THE RELATIONSHIP BETWEEN INTERACTIVE LEARNING, INNOVATION SYSTEMS, AND TECHNOLOGY DIFFUSION IN SMALL WIND TURBINE INDUSTRY IN KENYA

BY

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DECLARATION

I hereby declare that this proposal is my original work and has not been presented for a degree in any other university. No part of this proposal may be reproduced without the prior written permission of the author and/or Moi University and Aalborg University

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This proposal is dedicated to:

The Almighty God with whose blessings I learnt to develop a spirit of resilience and endurance;

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My earnest prayer is that this study will prove to be an inspiration to you all to make bigger and better contribution to academic knowledge, development and society.

IT ALWAYS SEEMS IMPOSSIBLE UNTIL IT IS DONE

NELSON MANDELA

ABSTRACT

The diffusion of small wind turbine (SWT) technology in Kenya is slow despite the fact that wind development dates back to 1977 (MOE/UNDP, 2015). Large wind systems which are grid connected have been profiled by the government as playing a key role in access to clean energy while decentralized SWT have not diffused much in the country to date. The objective of this research is to study the relationship between technology diffusion (TD) of SWT technology, firm capabilities and interactive learning (IL) in the context of the National Innovation System (NIS) for SWT. It is hypothesized that SWT firms in Kenya have limited capabilities and interactive learning and therefore they have not been able to diffuse the technology. This study will be guided by the theory of NIS, Resource Based View (RBV), TD and IL. A qualitative mixed methods approach will be used for data collection and analysis. Respondents will be drawn from various levels for comparability of the responses. In-depth case studies of three (3) firms will be conducted and supplemented by a survey of 28 other firms, other actors in the NIS and selected projects. A census approach will be used because of the limited number of actors in the NIS. The data will be collected using case studies and survey. Data will be analyzed by transcribing, coding and identification of common themes that relate to hypotheses and theory. Conclusions will be drawn and recommendations based on the relationships established between hypotheses, theories of NIS, TD, RBV, and IL, policy and practice.

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ABBREVIATIONS

AWEA	American Wind Energy Association
CanWEA	Canadian Wind Energy Association
CBV	Competence Based View
CIS	Community Innovation Survey
CKM	Customer Knowledge Management
DANIDA	Danish Development Agency
DC	Dynamic capabilities
DSWTA	Danish Small Wind Turbine Association
DTU	Danish Technical University
EU	European Union
EUR	Euros
FIT	Feed-In-Tariffs
GHG	Greenhouse Gases
GW	Giga Watts
ICT	Information and Communications Technology
IEC	International Electro-Technical Commission
IL	Interactive Learning
IREK	Innovation and Renewable Energy Electrification Kenya
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KEREA	Kenya Renewable Energy Association
KU	Kenyatta University
kW	Kilo Watt(s)
kWh	Kilowatt hour
LED	Light Emitting Diode
m^2	Square metre (s)
MCS	Microgeneration Certification Scheme

MOE	Ministry of Energy
MOEP	Ministry of Energy and Petroleum
MW	Mega Watt(s)
NGO	Non-Governmental Organisation(s)
NIS	National Innovation System
OECD	Organisation for Economic Co-operation and Development
PhD	Doctor of Philosophy
PV	Photovoltaic
R&D	Research and Development
RBV	Resource Based View
REA	Rural Electrification Authority
RETs	Renewable Energy Technologies
S/S	South-South
SME	Small and Micro Enterprises
SWCC	Small Wind Certification Council
SWT	Small Wind Turbines
T1 and T2	Technician 1 and Technician 2
TD	Technology Diffusion
UN	United Nations
UNDP	United Nations Development Programme
USA	United States of America
USD	United States Dollar
W	Watt (s)
WWEA	World Wind Energy Association

OPERATIONAL DEFINITION OF TERMS

Technology Diffusion: The sale of wind turbines by business firms.

Firm capabilities Are socially complex, combinations of interconnected resources, skills/competences and knowledge that are deployed to carry out a task (IREK, 2017)

Innovation: A process of conceptualising, developing and adapting new or significantly improved products, processes and organisational methods (new to the world or new to the context) (IREK 2017)

Innovation System: "... The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country" (Patel and Pavitt, 1994: p.5)

National Innovation System: According to Freeman (1987), the national innovation system is essentially "a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies"(Ferretti & Parmentola, 2015)(Sobanke, Adegbite, Ilori, & Egbetokun, 2014).

Interactive learning: Learning that occurs between and among individuals, communities or institutions, in a business or social setting (IREK, 2017).

Small wind turbine technology: Wind based energy systems for generating electricity in the range of less than 100KW.

Technology: A combination of hardware (equipment, capital goods), software (knowledge and skills) and org-ware (organisation) which results in a product/outcome (IREK, 2017)

CHAPTER ONE: INTRODUCTION

1.1. Overview

This chapter covers the introduction to the study: Section 1.2 covers the background to the study; Section 1.3 covers the statement of the problem; Section 1.4 covers the objectives; Section 1.5 covers the hypotheses; Section 1.6 covers the research questions; Section 1.7 covers the significance of the study and Section 1.8 covers the scope of the study.

1.2. Background to the study

The study of the relationship between diffusion, innovation and interactive learning is useful in making more reliable generalisations in specific industries and the entire economy (Freeman, 1994). Technology diffusion is important for the advancement of the energy sector in the context of reducing the emission of greenhouse gases (GHG), efficiency and universal energy access for populations living in off-grid areas (Jacobsen, 2000). Innovation for renewable energy technologies (RETs) is often portrayed as capital and scale intensive, and it depends on high quality networked infrastructure, skilled labour and is product focused, an approach which meets the needs of the well to do while disadvantaging the poor as consumers and producers (Chataway *et.al.*, 2014) however, in developing countries this is not the case. The multifaceted nature of innovation has largely been neglected thus making it difficult to efficiently utilise available resources and draw on synergies between different actors; severely limiting innovation capabilities (Chataway *et. al.*, 2014). "In practically all parts of the economy, and at all times, we expect to find on-going processes of learning, searching and exploring, which result in new products, new techniques, new forms of organization and new markets" (Lundvall, 2000, p. 8).

The International Renewable Energy Agency (IRENA, 2013) indicates that RETs hold the ultimate solution to energy security, energy poverty and climate change. This is with respect to enhancing access to clean energy sources and their contribution to the global energy mix and improving efficiency in line with the objectives of the Sustainable Energy for All Initiative, which was launched in 2011 by the United Nations (UN) Secretary General. For over three decades of deployment of RETs, significant barriers ranging from high costs, positive and negative externalities, infrastructure lock-in, engrained consumer habits and resistance from well-established conventional firms are believed to inhibit the options available to scientists, entrepreneurs, and policy makers, particularly in developing countries (IRENA, 2013). The economics of implementing RETs in the residential sector are reported to be the most daunting (Bley, 2012). The firm is considered a key element in the national innovation system (Freeman, 1991) with respect to learning and innovation. Factors that hinder entrepreneurial activities include lack of start-up finance, risk averse attitude from potential lenders, underdeveloped specific capabilities, and knowledge diffusion. Teece (2010) observed that the absence of a well-developed business model makes innovators fail to either deliver or capture value from innovations. Strong and close relationships hamper innovation or give rise to 'unsatisfactory innovation': the problem of lock-in and weak user competence (Lundvall, 2012).

Different countries are endowed with varied quantities of renewable energy resources including hydropower, geothermal, wind, solar and biomass. As a result of the changing attitude towards renewable energy, wind power has been one of the most rapidly growing renewable energy sources over the last decade. In Africa, including Kenya the diffusion of small wind turbines has been slow. However large scale generation systems have gained significance with the latest installation of 310MW in Turkana county.

1.3. Statement of the problem

Technology diffusion in developing economies is faced with the high initial cost of transferring modern technology that makes consumers reluctant to switch to more efficient innovations. The public may resist the adoption of new technologies due to lack of information and the inability to finance installation of systems (Attewell, 1992; Soete, 1985; World Bank, 1998). Universal access to clean energy is yet to be realised in the country. The potential for stand-alone wind generation for electricity supply remains unexploited to date despite the long history of wind development in Kenya which faces major challenges to increasing grid connectivity to the sparsely populated rural areas. This could provide a great opportunity for decentralized generation.

The local resources and capabilities are poorly utilized, and the limited know-how in training of local employees in operation and maintenance suggests a need for institutional support to effect the desired technology-push (Suzuki (2014). The diffusion of small wind turbines in Kenya is characterized by one-time experiments, limited research and development, fragmented learning experiences, lack of focus and low quality products and services, a weakly aligned network, many underperforming actors and the inability to attract buy-in from utilities to embrace innovation in the provision of energy services. Overall, the sector has seen a long and cumbersome development trajectory, characterized by malfunctioning wind turbines and low quality products and services. In Kenya there is no standardized training curriculum for training site assessors who instill confidence in consumers and this could potentially contribute to low diffusion.

Strong local companies which ensure the use of advanced digital monitoring, first line maintenance by trained local engineers and second line support wind energy suppliers are still lacking. Many of the companies that claim to deal with small wind are more oriented to solar PV services (Ulrich, 2016). The logistics of planning for transportation of equipment presents significant difficulties, because wind resources in Kenya are found in difficult to access areas, served by poor infrastructure and therefore it takes significant resources to successfully plan access. It is not clear whether companies with a local presence have sufficient experience to handle the diffusion of small wind turbines to potential areas. Interactive learning between the actors in the small wind turbine innovation system is still weak and so are the relationships with foreign companies to promote business-matching and capacity building (Pueyo and Linares, 2012). There is limited technology-push (in the renewable energy sector) through implementing demonstration projects and demand-pull policies which could improve internal capabilities through learning by doing (Pueyo and Linares, 2012). Innovation in policy based on best practices is still limited and this subsequently curtails the ability to develop strong networks, promote interactive learning, research and development, capacity enhancement of local institutions thereby enhancing diffusion of small wind turbines. This study therefore seeks to bridge the knowledge gap in the relationship between small wind turbine innovation system and technology diffusion with a view to enhancing widespread use of small wind turbines in the provision of clean energy.

1.4. Objectives of the study

1.4.1 General objective

The general objective of the study is to study the relationship between interactive learning and firm capabilities and how this influences technology diffusion of SWT

1.4.2 Specific objectives

Major Objective A: To study the relationship between interactive learning and firm capabilities

Sub Objectives

1. To explore the effect of interactive learning within firms on firm capabilities
2. To investigate the effect of interactive learning between firms on firm capabilities
3. To study the effect of interactive learning between firms and other actors of the IS on firm capabilities

Major objective B: To study the influence of firm capabilities on technology diffusion

Sub Objectives

1. To investigate the effect of Technological capabilities on technology diffusion
2. To explore the influence of marketing capabilities on technology diffusion
3. To assess the influence of after sales service capabilities on technology diffusion

1.5 Hypotheses

Key Hypothesis: Interactive learning has an effect on firm capabilities which also influences technology diffusion of SWT

Sub Hypotheses

1. Interactive learning within firms, between firms and with other actors has an effect on firm capabilities within the context of the SWT innovation system in Kenya?

2. Firm capabilities have an influence on technology diffusion of small wind turbines within the context of the SWT innovation system in Kenya?

1.6 Research Questions

In order to explore the objectives stated in Section 1.4, the study will seek to answer the following research questions:

Key Question 1: How does interactive learning impact on firm capabilities and how does this influence the technology diffusion within the context of the small wind turbines innovation system in Kenya?

Sub Q1: How does interactive learning within firms, between firms and between firms and other actors affect capabilities of firms within the context of the SWT innovation system in Kenya?

To answer sub question 1 the study will answer the following questions:

1. How does interactive learning within firms affect firm capabilities?
2. How does interactive learning between firms affect firm capabilities?
3. How does interactive learning between firms and other actors of the Innovation System affect firm capabilities?

Sub Q2: To what extent and how do firm capabilities influence technology diffusion of small wind turbines within the context of the SWT innovation system in Kenya?

To answer sub question 2 the study will answer the following questions:

1. How do technological capabilities affect technology diffusion?
2. How do marketing capabilities influence technology diffusion?
3. How do after sales service capabilities influence technology diffusion?

1.7 Significance of the study

This study seeks to contribute to academic knowledge with respect to theory on interactive learning on technology diffusion of small wind turbines. It will provide a basis for sustained empirical research on the interaction of firms as elements of the innovation system within themselves, with other actors, institutions and networks with respect to diffusion of clean energy technologies. This is useful in understanding the role of firms and their linkages in the delivery of sustainable energy services. The study will bring out additional areas for investigation, thus supporting development of innovative ways of ensuring universal access to clean energy sources, with the firm as the central focus in improving the empirical application of the innovation system to developing the energy sector, which was noted to be lacking (Malerba, 2002, 2006).

The results of this study will be useful to policy makers and practitioners, development partners, and civil society with respect to policy review and development in line with the national objectives of the Sustainable Energy for All Initiative to improve energy access, efficiency and renewable energy use. In particular, the study will improve the comprehension of interactions between actors of the innovation system with a view to enhancing technology diffusion by energy practitioners in the design of decentralized energy systems. This is useful in improving energy access in developing nations as well as tapping into advancements made in international markets. Understanding the innovation behavior at the systems level is important to government policymakers because it enables discovery of how the locus of product innovation can be shifted strategically by altering incentive structures and re-ordering relationships between users and producers(C Edquist, 1999)

New avenues for utilities to engage in decentralized renewable energy development for the benefit of customers and society as new revenue will be opened. This will provide impetus to the national blue print, Vision 2030 under which the country aspires to become a middle income economy by 2030. It will contribute to the potential for small scale generation to reduce the need for grid extension and establishment of large storage capacities for renewable energy Richter (2013). The innovation capacities of existing firms plays an important role in promoting joint venture partnerships with firms from other countries. Pursuit of international competitiveness is likely to open up avenues for commercial scale up and technology venturing and offers the possibility of success across multiple markets.

1.8 Scope of the study

The main focus of the study will be on the business firm as a key element of the small wind innovation system. The investigation will focus on the effect of firm capabilities and linkages on technology diffusion. Other actors, institutions and networks within the innovation system have a bearing on the functioning of the firm with respect to the diffusion of small wind turbines and therefore they will also be incorporated as appropriate. For the purpose of this study, the definition of small wind systems is restricted to electrical systems with an installed capacity below 100 kW. This emanates from the fact that categorization of small wind systems has not been done in Kenya (MOEP, 2012). It is also in harmony with the classification of small wind turbines by(Gardner et al., 2009) -Table 1). In other countries, the limit of 100 kW is defined as the maximum power that can be connected directly to the low voltage grid. The pico-wind range is commonly accepted as those SWTs smaller than 1 kW(Gardner *et al*., 2009).

Table 1: Classification of Small Wind Turbines

Rated Power (kW)	Rotor Swept Area m^2	Sub Category
P_{rated} < 1kW	A<4.9m^2	Pico-wind
1kW<P_{rated}<7kW	A<40m^2	Micro-wind
7kW<P_{rated}<50kW	A<200m^2	Mini-wind
50kW<P_{rated}<100kW	A<300m^2	No clear definition adopted yet

Source:(Gardner et al., 2009)

The classification of energy supply systems (mini-grids by size, based on Pedersen, 2016):

- DC Village Mini-Grids : 0.2-5 kW
- Anchor-Business-Customers (ABC) Mini-Grid: 0.2 – 15 kW
- AC Village Mini-Grid : 1 – 300 kW
- Large Mini-Grid : >300 kW – 2 MW

There is still no globally unified definition of small wind WWEA (2014). In practice, the major pattern of today's upper limit capacity leans towards 100 kW, although the IEC defines a limit of equivalent to 50 kW. In Kenya, small-scale wind projects are considered a small niche of the off-grid solar market. There are in the order of five hundred stand-alone wind systems in the country ranging in size from 500W to 50 kW. KEREA however indicates that an average of 80-100 small wind turbines (400W) have been installed to date by telecom players, NGOs, commercial and household clients in windy parts of the country, often as part of a Photovoltaic (PV)-Wind hybrid system with battery storage (MOEP, 2016). Given the different categorization of small wind systems across the globe, this study will focus on small wind turbine technology systems less than 100kW.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers the literature review. Section 2.2 covers the concept definitions; Section 2.3 covers the theoretical perspectives; Section 2.4 covers the empirical literature and research questions and Section 2.5 summarises the gaps and conceptual framework for the study.

2.2 Concept Definitions

2.2.1 The Concept of National Innovation Systems

An innovation system is defined as "... That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe, 1995 Sourced from: Niosi, 2002, p. 292.). The main function of an innovation system is defined as the generation, diffusion and utilization of technology(Etzkowitz & Ranga, 2013). Innovation systems have been examined from the perspective of national or regional innovation systems, sectoral innovation systems and technological innovation systems. These approaches to innovation systems can be argued to complement each other rather than exclude each other (Edquist, 1997). The innovation systems approach places innovation and learning processes at the center of focus, based on the understanding that technological innovation is a matter of producing new knowledge or combining existing elements of knowledge in new ways and is therefore in a broad sense a "learning process"(C Edquist, 1999).

Innovations are determined by both the elements of the systems and the relations between them(C Edquist, 1999). They encompass product technologies and organizational innovations, based on the understanding that developing a differentiated concept of innovation is necessary to comprehend the complex relations between growth, employment, and innovation. They also value the central role of institutions, which helps in understanding the social patterning of innovative behaviour which is considered to possess a "path-dependent" character. This in turn reflects the role played by norms, rules, laws, etc. and by organizations in an innovation system(C Edquist, 1999). Successful innovation happens through building and improving effective routines. Knowledge plays a central role in innovation and production. It encompasses both tacit and codified elements, and is closely related to the problem solving activities of firms(Malerba et al., 2007). Knowledge acquisition presents itself in different dimensions. Knowledge that is external to firms may be internal to the sector, a situation which favours imitation or external to the sector (thus affecting the availability of technological opportunities to incumbents and new firms). Whichever case it may be, greater accessibility of knowledge decreases industrial concentration, and if this happens internally it leads to lower appropriability. Under these circumstances, competitors may gain knowledge about new products and processes and, if competent, imitate those new products and processes. Access to knowledge which is external to the industry is related to scientific and technological opportunities with respect to level and sources(Malerba et al., 2007).

The effect of the external environment on firms may occur through human capital with a certain level and type of knowledge or through scientific and technological knowledge developed in firms or non-firms organizations such as universities or research laboratories. The sources of technological opportunities are varied depending on the sector and may include: conditions are related to major scientific breakthroughs in universities; advancements in external R&D; equipment and instrumentation; and suppliers or users. However, not all external knowledge may be easily used and transformed into new artefacts. According to Winter, 1984 ease of access to external knowledge and ease of transformation into new artefacts and exposure many actors (such as customers or suppliers) may lead to innovation. Advanced integration capabilities may be necessary where the industry is concentrated and formed by large established firms. The knowledge base underpinning firms' activities becomes highly distinctive at the firm level. The key actors in a sectoral system are the firms. They are involved in the innovation, production and distribution of sectoral products, and in the generation, adoption and use of new technologies(Malerba et al., 2007). Innovation requires firms' ability to recognize and understand effective routines (whether developed in-house or observed in another firm) and facilitating their emergence across the organization(Tidd, Bessant, & Pavitt, 2005).

The study of national innovation systems offers fresh rationales and approaches for government technology policies. Most government intervention is targeted at correcting market failures or the tendency by private sector to underinvest in technology development due to inability of firms to reap substantial benefits. (Kristinsson et al., 2016). The concept of national innovation systems draws the attention of government to possible systemic failures that may impede industries to innovate. Consequently, for a nation to improve its competitiveness or experience improved productivity and economic growth, it needs to pay attention to the accumulation of technological capability by firms. Critical resources and capabilities will differ for different types of services (Story, Raddats, Burton, Zolkiewski, & Baines, 2015). Currently there is limited research that examines the capabilities developed by network actors. The functioning of a Renewable Energy innovation system has been conceptualized as comprising both blocking and inducing mechanisms(Charles Edquist et al., 2014), Figure 3. The blocking mechanisms impede the proper functioning of the innovation system while the inducing mechanisms promote the effective functioning. The combination of blocking and inducing mechanisms in any innovation system varies across sectors and countries and it is may not possible to draw generalisations across sectors or countries. This makes the study of the small wind turbine innovation system pertinent so as to facilitate identification of blocking and inducing mechanisms that may be unique to the Kenyan situation.

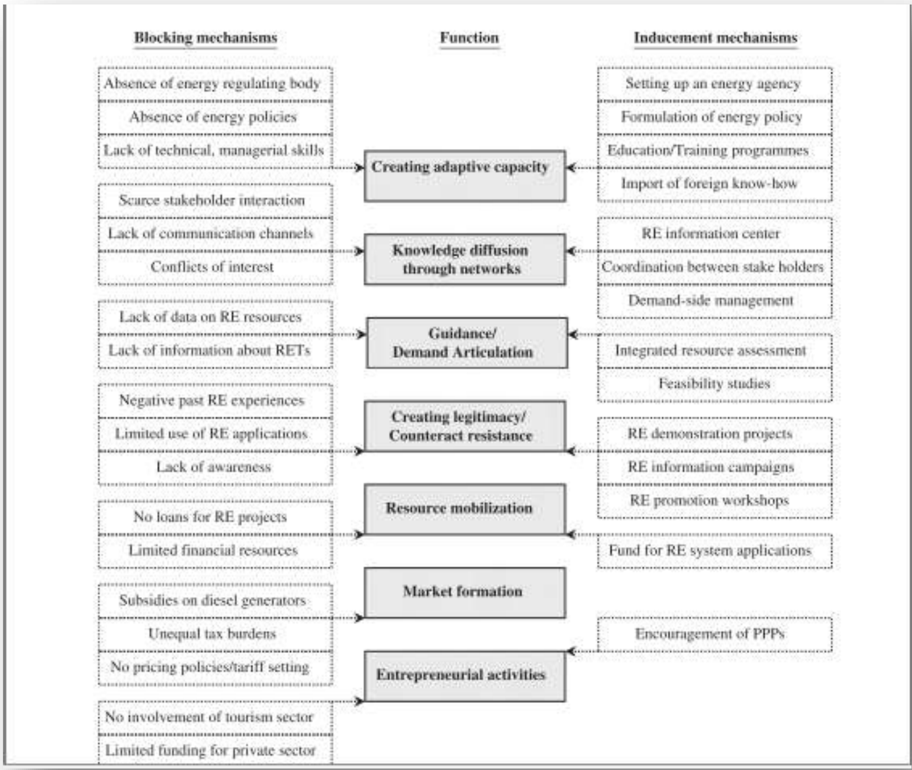

Figure 1: Blocking and inducing mechanisms in a National Innovation System

2.2.2 The Concept of Technology Diffusion

The importance of technology diffusion to traditional manufacturing sectors and service industries who may not be R&D performers or innovators themselves cannot be gainsaid. Governments have consequently adopted a variety of schemes and programmes to diffuse technology to industry, from manufacturing extension centres, to demonstration projects to technology brokers(Dytianquin, 2011). The diffusion of innovations is a slow process, sometimes taking place over a number of years. While the rate of adoption of technology varies significantly between sectors, it depends on both the national context and a variety of firm level characteristics. Many empirical studies have identified trade as the most important channel of technology diffusion(Islam, 2014) and international trade has been identified as the main carrier of productivity gains. Political barriers have long been believed to be an important deterrent to technology diffusion(Hanseman & Gustafson, 2014). Other agents of diffusion include non-firm organizations such as universities, financial institutions, government, local authorities. They support in various ways innovation, diffusion of new technologies and production of firms within a sectoral system, but again their role greatly differs among sectors (Malerba et al., 2007). New agents (both new firms and non- firms organizations) play an important role in sectoral systems by bringing in the innovation and production processes a variety of approaches, specialization and knowledge, and contribute to the major changes in the population of agents and in the transformation of technologies and products in a sector. Measuring political barriers is however complex due to the fact that there are no direct measures for such barriers. The measures relating to these barriers are endogenous; and comprehensive data sets for adoption of specific technologies are necessary but in many cases they do not exist.

Adoption rates of new technologies can be measured and tracked over time through the use of specific technologies and diffusion curves(Fichman, 1992). Most of these surveys do not generally reveal the source of the equipment or technology, and this limits their usefulness in tracking technology flows among actors within an innovation system. Key barriers to technology diffusion identified through such surveys include: lack of information; lack of financing and lack of technical expertise(Fichman, 1992). More in-depth research reveals other barriers such as general organisational and managerial deficiencies. Seven functions of innovation systems have been identified as: (1) knowledge development, (2) knowledge diffusion through networks, (3) guidance of the search/articulation of demand, (4) creation of legitimacy/counteract resistance to change, (5) resources mobilization, (6) market formation, and (7) entrepreneurial activities(Charles Edquist et al., 2014)

2.2.3 The concept of firm Capabilities

Firms are considered a bundle of different capabilities and resources which they use to maximize their profit(Chaminade & Edquist, 2005). Analysing firm capabilities raises questions both about the internal characteristics of a firm, that is, the ways in which functional and divisional operations are co-ordinated and about the ways in which a firm's organisation interacts with its environment (Antonelli & Quere, 2002)). The main function of an innovation system is the generation, diffusion and utilization of technology and the competencies necessary to achieve this function are described in terms of four types of capabilities: (a) selective (strategic) capability; (b) organizational (integrative or coordinating) ability; (c) technical or functional ability; and (d) learning (adaptive) ability(Etzkowitz & Ranga, 2013). Firms that possess these capabilities are able to make innovative choices of markets, products, technologies and organizational structure; to engage in entrepreneurial activity; to select key personnel and acquire key resources, including new competence; to organize and coordinate the resources and economic activities within the organization; to implement technologies and utilize them effectively in the market; to learn from success as well as failure, to read and interpret market signals and take appropriate actions, and to diffuse technology throughout the system (Carlsson et al, 2002, p 235).

At the firm level, technological capabilities facilitate innovation which, in turn, drives productivity growth(Sobanke et al., 2014). The fundamental adaptive challenge facing firms is the need to both exploit existing assets and capabilities and to provide for sufficient exploration to avoid being rendered irrelevant by changes in markets and technologies(Reilly & Tushman, 2013). Firms can pursue efficiency and innovation and be able to compete in multiple markets by developing the capabilities necessary to compete in new markets and technologies that enable their survival in the event that market conditions change(Reilly & Tushman, 2013). Innovative performance of firms depends on their ability to put technology to work by adopting and using innovations and products developed elsewhere. The modern Danish wind turbine industry developed as a result of capabilities originating from its home market and this provided the necessary testing ground to enhance their manufacturing processes and wind technology, an experience which has helped Danish firms to establish themselves in India(Creswell et al., 2008). Wind farm developments in India have drawn substantial benefits from Danish involvement and expertise through the use of Danish wind technology and through knowledge transfers in demonstration projects, and capabilities gained through the build-up of the Centre for Wind Technology(Creswell et al., 2008). Western companies are different from Japanese companies not because their senior executives are less capable than their counterparts in Japan nor that Japanese companies possess greater technical capabilities. The difference emanates from the adherence of western companies to a concept of the corporation that unnecessarily limits the ability of individual businesses to fully exploit the deep reservoir of technological capability that many American and European companies possess(C. K. Prahalad & Prahalad, 1990).

There are non-technical barriers which impede the implementation and diffusion of RETs. A study of forms of knowledge and modes of innovation for Renewable energy technologies in the Maldives indicated that such non-technical barriers include lack of information, insufficient capabilities, political and economic barriers, lack of understanding of local needs, business limitations, and institutional limitations(Charles Edquist et al., 2014). Technological capabilities on the supply and demand side are largely a by-product of development processes, as well as changes in the economic framework conditions and institutions of governance and policy(UNIDO & UNU-Merit, 2014). Technical capabilities are not sufficiently articulated by the Clean Development Mechanism as part of technology transfer options even where such opportunities for developing renewable energy uptake exist(UNIDO & UNU-Merit, 2014). Weaknesses in domestic capabilities for manufacturing the necessary equipment contribute to market imperfections

It is widely accepted that an innovative firm displays a number of key features: thick horizontal information flows between its R&D, manufacturing and marketing divisions; a high premium on decentralized learning procedures; high receptivity to a multiple channels of information (from customers, suppliers and competitors on the external side and, internally, from employees). A key intangible asset within the firm is the workforce which feels a sense of 'belonging' to the firm. The presence of such an asset gives workers the impression that by developing creative solutions to problems they are not necessarily driving themselves out of employment. This asset is inimitable, for example, kaizen, the process of continuous improvement through interactive learning and problem-solving, pioneered by Japanese firms (Morgan, 1997).

Firms are likely to utilize their wider networks for developing capabilities, since advanced services generally require providers to take over a customer's business process activities, an activity that is both costly and difficult (Story et al., 2015). Firms could also develop in-house capabilities, and this is advantageous with respect to competitive advantage. On the other hand, a firm could utilize its networks and outsource or co-develop capabilities with customers/partners, a move that is consistent with Loasby's (1998) idea of indirect capabilities, which spells out the ability of a firm to access but not control the capabilities of other firms. There are disadvantages associated with both options: for example, the former could lead a firm to become a 'jack of all trades and master of none' if they go it alone, or else risks may arise with respect to opportunistic behavior of business partners and an increase in co-ordination costs, if they utilize network actors (Story et al., 2015).

Competitive advantage can be drawn from a comprehensive knowledge of a product and reputation. However, developing new capabilities such as developing a service culture, risk management, pricing services on a risk/reward basis, offering services more cheaply than other service providers and the ability to generate efficiency gains is also important as it ensures the firm's capability to understand customers' service needs while aligning their services to customers' operational processes. Capabilities related to design and innovation activities that support the development of new services have also been known to play an important role. Relational capabilities are a central factor and are supported by personnel who possess technical expertise, a strong customer focus, and knowledge of third party products(Story et al., 2015). Technological knowledge is both firm and context specific. It is systemic and therefore largely depends on the specific characteristics of the technological knowledge itself and on product and market contexts. Analysis requires the ability to accommodate the interplay between such factors (Antonelli & Quere, 2002).

2.2.4 The Concept of Interactive Learning

The dissemination of technology as new equipment and machinery is perhaps the most traditional type of knowledge flow in an innovation system(Chaminade & Edquist, 2005). Significant innovation occurs in firms that are able to access outside knowledge and to link into knowledge networks, including informal contacts, user-supplier relations and technical co-operation. In addition, the ability to adapt the technology and knowledge to their own needs has been found to be important. Knowledge encompasses information and tacit knowledge. It can be both general and specific and to the firm or to the industry(Chaminade

& Edquist, 2005). This therefore points towards the collective nature of the innovation process through which technologies are created and used and the fact that the process is shaped by institutional and knowledge-sharing systems. “Different sectors are characterized by different knowledge bases, and knowledge plays a central role in innovation and affects the types of learning and capabilities of firms”(UNIDO & UNU-Merit, 2014). Learning occurs in specific institutional contexts which include systemic environments (policy institutions and actions) shaped inter alia by regulation, law, political cultures, and the ‘rules of the game’ of economic institutions(Mytelka & Smith, 2002).

Learning processes in firms are path dependent. The directions of search strongly conditioned by the competencies accumulated for the development and exploitation of their existing product base. Moving from one path of learning to another can be costly, or even impossible, given cognitive limits such as learning a foreign language from scratch. Effective learning in innovation requires strong feedback between decisions and their implementation (in other words, between analysis and action). It is therefore necessary to effectively integrate information and knowledge across functional and divisional boundaries. Innovation is increasingly about teamwork and the creative combination of different disciplines and perspectives. Success is driven by people working together in high- performance teams(Tidd et al., 2005). Firms have increasingly appreciated the value in using networks to gain extra traction on the learning process(Tidd et al., 2005). Networking is useful in the innovation process because it provides support for shared learning and helps to spread the risk and in the process, extends the range of things which could be tried. This is particularly useful in the context of smaller firms where resources are scarce. Such networking could be firm to firm as well as rich linkages within the national system of innovation(Tidd et al., 2005). Long-lasting innovation networks can create the capability to ride out major waves of change in the technological and economic environment. The potential to learn from others is enormous, however, simply copying what seems to work for another organization can be costly as it may distract the firm from devising its own way of dealing with a particular problem(Tidd et al., 2005). Learning is a process of acquiring good or bad experiences, evaluating and reflecting on them and applying the lessons to similar experiences whenever they occur. This is often easier said than done resulting in a regular pattern of mistakes and failure to learn from misfortunes of others(Tidd et al., 2005).

With respect to learning, the institutional set-up of a specific firm, a constellation of firms or a nation is an important dimension of the system of innovation. Institutions provide agents and collectives with guideposts for action and make it possible for economic systems to survive and act in an uncertain world. This could be through routines or guiding everyday actions in production, distribution and consumption. It could also be guide posts for change. Institutions are characterized by stability over time and they arise because in a changing and uncertain world, agents and organisations need guidance and institutions make life more manageable and comfortable (not necessarily more efficient in the sense of this term) for them. Institutions are thus fundamental because they provide the stability needed for innovative efforts to take place and to be successful.

2.3 Theoretical Perspectives

This study will be guided by theories of innovation systems, resource based view and the competence based view and dynamic capabilities, technology diffusion theory.

2.3.1 Empirical Literature review

The World Wind Energy Association (2014) observes that the diffusion of small wind turbines is driven by the cost of the technology, presence of supportive policies and economic incentives, fossil-fuel prices, investor interest, consumer awareness, certification and quality assurance, permitting processes and regulations, and wind evaluation tools. The Association anticipates high growth rates of production if consumer demand increases. The cost of small wind turbines continues to pose significant challenges with costs in the USA ranging between $2’300/kW and $10’000/kW in 2011 while in China costs are significantly lower (1'900 USD – 1'500 EUR)/kW. Economies of scale are likely to reduce this cost but the growth of the market requires the use of appropriate legal frameworks, support schemes and political incentives (WWEA, 2014). The importance of feed-in tariffs, net metering, tax credits, and capital subsidies is underscored by the WWEA (2014) as the major energy policies geared towards small wind. It is however notable that only a few countries globally have taken advantage of FIT for grid connected small wind.

Denmark has successfully utilized net-metering especially when the wholesale price of electricity has been sufficiently high. Standards and certification are useful in promoting sales of better performing technology and they also contribute to stability of markets. Of particular importance to technology users is the safety and noise. This has led to development of the internationally accepted standards such as the IEC 61400-2 (3rd edition, 2013) standard, from the International Electro-technical Commission which stipulates specific safety design requirements; the 2009, American, Canadian, and British Wind Energy Associations (now RenewableUK) coordinated Small Wind Turbine Performance & Safety Standard, a subset based on IEC61400-2 (SWTs design), IEC61400-12-1 (performance) and IEC61400-11 (acoustics). These standards were later adopted by the American Wind Energy Association (AWEA) and RenewableUK for their certification programs Small Wind Certification Council (SWCC) and Microgeneration Certification Scheme (MCS), respectively.

Despite the high growth, around the world, wind energy development has been obstructed with high investment cost, market failures and substantial opposition by established energy incumbents (Kristinsson and Rao, 2007). The cost of wind resource assessment tools in relation to the cost of the wind turbine is expensive and therefore presents an impediment to obtaining site specific data. Thus the lack of data at relevant heights requires inexpensive and efficient methods of predicting and collecting site specific data which calls for innovation and cost reduction in the technology used for data collection. Urban environments present special challenges because of neighbouring obstacles that produce patterns that are difficult to predict.

Small-scale, decentralized systems can play a significant role in meeting the combined challenges of development and environmental conservation(Daniel, 1999). Recent efforts to develop mini-grids using diesel and in some cases renewable energy have resulted in dramatic improvements in performance, market power, sales and leasing opportunities, and end-user satisfaction in both developed and developing nations (Daniel, 1999). Some of these technologies have already had a significant impact on local patterns of energy use, economic activity, and the environment. However, a general pattern of neglect and underinvestment in such systems is evident in many countries. Institutional capacity to support such ventures, inadequate financing and limited political support to governmental and non-governmental organizations (NGOs), and the private sector limits the development and diffusion of the desired technologies (Daniel, 1999).

The Africa Progress report(Kabendara, 2015) notes that currently financing for Green Climate is still disintegrated and requires some consolidation in order to drive the clean energy agenda more effectively. Kenya is one of the few African countries that has received

Green Climate Financing to accelerate development of renewable energy with respect to mitigation and adaptation to climate change(Kabendara, 2015). This has enabled the country to increase the contribution of renewable energy to the national energy mix through expansion of generation from geothermal resources. According to the Ministry of Energy and Petroleum (MOEP, 2016) access to electricity in Kenya was estimated at about 46 percent of the population. Key sources of electricity power generation include geothermal (33.28%), hydro (19.97%), thermal (19.41%), solar (13.37%), wind (9.98%), cogeneration (3.99%), and biogas (0.07%) (MOEP, 2015). Wind technology development in Kenya dates back to 1977 (MOEP/UNDP, 2015).

Design and demonstrations projects have been installed in Thika, followed by *Kijito pumps* in the late 1990s. The wind potential in Kenya is classified as low to moderate and integrated energy planning for wind as a substitute for fossil fuels is recommended in line with the national economic, social and environmental policies (MOEP, 2008). The Energy Policy, 2004 and the draft energy policy 2015 recommends both isolated and grid connected wind technology innovation systems. Kenya's 5000+ MW Investment Prospectus, which is implemented under the auspices of the national development blueprint, Kenya Vision 2030 projects a wind generation capacity of 630 MW by 2016 (MOEP, 2013). Grid-tied large electrical wind projects have gained prominence over the last 10 years and currently contribute 25MW to the national energy mix, anchored on the MoEP feed-in tariff policy and proven wind resource potential. Off-grid systems contribute 1MW mainly for greening the diesel powered generation (MOEP 2016). Standalone small wind electrical systems (<100 kW), although appearing to have great potential, have achieved modest market penetration (UNDP, 2016). Such systems would primarily supply power to small scale businesses in selected locations for charging portable light emitting diode (LED) lamps, mobile phones, village enterprises Information and Communications Technology (ICT) training, community centres, schools and dispensaries. Case by case investigation of demand centres is recommended in sparsely populated areas (MOEP, 2008).

Proposed Kenyan policies relating to small wind turbines include studies on capital expenditures and operating costs and development of analytical tools to inform the level of tariffs for different technologies and provision of capacity building programs and financial assistance to community projects. The auction system is also being considered. These policy provisions have so far not been operationalised to benefit the small wind sector and the draft energy bill does little towards this front. The case of small wind turbine generation at consumer level point towards the need for more targeted policy instruments such as financial subsidies for capital investments, and tariff subsidies on standard tariff rates (Whelan and Mchapondwa, 2011) both of which are still not in use in Kenya. The study of the policies in South Africa on small wind turbines by Whelan and Mchapondwa (2011) suggests that adopting policy incentives that benefit the consumer for own generation as well as export back to the grid have the potential to accelerate the diffusion of consumer side generation. This form of tariff subsidy is backed by Bahaj *et. al.* (2007) who fronts for the Obligation Certificate Programme implemented in the United Kingdom and other countries. The study also suggests that capital subsidies at the time of initial investment could contribute to exponential growth in the computed Internal rate of return (IRR) for small wind turbines as they support consumers in dealing with the high initial capital investment costs which are considered to be a significant barrier to the diffusion of small wind turbines.

The 2015 Africa Progress report reported that prices for renewable technologies, especially solar and wind-power, are falling at an extraordinary rate to the point at which they are competitive with fossil fuels Solar PV and other renewable options, including small hydro and small wind power, are more competitive than diesel generators in off-grid or mini-grid applications (Figure 1). The report further notes that the potential to exploit renewable energy sources of power is limited by the lack of finance, technology and institutional capabilities in many countries.

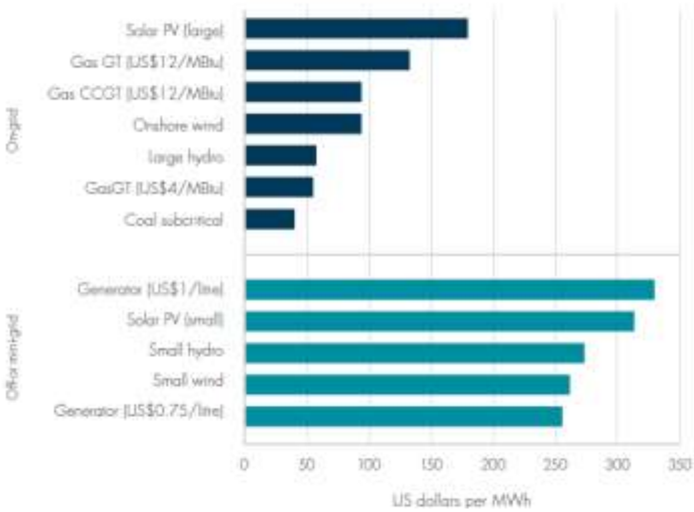

Figure 2: Levelised cost for Sub-Saharan Africa (2012)

Source-(Kabendara, 2015)

In spite of the existing barriers, the market in developed countries is promising for grid-connected and off-grid applications, due to promotion policies (such as capital cost buy-down, feed-in tariffs and net metering), and even more so for developing countries, because of the continuing decrease in specific costs and the increasing need for energy(Gardner et al., 2009). The justification for small wind turbines (SWT) despite their high production cost per kWh compared to grid connected wind systems lies in the ability to provide a relatively economical power supply compared to fossil fuel generation. Alternatives such as diesel generators have high fuel costs when used for continuous power supply. SWT have greater versatility than large grid connected systems which require mature power grids. Further, SWT can be applied both on and off existing power grids as a result of their size and low energy output (LaMonica, 2011). Off grid application avoids the high cost of expanding transmission lines to rural regions of developing countries and their ability to operate on lower wind speeds presents more placement options. Correct placement in suitable locations assures more energy per dollar than other common alternative energy sources such as photovoltaics (LaMonica, 2011).

The study of small wind turbine technology is justified by the fact that other renewable energy forms such as Solar PV and small hydro power have been studied extensively. There is more to contribute to the knowledge base on small wind advantages versus solar and yet the diffusion of small wind turbines still lags behind. (Kamp & Vanheule, 2015) indicate that small wind in Kenya has not been adequately studied. It is also envisaged that achieving universal access to clean energy for the 64 percent of Kenyans who still lack access can be accelerated using multiple methods. Small wind technology could complement Solar Home Systems, mini-grids and small hydro power and in particular reaching areas which do not make economic sense for extending grid supply but are rich in the wind resource. Solar PV and small hydro power have received significant attention and they owe their success to targeted efforts to enhance their use led by the Government. It is however evident that alone, solar PV and small hydro power have not lived up to the expectation of fulfilling the energy needs of disadvantaged communities in areas that are rich in wind and solar but have not been able to benefit from grid connected electricity.

The need for government to focus attention on small winds has been demonstrated by the stakeholder responses to preliminary interviews for this study conducted in February, 2017. The respondents (from Government (4), networks(2), Consultants (1), and private sector (4) were of the general opinion that wind was a much easier technology to deal with compared to solar PV and yet it has not received much attention from government. Much as government reiterates the use of mini-grids to enhance electricity access in Arid and Semi-arid areas (MOEP 2013), mini-grids do not necessarily respond to the energy poverty that is rampant in communities that do not live in the vicinity of the planned units. It is therefore clear that unless targeted efforts are exercised to promote electricity access in wind-rich areas, it may take a painfully long period for some of these people to enjoy the benefits of having electricity in their households and businesses for improved livelihoods. Such targeted efforts must be evidence based so as to secure government buy-in to provide the necessary leadership in promoting small wind technology. The same evidence could be used to convince development partners who are willing to support the various actors in the diffusion of small winds to do so, by providing a basis of developing bankable project proposals that will contribute the growth of the market, thus improving awareness and stimulating the demand for small wind turbines.

The growth of the small wind installations in Denmark indicate the need for continuous government support. The role of subsidy in accelerating diffusion is demonstrated by the net metering support program for up to 6kW systems introduced in 2010 for household supply with solar, wind and biomass. Phasing out of the support scheme in 2012 in Denmark contributed to a shocking decrease of 41% in sales in 2013 (Conti, 2016). Subsequent introduction of a Feed-in Tariff program in February, 2015 resulted in installation of an additional 323 turbines just after eight months. The need for national market stability instead of intermittent support strategies has also been demonstrated in the Danish market. The Danish certification scheme (BEK 73) is seen as a model to emulate by other markets in the US, China and UK. It is also seen as a driving factor to boost reliable turbines (Conti, 2016). Long-term government support strategies are cited as a key to maturity and independence from financial incentives. The establishment of the Danish Small Wind Turbine Association (DSWTA) in 2009 to promote the supply of wind power to individual homes, SMEs, and small farms seems to have played a key role in the success of small wind systems. According to the Chairman of the Association, (Petersen M.V, n.d) the price of electricity is on a level where the payback time for having the own supply is under 5 years, and new ways of financing small wind turbines in rural areas are coming up.

High standards of small wind turbines have also been achieved thus making small wind turbines a viable alternative to existing technologies such as diesel generators. The Chairman of the Association (Petersen M. V, n.d) recognizes the potential for cooperative ownership of small wind turbines which could provide a springboard for small agricultural societies without access to grid connected electricity or individual home supply where the latter makes economic sense. The Association emphasizes the importance of testing and certification in ensuring that small wind turbines which look very good on paper satisfy the expectations of customers and highlights that, what is written down often fails to be transparent in terms of what the buyer needs to know before making the purchase. The Association points out that a potential barrier could be strong influence from centralized power suppliers who can make it difficult to get the necessary allowance to erect turbines. For the case of Kenya this could be avoided by obtaining the plans for grid extension within the target location of isolated systems.

A Danish committee (CanWEA-2015) comprising manufacturers, blade producers and software consultancy who could be considered as competitors formed a partnership, which in collaboration with Danish Technical University (DTU) Wind Energy achieved a historical milestone through identification of market potential in foreign markets. DTU Wind is a well-established national leading research center in Denmark with over 35 years' track record of pioneering the development of the wind energy industry (Conti, 2016). The success of the Danish small wind turbine sector could be attributed to collaboration of this research centre with Danish small wind turbines manufacturers and blade producers in several projects. Such collaboration has seen state-of-art online software developed exclusively for optimizing siting of small wind turbines in the vicinity of obstacles, including buildings and trees characterizing most of the small wind installation sites.

America which is one of the countries cited as recording success in small wind turbines established a standard (AWEA9.1 2009), whose objective is to provide consumers with a measure of confidence in the quality of small wind turbine products meeting the standard, and an improved basis for comparing the performance of competing products. In September 2008, the American Wind Association introduced a law that allows homeowners and small business people to put up photovoltaic generators and small windmills and any other new sources of widely distributed generation that they can come up with. The Association has also developed Occupational Safety & Health Administration regulations enforceable by law and failure to adhere is subject to fines or jail. This is still non-existent Kenya. Individual motivation to buy in America is driven by the desire to have own renewable energy supply; residence in rural areas; interest in innovative technology and reasonable payback period of 6-10 years. Across the rest of the world the experience in the growth of small wind turbines is varied as demonstrated in Figure 2.

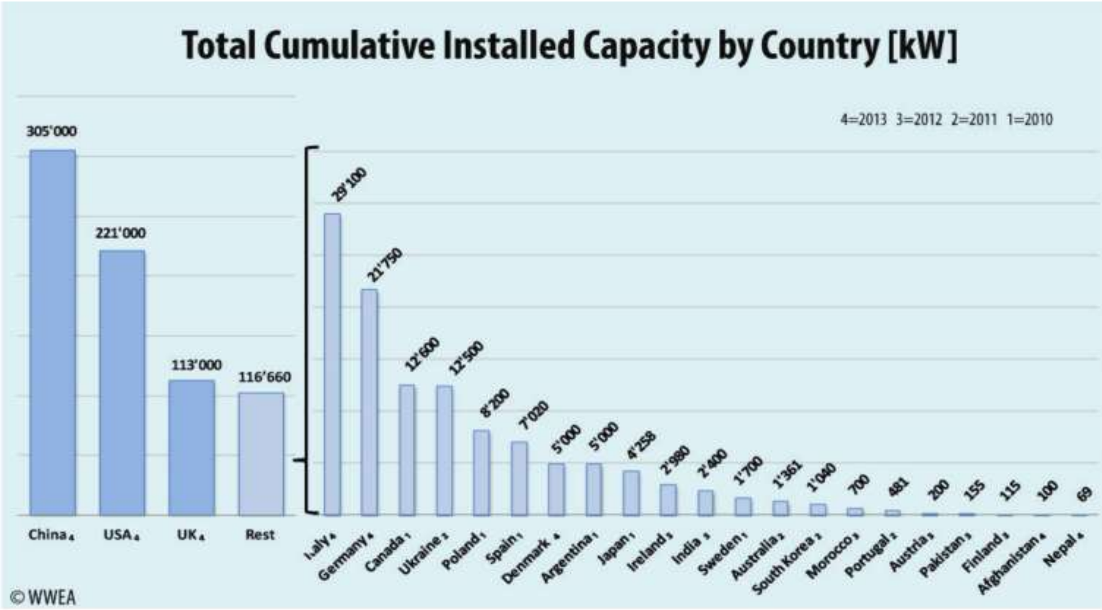

Figure 3: Total cumulative Installed Capacity by Country

Source: (Gsänger & Pitteloud, 2015)

It is in view of the foregoing background that this study therefore seeks to explore the moderating effect of interactive learning on the relationship between innovation systems and technology diffusion, and how this could contribute to accelerated diffusion of small wind turbines as a viable clean energy supply option for Kenyan communities that are not served by the grid.

The Mike Project (1980-83) which studied diffusion and use of technology in industrial settings confirmed the importance of interactive learning between the users and producers (Lundvall, 2012). Lundvall also noted that the quality of the relationship was just as important as the strength. Strong and close relationships were found to hamper innovation leading to a lock-in effect and weak user competence. He observed the relevance of information needs of producer and user in product innovation, noting that learning to communicate (by investing in codes and channels) in addition to building trust and patterns of dominance was key to development of organised markets. Government investment in skills and training is a prerequisite in facilitating technological diffusion (Binz, Truffer, Li, Shi, & Lu, 2012; Goldemberg, 1998; World Bank, 2008).

Jiménez and Sanz-Valle (2011) established a close relationship between organizational learning capability and the process of developing a new product. Organisational learning was found to facilitate the acquisition, sharing and storage of information. The limited number of private industry experts with knowledge related to the diffusion of small wind technologies could be enhanced through integration of renewable energy oriented post graduate curricula in higher institutions of learning. Integration of knowledge development with industry development has the potential to contribute to successful innovation systems in the developing and developed economies. Behavioural features such as high levels of risk avoidance (and fear of blame), high centralisation of authority, and high respect for authority can inhibit creativity of organizations and the transition to an innovation based culture (Vidican *et. al*. 2012). The absence of appropriate networks that provide ample opportunity for interaction, coordination and learning between the driving institutions inhibits the learning process.

Learning from foreign firms with expertise could be instrumental in developing the production capabilities as well as the market potential. It is less common to find multinational firms learning a great deal from their branch plants and in many cases they are more engaged in routine activities `grubby and pedestrian forms of knowledge' (Morgan, 1997). Rosenberg argues that these forms of knowledge-engineering, production and the like often play a `disconcertingly large role' in learning and innovation, and yet they tend to be ignored by scholars and managers in the West. Qualitative studies have suggested that, organizational learning could be used as an intervening variable to increase organizational performance of innovation Kalmuk and Acar, (2015). For instance; Forrester (2000) found a positive relation between innovation and organizational learning, in innovations made by two auto manufacturing firms to decrease costs. In some quantitative studies, the relation between organizational innovation and learning was analysed and a cultural approach was adopted (Hult *et al*., 2004; Hurley and Hult, 1998; Keskin, 2006). Some studies have established a positive relationship between knowledge acquisition and product innovation. Morgan (1997) noted that interactive learning helps organisations develop inimitable skills such as kaizen, which are important for continuous improvement, problem solving and innovation.

Bell (1984) interpreted the process of knowledge transfer as occurring via four specific means: 1) technological artefacts or accompanying manuals; 2) reverse engineering on the part of the recipient; 3) additional transfer in form of formal training sessions by suppliers to recipient and; 4) learning by doing, which increases the competence of practitioners while engaging in the innovative process. Bell also described this as a mentor/apprentice relationship in which both parties benefit from increased interaction (Kristinsson and Rao, 2007). Dynamics, process and transformation are at the centre of the analysis in the evolutionary theory where learning and knowledge are key elements in the change of an economic systems. Innovation systems literature emphasizes learning as a key element of development.

Arrow (1962) demonstrated that the efficiency of a production unit grew with the number of units produced. He argued that this reflected experience based learning. Rosenberg (1982) introduced 'learning by using' to explain increased efficiency over time. Kristinsson and Rao (2007) changed from a linear to an interactive view of learning whereby the innovation process was described as a process of interactive learning which entailed increase in competence while engaging in the innovative process.

The Sappho Project of 1972 (Sussex University) demonstrated that successful innovation depends on the close interaction between firms and customers, suppliers and knowledge institutions and within the firm (across departments) (Lundvall, 2012). The view that innovation is an interactive process has received increasing support. It is now believed that innovation is an interactive process between firms and the basic science infrastructure, between the different functions within the firm, between producers and users at the interfirm level and between firms and the wider institutional milieu. This process should be conceived as a process of interactive learning in which a wide array of institutional mechanisms can play a role (Morgan, 1997; Lundvall, 1992; OECD, 1992). The accelerating pace of innovation caused Lundvall to argue that know-how is the key resource for firms to stay abreast of product and process innovation (Morgan, 1997). It would not be prudent to reduce know-how to the status of a commodity because even if parts of know-how can be sold as patents, and turn-key plants, important parts of knowledge remain tacit and therefore cannot be removed from the human and social context. This makes the labour market for know-how and other elements of tacit knowledge to be collective rather than individual (Morgan, 1997).

It has been suggested that know-how and openness to innovation can be improved through organisational structure and external partnerships (Richter, 2013). This entails establishing special venture units to overcome internal barriers to new ideas. This belief is espoused in the finding that successful business innovation occurs through trial and error (Richter, 2013). The learning process comprises four sub-processes: obtaining information, distribution of information; sharing of information and documentation and storage. The presence of bottleneck problems in production or use of a product makes the agendas of producers change, affecting the direction of their innovation efforts. Everyday experience brings about increase in technical knowledge and gives ideas about the direction that provides solutions.

A case study approach was used by Marika (2015) to conduct a qualitative study on transformation of business models. This was justified by the explorative nature of the research question, the limited amount of research conducted on the subject and the unique characteristics of open innovation and business models in the SME context. Morgan (1997) found it necessary to shift the design and delivery of innovation support to less favoured areas which includes addressing the supply problem (the lack of capacity and mechanisms for diffusing technology) and more importantly the problem of demand. Learning by doing increases efficiency of production operations (Arrow, 1962). Learning by interacting, involving users and producers in an interaction results in production innovations (Lundvall, 1988). If innovation reflects learning and if learning partially emanates from routine activities, innovation must be rooted in the prevailing economic structure. Technical advancement thus takes place where a firm or a national economy is already engaged in routine activities.

2.4 Theoretical Literature Review

2.4.1 Innovation Systems Theory

The innovation process is interactive within the firms and among the different actors in the innovation system. At the level of the firm innovation can take place in any part of the firm(Chaminade & Edquist, 2005). The Systems of Innovation (SI) approach emphasises the fact that firms do not innovate in isolation but with continuous interactions with the other actors in the system (at regional, sectoral, national, and supranational level). Systemic problems in innovation system may manifest themselves as transition problems. These could be the difficulties that arise when firms and other actors encounter technological problems or face changes in the prevailing technological paradigms that exceed their capabilities at a given point in time(Chaminade & Edquist, 2005). They could also be capability problems, linked to the transition problems, such as the limited capabilities of firms, especially small and medium size enterprises (SMEs), that might limit their capacity to adopt or produce new technologies over time(Chaminade & Edquist, 2005). New entrants are characterized by different capabilities compared to incumbents and they may be the socio-economic carriers of innovations by bringing new ideas, products, and processes. Government creation of an environment favorable to the entry of new firms and the growth of successful small- and medium-sized firms is therefore important. Survival and growth of existing firms often require continuous or multiple innovation(Chaminade & Edquist, 2005).

Entrepreneurship and intrapreneurship can be enhanced by supporting changes in the production structure in the direction of new products through: 1) diversification into new products by existing firms eg Japan and South Korea; 2) growth of new firms into new product areas eg. the United States; 3) investing in new product areas in the country eg. Ireland. Addition of new products is important as the demand for new products is likely to grow more rapidly(Chaminade & Edquist, 2005) (if the new products respond to the needs of consumers better than old products). Such growth may be accompanied by job creation and economic growth, and high productivity growth.

Knowledge may be more or less cumulative (new knowledge builds upon existing knowledge). This can occur through learning processes, organizational capabilities, and feedbacks from the market. Cumulativeness may be observed at various levels including the sectoral, technological, firm or local level. At the firm level, characteristics of high technological opportunities, low appropriability and low cumulativeness conditions and a limited role of generic knowledge are commensurate with a Schumpeter Mark I pattern. Still at the firm level, characteristics of high appropriability and high cumulativeness conditions and a generic knowledge base are commensurate with Schumpeter Mark II pattern. The evolution of sector industries may lead to changes in Schumpeterian patterns of innovations whereby a Schumpeter Mark I pattern of innovative activities may turn into a Schumpeter Mark II(Malerba et al., 2007). The early history of an industry, is characterized by rapid changes in knowledge, high levels of uncertainty, and low barriers to entry and new firms are the major innovators and are the key elements in industrial dynamics. Development of the industry and eventual maturity leads to well-defined trajectories of technological change, economies of scale, learning curves, barriers to entry and importance of financial resources in the competitive process. This propels large firms with monopolistic power come to the forefront of the innovation process(Malerba et al., 2007). The converse can happen in the presence of major knowledge, technological and market discontinuities, whereby a Schumpeter Mark II pattern of innovative activities may be replaced by a Schumpeter Mark I. Under these circumstances, a rather stable organisation characterised by incumbents with monopolistic power is displaced by a more turbulent one whereby new firms use the new technology or focus on the new demand. Differences may occur across sectors and similarities across countries in the patterns of innovative activities for a specific sector (Malerba-Orsenigo, 1996). This corroborates the support for the relevance of technological regimes in determining sectoral invariances in the patterns of innovative activities provided that similarity exists across countries with reference to opportunity, appropriability and cumulativeness conditions.

2.4.2 Diffusion theory

Diffusion theory encompasses not only the spread of new objects but also new ideas(Redmond, 2016). Diffusion is compatible with the notion of technology as tools and the notion of technology as organized intelligence. Diffusion is a generalized phenomenon, because is has been studied from such diverse perspectives as developmental economics, rural sociology, medical sociology, cultural anthropology, and marketing among others. Everett Rogers' book, “The Diffusion of innovations, (1962, 1995)”, is a compilation and synthesis of diffusion research and is regarded as the "bible" of diffusion theory. Rogers articulates central tenets of diffusion theory such as normally distributed adoption timing and the five-part segmentation of adopters. The application of the diffusion theory, as described by Rogers were found to be problematic for institutional analyses in two respects(Redmond, 2016): 1) the model of individual behaviour is embedded in the rational choice mode.

While diffusion theory is not explicit about cognitive assumptions, bounded rationality is the underlying hypothesis. Potential adopters are assumed to weigh the costs and benefits of an innovation in a more or less traditional economic sense and from a more or less individualistic perspective. While the rational choice model might prove adequate to understand the diffusion of instrumental innovations, it seems inadequate to explain such consumer phenomena as the spread of electronic pagers among teenagers or the surge of demand for sports utility vehicles among adults. Understanding such phenomena requires an institutional perspective. 2) time lag between the introduction of an innovation and its adoption by a given individual. In diffusion theory, delay in adoption is explained as a lack of awareness of the innovation or by lack of adequate information on which to base the decision to adopt. The diffusion process is equated with communication, and delay is equated with inadequate communication. An institutional perspective, on the other hand, necessitates attention to the binding force of habit and tradition as well as the impact of adoption on social relations. Outright rejection of an innovation is regarded in diffusion theory as unreasoning atavism. However, the possibility of an informed resistance to innovation, based on values, does in fact happen and is compatible with the institutional perspective.

Innovation diffusion theory provides a useful perspective on one of the most persistently challenging topics in the energy field, namely, how to improve technology assessment, adoption and implementation. For this reason, diffusion is growing in popularity as a reference theory for empirical studies of energy technology adoption and diffusion. It provides well-developed concepts and a large body of empirical results applicable to the study of technology evaluation, adoption and implementation. Diffusion theory provides tools, both quantitative and qualitative, for assessing the likely rate of diffusion of a technology, and additionally, identifies numerous factors that facilitate or hinder technology adoption and implementation. These factors include characteristics of the technology, characteristics of adopters, and the means by which adopters learn about and are persuaded to adopt the technology.(Fichman, 1992). Rogers's innovation diffusion theory combines the Concerns-Based Adoption Model, the Technology Acceptance Model, and the United Theory of Acceptance and Use of Technology. Incorporating all three models (Straub, 2016) suggests technology adoption is a complex, inherently social, developmental process; individuals construct unique yet malleable perceptions of technology that influence their adoption decisions. Thus, successfully facilitating technology adoption must address cognitive, emotional, and contextual concerns. the four primary components of diffusion theory include: (a) the innovation itself, (b) communication channels, (c) social system, and (d) time. The four elements interact to describe how individual adoptions combine to represent diffusion. The five attributes of an innovation that influence its adoption include: relative advantage, compatibility, complexity, trialability, and observability(Straub, 2016).

2.4.3 Resource Based Theory

The resource based-view (RBV) of the firm considers firms as bundles of resources and capabilities that when combined in a conscious and systematic way can provide firms with a strategic competitive advantage (Story et al., 2015). Success in firms is related to the extent to which resources and capabilities are aligned to deliver sustainable value-creation strategies together with, and for, its counterparts within a value-creation network (*ibid*). Customer knowledge management (CKM) is believed by scholars as a strategic resource for businesses to improve innovation, facilitate the detection of new market opportunities, and support long-term customer relationship management(Fidel, Schlesinger, & Cervera, 2015). Results also show that CKM has a greater effect than innovation orientation does on improving marketing results. These factors positively improve marketing results, with CKM being the most important factor. There is however inadequate understanding of the role of customer collaboration in the innovation process and innovation orientation in CKM. Customer contact comprises three dimensions called communication time, information richness, and intimacy.

The key success factor is the capability to adapt to customers' changing needs before and throughout service provision. The two main challenges of service individualization are providing proper communication channels and interlocutors to manage the communication process and designing suitable processes to allow the customer to act as a value co-creator. Sharing knowledge through collaborative innovation is important, and research has shown that knowledge management implementation enhances successful innovation activities (Alegre, Sengupta, & Lapiedra, 2011; Nesta & Saviotti, 2005). Organizations can learn, to meet customer demands, to improve performance (Prahalad & Ramaswamy, 2004) through Customer collaboration. Customer collaboration in the innovation process refers to “information and feedback on specific issues” and “extensive consultation with users by means of interviews, focus group and team discussion” (Alam, 2002, p. 255). Knowledge management in this respect includes organizational practices and dynamic capabilities related to knowledge creation, preservation, and transfer. Knowledge creation mainly affects the dynamic capabilities within knowledge management dimension.

The relationship between innovation orientation and knowledge management has been empirically confirmed by Cantner, Joel, and Schmidt (2009), and the presence of adequate CKM policies in firms have been established to facilitate detection of emerging market opportunities as compared to competitors (Fidel et al., 2015). It has further been established that managerial and organizational capabilities strengthen service quality and marketing capabilities(Cruz-Ros & Gonzalez-Cruz, 2015). A direct relationship between service quality and marketing capabilities with firm performance has also been established. Firm that offer services with high customer contact have been known to contribute positively to marketing capabilities firm performance. The converse has also been established to be true. Customer interaction revolves around the transaction rather than the relationship it relies on highly standardized processes with low risk and uncertainty for both the service provider and the customer. In this case, process reliability is the main challenge(Cruz-Ros & Gonzalez-Cruz, 2015).

2.4.4 Competence Based View

Core competence is defined as the knowledge set that distinguishes a firm and provides a competitive advantage over others (C. Prahalad, Hamel, Agha, Alrubaiee, & Jamhour, 1990). Today, firms operate in highly competitive environments, that demands fact action so as to secure their financial situations and market positions(C. Prahalad et al., 1990). The struggle to attain competitive advantage is a continuous process. It requires dependence on internal distinguished strengths to provide more added customer value, strong differentiation and extendibility so as to have reliable “core competences”. Literature review indicates that core competencies are at the base of all competitive advantage (Srivastava, 2005). Core competency is purely about the knowledge on successes or failures in recommending knowledge resources (Banerjee, 2003). “Core” is defined as “the ability to operate efficiently within the business environment and to respond to challenges” (Chen, et al., 2007: 159) and is directly related to performance. For the service industry, the capabilities that receive most attention in the literature are managerial capabilities (Sirmon & Hitt, 2009), organizational capabilities (Hitt, Biermant, Shimizu, & Kochhar, 2001), service quality capabilities (Chen, Tsou, & Huang, 2009), and especially marketing capabilities (Morgan, Vorhies, & Mason, 2009).

However, studies from a systems approach that analyse interactions between capabilities while measuring their joint effect on performance are much scarcer(Cruz-Ros & Gonzalez-Cruz, 2015). From the competence-based view, the focus is on conceptualizing capabilities, measuring their value, and assessing their direct contribution to performance. Despite remaining a dominant theoretical framework among strategy academics, this theory is the subject of criticism. The establishment of a direct relationship between capabilities and performance, researchers often ignores the fact that capability type affects whether the capability–performance relationship is indirect and whether the relationship depends on the firm's endowment and strategic value of other capabilities(Cruz-Ros & Gonzalez-Cruz, 2015)

2.4.5 Dynamic capabilities

Four key capabilities in the service industry include managerial capabilities organizational capabilities, service quality capabilities, and marketing capabilities(Cruz-Ros & Gonzalez-Cruz, 2015). Managerial capabilities are the combination of know-how, values, and attitudes that top management teams accumulate to perform their tasks and make organizational decisions. The importance of managerial capabilities is embedded in the realisation that firm performance depends largely on such capabilities. Managerial capabilities can be both administrative and entrepreneurial. The former refers to the capability of sustaining competitive advantage through planning and long-term vision, including establishing organizational routines to analyze, solve problems, and allocate resources. The entrepreneurial dimension refers to the capability to explore and build new business opportunities that emerge from innovation, creativity, initiative, risk orientation, and entrepreneurial orientation(Cruz-Ros & Gonzalez-Cruz, 2015). Managerial capabilities are a key element to understanding present and future performance. They are the cornerstone of organizational processes and focus on exploring new combinations of resources and capabilities (Collis, 1994; Lado, Boyd, & Wright, 1992). As Barney (1986) points out, managerial capabilities enable firms to acquire valuable resources and new capabilities cheaply and ahead of competitors(Cruz-Ros & Gonzalez-Cruz, 2015). Results show that managerial capabilities contribute to firm performance indirectly through the development of other functional capabilities, namely marketing capabilities and service quality capabilities.

Organizational capabilities refer to organizational structure and process design (Durand, 1997). They are also called integrative capabilities because their main function relates to the rapid, effective deployment of other resources and capabilities the organization possesses (Petts, 1997; Wallin, 1997). Organizational capabilities include specific firm assets such as organizational routines, history and culture (Barney, 1986, 1995, 1997), and the basic principles of organizational design (Henderson & Cockburn, 1994; Nelson &Winter, 1982). In the service industry, buyers use service firms' production processes to differentiate between competing organizations. Organizational capabilities support key functional elements of the service offer such as service delivery methods and processes, marketing capabilities, and service quality capabilities.

Marketing capabilities are a set of complex marketing resources and skills that emanate from the process of knowledge accumulation process and the integration of this knowledge with values and norms deriving from organizational processes from the whole firm. Numerous studies report a positive, significant, direct relationship between marketing capabilities and performance. Firms with greater endowments of marketing capabilities enjoy better performance than competitors do. Marketing capabilities and service quality capabilities directly and significantly affect firm performance. Overall, results corroborate the assertion that the value of a capability depends on its fit with the firm's endowment of resources and capabilities.

Service quality capabilities relate to the set of processes that enable rapid, reliable, secure service provision (Ponsignon et al., 2011) and after-sales processes. Research establishes linkages between service quality capabilities, customer satisfaction, and firms' long-term profitability(Cruz-Ros & Gonzalez-Cruz, 2015). For the case of low customer contact, service quality capabilities directly and significantly affect firm performance, whereas marketing capabilities do not. Because firms establish service specifications before customer contact, customers build expectations that serve as a reference to evaluate service quality. In these cases, process reliability and responsiveness are paramount. Capabilities' relative value and contribution to performance differ depending on a service's customer-contact level.

2.4.6 Interactive learning theory

The interactive learning theory advances a policy perspective based on learning through user–producer interaction in organized markets. Greater emphasis is placed on quality of demand rather than quantity as a basis for strategic intervention in innovation processes(C Edquist, 1999). The theory highlights the domination of innovation processes by producers as a fundamental problem and argues for public intervention to restructure user–producer relationships. It suggests that during periods of rapid technological change governments have a responsibility in overcoming inertia based on vested interests and making organized markets conducive to innovation (C Edquist, 1999). Despite historical neglect of the demand side policies in standard economic analyses of innovation, they remain important and now appear to be gaining greater practical significance in economic policy making(C Edquist, 1999). Technological knowledge is often specific, complex and cumulative in its development. It is specific to firms where most technological activity is carried out, and it is specific to products and processes. Knowledge is also accumulated through experience in production and use ('learning by doing' and 'learning by using)(Dosi & Grazzi, 2009). Foreign firms may facilitate learning by employing local workers, but it is unlikely that much expertise will end up in the hands of domestic firms(Lewis, 2007).

2.4.7 Technology Diffusion and Models

The chain-linked model places a strong emphasis on the important role of the demand side in innovation processes and focuses on product markets and product innovation. The model stresses that management of innovation (including public policy) needs to recognize complementary strengths of different types of firms and seek to coordinate their efforts through creation of viable "chains of innovation" involving linkage structures among firms and other actors(C Edquist, 1999). The Dutch model of establishing R&D centers in the middle of regional learning networks related to a specific technical expertise is a practice that has been experimented by wind turbine or components manufacturers with global presence such as Vestas, Gamesa, and GE(Lewis, 2007).

2.5 Empirical Literature and Research Questions

2.5.1 Technology diffusion and Firm capabilities

Most studies on technology diffusion indicate that the skills and networking capabilities of personnel are key to implementing and adapting new technology(ILO, 2016). This therefore implies that investments in advanced technology must be matched by "adoption capability" which is largely determined by the qualifications, overall tacit knowledge and mobility of the labour force. The production of higher quality products, the incorporation of more sophisticated technologies or the addition of new industry capabilities require employees with higher skills(ILO, 2016). Innovation is particularly about learning, with respect to acquiring and deploying knowledge in strategic fashion(Tidd et al., 2005). Successful adoption and use of an innovation depends on the extent to which users are aware of and know its benefits. Awareness creation of the new products being introduced in the market in therefore important. The ability of the salesperson to understand the product, explain it well to the customers or make a great effort to achieve this is equally important(Kibet & Korir, 2013). Interactive learning within the NIS enables firms to 1)develop strong capacity to compete through innovation 2) become potential sources of improvement in the corporate management of innovation, and in national systems of innovation and 3) benefit more specifically from the technology generated in foreign systems of innovation(Tidd et al., 2005).

Business models can serve as pivotal catalysts of the diffusion of new technologies by overcoming both internal and external barriers (Strupeit and Pahn, 2015). Specifically they have been found to be key in diffusion of sustainable innovations and for enabling a more sustainable use of technologies(Strupeit and Pahn, 2015). Teece (2010) observed that the absence of a well-developed business model makes innovators fail to either deliver or capture value from innovations. He noted the importance of a business model in establishing the logic, data and evidence that delivers value to customers. Research studies on business models in the energy sector is still very young (Richter, 2013). The need for business models beyond the delivery of electricity as a commodity was underscored by Richter (2013). He argued for the proactive encouragement of new regulation for new sustainable business models as a way of giving an impetus for small scale generation. He also noted that this had the potential to reduce the need for grid extension and establishment of large storage capacities.

2.5.2 Firm capabilities and interactive learning

The build-up of knowledge capabilities is blocked by the limited linkage between the private sector and public agencies. For example, in Rwanda, technology research centers and training institutes are marginal partners with respect to the diffusion of biogas digesters(Tigabu, Berkhout, & Beukering, 2014). The innovation process is interactive within the firms and among the different actors in the innovation system. At the level of the firm (Kline & Rosenberg, 1986), innovation can take place in any part of the firm. Firms that possess technology innovation capabilities are likely to play a key role in the functioning of interactions and relationships across networks. This can facilitate interactions and monitoring within relationships via smart communication between systems, assets and people that can also build barriers to entry. Improving insight for innovation requires collaboration with actors possessing desired capabilities. Informal linkages and contacts among firms are also important but more difficult to measure. They involve the transfer of knowledge and know-how, including relationships among users and producers and the role of competitors as both a source for and stimulus to innovation(Dytianquin, 2011). The role of the informal contacts among competing firms and those involved in horizontal and vertical relationships is however not clear. Such linkages are best captured through cluster analyses, firm surveys and other techniques.

While recommending the use of public funds to support fundamental research, development and demonstration, he notes that directing public procurement towards emerging climate friendly technologies can create markets and foster technology pull. International institutions can partly play an important role by facilitating the network between international and local actors, for example, through bilateral initiatives which enhance networks among research institutions, industry-based programs for technology innovation (Suzuki, 2014). The customer side generation is reported to be a potential pillar for the future of energy landscape and are linked with beneficial environmental aspects (Richter, 2013). They can enable buildings to be self-sufficient in electricity supply. Suzuki (2014) argues for the strong need to provide institutional support for accessing information on technologies and enhancing local capacity to handle technologies at the diffusion stage of technology development. He identified government and private sector capacity to be limitation, and recommended the need for firms to take specific action to acquire knowledge and expertise as part of technology diffusion process. He noted that improving firms' capacity to absorb new technologies is essential to enabling them to take full advantage of new low carbon technologies.

2.5.3 Interactive Learning and Technology Diffusion

In horizontal networks of firms, producers deepen their own capabilities by engaging in close, nonexclusive relations with other specialists in their field (learning by interacting). Learning networks are believed to have played a key role in the development of wind turbine technology over time(Lewis, 2007). The wind industry is characterized by small numbers of firms, highly specialized technology, and geographically specific hubs of innovation (often near wind development locations). Literature suggests that learning networks are a crucial determinant in a firm's ability to obtain success with a new technology(Lewis, 2007). The success of the wind sector in Denmark is partly attributed to the presence of innovation systems whose focus was on knowledge transfer between turbine producers, turbine owners and researchers and optimal conditions for learning by interacting. This enabled progressive and successful scaling up and improvement of wind turbines. A contrasting situation is the

United States of America where the industry has been characterized by a lack of collaboration, and actions taken by firms to impede information flow among firms, that inhibited the transfer of hard-won experience(Lewis, 2007).

Capitalizing on the capabilities within the network of actors, may spell the disparity between successful firms and those that struggle to succeed(C. Prahalad et al., 1990). Under current competitive conditions in many sectors, competitive advantage emanates from knowledge, because what firms know and have is hard to copy and requires others to go through a similar learning process(Tidd et al., 2005). Accelerated diffusion is enhanced by availability of appropriate financing mechanisms, owing to the low purchasing power of rural consumers who form the majority of the users of decentralised energy services in areas (Richter, 2013). The availability of attractive financial services greatly improves the growth of the customer base, and while linking local sales and services through established partnerships, enhances cooperation and has the potential to expand outreach. Meier (2014) noted the need for an elaborate distribution mechanism and where this is not feasible, partnering with other well established companies offering complementary products improves the rate and diffusion. This was brought about by the realization that developing a well-established distribution network demands both time and patience. Sustainability is enhanced through development of competitively priced complementary products.

At the advanced stages of technological development, the roles of the private sector including project developers, equity investors, and commercial banks become essential in technology diffusion. At the national level, introduction of a feed-in-tariff program has received greater attention among the developing countries. For one to derive profit from innovation, business pioneers need to excel at product innovation which includes business model design and comprehension of business design options. This further requires one to understand customers' needs and technological trajectories. A successful business model is that which delivers competitive advantage. To achieve this the model must be sufficiently differentiated and inimitable by incumbents and new entrants. Three factors seem to be relevant in checking the imitability of a business model: low replicability of systems and processes, a degree of opacity, and adoption of features that make imitations difficult (Teece, 2010).

2.5.4 Technology Diffusion, Firm capabilities and interactive learning

A central component of understanding the dynamics of innovation as a whole needs to include the nature and effects of learning within policy systems(Mytelka & Smith, 2002). The co-evolution of theory and policy are considered a process of interactive learning(Mytelka & Smith, 2002). Learning feedbacks between marketing, production and development is considered as a basis for the wider process of the innovation process(Mytelka & Smith, 2002). By focusing on the knowledge, learning and interaction among actors that gives rise to "systems of innovation" it is possible to examine the "national or local environments where organisational and institutional developments produce conducive conditions to the growth of interactive mechanisms on which innovation and the diffusion of technology are based"(Mytelka & Smith, 2002). In the Lundvall framework, innovation is conceptualised as learning. This is because by definition, innovation is in the capabilities and knowledges which make up technology.

By ensuring continuous technological innovation and continuous learning that entails deployment of new business consumer marketing models, the decrease in income and profit can be prevented (Kalmuk and Acar, 2015; Stat, 1989; Foster, 1986). This could take the form of market segmentation or new financing models for consumers. The absorption of new ideas is related to the capacity to understand and assimilate new ideas as well as increase in commercial income. Through innovation, information is acquired, shared and transformed or implemented. The sustainability of this process is ensured by a strong relationship between the ability to learn and innovation. It is the process of sharing of information and developing new and common understanding within the organisation by employees that brings about improved innovation.

Innovation depends on an organization's ability to transform, learn and acquire new sources of information (Kalmuk and Acar, 2015; Stat., 1989). Innovations may spread through impersonal marketing methods such as advertising and media, however, it is conversation that spreads adoption. Adoption of new products or behaviours entails some management risk and uncertainty. For this reason, only those personally known and trusted are relied upon to give credible reassurance that adoption of a new product will be met with embarrassment and a feelings of financial loss or wasted time.

2.6 Summary of the Gaps and Conceptual framework

2.6.1 Summary of the Gaps

More work is necessary to come up with “a finer grained analysis of the relationship between knowledge and innovative activities at the sectoral level”(Malerba et al., 2007). There is need for research on RETs improve their research efforts and build up capabilities to better meet the immediate need of RET suppliers/marketers(UNIDO & UNU-Merit, 2014). There is inadequate understanding of the role of customer collaboration in the innovation process and innovation orientation in customer knowledge management. The two main challenges of service individualization are providing proper communication channels and interlocutors to manage the communication process and designing suitable processes to allow the customer to act as a value co-creator. Studies from a systems approach that analyse interactions between capabilities while measuring their joint effect on performance are much scarcer. When establishing a direct relationship between capabilities and performance, researchers ignore the fact that capability type affects whether the capability–performance relationship is indirect and whether the relationship depends on the firm's endowment and strategic value of other capabilities. Measurement of informal networks among researchers (professional associations, conferences, etc.) is rather difficult. Research studies on business models in the energy sector is still very young. The role of the informal contacts among competing firms and those involved in horizontal and vertical relationships is however not clear. More systematic empirical research and empirical work is necessary to understand the interaction and relationship with knowledge and technology taxonomies as well as the indicators (Lundvall 2012). Barriers between disciplines, professions, functional departments and nation states could constitute barriers to innovation. A study of social relationships is therefore necessary to understand innovation at national and enterprise level (Lundvall, 2012).

2.6.2 Conceptual Framework

The conceptual framework for this study will be guided by theories of innovation systems, technology diffusion, resource based view, core competences and dynamic capabilities and interactive learning. Firms and non-firms organizations are the main types of agents in a sectoral innovation system. As mentioned earlier, however, the firm is not always the most appropriate unit of analysis for specific sectors. In fact, in some sectors agents may be examined at a different level of disaggregation, either lower or higher. The network of firms with its alliances and close relationships is often a more appropriate unit of analysis. The difficulty in resolving the demand problem is that it involves modification of the internal routines within the firm to promote technological competence, and the learning ability, which partly involves structuring a firm's organizational and management routines such that they can absorb information on changing markets, new technologies and innovative organizational structures. It is important to recognise that firms are most receptive to, and likely to learn most from, other firms especially from customers, suppliers and competitors (Morgan, 1997; Cookie and Morgan, 1990; Dankbaar, 1994). The design and delivery of innovation support therefore needs to be founded on this important reality. It is for this reason that the key unit of analysis will be the firm. However, other actors in the Innovation system Figure 4 including government agencies, networks and consultants, R&D agencies, technology adopters, development agencies, and representatives of multinational corporations will be contacted in line with the observation by Erica Schoenberger(1991), who reminds us that learning, knowledge-acquisition and other transformative impulses flow in more than one direction(Morgan, 2004). They should not be seen as flowing in just one direction, from centre to periphery, from top to bottom, even if this is the dominant direction. The conceptual framework for this study is depicted in Figure 5.

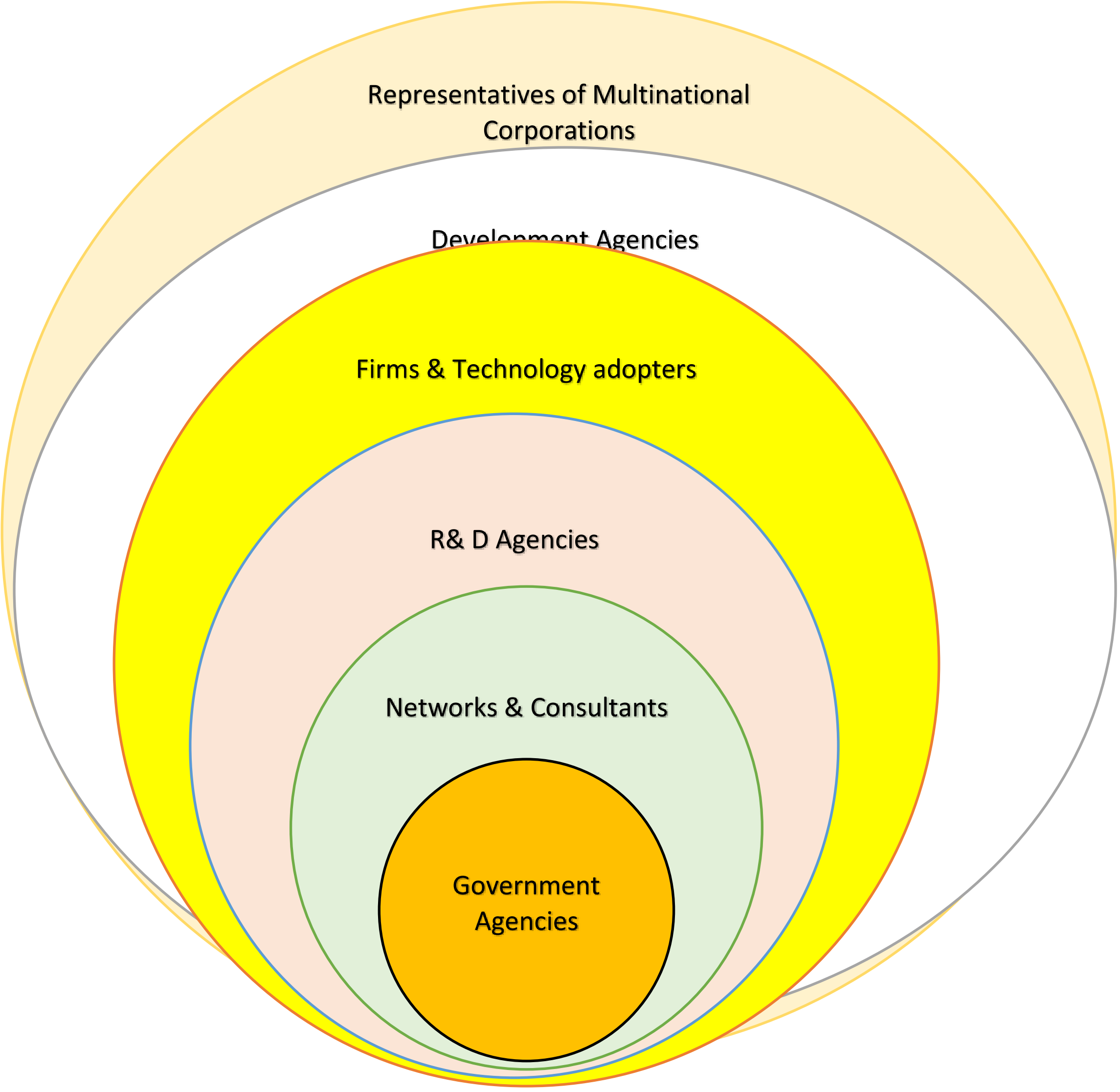

Figure 4: National Innovation System

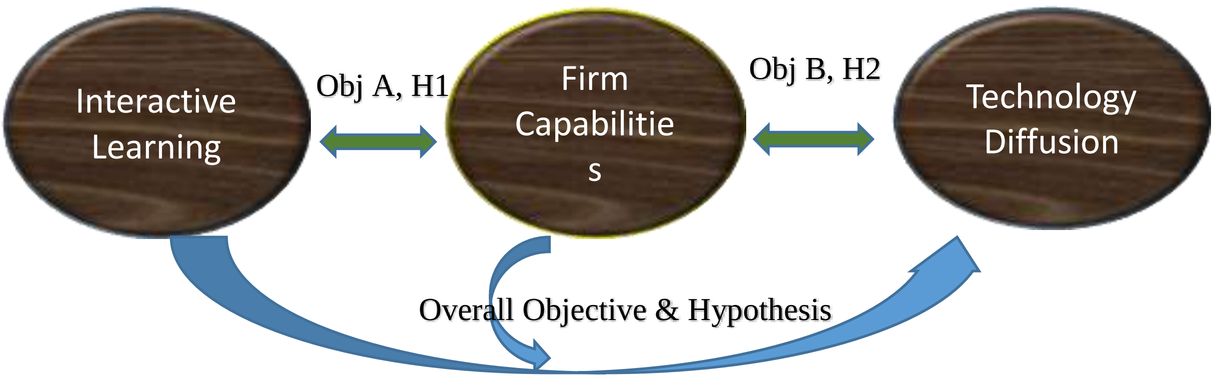

Figure 5: Conceptual Framework

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers the research methodology. Section 3.2 covers the research philosophy; Section 3.3 covers the research design; Section 3.4 covers the study area and target population; Section 3.5 data collection and measurements; Section 3.6 covers data analysis; Section 3.7 covers reliability and validity and Section 3.8 covers ethical considerations.

3.2 Research Philosophy

The design of this study is based on the philosophy of realism which states that what the senses show us as reality is the truth. Objects are believed to have an existence independent of the human mind(Saunders, Lewis, & Thornhill, 2009). Realist evaluation methods prioritise understanding context in explaining variations in outcomes. It begins with skepticism about the generalizability of interventions effects across participants and contexts. It seeks to understand and explain what works for whom, in what ways, in what mechanisms and in what contexts (Patton, 2008). The philosophy of realism is that the reality is quite independent of the mind. Programs are viewed as theories that, once actually implemented, are embedded in open social systems and must be understood with and in the context of the system within which they operate (Patton, 2008). In this sense, realism is opposed to idealism, the theory that only the mind and its contents exist. It assumes a scientific approach to the development of knowledge, an assumption which underpins the collection of data and the understanding of those data(Saunders et al., 2009). The choice of the philosophy of realism is informed by the research onion, Figure 6(Saunders et al., 2009).

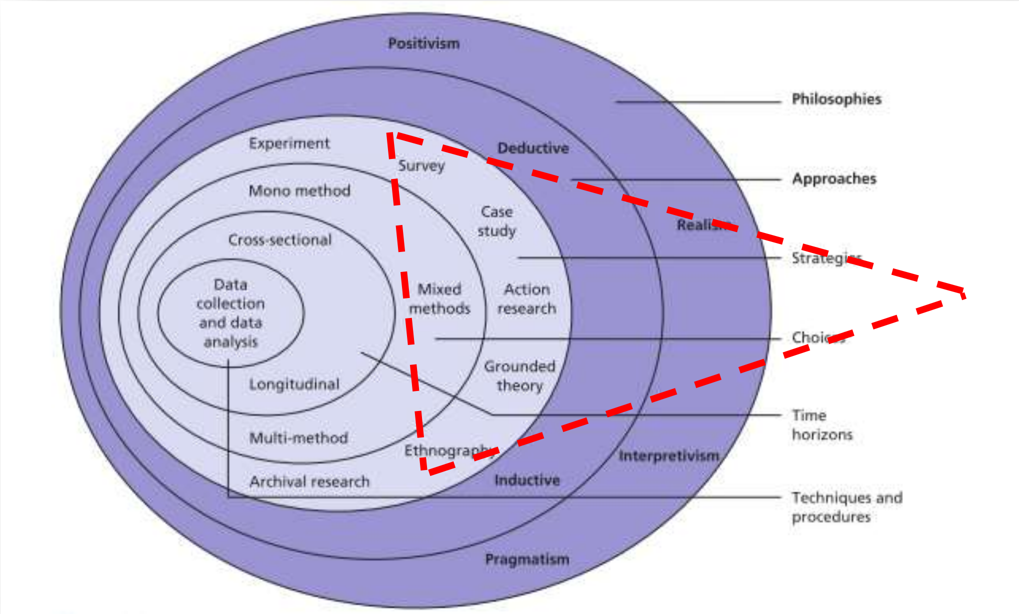

Figure 6: Research Onion

Source:(Saunders et al., 2009)

3.3 Research design

The research philosophy of realism can utilize a range of research designs and so can be quantitative or qualitative, action or outcome oriented and contemporaneous or retroactive. It follows the same logic of inquiry as that underpinning any natural science (Pawson and Tilley, 1997) It starts by framing a theory in abstract terms and is concerned with identification and explanation of regularities. Specific hypotheses are derived from these theories and state where and when regularities should be found. The hypotheses are tested through observations of various kinds and these inform generalisations which may or may not conform to those expected from a theory. Non conformity suggests either some critical weakness in the research design intended to test the theory or that the theory itself needs revision (Pawson and Tilley, 1997). This facilitates development of a realistic theory making sense of the ways in which actions are taken in different contexts and triggering mechanisms that generate complex outcome patterns. Innovation is derived from knowledge acquisition dominated by and organized around the development of realist propositions linking mechanisms, contexts and outcomes (Pawson and Tilley, 1997). Relating this to data collection therefore, the researcher needs to ask well informed questions, placing the subject in a position to give even better informed replies. It therefore follows that the research needs to be organized around the development of CMO propositions, ie. What works for whom in what circumstances (Pawson and Tilley, 1997).

Mixed method designs will be used because one method alone does not provide a comprehensive answer to the research question(Maxwell, 2006). A parallel design commonly used in mixed method designs (Sharlene, 2010) will be applied because it enables triangulation or corroboration of a specific research finding. While the data collection and analysis methods will remain parallel, they will find convergence in the discussion of findings. This will be a primarily qualitative study and as depicted in figure 6, a mixed methods study could utilize combinations of survey, case study, action research or grounded theory. A case study approach will be combined with a survey because a preliminary internet search conducted in March, 2017 established that there are 31 firms in Kenya which deal with small wind turbines. Out of these a comprehensive study of the websites of the 31 firms established that only 3 of them have ongoing activities on small wind turbines. For this reason, a case study approach will be applied to the 3 active firms, a confirmatory survey to the remaining 28. Snowball sampling will be applied to identify any other firms that may be in existence but not necessarily be maintaining websites. Such measurement enhances descriptive understanding of the situation within the small wind turbine industry.

The use of a predominantly qualitative research methodology, is justified by the general lack of understanding of a phenomenon and an associated need for exploratory research to create improved understanding of the underlying causes of human action (Story et al., 2015). Qualitative methods have been accepted in social science and business research because they have been found to be different from a scientific positivist paradigm. Secondary data bases such as Work Package 5 will be consulted to augment the findings from qualitative study.

3.4 Study area and target population

The study area is the business sector for small wind turbine technology sector in Kenya. The target population for this study are business firms currently engaged or established from internet sources as dealing or having dealt with small wind turbine technology at one time or another. Other respondents of the survey will be drawn from the actors in the small wind turbine innovation system as depicted in the concepulisation of the NIS for small wind Turbines, Figure 5. These include Government agencies, Research and Development Agencies, Representatives of multinational Corporations that have an interest in SWT technology, Technology adopters (individuals, communities and institutions), Non-Governmental Organisations; Networks, Consultants with strong knowledge of the SWT industry and Development Agencies with an interest in SWT. Selected companies currently dealing with solar PV such as Powerhive and, Powerpoint will be interviewed to establish why they have not taken up interest in small wind turbine technology. A selection of SWT projects (successful and unsuccessful) will be identified for investigation to determine the interaction of actors in the SWT innovation system who contributed to setting the projects up and whether the interaction has any linkages with the success or failure of the projects. Stratified purposive sampling will be used to identify respondents from business firms, government agencies, institutions and networks, consultancy services, development partners and other actors in the innovation system. Given the small size of the population the whole population will be interviewed. The population of study is presented in Appendix 4 and 5.

The unit of observation will be the firm. The operations of business firms are impacted on by actions of the elements of the innovation system which comprise actors, institutions and networks. The aim is to identify existing capabilities and linkages across a range of actors in the innovation system and the interplay that leads or fails to lead to diffusion of small wind turbines. The views of 2-3 respondents in each organisation studied will be sought where possible for purposes of comparison. Target respondents will be owners of businesses, level of managing director or equivalent as well senior technical staff responsible for renewable energy promotion and development because they are best placed to know the extent of engagement of identified actors in small wind turbine technology. They are also well placed to articulate the opportunities and challenges experienced and are likely to direct the interviewer to the next alternative person if they are unavailable.

Among the end users home owners of individual systems will be targeted because they are likely to be more knowledgeable on how and why the systems came into being as well as the specific benefits accruing and challenges experienced in operating the system. Other members of the household who can talk about the systems will also be identified. For community and institutional use, a spokes-person, operator and maintenance technician will be targeted for interview where available. The choice of respondents is informed by the amount of information that could possibly be provided owing to the position of responsibility as well as the regular interaction with the technology under study. The objective is to realise a purposive sample of respondents who are likely to possess informed opinions on capabilities created through an integrated network of actors, covering a range of contexts(Story et al., 2015).

3.5 Data collection and Measurements

3.5.1 Type and source of data

Qualitative primary data will be collected from actors in small wind turbine technology innovation system. These include business firms, government agencies, Networks, Non-Governmental Organisations, Development agencies, R & D agencies, Consultants, Representatives of Multinational Corporations, technology adopters such as individuals, institutions and communities. Qualitative secondary data will be sourced from the websites of identified actors where they exist, published documents such as previous studies on SWT technology, and databases such as Work Package 5 of the Innovation and Renewable Energy Electrification Project Kenya (IREK) because it may contain information relevant to this study.

3.5.2 Data collection methods

Innovation systems can be measured and assessed on the basis of four types of information flows: 1) interactions among enterprises, primarily joint research activities and other technical collaborations; 2) interactions among enterprises, universities and public research institutes, including joint research, co-patenting, co-publications and more informal linkages; 3) diffusion of knowledge and technology to enterprises, including industry adoption rates for new technologies and diffusion through machinery and equipment; and 4) personnel mobility(Dytianquin, 2011). National innovation systems can be analysed through the use of firm level innovation surveys, whereby firms are questioned on the source of knowledge most relevant to innovation and ranking done by industrial sector.

Four main techniques have been used to measure knowledge flows between the public and private sectors in national innovation surveys(Dytianquin, 2011): i) Joint research activities – the number of joint research and technical activities between firms and universities/research institutes can be obtained from data published by government funding agencies, universities and other sources; ii) Co-patents and co-publications – The number of co-patents or co-publications developed by enterprises in collaboration with a university or research institute can be compiled by analyzing patent records and publication indices. Through the use of computer technology it is possible to scan published patents and science-based articles to gain

In-depth Case studies will be conducted for 3 firms identified through internet sources to be active in SWT technology dissemination; survey of 28 firms identified through the internet as engaged in SWT will be conducted to confirm the intensity of activity; survey of other actors in the innovation system   Information on existing projects will be sourced from business firms, government agencies involved in installation and users of the technology. Qualitative data will be obtained from Business firms using the interview schedule presented in Appendix 1.

In firm-level innovation surveys, sources of knowledge relevant to innovation are important. The source of knowledge about technologies may be customers and suppliers as well as competitors and public institutions. These surveys also gather data on firm R&D expenditures and other innovation inputs as well as R&D-related performance and other innovation outputs as these are the most broad-based sources of information on the general patterns of technological collaboration and information use of firms from the national innovation systems perspective. These data provide a rich source of qualitative information about the interactions of various actors in innovation systems from the firm perspective, including inter-industry activities, alliances with the public sector and personnel movements. According to the Community Innovation Survey (CIS) developed between 1991 and 1993 by the European Commission, sources of information relevant to innovation can be classified into 1) Information sources within the firm or its group; 2)market sources such as suppliers, customers and consultants; 3)public research sources such as universities and government agents and 4)patents, conferencing and meetings (Dytianquin, 2011).

All respondents will be approached independently and qualitative information collected using independent semi-structured interview guides developed for businesses, government agencies, institutions and networks and intermediaries and end-users, to explore the existence of capabilities and linkages that may contribute to or hinder accelerated diffusion of small wind turbines. Government agencies (Ministry of Energy and Petroleum, Rural Electrification Authority, Energy Regulatory Commission, Kenya Power Engineering training school) will be targeted because they influence policy. Members of networks such as Kenya Renewable Energy Association (KEREA), academic institutions such as Jomo Kenyatta University of Agriculture and Technology, development partners such as the Danish Development Agency, DANIDA and United Nations Development Programme (UNDP) will also be contacted. Consultancy firms which have been involved in the study of small wind systems will also be contacted.

Government agencies are likely to provide first-hand information on the interactions with the business sector which can also be used to countercheck information supplied by the firms. Tertiary Institutions are targeted because of their engagement in research and development and exchange of information which is part of interactive learning. Networks such as the Kenya Renewable Energy Association are likely to have good information on the dependent, independent and mediator variables since they are in touch with a broad section of actors in the renewable energy industry and specifically wind development which is the subject of investigation in this study. The businesses are targeted because they play a major role in the diffusion of small wind and they are subject to policy and regulation, they implement specific business models and are in touch with suppliers of small wind turbine technology.

3.5.3 Qualitative methods of data collection

Qualitative samples are usually non-random and purposive or judgmental (Sharlene, 2010). They are governed by clear rules and offer a way of exploring issues, which cannot be expressed by numbers. In qualitative research, the focus is not on trying to estimate things about a population, but in trying to understand or relate the data to theory or ideas. It may involve talking to several people or just one to obtain in-depth information about the subject of study (Greener 2008). "What" and "How" questions will be applied with a view to exploring the specific dynamics or processes of everyday life. "When" and "why" questions will be used to establish the timing of implementation and the reasons behind specific actions respectively. These questions focus on a specific social context, and these processes and dynamics are often difficult to quantify and often remain hidden. Qualitative approaches have the goal of looking at a process, or subjective understanding.

Qualitative data from target respondents will be collected using semi structured interviews (Appendix 1 and 2) which will last one to two hours. The audio recorders will be pretested prior to conducting interviews to ensure functionality and avoid loss of any information. Prior consent for recording the interviews will be sought. A context sheet will be maintained to record non-verbal interventions or interruptions. Rules for referring to individuals will be decided to maintain confidentiality. Repetitions of words and phrases will be edited as appropriate without losing meaning to the message conveyed. Respondent validation will be conducted to check the correctness of the message in the transcripts. Every transcript will be checked against the recording to minimize mistakes that could lead to errors in analysis. Key questions will be prepared in advance. Flexibility will be allowed to avoid overdependence on pre-prepared questions and to allow the respondent to incorporate their own perspective on the issue under discussion for enjoyment and richness. Care will be taken to prevent respondents from veering off the topic. If the respondent happens to tackle questions that come later in the interview schedule, they will be allowed to do so to prevent them forgetting the issue they intended to talk about. If the specific question is adequately addressed it will be skipped, and if not a follow up question will be asked to get more information.

3.5.4 Data Measurements

Table 2: Data Measurements

Variable	Variable Type	Indicators	Unit of measure
Technology Diffusion	Dependent	• Sales of small wind turbines • Number of functional systems • Number of non-functional systems	• Numbers • Numbers • Numbers
Firm Capabilities	Dependent	• Technological capabilities • Marketing capabilities • After sales service capabilities	• Number of staff qualified in mechanical and electrical engineering • Type of technology sold relative to the most recent in the market • Number of outlets • Frequency of attention to problems reported
Interactive Learning	Independent	• Intra firm linkages • Interfirm linkages • Linkages with other actors in the IS	• Frequency of interaction of units within the firm • Frequency of firm interaction with other firms • Frequency of interaction with Government agencies, networks,

			R&D Agencies, NGOs & Development agencies

3.6 Data analysis

At the data analysis stage a comparison of the findings from the qualitative approach will be examined and triangulated with the quantitative approach. The findings of both methods will be thoroughly addressed and where possible integrated. The analysis will strive to be as rigorous and transparent as possible to enable readers understand how the conclusions and findings are arrived at.

3.6.1 Qualitative data analysis:

Interviews will be audio recorded, transcribed, and shared with respondents in order to sense check and ensure that their views are fully represented. Audio typing of the transcript will be done directly. Contextual notes will be made immediately after the interview to shed more light. This will cover personal impressions of the interview, state of mind of the respondent from my own perspective. Transcribing of the interview will be done as quickly as possible within a day of the interview to help in remembering what the respondent was trying to express, because waiting until later may make it very difficult to remember. The collected data will be developed into themes, categories or ideas using deductive (from literature) and inductive (from data) approach. This is essentially inductive research which leans more towards theory building as opposed to theory testing. Coding will be done to find units of meaning within the data which relate to, adds to or amends categories. Constant comparative method will be used to check how the data meanings fit the categories or themes. Researcher summaries will be used to provide further explanatory detail to transcripts or observations.

Thematic coding of the transcripts will be done. The analytical framework in figure will be used to analyse the data. This will enable me to structure the findings in a manner that shows the relationships between the business firm and intermediary capabilities and the complementary end-user capabilities. Validity of the data is supported by Creswell and Miller's (2000) position(Story et al., 2015). This is in view of the qualitative nature of the study. Validity refers to the inferences I draw from the data collected.

This research is considered a ground breaking study that will open up other opportunities for further research. The results of this study cannot be generalised for other similar situations and therefore such challenges are very much in order.

3.7 Analytical framework

Table 3: Analytical Framework

		Formal Firm Capabilities			**Informal Firm Capabilities**		
		Technological	Marketing	After sales service	Technological	Marketing	After sales service
Interactive Learning	Intra firm						
	Inter firm						
	Between firms and other actors in the IS						

Ideal situation

3.8 Reliability and validity

3.8.1 Reliability

Reliability is required of research studies. Transparency and clarity will be ensured so that a reader undertaking the same research using the same methods will obtain the similar results. Triangulation of qualitative approaches will ensure that the results obtained in this study are reliable.

3.8.2 Validity

Face validity will be ensured by using valid methods of research such as active participation of respondents. Methods used to collect data must make sense to any person who may wish to interrogate the study. Construct validity will be ensured by checking the questions to ensure they elicit responses that correspond to the construct being measured. Questions will be made simple and unambiguous. Internal validity will be ensured by inquiring for any other factors that account for the relationship.

3.9 Ethical considerations

The respondents will be given full disclosure of the purpose of study, and my role and status as researcher. Care will be taken not to cause embarrassment, stress, discomfort or pain through acts of omission or commission. Informed consent will be obtained before conducting interviews or discussions. Respondents' decision to take part or not in the study will be respected. All requests for anonymity and confidentiality and use of data will be observed and limits clarified as appropriate. Objectivity will be maintained during data collection, analysis and reporting. Any questions arising from the above ethical issues will be addressed after seeking the Moi University ethical committee.

Misrepresentation will be avoided. My participation as a subject in the research to avoid skewness and bias, in view of my affiliation to the Energy Sector which is at the core of this study. The research will be conducted in a language that is fully comprehensible by the research subjects to ensure respect for persons and where this is not easily attainable, the services of a translator will be sought.

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APPENDICES

Appendix 1: Questionnaire for Business Firms

Interview Date:……………………Time………………………….

Research on Technology Diffusion, Firm Capabilities, and Interactive learning

A. Information about the business enterprise

1. Name of Business Enterprise:……………………………………………………….
2. Date established…………………………………………………………….
3. Designation of the respondent……………………………………………………..
4. Period of service in the firm……………………………………………………..
5. Ownership of business A) Private B)Partnership
6. Size of the firm (No of Employees): a) 1-10 B) 11-20 C) 21-30 D) Over 30
7. Core Business engaged in: In descending order of priority
   a. ……………………………………………………
   b. ……………………………………………………
   c. ……………………………………………………
   d. …………………………………………………....

B. Technology Diffusion

1. How many small wind turbines did you sell in 2017……..2016………2015………2014………2013…………….
2. How many of the systems are functional?
   2017……..2016………2015………2014………2013…………….
3. How many are not functional?
   2017……..2016………2015………2014………2013…………….

C. Firm Capabilities

1. How many of your staff are Mechanical Engineers?
2. How many are electrical engineers?
3. How many outlets do you have for the sale of small wind turbines?
4. What type of SWT technology do you deal with?

5. What is the most common type of SWT in the Kenyan market
6. How many times a year do you offer after sales service?
7. How many requests do you receive for repair for each system sold
8. How do you respond to such requests?
9. How would you describe the strength of your firm capabilities in relation to the diffusion of wind turbines?

D. Interactive learning

1. What is the frequency of communication between staff in your firm in relation to SWT
2. What is the frequency of communication between your firm and other firms selling SWT in one year?
3. How frequently do you interact with:
    a. Government agencies
    b. Network Associations
    c. Research and development institutions
    d. Consultants
    e. Representatives of Multinational corporations
    f. Tertiary Institutions of learning
    g. Development agencies?
    h. What is the sources of your firm knowledge relevant to innovation?

Appendix 2: Interview Schedule for Other Actors in the IS

This interview schedule is meant for actors in the innovation system other than business firms. They include Ministry of Energy, Kenya Power, Rural Electrification Authority, Energy Regulatory Commission, KEREA, DANIDA, UNDP, consultancy firms, Universities,

A. Basics

1. Name of the organisation/firm…………………………………………………….
2. Type of organisation (Government agency, Institution, Network, Consultancy firm, University)
3. Size of the firm (No. of employees) dealing with small wind turbine technology
4. Title/Designation of respondent in the organisation
5. Period of service in the organization

E. Technology Diffusion

4. How many small wind turbines are you aware of that were sold in 2017……..2016………2015………2014………2013…………….
5. How many of the systems are functional according to your knowledge? 2017……..2016………2015………2014………2013…………….
6. How many are not functional according to your knowledge? 2017……..2016………2015………2014………2013…………….

F. Firm Capabilities

7. How many of your staff are Mechanical Engineers?
8. How many are electrical engineers?
9. How many outlets are you aware of for the sale of small wind turbines?
10. What is the most common type of SWT in the Kenyan market?
11. How many times a year do firms offer after sales service to installed systems?
12. How many requests for repair are you aware of per system sold?
13. How do firms respond to such requests?
14. How would you describe the strength of firm capabilities in relation to the diffusion of wind turbines?

G. Interactive learning

4. What is the frequency of communication between firms and staff in your organisation in relation to SWT
5. What is the frequency of communication between business firms and other firms selling SWT in one year?
6. How frequently do you interact with the following in relationship with SWT?
    a. Government agencies
    b. Network Associations
    c. Research and development institutions
    d. Consultants
    e. Representatives of Multinational corporations
    f. Tertiary Institutions of learning
    g. Development agencies?

Appendix 3: Interview Schedule for projects

This interview schedule is meant for projects of SWT

A. Basics

1. Name of the Project……………………………………………………
2. Date Intalled………………………………..
3. Institution responsible for installation (Firm, Government agency, Institution, Network, Consultancy firm, University)
4. No of direct beneficiaries from the electricity supply
5. No of indirect beneficiaries (Describe)
6. Title/Designation of respondent in the organisation
7. Period that you have known about the project

B. Technology Diffusion

8. How many small wind turbines are you aware of that were sold in 2017……..2016………2015………2014………2013…………….
9. How many of the systems are functional according to your knowledge? 2017……..2016………2015………2014………2013…………….
10. How many are not functional according to your knowledge? 2017……..2016………2015………2014………2013…………….

C. Firm Capabilities

11. How many of the project beneficiaries have the knowledge of operating the system?
12. How many the project beneficiaries have the capability of attending to system breakdown?
13. How many outlets are you aware of for the sale of small wind turbines in Kenya?
14. How many types of turbines are you aware of in the Kenyan market?
15. How many times a year does the system break down?
16. What do you do to ensure that it operates again?

D. Interactive learning

17. What is the frequency of communication between firms and project beneficiaries?
18. What is the frequency of communication between business firms and other firms selling SWT in one year?

19. How frequently do firms interact with the following in relationship with SWT?

h. Government agencies
i. Network Associations
j. Research and development institutions
k. Consultants
l. Representatives of Multinational corporations
m. Tertiary Institutions of learning
n. Development agencies?

Appendix 4: Business firms from which Case studies will be drawn

	Company Name	Location	Brief Description of engagement in SWT
1	Craftskills EA Ltd	Nairobi Umoja One – Moi Drive	Has done over 80 wind turbines in Africa (Kenya Tanzania, Rwanda, Cameroon and Nigeria). They indicate that their turbines are secure running machines that are not easily tampered with, and only require greasing after a long while they come with control panels to manage battery charging and halt the turbine during extreme wind conditions. The compant offers training for turbine maintenance on site for or clients. They serve the following categories of customers: 1. Rural Homes: community and individual power -- lighting, security, water pumping, entertainment etc. 2. Market places: lighting, security, cold rooms, welding, shops, salons, battery charging, repair etc. 3. Schools: lighting, security, water pumping, entertainment, labs, staff quarters etc. 4. Industries: lighting, office equipment, machinery etc. 5. Health Facilities: mortuary facilities, lighting, equipment, refrigeration etc. 6. Hotels and Lodges: lighting, cold rooms, security, entertainment communication, equipment etc.
2	Go Solar systems Ltd.	Nairobi	Go Solar is an alternative energy company run by highly qualified professionals that have a strong background in electrical engineering and renewable energy. They have undertaken numerous projects for NGO's, governments of Kenya and South Sudan as well as various public and private institutions in the East African region. The Company indicates that, the AIR-X is by far the world's number one selling small wind turbine. In late 2001, they introduced an entirely new level of technology which previously was only found in today's state-of-the-art mega-watt-class wind turbines.
3	Windgen	Nairobi	WindGen Power provides access to reliable and affordable renewable energy from the wind and sun. Their target customers are the more than 70% of Kenyans living without access to consistent power, with the aim of enabling the offgrid communities gain access to electricity. They are based in Kenya but also have offices in the USA. They have developed 200W, 400W and 1kW Kenyan-made micro wind turbines that are reported to be more durable and cost-effective than imported wind turbines. As a local manufacturer they offer a level of service and

			support for their products that is unmatched by imported energy systems. The turbine design is innovative, robust and manufactured exclusively in Nairobi for the local market. Their wind products include the Twiga Turbine (120W/1.5m diameter), applicable in small homes and businesses.

Appendix 5: Description of other Stakeholders to be contacted

S/No	Stakeholder	Designation of respondent	Engagement in small wind systems
1	EED Advisory Limited	Managing Partner	EED is a consulting Company with good knowledge of the SWT promotion in Kenya. They are currently engaged in developing a proposal for addressing some of the barriers to the development of SWT in Kenya in collaboration with Ministry of Energy and Petroleum and United Nations Development Programme. They have identified key barriers as the incomplete value chain; limited awareness of the technology in the market; limited flexible financing to enable potential users to acquire systems; lack of data. They suggest the need for adventurous money to popularize the technology through demonstrations as a way of creating demand and growing the market, which happens not to be quantified.
2	Rural Electrification Authority (REA)	Head of RE Department	The Rural Electrification Authority is responsible for rural electrification in Kenya. They do not have an active programme for SWT but are still discussing the Government of Poland on how to facilitate local manufacture of turbines
3	MOEP	Principal Renewable Energy Officer	The Ministry of Energy and Petroleum through the Renewable Energy Directorate is mandated to promote the development of renewable energy resources. However it has not given sufficient attention to small wind systems a factor which is assumed to contribute to the low diffusion of the technology. Demonstration systems have been installed by MOEP in Marsabit at Bonaya Godana Memorial school, St. Peters Primary School Magadi, and Turkana Energy centre. Other installations include the hybrid minigrids installed in Habaswein and Marsabit. These are not known to have created awareness in neighbouring communities as people still seem to harbor the impression that the technology is only applicable to institutions but not households. Wind systems for water pumping resonate more with the ASAL communities
4	KEREA	Chairman/ Secretary	The Kenya Renewable Energy Association is a body that brings together all the private sector players in Renewable energy in Kenya. KEREA organises tours to developed countries for interested parties who wish to learn more on RE. Skills are mostly drawn from track proven countries in Asia and Europe.

Interviews to conduct

1. The 28 firms to be surveyed

	Company Name	Location
1.	Kijito	Thika
2	Access:Energy/Steamaco	Nairobi
3	Broadband Communications Ltd (Airtel/Safaricom)	Kalson Towers Nairobi
4	Sollatek	Service centers with qualified engineers in Nairobi (2), Msa, Ksm, Meru, Dar es Salaam, Arusha & Kampala.
5	Energy Outfitters Ltd	Woodvale Groove Westlands, Nairobi
6	PowerGen	Nairobi
7	Chloride Exide	17 branches and over 400 dealers in the region
8	PowerPoint Systems EA Ltd	Nairobi
9	Davis and Shirtliff Solar	31 Branches in Kenya, Head office Nairobi
10	Telesales solar	Nairobi
11	East African Wind Energy Ltd	Nairobi
12	Ecosolar Options Ltd.	Nairobi
13	Greenleads Ltd.	Nairobi
14	Greenmillenia Ltd.	Nairobi
15	Socabelec East Africa Ltd	Nairobi
16	Sun Power Technologies Ltd	Nairobi
17	Adept Pacesetters Ltd	Nairobi
18	Continuum Africa	Nairobi
19	Energy Alternatives Africa Ltd.	Nairobi
20	Solar Home power	Kitale
21	Ecocare International Ltd	
22	Generic Energy Ltd	Nairobi
23	Centre for Alternative Technologies Kenya Ltd.	Outering road Nairobi
24	Properguard systems and electricals	Nairobi
25	Wilson's power and technologies Ltd	Nairobi
26	Plexus Energy Ltd.	Nairobi
27	Green rays Energy	Nairobi
28	Battery World	Woodvale Groove Westlands Nairobi

* Blue: Firms already visited in February 2017

**Orange: Firms whose wbsites had scanty information

Other Actors in the innovation system:

1	DANIDA Kenya		
2	Dedan Kimathi University	Prof. Ndirangu Kioni	Nyeri
3	Devki Steel		
4	EED Advisory	Barasa Murefu	Nairobi
5	ERC	Eustace Njeru	Nairobi
6	GIZ	Walter Kipruto	Nairobi

7	Integral Advisory	Ashington Ngigi	Nairobi
8	JICA Kenya		Nairobi
9	JKUAT	Wind energy project div.	Ruiru
10	Kabete Technical		
11	Kenya Polytechnic University		Nairobi
12	Kenya Power Energy Institute	Dr. Kiplagat	Nairobi
13	Kenyatta University	RE instititute	Juja
14	KEREA	Cliff Owiti	Nairobi
15	KIPPRA		
16	KIRDI	Nathan Bogonko	Nairobi
17	Lighting Africa	Nana Asamoah	Nairobi
18	MOEP	Kihara Mungai Julius Gitonga	Nairobi
19	Nairobi Technical	John Mbugua 0721331706	
20	REA	James Muriithi	Nairobi
21	Simon Batchelor		
22	Strathmore University	Teddy Nalubega	Nairobi
23	Tameezan Gathui	Energy Consultant	Nairobi
24	UNDP	Timothy Ranja	Nairobi
25	University of Nairobi	Jacob Kithinji	Nairobi
26	Wangari Maathai Institute		
27	World Bank	Patrick Balla	Nairobi

Other sites that may be suggested by Business firms

Projects sites

The 7 Projects Highlighted will be surveyed

	Project Name	**Location**	**Company Responsible**
1	Githunguri	Githunguri	Energy Outfitters
2	Kijabe	Kijabe	Energy Outfitters
3	Marsabit	Marsabit	Energy Outfitters

4	Machakos	Machakos	Energy Outfitters
5	Ngong	Ngong	Energy Outfitters
6	Lake Victoria	Kisumu	Telesales
7	Machakos	Machakos	Telesales
8	Kitui 4 Units (Water Pumping)		Kijito
9	Wajir (25 Units (Water Pumping)		Kijito
10	Narok Catholic Based School	Narok	Green Millenia
11	Dr. Leakey School		Green Millenia
12	Safaricom	Various	Broadband Communications
13	Bonaya Godana Memorial School	Marsabit	MOEP
14	St. Peters Primary School	Magadi	MOEP
15	Turkana Energy Centre	Lodwar	MOEP
16	Indupa Primary School	Kajiado	Craftskills
17	Kilonito Primary School	Kajiado	Craftskills
18	Tikoishi Primary School	Kajiado	Craftskills
19	Ben Tagi Home	Eldama ravine	Craftskills
20	Peter Ngui	Kimanza	Craftskills
21	Mrs Raveen Mbithi	Oldonyo Sabuk	Craftskills
22	Maji Mazuri Children's Centre	Kiserian	Craftskills
23	Kathuna Dairy	Nanyuki	Craftskills
24	St. Cecilia Miaani Catholic church	Machakos	Craftskills
25	John Mutiso Mbinda	Machakos	Craftskills
26	Kimumu (Mr Korir)	Eldoret	Craftskills
27	Gichanga Home	Kiserian	Craftskills
28		Malindi	Go Solar
29		Lamu	Go Solar
30		Pate	Go Solar
31		Manda	Go Solar
32		Voi	Go Solar
33		Garissa	Go Solar
34		Tana River	Go Solar
35		Lagdera	Go Solar
36		Kitui	Go Solar
37		Mwingi	Go Solar
38		Baringo	Go Solar
39		W.Pokot	Go Solar
40		Lokichar	Go Solar

Budget

	Specifics	Unit of Measure	UNIT COST (KSh)	Total Units required	Total Cost (KSh)
1	Printing papers	Reams	500	10	5,000
2	Ruled papers	Reams	500	10	5,000
4	Vehicle Hire/Taxi	Trips	10,000	62	620,000
5	Accommodation in field	Nights	15,000	10	150,000
6	Interview transcription	Pages	61	1000 (TBC)	61000
7	Printing and Binding	No of copies	TBA	AAU	TBA
9	Air time for communication and internet	Lump sum	10000	-	10,000
	TOTAL	**To be revised**			**851,000**

Work Plan

			Scheduling																																
			2017									2018												2019											
S/No	**Deliverable**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
1	**1st stay in Denmark**																																		
2	PhD Plan (Excel) - Overall																																		
3	PhD Plan (AAU)																																		
4	Draft Working Paper C for IREK Project																																		
5	Presentation to IKE																																		
6	Presentation to Moi																																		
7	Revised proposal																																		
8	Revised Conceptual framework, Unit of analysis, Variables																																		
9	Tentative structure/outline of the thesis																																		
10	Questionnaire for firms already contacted																																		
11	Questionnaire for firms not yet contacted																																		
12	Schedule and budget for covering the 34 firms																																		
13	Field Work																																		
14	Publishing strategy																																		
15	2nd Stay in Denmark																																		
16	Input for co-authored journal article on size & shape; a disaggregated perspective on SIS in RE pathways																																		
17	1st Journal Paper Conceptual Framework																																		
18	2nd Journal Paper Methodology & Findings																																		

19	Final Working Paper C																																		
20	Draft Journal Article D on Small Wind Turbines in Kenya																																		
21	Book Chapter E on Small Wind Turbines in Kenya																																		
22	Annual Progress Report																																		
23	Phd Thesis Submission																																		
24	Defense of PhD																																		
25	Thesis Online																																		
26	Degree Award																																		