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Patrick Kioko MWANZIA

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A Case Study of Nairobi City

Defended on 03/09/2018 Before the Following Committee**:**

Chair	**Prof.** Bekhechi Smaine	**Lecturer**	University of Tlemcen
Supervisor	**Dr.** Samuel Obudho	**Deputy Director**	KICD
External Examiner	**Dr.** Justus Simiyu	**Lecturer**	University of Nairobi
Internal Examiner	**Prof.** Azzedine Chikh	**Lecturer**	University of Tlemcen

FACTORS AFFECTING ADOPTION AND SCALING UP OF ROOFTOP SOLAR PV DEPLOYMENT IN URBAN CENTRES

A Case Study of Nairobi City

BY

PATRICK KIOKO MWANZIA

A RESEARCH PROJECT REPORT SUBMITTED TO **PAN AFRICAN UNIVERSITY INSTITUTE OF WATER AND ENERGY SCIENCES** (Including CLIMATE CHANGE) IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF SCIENCE IN ENERGY POLICY

SEPTEMBER 2018

DECLARATION

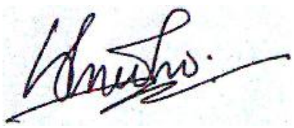
I Patrick Kioko Mwanzia, hereby declare that this project report is my original work and has not been presented for a degree in any other time before in any University. I also declare that all information, material and results from other works have been fully cited and referenced in accordance with the academic rules and ethics.

Signature:  Date: 13.09.2018

Patrick Kioko Mwanzia

PAUWES/2016/MEP03

This Research Project Report has been submitted with my approval for examination in Pan African University Institute of Water and Energy Science (Including Climate Change)

Signature:  Date: 10.09.2018

Dr. Obudho Samuel Omondi

Deputy Director,

TIVET Division- KICD.

DEDICATION

This project is dedicated to my mother Domitila Mwanzia, who sacrificed her all and worked tirelessly to see me through education, my brothers and sisters, for their support throughout my academic journey. May God bless them all.

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LISTS OF ABBREVIATIONS

SPV	Solar Photovoltaic
KPLC	Kenya power and Lighting company
KenGen	Kenya generation company
GDC	Geothermal Development Company
MoE&P	Ministry of Energy and Petroleum
KEREA	Kenya Renewable Energy Authority
CEEC	Centre for Energy Efficiency and Conservation
EAC	East African Community
ERC	Energy Regulatory Commission
FiT	Feed in Tariff
GHI	Global Horizontal Irradiance
IPP	Independent Power Producer
KAM	Kenya Association of Manufacturers
kVA	Kilo Volt Ampere
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
NITA	National Industrial Training Authority
PAYG	Pay As You Go
PV	Photovoltaic
REA	Rural Electrification Authority
PPA	Power Purchase Agreement
SC	Small Commercial Electricity Tariff
SHS	Solar Home Systems
GWh	Gigawatts hour
MW	Megawatts
GW	Gigawatts
KETRACO	Kenya Elecyricity Transmission Company
PAYG	Pay As You Go
UN	United Nations
SDGs	Sustainable Development Goals
EU	European Union
REs	Renewables
PPA	Power Purchase Agreement

ADB Asian Development Bank

AfDB African Development Bank

TPO Third Party Ownership

Table of Contents

DECLARATION .... **iii**

DEDICATION .... **iv**

ACKNOWLEDGEMENT .... **v**

LISTS OF ABBREVIATIONS .... **vi**

LIST OF TABLES .... **xii**

LISTS OF GRAPHS .... **xiii**

LISTS OF FIGURES .... **xiii**

ABSTRACT .... **xiv**

EXECUTIVE SUMMARY .... **xv**

CHAPTER ONE: INTRODUCTION **1**

1.1 Background of the study **1**

1.2 Rationale of the study 2

1.3 Problem statement 4

1.4 Objectives 5

1.5 Research questions 5

1.6 Scope of the study 5

CHAPTER TWO: LITERATURE REVIEW **7**

2.0 Introduction **7**

2.1 Theoretical review **7**

2.1.1 Evolving theories on sustainability and firms' contributions to renewable energy 7

2.2 Empirical review **9**

2.2.1 Global Renewable Energy Status 9

2.3 Estimation of rooftop solar PV potential in urban centres 14

2.4 Challenges and barriers to renewables including rooftop solar ... 16

2.5 Opportunities, business models and key drivers to renewable energy deployment ... 18

2.6 Energy Sector in Kenya ... 20

2.4 Conceptual Framework for Rooftop SPV Adoption and Scaling Up ... 26

2.5 Research gaps ... 27

2.6 Summary of the literature review ... 27

CHAPTER THREE: RESEARCH METHODOLOGY ... 28

3.0 Introduction ... 28

3.1 Research Design ... 28

3.2 Research Approach ... 28

3.3 Research Methodology ... 29

3.3.1 Area of study and study population ... 29

3.3 Data Collection Methods ... 31

3.4 Data analysis ... 32

3.5 Ethical Considerations ... 33

3.6 Limitation of the study ... 33

3.5 Data Analysis and Needs ... 33

CHAPTER FOUR: DATA ANALYSIS, PRESENTATION AND INTERPRETATION ... 35

4.0 Introduction ... 35

4.1 Response Rate ... 35

4.2 Distribution by Gender ... 35

4.3 Distribution by Job Position ... 36

4.4 Solar PV Products ... 36

4.5 Objectives of Installing Rooftop Solar PV ... 36

4.6 Key Drivers that Motivate Consumers and Companies to Use Solar PV ... 37

4.7 Challenges or Barriers Faced by all stakeholders involved in rooftop Solar PV deployment ... 38

4.8 Opportunities Rising from rooftop Solar PV deployment ... 39

4.9 Ownership Model for use of Solar PV ... 40

4.10 Consumer Awareness on Solar PV ... 40

4.11 Rooftop Solar PV capacity estimation of Nairobi city ... 41

4.12 Roof area feasibility study for rooftop solar PV deployment ... 42

4.13 Recommendations on Areas to Improve in Scaling Up of Solar PV ... 42

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMEDATION ... 45

5.1 Introduction ... 45

5.2 Summary of Key Findings ... 45

5.2.1 Major Challenges and Barriers in Adoption and Scaling Up Rooftop Solar PV in Urban Centers ... 45

5.2.2 Key drivers and opportunities for roof mounted solar PV that can be adopted to scale up solar rooftop PV in urban centers ... 47

5.2.3 Existing business models that can be applied to scale up solar PV rooftop ... 47

5.3 Expected Changes to the Legal and Regulatory Framework ... 47

5.4 Policy interventions that can be used to scale up roof mounted solar PV in urban centers ... 48

5.5 Conclusion ... 49

5.6 Policy and Process Recommendation for Improvements **49**

5.6.1 Introduction of Net Metering proposed in Energy Act of 2015 49

5.6.2 Shortening waiting period experienced during application and approval process 49

5.6.3 Creating awareness programmes and making key information easily accessible 50

5.6.4 Introduction of promotional programmes 50

5.7 Suggestion for Further Studies **50**

REFERENCES **51**

APPENDICES **54**

Appendix 1: Questionnaire for Electricity Consumers **54**

Appendix 2: Questionnaire for Engineering, Procurement and Construction (EPC) **59**

Appendix 3: Questionnaire for Developers **62**

Appendix 4: Questionnaire for Manufacturing and Distributing firms **66**

Appendix 5: Budget **69**

Appendix 6: Time Schedule **70**

LIST OF TABLES

Table 2.6.3: Electricity generation capacity in Kenya ………………...................…………………26

Table 2.6.4.1: Market segments of Solar PV in Kenya …………………………..................………...28

Table 3.1: Data Analysis and Needs ………………………………………..................………...39

Table 4.1 Response Rate...40

Table 4.2 Distribution by Gender …………………………………………………..................….4

Table 4.3 Distribution by Job Position ……………………………………………..................…...4

Table 4.4 Solar PV Products ……………………………………………………..................…….…4

Table 4.5 Objectives of Installing Rooftop Solar PV……………………….................……..........42

Table 4.6 Key Drivers that Motivate use of rooftop Solar PV………................………………...…...43

Table 4.7 Challenges Faced by all stakeholders in rooftop SPV ………………..................………44

Table 4.8 Opportunities Rising from Solar PV Installation ……...................……………………...45

Table 4.9 Ownership Model for the Use of Solar PV 46

Table 4.11 Rooftop SPV existing projects in Nairobi …………………..................……………....47

Table 4.12 Roof Area feasibility study within Nairobi ……………………..................……….…48

Table 4.13 Recommendations on Areas to Improve ……………………..................……….......50

LISTS OF GRAPHS

Graph 2.2.1: Global installed capacity comparison between 2015 and 2016...……………...12

Graph 2.2.2: Continental, Regional and National Role-players ………………………......14

Graph 2.2.4 The rise of Solar PV …………………………………………………………16

Graph 2.6.2 Electricity Demand, Supply and Access …………………………………….24

Graph 2.6.3: Electricity Generation Capacity …………………………………………….27

LISTS OF FIGURES

2.4 Conceptual Framework for Rooftop SPV Adoption and Scaling Up …………………...30

ABSTRACT

Urban centres in developing countries are growing at unprecedented rate. This is attributed to high population growth being experienced in those nations and more people moving to urban centres and the desire for those nations to industrialize. These developing countries have abundant and underutilized natural resources that are backbones of economic growth making them attract foreign investments across the world. Energy demand on other side is rapidly increasing as more energy is needed to support urbanization and industrialization. This study was aimed at upscaling rooftop solar PV in urban centres. It explores on the factors affecting the deployment of the solar PV using Nairobi City in Kenya as the case study. The objective of the study was to establish the reasons why roof mounted Solar PV has not been scaling up in urban centres despite the high energy demand being experienced so far. The study used mixed research design to explore both qualitative and quantitative characteristics of the target population. Commercial industries and institutions using solar PV within Nairobi were targeted where a sample of **50 respondents** was purposely selected. It was noted that high initial costs, lack of qualified technicians, bureaucracy delay in application and approval process and lack of awareness were among the major challenges affecting adoption and scaling up of rooftop SPV. Most consumers installed rooftop SPV to save on electricity bills. Others like SERC installed for training purposes and climate change awareness. Recommendations given included introduction of net metering, online platform to create awareness to help in decision making, data bases to facilitate tracking of all processes among others.

EXECUTIVE SUMMARY

The study focused on upscaling rooftop solar PV deployment in urban centres using Nairobi city as the case study. Urban centres in Africa and Asia continents are growing at high rate due to rapid rural-urban migration and urban internal growth hence need for alternative and sustainable energy source. Rooftop solar PV deployment remains main viable option that can be deployed across all electricity consumer categories. The report covered the following: an overview of the solar PV sector in Kenya; a review of already existing rooftop solar projects within Nairobi city and its outskirts; analysis on the existing financing options and business models applied and recommendations on business opportunities and gaps that can be utilized to scale up rooftop Solar PV deployment in urban centres.

The objectives of carrying out the research were

i) To establish major challenges in up scaling rooftop Solar in urban centres
ii) To investigate key drivers and opportunities for roof mounted solar PV that can be adopted to scale up solar rooftop PV in urban centres
iii) To evaluate existing business models that can be applied to scale up solar PV rooftop
iv) To estimate rooftop solar PV potential in Nairobi county

The key findings of the research are summarised below

Key drivers and opportunities: A great number of respondents agreed that savings on electricity bills was the major driver that motivated them to deploy rooftop Solar followed closely by environmental concerns. Other drivers and motivators included capacity building programs, consumer awareness programs and return on investment among others.

Existing business models and financing options: The following existing business ownership models were found to be in use. Self-ownership model was commonly applied across all consumer categories with 57.1% popularity followed by Third party Leasing ownership model with 22.9% and finally Power Purchasing Agreement recording 20.0%.

Key challenges to adoption and scale up

The following challenges were found to be affecting adoption and scaling up of rooftop solar PV deployment.

- **Delays experienced in application and approval stage**

Most respondents were unsatisfied by the whole process as it characterised by delays and uncertainty. The first stage in installing any power generation system in Kenya is submitting an Expression of Interests (EoI) and detailed feasibility study to the MoE&P for approval. This process requires at least 90 days before approval then followed by a series of other processes before finally that take quite a

long time. This whole process can be done within a short time if the relevant authorities cooperate to avoid such delays experienced right now.

- **High upfront cost required**

High customer acquisition cost was the major barrier affecting adoption and scaling up of solar energy sector globally. Most consumers interviewed had to source funds from external sources such as banks and donors. Learning institutions who have installed rooftop solar relied on donor funds from international agencies like the case of ICIPE which is a government institution that was funded by Swiss Agency for Development and Cooperation. Those who could not raise the high initial capital opted to use third party mode of ownership through Leasing and Power Purchase Agreement.

- **Grid availability constraints in case of excess electricity**

Electricity prosumers who produce excess electricity and are grid tied are feeding the excess to the grid at no benefit. This is due to lack of Net Metering Policy proposed in Energy Act of 2015 but yet to be approved due to disagreements among the relevant authorities. Net metering policy if approved will be a major breakthrough to future users of rooftop solar PV both in commercial, industrial and domestic users.

- **Lack of consumer awareness programmes on use of Rooftop Solar PV deployment**

It was clear that many respondents knew about rooftop solar PV sector through informal means like word of mouth referrals from their friends and other users. The information given depends on the past perceptions and experiences of those parties thus it can be misleading and in accurate. This is greatly affecting decision making across all the stakeholders involved in the sector. There is need for consumer awareness programmes aimed at promoting use of solar energy to create proper consumer awareness.

- **Lack of skilled man power and capacity building programmes**

Most of the trainings in the solar sector are done using informal means. Strathmore university through Strathmore Energy Research Centre is currently the only institutions with a well-structured curriculum, qualified staff and reliable resources within the country been involved in energy training mainly solar. High cost of training is another barrier preventing those willing to train to undertake such training. Other organizations undertaking training include Kenya Association of Manufacturers (KAM) mainly to its members and National Industrial Training Authority (NITA).

- **Poor building structures and planning**

Most buildings did not take rooftop solar PV deployment into consideration during construction. This barrier is making it difficult for interested consumers who wish to invest. Some consumers using rooftop solar PV had to modify their roofs to accommodate the same. There is need for cooperation among all the parties involved before designing new building to consider rooftop solar PV deployment in the future.

Recommendation for Improvements

The following recommendations can be implemented to aid in adoption and scaling up of rooftop solar PV deployment

- **Introduction of Net Metering proposed in Energy Act of 2015**

Net metering is the way to go since it can be applied across all the consumers who produce excess electricity. Energy Act of 2015 proposed that consumers who owns an electric power generator of capacity not exceeding 1MW may apply to enter into Net Metering system agreement with a distribution licensee or retailer if the consumer has a generation facility located within the area of supply. If approved, this will enable electricity prosumers invest heavily in solar in general to save on rising electricity and at the same time sell excess electricity to grid. FiT for solar needs to be adjusted to remove a limit of 0.5MW as the minimum capacity of electricity to be fed to the grid. This will accommodate small scale electricity prosumers.

- **Shortening waiting period experienced during application and approval process**

Delays and uncertainty experienced during application and approval processes should be addressed by developing a website to facilitate tracking of all processes involved. Timelines for each stage should be well defined and if delays occur, an update of the reasons behind given and a penalty applied if the reasons given are not bidding.

- **Creating awareness programmes and making key information easily accessible**

Rooftop solar PV remain the only option for massive renewable energy deployment in urban centres whose population tend to be increasing due to rural urban migration. Lack of awareness programmes on use of rooftop solar is affecting final decision making for parties interested in investing in the sector.

- **Introduction of promotional programmes**

Government should adopt non-financial incentives like issuing green certificates to consumers who use rooftop solar among other sustainable sources of energy. Government institutions nationwide need to be frontiers in social media campaigning for deployment of rooftop solar to raise awareness and label the move as a way of addressing environmental concerns which is now a global crisis. These non-financial incentives will sound as tangible benefit for all stakeholders involved.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Urban centres are growing at unprecedented rate in developing nations. This growth is being experienced more in Africa and Asia continents. This is attributed to high population growth being experienced in those nations and more people moving to urban centres and the desire for those nations to industrialize. Urban centres serve as hubs of economic growth as most activities occur there due to presence of supportive environments such as ready market for finished goods and labour availability (UN-Habitat, 2012). These developing countries have abundant and underutilized natural resources that are backbones of economic growth making them attract foreign investments across the world. Energy demand on other side is rapidly increasing as more energy is needed to support urbanization. Electricity generation though remains to be backbone of industrialization is regarded as one among the larger contributors of greenhouse gas emissions associated with climate change.

Urban centres are more vulnerable to severe climate change effects hence need for measures to make them more economic and environment sustainable (A. Hunt & P. Watkiss, 2007). This dilemma between climate change and industrialization has led to emergence of use of renewable energy sources led by rooftop Solar PV that are believed to be environmentally friendly. Rooftop solar PV is an emerging sector targeting urban centres. There has been no enough attention given to addressing challenges facing its use in urban centres. This study aims to close the information gap that exists in embedded solar PV generation on rooftops by assessing challenges and barriers. The city of Nairobi and its outskirts was the focus of the study which hosts all sorts of commercial, residential and industrial buildings.

In an attempt to address increasing energy demand and to shift from overreliance of fluctuating fossil-based fuels for electricity generation, renewable energy has been deployed as an alternative. Climate change mitigation measures and energy security has also played role in renewable use (REN21, 2014). Electricity power generating capacity from renewables increased in 2016, with an estimated annual 161GW added in 2016. Solar PV use has been on rise over a decade. This has made solar PV record high additions for the first time than any other power generating technology (REN21, 2016). Reduction in production costs leading to low prices and its availability worldwide led to this record. The ongoing growth and expansion of renewable energy power capacity is being driven by the continued decline in prices for renewable energy technologies mostly solar, rising power demand in some countries characterized by rapid population growth leading to growth in urbanization thus targeting renewable energy support mechanisms to help address energy crisis in developing countries (REN21, 2016). Solar PV and wind power are now challenging fossil fuels in a growing number of locations. Rural electrification has also helped in promoting decentralized solar PV deployment in marginalized areas. China is now leading in Solar PV (REN21, 2017).

Kenya is now focussing on Geothermal energy whose potential capacity is 10GW making it leading in the region in geothermal use (REN21, 2017). Kenya's solar energy market is growing drastically due to enabling business environment and government efforts to increase electricity access in rural areas. The nation is among the countries located along the equator with abundant supply of solar energy throughout the year. The daily average solar irradiation for Kenya ranges between 4-6kWh/m^2 which is considered one of the best for solar energy production if well utilized in Sub-Saharan Africa (GeoModel Solar, 2013). This places Kenya in a better position to utilize solar energy throughout the year.

1.2 Rationale of the study

Urban centres and cities are hub of economic growth and development of any nation. This is due to concentrated industries within cities and high population density attracting market for finished goods and services. As a result, cities consume more electricity and other forms of energy and other resources available. Energy generation on other hand is considered as the main source of greenhouse gases emissions and other environmental pollutions leading to climate change menace. Hence a need to balance economic growth and climate change adaptation in urban centres as the level of urbanizing is rapidly increasing on daily basis. Urban centres occupy less than 5% of total earth's total land though account for more than 75% of resource and energy use. Asian countries among other developing nations are urbanizing at high rate and according to United Nations projections of 2004, more than 55% of total population in Asia will be residing in urban centre (UN- Habitat, 2014). This will impact negatively on environment leading to climate change disaster as many Asian countries rely on fossil-based fuels for electricity generation and other energy sources.

Urban centres now have the challenge to come up with ways of transforming them from hotbed of pollution and greenhouse gases emissions to hub of sustainable green economy by supporting economic growth in a sustainable manner. This can only be achieved by restructuring the energy supply and demand by exploiting different ways available. Due to scarcity of large lands to deploy renewables such as wind and solar, deploying rooftop solar PV remains viable solution in urban centres (John Byrne, Job Taminiau, Lado Kurdgelashvili, & Kyung Nam Kim, 2015). There is need to estimate the renewable energy potentials mainly rooftop solar PV in urban centres, and creating awareness to policy makers, regulators in government institutions as well as private sectors on the need of using rooftop solar PV in urban centres. Some argue there has been neglect in rooftop solar PV buildings contribution to the energy mix of cities in as many are bias towards large scale utility that cannot be applied in urban centres due to lack of space. Building complexity and geographic spread of buildings characterized by varying architectural configurations make it challenging to deploy the same (Kumar & Shekhar, 2014).

Kenyan government has put measures to promote renewables energy mostly solar by providing conducive environment such as excluding taxes on solar PV related goods and introduction of FiT tariffs that was introduced in 2008 and revised in 2010 and 2012. Energy Act of 2015 is providing a provision of introduction of net metering and Auction based tariffs to promote solar PV deployment (MoE&P, 2015). Rooftop solar PV use has of late been deployed mainly by commercial and industrial as they try to offset electricity bills that are consuming more than 40% of their total expenses with private firms mainly in flower farming installing as high as 1MW rooftop solar power. Commercial buildings such as shopping malls are doing the same. Public learning institutions are also making use of idle roofs to generate electricity from solar. Strathmore University was the first learning institution to install a 600KW rooftop solar PV followed by ICIPE that surpassed Strathmore University capacity by installing 1MW plant funded by Swiss development corporation. London distillers on the other hand have installed 1MW of rooftop solar PV in their premises to offset their electricity bills (Solar century , 2017).

The research problems and answers will contribute to the awareness of broad advantages of using rooftop solar PV in urban centres that will create room for new opportunities and addressing challenges associated with the same. The development of relevant policies as well as support mechanisms to boost deployment of rooftop solar PV systems in urban centres such as appropriate funding schemes like tax evasion, subsidies among others, utility planning, and grid connection of distributed generating units, can well be addressed adequately when challenges faced when scaling up are well addressed. The outcome of this study is important for key stakeholders including private sector, local communities, energy policy makers, energy regulators (Kumar & Shekhar, 2014). It is also relevant for city planners as they develop infrastructure plans to create green cities and pursue sustainable urban spaces and infrastructure. Although the study focuses on rooftop Solar PV, the estimates of building roof areas derived from it can also be used in solar thermal technology deployment that was put in place in 2012 by the energy regulatory commission that stated that any building consuming more than 100 litres of water daily requires to install solar water (MoE&P, 2012).

1.3 Problem statement

Kenya is among the nations facing energy crisis as they aim to get industrialized. To speed up industrialization, the Kenyan government launched Vision 2030 whose objective was to transform Kenya into a newly industrialized and middle-income nation by 2030 (Kenya Vision 2030, 2007). To increase electricity access across the country, the country embarked on measures that were aimed at increasing electricity generation capacity. In 2008, Feed-in-Tariff was introduced to encourage independent power producers (IPPs) to invest in electricity generation mainly targeting Renewables. This was aimed to integrate renewables in Kenyan energy mix that relied heavily on hydro and fossil-based generation (MoE&P, 2008). In 2012, solar related products were exempted from taxation to encourage its deployment mainly targeting rural areas where no national grid was available.

In spite all these efforts, solar PV deployment in urban centres has remained low despite the fact that urban centres are major consumers of total electricity generated in a country with some countries consuming more than 70% within urban centres. There is increasing concern of rapid urbanization globally fuelled by high population been experienced in developing countries and the need to address climate change. There is a need to integrate renewable energy generation within urban energy mix globally especially solar which is available all over the world. Many studies have been carried to assess the solar PV potential within urban centres targeting mainly rooftop that seems viable all over the world (MNRE, 2015). Similarly, many studies have been carried to access the solar PV deployment and impacts in Kenya mainly targeting rural areas in view of scaling up use of solar energy.

Nairobi is said to be among the best regions in Kenya where solar PV deployment can work well in the country with average solar irradiance of 4.5kwh/m^2 throughout the year (GeoModel Solar, 2013). The challenge is how to install such projects that require large pieces of land that is not available within the city of Nairobi and her surroundings. The only option remaining is use of rooftop solar that can be applied across the region well. However, no studies have been conducted to assess and address the challenges facing scaling up of Solar rooftop in urban centres in Kenya despite some public institutions and commercial sectors installing rooftop solar within Nairobi that are working well (MoE&P, 2012). It is aim of this study to fill this gap and address the challenges and recommend some policy interventions that can aid in scaling up rooftop solar and at the same time play major role in transforming Nairobi into a more sustainable city.

1.4 Objectives

1.4.1 General Objectives

The general objective of the study was to investigate factors affecting adoption and scaling up of roof mounted Solar PV in urban centres using Nairobi as the case study.

1.4.2 Specific Objectives

The following specific objectives were applied to aid in achieving the general objective of carrying out this study

i) To establish major challenges in Adoption and up scaling rooftop SPV in urban centres
ii) To investigate key drivers and opportunities for roof mounted SPV that can be adopted to scale up solar rooftop PV in urban centres
iii) To evaluate existing business models that can be applied to scale up SPV rooftop
iv) To recommend policy intervention to aid in adoption and scaling Up of rooftop SPV

1.5 Research questions

i) Which interventions can be used to address the barriers facing roof mounted solar deployment in urban centres?
ii) What are the key drivers and opportunities that can be utilised in scaling up rooftop solar PV use?
iii) How can the available business models be used effectively to encourage rooftop solar PV use?
iv) Which policy mechanisms can be recommended for adoption to scale up rooftop solar PV use?
v) What role can the government play to enforce and promote use of rooftop solar PV?

1.6 Scope of the study

1.6.1 Geographical Scope

The study was conducted out in Nairobi which is the capital city of the republic of Kenya. This case study was selected because it hosts all sorts of activities carried out in a modern city in the world and most of the rooftop solar projects have been installed within the city and its surroundings. Another determining factor is its accessibility to the researcher and resources needed to successfully carry out the research.

1.6.2 Time Scope

The study focussed on the period between 2012 to 2018 since most changes in solar PV deployment have occurred after the Energy Act of 2012 exempted solar products from taxation and reviewed FiT targeting solar energy use among other renewables.

1.6.3 Subject Scope

The research focussed on the factors affecting adoption and scaling up of roof mounted solar PV as well as the key drives to the same across all the key stakeholders that are involved in rooftop solar PV. Policy interventions that will help to enforce rooftop solar and changing building design to create room for rooftop solar will be a necessity.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This section focusses on the review of research that have already been conducted and are related on the topic under study whose main objective is to reveal the contributions made by earlier researchers and try identify the shortcomings and gaps in the existing knowledge and highlight the lessons learnt from their studies. It is composed of sections which include theoretical review, empirical review, conceptual review, summary of the literature review and different related studies done by previous researchers that will be used as a guide to this study.

2.1 Theoretical review

The study is focusing on factors affecting adoption and scaling up of rooftop solar PV deployment in urban centres that is seen as the key drive to making urban centres take part in climate change mitigation by reducing greenhouse gases emissions. Urban centres still remain the main consumers of electricity generated globally which is seen as the major source of climate change through pollution in the process of generating electricity for use. Many theories and models about the use and deployment of renewable energy have been developed and used globally. Some of these theories have been key in scaling up renewable energy mainly solar. Others have been negatively affecting REs use.

2.1.1 Evolving theories on sustainability and firms' contributions to renewable energy

Many theories have been evolving on the role of firms on sustainability and renewable energy use. These theories have assisted in the scaling up of REs deployment globally. Among the evolving theories include Corporate social responsibility, stakeholder theory, corporate sustainability, green economics, multi-level perspective, co-evolution theory in management and transition management. These theories have been applied at all levels of firm's management and organizations.

2.1.1.1 Corporate social responsibility theory

Firms have critical role to play in REs deployment through their influences on decision making that affect the lives of citizens. Large firms are understood to be critical centres of powers hence their actions largely affect the policy making in the field of sustainability and political system that influence REs use in any nations (Bowen, 1953). Their actions determine the outcomes of country's economic gains, society welfare and environmental sustainability. Such firms can be used as agents of REs use and deployment across the globe. Some have already taken initiatives of promoting REs by using electricity generated from renewables or by installing solar PV that is either ground or roof mounted within their premises.

2.1.1.2 Stakeholder theory

Firms success depends on how they relate with their stakeholders. Companies need to understand the needs and relationships with all their stakeholders to help them manage their organizations well (Freeman E. R., 1994). These stakeholders include customers, suppliers, government, environmentalists among others. Since firms are actors in social environment, there is need for them to respond to demands and pressures across all their stakeholders that can help to address the use of REs and thus agents of climate change mitigation measures if they are to achieve their strategic objectives.

2.1.1.3 Corporate sustainability theory

Corporate sustainability is defined as the ability of a firm to meet the needs and demands of stakeholders without compromising the ability to meet the needs of the future stakeholders (Dyllick & Hockerts, 2002). Firms are supposed to emphasize the need to meet stakeholders demand as well as balancing the social, economic and environmental dimensions of their performance (United Nations, 1987). If this theory is adhered to by all firms, it will promote the use of REs and play important role in environmental protection and climate change mitigation as they aim to achieve future sustainability.

2.1.1.4 Green economics theory

Green economics is defined *"as the one that results in improved human well-being and social equity while at the same time significantly reducing environmental risks and ecological scarcities"* (UNEP, 2010). According to Richard Schmalensee (2012), green growth needs more than firms' voluntary policies to be successful in all industries. There is need to balance between voluntary policies and regulatory mechanisms for industries to embrace green economy. Green economy theory has of late being used by industries and institutions to promote use of renewable energy as they try to ease effect of climate change and trying to comply with some national and international standards and requirements that have been put in place areas and line of operations.

2.1.1.5 Gender role, Renewable Energy and climate change theory

Gender has played key role in renewable energy use and address to climate change crisis. The effects of environmental deterioration will affect both gender but women are likely to suffer a lot with regard to their responsibilities (Wamukonya & Skutsch, 2001). Culture traditional practices has for the past regarded women as agents of child upbringing thus confining them to activities of taking care of the family such as collecting firewood and fetching water for the family. In some places, girls can't access education due to duties assigned to them. This has led to organizations coming up with foundations to promote the role of women in sustainable development thus promoting the use of renewable energy as they aim to achieve MDGs and SDGs. Some theories argue that climate change impacts will affect everyone though they claim Africa as the most vulnerable and severely affected due to high poverty levels and over reliance on biomass as the main source of energy (Wamukonya & Rukato, 2001).

This has led to African countries and the entire world turn to renewable energy deployment mainly solar energy that is readily available globally. More emphasize is now being directed on how to integrate solar PV in urban centres that remain to be major consumers of electricity generated among all the nations. Multi-level perspective theory has of late been used to explore the complexity of using government policies to achieve renewable energy deployment goals. This theory has led to rise of China as the giant when it comes to renewables mainly solar. Germany has followed suit by using government policies that has increased wind and solar capacity generation in the total energy generation capacity. Critical review of all these theories shows that renewable energy use and deployment has been heavily related to these theories and if all stakeholders are to follow them bit by bit, a lot can be achieved through renewable energy despite many questioning renewable energy capability to industrialize developing countries.

2.2 Empirical review

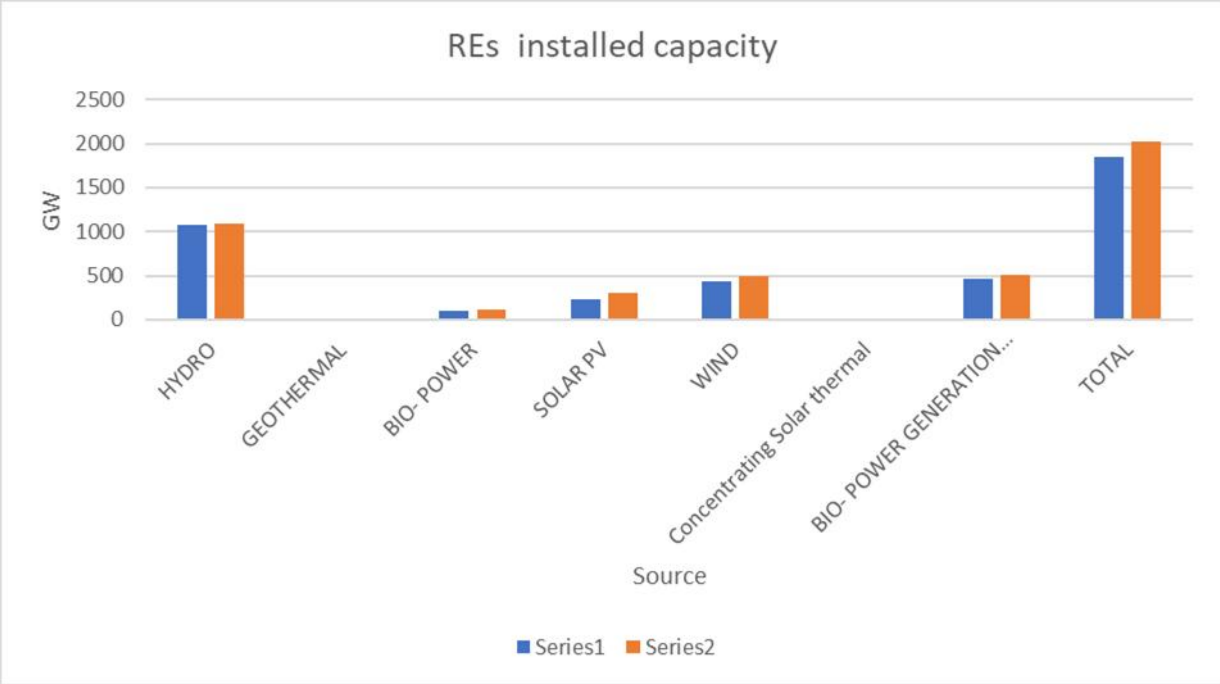
Several studies on rooftop solar have so far been conducted and concluded. These findings are based on actual observations and measured phenomena unlike theoretical review that is based on theories and beliefs. Previous research on rooftop solar in urban centres have focused more on quantifying the potential of various cities as initiatives to establish whether the projects is economic viable and can be used to offset reliance on fossil-based fuels in electricity generation. Indian government has taken a step forward by setting a target of 40GW of rooftop solar PV deployment across her cities and upcoming urban centres by 2022. The target is termed over ambitious by many though the Indian government is putting up measures to address the challenges outlined and faced so far by the ongoing deployment across the country.

2.2.1 Global Renewable Energy Status

Renewable energy has been deployed globally as means of climate change mitigation measures, energy security and diversification planning of most nations as well as been regarded as a mainstream policy response to matters of social equity, health, poverty, empowerment, and employment (REN21, 2014). This has led to record breaking in terms of renewable energy deployment both in energy output and capital investment injected in the sector over a decade. The growth in capacity deployment of renewables has subsequently fueled a technology cost reduction trend and rolling adoption of policy-driven support mechanisms for the sector on every continent as experienced in the case of solar and wind energy (REN21, 2014). Government and other stakeholders have developed Strong policy support, capital investment, advanced technology, and improved manufacturing efficiency that have been identified as key drivers for the sector's stellar performance.

The 2016 renewable energy global status report estimated a 19% contribution of renewable energy to the final global energy consumption in 2012, with modern renewable energy technologies (solar, wind and hydro) accounting for about 10% of the share, whilst biomass accounted for the balance (REN21, 2016). The renewable energy deployment has been graphically displayed below.

Graph 2.2.1: Global installed capacity comparison between 2015 and 2016



Graph 2.2.1: REs Installed Capacity; Source: REN21, 2017

In 2016, renewables accounted for an estimated nearly 62% of net additions to global power generating capacity. Solar PV saw record additions for the first time has accounted for more additional capacity than any other power generating technology (REN21, 2016). This has been promoted by reduction in cost of production as well as installations and initiatives aimed at promoting solar PV deployment globally as it is seen as the only source readily available across the globe. Solar PV represented about 47% of newly installed renewable power capacity in 2016, and wind and hydropower accounted for most of the remainder, contributing 34% and 16%, respectively. The ongoing growth and geographical expansion of renewable energy power capacity is being driven by the continued decline in prices for renewable energy technologies, rising power demand in some countries characterized by rapid population growth leading to growth in urbanization thus targeting renewable energy support mechanisms to help address energy crisis in developing countries (REN21, 2016).

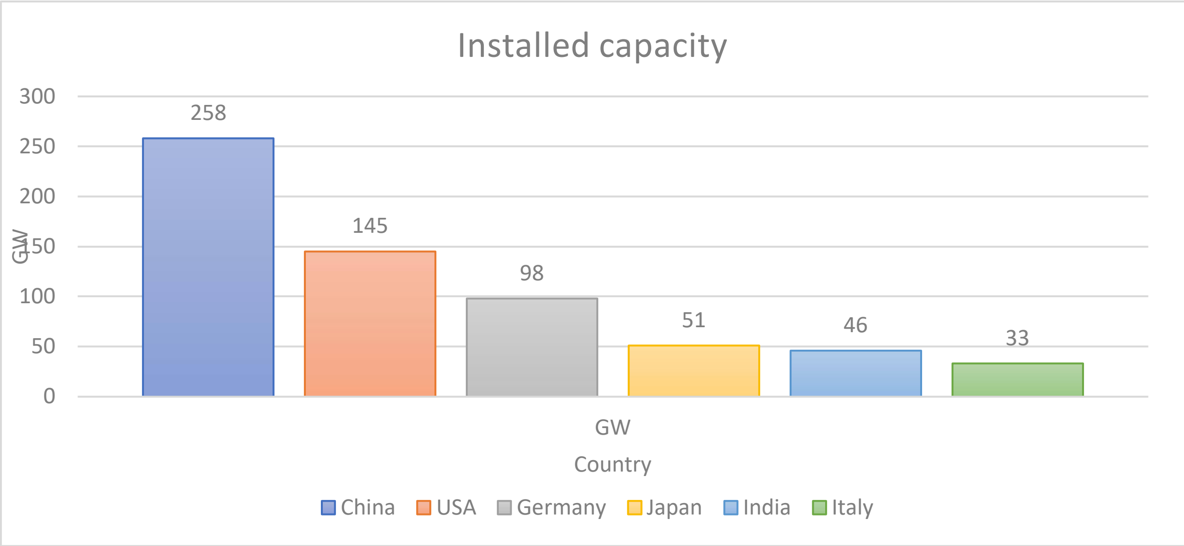
Well-established renewable energy technologies, such as hydropower and geothermal energy, have long since become cost-competitive with fossil fuels where resources are plentiful. Solar PV and wind power are now challenging fossil fuels in a growing number of locations. Plants owned by utilities or large investors dominate renewable electricity production in 2016, and the scale of renewable energy plants continued to grow. Rural electrification has also helped in promoting decentralized solar PV deployment in marginalized areas. china and India are now leading in Solar PV power plants with high capacity globally (PV group GmbH& Co. KG, 2017).

2.2.2 Continental, Regional and National Role-players

Renewable energy deployment has been shifting from one country and/or region to another recently. Initially, EU has been the leading consumer of Renewable energy including Hydro and Geothermal power. Asia has overtaken now with China, Japan and India leading in total renewables installed capacity recently. Globally, China is the leading followed by USA, Germany, Japan, India, Italy and Spain. SSA remains with least electricity access with rural areas having less than 10% excluding South Africa which relies mainly on coal for electricity generation (AfDB, 2012).

Egypt and Morocco are the RE use giants in Africa continent whereas other nations have high potential for achieving 100% REs if they can utilize all their resources. Ethiopia are in the process of constructing Grand Renaissance dam of 6GW that will help the country achieve 100% REs electricity generation. Most countries in SSA rely on hydro power. The progress is summarised below as per top six countries in REs deployment. This displays how individual countries/ regions are taking the issue of climate change serious to save the future generation of the same.

Graph 2.2.2: Continental, Regional and National Role-players



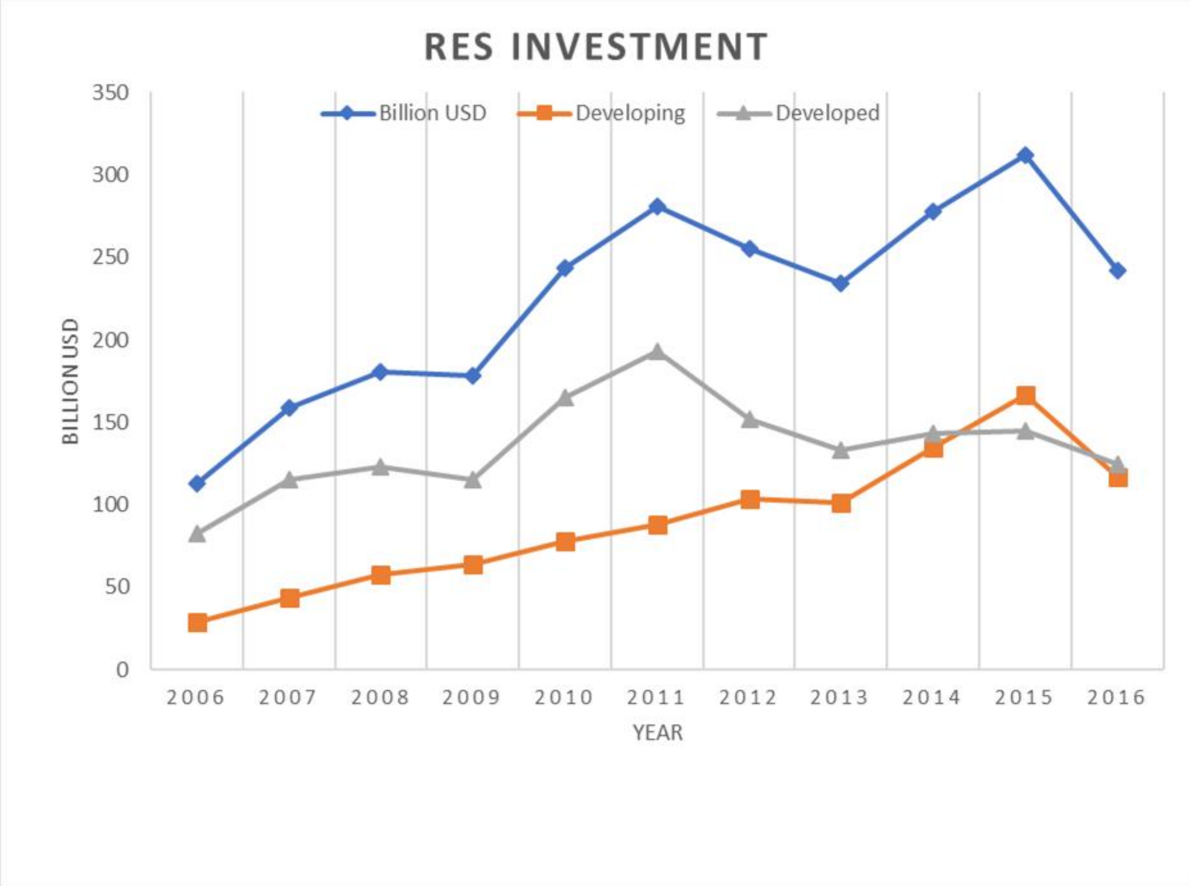
Graph 2.2.2: Top six Countries; source: REN21, 2017

2.2.3 Global Renewable Energy Investment and Mobilization

New investment in Renewable energy power and fuels (not including hydropower projects larger than 50 MW) was USD 241 .6 billion in 2016, according to Bloomberg New Energy Finance (BNEF) thus representing a 23% decrease compared to 2015, the decline accompanied a record installation of renewable power capacity worldwide in 2016. Decline in global investment was due to two factors that involved slowdown in investments in Japan, China and some other emerging countries as well as the significant cost reductions in solar PV and onshore and offshore wind power, which also improved the cost-competitiveness of those technologies.

This resulted to 2016 investors being able to acquire more renewable energy capacity for less money compared to previous years. Developing and emerging countries for the first time overtook developed countries in terms of investment in renewable energy making Asia continent the leading. Europe investment declined most for the first time since the rise of renewable energy (REN21, 2017). The investment trend is over the last ten years is shown below by the line graph.

Graph 2.2.3: Global Renewable Energy Investment and Mobilization



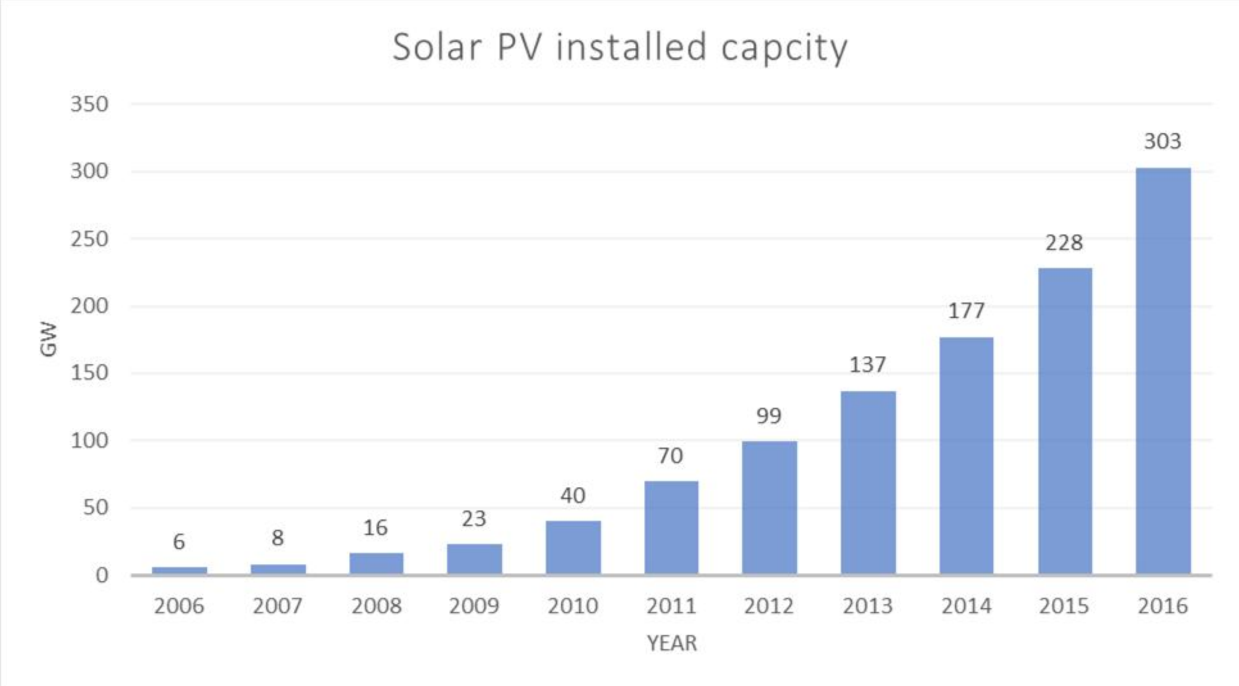
Graph 2.2.3: REs investment, Source: REN21, 2017

2.2.4 The rise of Solar PV

For the last ten years, solar PV market and deployment has been rising rapidly compared to other renewables since solar energy resource is available to almost every country. Wind and Geothermal energy have also been in the rise but Solar PV has surpassed them. Europe and USA have been leading in solar PV deployment but now Asia continent has overtaken them. China, Japan and India have invested a lot in solar PV making Asia the leading in solar PV in the end of year 2016 (REN21, 2016).

At least 75GW of solar PV was added in 2016 alone globally taking the total installed capacity to 303GW of the same worldwide. This has been facilitated by already laid policies to help promote the same. Solar PV market expansion has been facilitated by the increasing competitiveness of solar PV, rising demand for electricity in marginalized areas and improved awareness of solar PV's potential in reducing pollution and greenhouse gases emissions. New emerging markets consider solar PV cost competitive source of energy (REN21, 2017).

Graph 2.2.4 The rise of Solar PV



Graph 2.2.4: Solar PV capacity for 10 years, Source: REN21, 2017

2.3 Estimation of rooftop solar PV potential in urban centres

In 2009, the Energy and Resource Institute, TERI, New Delhi came up with a master plan in an attempt to make Chandigarh a solar city that was among the earliest efforts by the Indian government to deploy rooftop solar PV (TERI, 2009). MNRE in 2014 launched sixty solar cities across India whose objective was to meet at least 10% of the expected energy requirements targeting roof mounted solar in urban centres. This was aimed at addressing increasing demand of energy across the country characterized by high population rate leading to rapid urbanization (MNRE, 2015).

Bridge to India released a report in 2013 of estimating the rooftop solar potential of Delhi using Google Map Earth for estimating and Wikimapia for classifying the building into three main categories namely residential, commercial and industrial across the city of Delhi. It was concluded that 2GW of electricity can be generated using rooftop solar. This can be a great achievement with a city total peak demand of 6GW (Bridge to India, 2013). Later in 2014, a city of Patna was estimated to have a rooftop solar potential of 759MW whereas anticipated peak demand was found to be 600MW from the study carried by Bridge to India. The potential exceeded the peak demand suggesting excess electricity generated can be exported to nearby cities through national grid (Bridge to India, 2014).

Potential estimates of roof mounted solar in urban centres have so far provided promising results and opportunities of utilizing roof for power generation globally. The great city of Mumbai in India has an average total demand of 3GW according to a study carried. Rooftop solar potential of approximate 1.72GW was estimated by applying satellite-based assessments using google maps and google earth incorporated with site visits to ascertain electricity use across all the sectors of the city. 3D models were used to extrapolate the suitable area for rooftop solar use. It was concluded that more than 1.72GW of electricity can be generated by using rooftop solar across the city (MNRE, 2016). A need for further study on the points of sinks to determine the nature of off-peak and peak demands can be useful if roof mounted solar is to be effectively utilised. This requires corporation and support among all the stakeholders including utility companies.

J.M Pearce et al (2010) argued that resources to deploy solar PV in urban centres are not the main limiting factors. A five-step procedure was used to quantify rooftop solar potential to be used for the region of Ontario using GIS and advanced feature extraction algorithms to estimate Ontario rooftop solar PV potential. FIT policy was found to have the potential to facilitate an initiation to significant rooftop solar deployment in urban centres. A more in-depth analysis of roof area population data points from the municipal was recommended that can be used for the purpose of estimates as the municipal lack data of the buildings and land use (J.M. Pearce, H. T. Nguyen, & L.K. Wiginton, 2010). A research gap exists there for identifying more challenges faced by rooftop solar deployment in such areas that can aid all stakeholders in planning for such.

John Byrne et al, 2015 conducted a study to estimate rooftop solar electric potential of the city of Seoul, South Korea by applying arc-GIS for estimation using cartographic information of 2002 and AutoCAD 2013 for extraction of suitable roof area for solar use. It was concluded that a total of 11.255GW can be generated by using rooftop solar in the city representing 30% city total electricity use. They argued that assessment of cities' rooftop solar PV potential is vital since it is the only resource that each country possesses (John Byrne, Job Taminiau, Lado Kurdgelashvili, & Kyung Nam Kim, 2015). Rooftop solar PV potential of Gangnam district of Seoul was estimated by using a three-step process involving data collection and conversion, building shadow analysis by application of Hillshade analysis and estimation of available rooftop area. It was concluded that 4,903,079m^2 on average can be used for electricity generation through solar representing 65.22% of the total roof area in that district. The method was argued to be simple to use and accurate and least expensive compared to others despite some challenges encountered in the process (Hong, Lee, Koo, & Kim, 2016).

A detailed assessment of technical rooftop solar PV potential was conducted using DHS Lidar data set that covered 23% of building stock and 40% of USA nationwide population. For regions without Lidar data, leveraged DHS Lidar data was used to build models for estimating the total amount of suitable roof area for solar utilization. The estimated technical potential was found to be 1118GW of installed capacity and 1432TWh of total annual electricity sales (NREL, 2012). It was concluded that the estimates were greater than previous studies by NREL estimates of 800TWh of annual nationwide generation and 664GW of installed capacity (Lopez, Anthony, Billy , Heimiller, & Nate, 2012). M. Luqman et al, 2015 carried a study by estimating the rooftop solar energy potential of Punjab government servants housing society using arc-GIS model and concluded that a potential of 399613072KWh was achievable that accounted for 11% of total energy consumption of the entire community. That represented high potential despite the fact that the study did not utilize all the available roof area in the entire institutions. A high generation is achievable if all the roof areas are considered (Luqman, et al., 2015).

The CBD of the city of Johannesburg was estimated to have a rooftop solar PV potential of approximately 22.6MW of electricity capacity representing less than 1% of city's current electricity consumption. The study was carried using GIS and Google earth pro for estimations with the help of PV watts calculator. The low potential capacity was attributed to the nature of buildings and congestions thus shading taking the larger party of the roof area. The research concluded rooftop solar PV deployment with the CBD of city of Johannesburg is not economic feasible (Ntsoane, 2017).

Private sector and donor funded projects in Kenya are the leading in solar PV deployment. The rapid use of solar PV is promoted by the government initiatives such tax exemptions of all solar PV related products including panels and inverters. Rooftop solar has not been well utilized across the country despite the fact that solar PV use requires large pieces of land thus competing with other land use. Learning institutions and commercial buildings are now turning to use of rooftop solar as they try to offset high electricity bills from fossil-based fuels (MoE&P, 2015). No study has been done assess the rooftop solar potential of Nairobi city despite having the best average solar irradiance of 4.5KWh/m^2 throughout the year (GeoModel Solar, 2013). Nairobi remains to be the hub of all economic activities of Kenya and her neighbour nations. There is need to look for ways to utilize use of solar using roof area to offset over reliance on thermal generation and hydro power that is severely affected by drought experienced within the country (MoE&P, 2008).

2.4 Challenges and barriers to renewables including rooftop solar

Many studies and analyses have been conducted to assess the challenges and barriers to scaling up renewable energies worldwide. A survey was conducted to assess the barriers to rooftop solar PV in Puducherry smart grid pilot project in India. It was concluded that consumer awareness of rooftop solar PV was the major challenge compared to initial costs and consumer payback period. A suggestion to deploy rooftop solar in public places such as schools, hospitals and hotels as means of creating awareness to the members of the public was recommended. Consumers those had prior knowledge preferred to use net and gross metering to deploy roof mounted solar (Kappagantu, Daniel, & Venkatesh, 2015).

Izael Da Silva identified four categories of challenges facing solar technology diffusion in Africa using Kenya as a case study. These challenges included lack of enabling environment, limited access to finance, lack of public awareness and inadequate technical support. He recommended innovative approaches leading to alternative energy sources penetration, green credit mechanisms, subsidies and tax exemptions mechanisms on renewables and FiT and net metering that was proposed in energy act of 2015 as well as training of solar PV technicians that will aid in installations (Da Silva, 2015). A survey conducted concluded that lack of awareness among electricity consumers, wide networks of service providers, smart grids to allow interconnections configurations, limited financing and lack of standardized solar PV system packages were challenges facing rooftop solar PV use in six different cities in India namely Bangalore, Bhubaneswar, Chandigarh, Delhi, Gandhinagar and Pune. Electricity consumers expected government intervention to lower upfront costs through subsidy and open and accountable processes in acquiring such subsidies and a guaranteed and affordable annual maintenance contract from the supplier (S. Sundaray, L. Mann, B. Ujjwal, S. Garud, & A. K. Tripathi, 2014).

Solar PV use in Nigeria remain low despite high solar irradiance experienced within the country throughout the year and low electricity access experienced in the country whose high population can be huge market for solar PV market globally (Sambo & Bala, 2012). This was attributed to lack of solar initiatives research, socio-cultural behaviour and awareness issues, lack of financial assistance and mechanisms, legal barriers and political instability and insecurity experienced within some parts of the country that has scared potential investors in the domain of renewables (D Abdullahi, S Suresh, S Renukappa, & D Oloke , 2017). SSA excluding South Africa electricity access remain to be low with rural areas electricity access remaining at less than 10% where majority rely on biomass as the main source of energy (UNEP, 2010). Renewable energy penetration and investments that can be used to offset such energy crisis still remain low despite the high potential within the countries. Subsidies on fossil-based generations without factoring in environmental and social costs associated with power generations through fossil fuels, lack of financial and enabling policy mechanisms to support RE use, and high front costs needed in Renewable energy are the major barriers. (Lopez, Anthony, Billy , Heimiller, & Nate, 2012).

To address the increasing energy demand in SSA, more than 7GW of electricity generation capacity has to be installed annually (AfDB, 2012). Despite the increasing energy demand in SSA, there exist large financing gaps for renewables that can be addressed by incorporating private investment with existing government and international agencies investments (AfDB, 2012). Renewable energy private investment in SSA still remains low despite the abundant natural resources in the continent. This is attributed to lack of level playing ground, high political and regulatory risks experienced among the countries and difficulties experienced in accessing energy markets and grid connection on competitive grounds. Most SSA nations rely on either government owned electricity utilities controlled by corrupt cartels that do not pave way for private investors to venture in such businesses.

Kenya is among the SSA countries characterised by low electricity access despite abundant renewable energy sources (AfDB, 2009). Overreliance on hydropower and thermal generation has been a major issue in addressing high energy demand in the country. Series drought and fluctuating oil prices experienced has affected the electricity generation stability thus forcing the country to look for alternative energy sources (MoE&P, 2012). Renewable energy investments remain low than expected due to lack of finance, building capacity as the country lacks well equipped institutions to train personnel who will be in charge of renewables deployment and operations (UNEP, 2010). Subsidies on fossil-based fuels have also been a major blow to renewable energy penetration in Kenya. Despite the efforts made by the GoK to scale up renewables, still there is a lot to do in streamlining regulatory and legal policy mechanisms. Monopoly exercised by KPLC in buying and selling of electricity across the country has made it difficult for private investment to penetrate in Kenya. This has led to high electricity prices despite fall of oil prices globally (MoE&P, 2015).

2.5 Opportunities, business models and key drivers to renewable energy deployment

Various opportunities and key drivers have led to massive deployment of rooftop solar PV among other renewables according to previous studies. M. Bruce and P. Szuster found that the three key factors leading to massive deployment of rooftop solar PV in Australia were due to rising prices in electricity forcing household option to use rooftop solar to offset their electricity bills, subsidies through capital subsidies achieved through certificates schemes and productions subsidies through FiT and the recent decline of solar PV systems costs. Such factors led to massive installation of PV systems to increase from 8000 to 1.4 million between 2007 and 2014. Key drives identified during the study included regulatory policy frameworks, technology advancements been experienced in renewables mainly solar, market developments and models as well as FiT structure which favoured rooftop solar (Mountain & Szuster, 2015).

The introduction of Third Party Ownership business model in USA has promoted the use of rooftop solar across the country. This business model has addressed the challenges associated with initial capital needs, permitting, installations and maintenance concerns that were affecting both residential and commercial users (Harald, 2015). Removing of prohibitive legislation preventing solar TPO penetration in some regions of the country, integrating net metering to rooftop solar, financial mechanisms such as investment credit tax to support solar TPO and easy processes involved in installing rooftop solar should be encouraged, were some of the recommendations suggested to scale up rooftop solar in USA (Harald, 2015). TERI and Shakti identified two ownership business models namely self-owned SPV system and third-party ownership that can be applied in six Indian cities that were selected as case studies in a survey carried in 2014 that can be used to implement rooftop solar (S. Sundaray, L. Mann, B. Ujjwal, S. Garud, & A. K. Tripathi, 2014).

Nigeria has a high solar PV deployment potential and opportunities as a result of high solar irradiance experienced throughout the year, high population that can be a huge market for solar related products and low electricity access characterised by power outage across the country (D. Abdullahi et al, 2017). Recently renewable energy use has increased in SSA. Climate change mitigation initiatives and attempts to increase energy access rates in Africa has been the key driver in renewable energy use (UNEP, 2011; AfDB, 2010). Introduction of FiT and net metering in some African countries has attracted international investors in Res. National RE targets among nations, Quota mechanisms and investments in clean development mechanisms (CDM) funds such as carbon prices are other key drivers and opportunities helping SSA renewable energy uptake (Jenny Lopez et al, 2011).

Kenya is ranked among the countries with high renewable energy potential in Africa (UNEP, 2009). To promote investment in renewable energy, feed in tariff was introduced in 2008 covering Wind, Hydro and Biomass electricity generation. In 2012, the FiT was revised to incorporate Solar and Geothermal that triggered private investment in Solar and Geothermal (Energy Act, 2008;2012). Renewable energy products were exempted from taxation mainly solar products that made it easy for solar PV deployments in the country. This was aimed at increasing the electricity access in marginalised rural areas (The Energy Act, 2012). Geothermal potential capacity of 10GW has been a major boost towards achieving Vision 2030 goals (Kenya Vision 2030, 2007). More investments through government initiatives, donor funding, private sector investment and international funding through clean development mechanisms has seen geothermal emerge among the main source of electricity in Kenya after hydro and thermal.

Geothermal will surpass thermal and hydro if the proposed projects will be implemented (MoE&P, 2015). There has been series transformation in energy policy regulation and governance aimed at attracting investments in renewable energy as the country aim to be a middle economy nation by 2030. Net metering and power Auction have been proposed in energy act of 2015 (ERC, 2015). This is targeting investment in Solar PV integration with grid for those who wish to invest in solar and are connected with national grid to enable them sell excess electricity to the grid at pre-agreed price.

These government initiatives and commitments coupled with high electricity prices, series power outages and the public awareness to advantages of using renewable energy mainly solar have been the key drivers and opportunities behind recent rise of solar energy as the integral solution to energy poverty in the country.

2.6 Energy Sector in Kenya

2.6.1 Background and Context

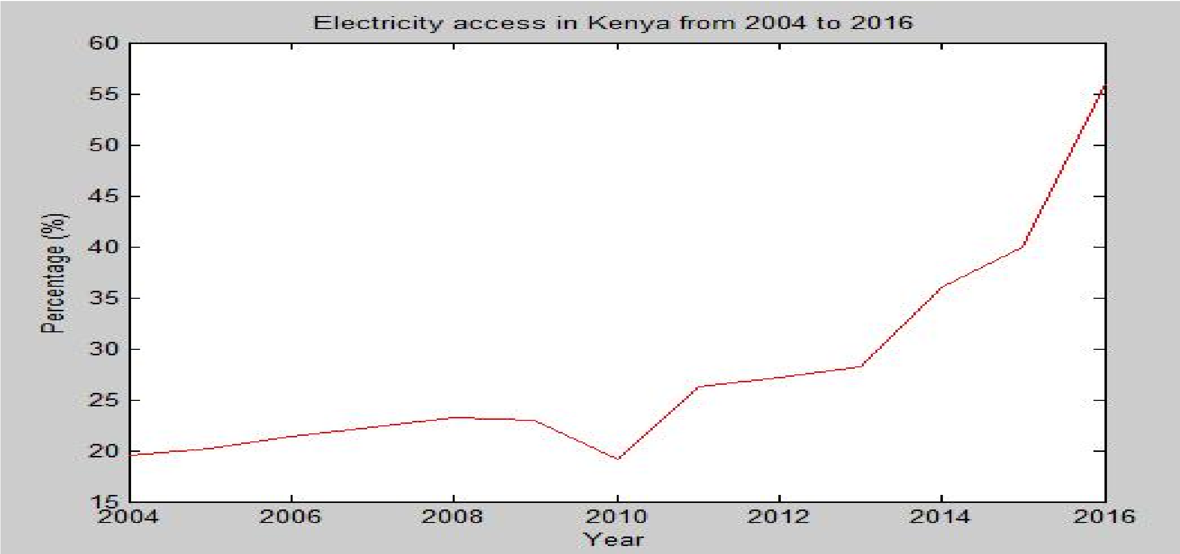
The republic of Kenya lies across the equator on the Eastern part of Africa with abundant natural resources including beautiful wildlife. Despite small in size, it is the fourth largest economy in Africa with a population of approximate fifty million people using 2009 census projections (World Economic Outlook, 2018). Rapid population growth and rapid urbanization are magnifying the energy challenges of most developing nations Kenya being in that category. Increasing demands to electrify and to provide access to modern energy services are stretching the region's limited energy sources thus need for investing in renewable energy as alternative. The energy situation in Eastern Africa region where Kenya is located is characterized by overreliance on solid biomass for cooking and heating, low electrification rates and increasing demand for transportation fuels.

Electricity demand is projected to grow by an estimated 5.3% annually to 2020, meaning that the region's power generation capacity will have to increase significantly. Projections indicate that capacity will have to grow by 37.7% in Uganda, 75.3% in Tanzania, 96.4% in Kenya and 115% in Rwanda (REN21, 2016). Funding for renewable energy projects in the SSA region continues to be a significant challenge with major barriers including uncertainties about political stability as well as the reluctance of major investors to commit to long-term financing which forced some member states to adopt Feed in Tariffs.

2.6.2 Electricity Demand, Supply and Access

East African countries electricity sector is characterized by low electricity access and reliance on solid biomass for cooking and lighting purposes with Kenya leading in terms of electricity access. Overall electricity access in Kenya is 56% with urban having 77.6% access while rural have 39.3% access. The electricity installed capacity currently stand at **2300MW** (KPLC, 2017). High deficit in terms of generation capacity still exists before the country achieves her universal electricity access milestone of 2020 targeting to reach at least 5600MW. This gap can be reduced by deploying rooftop solar PV in urban centres and public amenities in rural areas where there exists no grid network.

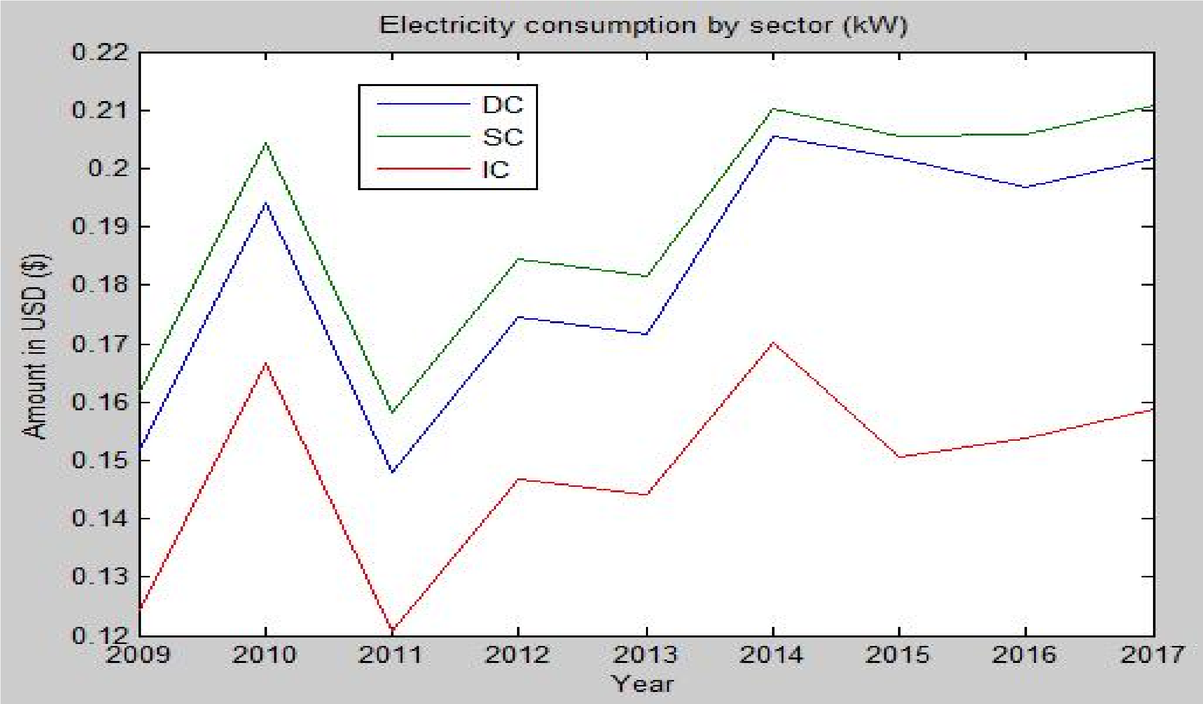
Graph 2.6.2 Electricity Demand, Supply and Access



Graph 2.6.2.1: Electricity access; Source: ERC, 2017

The electricity sector in the Kenya is characterized by low electrification rates and low average electricity consumption, accompanied by regular blackouts within Nairobi which consumes approximate 60% of total installed capacity in Kenya. The country's electricity sector has relied extensively on renewable energy, primarily hydropower and Geothermal. Kenya is making great progress by investing heavily on Renewables aiming to produce more than eighty percent of the total electricity from renewables promoted by presence of Geothermal. Although grid extension has advanced during the last decade, electrification rates remain low, hindering economic development.

Electricity consumption prices in USD for every kWh varies from sector to sector; Domestic Consumption (DC), Small Scale Consumption (SC) and Industrial Consumption (IC). The prices for Small Scale consumption are higher as compared to industrial and domestic. There are fluctuations in the electricity prices from 2006 to 2017 influenced by global fuel prices and varying amount of water due to climate related issues. With geothermal power taking over slowly, electricity prices will soon stabilize (KPLC, 2017).



Graph 2.6.2.2: Electricity Prices; Source: KPLC, 2017

2.6.3 Electricity generation capacity in Kenya

Electricity generation in Kenya has been largely dominated by Hydro power which has been the primary source of electricity since independence and thermal generators. Geothermal energy use has been increasing rapidly over the last five years adding the major share of renewable use in Kenya energy mix (MoE&P, 2012). The potential capacity of geothermal is estimated to be 10GW in the country which if fully utilized can make the republic of Kenya shift fully green. That will be a huge mile in climate change mitigation that is been addressed as a global threat to human existence in the future. Wind power and solar which constitute to almost 1% of total installed capacity also play a role in the energy mix. Solar energy is mainly used in off grid and in stand-alone systems mainly in rural areas.

In urban centres, use of rooftop solar PV has been a lucrative business catching up rapidly despite challenges been experienced due to lack of clear FiT and Net metering policy that was proposed in 2015 Energy Act. This has made it difficult for rooftop solar PV use to get access to national grid where they can sell extra power from their solar system. Those connected have been forced to give their extra power at zero earning to KPLC despite solar FiT introduced in Energy Act of 2012 at 0.12 USD/kWh due to lack of electricity generation license from Energy Regulatory Commission (ERC, 2015). Biogas power is also being used in small scale mainly by processing companies and public institutions and solid waste management entities.

Kenya currently has approximately 2300MW of installed capacity dominated by hydropower 36%, Thermal power 30% and Geothermal power at 27% with others such as Gas turbine at 2.5%, Wind power at 1% excluding the Turkana wind powerplant with installed capacity of 310MW yet to be connected to the national grid due to lack of transmission lines, Cogeneration 1% and solar at less than 1% connected to the national grid (MoE&P, 2017).

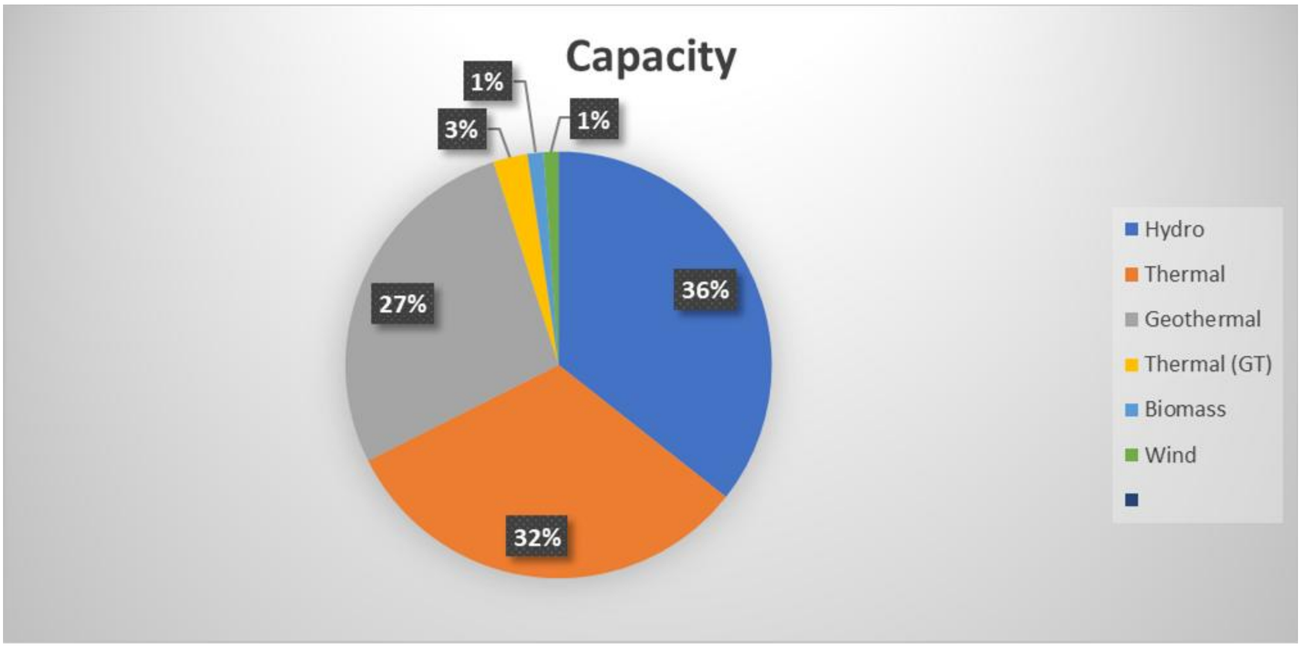
Table 2.6.3: Electricity generation capacity in Kenya

CURRENT GENERATION CAPACITY IN MW		
SOURCE	**INSTALLED**	**EFFECTIVE**
Hydro	820.73	800
Thermal	716.32	690
Geothermal	632	624
Temporary Thermal	30.00	30
Thermal (GT)	60.00	54
Wind	26.50	26
Biomass	28.00	24.00
Off Grid Thermal	27	23
TOTAL	**2,340.55**	**2,271**

Table 2.6.3: Current generation capacity; Source: MoE&P, 2017

Wind and Geothermal share in the electricity generation mix are expected to increase with Turkana Wind Power 310MW expected to be connected in the national grid by end of this year. More Geothermal power is expected to be added to the electricity generation mix with KenGen planning to add extra **1745MW** by 2025 (Obulusta & Evans, 2018). Coal is also expected to be included to be part of the energy generation mix in Kenya in the near future with expected **1050MW** Lamu coal power plant to be operated by AMU ltd using imported coal from South Africa. Coal mines at Mui Basin in Kitui county is also expected to be used in a 750MW powerplant at Kitui county despite the two powerplants experiencing environmental related blockage from local communities as well as international pressure where Kenya signed Pars agreement on Climate change mitigation (MoE&P, 2012).

Graph 2.6.3: Electricity Generation Capacity



Graph 2.6.3: Electricity Generation Capacity; Source: MoE&P, 2017

2.6.4 Solar PV deployment in Kenya

Kenya is located along the equator with an average daily solar irradiance of 4-6 kWh/m^2 which is considered as one of the best areas for solar energy harnessing in the continent of Africa despite having regional and seasonal differences across the country. Nairobi experiences high solar irradiance between the month of December and February whereas low irradiance experienced between June and September (GeoModel Solar, 2013). Initially international donors and NGOs were dominating Solar energy in Kenya followed closely by government stand-alone systems targeting public amenities in rural areas. Currently, Kenya has a vibrant private sector in solar both in commercial and small scale. This has enabled Kenya to be ranked among the best markets of Solar energy related products globally.

Despite this growth over a decade, KEREA has identified some market spoilage being experienced through poor quality products, lack of expertise in the sector among others that is hindering the growth of the sector (KEREA, 2015). University of Nairobi and Strathmore Energy Research Centre (SERC) have then started training solar technicians to address the lack of expertise (Da Silva, 2015). Kenyan government in a bid to boost use of renewable energy exempted Solar PV products from paying tax. This has enabled the sector to thrive despite some challenges. Most Solar PV distributing companies in the country import their products from China, USA and UK. Storage batteries are manufactured locally by Chloride Exide Ltd. A Solar PV manufacturing company in Naivasha owned by Ubbink East Africa was established in 2011 to manufacture solar panels targeting rural areas in Kenya (MoE&P, 2012). The country has over 30MWp of Solar PV installed capacity with more projects underway that will boost solar PV installed capacity to more than 100MWp in the near future (MoE&P, 2017).

2.6.4.1 Market segments of Solar PV in Kenya

The Kenyan solar PV market is currently divided into five segments as described below. Private sector is currently leading in solar PV deployment whereby many private companies in processing and manufacturing industries have opted to use solar power to supplement expensive electricity from the grid.

Table 2.6.4.1: Market segments of Solar PV in Kenya

Segment	Description	Market status
Pico Applications	Systems less than **10Wp** for lanterns and small mobile chargers	Pay-As- You- Go (PAYG) model that is growing rapidly
Solar Home Systems (SHS)	Systems less than **100Wp** for households' purposes	PAYG
Stand-alone institutional PV systems	Installed in public amenities such as schools etc	Donors, NGOs or Government initiatives
Mini-grid Solar Projects	Institutional systems, mini-grid systems mostly deployed in marginalised rural areas	Driven by donors, NGOs or government initiatives
Grid tied systems	Mostly for Embedded or Captive use	Utility scale or grid connected plants

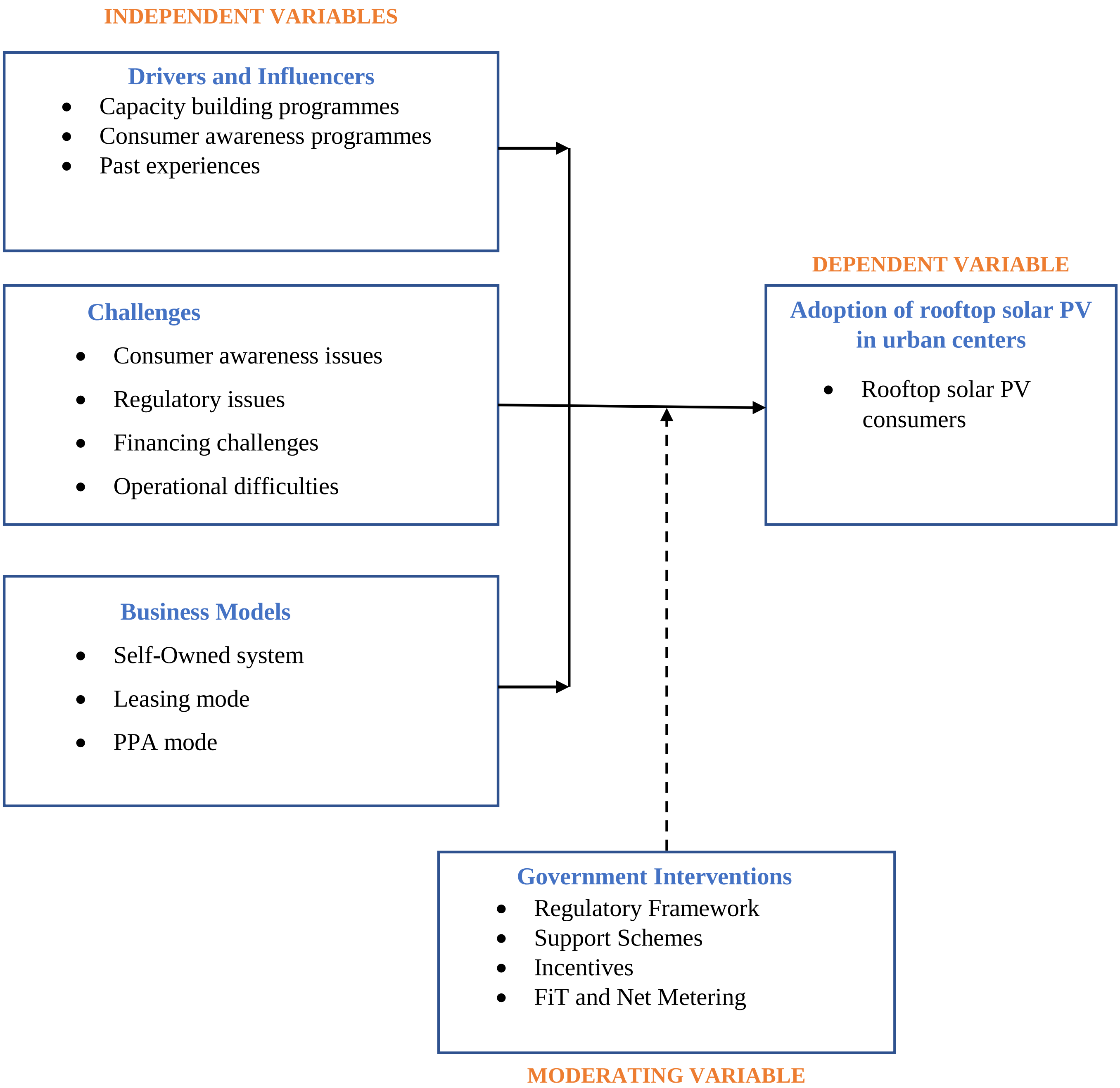
Table 2.6.4.1: Solar PV market segments in Kenya

2.6.4.2 Rooftop Solar PV deployment in Kenya

Rooftop solar PV use has of late been deployed mainly by commercial and industrial as they try to offset electricity bills that are consuming more than 40% of their total expenses with private firms mainly in flower farming installing as high as 1MW rooftop solar power. Commercial buildings such as shopping malls are doing the same. Public learning institutions are also making use of idle roofs to generate electricity from solar. Strathmore University was the first institution to install a 600KW rooftop solar PV followed by ICIPE that surpassed Strathmore University capacity by installing 1MW plant funded by Swiss development corporation.

London distillers on the other hand have installed 1MW of rooftop solar PV in their premises to offset their electricity bills (Solar century , 2017). The company has estimated to be saving almost USD 180,000 annually for the next 25 years and above. Despite the progress of rooftop solar PV systems catching up, there is a need for enabling policy frame to give room for rapid expansion of the same. This needs to be addressed by different stakeholders from all sectors including those designing buildings to give rooms for rooftop solar PV systems in all new architectural designs in buildings as a way of developing sustainable urban centres in the future (AfDB, 2012).

2.4 Conceptual Framework for Rooftop SPV Adoption and Scaling Up



2.5 Research gaps

Solar energy use has been increasing each day. More focus is now being directed on how to deploy solar use within urban centres that is characterised by high population leading to high resource consumption electricity been among the resources highly consumed. Due to nature of land use within urban centres rooftop solar remain only viable means to deploy solar PV and thermal. Many research studies have been focussing mainly on assessing and quantifying the solar PV potential within the city. This alone can't be applied to scale up the use of rooftop solar as means of integrating solar energy within urban energy mix. establishing key challenges and barriers facing the same is a necessity that will aid in policy making.

2.6 Summary of the literature review

The literature review has identified several challenges facing rooftop solar PV deployment globally including urban centres. These challenges include lack of initial capital, awareness among consumers, inadequate qualified and able technicians, institutional and legal barriers, buildings structure complexity and congestion leading to shading among others. These challenges and barriers have made it difficult for use of the abundant available energy resource within the urban areas by utilizing the idle roof for power generation. Despite the challenges and barriers identified, there still exist some hope in opportunities and key drivers that has seen the use of rooftop solar uptake in some places. Enabling and friendly policies, variety of financing options such as Third-Party Ownership (TPO), high electricity prices and frequent power outage experienced in some areas, friendly business models such as FIT, Net Metering and Net Billing have been the key drivers to rooftop solar use. Climate change mitigation measures have also contributed a lot to the emergence of renewable energy use worldwide.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This section covers and elaborates research procedures to be applied in conducting out this study. The selection of a research methodology and design is primarily founded on the description of a research problem or the subject being tackled (W. Creswell, 2009). It describes how the research questions and objectives raised were achieved. It also indicates how data for the study were collected, analysed and interpreted in order to achieve the research objectives that were stated. This chapter therefore comprised of research design and methodology that include study population, determination of sample size, sampling techniques, data collection methods, data collection instruments, quality control, data collection procedures, data analysis, measurement of variables, and ethical considerations. Research design and methodology are two different things as explained below.

3.1 Research Design

Research design is plan or a roadmap for conducting a scientific study by providing the overall framework for collecting data and research sites in a view to provide answers to research questions (W. Creswell, 2009). It is also a strategic framework for actions that serves as a bridge between research questions and the execution or implementation of the research strategy. Research methodology on the other hand is described as theoretical and systematic analysis of the method applied in a field of study. It can also be defined as a theory of how an enquiry can proceed. It involves using different ways and methods to solve a problem. Research design generally involves the planning and designing the structure of the research approach and data collection process whereas methodology deals with the actual data collection methods or techniques (Bryman, 2011).

Quantitative and qualitative approaches were used for this study. It used descriptive survey. Descriptive research is a design used to describe facts and characteristics of the target population in a systematic manner (Jane, 2009). It involved collecting of data from consumers, manufacturers, distributers and other dealers in Solar PV. The type of data collected was used to test whether the hypothesis of the study is valid. The research gives an account of how the solar PV installation in Kenya has had impact on the sources of power within the country in terms of economy.

3.2 Research Approach

The study used mixed method research approach. This involved using both qualitative research paradigm in one phase of a study and quantitative paradigm in another phase of the study. The combination gives a better understanding of the research problems and should be sufficient enough to obtain multiple validities legitimacy. Thus, the primary goal is to expand knowledge and understanding of the research problems (Johnson & Christensen , 2017). This method deploys measurable data to formulate facts as well as other methods from natural sciences designed to ensure objectivity, reliability and generalizability. Researcher remains to be the key instrument throughout the study starting from data collection to analysis. This requires careful analysis of the information from each method taking into considerations both weaknesses and strengths to be successful (Johnson & Christensen , 2017). Mixed research method remains the suitable method to use in this kind of study.

3.3 Research Methodology

3.3.1 Area of study and study population

3.3.1.1 Case study

The research was conducted as a mixed method case study since the issue being studied allows the researchers to explore different individuals as well as organizations as they seek to understand different phenomena within their context. It was considered essential to conduct in-depth considerations of the nature of the case, historical background as well as political institutions or contextual factors influencing the study (Yin R. , 3rd Edition, 2003). Research utilizing case study including participatory methods can be used to provide insights into energy projects including rooftop solar, since they assist in the acquisition of first-hand data from the field and stakeholders involved (Yin R. , 3rd Edition, 2003).

Schwandt (2007) states that, in case study, the case itself is at the centre stage of the study and not outside of the inquiry and the researcher may be trying to unearth the correlation between a phenomenon and the context in which it is happening. Case studies are instrumental in broadening understanding of a particular problem, issue, or perceptions by pursuing to generate knowledge of the particular problem in diverse settings in order to make meaning of them. It is more relevant when answering research questions ‘’why and how’’ seeking to explain some present circumstances and whereby the researcher cannot manipulate the behaviour of those involved in the study (Yin R. , 2014).

3.3.1.2 Study Area

Nairobi is the capital and the largest city of the republic of Kenya. It was founded by 1890s by British colonialists. It hosts more than four million people. It serves as hub of all economic activities in Kenya and larger parts of East Africa. All sorts of industries and commercial buildings are located within Nairobi and her outskirts. Many industries and commercial buildings as well as institutions and residential sectors have opted to deploy rooftop solar PV to offset high electricity bills and power blackouts experienced within Nairobi. Some commercial buildings within the CBD can make use of their roofs for electricity generation.

The commercial industries targeted under study are located at the outskirts of Nairobi city CBD mainly in industrial area where they rely so much on electricity from thermal generation power plants. These industries consume more electricity hence a need to look for alternative sources of cheap electricity. Some have already embarked on Rooftop solar PV deployment within their premises as they lack enough land space to deploy ground solar PV (MoE&P, 2015). Moreover, many industries have warehouses and stores whose roofs if well utilised can be integral in offsetting their electricity bills from fossil-based fuels thus help in addressing energy crisis as well as Climate change. Some maybe lacking awareness on the importance of using roof mounted solar to generate their own electricity for use.

3.3.2 Sample Size and Sample Determination

The companies under study were selected through purposive sampling. Purposive sampling is used to sample cases or participants that are strategically important to address research questions at hand and may be used after a pre-test investigation has informed the right group for one's study. It involves identification and selecting participants that have knowledge and experiences of the case under study. The participants ought to be willing and available on top of having the ability to communicate in an expressive and reflective manner for the study to be successful and accurate (Creswell, Plano Clark, V. L., & J. W., 2011). The assessment covered key stakeholders that are affected by solar PV rooftop including private developers, project financiers, technicians, consumers as well as government agents dealing with solar rooftop. More focus was given to companies and institutions that have already installed rooftop Solar as they understand the sector now well than those planning to install in the future. Some companies have already expressed interest in roof mounted solar technology and were chosen as potential pilots by the Kenya Association of Manufacturers using economic and technical parameters such as rooftop size availability, building structure and power cost structure.

Kenya Association of Manufacturers (KAM), has been assisting its members to adhere to the Energy Management Regulations Act of 2012 by offering subsidized energy audits. Based on these audits, various recommendations aimed at reducing energy consumption are made. Some of these recommendations include installation of solar PV systems. In its recent publication, Supporting Economic Transformation, KAM has identified securing affordable, reliable and sustainable energy as one of its policy priorities to promote industrialization in Kenya. This policy priority aims to lower the cost of energy by removing all levies on power costs and apply appropriate tariffs for industrial usage. Its member database which has 726 members to date would make a good resource for companies that would be interested to enter the Kenyan market. This is done in line with the Energy Management Act of 2012 that provides guidelines on energy efficiency and energy management practices.

3.3 Data Collection Methods

3.3.1 Interviews

Interviewing has been used as vital means by researchers for engagement between the social sciences, business, and the society concerning issues that matter to them and the society in general (Rapley & T. J. , 2001.). Interviewing has been widely used in qualitative research for it helps the researcher to obtain information from participants using either structured, semi structured or unstructured questionnaires depending on the knowledge the participants have on the study topic, their willingness and time available for the researcher and the participants. Interviews were used to collect primary data from the target population.

The study involved use of a structured and semi-structured questionnaire for the study to be complete and successful within the stipulated time schedule. Semi-structured questionnaire was mainly deployed as it clearly gave guidance on what was to be interviewed as well as allowing elaborations of information and understanding that is key to the participants but may not have been considered by the researcher (Jackson, 2011). Open minded interviews were deployed when carrying out interviews with energy experts who are more equipped with knowledge and past experience. This provided more insights on what is going on currently within energy sector in Kenya and globally.

3.3.2 Administering of questionnaires

Semi-structured questionnaire was mainly deployed as it clearly gave guidance on what was to be interviewed as well as allowing elaborations of information and understanding that is key to the participants but may not have been considered by the researcher. Semi-structured questionnaires were used to generate information about the details of the respondents and their overall experiences on roof mounted SPV. This method dominated data collection where targeted respondents were not willing for face to face interviews or were far away. Phone calls were made in case of further consultation and clarification.

3.3.3 Documentary Review

It is usually conducted if the researcher is required to study issues that have been under existence for a certain period of time. This method was used to collect secondary data from reports and documents that have been documented from previous studies concerning the same for comparisons and was guided by a documentary review checklist. Documents from various energy departments were used as well as energy reports from the same and existing rooftop solar PV plants in Kenya and globally. Rooftop solar PV capacity estimation used secondary data from reliable sources that had similar interests and objectives of the research.

3.3.4 Field observation and photography

This method was used to generate data by systematic description of events, activities and behaviours of people in the area of study in the natural setting. It involved using either structured or unstructured observation. Structured observation is a systematic technique, which a researcher employs to generate physical data from the behaviour of individuals, an environment or events that appear naturally from social settings (Bryman, 2011). Tangible evidence in qualitative research constitutes the foundation for our capacity to build rational conclusions about things as they appear to us through prolonged observation.

In observation, researchers can obtain data in a manner that may not necessarily be known to the inhabitants, such as taking photographs and recordings that can be used as a physical evidence to strengthen interpretive results from qualitative research (Bernard, 2011). This method was used to assess the challenges faced by technicians when installing roof mounted solar as well as other factors such as building designs that hinder scaling up of solar rooftop to aid in comparison purposes with other primary sources of data that were deployed.

3.4 Data analysis

The practice of data analysis simply denotes a researcher's intention to make sense out of the raw text, audio, and visual resources collected from diverse sources (W. Creswell, 2009). The voluminous data was abridged by summarizing, reconstructing, and categorizing for a cogent interpretation (Miles & Huberman, 1994). Qualitative content analysis approach in conjunction with the energy technology sustainability framework is employed for data analysis of this study. Content analysis according to several authors has been defined as: "a method for describing the meaning of qualitative material in a systematic way" (Schreier, 2012) or "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh & Shannon) or any qualitative data reduction and sense-making effort that takes a volume of qualitative material (interview transcripts, diaries, or documents) and attempt to identify core consistencies and meanings" (Patton, 2015).

The above definitions show that qualitative content analysis accentuates a cohesive view of speech/texts and their precise contexts. The choice of content, analysis for this study was based on its emergence as one of the best methods used to analyse interviews with emerging and recurring themes, which are absent in other methods (Miles & Huberman, 1994). Moreover, this study deals with meanings that are less obvious to identify instead of highly standardized meanings, which are easily identifiable. For example, a research study that seeks to know gender balance in a school institution has a standardized meaning and can be easily identified. Creswell (2009) has developed a systematic qualitative data analysis process that suggests a linear, hierarchical technique building from the bottom up, which follows steps from the general to the specific. The process is preferred in the data analysis of this study because it appears interactive in practice (W. Creswell, 2009).

3.5 Ethical Considerations

The ethical considerations and concern anticipated in this study was the privacy and confidentiality of the information and their identities of the target population. To ensure privacy, the subjects were informed upfront that their details will not be required, they had the right to leave questions unanswered for which they did not wish to offer the requisite information, and that the researcher would not put the respondent under pressure at all circumstances. The information provided was primarily for assessment purposes.

3.6 Limitation of the study

All studies have their own limitations hence no exemption to this research. The study is based on the assessing the challenges faced on scaling up rooftop solar PV potential in urban centres in Kenya where Nairobi city is chosen as a case study. Different projects of the same face different challenges ranging from lack of finances, technical capacity building, maintenance and operations costs, and grid connection difficulties among others. Rooftop solar installers power demands and use range from one user to another and the choice of design of installations also differ. Renewable energy deployment impacts thus will vary from one individual to another. This suggests that the results got from different correspondents may not represent the entire and reality as it is for all electricity consumers despite common challenges encountered.

3.5 Data Analysis and Needs

The following table show a summarized information about the required data, the methods of data collection and analysis.

Table 3.1: Data Analysis and Needs

Objective/Research Question	Data Collection Method	Data Analysis	Presentation
1. To estimate rooftop solar PV potential using secondary data	Documentary review	Descriptive statistics	Tables Graphs
2.To identify major challenges and barriers in scaling up rooftop solar in urban centres	Questionnaires Interviews	Descriptive statistics	Tables Graphs
3.To investigate key drivers and opportunities for roof mounted solar PV that can be adopted to scale up solar rooftop PV in urban centres	Questionnaires Interviews	Descriptive statistics	Tables Graphs
4.To identify and evaluate existing business models that can be applied to scale up solar PV rooftop	Questionnaires Interviews	Descriptive statistics	Tables Graphs

5.To recommend policy interventions that can be used to scale up roof mounted solar PV in urban centres	Questionnaires Interviews	Descriptive statistics	Tables Graphs

CHAPTER FOUR: DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.0 Introduction

This chapter analyses data, interprets and presents it. The findings of the study are based on the objectives of the study which are; to identify major challenges and barriers in scaling up rooftop Solar in urban centres, to investigate key drivers and opportunities for roof mounted solar PV that can be adopted to scale up solar rooftop PV in urban centres, to identify and evaluate existing business models that can be applied to scale up solar PV rooftop, and to recommend policy interventions that can be used to scale up roof mounted solar PV in urban centres. The results are obtained from the respondents who made **%(n=50).** Graphs and tables are then used to present the findings of the study.

4.1 Response Rate

This section presents the response rate for Consumers, Manufacturing and Distribution companies, Engineering, Procurement and Construction companies (EPC), and the Developers. The number of respondents conducted were 65 in Total with 50 respondents agreeing to participate in this survey.

Table 4.1 Response Rate

Category	**Frequency**	**Percentage (%)**
Consumer	12	24
Manufacturing and distribution firms	15	30
Engineering, Procurement and Construction companies	15	30
Developers	8	16
Total	**50**	**100**

Manufacturing and distributing companies tied with Engineering, Procurement and construction firms with 30% each followed by consumers with 24% and finally developers with 16%.

4.2 Distribution by Gender

Table 4.2 Distribution by Gender

Gender	**Frequency**	**Percentage (%)**
Male	40	80
Female	10	20
Total	**50**	**100**

Table 4.2 above shows distribution of respondents by gender. It shows that the respondents were 80% and 20% for male and female respectively.

4.3 Distribution by Job Position

Table 4.3 Distribution by Job Position

Position	Frequency	Percentage (%)
Director	21	42
Manager	26	52
Principal	3	6
Total	**50**	**100**

The above Table 4.3 shows the distribution of respondents by job position. Directors make 42%, managers (operations, sales) make 52%, and Principals / head of schools make 6%.

4.4 Solar PV Products

The following table below is a representation of solar related products the interviewed respondents deal with across all the four categories covered in the survey. It shows that solar panels are the popular products which makes a percentage of 44% followed by batteries with 22%, inverters with 16%. Charge controllers make 6% and SHS kits make 4% and other products make 2%.

Table 4.4 Solar PV Products

Product	Frequency	Percent (%)
Solar Panels	22	44
Batteries	11	22
Charge Controllers	3	6
Inverters	8	16
SHS kits	3	4
Others	2	2
Totals	**50**	**100**

4.5 Objectives of Installing Rooftop Solar PV

The table below represents a list of objectives on why the consumers have installed roof top Solar PV. The objectives include; Reduce electricity bills, Environmental concerns through climate change awareness programmes among other objectives. It is clear that many rooftop solar PV consumers installed rooftop solar PV system primarily to reduce electricity bills and to some extend due to environmental concerns. Other objectives include training for the case of learning institutions.

Table 4.5 Objectives of Installing Rooftop Solar PV

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean	Std dev
Reduced electricity bills	0	0	0	7	5	4.4167	0.51493
Environmental concerns	0	0	0	7	5	4.4167	0.51493
Others	0	0	0	6	6	4.5	0.52223

The mean and standard deviations are represented as follows in the table in order of popularity. The mean is 4.4167 both for reduction on electricity bills and environmental concerns while other objectives' mean is 4.5. Standard deviation is 0.51493 for both reduction in electricity bills and environmental concerns whereas other objectives is 0.52223.

4.6 Key Drivers that Motivate Consumers and Companies to Use Solar PV

The following are the key drivers that motivate stakeholders involved in the study to use rooftop Solar PV as represented in the table below.

Table 4.6 Key Drivers that Motivate use of rooftop Solar PV

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Mean	Std dev
Saving on electricity bills	0	0	5	27	18	4.2600	0.63278
Capacity Building Programmes	0	0	8	29	13	4.1000	0.64681
Past Experience	0	0	9	26	15	4.1200	0.68928
Consumer Awareness Programs	0	0	5	29	16	4.2200	0.61578
Return on	0	0	8	29	13	4.1000	0.64681

Investment							
Environmental concerns	0	0	6	26	18	4.2400	0.65652

The Table above show extent to which stakeholders agree with the given drivers. It clearly shows that a great number of respondents agreed that savings on electricity bills, capacity building programs, consumer awareness programs, return on investment, and climate mitigation are the key drivers motivating stakeholders to install Solar PV. It is followed by those who strongly agree, and finally those who neither agree nor disagree. It also shows that the sampled population do not disagree. Means and standard deviations are also represented in the table. The means in order of popularity are 4.260, 4.100, 4.120, 4.2200, 4.100, and 4.240 for savings on electricity bills, capacity building programs, consumer awareness programs, climate mitigation and return on investment respectively. The standard deviations follow in the same order with 0.6327, 0.64681, 0.68928, 0.61578, 0.64681, and 0.65652.

4.7 Challenges or Barriers Faced by all stakeholders involved in rooftop Solar PV deployment

Table 4.7 below shows the challenges faced stakeholder involved in rooftop Solar PV deployment

Table 4.7 Challenges Faced by all stakeholders in rooftop Solar PV

	Strongly Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Std dev**
Market strategies	0	1	8	30	11	4.0200	0.68482
Customer awareness	0	0	4	28	18	4.2800	0.60744
Government policy and regulatory framework	0	3	8	27	12	3.9600	0.80711
Cheap importation of similar products	0	0	9	25	16	4.1400	0.70015
Capacity building	0	0	4	31	15	4.2200	0.58169

challenges							
Others	0	3	6	30	11	3.9800	0.76904

It shows that majority of respondents agree that, market strategies to reach target people, customer awareness programmes, government policy and regulatory framework, cheap importation of similar products, capacity building challenges among others are the challenges they face. This is followed by those who agree, those who neither agree nor disagree, and those that disagree with some of the listed option. It also shows means and standard deviations for the same with customer awareness recording the highest mean of 4.28 and a standard deviation of 0.60744, followed by capacity building with a mean of 4.22 and standard deviation of 0.58169, cheap importation of similar products with a mean of 4.14 and a standard deviation of .070015, market strategies with mean of 4.02 and standard deviation of 0.68482, government policy and regulatory framework with mean of 3.96 and standard deviation of 0.80711 and other challenges with mean of 3.98 and standard deviation of 0.76904.

4.8 Opportunities Rising from rooftop Solar PV deployment

The following table shows the opportunities which rise from the Solar PV deployment. They include reduced cost of solar products, regulation in solar products, availability of various financing mechanisms, availability of different business models, capacity building programmes and other opportunities.

Table 4.8 Opportunities Rising from Solar PV Installation

Opportunities	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Std dev**
Reduced cost of solar products	0	0	6	28	16	4.2000	0.63888
Regulation in solar products	0	0	6	32	12	4.1200	0.59385
Various financing options	0	0	8	27	15	4.1400	0.67.36
Business model available	0	0	5	31	14	4.1800	0.59556
Capacity building	0	0	5	27	18	4.2600	0.63278
Others	0	2	9	30	9	3.9200	0.72393

It is clear from the table that most respondents agree that the opportunities listed are among opportunities which rise as a result of rooftop Solar PV deployment. A good number strongly agree with the same. The means from the highest to the lowest are represented along with the standard deviations. Capacity building has a mean of 4.26 and a standard deviation of 0.63278, availability of various financing options has a mean of 4.14 and a standard deviation of 0.67360, availability of different business models has a mean of 4.1800 and a standard deviation of 0.59556, reduced cost of solar products has a mean of 4.200 and a standard deviation of 0.63888, regulation in solar products has a mean of 4.1200 and a standard deviation of 0.59385, and finally other opportunities give a mean of 3.9200 and a standard deviation of 0.72393.

4.9 Ownership Model for use of Solar PV

Table 4.9 below shows the models of ownership used in rooftop Solar PV deployment. The models listed are Self-Owned, Leasing and Power Purchasing Agreement and other types of models. In order of popularity they are Self-Owned with 57.1%, Leasing making 22.9% and Power Purchase Agreement with 20.0%.

Table 4.9 Ownership Model for the Use of Solar PV

Ownership Model	Frequency	Percent (%)
Self-owned	20	57.1
Leasing	8	22.9
Power Purchase Agreement	7	20.0
Total	**35**	**100.0**

4.10 Consumer Awareness on Solar PV

The table below shows the ways used to create awareness to the consumers and companies which deal with Solar PV. They include; consumer awareness programs on TVs, seminars and workshops, word of mouth from referral by users and other types. In order of popularity, consumer awareness programs on TVs recorded the highest percentage of 42% followed by seminars and workshops with 36%. It is then followed by word of mouth from referral by users with 16% and finally other means which make 6%.

Table 4.10 Consumer Awareness on Solar PV

Awareness	Frequency	Percent (%)
Consumer awareness programs on TVs	21	42.0
Seminars and workshops	18	36.0

Word of mouth from referral by users	8	16.0
Others	3	6.0
Total	**50**	**100.0**

4.11 Rooftop Solar PV capacity estimation of Nairobi city

Nairobi county which hosts the capital city of Kenya covers approximate **694.9 km^2** being a home of about 4,410,000 people according to 2009 census projections having annual growth of 4.05%. Approximate **300-350 km^2** is to be covered by buildings that can be utilised for rooftop solar PV for power generation. From the data collected, currently less than **10MW** of rooftop solar PV is being utilized within the whole of Nairobi county despite the town lying along equator with an average daily irradiance of 4.5kwh/m^2 throughout the year. Using thumb rule assumption that states that **10m^2** is required to produce a **1kW** capacity solar PV system, rooftop solar PV deployment in Nairobi city can fully cater for more than 70% of its peak demand during the day.

Despite this potential, the following companies are the only ones who have deployed rooftop solar PV in their premises within Nairobi and its outskirts. This is due to challenges discussed below. The following table provides an overview of existing rooftop solar PV projects for own consumption.

Table 4.11 Rooftop Solar PV capacity estimation of Nairobi city

No.	Client & Location	Sector	Size of System	Type of Installation
1.	**Two Rivers Mall**	Commercial	2 MW	Roof top/Carport
2.	**ICIPE – Nairobi**	Institution	950 kW	Roof top
3.	**ICIPE - Thomas Odhiambo Campus Western Kenya**	Institution	204 kW	Roof top
4.	**Garden City - Nairobi**	Commercial	858 kW	Rooftop/ Carport
5.	**Strathmore University - Nairobi**	Institution	600 kW	Roof top/ carport
6.	**UNEP Headquarters - Nairobi**	Institution	515 kW	Roof top
7.	**Swissport-JKIA**	Commercial-Airport	105kW	Rooftop
8.	**USAMRU-Kericho**	Institution	120kW	Rooftop

9.	**Bidco Oil - Thika**	Industrial	1.2 MW	Roof top
10.	**London Distillers - Athi River**	Industrail	1 MW	Roof top
11.	**Uhuru Flowers**	Horticulture	102 kW	Roof top
12.	**Baraka flowers - Nyandarua**	Horticulture	110 kW	Roof top
13.	**Olij flowers - Naivasha**	Horticulture	100 kW	Roof top

4.12 Roof area feasibility study for rooftop solar PV deployment

African Solar Designs (ASD) ltd conducted feasibility study to the following named companies who showed interests of installing rooftop solar PV in their premises through Kenya Association of Manufacturers (KAM). The pre-selection was based on an analysis of energy audits that had been conducted by auditors registered with KAM. The objective of ASD conducting the sites visits was to substantiate the data provided in the energy audits. The companies selected normally operate for more than 12 hours depending on their production schedule hence high electricity bills incurred.

Table 4.12 Roof area feasibility study for rooftop solar PV deployment

No.	Name	Roof area in M^2	Max PV yield in kWp	Solar PV % contribution
1	Brookside	35,160	3500	31
2	Ban Bros	14,492	1429	11
3	Thika Road Mall	1,579	200	4
4	Haco Tiger Brands	8,796	880	35
5	East African Packaging	1,219	120	17
6	Kip Melamine	2,296	230	30
7	Candy Kenya	3,554	355.4	41
8	East African Maltings	1,593	159	3

4.13 Recommendations on Areas to Improve in Scaling Up of Solar PV

The table below shows the recommendations given on the areas to improve in scaling up of rooftop SPV deployment. They are as follows; create awareness programmes, increase in finance mechanisms options, use the best market strategies, investment in capacity building programs, government regulatory programs, information availability, operational issues and promotions programs. It shows that the greatest number agree that the above listed recommendation should be implemented to help in scaling up of rooftop Solar PV deployment, a good number strongly agree, some neither agree nor disagree and a small number disagree with the list.

The means and standard deviations are also shown. In order of popularity the means are; 4.2000, 4.1800, 4.1800, 4.1600, 4.1000, 4.0400, 4.0000, 3.9400, and 3.9400 for promotional programmes, information availability, government regulation, application and connection process, capacity building programs, creation of awareness programs, use of the best market strategies, increase in finance mechanisms and operational issues. The standard deviations in order of popularity are 0.91272, 0.85714, 0.83930, 0.81716, 0.77433, 0.72731, 0.71027, 0.71027, and 0.67006 in order of popularity for increase in financing mechanisms, use of best marketing strategies, capacity building programs, application and connection process, government regulatory framework, creation of awareness, information availability, operational issues and Renewable energy promotional programs respective

Table 4.13 Recommendations on Areas to Improve in Scaling Up of Solar PV

Recommendation	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Std dev**
Create awareness	0	2	6	30	12	4.0400	0.72731
Increase in finance mechanisms	0	5	7	24	14	3.9400	0.91272
Use the best market strategies	0	4	6	26	14	4.0000	0.85714
Capacity building programs	0	4	3	27	16	4.1000	0.83930
Government regulatory programs	0	2	5	25	18	4.1800	0.77433
Application and connection process	0	2	7	22	19	4.1600	0.81716
Information availability	0	6	6	23	15	4.1800	0.71027
Operational issues	0	0	9	24	17	3.9400	0.71027

Promotional programs	0	0	7	26	17	4.2000	0.67006

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMEDATION

5.1 Introduction

This chapter is a representation of the key findings of the study and explores the findings against the literature review. It gives a conclusion on the same, gives a recommendation based on the findings and gives a suggestion for further studies.

5.2 Summary of Key Findings

The section gives a summary of key findings for each given objective in the research. The following were key findings for each objective of the research.

5.2.1 Major Challenges and Barriers in Adoption and Scaling Up Rooftop Solar PV in Urban Centers

The following challenges were found to be affecting adoption and scaling up of rooftop solar PV deployment.

5.2.1.1 Delays experienced in application and approval stage

Most respondents were unsatisfied by the whole process as it characterised by delays and uncertainty. The first stage in installing any power generation system in Kenya is submitting an Expression of Interests (EoI) and detailed feasibility study to the MoE&P for approval. This process requires at least 90 days before approval. This is followed by application for electricity generation license by Energy regulatory commission (ERC) that requires at least another 90 days before approval. If approved it gives room for FiT Power Purchase Agreement negotiation process with Kenya Power and Lighting Company (KPLC) that requires a minimum of 180 days of waiting followed by 90 days of negotiation. If FiT PPA is successful, this allows ERC to approve the FiT policy that requires 30 days book days. This whole process can be done within a short time if the relevant authorities cooperate to avoid such delays experienced right now.

5.2.1.2 High upfront cost required

Most respondents expressed concern over high customer acquisition that is affecting adoption and scaling up of solar energy sector globally. Most consumers interviewed had to source funds from external sources such as banks and donors. Learning institutions who have installed rooftop solar relied on donor funds from international agencies like the case of ICIPE which is a government institution that was funded by Swiss Agency for Development and Cooperation. Those who could not raise the high initial capital opted to use third party mode of ownership through Leasing and Power Purchase Agreement.

5.2.1.3 Grid availability constraints in case of excess electricity

Electricity prosumers who produce excess electricity and are grid tied are feeding the excess to the grid at no benefit. This is due to lack of Net Metering Policy proposed in Energy Act of 2015 but yet to be approved due to disagreements among the relevant authorities. From the data collected, it was noted that Strathmore University has been feeding the grid with 0.25MW excess electricity since 2015 at zero earnings due to lack of electricity generation license that was issued in June 2017 pending FiT PPA Policy negotiation with KPLC before approval by ERC. Further engagements led by Prof Izael Da Silva are underway that will enable backdating of the FiT PPA policy to compensate for the entire period the university has been feeding the grid. Net metering if approved will be a major breakthrough to future users of rooftop solar PV.

5.2.1.4 Lack of consumer awareness programmes on use of Rooftop Solar PV deployment

It was clear that many respondents knew about rooftop solar PV sector through informal means like word of mouth referrals from their friends and other users. The information given depends on the past perceptions and experiences of those parties thus it can be misleading and in accurate. This is greatly affecting decision making across all the stakeholders involved in the sector. There is need for consumer awareness programmes aimed at promoting use of solar energy to create proper consumer awareness.

5.2.1.5 Lack of skilled man power and capacity building programmes

Despite solar energy been the fastest growing energy generation technology globally both in small, medium and large scale, capacity building programmes in Kenya has not been so far well addressed. A lot need to be done to cater for high demand of qualified personnel required in the sector. Most of the trainings in the solar sector are done using informal means. Strathmore university through Strathmore Energy Research Centre is currently the only institutions with a well-structured curriculum, qualified staff and reliable resources within the country been involved in energy training mainly solar. High cost of training is another barrier preventing those willing to train to undertake such training. Other institutions undertaking training include Kenya Association of Manufacturers (KAM) to its members and National Industrial Training Authority (NITA).

5.2.1.6 Poor building structures and planning

Most buildings did not take rooftop solar PV deployment into consideration during construction. This barrier is making it difficult for interested consumers who wish to invest. Some consumers using rooftop solar PV had to modify their roofs to accommodate the same. There is need for cooperation among all the parties involved before designing new building to consider rooftop solar PV deployment.

5.2.2 Key drivers and opportunities for roof mounted solar PV that can be adopted to scale up solar rooftop PV in urban centers

A great number of respondents agreed that savings on electricity bills was the major driver that motivated them to deploy rooftop Solar followed closely by environmental concerns. Other drivers and motivators included capacity building programs, consumer awareness programs and return on investment among others.

5.2.3 Existing business models that can be applied to scale up solar PV rooftop

The following existing business ownership models were found to be in use. Self-ownership model was commonly applied across all consumer categories with 57.1% popularity followed by Third party Leasing ownership model with 22.9% and finally Power Purchasing Agreement recording 20.0%.

5.3 Expected Changes to the Legal and Regulatory Framework

The current energy policy and law is contained in the **Sessional Paper Number 4 of 2004** and the **Energy Act 2006**. A Final Draft National Energy and Petroleum Policy is in place and the Energy Bill 2015 is currently in the parliament and is expected to be passed and signed into a law despite challenges and power wrangles among stakeholders in the energy sector. If approved replace the Energy Act of 2006. The Energy Bill 2015 seeks to clarify and differentiate the legal and regulatory framework with regards to the roles of both the National Governments and County Governments, following the creation and implementation of the devolved government. It proposes a number of changes in the energy sector, among them ending the Kenya Power and lighting company monopoly by introducing both power wheeling and net metering. These proposed changes as identified are discussed below.

5.3.1 Net Metering

Net metering refers to a system whereby a renewable energy generating plant operated by an electricity consumer connected to the grid is allowed to feed excess generated electricity into the grid, thus off-setting electricity consumption from the grid with electricity supply from an on-site net metered system. The system requires two-way smart metering system. The draft energy policy looks at developing regulations for net metering to facilitate and encourage the sale of electrical energy generated from distributed RE systems to the grid distribution licensees. The Energy Bill of 2015, on the other hand, gives a go ahead to net metering application in Kenya by having the following provision in section 190 (1):

A consumer who owns an electric power generator of a capacity not exceeding one megawatt may apply to enter into a net-metering system agreement to operate a net-metering system with a distribution licensee or retailer, if that consumer has a generation facility that is located in the area of supply of the distribution licensee or retailer.

5.3.2 Power Wheeling

Power wheeling is described in the Bill as "the operation whereby the transmission system, distribution system and associated facilities of a transmission licensee or distribution licensee, as the case may be, are used by another person for the conveyance of electricity on payment of charges to be determined". The transmission licensee, currently either KPLC or KETRACO, will be required to provide "non-discriminatory open access" to any licensee or eligible consumer. The wheeling charges will be determined by the regulations which will be made once the Act is passed.

5.3.3 Energy Auctions

The Kenyan Government through the MoE&P commissioned studies exploring the replacement of the current FiT scheme with Energy Auctions. The energy auctions were originally scheduled to commence in early 2017, but there have been numerous delays in the implementation of the new system. The MoE&P is reviewing the ongoing PPA negotiations, with an aim of converting them into the energy auction program. It further suspended any Expression of Interest under the FiT scheme until the review process was concluded.

Under the auctions scheme, the Government will issue a tender either to pre-qualified Independent Power Producers (IPPs) or an open call for generation of power with the Government specifying the capacity of the plants required and the eligible technologies. The bidders will then submit their bids and the bidder(s) offering the lowest tariff and the highest efficiency are selected. ERC is in the process of drafting new regulations that will provide the necessary framework for the auction scheme.

5.3.4 Multiple Buyer Model

Kenya Electricity Generating Company (KenGen) plans to supply electricity directly to consumers. The move aims to cushion KenGen from risks associated with the current single buyer model where Kenya Power and Lighting Company buys all the power generated in the country for resale to retail consumers. The firm said it was awaiting the enactment of the Energy Bill, currently in Parliament, before it comes up with a concrete plan on how to target customers directly. The bill will open up the market to multiple buyers which has been one of the main challenges for IPPs.

5.4 Policy interventions that can be used to scale up roof mounted solar PV in urban centers

Government willingness and involvement in policy and regulation will remove a major impediment in adoption and scaling up of rooftop solar deployment in urban centres. Despite numerous bills of Energy Act being introduced in the constitution, still there exist gaps in policies and regulation that can be utilised to scale up rooftop solar adoption and deployment. Approval of Net Metering that was proposed in the Energy of Act of 2015 remain a major boost that can be applied to scale up Solar PV deployment nationwide. This regulation requires willingness from all the stakeholders involved and relevant authorities.

Up to date, no regulation has been made to enforce use of solar PV power whether in rural areas or in electricity generation despite government regulation on tax exemption on solar products in the Energy Act of 2015. Rooftop solar PV regulation can play a major role in energy mix within urban centres that remain major users of electricity generated. A new bill to enforce all new buildings to be designed to accommodate rooftop solar installation at a later stage should be proposed and approved. This will address challenges being experienced by current buildings whose roofs are too weak to support rooftop solar system or are too complex to be utilised for the same.

5.5 Conclusion

Rooftop solar PV technology sector deployment just like any other upcoming technologies in the market has been facing challenges that need urgent intervention by all stakeholders involved. The study concludes that a number of factors influenced the adoption and scaling up of rooftop solar PV technology use. These challenges range from policy barriers involving government regulatory framework, technical barriers that involves lack of capacity building programmes and unskilled labour, socio technical barriers to economic barriers involving financing issues associated with high initial customer acquisition costs. These challenges require will from all parties involved and regular monitoring and evaluation.

5.6 Policy and Process Recommendation for Improvements

From the key findings of the research, the following recommendations can be implemented to aid in adoption and scaling up of rooftop solar PV deployment.

5.6.1 Introduction of Net Metering proposed in Energy Act of 2015

Net metering is the way to go since it can be applied across all the consumers who produce excess electricity. Energy Act of 2015 proposed that consumers who owns an electric power generator of capacity not exceeding 1MW may apply to enter into Net Metering system agreement with a distribution licensee or retailer if the consumer has a generation facility located within the area of supply. If approved, this will enable electricity prosumers invest heavily in solar in general to save on rising electricity and at the same time sell excess electricity to grid. FiT for solar needs to be adjusted to remove a limit of 0.5MW as the minimum capacity of electricity to be fed to the grid. This will accommodate small scale electricity prosumers.

5.6.2 Shortening waiting period experienced during application and approval process

Delays and uncertainty experienced during application and approval processes should be addressed by developing a website to facilitate tracking of all processes involved. Timelines for each stage should be well defined and if delays occur, an update of the reasons behind given and a penalty applied if the reasons given are not bidding.

5.6.3 Creating awareness programmes and making key information easily accessible

Rooftop solar PV remain the only option for massive renewable energy deployment in urban centres whose population tend to be increasing due to rural urban migration. Lack of awareness programmes on use of rooftop solar is affecting final decision making for parties interested in investing in the sector. Despite solar energy use in Kenya growing each day, no reliable data that can be used as reference for future use. Most of the projects are conducted by private sector hence a need for central data base for future use and planning that can be easily accessed by the members of the public if needed to help in decision making.

5.6.4 Introduction of promotional programmes

Government should adopt non-financial incentives like issuing green certificates to consumers who use rooftop solar among other sustainable sources of energy. Government institutions nationwide need to be frontiers in social media campaigning for deployment of rooftop solar to raise awareness and label the move as a way of addressing environmental concerns which is now a global crisis. These non-financial incentives will sound as tangible benefit for all stakeholders involved.

5.7 Suggestion for Further Studies

The following areas are recommended for further study with an aim of better unlocking the factors affecting the adoption and scaling up of rooftop solar PV deployment.

i. The relationship between capacity building programmes and adoption of rooftop SPV technology
ii. The effect of government regulation in adoption of rooftop SPV technology
iii. The role of Research and Data Availability in adoption and scaling up of rooftop solar PV

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APPENDICES

Appendix 1: Questionnaire for Electricity Consumers

Introduction

I introduce myself as **Patrick K. Mwanzia** (Msc. Student at **PAUWES-ALGERIA**) currently carrying out a research tilted Scaling Up of Rooftop Solar PV Deployment in Urban Centres. The objectives of carrying out this questionnaire is to

i. Establish the major challenges to scaling up rooftop solar PV in urban centres
ii. Identify the key drivers and opportunities in scaling up rooftop solar PV use
iii. Understand the procedure and necessary steps for installing rooftop solar

The information gathered will be treated as private and confidential and will only be used for academic purposes of this research. Kindly feel free to respond to all the questions.

Part one: Company profile

a. Position of interviewee ____
b. Gender: a) Male [ ] b) Female [ ]
c. Professional Qualification: ____
d. Name of the company ____
e. Consumer category ____
f. Average monthly electricity bill ____________________________________
g. Installed capacity in KW ____

Part two: Adoption and Scaling up

1. **Consumer awareness and drivers of rooftop solar PV use**
   a. How did your company/ organization come to know about Rooftop Solar PV use?
      i. Consumer awareness programmes in TVs programmes
      ii. Seminars and workshops
      iii. Word of mouth referrals from other users
      iv. Others(specify)____

b. What were the objectives of installing rooftop solar PV?

Objective	Rankings in terms of importance (1-5)
1. Reduce electricity bills	
2. Climate change awareness	
3. Others(specify)	

c. What were the key drivers that motivated you to use Rooftop solar PV?

• Capacity building programmes	
• Past experiences from other users	
• Consumer awareness programs	
• Return on investments	
• Climate change mitigation	
• Others(specify)	

d. By the time of installations, was your company aware of any government/ non-government interventions or incentives on use of rooftop solar PV?

____

____

____

____

2. Ownership model

Which ownership model is your company solar system using?

Model	Reason for choosing
1. Self-Owned	
2. Leasing	
3. Power purchase agreement (PPA)	
4. Others(specify)	

3. Financial experience

a. Did your company experience any difficulties in raising upfront costs while installing the system?

____

____

b. How did you finance your solar system?

____

____

c. If the source of finance was banks;

i. How many banks did you approach and their response?

____

____

ii. Any challenges faced in the process of securing the loan?

____

____

d. Overall experience with the financing mechanisms of rooftop solar.

____

____

4. Consumer installations experience

a. Any challenges faced during installation process?

____

____

b. What are some of the key challenges your company has been facing in running the solar systems?

____

____

c. Your experience so far in terms of

i. Operating and maintenance costs.

____

____

ii. Return on investments (savings).

____

____

iii. Is the system economic sensible in a competitive electricity market?

____

____

iv. Your expected system payback time?

____

5. Connection process to the National Grid

a. Did you experience any challenges during the following processes?

i. Application process

____

____

ii. Approval process?

____

____

iii. Inspection and commissioning process by government authorities

____

____

b. Do you sell excess electricity to KPLC and **if YES**, which policy do you use?

1. Feed in Tarif	
2. Net metering	
3. Net billing	
4. Others(specify)	

i. How effective is it?

____

____

6. Are you aware of climate change and the impact on use of renewable energy?

____

____

7. Can you recommend rooftop solar PV use to your friend?

____

- If yes, reasons for recommending use of the same. ____ ____

8. Which areas do you recommend for improvement in a move to scale up rooftop solar PV use in terms of?

Recommendation		Improvement
i.	Awareness creation	
ii.	Financing mechanisms	
iii.	Marketing strategies	
iv.	Capacity building programmes	
v.	Government regulatory framework	
vi.	Application and connection procedures	
vii.	Others(specify)	

Appendix 2: Questionnaire for Engineering, Procurement and Construction (EPC)

Introduction

I introduce myself as **Patrick K. Mwanzia** (Msc. Student at **PAUWES-ALGERIA**) currently carrying out a research on challenges facing scaling up of rooftop solar PV use in urban centres. The objectives of carrying out this questionnaire is to

i. Establish the major barriers encountered when installing rooftop solar PV.
ii. Identify the key drivers and opportunities to rooftop solar PV use in urban centres.
iii. Understand the role of government regulation in scaling up rooftop solar PV use.
iv. Establish the past experiences with existing clients.

The information gathered will be treated as private and confidential and will only be used for academic purposes of this research. Kindly feel free to respond to all the questions.

Part One: Company profile

a. Position of interviewee ____
b. Gender: a) Male [ ] b) Female [ ]
c. Professional Qualification: ____
d. Name of the company ____
e. Capacity installed ____
f. Business model used ____

Part Two: Adoption and Scaling up

1. For how long you have been installing rooftop solar?

a. Less than a year	
b. 1-2 years	
c. 2-5 years	
d. 5-10 years	
e. More than 10 years	

2. Have you ever before installed rooftop solar PV outside Kenya?

____

If YES, how can you compare your experience abroad with Kenya.

Positive	Negative

3. Any challenges/ barriers faced across the different consumer/ clients' categories?

____

____

____

4. Any opportunities that exist in this sector of rooftop solar PV deployment in urban centres?

i. Reduced costs of solar products	
ii. Regulation on solar products	
iii. Various financing options	
iv. Business models available	
v. Capacity building	
vi. Others(specify)	

5. Which consumer category if given a choice to work with in the future would you prefer and why?
   a. Commercial and industrial sector [ ]
   b. Learning institutions sector [ ]
   c. Domestic sector [ ]
   d. Others(specify)____

6. Does Kenyan building design affect scale up of rooftop solar PV use in urban centres?

   a. Yes [ ]   b. No [ ]

   if Yes, how can we improve it?

   ____

7. Do Kenyan market has enough and qualified technicians to do the installations? If not, how can we address this challenge?

____

____

____

8. Do you offer after sale service such as maintenance or training of some staff members who will be in charge of the solar system in those clients?

   a. Yes [ ]   b. No [ ]

   If Yes what type of after sale service do you offer?

   ____

9. What is your past experience across all the consumer segments?

Positive	Negative

10. Which role can the Kenyan government play in ensuring increased use of rooftop solar PV?

a. RE Incentives and subsidies	
b. Regulation	
c. Promotional activities	
d. Quality measures	
e. Capacity building	
f. Others (specify)	

11. Which recommendations can you suggest in aim of scaling up rooftop solar PV use?

Recommendations	Improvements
a. Operational issues	
b. Legal framework	
c. Availability of grid connection	
d. Financing challenges	
e. Market business models	
f. Information availability	
g. Promotional programmes	
h. Others(specify)	

12. Are there any gaps in regulation framework that can be used to scale up rooftop Solar PV deployment in Kenya?

   ____

Appendix 3: Questionnaire for Developers

Introduction

I introduce myself as **Patrick K. Mwanzia** (Msc. Student at **PAUWES-Algeria**) currently carrying out a research on challenges facing scaling up of rooftop solar PV use in urban centres. The purpose of carrying out this questionnaire is to

i. Establish the major barriers in scaling up rooftop solar
ii. Identify the key drivers and opportunities to rooftop solar PV use in urban centres
iii. Understand the role of government intervention and regulation in scaling up rooftop solar PV use
iv. Asses the perspective of developers on existing business models and their impacts across the different customer segments

The information gathered will be treated as private and confidential and will only be used for academic purposes of this research. Kindly feel free to respond to all the questions.

Part One: Company profile

a. Position of interviewee ____
b. Name of the company ____
c. Professional qualification____
d. Gender: a) Male [ ] b) Female [ ]
e. Capacity installed ____
f. Business model used

Model	Reason for choosing
a. Self-Owned	
b. Leasing	
c. Power purchase Agreement (PPA)	
d. Others(specify)	

Part Two: Adoption and Scaling Up

1. For how long have you been in rooftop solar PV business?

i. Less than a year	
ii. 1-2 years	
iii. 2-5 years	
iv. 5-10 years	
v. More than 10 years	

2. Which customer sector do you prefer and why?

i. Commercial and industrial sector [ ]

ii. Learning institutions sector [ ]

iii. Domestic sector [ ]

iv. Others(specify)____

3. What are some of the challenges faced across each consumer segments with reference to

a. Customer Acquisition and awareness past experiences

Challenge	Past experience
Consumer awareness and interests	
Contractual engagements among stakeholders	
Customer acquisition costs	
Returns on investments expectations	
Others(specify)	

b. Operational challenges during

i. Application process

____

____

ii. Approval process

____

____

iii. Inspections and commissioning process

____

____

c. Regulatory issues including settlement period

____

____

d. Technical issues involving grid accessibility and availability

____

____

____

e. Financing challenges depending on ownership model applied

i. Securing debt for third party PPA

____

____

ii. Soft loan impact

____

____

f. Nature of building design structure

____

____

4. Which business model is suitable for each consumer segment and how effectively can they be applied?

Model	Reason for preference
a. Self-Owned	
b. Leasing	
c. Power purchase Agreement (PPA)	
d. Others(specify)	

5. What are some of measures can be undertaken to scale up rooftop solar PV use?

____

____

6. Which roles or mechanisms can the government play or use to ensure scale up of rooftop use in urban centres considering the following areas?

a. RE Incentives and subsidies	
b. Regulation	
c. Promotional activities	
d. Quality measures	
e. Capacity building	
f. Others (specify)	

7. Have you ever conducted rooftop solar PV business outside Kenya? If YES,

i. How do you compare Kenya with other countries in terms of solar rooftop?

Positive effects	Negative effects

ii. Can you recommend other developers to venture in Kenyan market in the future?

____

____

8. Which recommendations can you give which can be applied to scale up rooftop solar PV?

Recommendations	Improvements
a. Operational issues	
b. Legal framework	
c. Availability of grid connection	
d. Financing challenges	
e. Market business models	
f. Information availability	
g. Promotional programmes	
h. Others(specify)	

Appendix 4: Questionnaire for Manufacturing and Distributing firms

Introduction

I introduce myself as **Patrick K. Mwanzia** (Msc. Student at **PAUWES-ALGERIA**) currently carrying out a research on challenges facing scaling up of rooftop solar PV use in urban centres. The purpose of carrying out this questionnaire is to

v. Establish the major barriers in manufacturing the Solar products

vi. Identify the key drivers and opportunities in the sector

vii. Understand the role of government regulation in the sector and how effectively it can be implemented.

The information gathered will be treated as private and confidential and will only be used for academic purposes of this research. Kindly feel free to respond to all the questions.

Part One: Company profile

a. Position of interviewee ____

b. Professional qualification____

c. Gender: a) Male [ ] b) Female [ ]

d. Name of the company: ____

e. Nature of the business: [ ] Manufacturer
[ ] Distributer
[ ] Partnership
[ ] Retail
[ ] Others (specify)

Part Two: Adoption and scaling Up

1. Which solar products do you manufacture or trade in? Tick where applicable

i. Solar panels	
ii. Batteries	
iii. Charge controllers	
iv. Inverters	
v. SHS kits	
vi. Others (Specify)	

2. How often do you test your solar products to ensure set standards are met?

____

3. Which is your estimated life span of your products?

i.	1-2 years	
ii.	2-5 years	
iii.	5-10 years	
iv.	More than 10 years	

4. For how long you have been manufacturing solar PV panels in Kenya?

____

____

5. Does the company have other branches manufacturing solar PV panels outside Kenya mainly in Africa?

____

If YES, how can you compare your experience with Kenyan market.

____

____

6. Which customer segments do you serve or your target market?
   a. Distributors
   b. Wholesalers
   c. Retailers
   d. End users
   e. Others(specify)________________________________

7. What are some of the means used to reach the target market?
   a. TV advertisements
   b. Radio programmes
   c. Promotions and workshops
   d. Publications and business magazines
   e. Others(specify)________________________________

8. Do you offer training to your customers on the installations and maintenance?

____

____

____

9. Mode of payment commonly used by the customers?
    a. Cash [ ]
    b. Credit [ ]
    c. Others(specify)____

10. Main challenges faced across the different consumer/ clients' categories?
    a. Marketing strategies [ ]
    b. Customer awareness [ ]
    c. Government policy and regulatory framework [ ]
    d. Cheap Importation of similar products [ ]
    e. Capacity building challenges [ ]
    f. others(specify)____

11. Any technical needs your company is experienced and any suggestions to improve production?

    ____

    ____

12. Major opportunities in use of solar PV products from your past experiences?

    ____

    ____

    ____

13. Which role can the Kenyan government play in ensuring increased use of solar PV products in the Kenya?

    ____

    ____

14. Which recommendations can you suggest in aim of scaling up solar PV use?

    ____

    ____

Appendix 5: Budget

EXPENDITURE REPORT

NO	ITEM	DESCRIPTION	AMOUNT IN KES
1	**Transport Costs**	**-Flight ticket** from Tlemcen to Kenya (Round trip) • This includes transport to and from Airports	**100,000**
		-Transport to cater for data collection • **50** companies/firms/institutions were covered	**63,800**
2	**Research Equipment and Materials**	**-Airtime** for Data Collection and Data bundles	**23,000**
		-Questionnaires Printing for Data Collection	**5,200**
3	**Training and Conferences**	-The **Trainings and Conferences** were used to aid in Data Collection and Report Writing -The Trainings were part of the Internship and Data Collection and all were done in Strathmore University Energy Research Centre **(SERC)**	**100,000**
4	**Thesis Binding and Printing**	Costs for Printing and Binding of Five Copies	**8,000**
5	**TOTAL**		**300,000**

NB. EXCHANGE RATE FOR **1 USD = KES 96.2**

Appendix 6: Time Schedule

No	ACTIVITIES	MONTH - 2018								
		Jan	Feb	Mar	April	May	June	July	Aug	Sept
1	Topic Identification and Formulation									
2	Proposal Writing									
3	Internship									
4	Data Collection									
5	Data Analysis Training and Assistance									
6	Thesis Writing and Updating									
7	Thesis Submission									
8	Defence									