MIDLANDS STATE UNIVERSITY

DEPARTMENT OF DEVELOPMENT STUDIES

TOWARDS GREEN ENERGY SOCIETIES; PROSPECTS AND CHALLENGES OF SOLAR ENERGY DRIVEN DEVELOPMENT IN ZIMBABWE.

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Reg. Number: R124703P

Being a dissertation submitted to the Department of Development Studies, Midlands State University in partial fulfillment of the requirements for the Master of Arts Degree in Development Studies.

November 2019

RELEASE FORM

NAME OF STUDENT ZODWA MUTISI

DISSERTATION TITLE:

TOWARDS GREEN ENERGY SOCIETIES; PROSPECTS AND CHALLENGES OF SOLAR ENERGY DRIVEN DEVELOPMENT IN ZIMBABWE.

DEGREE PROGRAMME **MASTERS OF ARTS IN DEVELOPMENT STUDIES**

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I, ZODWA MUTISI, author of this thesis, do hereby declare that the work presented in this document entitled: "TOWARDS GREEN ENERGY SOCIETIES; PROSPECTS AND CHALLENGES OF SOLAR ENERGY DRIVEN DEVELOPMENT IN ZIMBABWE", is a result of my own research and personal work. I also declare that all sources used in this document have been acknowledged and referenced as listed in the reference list. I hereby testify that this research has never been published or presented in any institution of higher learning besides Midlands State University.

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ABSTRACT

Solar energy is gaining momentum because of myriad challenges the world is facing as a result of climate change. Globally various efforts have been muted to ameliorate the effects of climate change among them, the ongoing international engagements under the banner of United Nation Framework Convention on Climate Change (UNFCCC). Various outcomes of these engagements include among other outcomes, the embrace of renewable energy to both address the bedeviling energy challenges and to reduce greenhouse gas (GHG) emissions. Globally, parties to the UNFCCC have committed to nationally determined contributions (NDCs) which, in many countries have been rooted in addressing the ways nations drive their development especially in the energy sector. The research is premised in the qualitative paradigm with the interest to understand the prospects, development, embrace, and challenges of solar energy in Zimbabwe. It employs an exploratory qualitative research design which draws data from oral interviews in order to fully understand the development and transition from conventional energy driven development towards solar energy driven development in Zimbabwe. The focus of the study is on the main players in the solar energy sector which include solar energy companies in Harare, Ministry of Energy and Power Development (MEPD), Zimbabwe Energy Regulatory Authority (ZERA) and other supporting institutional formations which influence the sector. The research established that, the transition from fossils driven development to renewable energy is spreading rapidly given the challenges conventional sources of energy are facing. In Zimbabwe, solar energy is becoming more indispensable in extending access to electricity energy to about 68% of the population residing in rural areas. Off grid solar energy initiatives are poised to transform the energy situation of the rural majority of the Zimbabwean population. In the same vein, the research also established that the renewable energy sector in Zimbabwe is still littered with structural impediments despite concerted efforts by the responsible institutional formations to make it navigable and lucrative. The research ends by recommending that though solar is highly promising, various structural formations should be put in place to cushion consumers from poor technologies and rogue players in the solar energy sector in order to make the transition sustainable.

ACKNOWLEDGEMENTS

This work was made possible by the immeasurable contributions of various people who selflessly devoted themselves to offer their support in many ways. Firstly I would like to extend my gratitude to my supervisor Mr C. Munhande whose constructive criticism and insights perfected this work. Secondly I would want to thank the contribution of my fiancé Nyasha Phiri for the support and encouragement worth of a closest helper. I am highly indebted to the formidable support of Joseph Mutisi (Baba Mumu), financially and morally. Let me acknowledge the contributions of the Mhazo C. family for the support and hospitality they offered during my studying towards this degree. I would also want to thank my friend Cephas K. Mandirahwe for the inspiration and encouragement to carry on with my studies. Last but not least, I want to thank God Almighty for making me triumph over the barriers which could have made me to give up on this research. I will forever worship you!

DEDICATION

To my favorite first born girls Alisha Munashe Mutisi and Lennah Emily Mutisi. Love you!

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ACRONYMS

AFDB – African Development Bank

AHDR – African Human Development Report

BEM – Balanced Energy Mix

CBS – Conformity Based Assessments

CDM – Carbon Development Mechanisms

COP – Conference of Parties

CO_2 – Carbon dioxide

CSP – Concentrated Solar Power

CUT – Chinhoyi University of Technology

DECRE – Department of Energy Conversation and Renewable Energy

EE – Energy Efficiency

FHI – Family Health International

GHG – Green House Gas

GW – Giga Watts

GEF – Global Environment Facility

$GtCO_2Eq$ – Gigatonnes Carbon dioxide Equivalent

IPCC – Intergovernmental Panel on Climate Change

IRENA – International Renewable Energy Network Agency

IPP – Independent Power Producers

IEC – International Electro-technical Commission

LUC – Land Use Change

MEPD – Ministry of Energy and Power Development

MW – Mega Watts

NDCs – Nationally Determined Contributions

NCCP – National Climate Change Plans

NREP – National Renewable Energy Policy

NGOs – Non Governmental Organizations

NCP – National Climate Plans

PAYG – Pay As You Go

PV – Photo-Voltaic

PPAs – Power Purchase Agreements

RE – Renewable Energy

RET – Renewable Energy Technologies

REA – Renewable Energy Authority

REAZ – Renewable Energy Association of Zimbabwe

SD – Sustainable Development

SE4ALL – Sustainable Energy for All

SSA – Sub Saharan Africa

SAZ – Standards Association of Zimbabwe

TFEC – Total Final Energy Consumption

UNFCCC – United Nations Framework Convention on Climate Change

UNDP – United Nations Development Programme

UNCED – United Nations Conference on Environment and Development

UNEP – United Nations Environment Programme

UZ – University of Zimbabwe

ZBC – Zimbabwe Broadcasting Corporation

ZERA – Zimbabwe Energy Regulatory Authority

ZESA – Zimbabwe Electricity Supply Authority

ZPC – Zimbabwe Power Company

ZETDC – Zimbabwe Electricity Transmission and Distribution Company

ZIMRA – Zimbabwe Revenue Authority

CHAPTER 1

INTRODUCTION TO THE STUDY

1.1 Introduction

The global community is calling for concerted efforts for effective and progressive response to the urgent threat of climate change on the basis of the best available scientific knowledge. The Paris Agreement presents the first of its kind agreement where major economies under the United Nations Framework Convention on Climate Change (UNFCCC) 1/CP21, universally committed to implement the National Climate Change Plans (NCCP). In this agreement 196 countries agreed to a legally binding consensus to hold the increase of the global temperature to below 2^0C and a long term target of 1.5^0C above pre- industrial level (UNFCCC 1/CP 21). The International Energy Agency (2015) observed that; “This agreement is more than just a mere diplomatic settlement between nations, but a historic catalyst that makes the transformation to a low carbon economy inevitable, irresistible and irreversible”, (Wei; 2016 et-al and Energy Agency 2015).This declaration is sending clear indications that the world is moving from conventional fossils energy driven development towards a thriving clean energy driven development. The important steps adopted by the consensus under the Paris agreement came after decades of negotiation in the international arena, marking a paradigm shift in the manner in which the world is going to respond to the urgent threat of climate change with all parties obliged to prepare, communicate and maintain National Determined Contributions (NDCs) which they intend to achieve (Paris Agreement 2015).

The energy sector alone has always been accounting for the largest global greenhouse gas emissions which entails that any meaningful reductions to the greenhouse gas emissions to meet the national determined targets by states under the Paris Agreement, significant changes has to happen in the energy sector of economies. Worldwide, governments have adopted a mix of policies and targets to deploy renewable energy and energy efficiency to expand energy access and provide reliable energy services to meet growing energy demand (1Gigaton Coalition 2017). Research has shown that most of the developing countries still lag behind in extending energy access to their citizens with most of the states resorting to conventional sources of energy to power their development endeavors. The uptake of clean energy in most of the developing countries, Africa specifically, has largely been low due to a myriad of country specific factors. It is without exception that clean energy and energy efficiency projects in Africa are crucial means to reduce the emissions gap and de-carbonizing future energy growth. Whilst the transition from conventional sources of energy to green energy (Renewable energy) has been faced with criticism across the academic divide, political formations and policy analysis cycles, it is the best option available to power the large populations in the rural areas using decentralized energy sources. According to Jose (2008 and Green 2004), analysts have pointed that evaluations for renewable energy initiatives are not yet clear enough to inform policy makers about the best rural energy policy choices. Jose (2008) and (Drennen et al 1996), also stated that; other commentators have characterized the focus on renewable energy focus as a technological "supply push" fostered by the developed world and its institutions. Other authors are also of the view that restricting developing countries energy options to renewable resources while developed countries continue to rely on polluting fossil fuels is to say the least, a disingenuous and inequitable argument (Jose ibid: Lucas et al 2003). All these arguments are crucial and need to be looked at, nevertheless pressing urgent climate threat which is largely attributed to emissions from mainly fossil energy driven development present a strong argument to embrace clean energy options available. In addition, due to high costs and limited budgets, vast populations of people living in the rural areas are likely not going to get access to the grid electricity any time in near future. This also present a good reason for continual development of alternative decentralized power generation options in the energy mix (ibid). Waiting for the grid as the only energy source would see a couple of most rural generations grow up and go by in the dark (Tomlison 2017).

This research is premised in the sustainable development framework and seeks to bring about factors leading to the need to adopt green energy with specific focus on solar. Solar energy is one of the many alternatives that can be utilized to improve the country's energy generation mix that has previously been dominated by thermal and hydropower. Whilst there are many players in distribution of solar energy in Zimbabwe, this research is mainly interested in the solar installations by a private companies. This interest comes from the fact that private companies are considered to be efficient in their operations and mainly employs customer centric models. Some private companies like Zonful energy solar Company have employed inclusive financial models such as the Pay As You Go model (PAYG model) and has sought to improve energy access to the rural areas which largely have no access to the national grid. Whilst most of the solar energy companies uses cash upfront models to distribute solar energy appliances, the pay as you go model allows access to the energy whilst paying in instalments. Cash upfront models widely used by most energy companies in Zimbabwe have proved to be too expensive to the rural poor communities which are isolated from the grid. Efforts to bring clean energy to these communities cannot go without mention.

The study also seek to establish the prospects, challenges and possible ways to overcome the barriers to embracing green energy in Zimbabwe. Despite a lucrative renewable energy resource base, there has been low investment in the energy sector albeit several market studies carried by investors and for investors. With considerable interest shown by investors to invest in the sector, it is baffling that no meaningful investment has happened yet. Zimbabwe records over 300 days of sunshine per year (The Herald 2019 July 15), with a vast solar energy radiation of $20MJ/m^2$/day (Zimbabwe Renewable market entry study report 2017). Mukeredzi (2017), noted that the renewable energy industry in Zimbabwe is littered with structural pitfalls. This has obstructed the development of off grid power which is styled as the quickest way to get clean energy to millions of poor people without electricity. Other bedeviling challenges include policy gaps, high upfront costs for the promotion of the solar energy technologies, lack of clear strategies to harness renewable energy and lack of appreciation of the unsustainability of the conventional energy sources. Also important is lack of quality control measures to ensure that all imported solar technologies are of good quality and durable. This is important especially considering that some of the installed solar technologies have since stopped working properly with some of the solar powered street lights having stopped working completely in cities like Gweru and Harare.

The Kariba South Hydroelectric power plant has been facing challenges of low levels of water in the Kariba Dam which has resulted in the electricity distributing authority rolling power outages which could last up to 12 hours per day in some areas. The problem of low levels of water in the Kariba Dam is not a new problem, it happened before and it is likely going to worsen as it is a climate change problem whose solution is to reduce greenhouse gas emissions through embracing green energy among other ways. The source of the water which feeds into Zambezi River is from Central Africa and currently central Africa is in serious water crisis.

Finding lasting solutions to energy poverty in developing countries and improved access to modern energy technologies means a better and more stable world for all people. Energy solutions for most of the developing countries seem to be largely centralized on one source which is the national grid. Zimbabwe as a state is not spared in this dilemma; as the major player in the electricity energy sector is the state owned Zimbabwe Electricity Supply Authority (ZESA) holdings whose efforts and initiatives are all stuck on the national grid. Research has shown that, Zimbabwe's average access to electricity is standing at 21% in the rural and 80% in the urban areas (Zimbabwe Renewable Energy market entry study report 2017). Penar (2017) noted that the problem of accessing electricity varies across regions and countries; with many North African countries achieving high rates of access and West and East countries lagging behind other regions in extending the grid. According to the survey, 94% urban dwellers have access to the grid and 45% in the rural areas. Most of the Southern African countries falls below the 36- country survey (by Afro Barometer) average of 66%; with Zimbabwe having an average access of 62% (Penar 2017). More importantly, there is also need to look at the implications of access to different areas as some areas might have access without a connection to the grid and some might have a connection to the grid but with occasional and unreliable supply of the electricity.

The research will endeavor to proffer insights and to explore the feasibility of the renewable energy mix with particular focus on solar, which is hoped to help achieve reductions of greenhouse gas to meet the stabilization measure of 2^0C above the pre- industrial level. The research is motivated by the existing fact that; development needs are infinite and planet earth is finite; therefore it is meaningless to pursue infinite needs in a finite space without instituting sustainable solutions.

1.2 Background to the study

1.2.1 Global conventional energy challenges

The energy sector is one critical sector which drives industrialization and subsequently bringing development for all people yet is the largest contributor to global greenhouse gas emissions (robust evidence, high agreement) (Bruckner et al 2014). In 2010, the energy supply sector was responsible for approximately 35 % of total anthropogenic GHG emissions (ibid). Both for industrial and household use, energy bring development through improved standard of living for humanity. Global energy needs are expanding substantially as population grows and economies developing exponentially around the world. Given the incessant need for development and pursuit of different development trajectories; the world need to be cognizant of the reality that it is pursuing infinite development needs in a finite planet earth. There is need to embrace sustainable development in all development endeavors to strike a balance between development and the environment. The available scientific evidence shows that continued use of fossil fuels as the world's dominant energy supply is causing damage to the environment and the release of GHG gases which cause high concentration of carbon in the atmosphere resulting in global climate change. Climate change is having serious effects to the livelihoods and way of life for various regions across the world, especially in developing countries.

Since the mid-1800s, scientists have known that carbon dioxide is one of the main green-house gases of importance for the earth's energy balance. According to the National Academy of Sciences (undated), from 1800 – 2012 measurements of different forms of carbon revealed that the increase of 40% of carbon dioxide in the atmosphere recorded is caused by human activities. Climate change is based on the understanding of how greenhouse gases trap heat. Studies have shown that natural causes alone are inadequate in explaining the recent observed changes in in climate. Natural causes include variations in the climate system such as the sun's output, and in earth's orbit around the sun, volcanic eruptions and internal fluctuations in the climate system. The National academy of sciences report (ibid) also highlighted that calculations using climate models which have been used to simulate what would have happened to global temperature if only natural factors were influencing the climate system yielded very little warming over the 20th Century. Only when models which include human influences on the composition of the atmosphere are consistent with the resulting temperature changes consistent with the observed changes. The rise of the gaseous concentration to 40% by 2012 can only be attributed to human activities which include accelerated global energy consumption. Human activities like oil extraction, burning and extraction of coal (fossil fuels), deforestation and other land uses releases carbon into the atmosphere. This carbon is supposed to be absorbed by the natural processes and because of the overwhelmed capacity of the ecological footprint, the process of absorbing the carbon becomes very low resulting in the bulk of the carbon to be trapped in the atmosphere. It is the trapped carbon in the atmosphere which causes warming. The natural ecological system is overwhelmed by the speed of the human activities release of carbon in the atmosphere and can no longer restore the balance of nature. This imbalance of nature explains the cause of global warming resulting in climate changes being experienced.

The world seems to be firmly entrenched in carbon intensive growth pathway with ever increasing GHG emissions. The 2^{0}C stabilization measure by the UNFCCC 1/CP21 Paris Agreement 2015 seeks to reverse the trend of global emissions by 2020. More than 80% of the global energy is predominantly based on fossils sources (ALPS International Symposium 2012). The intuitive imperative for-goes the fact that, fossils are non-renewable and at some time they will run-out. Green energy resources on the other hand which include energy obtained from the sun, wind, biomass, geothermal and rain among others are sustainable compared to the conventional sources of energy. There is a growing energy transition around the world's energy systems which is likely to affect the way businesses operate and how people power their homes, industries and fuel their cars respectively as a result of the conventional energy challenges. The impacts of the climate change as a result of GHG emissions from fossils driven development endeavors are so huge and invariably diverse to the extent that many regions are under threat. Below is a table which shows the amounts of carbon emissions produced by fossil fuelled power generations per person per day and net amounts of carbon emissions that can be avoided as a result of solar power generation processes.

Table 1.1 1Annual technical potential of solar energy and energy demand (Mtoe)

Region	Minimum technical potential	Maximum technical potential	Primary energy demand (2008)	Electricity demand (2008)
North America	4,322	176,951	2,731	390
Latin America & Caribbean	2,675	80,834	575	74
Western Europe	597	21,826	1,822	266
Central and Eastern Europe	96	3,678	114	14
Former Soviet Union	4,752	206,681	1,038	92
Middle East & North Africa	9,839	264,113	744	70
Sub-Saharan Africa	8,860	227,529	505	27
Pacific Asia	979	23,737	702	76
South Asia	907	31,975	750	61
Centrally Planned Asia	2,746	98,744	2,213	255
Pacific OECD	1,719	54,040	870	140
Total	**37,492**	**1,190,108**	**12,267**	**1,446**

Source: *Govinda R., et al (2011): Johansson et al. (2004); IEA (2010)*

Table 1.2 1 Break down of amounts of CO_2 emissions produced by a fossil fuelled power generation per person per day (kg) and net amounts of CO_2 emissions (kg) that can be avoided per person per day because of the use of solar PV power generation processes.

Base case system CO_2 reduction summary			**Fuel consumption in power generation per person per day (kWh)**	**CO_2 emission factor (Kg)**	**CO_2 emissions produced on power generation per person per day (Kg)**
Fuel type	Fossils				
Electricity	100.00%		2.54	0.435	1.10
Total	100.00%		2.54	0.435	1.10
Proposed case system CO_2 summary (Solar power project)			**Fuel consumption (kWh)**	**CO_2 emission factor (Kg /kWh)**	**CO_2 emission avoided on solar power generation per person per day (Kg)**
Fuel type	Solar energy				
Electricity	100.00%		2.54	0.000	0.0
Total	100.00%		2.54	0.000	0.0
CO_2 emissions lost due allowing for 20% T&D losses while exporting electricity to the grid per day	(kWh)	0.50	2.54	0.435	0.220
CO_2 emission reduction summary Solar photovoltaics power project	**Base case CO_2 emission on fossil fuel power generation per person per day (Kg)**	**Proposed case CO_2 emission per person per day (Kg)**	**Gross CO_2 reduction on solar power generation per person per day (Kg)**	**CO_2 credits transaction fee %**	**Net emission avoided on solar power generation per person per day (Kg)**
Net annual CO_2 emission reduction	1.10	0.220	0.87	2%	0.70

***Source**: Adopted from Sadiq Ali Shah (2012: REA 2011).*

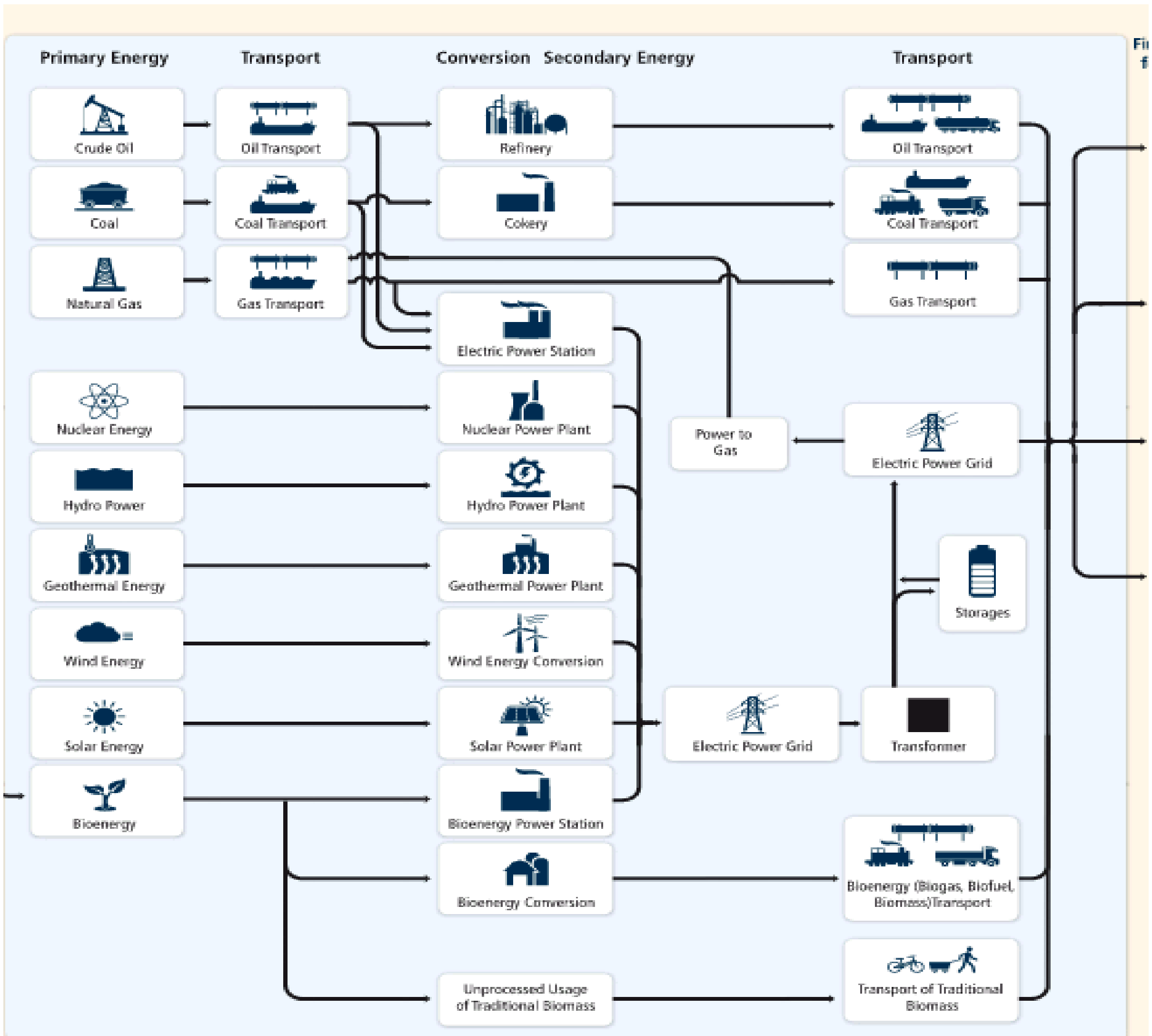
The annual GHG-emissions growth in the global energy supply sector accelerated from 1.7 % per year from 1990 ‑ 2000 to 3.1 % per year from 2000 ‑ 2010 (Bruckner et al 2014). This growth pathway in carbon emissions was despite the UNFCC Kyoto protocol which sought to harness global efforts to reduce GHG emissions. This increase in GHG emissions is more attributable to the rapid global industrialization and population growth relying on conventional sources of energy. The IPCC 2014 report by Brunkner et al (2014) highlighted that, the main contributors to this trend were a higher energy demand associated with rapid economic growth and an increase of the share of coal in the global energy mix. Further to that, the 2018 global carbon dioxide and GHG emissions report by Olivier and Peters, also revealed that the growth path in carbon emissions is increasing (Olivier and Peters 2018). According to the report, The growth in total global greenhouse gas (GHG) emissions resumed in 2017 at an annual rate of 1.3%, reaching 50.9 gigatonnes of CO_2 equivalent ($GtCO_2$ eq) after two years of virtually no growth (0.2% in 2015 and 0.6% in 2016) (ibid) . There is need for the stabilization of GHG concentrations at low levels which requires a fundamental transformation of the energy supply system, including the long-term substitution of unabated fossil fuel conversion technologies by low-GHG alternatives. Options to reduce the energy supply sector GHG emissions include efficiency improvements and fugitive emission reductions in fuel extraction as well as in energy conversion, transmission, and distribution systems; fossil fuel switching; and low-GHG energy supply technologies such as renewable energy (RE), nuclear power, and carbon dioxide capture and storage.

Present greenhouse gas emissions are about 55% higher than in 1990 and 40% higher than in 2000 (Olivier and Peters 2018). The 2017 global greenhouse gas emissions are 55.1 Gt when including the very uncertain land-use-change emissions, which are estimated at 4.2 Gt CO2eq

(Olivier and Peters 2018). According to the Trends in global carbon dioxide report 2018 (ibid), there are five countries and the European Union which emit the largest amounts of GHG together accounting for 63 % globally. China accounts for 27%, the USA for 13%, the European Union (EU) 9%, India7%, Russia 5% and Japan 3%. These countries also increased in GHG emissions in 2017; with India (+2.9%), China (+1.1%), European Union (+1.1%), Russian Federation (+1.0%) and Japan (+0.3%) (except for the United States, where emissions remained constant, at 0.1%)(ibid). This growth pathway in GHG emissions has increased the amount of carbon concentration in the atmosphere causing changes in temperature (with 2017 having an average global temperature (above both land and ocean surfaces) of 0.84 °C above the 20th century average of 13.9 °C (above land, this was 1.41 °C) (Olivier and Peters 2018). Global efforts are calling for the embrace of sustainable energy sources in the global energy mix.

Furthermore, the 2018 emissions gap report revealed that, all GHGs have shown strong growth in the last decades, except for emissions from land use change (LUC), which have remained relatively steady (UNEP 2018). In 2017 alone, the total GHG emissions, excluding emissions from land-use change (LUC), reached a record 49.2 $GtCO_2e$. Including LUC adds another 4.2 $GtCO_2$, bringing the total to 53.5 $GtCO_2e$, which is an increase of 0.7 $GtCO_2e$ (1.3 percent) compared with 2016 (ibid). If the world remain in this carbon emissions growth path, there are going to be very serious effects of climate change as a result of carbon dioxide concentrations in the atmosphere especially in developing countries. The report has also shown that the world is releasing more carbon than it can absorb causing serious threats of climate change. Figure 1 below shows an illustrative global energy supply paths.

Figure 1.1 1 Illustrative energy supply paths shown in order to illustrate the boundaries of the energy supply sector (Adopted from Bruckner et al 2014).



Source: Bruckner et al 2014

1.2.2 Regions under threat

While climate change mitigation is an important aspect of development, less than 10 per cent of the rural population in sub-Saharan Africa has access to modern energy services, with just over 20 per cent of the total population connected to electric power supply (Donald Brown 2012 et al :

AFDB, 2008). Most of the UNFCCC analyses and forecasts on the impacts of climate change which influence most of the global agreements are based on the carbon emissions and forecasting models of global warming mainly cover countries and regions whose relevant data are readily available. Lilsk (2009) observed that this leaves out most of the developing countries and regions particularly Africa due to unavailability of data and trajectories. This is despite the fact that most of the developing countries are susceptible to climate change due to vulnerabilities and in ability cope with the adverse outcomes of the climate extremes. According to Lilsk (ibid), existing adaptation mechanisms and resources under the Kyoto agreement designed to mitigate climate change's effects on Africa (and other developing regions), have been directed at limiting future carbon emissions, rather than addressing the region's vulnerability and lack of resilience to the impacts of climate change on its economies and populations. Africa's concern about climate change is not mainly in terms projections of carbon emission and future environmental damages. It is more about the links between climate change and droughts, desertification, floods, coastal storms, soil erosion, contemporary disaster events that threaten lives and livelihoods, and hinder the continent's economic growth and social progress. In short, whilst mitigation of climate change is equally important, focus should equally be reinforced on addressing the effects of climate change which are so overwhelming and unprecedented to the continent.

Climate change is a visible reality to Africa which does not take complex methods to ascertain, the climate events which unfolded in the region in recent years speaks for themselves. The persistent and amplified droughts in eastern Africa; unprecedented floods in western Africa; exhaustion of rain forests in equatorial Africa; and an increase in ocean acidity around Africa's southern coast are a sure reality of climate change. Vastly altered weather patterns and climate extremes threaten agricultural production and food security, health, water and energy security, which in turn undermine Africa's ability to grow and develop. Lilsk (2009) also noted that climate and environmentally induced disasters have also threatened human security, can induce forced migration and produce competition among communities and nations for water and basic needs resources, with potential negative consequences for political stability and conflict resolution. UNFCCC (undated) reiterated that, Africa is already a continent under pressure from climate stresses and is highly vulnerable to the impacts of climate change. Estimates indicate that one third of African people already live in drought- prone areas and 220 million are exposed to drought each year (ibid).

As a result of global warming, the climate in Africa is predicted to become more variable, and extreme weather events are expected to be more frequent and severe, with increasing risk to health and life (UNFCC undated). This is worsened by the incapacity to cope and adapt due to lack of technology, poor institutions, poor governance and armed conflicts. Further to that, studies have shown that Africa will face increasing water scarcity and stress with a subsequent potential increase of water conflicts as almost all of the 50 river basins in Africa are trans boundary (UNFCCC ibid: Ashton 2002, De Wit and Jacek 2006). Implications of the obtaining water crisis cannot be taken lightly as hydro power is considered to be the main energy source to many African countries. From 2007 to date, Zimbabwe has been experiencing year in - year out abating water levels to its hydro-electric power stations which has negatively affected power generation for the country. The table below shows the impact and susceptibility of the African region to Climate change.

Table 1.3 1 Impacts and vulnerabilities to climate change in Africa

Impacts	Sectoral vulnerabilities	Adaptive capacity
Temperature – Higher warming (x1.5) throughout the continent and in all seasons compared with global average. – Drier subtropical regions may become warmer than the moister tropics. ***Precipitation*** – Decrease in annual rainfall in much of Mediterranean Africa and the northern Sahara, with a greater likelihood of decreasing rainfall as the Mediterranean coast is approached. – Decrease in rainfall in southern Africa in much of the winter rainfall region and western margins. – Increase in annual mean rainfall in East Africa. – Increase in rainfall in the dry Sahel may be counteracted through evaporation. ***Extreme Events*** – Increase in frequency and intensity of extreme events, including droughts and floods, as well as events occurring in new areas.	***Water*** – Increasing water stress for many countries. – 75–220 million people face more severe water shortages by 2020. ***Agriculture and food security*** – Agricultural production severely compromised due to loss of land, shorter growing seasons, more uncertainty about what and when to plant. – Worsening of food insecurity and increase in the number of people at risk from hunger. – Yields from rain-fed crops could be halved by 2020 in some countries. Net revenues from crops could fall by 90% by 2100. – Already compromised fish stocks depleted further by rising water temperatures. ***Health*** – Alteration of spatial and temporal transmission of disease vectors, including malaria, dengue fever, meningitis, cholera, etc. ***Terrestrial Ecosystems*** – Drying and desertification in many areas particularly the Sahel and Southern Africa. – Deforestation and forest fires. – Degradation of grasslands. – 25–40% of animal species in national parks in sub-Saharan Africa expected to become endangered. ***Coastal Zones*** – Threat of inundation along	Africa has a low adaptive capacity to both climate variability and climate change exacerbated by existing developmental challenges including: – low GDP per capita –widespread, endemic poverty – weak institutions – low levels of education – low levels of primary health care – little consideration of women and gender balance in policy planning – limited access to capital, including markets, infrastructure and technology – ecosystems degradation – complex disasters – conflicts

	coasts in eastern Africa and coastal deltas, such as the Nile delta and in many major cities due to sea level rise, coastal erosion and extreme events. –Degradation of marine ecosystems including coral reefs off the East African coast. –Cost of adaptation to sea level rise could amount to at least 5–10% GDP.	

Source: UNFCCC (UNDATED): Boko et al. (2007),: Christensen et al (2007).

Besides Africa other regions like Asia, and Latin America are also equally under serious threat from climate change. Asia is regarded as the largest continent on earth which spreads across various climatic zones. The region has been subject to natural hazards such as the 2004 Indian Ocean Tsunami, the 2005 Pakistan Earthquake, and the 2006 landslides in the Philippines. There is evidence of prominent increases in the intensity and/or frequency of many extreme weather events such as heat waves, tropical cyclones, prolonged dry spells, intense rainfall, tornadoes, snow avalanches, thunderstorms, and severe dust storms in the region (Cruz et al. 2007). Climate change is forecasted to cause mayhem in many sectors which include water resources, agriculture and food security, ecosystems and biodiversity, human health and coastal zones. Many environmental and developmental problems in Asia will be exacerbated by climate change in the near future (UNFCCC undated).

The threats of climate change in Latin America region are also huge and extreme. Torrential rains and resulting floods, including those associated with tropical cyclones, have result in tens of thousands of deaths and severe economic losses and social disruption in the region in recent years, for example in 1998 hurricane Mitch caused 10,000 deaths and severe damage to infrastructure, with Honduras and Nicaragua the worst hit (UNFCCC undated). Northeast

Brazil, on the other hand, is particularly affected by drought and its associated socio-economic impacts (UNFCCC ibid: Charvériat 2000).

1.2.3 Effects of climate change on the electricity energy sector in Zimbabwe

There are two major sources from which electricity is generated in Zimbabwe, which are hydro power and thermal power which uses coal. Climate change is likely to compromise energy development, especially hydropower, which represents 45 per cent of electric power generation in sub-Saharan Africa (Donald Brown et al 2012; AfDB 2008; Bates et al., 2008). The commercial energy sector in Zimbabwe is dominated by electricity while in rural areas fuel wood provides the majority of energy for domestic use. The majority of electricity is produced by the Kariba dam with a theoretical capacity to generate 750 MW (40 per cent of national supply), and the Hwange thermal power station 46 per cent of national supply), Harare thermal power station (5 per cent of national supply), Bulawayo thermal power station (4.5 per cent of national supply) and Munyati thermal power station (5 per cent of national supply) (Brown et al 2012).

Due to the depreciation and out dated technology, Hwange power station has reduced its capacity to generate electricity far below the installed capacity. More so, coal has high carbon emission and continual use will defeat the global efforts of reducing GHG emissions. On the other hand the hydro power is facing challenges owing to the abating water levels in the Kariba Dam year in - year out. According to Brown et al (ibid), Low water supplies since 2007 has also meant that the Kariba hydro-power station is operating at only 87 per cent of its full capacity. To date its generation capacity has further decreased to far below 50% as shown by the ZPC Zimbabwe energy generation mix which reveals that as at 22 August 2019, Kariba hydro power station was generating between 162 - 217 MW against installed capacity of 750 MW (www.zpc.cozw). The UNFCCC have since warned that because of the climate change, Sub

Saharan Africa is likely going to experience water shortage due to intensified desertification, and exhaustion of equatorial forests. This follows that the water which flows into the Zambezi River comes from the river basins in the Central Africa where currently there is water crisis. According to the UNFCCC; studies have shown that Africa will face increasing water scarcity and stress with a subsequent potential increase of water conflicts as almost all of the 50 river basins in Africa are trans boundary (UNFCCC ibid: Ashton 2002, De Wit and Jacek 2006).

1.2.4 Current energy situation and challenges in Zimbabwe

Table 1.4 1 Zimbabwe power supply status as at 22 August 2019

Source/ Power station	Quantity	Comments
Hwange **thermal power station**	349 MW	Against an installed capacity of 900MW. Challenges being ageing technology and lack of maintenance.
Kariba **hydro power station**	162 – 217 MW	Against an installed capacity of 750 MW and a hydro potential of 18500 Gwh per year.
Harare **thermal power station**	16 MW	Carbon intensive energy source which the world if calling for transforming
Munyati **thermal power station**	0 MW	Carbon intensive source
Bulawayo **thermal power station**	20 MW	Carbon intensive source
Imports	0.450 MW	Reminiscent of the economic challenges facing the country as it could not manage to import adequate power to cushion the country from the current energy crisis.

Total power being generated	528 MW	Against a peak demand of 2000MW per day

Source: https//www.zpc.co.zw

Zimbabwe is currently going through energy supply challenges with less than a quarter of the rural population having access to electricity. With an average access of 21% in the rural areas and 80% in the urban areas, the need for alternative sources of energy remains real than ever. This is not withstanding that about 68% of the population in Zimbabwe lives in rural areas (NREP 2019). The electricity sector is still dominated by the Zimbabwe Electricity Supply Authority Holdings, a state owned company which through its subsidiaries, Zimbabwe Power company (ZPC), and Zimbabwe Electricity Transmission and Distribution Company (ZETDC) generates, transmit and distribute all electricity in the country. The hydro power potential is concentrated along the Zambezi River. The country has a gross theoretical hydro power potential of 18500gwh per year. To date less than 20% of this potential has been exploited. (Makonese ibid) Quite a number of sites have also been identified to be of great potential in the generation of hydro power. These include Osborne Dam, Manyuchi dam, Mutirikwidam, TugwiMukorsi dam, Gairezi river, Duru river and Tsanga river (Makonese 2016). The institutional arrangements for the energy sector are dominated by the government which is critical for national energy security. Zimbabwe has also a high political risk profile which makes it unattractive for foreign energy investors.

The grid is currently in poor state owing to lowering of water levels in Kariba Dam and outdated technology for generating power at full capacity at the Hwange power station. This has seen the Kariba South Hydro power station generating 500 MW against installed capacity of 750 MW

(Permanent Secretary MEPD 2019 ZBC tv.). The Hwange power station on the other hand generating 250 MW against installed capacity of 900 MW. This has resulted in the demand of the electricity growing higher than the capacity of the grid. The national electricity demand is about 2.200 MW and only about 1200 MW is generated in Zimbabwe (Brown et al 2012). Little has been done at national level by the state owned sole power supply authority (ZESA) to harness solar energy. Earlier on efforts to harness the clean energy were to be effected through the establishment of a solar power plant in Gwanda through a government funded initiative of an amount of US$5 million in 2016. These efforts ended up scandalous to the extent that courts had to be used to solve the impasse. Up to date, it is not clear whether the project is going to take off or the mismanagement of the funding marked the death of the efforts.

Due to these difficulties, Zimbabwe had to resort to importing electricity from neighboring countries like South Africa and Mozambique. The current economic status has worsened the situation as the government is struggling to service its debt with the South African electricity company (ESKOM). This has seen ESKOM threatening to cut its power supply to Zimbabwe further weakening the grid and the potential of ZESA to meet the electricity demand in Zimbabwe. In efforts to ration electricity, ZETDC has rolled out a power load shedding schedule which has seen widespread power outages which lasts up to 17 hours per day in some areas.

The government has committed to provide adequate and sustainable energy supply through formulating an effective regulatory framework and policies and promoting greater use of new sources of energy, nevertheless the environment for renewable energy revolution seem to be not yet conducive. The enactment of the National Electricity Act in 2002 opened up the energy sector to independent players but still there is no meaningful investment in the sector. In 2012 the National Energy Policy (NEP) was also enacted. The country however lacks a specific policy for renewable energy. There is currently no specific long term targets, clear action plans, timelines and implementation strategies for renewable energy (Mukeredzi, 2017). Mukeredzi (ibid) also noted that there are currently no reporting, monitoring and evaluation frameworks to guide the progress.

The Ministry of Energy and Power Development (MEPD) over sees the whole energy fraternity. The ministry has since committed itself to the development and adoption of solar energy through the set-up of structures to champion the cause. Amongst the structural set-ups put in place include the department of energy conservation and renewable energy (DECRE) Makonese (ibid).This department is a technical department responsible for energy conservation technologies and techniques as well as the promotion of new and renewable sources of energy (ibid). In his research, Makonese also observed that, institutions of higher learning are collaborating with this department in efforts to research on renewable energy technologies and energy efficiency in both industrial and household sectors. These structural developments are in tandem with the government’s 2030 vision of providing sustainable energy solutions to all citizens irrespective of their geographical location. The government’s objectives for Sustainable Energy for All (SE4ALL) BY 2030 agenda are: to achieve universal energy access, renewable energy, and energy efficiency.

According to the Herald of 16 July 2019, the government has approved duty waiver on all solar equipment which is a positive move towards promoting the embracing of solar energy technologies. The government is beginning to realize that solar energy is an alternative that can be utilized to improve the country’s energy generation mix. In 2016, the government indicated that it will ban the use of electric geysers in residential and commercial sectors in a bid to serve 400MW of electricity. The regulation would make it mandatory for all new buildings to use solar water heaters or solar geysers instead of electric geysers. Harnessing solar energy is not only an alternative to improve the energy generation mix, but a cheaper way of extending decentralized energy options for the people of Zimbabwe especially the rural folk. This is relative to the high costs associated with extending the grid to the vast rural population in the country.

1.2.5 General view of renewable energy resources in Zimbabwe

The renewable energy sector is expected not to only lower carbon emissions, but improvement in national energy production and security, employment creation, access to energy, poverty reduction and improved livelihoods without adverse effects to the climate. Zimbabwe's solar energy resource base is made up of vast solar energy radiation of 20MJ/M^2/day with over 300 days of sunshine per year (Herald 15 July 2019). According to (RECP 2015), Zimbabwe has one of the best solar regimes worldwide, with an average high direct insolation of 2,100 kWh/m2 per year and minimum cloud cover. The average solar insolation in the country varies between 5.7 and 6.5 kWh m-2 day (Makonese 2016). The potential for renewable energy for domestic use from solar PV and solar water heaters is huge to about 300 MW (ibid). For commercial purposes, concentrated solar power has been found to be very lucrative for the country especially in the north-west and south- west parst of Zimbabwe because of the abundant solar radiation (S. Ziuku et al 2014).

Hydro power is another renewable source of energy which can be harnessed in Zimbabwe. Zimbabwe is one of countries in the Southern Africa with many dams. The gross theoretical hydropower potential is estimated at of 18500 GWh a year, of which the technically feasible potential is approximated at 17 500 GWh per year (Makonese 2016). In addition, with the completion of the Tokwe Mukosi dam, the hydro power potential increased to an estimate of

18600 GWh per annum; and about 120 MW on internal rivers (mostly in the Eastern Highlands) and dams (Zimbabwe Renewable energy market study report 2017). Very little of this potential has been exploited to date. However, Zimbabwe's water supply is vulnerable to the impacts of climate change and climate variability, also affecting hydro power generation. The table below shows the renewable energy potential for Zimbabwe.

Table 1.5 1 Renewable energy potential for Zimbabwe.

Source	Quantity	Comments
Solar	5.7KWh/m^2/day	North and west regions have the highest radiation
Hydro potential	18500GWh/year–18600GWh/year	More potential might have added with the recent completion of Tokwe Mukosi dam
Bioenergy potential	633 Gwh	Source of power generation is obtained from waste material of sugar cane production
Geothermal	50MW	Identified in 1985, more research is needed to establish the current potential
Wind	3.5m/s	Estimated wind speed. Wind speed varies with regions with other regions like Bulawayo and Eastern Highlands ranging from 4 – 6 m/s

Source: https//www.africa-eu-renewables.org & Zimbabwe renewable energy market study 2017

1.3 Statement of the problem

The use of fossils to generate energy has largely been blamed for serous emissions across the globe. The world is still entrenched in carbon intensive energy pathway which needs to be addressed to ameliorate the impacts of climate change. Conventional energy sources have been blamed for accounting to 30% of the global greenhouse gasses and therefore considered as unsustainable sources of energy.

Zimbabwe's power generation mix is currently dominated by Hydro power and thermal power generated from coal. The latest power generation capacity as at 22 August 2019 according to Zimbabwe Power Company (ZPC) shows that, the hydro power being generated is between 162MW and 217MW respectively (www.zpc.co.zw). This is against the installed capacity of 750 MW at Kariba hydro power station and a hydro theoretical potential of 18500GWh per year in the country (Makonese 2016). Thermal power which accounts for approximately 46% of the national power generation is currently generating a total of 385 MW, with Hwange power station generating 349MW against the installed capacity of 900MW, Harare thermal 16MW, Munyati 0MW, Bulawayo 20MW (ibid). Thermal power being generated in the country adds up to 385MW of power. This added with the total hydro power being generated adds up to 527MW being produced domestically. The country is also importing power worth 0.450MW, giving a total of 528MW of power available in the country against a peak demand of 2000MW per day. This shows that the country is facing serious power shortage owing to varied challenges. The hydro – electric power related challenges include deteriorating water levels at Kariba which is the main hydro power station and lack of meaningful investment in the energy sector. Thermal power challenges relate to ageing technology and poor maintenance of the power stations. With these challenges, hydro power and thermal are becoming unreliable and unsustainable. Solar has always remained a viable renewable energy resource for Zimbabwe with an average high direct insolation of 2,100 kWh/m2 per year and minimum cloud cover (RECP 2015) and an average solar insolation of between 5.7 and 6.5 $kWhm^2$ per day (Makonese 2016). Currently very little of this potential has been exploited at national level. Private companies have come in to play a central role to the exploitation of the vast solar energy through the introduction of various technologies into the energy mix to harness solar energy. With the current efforts by the government to incentivize solar, it is likely that more companies are going to come up adding to the solar technologies available in the country. Very little has been done in analyzing the initiatives of these solar companies' installations of solar technologies. It is in the interest of this study to assess the solar installations by private companies in championing solar energy driven development in Zimbabwe. The study is aware of the pay as you go solar projects by the NGOs but is not much interested in those as they are largely area specific and donor driven. Rather, private companies' PAYG models have attracted much of the attention of this research.

1.4 Research aim and objectives

The main objective of the research is to examine the prospects of solar energy technologies and the contribution of solar towards addressing the power shortages being experienced in the country as well as challenges such initiatives. Special focus is on the private companies distributing solar energy technologies using various distributive and financial models among them the 'pay as you go financial model'.

1. To assess the contribution of solar energy companies in enhancing access to solar energy in Zimbabwe.
2. To assess the role of state institutions in facilitating the development of solar energy in Zimbabwe.

3. To determine the prospects of solar energy as an alternative power generation option in Zimbabwe.
4. To evaluate the efficiency and reliability of solar technologies being distributed in Zimbabwe
5. To assess the challenges in adopting solar energy in Zimbabwe

1.5 Research questions

The research questions will be:

1. To what extent can the adoption of solar technologies help in the alleviation of the current power crisis?
2. How effective is solar as an alternative for power generation in Zimbabwe?
3. What are the main challenges to the adoption of solar energy driven development?
4. How reliable are the solar technologies being distributed in Zimbabwe?
5. What could possibly be done to address the challenges hindering the adoption of solar energy?

1.6 Theoretical framework

This research is premised in the theory of sustainability. The theory is inherently conceptualized in the context of the sustainable development concept. Sustainability can be defined as the capacity to maintain or improve the state and availability of desirable materials or condition over the long term (Harrington 2016). Sustainability can be considered to be as both a concept and theory broader than sustainable development. Sustainable development focuses on human well-being (WCED 1987), while sustainability may be focused on ecosystem or biodiversity status without explicit attention to human well-being (Harrington ibid). The pursuit of sustainability is oriented towards long term treatment of natural resources, social systems, and people in ways that are consistent with human well-being and dynamic system stability. Thus generally sustainability as a theory is intertwined with the sustainable development concept. The Africa Human Development Report 2011 (AHDR) published by UNDP, sub-Saharan Africa on Green economy issues whose theme was "*Sustainability and equity*", echoed the same sentiments about the importance of human well-being as the focus in the pursuit of sustainability. This entails that it is difficult to think of sustainability outside of human well-being. The sustainable development concept has links to renewable energy; however, sustainable development was tightly coupled with climate change at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992. Sustainability is built upon three pillar models such as economy, ecology and society which are considered to be interconnected and relevant for sustainability (Abaka et al 2017). The three-pillar model explicitly acknowledges the integrated nature of the sustainability concept and allows a graphic categorization of sustainability issues. This is however criticized by Brand and Jochum, in 2000 who sees the three-pillar model as diluting a strong normative concept with vague categorization and replacing the need to protect natural capital with a methodological notion of trans-sectoral integration (ibid).

Sustainable development should be understood to be development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). The Bruntland Commission which published a report in 1987 introducing the concept of sustainable development sought to link the issues of economic development and environmental stability. The concept of sustainable development aims to maintain economic advancement and progress while protecting the long term value of the environment. It provides a framework for the integration of environment policies and development strategies (Emas 2015: United Nations General Assembly 1987).

Long before late 20th Century, scholars argued that, there need not be a trade-off between environmental sustainability and economic development (Emas 2015). This could have largely been based on the environment management model of that time. To this end, the ethical model of environment according to Robin (1998), stresses that environment management strategies are driven by the understanding of the human-nature relationship. According to this model, (ibid), all human activities takes place in the context of certain types of relationships between society and nature. Two schools of thought emerged in the environmental ethics; the anthropocentric school of thought and the eco-centric school of thought respectively. The anthropocentric school of thought holds that nature exists only for the benefit of humanity and therefore views nature as a commodity to be exploited solely for the benefit of human beings (ibid). The Anthropocentric view of nature in environment management therefore entails the conservation of the environment which places the interest of human beings first. This paradigm employs the '*think about the environment later stance'* in the pursuit of development. On the other hand, the eco-centric school of thought stresses that nature has intrinsic value which should be conserved. Human beings must use nature wisely to survive. This view seeks to strike a balance between the preservation of the environment and its utilization for survival of humanity (ibid). The eco-centric school of environment management bases on the common scientific concept of the carrying capacity. Put simply, it stresses the need to ensure that development meets the carrying capacity of the given environment. More so, the economic model on environment management stresses that; the economy depends upon the goods and services provided for by the environment. Environment sustainability must co-exist with economic sustainability. This inherent interdependence between the environment and the economy is the field of sustainable development.

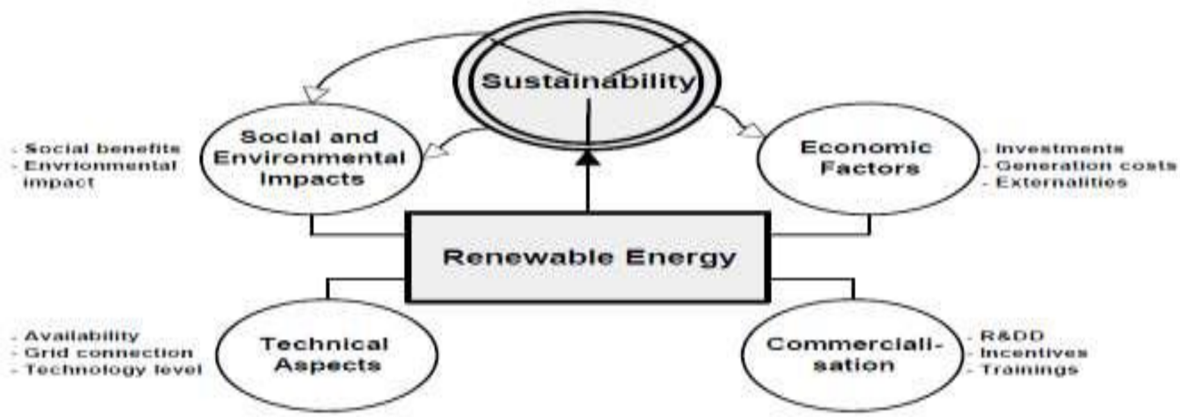
Scientists know that greenhouse gases are responsible for causing global warming because of the capacity of carbon to capture heat. Research has shown that human activities are the only explanation to the ever increasing global temperature that is causing global warming. This increase in temperature is explained by the release of unsustainable amounts of carbon into the atmosphere. The natural process which should regulate nature to maintain the ecological balance is being overwhelmed by the rate at which the world is emitting into the atmosphere. This then follows that the natural system is no longer able to absorb the carbon matching the emission rate, resulting in most of the carbon trapped in the atmosphere, causing global warming. If the world continue in this unsustainable pathway of development, humanity is likely going to face more catastrophic events due to climate change. There is need to institute sustainability in all sectors of policy planning and development.

The overall goal of sustainable development is the long term stability of the economy and the environment. This is only achievable through the integration and acknowledgement of economic, environmental, and social concerns throughout the decision making process (Emas 2015). Strong sustainability recognizes the unique features of natural resources that cannot be replaced by manufactured capital (ibid). Sustainable development concept is a holistic concept which distinguishes sustainability from other forms of policy. In practice, sustainable development requires the integration of economic, environmental and social objectives across all sectors. This is only achievable with governance systems which employs an integrated approach to policy planning and formulation because sustainable development is integrated in nature. Since climate change is a global issue which transcends boundaries of states, an in integrated approach to deal with its impacts and threats is the best option available. The sustainability theory fully comprehends the need to embrace sustainable options available in the energy sector thus it's the best theory that explains the dire need to embrace sustainable options for the transformation of the energy sector.

To foster sustainability is succinctly the core of the global push to green energy societies with roadmaps and projection driving the transformation to 2050. For sustainable development, an energy transition from fossil fuels to cleaner alternatives is needed both in developed and developing countries. Green energy has an important role to meet the energy needs of both the present and future generations in both rural and urban areas across the world. Conventional energy sources have proved to be unsustainable and as well responsible for posing a threat on humanity lifestyles through emissions which are causing climate change.

Recent studies has shown that solar PV is going to contribute significantly to the power generation in Africa in the coming decades. One key ingredient to solar energy technologies is the aspect of sustainability. Abaka etal (2017) observed that, renewable energy seems to be the source of energy to address the present situation of energy in Africa but the effort has been undermined by bad experiences, misinformation, technology push, and consequent negative perceptions. According to Makonese, (2016: Quadir et al 1995), socio-cultural barriers may exist when the technology fails to satisfy the perceived needs of the user and non-integration of the technology with the social structure, and disharmony with prevailing social values and ideology. To date most of the solar technologies have failed to pass the test of sustainability especially the installed technologies in the sub- Saharan Africa. For instance, in Zimbabwe several installed solar technologies have lied idle after they have failed to work for more than five years. In the city of Gweru, the 2014 installed solar powered traffic lights have since stopped working from 2017 to date. Solar powered street light installed technologies have also stopped working for quite some time now. Zvamavande hospital in Shurigwi has a very big solar technology installed which is currently not working and lying idle for years now. This failure to pass the sustainability test has had a negative effect to the embrace of solar technologies. Be that as it may, sustainability should be fostered in both renewable energy and renewable energy technologies, especially solar technologies.

Figure 1.2 1 **Major considerations for developing sustainable renewable energy technologies**



Source: Abaka J.U etal 2017: Hui 1997

1.7 Conceptual framework

The study will focus on solar energy as a panacea to the crippling energy crisis in Zimbabwe. While the main sources of energy in the country are coal and hydro power, they have failed to end the power shortages in the country. Coal which generates thermal power has been placed on the world spot light for causing emissions which are posing global climate threat. The world is moving from fossils generated energy towards sustainable clean energy.

Green energy entails energy that comes from natural sources such as sunlight, wind, water, rain, plants, geothermal heat and algae. These energy resources are naturally replenished which means they are renewable. In this research, 'green energy' and 'renewable energy' are terms which means one and the same thing and are used interchangeably.

Solar energy is energy that is generated from the sun and is typically produced using photovoltaic cells which captures sunlight and turn it into electricity. Solar energy is used to heat buildings, water, provide lighting and cook food and to power household or commercial water pumps among other uses. Solar technologies have become so powerful to power almost everything from small hand held gadgets to entire neighborhoods.

1.8 Significance of the study

The main purpose of this study on: *Towards green energy societies; prospects and challenges of solar driven development in Zimbabwe;* is to initiate and to develop a knowledge base on the available options to save the people of Zimbabwe from the impasse of critical power deficit. This can be achieved through assessing the factors necessitating the adoption of solar energy, assessing the contribution of solar energy companies in Zimbabwe as well as evaluating the prospects and challenges for the adoption of the solar energy. There seems to be a dearth of information on the role being played by private companies to enhance energy access to rural communities and available modern solar technologies. The Zimbabwean society seems to be slow in moving towards embracing solar for household use and for agricultural purposes. All eyes are stuck on the grid. Waiting for the grid as the sole source of energy is not going to help in any near future. There is need to promote off grid energy options to enhance energy access in Zimbabwe.

1.9 Delimitations of the study

Delimitation refers to the characteristics that limit the scope and define the boundaries of the study. Whist green energy is broad to encompass renewable sources such as wind, solar, geothermal, bioenergy and hydro power, this study is mainly interested in solar energy and solar technology installations. It is also imperative to observe that whilst there are many players in the solar energy sector, l this study puts more interest in the solar installations by private companies in Zimbabwe.

1.10 Chapter breakdown

To have a full picture of the transformation to green energy societies and the assessment of solar installations by private companies in Zimbabwe, the chapters were organized as follows:

Chapter 1: outlines the introduction, background to the study, research aim and objectives, statement of the problem, theoretical/conceptual framework and the significance of the study.

Chapter 2: Literature review. The researcher reviewed relevant literature on the problem under research.

Chapter 3: This chapter deals with the methods and tools which were used for data gathering. The research also the usefulness of the methods used to be able to overcome the challenges on each and every method.

Chapter 4: This chapter deals with data presentation, interpretation and the analysis of findings. Results are presented in line with research objectives and questions.

Chapter 5: Conclusions and recommendations are presented in this chapter

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

There is a lot of research which has contributed to the available literature on green energy in various regions of the world; mainly by the United Nations Environment Programme (UNEP) together with its agencies, international research organizations and independent scholars. Most of the literature has been contributed by international energy agencies and organizations like International Energy Agency (IEA), International Renewable Energy Network Agency (IRENA), and Renewable Energy Policy Network for 21st Century (REN21) among others. There seems to be a dearth of information relating to the area of renewable energy in Zimbabwe. While there are a few researches which provide literature on renewable energy, most of it focused on prospects and challenges for renewable energy in Zimbabwe and potential of utilization of solar energy. However, there is scarce information on assessing the current efforts to promote and enhance access to green energy in Zimbabwe especially for rural areas which have low access to the national grid. This research will seek to generate frontiers of knowledge as well as promoting the utilization of solar energy through assessing the contributions of solar energy companies in Zimbabwe.

2.2 Global challenges to renewable energy pathway

2.2.1 Climate change debate

Renewable energy pathway though regarded as the best option the world can take to sustainable energy and increased energy security, has faced varied pitfalls. The pitfalls are conjointly entrenched in the climate change debate as the drive for the transformations to renewable pathway is influenced by the need to reduce global warming. According to Sathaye (2011), RE technologies are providing access to energy, creating employment opportunities in the formal (i.e., legally regulated and taxable) economy, and reducing the costs of energy imports (or, in the case of fossil energy exporters, prolong the lifetime of their natural resource base) in developing counties. Though it could be true, countries are at different levels of development and there continue to be an imbalance of incentives generated out of the RE pathway. Power relationships and vested interests have frequently played a critical role in determining what acceptable science is or is not (Brian, et al 2016). This is also likewise with the acceptable good in the world. Kuhn (1962) also points to an often-repeated process whereby scientific paradigms become locked in and resist challenges to their validity because knowledge production is socially controlled and deeply invested in the political currents of the day. To this end, these dynamics and views to the impasse of climate change has influenced positions with regards to the international negotiations to the technological interventions among other ways to address the issue of climate change. In short, the pathway to RE is deeply rooted in the contentious debate of climate change which has influenced the positions of nation states in the international negotiation forums on issues to do with GHG emissions reduction.

The first bone of contention comes from scholars who subscribe to the notion that climate change is an anthropogenic issue that means it's a natural process which has nothing to do with human activities. Brian et al (2016), has this to say on the climate change debate: "What could have been a fruitful, albeit perhaps contentious debate over decision making when addressing highly complex phenomena has degenerated into a prolonged contest." These contentions are influenced by different political interests which despite the availability of robust evidence of climate change, still presents it as an issue of contention in the international negotiation forums.

Alex Evans and David Steven (2007) even reinforces that, “What’s usually missing on various groups which thinks climate change is happening is a robust account of how human behaviour, identity, values and aspirations fit in of the stories that people tell themselves and each other, which will ultimately determine what they hear when someone says the phrase ‘climate change’ to them, and what they will do about it.” They further argued that; “True, there is some polling data on how various groups think climate change is happening, whether they believe that humans are causing it, whether they believe that it’s more important not to take long haul flights or not to leave their televisions on stand-by. But there is almost no data that can tell us why people give the answers that they do to such questions” (ibid).

These scientific contentions are somewhat strange but important to look at as they contribute to how parties behave in the international negotiation forums with regards to the subject of climate change. Firstly, some have branded the whole climate change issue as a business issue which is poised at enriching those countries which has enough technological sophistications to meet the demands of climate mitigation processes. The arguments from this are presented from the nature through which the solution to the climate problem are sought. Terms like carbon markets, clean development mechanisms (CDM), carbon banking, and carbon stocks are seen to be more benefiting to the countries which are responsible for mass emissions through industrialization at the expense of the low emitting countries. Most of developing countries for instance had to take a position that this whole climate change issue is a maker of the western countries and they should take full responsibility of its effects and that developing countries should also be allowed to emit as they industrialize to also become developed. In recent years, most of the developed countries had to go to developing countries to buy vast lands of forests as carbon stocks. These carbon stocks are later on banked and sold at a much higher premium on the international market which is far much more than the price which the forest was purchased this somehow justifies the arguments towards branding the whole climate issue as a business.

Secondly the climate change issue has been branded as a technological supply push agenda. The history of climate change shows that perceptions of the issue are by no means driven only or even primarily by facts, evidence and rational argument: images, narratives, relationships and values matter at least as much (Alex Evans and David Steven 2007). Politics, business interests and hegemonic battles were part and parcel of climate change even to date. For instance, in the late 1980s saw the emergence of the formidable Global Climate Coalition, a grouping of car, oil and other industrial companies that operated from a base at the US National Association of Manufacturers. This coalition claimed to represent over six million businesses around the world (ibid). The coalition's opposition to the Kyoto Protocol was based on three arguments: that American economic prospects would be damaged, that consumers would suffer from 'skyrocketing' energy prices, and that large developing countries would benefit at the US's expense (ibid: www.sourcewatch.org/index.php?title=Global_Climate_Coalition).Though the Global Coalition for Climate change later on disbanded, some of such perceptions and interests in the international climate negotiation fora are still evident.

Nevertheless, several arguments and perception on the climate change, hegemonic interests pursuits and differences; it is difficult to challenge the goodness or the benefits we have from sustainable energy sources and low emitting technologies. According to (www.ucsua.org: IPCC, 2011), in terms of emissions, burning natural gas for electricity releases between 0.6 and 2 pounds of carbon dioxide equivalent per kilowatt-hour (CO_2 E/kWh); coal emits between 1.4 and 3.6 pounds of CO_2 E/kWh, wind , on the other hand, is responsible for only 0.02 to 0.04 pounds of CO2E/kWh on a life-cycle basis; solar 0.07 to 0.2; geothermal 0.1 to 0.2; and hydroelectric between 0.1 and 0.5. This shows that, renewable energies tend to have much lower emissions than other sources which is safer and healthy for all people. Increasing the supply of renewable energy would replace carbon-intensive energy sources and significantly reduce global warming emissions.

In addition, RE sources can result in increased health. The air and water pollution emitted by coal and natural gas plants is linked with breathing problems, neurological damage, heart attacks, cancer, premature death, and a host of other serious problems (www.ucsua.org). The pollution affects everyone: one Harvard University study estimated the life cycle costs and public health effects of coal to be an estimated $74.6 billion every year (Epstein, 2011). Renewable energy can also provide affordable electricity across world and can help stabilize energy prices in the future. Although renewable facilities require upfront investments to build, they can then operate at very low cost (for most clean energy technologies, the "fuel" is free). As a result, renewable energy prices can be very stable over time. This generally explains the fact that renewable energy pathway is ideal for everyone though the transition to it can have its challenges which needs counterbalance.

2.2.2 Technical and Technological challenges

To have a successful mitigation and sustainable development takes to overcome a couple of challenges. To begin with, there is the challenge of ensuring that people and policymakers learn from scientific and factual evidence and modify their views and current consumption patterns accordingly (world economic and social survey 2013). Even if the world has learnt of the catastrophic effects of the current fossil driven development, the transformation to safer and sustainable energy pathways is proving to be a daunting task. According to the World economic and social survey, it is believed that the technologies for supporting the transition to sustainable energy development are available (ibid). The challenge is how to improve these technologies, how to accelerate cost reductions and achieve meaningful changes, how to integrate them along coherent development paths that respond to specific local and sectoral needs, and how to provide incentives and mechanisms for rapid innovation, diffusions and knowledge-sharing (United Nations, 2011b, p. ix).

Whilst the IPCC special report of 2012 content that, technology is not the main problem, through scenarios where emissions were controlled and the use of renewables increased significantly (IPCC 2012); issues of efficiency and effectiveness of the technologies available still presents a big challenge. The 2011 IPCC special report on renewable energy states that, RE technologies, quantitative indicators include price of generated electricity, GHG emissions during the full lifecycle of the technology, availability of renewable sources, efficiency of energy conversion, land requirements and water consumption (Sathaye etal 2011:Evans et al., 2009). Whilst solar requires no water consumption and ever available, efficiency of energy conversation and land requirements especially for big solar projects still presents a challenge. In developing counties for instance, most of the imported renewable energy technologies have failed to live beyond five years. There are a lot of idle renewal energy technologies. Though other explanations to this can be lack of maintenance and RET technical skills in most developing countries, most of the affordable renewable energy technologies imported by developing countries have low efficiency and durability. This has further strained the positive perceptions towards RETs hence difficult to transform from conventional energy sources to renewable energy.

The UNEP 2012 emissions gap report estimates that the technological potential for reducing emissions between now and 2020 to be anywhere between 14 and 20 GtCO2e, which is enough to accomplish the emissions reductions of 8-13 GtCO2e that still need to be achieved beyond current reduction commitments (UNEP 2012). This scenario takes us to the second important scenario of the technical and technological challenges which is accessibility and affordability. According to IRENA (2018), the costs of renewable energy technologies (RET) have declined steadily, and are projected to drop even more. For example, the average price to install solar dropped more than 70 percent between 2010 and 2017 (ibid). The cost of generating electricity from wind dropped 66 percent between 2009 and 2016 (ibid). Costs will likely decline even further as markets mature and companies increasingly take advantage of economies of scale. Though research has shown that the cost of installing RET has significantly gown down in recent years, it is not reflective of the scenarios of the developing countries which are still struggling to afford the least efficient renewable energy technologies. In addition, in most of the developing countries there are no manufacturing factories or plants for the renewable energy technologies which means most of the technologies have to be imported. Whilst developed countries are at a better footing for implementing RETs, developing countries are still facing challenges.

The third challenge relates to technical barriers. It is true that with the renewable energy pathway, more jobs will be created. For instance in 2016, the wind energy industry directly employed over 100,000 full-time-equivalent employees in the USA in a variety of capacities, including manufacturing, project development, construction and turbine installation, operations and maintenance, transportation and logistics, and financial, legal, and consulting services (American Wind Energy Association (AWEA 2017). In 2016, the solar industry employed more than 260,000 people, including jobs in solar installation, manufacturing, and sales, a 25% increase over 2015 energy standard found that such a policy would create more than three times as many jobs (more than 200,000) as producing an equivalent amount of electricity from fossil fuels (www.ucsua.org:UCS 2009). According to a recent study prepared by UNEP (2008a), RE already accounts for about 2.3 million jobs worldwide and in many countries job creation is seen as one of the main benefits of investing in RE sources (Sathaye et al 2011). In most developing countries however, there are very few skill which relates to the RETs and therefore most of the RETs projects installed or underway in most developing countries (Africa specifically) have created both market and employment opportunity for qualified personnel from developed countries. The situation with this dilemma is worsened by that after installing the RETs technologies, those companies from the developed world will return to their mother countries without leaving any form of after sales service or maintenance provisions for sustenance of their technologies. When the installed technologies failed, there is no one to fix it and before we even know it we are back to where it started before the installation of the RETs. Skills development for renewable energy technologies is very important is for developing countries if ever they are going to be an integral part of the green energy transition.

2.2.3 Policy and institutional challenge

Nation states which are parties to the United Nation Framework Convention on Climate Change Conference on Parties (UNFCCC/ COP), have agreed to various commitments and contributions so far towards addressing the issue of climate change but most of these commitment are not legally binding. Policy issues and institutional set-ups are privy to nation states; whether they comply, rectify or implement it's entirely upon them. Progress has been largely assessed by the IPCC assessments whose reports are then adopted and debated in the climate international negotiation fora. There seems to currently no clear monitoring system and legally binding mechanisms through which nation states are held accountable for not implementing sustainable environmental measures. This has proved to be a daunting task which calls for careful implementation of the sustainable development concept throughout the whole process. Lack of legal and regulatory frameworks, limited institutional capacity and excessive bureaucratic procedures are common challenges in most developing countries.

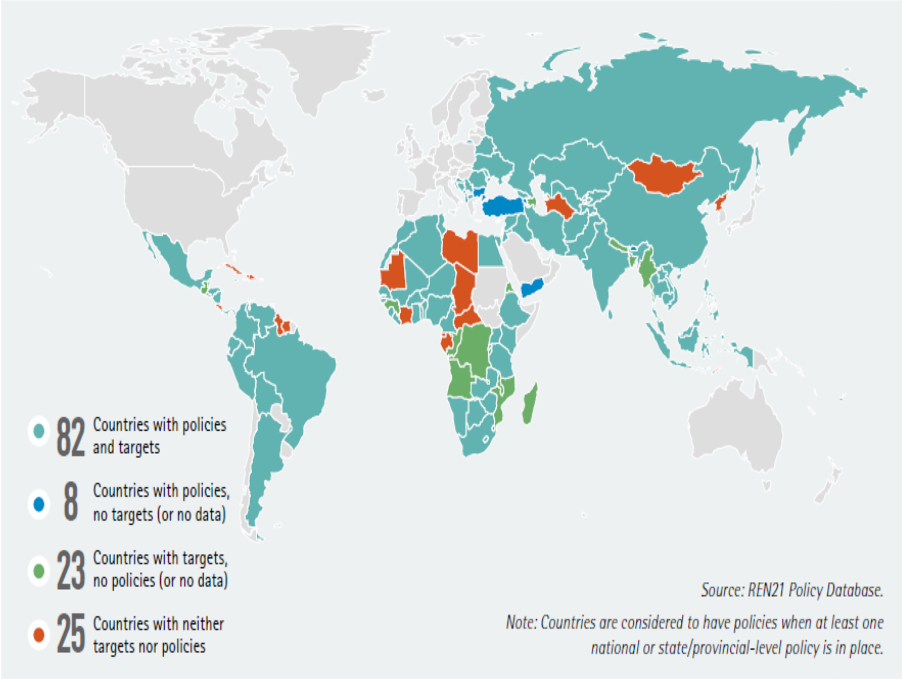
Energy security, sustainable development and wellbeing are currently the energy policy drivers around the world (Prasad S. et al 2019). The IPCC special report on renewable energy sources and climate change mitigation emphasized on the link between renewable energy technologies and sustainable development and has put indicators such as energy access, energy security, and efficiency of energy conversion, land requirements, water consumption and the price of the generated electricity as guides to sustainable renewable energy pathway (Sathaye et al 2011). Mainstreaming the sustainable development concept into the policy framework of nation states has become the mantra of policy formulation processes among states yet a very complex principle because of its integrated nature. Public support of RE at the generic level does not necessarily translate into active support and acceptance of RE at the local implementation level, where RE deployment is often associated with direct impacts for individuals and groups (IPCC 2011: Painuly, 2001; Bell et al., 2005; Wustenhagen et al., 2007). Integration of RE policymaking and deployment activities in sustainable development (SD) strategy frameworks implies the explicit consideration of inter-linkages (synergies and trade-offs) with the three pillars of SD and related SD goals. In this way, RE policies as well as project planning, construction and operation are rooted in the specific social, economic and environmental context and support the strategic development objectives of a given society or project location.

Socio-cultural barriers or concerns with respect to the deployment of RE and its potential SD tradeoffs have different origins and are intrinsically linked to societal and personal values and norms (Sovacool and Hirsh, 2009). Such values and norms affect the perception and acceptance of RE technologies and the potential impacts of their deployment by individuals, groups and societies (GNESD, 2007b; Sovacool, 2009; West et al., 2010). The challenge of policy in this regard is to integrate these three components or pillars of sustainable development which are: social concerns, economic implications and environmental sustainability into the policy. Country-wide policies often start with the adoption of a fixed long-term target for sustainable energy modernisation followed by an overhaul of regulations and policies. The IRENA report on towards 100% renewable energy also indicated that; thus far, countries most directly vulnerable to the impact of climate change, such as small island states, have taken the lead in committing to 100% renewable energy (IRENA 2019). In November 2016, at COP22 (the 2016 United Nations Climate Change Conference) in Marrakech, Morocco, the 48 members of the Climate Vulnerable Forum committed to meet 100% domestic renewable energy production by 2050 at the latest (ibid). Many of the national 100% renewable energy commitments and policies originate from community-led local or regional initiatives advancing comprehensive sustainability and development goals. Local-level policy development can shape and drive national governments to remove legal and institutional barriers. Conversely, local renewable energy policy-making processes are enhanced when the national government adopts an enabling framework including commitments to a clear, time-bound target.

To enable a successful transformation to 100% renewable energy, ambitious targets supported by stable, long-term and reliable policies are of crucial importance. Targets according to 1Gigaton Coalition report (2017) are an important tool used by policymakers to outline development strategies and encourage investment in energy efficiency (EE) and RE technologies. Government targets for renewable energy provide a high-level important signal of commitment to citizens, investors and other stakeholders (IRENA 2019). The complexity of the energy system and its increased integration across sectors require any renewable energy target to be well-defined in terms of scope and boundaries in order to provide transparency and legitimacy hence reducing the risk of greenwashing. A credible and clear target is further important as a foundation for policies and planning.

Policy is also critical for incentivizing green energy. Policy mechanisms to incentivise renewable energy deployment include Renewables Portfolio Standards (RPSs), public tenders or auctions, feed-in policies, net metering/billing policies, fiscal incentives and grants, mandates, emission standards, and technology standards (IRENA 2019). Renewables portfolio standards according to IRENA are mechanisms which encourage electricity producers within a given jurisdiction to supply a certain minimum share of their electricity from designated renewable sources (ibid). At least 103 countries addressed EE and RE in the same government agency, including at least 79 developing and emerging countries, while an estimated 81 countries had policies or programmes combining support to both sets of technologies, including approximately 75 developing or emerging countries (1Gigaton Coalition 2017).The figure below shows the state of global RE policy:

Figure 2.1 1 Developing and emerging countries with RE policies and targets by end 2016



Source: *Third Report (2017), The 1Gigaton Coalition: REN21 Policy data base*

2.2.4 Financial barriers

Despite the six fold increase in global investments in renewable energy in the period 2004 - 2011, investments leading to sustainable development still fall far short of what is needed (world economic and social survey 2013). The IPCC 2011 report noted that for developing countries, the associated costs are a major factor determining the desirability of green energy to meet increasing energy demand, and concerns have been voiced that increased energy prices might endanger industrializing countries' development prospects (Sathaye et al 2011: Mattoo et al., 2009). Prices for RETs have lowered and predicted to go even lower in years to come but most developing countries still face financial barriers in accessing and installing renewable energy technologies with lack of financial capacity being the major reason. IRENA's road map to 2050 noted that, the cost of renewable energies has substantially decreased in recent years, making them cost-competitive with fossil fuel technologies and leading to record-high renewable power capacity additions in 2017 (IRENA 2018). Though renewable energy technologies have high upfront costs, RE has been shown to bring about potential cost savings compared to fossil fuels (such as diesel generators) in poor rural areas without grid access (Sathaye 2011; Casillas and Kammen, 2010).

According to a study for assessing barriers to the adoption of renewable energy in Vietnam, the financial hurdle is the most important barrier, and the economic issue of high production cost the least (Nhan .et al 2010). Financial issues appears crucial for the development of RETs in most of the developing countries. Weak financial and managerial capabilities of investors and project developers, the poor performing economies, an inadequate electricity pricing system, and a deficiency in the governments' policies and incentives adds to the challenges to fully embrace RETs in most developing countries.

2.2.5 Renewable energy financing

The Copenhagen accord recognized that for the period 2010 to 2012 USD 26 billion should be made available for climate measures in developing countries (including mitigation and adaptation), and that this sum should be scaled up to USD 86 billion per year by 2020 (IRENA 2019: UNFCCC, 2009). Obviously, such sizeable financial inflows can play an important role in supporting the transition towards RE-based energy systems. However, the appropriate governance of substantial financial inflows is also critically important, ensuring that these transfers result in actual SD benefits instead of undermining development by inducing rent seeking behaviour and crowding out manufacturing activity (Strand, 2009). Be that as it may, several other factors still hinder most developing countries to access the available funding for RE. Firstly, some of the funding is attached with conditions some of which transcends administrative requirement to even require political reformations. Secondly, to access the climate change financing, there are rigorous processes and requirements needed for accreditation. This takes technical expertise to be able to prove that good financial management mechanisms are available to qualify for the funding. Most of the developing countries lack this expertise needed to access the RE funding. Thirdly, countries with high political risk profiles are considered to be unsafe for investment. For instance, countries with high index of corruption are sidelined from accessing the available RE funding. Corruption is rife in developing countries (Africa) specifically which presents challenges in securing funding for RE development. Last but not least, policy frameworks for RE are considered to be key in the process of accessing RE finding. Developing countries have been found to have policy deficiency which strains efforts to secure funding for RE projects.

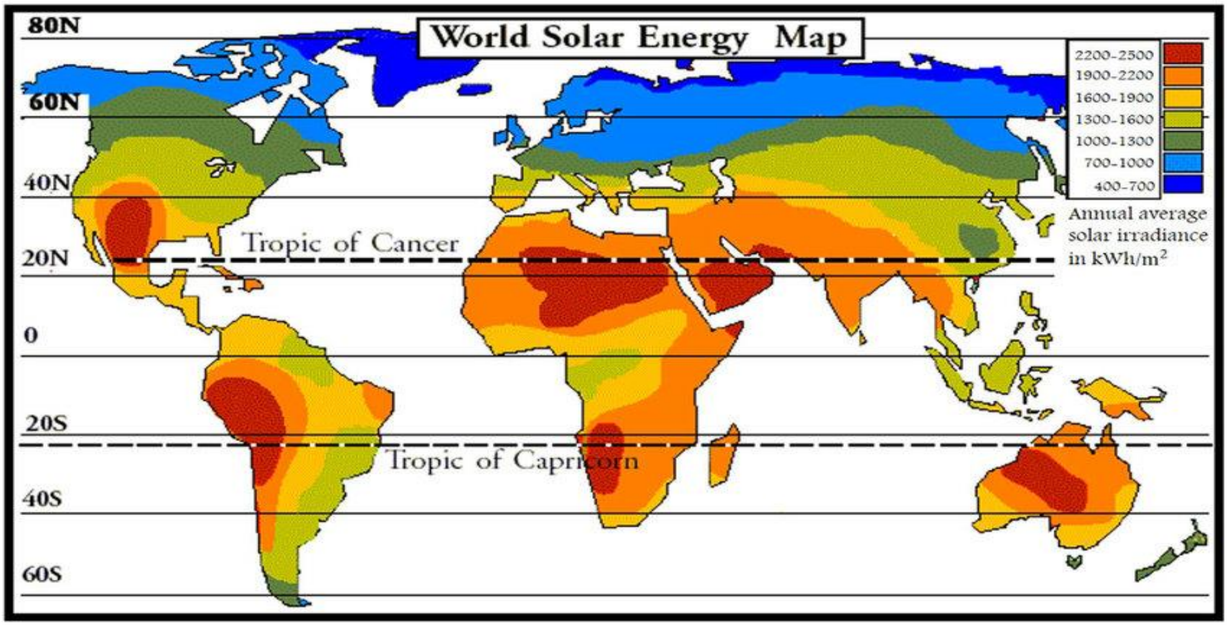
According to IRENA's estimates, a cumulative USD 22.3 trillion would need to be invested in renewable energy in the 2015-50 period in its RE map case, compared to USD 9.6 trillion in the current and planned policies scenario (IRENA 2019 and IRENA, 2018a). To reach the scale of investment required for 100% renewable energy, additional capital pools need to be activated – ranging from large institutional investors to community finance groups, which must increasingly be drawn into the renewable energy sector. While market risks have been reduced by the use of long-term contracts and other instruments, perceived or real political risks are still a limiting factor for investors in some regions.

2.3 Global outlook on solar energy

As a result of ever increasing climate threat, the world forums on climate change through the United Nations Framework Convention on Climate Change (UNFCCC) held several Conference of Parties (COP) meetings to discuss on way to mitigate the impacts of climate change. In 2015 UNFCCC 1/CP21, all parties agreed to lower the global warming temperature by 2^0C. This has been effected through all parties committing to National Determined Contributions (NDCs) and to institute National Climate Plans (NCPs) to be reviewed every after 5 years (Paris Agreement 2015). These commitments are hoped to reduce greenhouse gases emission with the goal of achieving net zero emissions by the second half of this Century (2050). One of the ways to achieve this is through transformation from fossils driven development to sustainable clean energy driven development. Wei et al, (2016), asserted that; the recent global developments (Paris Agreement), sends a clear intend to sunset the era of fossil fuel driven development and are sending unequivocal signal to the market that the transition to a thriving clean energy is now inevitable , irreversible and irresistible. Collectively, the national climate plans under the Paris Agreement represent about USD13.5 trillion market for the energy sector alone up to 2030 (Wei et al 2016).

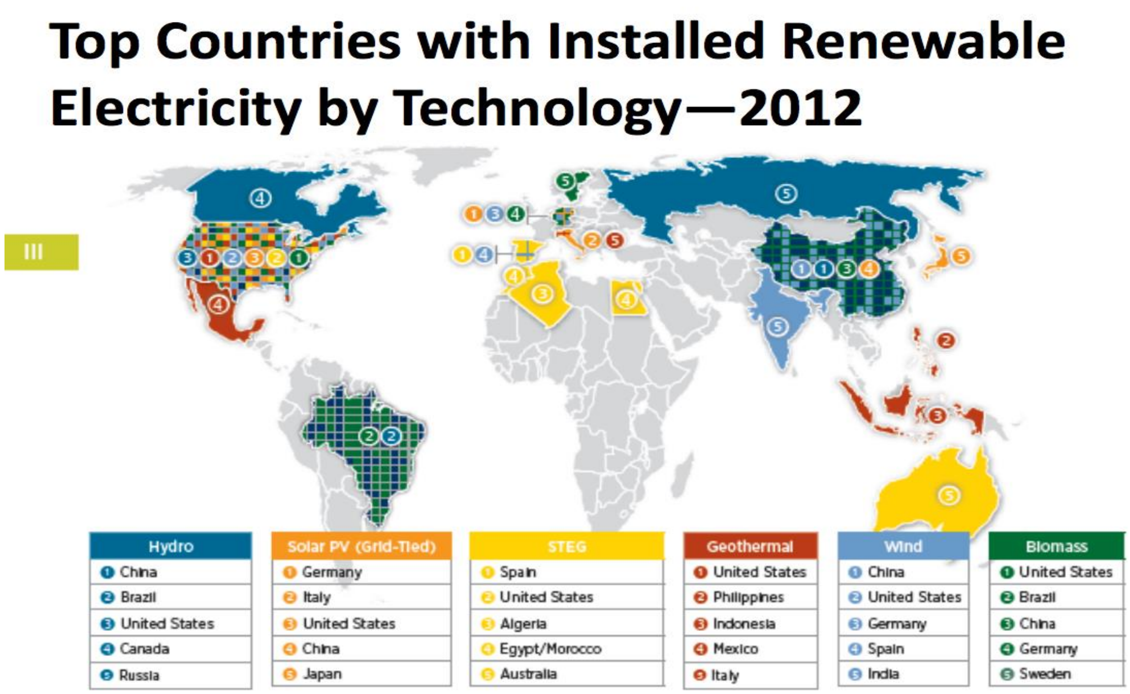
For the first time the private sector is recognized as an integral part of the global solution to address climate change. IRENA (2018), asserted that the world need to increase the share of renewable energy total final energy consumption (TFEC) from 19% in 2012 to two thirds by 2050. Although addressing climate change is the main driver, the energy transition brings much wider benefits than simply carbon emission reduction. Firstly it can increase energy access, secondly it can improve human health, thirdly it will increase energy security and fourthly it diversify energy supply. While many approaches can reduce energy related carbon emissions, (a key driver of climate change), there is universal agreement that energy efficiency and renewable energy are the main two pillars (IRENA ibid). Additions to renewable power have far exceeded fossil fuel generation. In 2017 the renewable energy sector added 167 Giga Watts (GW) capacities globally (ibid). A robust 8.3% from the previous year and a continuation of previous growth rates since 2010 averaging at 8-9% per year (ibid). Solar PVs are even expected to fall again in price by 2020 relative to 2015 – 2016. This is incredible indication that the world is fast embracing the renewable energy options in the energy generation mix. The African continent is still however deeply mired in energy crisis though slowly moving in to adopt renewable energy a viable source in the energy generation mix. Daniel Tomlison (2017), has this to say about Africa's energy challenge, "The challenge to develop Africa's energy market and bring modern electricity access to the continent is immense. It constitutes an all hands on deck seriousness where solutions are aligned to the right contexts."

Figure 2.2 1 Map showing the global distribution of solar energy.



Source*: www.researchgate.net*

Figure 2.3 1 Map showing top countries which installed Renewable electricity



Source*: Deepresource.wordpress.com*

Despite the lucrative solar radiation of the African continent which ranges from an average of 1900 – 2200 KWh/m^2, as shown by the figures above, there was a very low installation of solar energy technologies by 2012.

2.4 Sub Saharan Africa energy mix and implications for solar

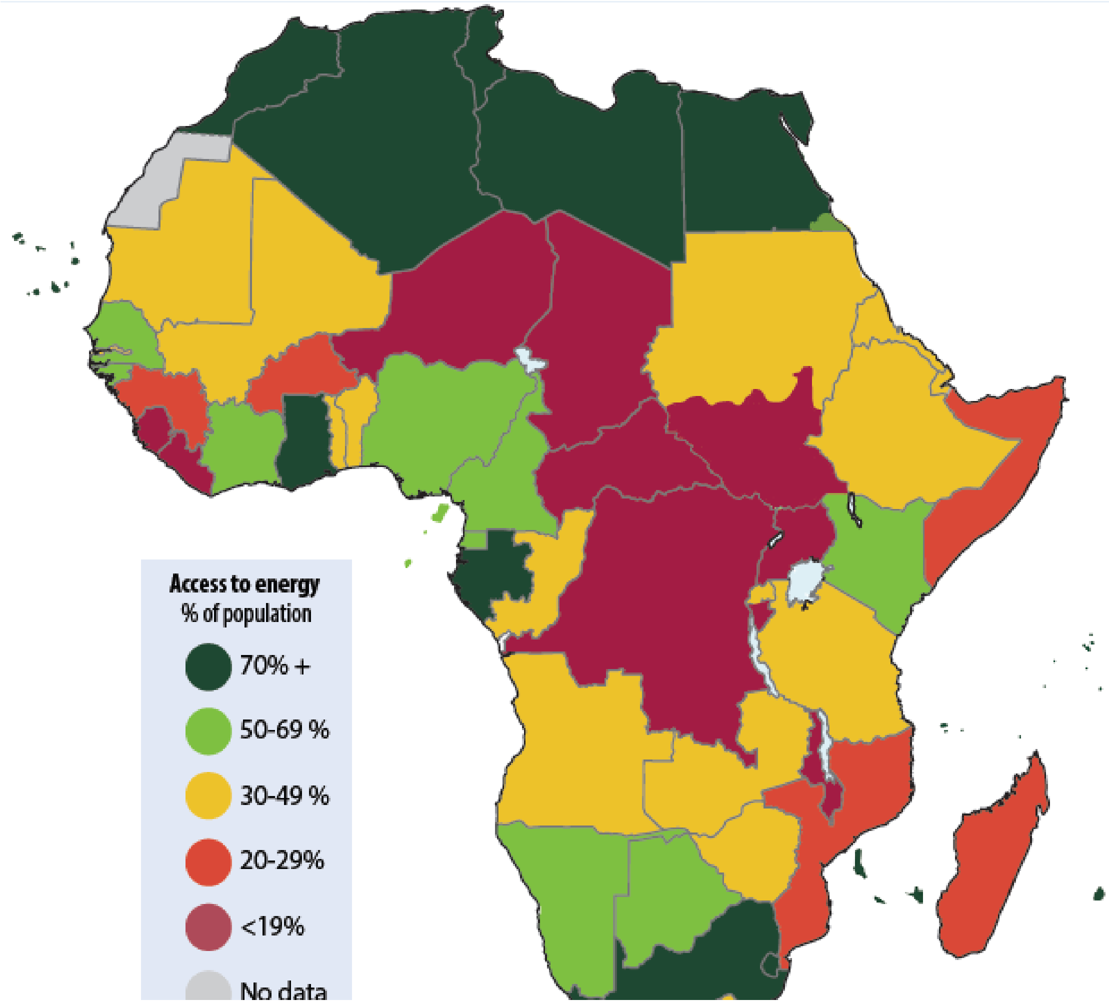
The Sub Saharan Africa energy mix is still dominated by conventional energy sources marked by low access to electricity and large dependence of fuel wood for heating and cooking for most rural dwellers. The region currently has the lowest electricity generation capacity and experiences the most acute forms of energy poverty in the world (Oxfam America 2016). Only 8% of rural households have access to electricity and 85% of the people depend on biomass energy (OECD/IEA 2010; Ram, 2006; ICSU, 2007). This resultantly led to deprivation, pollution, environmental damage, drudgery, and forgone economic opportunities. With the compounding climate challenges and vulnerabilities to climate change, traditional pathways to increasing energy supply, based on the burning of fossil fuels, will become increasingly unviable leading to more acute shortage of electricity in the region. Parastatals monopolizes most of the energy sector in the region with countries like Zimbabwe, Malawi, Nigeria, Ethiopia, Kenya and Nigeria having government controlled parastatals as monopolies of the energy sector (UNIDO,2012). According to Ganda and Ngwakwe (2014), continued employment of fossil fuel subsidies; presence of monopoly structures in the energy sectors; regulatory and macroeconomic risks in sustainable energy schemes; large capital required to fund sustainable schemes; high transaction costs; low carbon risk and negative social impacts are major problems to sustainable energy in Sub Saharan Africa. With the recent reductions in the cost of renewable energy new opportunities for sub-Saharan Africa to address the energy challenge without increasing greenhouse gas emissions is no later than now especially with abundant solar radiation.

Sub Saharan Africa has been experiencing economic growth in recent years and this has triggered energy demand (UNECA/UNEP, 2007). The current challenges facing SSA include lack of access to energy. For instance, electricity access in 47 countries that are in sub-Saharan Africa (SSA), with the exception of South Africa, equals generation capacity of Argentina alone (US EIA, 2011). Furthermore, a quarter of its generation capacity lacks adequate maintenance and has outdated equipment (Ganda and Ngwakwe 2014: US EIA, 2011). The cost of generating electricity in SSA adds up to a high US$0.18/kWh when compared to South Asia-US$0.04/kWh and East Asia-US$0.07/kWh (ibid: AfDB, 2010). So, SSA possess only 24% share towards electricity access which is the lowest globally (Eberhard et al., 2008). Therefore, Africa's energy sector has poor electricity reliability shown by 56 days of electricity outage annually (UNEP, 2013). In the same vein, public health risks have also been identified in mining and production industries through burning fossil fuels as well as inhalation of black-carbon smoke from cook-stoves, causing up to 1.9 million deaths in Africa's (UN-Energy/Africa, 2011; UNEP FI, 2012). Literature also records that 393 000 deaths in SSA for the year 2002 were a result of inhaling polluted air from burning biomass sources of energy (Ganda and Ngwakwe 2014: ICSU, 2007).

Hydroelectricity is the main energy source in SSA (ICSU, 2007; UNEP, 2008), but because of the effects of climate change, water challenges has increased leading to difficulties in generating hydro power at large scale. That being the case, other renewable energy sources need to be integrated in many SSA countries. For instance, rural areas in SSA (where 66% of the population lives) could be supplied with renewable energy systems that are decentralized and deployed in a modular structure, thereby providing the most appropriate energy source for both small and off-grids by reducing high costs (AfDB,2010). REN21 (2010) explains that off-grid renewable energy frameworks are sustainable and are less expensive; hence rural areas in developing countries can significantly benefit from its network. Consequently, small and off-grid energy (for instance, roof top solar and heater systems) are significantly cheaper than large scale built energy networks which have proved to be expensive for most SSA countries (AfDB, 2008; Martinot et al., 2002).

With myriad challenges facing the current energy mix of the SSA, the transition to solar energy systems is long overdue. Initiatives to boost solar like the World Bank supporting the Ethiopian Development Bank to set up a fund for solar off-grid products and other initiates to harness renewable energy will go a long way in improving the energy mix of SSA countries (Diecker et al 2016). The fund lends against collateral to companies and facilitates access to finance in USD currency which has allowed companies to expand their activities in the country (ibid). In the first 18 months of operation, this facility enabled over 300,000 quality verified solar lights to be imported (ibid: UNEP, 2015).

Figure 2.4 1 Map showing low access to electricity in Africa



Source: UNDP 2018: IEA 2017

2.5 Viability of solar as a sustainable energy option in Africa

The viability of solar in Africa is determined by various factors such as policy frameworks, energy efficient technologies, affordability, technical expertise and social perceptions. With so many barriers to the adoption of efficient solar energy technologies, the initial set up of solar technologies is associated with high cost upfront. Africa generally has high potential of solar energy which ranges from an average of 260w/m^2 solar radiance annually (UNDP 2018). Most of this potential is unexploited leaving a big opportunity for solar energy investment. Whilst hydro power generation is associated with climate change threats and burning fossils for thermal power associated with high carbon emissions, solar only needs to overcome the technological challenge. IRENA (2019) has indicated that solar energy technologies have significantly gone down and will further go down in the near future. This presents solar energy as a viable sustainable option in the energy generation mix of Africa.

Governments in most of the African countries have policies and commitments for the deployment of renewable energy sources which is a positive stance towards the transformation to green energy societies. According to the 3rd report of 1Gigaton Coalition, 79 developing countries have policies which are geared towards embracing and promoting renewable energy especially solar energy. In addition, most African countries have removed tariff barriers, import barriers, to ease solar products introduction and market development (ibid). Given that on 8% of the rural population in Africa has access to electricity in spite of the fact that rural areas are home to 66% of the African countries cost-effective renewable energy therefore becomes the most effective solution to rural electrification in Africa (UNDP 2018).

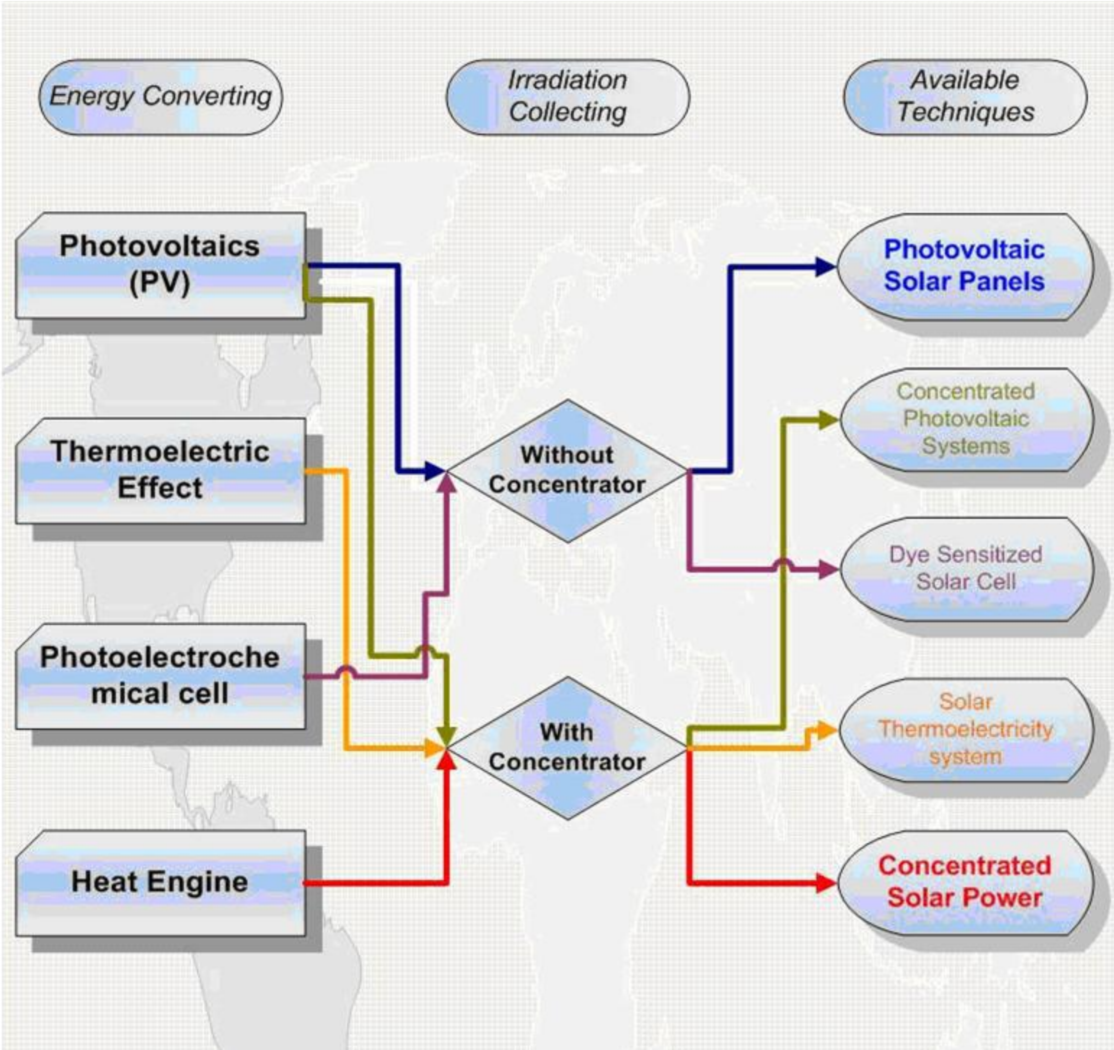
2.6 Solar energy technologies: efficiency and effectiveness

Solar energy has become one of the most attractive sources of energy for electricity generation because of its abundance and reliability. The most common solar technologies are concentrated solar power (CSP) and solar photo voltaic (PV). CSP is only suitable for regions without frequent clouds or haze, and CSP is currently more costly than PV (MIT 2015). Solar PV continue to dominate and is estimated to be the main source of solar generation globally. Quality of solar products, and particularly counterfeits and products which falsely claim a level of quality they do not achieve, defraud consumers and undermine consumer trust in the technology, spoiling the market are wide spread (Diecker et al 2016). These products imitate the look and feel of renowned brands but use inferior technology, often leading to early product failure (ibid). More interest is on the efficiency and effectiveness of the available solar technologies. Diecker et al (2016), observed that Adopting and enforcing minimum standards is key to maintaining consumer confidence and supporting market growth. By adopting internationally recognized standards, governments can avoid raising unnecessary barriers and imposing unnecessary costs on good quality solar products. Most of the developing countries tend to face the challenge of opening their markets to faulty technologies because they do not have international standards requirements on the products imported to their countries.

Using solar energy to generate electricity can be done either directly and indirectly. In the direct method, PV modules are utilized to convert solar radiation into electricity (Mohammad Hossein Ahmadi et al 2018). In the indirect method, thermal energy is harnessed employing concentrated solar power (CSP) plants such as Linear Fresnel collectors and parabolic trough collectors (ibid). CSP systems are not appropriate for small-scale power generation since they require high capital cost. (ibid). The technology of PV is sustainable especially for small-scale applications hence more suitable for decentralized energy models (off-grid power generation) though it can as well be used for grid connected electricity generation. The PV technology can be applied for other purposes including transportation, telecommunication, and rural electrifications among other purposes.

Since various factors are considered in the selection of the renewable energy system; factors like efficiency, economic aspects, social acceptance, and environmental effects are important criteria in selecting sustainable power generation system (IRENA 2012). In comparison, CSP solar power has high capacity in electricity generation that PV solar. Although the overall efficiency of PV plants is lower in comparison to CSP plants, PV systems require smaller land for installation (Mohammad Hossein Ahmadi et al 2016). Studies have shown that PV systems have small size, higher number of PV systems can be installed in the same area in comparison with CSP plants (ibid). Schultz et al (2017), obtained that the conversion efficiency of conventional available PV modules are in the range of 14% to 22%

Figure 2.5 1Overview of solar technologies



Photovoltaic Solar Panels	Most commonly used techniques in today's market
Concentrated Photovoltaic Systems	The highest efficiency ever achieved in lab
Dye Sensitized Solar Cell	Biomimics techniques based on cheap organic materials
Solar thermoelectricity system	Based on the application of thermoelectricity materials
Concentrated Solar Power	Commonly used based on the application of mature heat engine

Source: Adopted from Yinghao Chu (2011), Global Energy Network Institute (GENI)

2.7 The applicability of sustainability as a panacea to energy challenges

Sustainability is at the center of any discussion relating to energy sources both from the economic perspective, environmental perspective and from the larger perspective of society's interest in continued survival. Addressing the topic of sustainability is essential to a serious response to current environmental and public health threats posed by global climate change and other environmental hazards. Whilst energy is crucial to all aspects of the economy, energy production and use are central to the issue of global climate change (Irma S. Russell 2013). The term sustainability has several meanings. It is defined by Harrington L.M.B as the capacity to maintain or improve the state and availability of desirable materials or condition over the long term (Harrington L.M.B. 2016). The common use of sustainability is within the concept of “sustainable development”. A report in 1987 by the United Nations Brundlant Commission define sustainable development as the ability to meet the needs of the present generations without compromising the ability of future generations to meet their own needs as well (UN 1987). Reliable energy has always been recognized as the backbone of the economic activity. Instrumental goals of reliable and sustainable energy are inextricably linked to each other and to the public interest, making it difficult to overstate the importance of sustainability in the energy sector (Irma S. Russell 2013). Energy’s importance on the economies and the sustainability of the planet is the most threatening challenge facing humanity today. It is with utmost concern that a look into sustainability be discussed given the vast terrain of the concept in addressing energy policy and the challenges of sustainability.

Sustainable development as both a concept and a principle calls for an integrated approach in all levels of policy planning and implementation. The most crucial aspect about sustainable development is that it recognizes the need to minimize environmental harm as well as balancing the economic and social needs. The IPCC report (2011), stated that Pursuing a RE deployment strategy in the context of sustainable development (SD), implies that all environmental, social and economic effects are taken explicitly into account. It further reinforces that, integrated planning, policy and implementation processes can support this by anticipating and overcoming potential barriers to and exploiting opportunities of RE deployment. Policy planning in this regard becomes the challenge. The sustainable development concept anchored by three pillars which are economic, social and environment requires explicit consideration of inter-linkages of the pillars. According to IPCC (2011), barriers may arise against the deployment of RE technologies if these pillars are not fully considered. Such barriers include; socio-cultural concerns, which include barriers related to behaviour; natural habitats and natural and human heritage sites, including impacts on biodiversity and ecosystems landscape aesthetics; and water/land use.

2.8 Solar Energy situation in Zimbabwe

The first large scale solar energy technologies came to Zimbabwe in 1980s as solar was seen as a viable alternative to the grid (Kuijk 2012). In the early nineties a large subsidy was set up by the Global Environment Facility (GEF) to increase the use of solar energy (ibid). The GEF program invested more than 7million USD in the solar PV sector in Zimbabwe (Kuijk 2012: Mulugetta, Nhete and Jackson 2000). Kuijk 2012 extended that due to the subsidy, many new solar businesses emerged and solar PV installations grows from almost nothing to about 10 000 during the period of GEF program. The GEF program withdrew its subsidy in 1997, half a year after this subsidy stopped; more than 90% of the domestic solar companies disappeared from the market (ibid). This was clear evidence that the solar industry could not function without subsidies. This could probably be as a result of the expensive solar technologies during that time. One major reason for this research to focus on private solar companies in Zimbabwe instead of NGOs solar projects comes from this dilemma. NGOs solar projects may not last beyond the donor intervention as they are heavily subsidized and the prices of their solar technologies may not reflect the true picture of the prevailing situation in the country. They may also not have after sales services which are crucial for the sustenance of the solar technologies.

Most of the solar energy companies have largely been concentrated in the urban areas than rural areas maybe because they perceive rural areas to be unable to afford their solar products and technologies. Kuijk (2012) in his research observed that solar PV market in Zimbabwe has predominantly been urban market for the affluent or the urban affluent who procure for their relatives in rural areas. It is however important to note that some private companies have by now made inroads into the rural solar market through coming up with innovative pricing models such as pay-as-you-go.

NGOs has formed the major players of the solar energy technologies distributors in the rural areas, the notable one being the GEF program of 1990s. The SNV survey of 2012 established that; twenty (20) solar companies in Zimbabwe existed by 2012, mainly in Harare, Bulawayo and Mutare, (Maphosa 2012). More solar companies have since been formed from 2012 as a result of the ballooning energy crisis. New solar technologies have also been introduced into the market since then. For instance Econet wireless has also moved in to occupy a considerable share in the solar energy business and recently has indicated that it is considering to introduce the pay as you go payment model. Almost all of the solar products and technologies in Zimbabwe are imported. This is because the main component of the solar system is the solar panel and is manufactured under high technology which the country does not have (Kuijk 2012).

Solar energy is one of the many renewable energy alternatives which Zimbabwe can adopt to improve its power generation mix. The energy generation mix is currently dominated by thermal and hydro power. There are many ways through which solar energy can be harnessed. Ziuku et al (2014), in their research on potential of concentrated solar power (CSP) asserted that, solar radiation can be harnessed using concentration solar power, solar thermal systems and photovoltaic (PV) technologies. According to the research, CSP is said to have a potential to generate about 7% of the total electricity demand of the world by 2030 and 25% by 2050 (ibid: Izquierdo et al 2010). Unfortunately there has been no attempt as yet for installing CSP solar systems technologies in Zimbabwe. The commonly used technology is the photovoltaic (PV) solar system technologies.

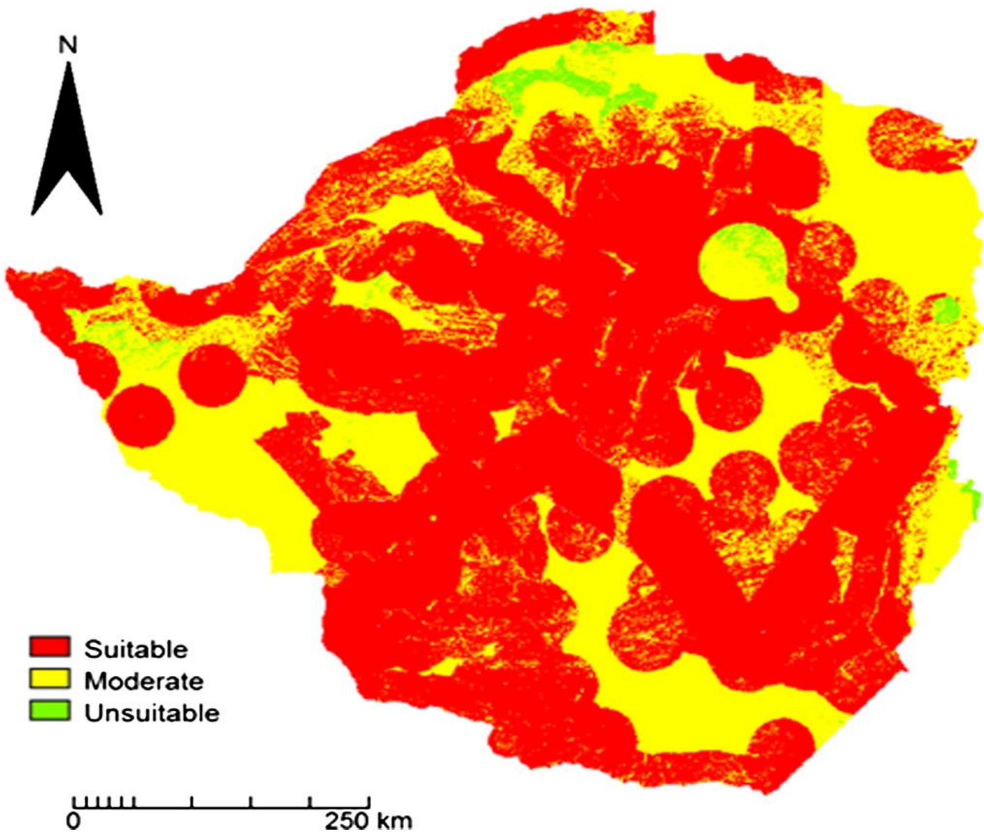
Table 2.1 1 Potential solar energy providers in Zimbabwe

Renewable energy manufacturing and installation companies
Non-government organisations (NGOs)
Universities and research organisations
Energy efficiency and environmental consultancies
The private sector
Energy companies exploring possibilities of alternative forms of energy
International aid organisations

Source: Zimbabwe policy brief 2015

Zimbabwe has vast solar radiation with a maximum average of 9.5 hours of sunshine per day in the winter season (May – August) and a minimum of 5.5 hours per day in December when the cloud cover is highest (Ziuku et al 2014). Global solar radiance for the country varies from 5.7 to 6.5 $KWh/m^2/day$ (ibid). The country has a total area of about $250000km^2$ suitable for solar (ibid). With this assumption, Ziukuetal 2014 asserted that, if only 10% of the land is used, about 892GW of electricity can be generated. With the least efficient technology used, about 71.4GW can be generated which multiplies the current energy demand for the country by 30 times (ibid). In their research, they concluded that technology and capital cost present the two major barriers to harness solar power in Zimbabwe. All this shows that there is a great potential of solar power in Zimbabwe which requires more than just one way of energy generation but all hands on the deck approach where private players, NGOs and the government harness the resource for the greater good of the people of Zimbabwe.

Figure 2.6 1 Map showing the distribution of areas with solar energy potential in Zimbabwe.



Source: *Ziuku S. et al (2014) Consolidated map for areas with a potential for CSP*

Conclusion

The transition towards solar energy is slowly but surely taking shape with most developing countries leading in solar power generation whist in developing countries the uptake is still low. Solar is very promising to most developing countries especially in Sub Saharan Africa where solar radiation is very lucrative. As a resource, solar is abundant and largely unexploited in Zimbabwe with the radiation varying between 16 -20 MJ/m^2/day. However the means to convert it into a useful form is still very expensive and out of the reach of the majority of the population.

Chapter 3

Research methodology

3.1 Introduction

The study is premised in qualitative exploratory research design. Qualitative research can be defined as research which uses exploratory and explanatory approach to a phenomenon by words than by statistics. Its ability to present a detailed picture of the energy sector in policy circles, market dynamics, social perspectives and general opinions on green energy in Zimbabwe presents it as the appropriate research method for this study. All these have a significant contribution towards how the society views green energy and the essence of its embrace. Issues of efficiency can be measured relative to the user of the solar energy technologies than the quantitatively calculated technology based efficiency. Technology is counted as efficient and effective if it manages to meet the perceived expectations and aspirations of user.

The research mainly dwells on qualitative epistemology than quantitative to get wide views of the diverse formations of renewable energy in Zimbabwe. A desk review of existing information was also done prior to primary research. Such reviews helped to guide the direction of primary research and cross checking the information collected in the field (Holzmann and Boudreau, 2008).

One of the major distinguishing characteristic of the qualitative research methods is the fact that the researcher attempts to understand people in terms of their definition of their world. In this case, qualitative study was useful in gathering the embrace of the transformation to green energy societies, the locally derived prospects as well as the challenges in the assessment of green energy companies in Zimbabwe. Whilst it is important to interrogate the policy level efforts, corporates efforts and institutional set ups, it is equally important to hear what the final users (consumers) of the various solar technologies feel or perceive. The essence of the general transition from fossils energy driven development to renewable energy can also be established. This satisfies the three pillars of the sustainable development concept which are economic, social and environmental aspects inter-linkages. Thus it is imperative for this study to adopt a qualitative study in assessing green energy companies. This study seeks also to measure the extent to which the financial models used in the distribution of solar energy technologies is helpful to enhance access to RE in Zimbabwe. This made qualitative research methods useful as they were adaptable to dealing with multiple realities. Since socio-cultural perceptions are part and parcel of the pillars of research, qualitative research approach has been an appropriate approach for assessing green energy companies and prospects and challenges thereof. Socio-cultural barriers may exist when the technology fails to satisfy the perceived needs of the user and non-integration of the technology with the social structure, and disharmony with prevailing social values and ideology (Makonese T. 2016: S.A. Quadir et al 1995).

3.2 Research design

Generally defined; research design is the means through which research questions are answered and objectives of the study are achieved. It is the blue print for achieving research objectives and answering research questions (Saunders et al 200). The function of a research design is to ensure that the evidence obtained enables to answer the research questions as unambiguously as possible. The study used exploratory and descriptive research design. Both descriptive and exploratory approaches used by the researcher, helped to obtain an in-depth understanding of the current energy situation in the country and the general embrace of solar energy, limitations and possibilities thereof. Leedy (1997:195) defines research design as a plan for a study, providing the overall framework for collecting data. MacMillan and Schumacher (2001:166) define it as a plan for selecting subjects, research sites, and data collection procedures to answer the research question(s). It can generally be defined as a framework for achieving research aims and objectives.

The researcher adopts a mix of qualitative data collection methods, data collection tools and qualitative sampling throughout the research process. Interviews were used to collect data with semi structured interview guide administered specifically to Zonful Energy Company clients. Interviews were physically conducted to four solar energy companies in Harare which include Zonful Energy Company, Global solar Private Limited, and SustiGlobal, using unstructured interview guide designed for solar companies. Unstructured interview guide designed to collect data at institutional level was administered to the Ministry of Energy and Power Development and Zimbabwe Energy Regulatory Authority. An observation guide was also administered at all levels. The researcher also adopted qualitative sampling techniques throughout the research. Data collection tool, sampling techniques and data sources are discussed in detail in the following sections.

3.3 Study population

The population in this study comprises of the data sources which study has consulted. At institutional level, interviews were conducted at the Ministry of Energy and Power Development (MEPD) and Zimbabwe Energy Regulatory Authority (ZERA). Solar energy companies where interviews were conducted include Zonful Energy Company, Global Solar private Limited, and Sustiglobal. Using Zonful Energy Company data base, the study also randomly selected fifty (50) clients who have solar technologies installed on their homes. Out of interest to have insights of how the Midlands State University is thinking about solar and how it is coping with the current energy needs, an interview was also conducted with the Director of Projects. Population in this study also designates other successful or struggling solar projects in the country which have been denoted by the researcher.

3.3.1 Data sources and collection procedure

The primary data for this study was generated from physically conducted interviews from the study population as well as the data base herein used to randomly select 50 clients who were telephone interviewed. There are mainly two data collection tools used to collect data in this study which are: unstructured interviews and semi structured interviews. Semi structured interview guide was administered to 50 clients which were randomly selected from the Zonful Energy data base and unstructured interviews were tailor made and administered to ZERA, MEPD and solar energy companies.

3.3.1.1 Solar energy Companies

Since this research is premised in qualitative explorative and descriptive design, it was imperative to have an in-depth look into the drivers of solar energy. A focus group discussion was organized by the management as per the request of the researcher at Zonful Energy Company. Other two interviews were also carried out with the senior management at Zonful energy which are the Chief executive officer (CEO) and the chief finance officer. One interview was also conducted at Global Solar with the senior management (Projects engineer). One interview was also physically conducted with the CEO of Sustiglobal.

3.3.1.2 Zonful energy Company clients

Whist Zonful energy clientele base is over fifteen thousand across the country, the researcher sampled fifty clients randomly, from different regions across the country. Semi structured interviews were administered to over the phone. Primary data was generated from this source. The Zonful Energy data base also generated primary data which the study used to assess the viability of the installed solar technologies and the responses from the clients. The responses were recorded by means of ticking the questionnaire guide and noting down on specific responses.

3.3.1.3 Ministry of Energy and Power Development (MEPD)

The Ministry of Energy and Power Development (MEPD) is responsible for all power generation and development in the country and it oversees all state owned energy companies like ZESA holdings and its subsidiaries such as ZETDC, Hwange Colliery, Powertel among others. It is a key institutional formation for the energy sector that's it has been key in this research. Unstructured interviews were used for data collection. Two interviews were physically conducted in the Renewable Energy Department. Since this study employed purposeful sampling ant institutional level, the interviews were conducted with the senior officers in the department which are the Director of the department and the senior liaison officer.

3.3.1.4 Zimbabwe Energy Regulation Authority (ZERA)

ZERA is also another key institutional formation in the energy sector in Zimbabwe. Its mandate is to formulate and regulate the energy sector in Zimbabwe. Of interest is the policy and regulation aspect especially on renewable energy sector in Zimbabwe. An expert (senior engineer) in this institutional set up was interviewed using unstructured interviews to get an in-depth outlook on policy, prospects and challenges for solar energy in the country.

3.4 Sampling procedure

Gentles et al (2015:pp1775), defined sampling as, "the selection of specific data sources from which data are collected to address the research objectives." Even if it were possible, it is not necessary to collect data from everyone in a community in order to get valid findings (FHI guide undated). Only a sample of a given population is selected in any given study. According to (FHI ibid), "The study's research objectives and the characteristics of the study population (such as size and diversity) determine which and how many people to select." In this study, Purposive sampling was largely used to select participants in the research. The Zonful energy clients were however sampled randomly from the data base.-

1. **Purposeful sampling**

According to Patton (2015: pp 264), "The logic and power of purposeful sampling lie in selecting information-rich cases for in-depth study. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the inquiry…Studying information-rich cases yields insights and in-depth understanding." For in-depth study and focus group discussion, purposive sampling has been seen as effective. It is an approach that is frequently used as a method of extending knowledge by deliberately selecting sample participants who are known to be rich sources of data. All data sources used for the purpose of this study have been sampled purposefully.

3.4.1 Sample size

In most quantitative researches, large sample sizes are regarded as the true representation of the generalizations because of the need to produce statistically precise quantitative estimates. Nevertheless, with qualitative research, sample sizes are determined by the need to acquire information that is useful in understanding the phenomenon under study. Gentles et al (2015: pp.1782) asserted that, "the general aim of sampling in qualitative research is to acquire information that is useful for understanding the complexity, depth, variation, or context surrounding a phenomenon, rather than to represent populations as in quantitative research." The commonly proposed criterion for determining when sufficient sample size has been reached in qualitative research is ‘saturation’ (ibid). The sample size of this study is fifty eight (58); composed of 50 clients from Zonful energy, two interviews from the MEPD, two interviews from Zonful Energy, one interview from ZERA, one from Global solar, one from Sustiglobal and one from Midlands State University.

3.5 Data collection tools

There are essentially various data collection tools which can be used in qualitative research. The most common data collection methods include interviews, focus group discussions and observations among other methods. There are three fundamental types of research interviews: structured, semi - structured and unstructured interviews. Structured interviews are, essentially, verbally administered questionnaires, in which a list of predetermined questions are asked, with little or no variation and with no scope for follow-up questions to responses that warrant further elaboration (Gill et al 2008). Contrariwise unstructured interviews do not reflect any pre conceived theories or ideas and are performed more liberally without some form of organization. Semi-structured interviews consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge in order to pursue an idea or response in more detail (ibid). These kind of interviews provide the participants with some form of guidance on what to discuss about.

For the purposes of this research, unstructured and semi structured interviews were used. A semi structured interview guide was administered on clients of Zonful Energy Company and unstructured interviews carried out for in-depth study on institutions and solar energy companies experts in the field of renewable energy development in Zimbabwe.

3.5.1 Semi structured Interview guide

A semi structured interview guide is one of the major data collection tools used to collect data from Zonful Energy Company clients. The interview guide comprised of semi structured questions which were administered to the randomly selected clients of Zonful energy. The sample of the interview guide is annexed in the appendix section.

3.5.2 Key informants interview guide (unstructured interviews)

Seale, Giampietro, Gubrium and Silverman (2004) define an interview as a social encounter where speakers collaborate in producing retrospective and prospective accounts or versions of their past or future actions, experiences, feelings and thoughts. Unstructured interviews were carried out amongst the key institution personnel in the energy and development industry as depth interviews. The purpose of the research interviews was to explore the views, experiences, beliefs and/or motivations of individuals on solar energy (eg factors militating against the embrace of solar energy). Key informant interviews were selected purposively among the solar energy companies and the institutional formations. The sample of the unstructured interview guide in annexed in the appendix section.

3.5.3 Insights and observations

Insights and observations are also data collection methods usually used in qualitative research. Insights in this case comes from the researcher's personal experience (both professional experience, academic experience and social experience) and also of living in Zimbabwe for over 25 years and engagements with the energy sector in professional spheres. An observation guide has also been used. Sample of the guide is annexed in the appendix section.

3.6 Data validation, reliability and analyses procedure

Research validity can be can be classified into two categories. According to Campbell and Stanley (1963), there is internal validity and external validity. Internal validity jeopardize research on issues of how the research conditions warrant the conclusions and without proper research conditions, research findings are uninterpretable. In this research, data analyses and validation was achieved though controlled data collection processes. Most of the informants who contributed to the data used in this research are deemed experts in the respective fields of their professions, have considerable experience with various solar technologies distributed in the country.

External validity according to Campbell and Stanley (1963), threatens research whenever there exists uncontrolled extraneous variables that might otherwise account for the results of the research. Such variables may include history, maturation, testing and instrumentation among others. Generally external validity of research is concerned with whether the results of a study can be generalized beyond the study itself (ibid). To overcome barriers to external validity of research, the researcher adopted a longitudinal approach in assessing the contribution of green energy companies to the transition to green energy societies. This approach is whereby the researcher looked into the state of the energy sector before the coming in of the renewable technologies and the current state, which is after the distribution of renewable energy technologies to respective clients of the company under study. The researcher also sampled other solar energy companies in Harare to improve the generalization of the research findings from the renewable energy sector to Zimbabwe. The researcher also sampled experts from institutions responsible for energy development, and distribution such as ZERA, MEPD, and EMA. This has helped in improving the external validity of the research findings.

3.6.1 Peer review

Peer review was also used to enhance data validation and reliability in this research. Peer review is the process of data review by someone who is familiar with the research of the phenomenon being explored. According to Lincoln and Guba (1985), a peer reviewer provides support, plays bad guy's role, challenges the researcher's assumptions, pushes the researcher to the next step, and asks in-depth questions about methods and interpretations. This method for data validation and reliability was used throughout this research. The peer reviewers were well experienced friends who are academics among which includes lecturers from the Midlands State University, friends who have completed their studies at masters and Phd level.

3.7 Limitations of the study

There is a dearth of information on the assessment of green energy companies in enhancing energy access in Zimbabwe. The researcher also faced clearance challenges in some of the solar companies which were strategically targeted for this research. Nevertheless subsequent mechanisms for ensuring data reliability and validity have been put in place. Generalization of findings to Zimbabwe are to the best knowledge of the researcher guaranteed.

3.8 Ethical considerations

The researcher sought clearance for research from the Department of Development Studies at Midlands State University. The letters of clearance for this research are annexed in the appendix section. The research is entirely for academic purposes and the researcher was bound by the research ethics through-out the research.

3.9 Conclusion

This chapter had two foci, firstly to outline the research methods used in this research and secondly to bring out how these methods were used to answer the research questions and to satisfy the objectives of this study. The research design, data sources and collection procedure, sampling procedure, data collection tools and data validation procedure has all been articulated.

Chapter 4

Data presentation and analyses

4.1 Introduction

This chapter is structured on the basis of the research objectives and the envisaged research findings. Since this research is vested in the qualitative paradigm, the data presentation is also qualitative in nature than quantitative. Key interests in this research were the institutional formations which influence the transition to green energy societies, operational frameworks, challenges and possibilities in the renewable energy sector with particular interest on solar energy. Needless to say, solar energy as a resource is abundant but harnessing it is another issue. This chapter will explore the current efforts to harness solar energy in Zimbabwe, the *modus operandi* within the structural set ups and the challenges being faced. Key interests in this case are technologies being distributed by solar companies, the mode of operation in their distribution of solar energy and the impact they has made towards increasing energy access to the areas isolated from the grid. Data were collected using interview guides administered at three levels which are: institutional (structural) level, corporate level and at household level (for solar energy distribution of Zonful energy Company). At institutional and corporate level, a tailor made interview guide was administered and interviews conducted physically. Fifty (50) clients (referred to as households) were randomly selected from the Zonful energy clientele data base, in various region across the country. Phone call interviews were used to collect data using a structured interview guide. All data collection tools used for this research are annexed in the appendix section.

4.1.1 Data interpretation and analyses procedure

Since qualitative research deals with narratives, explanations, experiences and observations, data interpretation and analysis is based on descriptive analysis and exploratory approaches. Experience and level of exposure and even designation of the interviewees or sources of data and also places where data were collected are crucial in data validation. For example; if the data is coming from experts and highly experienced sources in the research, it can be regarded as more valid than data coming from less experienced sources. In this research most of the sources from which data were collected are experts in their areas of specialty and well experienced in their respective fields. Methods like comparative analysis on data collected using the same data collection tools were mainly used for data analysis and interpretation in this study.

4.2 Institutional set ups and Regulatory frameworks for Renewable energy in Zimbabwe

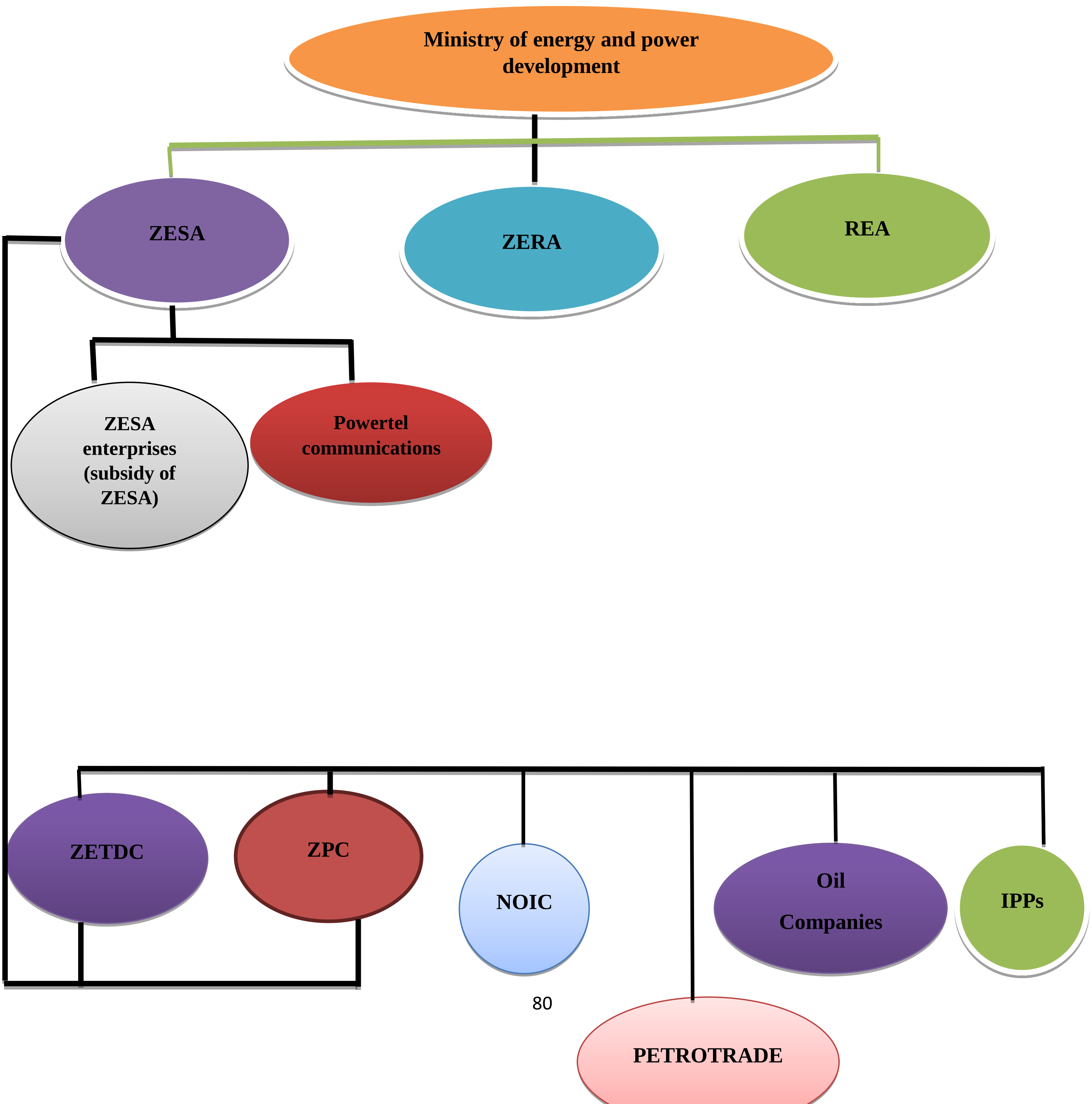
There are two major institutional formations in Zimbabwe which are responsible for regulating the energy sector and policy formulation. These institutions are a product of Acts of parliament which gives them mandate to act in the best interest of the state in their areas of jurisdiction. The Ministry of Energy and Power Development (MEPD) is the mother body of the energy sector which oversees all functions to do with energy development, distribution, regulation and policy and tariff structures in the country. Zimbabwe Energy Regulation Authority ZERA) is the other institutional formation whose mandate is derived from the Electricity Act [Chapter 13: 19] (2002). The major functions of this institutional formation has been seen to be “licensing and regulation for the generation, transmission, distribution and supply of electricity by the utility and IPPs” (National Renewable Policy 2019). Whilst Zimbabwe Electricity Supply Authority (ZESA) and Rural Electrification Authority (REA) are incorporated at the same level in the energy sector structure, their composition may not encapsulate the notion of institutions that govern the energy sector. Institutions should be seen to be rules and regulations which governs the energy sector. In retrospective, ZESA is more of a state owned company than an institution, the same goes with REA. Be that as it may two crucial institutions in the energy sector are the Ministry of Energy and Power Development and ZERA which is supervised by the ministry.

For renewable energy, there is a department in the ministry of energy which specifically looks into issues of renewable energy development. The department's mandate is to develop and promote renewable energy in a sustainable way across the country. Through the ministry and government, the department in conjunction with the Rural Electrification Agency has distributed a number of solar technologies across the country in hospitals and schools to support the energy requirements of public amenities through sustainable energy technologies in the rural areas. The move though highly applauded, encountered a number of challenges relating to operation and maintenance which greatly affected the reliability and subsequently sustainability of the solar energy technologies across the country. This challenge is common amongst most of the solar technologies installed for public convenience such as solar powered street lights, solar powered traffic lights and hospital installed solar technologies. Once installed, the solar technologies are left to function without a pre conceived plan on operation and maintenance. The dust which accumulates on the solar panel and the technical faults which happens with the technologies are left with no one to attend to leading to negative view of solar as a reliable and sustainable source of energy in the country due to short lived function of the technologies. Institutions and technicians must treat solar at no difference with the conventional energy systems which sets in place maintenance and operations structures to ensure continuity of the power generation in the energy mix. This is also coupled with technical skills deficiency for solar technologies.

Technical skills development as championed at institutional level is discussed in detail in section 4.1.2 below

Figure 4.1 1 Zimbabwe Energy sector structure

Source: *Ministry of energy and power development (2019)*



4.2.1 Technical skills development for Renewable Energy sector

Technical skills for renewable energy in Zimbabwe has been seen to be a crucial component if the transition to green energy societies is going to thrive. Nevertheless, there has been very little effort with regards to skills development in the area of renewable energy development in Zimbabwe. The responsible ministry for the energy sector has pointed out that there is still a deficiency of skill for the renewable energy sector. Most of the technical skill being used to develop big renewable energy projects in the country are being imported from outside Zimbabwe and mostly out of Africa. It is critical that skills development be taken seriously if the transition to green energy societies is ever going to be a reality.

There are training programmes being initiated by the ministry to bridge the skills gape in the renewable sector. Firstly, there has been a training programme run by SIRDC where the ministry send some technical staff hoping that they will be trainers of others in the renewable energy sector for the enhancement of skills. The Ministry only send ten people for training in order to enhance skills in the renewable energy sector. This was a once off training exercise yet the skills gape remains huge. From the general look, it could be said that the programme was not that big to fully address the skills gape in the country. More is expected given that the push to the adoption of renewable energy technologies in the country has risen. There has been rampant dismantling of conventional energy powered streets and traffic control lights in the country which has seen mainly solar powered street lights dominating especially in Harare which is the capital city of Zimbabwe. Most of these lighting solar technologies are not working to date because of a number of factors one being lack of skills for operation and maintenance. Another observation is that, most of the installers of these solar energy technologies are foreign companies who only installs, maintain within the guarantee period and leave. Beyond the guarantee period, there is virtually no plan or mechanism for operation and maintenance which has seen most of the solar installed technologies lying idle across the country.

Secondly, the University of Zimbabwe is offering a Master's degree in Renewable Energy Engineering. The degree programme started in 1997 and stopped in 2008, most probably because the teaching staff had left the country in search of greener pastures leading to the collapse of the programme. The programme was resuscitated in 2015 through the instigations of the Ministry of Energy and Power Development and is running to date. Pitched at master's level, the programme is way off ahead of the basic skills level needed to address the skills challenges in the renewable energy sector. At master's level, nothing much is taught about the hands-on technical skills needed in the country to make renewable energy continue beyond installation. What is needed at the time being may not necessarily be engineers of the renewables, but the technicians. At master's level engineers are mainly interested with designing and planning on the renewable energy than the technical hands-on aspects.

Thirdly, Chinhoyi University of Technology (CUT) is offering a Bachelor's degree in energy and fuels engineering. In that degree, there are certain aspects of renewable energy which are touched on as a module. Issues of technical operation and maintenance still remain crucial and unsatisfied in the renewable energy sector. There is virtually no polytechnic or vocational training which offers courses on renewable energy in the country for the mean time. Whilst there could be modules which focus on renewables like solar biogas among others, there is no specific course on particularly solar energy. This is a critical gap in the renewable energy sector in Zimbabwe. This is more so considering that most of the solar energy technologies used in the country are all imported.

4.2.2 Renewable energy policy

The Electricity Act [Chapter 13:19] (2002) was largely used to address issues of renewable energy up until a National Renewable Energy Policy (NREP) was crafted in March 2019. The NREP is one development which merits applause in the transition to green energy in Zimbabwe's energy mix. Its shows commitment to develop the renewable energy sector which is good. It is from policies where laws which governs the energy sector can be enacted. The renewable energy policy is useful in many areas, which include that it sets out the renewable energy targets by 2030 and is set to be reviewed periodically to enable adjustments to be made in tandem with the technological changes as well as business environment. In this respect, it is very useful to have policies which can be reviewed to avoid rigidity as well as to incorporate new ideas. Unrevised policies becomes archaic and unable to answer development questions which arise over changing time.

In addition, the NREP is also useful in seeking to incentivize renewable energy in Zimbabwe. Sections 7 of the renewable energy specifically spells out the nature and composition of the renewable energy incentives for the renewable energy sector. One of the incentives includes reduced licensing fees and requirements for developers of renewable energy projects. Below is a table which shows licensing fees for RE.

Table 4.1 1 Licensing fees for RE in Zimbabwe

Technology	Capacity Factor	Ratio	Licensing fee for Generation in USD		
			1-10 MW	Beyond 10 MW	
			Fixed	Fixed	Variable per 25 MW
Conventional power plant	0.8	1	10,000	20,000	10,000
Solar PV	0.23	0.2875	2,875	5,750	2,875
Biomass	0.6	0.75	7,500	15,000	7,500
Small hydro	0.55	0.6875	6,875	13,750	6,875
Geothermal	0.72	0.8961	9,000	18,000	9,000
Wind	0.3	0.375	3,750	7,500	3,750

Source: NREP 2019 (Draft).

Though useful in many areas, the NREP is also deficient in some aspects. Firstly the policy assumes that all renewable energy players in their diversity have similar interests thereby integrating them together. Key to note is the fact that policy also seeks to guide investors who would want to invest in a specific area of interest. It is irrational to assume that the interests of an investor who want to invest in solar are similar to the interests of an investor seeking to invest in wind energy. These subsectors have different dynamics, requirements and connotations to the environment and should be regulated differently. It could have saved better to have a policy for solar, for wind and biomass among other renewable energy sources separately. This would make it easy especially when an investor wants to invest in a particular area of renewable energy they would simply look for a policy to do with that area than to sift the whole combined renewable energy document.

Secondly, there is no e-waste management plan in the policy document. Most of the renewable energy technologies imported in the country don't last forever. They specifically have time frames and when they expire, they have to be disposed properly. In addition most of these technologies; for instance batteries, are made from harmful substances and heavy metals which can pose serious danger to the environment if not disposed properly. It becomes even worse especially considering that in Zimbabwe underground water is becoming the main source of clean water in the country. Poor disposal of these heavy metals can lead to contamination of underground water. The policy document lacks guidance on how electronic waste from renewable energy technologies can be managed.

4.2.3 Policy formulation process

Any policy formulation process should be seen to be an integral process of stakeholder's involvement. In the context of sustainability, policies should be viewed as a process than a technical event. It is also key to look at the composition of the stakeholders being involved as lack of this would see the process happening but with wrong or uninformed stakeholders in the area to which policy would be formulated. In this subsection of the research, the researcher sought to understand the policy formulation process because policy is key in ushering the transformation towards green energy societies. Basically the researcher noted that most of the key players in the green energy sector were not made an integral part of the National Renewable Energy Policy formulation processes, rather they were treated as appendages to the process of the policy formulation. In-depth interviews with key players in the solar energy sub sector revealed that not any one of them were part and parcel of the policy formulation process. Instead, they were involved as appendages in the final stages of the policy formulation process which generated different gaps and insights which punched holed in the NREP document. Some of the players in the solar energy industry even confessed ignorance of the existence of the renewable energy policy yet they are registered with the ministry through ZERA as players in the renewable energy sector.

Whereas the NREP was crafted based on stakeholder consultation, the process might have left out ‘key stakeholders’. The responsible authorities presiding over the process of the policy formulation might have overlooked or sidelined the importance of these stakeholders in the policy formulation process. Key to this is the fact that the responsible authorities might have learnt of key omissions and deficiencies of the policy at a point of no return. The policy itself had already passed through Parliament and got approved, but without the contributions of ‘key’ stakeholders. It turned out that the contributions of the key stakeholders which were not the integral part of the policy formulation process from the inception were so pertinent to the extent that the document would be an embarrassment if published without the contributions from these stakeholders. In the interviews, the researcher noted that the responsible authorities still withholds the policy document from the public domain as they still regard it as a ‘draft’ though it had already passed through Parliament. The authorities clearly stated that there are some things which still need to be corrected in that policy document. Some of the key contributions and concerns from the stakeholders have partly been discussed in subsection 4.2.2 of this chapter as highlighted by some of the solar energy players.

Despite these pitfalls in general, the National energy policy is useful for the nation in so many ways and is a positive sign of the embrace of the transition to green energy societies.

4.2.4 Solar energy incentives

Incentivizing solar has made rounds in the state print media as well as public pronouncements on the national television by the responsible authorities in the energy sector early 2019 in Zimbabwe. On the 15^{th} of July 2019, the Minister of Energy and power development indicated that there would be a move to lift duty on all solar products. This was partly because of the escalation of serious power outages being experienced in the country. The National Renewable energy policy has devoted a whole section (section 7 NREP 2019) to incentives for promoting investment in renewable energy. Since there is no specific policy on solar, the available policy document for renewable energy provide no specific incentives on solar energy technologies and does neither explain what is composed of solar technologies. The statutory instrument 147 of 2010 [CAP. 23:2 Customs and Excise (suspension) (Amendment) Regulations 2010 (No. 39)], exempted specific solar products as shown in the following excerpt:

"Commodity Code	Description of goods	RATE OF DUTY
8419.1910	Domestic storage water heaters	0%
8419.1990	Other	0%
8539.3920	Compact fluorescent tubes and bulbs of a gas type of not exceeding 25w and voltage exceeding 170v	0%
8541.4000	Photosensitive semiconductor devices, including photovoltaic cells whether or not assembled in modules or made up into panels; light emitting diodes	0%
9032.8900	Other instruments and apparatus not specified elsewhere	0%".

Source: statutory instrument 147 of 2010 [CAP. 23:2 Customs and Excise (suspension) (Amendment) Regulations 2010 (No. 39)]

This exemption of solar products is key in promoting clean energy. However, it is important to note that from the time the statutory instrument was instituted up to date, there are a lot of technological changes which happened. New technologies have seen other solar products with features not specified in the statutory instrument in place to date making it difficult for the revenue authority to exempt them from duty. One of the players in the solar energy sector clearly stated that:

> "The government through the Minister of Energy and Power Development publicly pronounced that all solar products are entering the country duty free but that is not what is on the ground. We have imported large consignments of solar products but we were asked to pay duty on all solar products…"

These disparities in pronouncements and the reality on the ground could have emanated from the fact that, the statutory instrument being used to exempt solar products from duty is outdated, and does not encapsulate the technological changes which have seen solar products changing in terms of composition and add-ons which would increase efficiency on the solar systems. There is need to understand solar and all its components because solar as a system is composed of quite a number of components. Be that as it may, the indications and intentions from the institutional frameworks in the country are key in promoting renewable energy though they need to be perfected.

4.2.5 Standards and quality monitoring mechanisms

With the institutional frameworks in the country showing signs of promoting renewable energy, there is likely going to be an influx of different renewable energy technologies in the country given that almost all of the technologies are acquired from outside the country. Most probably it would also follow that there is going to be an increase in the number of players in the renewable energy sector especially solar energy. Whereas it can be regarded as a positive move in promoting clean energy and energy access across the country, it can have negative effects if not managed properly. Firstly, there is need to guard and protect consumers from fake and poor quality products and technologies as well as ensuring that there is sanity in the solar energy business from the private sector. Secondly, there is also need to institute standards on all solar technologies and products which would be entering the country. These two aspects are key for ensuring sustainability and promotion of solar energy at large.

The institutional formation which institutes standards in Zimbabwe is the Standard Association of Zimbabwe (SAZ). The challenge with the standards in Zimbabwe at the moment is that they are voluntary and not compulsory. Nevertheless, during interviews the responsible authorities highlighted that the institutional formation will soon be made a mandatory requirement and legally binding though there were no specific timelines given. Now this presents a challenge especially considering that the solar technology market is fast growing and this could risk the country to be a destination of technological dumping. If not regulated, it is most likely that outdated technologies, poor quality technologies and fake technologies will be entering the country. The study noted that in all solar energy companies visited and interviewed, have had a time in the business operations where they go for cheap than quality which has led to troubled relations with their clients. One projects engineer in one of the solar energy companies even highlighted that they have had instances where they had to replace over 30 faulty installed solar technologies which had even failed to last beyond the warranty period. Since then, most of the solar energy distributors have self-regulated systems of ensuring that all the technologies they import have internationally recognized standards.

At national level, there also are challenges in enforcing standards in the meantime emanating from lack of testing labs and equipment and a framework for regulating all products entering the country based on specific standards. The NREP (2019) on standards and specifications (section 10, sub section 10.1.1 page 36) states that; “All the available renewables based off-grid products shall adhere to the specified quality standards. The regulator along with Standards Association of

Zimbabwe (SAZ) have endorsed the International Electro-technical Commission (IEC) standards for solar PV and lighting as national standards for use in Zimbabwe among others." However, as mentioned earlier SAZ standards are voluntary and not mandatory. Secondly, there is no enforcement mechanism to enforce the current standards. For this to be possible, the government must first authorize Zimbabwe Revenue Authority (ZIMRA) to do conformity based assessments (CBS) on the solar products entering the country. The study found out that there is currently no mechanism for enforcement of standards as there are no technical staff in the boarder entrances which are technically qualified to assess the quality of the solar technologies entering the country. This lack in the institutional formations in the country could probably explain the existence of idle technologies in the country which last worked a couple of years ago.

4.2.6 Power purchase agreements (PPAs)

Most of the solar energy players interviewed, have shown no interest in producing power to put on the national grid citing the PPAs as the main challenge. One of the renewable energy players explicitly explained how they are fighting for common ground with the responsible authorities over the purchase of produced power by independent energy producers. Lack of confidence is also emanating from the continuous breach of the current Power Purchase Agreements with no clear course of action which to be taken by the producer to find recourse. The National Renewable Energy Policy highlighting on PPA on solar PV and CSP stated that;

> "Considering that the costs of solar modules and equipment are continuously changing, Competitive Bidding shall be the mode of procurement for all ground mounted solar PV and solar CSP. A plug and play solar park model shall be adapted for this procurement method. In this model projects will be packaged wherein government shall provide all the land, clearances and a bankable PPA…" (NREP 2019 p. 26).

There is generally no clear tariff structure for grid connected renewable energy projects; which is brewing conflict between the state utility (ZESA) which owns the grid and the independent power producers. Power purchase agreements between ZESA and independent power producers need to be clear.

4.2.7 Managing solar energy companies in Zimbabwe

Solar companies are formally required to be registered with Zimbabwe Energy Regulatory Authority (ZERA). Unlike any other company which produces and sell products to consumers, solar energy companies are in the renewable energy sector should be seen to be distributing energy with the view of sustainability in their workmanship. Pursuant to the principle of sustainable development, their workman-ship should augment and should not regress the current efforts of transiting from conventional energy driven development to green energy societies. Thus their activities should be monitored and conform to the standard requirements of electrical installations.

Most of the installations being done especially for house use, are mainly done by technicians from either the installing company or as free-lance without specific procedural standards from any recognized institution formation in the country. This has led to many shoddy jobs done across the country which have even led to some dismissing solar as a reliable energy due to poor workmanship. There is currently no code of contact through which the solar energy companies could be regulated to conform to best practices.

In efforts to manage the activities of solar energy companies, setting up an association which is binding and widely recognized can save better. If any client have serious complains about the installed technologies and the designs and having challenges on finding common understanding with the responsible company, they can report to the association and the association can deal with the company through many ways, either by deregistering it and prohibit it from operating through black listing it. Through that way maybe the workman-ship from among the companies in the solar energy business can improve. Currently there is an association of renewable energy companies called Renewable Energy Association of Zimbabwe (REAZ). From the interviews conducted, indications are that the association is not viable and binding enough to cause meaningful improvement among the solar energy companies operations.

The other way to manage solar energy companies is through the government instituting operation standards which are monitored. This is critical especially looking at sustainability as a key component of the transition towards green energy societies.

4.3 Balancing prospects and challenges for solar energy

In as much as there are huge prospects for solar in Zimbabwe, there is also need to balance the prospects and challenges thereof. Solar has its advantages as well as challenges. To strike a balance between the challenges and prospects, there is need to manage the transition from conventional energy sources to solar. The transition should not be abrupt but gradual, as abrupt transition would portray the global push to embrace renewable technologies as a fallacy after having experienced immense challenges with no plan to balance the prospects and challenges especially for public convenience installed solar technologies. The researcher observed that in most areas where the local authorities completely dismantled the conventional energy powered street lights and traffic control lights, they are facing serious problems as solar system challenges begin to show.

4.3.1 Prospects for solar in Zimbabwe

Solar energy as a resource is available in abundance and is free, clean and reliable, given that the sunlight will rise in most of the days. From a resource perspective it can be established and guaranteed that solar energy is available. Feasibility studies of solar potential has shown that Zimbabwe has a solar potential of 16 – 20 MJ/m^2/day which is currently unexploited (NREP 2019). The major challenges come from the technologies to convert solar into usable energy form which could be heat or electricity. Be that as it may, solar prospects in Zimbabwe are very huge given that at government level, the institutional frameworks are geared to embrace and promote solar through a number of ways. Firstly, the crafting of the Renewable Energy Policy is a milestone gesture towards embracing the renewable energy. Secondly, the government has constantly been muting steps to incentivize solar and other renewables through lifting duty for all imports and reducing licensing fees for companies seeking to invest in that sector. Though these pronouncements are still to be instituted and put in place, such efforts are a good gesture for huge prospects in the solar energy sector.

Solar is most likely going to be the most convenient household energy of the future. Research has shown that of the 68% of the population in Zimbabwe who live in rural areas, only 13% have access to the grid electricity and 83% have access in urban areas (NREP 2019). It is also important to look at the meaning of ‘access’ based on whether it is reliable access or not. Overall, only 40% of the population in Zimbabwe have access to electricity (ibid). This statistical presentation shows a very big gape of electricity needs in the country. This need is most likely not going to be satisfied through the extension of the grid because the grid itself is currently in bad shape and it would be more expensive. If ever this electricity need is going to be satisfied, it will be satisfied through off grid power generation initiatives which includes solar technologies distribution and installations across the country.

There are different types of solar systems but solar photovoltaic (Solar PV) have dominated the Zimbabwean solar energy market with most of the technologies varying from solar lighting, heating, and water pumping among others. In the agriculture sector, solar water pumping technologies have also made inroads as they have been found to be reliable and effective. Diesel is becoming expensive and the whole situation degenerating to an extent where it is becoming impossible for organizations to continue in the fossils driven development pathway. Universities are also a living reality of how generators are expensive to depend on as back-up power given the current situation in the country where electricity is unavailable for up to seventeen hours per due to power challenges being currently experienced. The diesel fuel requirements are so huge such that there are no signs of sustainability. From the interview conducted at Midlands State University (MSU), the Director of Projects indicated that, the institution is running with twelve generators each consuming 200litres of diesel per day. Running the institution using diesel is costing the institution ZW$4200 per day. This is becoming unsustainable to the extent sometimes the institution can go the whole day without power. The University is however looking for the best and affordable solar technologies to power the operations of the institution. Solar is making inroads and gaining firm as the next form of energy to bring a paradigm shift in the way societies are going to power their operations and address their energy needs.

4.3.2 Challenges

Solar has also its challenges which cannot be ignored especially looking at sustainable development concept. Firstly solar energy is available during the day and is not available during the night. This brings in a crucial aspect of energy storage on solar. Whereas there are technologies which have endeavored to resolve the challenge of storage on solar energy, it is still facing challenges especially considering that most of these technologies are imported in most developing countries. Most of the faults on installed solar energy technologies in Zimbabwe have always been revolving on issues to do with storage. Storage is basically the albatross in the solar energy systems as batteries used for storage are still expensive and are unreliable. Lithium phosphate batteries are largely regarded as durable and portable as they can last up to 25 years but they are still very expensive and unaffordable for the average earners in Zimbabwe. Gel type of batteries are the commonly used batteries by most solar energy companies in their solar energy technologies projects and installations. However these have a short life span of 12 years or below depending on how the system charge and discharge the battery.

The second challenge of solar is on operations and maintenance. This challenge is mostly common with solar technologies which are installed or will be installed for public convenience. Solar technologies like solar powered traffic control lights and solar street lights. In most cases these projects to do with public convenience are so big and requires huge manpower for maintenance. The current solar technologies installed for public convenience by city councils in Zimbabwe have faced the challenge on maintenance and because of lack of this, they have since stopped working for some time for now. Some of the maintenance requirements might be very simple but may take a lot of time. For instance, solar panels installed for solar lighting in streets may accumulate dust and the dust can disturb radiation rendering the technology ineffective. The big question would be how many people would be required to wipe the dust from the solar panels installed in the whole city from time to time. This is another cost on solar which is not usually factored in especially when planning for the installation of solar technologies for public convenience. The same goes on with similar components on the solar systems such as lights and batteries. The problem of maintenance even extends to home installations as in most cases consumers are not taught on maintenance.

The third challenge is on heavy loads and sectors of the economy which requires constant, reliable power supply. Solar may not be as reliable as conventional sources in powering these sectors. For instance, if operating a mine or industry solar is limited in a number of ways. In terms of feasibility on powering these sectors, there should be a mix of solar, coal and hydro to have a balanced energy mix (BEM). Firm power is needed in heavy industries which solar can't give currently confining it to a supportive role than as the sole dependable source of energy in these sectors.

The fourth challenge is on the cost of solar. Recent literature argue that solar is no longer expensive because global prices for solar technologies have tumbled down. It true that globally the price of solar as compared to conventional energy technologies have abated but a close look at development levels across the globe, signs are that solar is still expensive in most developing countries. The most efficient solar technologies are still regarded as affordable to the affluent only. Efficient solar technologies are install at a cost not less than USD$400. Currently an average Zimbabwean is earning USD$50 or below. What this means is that solar is still too expensive for the majority of Zimbabweans. From to the interviews conducted, the households with the cheapest and pay as you go solar technologies installed on their homes, still contend with paying the instalment highlighting that it's still expensive for them. Generally solar is associated with high upfront costs and the costs tend to go lower as time goes on.

4.3.3 Possibilities

Solar energy technologies dominating in the country have shown that solar energy is proving to be more useful for household use. Household use requirements for solar maintenance are very easy and simple to manage. For large projects and heavy loads, solar needs to work side by side with firm power sources to have a balanced energy mix. Given the huge percentage of people without access to the grid electricity in Zimbabwe, there are many possibilities with solar that can be explored.

Firstly, there is need to assess the key energy need areas so as to be able to come up with technologies which address these needs. There is also need to assess the financial capacity of the people to which the technology is intended. In this regard the majority of the people without access to the grid are from the rural areas. Most of the livelihoods of these people are centered mainly on crop farming (subsistence of which surplus would be sold) and livestock rearing. Pressing energy needs of this population are mostly for lighting, phone charging and for powering a radio or television. This entails that an affordable solar technology to satisfy the energy needs of this population would be derived from these characteristics. In short, any meaningful investment in the solar energy sector should be based upon research.

The study observed that most of the solar energy companies have very few solar technologies which are affordable to the large population which has no access to the national electricity grid. In particular, they seem to be servicing areas which already have access to electricity who wish to augment their energy supply with solar. Most of the solar technologies are way off the reach of the disadvantaged populations in the rural areas who have nagging basic energy needs. Most of these technologies are earmarked for the affluent, commercial farmers, organisations and business people.

4.4 Modes of operation by solar energy companies in Zimbabwe

There is need to differentiate between a solar energy company and a solar appliances shop. Generally what differentiates the two is the mode of operation. There are quite a number of shops and hardwares in Zimbabwe which sell solar energy appliances such as batteries, solar panels, solar lamps, solar water pumps, and inverters among other things. They too can give warranty just as solar energy companies does. In my view, that doesn't make them solar energy companies because what they distribute are solar appliances and not solar energy. Solar energy companies are expected to distribute solar energy and not only solar appliances. This entails that the responsibility of continual functioning of any installed technology be it on a house, at school or a hospital should be entirely upon the solar energy company which installed that technology. Issues of maintenance, upgrading of installed technologies and ensuring continuity should be seen to be the functions of solar energy companies. From their functions, solar energy companies among other things must have faults reporting mechanisms and the technical staff that can attend to the faults in their management structures. This means that companies establish a clientele base which has lasting relationship based on agreements that can be made. If that cease to happen, then there is no difference between the solar appliance shops and solar energy companies.

It was noted that most of the solar energy companies are still in their infancy to be more efficient and effective in influencing Zimbabwe society towards clean energy. Generally some of the companies interviewed by are just operating at no difference with solar appliance shops. The slight difference they have is that they design the solar system based on the purpose it intend to achieve and possibly that they do the installation unlike most of the solar appliances shops. Most of the interviewed solar energy companies only maintain and attend to faults on installed solar technologies within the warranty period, after the warranty period the clients are left to make decisions on how they maintain and resolve faults to their solar systems.

Most of the solar companies besides Zonful Energy use upfront payment models to access the solar energy technologies they sell. Solar technologies can only be given on credit after having a legally binding agreement and or trust between the client and the company. The researcher also observed that the thrust of most of these solar energy companies is to sell as many solar energy technologies as possible. Though it is through the sold solar energy technologies that the energy is distributed to the people, mechanisms which promote sustainability and continuity are equally important.

4.4.1 Implications on sustainability

Sustainability is key in ensuring a good transition from fossils energy driven development towards green energy societies. The thumb-print factor of sustainability is "continuity". If there is lack of continuity in the implementation of the green energy projects then there would be problems with the whole process of transition. Firstly continuity can be understood to be in form of 'continual spread of the green technologies being installed in a country' and secondly 'persistent functioning of the installed technologies in that country'. In this regard' if the already installed technologies are lacking continuity, what inspires the continual installation of new technologies especially for installations which are for public convenience is actually questionable. There would be virtually nothing to inspire continuity. Solar energy companies in their projects and installations should mainstream sustainability measures to ensure continuity in the in the transition towards green energy societies.

The study noted that for household installations of solar systems, it is feasible to institute sustainability as most of the solar energy companies can ensure that. Besetting factors threatening sustainability of solar for household installations is the mode of operation being assumed by other solar companies who have adopted a mentality of pushing out large volumes of solar products without pre-conceived mechanisms which encourages sustainability of the same. Failure to achieve sustainability and improved efficiency would defeat the transition to green energy societies.

4.5 A comparative analysis of solar energy companies using Zonful as a model

Zonful Energy Company has been noted to be a solar company with best practices so far in the solar energy sector. Currently it is the only company in Zimbabwe offering solar products using the pay as you go (PAYG) model. More so, it has targeted the 68% rural population which has only 13% access to the national grid electricity. In its inception, the company formerly launched its pilot projects in Mashonaland West province in rural areas such as Mhondoro Ngezi, Mhondoro Mubaira, Chegutu, Hurungwe, Karoi, among other places in the province. The company boasts of having managed to penetrate all the 10 provinces of Zimbabwe though most of its firm is still recorded in areas where it launched it pilot projects in its inception in 2013. The company also records a clientele base of over 15000 households across the country with its ambitions and targets aiming at reaching up to 25000 households by end of year 2019.

Through its high impacts projects in solar installations, the company also managed to attract funding from international foundations and institutions for its solar installations. In 2015, the UNFCCC CP/21 Paris Agreement formerly recognized private players in the energy sector as key in ameliorating climate change through facilitating the green energy revolution. This also opened the funding door for private players in the renewable energy sector. The founder of the company said he moved around the world in various international forums making presentations on how the envisioned clean energy projects would revolutionize the solar energy sector. Forums like the World Bank, the United Nations Framework Convention on Climate Change and other COP meetings, have all heard from the company's vision in enhancing energy access and improving the energy access situation of the rural societies not only in Zimbabwe but to Africa as a whole. This had increased the funding prospects of the company as it stands to date. Be that as it may the company is also set to start establishments of solar projects in Mozambique in the near future.

The establishment of the company came as a result of research which took up to three years. The research sought to understand the energy needs and the pains of not having access to electricity especially for the rural and disadvantaged populations in the country which are isolated from the national electricity grid. According to the data collected from the company, the major establishments of the research for the establishment of the company revealed that the most troubling pains of lack of access and drivers to want access to electricity relates to two factors which are: food security and cell phone charging. Other factors were also among the list but not as pressing as these two. The food security factor has to do with the need to pump water to irrigate and even for household use. The cell phone factor was largely driven by the fact that 90% of the rural population is unbanked and depend on mobile cellphone money either send as remittances from their children abroad or from the urban areas.

This understanding of the rural low income population drive the business model of the company in its engagement with its clients. Firstly they don't just offer generic solar products but they offer tailor made/custom-made products to address specific needs of the clients. They basically have a customer centricity business model. An assessment of the solar installations by this company would bring a balanced picture of the transition towards green energy societies.

4.5.1 Goals and intentions

The company envisions itself as the next big provider of sustainable energy to Africa. The major intention of the company is to improve access to electricity especially on populations which are isolated from the national grid through distributed off grid energy, innovation and instituting favorable financial models which are inclusive of all people. Innovation is one key intent of the company. The company employs a customer centricity model in order to address the energy needs of the people in their own context.

4.5.2 Solar technologies

The solar energy technologies being offered by Zonful Energy are varied and tailor-made. Their products are acquired from internationally recognized manufactures with specifications on the purpose to which the products should fulfil. The company orders solar technologies direct from specific manufacturers manufacture the products on specified purpose and also in such a manner that the product manufacturer and the solar energy company work as partners in the energy distribution chain.

At entry level, the company is offering basic lighting and phone charging solar systems which are composed of 3 energy efficient lights home 60 solar panel, battery and regulator mounted together. On the battery there is also a numerical key board where the customers can punch the digits of the codes on their tokens. This basic system can power up to three lights and a port of phone charger. The battery can provide up to 36hours of light. Other systems also power television set and provide lighting. Solar powered borehole pumps and other big systems are also being offered. All solar systems being sold by Zonful Energy are on PAYG.

There are a couple of solar technologies which the company is set to launch especially for urban market and for commercial purposes. There has been no formal launching of the urban market but because of the diffusion of technologies, the urban market also on its own went on to require the basic solar systems which were being distributed mainly for rural populations. Because of the current energy challenges which the country is facing, the urban energy needs are also growing resulting in the company extending its technologies to cater for the urban market. The company is also set to introduce what they termed ‘solar powered electronic libraries’ systems which is hoped to enable people from off grid areas to access wifi and internet services as the system will be able to power laptops or computers and wifi among other things. On refrigeration the company has a proto type of the system they are hoping to introduce soon into the market.

Pertaining to producing power for the grid, the company has a proposed project in place where need to establish a solar power plant which will generate power to put on the grid. There however are concerns on the power purchase agreement for solar energy which is not clear. The company implores the responsible authorities to institute a clear tariff structure for solar energy and a legally binding agreement with independent power producers.

4.5.3 Efficiency and effectiveness of the technologies

Most of the technologies being offered by Zonful energy have stipulated life span depending on the nature of the solar system. The basic solar system has a solar panel with a life span of up to 25 years, the lights have no definite life span, they can last for 12 years or more, the battery have a life span of 5 years. Lithium batteries technologies are a bit expensive as they last up to 25 years. Aspects of efficiency and effectiveness are determined by the quality and maintenance of standards. Effectiveness could also be measured by the performance of the technologies in fulfilling what they are intended for. The researcher managed to interview fifty clients of Zonful Energy Company who are using various technologies distributed to them by Zonful energy.

The majority of the clients interviewed indicated that they are happy with how the technologies are working for them. Only a few have indicated that they encountered problems with how the installed technologies are working. Probably the faults might be emanating from errors during installation.

4.5.4 Skill and technical capacity

Zonful energy has a comprehensive company structure from the top management down to the general personnel. In its top management, there are several qualified electrical engineers who plays a supervisory role to technicians who are spread across the ten provinces of the country in respective districts. Each region has got an engineer responsible of it and various coordinators operating at ward level according to the political demarcations of the country.

Since the majority of the solar systems are aimed at the rural population which have no access to the grid, the majority of them are modular and not so complicated to install as do not interfere with the grid wiring at homes. The company has undertaken to train its technicians as recruited at ward level initially from that same ward. This has also promoted and opened employment opportunities for rural populations as those who qualify and are trainable are found eligible to get employed by Zonful energy. The employment pact with these locally trained technicians is however based on free training and commission. That is to say one is paid according to the number of solar systems they would have installed or serviced. Faults are reported through the Zonful call center and coordinators are furnished with the details of where the fault has occurred so that they would attend as appropriate.

4.5.5 Energy distribution model

Firstly, the company has got a 24 hours call center which helps on disseminating information on issues to do with faults and areas that need attention across the country. This is a good structural formation which enable continuity in energy provision across the country. Secondly, the company is now at an advanced stage of establishing containerized distributional offices which would be doted across the country. Coordinators for every region are ever available and would be furnished with information on faults and technical challenges encountering the technologies and also to identify new energy needs. Zonful has evolved from just being a company to a people centered organization as in places where it has penetrated, it has established binding relationships with the local people including the traditional leadership formations through various programmes which had empowered the rural people, which include skills development and employment creation for the local people of such ward and villages where it would have established.

More importantly, Zonful has also endeavored to establish lasting relationship with all its clients through the provision of services which would allow continuous interaction with its clients. Most of the technologies have a warranty of 2 years and the company continue to provide after sales services to its clients at very reasonable rates. There are also provisions through which the clients can upgrade their solar technologies on pay as you go especially for products such as batteries and lights which can have short life span.

4.5.6 Market response

The market response to the Zonful energy solar products and operations has so far been great. The researcher assessed the market response through analyzing the responses from the Zonful clients who were interviewed using a semi structured interview guide and generated information from the Zonful clientele data base. The data obtained shows that most of the customers of the basic entry level solar systems are mostly women residing in rural areas. The average income per month of the majority rural clients revolves around ZW$100. The mainstay livelihood of the majority being crop farming and livestock. According to the Zonful clientele data base used, the number of defaulters of payments who have seen power disconnected from their homes are very few and do not even have up to ten days without power. This shows that the market has embraced the products and are happy to pay for the energy through their consistent honouring of their instalments.

4.5.7 Business functional model

The Zonful business model is based on customer centricity. Customer centricity seeks to address the needs of the customer than anything else. To achieve this, there has been a comprehensive set up of structures from village, ward and district level so as to achieve and meet customer needs. Most of the functions of the company are still concentrated at the headquarters but there are various formations of sub structures in every province which operates on commission. The company has also trained technicians for free especially those from rural areas. The technicians are responsible of installing the solar systems as well as servicing and attending to faults. They too are paid based on the amount of work they have done. This generally means that the technicians play a double role of marketing the systems to ensure that they install as many as possible per month.

All solar systems of Zonful energy has a warranty of two years. When the warranty period lapse, the company also provides after sales services which are agreed on a very low premium. After sales services for solar technologies are very important and a necessary factor in enhancing sustainability of the solar technologies. Whereas most of the solar companies visited by the researcher do not necessarily provide after sales services, Zonful energy has put in place mechanisms that would enable continual interaction with its clients through offering after sales services. For instance, most of the batteries for smaller systems have a life span of five years after five years, customers can still get new batteries for their systems on pay as you go.

4.5.8 Implications on sustainability

Sustainability is key to assure in all solar technologies without which the transition to green energy societies is threatened. Various factors influence sustainability. Firstly, the quality and life span of the solar technologies determines the sustainability of solar energy. Secondly, operations and maintenance is also very key in ensuring continuity on any installed technology.

Generally, the company has done so much in ensuring sustainability of its installed technologies. Firstly, the company has an array of structural and technical mechanisms which allows for the maintenance of all technologies which it installs. Besides that, the company through its regional coordinators train clients on how best to handle and preserve the installed technologies for longer life span. Another key aspect is longer warranty that the company give on its solar technologies.

Two years' warranty is longer especially considering that some of the technologies have a life span of five years.

4.5.9 Pay as You Go model

The pay as you go (PAYG) model is a financial business model which allows the customer to make an initial small deposit and progressively pay for both energy access and asset ownership within an agreed period. The customer after fully paid off for the system is given a permanent code to have access for energy without having to pay for it. The system is designed in such a manner that when a customer defaults on payment, the power automatically cuts off. When the customer pays for the system through their mobile money platforms such as ecocash, Onemoney and or Telecash and they are given a code to punch on the battery of the system to have access to power.

The financial model can be said to have largely promoted energy access to rural populations as the solar systems would have become affordable to most of the rural people. According to the Zonful data base, there are no defaulters as yet to the payment for the systems installed on their homes. Delays in payment on saw customers going for hours or just a few days without power. The highest defaulters would have gone for five days with access to power.

4.5.9.1 Market views and observations on solar installations by Zonful energy

The market views have been obtained from the responses of the fifty households who have Zonful Energy installed technologies at their homes interviewed by the researcher. The zonful energy data base also reveals key aspects about the market behaviors in relation to reliability of the systems payment of instalments.

The targeted market indicated that it is satisfied with the services and the technologies which Zonful is distributing. The Zonful data base shows that there are no defaulters yet in the payment for the solar systems on PAYG. Since the technologies are tailor-made to address specific needs of the targeted population, they seem to have partly addressed the needs of the rural energy needs. Though other major needs like solar water pumping are also critical in the rural areas, the company is still coming up with the most convenient model which makes the relevant technologies affordable and accessible to rural areas. The researcher also observed that the urban market is also requesting for the technologies being offered by the company to the rural areas straining the demand or even ending up devouring stocks meant for the rural targeted population. The company have been turning down urban customers but later considered to embrace them but on a different rating in the pay as you go model compared to the rural areas. Be that as it may, other big systems which can holistically address the energy needs of both the rural and urban market are needed to ameliorate greenhouse gas emissions as a result of use of conventional energy sources.

4.6 Conclusion

This chapter sought to present the findings of the collected data in qualitative form. Firstly data presented was obtained from the institutional formations responsible for the energy sector and renewable energy sector specifically. Secondly the researcher also sought to have an overview of the solar energy sector and the players in that sector. In this regard, the researcher sourced dada from solar energy companies operating from Harare; the capital of Zimbabwe. This data is also presented in a holistic form which pictures the whole solar energy sector presenting the prospects and challenges thereof. The last segment in this chapter narrowed down to the case study of this research (Zonful Energy Company solar installations), seeking to bring about the prospects, challenges and possibilities of solar in Zimbabwe.

The researcher established that, the renewable energy sector is still littered with structural pitfalls though the transition is slowly but surely taking shape. Positive development towards green energy societies in the institutional formations includes the crafting of the renewable energy policy, incentivizing renewable energy and promises of instituting standards to ensure good quality of technologies entering the country. The solar energy companies operating in the country are still in their infancy stage and has a lot of things which needs to be put in place to ensure that there is sustainability in their solar installations projects. Zonful Energy Company has so far put in place the yardstick framework that would enable inclusive access to electricity through distributed off grid technologies in the country especially for the larger part of the population which is isolated from the national grid.

Chapter 5

Summary Conclusions and recommendations

5.1 Introduction

The current global efforts to transform from fossils energy driven development which have been instituted through the embrace of sustainable development, to both balance the sustainability of the energy sector and reduce GHG have largely been hinged on reforming the energy sector. The transition towards green energy societies has seen a number of developments in the renewable energy sector both for public convenience and home use being championed by either the local authorities, the government or private players in the energy sector. Various solar technologies have since come into scene since the global push for sustainable energy sources, in efforts to minimize greenhouse gas emissions. Governments have been encouraged to come up with policies and national climate plans and to formulate Nationally Determined Contributions (NDCs) which in most cases have been presented in form of renewable energy projects among most of developing countries. To fully assess the contribution of solar energy companies, and to determine the prospects and challenges of the transition towards solar energy driven development, the study interrogated the institutional formations as well as the efficiency of the solar energy technologies being distributed by the solar energy companies in Zimbabwe. The summations are presented in this chapter.

5.2 General overview of the transition towards green energy societies

The transition towards green energy societies is a mixed picture of both progress and unforeseen challenges. In Zimbabwe there are quite a number of solar energy technologies which have been installed by various societal formations and institutions. Firstly, the local authorities muted large solar lighting projects across the country in the past years especially from 2015. The projects saw the replacement of the conventional street lighting systems by solar lighting technologies all over Harare, the capital of Zimbabwe. Secondly the government also distributed over hundred solar power technologies in hospitals and schools in the rural areas with low access to electricity through Rural Electrification Agency (REA). Thirdly, private companies and non-governmental organizations are also leading the transition through installing various solar technologies for home use, community use and for commercial purposes around the country. From a general on look, this can be marked as great progress in the transition towards green energy societies. The only challenge with the transition is that most of these technologies especially those installed for public convenience and in hospitals and schools; are currently not working owing to the showing up of the solar energy challenges among other things. The most common challenges are related to poor quality and inefficient solar technologies, lack of technical skills for operations and maintenance and high upfront costs in installing the technologies. However, technologies installed for private use in homes and commercial establishments seem to be doing very well.

5.3 Policy and institutional frameworks

Structural establishments in any nation or organization are very key in driving any change. Currently the major institutional establishments in the energy sector are the Ministry of Energy and Power Development (MEPD) which plays an oversight role in the whole energy sector and the Zimbabwe Energy Regulatory Authority which is established as a result of the act of parliament Electricity Act [Chapter 13: 19] (2002). ZESA and REA according to the ministry structuring of the energy sector are among the structural formations but they operate more as entities though under the supervision of the state responsible authority which in this case is the ministry of energy.

The structure of the energy sector alone and the institutional formations shows that the state has been playing a larger part in the energy supply chain. Sate owned companies like ZESA and its subsidiaries still play a pivotal role in the electricity supply sector. Very few companies have meaningfully invested in the energy sector. Nevertheless, with the push for embracing renewable energy, many players emerged in the renewable energy sector mainly targeting solar energy. This has coincided with the bedeviling challenges facing the country in generating electricity partly because of the effects of climate change affecting hydro power generation and ageing technologies in coal power stations. Conventional energy sources are largely becoming unsustainable. The electricity Act (2001), have largely been used to manage the transition effected by the escalation of private solar energy companies up until it has been found that policies are also needed to manage and promote the transition from conventional energy sources to sustainable energy sources. The recently crafted draft of the National Renewable Energy policy is a manifestation of the need to manage and promote this transition from conventional energy sources to sustainable energy sources. The study also noted that though the NREP is meant for the whole renewable energy sector, it is largely biased towards solar energy.

5.3.1 Renewable energy policy 2019 Draft

The National Renewable Energy Policy (NREP) is a milestone movement towards the promotion and embrace of green energy in Zimbabwe. The policy itself has a number of positive and useful establishments which will propel the renewable energy sector in Zimbabwe for the present and future generations. Firstly, it has formally has laid a foundation for ensuring that the government and all relevant ministries and departments embrace and incentivize renewable energy in all their formations. Secondly it also sought to establish standards in efforts to regulate technologies which enters the country which is a very critical and useful move towards ensuring sustainability in the renewable energy sector.

Nevertheless, the policy document is also deficient in some areas in a number of ways. Firstly, it generally assumes that the interests of the players or investors in the renewable energy sector are the same. This has many challenges especially considering that renewable energy sector requirements are different. Interests of investors in solar energy can never be likened to those in biomass or geothermal energy. It would have saved better if each renewable energy source has its separate policy independently. If any investor intend to interest in that particular renewable area, would just pick a policy in relation to their interest. Secondly the policy standards in relation to technologies in the renewable energy sector are voluntary and not mandatory. Generally, most of the standards in Zimbabwe are currently voluntary and not legally binding. The Standards Association of Zimbabwe (SAZ) a board which certifies standards in Zimbabwe is a voluntary organization. Given that there are efforts to incentivize renewables especially solar, there is likely to be an influx of various solar technologies in the country as solar products are set to be exempted from duty. If not properly regulated by way of instituting standards, the transition to green energy would be contaminated by fake and poor quality technologies by once off chancers.

Last but not least, the policy document does also not provide direction on e-waste management. E-waste management is very important especially given that most of the technologies which are imported into the country have specified life span. Also, given that ground water is becoming our source of safe water, heavy metals from which some of these technologies like batteries are made from are toxic and can contaminate ground water aquifers if not disposed well. This link is also missing in the renewable energy policy.

5.4 Solar energy companies in Zimbabwe

There are forty (40) solar energy companies registered with ZERA in Harare, seven (7) in Bulawayo, one in Mutare and one in Zvishavane. These solar companies are playing a big role which cannot be ignored in the transition towards green energy societies. The study also noted that not all of the registered companies are operational. Some have since came out of business. Key aspect about these companies noted by the researcher are that, most of them are driven by the need to make profits through distributing as many solar systems as possible, almost operate at the same level with solar appliance shops and that their financial models are mainly reachable by the affluent and the upper working class. Most of these companies are not providing after sales services beyond warranty which can be seen as a setback on sustainability of the technologies they install.

5.5 Challenges and prospects

Solar has huge prospects in Zimbabwe given that there is vast sunshine. From a resource perspective, solar can be the next form of sustainable energy source in Zimbabwe. The solar radiation is between 16 – 20 $MJ/m^2/day$ in Zimbabwe. However, the challenges are equally huge from institutional level to operational level by individuals and solar energy companies. There are little technical skills in the country to deal with solar energy technologies. Currently there is no tertiary institution offering courses at technical level for renewable energy technologies in Zimbabwe. The renewable energy tertiary programmes starts at bachelor’s degree and masters level which is way off above the technical level. Though solar is said globally being regarded as cheaper, in most developing countries it is still regarded as expensive. Most of the technologies being distributed by soar companies in Zimbabwe are still far beyond the reach of the majority of the people, especially the 68% rural population which has only 13% access to electricity. Given that an average Zimbabwean is earning around USD$50 or below, solar is still very expensive Given that an average Zimbabwean is earning around USD$50 or below, solar is still very expensive. Pay as you go model being offered by Zonful Energy Company has however proved to be working better for accessing solar energy. PAYG has great potential to improve solar energy access in Zimbabwe.

5.6 Recommendations

The study recommend to the ministry of energy that instituting standards for solar technologies which gets into the country is very key in ensuring a smooth transition to green energy societies. As long as faulty and poor quality solar technologies still finds their way into the country at large quantities especially as consignments by solar energy companies, the sustainability of the transition is littered with forth and backs. Secondly, the ministry should also endeavor to come up with separate policies for each and every renewable energy to encapsulate diverse interests of investors. More so, the ministry must institute e-waste management plan in the renewable energy policy so as to be consistent with the need to protect the environment and avoid pollution. The study also recommend that; solar installations for public convenience should be done by the locally registered and qualified solar companies than having a scenario where foreign based companies come and install the technologies and after the warranty period they return back to their countries, leaving no mechanisms through which the installed technologies can be maintained for continuity. Tertiary institutions must also be intentionally encouraged to offer courses in renewable energy engineering to bridge the skills gape in the country for RE technologies.

Solar energy companies should be encouraged to provide after sales services. After sales services are very crucial for continuity of the technologies installed. The green energy transition should not just be a moment but a long life transitions which will change generations and generations. Good quality of technologies is also a crucial component to ensure that the installed technologies last long and not turn out to be more expensive in the long run.

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APPENDIX A 1

Annex 1 1

Interview guide for solar energy Companies

My name is Zodwa Mutisi, I am a student of masters of Arts degree in Development Studies at Midlands State University. I am undertaking research on: *TOWARDS GREEN ENERGY SOCIETIES; PROSPECTS AND CHALLENGES OF SOLAR ENERGY DRIVEN DEVELOPMENT IN ZIMBABWE.* The information obtained in this research is solely for academic purposes and your responses will remain confidential. Kindly note that, there is no any material benefit which will accrue as a result of your participation in this research. Should you wish to decline to be interviewed before or during the interview, you are at liberty to do so without restriction.

Should I go ahead with the interview? | Ye s | No |

1. Which solar technologies do you offer in the solar energy mix?
2. How effective are your solar technologies in changing people's energy situation in Zimbabwe?
3. What would you say of the institutional frameworks in the country? Are they supportive or not?
4. What has been the response of the Zimbabwean market to your solar technologies?
5. Have you ever received any complaints from your clients pertaining to the solar technologies you distribute?
6. What are the financing and pricing models you use for the distribution of your solar technologies?
7. Do you offer after sales services?
8. What are the challenges you are facing in the solar energy sector?
9. What would you recommend that the government and its institutions do to improve solar energy in the country?

Annex 2 1

Unstructured interview guide for institutional formations

My name is Zodwa Mutisi, I am a student of masters of Arts degree in Development Studies at Midlands State University. I am undertaking research on: *TOWARDS GREEN ENERGY SOCIETIES; PROSPECTS AND CHALLENGES OF SOLAR ENERGY DRIVEN DEVELOPMENT IN ZIMBABWE.* The information obtained in this research is solely for academic purposes and your responses will remain confidential. Kindly note that, there is no any material benefit which will accrue as a result of your participation in this research. Should you wish to decline to be interviewed before or during the interview, you are at liberty to do so without restriction.

Should I go ahead with the interview? | Ye s | No |

1. What would you say of solar; is it a viable energy option for Zimbabwe?
2. How effective is solar as an alternative for power generation in Zimbabwe?
3. What are the main challenges to the adoption of solar energy technologies?
4. How reliable are the solar technologies being distributed in Zimbabwe?
5. What could possibly be done to address the challenges hindering the adoption of solar energy?

Annex 3 1

Semi structured interview guide for Zonful energy Clients

My name is Zodwa Mutisi, I am a student of Master of Arts degree in Development Studies at Midlands State University. I am undertaking research on: *TOWARDS GREEN ENERGY SOCIETIES; PROSPECTS AND CHALLENGES OF SOLAR ENERGY DRIVEN DEVELOPMENT IN ZIMBABWE.* The information obtained in this research is solely for academic purposes and your responses will remain confidential. Kindly note that, there is no any material benefit which will accrue as a result of your participation in this research. Should you wish to decline to be interviewed before or during the interview, you are at liberty to do so without restriction.

Should I go ahead with the interview? **Yes** No

1. Have you ever had problems with the solar technology installed at your home?
2. How is solar working for you so far?
3. What would you recommend Zonful Energy Company to do for the improvement of solar energy?
4. Is the solar technology installed at your home working according to your expectations?
5. Would you consider solar energy as a reliable source of energy in your area?

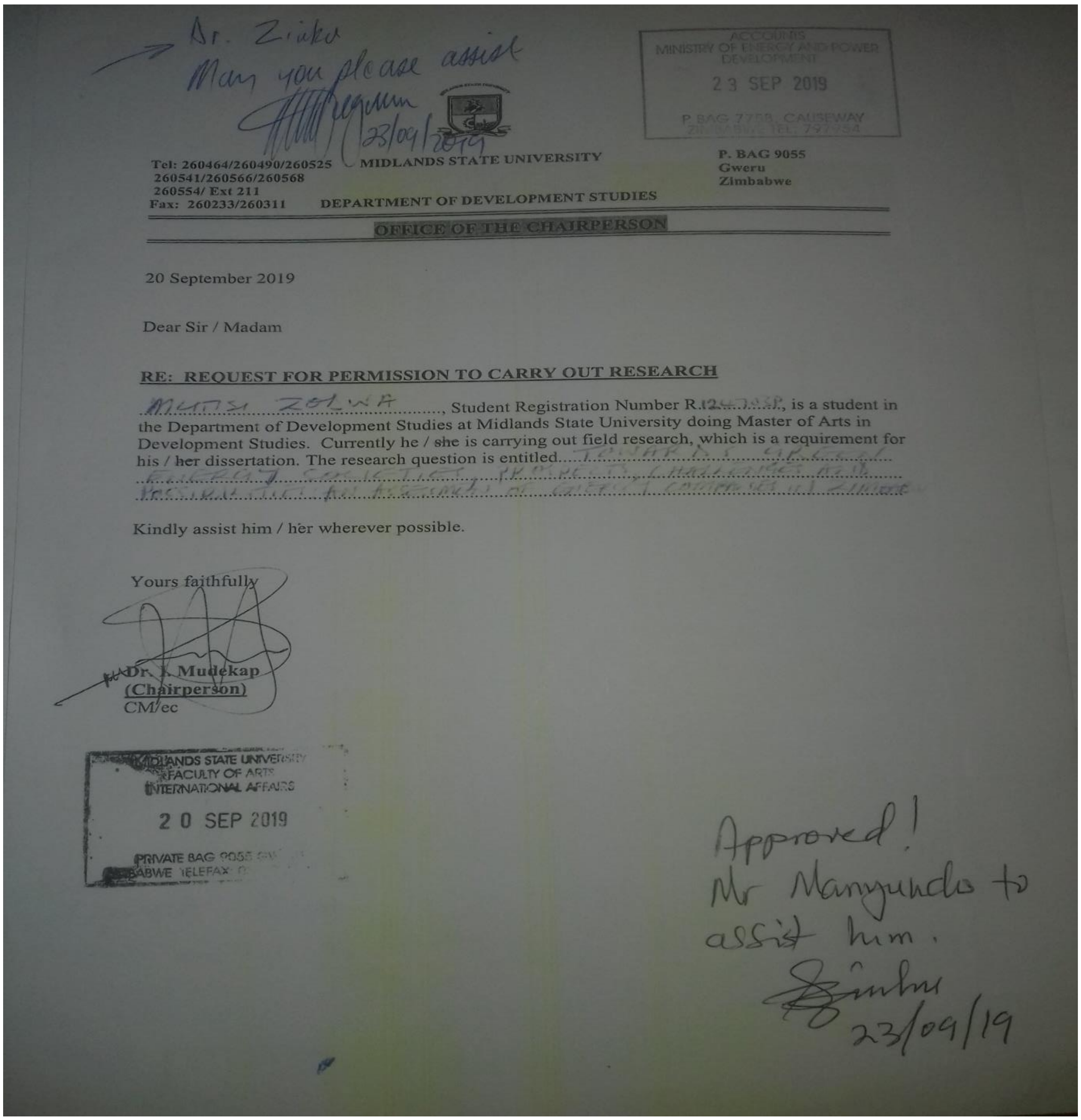
Livelihoods related questions

1. Are you formally employed? Yes/No
2. What is your average income per month? Between ZW500 -100 or below or above?
3. What are your household assets? Tick where applicable:
    - Car
    - House

- Wheelbarrow
- Cattle: how many
- Goats
- Radio
- Television
- Fridge
- Cooking stove : Electric Gas
- Other assets ------ kindly state

APPENDIX B 1

Annex 1 2: Research clearance letter



Dr. Ziiko
May you please assist
23/09/2019

ACCOUNTS
MINISTRY OF ENERGY AND POWER DEVELOPMENT
23 SEP 2019
P. BAG 7758, CAUSEWAY

Tel: 260464/260490/260525
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MIDLANDS STATE UNIVERSITY

P. BAG 9055
Gweru
Zimbabwe

DEPARTMENT OF DEVELOPMENT STUDIES

OFFICE OF THE CHAIRPERSON

20 September 2019

Dear Sir / Madam

RE: REQUEST FOR PERMISSION TO CARRY OUT RESEARCH

[illegible], Student Registration Number R[illegible], is a student in the Department of Development Studies at Midlands State University doing Master of Arts in Development Studies. Currently he / ~~she~~ is carrying out field research, which is a requirement for his / ~~her~~ dissertation. The research question is entitled [illegible]

Kindly assist him / ~~her~~ wherever possible.

Yours faithfully

Dr. J. Mudekap
(Chairperson)
CM/ec

MIDLANDS STATE UNIVERSITY
FACULTY OF ARTS
INTERNATIONAL AFFAIRS
2 0 SEP 2019
PRIVATE BAG 9055

Approved!
Mr Manyundo to assist him.
23/09/19