AN ANALYSIS OF THE SOCIO-ECONOMIC AND TECHNICAL BARRIERS TOWARDS ADOPTION OF SOLAR LANTERN IN CAMEROON

by

Joseph Ndjana Levodo

MEng (Mechanical Engineering Design), BEng (Automotive Engineering)

https://orcid.org /0000-0002-5783-9881

A thesis submitted in partial fulfilment of the

requirements of London South Bank University

for the degree of Doctor of Philosophy

January 2019

School of The Built Environment and Architecture

London South Bank University

Supervisors

Prof. Andy Ford and Dr Issa Chaer

Abstract

Nowadays, 1.2 billion people worldwide are without access to electricity; 48% live in Africa and about 80% live in rural areas (IEA, 2014), and rely on traditional kerosene lamps for lighting. Kerosene lamp usage is linked with indoor air pollution (IAP), and degradation in economic, social, health and education parameters. At the same time, grid extension and connection require high capital investment. In other words, the state's limited financial resources do not allow the sustainable development of rural electrification, while rural families cannot afford the installation and consumption costs of electricity in the areas where the grid connection has reached.

In recent years, alternative solutions to grid connection, such as solar photovoltaic (PV), have appeared and offer the opportunity for people to access cleaner, cheaper, affordable and healthier sources of electricity. At present, policy, environmental and academic studies have taken place on solar energy and its ability to solve the problems facing rural populations in developing countries, mostly Sub-Saharan African countries, while at the same time trying to help to reduce greenhouse gas emissions. However, literature on this technology is incomplete and limits the understanding of the success of some countries in Sub-Saharan Africa compared to Cameroon.

This thesis explores urban and rural electrification processes in Africa, and Cameroon in particular. It will contextualise the energy resource, socio-economic factors and technical barriers. By investigating the dynamics of rural and urban electrification and energy needs, it explores forces underpinning the uptake of solar PV technology through solar lanterns in Cameroon. The result of this thesis has revealed that Cameroon has infinite renewable energy resources, especially solar radiation, for electricity generation. This has led the author to investigate alternative affordable options for the whole country. Through investigating socio-economic, health and environmental factors and barriers that mediate the uptake of solar photovoltaic energy, it has been identified that solar lanterns offer a viable start-up solution in urban and rural areas in Cameroon.

Declaration

I hereby declare that this research is the result of my exertion and hard work. This thesis has never been submitted in part or in whole for a degree at any institution. References to other sources or people's works have been duly cited and acknowledged.

The work was carried out at the School of The Built Environment and Architecture, London South Bank University, under the supervision of Professor Andy Ford and Dr Issa Chaer.

Joseph Ndjana Levodo

Dedication

I dedicate this research to my late mum Elisabeth Ngono who was my prime source of motivation.

Acknowledgements

I would like to thank my supervisors Professor Andy Ford and Dr Issa Chaer for their help, advice and guidance during the research on this thesis. Acknowledgement also goes to the School of The Built Environment and Architecture for the financial support rendered for the conferences I attended. My gratitude to Dr Metkel Yebiyo for help and guidance, and to Mrs Ndjana Ekassi Angele for her valuable comments about this thesis. In addition, I am indebted to all academic and non-academic staff of the School of The Built Environment and Architecture at London South Bank University. For this research, data was essential and collecting data is invariably a trying experience. Hence, I would like to thank the following individuals and institutions for their various contributions that made the data available for this study: Ebebda district authorities for making their personnel available for the survey; SolarAid for supporting with the survey data for Kenya, especially Ms Kat Harrisson, Director of Research from SolarAid; the Ministry of Water and Energy in Cameroon, especially Mr Ngonan, Director of Electricity, for providing me with texts governing the energy sector in Cameroon; and CANMET for making available a powerful software RETScreen free of charge and also for their continuing support and guidance through emails when I encountered teething problems with the software. I am also greatly indebted to Mr Anthony Derrick from IT Power for advising me on some areas of this thesis. Moreover, I am thankful to all my critics and friends, especially, Capt. Eddie Achunche and Mr Celeste Mballa Onana, for their encouragement and abiding succour from inception up to the end of this work. It would do nobody justice if I conclude without specifically expressing my profound gratitude in clear and precise terms to my senior brother and de-facto father Mr Robert Ndjana, for his very personal and substantial support of this thesis. My family, especially my son Joseph Bryce, my brothers and sisters, Ndoumba Ndjana, Ohantsimi Ndjana, Mbassi Ndjana, Mballa Rose, Ngah Ondoa Ndjana, nieces and nephew for supporting me morally throughout my studies. My parents, Mrs Elisabeth Ndjana, Mrs Adeline Ndjana and Mr Robert Ndjana of blessed memory, rightly deserve to be acknowledged and congratulated for the parental responsibility they exercised over me. My mother-in-law, Ms Agnes Madanhi, for her support and prayers. Finally, my heartfelt gratitude must be rightly, properly and justly reserved for my dearest and loving wife, Mrs Natasha Levodo, for her unflinching support, encouragement and love.

Contents

List of Figures

List of Tables

Glossary of Abbreviations

CFL	Compact Fluorescent Lamp
CHP	Combined Heat and Power
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
ENEO	Energy of Cameroon
ETS	Environmental Tobacco Smoke
GHG	Greenhouse Gases
GOGLA	Global Off-Grid Lighting Association
GWh	Gigawatt Hour
IAP	Indoor Air Pollution
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
KEREA	Kenya Renewable Energy Association
kWh	Kilowatt Hour
LED	Light-Emitting Diode
MDG	Millennium Development Global Goals
MINEE	Ministry of Energy and Water
MINFI	Ministry of Finance
MWh	Megawatt Hour
NAMA	National Appropriate Mitigation Action
NEAP	National Energy Action Plan
NGO	Non-Governmental Organisation
PAHs	Polycyclic Aromatic Hydrocarbons
PM10	Particulate Matter
PM2.5	Fine Particulate Matter
PV	Photovoltaic

RETs	Renewable Energy Technologies
SCOT	Social Construction of Technology
SHSs	Solar Home Systems
SNH	National Hydrocarbons Corporation
SO_2	Sulphur Dioxide
SPLs	Solar Portable Lights
TV	Television
UNDP	United Nations Development Programme
VAT	Value-Added Tax
VOCs	Volatile Organic Compounds
W	Watts

Published Papers from this Research

J. Levodo, A. Ford, I. Chaer (2015). Implementation of Renewable Energy Technologies in Rural Africa. Presented at the 17th international conference on Energy Efficiency and Renewable Technologies. Morocco 2015.

J. Levodo, A. Ford, I. Chaer (2017). Scaling-up Renewable Energy Technologies using Solar Lantern in Rural Africa. Presented at international conference AmPS 2017, London South Bank University. United Kingdom.

J. Levodo, A. Ford, I. Chaer (2017). Rural Electrification using Off-grid Solar PV Lanterns in Africa. Presented at international conference Africa 2017 Water Storage and Hydropower Development for Africa. Morocco 2017.

Chapter 1

Introduction and Background to the Study

1.1 Introduction

According to the UN (2014), 79 % of the rural population of Cameroon live without access to electricity and rely on wood for cooking and traditional kerosene lamps for lighting. The intensive use of kerosene lamps for lighting by the rural population puts great pressure on the environment, family and social life. At the same time, men, women and children are exposed to indoor air pollution that puts their health at risk (Yeh, 2014).

Energy of Cameroon (ENEO) is the sole national energy provider company in Cameroon and the lack of electricity access to some areas in Cameroon has made the company charge higher prices for energy (i.e. electricity, kerosene). In the case of kerosene lamps, people have to walk long distances to find kerosene and the most affected people are women and children as they do all the household tasks. Kerosene lamps and candles have a big impact on the health of rural populations and the environment. In previous years it was believed that only poor people used kerosene lamps; however, nowadays in Cameroon even rich people are using kerosene lamps as Cameroon is affected by high energy poverty and an increased population size. Cameroon is endowed with abundant natural resources suitable for renewable energy, with solar radiation between 4.9 and 5.8 kWh/m^2/day in the north of Cameroon (IEA, 2016). This could serve rural community households; however, the absence of a good energy policy in Cameroon makes it difficult to tackle the socio-economic and environmental issues in the country.

1.2 Climate Change

Cameroon has different ecosystems and has signed different international conventions regarding desertification, biological diversity etc. (UN, 2014). The country signed the convention on organic pollutants at the climate change convention in Stockholm in 2004. Cameroon has the highest deforestation rate in Africa with 0.9% per year (Ayalon et al., 2016). The government of Cameroon has adopted an integrated water resource management plan. The aim of this plan is to manage and integrate a state-owned forest, protect soil fertility, conserve water resources and safeguard biodiversity. According to Ayalon et al., (2016), greenhouse gas emissions in the atmosphere are increasing and the world is becoming warmer every day. It should be highlighted that climate change can have unpredictable and far-reaching economic, social and environmental consequences. It should also be noted that the change in temperature can influence climate patterns such as storm intensity and wind. This can influence natural disasters such as erosion, increased risk of forest fires and water shortage/drought.

According to the World Bank (2016), Cameroon is ranked 172 out of 229 countries when considering income per capita with about 40% of the population living on less than $2 a day. Most Cameroonians live in rural areas and are engaged in the agricultural sector, which contributes about 45% of the GDP of the country (Molua et al., 2016).Tingem et al., (2014) predict that the average temperature in Cameroon is expected to rise by 0.7°C to 0.8°C by the year 2020 in the region as a result of global warming. The risks of climate change in Cameroon have touched almost all developing sectors in the country, causing death and sickness. Malaria is increasing in the country and this could possibly be because of the country's rising temperatures.

The predictions regarding Cameroonian climate change also focus on the predictability of rainfall and volume reduction. Statistical figures have shown that rainfall has decreased over 2% in past years (Molua et al., 2016). Cash crops and crop yield have also been affected by unsteady rains in the country. Cameroonian vulnerability from climate change is exacerbated by poverty. Most natural disasters are related to climate, water, electricity or weather (Ayanji, 2016). Cameroonian agriculture is up to 90% rain-fed. Agriculture constitutes about 70% of foreign exchange after timber and oil, and accounts for more than 40% of the country's GDP. All of this is affected by climate change. Cameroon's poorest populations are very sensitive to climate change, mostly in the Sudano-Sahelian zone, and these people are struggling to cope with the current climate variability and weather conditions. The most affected sectors in Cameroon are health, agriculture, energy resources, food security and water resources (UNEP, 2013).

Cameroon's forest landscape has been affected by the vulnerability of climate change. In Sub-Saharan Africa, especially in Cameroon, climate change has added to stress and pressure on the population with poor living conditions. It should be noted that tree felling, inappropriate land use, flooding of low-lying areas, soil erosion and deforestation have increased the levels of forest degradation causing climate change in the country. There is insufficient information available to have confidence in a quantitative assessment of Cameroon's ecology. According to the World Bank (2016), in the next few years Cameroon's population is expected to rise and wood fuel energy demand will increase in rural areas. The consequences of tree felling in the next few years will be severe in Cameroon as the rising global energy prices and lack of electricity will make populations dependent on wood fuel, charcoal and other biomass sources. As Cameroon's population is growing, managing and protecting trees will require specific skills, therefore, the government should put in place a credible training institution for young people to fight against deforestation.

1.3 Theory

Household indoor air pollution is an issue in Cameroon. The Cameroonian population has not realised the negative impact of IAP caused by the use of kerosene lamps and, still now, nothing has been done to ameliorate the situation. Energy professionals, experts and government officials appear to be indifferent to household energy poverty. It should be highlighted that kerosene lamps have been in circulation in the country since 1960. Cameroon has abundant natural resources but there is unequal distribution of resources. Some people have plenty but there is a shortage for others. Where there is a shortage, action should be taken to solve the problems. Where there is not a shortage, good sustainability management is needed. For both aspects, there should be a solution to improve the life of rural people; the adoption of renewable energy could be that solution.

In Ebebda, the case study area, rural people use kerosene lamps and candles during the night time; the kerosene lamps cause respiratory problems (caused by smoke), headaches, eye problems, and sneezing for the women and children (Bruce et al.,2016). It should be highlighted that the rural population is more at risk from household indoor air pollution than the urban community. In rural areas, the hardship and living cost conditions make it difficult to access electricity. In urban areas, although people are able to afford electricity, this is often inadequate and the supply is unpredictable. Solar energy is a form of renewable energy that may provide the Cameroonian government with the opportunity to address energy challenges without the need for expensive power generation projects, transmission and distribution networks. A solar lantern, also known as solar light or solar lamp is a system comprising a photovoltaic solar panel/s, charge controller, electrical batteries and an LED lamp which provide light.The solar photovoltaic panel normally charge the batteries during the day, using day light, which then can be used to power the LED during the night-time.The current system used by SolarAid is produced by Kavita Solar (SolarAid, 2016), but there are other manufacturers in the world such as Ritika Systems and Bharat Solar Energy (Lighting Africa, 2018). At present, there are no solar lanterns in use in Cameroon (the author is familiar with this Sub-Saharan African country). Other African countries such as Nigeria, Congo, Chad and Gabon face blackouts each day, receiving electrical power for as little as one hour each day or not at all (World Bank, 2016). Solar energy provides only a tiny fraction of the power generation in Nigeria, even though the country receives maximum sunlight exposure. Kenya, on the other hand, has vast renewable energy resources such as solar, wind, biomass, biofuel and hydropower, but their use has been limited (Lighting Africa, 2018). In addition, no academic research has been carried out on this topic in Cameroon. This could be because of lack of knowledge or resources.

1.4 Aim

The main aims of this research are to study the socio-economic and technical barriers that mediate the uptake of solar PV energy in rural and urban areas in Cameroon, and explore the possibility of adopting solar lanterns as an interim option to promote wider PV adoption and elimination of the use of kerosene lamps in Cameroon.

1.5 Research Objectives

Utilisation of kerosene lamps for lighting in low-income communities in developing countries has a negative impact on the health of those individuals. The objectives of this research are as follows:

- ❖ To investigate the socio-economic impact of poor lighting on health and environmental issues in Cameroon.
- ❖ To identify technical barriers that mediate the uptake of solar PV in Cameroon.
- ❖ To carry out a comparative study of existing kerosene lamps against solar lanterns in the case study area.
- ❖ To identify the positive impact of solar lanterns (i.e. on health, income and employment etc.).
- ❖ To explore the utilisation of solar lanterns in rural and urban areas in Cameroon to potentially eliminate the use of kerosene lamps.

1.6 Research Questions

As stated above, this research will be carried out by answering the following questions:

- What types of energy sources are used in households for lighting in the study site?
- What level of knowledge do Cameroonian people have about household energy and the impact of indoor air pollution on health?
- What type of new technology can be adopted by rural communities in Cameroon to replace kerosene lamps for lighting?
- What barriers are preventing the adoption of solar lanterns in Cameroon?

1.7 Contribution to Knowledge

The contribution to knowledge from this study is as follows:

- The result of the survey has clearly demonstrated a link between household health issues and the use of kerosene lamps in Cameroonian households.
- Based on the study, solar lanterns have an important place as an interim technology for the transition from kerosene to full electrification.
- The output of the study could form a key document to unlock solar PV barriers in Cameroon.
- The research shows that it is possible to gain financial savings using solar lanterns compared to kerosene lamps, and this constitutes a boost for many poor populations with a limited income. Though both solar lanterns and kerosene lamps have fixed costs, use of kerosene lamps requires households to spend money on fuel, whereas the solar lanterns can be charged for free using sunlight.

1.8 Structure of the Thesis

This thesis is divided into ten chapters.

Chapter one deals with the background of the study, aims and the theory which inform the thesis, research objectives and research questions.

Chapter two comprises the literature review of the study. The chapter looks at rural and urban electrification in Africa, and Cameroon in particular, and the potential of solar PV in the country.

Chapter three looks at the methodology used in this thesis and provides information and insight into the study area in Ebebda district and how data was collected. The chapter closes with a sketch of the problem and the limitations of this thesis.

Chapter four looks at the socio-economic status of Cameroon, and the challenges and opportunities of the country. The chapter closes with the institutional framework of the Ministry of Water and Energy of the country.

Chapter five outlines innovation theories and solar PV barriers in Cameroon. The chapter looks at different types of barriers blocking the adoption of solar lanterns, and innovation theories for adoption of solar lanterns in Cameroon.

Chapter six analyses the results of the survey and questionnaire that were carried out in the case study area in Cameroon.

Chapter seven looks at the potential of PV utilisation in Cameroon. The chapter examines different options available for rural and urban areas, and the advantages of solar lanterns.

Chapter eight examines factors that could influence the success of solar lantern use in Cameroon based on the Kenya model and analysis of secondary solar lanterns data.

Chapter nine highlights solutions to unlock solar lantern barriers in Cameroon.

Chapter ten provides the main findings of the study and concludes with the key issues that are discussed in this study.

Chapter 2

Literature Review of the Study

2.1 Introduction

Energy is necessary for any country's economic development and essential for economic growth (Entsua Mensah, 2016). Energy plays an important role in the global economy by securing the flow of goods, services, distribution and production. The majority of countries have different natural resources and the development of these differs. This means that to create a new capacity, countries adopt different approaches. In 2002, during the deliberation at the World Summit on Sustainable Development and Millennium Development Goals in Johannesburg, there was global support for modern energy, such as electricity, that has participated in the advancement of countries in terms of economic growth, healthcare provision, employment opportunities, living standards and education specifically in rural and urban areas in developing countries.

It should be highlighted that countries with better access to energy, specifically electricity, could have a better chance of achieving economic and social prosperity for their population. According to the World Bank (2014) the lack of electricity access in rural areas is above all a manifestation of poverty. The World Energy Outlook (2016) estimates that in Sub-Saharan Africa, there are about 600 million people living without access to electricity. This equates to approximately 58 % of the total Sub-Saharan population; and in the Republic of Cameroon, the total population without access to electricity stands at 8.8 million equating approximately 37 % of the total population. Around 79 % of those without electricity access in Cameroon reside in rural areas and 21% in urban areas.

2.2 Worldwide Energy Use

At present there are about 7.2 billion people in the world, of which about 2 billion rely on wood, kerosene and other biomass fuel, which results in exposure to indoor air pollution; this causes 14,661 deaths per year in Cameroon (World Factbook, 2017). Except biomass fuels, at present, renewable energy is a small contributor to the Sub-Saharan African energy sector, covering less than 2% of supply (Karekezi, S. and Ranja, T., 2014). It is relevant to wonder if Sub-Saharan African countries will one day have access to an efficient, sustainable and affordable decentralised energy supply for everybody in the future. It should be noted that there cannot be economic and social development without energy for all. In most cases, people's lives deepen according to the type of energy they use for their lifestyle. It also should be highlighted that wood is the most used biomass fuel after animal dung and crop residues (De Koning et al., 2014). Biofuel or biomass is defined as any animal material or plant burnt by a human to generate energy. Coal is used as an energy source as well. All these solid fuels produce carbon emissions that affect the health of poor populations in rural and urban areas in Cameroon. Nowadays, solid fuels are one of the most important fuels in the world, particularly in developing countries (see figure 2.1).

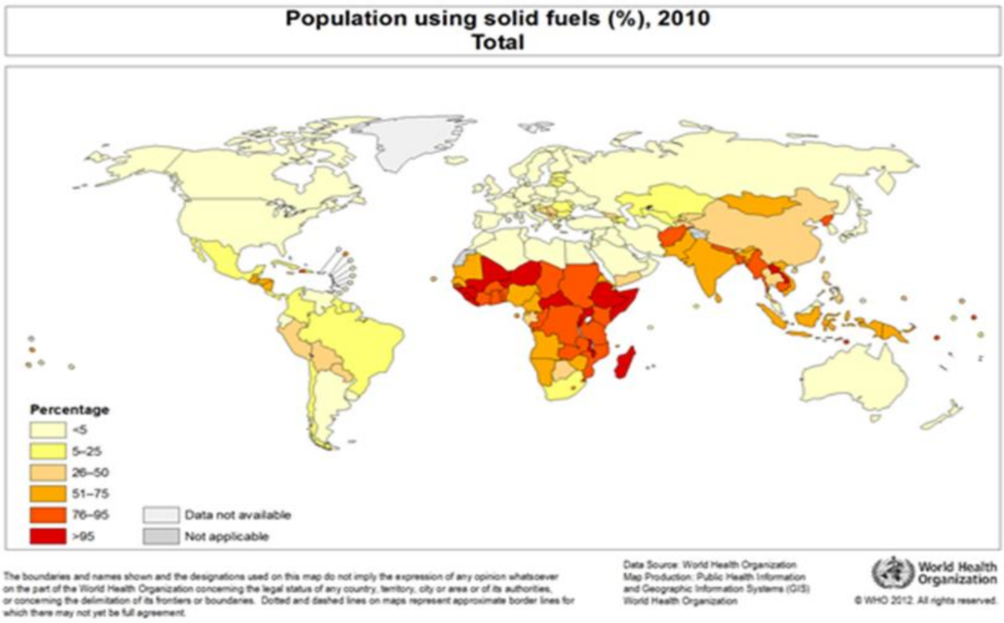


Figure 2.1 Distribution of household fuel uses in the world
Source Smith et al. (2010)

Wood, agricultural residues, charcoal and dung for cooking and heating are traditional fuels for some 2.4 billion people in the world and that number will in the future increase to 2.6 billion by 2030 (World Bank, 2016). There is an uneasy situation in Sub-Saharan Africa: 80% of people live in remote areas and the rate of electrification is around 42.7% (World Energy Council, 2015). The question here is, what can be done in such a way that affected people can benefit from affordable and sustainable technologies? It should be highlighted that 78.4% of the world's population use fossil fuels as a source of energy (see figure 2.2).

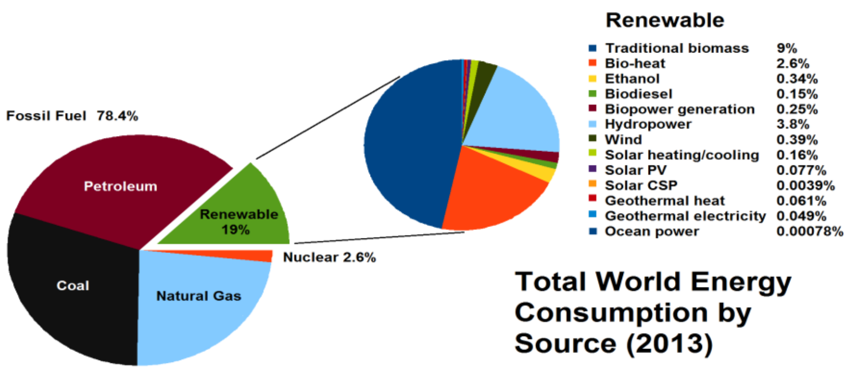


Figure 2.2 The world's energy consumption by source
Source Adapted from Jacobson (2013)

The most important fuel in the world is biofuel, when looking at the number of affected people and considering that it is the most important fuel used in developing countries. Fossil fuels, on the other hand, fall in first position in the world (see figure 2.2) (Sksena et al., 2015). The energy ladder (see figure 2.3) has been used by Smith et al., (2014) to illustrate the fuel choice for developing countries. At the lowest rank of the ladder is crop dung and waste, followed by wood, charcoal and coal. The preference is for people to move up the ladder. But where there is income change, some people are forced to move back down the ladder. The historical movement of fuel use is important to describe, as some households use more than one type of fuel depending on the time of year. The shift of fuel is based on other parameters such as economic situation.

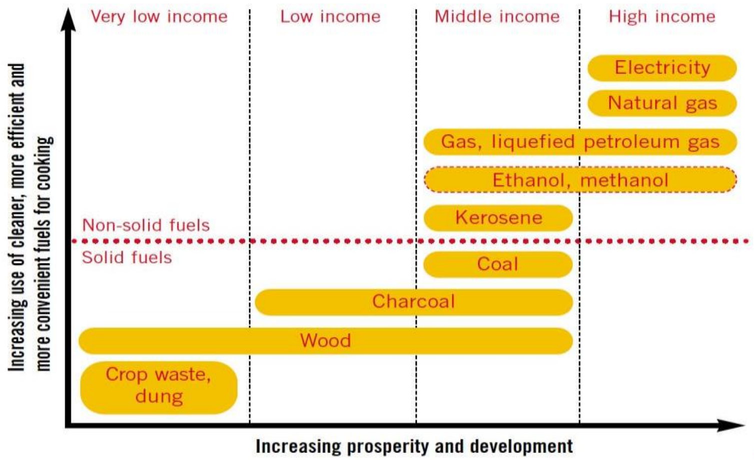


Figure 2.3 Generic household energy ladder
Source Adapted from Sagar and Smith (2018)

2.3 Indoor Air Pollution

According to McGranahan and Murray (2016), ‘air pollution is defined as the presence of substances in the air at concentrations, duration and frequencies that adversarily affect human health, human welfare or the environment’. It should be highlighted that indoor air pollution causes about 3.8 million deaths every year of the global population (WHO, 2016). According to WHO (2015) there were about 396,000 deaths in 2002 in Sub-Saharan Africa due to IAP caused by smoke from kerosene lamps. It can be ascertained from table 2.1 that 3.8 million people a year die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels and kerosene for lighting.

Attributable to indoor air pollution particles (total deaths/year)	Illnesses				
	Pneumonia	Stroke	Lung Cancer	Ischaemic Heart Disease	chronic obstructive pulmonary disease (COPD)
3.8 million	27%	18%	8%	20%	27%

Table 2.1 Deaths attributed to indoor air pollution particles
Source WEO 2017 Special Report: Energy Access Outlook

According to Follansbee (2016), indoor air pollution contains a mixture of air pollutants that makes it impossible to determine the exact combination of pollutant and exposure concentration under controlled conditions. According to McGranahan and Murray (2013), indoor air pollution is worse than outdoor air pollution when there is another polluting source, for example, tobacco or open fuel. According to the WHO (2016), almost 30% of the households in countries such as China still predominantly use solid fuel (wood and coal). According to the World Health Organisation (WHO) and United Nations Development Programme (UNDP), indoor air pollution is defined as the killer in the house. On 25 October 2005 in Geneva, the WHO and UNDP issued a statement calling the world to wake up to this silent killer. It raises the alarm for governments to take action against indoor air pollution. The World Bank declared indoor air pollution to be one of the top four health and environmental problems in developing countries (World Bank, 2014). The International Energy Agency (IEA), UNDP and WHO on October 2004 in Paris raised concerns about biomass fuels and drew attention to solving indoor air pollution. In their report they pointed out that to achieve the Millennium Goal, indoor air pollution must be reduced.

In developing countries, particularly in Cameroon, indoor air pollution is caused by the use of solid fuels instead of electricity in households; this is a major problem in Sub-Saharan African countries as a whole. It should also be highlighted that developed countries are not heavily affected by household indoor air pollution (IAP) when compared to developing countries because these countries currently use cleaner energy.

Indoor air pollution is generally assessed by measuring certain factors against certain types of fuel use to measure their pollutants. It should be noted that in developing countries such as Cameroon, the measurement of indoor air pollutants is very limited or non-existent due to lack of equipment and the absence of engineers and technicians; however, using factors such as proxies is very useful in these countries (Bruce et al., 2013). This is generally done with any fuel that generates combustion heat (energy) and CO_2. To measure the intensity and amount of pollutants depends on the type of household fuel used. The type and quality of fuel is directly proportional to the level of emission (see figure 2.4), and this is because cleaner fuel produces fewer pollutants than crude solid fuels produce. It should also be noted that, in developing countries, using these fuels in poorly ventilated households can have serious health effects. According to Ezzati et al., (2011), wood can release 50 times more pollution than a gas stove. It should also be highlighted that the intensity of indoor air pollution depends on the energy ladder (see figure 2.3 above), because the cleaner the fuel, the less IAP is produced.

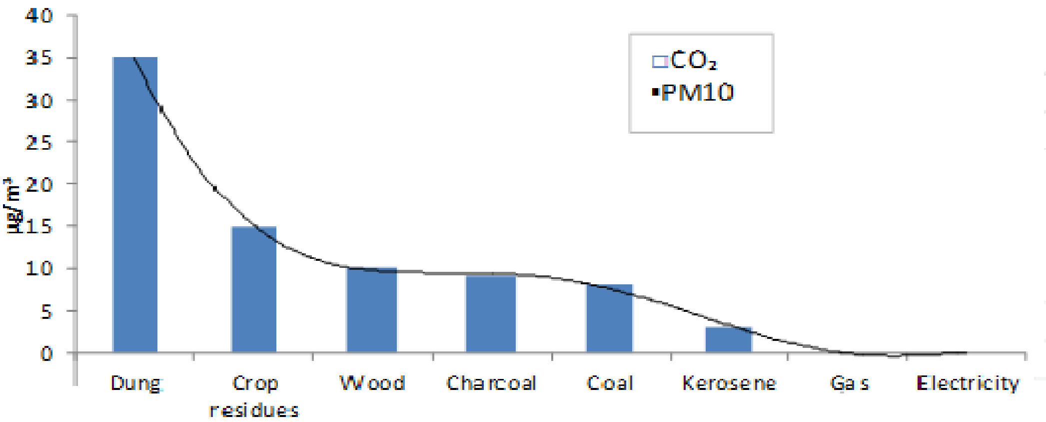


Figure 2.4 Emissions along the household fuel ladder
Source Adapted from Akintan (2018)

2.4 Level of Indoor Air Pollution Measurement in Developing Countries

Measurement of indoor air pollution is a complicated process and requires advanced technology, human skills and equipment. According to the WHO (2016), for IAP measurement to be carried out, the method and sampling selection is very important and depends on portability, accuracy, precision cost and instrumentation validation. It should be noted that the determination of the level of indoor air pollution is determined by carbon particles (black smoke). There are different ways of measuring indoor air pollution and these can be classified as emerging and traditional. In the past, air samples were taken in an air bag or cylinder to the laboratory for testing. In the 1970s, there were portable pumps that put air samples into a sampling filter and this was used as personal exposure and called an active sampler. It should be noted that this method of indoor air pollution measurement was very limited in the field because of time limitations and high cost. In the 1980s, passive samplers were introduced for industrial testing and then this was later adopted for field surveys (WHO, 2012).Nowadays, passive air samplers are commonly used as they are portable and maintenance-free, can be used in rural areas where there is a lack of electricity and are relatively cheap methods costing less than US$130 (World Factbook, 2018). To estimate people's exposure to indoor air pollution, the passive air sampler is widely used for testing (see figure 2.5).

Figure 2.5 Passive air sampler
Source Adapted from Akintan (2018)

Exposure to indoor air pollution is measured by using proxies (distal factors) such as house characteristics (for example, the number of rooms in the house, size of the house, number of windows, house arrangement/layout, building materials used and number of occupants in the house). Other considerations, such as the type of fuel used in the household and socio-economic factors, are also used to determine indoor air pollution exposure.

2.5 Rural Electrification

Rural electrification has been a major subject at international conferences and seminars; many discussions about the meaning of rural electrification have taken place. According to Mbewe (2015), the term ‘rural electrification’ can have different meanings and different definitions. For example, electrification in rural areas can be defined as grid extension to isolated systems. However, in some developing countries where electrification is still new, it is defined as remote area electrification to improve people’s lives. According to Barnes (2014), electrification in rural areas is the availability of electricity in remote areas. Yaron et al., (2015) define electrification in rural areas as bringing electricity to remote areas. In the case of this study, the author herein defines rural electrification as ‘grid connection where there is more than one household in the village electrified ’.

2.6 Socio-economic Studies on Rural Electrification

Several studies have explored the factors and results of electrification in third world countries. Kanagawa and Nakata (2016) studied energy and economics to examine the possibilities of electrification for rural areas in India and extracted results on the increase in children’s literacy. In 2011, Wamukonya and Davis published a socio-economic impact comparative study between grid connection, solar home system (SHSs) and unelectrified households in Namibia that has a similar method to this thesis. Interviews were carried out and 371 questionnaires were completed in order to make a statistical analysis of the research question. As with other studies, Wamukonya and Davis (2013) found that electrification improves studying conditions and safety, while also providing access to services such as television, refrigeration, mobile phone charging etc.

However, in contradiction to Kirubi et al., (2015), they concluded that access to electricity does not change income and growth activities, while there is also no impact on immigration to urban centres. Contrary to that, related research by Waerras et al., (2014) on the impact of renewable energy projects for southern African countries was carried out through questionnaires and showed that the most positively affected socio-economic aspects are education, security and migration. Similar benefits of access to electricity were found in the following publications with similar methodologies. Liu et al., (2013) focused on the case study of Tiber, Gordon and Spicker (2015) on the case study of Zambia. Wijayatunga and Attalage (2016) and Khandker et al., (2012) focused on the case study of Bangladesh. They noted that having access to electricity improves children's education, social aspects for households and increases school enrolment by about 63 percent for boys from 1808 to 2956 and 29 percent for girls from 2334 to 3002.

2.7 Social and Household Activities in Rural Areas

Access to modern lighting equipment and services has a great impact on social and household activities in developing countries. Poor lighting conditions create insecurity and migration tendencies for the users, they do not allow them to extend their productive activities into the evening hours, they force them to drudgery and they prevent them from socialising at a family or community level. In addition, people who rely on kerosene lamps (see figure 2.6) for lighting are not able to charge their mobile phones and so must either visit a local store or a neighbour's house that is often located a great distance away. The questions of this section are concerned with the safety and migration tendencies people have in order to achieve access to electricity, the social and household activities they do in evening hours and the way they manage to charge their mobile phones if they have them. At this point it should be mentioned that mobile phones are considered essential equipment that even the poorest households have, as they are the quickest, most popular and efficient way of communication in both urban and rural areas.

Figure 2.6 Kerosene lamp
Source CVUC (2015)

2.8 Energy Situation in Cameroon

Based on the study carried out by the Ministry of Water and Energy in 2006 and reported by the World Bank (2016), about 79% of rural population (approximately 22.5 million of this small central African country) (MINEE, 2016) are still using kerosene lamps and biomass fuel for lighting and cooking. Out of 30,000 villages in Cameroon, 2,000 have the opportunity to get access to a grid connected to ENEO, the main electricity provider in Cameroon (Tetchiada, 2015). It should be highlighted that Cameroon possesses very good renewable energy potential, but it is under-exploited (Wirba et al., 2015). The distribution, production and transportation of this system are still informal. The country possesses a huge potential for other renewable energies such as solar, geothermal and micro-hydro, but they are undeveloped (Kana et al., 2017).

Cameroon relies on hydro power as it is the most popular energy in the country. In central African countries, Cameroon is second only to the Democratic Republic of Congo, with a hydroelectric potential of 23 GW of which only 4% has been developed so far (Belda, 2014). The country has some PVs that have been tested at Yaoundé post office for the benefit of traffic lights. Based on figure 2.7 and according to (World Factbook, 2018) the use of biomass and waste for lighting and cooking is high, and primary solid biomass (including fuel and wood) accounts for 64.1% of Cameroon's primary energy supply. According to figure 2.7, fossil oil accounts for 27.2%, hydroelectricity for 5% and gas for 3.7% (World Factbook, 2018)

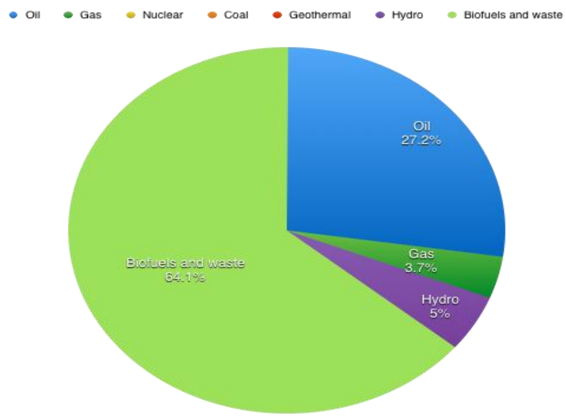


Figure 2.7 Energy resources in Cameroon
Source World Factbook (2018)

2.9 Energy Consumption Distribution in Cameroon

During the year 2014/15, consumed energy sources in Cameroon were reported as being 21% petroleum, 16% electricity and 60% from wood fuel. However, the figure shows that only 3% was from biomass waste, charcoal and agricultural waste (see figure 2.8). It should be noted that, in that same year, the industry sector consumed the largest amount of energy (55%), with the residential sector consuming 21%, agriculture/forestry 1.% and public services and the commercial sector 23% (see figure 2.9). It can be concluded that wood fuel is the primary source of energy for most Cameroonians and accounts for 60%.

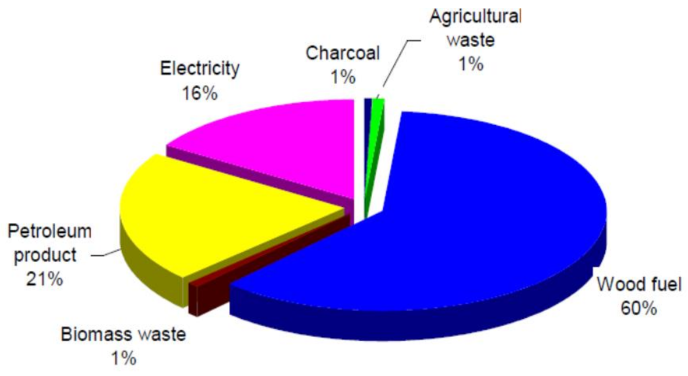


Figure 2.8 Cameroon energy consumption distributions
Source UNDP (2015)

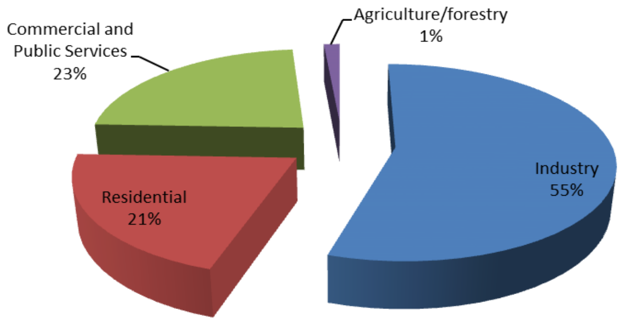


Figure 2.9 Cameroon's energy consumption
Source Adapted from Kaz (2016)

With the limitation of lighting technology and the rise of indoor air pollution, global warming, climate change and deforestation challenges in Cameroon, the expertise and research in these areas cannot be overplayed. Figure 2.10 depicts the situation of informal settlements in Ebebda, where there is a lack of indoor lighting during day and night. The family are all huddled around a tin can lamp to carry out the productive activities; other households have access to electricity and can afford to turn on the lights; while the others continue to use kerosene lamps or candles.

Figure 2.10 A family using a tin can lamp at night in a house in Ebebda
Source Author's collection (2015)

The use of kerosene lamps in households in Cameroon has a negative impact on health and the environment. Figure 2.11 portrays a woman using a kerosene lamp for both lighting and cooking purposes, exposing her to several health issues. The lack of a renewable energy policy in Cameroon and some minor reforms in the energy sector make it harder for the country to catch up with other leading countries such as India and some southern African countries. It should be noted that in Uganda, for example, wood is the highest biomass source, with 93% as the primary energy consumption; the percentage of rural electrification stands at 1% (GTZ, Energy Policy Advisory Service, 2013).

Figure 2.11 A woman cooking using a kerosene lamp at night in a village in Cameroon
Source Author's collection (2015)

2.10 Kerosene Lamps in Cameroon

Access to modern energy for lighting continues to be a major challenge in Cameroon, where kerosene lamps are the most popular sources of lighting for unelectrified households. In the small urban commercial centres, kerosene lamps and fuel can be found easily as they supply the nearby communities that are not connected to the grid. Figure 2.12 depicts the people selling kerosene on the streets of Cameroon to cater for the growing use of kerosene lamps for lighting and cooking.

Figure 2.12 Local population selling kerosene fuel
Source Author collection (2015)

Figure 2.13 portrays the three main types of kerosene lamps that can be found in rural Cameroon: tin can lamps, hurricane lamps and pressure lamps. Tin can lamps are made from used food cans and jars and they are the cheapest option as they are usually handmade and have a very poor quality of lighting. Hurricane lamps and pressure lamps are more expensive as they are manufactured at an industrial level; they produce less smoke, use less fuel and are safer than tin can lamps. The widespread use of kerosene lamps is further evident in figure 2.14: this figure shows how young children are exposed to high levels of indoor air pollution each day by reading their books.

Figure 2.13 Different types of kerosene lamps
Source CVUC (2015)

Figure 2.14 Primary school children using a kerosene lamp during classes
Source Author collection (2015)

2.11 Energy Resources in Cameroon

According to Painuly and Fenhann (2016), Cameroon has abundant renewable energy resources that include solar, biomass, wind and hydroelectric. If exploited, the country could solve electricity deficit issues for urban and rural populations. Energy is vital for any economic development. Not only is it important for the economics of a country, but it also provides services that enhance social development, such as population health and nutrition, education, humanitarian assistance, environment, good governance, job creation and agriculture for rural and urban populations, as shown in figure 2.15 below. The country should have a good energy programme, policy and strategy for these sectors to be developed and benefit the community. It should be highlighted that when a country has a good energy programme, the country's economy will grow because these sectors work together for the country.

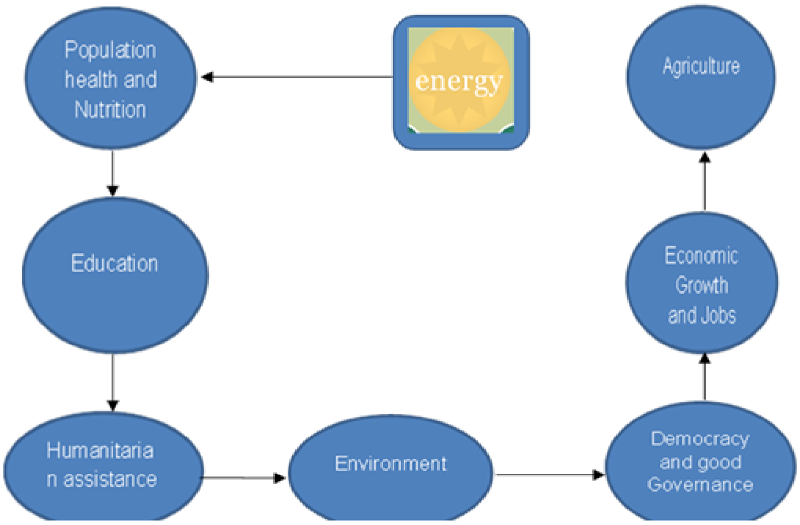


Figure 2.15 Link between energy and other sector development
Source Author's own construction (2015)

2.12 Energy Consumption Patterns in Cameroon

According to the report of World Data (2014), the most important measure in the energy balance of Cameroon is the total consumption of 5.70 billion kWh of electric energy per year; Per capita this is an average of 237 kWh per annum. The total production of all electric energy- producing facilities is 7bn kWh, which is 116% of its own requirements. The rest of the self-produced energy is either exported to neighbouring countries; along with pure consumption, imports and the production of exports plays an important role. Other energy sources such as natural gas or crude oil are also used see figure 2.16.

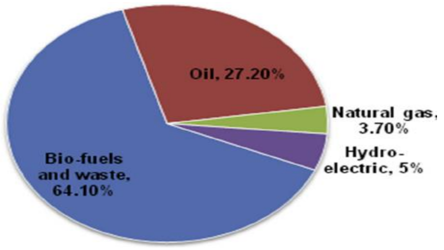


Figure 2.16 Sources of energy
Source Adapted from Wirba et al. (2014)

As evident in figure 2.16 above, Cameroon has great potential to produce electricity, but it is still not the most used source of energy. This limited access is mostly because of the subscription cost from the main provider. About 21% of the population in remote areas have access to electricity whereas 91% have access in urban areas (World Bank, 2016). Petroleum is also a major source of energy, with quite a good number of companies currently involved with the marketing and distribution of oil and domestic gas in Cameroon. Figure 2.17 gives an overview of the respective market shares with respect to a particular commodity.

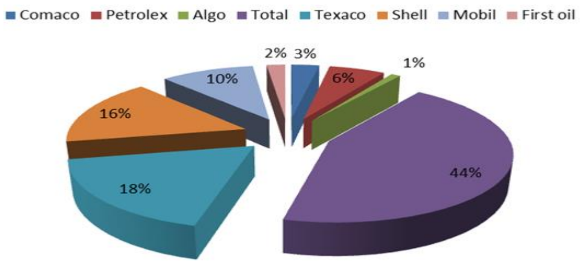


Figure 2.17 Market share of kerosene in Cameroon
Source Adapted from Ainah (2015)

The solar energy potential is quite good (World Bank, 2016) but traditional fuels are still the main source of energy in Cameroon (see figure 2.18). Besides being used for cooking and lighting, they are also used for drying crops.

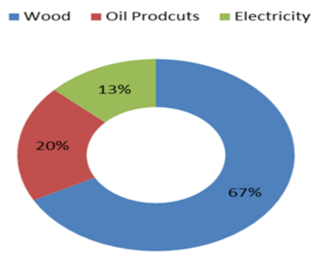


Figure 2.18 Energy sources within Cameroonian households
Source Adapted from William (2017)

This traditional form of energy is used by all social demographics of the population (see table 2.2); however, its use is more prominent among the poorer sections of the population. This is partly due to the fact that they have no other source of energy and cannot afford a different type of energy source. It is evident in the table that wood is the easiest available source to meet the demand for firewood or fuel wood cooking; a vast majority of the populations cooks meals with the three stone fireside, stoves or open fires. Deforestation has thus been increasing at an alarming rate in the region of Cameroon.

Households	Wood	Domestic gas	Kerosene	Others
20% of poorest	98.7%	0.2%	0.9%	0.2%
20% of poorer	94.5%	1.7%	3.1%	0.7%
20% of richer	78.9%	10.3%	10.0%	1.3%
20% of richest	48.9%	33.4%	14.4%	3.3%

Table 2.2 Relationship between household incomes and their cooking energy
Source Adapted from Jacobson (2013)

- **Population production of deforestation**

Deforestation for human purposes has a long history. Historically, deforestation has often gone hand in hand with human population growth and development. Up until the 20th century, most of this growth, development and therefore deforestation took place in temperate regions. There is a common belief that providing food for the global population includes the need for more agricultural land which leads to deforestation. Although forests still cover 30% of the world's land area (FAO, 2018), about 7 million hectares of forest are lost each year; deforestation is one of the most widespread and important changes that people have made to the surface of the earth. The cumulative loss of forest land is followed by the global growth rate of the human population. The trajectory of population growth and deforestation is shown in figure 2.19.

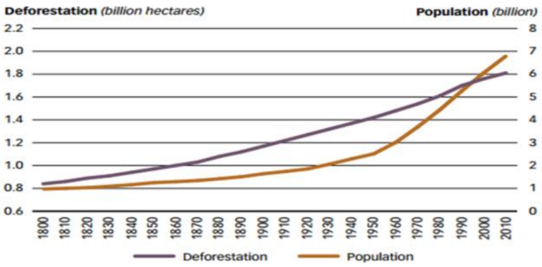


Figure 2.19 Population and deforestation growth
Source Adapted from Williams (2016)

2.13 Resources and Environment

Cameroon has a very rich forest potential. However, wood energy is unevenly distributed, such that the Sahel region experiences advanced desertification, and the extreme tropical humid zone of the south is suffering from a deficit of combustible fuel. However, in 1985, about 28,233 hectares were reforested; nearly seven times as much is degraded on a yearly basis (MINEE, 2015). In the period between 1990 and 2000, Cameroon lost an average of 220,000 hectares of forest every year; this amounts to an average annual deforestation rate of 0.9% per year Katz (2014). By implication, the regeneration level has not kept up with the degradation rate. When biomass is burnt, carbon dioxide is released and this contributes to global warming. Meanwhile, felled trees are no longer available as a carbon dioxide sink. Forests and woodlands not only act as habitats for certain species but provide natural protection systems for the earth. They also have important functions with regard to the water reservoir, soil protection from erosion, climate regulation, temperature balance, air filtration and regional distribution of humidity at the macro- and micro-climate levels. Therefore, high deforestation levels contribute enormously to climate change and the loss of biodiversity.

Poor investment in Cameroon's energy sector over the past ten years has made it difficult for the electricity sector to greatly contribute to the economic growth of the country. Given the importance of agriculture to the country, the level of energy consumption within the agricultural sector is relatively low (FAO, 2014). The effects of this low energy consumption cannot be minimised. In Cameroon, the different energy options have not been fully exploited because, besides the use of wood, hydro power and crude oil, there is no other energy from renewable sources being used for agricultural purposes. In an attempt to address this problem and other challenges facing the energy sector, the government of Cameroon, in collaboration with the World Bank and the United Nations Development Programme, have come up with a national energy policy document. The policy has a dual purpose: to address the problems of the energy sector and at the same time enable Cameroon to meet the Millennium Development Goals (MDG). The objective of the national energy policy document is to make energy both affordable and accessible to poorer sections of the population. Some specific objectives to be implemented over the years 2018–28 are cited below:

- Reducing traditional fuel for cooking in favour of domestic gas.
- Identifying and supporting micro hydroelectric projects in isolated rural areas.
- Reducing the energy bills for households and institutions.

- Supporting small companies that are active in the energy industry.
- Creating an environment favourable for the implementation of modern sources of energy, which could boost economic growth.
- Exploring pilot micro projects which can help the energy sector and also reduce poverty.

2.14 Biomass Energy Resources in Cameroon

According to African Economic Outlook (2015), most energy consumed in Cameroon is biomass and that includes wood, crop residues and human/animal waste, all of which account for about 66.7% of consumption. It should be noted that wood, coal and diesel are dominant energy sources, with electricity accounting for 10% and petroleum 20%. Cameroon has the third largest biomass potential in Africa and it forms the dominant source of energy (Edjekumhene et al., 2013). Consequently, the economy of Cameroon depends mainly on the forestry sector for revenue. It should be highlighted that a quarter of its forest territory has coverage of about 25 million hectares. However, the use of this type of unsustainable energy resource has caused a high level of deforestation in the country. A major section of the forests in the regions is transformed into banana, rubber and palm plantations every year. The demand for these crops is high in the other regions; forests are thus viewed as a medium for revenue by the government and private companies, who acquire land to grow these crops. The lack of proper education has left the people of this region devoid of knowledge about proper land management techniques. With about 200,000 hectares per year annual clearance and only 3,000 hectares of regeneration per year, the majority of Cameroon's biomass use is for cooking (domestic use) and other commercial sector uses.

The biomass boiler is an efficient solution to reduce the quantity of wood and electricity used to cater the need for energy. The biomass boilers, similar to the conventional gas boilers, provide a way to heat the house and water for the entire household, and combust wood pellets instead of gas or oil to produce heat. As the region has a great potential for biomass, the use of wood rather than oil or gas is a sustainable option to avoid long-term climate changes. The cutting down of huge areas of forest, without replacing the trees that have been removed, causes an inadvertent change in the amount of carbon dioxide present in the atmosphere, which can impact the rest of the world immensely. Wood pellets are further not harmful for the local population as the carbon dioxide that is released during the process of combustion is absorbed during the development of the tree, making this option essentially carbon neutral.

2.15 Solar Energy Resources in Cameroon

Cameroon is endowed with a solar energy resource and receives annual sunshine of over 3,000 hours per year with solar radiation intensity of 240 w/m² (IEA, 2014). It should be highlighted that Cameroon has a solar radiation of 5.8 kWh/m^2/day in the north (see figure 2.20) while the rest of Cameroon has 4.9 kWh/m^2/day (IEA, 2014). With all this solar potential, conditions are ideal to exploit solar energy resources through different type of conversion technologies. It should be noted that solar already contributes to the community through unqualified channels in some sectors such as fish, fuel wood, clothes and drying agricultural products. According to Abdullahi et al. (2014), 'in most parts of the country, the mean solar irradiance is approximately 5.8 kWh/m^2/day' (see figure 2.20). Solar power is currently used for powering cellular-based transceiver stations and only 50 solar PV installations exist and are not currently in operation as street lighting (Wirba et al., 2015).

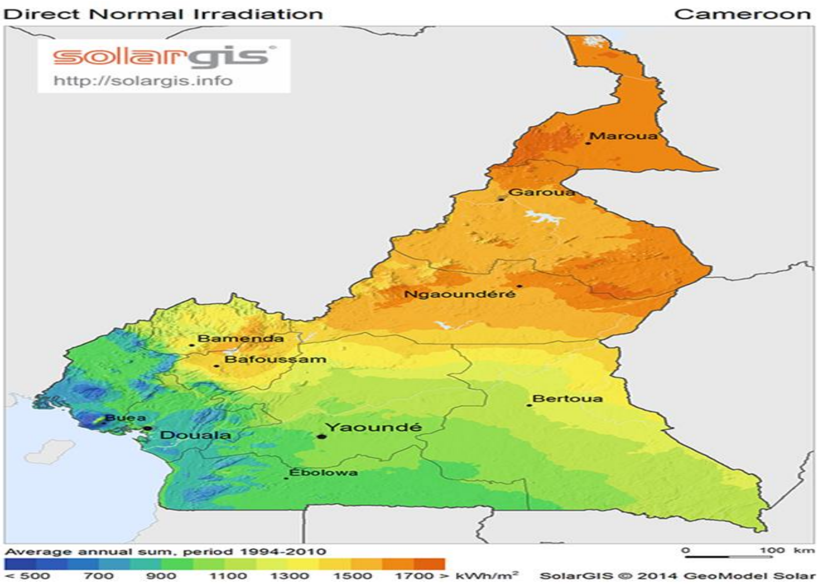


Figure 2.20 Solar radiation map of Cameroon

Source: http://solargis.info/doc/_pics/freemaps/1000px/dni/SolarGIS-Solar-map-DNICameroon-en.png Accessed 19/06/2014

2.15.1 Wind Energy in Cameroon

As a developing country, Cameroon's wind energy has never been studied properly. According to Mas'ud et al., (2017), a few attempts have been made and the result of that study revealed that Cameroon possesses an annual wind speed of 3 m/s most of the time and in Adamawa province the wind speed is 2 m/s while the rest of the country's wind speed is 1 m/s. According to the study conducted by Mas'ud et al., (2017), wind has no commercial viability in the country as there is lack of a renewable energy policy by the government to accelerate the growth of wind as an alternative and efficient source of energy in the country.

2.15.2 Geothermal Energy in Cameroon

At present there is an unknown potential geothermal energy resource in Cameroon. However, according to ENEO (2016), there are warm springs in the Mont Cameroon, Ngaoundere and Manegoumba regions. Geothermal energy has never been studied in Cameroon before and this could be because of a lack of knowledge or financial difficulty for the country.

2.16 Hydroelectric Power Station Energy Resources in Cameroon

With a production potential of 103 TWH per year and an estimated 23 GW, Cameroon has the second largest hydropower potential in the central African states, after the Democratic Republic of Congo (see figure 2.21).

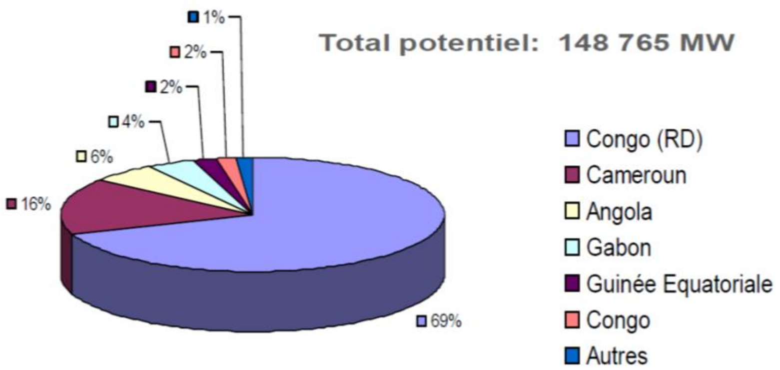


Figure 2.21 Hydroelectric potential in central African states
Source Central African Power Pool (2015)

Cameroon has four main power station facilities: Song Loulou 384 MW, Lagdo 72 MW, Edea 204 MW and Memve'ele 200 MW (still under construction). Cameroon has a small level of hydropower of 1 MW in the western region of the country (MINEE, 2015).

2.16.1 Edea Power Station

Edea power station is a hydroelectric power plan of the Sanaga river in Cameroon (see figure 2.22). It has a power generation capacity of 204 MW with an output of 1584.87 GWh, enough to power over 136,600 homes (ENEO, 2015).

Figure 2.22 Edea power station
Source Eneo/AS Sonel (2015)

2.16.2 Lagdo Power Station

Lagdo power station is a hydroelectric power plant of the Lagdo river in northern Cameroon (see figure 2.23). It has a power generation capacity of 72 MW with an output of 222.06 GWh (ENEO, 2015).

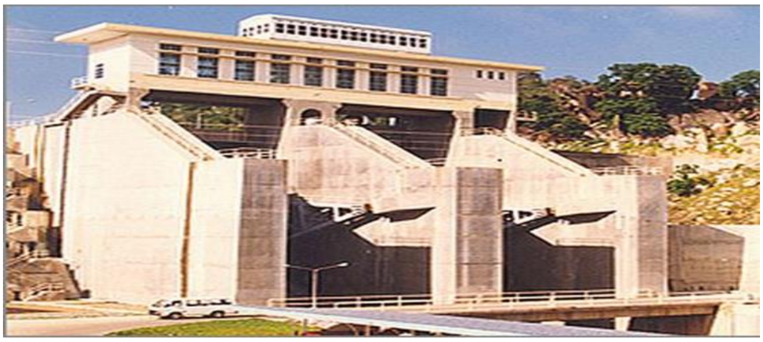


Figure 2.23 Lagdo power station
Source Eneo/AS Sonel (2015)

2.16.3 Memve'ele Power Station

Memve'ele power station is a hydroelectric power plant at Ntem in the south of Cameroon (see figure 2.24) and will have a power generating capacity of 200 MW (the power station is still under construction).

Figure 2.24 Memve'ele power station under construction
Sources Eneo/AS Sonel (2015)

2.16.4 Song Loulou Power Station

Song Loulou hydroelectric station has an output of 2425.54 GWh, speed of 120 rpm with head of 39.2 m, and a running diameter of 4,500 mm with a capacity of almost 385 MW (ENEO, 2015). The power plant produces 57% of electricity and is located in the Sanaga river, in Douala in southern Cameroon (see figure 2.25). Song Loulou hydropower plant production is vital for a healthy Cameroonian economy.

Figure 2.25 Song Loulou hydroelectric power plants
Source Eneo/AS Sonel Cameroon (2015)

- **Sanaga river**

The Sanaga river is the largest basin in Cameroon with five rivers, namely, Niger, Lake Chad, Sanaga, Congo and coastal rivers as shown in figure 2.26 below. It should be noted that three of these rivers (Congo, Niger and Lake Chad) are shared with Cameroon's neighbouring countries, Nigeria, Chad and Central African Republic. The coastal rivers flow directly to the Atlantic Ocean and this makes the Sanaga river one of the largest in the country. It should be highlighted that Cameroon has two main climate regions: a tropical climate in the central and northern regions between 60° and 130° (Sahara climate zone) and a humid equatorial climate in the south between 20° and 60° (MINEE, 2016).

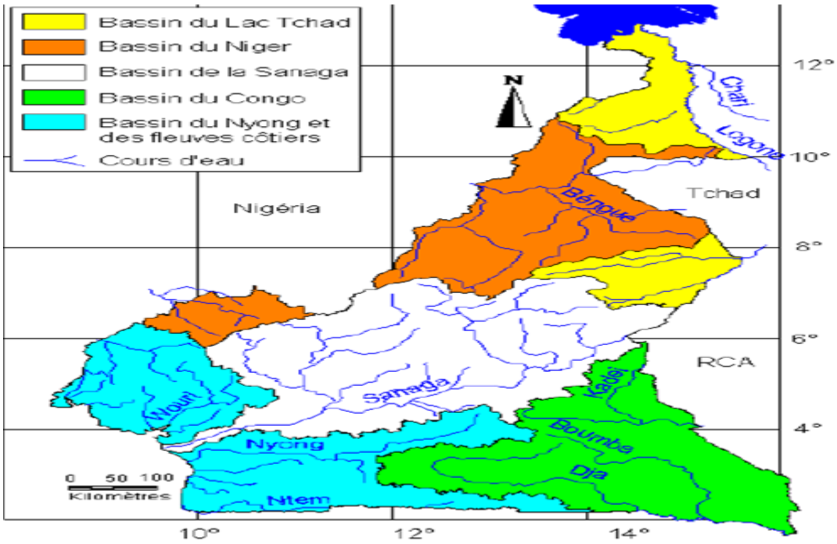


Figure 2.26 Diagram for regulation of the Sanaga river
Source MINEE (2015)

2.16.5 List of Power Stations in Cameroon with their Capacities

Cameroon has seven power stations: three are in production and the fourth is under construction (Memve'ele power station). The capacity of the latter is not yet known. The others are in retention. It should be noted that the largest retention has the capacity of 3.500 million m^3 and was constructed in 1985 and 1987 as can be seen in table 2.3.

Hydroelectric power stations	Types	Capacity	Year of construction	Name of reservoir/production
Edea power	Production	254 MW	1953	Edea power station
Song Loulou	Production	396 MW	1981 & 1988	Song Loulou power station
Lagdo	Production	72 MW	1982	Lagdo power station
Mmve'ele	Production	Under construction	2013(under construction)	Memve'ele power station
Mape	Retention	3.500 million m^3 water	1985 &1987	Mape power station
Mbakaou	Retention	2.300 million m^3 water	1971	Mbakaou power station
Bamendjin	Retention	2.000 million m^3 water	1972 & 1974	Bamendjin power station

Table 2.3 List of power stations in Cameroon
Source MINEE (2015)

- **Some figures for yearly hydroelectric production**

Song Loulou power station is the biggest in the country with 2425.54 GWh, as can be seen in table 2.4.

Song Loulou	2425.54 GWh
Edea	1584.87 GWh
Lagdo	222.06 GWh

Table 2.4 Yearly hydroelectric production
Source MINEE (2015)

2.17 Conclusion

The energy sector in Cameroon has been described geographically in this chapter. Cameroon has a population of 22.5 million and an annual population growth of 1.25% (World Bank, 2016). It should be noted that 57% of the population of Cameroon reside in rural areas (MINFI, 2016). The majority of people in Cameroon are farmers. They are poor and reside mostly in the north of the country. With diverse energy resources, hydro and biomass power have been exploited for some time now but solar and wind power have not. Cameroon has an installed generating electricity capacity of 1545 MW (World Factbook, 2018); the primary source of electricity in Cameroon is hydraulic power. Almost 57% of the electricity is produced from hydro and the rest from thermal sources based on heavy and light fuel and also gas.Further, as concluded by Enongene, Murray, Holland and Abanda (2017), the substitution of radiant lamps such as the compact fluorescent lamp (CFL) and light emitting diode (LED) that use more electricity, has resulted in a reduction of greenhouse gases (GHG) being emitted from dwellings due to lighting by 66.6% and 83.3% respectively. It can be ascertained that a transition towards efficient lighting in the residential sector of Cameroon can bring economic and environmental benefits. Thus, there is a need for the government of Cameroon to accelerate the uptake of LED by formulating and implementing favourable policies.

In general, the national electrification in Cameroon stands at 60% (ENEO, 2016). With the level of solar radiation that Cameroon possesses, the country should find a way to exploit this technology so that the population can have access to electricity. It should be highlighted that solar is a clean energy that will help the rural population to cease using kerosene lamps that emit carbon dioxide and affect human health. On the other hand, with hard living conditions, the rural community in Cameroon cannot afford grid connection, which is why it is imperative for the government to find an alternative way to provide electricity for all the population, especially in rural areas of the country.

Chapter 3

Methodology

3.1 Introduction

Developing the methodology for this research has been a challenge, as the study touches upon a wide range of issues, including solar lanterns, technologies adoption, socio-economic issues and solar lantern barriers in Cameroon, and combines different disciplines and methodological tools. Early on, it became clear that the research has a double spatial dimension: a global and a local one. However, technology adoption aspects follow more local ones as they are more related to the national characteristics of the energy sector and, most importantly, are dependent on national regulations and policy incentives. The research structures and methods used are described in the following sections in order to provide a guide for the reader through the various elements and areas of analysis discussed throughout the thesis.

3.2 Case Study Area Ebebda District

For the case study, the selection of the rural area is in the central province of Yaoundé, where the author was born and with which he is most familiar. This choice meant the author was able to get resources and access to data from family, relatives and acquaintances to carry out the research. The district of Ebebda (see figure 3.1), where the author was born, is a local government area of the central province of Cameroon and was created by Decree No. 92/187 of 1 September 1992. It is located in the department of Lékié, Central region. The average annual rainfall from 1966 to 1995 was about 1,500 mm (MINEE, 2016). The district of Ebebda covers an area of 250 km² and has 33 villages with 28,000 inhabitants (MINAT, 2015). It is limited to the west by the Bokito District, the north by the Sa'a District and to the south and east by the Monatélé District.

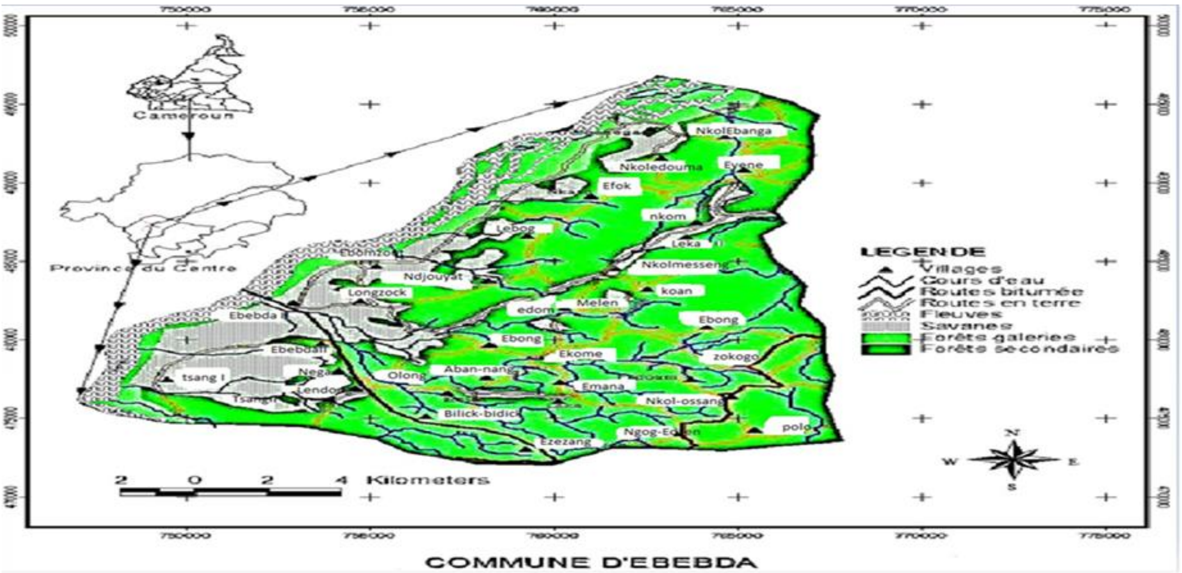


Figure 3.1 Case study area
Source CVUC (2015)

3.3 Criteria of Choice and Sampling Procedure

The selected methodologies employed in this research were the purposive sampling method and simple random sampling. The political, socio-economic, cultural, environmental and ecological divisions of the country were reviewed in making a choice of the case study area, considering the climatic and economic aspects of Cameroon. It is divided into provinces, divisions, sub-divisions, districts and villages. Each village is ruled by a traditional chief, the divisions and sub-divisions are governed by the divisional officer or sub-divisional officer, and provinces are governed by governors while the entire country is headed by a president. Following the ecological and vegetation distribution, Cameroon can be divided into three regions, namely, semi-arid, savannah and highlands.

The semi-arid region is found in the northern part of the country. Although this region is dotted with some savannah areas, it suffers most from scarcity of wood, caused by poor soil type and climate which inhibits the growth of plants. However, the inhabitants of this area are herders who rear cattle, sheep and goats, thus there is an availability of dung which can be used as fuel to substitute for wood. The savannah region, which is principally the eastern and southern parts of the country, is blessed with good soil and rainforest that boost the agricultural situation of the area and thus the availability of wood. It is very rich in natural resources and a biodiversified equatorial forest. The highland region (western and north-western parts of the country) has the most fertile soil and a relatively healthy environment.

However, the cultural, social and customary beliefs that exist make a difference. The inhabitants of this locality are predominantly farmers, who depend on farming for their upkeep, with a few civil servants and businessmen. However, there is still the need for improved technology and a need for wood to be judiciously and sustainably used.

The case study area falls within this region. After having an insight into how Cameroon is structured, there is now a shift from socio-economic, climate and ecological aspects to the reason behind the choice of the case study area. To facilitate this research with maximum efficiency, the author settled for the above-mentioned case study area. He is quite familiar with this region and traditions. Furthermore, the problems existing in this area were easily identified and information was easily accessible.

3.4 Survey Methods

Following the methodological approach to this thesis, the quantitative and qualitative survey methods were used to ease the success of this research, including standard questionnaires, interviews, focal group discussions and personal conversations. The study is based on the questionnaire survey that was conducted in Cameroon (Ebebda district); the questions were developed by the author according to the literature review and the aim of this study. The target was to define the questions in such a way that they would be simple in order to make sure that the answers of the respondents were accurate.

3.5 Questionnaire Layout and Parameters

The first part of the questionnaire had questions of general interest, such as age and gender of the household. The purpose of these questions was to provide general statistical information on the total sample of population that participated. The second part of the questionnaire was regarding the sources of energy they used for lighting. The questions concerned the number of items, equipment used, the expenditure on fuel or replacement of lighting equipment, the refuelling and replacement frequency, and the distance they had to cover to find fuels or new devices. Furthermore, the participants were asked how satisfied they were with the source of lighting. This section aimed to study the different aspects that each source of lighting had and to examine how they affected the income and quality of life of households.

The third part was the most essential and important part of the questionnaire as it concerned knowledge about indoor air pollution caused by kerosene lamps; it provided the data that was used for the research. The fourth part of the questionnaire was important as it concerned the socio-economic impact of the case study area population. The questionnaire touched on a wide range of problems faced by the rural population in Ebebda district. The fifth part of the questionnaire was about the environment and how the use of kerosene lamps affects the environment (questions were answered based on a yes and no related to environmental impact and deforestation). The sixth part of the questionnaire was about socio-cultural impacts, and the seventh and last part of the questionnaire was about personal health and how many people they consulted regarding indoor air pollution; the questionnaire is below.

1 - Demographic

Area of residence		
Gender	Male	Female
Age		
Number of household members		
How many adults and children in the house?		
Profession/occupation		

2- Use of Kerosene Lamps. Please answer the following.

What source of lighting do you use?	Kerosene							Candle		Other	
How many kerosene lamps do you have?	Number										
How long do you use your kerosene lamp at night?	Number of hours										
How much do you spend per/month on kerosene?											
How frequently do you buy kerosene per week?	Week							Month			
	1	2	3	4	5	6	7	1	2	3	4
How much do you pay for a litre of kerosene?											
How long do you have to walk to find	Minutes							Hours			

kerosene fuel for your lamp?		

3- Knowledge / Awareness

What is your knowledge about the source of indoor air pollution?

Idea ☐

No idea ☐

Do you know that kerosene lamp smoke is dangerous for your health?

Yes ☐

No ☐

No idea ☐

Do you think that adopting new technology for lighting would improve indoor air pollution?

Yes ☐

No ☐

I don't know ☐

4- Socio-economic Impact

<table>
<tr><td>How often do you read at night?</td><td colspan="10"></td></tr>
<tr><td rowspan="2">What source of light do you use at night?</td><td colspan="5">Kerosene</td><td colspan="5">Candle</td></tr>
<tr><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td rowspan="2">When do your children study?</td><td colspan="2">Night</td><td colspan="2">Day</td><td colspan="6">Both</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td rowspan="3">How are your children's grades with kerosene lamp use?</td><td colspan="10">Ratings</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Do you feel safe using a kerosene lamp?</td><td colspan="5">Yes</td><td colspan="5">No</td></tr>
<tr><td colspan="5"></td><td colspan="5"></td></tr>
<tr><td rowspan="2">Do you consider emigrating because of lack of electricity?</td><td colspan="5">Yes</td><td colspan="5">No</td></tr>
<tr><td colspan="5"></td><td colspan="5"></td></tr>
</table>

Do you have any health problems associated with the use of kerosene lamps?	Asthma, Bronchitis	Cataract (blindness)	Lung Cancer	Pneumonia	Tuberculosis	Others, please specify
Do you have a business?	Yes			No		
If yes, do you run it at night?	Yes			No		
What type of lighting do you use for your business?	Kerosene			Candle		Other
How much do you spend on kerosene?	Week			Month		Other
Are you happy /ready to accept new technology for lighting?	Yes			No		Other

5- Environmental Impact

Do you use wood for cooking? Yes ☐

No ☐

Other ☐

Do you see any change in your environment?

Yes ☐

No ☐

Has deforestation increased in your area in the past year?

Yes ☐

No ☐

Do you think there is a big risk in the change in the environment?

Yes ☐

No ☐

6-Socio-cultural Impact

Who takes the decision to buy kerosene lamps in the household?	Father		Mother		Both
Who spends the most time in the kitchen?					
How many hours do you spend in the kitchen per day?	3 hours	4 hours		5 hours	6 hours

7- Health Experts / Medical Doctors

Do you consult people about illnesses caused by indoor air pollution? Yes ☐

No ☐

How many people do you consult per month about indoor air pollution problems? ______

What type of illness do you have related to indoor air pollution?

Asthma, Bronchitis	Cataract (blindness)	Lung Cancer	Pneumonia	Tuberculosis	Others, please specify

Is there any campaign for reducing indoor air pollution?

Yes ☐

No ☐

I don't know ☐

If the answer is yes, who is the main campaign organiser?

NGOs ☐

Government ☐

Other, please specify ☐

Thank you – The End

- **Sketch of the problem**

The sketch below (see figure 3.2) for this thesis represents the main problems of this research and the aim is to understand how the problems can be solved. It has been identified by the author herein that these problems fall into six categories: socio-economic issues (lack of affordability, poor living conditions of the community, sex discrimination), health issues (indoor air pollution), environmental issues (unsustainable use of fuel and deforestation), political issues (lack of good energy policy), kerosene lamp use (absence of adopting suitable technology) and unlocking solar lantern barriers (failure to attract investors in the renewable energy sector).

ENEO is the main national grid company provider in the country and is unable to supply power demand to all Cameroonians, mostly in rural communities. It should be noted that the lucky and rich people in the urban areas in the country who have access to electricity and are able to pay for their bills are being charged a high rate and the fluctuation in prices for petrol, kerosene and electricity worry Cameroonian people; for example, one litre of kerosene in Cameroon now equals the cost of one litre of palm oil (MINCOMMERCE, 2016), and this increase in fossil fuel use has brought people back to using wood fuel which results in tree felling and climate change within the country.

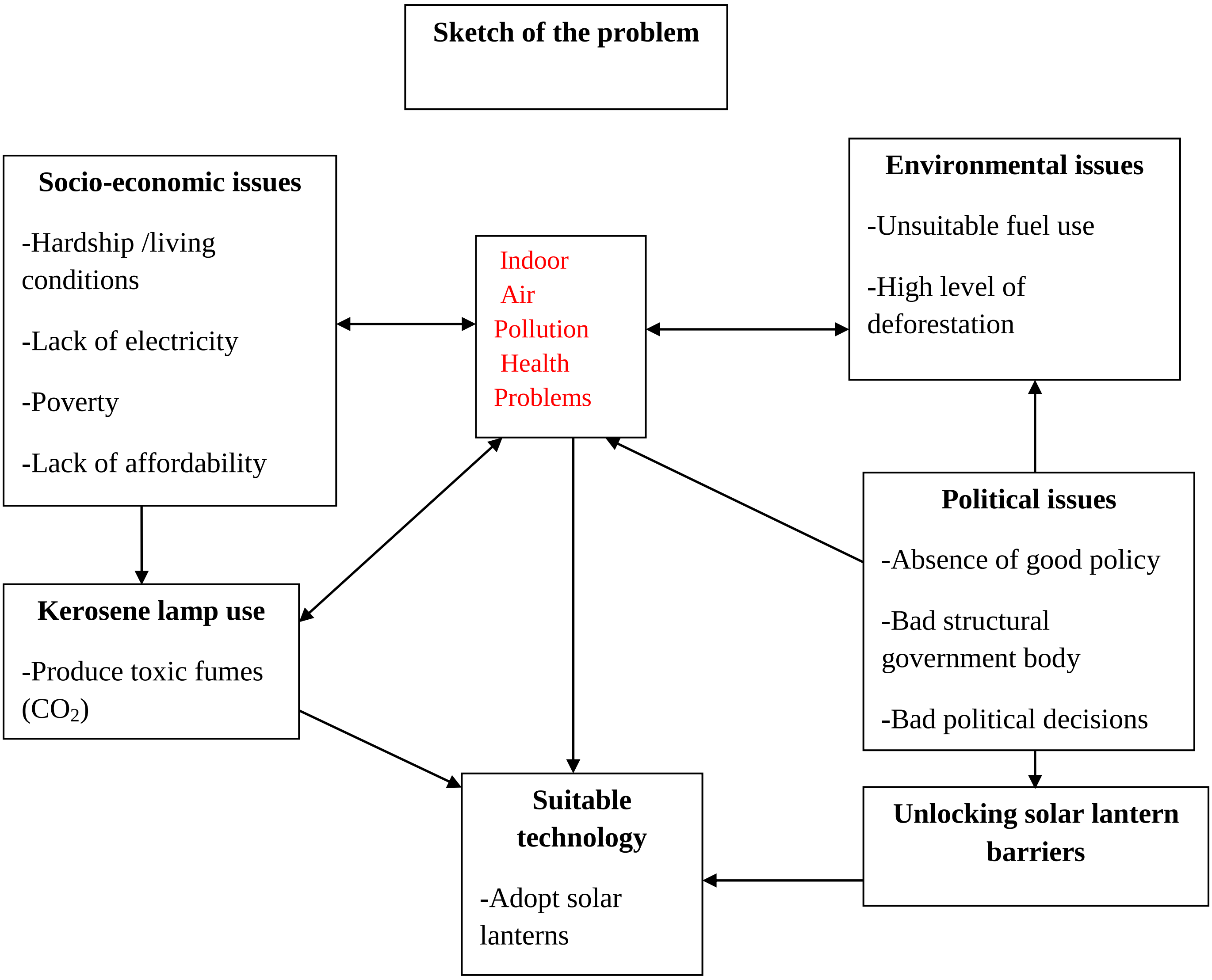


Figure 3.2 Schematic sketch of the problem
Source Author's own construction

As discussed above, despite the immense renewable energy potential of the region, it is suffering from poor renewable energy and energy efficiency promotion. The government and local population have failed to contemplate the consequences of not turning towards renewable sources of energy. Peh and Drori (2015) associate the situation of Cameroon with the corrupt government of the region. They assert that though it is not clear if the government or the people are to be blamed, efforts need to be made by both. Although some actions and measures have been taken, more specific efforts are required in the region at several levels.

- **Based on the above, the author's research hypotheses**

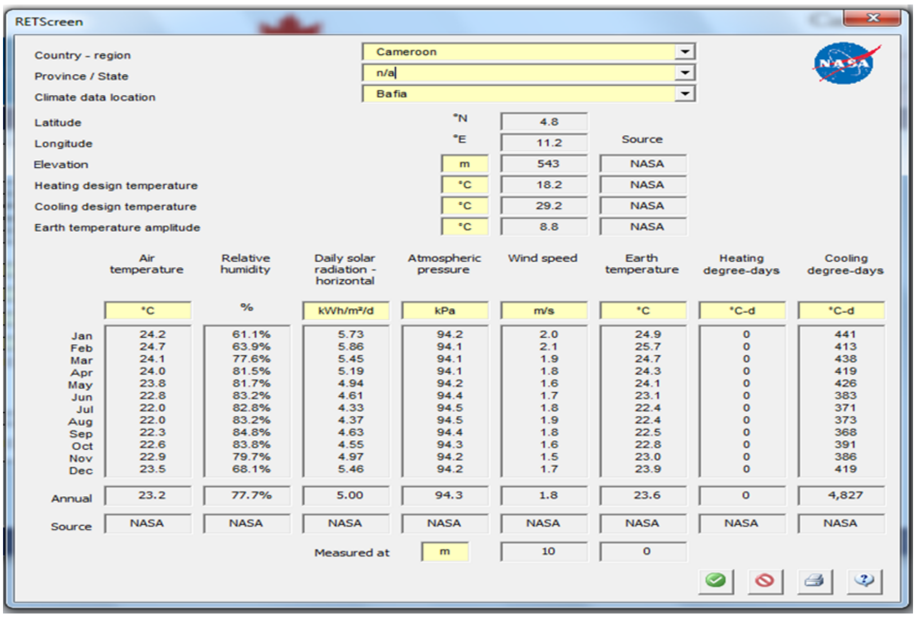
Indoor air pollution is a big issue in Cameroon but the authorities and general population have not realised the consequences of this. Kerosene lamp and wood fuel have been used in Cameroon for a long time but the health consequences are unnoticed. It should be highlighted that policy makers and energy experts are indifferent to the situation and till now, nothing has been done to ameliorate the situation. In the recent years, several researchers have attempted to explore the issue of indoor air pollution. Bruce et al., (2014) focussed on indoor air pollution in developing countries such as Uganda, South Africa etc. They claimed that indoor air pollution creates several health challenges such as acute upper respiratory infections and chronic obstructive respiratory diseases.

Further, Muindi et al., (2016) conducted a study to assess the level and source of household air pollution in the urban slums of Nairobi, Kenya. They concluded that the people were exposed to high-level risk of health issues and diseases primarily as a result of cooking and lighting fuels and also indoor smoking of cigarettes. They also claimed that most of the houses lacked windows or any other source of ventilation, forcing them to rely on the door as the only source to vent indoor emissions. Also, several households left the door closed during cooking, with a consequence that kerosene and wood were not properly burned; especially, lamps were used more widely in the evening, which increased the chance of higher pollutant concentrations; the dependency on kerosene lamps for lighting was a major contributor of indoor fine particles.

Most people believe that indoor air pollution only affects rural areas (villages) rather than urban areas, but this is not the case because even rich people living in cities are turning now to using kerosene lamps because of the fluctuation of prices of kerosene (MINCOMMERCE, 2016). In fact, the migration of people from rural to urban areas makes the number of people using traditional fuel increase, as they continue to do so even when in the city. It should be noted that the level of damage caused by indoor air pollution varies between individuals and communities. It should also be highlighted that there is no ongoing research (field based or laboratory based) in this area within Cameroon at the moment.

3.6 Site Reference Climate Data

Based on available RETScreen data, no weather information for Ebebda was available, so Bafia was chosen as it is only a short distance from the study area. It should be highlighted that the topography and building density are the same, along the weather line of Bafia and Ebebda. Bafia is a small town in the Centre region of Cameroon, located at latitude 4.8°N and 11.2°E. It has an estimated population of 77,713 inhabitants with an annual growth rate of 4.25% (World Bank, 2016). This makes Bafia the third largest area of the region after Yaoundé and Mbalmayo. The town is very close to the West region, just 35 km from the regional boundary, about 20 km from Ebebda and some 80 km from Bafoussam. Bafia has a moderate climate with high humidity ranging between 61% and 85%. The average air temperature for the town is 24.2°C and obtains between 4.33 and 5 kWh/m²/d daily solar radiation. Wind speeds in this area are not high, in the range of 1.5–2.0 m/s (RETScreen, 2015). National Aeronautics and Space Administration (NASA) provides some information relating to renewable resources that are available in Bafia (closest representative town to Ebebda). The data was collected from RETScreen Clean Energy Project Analysis Software. Data in table 3.3 shows that Ebebda has a good energy yield, with a daily solar radiation of 5.00 kWh/m^2/day.



RETScreen

Country - region		Cameroon	
Province / State		n/a	
Climate data location		Bafia	
Latitude	°N	4.8	
Longitude	°E	11.2	Source
Elevation	m	543	NASA
Heating design temperature	°C	18.2	NASA
Cooling design temperature	°C	29.2	NASA
Earth temperature amplitude	°C	8.8	NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	24.2	61.1%	5.73	94.2	2.0	24.9	0	441
Feb	24.7	63.9%	5.86	94.1	2.1	25.7	0	413
Mar	24.1	77.6%	5.45	94.1	1.9	24.7	0	438
Apr	24.0	81.5%	5.19	94.1	1.8	24.3	0	419
May	23.8	81.7%	4.94	94.2	1.6	24.1	0	426
Jun	22.8	83.2%	4.61	94.4	1.7	23.1	0	383
Jul	22.0	82.8%	4.33	94.5	1.8	22.4	0	371
Aug	22.0	83.2%	4.37	94.5	1.9	22.4	0	373
Sep	22.3	84.8%	4.63	94.4	1.8	22.5	0	368
Oct	22.6	83.8%	4.55	94.3	1.6	22.8	0	391
Nov	22.9	79.7%	4.97	94.2	1.5	23.0	0	386
Dec	23.5	68.1%	5.46	94.2	1.7	23.9	0	419
Annual	23.2	77.7%	5.00	94.3	1.8	23.6	0	4,827
Source	NASA	NASA	NASA	NASA	NASA	NASA	NASA	NASA
			Measured at	m	10	0		

Table 3.1 Climate data for Bafia
Source RETScreen (2016)

- ➢ **RETScreen Software**

According to NASA (2016), RETScreen software is one of the most powerful tools allowing financial planners, architects and engineers to analyse and model any renewable energy project. The software can be conducted in five steps: sensitivity and risk analysis; emission analysis; energy analysis; cost analysis; and financial analysis. RETScreen software includes all types of energy technology and contains non-traditional, conventional energy, clean energy and traditional technologies. Examples of projects carried out by RETScreen include:

- ❖ Power (e.g. hydro, wind, wave, geothermal, solar).
- ❖ Conventional technologies (e.g. reciprocating engines, steam turbine, power).
- ❖ Combined heat (cogeneration).
- ❖ Energy efficiency (e.g. individual buildings and big industrial facilities).
- ❖ Cooling and heating (e.g. solar, air/water heating, heat pumps, and biomass).

RETScreen is equipped with some powerful tools, examples of projects, and hydrology, product and climate databases are linked with energy resource maps worldwide for users to employ for analysis; therefore, this software will be used in this thesis.

- ➢ **RETScreen Features**

The software has been extended from discreet energy, renewable energy, cogeneration heating to cooling technologies, energy efficiency and clean power also, and this has also been expanded with climate data including isolated grid connected, off grid and central grid connected, which means that the software can cover the entire planet. According to NASA (2016), the main key features of RETScreen are as follows:

RETScreen has been expanded to a climate database of 4,700 ground station locations around the world that have been approved by NASA. Solar energy data sets for populated areas and the meteorology surface are incorporated directly into RETScreen software. There has been a new model developed to allow the evaluation of energy efficiency for communities, industrial facilities, commercial/institutional buildings and residential settings. The software has been translated into different languages: French, Chinese and German. The software information has been disseminated via their website. Energy efficiency measures, wind energy, and combined heat and power included in the new model have been stored into a single software file.

3.7 Limitations of the Study Method

For every research study undertaken, the limitations of the research method need to be addressed and taken into consideration. Generally, quantitative research is a knowledge subject, relying on the training, skills and experience of the researcher. The research design of any thesis is influenced by the quality of these characteristics. For this research, limitations include carrying out the survey in the Ebebda district of Cameroon alone. This could, however, be overcome by carrying out community-specific socio-economic studies of the entire country. This is beyond the scope of this PhD research, considering the enormous resources and time required to embark on such a survey in a huge country such as Cameroon, and the insecurity and bad infrastructure for travelling within the whole country. The timeframe to complete this thesis did not allow the author to conduct the survey across the entire country. If the timeframe had been longer, it would have been good to conduct the survey in all socio-economic aspects, in order to correctly set out the harmfulness of kerosene lamps and the solar PV barriers in Cameroon. However, the gathered data of this thesis can delve a little into the socio-economic and barrier issues for adoption of solar lanterns in the country.

3.8 Ethical Considerations

For any research undertaken, voluntary participation ethics are the most important principle of the study. The survey was conducted and completed voluntarily by the participants. They contributed by providing information about the research topic. It should be highlighted that confidentiality and anonymity were also offered to the participants so that the data could be used without revealing their identity. The participants' opinions and knowledge concerning the topic were taken into consideration and they were free to speak about the research topic without any difficulty.

3.9 Conclusions

To conclude, chapter 3 has presented how data was collected for this study. Quantitative and qualitative methods were used for data collection and the analyses that were carried out. The use of qualitative and quantitative methods for this research was to effectively answer the questions of this thesis and to fulfil its objectives. On the other hand, the chapter has raised the problem of this thesis by sketching the schematics of the problem and giving the causes of indoor air pollution that cause health problems for rural populations in Cameroon. The sketch raised the issue of adopting clean energy, namely, solar lanterns, by eliminating the use of polluting kerosene lamps by rural populations.

RETScreen software analysis of the study site was carried out to determine solar radiation in the study site and it was revealed that Ebebda has a solar radiation of 5.00 $kWh/m^2/day$ as can be seen in table 3.3. The amount of solar energy in the study site is enough to light up the district's rural villages. It should be noted that ethical considerations have also been highlighted in this thesis. The confidentiality and anonymity of participants were respected during the survey and everyone was free to speak about the topic without revealing their identity. Data collection problems have also been raised in this study along with the limitation of this research.

Chapter 4

The Socio-economic Situation of Cameroon

4.1 Republic of Cameroon

The Republic of Cameroon is a central African nation. The country gained its independence from colonial France on 1 January 1960. It lies on the geographical coordinates of 600°N latitude and 1200°E longitude and is usually referred to as 'Africa in Miniature' (see figure 4.1, Map of Cameroon). With 475,440 km^2 on the west coast of Africa, Cameroon shares boundaries 1.094 km to the north-east with the Republic of Chad, 797 km to the east with Central African Republic, 532 km with Congo, 189 km with Equatorial Guinea, 285km with Gabon to the south, and 1.690 km with the Federal Republic of Nigeria to the west. Cameroon is divided into 10 regions, namely, Far North, North, Adamawa, North West, West, Centre, East, South, Littoral and South West.

Figure 4.1 Map of Cameroon
Source http://www.lib.utexas.edu/maps/africa/cameroon_rel98.jpg Accessed 15/05/2015

Cameroon has a population of 22.5 million inhabitants (UN, 2014) and a growth rate of about 2.02% (IERN, 2014). The human population of Cameroon is very unevenly distributed, with an estimated population density of 34.45 persons per square kilometre (IAEA, 2014). Some areas of the country have populations exceeding 100 persons/km^2. The human population density in some parts of the country, especially to the south east, is very low, approximately below 1 person per square kilometre (IERN, 2014). According to the World Bank (2016), Cameroon has a total surface area of 475,440 square kilometres.

4.2 Demography

According to the UN (2014), the population of Cameroon stands at about 22.5 million inhabitants (see figure 4.2). Of this number, 57% live in rural areas while 43% live in towns and suburban centres. In all, 70% of this population occupy only 30% of the habitable surface area, with an average density of 25 inhabitants per km² in 1992. This shows a sharp disparity in the population distribution. The degree of urbanisation is steadily increasing from 28% in 1976 through 38% in 1987 to 42% in 1992. Estimates show that by the year 2020, the population of Cameroon will stand at about 26.01 million inhabitants, with 68% living in urban centres. About 60 towns now have more than 10,000 inhabitants with eight towns having more than 100,000 inhabitants (MINAT, 2015).

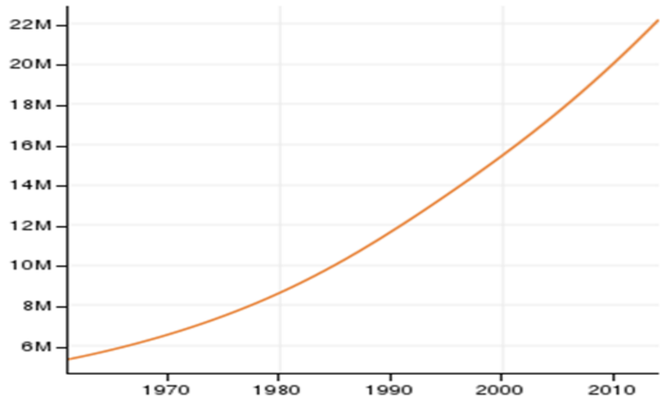


Figure 4.2 Cameroon population graph

Source https://www.quandl.com/data/UN/DEV_POPULATIONTOTAL_CMR-Population-Total-Cameroon?utm_medium=graph & utm_source=quandl Accessed 17/05/2015

Cameroon has approximately 250 local languages, including Ewondo, Bulu, Duala, the Bamileke languages, and Fulfulde (MINAT, 2018). Both French and English are taught in school, but only those with a secondary education are fluent in both. Most people speak at least one local language and one official language, and many people are multilingual.

Cameroon's governance and security problems for many years have attracted little outside attention; the country now faces violence in three regions: the Far North, where Boko Haram continues to mount small-scale attacks, as well as the North West and South West, where an incipient Anglophone insurgency emerged in 2014 (World Factbook, 2018). Boko Haram, active in Cameroon's Far North since 2012, has killed about 1,800 civilians and 175 soldiers, kidnapped around 1,000 people, and burned and looted many villages. While the conflict has displaced some 242,000 people and badly disrupted the local economy, Boko Haram remains a threat in the Far North. In 2017, the group killed at least 27 soldiers and gendarmes, as well as 210 civilians (MINAT, 2018). It could gain more strength if Cameroonian authorities neglect the crisis.

4.3 Challenges and Opportunities

There can be no real social or economic development without secure energy services. A publication by Food and Agricultural Organisation (FAO) in 2000 states that 'the energy challenge now faced by countries around the world is to provide energy services that allow all people to achieve a decent standard of living consistent with sustainable human development. This link between energy and development remains a key factor in development policy. It will be shaped by current trends of globalisation, markets and popular participation in decision-making processes, the changing roles of government and energy utilities, and the mix of sources of national and external funding' (Myrdal, 2013). Therefore, the real challenge is to reach economies of scale in order to make the technologies accessible to the majority of the poorer sectors of society.

This leaves the government with the task of addressing the challenges at all levels – environmental, economic and social. The challenges emanating from renewable energy vary from technical issues and resource management to human development and policy formulation. How we use lighting and what lighting is used for is tightly linked to our culture, lifestyle and resources. People's lifestyles, to a large degree, are determined by the type of affordable energy sources available. Lack of access to appropriate energy sources, undoubtedly, is one of the root causes of poverty. Cameroon mostly relies on biomass and water for its energy generation (electricity). The country has a huge potential for hydro power (medium and large), the second in the central African states.The use of trigeneration with biofuel powering combined heat and power (CHP) which is connected to an absorption chiller might also help address cooling system. Cameroon can reach an RE contribution level of 7.7% of energy in 2020 (including all power capacities of hydro) and if traditional biomass is excluded from the total consumption, the RE contribution will be 25% (RECIPES, 2016).

4.4 Economic Approach Situation in Cameroon

For the past few years, the Cameroonian economy has been dominated by the agricultural sector (with 22.3% GDP) and the oil sector, with revenues of 25% and 50% from exports respectively. The GDP of Cameroon has been growing steadily since 2010, averaging 5.8% from 2013 to 2015 before it reduced to 4.7% in 2017 (World Bank,2018). The workforce is a rising value of the primary sector and employs about 60% to the population and contributes almost 20% of the GDP (African (Development Bank, 2016). According to the National Hydrocarbons Corporation SNH (2018), Cameroon produced 27.72 million barrels of crude oil in 2017 against a production of 33.69 million barrels in 2016, and sold 16.86 million barrels of crude oil in 2017 against 20.51 million in 2016 between the periods; this represents a decrease of 3.65 million barrels (SNH, 2018). It can be ascertained that the decline observed is due to a fall in production.

The poor quality and lack of rural infrastructures are big barriers to Cameroonian economic growth. The drying-up of some oil sources, lack of competitiveness and lack of electricity supply represent 33% of the GDP and are considered as the secondary sector. It should be noted that the tertiary sector is also emerging and represents almost 46% of GDP, with the arrival of the telephone and transport sectors (see figure 4.3). The growth continues at an average rate of 6% for the sector and the total GDP growth of the country stands at 4.7% per year (World Bank, 2016).

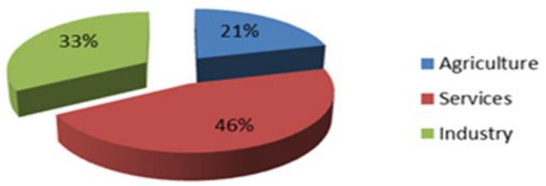


Figure 4.3 GDP by sector
Source African Development Bank (2016)

4.4.1 Economic Development in Cameroon

Economic growth increases regional capacity and creates jobs and opportunities at local and regional levels; this depends on the development of different factors such as facilities, equipment, labour, financial capital, public and private infrastructure and other physical resources (Kane and Sand, 2014). For any good economic development in Cameroon, it is important to have effective instruments for the growth of the nation. Economic development relies on the quality of change, the development of good services and how well a country creates services, information, financial arrangements, production methods, technology and workforce participation. The development of Cameroon's economy depends on so many factors, such as independent participation with the private sector. It should be noted that Cameroon's economy should be shaped by consumers, workers, corporate officials, entrepreneurs, students and investors, with every entity making a choice to take action for economic growth in the country.

Economic growth and development is basically a quantitative means by which the population operates within the economic sphere. It should be noted that economic development in a country is more than growth alone and, according to Kuznets (2013), economic growth is generally referred to as a structural change from everything being the same everywhere. It should be highlighted that economic growth in Cameroon should improve people's lives and hence reduce poverty in the country. In the past few years, and according to Myrdal (2013), there has been a consensus between developing countries and political leaders to reduce poverty by introducing a change to society involving modernisation that can suit everyone. However, introducing this type of modernisation is very challenging because it involves different issues such as:

- Standard of living improvement.
- Improving technological and knowledge exchange.
- Improving social relations by structuring thinking about means and objectives.
- Rationality in policy application.
- Development of infrastructure planning.
- Increasing production per worker and per capita of the country.

Increasing productivity in general, for example, creates institutions that would allow more mobility etc. It should be highlighted that modernisation is a good concept for possible economic development. For this concept to be successful, it would be necessary to choose what is right for the country as long as this journey starts with a step in the right direction. The Cameroonian government could start applying this type of modernisation by respecting all the variable factors cited above for the country's economy to grow.

The variation of the macroeconomy in a country is determined by the stability of economic growth. According to MINFI (2016), Cameroon has experienced different forms of macroeconomics since independence in 1960. The country has gone through some good and bad periods in economic growth, particularly the progressive period from 1960 to 1986 and from 1986 to 1994. The gross domestic product (GDP) was the lowest in 1960, 0.62 US$ billion (World Bank, 2016). There was another good period when economic recovery started to pick up from 1995 to a certain period called the globalisation period.

It should be highlighted that Cameroon's economy has long been considered as a lower-ranking economy in Africa since gaining independence. Cameroon's economy relies on exports of products such as cocoa, coffee, cotton and petroleum. However, bad management of the country's economy has led the country into a deep recession. In 1994, the gross domestic product (GDP) of Cameroon fell by 50%, with fiscal deficit and the growth of foreign debt. Despite the recession, Cameroon remains a relatively healthy economy among Sub-Saharan African countries (Molua and Laqmbi, 2016). The GDP in Cameroon averaged 11.50 US$ Billion from 1960 until 2017, reaching an all-time high of 34.94 US$ billion in 2014 and was worth 34.80 billion US dollars in 2017(World Bank, 2018). Further, owing to its oil reserves and favourable agricultural conditions, Cameroon still has one of the best-endowed primary commodity economies in Sub-Saharan Africa.

4.4.2 Link between Economic Development and Renewable Energy in Cameroon

According to energy experts, there is a good link between the economy and energy. Gerhard et al. (2014) point out that any national economic development is related to energy consumption. It is imperative that for any economy to see growth, human and animal power must work together with machine power, which requires fuel or electricity to function. Renewable energy technologies will benefit households by providing them with electricity for their day-to-day life to increase their wellbeing. It should be noted that the adoption of clean energy (i.e. solar lanterns) in Cameroon could create jobs and hence help the economic growth of the country. According to Bekele (2014), renewable energy technologies in any developing country could generate job opportunities away from the fossil fuels sector. According to Ngalame (2015), a South African company named GSC Energy has entered into a five-year partnership agreement with the Kenyan government to provide solar lanterns to the country. The project has the capability to create almost 5,000 direct and indirect jobs by recruiting young people for solar lantern maintenance, repair, retail, installation and assembly. According to SolarAid (2016), solar lanterns have created 15,000 jobs in Kenya, Uganda, Zambia and Tanzania.

Cameroon poverty rates remain very high and according to Ayanji (2016), the country is in need of financial assistance in terms of hospitals, road infrastructure and energy to help with economic growth. All this should make the Cameroon government review its development strategy plan by requesting foreign financial assistance and encouraging foreign investors to invest in the country.

4.5 Salary Scale

The government of Cameroon categorises its state functionaries into two groups, namely, civil servants and contract officers/state agents. While civil servants must have undergone some sort of training in one or more of the many institutes of professional training, contract officers or state agents are those who are not trained professionals but who are qualified based on their academic achievements. Payment of functionaries is based on an individual's qualification or functions according to his/her post of duty. Salaries are low and even government employees cannot necessarily afford the energy sources they might prefer (see Appendix G). Functionaries of the lower categories, poor traders, farmers and unemployed people would rather consider affordability rather than the efficiency and/or sustainability of the technology and energy types used.

This can be explained by the fact that their meagre salaries cannot cater for their basic needs. Worse still, the jobless and poor farmers, who have no consistent source of income, are the most desperate. It is therefore a challenge for the government to improve the standard of living for Cameroonian citizens by creating more job opportunities, increasing salaries or by reducing the cost of fuel. The government could equally encourage private investment in renewable energy technologies (RETs) by cutting taxes and providing loans.

4.6 Fluctuations in Fuel Prices

Energy prices can have a negative impact on individual choice and can affect the growth and development of the economy. They can also affect transportation costs which could eventually have adverse effects on businesses, employment and social welfare. Low income earners tend to spend more on fuel and are therefore not able to cater for other important daily needs such as school fees for their children, good medical care and better quality food.

Furthermore, where wood fuel has to be bought, biomass-using families often spend a substantial amount of their total income on fuel, not only in relative but in absolute terms. This is because poorer families can only buy in small amounts, while richer families can afford to buy in bulk, where a kilogramme of wood, for example, may cost only a fraction of the retail price. For example, in the North West Province, one cubic metre of wood (1 m long x 1 m high x 1 m wide) sold at US$3.54 in 2003. Today, 1 cubic metre of wood is sold at US$5.1 with a 2.9% inflation rate (MINFI, 2016). Who knows how the price of the fossil fuels will rise in the future? Kerosene, sold at US$0.13 per litre in the 1970s, rose to US$0.21 in the mid- nineties, and then rose again to US$0.35 with an inflation rate at 2.9% in 2003. Today, it sells at US$0.45 with a 2.9% inflation rate. A bottle of gas (25 kg) which sold at US$8.06 in the early 2000s is today sold at US$11.64 with an inflation rate at 2.8%. According to the 2001 estimate, the distribution of family income index of Cameroon stands at 44.6 (World Bank, 2016). Although the prices of wood fuel, kerosene and gas are on a more or less regular increase, the pressure on wood fuel remains the same as it still the most affordable and most used. The regular increase in prices could therefore have an impact on other natural resources. Interest could now turn to the sustainable use of wood fuel and the promotion of solar energy and biogas fuel, for example, so as to mitigate the situation; and according to this research, a solar PV lantern costs now US$18 and US$35.

4.7 Lighting Load in Urban Area in Ebebda

Ebebda district is known as a centre of excellence because of its commercial activities: extraction of sand and agricultural businesses. The power holding company, American Electricity Supply (AES) Sonel/Eneo, generates less than 1545 MW (Word Factbook, 2018) for 10 provinces, including the capital Yaoundé. When shared, it is possible to imagine how |much power would be available for each state. However, the rural district of Ebebda uses fuel generators (see figure 4.4) and kerosene lamps to power and light their homes and these emit carbon dioxide of 5.75 kg of CO_2 and unburnt carbon of 0.004% to the atmosphere (this has been calculated; see below).

- **Unburnt carbon generator**

Density of petrol is 0.832kg/l (IEA, 2018)

Petrol ash 0.2% (IEA, 2018)

Thank capacity 2.5 litres of petrol

Thus unburnt carbon would produce 0.004%.

Figure 4.4 Petrol generator in a house in Cameroon that produces carbon dioxide
Source Commune rural Ebebda (2015)

A power rating for the average residential home in urban areas in Cameroon state is 154 w (ENEO, 2015). It is worth noting that due to the erratic supply of electrical power from the power holding company of Cameroon (AES Sonel/Eneo), most homes in Cameroon use diesel or petrol generating sets which emit more carbon dioxide and unburnt carbon than electricity sourced from AES Sonel/Eneo. The power rating of the generator is 700 w with fuel tank capacity 2.5 litres of petrol (ENEO, 2015).

- **Petrol generator carbon dioxide CO_2**

Burning 1 litre of petrol produce 2.3 kg of CO_2 (IEA, 2018)
Tank capacity of the 700 w generator is 2.5 litres of petrol
Thus 2.5 litres of petrol would produce 5.75 kg of CO_2.

4.8 Household Indoor Air Pollution: Sources and Exposure of Particulate Matter in Cameroon

Indoor air pollution in developing countries, including Cameroon, could be attributed to a number of flame based sources such as kerosene lamps, candles, the burning of wood, charcoal, coal, crop residues and animal dung and tobacco cigarette smoke in the house (Nweke and Sanders, 2018). Incomplete combustion of biomass fuels causes the emission of pollutants from cooking stoves, which includes carbon monoxide (CO), particulate matter (PM), sulphur dioxide (SO_2), aldehydes, chlorinated dioxins, VOCs (volatile organic compounds) and PAHs (polycyclic aromatic hydrocarbons) (Black et al., 2016).

This contributes to poor air quality, especially when there is inadequate ventilation in the building (Smith, 2015). Wood smoke also contains polycyclic aromatic hydrocarbons, which are carcinogenic, potentially genotoxic and harmful to health when used in preserving (smoking) products (Stolyhwo and Sikorski, 2015). Previous studies conducted in various parts of Sub-Saharan African countries, particularly Cameroon (Jessica et al., 2014), indicate that indoor air concentration of PM10 and PM2.5 often increase 13% beyond World Health Organization (WHO) guideline levels (see table 4.2). Other sources of poor air quality include the presence of biological particles (i.e. house dust, moulds and microorganisms) and environmental tobacco smoke (ETS), which should not be neglected as a source of pollution (Bruce et al., 2016).

- **Carbon Dioxide (CO_2)**

Carbon dioxide is primarily a by-product of human metabolism and is constantly being emitted into the indoor environment by building occupants. Carbon dioxide may come from a combustion source as well. The major sources of indoor carbon dioxide are people, kerosene, gas space heaters, tobacco smoke and outside air. Illumination from kerosene-based devices follows the principle of incandescence. In the incandescent lamps, most energy is lost in the form of waste heat. Moreover, combustion processes produce unwanted air pollutants. Kerosene lamps smoke and smoking tobacco cigarettes in the house are responsible for serious eye infections, cataracts, and respiratory problems (see figure 6.6). Citing Nweke and Sanders (2018), in breathing, we expire carbon dioxide (CO_2) which can build up in the air of a room, in the home. In rooms where there are several people there can consequently be very high levels of CO_2 and this can cause health problems to the household inhabitants.

- **Pollutants Indicators and Types of Indoor Air Pollutants**

In measuring pollution concentration in homes, table 4.1 indicates WHO air quality guidelines in buildings.

Pollutants	WHO guideline values		
	Annual mean	Average 24 hours	
PM2.5	10 µg/m³	25 µg/m³	
PM10	20 µg/m³	50 µg/m³	
SO_2		20 µ/m³	500 µg/m³(10-minute mean)
NO_2	40 µg/m³		200 µg/m³(1-hour mean)

CO		7 µg/m³	100 µg/m³15-minute mean 35 µg/m³(1-hour mean) 10 µg/m³(8-hour mean)

Table 4.1 World Health Organisation guidelines
Source WHO (2018)

4.9 Particulate Matter (PM)

Particulate matter, also known as particle pollution, is a complex mixture of small particles and liquid droplets composed of potentially hundreds of chemicals (WHO, 2018). Given the complexity of their composition, particles are mainly classified according to their size. Particles of a diameter between 10 and 2.5 microns are also known as ‘coarse particulate matter’ or ‘inhalable coarse particulate’ (PM10), while particulates of a diameter under 2.5 microns are known as ‘fine particle matter’ (PM2.5). There is a little evidence to suggest a threshold below which no adverse health effects can be expected, but PM2.5 concentrations beyond the guideline (see table 4.1) levels are expected to increase mortality (Jessica et al., 2014). Particle size is inversely linked to its potential for causing health problems. Both PM10 and PM2.5 can pass through the throat and nose and enter the lungs; however, being smaller, PM2.5 can get deeper into the lungs and can also enter the bloodstream, thus causing more damage than PM10 (WHO, 2018). According to the World Health Organisation, PM10 and PM2.5 have been shown to cause or aggravate heart and lung diseases. Further, there is evidence that they weaken the immune system, making the body more vulnerable to disease in general (Pokhrel et al., 2015). Other than by size, particles that compose particulate matter are usually classified as primary or secondary. Primary particles are emitted directly at source, such as kerosene lamps, candles, charcoal, coal, cooking stoves and cigarette smoke. This thesis deals with the primary category.

4.10 Previous Studies of Particulate Matter in Cameroon and Sub-Saharan Africa

Household indoor air pollution remains a public health threat in developing countries. Several studies have taken place in Sub-Saharan Africa, particularly in Cameroon. Massey et al. (2016) carried out a comparative 24-hour study of indoor and outdoor concentrations of PM2.5 in the rural area of Mbalmayo in Cameroon. Their analysis showed that indoor particulates ranged between 143.36 $\mu g/m^3$ and 198.38 $\mu g/m^3$ in the buildings, while 127.86 $\mu g/m^3$ to 182.05 $\mu g/m^3$ was recorded for outdoor areas. Their study showed that the average concentration of indoor and outdoor particulates was high. In their study, Gao et al., (2017) compared the PM2.5 concentration levels of indoor microenvironments (i.e. kitchen, living room and bedroom) in the rural area of Korogocho in Kenya. The estimated daily 24-hour averages for kitchen, living room and bedroom were put at 134.91 $\mu g/m^3$, 103.61 $\mu g/m^3$ and 76.13 $\mu g/m^3$ respectively.

The outdoor air concentrations were estimated at 78.33 µg/m³. Their results show variation in PM2.5 levels in different microenvironments; the kitchen area had the highest pollution level compared to other areas in the building. The main sources of indoor air pollution in the area are from lighting and cooking activities. It should be noted that it is not only fuel type that contributes to poor ambient indoor air pollution, as household-specific factors (i.e. cooking, location, structural materials and ventilation practices) also influence air quality in buildings (Dasgupta et al., 2016). If changes are not made to fuel type and household-specific factors, the magnitude of health risks associated with indoor air pollution are likely to increase in developing countries such as Cameroon.

4.11 Institutional Framework

On 25 May 2005, the Ministry of Energy and Water was created by Decree No. 2005/087, headed by a minister with seven sections, sub sections and departments (figure 4.5). The Renewable Energy Department concentrates on biomass, hydro and solar energy. Geothermal and wind energy are not represented in their organogram and have caused gaps in energy management within the country. In the same year, the National Energy Action Plan (NEAP) was created and in 2006 the programme started to be implemented to run for 10 years. It should be noted that in 1998 the Cameroonian electricity law focussed only on hydroelectricity. The new NEAP programme aims to provide electricity for rural communities, develop biomass and mini hydropower, and off-grid electrification in the country. The distribution of electricity is not open because of high tax prices, and access to loans is very difficult for small businesses/companies. Even foreign companies have difficulty doing business in the country and have criticised the management system. In 1990, the country had a good national energy plan policy where all energy was considered at the time and was implemented. In the late 1980s, the Ministry of Energy and Water was called the Ministry of Mines and Power. When the 2005 decree was promulgated by the president, it officially became the Ministry of Energy and Water (MINEE), headed by the minister. Its structure can be seen in figure 4.5.

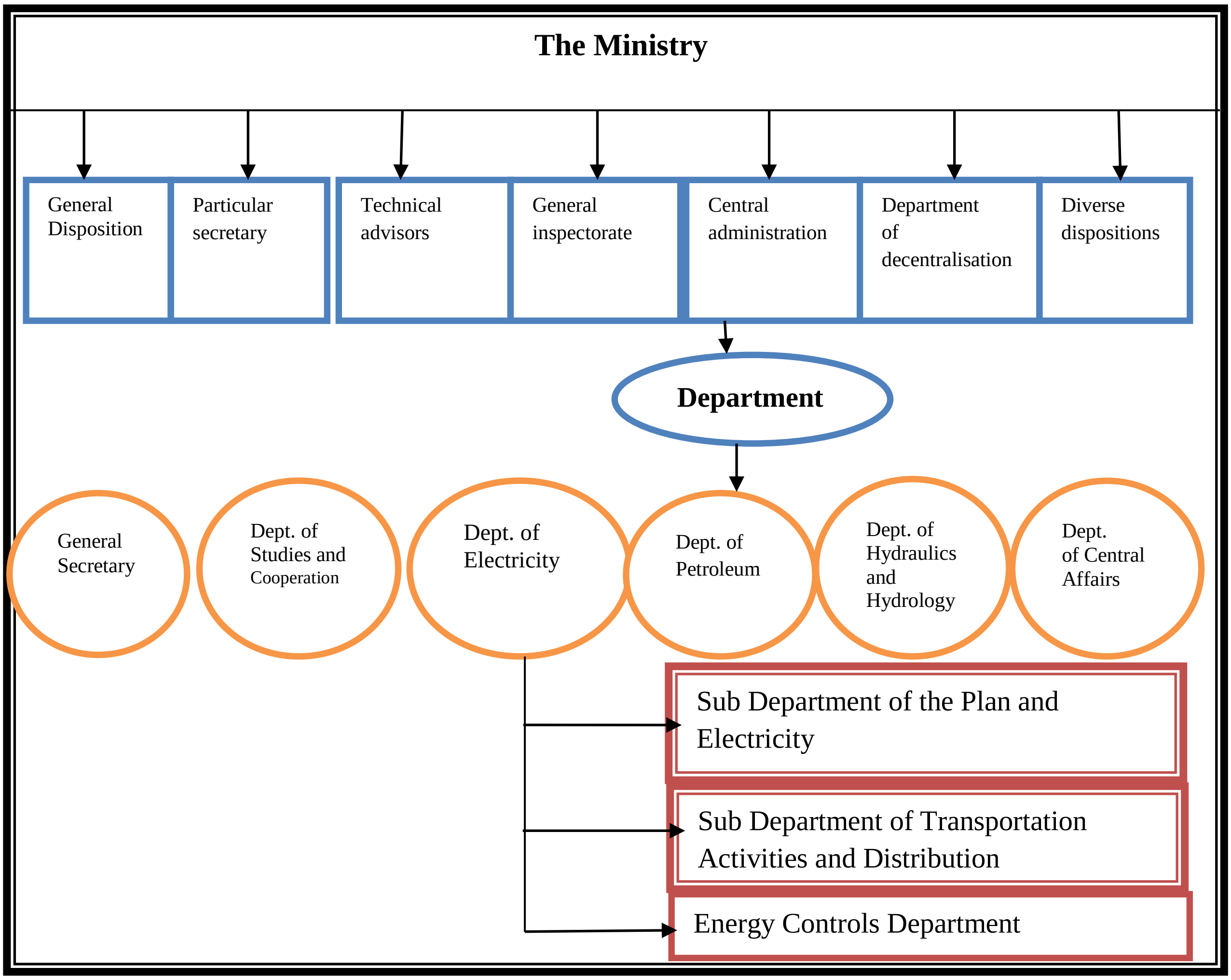


Figure 4.5 Organisation of the Ministry of Energy and Water in Cameroon
Source MINEE (2016)

4.12 Cameroon's Energy Sector Agencies

- **Cameroon Ministry of Energy and Water (MINEE).** The ministry is responsible for enforcing and implementing the government energy plan at national level by overseeing activities in the energy sector in the country, formulating policy for the energy sector and providing technical and administrative duties.
- **Rural Electrification Agency (AER).** This agency was created in 1999 and is responsible for managing the rural energy fund and implementing and promoting the Cameroon rural electrification programme.
- **Electric Sector Regulation Agency (ARSEL).** Responsible for setting the electricity rate, determining the standard and regulating the electricity sector.
- **Electricity Development Corporation (EDC).** Responsible for the development and construction of hydroelectric project in the country. Created in 2006, the agency also plays a strategic role for the development of electricity in the country.
- **ENEO Cameroon.** The agency manages two-thirds of electricity in Cameroon and was created in 2015.

4.13 Conclusions

Our world today can be referred to as a 'global village'. In order for certain wrongs to be corrected in the Cameroonian energy system, the influence of the industrial world is necessary. Many lives could be saved and the standard of living of the poor and destitute could be upgraded by just providing a household with electricity through renewable energy technologies (e.g. solar lanterns). This is where leading organisations and countries could intervene to fight against the poverty, deforestation and climate change that are plaguing the developing world. Although the governments of Cameroon and other developing countries have a major role to play in the mitigation process, the challenge still remains in the hands of NGOs and research personnel.

Little has been done so far in Cameroon concerning electrification in urban and rural areas. A great majority of the population are indifferent to the effects of indoor pollution that cause health problems in society. The Ministry of Energy and Water of Cameroon should work in collaboration with energy agencies and other stakeholders in the energy sector to find a way to provide the country with electricity. Rural populations as are the ones that suffer the most from indoor air pollution by using polluting kerosene lamps, candles and biomass fuel. It should be noted that deforestation is a big issue in the country because of tree felling by rural populations to use as alternative fuel because of the lack of electricity in the country.

Chapter 5

Innovation Theories and Solar PV Barriers in Cameroon

The propose of this chapter is to explore how innovation happens and set out different types of innovation theories and solar PV barriers used in this thesis. The chapter encompasses two main parts: the first part enumerates different innovation theories used in this thesis. The second part of the chapter lays out solar PV barriers and challenges in rural and urban area in Cameroon.

According to Jackson and Oliver (2014), in recent years solar PV has attracted attention in delivering sustainable electricity by reducing the burden on fossil fuels and the subsequent effects on the environment. Consideration has been given to its dissemination in developing countries. It is believed that it is the solution for energy needs in remote areas of developing countries and will reduce pressure on the environment. However, the complexities of socio-economic issues in rural and urban areas of developing countries make the predictions for adopting solar PV by rural populations difficult to determine. Renewable energy technology diffusion is a difficult issue because of the availability of a particular renewable energy technology, due to the remoteness of households where, in practice, the electricity grid will never reach in the future. It should be noted that socio-economic and cultural behaviour influences innovation to adopt a particular technology.

5.1 Innovation Diffusion Technology Theories

Nowadays, there is a good relationship between technology, society and diffusion innovation with different types of diffusion innovation theories being developed along with the social construction of technology. Some of the theories will be considered in this thesis and provide a good background for this study.

5.1.1 Social Construction of Technology and Innovation Diffusion Models Theory

According to Strang and Soule (2013), Surry (2015) and Clark (2013), innovation of diffusion of a new technology must come from the source of invention for the benefit of adopters or users. It should be noted that, in the past few years, social scientists have been interested in the theory of diffusion but there are different views to understand the term.

According to Surry (2015), ‘the most important fact to consider in discussing diffusion theory is that the theory must be well defined, unified, and comprehensive theory. A large number of theories, from a wide variety of disciplines, each focussing on a different element of the innovation process, combine to create a meta theory of diffusion.’ Recent success of adoption and diffusion come from the existing structural and cultural conditions (Katz, 2014).

5.1.2 Lag Cultural Theory

The lag cultural theory was created by Ogburn and is one of the theories used for diffusion and adoption of technology. This theory defines the time lag between innovation and invention. The theory is used in social adjustment and through society. On the one hand, the theory states that when technologies are invented, some of them change very fast in the social domain; however, others do not change at all. In his analysis, Ogburn (2013) noted that, in this theory, technology is an independent factor and is, in most cases, responsible for the social change.

5.2 Rogers’ Theory of Diffusion of Innovations

This theory looks at how the technology innovation can be taken up by the community. Rogers (2014) defines ‘diffusion of innovation as a special type of communication concerned with the spread of messages that are perceived as new ideas’. In Rogers’ theory, he maintained that there are four crucial elements (time, communication, innovation and social system), where innovation is introduced. From Rogers’ point of view, research diffusion investigates the role played by these factors that mediate the adoption practice among some members or specific products in a particular adopter group.

5.2.1 Communication

According to Rogers (2014), communication innovation diffusion theory is defined as where the message travels from one person to another. In other words, diffusion here can be defined as a form of communication where the message concerns something novel. However, according to Hagerstrand (2013), communication is the outcome of a learning process to spread innovation at the early stage, and this type of communication will help to warn the potential technology adopters by helping them to take any decision to reject or adopt a technology. According to Rogers, for a technology to be adopted, mass media is the best and most rapid way of informing a population of an innovation. Howard (2011) and Coleman et al. (2014) noted that face-to-face communication is also important in transmitting information for someone's attitude to change.

5.2.2 Time

According to Rogers (2014), time plays a crucial role for any technology to be successful because it defines its progress, individual position and evolution. Rogers suggested five types of categories of adopters, namely, innovators, early adopters, early majority, late majority, laggards. Figure 5.1 illustrates the bell shape and the percentages. According to Rogers' innovation theory, in any society the bell-shaped curve will at some point turn into an S-shaped curve (figure 5.2) because innovation is moving slowly and then it will grow rapidly.

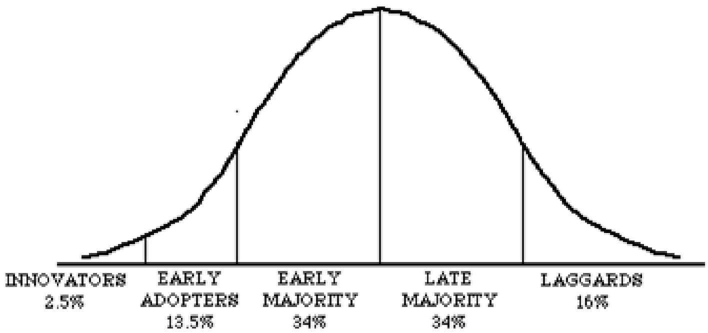


Figure 5.1 Bell-shaped curve showing categories of individual innovation and percentage within each category
Source Adapted from Rogers (2014)

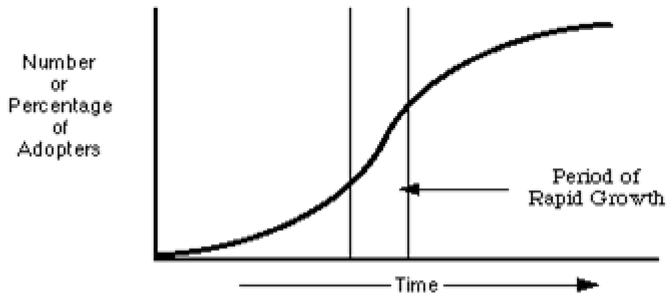


Figure 5.2 S-shaped curve representing rate of adoption of an innovation over time
Source Adapted from Rogers (2014)

5.2.3 Innovation

According to Rogers (2014), for an innovation to be adopted, the adopters' opinions should be taken into consideration. In his theory, Rogers defines 'innovation as practice or object that is perceived as new by an individual or other unit of adoption.' Citing Rogers (2014) and Brown (2015) also refers to an innovation as an idea, practice or object perceived as new by an individual. Innovation has five attributes to be adopted or rejected: theory list, compatibility, trialability, observability and relative advantage. For an innovation to be adopted there must be some elements to be overcome, for example, social prestige, economic issues etc. In practice, some technologies are adopted because of social prestige advantage and some because of economic advantage. It should also be noted that economic and social issues are not enough for a technology to be adopted. There are other factors, such as institutional, political and cultural issues, that can also affect adoption of a new technology.

5.2.4 Social System

The social system is one element defined by Rogers as 'a set of interrelated units that are engaged in joint problem solving to accomplish a common goal' and the social system member can be an organisation, informal group, individual etc. For a new idea to be adopted by the social system, the opinion of the leaders is very important in the decision-making process. However, the influence of power, institutions and politics in innovation has not been taken into consideration by the social system in this theory. It should also be noted that Rogers' theory is considered within this study and fits with this thesis as it touches upon the social system, communication, time and innovation.

5.3 Social Construction of Technology Theory (SCOT)

In SCOT theory, the development of a technology is examined herein. Technology is defined as working or not working, and socially constructed for social groups or organisations. It uses the word 'artefact' to refer to a technology (Pinch and Bijker, 2016, and Bijker, 2016). Interpretations of social groups here denote different interpretations of technological artefacts (Pinch and Bijker, 2016), and help to unveil some conflicts and how these conflicts can be solved. In SCOT theory, there is always interaction between social groups when it comes to technology. In most of the cases, in order to draw consensus, there are some influence groups that are neglected in decision-making due to economics, power, politics and ideology in design. For any technology development, SCOT is an ideal tool for analysing the social issues, offering a step-by step guide to studying the development of any technology. Therefore, SCOT is capable of providing insight for this thesis regarding adopting solar lanterns in urban and rural areas in Cameroon. In other words, the aim of this research fits with SCOT theory because it helps examine the socio-economic issues.

5.4 Solar PV Barriers to Development in Rural and Urban Areas of Cameroon

The author uses the terminology of barriers in this thesis to define factors that obstruct the diffusion of renewable energy technology in Cameroon. It should be noted that these barriers are related and it will be difficult to separate them. Every country has its own way of determining renewable energy barriers, as the transfer of technology is different in developing countries and industrialised countries. In developing countries, most of the renewable energy barriers result from bad policies, insufficient government targets and bad development plans.

5.5 Barriers and Challenges to Rural and Urban Electrification in Cameroon

Barriers	**Challenges**
Lack of recognition of solar PV for lighting as a provisional option for access to electricity by rural populations	Solar PV energy solutions for rural populations are not currently mentioned in Cameroon's policy development closure.
Off-grid lighting incentive limited	The majority of countries are promoting solar energy by removing fiscal incentives in solar energy products; however, the Cameroonian government does not encourage the use of clean energy due to high taxes.
Cost of doing business in Cameroon is very high	The high customs duty for private companies in the off-grid sector makes it difficult to do business to invest in Cameroon.
Off-grid lighting product cost and the existing fiscal barriers in market	Most of the importers of off-grid products increase the price of their product because of fiscal measures. Therefore, the majority of households cannot afford the new lighting technologies.
Off-grid lighting is not the priority for consumers	Off-grid lighting in Cameroon is not valued by customers such as e.g. mobile phones or grid-connected products.

Absence of good quality products on market	As with most African countries, the absence of good quality standard methods makes it difficult for buyers and consumers to distinguish between good and bad products.
Absence of research in off-grid lighting sector	Cameroon does not have off-grid lighting products and the market is not mature. There is also an absence of academic research on solar PV.
Absence of off-grid products on the market	The Cameroonian market lacks off-grid lighting products.
Difficult access to finance	In Cameroon, companies find it difficult to access bank loans as the rates are too high.
Cultural and social behaviour	Rural populations do not have confidence in and do not accept solar PV or innovation.
Absence of local skills	Cameroon’s lack of solar PV engineers and training technicians.

Table 5.1 Barriers and challenges to rural and urban electrification in Cameroon

For Cameroon to overcome energy poverty, it is important for the government to remove all off-grid barriers to allow everyone in the country to have access to clean and affordable electricity and to adopt solar lanterns. Cameroon should follow others in Sub-Saharan African countries, e.g. Uganda and Kenya. It should be noted that these countries have enjoyed good solar lantern uptake. Cameroon should look at all renewable energy sector barriers listed above in table 5.1. There are different factors that influence the adoption of solar lanterns such as lack of skills (the country suffers from a lack of qualified solar lantern technicians), rural people refusing to recognise off-grid as an alternative to kerosene lamps/candles, and importantly, a lack of off-grid research. It should be highlighted that off-grid is not recognised by consumers. The government should design a mechanism whereby local communities are given information about off-grid being an alternative to kerosene lamps and candles. The most important barriers of solar PV in Cameroon can be classified into four categories: Technological, Social/Environmental, Institutional and Financial.

5.5.1 Technological Barriers

Availability of technological assistance close to the end users is a key factor for solar lanterns in developing countries. The principal technological barriers to solar lanterns are to do with the lack of knowledge and understanding of a solar lantern system, inadequate training facilities and lack of skilled personnel for manufacturing solar lantern parts. One of the fundamental barriers related to technology transfer to developing countries is that the technology being transferred is not appropriate to the local context and needs be adapted to the local environment and situation (e.g. corrugated iron roof technology has been adapted to the Cameroon environment). The best option is to understand the situation of developing countries, identify the problem and energy demand and then choose the right technology. This can be done by investing in research and knowledge transfer, and demonstrating the development of a new technology.

5.5.2 Social and Environmental Barriers

For solar lanterns to be adopted in Cameroon, it is important for the technology to be socially accepted. For example, Wilkins (2011) notes that some energy from waste and gas may not be accepted in society, but women use this type of energy for households. Therefore, solar lantern companies should understand the relationship between technology, gender, religion and the culture of the community. Cameroon is a multicultural country, so for any technology to be accepted, solar lantern companies should consider the environmental, cultural and social issues of Cameroon. All of this needs to be considered when planning any project in the country. Conflicts can arise when any solar lantern project is carried out, as some communities may be displaced or may even refuse to adopt the technology. For this reason, deep analysis and evaluation in terms of environmental and social issues should be carried out by consulting rural populations and stakeholders so that any conflicts before, during and after can be solved.

5.5.3 Institutional Barriers

Adoption of solar lanterns and the development of rural electrification in Cameroon are affected by the lack of policy and poverty development goals. The structure of Cameroon means that energy development is still under the control of the government and this creates a conflicted macroeconomic environment that discourages investors. Cameroon's energy sector lacks a legal policy and regulatory framework. It should be noted that for solar lanterns to be adopted or developed, it is important for the country to have a good energy policy in place and remove all fiscal policy barriers to support small businesses in the renewable energy sectors. Cameroon lacks intellectual property rights, legal regulations and fiscal policy and these are important requirements when developing solar lanterns in the country. Without government commitment and support, off-grid developers, investors and suppliers, it is difficult to invest funds and time in developing solar lanterns in the country.

5.5.4 Financial Barriers

Financial barriers are related to cost and benefit. Companies and consumers of renewable energy technologies need to have access to capital. For companies, the main barrier is access to finances. Therefore, Cameroonian policymakers should design an appropriate policy instrument which will offer facilities to gain access to funds, e.g. access to loans at a lower rate. Economic options, including subsidies, tariffs, taxes and favourable financial schemes, need to be put in place by the government to benefit companies working in the solar lantern sector. Due to the negative perception of off-grid energy, the capital cost could go up as a result of economic and political instability and corruption. For these perceptions to be eradicated, it would be important for the country to use subsidies to encourage companies and the private sector to invest in the off-grid sector. It should be noted that subsidies will be important because they could support some company objectives by providing rural or urban populations with electricity or even developing new technologies. There are some financial opportunities that the country could use for projects but because of restrictions, requirements and rules in the country, it is difficult for financial institution to release funds to support off-grid projects in the country. To respond to the challenges of off-grid energy, there should be the right mix of supporting policies, institutions, reforms, infrastructure and markets, and all this should be done by considering the country's circumstances.

5.6 Social Capital

This section discusses the relationship of social capital to the environment, technology, institutions and finances as factors (classified herein as barriers) influencing the adoption of off-grid technology in Cameroon. The aim of this section is to show how social capital theory interacts with the various factors cited above, as these represent off-grid barriers to the adoption of solar lantern approaches in Cameroon. This section discusses social capital's negative impact on adopting off-grid technology in Cameroon, by looking at the roles played by civil society, government and other agencies in the off-grid sector.

5.6.1 Social Capital Definition

Social capital is threaded with different social variables and relationships; therefore, social capital can be defined as an aspect of networking with stakeholders, social groups and government agencies for a project to gain profit. Social capital is not rooted in one entity but rather has some common elements that facilitate action by corporate persons within the sector. It should be noted that social capital includes civil social capital and government social capital (institutions) that can influence communities to adopt a particular technology to benefit everyone. Civil social capital shares informal networks and common values that enable people to work together to achieve the same result. It should also be highlighted that if the two types of social capital (civil social and government social) work together, this will accelerate the adoption of any new technology in Cameroon, especially solar lanterns.

5.6.2 Relationship between Information Flow and Social Capital

Social capital and information flow is knowledge sharing between organisations and social groups, with the key factor here being innovation and technology. The more people interact with each other, the more positive the results will be. For example, in sports groups, education, religions and society, it becomes more possible to adopt new technologies. Research on the theory of social capital clearly shows the importance of networking in this theory. As information flows between groups, it becomes easier to adopt new technologies and increase production by the community. The assumption here is that social capital will facilitate the creation and sharing of knowledge between firms and employees. For any technology to be successful and be adopted, it is vital to employ good networking in relation to social capital.

5.6.3 Relationship between Economic Performance and Social Capital

Economic activities intertwined with specific social issues that could influence the adoption of any new technology are not new. Rather, most economic decisions are based on market forces (i.e. prices); however, economic performance is also affected by social issues such as personal relationships and cultural issues. For developing countries, particularly Cameroon, access to credit is very difficult and this makes investors unwilling to take risks to invest in the off-grid sector in Cameroon, because of the lack of a relationship between social and economic issues. According to the World Bank (2016), the off-grid sector in Cameroon is not well developed yet and this makes it difficult for the country to have a strong relationship between economic and social capital.

5.7 Conclusions

Findings from this section show that in order for any technology to be adopted in Cameroon, different types of innovation need to be considered to allow rural populations to accept the new technology. To challenge modern energy access to rural populations and to completely eradicate the use of traditional forms of energy, it could be important to first identify and unlock all off-grid barriers, and thereafter secure significant funds for all energy projects in the country and allow research into off-grid technology by financing the private sector and universities in the country. Cameroon should design a system that will allow the unlocking of all off-grid barriers. It should also be highlighted that there is currently an insignificant amount of investment and finance coming from the private sector, which is largely due to the unattractive nature of rural energy projects in terms of profitability and return on investment in the country. Thus, there is a need for some effort on the part of major stakeholders (multilateral/bilateral institutions and researchers) to develop business models that are commercially viable in providing large-scale modern energy services to the rural areas in

Cameroon. The above gaps have to be filled by first embarking on country-specific studies and analysis of rural electrification access needs and investment requirements.

Chapter 6

Results Interpretation and Questionnaires Analysis

6.1 Primary Data

This chapter presents the results of the data collection in the study site. The purpose of the interview, survey and focal group discussions sessions was to gain insights and obtain primary data with respect to solar lantern adoption in Cameroon. The chapter has five main parts: the first part of the chapter is about the demographic data collection in the study site; the second part of the chapter concerns health and indoor air pollution issues; the third part of the chapter is about the socio-economic impact in the study site; the fourth part of the chapter is about environmental issues; and the fifth part of the chapter closes with the socio-cultural impact in the study site.

The data in question is principally the results from the questionnaires, surveys, interviews and focal group discussions. The fieldwork questionnaires can be found in Appendix C. This section refers to the general information of the participants in the survey and includes statistical data and the characteristics of the sample population in Ebebda district, Cameroon.

6.2 Demographic Data

This thesis advises the eradication of kerosene lamps and the adoption of solar lanterns in order to improve the social and health issues of rural and urban people in Cameroon. The survey was successfully carried out with the acquisition of respondent contributions. In all, 150 questionnaires were distributed randomly, with feedback expected from 50. According to the questionnaires, there were 54 respondents and more female than male respondents (see figure 6.1).

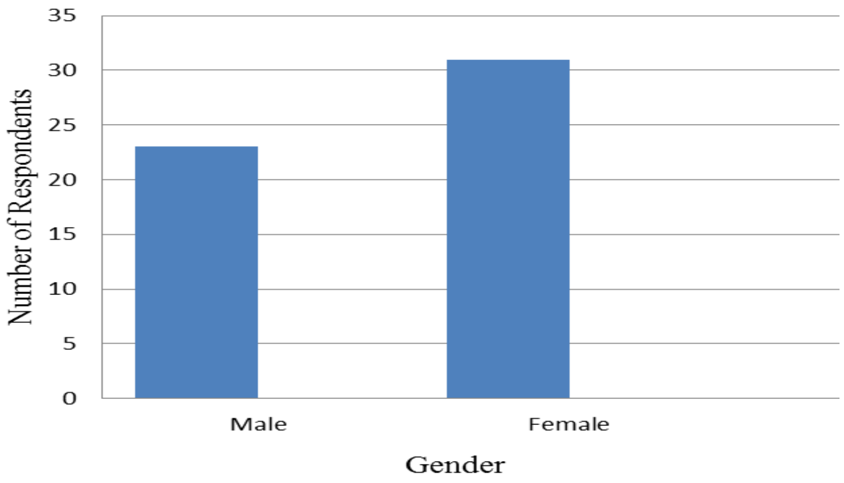


Figure 6.1 Respondent categories in Ebebda

During the survey in the Ebebda district, 31 respondents were female and 23 were male in a total of 54 respondents (see figure 6.1). The difference between these statistics can be explained by the fact that women participated in the survey more than men at the study site. To arrive at a sound conclusion, it was important to note the occupations of the respondents. Out of 54 respondents, 8 were students, followed by 11 housewives, 16 farmers, 6 businessmen, 9 health experts and finally 4 civil servants (see figure 6.2). These results show the choice of the study area, because they clearly show the difference in communities with the poorer in rural (village) areas and the richer in towns.

Figure 6.2 Representation of respondents

This section refers to the general information about the participants in the survey and includes statistical data and characteristics regarding age range. The highest-age respondents were between 65 and 80 and the youngest respondents were aged between 18 and 25 (figure 6.3).

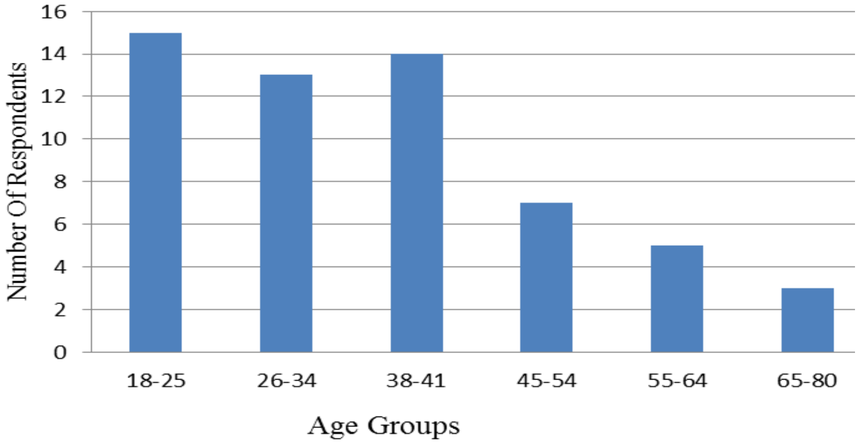


Figure 6.3 Representation of the population

6.3 Awareness/Knowledge Assessment of Indoor Air Pollution (IAP)

Out of 54 respondents, 18 of them knew what indoor air pollution meant or at least had an idea, and 36 had no idea about IAP (see figure 6.4). This result is contrary to that expected as it is generally believed that there are more illiterate people in villages than in towns. According to UNICEF (2016), approximately 57% people living in rural area and 43% in urban area. However, the high level of literacy in Cameroon can be explained by the presence of several government and private educational institutions. This, therefore, is a peculiar case unlike other rural settings.

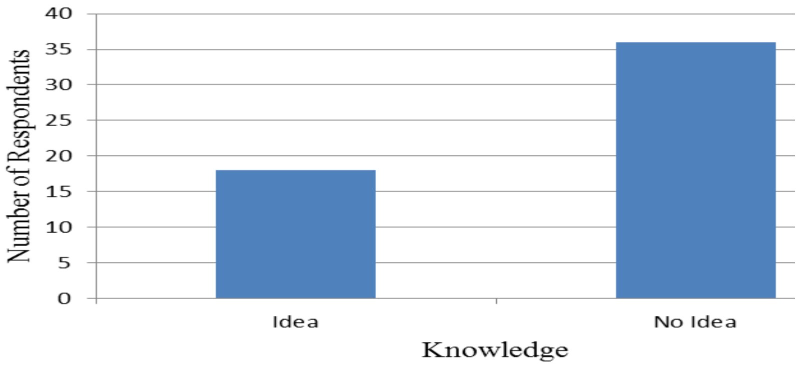


Figure 6.4 Level of awareness/knowledge of indoor air pollution

Another important issue was to get to know the respondents' sources of information and knowledge about IAP, so as to use this information to reach out to others who are in ignorance. In Ebebda area, most of the respondents learnt about IAP by reading books and a few of them used personal experiences. Very few attended seminars or community-based campaigns on IAP and health. Out of 54 respondents, 17 respondents had an idea about indoor air pollution and gained knowledge from personal experiences based on their observations during lighting use (smoke, eye irritation etc.), 24 were ignorant and 13 did not know anything about IAP (see figure 6.5).

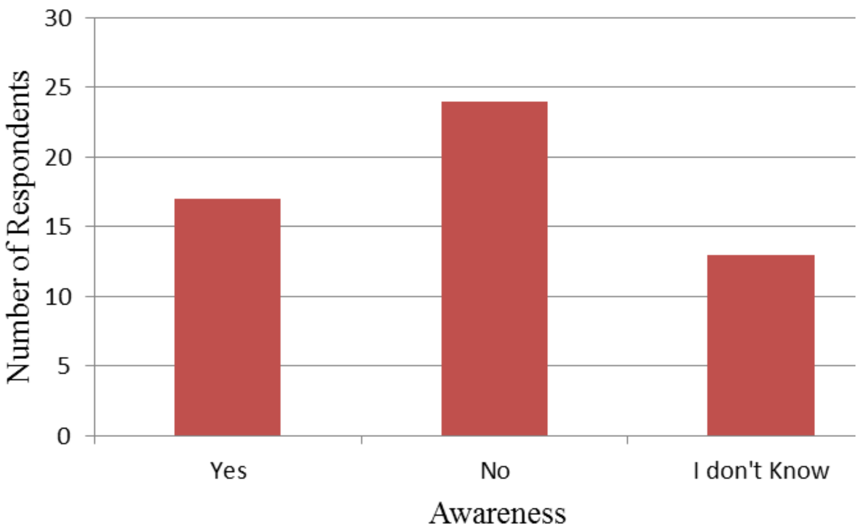


Figure 6.5 Awareness of health caused by kerosene lamp smoke inhalation

6.4 Health and Indoor Air Pollution

As explained and demonstrated in figure 6.6, the health of people in rural areas is inseparably linked with the source of lighting they use. Indoor air pollution has a wide range of negative health impacts; figure 6.6 features summary data from this thesis on the extent of proven links between lighting use and potential health outcomes. These health outcomes range from respiratory infections (caused by smoke) to allergies and eye problems, and have varying effects on the population depending on factors such as age and gender. Participants were asked questions regarding the different health effects that kerosene lamps have on both children and adults and how these would be avoided if they changed to cleaner and healthier lighting sources such as solar lanterns. However, the overall health effects can be identified only under laboratory conditions and analysis.

Therefore, the purpose of the health section was to identify the most obvious health problems caused by the toxic fumes of kerosene lamps, candles and smoking tobacco cigarettes in the house, and the effect of people’s selection of and behaviour regarding sources of lighting. In this section of the survey, all participants were asked about the different health effects of indoor air pollution, regardless of the fuel used for lighting. The reason is that the majority of Cameroonian people have used kerosene lamps for lighting, and have smoked cigarettes/breathed cigarette smoke at some point in their lives (even if they have turned to using modern lighting). Out of 54 respondents, 11 said they had respiratory problems (caused by smoke), 7 illness, 10 eye problems, 3 headaches, 2 sneezing, 1 allergy, 6 fire-, 9 dirt- and 5 smell-problems as shown in figure 6.6.

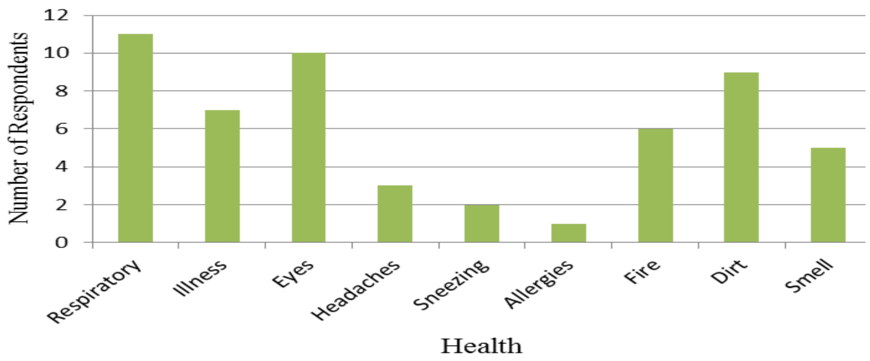


Figure 6.6 Health issues and indoor air pollution

- **Follow-up survey interview**

During the follow-up survey interview at the study site, out of 54 respondents, 3 said they smoke tobacco cigarettes in their house and 51 said they do not smoke (see figure 6.7). It is important to note that only 3 men acknowledged smoking tobacco in their houses.

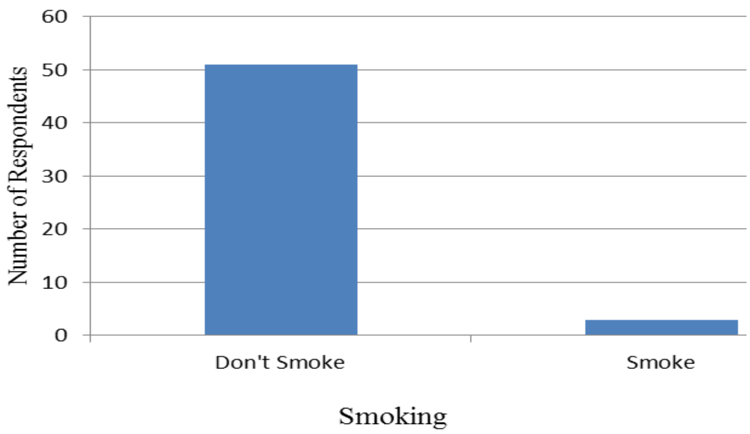


Figure 6.7 Representation of smoking tobacco cigarettes in the house

To facilitate the applicability of an appropriate technology in the study site, it was important to know the level of acceptability of new technology. Out of 54 respondents, 35 of the respondents thought that improving the lighting would dramatically reduce indoor air pollution, and would welcome new innovation/ technology; however, 11 said that new technology was not welcome and 8 did not know (see figure 6.8).

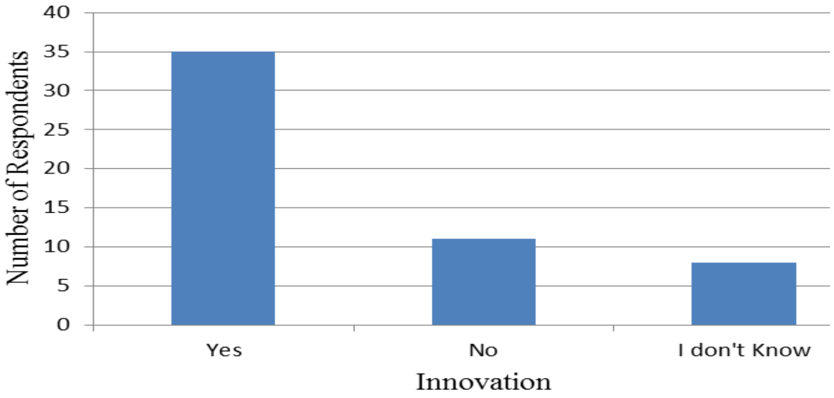


Figure 6.8 Acceptability of lighting innovation

6.5 Socio-economic Impact

The viability of any economy is very important for any community as far as purchasing and producing any product in rural areas is concerned. In developing countries, affordability plays an important role in people's lives especially for the less privileged. Out of 54 participants in the survey, 30 said their income is reliable and 24 of respondents said their income is variable, with an average monthly salary in a typical house in Cameroon set at $118.77. The result of the research shows that most of the households in Cameroon do not have a regular salary (their income is variable, which means that they do not have the same amount of salary every month) and this makes their lives very difficult (see figure 6.9).

Figure 6.9 Income profile of participants

There is a discriminatory attitude towards women when it concerns households. Women and children fetch the fuel and do most of the work at home. It is interesting to know that those fathers who cook or do some work at home are single parents, divorcees, bachelors or do not live with their wives, maybe for academic or job reasons. This is the same for the male child, in the African setup and especially in the cities; it is common to have adult male or female house help. In the case where a boy child is brought in as a house help, he automatically takes over cooking and household chores.

6.5.1 Kerosene Lamp Users

The main source of lighting in Cameroon is the kerosene lamp (ENEO, 2015). Rural people spend each night using kerosene lamps for lighting and these lamps produce indoor air pollution that affects human health. The following graph shows the different hourly usage of kerosene lamps in the study area (see figure 6.10). According to the results of the research, households own an average of 1.73 kerosene lamps with a mean cost of US$3.42 per lamp (this cost US$ 9 per year), and they change them approximately every eight months. The usage of lamps takes place daily, showing that it is an essential device for households in Cameroon. Despite the inconvenience and health risks, there are no other available means of lighting. Out of the 54 respondents, 17 use kerosene lamps for 1–2 hours per day, 24 for 3–4 hours per day, 9 for 5–6 hours per day and 4 for 7–8 hours per day.

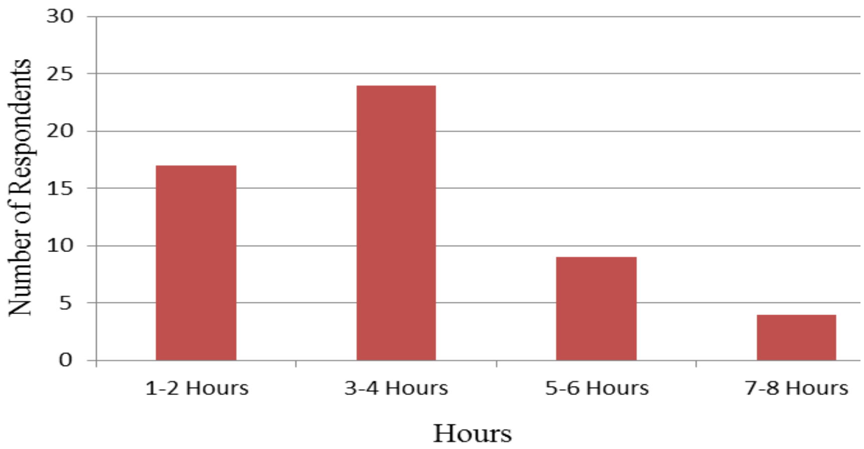


Figure 6.10 Hourly daily use of the kerosene lamp

Another important part of the questionnaire was regarding the frequency of use of kerosene lamps and out of 54 respondents, 40 of the respondents use kerosene lamps every day, and 14 once a week (see figure 6.11).

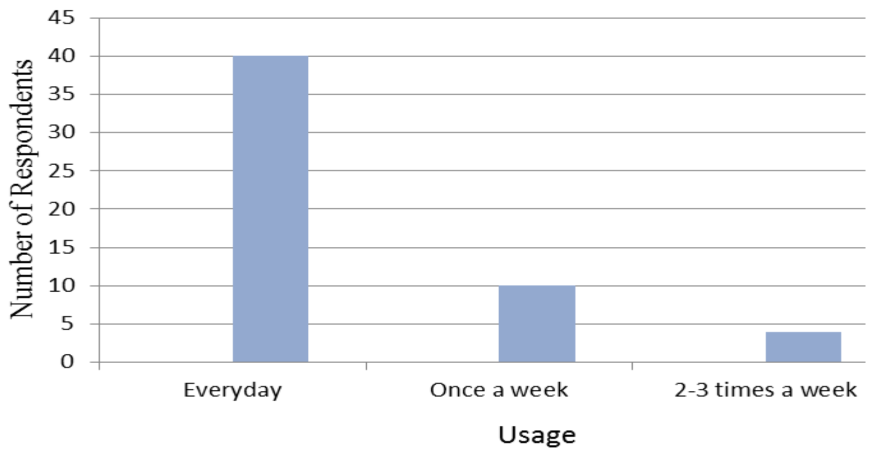


Figure 6.11 Frequency of usage of kerosene lamps

According to the research, the mean walking time in order to find fuel is 33 minutes. This is explained by the fact that many respondents said they have to walk long distances. During the study, some participants said they might end up walking for 1.5 hours in order to buy kerosene as the retail shops can be significantly further away in rural areas of the country. In addition, as can be seen in figure 6.12, out of 54 respondents, 35 buy kerosene on a 2-day basis, 15 weekly, and 4 monthly. As a result, the combination of walking time and frequency of purchase means that kerosene lamp usage results in drudgery for many households.

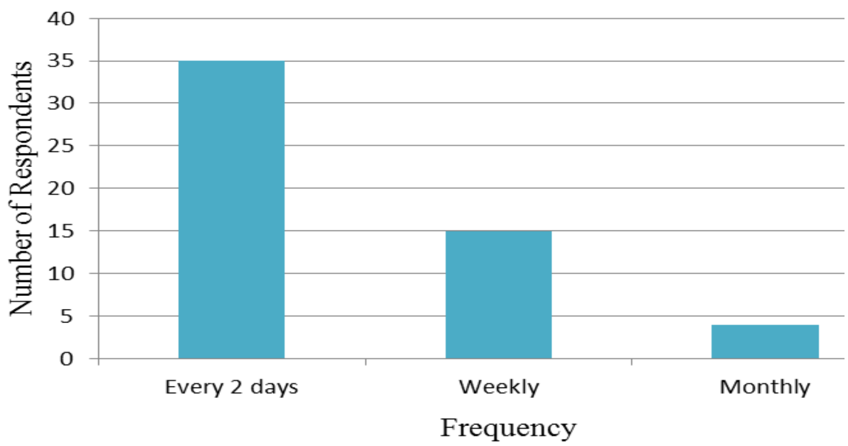


Figure 6.12 Frequency of kerosene purchase

6.6 Environment

Environmental and climate change are big problems in Cameroon and indeed have become major issues in the world due to the repercussions of CO_2 emissions and greenhouse gases. Out of 54 respondents of the survey, 35 were aware of environmental change, 15 said they were not aware of any environmental change and 4 did not know (see figure 6.13).

Figure 6.13 Level of awareness of environmental change

Another problem in Cameroon is deforestation, but the government is doing little or nothing to fight it. Out of 54 respondents, 42 said they were aware of the effects of deforestation, while 8 said they were not aware of anything and finally 4 did not know anything about deforestation (see figure 6.14).

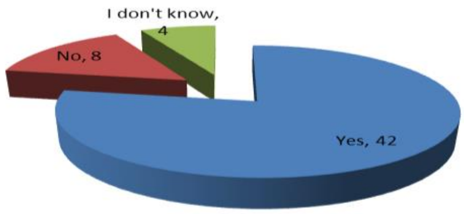


Figure 6.14 Deforestation awareness effect

Safety in any community is very important and part of the research question was about kerosene lamp safety. The result of this study shows that out of 54 respondents, 34 kerosene lamp users said they do not feel safe and 20 feel safe (see figure 6.15); this shows the level at which the rural population put their lives at risk by using kerosene lamps.

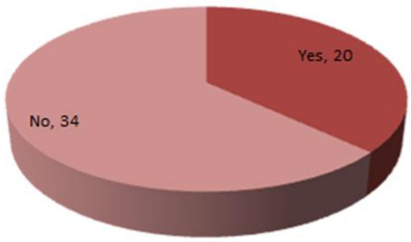


Figure 6.15 Feeling of safety by source of lighting (kerosene)

6.7 Socio-cultural Impacts

In a typical African home and according to most African cultures, a woman's place is in the kitchen. 'Cooking is a woman's thing' so it is said, yet the best cooks are men (Dhanyasree, 2016).

Most of the household work is done by women, girls and children, who normally spend long hours doing kitchen work. According to this study, out of 54 respondents, 35 spend 3 hours each day in the kitchen, 15 spend 4–6 hours and 4 spend 7 hours (see figure 6.16)

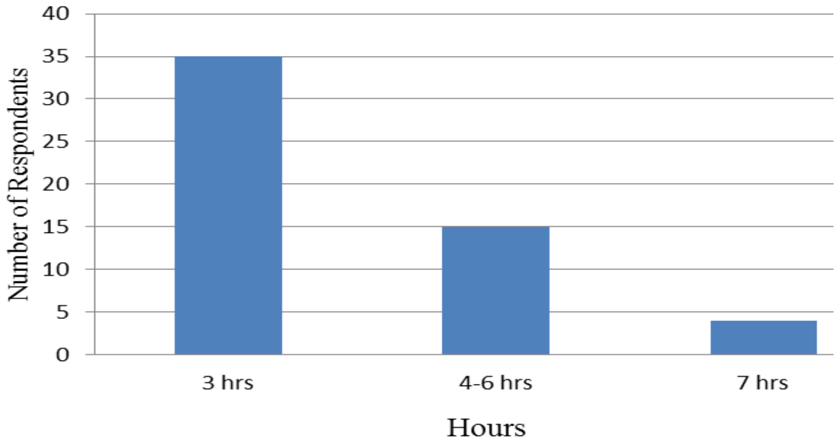


Figure 6.16 Number of hours spent in the kitchen per day

6.8 Health Issues

In Cameroon, particularly in Ebebda district, there is only one healthcare centre for the district, headed by a medical doctor and nurses. The healthcare centre suffers from a lack of qualified staff and a lack of facilities, equipment and medication. According to the health expert who participated in this study during the survey in Ebebda, about 13% of patients with indoor air pollution illness caused by kerosene lamp smoke consult every month. It should be highlighted that during the study in Ebebda, many problems were encountered concerning how to identify a person with IAP-related illnesses. Due to the lack of equipment in this medical centre, most of the health expert work is done by guessing, as most indoor air pollution illness presents with factors such as coughs, headaches, cataracts or colds. With the lack of equipment, it is very difficult to identify such patients according to health experts in the study area.

However, according to a medical professional in Ebebda during the survey, the most common IAP illnesses caused by kerosene lamp-related smoke are eye problems, tuberculosis cough, asthma, chest pain, pneumonia, bronchitis, coughs, pharyngitis, conjunctivitis, convulsions, headaches and catarrh. It should be highlighted that not all these illnesses are common; the most common are: catarrh, coughs, chest pain, pneumonia and asthma, with an average of 7% of patients consulting per month with these illnesses, according to health experts in the survey.

The lack of finances, equipment and qualified staff in this healthcare centre are some factors that make the low number of patients consulting; therefore, the result of this study should not hamper the picture of the low number by minimising the use of kerosene lamps that cause IAP in Ebebda district.

People in the study area lack the finances to go to hospital for consultations, and the government/NGOs provide less help to rural people and do not pay attention to reducing IAP. By analysing how the Cameroonian government tackles indoor air pollution, it seems to be very different when compared to what other African countries do, e.g. the Sudan and Kenyan governments, through a partnership with Practical Action (NGO) and via the Ministry of Health, tackle kerosene lamp smoke in households (World Bank, 2016). Cameroon should follow the example set by these countries by taking action to tackle IAP and improving rural community health. The government should seek health expert and academic knowledge and partner with the international community to tackle indoor air pollution in the country.

6.9 Conclusions

According to the overall results of the study, eradicating kerosene lamps could improve the lives of millions of households in Cameroon. For this change to be carried out, the turn towards modern, clean, affordable and healthy energy sources by replacing kerosene lamps with solar lanterns as an alternative energy to electricity for the rural population, could be beneficial. It should be highlighted that kerosene lamp use affects all aspects of human development and quality of life, such as health, income, education, social life and productive activities. More specifically, according to this study, the average monthly expenditure on kerosene used by rural households in Cameroon (an average of 9.5 litres per month cost households US$ 71.82 per year) could be spent on modern energy. It should also be noted that, during the survey, it was found that rural people can walk from 33 minutes to 1.5 hours per day to find kerosene and better light quality.

Furthermore, and according to this study, several health impacts and dangers such as indoor air pollution are related to kerosene lamps and cigarette smoke. Figure 6.6 show that rural people in Ebebda have breathing problems, coughs, chest problems and eye irritation. These ailments were reported by many users of kerosene lamps during the study. The safety issues were also raised, e.g. risk of house fire and skin burns when using kerosene. On the other hand, climate change and environmental problems were also reported in this study. As a conclusion, changing kerosene lamps to modern, affordable and clean energy could improve domestic work and activities and student homework by extending studying hours at night, as well as reduce environmental and climate change problems in the country.

Chapter 7

Potential for PV Utilisation in Cameroon

7.1 Introduction

As an innovation for the community and by the community, solar PV has a definite role to play in societal development. This chapter provides strong evidence about solar PV and its positive impact on households for rural people in developing countries. Further, the role of the different options when adopting solar PV through solar lanterns as an alternative to electricity use in other countries is presented. The advantages of this system as an interim solution for electricity, namely, to improve rural people's healthcare, education, quality of life, communication etc., are presented in this chapter.

❖ **Photovoltaic advantages (domestic use)**

According to Sue, R. et al. (2003), solar PV:

- Provides power where there is no grid.
- Provides power during blackouts.
- Can be moved between buildings and is transportable.
- Is low in maintenance once installed (the surface just needs to be cleaned, especially in dusty environments).
- Has a panel warranty of 20 years.
- Is reliable.
- Can have a working life of over 20 years and the payback period (the time the PV produces as much energy as required for the manufacturer) is 2–5 years.
- Does not produce CO_2, SO_2 or NO_x emissions.
- Is made of silicon so is non-toxic.

7.2 Available Technological Solutions for Rural Cameroon

There are various technical and technological options available in order to increase access to electricity in Cameroon. The following solutions are considered for rural electrification in Cameroon:

1. Grid connection
2. Microgrids

3. Solar Lanterns
4. Solar Home Systems (SHSs)

7.2.1 Grid Connection

The extension of the Cameroonian electricity grid has been one the most important priorities of the Cameroonian government. Theoretically, grid connection can provide households with the ability to use appliances without any restrictions. However, the reality in developing countries such as Cameroon is different. A number of factors limit grid extension, connection to rural households and reliable usage. First of all, the unsuppressed demand of the country is high, while the effective capacity power generation is 732 MW currently providing electricity to 60% of the country (World Factbook, 2018). In other words, Cameroon needs at least to double the generation output to enable 100% electrification of the country. Furthermore, the construction of lines has an average cost of US$10,000 per km (ENEO, 2015).

This means that the extension of the national grid requires a very high capital which, of course, cannot be provided by local communities. In addition to that, the fee for a new single phase connection is US$0.70 while for a three-phase connection it is US$ 0.78. As a result, it is easy to understand that even if the electricity grid has reached a community, it is financially very difficult or impossible for rural households to obtain access. That is the reason why in Cameroon there is a very high number of 'under-grid houses', which are dwellings very close to the transmission lines but where the residents cannot afford the connection. The financial characteristics, parameters of grid expansion and the poverty of rural households require the development and implementation of alternative solutions in order to increase the access to electricity in Cameroon.

7.2.2 Microgrids

Microgrids are small-scale electricity grids that are not connected to the mains electricity grids of countries or wider regions (see figure 7.1). Grid expansion requires a very high capital while also in some areas it can be technically challenging because of the geographical characteristics and the spread of rural communities. The main advantage of microgrids is that they bypass the grid extension in order to electrify regions or communities, which means that electrification requires fewer financial and technical resources.

Furthermore, an advantage of the same importance is that through microgrids, the transmission losses of the main grid are minimised, resulting in lower operation and maintenance costs. As microgrids aim to provide the required energy needs of small communities, they have the technical ability to exploit local micro-climate energy resources and maximise power generation efficiency.

For example, if a small region is characterised by high wind speeds, then wind power can be used in order to supply the energy system and minimise the need for fossil fuels. Therefore, microgrids can effectively harvest local renewable energy resources and could be a sustainable and affordable electrification solution as they do not require fossil fuels and do not produce any emissions in order to generate power. However, the power generation of microgrids is often currently based either on diesel generators or on hybrid diesel/renewable energy systems. There are several reasons that this happens, especially in Sub-Saharan rural areas. Usually, diesel or hybrid systems require lower initial capital in comparison to renewable energy systems, but they have higher lifetime costs because of their dependence on fuels. At the same time, some governments adopt a short-term way of thinking as far as the policies are concerned, in order to avoid the political cost of high budgets or increased taxes during their governance. As a result, they choose to increase the access to electricity through the minimum initial cost choices, such as diesel generators, without considering the total lifecycle cost of a project. Also, the stochastic nature of renewable energy sources sometimes makes necessary the installation of the parallel installation of renewable energy technologies and diesel generators in order to equilibrate the fluctuations in power generation.

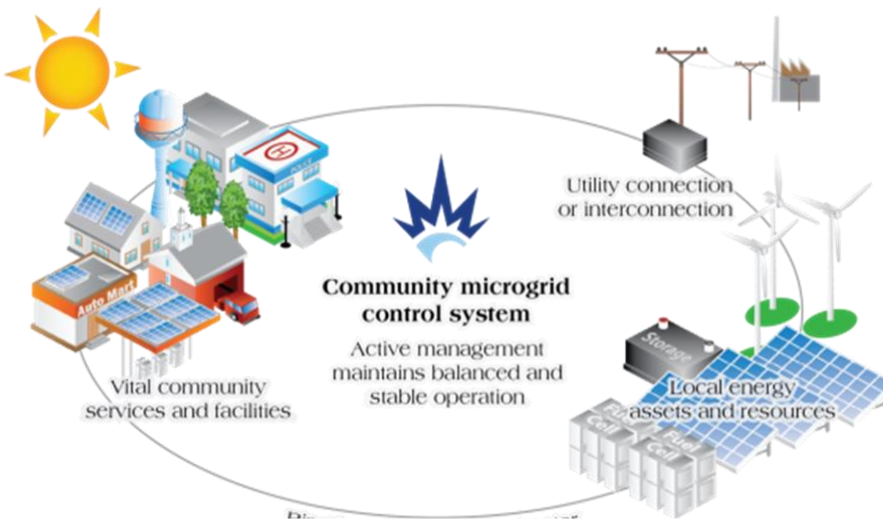


Figure 7.1 Microgrids
Source Adapted from SolarAid (2015)

7.2.3 Solar PV Home Systems (SHSs) and Stand Alone PV Systems

Solar PV home systems are integrated energy systems for off-grid electrification. Typically, they consist of the power generation part which is either PV panels or wind turbines, and the energy storage part which is the battery bank. In addition, they include an inverter that increases the power voltage, and a charge controller that protects the batteries from overcharging and deep discharging (see figure 7.2).

If the system is on-grid, then it can use the electricity grid in order to charge the battery bank when there are shortages in the power generation as a result of lack of sunshine or low wind speeds. When the battery bank is fully charged and the power generation part is working and generating power, then the owner can supply the grid with electricity and thus earn money. This scheme is called feed-in-tariff policy, according to which, individuals receive a payback capital according to the kilowatt hours of electricity they have provided to the grid. Solar PV home systems are a reliable and effective solution for off-grid houses. However, they require high capital and most of the time they are not affordable for rural populations in developing countries. Therefore, they are not orientated for the bottom of the economic pyramid.

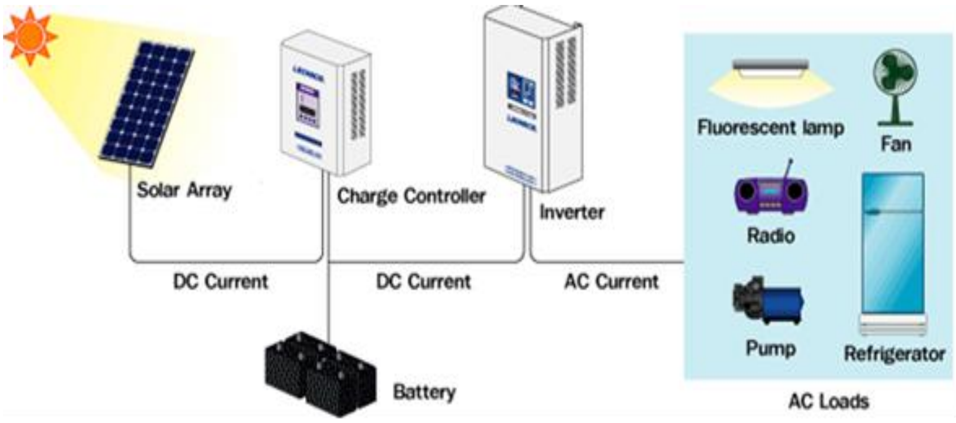


Figure 7.2 Solar PV Home System
Source Adapted from Sovacool et al. (2011)

7.2.4 Solar PV Lanterns

The solar lantern system is the easiest and simplest application for electricity for light use in rural areas. The system consists of LED light, battery storage, power outputs, micro-charger controller and integrated PV panel (see figure 7.3). Solar lanterns produce light in the evening after the lantern is charged during the day by the sun; it has a rechargeable battery, and can be moved anywhere in the house. The system is easy to handle, safe and can be leased or rented.

Figure 7.3 Solar lantern with an integrated PV
Source Adapted from SolarAid (2018)

For the majority of Cameroonians, the connection to the grid and installation of solar home systems (SHSs) are electrification solutions which they either cannot afford or do not have physical access to. In addition, the development of microgrids is a solution for rural populations; however, the high cost of maintenance is a barrier for rural populations to maintain such a system. Affordable and sustainable solutions that can provide communities with a number of services are solar lanterns as shown in figure 7.4.

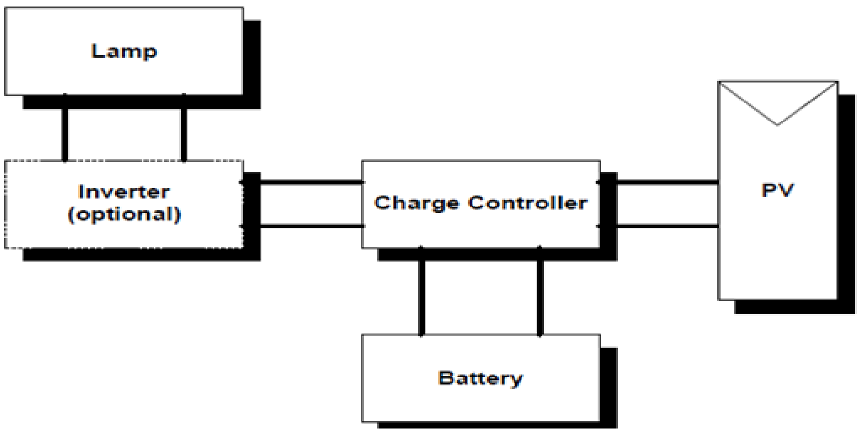


Figure 7.4 Solar lantern components
Source Adapted from SolarAid (2015)

Solar lanterns are compact systems with an integrated PV (see figure 7.3) and are distributed as one package: the system can be charged free of cost through sunlight and can provide the following services:

- Lighting
- Phone charging
- Radio
- Fan

7.3 Techno-economic Study of Solar Lanterns

The basic purpose of solar lanterns is to provide poor households with an alternative solution to kerosene lamps which cost a significant amount of the household budget and also produce toxic fumes. Solar lantern use has several advantages, such as increased study time for children, more time for the household's productive activities, money savings, health improvement and job creation. In addition, most of them include phone charging outputs and this aims to solve the problem of people who do not have access to the grid and have to walk long distances in order to recharge cell phones. As a result, these basic activities are provided by solar lanterns that are available on the market. Additional appliances, such as radios, TVs and fans are included in larger systems (see figure 7.5) that have bigger PV panels and battery capacities, and higher prices.

Figure 7.5 Different types of solar lanterns and a larger solar kit
Source Adapted from SolarAid (2015)

The impact of basic solar lantern household systems is improvement in the household finances, quality of lighting, communications, health, education, environment, employment, income generation and quality of life. Figure 7.6 clearly depicts young people undertaking solar lantern service and assembling training in Kenya.

Figure 7.6 Young people training in Kenya undertaking servicing of solar lanterns
Source SolarAid photo (2015)

Figure 7.7 A man charging his mobile phone in a charging station
Source SolarAid photo (2015)

In Cameroon, solar lantern systems are not adopted yet, but the system exists in some African countries. The NGO SolarAid is the largest distributor of solar lanterns in some Sub-Saharan African countries. To date, they have distributed more than 1,350,000 energy systems (SolarAid, 2015), but not in Cameroon as this system is not yet adopted. Solar lanterns in developing countries are a cheap alternative to the solar home system and provide a high quality lighting service of between 4 and 5 hours per day. Solar lanterns provide a better quality of light (see table 7.2) than kerosene lamps or candles.

In developed countries, solar lanterns can be used in the garden, for street lighting or on the driveway, and for other activities such as road signs. The system is durable for any form of temperature and weather, and can provide a phone charging facility (see figure 7.7). They can produce 15 hours of power for listening to the radio. It is important to note that 15 hours of a solar lantern with a 5w PV panel cannot power a television.

7.3.1 Categorisation of Solar Lantern Household Systems

This section categorises the household energy system by setting out the levels of household energy. Cameroon should follow the solar product energy ladder (figure 7.8) to ensure that populations have access to electricity by following the example of other Sub-Saharan African countries such as Kenya. The categorisation of solar lantern household systems in table 7.1 below describes the different tiers of the ladder, starting at Tier 0 where rural people use kerosene lamps and candles that produce toxic fumes which affect their health. Tier1 then describes how people can move to the next level by using solar lanterns that can produce 3 w to 10 w for lighting; they can also use the power to charge mobile phones. This system is a clean energy and does not produce toxic fumes. According to this research, this system is cheaper, cleaner and more affordable for rural populations in developing countries such as Cameroon (GOGLA, 2016). Tier 2 relates to general solar lanterns that can produce 50 w and this system is very beneficial for producing light and charging mobile phones; consumers can also enjoy TV and fans. Tier 3 can produce 200 w and could light medium-sized appliances in the house. Tier 4 is the highest power of solar lantern and this system is a combination of Tiers 3 and Tier 4 with an output of 800 w. A combination of Tier 3 and Tier 4 could power all appliances in the household. Tier 5 is the highest power and includes all tiers with an output of 2 kw and could power all appliances in the household. This table shows how a community can move from polluting kerosene lamps and candles to clean and affordable energy.

Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Kerosene lamps/ candles	Solar lantern lighting & phone charging	General solar lanterns lighting & TV/ fan	Tier 2 & medium power appliances	Tier 3 & high power appliances	Tier 4 & very high power appliances
	> 3 w & < 10 w	> 50 w	> 200 w	> 800 w	> 2 kw

Table 7.1 Categorisation of solar household systems
Source Adapted from GOGLA (2016)

Figure 7.8 represents the solar product energy ladder and explains how consumers can move from solar lanterns to large solar home systems. It should be noted that the solar product ladder (SPL) replaces kerosene lamps and offers phone charging. This system is the cheapest and most suitable for rural communities in developing countries such as Cameroon who cannot afford or do not have access to grid connection. It provides clean energy and costs $10 to $40 per system (GOGLA, 2015). If a consumer’s financial situation changes at any time, they can move to the next level of solar product. It should be noted that solar home systems can supply multiple LED lamps, small TVs and radios for rural populations, but this system is expensive and could cost US$50 to US $200 for consumers with an annual household income of US$500 to US$1,200. Another solar product is the large solar home system and can supply a large TV and a small fridge; this system can replace diesel generators that produce CO_2. However, this system is expensive as well, and consumers should have an annual household income of around US$2,000 to US$5,000.

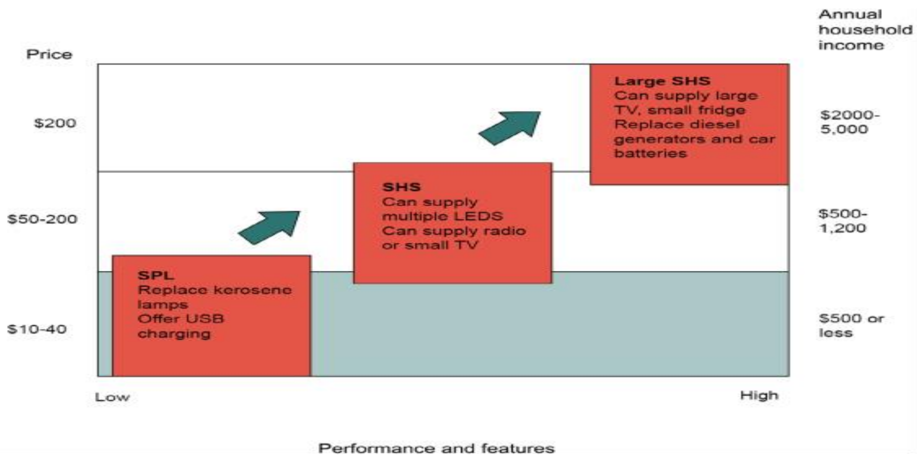


Figure 7.8 Solar product energy ladders
Source Adapted from SolarAid (2016)

7.3.2 Solar Lantern Advantages in Rural Areas in Developing Countries

This section outlines solar lantern advantages in households for meeting the goals of developing countries such as Cameroon, for improving health, education and quality of life, reducing indoor air pollution and supporting poverty alleviation in rural areas.

- **Improvement in Health**

According to the World Bank (2015), women and children breathe kerosene lamp fumes equivalent to smoking two packets of cigarettes a day. Houses are poorly ventilated and kerosene lamp fumes can cause serious health problems. By adopting solar lanterns, these health problems could be eradicated.

Solar lanterns improve people's health, and this is important for rural people who are not connected to the national grid or cannot afford to pay for the service of the grid's national provider. It should also be noted that solar lanterns are very helpful for rural communities because of different advantages of the system (i.e. easy to handle, can be moved between buildings etc.). According to the World Bank (2016), solar lanterns have helped rural populations with health-related problems by eliminating the use of kerosene lamps and candles that produce toxic fumes in the house. It has been proved that solar lanterns reduce indoor air pollution and the danger of fire in the house.

- **Indoor Air Pollution Reduction**

Solar lanterns dramatically reduce indoor air pollution and the amount of kerosene used for lighting. This reduces the level of indoor air pollution that affects the health of rural populations. It should be noted that solar lanterns are a clean form of energy that do not produce toxic fumes.

- **Greenhouse Gas Emissions**

According to Lam et al., (2012), kerosene lamps are significant sources of atmospheric black carbon and emit 20 times more than previously estimated. At least 270.000 tons of black carbon per year is estimated to be emitted from kerosene lamps worldwide, having a climate warming equivalent close to 240 million tonnes of CO_2 (Lam et al., 2012). Switching from kerosene lamps to solar lanterns could reduce annual household gas emissions.

- **Working Day Hours Extended in Rural Areas**

The main advantage of solar lanterns is that they extend working hours for rural families in the evening and also extend student reading hours at night. Adopting solar lanterns in rural areas could increase economic gain. For businesses that operate in the evening, solar lanterns can also encourage local small businesses to operate at night.

- **Reduction in Urban Emigration**

Solar lanterns improve the quality of light for rural households, and this stops people emigrating from rural areas to the city once they have acquired a solar lantern for their house. People can have extra hours of good quality lighting at night. Rural people can enjoy clean and sustainable lighting that does not produce CO_2 which puts their health at risk.

- **Improvement in Fire Reduction**

This is the most important hazard in developing countries and comes from kerosene lamps and candles killing 1400 innocent people each year in Cameroon (WHO, 2018). Another safety threat is gasoline and diesel fuel being stored in small generators. Solar lanterns are the safest option for rural people in Cameroon.

- **Reduction in Maintenance**

The use of kerosene lamps and generators by the rural population is time-consuming. By adopting solar lanterns, maintenance time is reduced. It should be noted that kerosene lamps and generators can be filled many times a day; buying kerosene lamps in developing countries is expensive and very difficult to find and according to this research, rural populations can walk a minimum of 33 minutes to find fuel. Kerosene lamps and generators need periodic maintenance. Solar lanterns are maintenance-free; they can just be charged and used.

- **Quality of Life Impact**

Solar lanterns could have a positive impact on quality of life. During the survey, respondents agreed that solar lanterns increased the confidence in their social status. Solar lanterns increase the amount of time spent by rural people on social activities.

- **Availability of Brightness**

Brightness is very important for any lamp and is measured in lumens: see table 7.2 below showing different types of lamp lumens.

Type of lamps	Lumens
Solar lantern	20 to 200 (this depends on lamp settings)
Kerosene lamp	20
Single lamp wick	10
Candle	10

Table 7.2 Availability of lamp brightness
Source Practical Action 2018

- **Positive Impact on Education**

As previously discussed in chapter 6, quality of light is very important for households for productivity and this can also enable children to have extra hours to spend time on their homework. During the study of this thesis, most students rated limited lighting as the top factor in challenging their opportunity to do their homework at night.

- **Positive Impact on Access to Information and Telecommunications**

Beyond lighting, solar lanterns improve access to information and communication by allowing rural people to charge their mobile phone, listen to the radio and use their mobile phone to access financial services such mobile money. With solar lanterns, the rural population can watch TV and listen to the radio to be informed about health, national disasters and even weather news related to the country.

7.4 Conclusions

This chapter investigated solar lantern advantages. Based on the study, it was identified that solar lanterns have an important place as an interim technology and innovation for the transition from kerosene lamps to solar lanterns, as there is a full electrification shortage in Cameroon. Solar can help in job creation in rural and urban areas in the country, and it was identified that solar lanterns do not produce CO_2 and do not harm people's health. Solar lanterns extend small business lighting time in the evening and increase their finances. In the education sector, it was identified that solar lanterns extend student study time which helps the students to get a good grade at school.

The other findings in this chapter are that solar lanterns do not need maintenance, and also reduce migration from rural to urban areas. Most importantly, this chapter has outlined the importance of safety: solar lanterns reduce dramatically fire hazards. They can also be moved between buildings and are very easy to handle. It should be highlighted here that solar lanterns produce energy without generating any pollution or waste. Solar lanterns operate without any intervention by the user. Power generation here is very economical compared with grid connection or fuel in rural areas, where grid connection is difficult, impossible or costly.

Chapter 8

Factors that could Influence the Success of Solar Lanterns in Cameroon based on the Kenyan Model

8.1 Introduction

Chapter 7 examined potential solar PV utilisation in the community, by setting out solar lantern advantages providing a positive impact on households for rural people in developing countries, particularly Cameroon. Using evidence from Kenya and extensive historical literature, chapter 8 identifies the factors that can influence the success of solar lanterns in Cameroon based on the successful adoption of solar lanterns in Kenya.

This chapter carried out a comprehensive deep analysis of different factors of successful adoption of solar lanterns and trajectories in Kenya that can be used by the Cameroon government, energy experts and communities. The following questions will be answered and explained by this chapter. What is the main force for the successful adoption of solar PV in Kenya? Why has solar PV not been adopted in Cameroon?

It should be highlighted that Kenya has been chosen for analysis for this study because the country shares the same climate, socio-economic, political and socio-cultural issues with Cameroon, and Kenya is one of the largest Sub-Saharan African countries in the solar photovoltaic and solar lantern market in Africa. Many authors such as Jacobson (2013), Duke et al. (2015) and Hanking (2016) have viewed Kenya as the leading solar PV market in Africa, and the Global Energy Network Institute; Mbewe (2015) and Otieno et al. (2012) concluded that it is a solar PV success story in Africa. It appears that Cameroon is one of the least PV developed countries in terms of adopting solar PV in Africa. As can be seen in figure 8.1, Kenya and Cameroon are on the same equator line and have similar solar irradiation of around 2,000 kWh/m^2 per day.

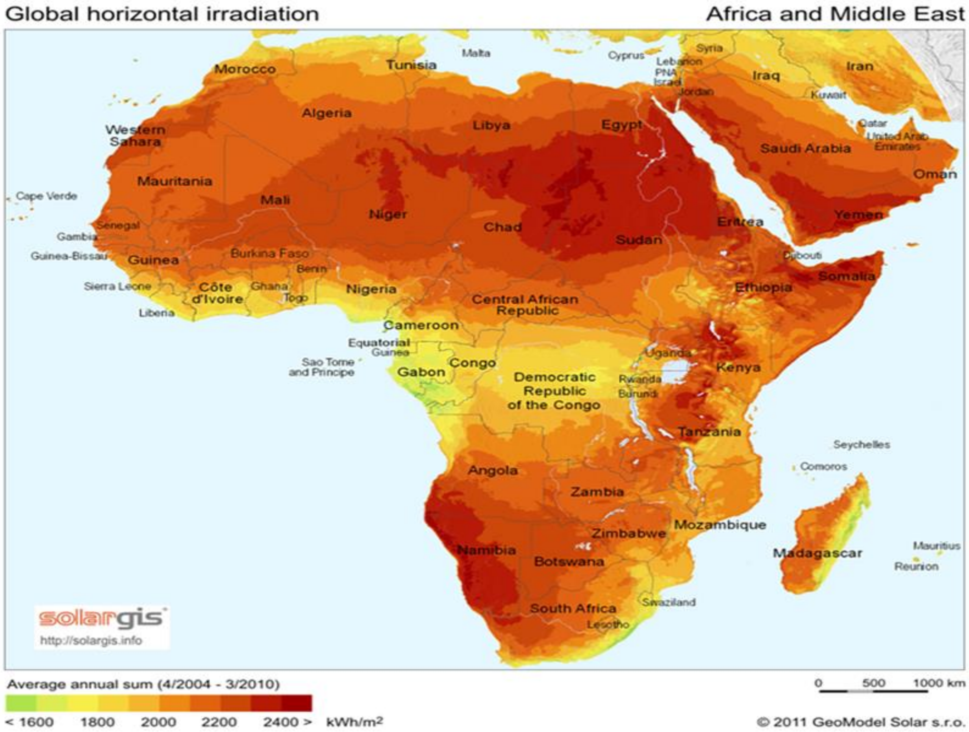


Figure 8.1 Africa solar irradiation map
Source http://geosun.co.za/solar-maps/ Accessed 20/05/2016

8.2 Kenya's Successful Solar PV: Key Factors

Based on chapter 7's solar lantern advantages, this section shows the key measures taken by the Kenyan government for solar PV success by unlocking all PV barriers in rural and urban areas in the country (see table 8.1).

Area	Current Situation	Future Opportunity
Policy framework	The Kenyan government supports solar PV policy and has removed taxes from all solar products.	Solar PV companies work with the Kenyan government, NGOs and international organisations to support the off-grid policy framework.
Access to finance	The solar PV market in Kenya is very strong with access to loans for small businesses.	The Kenyan government supports small businesses and technology innovation in the off-grid sector.
Fiscal barriers	VAT exemption can be obtained from the Kenyan Energy Regulatory Commission.	Get government support for VAT exemption for off-grid products.
Consumer protection and quality assurance	Consumers in Kenya can buy a good product in the market	The government helps consumers get a very good product all over the country.
Consumer awareness	In Kenya, consumers can get a good product in the market because there's a high level of awareness for fake products.	Good community education and the presence of good quality products in the market.
Level playing field	In Kenya, off-grid and grid connections are subsidised; however, kerosene lamps are not subsidised.	Government officials and communities are educated about off-grid products and management.

Consumer financing	In Kenya, solar PV customers are regrouped into cooperatives that facilitate access to finance for off-grid customers and small businesses.	Creation of innovation schemes in the financing sector and low-income households supported by the scheme.
Level of local skills	The Kenyan government has put a training strategy in place for local skills so that the sector can utilise them.	The Kenyan government increases support for training programmes.

Table 8.1 Reasons for Kenya's successful adoption of solar PV
Source GOGLA (2016)

By unlocking all solar PV product barriers, Kenya has put in place a good strategy for rural and urban populations to have access to electricity by using clean, affordable energy, specifically solar lanterns. This strategy should be followed by the Cameroonian government for the adoption of solar lanterns to unlock all solar lantern product barriers in the country.

8.3 Secondary Data Analysis

This section focuses on solar lantern secondary data analysis of the survey results that were collected in Kenya by SolarAid in collaboration with the author herein and compared with the kerosene lamp survey carried out by the author in the study area in Cameroon, namely Ebebda district (see chapter 6). In Kenya, there were 100 respondents (57 females and 43 men) and the questionnaire differed from the Cameroon survey.

8.4 Solar Lantern Data Results Analysis

The data in question is principally the results from the questionnaire survey and focal group discussions that were collected by SolarAid in collaboration with the author herein, focussing on solar lanterns.

8.4.1 Demographic Data

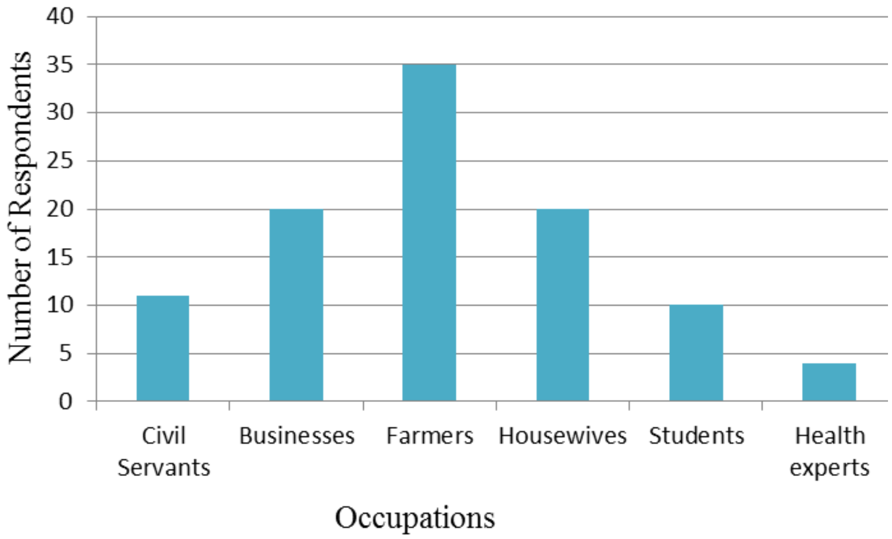


Figure 8.2 Representation of respondents

The tradition in Kenya is that the country has a seven-day-week calendar, of which one day of the week is named a 'country Sunday'. This is a day when no one is expected to go to the farm and most traditional group meetings or quarter meetings take place on this day. The country Sunday could fall on any day of the usual seven day calendar; however, the day of choice follows a certain pattern. This made it easier for the survey to be carried out; meanwhile, the weekend was used to carry out questionnaires in the research area so that respondents could participate (see figure 8.2).

8.4.2 Energy Modelling Solar Lantern Users

The average number of solar lanterns per household is one lamp and owners use their lamps for 4 to 5 hours per day.

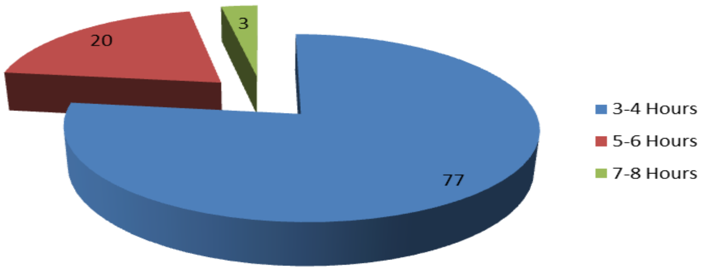


Figure 8.3 Hours of daily usage of solar lantern

Out of 100 respondents, 77 of people use the solar lantern for 3–4 hours daily; this is logical as, under normal to intensive mode, the solar lantern battery lasts for this amount of time. In all, 20 people use it for 5–6 hours which can be done under battery-saving mode, and 3 for 7–8 hours. This allows the conclusion that solar lanterns are easily adopted by users.

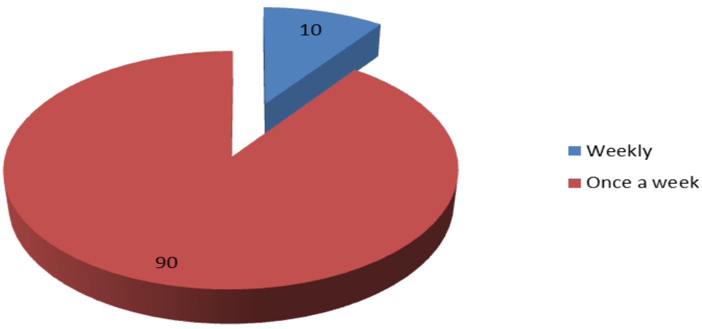


Figure 8.4 Frequency use of solar lantern

Out of 100 respondents, 90 people said they use their solar lantern once a week and 10 people weekly (see figure 8.4).

Solar lanterns release the household from toxic smoke, high expenses, drudgery and many other disadvantages of kerosene use. As expected, the vast majority of people declare that they are very happy or happy (see figure 8.5), while there were no people who stated that they were unsatisfied with using solar lanterns. This result is very significant.

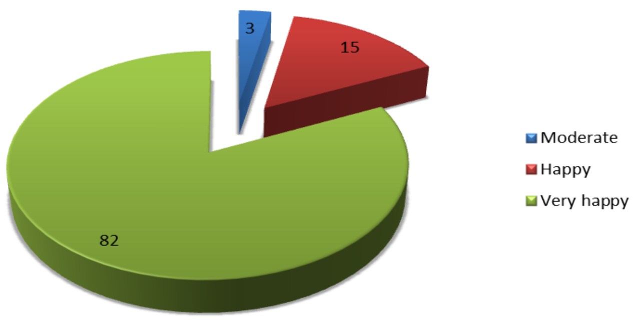


Figure 8.5 Satisfaction of solar lantern users

For the solar lantern users, 82 were very happy, 15 happy and 3 moderately happy.

- **Solar lantern light available**

Households use an average of 3.8 hours per day with traditional lighting, but after purchasing a solar lantern, the lighting hours increased to 5 hours per day (see figure 8.6) and households consumed an average of 15% more lighting. It should be noted that solar lantern use increases the light by about 1 hour per day and that is equivalent of 50 days per year.

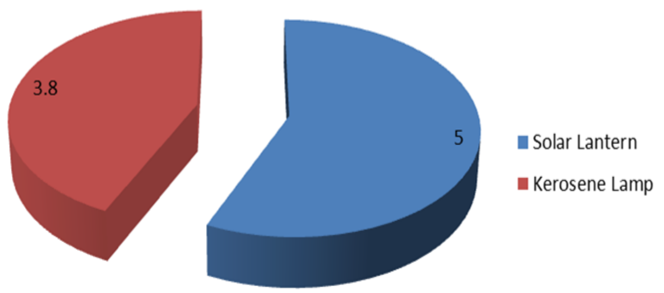


Figure 8.6 Duration of daily studying by source of lighting comparison

8.4.3 Feeling of Safety

A big difference is recorded between kerosene lamp users and solar lantern users as far as the feeling of safety is concerned. Half of the respondents that use kerosene lamps said that they do not feel safe during the night. However, 97 of lantern users stated they feel safe during the night (see figure 8.7). It can be seen that more reliable lighting sources can affect the feeling of safety. However, it should be mentioned here that safety, as with many other aspects, is affected by many parameters, such as location, type of housing, local criminality and previous incidents. It can be considered though, that the influence of these parameters is decreased by the fact that both kerosene lamp users and solar lantern users come from the same areas and have similar wealth profiles.

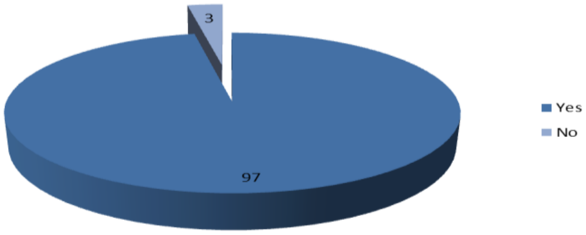


Figure 8.7 Feeling of safety by source of lighting (solar lantern)

During the research, out of 100 respondents, 97 of respondents said they felt safe with solar lanterns and 3 gave a negative answer**.**

8.4.4 Migration

The migration tendency of people is highly dependent on access to energy. The following figure (figure 8.8) shows that among solar lantern users, 79 of respondents said they would not emigrate, while 21 said they would emigrate. It is very clear how the quality of life is upgraded by even a small step up the energy ladder. Nevertheless, migration tendency is a multi-factor parameter. However, the respondents were asked specifically if they would move to another place in order to have access to electricity. Therefore, it can be assumed that the effect of other socio-economic factors on the research results is minimised.

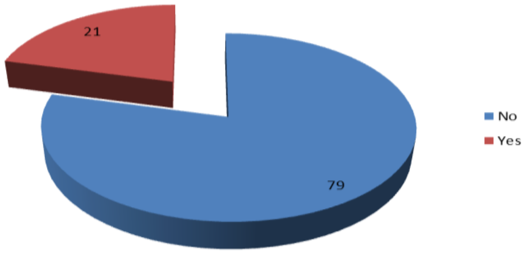


Figure 8.8 Tendency of migration by source of lighting (solar lantern)

8.5 Change in Spending on Lighting from Kerosene to Solar Lantern

The most important benefit of solar lanterns is economic gain (financial savings) from people using solar lanterns. This research shows the empirical evidence of financial savings for solar lanterns against kerosene lamps. During the research interview, the study found that a typical family home size of six people spends about 10% of their income for four hours' light at night using torches or kerosene lamps. The monthly income is US$118.77, and these people live below the US$1.25 per person per day poverty line (World Bank, 2016).

- **Cost analysis of solar lantern and payback period**

Before the adoption of solar lanterns, families spend US$1.20 per week to have light for the household for only four hours a night. According to this research, the result shows that a typical family of six saved US$60 a year and spent only 2% of their household's income after adopting solar lanterns (8 hours of medium and 5 hours of high brightness on settings with an 8-hour charging time per day and free of cost through sunlight).

After adopting solar lanterns, a typical African family of six went from buying 9.5 litres of kerosene per month to 1 litre. Solar lanterns offer a 1:1 ratio (one solar light replaces one kerosene lamp). The lifespan of a solar lantern is three years (SolarAid, 2016). After the cost of the solar light is taken into account, families save around US$180 in 3 years. The cost of a solar lantern with an integrated PV is between US$18 and US$35 and these prices are very popular in rural areas in some African countries where people are waiting for governments to deliver grid connection. It should be noted that solar lanterns are more expensive to buy than kerosene lamps that cost only US$6. However, solar lanterns do not require the same running costs as kerosene lamps, whereby one litre of kerosene costs between US$0.47 and US$0.63, with a household using 9.5 litres of kerosene per month (114 litres per year). And according to this research, the payback period of a solar lantern is 2 to 6 months. It is important to note that a solar lantern with an integrated PV (see figure 7.3) can be charged free of cost through sunlight, as the PV is integrated: the user just needs to expose the solar lantern to the sun. The solar lantern PV should be in direct sunlight so that the photovoltaic cells absorb the sunlight for 8 hours a day, to adequately charge the rechargeable batteries.

- **Problems**

According to the results of this study, a family home size of six went from buying 9.5 litres of kerosene a month for lighting to 1 litre a month after adopting solar lanterns. How much carbon dioxide is produced when 9.5 litres of kerosene is burned?

One gallon = 4.54609 litres

Kerosene produces 9.75 kg of CO_2 per gallon

Number of litres of kerosene burnt per month = 9.5

Number of litres of kerosene burnt per year = 9.5 × 12 = 114 litres of kerosene

By converting litres to gallons $\longrightarrow$ 114 ÷ 4.54609 = 25.07 gallons (1)

Amount of carbon dioxide (CO_2) produced when 114 litres of kerosene is burnt per year

Number of gallons × number of kg of CO_2 per gallon (2)

25.07 × 9.75 = 244.43 kg of CO_2

In one year, 114 litres of kerosene produces ≈ 244.43 kg of CO_2 (3)

❖ **Kerosene vs. solar lanterns in children's education**

Children's and adults' education is highly affected by the source of lighting they use. Kerosene lamps provide a very poor quality of lighting as shown in figure 8.9 where a child has difficulties in reading books at night, while kerosene lamps also emit toxic fumes. These factors create poor reading and studying conditions for the users and eventually they prevent them from spending time on these activities. Kerosene is also an expensive fuel, especially for a rural household, which means that it is not always available. In addition, both children and adults spend a great deal of time locating fuel. The questions regarding education were focused on the source of the lighting used by the adults and children of the households and it is clear that solar lanterns produce a good quality of light, as can be seen in figure 8.10. Moreover, questions were asked about the quality of lighting, time spent on studying, satisfaction of the users, children's school grades and usage of radio for educational activities.

Figure 8.9 A child studying with a kerosene lamp
Source SolarAid (2015)

Figure 8.10 A child studying with a solar lantern
Source SolarAid (2015)

8.6 Conclusions

According to the results of the survey, eradication of kerosene lamps could improve the lives of millions of households in developing countries, particularly Cameroon. For this change, solar lanterns can play a significant role. The turn towards modern energy sources by the replacement of kerosene with solar lanterns affects all aspects of development and quality of life, such as income, education, health, social aspects and productive activities. More specifically, the average monthly expenditure that rural households in Sub-Saharan African countries spend on the purchase of kerosene is enough to purchase a solar lantern. In other words, the expenditure on kerosene alone over a period of 2 months is more than enough to buy a solar lantern that has a lifetime of 3 years. This fact shows how easily change can happen, as the savings from fuel can be spent on education, food and other goods. In education, the study showed that children who do their homework by the light of solar lanterns study for 5 hours daily on average and have much better grades.

Furthermore, several health impacts and dangers were related to kerosene lamps. Breathing problems and eye irritation were reported by many users while also the risk of house fires and skin burns is considerable. In addition, solar lanterns make people feel safer during the evening hours, decrease the migration tendency and create more income for small businesses as they can extend their opening hours and attract more customers. Finally, the duration and timing of activities such as cooking, cleaning and social gathering during the night did not seem to be affected by the source of lighting as people answered that they practise them independently of having kerosene or solar lamps. As a conclusion, changing kerosene lamps to solar lanterns would improve the domestic work and activities environment and decrease the health problems.

Chapter 9

Unlocking Solar Lantern Barriers in Cameroon

9.1 Introduction

Energy delivery services in the world, and especially in Sub-Saharan Africa, have little success because rural problems are not being taken into consideration seriously by energy experts and policy makers. Until something is done, most rural solutions will not prosper and objectives will not be achieved in Africa, particularly in Cameroon. The reason for this is that planning projects starting from a top-down approach are not followed, and this results in a failure to address the needs of rural populations. In the case of Cameroon, the country should find a way of unlocking solar lantern barriers so that rural populations can have access to a clean and affordable energy. Cameroon should also attract investors, academics and energy experts to the country.

9.2 Potential Workable Approaches to Unlock Solar Lantern Barriers in Cameroon

Energy experts and policy makers have taken many approaches towards poor communities in Cameroon, keeping the very poor populations away from making their own decisions on energy (Lighting Africa, 2018). By doing this, rural people have limited opportunities to improve their lives on their own. But now, decentralisation and off-grid energy are gaining much attention in the world. Solar lanterns are an attractive and simple system that rural people should use as energy for lighting and, once obtained, can be expanded. Solar lanterns are very beneficial economically; they are environmentally friendly, clean, easy to handle and can be moved around the house. It should be highlighted that off-grid systems keep energy close to the users and allow them to make their own decisions about design, acquisition, consumption and placement. Solar lantern systems are very relevant in rural villages where grid connection is not possible and not feasible. While off-grid systems are gaining attention in rural areas, any successful adoption should take into consideration the local energy preferences, economies, reality and culture of the community to help them accept innovative technology. Possible solutions to unlock solar lantern barriers in Cameroon are listed below.

9.3 Solutions to Unlock Solar Lantern Barriers in Cameroon

To unlock solar lantern barriers in Cameroon, different factors should be taken into consideration to adopt this new technology. According to Rogers (2014), technology innovation is very complex with connected factors. This thesis has identified possible solutions to unlock solar lantern barriers in Cameroon and these could guarantee lower solar lantern prices, allowing rural and urban populations to have access to a clean, sustainable and affordable energy for their households. It should also be highlighted that the proposed solutions listed below should be closely and carefully coordinated by the private sector, stakeholders and the government of Cameroon in particular. Before taking any decisions on the proposed solutions, an analysis of the country's situation in terms of socio-economic, socio-cultural and socio-political issues should be carried out and this should be done by energy experts, policy makers and academics, so that the right solution can be chosen for implementation in the country.

9.3.1 Importation of Solar Household Equipment and Fiscal Barriers

For the Cameroonian government to unlock solar lantern barriers, all solar lantern products entering into the country should be exempt from import tariffs and value added tax (VAT). This should be done by signing international agreements for tax exemption between the Cameroonian government and renewable energy companies and providers. By removing import and fiscal barriers, this will speed up the import process and allow companies to set up a smooth and efficient supply chain of solar lantern products to deliver to the country at the lowest possible prices for rural and urban populations. A complex import process and slow supply chain will increase the costs to consumers and companies. High solar lantern product import tariffs and VAT will drive up consumer costs as well.

Table 9.1 shows some Sub Saharan Africa countries' VAT and tariffs rates.

Sub-Saharan African Countries	Value added tax (VAT)	Import tariffs
Kenya	16%	2.5%
Uganda	18%	6%
Rwanda	18%	5%
Tanzania	18%	5%

Table 9.1 VAT tariffs and import tariffs
Source African development bank group (2018)

- **Potential Implementation Solutions and Examples**

To implement these solutions, the Cameroonian government should propose for neighbouring countries the introduction of import tariff and value added tax (VAT) removal barriers for all solar lantern products entering Central African Economic and Monetary Community (CEMAC) state countries via their economic communities' states. There should also be a coordinated import tariff and VAT into CEMAC state regions. The government of Cameroon should also facilitate a solar lantern product clearing system at customs to reduce clearing time and this should be done by providing training to customs agents so that the process can be organised smoothly and efficiently. Removing import tariffs and VAT for solar lantern products should allow the rural population in the region, particularly in Cameroon, to purchase solar lanterns at lower prices.

A typical example of value added tax (VAT) removal in solar lantern products in Tanzania, Uganda and Kenya has helped these countries to adopt and promote the use of solar lanterns as electricity (SolarAid, 2016). It should be mentioned here that these countries have enjoyed strong solar lantern penetration into the market and this has benefitted rural populations who now have access to clean and sustainable off-grid based electricity. For the government of Cameroon to help its community to have access to electricity, a good solution would be to turn towards solar lanterns and follow the Kenyan example, as this Sub-Saharan country has enjoyed the successful adoption of solar lanterns.

Another good example is VAT exemption in Rwanda, where the government has put an assurance quality programme in place, so that only verified quality products in the market can enjoy VAT exemption. This encourages healthy competition and an increase in the availability of quality products on the market (GOGLA, 2015). According to SolarAid (2016), import tariffs and VAT exemption have proven to be effective in these countries and rural populations are the first beneficiaries. This has made solar lanterns for low-income households affordable and attractive. It has also speeded up the adoption of solar lantern lighting technology in some African countries such as Tanzania, Uganda and Kenya, where rural populations cannot afford grid connection. Cameroon shares the same climate, socio-economic, political and socio-cultural issues with these other Sub-Saharan countries.

9.3.2 Allow the Private Sector to have Access to Finance

The most important barrier in the solar lanterns sector is access to finance by the private sector. For the electricity demand to be met by the Cameroonian government, access to finance needs to be improved and the barriers overcome. In fact, the lack of funding and working capital makes it difficult for the private sector to have access to finance and makes long-term financing a dilemma. In Cameroon, getting a loan in a bank is very difficult for all borrowers everywhere, because companies with no previous business history are more of a risk if they do not have a strong business plan.

The government should make it easier for small and medium companies to get loans for their major projects in the renewable energy sector. The country should have a regulatory framework that will gather all data for companies in order to build a streamlined lending environment. The Cameroonian government should lower the loan rate and also look for a long period for paying back the loan. The country should also find a way to borrow in the international market. It should be noted that there is some international funding that requires the involvement of the Cameroonian government to help companies secure finances in the renewable energy sector. New companies should be able to demonstrate sustainable development and a strong business case to have access to finances for their business in the country.

- **Potential Implementation Solutions and Examples**

For this proposed solution to be implemented, the Cameroonian government should produce a guarantee to international and local banks for any risk investment for small and medium companies that are working on solar lanterns or off-grid power. Most of the time, local banks are not familiar with off-grid sector businesses and need to be introduced to this sector. For banks to give loans to companies, a credit guarantee could be a good idea to engage all lenders in the country. International currency exchange should also be relaxed to allow repatriation of company revenues.

A good example that the Cameroonian government could follow is that of the Nigerian and Niger governments that, through the Global Environment Facility (GEF), have secured funding for a rapid transition to off-grid based technologies (GOGLA, 2015). The funds include financing all companies in the off-grid sector to reach their needs. Another example is the Gambian government which taps into climate funding via Nationally Appropriate Mitigation Action (NAMA), to increase access to electricity by rural populations (SolarAid, 2016). The objectives of the climate funding are to reduce greenhouse gas emissions so that the country can get access to clean and affordable energy.

The Ethiopian government, with the support of the World Bank, has set up a development bank for financing all solar products. The bank lends money to all companies involved in the off-grid sector and also helps them to secure finances in US dollar currency (GOGLA, 2015). This has helped business activities to expand in the country. All these good examples could be followed by the Cameroonian government in order to unlock solar lantern barriers in the country.

9.3.3 Quality Assurance and Consumer Protection

As part of unlocking solar lantern barriers in Cameroon, consumer quality assurance should be protected. For this to be done, any solar lantern provider selling poor products to customers should be held accountable. The country should also introduce a legal consumer rights protection law that will protect customers. The Cameroonian government should also promote consumer protection confidence for them to purchase solar lanterns and this can be done by following examples from other African countries. The country should put in place a certification of the product before any solar product enters the country. The country should also put in place a training institution that will carry out activities including qualifications and the training of solar lantern technicians.

- **Potential Implementation Solutions and Examples**

For these solutions to be effective and implemented, all faulty solar lantern products should be returned immediately by customers. Solar lantern-based products should have a minimum period of warranty so that customers can return them if there are any problems and be reimbursed or be able to exchange the product. To make sure that warranties are effective in rural areas, customer satisfaction should be protected and all companies should have an obligation to satisfy them. For solar lantern manufacturers to advertise their product, the features and performance of the product should be supported by a test result with an accredited organisation.

A typical example is the Kenyan Renewable Energy Association (KEREA), which created an accreditation programme to make sure that all solar lantern sellers give advice and information to customers, and a complaint system is put in place. For sellers to participate in this programme, awareness about poor solar lantern quality and marketing activities has been delivered by KEREA (SolarAid, 2016). However, in Kenya, not all products have a warranty for customers.

Another good example is the government of Bangladesh. Through Infrastructure Development Company Limited (IDCOL), a fund was put in place that guarantees customers using off-grid systems that, if grid connection arrives within 3 years in their area, all customers will receive compensation covering the time that they have had the solar system (SolarAid, 2016). These examples should be followed by the Cameroonian government to allow rural populations to have access to clean and affordable energy.

9.3.4 Training of Skills in Local Areas

For solar lanterns to be adopted in Cameroon, there should be a qualified workforce in place so that the country can gain in value creation, and this should be done by collaborating with universities, private institutions and trade associations to promote technical skills, innovation, local businesses and regulatory capacity. Adopting solar lanterns in Cameroon should create jobs and this will require people with different skills such as repairing, maintenance, retailing and installation; according to SolarAid, the sector has created 15,000 jobs in Sub-Saharan African studied countries (SolarAid, 2016). It should be highlighted that, for any innovation of a technology to be expanded, skills need to be created for the industry to grow and this should be supported by the creation of employment and skills development in the country.

The government of Cameroon should educate the population about the benefits of solar lantern lighting in terms of health issues, and put in place a training system, particularly for the development of solar lantern technicians.

- **Potential Implementation Solutions and Examples**

To implement this, the government of Cameroon should create institutions that will provide training to solar lantern technicians on installation, repair and maintenance. The country should also collaborate with universities to benefit from academic expertise in the off-grid field. There should also be collaboration with international institutions for knowledge transfer in the off-grid sector.

A good example is the Economic Community of West African State (ECOWAS) which has put in place a supporting programme for institutions that provide training in renewable energy for technicians, including training in off-grid energy (Lighting Africa, 2014). This programme has been run by the 2iE University of Burkina Faso, one of the institutions that have been supported by the programme. Another example is the Kenyan government that passed a law requiring all off-grid technicians to have a minimum qualification to work in the sector. The Kenya Renewable Energy Association has also created a training academy for solar lantern technicians and collaborates with other institutions in the region (SolarAid, 2016).

9.3.5 Level Playing Field

Subsidies in diesel and kerosene make it look as if these products are cheaper, and this reduces the value proposition to households of solar lantern technology. This therefore slows down the development and adoption of the new technology and encourages rural populations to have access to polluting kerosene that puts their health at risk by the production of indoor air pollution. In normal circumstances, according to the World Bank (2016), the subsidising of diesel and kerosene in Cameroon stands at US$600 million per year. To encourage people to adopt a clean and affordable energy, subsidies should gradually start to disappear in the country. It should also be noted here that subsidies have difficulty achieving their goal, because it is a complex and expensive process which is why, most of the time, subsidies do not reach poor populations in rural areas of the country.

Table 9.2 shows some Sub Saharan Africa countries' kerosene subsidies by population.

Countries	Population (million)	Kerosene subsidies (US$)
Kenya	48.46 million	US$585 million
Rwanda	11.92 million	US$900 million
Uganda	41.49 million	US$623,33 million
Tanzania	55.57 million	US$683.53 million

Table 9.2 Some Sub Saharan African countries' subsidies
Source World Bank (2018)

- **Potential Implementation Solutions and Examples**

For this solution to be implemented, the Cameroonian government should get support from donors and this could help reduce or end subsidies on kerosene in the country. People could then turn towards clean and affordable energy (solar lanterns). Another proposed solution is that the subsidising of kerosene should progressively decrease, i.e. the scheme should not end abruptly and there should be a clear timetable for the government to end the scheme so that rural populations can still be supported. By doing so, the government will save some money and this could help rural populations in terms of education and health.

A clear example from India has introduced a smooth transition by cash transfer from the government for rural populations, so that they can make their own choice by deciding to buy kerosene at the normal price or turn towards clean and affordable energy (SolarAid, 2016). The benefit of this programme is that poor households use mobile money banking to gain access to financial systems and this is beneficial for them because they can make their own decisions.

9.3.6 Policy Measures

Off-grid energy policy in Cameroon should be carefully calibrated and coordinated with the private sector and stakeholders together. The aim of policy measures should be to accelerate the transition from polluting kerosene to clean and sustainable types of lighting using solar lanterns to help rural population have access to electricity. Before doing this, the country's socio-economic situation should be carefully analysed to see which proposed solution would fit with the country's situation prior to implementation.

Removing policy barriers in the Cameroon electricity action plan at national level could help with the adoption of solar lanterns, and this should make it easier for companies to have access to finance. It would also facilitate the importation of solar lantern equipment products for households and create a level playing field for solar lantern businesses in the country, consumer awareness, building a qualified workforce and consumer finances. Policy and strategy papers should also consider the superiority of off-grid lighting against traditional lighting (kerosene lamps, candles etc.), taking into account the wider benefits to health, education and safety as discussed in this thesis.

- **Potential Implementation Solutions and Examples**

For the energy policy in Cameroon to be effective, the government should acknowledge off-grid based electrification in their development and national growth plan. The country should also commit to targets for solar lantern product delivery into the country through set channels with a clear timescale. This could allow companies to quickly move into local markets and should also allow the government and stakeholders to assess the progress of the policy.

The Cameroonian government should develop a national electrification programme plan where all types of energy-based electricity will be present (solar, off-grid household systems, macrogrid, micro/mini grid etc.). It should also introduce off-grid based solar lantern electricity into the national development plan, so that the country can gain support from donors at national and international level to eradicate energy poverty. At the same time, introducing off-grid based solar lanterns for rural electrification for households could be an integral part of Cameroon's electrification agenda.

A good example for Cameroon to follow is Ethiopia, where off-grid based energy has been introduced into their national growth plan and transformation plan, and this has since benefitted rural populations (GOGLA, 2015).

9.3.7 Raising Consumer Education Awareness

To create a good and rapid environment for modern off-grid market development in Cameroon, raising awareness and education are fundamental for stakeholders and this must be done by targeting all market players: the private sector, all government agencies and the public should be educated about solar lanterns. There should be a mechanism in place for national awareness campaigns to inform consumers about how to obtain products that will benefit education, health and income generation. Educating people about the health benefits of solar lanterns, as discussed in previous chapters, is key to the population’s awareness. Also, educating children in terms of solar lantern health, safety, extra quality of light and extending learning hours at night for their homework would be beneficial.

- **Potential Implementation Solutions and Examples**

For solutions to be implemented, the Cameroonian government should use state and private media such as newspapers, radio and television to educate and increase awareness of the benefits of off-grid solar systems. The government could also organise events with social functions, such as football matches and traditional dances to pass on the message about off-grid advantages. This will give rural populations the opportunity to appreciate solar lantern products at first hand.

Recent good examples have taken place in Zambia, Malawi and Kenya where SolarAid is running an awareness and education pilot through schools. By working with head teachers as the first point of contact, students are able see and get interested in solar lantern technology, which they can then go and share with their parents at home (GOGLA, 2015).

Another good example is in Senegal where children are allowed to rent a solar lantern at a lower cost so that they can see the benefit of the lighting, and go and share the story with their parents at home. All these good examples should be followed by the Cameroonian government to implement the proposed solutions.

9.3.8 Uncertainty in Policy

Electricity policy uncertainty makes it difficult for Cameroon to attract investors and for the rural population to have access to electricity. For these barriers to be unlocked or removed, the country should include off-grid solar lantern use in their national electrification strategies, policies and regulations in rural electrification systems, so that it can help speed up the replacement of polluting kerosene and inefficient electrical products. It should also be highlighted here that policy uncertainty from the government on off-grid based solar electricity in households could make it very difficult for companies to secure funds and even attract customers in the sector.

The Cameroonian government should also recognise the benefits of and legitimatise off-grid based solar electricity in the country and make sure that relevant strategies, regulations, action plans and policies are aligned and incorporated into the country’s electricity programme.

- **Potential Implementation Solutions and Examples**

The Cameroonian government should create national energy maps that will assess different forms of energy costs in the country. The government should put in place a long-term national energy plan that will include all forms of energy for exploitation. It should have a policy in place to secure funding and attract foreign investors into the country. There should be a target for off-grid based solar products to be delivered through some mechanism that will be defined by country energy experts. The government should have a clear view about clean energy access to attract investors.

A good example is the Kenyan government that has put a strategy in place by recognising the benefits of solar lanterns and securing funds to attract investors to the country. According to SolarAid (2016), Kenya has been enjoying the penetration of solar lanterns into the country because of the removal of uncertain policy barriers. The sector has created more than 15,000 new jobs as a result of the transition to efficient and clean solar lantern lighting in the country. The Cameroonian government should follow Kenya's example to reduce energy poverty in the country.

9.3.9 Standardisation of Products

Counterfeits, fakes and bad quality products that always claim to be the original product in shops always undermine the technology and customer trust. To maintain customer confidence, the Cameroonian government should put in place a minimum enforcement plan to keep customer confidence in new technology. This can be done by imposing international standards on all off-grid products. All solar lantern products entering the country should be certified and labelled by appropriate authorities and must be good quality.

- **Potential Implementation Solutions and Examples**

To implement the above solutions, the Cameroonian government should put a system in place whereby all solar lantern products entering the country should have a mandatory quality standard label and technical specification.

The government of Cameroon, through the CEMAC states, should propose to adopt joint off-grid test results by a recognised laboratory, so that available new technology (off-grid) products can enter the country without any testing barriers. This will facilitate company and business implementation in the country. The government should also put a system in place to fight against the emergence of fake products in the country. Cameroonian authorities should have a legal framework in place by giving companies the power to take legal action against any company or manufacturer of bogus off-grid products. This can be done by engaging the private sector, providers, government and stakeholders.

A good example is the Economic Community of West African State (ECOWAS) countries, where a legal framework has been adopted so that all products entering the community states should have a minimum mandatory quality standard (GOGLA, 2015). This framework has unlocked product standard barriers and Cameroon could follow this example to be at the same level as other African countries.

9.4 Conclusions

This chapter has discussed unlocking solar lantern barriers and has proposed solutions to implement these measures in Cameroon. It should be highlighted that examples have been identified in some African countries which have successfully adopted solar lanterns and enjoyed the benefit of this new technology. The proposed solutions herein should be implemented by the government of Cameroon so that rural and urban populations can have access to clean and affordable energy. It should be noted that these solutions require implementation to unlock solar lantern energy barriers in the country.

The Cameroonian government should remove all policy uncertainty by including solar lantern energy into the national electrification strategy plan to speed up the transition from polluting kerosene to full solar lantern electrification. The country should also put a mechanism in place to mobilise funds in cooperation with banks and other financial institutions. At the same time, there should be the facilitation of the import of solar lantern products – tariffs and VAT barriers should be removed on all solar lantern products entering the country. Once solar lanterns are adopted in the country, there should be subsidy reviews for diesel and kerosene.

It would be important as well for the country to protect consumers by holding accountable any company which sells fake solar lanterns on the market by adopting a legal provision for households. The country should invest in promoting solar lantern energy and awareness about the health benefits of solar lanterns. This can be done by educating people or even using face-to-face education about or promotion of the new technology. The country should invest in training a qualified workforce in the solar lantern sector. This can be done by collaborating with universities, local businesses, private institutions and trade associations, even collaborating with international institutions for knowledge transfer. By implementing the proposed solutions above, the country should eradicate energy poverty and the rural population could have access to clean and affordable electricity.

Chapter 10

Conclusions and Recommendations

10.1 Introduction

Chapter 10 concludes this thesis by reflecting on its relevant findings, recommendations and further research. The research carried out here studied the socio-economic and technical barriers to adopting solar lanterns as an interim option for providing electricity in urban and rural areas in Cameroon.

Addressing these questions, the thesis has adopted a triangular framework analysis that was both quantitative and qualitative. An extensive literature review on renewable energy was carried out to understand the socio-economic situation in Cameroon, followed by a methodological approach with a survey questionnaire in Ebebda. Finally, the country's energy situations, electricity demand, supply and reports were reviewed.

Nowadays, developing countries still suffer economically, socially and health-wise from a lack of electrical lighting. For countries such as Cameroon, this represents 37% of the population without access to electricity (see chapter 2). This research has identified potential socio-economic and technical barriers to adopting solar lanterns in Cameroon; in particular, it has assessed the health, economic and environmental problems suffered by communities as a result of relying on polluting kerosene lamps and candles for lighting.

Examples from other countries such as Malawi, Uganda, Senegal and Kenya and their solar lantern experiences have been considered in this thesis. The study looked at the benefits of adopting solar lanterns as an interim measure in Cameroon's rural community. In the course of this research, the wider national barriers and measures that require unlocking to allow effective introduction of solar lanterns in the country have been reviewed, by proposing potential solutions and reviewing examples taken from countries that have enjoyed successful adoption and take-up of solar lanterns. It should be noted that adoption options for these potential solutions have been suggested, which the Cameroonian government could apply in its national energy strategies plan to help the rural population in the country to gain access to clean and affordable energy. This thesis has also looked at the energy profile load in Cameroon's urban area, Ebebda, the study site, to determine a typical household's energy consumption.

10.2 Key Findings from this Study

This research reveals that in Cameroon, very little is being done to eliminate the dangers of polluting kerosene lamps, and this has informed the need for first-hand research on this form of lighting and the feasibility of adopting solar lanterns as an interim alternative to unlock solar lantern barriers in the country.

Solar lanterns could be a good interim platform for renewable energy, and are affordable for the rural population in Cameroon. The result of the research shows that replacing kerosene lamps with solar lanterns could significantly reduce households' indoor air pollution that causes health problems for the urban and rural populations in Cameroon. According to this research, households using solar lanterns for lighting save US$60 a year for their families. The lanterns have a lifespan of 3 years and a payback period of 2 to 6 months. It should also be highlighted that beyond the financial saving, solar lanterns are reliable, easy to handle and deliver extra lighting hours. As this study reveals, solar lanterns typically produce 5 hours per day of lighting, while kerosene lamps typically provide 3.8 hours per day. This is a big rise for rural households.

The study also shows strong evidence of the solar lanterns' advantages in terms of safety. The lighting system can keep rural populations safe by reducing burns and fires.There is clear evidence that when children have access to a good lighting system (solar lanterns), their study time at night increases so they can study for longer. The result of this study also reveals that adopting solar lanterns in Cameroon could create income opportunities and job creation by extending productive business time beyond the normal hours. The final important finding in this thesis is the positive impact of solar lanterns on communication. This thesis has shown that because solar lanterns provide not only lighting but also charging facilities, they can improve access to information for rural people, as they enable these people to listen to radios and charge their mobile phones to communicate with their relatives. The potential option of utilising mobile payments can enhance business.

According to this study, a family of six went from using 114 litres of kerosene per year to 12 litres per year after adopting a solar lantern. The study reveals that 114 litres of kerosene emit ≈244.43 kg of CO_2 per year and this represents a significant amount of carbon dioxide for rural households. This reduces their carbon impact as well as the negative effect of other pollutants, such as PM10 and PM2.5 on their health. According to this thesis, during the survey at the study site, questions were asked about the effects of health problems from indoor air pollution. Out of 54 respondents, 34 said they have problems with health, 6 with fire, 9 with dirt and 5 with smell. These figures are enormous and show that this pollution damages rural people's health, especially that of children and women as they suffer the most. During the study, questions were asked about their knowledge of indoor air pollution. Out of the 54 respondents, 36 of the respondents said they do not have any idea and 18 have some idea. This results-difference shows the naivety of rural people about the danger of indoor air pollution in Cameroon. Consequently, respondents were also asked about their acceptance of innovative lighting. Out of the 54 respondents, 35 would accept the innovation, 11 said no and 8 said they did not know; this shows that people in Cameroon appear ready to accept the adoption and use of solar lanterns.

The key finding in this thesis on barriers concerns finances. The results of this study have shown that for any new technology (solar lanterns) to be adopted in Cameroon, barriers need to be unlocked. It should be noted that the cost of new technology should be associated with the development of the innovation. In the past few years, solar lantern-based electricity has emerged in the world as an alternative energy to grid connection, kerosene lamps, candles, biomass fuel etc. As this thesis reveals, access to finances to carry out solar lantern projects in Cameroon for households is very limited, because the banks in the country are not used to lending funds to businesses for these types of projects. As this study reveals, now is an opportune moment for the government, private sector and stakeholders to work together to mobilise funds to provide clean and affordable energy to the rural population in the country.

Another finding in this thesis concerns technological barriers. The study reveals that, for these barriers to be unlocked, the country should develop a building capacity and invest in off-grid solar research in collaboration with universities or other research institutions. The study also reveals that the country should consider designing a training programme to train the local population so that they can understand solar lantern technology and also use it in an appropriate manner in the future. It should be highlighted that knowledge transfer in the off-grid sector could also be beneficial for the country, as this will engage the economy and the local population. On the other hand, the study reveals that the government should consider involving local people in any solar lantern project in the country, so that the technology can be easily accepted and adopted by local populations. Social barriers can hence be quickly unlocked.

Institutional barriers are another key finding in this thesis. The study reveals that to unlock these barriers, the country should have better energy policies and regulations in place to address decentralised generation. The Cameroon Ministry of Energy and Water should work in collaboration with other stakeholders and various agencies in the country which are involved in all sides of the energy sector, so that institutional barriers affecting the off-grid sector can be removed. The study also reveals that for any successful solar lantern adoption, the country should organise consultations with civil society and private sector agencies. A national energy development strategic plan should allow the adoption of the proposed solutions. It should be noted that for this plan to succeed, everyone should be engaged in the off-grid sector. Institutional action involving solar energy legislation and policy decisions should not only be political. It should also consider other socio-cultural factors so that all entities can engage in such projects. The study reveals that the government of Cameroon should put in place a clear renewable energy policy and consult with the informal sector, energy experts, private sector, civil society and academics.

Other important findings in this thesis concern socio-economic and behavioural barriers. The study reveals that behavioural barriers are linked with the socio-cultural make-up of Cameroon’s population. Rural people’s preference for particular types of energy sources could influence the decision of adoption or non-adoption of solar lanterns. In a multicultural country with different local dialects, some people refuse to adopt innovation of technology because of their beliefs. The research also reveals that household size can explain adoption or non-adoption of the solar lantern. The key findings are that the number of people living in the household can determine if a family is able to adopt solar lanterns. This research has found that most families that adopt solar lanterns are families with one to six family members in the household, while the larger families of seven to twelve people refuse adoption. It is suggested that this is because bigger families need more of the basics such as food, so this will be prioritised by the family due to lower income per head.

Another most important finding on barriers is the shortage of technical skills and the lack of trained solar lantern technicians/engineers. This plays an important role in adoption or non-adoption of solar lanterns. The absence of qualified technicians and the non-existence of solar lanterns mean that knowledge is a major problem for the country. The survey disclosed that most respondents said they could not use or accept innovation because of a lack of technical knowledge of a new technology or the absence of trained technicians.

Political barriers are another factor preventing solar lantern adoption or non-adoption in the country. Politicians always put their interests first when it comes to renewable energy decisions. It should be highlighted that Cameroonian politicians, government officials, energy experts and people interested in the renewable energy sector need to address the country's forthcoming opportunities in the rapidly evolving solar distributed energy in the country, so that rural populations can benefit from this clean and affordable energy option.

10.3 Recommendations

Based on the findings of this research work, the following recommendations are suggested to the Cameroonian government, renewable energy experts and interested persons.

10.3.1 Good Organisational Framework on Energy Policy and Strategy

Cameroon should structure a ministry around managing distributed energy for both electricity and cooking, possibly introducing solar lanterns as the initial step towards a fully developed strategy plan for the country. Introducing solar lanterns and energy for cooking will reduce pressure on biomass fuel, and improve health and indoor air pollution for households in rural and urban areas in Cameroon

10.3.2 Training and Building Capacity

Training and technical skills are very important in off-grid promotion. At the same time there is a need for an awareness campaign to promote off-grid technology; this could be done by the media, trade fairs, advertising and demonstrations. All of this needs to target socio-cultural issues regarding certain communities and backgrounds. The best way to promote off-grid power is by targeting social groups. Off-grid experts could be hired to organise workshops and seminars so as to educate people, especially in rural areas. TV adverts or serials could also be used. An appropriate marketing strategy should be developed to attract customers. The country should create institutions for solar lantern technician training and for business skills. This will help and motivate customers to buy good solar lanterns, so that if any problems arise they will have help.

10.3.3 Raising Awareness

Raising awareness in people, especially women and children, through information and marketing campaigns is imperative. Educating communities and raising awareness about the availability of resources and the use of solar lanterns for the improvement of their health, education and environment are also important. As Cameroon is a multicultural country, massive support from traditional leadership and village development committees would be essential so as to enhance the acceptance of these innovations and new technologies in rural areas.

10.3.4 Promoting the Use of Efficient Techniques and Marketing Strategies

Off-grid projects should be encouraged by the government of Cameroon and the private sector. Such projects could be subsidised or credit facilities could be made available with low interest rates and long periods of repayment. The country should use strategies to attract foreign investors into the country and find out how to mobilise funds for a major project in the off-grid sector.

10.3.5 Networking with Other Partners

Cameroon should participate in off-grid activities at an international level. Being a member of leading organisations and a signatory to several treaties can help the country set standards. Besides, this would increase the country's exposure to foreign aid through subsidies or project execution. Practical Action has many off-grid projects in the eastern and southern parts of Africa.

These projects have, no doubt, reduced the levels of deforestation and indoor air pollution and have helped rural people to have access to electricity in rural areas, thereby reducing health risks. Meanwhile, Shell Foundation, SolarAid and GOGLA are also engaged in renewable energy programmes in Asia (India and Nepal), Africa and South America. If the responsible government department could approach such organisations, for instance during governmental consultations, and negotiate for assistance in this area, it would be helpful. This would show that the government of Cameroon has understood the importance of such activities and is willing to make an effort to improve the situation of its people.

10.4 Future Research

- The information presented in this research could form a platform for deeper research into governmental policy and strategies around renewables.
- In Cameroon, studies are needed to unlock solar PV barriers in the country.

- More studies are needed on how to integrate rural development policies with programmes in energy, health, education, agriculture etc.
- Further research into subsidy capture is needed for Sub-Saharan African countries.
- Future studies of the Cameroonian energy sector should include all forms of energy generation.
- More study is needed on how Cameroon can look towards long-term solar energy evolution.
- Extensive energy needs assessment studies are required across all of the rural and urban areas of Cameroon.
- A major review is needed of potential funding from international donors on solar lanterns as an interim step for the adoption of off-grid in Cameroon.

This thesis, through the aforementioned submissions, hopes to reach out to the many who are yearning to learn about solar lanterns. It lays the foundation for a good start for providing electricity to rural poor people in Cameroon by adopting solar lanterns. However, much remains undone, as the fact that technology keeps advancing and Cameroon is rich in natural resources does not point towards the successful adoption of solar lantern technology. Adopting solar lanterns in rural Cameroon is contingent on many different issues that include socio-economic/socio-cultural factors, technical barriers and the behaviour arrangements behind the uptake of solar lanterns. There is a need for further research in this area, along with proper implementation efforts. Furthermore, a general international agreement on solar lanterns should be put in place so as to minimise the already-existing conflicts in solar lantern monitoring results. This way, research is made easier and technology integration/adoption becomes less of a problem.

References

- Abdullahi, D. and Oloke, D. (2014). Key Barriers to the Implementation of Solar Energy in Nigeria: A Critical Analysis. London .Geo Books 24, (1) 73–89.
- Ayalon A., Bar-Matthews M. and Schilman B. (2014). 'Rainfall Isotope Characteristics at Various Sites in Israel and the Relationships with Unsaturated Zone Water.' Israel Geological Survey Report GSI, 14-15.
- Ayanji, Y. (2016). 'A critical assessment of the natural disaster risk management framework in Cameroon.'Yaounde, Messa Presse.
- Barnes, D. (2014). Financing Decentralised Renewable Energy: New Approaches. Energy Issues, World Bank. 15, 1–8.
- Bekele, G. (2014). Feasibility study of small hydro/PV/wind hybrid system for off-grid rural electrification in Ethiopia. Zambia, Probian. 97, 5–15.
- Belda, J. (2014). Photovoltaic Technology and Rural Electrification in Developing Countries: the Socio-economic Dimension. Ghana, Chronicle.
- Bijker, W. E. (2016). 'Sociohistorical technology studies' in Jasanoff, S. et al., (eds) Handbook of Science and Technology Studies. London: Sage Publications.
- Black, R. R., Meyer, C. P., Touati, A., Gullett, B. K., Fiedler, H. and Mueller, J. F. (2016). 'Emissions of PCDD and PCDF from combustion of forest fuels and sugarcane: A comparison between field measurements and simulations in laboratory burn facility.' Chemosphere. 83, 1331–38.
- Brown, L. (2015). Innovation diffusion: a new perspective. New York: Methuen.
- Bruce, N. G., Rehfuess, E. A. and Smith K. R. (2018). 'Household energy solution in developing countries.' In: Nriagu, J. O. (ed.) Encyclopedia of Environmental Health. 3, 62–75.
- Bruce, N., Perez, R. and Albalak, R. (2016). Indoor air pollution in developing countries. A major environmental and public health challenge. Bulletin of the World Health Organisation. 78 (9) 1078–92.
- Clark, G. (2013). Innovation, diffusion: contemporary geographical approaches. Norwich: Geo Books.
- Coleman, J., Shen, B. and Wallace, W. (2014). 'The economics of sustainable energy for rural development: a case study of renewable energy in rural China.' Energy Policy. 26 (1) 45–54.
- Dasgupta, S., Huq, M., Khaliquzzaman, M., Pandey, K. and Wheeler, D. (2016). 'Indoor air quality for poor families: New evidence from Bangladesh.' Indoor Air. 16 (6) 426–44.

- De Koning, K. Filatova., T. and Bin, O. (2014). 'Energy policies for sustainable development in developing countries.' Energy Policy. 22 (1) 29–36.
- Duke, R. D., Jacobson, A. and Kammen, D. M. (2015). 'Photovoltaic module quality in the Kenyan solar home systems market.' Energy Policy. 30 (6) 477–99.
- Enongene, K. E. Murray, P., Holland, J. and Abanda, F. H. (2017). 'Energy savings and economic benefits of transition towards efficient lighting in residential buildings in Cameroon.' Renewable and Sustainable Energy Reviews, Elsevier. 78 (C) 731–42.
- Entsua-Mensah, C. (2016). 'Towards Effective Institutional Networking for Renewable Energy Research and Development (R&D) Activities in Ghana: Some Issues for Consideration.' Journal of Energy Research and Technology. vol. 6 (Special Issue: Proceedings of the National Energy Symposium), 226–31.
- Ezzati, M. and Kammen, D. (2011). 'Quantifying the effects of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries.' Environ Health Prospect. 109: 481–88.
- Follansbee. T. (2016). Energy Prices, Energy Efficiency and Fuel Poverty. World Bank mimeo.
- Food and Agricultural Organisation of the United Nations, (FAO) (2014). 'Responding to agricultural and food insecurity challenges mobilising Africa to implement NEPAD Programmes.' Conference of Ministers of Agriculture of the African Union, Maputo.
- Gao, X., Yu, Q., Gu, Q., Chen, Y., Ding, K., Zhu, J. and Chen, L. (2017). 'Indoor air pollution from solid biomass fuels combustion in rural agricultural area of Tibet, China.' Indoor Air. 19 (3) 198–205.
- Gerhard, O. Falk, A. and Klaus, P. (2014). Economic Issues of Renewable Energy Systems. Cologne.
- GOGLA. (2015). Accelerating access to electricity in Africa with off-grid solar. Country Briefing Report.
- Gordon, D. and Spicker, P. (eds). (2015). The international glossary on poverty. London . Zed Books.
- Hagerstrand, T. (2013). Innovation diffusion as a spatial process. Chicago: University of Chicago Press.
- Howard, J. A. (2011). The Theory of Buyer Behaviour. New York: John Wiley.
- International Atomic Energy Agency (IAEA) (2017). Energy and Environment Data Reference Bank (EEDRB). Republic of Kenya.
- International Energy Agency (IEA). (2014). Energy Statistics and Balances of Non-OECD Countries, Paris.

- International Energy Agency (IEA). (2015). Energy and Poverty, chapter 13. Paris, France.
- Jackson, T. and Oliver, M. (2014). ‘The viability of solar photovoltaics.’ Energy Policy. 28 (14) 983–88.
- Jacobson, A. (2013). ‘Solar Electrification and Social Change in Kenya.’ World Development. 35 (1) 144–62.
- Jessica, A. and Sohir, C. (2014). Measuring ambient particulate matter in three cities in Cameroon, London. Geo Books.
- Kana, J. D., Djongyang, N., Raïdandi, D., and Ramadhan, B. T. (2017). ‘Appraisal of geothermal resources and use in Cameroon.’ African Journal of Science, Technology, Innovation and Development. 9 (6) 661–67.
- Kanagawa, M. and Nakata, G. (2016). ‘Rural Energy in Developing Countries: A Challenge for Economic Development.’ Annual Review of Energy and Environment. 21, 497–530.
- Kane, M. and Sand, T. (2011). Renewable Energy Technologies in Africa. London: Zed Books.
- Karekezi, S. and Ranja, T. (2014). Renewable Energy Technology in Africa. African Energy Policy Research Network, Stockholm, Sweden. p. 18.
- Katz, B. (2014). Cameroon Energy and Mining. Ebizguides, Cameroon, p. 116.
- Khandker, S., Barnes, F. and Samad, H. (2012). ‘The Welfare Impacts of Rural Electrification in Bangladesh. International Association for Energy Economics.’ The Energy Journal, 33.
- Kirubi, B. and Mabugu, R. (2015). ‘The energy transition in action: urban domestic fuel choices in a changing Zimbabwe.’ Energy Policy, 31(6) 553–62.
- Kuznets, S. (2013). ‘Economic growth and income equality.’ American Economic Review. 45, pp 12-13.
- Lam, N., Smith, K., Gautier, A. and Bates, M. (2012). ‘Kerosene: A Review of Household Uses and their Hazards in Low and Middle Income Countries.’ Journal of Toxicology and Environmental Health. Part B, 15 (6) 396–432.
- Liu, Y. and Barabbas, A. (2013). ‘Controllability of complex networks.’ Nature. 473, 167–73.
- Mas’ud, A. A., Wirba, A. V., Ardila-Rey, J. A., Albarracín, R., Muhammad-Sukki, F., Jaramillo Duque, Á., and Munir, A. B. (2017). ‘Wind Power Potentials in Cameroon and Nigeria: Lessons from South Africa.’ Energies. 10 (4) 443.

- Massey, D., Kulshrestha, A., Masih, J. and Taneja, A. (2016). 'Seasonal trends of PM10, PM2.5 and PM5.0 in indoor and outdoor environments of residential homes located in North-Central India.' Building and Environment. 47, 223–31.

- Mbewe, A. (2015). 'Rural Electrification in Zambia.' In: Ranganathan, V. (ed.) Rural Electrification in Africa. London: Zed Books Ltd.

- McGranahan, G. and Murray, F. (eds) (2016). 'Air Pollution and Health in Rapidly Developing Countries.' Earthscan. London.

- Ministry of Finance (MIFI) (2016). Economic Recovery Strategy for Wealth and Employment Creation. Yaoundé.

- Ministry of Territorial Administration, (MINAT) (2015). Census document of general population in Cameroon.

- Ministry of Trade (MINCOMMERCE) (2016). Building on Progress Development to End Poverty. Vol. 1, 2015, Yaoundé.
- Ministry of Water and Energy (MINEE) (2016). Cameroon Electricity general document.

- Molua, E. and Laqmbi, CM (2016). 'Assessing the impact of climate on crop water use and crop water productivity: The CROPWAT analysis of three districts in Cameroon.' CEEPA Discussion Paper No. 33, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

- Muindi, K., Kimani-Murage, E., Egondi, T., Rocklov, J., and Ng, N. (2016). 'Household air pollution: sources and exposure levels to fine particulate matter in Nairobi slums.' Toxics. 4 (3) 12.

- Myrdal, G. (2013). An inquiry into the poverty of nations. New York: Pantheon Books.

- Nweke, O. and Sanders, W. H. (2018). 'Modern environmental health hazards: A public health issue of increasing significance in Africa.' Environmental Health Perspectives. 117 (6) 863–70.

- Ogburn, W. (2013). On Cultural and Social Change: Selected Papers, Chicago: University of Chicago Press.

- Otieno, O. and Awange, L. (2012). Energy Resources in East Africa: Opportunities and Challenges. Netherlands: Springer.

- Painuly, J. and Fenhann, P. (2016). 'Barriers to Renewable Energy Penetration: Framework for Analysis.' UNEP Collaborating Centre for Energy and Environment, National Laboratory, Roskilde. Renewable Energy. 24 (2001)73–89.

- Peh, K. S. H., and Drori, O. (2013). 'Fighting corruption to save the environment: Cameroon's experience.' Ambio. 39 (4) 336–39.

- Pinch, J. and Bijker, E. (2016). ‘The Social Construction of Facts and Artefacts, or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other.’ In: Bikjer, W. E. Thomas, P. H. and Pinch, J. T. (eds.) The Social Constructions of Technological Systems: New Directions in the Sociology and History of Technology. Cambridge: MIT Press.

- Pokhrel, A. M., Bates, M. N., Verma, S. C., Joshi, H. S., Sreeramareddy, C. T. and Smith, K. R. (2015). ‘Tuberculosis and indoor biomass and kerosene use in Nepal case-control study.’ Environmental Health Perspectives. 118 (4) 558–64.

- RECIPES. (2016). Renewable Energy Potential Country Report Cameroon. ,Yaounde press.PP 5–13.

- Rogers, E. M. (2014). Diffusion of innovations (4th edition). New York: The Free Press.

- Sksena, S. and Smith, K. R. (2015). ‘The quiet (energy) revolution: analysing the dissemination of photovoltaic power systems in Kenya.’ *Energy Policy*. 24 (1) 81–111.

- Smith, K. (2015). Biofuels, Air Pollution and Health: A global review. New York: Plenum Press.

- Smith, K. and Schwela, R. (2014). ‘Indoor Air Pollution in Developing Countries.’ Annual Review of Energy and Environment. 18, 529–66.

- SolarAid. (2016). Facts about Kerosene.

- Stolyhwo, A. and Sikorshi, Z. E. (2015). ‘Polycyclic aromatic hydrocarbons in smoked fish – a critical review.’ Food Chemistry. 91(2) 302–11.

- Strang, D. and Soule, S. (2013). ‘Diffusion in Organizations and Social Movements: From Hybrid Corns to Poison Pills.’ Annual Review of Sociology. 24, 265–90.

- Sue, R., Manuel, F. and Stephanie, T. (2003). Ecohouse 2: A Design Guide. London. Routledge.

- Surry, D. (2015). Diffusion Theory and Instructional Technology. Paper Presented at International Conference of the Association for Educational Communications and Technology. Albuquerque, New Mexico.

- Tetchiada, S. (2015) ‘bringing solar home systems to rural El Salvador: lessons for small NGOs.’ Energy Policy. 34 (6) 721–29.

- Tiber, A., Gustavsson, S. and Ellegard, A. (2013). The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Services Company in Zambia. Renewable Energy. 29, 1059–72.

- Tingem M., Rivington M., Bellocchi G., Azam-Ali S., Colls J. (2014) Effects of climate change on crop production in Cameroon, Climate Res. 36, 65–77.

- UNEP – Patricia De Mowbray (2013) National Energy Action Plan for Poverty Reduction. UNDP, World Bank, 24–55.
- United Nations General Assembly Special Session (UNGASS). (2016) Five Years Following the Barbados Conference on the Transfer of Environmentally Sound Technology. New York: United Nations.
- United Nations, (2014). Energy for a Sustainable Future. New York: United Nations.
- Wamukonya, N. and Davis, M. (2013). 'Socio-economic impacts of rural electrification in Namibia: comparisons between grid, solar and unelectrified households.' Energy for Sustainable Development.
- Wearras, O. and Gro, H. (2014). The Socio-Economic impact of Renewable Energy Projects in Southern African Countries. European Commission Joint Research Centre
- Wijayatunga, P. and Attalage, R. (2016). 'Socio-economic impact of solar home systems in rural Sri Lanka.' Energy for Sustainable Development. 9.
- Wilkins, G. (2011). 'Technology Transfer for Renewable Energy: Overcoming Barriers in Developing Countries.' Royal Institute of International Affairs. United Kingdom.
- Wirba, A. V., Mas'ud, A. A., Muhammad-Sukki, F., Ahmad, S., Tahar, R. M., Rahim, R. A., and Karim, M. E. (2015). 'Renewable energy potentials in Cameroon: Prospects and challenges.' *Renewable Energy*. 76, 560–65.
- World Bank (2014). World Development Report 2014. 'Development and the Environment.' Oxford: Oxford University Press.
- World Bank (2016). Rural Energy programme 'Progress Toward Sustainable Energy' series. Washington DC.
- World Bank (2018). 'Household cookstoves, environment, health and climate change: A new look at an old problem.' Washington, DC: International Bank for Reconstruction and Development/ World Bank.
- World Energy Council (2015). Regional Energy Integration Report in Africa.
- World Energy Outlook (2016). Energy and Poverty, chapter 13. International Energy Agency. Paris.
- World Health Organisation (2012). Fuel for life: Household Energy and Health. World Health Organisation, Geneva.
- World Health Organisation (2016). Health and Environment in Sustainable Development, five years after the Earth Summit. World Health Organisation, Geneva.
- World Health Organisation (2018). Indoor Air Pollution from Biomass Fuel. World WHO/PEP/92–3 A. World Health Organisation, Geneva.

- Yaron, S. and Kithyoma, W. (2015). 'Renewable energy strategies for rural Africa: Is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of Sub-Saharan Africa?' Energy Policy. 30 (11–12) 1071–86.

- Yeh, E. (2014). 'Indoor air pollution in developing countries: Household use of traditional biomass fuels and the impact on mortality.' University press, Berkeley. p. 6.

Internet Sources

- African Economic Outlook (AEO) (2015). Ghana. Available online at: http://www.oecd.org/countries/ghana/32429910.pdf. Accessed 09/04/2016.

- Amissah, A. and Amonoo, J. (2014). 'Study of the Social and Poverty Impacts of Energy Interventions on Rural Communities in Ghana.' Final Report Study performed under the auspices of the Climate Technology Initiative (CTI) and sponsored by Natural Resources Canada (NRCan).
  at http://www.worldenergyoutlook.org/electricity.asp. Accessed 29/08/2018.

- Center for Appropriate Technology – CAT Cameroon (2013). Partnership for Clean Indoor Air. Available online at: http://www.pciaonline.org/partnerdetails.cfm?id=207 Accessed 12/06/2016.

- Dhanyasree, A. (2016). World best chefs. Available at:

  http://living.oneindia.in/men/best chefs.html. Accessed 24/09/2015

- Edjekumhene, I. Atakora, S. B., Atta-Konadu, R. and Bre-Hammond, A. (2013). Implementation of Renewable Energy Technologies. Opportunities and Barriers, Ghana country case. UNEP Collaborating Centre on Energy and Environment, Denmark. Available at: http://www.uneprisoe.org/RETs/GhanaCountryStudy.pdf Accessed 03/11/2014.

- Electricity of Cameroon (ENEO). (2016). Annual Report of Cameroon Electricity Sector. Available at :https://eneocameroon.cm/index.php/en/l-entreprise-a-propos-d-eneo-l-entreprise-en/l-entreprise-a-propos-d-eneo-en. Accessed 18/05/2015.

- FAO: Financing access for the poor. (2018). Available at: http://www.worldenergyoutlook.org/media/weowebsite/2018/weo2018_energy_for_all.pdf Accessed 04/09/2018.

- GTZ (2013). Programme for Basic Energy and Conservation (ProBEC) in Malawi. Available online at: http://www.hedon.info/goto.php/820/news.htm. Accessed 20/09/2016.

- Hanking, M. (2016). 'Choosing Financing Mechanisms for Developing PV Markets: Experiences from Several African Countries.' In: Krause, M. and Nordstrom, S.(eds). Solar Photovoltaics in Africa: Experiences with Financing and Delivery Models. United Nations Development Programme (UNDP) New York. Available online at: http://www.undp.org/gef/undpgef_publications/publications/solarphotovoltaics_africa

.pdf. Accessed 11/07/2016.http://living.oneindia.in/men/best_chefs.html. Accessed 24/09/2015.

- IEA World Energy Outlook (2018). The electricity access database. Available at: http://www.projectsurya.org/storage/worldbank-developmentreport-surya-12-2009.pdf. Accessed 26/09/2018.

- IERN, (2014). Country statistics Cameroon. Available online at: http://www.iern.net/portal/page/portal/IERN_HOME/IERN_ARCHIV/Country_Factsheets/Country%20Factsheet?pId=3062009andpPath1=AfricaandpPath2=Cameroon. Accessed 20/11/2014.

- International Atomic Energy Agency (IAEA) (2014). Energy and Environment Data Reference Bank (EEDRB): Republic of Zimbabwe. Available online at: http://www.iaea.org/inisnkm/nkm/aws/eedrb/data/ZWelp.html. Accessed 20/03/2016.

- Lighting Africa (2014). Off-grid Power and Connectivity: Pay-as you-go Financing and Digital Supply Chains for Pico-Solar. Market Research Report. Available online at:https://www.lightingglobal.org/wp-content/uploads/2015/05/Off_Grid_Power_and_Connectivity_PAYG_May_2015.pdf. Accessed 07/09/2015.

- Lighting Africa (2018). Energy for cooking in developing countries. Available at: http://www.worldenergyoutlook.org/docs/weo2018/cooking.pdf. Accessed 03/09/2018.

- National Aeronautics and Space Administration (NASA) (2016). Clean Energy Project Analysis 'RETScreen Engineering and Cases Textbook', 3rd edition. Ministry of Natural Resources Canada. Available online at: http://www.retscreen.net/ang/12.php. Accessed 04/07/2015.

- National Hydrocarbons Corporation (SNH) (2018). Annual Report online at: http://www.snh.cm/index.php/en/hydrocarbons-in-cameroon/key-data Accessed 15/08/2018

- Ngalame, E. N. (2015). How Cameroon is boosting renewable energy. Retrieved from: https://www.weforum.org/agenda/2015/05/how-cameroon-is-boosting-renewable-energy/. Accessed 22/07/2018.

- RETScreen, (2015). Clean Energy Project Analysis, 'RETScreen Engineering and Cases Textbook.' 3rd edition, Minister of Natural Resources, Canada. Available online at: http://www.retscreen.net/ang/12.php. Accessed 04/07/2015.

- Smoke and Health Project (2016). Available online at: http://www.practicalaction.org/smoke_and_health. Accessed 18/11/2016.

- United Nations International Children's Emergency Fund (UNICEF) (2016) Africa literacy late UNICEF DATA. Available online at https://data.unicef.org/topic/education/literacy/ Accessed 20/09/2018

- World Data (2014) Energy consumption in Cameroon: The official Report. Available at https://www.worlddata.info/africa/cameroon/energy-consumption. Accessed 24/10/2018.

- World Factbook (2018). Population, Environment, and Development: The concise report. Available at http://www.un.org/spanish/esa/population/C2001English.pdf Accessed 17/08/2018.

- Yaron, T. and Amomly, F. (2015). Biomass energy use in Malawi. Available online at: http://pubs.iied.org/pdfs/G03075.pdf. Accessed 04/09/2014.

Appendix A Letter of Introduction

Dear Mr Anthony Derrick,

My name is Joseph Levodo and I am a PhD student at London South Bank University, working on Solar PV in developing countries (Cameroon) under the supervision of Prof. Andy Ford and Dr Issa Chaer. I would very much like to have the opportunity to meet with you to explore, amongst other things, the following:

- In your opinion and experience, how can rural people in Africa best move from traditional kerosene lamps to the use of electricity through Solar PV?
- As a company, what engineering solutions have IT Power implemented for rural electrification in Africa? What lessons have been learned from this process?
- Given the evolution of technology both in electrical generation and energy reduction, what, in your opinion, might currently be an optimum solution for electrification utilising solar PV for communities in rural Africa?

I hope your answers and advice will help me to move forward with my thesis and my longer-term aim to guide energy development in Cameroon.

I am happy to travel to meet you or to discuss via Skype if you would find this an easier way to proceed.

Regards,

Joseph Levodo

Appendix B Conversation Letters

Dear Joseph,
Thanks for the information.
Please find attached my signed version – please print, sign, scan and email back.

I'm available this Wednesday at 12 noon if you'd like to come to the office. We're at The Foundry, 17 Oval Way, London, SE11 5RR (nearest tube: Vauxhall (Victoria line) or Oval (Northern line)). When you get to reception, just ask for me.

I look forward to hearing more about your research project and focus, and talking you through all our data and work.

Kat

Hi Joseph,
Here is the link to the DropBox folder for access to the two mega-databases I have put there:

https://www.dropbox.com/sh/1r0sa04omkd5cu8/AACihN8gda3GAWzZPzYLHqJ4a?dl=0

Please note: only you have signed the confidentiality agreement so please don't share this database with anyone for data protection purposes. Please do also keep me updated if you plan to publish any analysis or work on this.

Thank you,

Kat

Appendix C Field Questionnaires

Socio-economic and Environmental Impacts of Kerosene Lamps, used in Cameroon
Improving Indoor Air Pollution in Cameroon

Study area: Ebebda District, Cameroon

Dear Sir/ Madam,

My name is Joseph Levodo. This thesis investigates the socio-economic impact of poor lighting in rural and urban areas in Cameroon by following objectives and aims, and coming up with important recommendations that will benefit all Cameroonians. The author decided to focus on Ebebda as a case study area so that data collection and accessibility can be easy.

The author will be grateful if you could answer the following questions.

Please note that all answers will be treated with full confidentiality and the data is used for academic purposes only.

Contact:

Joseph Levodo

PhD student

School of The Built Environment and Architecture

Email: levodoj@lsbu.ac.uk

Mobile: 07469885627

Please use black ink to fill in the spaces that apply to you.

1 - Demographic

Area of residence		
Gender	Male	Female
Age		
Number of household members		
How many adults and children in the house?		
Profession/occupation		

2 - Use of Kerosene Lamps. Please answer the following.

What source of lighting do you use?	Kerosene							Candle			Other	
How many kerosene lamps do you have?	Number											
How long do you use your kerosene lamp/s at night?	Number of hours											
How much do you spend per month on kerosene?												
How frequently do you buy kerosene per week/month?	Week							Month				
	1	2	3	4	5	6	7		1	2	3	4
How much do you pay for a litre of kerosene?												
How long do you have to walk to find kerosene for your lamp?	Minutes							Hours				

3- Knowledge / Awareness

What is your knowledge about the source of indoor air pollution?

Idea ☐

No idea ☐

Do you know that kerosene lamp smoke is dangerous for your health?

Yes ☐

No ☐

No idea ☐

Do you think that adopting new technology for lighting would improve indoor air pollution?

Yes ☐

No ☐

I don't know ☐

4- Socio-economic Impact

<table>
<tr><td>How often do you read at night?</td><td colspan="10"></td></tr>
<tr><td rowspan="2">What source of light do you use at night?</td><td colspan="4">Kerosene</td><td colspan="6">Candle</td></tr>
<tr><td colspan="4"></td><td colspan="6"></td></tr>
<tr><td rowspan="2">When do your children study?</td><td colspan="2">Night</td><td colspan="2">Day</td><td colspan="6">Both</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td rowspan="3">How are your children's grade with kerosene lamp use?</td><td colspan="10">Ratings</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Do you feel safe using a kerosene lamp?</td><td colspan="4"></td><td colspan="6"></td></tr>
<tr><td colspan="4">Yes</td><td colspan="6">No</td></tr>
<tr><td>Do you consider</td><td colspan="4">Yes</td><td colspan="6">No</td></tr>
</table>

emigrating because of lack of electricity?						
Do you have any health problems associated with the use of kerosene lamps?	Asthma, Bronchitis	Cataract (blindness)	Lung Cancer	Pneu-monia	Tuberculosis	Others, please specify
Do you have a business?	Yes			No		
If yes, do you run it at night?	Yes			No		
What type of lighting do you use for your business?	Kerosene			Candle		
How much do you spend on kerosene?	Week			Month		
Are you happy /ready to accept new technology for lighting?	Yes			No		

5- Environmental Impact

Do you use wood for cooking? Yes ☐

No ☐

Other ☐

Do you see any environmental change in your environment?

Yes ☐

No ☐

Has deforestation increased in your area in the past year?

Yes ☐

No ☐

Do you think there is a big risk in the change in the environment?

Yes ☐

No ☐

6-Socio-cultural Impact

Who take the decision to buy kerosene lamps in the household?	Father		Mother	Both
Who spends most the time in the kitchen?				
How many hours do you spend in the kitchen per day?	3 hours	4 hours	5 hours	6 hours

7- Health Experts / Medical Doctors

Do you consult people about illnesses caused by indoor air pollution? Yes ☐

No ☐

How many people do you consult per month about indoor air pollution problems? _______

What type of illness do you have related to indoor air pollution?

Asthma, Bronchitis	Cataract (blindness)	Lung Cancer	Pneumonia	Tuberculosis	Others, please specify

Is there any campaign for reducing indoor air pollution?

Yes ☐

No ☐

I don't know ☐

If the answer is yes, who is the main campaign organiser?

NGOs ☐

Government ☐

Other, please specify ☐

Thank you – The End

Appendix D Confidentiality Agreement

DATED 24th September 2015

SOLARAID (INCLUDING SUNNYMONEY)

and

JOSEPH LEVODO

CONFIDENTIALITY AGREEMENT

relating to sharing of research data and results for collaborative analysis and learning

---

THIS AGREEMENT is dated 24th September 2015 and made

BETWEEN:

(1) **SolarAid** (the "Disclosing Party") registered in [England and Wales as charity number 1115960 and having its registered office at The Foundry, 17-19 Oval Way, London, SE11 5RR, UK]; and

(2) **Joseph Levodo** (the "Recipient Party"), London South Bank University, 103 Borough Road, London SE1 0AA

Background:

In connection with certain discussions relating to the "Project" (as defined below) the Disclosing Party is prepared to disclose certain confidential information to the Recipient Party on the basis that the Recipient Party will maintain the confidentiality of the information.

THE PARTIES AGREE THAT:

1. **Definitions**

In this Agreement the following expressions shall have the following respective meanings:

"Confidential Information" means:

(a) all information in any form relating to the Disclosing Party or the Project which is provided to the Recipient Party or independently acquired by any of them or any of their respective employees, agents or professional advisers in the course of the Project, whether before or after the date of this Agreement;

(b) all copies of any such information in whatever form; and

(c) all reports, analyses, compilations, forecasts, studies, memoranda and other documents prepared by or on behalf of the Recipient Party which contain, reflect or utilise any of the information previously referred to in this definition

provided that "Confidential Information" shall not include such information which:

(i) is proved to have been known to the Recipient Party before it was so provided to or acquired by the Recipient Party; or

(ii) has been independently acquired by the Recipient Party otherwise from the Disclosing Party without (so far as it is aware) the breach by any person of any obligation of confidentiality; or

(iii) has been specifically co-developed and/or acquired through collaborative research between the Disclosing Party and the Recipient Party.

"Disclosing Party" means SolarAid.

"Project" means sharing of research data and results for collaborative analysis and learning.

"Recipient Party" means Joseph Levodo.

References to either party to this Agreement in each case also include, where the context so requires or permits, their respective subsidiaries and holding companies and all such entities are hereafter referred to as "Group Companies".

2. Recipient Party's obligations

In consideration of the Disclosing Party agreeing to provide to and to permit the Recipient Party to have access to Confidential Information, the Recipient Party represents, undertakes, agrees with and acknowledges to the Disclosing Party in the following terms:

2.1 Confidentiality of Information

All Confidential Information shall be regarded as strictly confidential and shall remain the exclusive property of the Disclosing Party or its Group Companies, and accordingly shall not, without the Disclosing Party's prior specific written approval (which may be withheld in the Disclosing Party's absolute discretion), be disclosed to any person other than other signatories of this Agreement.

2.2 Privilege

Where the Confidential Information is also privileged, the waiver of such privilege is limited to the purposes of this Agreement, and does not and is not intended to result in any wider waiver of the privilege. Accordingly, the Recipient Party shall take all reasonable steps to protect the privilege of the Disclosing Party and its Group Companies in the Confidential Information, and shall advise the Disclosing Party promptly in writing if any step is taken by any other person to obtain any of the privileged Confidential Information.

2.3 Use of Information

None of the Confidential Information shall be used by the Recipient Party for any purpose other than analysis of data in research areas agreed by parties in advance. In addition, publication of articles may be done, only if agreed, in writing, by both parties. The Recipient Party shall not use any of the Confidential Information to procure a commercial advantage over, or in any manner whatsoever which is or is likely to be directly or indirectly detrimental to the business of, the Disclosing Party or any of its Group Companies. The Recipient Party shall be deemed not to have used any Confidential Information in connection with any action taken or decision made by it if the Recipient Party proves that it would have taken that action or made that decision without having access to that part of the Confidential Information.

2.4 Security of information

The Recipient Party will keep the Confidential Information safe in a secure place and properly protected against theft, damage, loss and unauthorised access (including, but not limited to, access by electronic means) and, without prejudice to the foregoing, will take all reasonable steps to keep the same confidential and exercise in relation to the Confidential Information no lesser security measures and degree of care as it applies to its own confidential information and all documents and other material reproducing or incorporating any of the Confidential Information will be kept separate from the Recipient Party's own information. If so required by the Disclosing Party, the Recipient Party will promptly identify the location at which any of the Confidential Information is kept. The Recipient Party shall notify the Disclosing Party immediately upon becoming aware that any of the Confidential Information has been disclosed to or obtained by any other person (otherwise than as permitted by this Agreement).

2.5 **Copies etc.**

The Recipient Party will not take or make any copies, notes or records of the Confidential Information or any of it, or authorise any other person so to do.

2.6 **Duration of confidentiality obligations**

The obligations contained in clauses 2.1 to 2.5 shall, unless and until superseded by any other agreement between the parties, survive the completion of the Project or any transaction arising out of the same or the abandonment of the Project and shall continue without limit of time but if and to the extent that any information forming part of the Confidential Information:

(A) is now or shall hereafter have entered into the public domain (otherwise than as a consequence of a breach of the terms of this Agreement by the Recipient Party); or

(B) was prior to the date hereof in the lawful possession of, or was prior to that date lawfully furnished to the Recipient Party by a third party (as evidenced by the written records of the Recipient Party); or

(C) in the reasonable opinion of the solicitors to the Recipient Party, is the minimum information which is required to be disclosed by law or pursuant to any requirement of any governmental, official or regulatory body not being within clause

then, and to that extent only, the obligation not to disclose shall cease to have effect, provided that in a case within clause 2.6(C) the Recipient Party shall immediately inform the Disclosing Party that such requirement has arisen, and consult with the Disclosing Party about the scope and manner of the disclosure and the Recipient Party shall use all reasonable endeavours to maintain, as far as practicable, the confidentiality of the information disclosed and, in particular, to obtain an order or other reliable assurance that confidential treatment will be accorded to such portion of the disclosed information as the Disclosing Party may reasonably designate.

2.7 **Applications for information and enquiries**

The Recipient Party shall apply for any Confidential Information it requires from, and shall direct all enquiries concerning any Confidential Information supplied to it to, such representatives of the Disclosing Party as the Disclosing Party may hereafter notify to the Recipient Party. The Disclosing Party may withhold any Confidential Information requested by the Recipient Party if it reasonably believes such information is not required for the furtherance of the Project.

2.8 **Return of information**

The Disclosing Party may by written notice to the Recipient Party require the Recipient Party to return the Confidential Information at any time and for any reason, whereupon the Recipient Party will at its own cost and expense forthwith return to the Disclosing Party all the Confidential Information in the possession or power of the Recipient Party insofar as the same shall be in tangible form, including all copies thereof, and the Recipient Party shall at its own cost and expense also, as far as is reasonably practicable, delete or procure the deletion of all Confidential Information from any computer, word processor or other information retrieval system of the Recipient Party but will destroy or similarly delete or procure the destruction or such deletion of any reports, analyses, compilations, forecasts, studies, memoranda and other documents prepared by the Recipient Party which contain, reflect or utilise any of the Confidential Information. This clause 2.8 shall not apply to the extent that the Recipient Party is required to retain any of the Confidential Information by any applicable law, or by any competent judicial, governmental, supervisory or regulatory body or in accordance with its generally adopted internal policy.

2.9 **Rights in the information**

(A) The Recipient Party shall not acquire any intellectual property or other proprietary rights in the Confidential Information, except any that may be under any further agreement relating to the Project.

(B) No liability whatsoever, whether in contract or tort or otherwise and including liability for negligent misstatement, is accepted by the Disclosing Party or any of its Group Companies or any of their respective directors, employees, advisers or agents for the accuracy or completeness of any of the information provided or opinions expressed by or on behalf of any of them or for any errors, omissions or misstatements but nothing herein shall avoid liability for fraud.

(C) Nothing in the Confidential Information constitutes a representation nor in the absence of express contrary agreement will any Confidential Information be warranted in any agreement relating to the Project and the Recipient Party will be required in any such agreement to acknowledge that it has not relied on or been induced to enter into the same by any representation or warranty other than as expressly stated in such agreement.

3. **Other provisions**

3.1 **Status of the Recipient Party**

The Recipient Party confirms to the Disclosing Party that the Recipient Party is acting in relation to the Project as principal and not as agent or broker for any other person.

3.2 **Remedies etc. cumulative**

The rights, powers, privileges and remedies provided for the Disclosing Party in this Agreement are cumulative and are not exclusive of any rights, powers, privileges or remedies provided by law or otherwise and:

(A) no failure to exercise nor any delay in exercising any right, power, privilege or remedy under this Agreement shall impair or operate as a waiver thereof; and

(B) no single or partial exercise of any right, power, privilege or remedy under this Agreement shall prevent any further or other exercise thereof or the exercise of any other right, power, privilege or remedy under this Agreement.

3.3 **Decisions by the Recipient Party**

The Recipient Party acknowledges that it is solely responsible for making its own decisions based on the Confidential Information disclosed to it.

4. **Governing law**

This Agreement, and all matters arising from it (including, without limitation, any dispute relating to the existence, validity or termination of this Agreement or any contractual or non-contractual obligation) shall be governed by and construed in accordance with English law and shall supersede any earlier agreement between the parties as to the confidentiality of information relating to the Project or any part thereof so far as the same shall be inconsistent with the terms of this Agreement. In relation to an legal action or proceedings arising out of or in connection with this Agreement (including any of the matters arising from it before mentioned) ("Proceedings") each of the parties irrevocably submits to the non-exclusive jurisdiction of the English courts and waives any objection to Proceedings in such courts on the grounds of venue or on the ground that Proceedings have been brought in an inappropriate forum. If any provision of this Agreement shall be held to be illegal, void, invalid or unenforceable under the law of any jurisdiction, the legality, validity and enforceability of the remainder of this Agreement in that jurisdiction shall not be affected and the legality, validity and enforceability of the whole of this Agreement in any other jurisdiction shall not be affected. No person who is not a party to this Agreement other than a Group Company of either party shall have any right under the Contracts (Rights of Third Parties) Act 1999 to enforce any term of this Agreement.

5. **Notices**

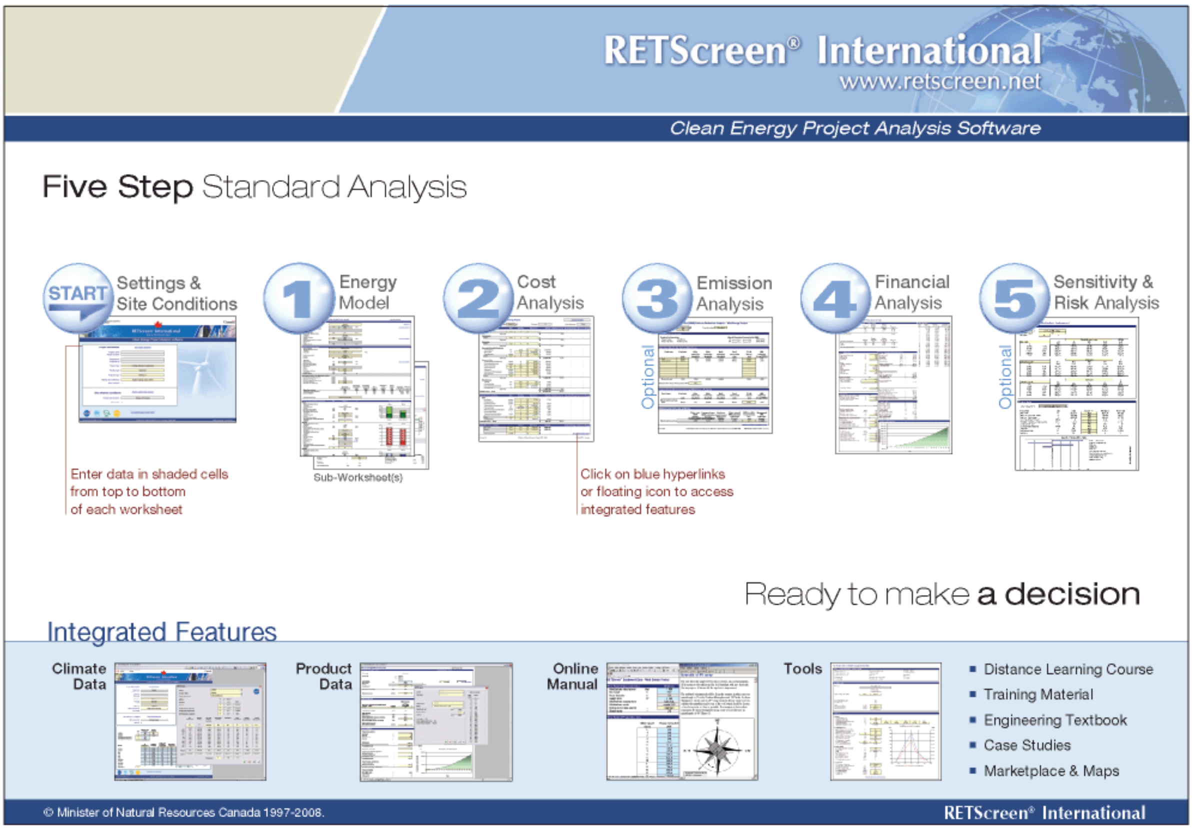
A notice from either party to the other shall be in writing in the English language and shall be sent to the party to be served at its address appearing in this Agreement for the attention of the signatory thereof and may be delivered personally (in which case it shall be deemed to have been given upon delivery at the relevant address) or by first class pre-paid post (in which case it shall be deemed to have been given two business days after the date of posting) or by facsimile (in which case it shall be deemed to have been given when despatched, subject to confirmation of uninterrupted transmission by a transmission report, provided that notice despatched by facsimile after 17.00 hours [at the place at which such fax is to be received] on any day shall be deemed to be received at [09.00] hours on the next following day which is not a Saturday, Sunday or public holiday).

AS WITNESS the hands of the authorised representatives of each of the parties, on the date first before written.

SIGNED on behalf of the Disclosing Party by, Kat Harrison, Director of Research & Impact, an authorised signatory of the Disclosing Party — 28/9/15

SIGNED on behalf of the Recipient Party by, Joseph Levodo — 28/09/15

Appendix E RETScreen



Appendix F Total Respondents of the Survey Participants

This appendix provides the methods used for collecting the historical data. As discussed above, in order to validate the historical data, the survey method was used**.** The data was collected in Ebebda district in Cameroon.

Ebebda District	Male	Female	Total
	23	31	54

Appendix G Cameroon Salary Scale

Index balance	Scale from 01 April 2008	Scale from 01 July 2014
100	43 470	45 644
105	45 644	47 926
110	47 817	50 208
115	49 995	52 495
120	52 164	54 772
140	60 858	63 901
150	65 205	68 465
165	71 726	75 312
180	78 246	82 158
185	80 420	84 441
200	86 940	91 287
205	89 114	93 570
210	91 287	95 851
225	97 808	102 698
235	102 155	107 263
250	108 675	114 109
270	117 369	123 237
280	121 716	127 802
290	126 063	132 366
295	128 237	134 649
300	130 410	136 931
310	132 193	138 803
330	135 758	142 546
335	136 649	143 481
370	142 888	150 032

375	143 779	150 968
405	149 126	156 582
420	151 800	159 390
430	153 583	161 262
445	156 256	164 069
465	159 821	167 812
480	162 495	170 620

Appendix H Baseline Customer Interview

KENYA

1	Name of student/ customer		
2	Type of light bought	Brand:	Type:
3	Date light bought/ date of order and location	Date:	Location (school and region):
4	Phone number		
5	Date of interview		
6	Interview conducted by		

Introduce yourself to the respondent: Hello, my name is [*your name*] and I work for SolarAid. We've received your details as you have just bought a [*name of product*] solar-powered lantern from [*school*]. We would love to ask you a few quick questions to better understand your energy use before the solar lantern. This interview is completely voluntary but if you have the time we very much appreciate you talking to us. Do you have ten minutes free?

7	How many adults and children live in your household?	Adults: Ages:	Children: Ages: *(if 0 children go to Q14)*
8	How many of the children go to school?	*(if 0 for boys and girls go to Q14)*	
9	Before the solar lantern, where did they do their homework/study?		
10	Did they do their homework/study in the evening/at night?	Yes	No (*go to Q14*)

<table>
<tr><td>11</td><td>How did they see to do their homework/study? (i.e. what lighting did they use?)</td><td colspan="7"></td></tr>
<tr><td rowspan="2">12</td><td rowspan="2">Did this affect their study time or motivation?</td><td colspan="3">Yes (positively)</td><td colspan="2">Yes (negatively)</td><td colspan="2">No</td></tr>
<tr><td colspan="7">Explain:
“
”</td></tr>
<tr><td>13</td><td>How many hours homework/study did they do each day? (not including school hours)</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>Don’t know</td></tr>
<tr><td>14</td><td>What is the household main source of income? i.e. farming</td><td colspan="7"></td></tr>
<tr><td>15</td><td>Do you have reliable monthly income or is it variable?</td><td colspan="3">Reliable (go to Q17)</td><td colspan="4">Variable</td></tr>
<tr><td>16</td><td>What times of the year do you have most and least income? (write month)</td><td colspan="3">Most:</td><td colspan="4">Least:</td></tr>
<tr><td>17</td><td>What is the average monthly income for your household? (if variable ask for low and high)</td><td>< 5,000 KSH</td><td>5,000–10,000 KSH</td><td colspan="2">10,000–15,000 KSH</td><td>15,000–20,000 KSH</td><td colspan="2">> 20,000 KSH</td></tr>
<tr><td>18</td><td>Does your home have grid electricity?</td><td colspan="3">Yes</td><td colspan="4">No (go to Q21)</td></tr>
<tr><td>19</td><td>(if have electricity) Is this grid electricity or electricity from another</td><td colspan="3">Grid electricity</td><td colspan="4">Other (go to Q21)</td></tr>
</table>

<table>
<tr><td></td><td>source? i.e. solar/battery</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>20</td><td>(if grid electricity) Do you experience power outages/ blackouts?</td><td colspan="3">Yes How many times does the power go off in one week?</td><td>No</td></tr>
<tr><td>21</td><td>Before the solar lantern, how did you light your home? (main source)</td><td colspan="4"></td></tr>
<tr><td>22</td><td>If kerosene, has your family ever had an accident involving the use of a kerosene lamp?</td><td colspan="3">Yes, please tell us more:
“

”</td><td>No</td></tr>
<tr><td rowspan="2">23</td><td rowspan="2">How many kerosene/paraffin lanterns did you have in your home?</td><td rowspan="2">Had:</td><td colspan="3">Used regularly:</td></tr>
<tr><td>Single-wick:</td><td>Hurricane:</td><td>Pressurised:</td></tr>
<tr><td>24</td><td>How much did you spend on lighting per week, before the solar lantern? (i.e. kerosene, candles, batteries)</td><td colspan="4">(Ok to leave blank if main source is electricity)</td></tr>
<tr><td>25</td><td>How many hours per night did you have lighting on, before the solar lantern?</td><td colspan="4"></td></tr>
</table>

<table>
<tr><td rowspan="3">26</td><td rowspan="3">Do you experience any health issues associated with using kerosene?</td><td colspan="5" rowspan="3">Yes please describe:
“

”</td><td>No</td></tr>
<tr><td>I don’t know</td></tr>
<tr><td>Not applicable (didn’t use)</td></tr>
<tr><td>27</td><td>Did your household have a solar lantern before this purchase?</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>28</td><td>Do you or someone in your household have a mobile phone?</td><td colspan="3">Yes how many are currently working?</td><td colspan="3">No (go to Q31)</td></tr>
<tr><td>29</td><td>How many times do you charge your phone(s) per week, on average?</td><td colspan="6"></td></tr>
<tr><td>30</td><td>How much does it cost to charge it each time?</td><td colspan="6"></td></tr>
<tr><td>31</td><td>Who made the decision to buy the solar lantern?</td><td>Me</td><td>Spouse</td><td>Me and spouse</td><td>Children</td><td>Family (as a whole)</td><td>Other: (write)</td></tr>
<tr><td rowspan="4">32</td><td rowspan="4">Where did the money that you used to buy the solar lantern come from? i.e. personal/household savings, borrowed money or recent income</td><td colspan="6">Ask this as an open question and then tick the appropriate boxes. Tick multiple boxes if more than one source of money was used.</td></tr>
<tr><td colspan="2">Source of income</td><td>Y or N</td><td colspan="3"></td></tr>
<tr><td colspan="2">Personal savings</td><td></td><td colspan="3"></td></tr>
<tr><td colspan="2">Family/household member savings</td><td></td><td colspan="3">If Y, write family member(s):</td></tr>
</table>

		Borrowed money		*If Y, write who borrowed from:*
		Recent income		*If Y, write source e.g. harvest, work:*
		Other		*If Y, write source:*
33	Did you know about these small solar lights before the campaign at your school?	Yes		No
34	How many people do you know who had small solar lights before you bought one?			
35	Do you feel the price of the lantern was expensive, reasonable or cheap?	Expensive	Reasonable	Cheap
36	Name of person spoken to and relation to student	Name:		Relation:
37	Do you mind if we use your name when making marketing materials?	Yes, you may use		No, please do not use
38	Gender of respondent	Male		Female

Thank you for your time.

Follow up customer phone interview (post-baseline)

Note: only use this interview sheet if the customer was interviewed for baseline.

1	Name of student/customer	
2	Date of interview	
3	Interview conducted by	

Introduce yourself to the respondent: Hello, my name is [your name] and I work for SolarAid. We have your details as you bought a [name of product] solar-powered lantern from [name of school] in [month and year]. We would love to ask you a few quick questions to find out about how you use this lantern. This interview is completely voluntary but if you have the time we very much appreciate you talking to us. Do you have ten minutes to talk to me?

4	Is the solar lantern you bought used at home?	Yes		No
5	What is the solar lantern you have bought used for?	" "		
6	Is the solar lantern you bought used for business?	Yes		No *(go to Q10)*
7	What is your business?			
8	Has the solar lantern affected your hours of business? *i.e. times of day and number of hours spent at work*	Yes (more hours)	Yes (fewer hours)	No (same) *(go to Q9)*
		Please explain: " "		
9	Has it affected the	Yes (positively)	Yes (negatively)	No *(go to Q10)*

	way customers interact with your business?	Please explain: " "		
10	Is the solar lantern you bought used for farming?	Yes		No *(go to Q12)*
11	Has the solar lantern affected your farming activity?	Yes (positively)	Yes (negatively)	No *(go to Q12)*
		Please explain: " "		

12	Have you had any problems with the solar lantern?	Yes *(please complete broken solar lantern interview sheet)*			No *(go to Q15)*	
13	On a scale of 1–5, with 5 being very satisfied and 1 being very dissatisfied, how satisfied are you with the lantern? Please explain your rating *(verify*	1	2	3	4	5
		"				

	rating number – see below)	”

1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, 5 = very satisfied

14	In your household, do all or some people use the solar lantern?	All		Some, how many?		
15	What are the top three activities that the solar lantern is used for? *(i.e. cooking, studying etc.)* And who uses it most for each activity? *(i.e. children to study or mother to cook)*	Activity 1:		Person:		
		Activity 2:		Person:		
		Activity 3:		Person:		
16	If you have children in your household, where do they do their homework?					
17	Do they do their homework in the evening/at night?	Yes		No (*go to Q24*)		
18	How do they see to do their homework? *(i.e. main source of lighting?)*					
19	How many hours homework/study do they do each day? *(not including school hours)*	1	2	3	4	5

<table>
<tr><td>2
0</td><td>Do they use the solar lantern for study?</td><td colspan="3">Yes</td><td colspan="2">No (go to Q24)</td></tr>
<tr><td>2
1</td><td>Do they study for longer since using the solar lantern?</td><td colspan="4">Yes why?
“
”</td><td>No</td></tr>
<tr><td rowspan="2">2
2</td><td rowspan="2">How many kerosene/paraffin lanterns do you have in your home?</td><td rowspan="2">Have:</td><td colspan="4">Use regularly (total):</td></tr>
<tr><td>Number single-wick:</td><td colspan="2">Number hurricane:</td><td>Number pressurised:</td></tr>
<tr><td>2
3</td><td>How much do you spend on lighting a week? (i.e. kerosene or candles)</td><td colspan="5">Ok to leave blank if use electricity</td></tr>
<tr><td>2
4</td><td>How many hours a night do you have lighting on?</td><td colspan="5"></td></tr>
<tr><td rowspan="2">2
5</td><td rowspan="2">Have you changed your lighting spending since having the solar lantern? Please explain.</td><td colspan="2">Yes (spend less)</td><td colspan="2">Yes (spend more) (go to Q29)</td><td>No (go to Q29)</td></tr>
<tr><td colspan="5">Please explain:
“
”</td></tr>
<tr><td>2</td><td>What do you spend the savings</td><td colspan="5"></td></tr>
</table>

<table>
<tr><td>6</td><td>on?</td><td colspan="6">“

”</td></tr>
<tr><td rowspan="2">27</td><td rowspan="2">Have you noticed a change in the health of household members since reducing kerosene use? If yes, please explain.</td><td colspan="2">Yes</td><td colspan="2">No (go to Q30)</td><td colspan="2">Don’t know (go to Q30)</td></tr>
<tr><td colspan="6">“

”</td></tr>
<tr><td>28</td><td>Do you own any other solar products or systems?</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>29</td><td>Are you aware that higher capacity solar products exist? i.e. that charge phones, radios etc.</td><td colspan="2">Yes (already own one)
(go to Q35)</td><td colspan="2">Yes (but don’t own one)</td><td colspan="2">No</td></tr>
<tr><td rowspan="2">30</td><td rowspan="2">Since using your pico-solar lantern, would you be interested in buying a higher capacity solar product or system? (explain what these are if</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td colspan="6">Please explain:
“</td></tr>
</table>

<table>
<tr><td></td><td>the respondent is not aware)</td><td colspan="3">” (if no, skip to Q30)</td></tr>
<tr><td rowspan="2">31</td><td rowspan="2">Has your ability to afford this altered since having the solar lantern you bought from SunnyMoney? Please explain.</td><td>More able to afford</td><td colspan="2">Less able to afford</td></tr>
<tr><td colspan="3">Please explain:
“
”</td></tr>
<tr><td>32</td><td>Do you know where you could buy another solar lantern?</td><td>Yes</td><td colspan="2">No</td></tr>
<tr><td rowspan="9">33</td><td rowspan="9">If you could expand the capabilities of your energy system, what would you like to add first?
Do not read options, just mark all that are mentioned</td><td colspan="2">Have more lights</td><td></td></tr>
<tr><td colspan="2">Have brighter and/or longer-lasting lights</td><td></td></tr>
<tr><td colspan="2">Charge (more) mobile phones</td><td></td></tr>
<tr><td colspan="2">Own and power a radio (or another radio)</td><td></td></tr>
<tr><td colspan="2">Own and power a TV</td><td></td></tr>
<tr><td colspan="2">Own and power a fan</td><td></td></tr>
<tr><td colspan="2">Other, write:</td><td></td></tr>
<tr><td colspan="2">Other, write:</td><td></td></tr>
<tr><td colspan="2">Nothing else needed</td><td></td></tr>
<tr><td>3</td><td>Do you feel the</td><td>Cheap</td><td>Reasonable</td><td>Expensive</td></tr>
</table>

4	price of the lantern was cheap, reasonable or expensive?			
35	What is your name?			Rather not say
		Relation to student:		
36	What is your age?			Rather not say
37	Do you mind if we use your name on materials?	Yes, you may use	No, please do not use	
38	Gender of respondent	Male	Female	

Thank you for your time.