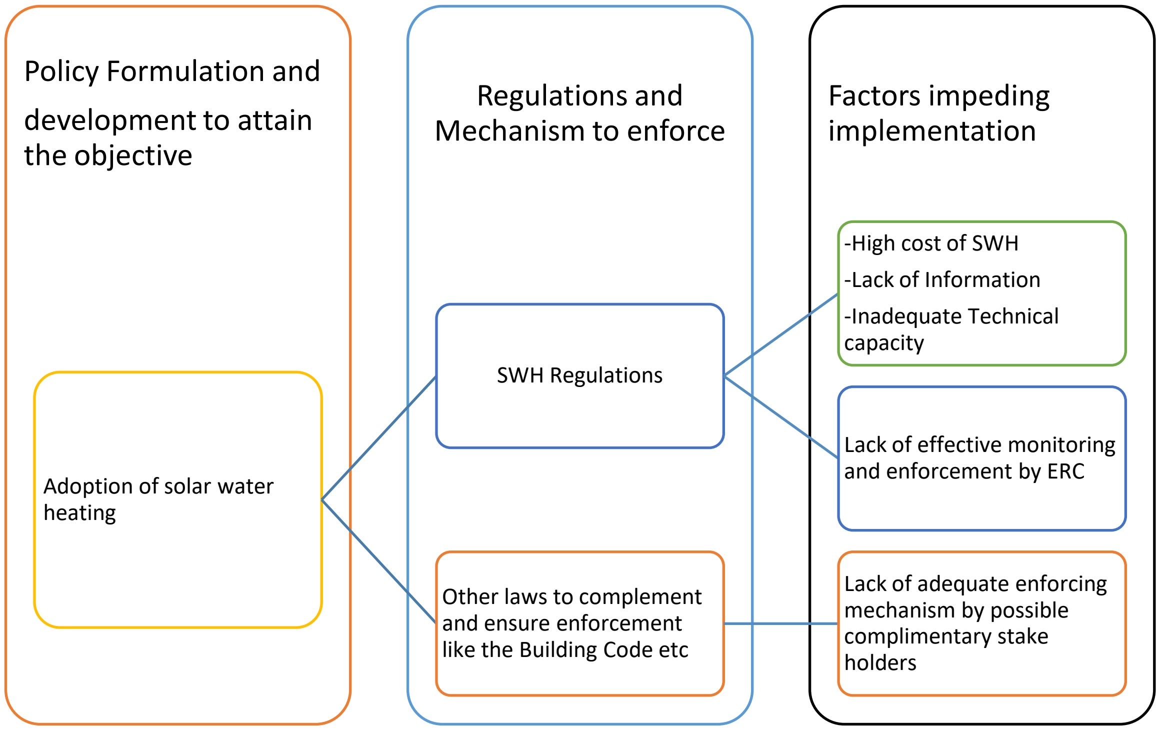

Figure 2.7 Relationship diagram

Source: Author, 2017

The research seeks to establish how the three factors has affected their decision either to or not to install SWH system in their houses.

Proposition

The proposition of this study is that the high cost of solar water heating systems, lack of adequate information on both the system and the mandatory requirement to install it, and unavailability of technical capacity in Kenya to both install and maintain the system has led to the low level of implementation of SWH systems by individual home developers in urban areas, despite of the SWH regulations having been enacted in 2012.

Chapter 3

RESEARCH METHODS

3.1 Research Design

This research intends to test the cited proposition through gathering of evidence from the field (Study area consisting of developed Households) as a representative of middle income urban neighborhoods. A representative sample shall be determined in which selected method of collecting the relevant data shall be applied.

The research will be conducted through various stages or with certain important components which will logically guide towards a conclusion. These components will include the mode which will be used to collect the data, how it shall be measured and finally analyzed.

The research focus is the geographic spread of the residential area of Syokimau which falls under the upper middle class status, and would consider the household as the basic unit. From the sampled population, it will determine the number of households which have installed the solar water heating system and those which have not, including the reasons for each case so as to either confirm or refute the proposition highlighted in the previous chapter.

Chapter two has highlighted the theoretical framework through which the problem cited in chapter one can be viewed with deeper understanding. By establishing the facts of the situation on the ground, more knowledge shall be created from the evidence established, as Mouton (2004) observes.

To date there exists no similar previously done studies of the reasons as to why the uptake of SWH has been very low in Kenya, but as seen in the case study cited in the literature review section, the situation is different in other parts of the world. There is need however to understand the local situation which will help in designing of more appropriate policies that would assist in the achievement of more extensive application.

The study will therefore pioneer a new area on which future researchers can build on and would involve a systematic approach involving collection of appropriate data with subsequent analysis and interpretation so as to generate findings and conclusions regarding the research problem.

The results will be analyzed using statistical tools, and this will lead to conclusions which will bring out a better understanding as to why Kenyan individual home developers do not to install the SWH despite of the existing policy and regulatory framework that requires them to do so.

The findings and conclusions would then be used to generate a model or framework which can be applied so as reverse the existing situation. Figure 3.1 shows the systematic approach of the design.

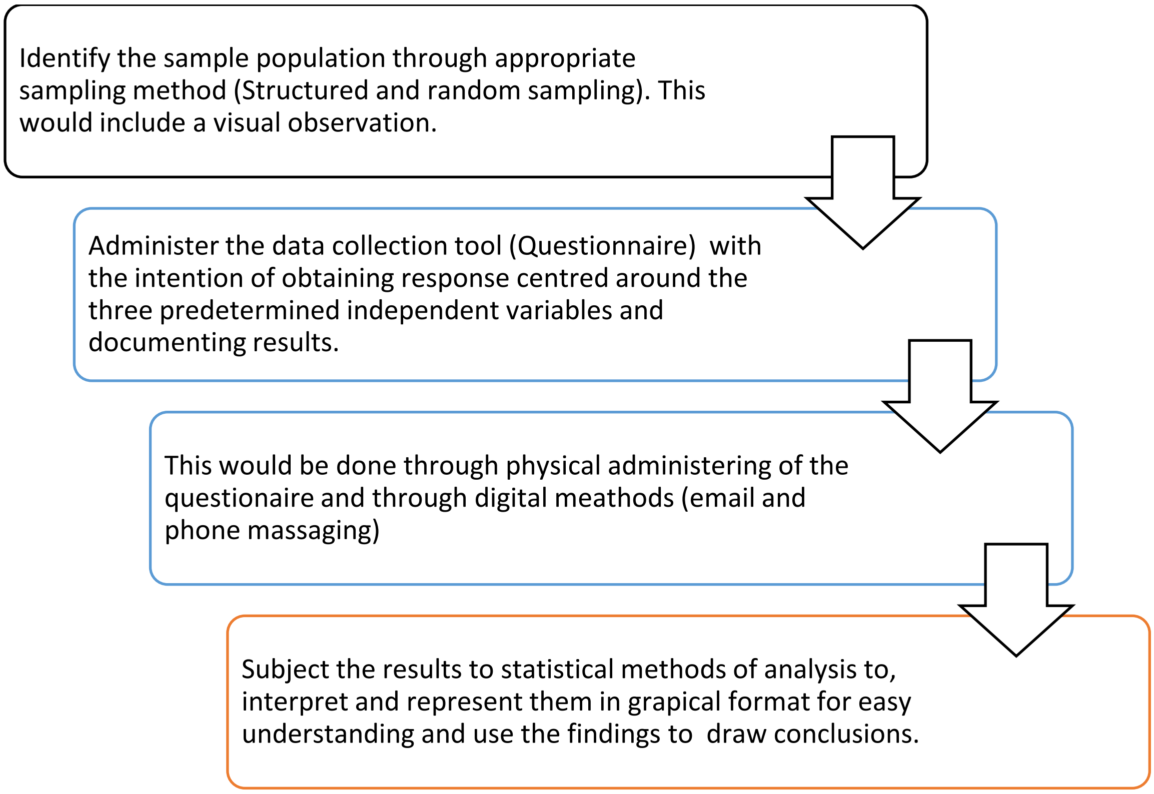

Figure 3.1. Flow chart of the main research activities.

Source: Author, 2017

3.2 Data Sources

Secondary data which in the case of this research will mainly be geographical in nature will be obtained through survey maps and also internet means. The map for the area will be used to define limit of the study area to support its description.

Primary data in turn will be collected through structured questionnaires with sampled members of the resident population in the study area, and through visual observation. Table 3.1 gives a summary of the data type, source and application intent.

Table 3.1 Data needs, data sources and variables assessed.

	Research Tool	Data needs	Data Sources	Variables stressed
1	Observation	Identify homes that have complied to regulations	Syokimau estate	Level of compliance to regulations on installation of SWH systems
2	Questionnaires	Reasons for compliance or non-compliance	Home owners	How the defined independent variables have influenced their compliance or non-compliance. Variables includes: • High cost of system • Lack of information • Lack of technical capacity in Kenya

Source: Author, 2017

3.3. Sampling Design

3.3.1 Geographical area/ location of the Study.

The study was limited to Syokimau which is a typical middle income housing estate that lies approximately twenty Kilometers from the capital City, Nairobi, but in the neighboring county of Machakos, in Mavoko sub-county. It is well connected to the capital by all major infrastructure components inclusive of Mombasa Road (class A104) and rail, with the Nairobi South Railways terminus being within close proximity. It is also barely five Kilometers from the Jomo Kenyatta International Airport.

Syokimau Estate has three main access roads from Mombasa road that run parallel to each other namely Airport road, Kiungani and Katani roads with minor distribution and linkage roads in between. Fronting Mombasa road are Commercial/ Industrial properties all developed with major companies/ Establishments existing which includes Mastermind Tobacco, Meds, Directorate of civil aviation, the Gateway shopping mall, Gas stations and various Industrial parks .

The main reasons for the choice of this area as the basis of the study included the following:

i) It is a middle income area which means that the monthly mean income per family is above Kenya Shillings One Hundred Thousand. This implies that the affordability of a solar water heating system is well within the resident's reach.

ii) Most of the home owners are well educated, relatively young (35-55 years of age) and have easy access to most of the publications.
iii) The climatic condition of Syokimau and the wider Machakos region is ideal for investment in solar equipment due to the long sunshine hours (8-10 hrs) of reasonably high intensity.
iv) The location of Syokimau in close proximity to the capital city gives it access to top of the range solar equipment (most recently developed)
v) The area has an active residents association where members interact digitally, which can be used as a vehicle for data collection.
vi) Most Homes in Syokimau constitutes of relatively young and growing families where consumption of electricity is significantly high.

Syokimau area is basically served by seven main roads namely Airport, Wananchi, Kiungani, Community, Parliament, Quarry and Syokimau-Katani, Which also defines specific communities within the larger community based on common access. The area selected for the study through random sampling was Kiungani road with the number of households registered by Syokimau Residents association (SRA) totaling to two hundred and fifty one houses (Independent houses each built in its own compound by owner).

The gated communities or flats were excluded since the occupants did not have to make independent decisions on whether to install SWH Systems or not.

3.3.2 Spatial/ Functional Characteristics

Kiungani road links up with Mombasa road at the “Nation” Junction where Mastermind Tobacco factory is located and goes all the way to “Jambush” a total stretch of three kilometers. Various access roads branch off from Kiungani road to serve various courts each consisting of up to fifty Housing units with each sitting on an eighth of an acre, though a few occupies a quarter of an acre. A typical court occupies five acres of land on average.

There are also some gated communities (housing developments) along Kiungani roads namely Springville and Lifestyle gardens and institutions as well namely Breakthrough International Church (BIC) Church, Good Samaritan centre (for Catholic Church), Mount Sinai CMI School, Notre-Dame school , St Veronica Catholic Church and the ACK Church. There also exists an administrative post complete with a chief’s office, Police post and resident association’s secretariat.

The area consists of controlled development, where development plan does not allow construction of low cost housing, flats or apartments, but rather single family dwelling with most of them ranging between 200 SqM for bungalows to up to 450 SqM for Maisonettes. This places the average construction cost of the individual houses at between six and Fifteen Million Kenya Shillings**.** Figure 3.2 shows typical houses found in the area.

Figure 3.2. Typical houses found in Syokimau
Source: Author, 2017

The houses developed in the gated schemes are however approximately 220 SqM and retails at on average thirteen million Kenya Shillings.

This is what qualifies the area as a middle income area. Figures 3.3 and 3.4 shows Springville and Lifestyle gardens estates respectively which are the two main completed gated housing schemes found on Kiungani road.

Figure 3.3: Springville estate
Source: Author, 2017

Figure 3.4: Lifestyle gardens
Source: Author, 2017

Most of these gated housing schemes however has solar water heating systems installed, which is a response by the designers to the favorable environment, and the cost of the systems is therefore always built in the total cost of the house. This means that the buyer does not get to make the decision on whether to install it or not because they find it in place. In a way this also makes them quite affordable since they end up forming a very little proportion of the house cost. Integrating the equipment cost with that of the house makes the buyer not to “feel” it as an extra cost.

It is also reasonable to assume that it is easier to enforce the law when it comes to large developments which involves formal construction arrangements with consultants who are obligated to obey the law. The temptation to do the contrary is minimal due to the enhanced visibility of the development as opposed to individual houses, many of which do not involve formally registered entities in their construction. In most of these, only the consultants are registered whose engagement may in most cases be on piece meal basis? Their numerous numbers and sparse distribution also makes following up difficult and more so when the enforcing entity is rarely on the ground. These housing schemes would therefore be exempted from the study since there is no deliberate decision making involved in installing SWH’s on the part of the user, though they are still in the minority.

3.3.3 Infrastructure

Syokimau in general is well serviced in terms of road network done mostly to murram standards though plans to pave the roads are at an advanced stage. The Water supply is through Mavoko municipal council in limited areas, and independent suppliers who have drilled some boreholes in the area, and distributes water to the residents have come up to cater for the inadequacy. It is common to find up to three boreholes within an area of five square kilometers.

Electricity supply is by Kenya power and lighting company, but there a few residents who have supplemented this with solar PV systems though these are in the minority. Every home has grid supplied electric power despite most of them from a visual inspection, lacking SWH systems. Garbage collection is done by independent service providers and soil water from the homes is managed by individual septic tanks.

3.3.4 .Sociology

Syokimau has an active resident association with membership drawn from all its five social districts (Airport, Wananchi, Kiungani, Community and Katani road).

Each district however consists of individual courts under a chairman who coordinates activities at court level. All residents through their court accounts financially supports the wider association which is duly registered through a monthly fee.

Within the association are committees consisting of elected volunteers, which deals with various aspects of area development and this includes the Planning , Finance, Infrastructure , Welfare and Environment committees. The membership registration data will provide an effective tool for reaching out to members at the data collection stage in this study.

Though not covered under this survey, it can be established that most of the home owners are within the age bracket of late thirties to mid-fifties, with most of the family units being young and having school going children. The average size of the family unit is four, but together with the domestic staff the average number of people for each family is five.

This is significant in calculating the hot water consumption, which if referred to the earlier calculations as per the hot water regulations 2012, each family would require to install a minimum 500 litres capacity solar hot water system.

Syokimau largely consists of people who are in various professions or business, but generally very well educated and exposed. In a typical day during working hours, the only people found in most of the homes are domestic staff, little children who are below school going age, security personnel and construction workers. This situation is typical of middle income neighborhoods.

Mornings and evenings experiences heavy traffic exiting and getting into the neighborhood respectively, consisting of family cars with parents going to their places of work, and school buses either picking or dropping children to and from schools.

There are only two major schools in the area of primary level, and these are run by the Catholic mission, and are functionally interlinked. Notre-dame school admits from class one to Three, after which the children enroll in Mount Sinai school which starts from class Four to Eight. Most of the school going children in the area however attends schools which are located outside the area and they mostly leave at the same time with their parents in the morning.

Mombasa Road which is the main access to the capital where most residents work, serves the broader area of Machakos and Kajiado counties as well, which also are dormitory areas to Nairobi. It therefore experiences heavy traffic jams both in the mornings as early as six o'clock and in the evenings. Due to this, Most of Syokimau residents start their day as early as four thirty, and the heavy traffic to work eases at seven o'clock. This situation also makes owning a vehicle for the residents almost mandatory so as to make this movement comfortable, and as a result literally every family owns at least one family car.

The following highlights can therefore be established:

i) Syokimau consists of a relatively enlightened populace comparing favorably with any middle income neighborhood anywhere in the world.
ii) The families are quite youthful with an average of five people and with most of them having school going children, who leave and come back home at the same time as their parents.
iii) This means that the peak consumption of hot water is in the mornings and evenings
iv) There exists active effective digital communication amongst the residents which can be made use of in data collection for the study.
v) The community is well organized, and with a registered residents association that also runs periodic publication which the residents use as a vehicle to disseminate information. It also organizes public exhibitions where residents showcase their businesses. Other communal activities includes holding annual marathons and regular dinners as a way of bonding. It is therefore quite a cohesive community.
vi) As middle income earners, almost all of the residents are capable of installing a SWH system if they would consider it a priority.

3.3.5 Climatic Conditions.

Syokimau is found within Machakos county, whose terrain is hilly, rising from vast plains and is largely classified as being semi arid. Syokimau falls within Mavoko sub county, though the general climate is basically similar through out the county.

Table 3.2 indicates the monthly average values for Temperature, Sunshine hours, Daily wind speeds, Average number of foggy days, Average monthly precipitation and the average daily relative humidity.

Sunshine hours represents the number of hours during the day when the sun is not obscured by the cloud cover.

Table 3.2. Monthly average values fo various climatic parameters

Month	Temperature		Sunshine hours	Average daily Wind speed Km/h	Averge Foggy (Days)	Precipitation (mm)	Relative Humidity %
	Max	Min					
January	26	13	8	14	3	33	66
February	28	13	9	14	2	54	58
March	28	15	8	14	3	89	64
April	26	15	5	12	5	120	75
May	24	14	5	9	3	117	76
June	23	12	6	9	1	21	73
July	23	12	7	9	1	15	71
August	23	11	7	9	1	30	69
September	26	12	8	11	1	21	63
October	27	14	7	13	1	37	63
November	25	14	6	14	4	102	76
December	24	13	7	15	4	77	73

Source :Weather Africa Policy Institute (API) Web Service.2014

From the table it can be determined quite clearly that the area enjoys significant levels of exposure to the sun with the relative temperatures being sufficient to heat water in a SWH System. Even during the cold months of June and July, the maximum temperatures are still suitable for this purpose.

3.4. Unit of Analysis

The household unit is ideal since the Energy Regulatory Act insists on the installation on a household basis. The households to be sampled are however those where the installation of the Solar water heating system is a household decision. This exempts cases where the owners of the house have purchased the house with the system already installed by a developer since in such a case it ceases to be a free choice.

The reason is because large scale developers of housing units can easily be made to comply with the law whereas installation in individually built housing units which constitutes a much larger number of housing units in this area largely depends on individual choices despite of the law.

3.5. Population and sample size

3.5.1 Population

Since the whole of Syokimau area has homogeneous characteristics, selecting a small representative section would be most appropriate and this would involve considering one section of the study area and selecting a representative sample.

As mentioned earlier in this study, Syokimau Area is divided or identified through Five Major roads, namely Katani, Community, Kiungani, Wananchi and Airport Roads. The development along all these sections (Roads) happens to be very similar since this is a controlled development low density residential area. This is in exception of the high density zone which is the strip one Kilometer wide along Mombasa road and the limited commercial zones within the estate.

To determine the zone in which the study was to be conducted, a random sample was performed and Kiungani Road was selected as the study zone. It also happened to have the following attributes.

a) It was the most central of the roads flanked on one side by Wananchi and Airport roads, and on the other Community and Katani roads.
b) It had the minimal commercial activities and could be termed as being very residential
c) It represented one of the earliest to be developed and therefore had some of the most established homes.
d) It had an established community which operated individually and also as a sub-set of the bigger Syokimau residents association, complete with digital linkages amongst the home owners, a factor that was be exploited in data collection.

3.5.2 Target Population

Kiungani road developments occupied an estimated area of approximately fifty acres and with an average of 500 parcels of land each measuring on average an eighth of an acre, though only about half of them were built-up with individual households. This number however was bound to increase as there was evident of more houses under construction.

The type of developments in these area were varied, with a mix of individually developed housing units, Commercially developed gated communities most of which had an average of between Twenty and one hundred housing units that took the form of maisonettes. A few apartment blocks and low rise mixed use buildings at the small commercial centers were scattered at certain points within the area.

The predominant population however were the individually built self-standing housing units, each in its own compound that numbers approximately 251 households and takes up to 85% of the study area, as is also characteristic of the entire Syokimau estate, and this formed the population frame. It is this population that was of interest in this research because they had to make individual decision to either install of not install SWH system.

3.5.3 Sample Size

With an accessible population of 251 households, the research targeted fifty one households, to represent the target population, who are to be selected through the sampling technique detailed below.

3.5.4 Sampling Technique

A purposive sampling method was adopted, with the first step involving identification of all the households where solar water heating systems were installed. These were five in number and fell under the sample of fifty one households, while the remaining forty six households without solar water heating system were randomly selected from the remaining four hundred and forty six households.

3.6 Research Tools and Collection Methods

The main field data collection tool was the questionnaire and this was formulated in accordance with the research questions as shown in Tables 3.3, 3.4, 3.5 and 3.6

Table 3.3 Variables required and detail in which data is measured for investigative question 1

Research question: To establish the extent to which SWH systems have been integrated in urban individual home developments.		
Investigative question	**Variable(s) required**	**Detail in which data is measured**
Have you ever considered installing a SWH system in your household	Affirmation or otherwise	(Answer any one) • Yes

		• No

Source: Author, 2017

Table 3.4 Variables required and detail in which data is measured for investigative question 2

Research question: To establish the factors that contributes towards the choice by individual home developers to install or not install SHW systems and to what extent they have contributed		
Investigative question	**Variable(s) required**	**Detail in which data is measured**
If you have not installed, what are the probable reasons	Factors that influence non-compliance	(Answer any or in multiples) • High cost of installation • Lack of information • Lack of technical support • Not interested
If you have installed SWH, what were your reasons	Factors that influenced compliance	(Answer any or multiple) • Economic benefits • Legal requirement • Believed in going green

Source: Author, 2017

Table 3.5. Variables required and detail in which data is measured for investigative question 3

Question theme: To establish the extent to which availability of technical competence affects the choice to install SWH system		
Investigative question	**Variable(s) required**	**Detail in which data is measured**
If you have installed SWH, how did you get to know about it	Extent to which various modes of sharing information are	(Answer any or multiple) • A friend/ consultant • Dealers promotion

	effective	• Government publication • Public mass media
If you have already installed, are you satisfied with the performance of the system so far in meeting your daily needs of hot water	Affirmation or otherwise	(Answer any one) • Yes • No
Do you believe that there exists technically competent people/ firms in Kenya who can both install and maintain SWH systems	Affirmation or otherwise	(Answer any one) • Yes • No
Is the technical support especially in maintenance of the system readily available	Affirmation or otherwise	(Answer any one) • Yes • No

Source: Author, 2017

Table. 3.6 Variables required and detail in which data is measured for investigative question 4

Question theme: To establish the effectiveness of enforcement mechanism as provided in ERC Regulations		
Investigative question	**Variable(s) required**	**Detail in which data is measured**
Are you aware that there is a legal requirement by ERC that if ones hot water vdemand exceeds 100 litres they should install a SWH system or be penalized	Affirmation or otherwise	(Answer any one) • Yes • No
Did KPLC enquire about your hot water demand capacity before connecting you into their	Affirmation or otherwise	(Answer any one) • Yes • No

power distribution grid		
Did KPLC enquire if you had the intention of installing a SWH system before connecting you to the electric power grid	Affirmation or otherwise	(Answer any one) • Yes • No

Source: Author, 2017

These questionnaires were administered both through hard copies and in soft copies by means of emails, WhatsApp and phone massaging which was converted into hard copies for the purpose of filing.

3.7. Data Analysis and Presentation

The data was collected through questionnaires, developed and structured such as to provide numerical data that has been explored statistically to yield results which have been generalized to the larger population.

The data has been processed so as to provide answers to the research questions, and Table 3.7 gives a summary of data needs and analysis techniques adopted.

Table 3.7 Data needs and analysis.

Research Question	**Type of data needed**	**Data sources**	**Technique of analysis**
What is the extent to which the solar water heating system has been implemented by individual urban home developers?	-Legitimize the problem -	-Primary data (Questionnaires) -Observations	-Descriptive
What are the implementation factors that determine the choice to install solar water heaters?	-Documentation -Decision making	-Primary data (Questionnaires)	-Descriptive -Inferential
What extent does the factors determine solar water heaters	-Documentation -Decision making	-Questionnaires	-Descriptive -Inferential

implementation by individual urban home developers?	-Develop Interventions		
What appropriate mechanisms can be put in place to ensure compliance in implementation of SWH systems by individual urban home developers?	-Policy formulation -Enforcement	-Questionnaires -Secondary data (literature)	-Descriptive

Source: Author, 2017

Primary data has been presented in figures, tables, charts and graphical formats, and Qualitative statements have been used to describe situations.

Secondary data have been presented in the form of statements tables and/or diagrams referenced to the source. Reliability of this data is found in the authenticity and reliability of the source. The data has been analyzed using standard statistical methods including pie charts, bar graphs and descriptions.

Findings of the study are presented in the form of figures and descriptions

Conclusions are in qualitative/ statement form while recommendations are presented in both quantitative and qualitative formats in the form of statements and tables.

Chapter 4

RESULTS

4 .1 Response to questionnaires

The total number of the target population approached was fifty one and the entire population responded which can be termed as excellent.

A significant number of those who responded actually requested that the researcher shares out the findings and recommendations of the research with them since many of them would want to install the system in future.

4.2 Descriptive Analysis

4.2.1 Extent of Installation of Solar Water heating system.

Desire to install SWH system

The extent of installation was to be established by Question 1 that also sort to establish the proportion of the population that has ever considered installing the solar water heating system, and from the findings, 42 out of the 51 respondents were actually found to be interested. This represents 82% of the population, and implies that there is a general desire to install the system.

For there to be an interest, it also implies that this proportion of the population is actually aware of the existence of the system which could point out to the fact that it is an enlightened society that could also probably be aware of the benefits of the system.

For this percentage of awareness, it would seem obvious that there are some impeding factors that stops the majority from actually installing the system other than lack of information.

The 18% who according to the research did not at any one point desired to install the system could have done so for other reasons, some of which the research sort to establish. Figure 4.1 shows the proportion of those who have at least considered installing against those who have never desired to install.

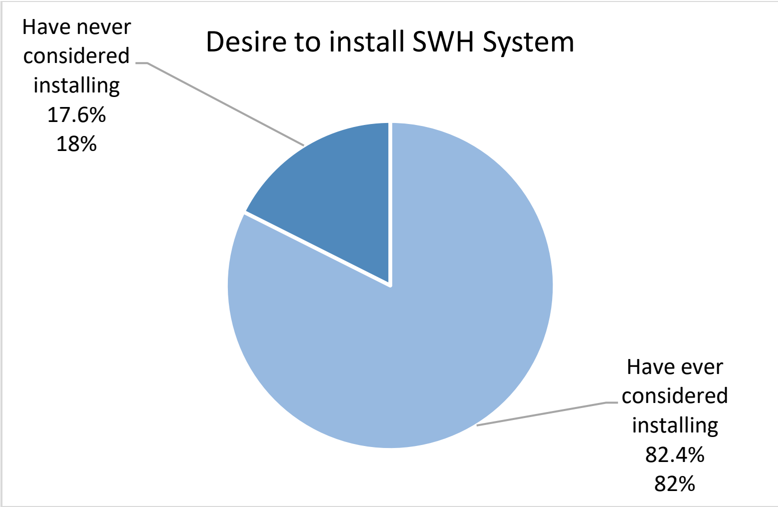

Figure 4.1 Pie Chart showing intention to install SWH system

Source: Author, 2017

It can be observed that the majority of respondents have in the past considered installing solar water heating system at 82.4 %

Actual Installation

Included in the 82.4% are those who went ahead and installed the system (5 in number) which represents 12% of all who had desired. Figure 4.3 shows the proportion of those who desired but also went ahead to install against those who desired but never proceeded on to implement.

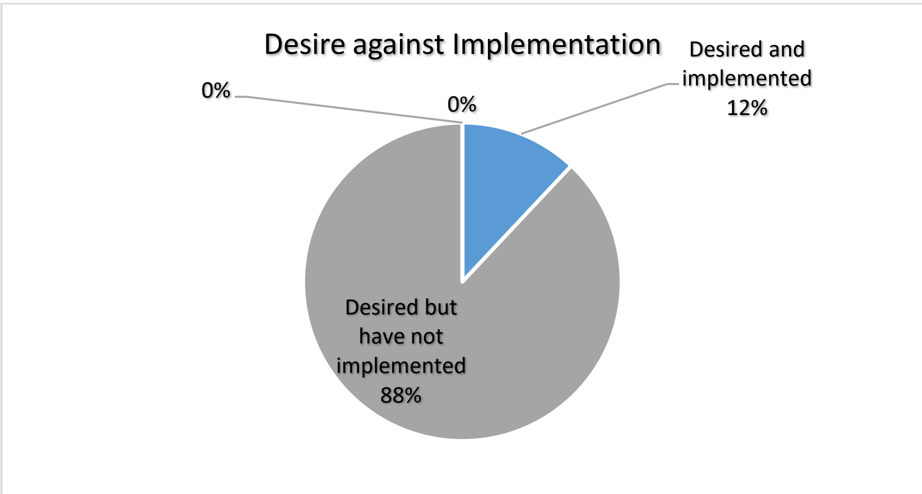

Figure 4.2: Pie chart showing intention to implement SWH system

Source: Author, 2017

This proportion again is quite low for those who had desired and the influence of the identified key factors that caused this including High Installation cost, Lack of Information, lack of technical support and lack of interest (Variables) was investigated so as to determine how each of the factors contributed towards this.

Since there seemed to be a high level of desire and low level of implementation, the findings points out to the areas where possible interventions can be effected to bridge the apparent gap, so as to ensure a higher level of implementation that the policy anticipates.

Extent of Implementation

The proportion of those who actually implemented the system against the entire population gave a measure of the extent of implementation as sort to be established by the first research question. Only five respondents in the sample population of fifty one had installed which is 9.8%.

Figure 4.4 graphically shows the extent of solar water heating application.

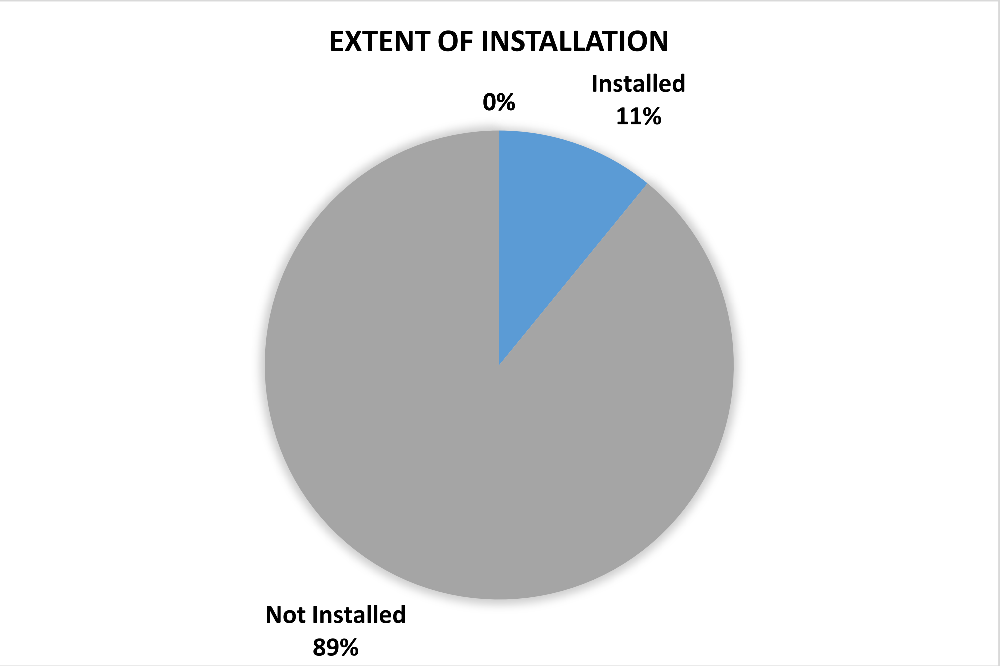

Figure 4.3: Pie chart showing the extent of Implementation.

Source: Author, 2017

4.2.2 Relative influence of the studied factors in the installation of solar water heating system

Considering those who had not implemented the system, the factors highlighted influenced the decision of not to implement SWH system in different proportions.

From the result it was quite clear that the single most prohibitive factor was the high installation cost followed by lack of adequate information necessary for one to make a decision. The nature of the information would be the kind that would make the user or developer know that there are some benefits in the installation of the system.

The researcher included the intention to go green (make use of renewable Energy) intentionally so as to gauge the general awareness of the population to the renewable energy concept, and actually two of those who had installed the system pointed out that it was also an influencing factor. *(*This could be a future new area of research)

Figure 4.5 shows the relative strengths of the factors studied in influencing the decision by the respondents of not to install SWH systems.

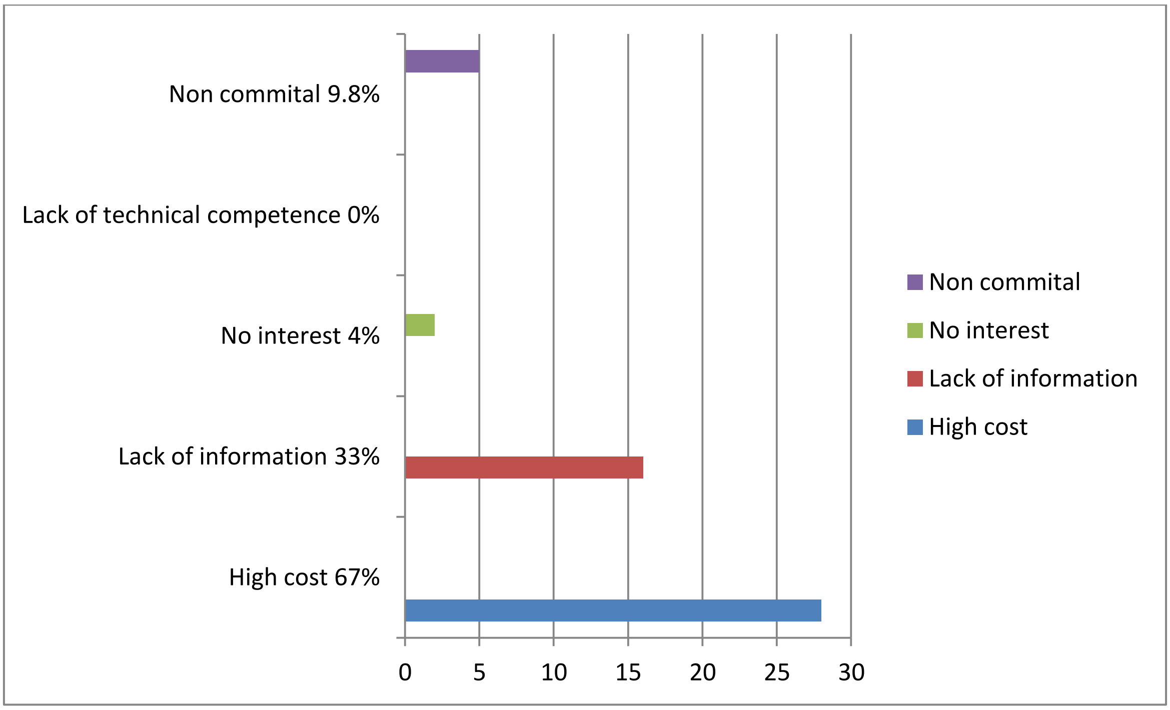

Figure 4.4: Bar chart showing influences of the various factors

Source: Author, 2017

The extent to which the various factors affected the decision not to install has been analyzed below.

i) High cost of Installation

Of the 46 respondents who had not installed SWH, 34 of them who represents 74% of the population cited this as one of the reasons as to why they have not installed the system. Whether this is perceptive or not, it actually seemed to be a key determinant. Most of the respondents however did not seem to have an idea of the cost of the system, but the general assumption was that the system is expensive. There is therefore a relationship between the influence of this factor and lack of appropriate information on the part of the respondents. Figure 4.6 graphically shows these proportions.

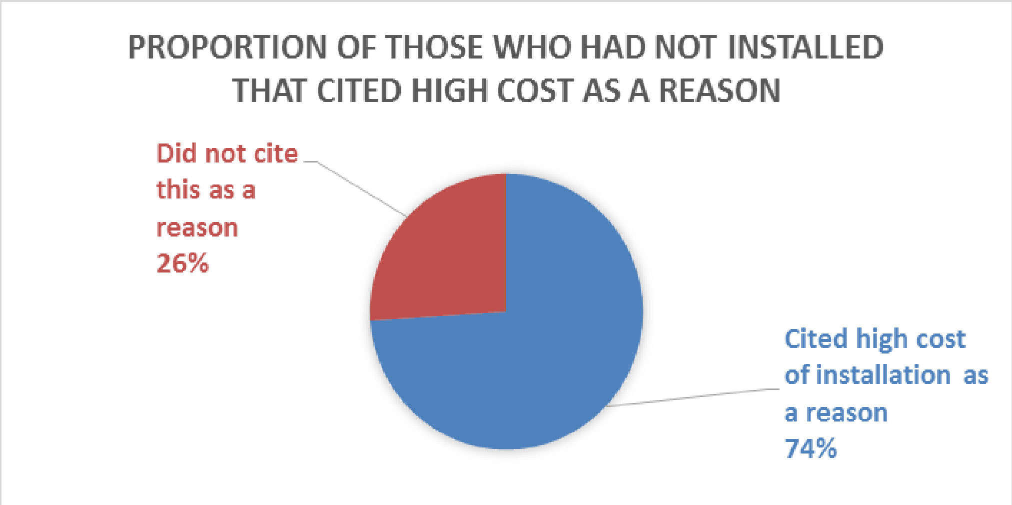

Figure 4.5: Pie chart showing influence of perceived high cost of installation

Source: Author, 2017

When compared to the cited case of the united states as represented in figure 2.4, it would appear that a larger percentage of Kenyans consider high cost as more as an impediment than Americans at 29%. This could either mean that the Americans forms a more informed society or have more reasons other than cost that they consider than Kenyans.

ii) Lack of Information on the solar water heating system.

From the total sample, 33% (18 respondents) cited lack of enough information as to be able to decide on whether to install the system or not. As a percentage of those who had not installed, this would be 39% and it therefore ranks as the second most influential factor towards impeding implementation of SWH systems. Figure 4.7 indicates the relative influence of this factor towards not the decision as not to install SWH system.

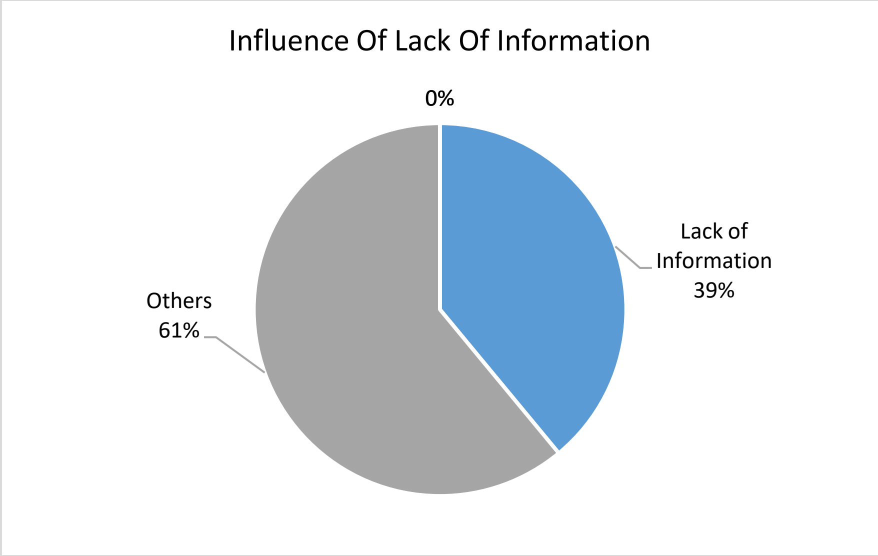

Figure 4.6: Pie chart showing relative Influence of lack of information.

Source: Author, 2017

This information includes the cost of the system, its advantages or disadvantages, the legal requirement to have installed and the existence of enough technical capacity to both install and maintain such systems in Kenya.

It brought out the obvious fact that the key stake holders including the Government, experts and the dealers of the system have not done enough in raising awareness, which in itself can be regarded as the key to the extensive failure of implementing the system.

iii) Lack of Technical Competence in the Kenya

Other than the 18% who lacked enough information on the SWH system, non-cited this as a reason for not having installed it. This implies that there is adequate general awareness on the existence of the technical capacity on the system in Kenya. Though the research did not specifically investigate how this awareness could have come about, it seemed that the general population was comfortable with the existing level of competence.

It could also imply that this is a minor consideration for those interested in installing the system at one time or another probably because they have a high confidence level in the management of the quality standards.

iv) No Interest/ Non-Committal

Seven out of the 51 respondents representing 14% of the population were either not interested or non-committal and had no specific reason as to why they have not installed the SWH system. This group was apparently comfortably with the status quo since they had reliably power from the grid, and could comfortably afford to pay their bills. This is the group that would require legal enforcement mechanism as an intervention in order to comply.

Even though this percentage may not appear to be huge, when applied to the entire population it would represent a large number of people who can make a huge difference. This in itself is enough justification as to why enforcement measures must be taken for the general objectives anticipated by the law to be achieved.

v) **Motivation for installation**

The third question sort to find out the main motivation/ reason behind the installation for those who had SWH System in place. This group had five households which represented 9.8%, and Figure 4.8 shows a graphical representation against the entire population.

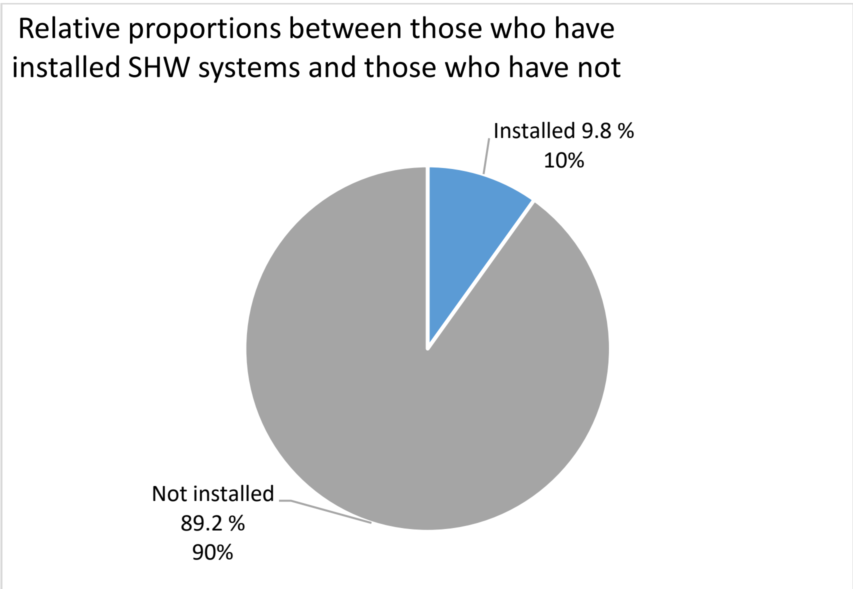

Figure 4.7. Pie chart showing extent of SWH system installation.

Source: Author, 2017

4.2.3 Reasons/ Motivation behind Installation of SWH Systems

The main motivation for those studied included Incurring savings (100%), to conform to the law (40%) and intention of going green (40%) as shown in **Figure 4.9.**

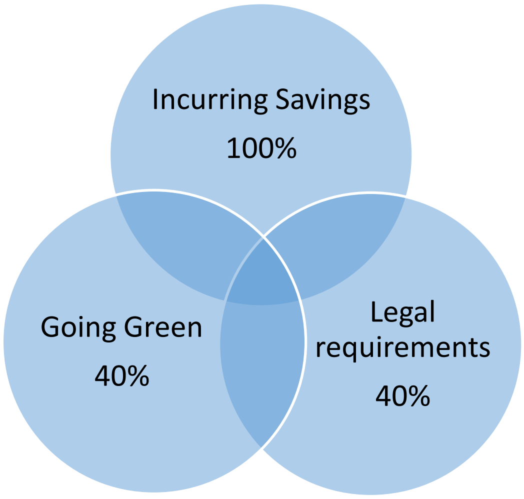

Figure 4.8. Motivation factors for installation of SWH system

Source: Author, 2017

i) Economic Benefits

All the five respondents (100%) who had installed SWH system cited this as one of the reasons. The high cost of electricity from the grid motivated them to invest in the system so as to effect some savings. This apparently was the greatest motivation, like in the case of the study in the United States represented by figure 2.3 where 76% of respondents cited it as the biggest advantage or motivation. It can be noted that one of the Government's main objective of ensuring adoption of SWH systems through the ERC regulations if also for economic benefit at a much larger scale

ii) Legal Requirement

Out of the five respondents who had installed the system, two of them were also aware that it was a legal requirement to do so which also contributed to their choosing to install it.

iii) Going Green

Again of the five respondents who had installed the system, two of them, representing 40% did so with an additional intention of going green through making use of renewable energy.

A closer scrutiny of the findings reveals that out of the five who had installed, only one did so for all the three reasons while two each did so for either as a legal requirement or with an intention of going green in additional to the economic benefit which cut all across. The remaining two did so purely for economic reasons.

4.2.4 Most effective way of raising public awareness

Lack of information had been identified as a factor that adversely affected implementation of SWH, and the fourth question sort to establish the most effective way of raising the awareness level from seeking to find out how those who have already installed the SWH system got to know about it and the options given included:

i) Hearing it from a friend or consultant

ii) Through a dealers Promotion

iii) Through a Government's Publication

iv) Through the mass media

Of the five who had installed, One had gotten to know about it through a dealers promotion while the remaining four (80%) had known about it from the mass media.

This could be due to the easy accessibility of information from the mass media while far much fewer people had access to either Government's publications like the acts of parliament and gazette notices and also to dealer's promotion events and Figure 4.10 illustrates this finding.

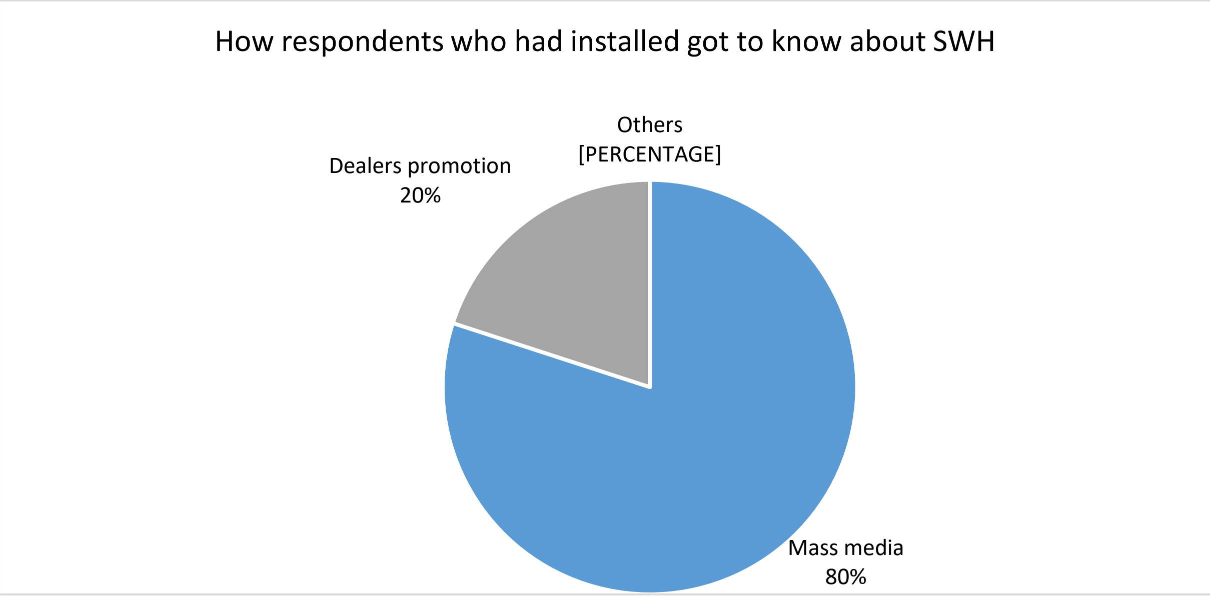

Figure 4.9. Pie chart showing relative effectiveness of publicity Medias.

Source: Author, 2017

4.2.5 Availability of Technical competence in SWH Systems in Kenya

Other than the nine respondents who showed no interest in SWH systems, all the other 42 (82%) believed that there exists adequate technical competence in Kenya to both install and offer technical support. This level of confidence implies that this was unlikely to be a factor that discouraged the majority from installing SWH system.

4.2.6 Awareness of the mandatory requirement by law to install SWH System.

Of the 51 respondent, only 9 were aware of the requirement which represents 15% of the respondents, while the remaining 85% were totally unaware, as represented in Figure 4.10. This is likely to be a key factor since it would appear that the majority of the respondents were not aware that they were breaking the law by not having installed SWH system.

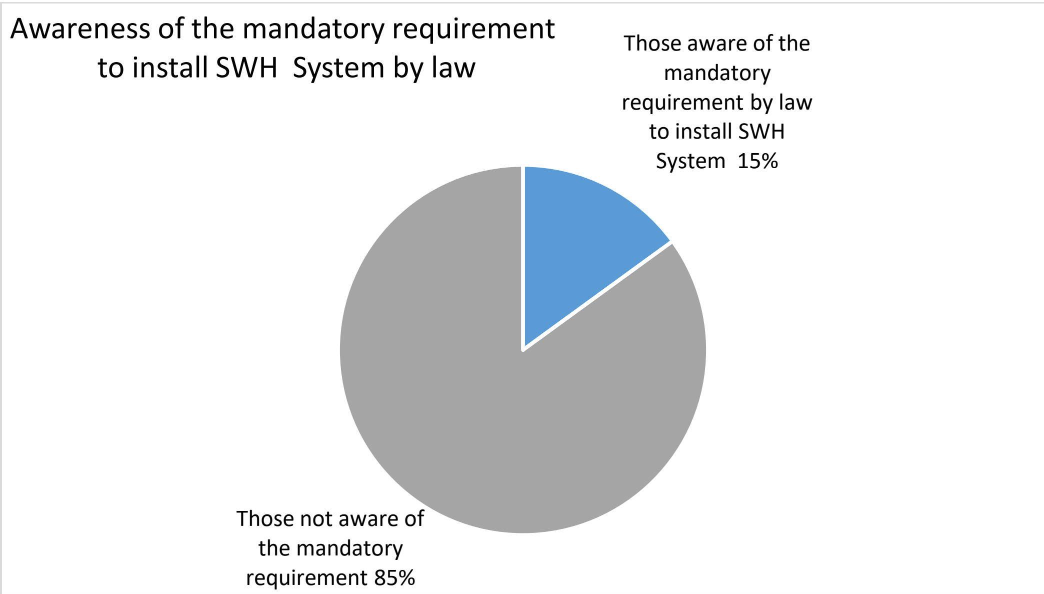

Figure 4.10.Pie chart showing awareness to the mandatory legal requirement to install SWH system.

Source. Author, 2017

The level of awareness to the mandatory requirement to install the system was quite low at 15% and this had a direct correlation with the number of people who have installed the system. It is worth noting that even though Economic benefits appear to be the main driving force towards installation, 40% of those who had installed cited the legal requirements as one reason.

But then, comparing the number of respondents who were aware of the law which was nine, to those who were aware but implemented who were two, it implies that enforcement would still be necessary since only 22% of those who were aware of the law had complied.

4.2.7 Enforcement

The SWH regulations anticipate the enforcement to be through denying the user/ developer access to the grid power if the system has not been installed. This is to be ensured by the Electric Power distribution company, namely the Kenya Power and Lighting Company.

All of the respondents were connected to the electrical grid, and none responded in the affirmative on whether KPLC enquired about not only the existence, but even an intention of installing the system in future.

This confirms that the anticipated mechanism of enforcement was a total failure, and if this is to be used as a tool of ensuring compliance, then it would have to be relooked at and enhanced especially through involving other enforcing agents like the local authorities.

4.2.8 Satisfaction Level with system's performance and availability of maintenance service

All (100%) of those who had installed the system were not only satisfied with its performance in terms of providing hot water and effecting some savings, but also confirmed that maintenance service was readily available. They observed however that the system did not require frequent maintenance service once in place. This is yet another positive aspect of the system.

4.3 Proposition proof

The findings have shown that the solar installation parameters cited including the cost of installation, lack of information of the system and the mandatory requirement to install have influence on the uptake of SWH systems. However, it was found that availability of technical capacity had minimal effect on the uptake.

Chapter 5

DISCUSSION

Even though the findings largely seems to qualify the proposition, certain observations needs to be made before conclusions are drawn.

From the percentage of respondents who have had the desire to install SWH System, it can be concluded that the system enjoys reasonable good will from the people but as assumed in the proposition, the highlighted factors have been proved to be prohibitive in one way or the other towards installation of SWH as proved by this study.

The discussion reflects on the four areas in the light of the theoretical framework developed earlier and literature studies and the results obtain so that objective conclusions can be drawn.

5.1 High Installation cost.

In the Introduction chapter where the global trend was considered, cost was a major impediment to prevalence of installation in the United States of America. However, most of the factors that inflated the cost were unique to that country and may therefore not necessary make the system cost in Kenya overly expensive. As was observed, the cost was determined by amongst others preferred technology and design. In the USA, the collector surface in the system was double that used in Israel because of unfavorable weather conditions in the larger part of US. Israel on the other part is located in the Middle East which experiences relatively a lot of solar exposure.

If this argument is applied to the Kenyan situation, the ideal collector would not require double collector surface, or indeed double storage capacity due to Kenya's relatively reliable sunshine with its being situated astride the equator.

The high requirement in terms of specification standards demanded by the US, and indeed the European market does not necessarily apply in Kenya and so if this factor was to be a prime consideration of cost, the Kenyan market would easily do with a cheaper system.

The issues that first should sort to be understood are those that tend to make the system expensive in Kenya, whether perceived of as a fact. The following is a discussion of those factors and how they affect the system's pricing in Kenya.

5.1.1. Price determined by market forces elsewhere

It is worth noting that all of these systems are imported from outside the country, and therefore there is a threshold in terms of pricing where they can't go below, especially the manufacturing cost. This implies that the cost of a system is partially determined by some market forces that exist elsewhere, and there is very little that the dealers can do about it. Also by the time the SWH unit arrives in Kenya, there is in addition some shipping costs that further increase the price.

In most of these countries, especially those in Europe, the cost of manufacture of good quality units is relatively higher than say what it would have costed if say they were manufactured locally which leads to high unit cost.

5.1.2 Taxation

These units are further subjected to taxation which adds into the cost of SWH units. The numerous duties that includes Import duty on the unit, Value added tax by the dealer and also the contractor in the labor charges adds further to the cost.

5.1.3 Low Demand

As seen in the study, the implementation of SWH system has been quite low due to the various factors pointed out, and as a result, the units that find their way into the market ends up being quite expensive since they don't have the advantage of economics of scale. It also means that the few importers can easily form a cartel and ensure that the price is beyond a certain point. Creation of demand and a much wider market would bring in competition and in the process lower the price.

5.1.4. Expensive installation and maintenance expertise.

Due to the low demand, there exists few technical personnel in the field who have the necessary technical qualifications to both install and maintain the system. As observed in section 2.4, most of these systems comes with a dual system that incorporates electric element and thermostat, which means that the maintenance team or person must be equipped with both electrical and plumbing knowledge, experienced and with sufficient knowhow in the system's design.

Such expertise would naturally charge dearly for his services, which adds to the expense of installation and maintenance of the system.

5.1.5 Poor positioning during installation.

Another latent cost could be in the system's inability to break even due to inadequate collection of solar energy that could be as a result of poor orientation that fails to optimize collection. This could happen since the installation comes at a point when the building is already in existence, and both the the roof and house orientation and design have already been determined. The system is then mounted on unfavorable position or if it is to be positioned in an optimal way, expensive modifications to the roof and the house design are made.

Most of the SWH systems installed after the construction has been completed often do not form a part of consideration at the design stages. This results in systems that are positioned in such a way that they do not maximize on their collection capacity, resulting in a much longer time in which they break even through savings.

This poor positioning could result from lack of appropriate consultation or simply sheer ignorance, and it makes them expensive to run since their economic viability is greatly compromised.

5.1.6 Installation is often an after-thought.

Another reason as to why the cost of installation probably becomes higher is because of the point at which the decision to install is made. Since this is mostly an after-thought, certain changes have to be made in the plumbing system and building structure so as to accommodate the system into the already existing building. Such would include chasing into masonry walls to install new pipes which in itself may interfere with other systems like electricity conduits and others concealed building services. In the cases surveyed in the study, those who have implemented the system did so after the construction was complete. In such cases the structural system may also require to be reinforced and in particular the roof system so as to be able to hold the additional weight imposed by the SWH system.

5.1.7 Possible Interventions.

Certain interventions can be undertaken to help in mitigating the above factors and hence increase the system's affordability and these includes the following:

i) Mitigation against External market influences, shipping costs and import duty.

To mitigate against influence by the external markets, expensive shipping costs and reduce on import tax, the Government can encourage foreign companies who currently manufacture these systems to establish local manufacturing companies, through the creation of a suitable investment environment like offering tax holidays and other incentives.

This has the potential of lowering the cost further since it will also result in technology transfer overtime, which would give rise to local manufacturers and hence increase supply with the inevitable effect of lowering the cost of the units.

The Government can also through the Ministry of Energy, the ERB, and Kenya bureau of standards determine the Kenyan standards that are both reliable and affordable to the local market. The SWH s in the Kenyan market today however seemed to serve well since from the survey, those who have installed the systems responded that they are quite satisfied with their performance and similar standards can be aimed for in local manufacturing.

The Government can through its research agencies not only determine the best system which is also cost effective for the local market, but also encourage research and development of this area so that these systems can be developed locally using home grown technology, a factor that would lower their cost as observed in the Chinese case.

ii) Mitigation against Taxation

The other intervention would be for the Government to introduce tax incentives and subsidies which would effectively lower the importation cost hence making them cheaper. This could mean total removal of tax on imported complete kits, Knocked down kits to encourage local assembly, or even relieve solar water heaters contractors some percentage of their income tax so as to make their services more affordable.

iii) Mitigation against low demand

This would require to be done from two fronts since from the study it was evident that there is a section of population that can only installed after enforcement while the other would voluntarily install if the inhibiting factors are mitigated upon.

With the first category, it would be prudent for the enforcing stakeholders to enhance their efforts towards enforcing the regulations through establishing clear mechanism of monitoring and policing implementation.

With the second category, the low demand can be mitigated through various ways including the following:

1) Involving financial institutions and cooperatives to facilitate provision of finances to individuals through soft loans. This model has worked well in facilitating for solar lighting in rural communities.
2) Devising ways to lower the cost of the units would increase demand.
3) Mounting campaigns to increase their popularity will in turn increase the demand
4) Introduction of special subsidies and low tariffs on power consumed from the distribution grid for those who have installed the system.

iii) Mitigation against Expensive installation and maintenance expertise.

Widespread technical training can be sponsored to increase the number of trained personnel in installation and maintenance of SWH systems. It can also be introduced as a unit in certain technical courses and offered through TIVET institutions at many levels of training.

Other bodies that are mandated to build capacity in the industry and in particular the National Construction Authority can administer a targeted training with an intention of building capacity in the industry for this specialized area.

iv) Mitigation against poor positioning during installation.

Before implementation the SWH's designs, its positioning can be submitted to the relevant authority for approval and this would include the positioning on the building and site orientation in relation to the movement of the sun. Consultants should be involved in the design process, and for new developments, the schematics can form a part of submitted drawings.

The planning regulations can take this further and create bylaws defining "solar access rights" which will be used to ensure neighboring developments are oriented in such a way that all have adequate access to solar energy.

v) Mitigation against solar water heating Installation often an after-thought.

This can be mitigated through ensuring that SWH is integrated in the building design from inception to approval through defining clear standards that are enforceable and entrenching it in the building code.

The consultants involved would be expected and compelled to include it in the scheme designs.

5.1.8 High cost of SWH can also be regarded as perception.

The issue of cost should be looked at in relative terms to the cost of building a home in Kenya. The cost of Installing a SWH system could be appears to be much to the majority of individual home developers probably due to the point at which they chose to install it, which is after the construction of the house has been completed and they have already moved in.

Average Market Cost of SWH Systems in Kenya

Tables 5.1 and 5.2 below shows the cost in Kenya shillings of typical units of various capacities found in the Kenyan Market. (Source: Values obtained from Trusun Limited a locally registered company dealing with solar systems)

Table 5.1 Prices for Evacuated tube solar water heater system. (Inclusive of Installation)

Item	System Capacity	Family size	Unit cost(Ksh.)	Extra Features
1	150 Litres	3	90,000	Digital Controller
2	200 Litres	5	98,000	Digital Controller
3	300 Litres	7	115,000	Digital Controller

Source: Trusun Limited, 2016

Table 5.2 Prices for Ezinc flat plate water heater systems

Item	System Capacity	Family size	Unit cost(Ksh.)
1	200 Litres	5	157,200
2	300 Litres	7	188,000

Source: Trusun Limited, 2016

Figures 5.1 and 5.2 show the two types of SWH systems, the evacuated tube system and Ezinc flat plate system respectively.

Figure 5.1 Evacuated tube system ***Figure 5.2 Ezinc flat plate system***

Source; Trusun Limited, 2016 ***Source;*** Trusun Limited, 2016

From the above it can be seen that the cost of installing the system in Kenya is approximately Kenya Shillings Two Hundred Thousand for a 300 litres system, which will be adequate for a typical family.

The average size of one house in the study area is 250 Square Meters, and taking the average cost of putting up a house of Kenya shillings Forty Thousand per square meter, we see that the average house in this area costed the individual a total of Kenya Shillings Ten Million to put up.

This means that the cost of the system would be a mere 2% of the total cost of the house which is quite negligible if it is integrated into the building cost.

From this discussion therefore, the key factors that influence the cost can be controlled if the system is installed at the right time, which is during the construction of the house and integrated with the house design.

A tight and foolproof enforcement mechanism that ensures that SWH system is well integrated in the development from planning stage will also ensure that it is included in the project's budget. This will ensure that it is funded together with the rest of the development and the perception of it being an "extra" cost will not occur.

5.2 Lack of Information

As has been pointed out in section 2.5.2.4, even if all other conditions favor implementation, end- user awareness remains very crucial and actually plays a key role in determining the extent of implementation. A case of Germany has been cited where it experiences less sunshine than the UK but since it has a higher awareness level has more solar water heating systems implemented than the UK.

Areas in which the people needs to be aware includes the benefits, cost, energy nature, statutory regulations and obligations.

i) **Benefits:** This would include the savings achieved both at individual and global level to the entire economy of the country. Reliability during power outages and rationing period can also count for much. Omitted risk of possible electrocution especially when the alternative is the instant heating system

ii) **Cost of System:** The real cost as proved in the earlier section may not be as high as imagined if the installation is done at the right time. The cost of installation against the long term saving needs to be brought out.

iii) **Energy Nature:** The energy from the sum being renewable, is clean and however much one consumes, it does not affect the source. Potential user would also require to be informed of the global shift towards clean energy so that they know that they are contributing towards the planet's sustainability.

iv) **Statutory Requirements, Obligations and penalties:** The potential users needs to be informed about the law demands. The mandatory requirements for them to install the system and also the penalty for non-compliance.

The role of educating the populace needs to be a joint effort by the National Government through its Ministries, County Governments, Educational Institutions, NGO's, Professional bodies, Community based organizations, Special interest groups, dealers in solar equipment and even Global organizations.

Dissemination and packaging of the information will depend on the target group and can take many forms including the mass media, which from the study was determined to be very effective, Campaigns, Integrated programs, training curriculums in institutions, Brochures and fliers, Consultants and Contractors, publications and Exhibitions amongst many other possibilities.

From the research results, 33% of the respondents cited lack of information as the reason as to why they have not considered installing SWH, and two out of the five who had installed were informed before they made the choice to install SWH system.

5.3. Lack of Technical Capacity

The Energy Regulatory Commission cited lack of technical capacity as one of the reasons as to why there is a low level of implementation. The result from the study however indicates otherwise as it has established that there is adequate competence to install and also for servicing and maintenance purposes.

Most of the respondents (80%) were confident that there exists adequate competence and so this was not a factor in the determination of their choice on whether to install the system or not. Without pre-empting their assumption, the respondents did not seem to think so. It was also established that for those who had installed the system, once installed it continued to operate satisfactorily and the amount of maintenance was also said to be very minimal.

It would appear that even those who had not installed had confidence in the technical competency available in the country. One of the reasons could because most of the dealers also offered installation services at a fee by their personnel, and the package includes a guarantee of free service for a given period of time.

5.4 Enforcement

Enforcement of the regulations faces significant challenges that make implementation difficult, and these includes the following:

i) The Energy regulatory Commission lacks the relevant policing tools to ensure compliance, and also fails to link effectively with other existing building requirements enforced by other agencies of Government.

ii) The regulatory framework has a structural dimension inclusive of materials and specifications of the components which has not been addressed by the building code, and this makes this requirements impossible to ensure during the buildings approval process even if there was a linkage with the code.

iii) The local authorities who are the main enforcers of building laws therefore have no reference of solar water heating systems within the building code. This means that at no one point within the building's approval process does any reference to SWH is made. Over and above approving development plans, the local authorities are also involved in regular inspections during the construction process to ensure that the developers comply with the set standards. They also issue the occupation certificates to completed buildings after certifying that it has been properly done. This means that their presence in a building site during construction and even after completion is continuous which makes them ideal for ensuring compliance.

iv) The Solar Water heating regulations 2012 transfer enforcement mandate to the power distribution company (Kenya Power and Lighting Company) by stating that no premises should be connected to Grid power system if solar water heater component has not been installed. KPLC has not effected this mandate and has not even made it part of their requirements before connecting one to the power grid. A logical explanation would seem to be that it is a company in business and for them as long as any power consumed is paid for they might not care much unless compelled. Actually the reduction in domestic power consumption from their grid as would be caused by adoption of solar water heating system might mean a reduction in business, yet the infrastructure already in place will not be any different.

v) The regulations also defines the qualifications of technicians to be involved in the installation and these again are not referenced by the National Construction Authority which ensures quality in the industry.

From the study, it was established that the Kenya Power and Lighting Company do not perform its role in ensuring compliance as anticipated by the ERC regulations. None of the respondents, all of who are already connected to the grid supply answered in the affirmative that KPLS even enquired of their intention to install SWH system, leave alone having it in place.

For a more effective implementation, all key stakeholders must be involved in one way or the other as indicated Table 5.3

Table 5.3 Expected Enforcement Matrix

Stakeholder	**Expectations**	**Building Type**	**Stated Tool of Enforcement**	**Penalty For non-compliance**	**Incentive**
Developer/ Occupier	-Ensure Inclusion in the designs -Carry out system's maintenance	Domestic New constructions, Extensions, Alterations, Existing buildings	Power company assumed to decline connecting noncompliant developments	Ksh one Million or jail term not exceeding one year or both	Project registered to benefit through CFM
Architect & Engineers (Consultancy)	Include SWH's in the designs		Non	Non	Non
Power Distributor	No connection of power to non-compliant developments		Non	Non	Non

Source: Author, 2017

The Act makes the groups mentioned in the matrix responsible for compliance without pointing out the main agent to ensure compliance. The question to ask which can determine the most effective agency to enforce would be which of them are the stake holders more answerable to and is involved in their activities and processes.

This can enhance the columns for Tools of enforcement, penalty and incentives which can ensure more effectiveness. More stakeholder involved with the developments at the grassroots also would require to be added to enhance compliance.

A close look at the enforcement matrix reveals that the penalty for non-compliance is only applied to the developer/Occupier while the other parties mentioned inclusive of the Consultancy (Architects and Engineers), and the Power distribution company goes scot free. Below is a close scrutiny of how effectiveness in compliances could be achieved from these other key stake holders.

5.4.1 Consultants

The responsibility of the consultancy team is to design and develop the schematics for any proposed development inclusive of extensions or alterations. From the building plans (developed by the Architect) other service drawings are developed inclusive those of Electrical and Mechanical works.

Professional engagement is regulated by the code of practice (e.g. Architects by Chapter 525). This law lays out the parameters of professional registration, and establishes a board responsible for ensuring discipline in the profession, and can strike off the register any member charged with professional misconduct.

The act does not cite quality of work, or omission of any prerequisite or mandatory building component as forming a part of misconduct and neither does it refer to adherence to the building code, local authorities by laws or indeed any other regulations in place.

Further to this, the local authority's Act simply allows it to approve buildings which are consistent with the building code, which makes no reference to the SWH system. This means that Designs that does not include the system still gets approved by the local authorities

The implication is that the consultants who are always keen to get their schemes approved for construction to take place will not feel expressly obligated to comply. As a consequence to this, the bills of quantity which are developed from the working drawings also miss out this component, and eventually its integration only becomes an afterthought.

If the consultant are to be made to comply therefore, SWH system must be made mandatory within the building code, and its specifications dictated. This would make it enforceable by the local authorities, who in turn would ensure that no building is either approved or put up without its inclusion.

Further to this, the code should also be tied to the professional conduct of the professionals involved, to emphasize its importance as a key GOK policy.

5.4.2 Local Power Distributor

The implementation matrix anticipates the power distribution company (KPLC) to be the key agent through which implementation is enforced by the virtue of them being the sole power distributors in the country. This would be done through disqualifying any application for power connection that refers to a premise where SWH system has not been installed.

The operations of KPLC are closely guided by the Electric Power Act, Cap 314 originally of 1972, but revised in 1986.

In this Act, the only scenario listed where a licensed power distributor may refuse to supply (section 28) are as follows:

a) If the supply of Electric Energy in such premises or to a part of them is prohibited by any other rule made under the act.
b) If the premise or a part of it is subject of an order for demolition made at the instance of the public or Local Authority within the area of whose jurisdiction the premise are situated.

This act has not been revised since the solar water heater regulations were passed into law in April 2012. This disconnect have made the power distributing company not feel obligated to refuse connecting its customers on the basis of lack of its installation.

For effectiveness, the implementation of the SWH regulations should have gone hand in hand with a revision of the Electric power act where lack of installation of SWH would have been included as a condition where power can be denied.

Another element in the act which can softly be used to compel consumers to install SWH system is in section 29 which describes the maximum power that the licensed distributor can give consumers.

The first part of the section states that the maximum power with which any consumer shall be entitled to be supplied with shall be of such amount as he may require to be supplied with, not exceeding what may reasonably be anticipated as the maximum power demand on his premise.

This part empowers the distributor to put a ceiling on the power consumed, though it means that the distributor would have to find a technical way of ensuring that the maximum consumption is not exceeded of alternatively highly pricing any power consumed beyond the ceiling as a deterrent.

In the power supply application form, the anticipated load is calculated from individual power consumption of the items within the premise, and in most cases there is an under declaration. Instant showers are rarely mentioned, and therefore in most cases the premises ends up consuming more power than that which is declared initially.

Since KPLC maintain the application data, and also that of billing, it is possibly to determine this discrepancy and take appropriate measures as a deterrent, which could push consumers into investing in SWH systems.

5.4.3 Local Authorities

The obvious agents who could be most effective, though not mentioned would be the local authorities since they have grassroots reach. Their regulating activities are based on the building code, their mandate being derived from Cap 625 of the laws of Kenya.

It can be observed from the Electric Power Act above that it is possible to make reference to another enforcing agent, in section 28 where the act points out that where the Local authority has earmarked a building for demolition, no power can be connected.

It can therefore work in a similar way, where the act can point out that no building can be supplied with electric power if it has not been approved by the local authority in their jurisdiction.

What would then be required is the inclusion of installation of the SWH in the building code and the laws would be linked together, which would most probably ensure enforcement.

One definite advantage of the local authorities being key in the enforcement is because they already are spread throughout the republic, and already have field inspectors who go round ensuring enforcement of various other aspects.

The local authorities also already assist in the implementation of various other acts including the Public health act, the physical planning acts and even parts of the lands act. This is because they have a mechanism that reaches the grassroots, part of which includes elected people's representatives which gives them more legitimacy amongst the people.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary Statement and Conclusion.

The strategy to adopt and enforce SWH systems as a way of saving energy by the Government of Kenya actually has a lot of currency, and more so because the urban population has maintained a steady increase.

It is estimated that 60% of the population in the developing world would be living in cities by 2030 and if an alternative energy source for heating water at a domestic level will not have been well established by then, it goes without saying that the energy burden will be quite significant to the Governments, and little wonder that GOK is left with little choice but to enforce the requirement as subscribed in the law.

From the research findings it has been established that the uptake of SWH is still very low, despite of the deadline for installation drawing quite close, where all homes falling within the described category are required to have installed SWH system by May 2017.

This study has shown that the main reasons for the low intake are perceived high cost of installation, lack of information pertaining to the SWH systems and inadequate enforcement mechanisms. Further, very few individuals seemed to be aware that it is a legal requirement and so they were not keen to install. Some of the key information that they lacked included the following:

i) The real cost of the system. Many of the respondents assumed that it was expensive without knowing the exact cost. This knowledge would help those who would like to install it to plan and even source for funding. The study established that the cost of a standard HWS for a typical family is approximately Kenya Shillings One Hundred and Fifty thousand only which is within the reach of a typical middle class family whose home's construction cost is upwards of Kenya Shillings six Million. This is the reason the study argues that it is a perception and is placed within the construction cost it will not be seen to be expensive.

ii) The Technical performance aspect of the system inclusive of the service and maintenance

Cost. Those who had installed the system nevertheless pointed out that it was almost maintenance free once in place, for over a long period of time. This means that it is quite cost effective. This could be attributed to the fact that the world market has long opened up and it is possible to import high quality systems from anywhere in the globe. The nature of SWH systems is such that they are quite robust, and once installed they stay fixed for quite a length of time and more often than not in locations which are not easily accessible especially on roof tops. This means that they are unlikely to suffer any mechanical or handling abuse which makes them last for quite some time. Deterioration of the system is also quite slow because overtime manufacturers have developed materials which are quite durable and also rust proof from contact with water and weather. This has greatly extended the life of the units to an average of thirty years, with minimal maintenance needs. In the past only a selected few dealers imported SWH units because of market limitations, they have easily stood out, and so were subjected to the required quality standards by the Kenya bureau of standards. This ease of control has resulted in acceptable quality. As much as the question of standard or quality of the systems is concerned therefore, evidently people believe that the standards and technical support is adequate, and more so those who have already installed the system.

iii) The mandatory obligation to install as required by the solar water heating regulations and the fact that it makes it punishable by law if one has not installed the system by the expiry of the set deadline has not been effective in enforcing the law. This could be attributed to the fact that first and foremost very few individuals are aware of the law as determined in the findings. This is because it has received very little publicity, and no effective enforcement mechanism exists on the ground. Kenya power and lighting company the key agency named in the Act as an enforcer has not played its role, where it is expected to deny power connection to any household that fails to install SWH unit. This in turn has mad the consumers insensitive to the law, hence the current situation.

iv) On the importance of going green. Only one of the respondent expressed the desire to go green as one of the reasons for installing the system. This implies that there is need to educate the general public on the world’s green agenda, including preservation of the natural resources, reduction of pollution and environmental degradation, and the role which adoption of renewable energy systems play towards achievement of this objective.

The Kenya Government's objectives towards this goal also needs to be understood as included in its development agenda the vision 2030 and also the important role that renewable energy will play in future towards alleviating the country's energy crisis. It also points to the fact that the majority of the population are largely ignorant of the world's trend of embracing the green agenda. There should therefore be deliberate efforts to educate the masses on the importance of both accepting and investing in renewable energy systems both from the local and global perspectives.

v) The cost verses the benefits of adopting the system that they would enjoy especially the significant drop in the expensive grid supplied power that would be caused by the adoption of this system. This would translate directly into savings as the study indicated in the analysis of the satisfaction levels of those who have already installed the system. From the study, economic benefits was cited by all of those who had installed the system as a key driving force and so educating the people on these benefits would certainly increase the uptake of the system.

6.2 Recommendations

The following recommendations points out to what needs to be done for the uptake of SWH's to increase, and the law fulfilled so that the economic benefits anticipated by the law can be achieved.

1. Enforcement should be coordinated with other agencies that oversee physical development, through empowerment by law. This implies that the Energy (Solar water heaters) regulations should refer to other acts and agencies especially the local authority so as to legitimize the exercise of the power.

2. Ensuring that SWH Systems is integrated into the other phases of project development namely design, costing, tendering and construction would make its cost to be absorbed in the project's funding since it would be an item in the bills of quantities. This would ease the burden of the user or developer of having to fund it after the project has been completed when fatigue from the building process is at its peak or is already paying off the mortgage. Integrating this cost to the rest of the building also means that the payments are gradual and so easy to pay off. This is the reason as to

why those people who purchase houses where solar water heating system is already in place do not feel the cost of the system.

3. The Government should consider measures beyond tax exemption that would make SWH System more affordable. This could include credit benefits, reduction of power cost for those who have installed as an incentive, cheap Government subsidized loans for the purchase of SWH Systems

4. To make them affordable the Government can also encourage local manufacturing of the systems through luring suitable investors, through offering some tax rebates amongst other incentives. External manufacturers can be lured into the country as investors and technology transfer encouraged which will eventually see establishment of local manufacturers that would produce the systems not only with local labor and materials, but also make them more affordable.

5. The Government can ensure that Kenya Power and Lighting company who have monopolized power distribution comply to the demands by the act, that no house that is supposed to install a SWH System gets connected to the power grid before the system is in place. The Minister of Energy has sufficient powers to enforce this. Other electric power distributors can also be encouraged to enter into the market so that KPLC can lose its monopoly which in the past has made it difficult to discipline it.

6. There is need to launch an effective campaign first and foremost through the mass media , which proved to be the most effective from the study , and educate the public on the advantages of Solar water heating systems , legal requirements, financing options and advantages of adopting renewable energy . Educational institutions, practitioners and consultants, distributors of SWH systems and local administration should be enjoined in this campaign since it is a Government policy.

7. The Government and its affiliated organizations should be in the forefront in employing these systems. A closer look reveals that the housing and office development by the Central and County Governments do not include SWH systems which in a way betrays the spirit of the act. It should first embrace then establish measures to enforce the same to the public.

6.3 Recommended implementation matrix framework

Table 6.1 shows an implementation matrix framework that if used would ensure effective installation of SWH systems in Kenya.

Table 6.1: Implementation matrix framework

	Stakeholder	Obligation	Enforcer	Mode/ Tools
1	Developer/ Occupant	Ensure SWH system is designed and installed in the buildings	-Consultants	-Mechanical & Electrical designs -Project costing -Project supervision -Ensure site planning is done with solar harvesting in mind
			-Local Authority	-Ensure inclusion of SWH systems before approval of development -Refuse issuance of occupation certificates to buildings without SWH -Can deny water supply service to those without SWH
2	National Government	Enact strong regulatory framework & Laws	-The judiciary -ERB	-Include SWH system as a mandatory item in the building code with standards -Strengthen the policing unit of ERB -Creation of solar rights in planning
3	Local Authorities	Ensure Design submitted for approval includes	-Local authority's	-Refuse approvals

		SWHs, and implementation is done on site	technical approval teams -Inspectorate unit	-Arrest developers who do not comply. -Refusal to issue occupation certificates to non-compliant buildings
4	ERB	-Ensure consistency of the law -Monitor Implementation -Ensure technicians are adequately qualified to install SWH's	-ERB Monitoring unit -Training institutions -NCA	-Maintain register of qualified SWH technicians -Sharing data with other agencies like NCA and local authorities on proposed projects -Including ERB personnel or certified people in the building approval process.
5	Consultants	-Ensure building designs are consistent with the legal requirement to include SWH -Ensure the designs allows for maximum harvesting of solar energy	-Local Authorities -Boards of registration for consultants	-The building code -As a requirement for approval -Disciplinary action from the registration boards
6	KPLC	Refusal to connect power to buildings where SWHs are not installed	-KPLC -ERB/ Ministry in charge of Energy	-New Power connection application (refusal) -Higher charges for power beyond certain thresholds of consumption exceeded due to instant heaters -ERB can take legal action on KPLC for non-compliance

Source. Author, 2017

6.4 Further areas of research

The general area of renewable energy, and specifically solar water heating has largely not been researched in Kenya, and therefore provides a rich ground on which many future researches can be based. Some of the topics that relates to this study includes, but not limited to the following:

i) How urban morphology affects solar energy potential in urban neighborhoods

ii) Accessing solar radiation on pitched roofs and flat roofs

iii) Methods and ways of improving accessibility of SWH system to the low income groups

iv) Solar potential mapping of Kenya/ Counties/ neighborhoods in relation to natural elements and physical design parameters.

v) Analyzing and reviewing the adequacy of the existing policies and regulatory framework towards encouraging investment in the renewable energy sector in Kenya.

vi) Renewable energy financing options for small scale investors in developing countries, Kenyan case.

iv) A study of residential neighborhood design/ planning parameters that would guarantee universal solar accessibility.

APPENDIX I

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APPENDIX 1I

Questionnaire

1.Have you ever considered installing SWH system in your house

a) Yes b) No

2. If you have not installed, what are the probable reasons

a) High installation cost b)Lack of information c) Lack of technical support d) Not interested

3. If you have already installed what were your reasons?

a) Economic benefits b) Legal requirements c) Believed in going green

4. If you have already installed, how did you get to know about SWH?

a) A friend/ consultant shared b) Dealers promotions c) Government publication d) Public media

5. Do you believe that there exists technically competent people/ firms in Kenya who can both install and maintain the system?

a) Yes b) No

6. Are you aware that there is a legal requirement by Energy Regulatory Commission (ERC) that if ones hot water demands exceeds 100 litres they should install a SWH System or are penalized?

a) Yes b) No

7. Did the Kenya Power and Lighting company enquire about your hot water capacity demands before connecting you into their power distribution grid?

a) Yes b) No

8. Did *KPLC* enquire if you have or have the intention of installing a Solar water heating system before connecting you to the power grid?

a) Yes b) No

9. If you have already installed SWH, are you satisfied with the performance of the system so far in meeting your daily needs of hat water?

a) Yes b) No

10. If You have already have installed, is the technical support especially in maintenance/ servicing of the system readily available?

a) Yes b) No

Sign (Optional)……………………………………….. Date ………………………………………….