BARRIERS AND PROSPECTS OF SOLAR MINI-GRIDS DEPLOYMENT IN NORTH-KIVU/DRC

MUSONGYA BISIMWA Dieudonné

College of Science and Technology

African Center of Excellence in Energy studies for sustainable development

Masters of Science in Electrical Power Systems Engineering

2022

UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY

AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

Rwanda University

College of Science and Technology

Title: ***BARRIERS AND PROSPECTS OF SOLAR MINI-GRIDS DEPLOYMENT IN NORTH-KIVU/DRC***

By: **MUSONGYA BISIMWA Dieudonné**

221000567

A Dissertation submitted to the African Center of Excellence in Energy studies for sustainable development (ACE-ESD)

In partial fulfillment of the requirement for the degree of MASTERS OF SCIENCE IN ELECTRICAL POWER SYTEMS

Advisor: **MULUGETA GEBREHIWOT (PhD)**

October, 2022

Kigali-Rwanda

DECLARATION

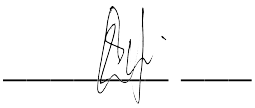
I, the undersigned, declare that this dissertation is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials used in work have been fully acknowledged in the correct academic format.

Names: MUSONGYA BISIMWA Dieudonné

Signature

Date of Submission: 17 .10.2022

This dissertation has been submitted for examination with my approval as a university advisor.



Thesis Advisor

Signature

DEDICATION

I dedicate this thesis

to my wife Katungu Kalemo Vanessa

and

my parents Musongya Wa Mapendo Séraphin & Masika Luthongo Charlotte

ACKNOWLEDGEMENTS

This thesis is a result of intense efforts that my modest person does not can claim to have provided alone. Allow me to express all my gratitude to God Almighty who gave me strength and intelligence to fulfill this work;

I give thanks to my Thesis Advisor MULUGETA GEBREHIWOT (PhD), who agreed to supervise this work, and who spared no time, no energy, and his expertise in imbuing me with the realities of research; all Lectures and Professors of the African Center of Excellence in Energy studies for sustainable development for all the knowledge they have allowed me to acquire;

Finally, big thanks to my wife KATUNGU KALEMO Vanessa for her true love and endless supports; my dear parents MUSONGYA MAPENDO Séraphin and MASIKA LUTHONGO Charlotte for their moral and financial supports and confidence in me; all my brothers and Musongya big family; the family of Dr. Philbert MWATSI for their support in Kigali; everyone who prayed for me.

ABSTRACT

As solar mini-grids and other renewable energy resources are now viewed as the least expensive alternative for electrifying remote areas away from the national grid, there is growing recognition that they will play a crucial contribution to obtaining global access to power.

The main objective of this thesis was to investigate and identify the most potential barriers and prospects to solar mini-grid deployment in North-Kivu/DRC. The specific objectives were to identify barriers and prospects to solar mini-grid deployment in urban and remote areas in the context of North-Kivu/DRC; to assess the prioritisation of these barriers to the deployment of solar mini-grids in North Kivu/DRC; to formulate recommendations on how to deal with those barriers and prospects identified for a better solar mini-grid deployment in North-Kivu/DRC.

A descriptive research design was used in three studies with three target populations respectively of 17 experts from 7 solar enterprises for the first and the second studies and 168 drawn from the customers connected to NURU solar mini – grid within Goma City in order to identify prospects of solar mini grid deployment in the region. Eighteen barriers were identified and validated by combining field research with literature reviews, dimensioned into political and regulatory, economic and financial, technical, socio-cultural, and environmental categories, and finally prioritized using the analytic hierarchy process (AHP) technique. The study on prioritization of barriers in North Kivu revealed that “Ineffective institutional arrangements” is the most important political barrier to the deployment of solar mini-grids; the “Access to finance” is the most significant financial barrier; the most important technical barrier is “Poor maintenance and technical support culture”; the Socio-cultural one is the “Land disputes” etc. This prioritization could help our investor readers to know by what barriers to begin to improve in the energy sector in the DRC in general and in North Kivu in particular. The study on prospects concluded that the use of Nuru's electricity has raised the standard of living of the customers, the services obtained have met the expectations of more than 50% of the subscribers, and the subscribers think that the mini grid is competitive.

The study recommended that the Government should discourage administrative burdens and facilitate access to exploitation permits in a fair manner. It should also look at mechanisms to facilitate investors' access to long-term loans and subsidies to enable them to stabilize and

provide energy at an affordable price. It recommend that investors should promote regular maintenance of equipment and the installation of fault detection systems to ensure the smooth running of the mini grids and to avoid untimely outages that discredit them in the eyes of customers.

Keywords: Analytic hierarchy process, Barriers; North-Kivu/DRC; solar mini-grids; Prospects, prioritization.

TABLE OF CONTENTS

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

ACERD	Association Congolaise pour les Énergies Renouvelables et Décentralisées (Congolese Association for Renewable and Decentralized Energy)
AHP	Analytic Hierarchy Process
ANAPI	Agence Nationale Pour la Promotion des Investissements (National Agency of Investment Promotion)
ANSER	National Agency for the Electrification of Rural and Suburban Areas
ARE	National Regulatory Authority for the Electricity Sector
C.R.	consistency ratio
CERC	Central Electricity Regulatory Commission of India
DRC	Democratic Republic of the Congo
GOGLA	Global Off-Grid Lighting Association
IEA	International Energy Agency
MEHR	Ministry of Energy and Hydraulic Resources
NZE2050	net zero emissions by 2050
R.I.	random index
SDGs	Sustainable Development Goals
SHS	Solar Home System
SNEL	Société National d'ELectricuté (National Utility)
SPSS	Applied Math Package for the Social Sciences
UNDP	United Nations Development Program

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Due to climate change, fossil fuels accounted for more than 75% of electricity generation in 2020. [1]. A number of nations have set goals to attain net-zero emissions by 2050. In order to achieve net zero emissions by 2050 (NZE2050), it was determined that between 2019 and 2030, CO2 emissions from the power sector must decrease by about 60%, and the proportion of renewable energy in the world's electricity supply must increase from 27% to 60%.[2].

In light of the fact that solar energy is quickly trying to overtake hydro as the leading renewable energy source, the NZE2050 requires that global annual solar PV additions increase from 110 GW in 2019 to approximately 500 GW in 2030, with essentially no subcritical and hypercritical coal plants still in working in that year.[2].

Across the globe, statistics show that around there are 759 million people without access to energy [3]. In 2019, over 580 million of people in sub-Saharan Africa regions live without access to electricity, as reported by the International Energy Agency (IEA 2020b). That amounted to, roughly, three-quarters of the world's population lacking access; the rate of access was only 46% [2], [3]. 471 million of those people live in rural areas. In addition, in 2020, the public health and financial crises in sub-Saharan Africa were expected to result in an increase in the number of individuals without access to power. Additionally, they predicted that an increase in global poverty levels may have made access to basic electricity services costly for even more than 100 million individuals who previously had access, forcing these homes to turn to more damaging and ineffective forms of energy.[2]. This indicates that from now to 2030, the accessibility rate will nearly triple. Throughout 2030, this will need connecting almost 85 million people annually in Sub-Saharan Africa exclusively [3].

On the other side, in January 2016, Sustainable Development Goals (SDGs) were set up by the United Nations Development Program (UNDP), of which 17 concentrate on providing access to clean and affordable energy for everybody [1].

Among the Top 20 access-deficit countries listed by “The Energy Progress Report 2021”, 2019's top two countries on the list were Nigeria as well as the Democratic Republic of the Congo (DRC), with 90 million and 70 million people, correspondingly, without access [3].

Since 2010, distributed renewable sources solutions for powering have advanced quickly. From 2010 through 2019, the amount of people using mini-grids supplied by different technologies doubled, increasing from 5 to 11 million [3]. Up from 85 million by 2016, 105 million individuals had accessibility to off-grid solar sources in 2019. 49 percent of them resided in Sub-Saharan Africa, while 29 percent did so in South Asia. From 2010, mini-grid and no connected grid policy frameworks have progressed more speedily than on-grid electrification frameworks [3].

Home to 86 790 567 people (2019), In Africa, the Democratic Republic of the Congo has the fourth-highest population. The largest nation in Sub-Saharan Africa is this one. Only 2.5 GW of the DRC's 100 GW of hydro potential—the most in Africa—has been realized. The DRC offers a lot of potential for solar energy and significant radiation from the sun, with an average daily solar irradiance of 6 kWh/m^2.[4].

The 2014 Energy Law allowed for private enterprises in the power industry. The Law ended the monopolistic control of the public utility (SNEL) and established a new legislative framework to encourage public-private cooperation and private sector participation. 98% of the installed electricity is produced by hydro power plants, 1.3% by non-renewable resources, and 0.7% by sun's electricity.[4].

The situation is still concerning, particularly in rural regions where just 4% of people have access to power, despite the fact that access rates have increased by the year 2019 and the people with electricity increased from 13% during 2010 reached 19%. Between 2010 and 2019, the annualized increase in access is 0.7% [3], [5].

1.2 Statement of the problem

In sub-Saharan regions, the Democratic Republic of the Congo is the largest nation with important energy potential of every kind. The hydro potential is around 100 GW, the biggest of

the continent. It has a solar energy potential with levels of radiation between 3.25 and 6 *kWh/m^2/day*, rendering photovoltaic installations viable throughout the country [6].

The contrast is that this country is marked by the underdevelopment of the energy sector. With its very large territory, the electrical grids are inaccessible by nearly 85 % of the Congolese living in rural areas and around 70 millions of people without access to electricity, yet this constitutes a large energy market.

Solar mini grid is becoming cheaper solution among renewable energies to allow rural inhabitants to access electricity[7]. But solar energy is underdeveloped with only 7 MW of capacity produced on a large scale in cities and some investors in towns and rural areas[8]. With an access rate of 19% in urban regions and 4% in rural regions in 2019, this country has a backwardness in accomplishing the United Nations Sustainable Development Goal of electricity to all by 2030[3].

In comparison to other countries, the growth of the access rate to electricity is very slow in DRC. According to statistics, years back, the access rate went up from 13% in 2010 to 19% in 2019[3], [5]. In spite of The Energy Law of 2014 which allowed for private enterprises in the power industry by removing monopoly status of the national utility's (SNEL) and promoting public-private partnerships and private investments, investors are likely to come and develop the energy sector. Not many solutions for households with the projects carried out so far. The liberalization of the sector has not solved the whole problem. Projects stay focused in the same areas [9].

However, we observe found that nearly 90% of the inhabitants, particularly in the domestic sector, uses wood as well as other biomass resources for heat generation, preparing food, and lighting, which has a number of adverse effects on the environment and the housing condition of the users, such as strenuous physical labor, forest destruction, or polluting indoor air.[6].

1.3 Objectives of the study

1.3.1 Major Objectives

This study's primary goal is to investigate and identify the most potential barriers and prospects to solar mini-grid deployment in North-Kivu/DRC.

1.3.2 The specific Objective

The particular goals are:

- To identify barriers and prospects to solar mini-grid deployment in urban and remote areas in the context of North-Kivu/DRC.
- To assess the prioritisation of these barriers to the deployment of solar mini-grids in North Kivu/DRC
- To formulate recommendations on how to deal with those barriers and prospects identified for a better solar mini-grid deployment in North-Kivu/DRC.

1.4 Scope of the study

This thesis will forward its arguments and findings based on universal scientific methodologies and facts. However, the relevant issues regarding the existing barriers and prospects of the solar based mini-grid deployments will focus on the context of DRC, case study of North-Kivu province.

1.5 Research questions and Significance of the Study

1.5.1 Research questions

The research will attempt to answer the questions below :

i. In the North-Kivu/DRC context, what are the barriers and prospects to solar mini-grid deployment in urban and remote areas?
ii. What are the dominant barriers affecting the deployment of solar mini-grid in North-Kivu/DRC?
iii. What are the opportunities offered by the prospects of solar mini-grid deployment in North-Kivu/DRC?

1.5.2 Significance of the Study

The major part of people in the DRC are underprivileged and reside in rural locations where extending the grid would be expensive. The United Nations Sustainable Development Goal (SDG) 7 aims to provide accessible, cheap, and sustainable energy by 2030, taking into account the global energy inequality that exists.

This study would be helpful in shedding light on the variables influencing the adoption of solar energy in rural North Kivu/DRC locations where securing access to electricity is difficult and solar radiation is exploitable throughout the year. The study's findings would offer a large amount of data on North Kivu/solar DRC's energy prospects and barriers at various levels. As a result, it would be helpful for any investor planning to develop renewable solar mini grid energy projects in North Kivu/urban DRC's and rural areas. The hurdles that have been revealed will be used to determine the next steps that will improve implementing effective project execution methodologies while taking into account the many possible causes discussed in this research.

Leaders in the Democratic Republic of the Congo will utilize the study's findings to help them figure out how to reduce the country's current energy deficit and preserve the environment. The study would offer useful details on how the prospects for solar mini-grid installations might be exploited as a chance to deploy such systems.

Scholars and academics could benefit from the study's findings by learning more about the challenges and potential of solar mini-grid power in North Kivu/DRC. Regarding the deployment and use of solar mini-grid electricity, the results can be used as a guide. The discoveries would also add to the body of information on solar energy technology already in existence and highlight the solar energy potential as a response to the nation's energy challenges.

1.6 Report organization

The significance of this proposed research is exploring the potent barriers and prospects of solar mini grid deployment in the North-Kivu/DRC. We have the introduction of the subject with problem statement, the second chapter talks about both literature reviews of the barriers and prospects of solar mini grid in the sub Saharan Africa regions. In chapter three, the focus of the work is to select better methodology by taking into account the previous used in the literature. Thereafter, we will make a good collection of data and data analysis in order find better results after the interpretation of different graphs. Finally, conclusions and recommendations will be drawn and the work will be winded up.

CHAPTER TWO

LITERATURE REVIEW

This chapter will cover the existing and up-to-date scientific literature when it comes to the factors affecting the deployment of solar based electric min grids. In this chapter an attempt will be made to assess and evaluate what previous researchers have contributed in this regard and relate to the case of the DRC. Therefore, key points will be summarized, research gaps will be identified and the potential contribution of this thesis work in filling those research gaps will be highlighted.

2.1 Review of the barriers problems

As there were only small distributed loads, Peters J. et al [10] proposed a semi-centralized or decentralized approach for many rural areas of African countries. The combination of inadequate regulations and reluctance to invest is the biggest obstacle to the deployment of small grids in Africa. The sector is still in its early stages of development and is not yet mature enough to handle secure private investments. Homes, small and medium enterprises development and industrialization of remote areas can all be empowering by mini-grids. Because of this, authors offered de-risking tools that will reassure investors, improve public-private partnerships, draw strategic investments, ease the circumstances of developers, demystify the mini-grid industry, and end the Sub-Saharan's power crisis.

Kanzumba K. [6] revealed a number of issues with the DRC's overall energy condition. The majority of these difficulties are actually connected to the financial component for many emerging nations. He demonstrated how poorly operating the current DRC power system is. Due to a lack of resources (both financial and technical), the equipment, from production to distribution, is not well maintained. These turbines, generators, transformers, or power cables are therefore not performing to their full design potential. The enormous initiatives of creating new hydropower plants or constructing new power lines capable of transmitting and distributing electricity make this finance dilemma even more crucial. On a lesser level, there is enormous potential for using renewable energy technologies to more affordably supply in remote and tiny rural areas. However, the main obstacles to the development, deployment, and

commercialization of renewable energy systems for distributed power generation in the DRC are a lack of proper policy, technological developments, political and economic instability, a low level of understanding and an absence of educational background.

A review and analysis of the obstacles to advancing the installation of decentralized renewable energy mini-grids in Ghana were provided by Dramani Bukari et al [11]. In this work, twenty-two limitations were discovered and validated, dimensioned into political, economic, technological, social, and environmental domains, and ultimately graded using the analytic hierarchy process (AHP) method. This was done by combining existing literature with collecting data. The group results placed environmental obstacles at the bottom of the list and political obstacles at the top. The final findings cluster the top 10 obstacles around the three major barrier types—political, economic, and technical—which account for 70% of the total weight of obstacles. The most significant factor, 11.7%, is given to access to capital, followed by unfavorable mini-grid policies, uninteresting tariff regimes, low industrial and productive use, a lack of framework that encourages private sector participation an unclear licensing and permitting system, a lack of viable business models, unreliable plans for grid extension and integration, political implication, and a sluggish government procurement process. The least significant factor, 3.8%, is limited paying ability. According to the paper, the major growth of mini-grids for timely universal access to electricity in Ghana is affected by a severe lack of funding, which is made worse by a policy that imposes intolerable subsidies, restricts innovation in business models, least supports productive uses, and discourages private capital investment. Consequently, the current policy needs to be modified.

The Deploy Mini-Grids for Rural Electrification in Developing Countries project was worked on by Valeria Gambino et al.[12] To successfully deploy a significant number of decentralized energy systems, it is necessary to lessen both the technical and economical hurdles by helping to scale off-grid power generation systems appropriately and by reducing the uncertainty in electricity needs. For the development of off-grid/mini-grid installations, authors created standardized, efficient approaches and procedures. According to them, the inability to estimate client electricity usage, which increases financial risk, and their willingness to pay, are major obstacles to the growth of mini-grids. The suggested methodology prioritizes information

gathering techniques that can produce a sizable sample that is reflective of the market and high estimation accuracy for power demand from electricity alternatives.

Jude T. Nuru[13] used a social construction of technology framework to pinpoint obstacles to the installation of solar mini-grids in isolated rural communities in Ghana. Direct observations, group discussions, and semi-structured interviews were used to gather the data. Infrastructure, regulatory, socio-cultural, financial, technical and research and development considerations are some of the obstacles that the study identified. The building of access roads, community engagement in initiatives, the transmission of technical know-how, the liberalization of the small grid industry, efficient research and development, and expanded generation capacity are some of the methods proposed by stakeholders for removing the obstacles.

Masako Numata et al[14] conducted their study in Myanmar. They evaluated and ranked the obstacles to mini-grid deployment. To determine the ranking of each barrier element, they performed a survey questionnaire with stakeholders utilizing the analytical hierarchy process. There was no single, predominate solution, as demonstrated by the K-means clustering method, which was utilized to identify tendencies. Their findings support the challenge of mini-grid implementation and recommend multi-faceted strategies that go beyond economic factors. The results of the barrier groups were clustered for further research because the economic, technological, and regulatory obstacles had reasonably high consensuses while the social/cultural and financial barriers had low consensuses.

Power Africa's research [15], on the DRC's off-grid solar business states that there are a number of challenges preventing further sector growth and investment. First, there are unstable political conditions and security issues in many different places. Second, corporate success in the DRC is challenging. The nation is ranked 184th out of 190 nations in the World Bank Group's 2017 Doing Business Report for ease of doing business. The lengthy and onerous visa formalities deter potential investments and discourage business trips. Corruption, a lack of credit, and inadequate infrastructure are additional factors. In fact, there are some parts of the nation that can only be reached by plane.

2.2 Review of the prospects of solar mini-grid

Prabhakar Y., Peter J. D. and Samuel A. S. [7]: In order to assess the potential for solar power use in rural regions, a survey of households using solar photovoltaic systems was conducted. Rural homes in Uttar Pradesh, India that obtained small-scale, subsidised solar systems, paid connections from solar microgrids, or who bought solar systems for reliable power are among the respondents. Rural residents expressed a high level of satisfaction with distributed solar PV systems. Income, education, the amount of time spent using solar energy, user satisfaction, the moment of day the power is supplied, and financial assistance for the purchase are all elements that can influence whether or not someone wants to purchase more solar energy. Additionally, their finding showed that the incentives for acquiring additional solar energy are not as strong when it is provided for free. This could also demonstrate the contradictory features of subsidies, which are frequently employed as a political and social tool to raise the standard of living for those who are less fortunate but fall short of addressing the fundamental structural problems with the power system that are highlighted by procedural justice issues. They suggested that in order to achieve long-lasting decentralized solar transitions, policies for decentralized clean energy in developing nations must take into account parallel energy transitions and energy justice frameworks. Without such two pillars working together, the cycle of energy poverty and carbon lock-in will be inextricably intertwined.

(ANAPI) (Agence Nationale Pour la Promotion des Investissements), in English, National Agency of Investment Promotion [4] presented in the sectoral book seven reasons to invest in DRC power sector.

They are below:

(i) peaceful rotation at the presidency of the country,
(ii) liberalization of energy sector which gives access to private actors to invest in it,
(iii) presence of abundant qualified young workforce in the energy sector,
(iv) availability of various natural resources to develop renewable energies,
(v) the energy sector is not yet saturated and the existence of a large share of the market available to new investors,
(vi) the sector of energy is crucial for industrialization of the country and

(vii) DRC has comparative advantages in this electricity sector in Africa (greater hydroelectric potential) and can meet up to 40% of the continent's electricity demand at a competitive price.

Unfortunately, this useful document highlights only hydroelectric sector by showing all steps to invest in DRC but solar energy and others renewable are not taken into account.

2.3 Critique of existing literature

The vast majority of literature has shown how mini grid is a key solution in electrification of sub Saharan Africa regions where a big part of the inhabitants resides in remote regions and is very far from the main grid. Actually, the DRC is facing this problem even in urban areas. While reading papers with reference to barriers of solar mini grid deployment in African countries, we perceived similarities between countries. Some barriers are common to countries despite different terminologies used. In addition, we noticed that there are specific barriers related to the context of each country.

In the middle of those similarities, we appoint regulatory inadequacy in [10] which is the same as the lack of proper policy in [6] and unfavourable mini-grids policy in [11]. The same case was noted for others barriers as financial aspect, reluctant investment, etc. However, in [6] authors discussed about political and economic instability, uncertainty in electricity consumption, etc to be particular barriers in the DRC. Among all these barriers discovered in literature, we will focus on those that are the most relevant in the DRC.

On the other hand, barriers identified in [11] were classified into technical, political, environmental, social and economic categories and in [13]authors assorted them into socio-cultural, infrastructural, financial, technical, research and development, and regulatory categories. In comparing the two classifications, we are of the opinion that infrastructural and financial could be the same as economic; regulatory could be included in political and research could be related to technical category. Thus, in this work we chose to adopt and use the classification done in [11] which is close to the one done in [14]. We will just augment several changes as it is seen in Table 2.1.

In this review, we identified 23 barriers to be validated and ranked in the context of DRC; we have arranged them in 5 domains which are political & regulatory, economic& finance, technical, socio-cultural and environmental as presented in Table 2.1 bellow. Notice that other barriers will be added to these after enterprises survey.

Table 2. 1: Potential barriers of solar mini grid deployment

Political& regulatory	Political instability and Political interference, Lack of regulatory framework, Ineffective licensing & permitting regime, Unattractive tariff regime, Unfavourable fiscal regime, Ineffective institutional arrangements, Security instability.
Economic & finance	Access to finance, Currency and inflation risk, Lack of viable business models, Limited paying capacity.
Technical	Lack of validated resource data, Poor maintenance and technical support culture, Lack of monitoring systems, Low productive use.
Socio-cultural	Inadequate community engagement, Limited political leverage in remote areas, Lack of stakeholder coordination, Land disputes, Ethnic/language difference.
Environmental	Lack of programs for electronic waste management, Use of mini-grids to power environmentally detrimental activities, Lack of recognition of environmental benefits of renewable mini-grids

2.4 Current solar energy situation of DRC

With an approximate 85.8 million citizens, the DRC ranks fourth in terms of population in Africa. Kinshasa, the nation's capital, is home to almost 12 million people. The remaining population has a low density of 38 people per square kilometer and is dispersed across the rest of the country. Its inhabitants are expanding at a 3% annual rate. Nowadays, urban regions are residence to more than 40% of the people. The Democratic Republic of the Congo (DRC) continues to be one of Africa's poorest and least industrialized nations and has persistent conflict

areas despite a recent period of economic improvement, especially expansion inside the electricity sector.[15].

There were roughly 500,000 registered connections with [SNEL] (Société Nationale d'Électricité), the National Electricity Company, as of 2019. Its estimated energy pricing that year was $0.07 per kilowatt hour (kWh), one of the cheapest throughout Africa. To date, the company is still facing illegal connections but as it has started using power metering; those illegal connections are being limited especially in Goma city. DRC currently possesses 5,510 kilometers of high-voltage transmission network, despite being one of the greatest nations in Africa. A significant option arose for the pv energy market in the DRC's undeveloped on-grid electricity sector. [15].

Households without access to electricity were estimated between 12 and 13 million in 2019, they can be found all over the nation, both within urban and rural locations. Off-grid options are thus likely to play a significant role in DRC's countrywide electrification effort. [15].

With 6 $kWh/m^2/day$ as solar radiation estimation, the DRC has excellent potential for deploying Solar Home System (SHS) or photovoltaic (PV) across the entire nation as we mentioned above that the access rate is still around 49 % in urban regions and 4% in remote regions by 2019[5]. Yet, that's not the case, as through the whole country there are only a total of 836 installed solar PV systems. The Table 2.2 below shows the total generating solar energy capacity in Megawatts from year 2009 to 2018. And in 2018 it was 7 MW[8].

Table 2. 2: Total Solar Energy Capacity in DRC (MW) from 2009 to 2018[8]

Years	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Capacity (MW)	0	0	0	0	0	1	1	3	5	7

According to projections made on the basis of existing grid penetration, 61 million residents in the DRC may eventually have access to mini-grids. The 141 major inhabitant centers off the grid comprise a 10 million-person mini-grid market with yearly revenue of $153 million. This estimation makes the assumption that mini-grids may serve as a connection for every person living in these areas.[15].

The primary regulatory body in the power industry is the Ministry of Energy and Hydraulic Resources (MEHR). MEHR's duties extend beyond managing the national utility SNEL to include program development, planning, oversight, and policy. According to the 2014 Energy Law, MEHR is in charge of overseeing the power sector, which is governed by both the provincial and national governments. The National Agency for the Electrification of Rural and Suburban Areas (ANSER), the Centre for Technical Energy Support, and the National Regulatory Authority for the Electricity Sector (ARE) are also required by the law to be established. Between 2017 and 2018, around 13 ministerial decrees were submitted to and adopted by the Government of the DRC. This resulted in the creation of ARE and ANSER which are working since the second semester of 2020. Drafting requirements for these kinds of transmission and generation projects is the job of ARE, which is also in charge of reviewing and approving new power prices put forth by each new supplier. Promoting and funding rural and peri-urban electrification, as well as mini-grids, is ANSER's mission.[15], [16].

[ACERD], (Association Congolaise pour les Énergies Renouvelables et Décentralisées): The Congolese Association for Renewable and Decentralized Energy was founded in July 2018 by the renewable energy enterprises in the DRC. In order to address issues with energy access and to foster the growth of the private sector for renewable energy, ACERD coordinated energy enterprises in the DRC. With only about 12 members at the moment, ACERD currently lacks capacity, but it is already making a name for itself nationwide and has joined the Global Off-Grid Lighting Association (GOGLA). The main goal of ACERD was to coordinate energy firms in the DRC in order to address the country's issues with electricity availability. Members include major players, such as Bboxx, Greenlight Planet, BURN, Altech group, and Dev Solaire which are Solar Home Systems (SHS) companies[15].

The study's primary hypothesis is that there are obstacles to the rapid solar mini-grids deployment in both rural and urban regions of the DRC. This study is a modest attempt to close the gap by examining and categorizing potential obstacles to and opportunities for the implementation of solar mini-grid in the context of the DRC.

2.5 Research gap

In this energy area of research as well as this solar mini-grid sector is concerned; after reading papers and reports, we discovered that there is any existing deep study linked to barriers and prospects of solar mini-grid deployment in the DRC. In addition, as other countries have pinpointed barriers according to their contexts, it is important and necessary to work on it considering the context of the DRC. As a matter of fact, further reports have noticed many opportunities of investing in renewable mini grid in general and some barriers of the Solar Home Systems market have been listed but SHS are pico-solar systems. Since the enforcement of the 2014 law on energies to date, the energy sector is not really developed despite the rewarding opportunities existing in the DRC and we believe that it is legitimate to do research on the barriers and the prospects of solar mini grid deployment.

2.6 Summary

Solar mini grid systems are among cheaper solutions to respond to the lack of electrical power in Sub Saharan regions and particularly in North-Kivu/DRC context. This solution is desirable either in urban or rural areas as many urban centers are far away from the grid. From this chapter we have understood the point of view of researchers about obstacles of acceleration of the solar mini grid deployment in Africa. Opportunities are increasing in DRC but investors are less likely interested in its energy sector due to others existing barriers. No deep study has been carried out on that and this is the contribution of this work.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The approaches that will be used to obtain data on the study area are presented in this chapter. In order to provide answers to various research questions, it will now demonstrate the methodology that will be used for data collection, analysis, and interpretation. The research problem can be solved carefully using research methodology. When describing research methodology, we don't just talk about the research methods; we also consider the justifications for the methods we use in the specific situation of our research project and also clarify why we're using a specific technique or approach and why we're not using others so that the study results can be assessed by the researcher or by a different group.[17].

In this work, it is about three groups of research methods which will be used: We will include approaches that are focused on data collection in the first group. As long as the information previously available is insufficient to arrive at the needed conclusion, these methods will be employed; the third group will include those procedures required to assess the accuracy of the results acquired; the second group comprises of statistical tools used for developing links between the data as well as the unknown.

3.2 Data Collection Methods

Referring to what is proposed by Painuly[18] and used by D. Bukari et al [11], we will combine literature reviews, questionnaire surveys and stakeholder interviews to identify barriers and prospects of deployment of solar mini grid. Due to the fact that some obstacles may be exclusive to a technology whereas others might be regional or national related, the literature reviews will help to identify Sub-Saharan region barriers which are presented in similar projects and those which are specific to solar mini grid. This first list will be completed by other barriers which will be identified by questionnaire surveys and stakeholder telephone interviews as specific to the North-Kivu/DRC. The opinion of the stakeholders on the barriers may highlight the deficiencies in the current policies and help in the identification of actions to fight the barriers, therefore this method will be vital to determining the obstacles and opportunities.. Stakeholders may include

owners of solar mini grid plants (theirs experts), consumers and policy makers (government, ANSER, ARE).

Concerning the sample size, we will first identify enterprises which work in solar mini grid plants in North-Kivu/DRC, and we will take 1 to 3 experts in each enterprise for questionnaire surveys. We will take also 1 to 3 government experts from ANSER and ARE. This group will constitute our sample. This means that for the barriers identification and prioritization, experts of owners of solar mini grid plants and government policy makers will be surveyed as done by D. Bukari et al [11]. Taking into consideration the greatness of the North-Kivu province, financial constraints and limited time, mailing of questionnaires seem to be the best method in our case [17]. This will consist of sending by mail the link of the questionnaire survey to be completed by experts. Questionnaire will be performed through Google forms. And for the barriers prioritization the questionnaire will be done through drop and pick later method as done by P. Yadav et al [7] and G. O. Ponde et al [19]. In addition, for prospects of deployment, consumers of NURU solar mini power plant in Goma town are the one to be surveyed as a case study, the administration of the questionnaires will be through Google forms but a team will be in charge of asking and collecting answers on phones.

3.2.1 Populations of the studies

A population is a large group of individuals or things taken into account for statistical purposes. Mugenda and Mugenda (2003) claim that a target population is a set of people to whom generalized findings from[19]. In this work, we consider two kinds of populations. The first population includes experts from selected companies which work in solar mini grid in North-Kivu/DRC and government experts from ARE and ANSER. The second population takes into account customers of NURU solar mini grid which is in Goma the capital city of North-Kivu/DRC, as they constitute our case study for the prospects of solar mini grid in North-Kivu/DRC.

Experts were interviewed twice, firstly for the validation of 23 barriers found in academic literatures including papers on barriers in sub Saharan countries mostly and others countries. Experts were asked to validate barriers according to the context of North-Kivu/DRC and to add others missing barriers which they are facing every day.

A survey questionnaire, involving 24 key experts from nine enterprises was selected to participate in this investigation. As a result, the analysis solely reflects the obstacles that experts believe to be the most significant and appropriate to the North Kivu/DRC situation.

Here are the nine enterprises which work in solar sector and were selected: NURU sarl, ALTECH Group, BBOXX DRC, Ets GOSHOP, and others are local companies that work in the subcontracting of their engineers like TECHPOWER, FUNDIPRO. We use also Renewable Energy Researchers in universities (ULPGL). We did not receive any answer for ARE and ANSER the two governments' enterprises of regulation of energy sector. The list of the nine selected solar companies with their expected experts is presented in Table 3.1.

In order to employ the AHP method as in [11], the barriers that were found and validated were formulated into paired comparison questionnaires. These surveys were administered to a group of properly selected of companies' experts. A nine-point scale that reflects the relative strength of preferences for barriers was used to moderate the expert respondents' responses.

Table 3. 1 Enterprises with number of experts

No	Enterprises	Number of experts
1	NURU sarl	5
2	ALTECH Group	3
3	Ets GOSHOP	4
4	BBOXX	2
5	TECHPOWER	2
6	FUNDIPRO	2
7	ULPGL	2
8	ARE	2
9	ANSER	2
TOTAL		**24**

To give an answer to our third research question on opportunities offered by the prospects of solar mini-grid deployment in North-Kivu/DRC, we work with customers of NURU solar mini

grid which is in Goma the capital city of North-Kivu/DRC. At the beginning of the survey, there were roughly 1600 clients linked to the NURU solar mini grid.

Kotler (2001) contends that samples of roughly 10% of a population can frequently provide reliable results when they are well chosen. [19]. In the light of this we carefully selected 24 enterprise's experts to constitute our sample for the first study about identification and ranking of barriers according to the Congolese context.

According to the changing in the sample that are most probably to have a wide range of values, the Fisher Formula was utilize to calculate the sample size for the connected clients. Equation (3.1) provided the sample size [17] [19]:

$$n = \frac{(p \times q \times z^2)}{e^2} \tag{3.1}$$

In which:

n= is minimum sample size needed;

p = the proportion belonging to the specified category;

q = the proportion not belonging to the specified category;

z = the value matching to the required degree of confidence (90% certain=1.65, 95%certain= 1.96 and 99% certain=2.57);

e= 5% = the margin of error required.

When there are fewer than 10,000 people, the sample needs to be changed in accordance with the minimum sample size formula (n'), as stated in Equation (3.2) below, according to Cochran W.G. (1977) [19]:

$$n' = \frac{n}{\left(1+\frac{n}{N}\right)} \tag{3.2}$$

In which :

n' = the adjusted minimum sample size

n = the minimum sample size (calculated)

N = the entire population

P=50%, Q=50% for variables with known and unknown characters discovered in the study, z=1.96 (95% certain), e=5% (i.e. within plus or minus 5% of the true percentage, the margin of error that can be accepted), and N=1600 were used to determine the sample size.

$$n = \frac{(50 \times 50 \times 1.96^2)}{5^2}$$

$$= \frac{2500 \times 3.8416}{25}$$

$$= \frac{9604}{25}$$

Adjusted minimum sample size = 384

$$n' = \frac{384}{\left(1 + \frac{384}{1600}\right)}$$

$$= \frac{384}{1.24}$$

$$= 309.67$$

Total sample size = 310

The formula determined that 310 NURU solar mini grid consumers made up the sample size for this investigation but we were able to survey 168 of customers which is 54,19% of our sample size. This sample size was chosen because it would have modest financial effects and would be simple to complete during a school semester. The fact that this study was individually funded and had limited financial resources is another factor in the choice of this particular sample. And more that 50% response rate is acceptable to conduct a study according to Babbie, (2002) [19].

3.2.2 Questionnaires administration

Taking into account the time limit imposed by the master program, we chose efficient methods and techniques that allowed us to finish in time.

For the questionnaire of the first phase which consisted in identifying the barriers to solar mini grid deployments in North-Kivu/DRC context. We used the telephone and e-mail survey by calling directly the respondents to give answers to the questionnaire. Or by emailing the questionnaire designed with Google forms to receive online responses as soon as the respondents

send their answers. We first contacted the companies to get the telephone numbers of their experts and then we contacted them individually.

For the second phase, in order to rank the different barriers identified, the second questionnaire was administrated to the same enterprises experts through drop and pick later method as they are just seventeen.

The opportunities offered by prospects of solar mini-grid deployment in North-Kivu/DRC were identified by questioned 168 customers of NURU solar mini grids. The administration of the questionnaire was done by a team that entered house by house to ask and collect the answers via Google forms. The people found available are those who responded to the questionnaire until reaching 168 subscribers that constitute 54.19% of our sample.

3.2.3 Instruments

The three questionnaire surveys utilized in this research were conceived with an introduction paragraph addressed to the respondents in order to assure them about the academic purposes of the study and the confidentiality of the information given. These three questionnaires are found in the Appendix A, B and C.

The first and the second questionnaires addressed to experts had 2 sections (section I and II), where section I centered on the identification of the respondent including gender, level of the study, the enterprise where they work and years of service.

The Section II of the first questionnaire was on identification of solar mini grid deployment barriers in North-Kivu/DRC context. This section was in 5 parts (A, B, C, D and E) according to the five categories we used to classify the different barriers found in the literature. In every part, we listed the barriers and asked experts to select the barriers they face in performing their jobs in North-Kivu/DRC and to add other barriers they feel are missing from the list in each category.

The Section II of the second questionnaire was on prioritization of the barriers identified by experts as the result of the first questionnaire. In this questionnaire we considered only the barriers chosen by 30% of experts and more as relevant in North-Kivu/DRC. In this section, the some experts were asked to make a pairwise comparison of barriers in the same category where they are rated according to the importance scale as displayed in Table 3.2.

The third questionnaire was addressed to the sample constituted by 310 customers of NURU solar mini grid to identify prospects of solar mini grid deployment in North-Kivu/DRC.

The questionnaire's purpose was to inform the respondents of what was wanted and to elicit the appropriate replies in order to accomplish the research's objectives. In consideration of the participants' busy schedules, all of the questions were clearly defined and narrowly focused.

3.3 Data Processing and Analysis methods

In literature on related subjects, a variety of techniques have been utilized for data analysis and processing. The statistical package for social science (SPSS) analysis software can be used to code and input the quantitative data that were found from the questionnaires. Tables can be used to compile responses in order to simplify comparison and additional analysis. Through tendency and percentages, this produced quantitative reports. This is achieved by G. O. Ponde et al [19] while identifying the elements influencing the sustainability of mini grid energy in rural regions of Kenya.

AHP is a decision-making technique created by Saaty in the 1970s and used in the energy domain by D. Bukari et al[11] and M. Numata et al[14]. In the AHP, a problem is hierarchically organized, and each factor is compared in pairs to determine its relative importance. Then, judgements are synthesized to provide the criteria or overall weights, and judgments are evaluated to ensure consistency or dependability.[11], [14].

For this work, we choose to apply AHP method as it was given adequate results in previous studies [11], [14], It is popular and simple to comprehend. The steps are as follows: problem modeling while taking into account the hierarchy of important factors; importance of the elements will be assessed by comparing pairs based on knowledge and emotion; each factor will then be prioritized; consistency of respondent scores will be checked using a consistency ratio (C.R.); and the average of the consistent weights in each category will be calculated [14].

3.3.1 Google forms

For the first and third studies, Google forms helped us to bring out immediately the different graphs that synthesize the results obtained. Note that these results will be presented and commented in the following chapter.

3.3.2 Analytic Hierarchy Process (AHP)

Numerous multi-criteria decision-making techniques can be employed to analyze problems related to energy fields but we opted for the AHP because of its popularity and simplicity. Saaty created the AHP, a decision-making technique that later gained popularity, in the 1970s [11]. In the AHP, a problem is arranged hierarchically, and each factor's importance is determined by a paired comparison of the factors.

The steps are as follows [21]:

1. The hierarchy of important factors is taken into account when modeling the problem.
2. By comparing the pairs based on knowledge and emotion and scoring them according to the importance scale provided in Table 3.2, it is possible to establish the importance of the elements.
3. By computing the eigenvalue of the judgment matrices, each factor's importance is ranked.
4. The consistency ratio is used to assess the consistency of the respondents' scores (C.R.).
5. The consistent weights (C.R. 0.2) in each category are averaged.

Table 3. 2 Fundamental scale [14].

1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

The respondents' pair-wise comparisons yielded judgments that were represented as square matrices with diagonal components. The consistency ratio (*C.R.*) from the random index (*R.I.*) (Table 3.3) must be used to check the findings for consistency, and Equation (3.3) must be used to determine the consistency index (*C.I.*) [14]. When calculating *C.R.*, use Equation (3.4).

$$C.I = \frac{\lambda_{max} - n}{n-1} \tag{3.3}$$

Here, n is the number of elements and λ_{max} is the judgment matrix's maximum eigenvalue.

$$C.R = {}^{C.I.}/_{R.I.} \tag{3.4}$$

Table 3. 3 Random index (R.I.) [14].

Matrix Order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
R.I	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

After determining the barriers in this study, we came up with the following:

- 6 barriers, or factors in the Political & Regulatory Category, resulting in a 6 ×6 matrix with an *R.I.* of 1.25 since the matrix has $n = 6$.
- 3 barriers which are the factors in the Economic & finance Category, resulting in a 3 × 3 matrix with an *R.I.* of 0.52 as the matrix is of $n = 3$
- 3 barriers, which are the Technical Category's factors, leading to a 3 × 3 matrix with an *R.I.* of 0.52 because the matrix has $n = 3$ elements.
- Barriers, which are factors in the socio-cultural category, total 4, creating a 4 × 4 matrix with $n = 4$ and an *R.I.* of 0.89.
- 2 barriers, which are the environmental category's factors, leading to a 2 × 2 matrix with a $n = 2$ matrix and an *R.I.* of 0

During the analysis of the data we used the software "***AnalyticHierarchyProcess***" (version 4.1.2.0 produced by spiceLogic inc enterprise) which facilitated us to make all calculations and to find results with a C.R. lower that 0.2 as recommended for a good consistency [22].

According to reports, if the respondents are experts, the AHP can be employed with a small sample. [23]. Therefore, in Nord-Kivu/DRC, where it is challenging to conduct an online survey with big samples, the AHP can be used for the ongoing study.

The AHP was used in this research to look into the barriers to the deployment of solar mini-grids in Nord-Kivu, DRC. Based on our barrier typology, we identified six factors in Political & regulatory barrier category, three factors in Economic & finance Category, three factors in

Technical Category, four factors in Socio-cultural Category and two factors in Environmental Category, where a pair comparison was executed. The participants compared 28 pairs as a result. It was carefully considered how many elements and categories to include in order making it as easy as possible for respondents to complete the survey. From July to September 2022, the survey questionnaire was circulated. The experts received the questionnaire sheets in person. For analysis, 17 questionnaires were sent, and 17 responses were obtained.

3.3.3 Statistical Package of Social Science (SPSS)

SPSS is a well-liked program for statistical analysis in social research (Statistical Package for the Social Sciences). With the use of the software, the researchers are able to visualize the data using different techniques, such as scatter plots and histograms, and to calculate statistics that range from simple descriptive graphs to complex analyses of multivariate matrices. Because of the SPSS, researchers no longer need to be adept at many of the calculations needed for applied math analyses. Massive amounts of data are gathered by researchers through surveys, experiments, and various kinds of observation. An easy way to store this data and generate descriptive and inferential statistics is by using an applied mathematics computing tool. The Applied Math Package for the Social Sciences (SPSS) is a useful program to understand because it is widely used for all types of survey analysis.

3.4 Summary

This chapter's importance centered on how well the techniques we'll employ for our research worked. We decided to adopt techniques that have been used in earlier, comparable studies and that have produced positive outcomes in those studies' contexts. To find further barriers, telephone interviews will be conducted. Questionnaire surveys will compare various obstacles to find the most significant ones. Data analysis will be performed using Analytic Hierarchy Process (AHP) method. To identify prospects, NURU consumers will be surveyed as a case study in Goma town.

CHAPTER FOUR

PRESENTATION OF RESULTS, INTERPRETATION AND DISCUSSION

4.1 Introduction

The presentation, analysis, and discussion of the findings on the barriers and prospects for the deployment of solar mini-grids in North Kivu, DRC, are highlighted in this chapter. Prior to analysis, the organized data collected from the study instrument was cleaned, sorted, and coded. The chapter is divided into various sections, each of which features the research objectives, which were to identify obstacles and opportunities for the installation of solar mini-grids in urban and rural North Kivu/DRC areas, as well as to rank these obstacles.

4.2 Results on identification of barriers

The research tools included both structured and unstructured questions with the goal of gathering pertinent data for this study. Data was examined using descriptive techniques.. The outputs flowed from the analysis of the data using Google forms. For readers' ease of comprehension, the information and statistics were presented as histograms and sectors.

4.2.1 Response Rate

The study used a virtual questionnaire designed with Google forms and sent online to the companies' experts. Here below in Table 4.1, we present the response rate obtained in relation to our forecasts and in relation to the contact details of the experts received from the companies.

Table 4. 1 Response Rate

Enterprises	types	Those who replied	Those who did not reply	Percentage (%) of those who replied
NURU sarl	Private company	4	1	80
ALTECH Group	Private company	3	0	100
Ets GOSHOP	Private company	3	1	75
BBOXX	Private company	1	1	50
TECHPOWER	Private company	2	0	100
FUNDIPRO	Private company	2	0	100
ULPGL	Academic company	2	0	100
ARE	Public company	0	2	0
ANSER	Public company	0	2	0
TOTAL		**17**	**7**	**70.83**

I was able to get responses from 17 responders to the study. A response rate of 70.83% resulted from the instruments being complete and considered valid for data analysis. The 7 surveys that were either never received or were partially received made up 29.16% of the sample and were thus excluded from the analysis. A 50% response rate is considered appropriate by[19]. This means that the 70.83% response rate is acceptable and suitable for analysis, conclusions formulation, and making suggestions. The response rate was improved by following-up with a phone call to the respondents, and we explained to them the objectives of the study and its usefulness.

4.2.2 Identification of the respondent

The characteristics of the study population are presented in the general information. Various aspects were employed to characterize the respondents. The study involved experts from solar companies in North Kivu/DRC as they are the most familiar with the barriers to the deployment of solar mini grids in the province of North Kivu in DRC. The first part of the questionnaire examined the interviewees' demographic data in order to acquire the essential information. The following headings are used to present them in this section: Gender, education levels, respondents' employers, and Work Experience.

A. Gender of the respondent

The proportion of respondents by gender is displayed in the results shown in Figure 4.1. This study's discussion of gender is seen as essential, in part because it offers a "balanced view" of the two sexes.

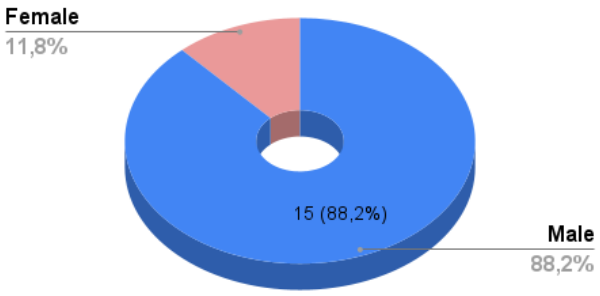


Figure 4. 1: Gender of the Respondents

According to the study, 88.2% of the respondents were men and 11.8% were women. These results show that in this field there are more male than female experts because we asked the existing respondents in the companies. Therefore we can consider that the opinions expressed in these results represent the opinions of both sexes.

B. Education Levels

The study was done on the education levels of respondents to ensure that they have a high level of knowledge to understand and participate effectively in this study. The study's findings were then displayed as Figure 4.2.

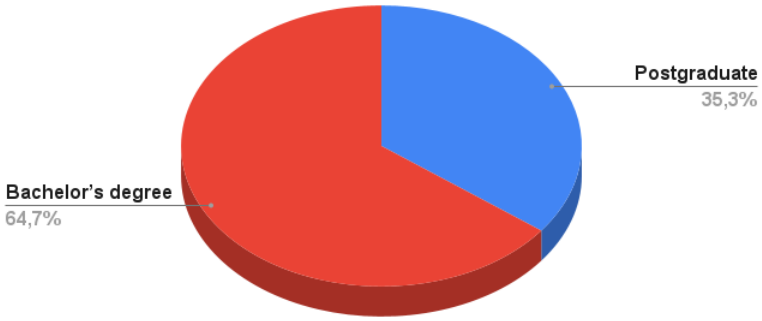


Figure 4. 2: Level of education of the respondents

According to the results of the study, the majority of the respondents, 64.7%, indicated that their highest education level was a bachelor's degree, 35.3% of them had obtained a postgraduate degree, which is not a considerable percentage. These findings suggest that most respondents had at least a bachelor's degree in the subject area, indicating that they were knowledgeable about the data that this study was looking for.

These results also suggest that all the participants had the educational qualifications and familiarity with the data the study was looking for.

C. Companies surveyed

The study aimed to collect data from experts of solar companies. The goal of the investigation was to determine the proportion of experts according to their companies, as shown in Figure 4.3.

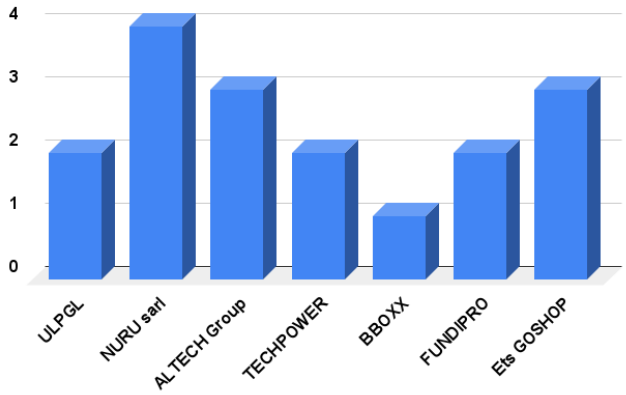


Figure 4. 3: Number of experts by company

According to figure 4.3, the number of experts who participated in the study is 3 to 4 for large companies such as NURU sarl, ALTECH Group and Ets GOSHOP and the number of 1 or 2 experts for other companies. Notice that here is presented the one who respond positively to our questionnaire by sending it back after well fill it.

D. Working Experience

The number of years that respondents have worked for the solar companies impacts how much they are aware of the study's target barriers. As a result, respondents were asked to specify how long they had been employed by solar energy enterprises. This inquiry is crucial because it enables us to assess the respondents' comprehension of the obstacles blocking the deployment of solar mini-grids in the DRC's North Kivu province.

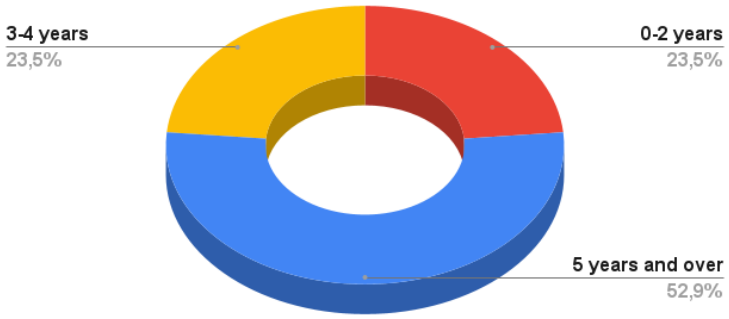


Figure 4. 4: Working Experience of experts

Figure 4.4 shows that 52.9% of the expert engineers claimed that they had all worked for solar mini-grid firms for five years or more, 23.5% said they had worked for these companies for three to four years, and 23.5% had worked for solar mini-grid companies for less than two years. This demonstrates that the majority of the specialists involved in the study had been employed by solar mini-grid companies for more than five years and were therefore familiar with the data the study was looking for.

4.2.3 Barriers of solar mini grid deployment in North Kivu/DRC

The second part of the questionnaire concerned the actual identification of barriers. This was done according to the selected areas or categories in which we classified the barriers found in the sub-Saharan region during the literature review. It should be noted that we have subdivided them

into five categories which are: Political & regulatory, Economic & finance, Technical, Socio-cultural Category and Environmental.

We considered as valid, the barrier that was cited by 30% of the experts, i.e. 5 experts out of 17, given that not all of them are confronted with the same realities in the companies. But also, we considered that a barrier identified by 30% of experts was not neglectable. Thus, we present here the results found after the analysis of the data collected.

A. Political & regulatory Category

In the political & regulatory category, we submitted 7 potential barriers to the experts for validation: Political instability and Political interference, Lack of regulatory framework, Ineffective licensing & permitting regime, Unattractive tariff regime, Unfavourable fiscal regime, Ineffective institutional arrangements, Security instability. The results of the survey are presented in Figure 4.5 below.

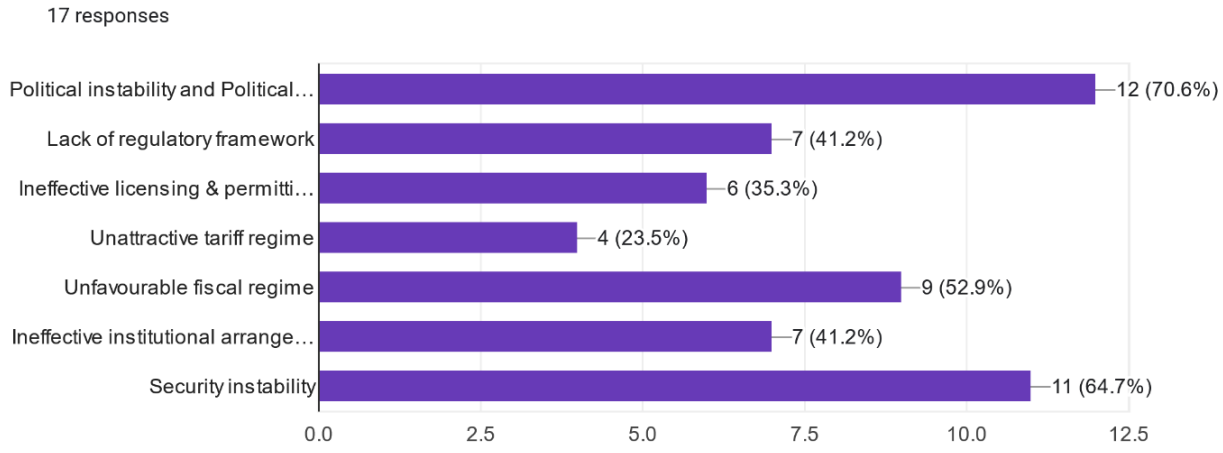


Figure 4. 5: Political & regulatory barriers

According to Figure 4.5, 70.6% of the experts validated "Political instability and Political interference" as a barrier to the deployment of solar mini grids in North Kivu in DRC, 64.7% of the respondents validated "Security instability" as a barrier, 52.9% of the respondents validated "Unfavourable fiscal regime" as a barrier, 41.2% of the respondents validated "Lack of regulatory framework" and "Ineffective institutional arrangements" as barriers also. 35.3% of the

respondents validated “Ineffective licensing & permitting regime” as a barrier too. The one which was not validated by 30% of experts is “Unattractive tariff regime”.

According to interviews with some experts, it was pointed out that the energy produced by the solar mini grids is expensive compared to that produced by the hydro power plants in the country. But solar energy is becoming competitive in areas where hydro power is not available. And this is, unfortunate, the case of the majority of urban and rural areas of North Kivu province. This may be the explanation that shows that “Unattractive tariff regime” is not really a barrier.

B. Economic & finance Category

Speaking of the Economic & finance category, we proposed 4 potential barriers to the respondents for validation: Access to finance, Currency and inflation risk, Lack of viable business models, Limited paying capacity. The results of the survey are shown in the following Figure 4.6.

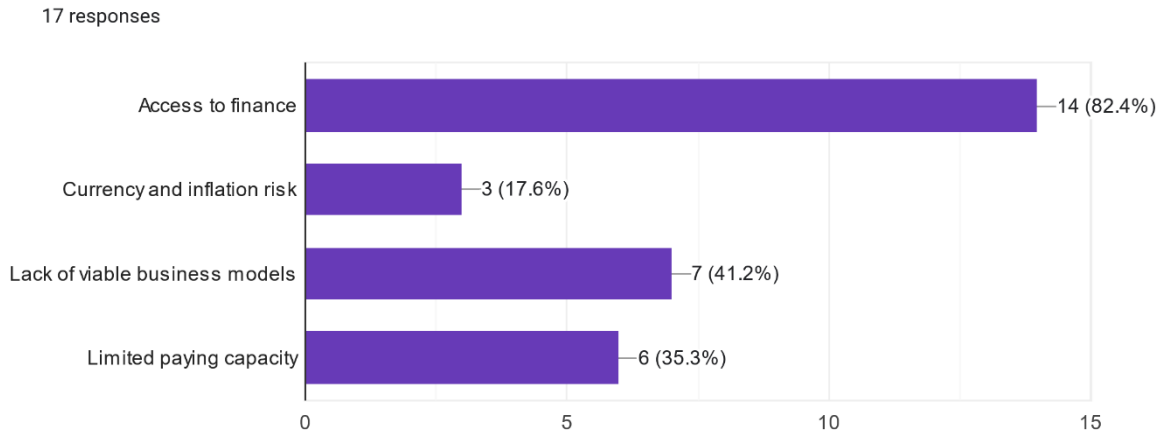


Figure 4. 6: Economical & financial barriers

From the study, respondents validated 3 of the 4 barriers respectively “access to finance” with 82.4%, “Lack of viable models” with 41.2% and “Limited paying capacity” with 35.3%. We can realize that the “Currency and inflation risk” was not validated because it had only 17.6% which is less than 30%. This can be understood in the following way: in the DRC, foreign currencies such as US dollars are used as if they were the local currency and therefore inflation does not significantly affect dollar bank accounts.

C. Technical Category

For the technical category, we found 4 potential barriers to be validated by respondents but they add two more barriers. Here is listed the 4 barriers found in the literature: Lack of validated resource data, Poor maintenance and technical support culture, Lack of monitoring systems, Low productive use. The 2 added barriers are “Lack of local skilled labour” and “Exploitation of hydroelectric energy”. The results of the survey are presented in Figure 4.7 down here.

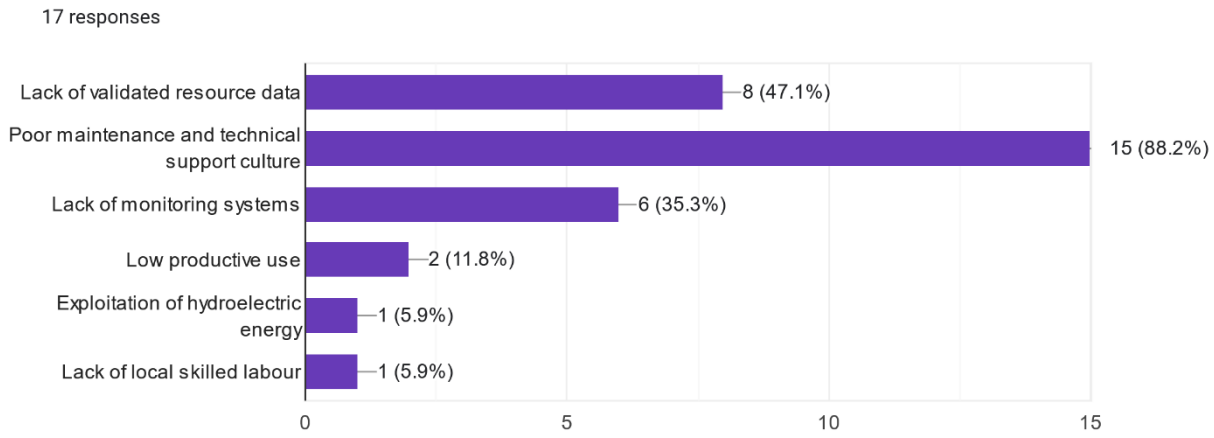


Figure 4. 7: Technical barriers

Of the six potential barriers shown in Figure 4.7, only three were validated by the experts, namely “Poor maintenance and technical support culture” with 88.2%, “Lack of validated resource data” with 48.1% and finally “Lack of monitoring systems” with 35.3%. Note that the last two were proposed by two different experts, but this is not enough for them to be validated, as “Low productive use” did not reach 30% to be validated. With solar mini grids it is possible to use them energy in small production factories.

D. Socio-cultural Category

In the Socio-cultural category, we showed 5 potential barriers to be submitted to the validation of experts which are the inadequate community engagement, Limited political leverage in remote areas, Lack of stakeholder coordination, Land disputes, Ethnic/language difference. After analyzing data, the Figure 4.8 displays the results found.

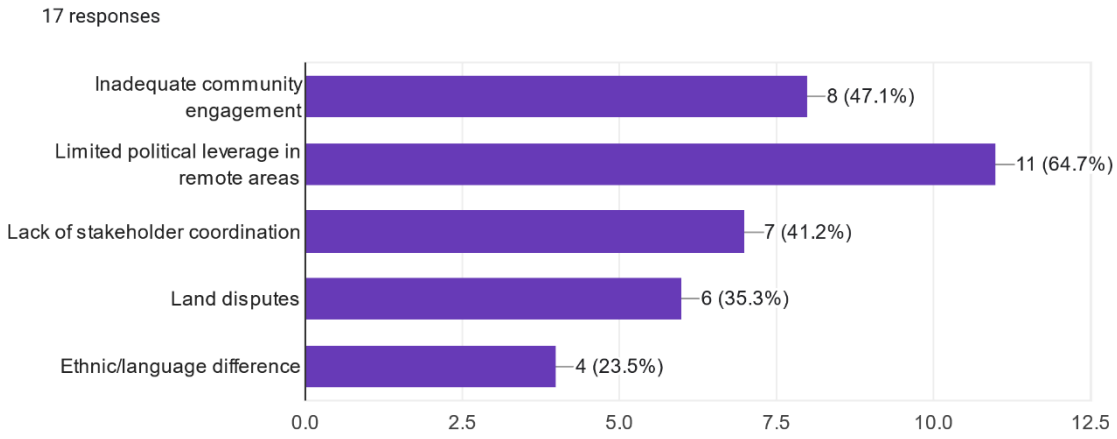


Figure 4. 8: Socio-cultural barriers

The Figure 4.8 shows that 4 barriers are beyond 30% and are consider to have been validated namely "Limited political leverage in remote areas" with 64.7%, "inadequate community engagement" with 47.1%, "Lack of stakeholder coordination" with 41.3% and "Land disputes" with 35.3%. The last one which is "Ethnic/language difference" was not validated as it had only 23.5%. The DRC is among the countries with several ethnic groups with different languages but this does not seem to be a barrier to the deployment of solar mini grids because energy needs come before ethnic differences and many villages are mono-ethnic or at most bi-ethnic, only the city of Goma, the capital city of the province of North Kivu is multi-ethnic.

E. Environmental Category

Speaking of the Environmental category, we proposed 3 potential barriers to be submitted to the validation of respondents which are Lack of programs for electronic waste management, Use of mini-grids to power environmentally detrimental activities, Lack of recognition of environmental benefits of renewable mini-grids. The results are shown in Figure 4.9.

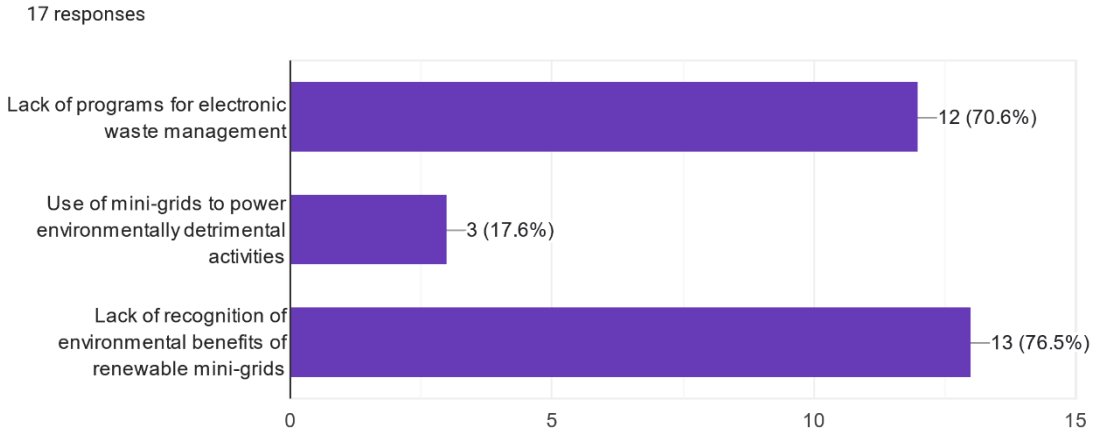


Figure 4. 9: Environmental barriers

According to the study's results, 76.5% of participants and 70.6% of respondents, respectively, agreed that barriers are the "lack of acknowledgment of the environmental benefits of renewable mini-grids" and "lack of programs for electronic waste management." The "Use of mini-grids to power environmentally harmful activities" was not verified since it only obtained 17.6%, or less than 30%, of the total votes. From interviews with some experts, we learned that in North Kivu, solar mini-grids are not use to power mining, oil exploration and other climate change intensive activities.

4.2.4 Conclusion

In conclusion, this study focused on the identification of barriers to the deployment of solar mini grids in North Kivu, DRC. Thus, to collect data from 17 experts from 7 solar companies, a questionnaire including 23 potential barriers was submitted to the experts' experience that validated 18 barriers that they recognized as barriers to the deployment of solar mini grids in North Kivu in DRC. Details and further explanation of the 18 barriers are given in Appendix D. It is essential to indicate that the 18 validated barriers will be the object of the prioritization in the following section.

4.3 Results on prioritisation of barriers

After identifying the barriers to solar mini grids deployment in the North Kivu province of the DRC, the second step was to prioritize these barriers to find out which ones are more significant. The second questionnaire was then submitted to the 17 experts for a pairwise comparison of the barriers but according to categories. Overall, each expert made 28 pair-wise comparisons, with 15 pair-wise comparisons for Political & regulatory category, which had 6 identified barriers, 3 pair-wise comparisons for Economic & finance Category, which had 3 identified barriers, 3 pair-wise comparisons for Technical Category, which had 3 identified barriers, 6 pair-wise comparisons for Socio-cultural barriers, which had 6 identified barriers, and finally 1 pair-wise comparison for Environmental Category, which had only 2 identified barriers.

Here is the presentation of the results of prioritization obtained after processing the data by the "*SpiceLogic Analytic Hierarchy Process software*". For the group decision, the aggregation method used was the weighted geometric mean as recommended in previous studies. And we have considered the preferences of all experts equally, which means that the relative priority of each expert was set to one. We supposed also that the first sub criterions which consist of barriers categories had the same weight. Note that the results of the interviews with the experts were postponed in the form of comments.

4.3.1 Political & regulatory Category

With the consistency ration (C.R.) calculated as 0.0022, the preferences of all experts aggregated in this criterion showed that "Ineffective institutional arrangements" is the most important barrier to the deployment of solar mini-grids with 20.61%. This is followed by "Ineffective licensing & permitting regime" with 18.22%, "Political instability and Political interference" with 17.81%, "Lack of regulatory framework" with 16.11%, "Security instability" with 13.69% and the least important of all is "Unfavourable fiscal regime" with 13.54%. For this criterion, the full assessment of barriers by experts is given in the following figure 4.10.

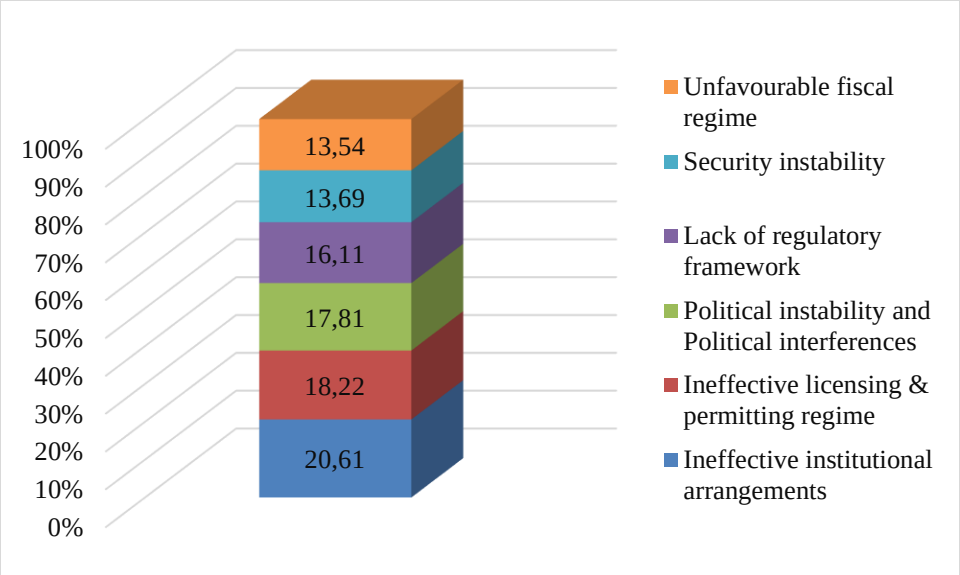


Figure 4. 10: Experts weights of importance for political & regulatory barriers

According to results shown above, there is not a big difference between political & regulatory barriers in that the former exceeds the latter by only 7%. One can say that all barriers have almost the same weight. Nevertheless, the institutional organization of the country does not facilitate the deployment of solar mini grids so far. The public administration is very slow in handling cases which would even be simple[24]. This explains why it is difficult to have a permit or license to operate in the field of solar energy also political interference facilitates some and blocks other investors. That's why these first three barriers are really the biggest in North Kivu. Provincial and national governments' ability to support the growth of the energy industry, especially through the introduction of clear laws on concessions for preserving operators' investments, will determine how quickly the private electricity sector develops. [25].

4.3.2 Economic & finance Category

In this criterion, the combined preferences of all experts demonstrated that “Access to finance” is The most important obstacle to the deployment of solar mini-grids with 57.06%. “Limited paying capacity” with 23.8% is the second one and the last one is “Lack of viable business models” with 19.14% with a consistency ration (C.R.) calculated as 0.0048. All these are presented in Figure 4.11 below.

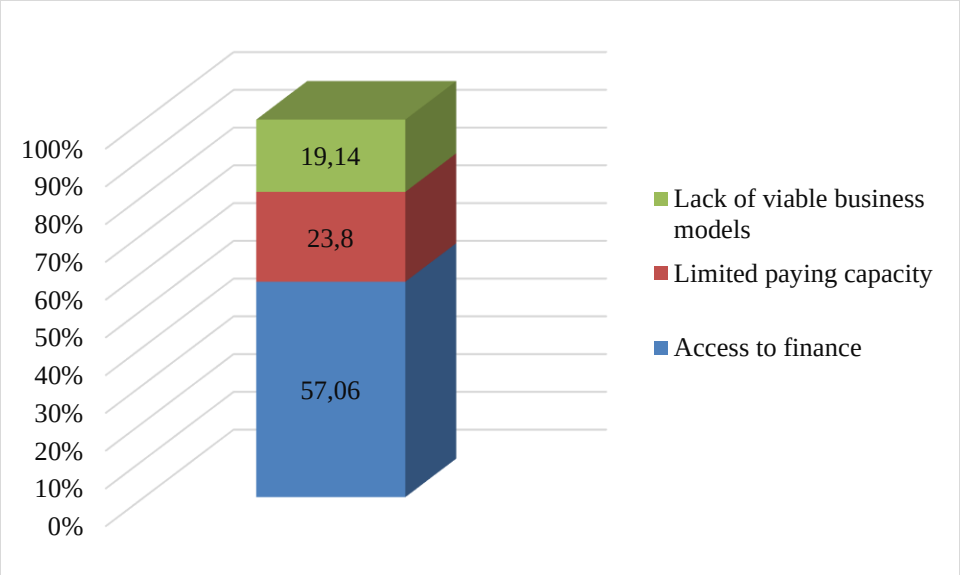


Figure 4. 11: Experts weights of importance for Economic & finance barriers

These results confirm once again that it is difficult to access local and international funding. As already rose in other studies done in other African countries[11]. Solar mini-grids are expansive projects. According to a Central Electricity Regulatory Commission of India (CERC) report, for solar PV plants in India, the capital cost per MW_p is anticipated to range between $500,000 and $600,000. This shown that finance is very important of start solar energy projects as, its capital cost is high. For loans from the commercial banking sector, private entrepreneurs in the DRC must struggle with extremely high charges and brief refund periods. The longest-term loans have a maximum maturity of one year, and interest rates are in the double digits. Consumers are the one to bear this high financial costs, slowing the growth of the energy access [25]. The second barrier is the limited paying capacity of customers as many of them are poor and in remotes areas, the cost of solar energy is still high [24].

4.3.3 Technical Category

As shown figure 4.12, the most important technical barrier to deployment of solar mini-grids with 44.76% is “technical support culture and Poor maintenance”. This is followed by “Lack of monitoring systems” (29.71%) and “Lack of validated resource data” (25.54%), with a consistency ration (C.R.) of 0.0015.

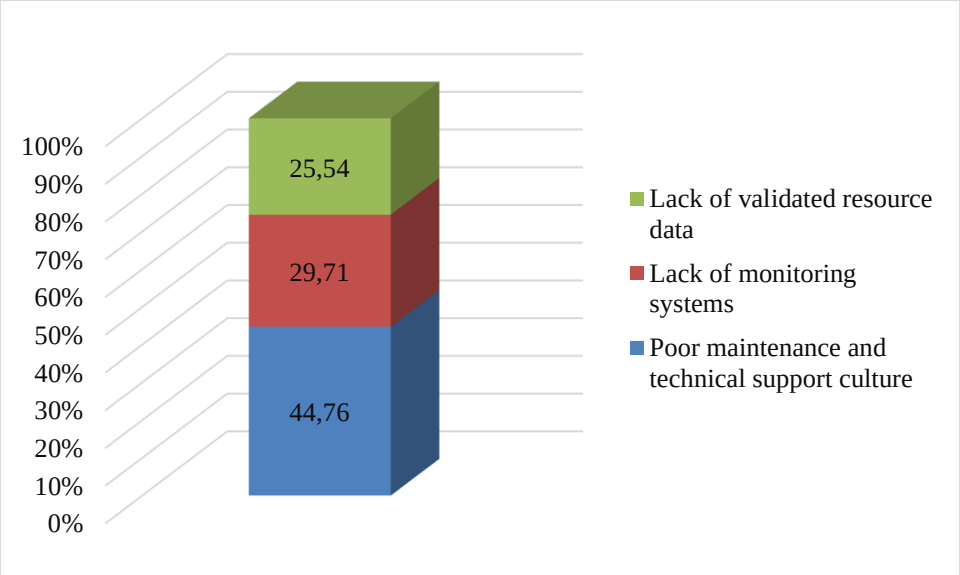


Figure 4. 12: Experts weights of importance for Technical barriers

Poor maintenance and technical support culture is the most crucial technical barrier to solar mini-grid deployment. Good maintenance is the basis for the durability of solar systems but also it increases the yield of solar systems unfortunately some companies are reluctant to pay the price. The second barrier is the lack of monitoring systems; It involves putting in place monitoring systems for demand management as well as problem detection systems. As solar systems can work without those monitoring systems, some companies consider it to be excessive spending especially in remote areas [26].

4.3.4 Socio-cultural Category

In this criterion, the combined preferences of all experts appointed the “Land disputes” as the most significant barrier to the solar mini-grids deployment with 37.24%. This is followed by “Lack of stakeholder coordination” (26.36%), “Limited political leverage in remote areas” (20.3%) and the “Inadequate community engagement” with 16.1%. These are well illustrated in the Figure 4.13 as following. Notice that the consistency ration (C.R.) was of 0.0058.

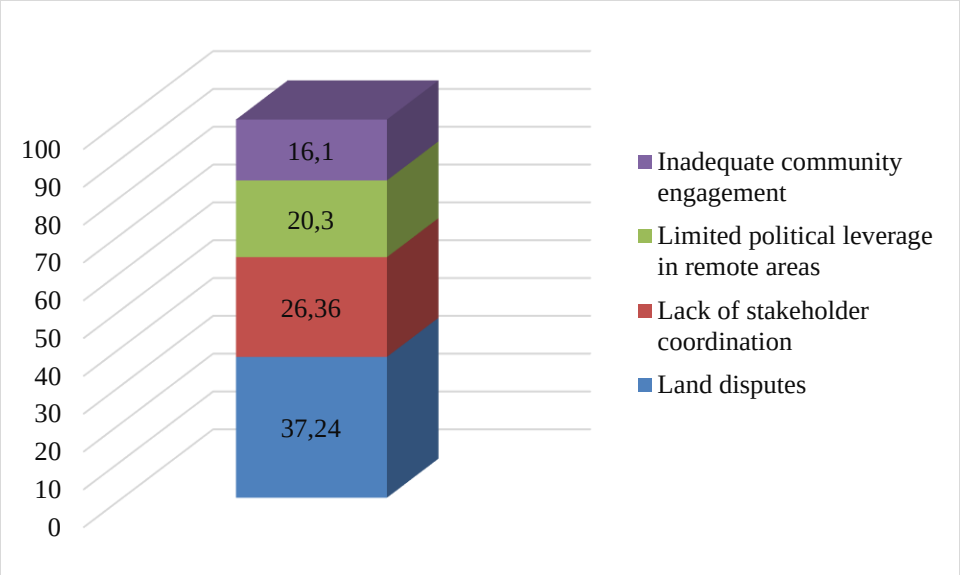


Figure 4. 13: Experts weights of importance for Socio-cultural barriers

Land disputes are very common in the province and many of cases are in court because of some landowners who sell lands to two or more different people, and other case is about strong men who snatch lands from the weak populations. It is in this context that solar companies also have to find big spaces for their solar parks. The stakeholder coordination, if it exists, would have the task of channeling the various demands and other important decisions to the authorities in order to find a solution. But if it does not exist, the decisions will not be unanimous and it will be difficult to find solutions for the advancement of the solar energy sector [27].

4.3.5 Environmental Category

The highest priority obstacle to the deployment of solar mini-grids, according to the synthesis of expert assessments in this criterion, is "Lack of acknowledgment of environmental benefits of renewable mini-grids," with a 68.05% score. With 31.95% of the vote, "Lack of programs for electronic waste management" comes in second. The following Figure 4.14 illustrates the comprehensive expert assessment of barriers for this criterion.

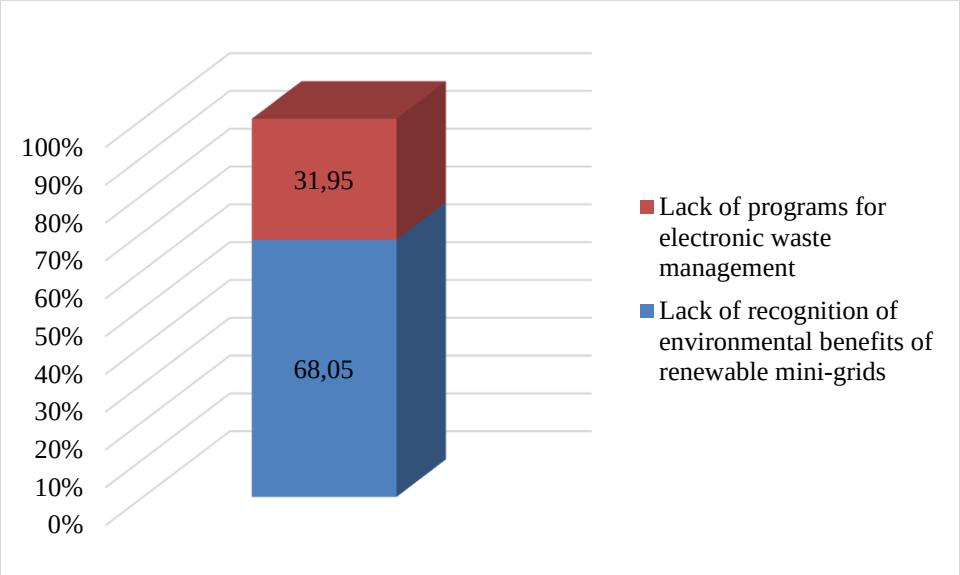


Figure 4. 14: Experts weights of importance for Environmental barriers

From this result, we can realize that many people in North Kivu ignore the environmental benefits of renewable solar mini-grids as they are living in a blessed regions speaking of environmental aspect. So some people would prefer to use fuel-powered generators if their energy is cheaper than the energy produced by solar mini-grids.

4.3.6 Conclusion

To conclude this study on prioritization of barriers in North Kivu, we found that “Ineffective institutional arrangements” is the most important political barrier to solar mini-grids deployment ; the “Access to finance” is the most crucial financial barrier; the most important technical barrier is “Poor maintenance and technical support culture”; the Socio-cultural one is the “Land disputes” etc. This prioritization could help our investor readers to know by what barriers to begin to improve in the energy sector in the DRC in general and in North Kivu in particular.

4.4 Results on identification of Prospects

The results' presentation and interpretation on the prospects for the solar mini-grids deployment in the province of North Kivu in the DRC, the case of the NURU mini-grid, are presented here. NURU sarl is an electricity company operating in the DRC and has a solar mini-grid with about 1600 clients until the day of the study. According to our calculations presented above, we found a sample of 310 customers, but taking into account other factors such as the limited time of the

program and insufficient finances, we were able to interview 168 customers or 54.19% of the sample. Given the limited time, part of the data analysis was done with SPSS and the histograms and sectors were done with Excel to facilitate the understanding and interpretation of the results for our readers.

4.4.1 General information of respondents

General details on the interviewees presented here allowed us to know the characteristics of our study population. The demographic data investigated shed light on the background of the respondents in four aspects, namely the son-in-law of the heads of households interviewed, their age groups, their education levels and their occupations.

A. Gender of the respondents

The distribution of the men and women interviewed is presented in Figure 4.15. In this figure, we see that men constituted 62% and women 38% of the sample considered. This result demonstrates that the viewpoints offered in this study have taken into account the gender representation of both men and women.

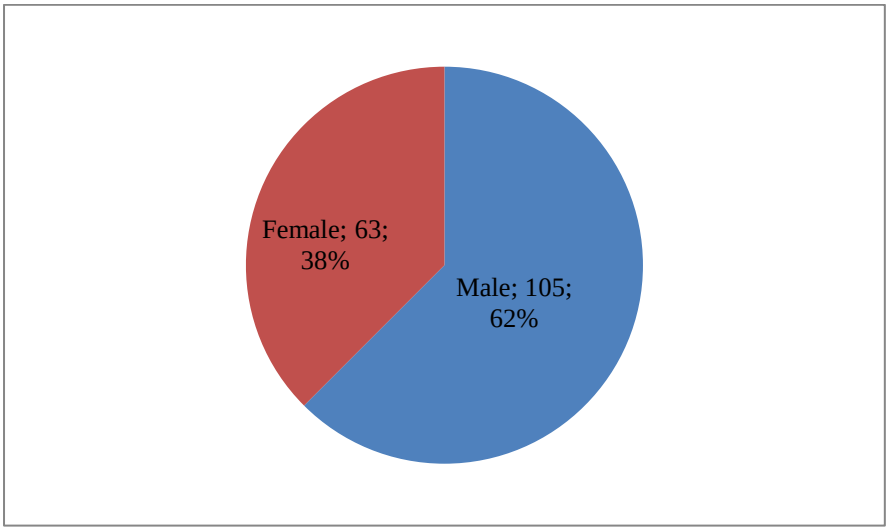


Figure 4. 15: Gender of the respondents

B. Age brackets of the respondents

According to Figure 4.16, the most of our interviewees, 41%, are between 26 and 35 years old, and 27% are between 36 and 45 years old, indicating that most of the parents interviewed are young and only a minority is over 46 years old. Thus, it can be said that the majority of our respondents are mature and experienced enough to participate effectively in this study by giving considered opinions. Also all age groups are represented and therefore we have been able to get different opinions from all age groups.

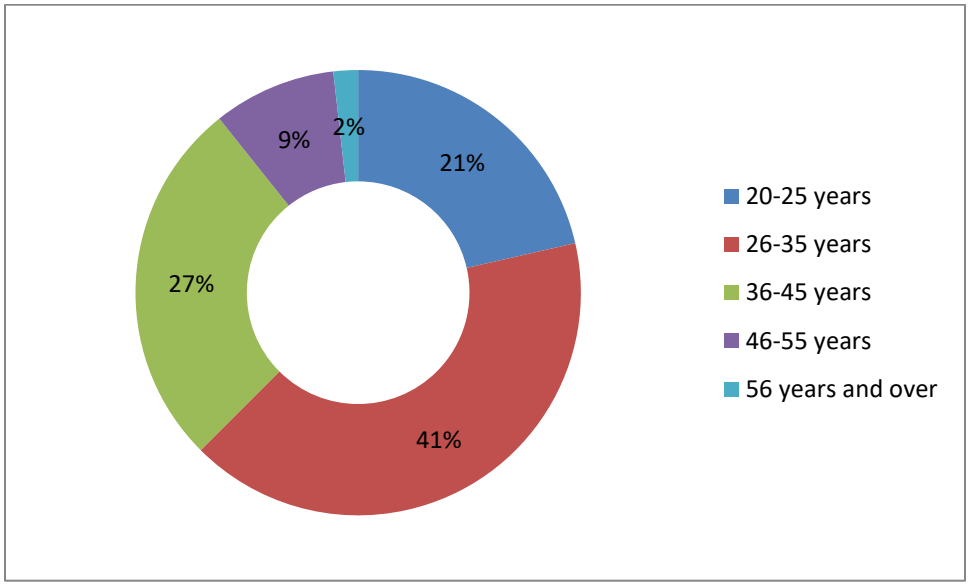


Figure 4. 16: Age range

C. Respondents Level of Education

The study gathered information from people with various educational backgrounds to see whether they were aware of the potential benefits of deploying solar mini grids in North Kivu, DRC. The study's findings were then displayed in Table 4.2.

Table 4. 2 Highest Level of education

Level of Education	Frequency	Percentage
Did not study	0	0.0
Primary school	21	12.5
Secondary School	63	37.5
Graduate level	81	48.2
Post graduate level	3	1.8
Total	168	100.0

According to the results shown in Table 4.2, we can see that 48.2% of our respondents have studied at university, 37.5% have attended and finished secondary school, these figures show us that the respondents are mostly intellectuals; only a minority of 12.5% has primary education. These findings indicate that the majority of interviewees had at least a postsecondary degree and so comprehended the data this study was looking for. These findings also show that all the respondents had the educational achievements and familiarity with the data the study was looking for.

D. Profession of respondents

As shown in Table 4.3, the most of our interviewees are made up of two groups: self-employed entrepreneurs (35.7) and employees of state or private enterprises (33.9%). This can be explained by the fact that we find several state institutions in the city of Goma, which is the capital of the province, but also many NGOs have offices in the city. Next come the traders who constitute 23.2%

Table 4. 3 Occupations of the responders

Professions	Frequency	Percentage
Trader	**39**	**23.2**
Employee	**57**	**33.9**
Entrepreneur	**60**	**35.7**
Housekeeper	**9**	**5.4**
Humanitarian	**3**	**1.8**
Total	**168**	**100.0**

These results show that the respondents have a minimum standard of living that can allow them to connect to the solar mini grid.

4.4.2 Use of electricity

In this section, we wanted to show the different uses made of the energy produced by the NURU solar mini grid. Thus, we asked the respondents to tick all the boxes corresponding to the appliances they connect to the mini grids and other uses they make of the electrical energy.

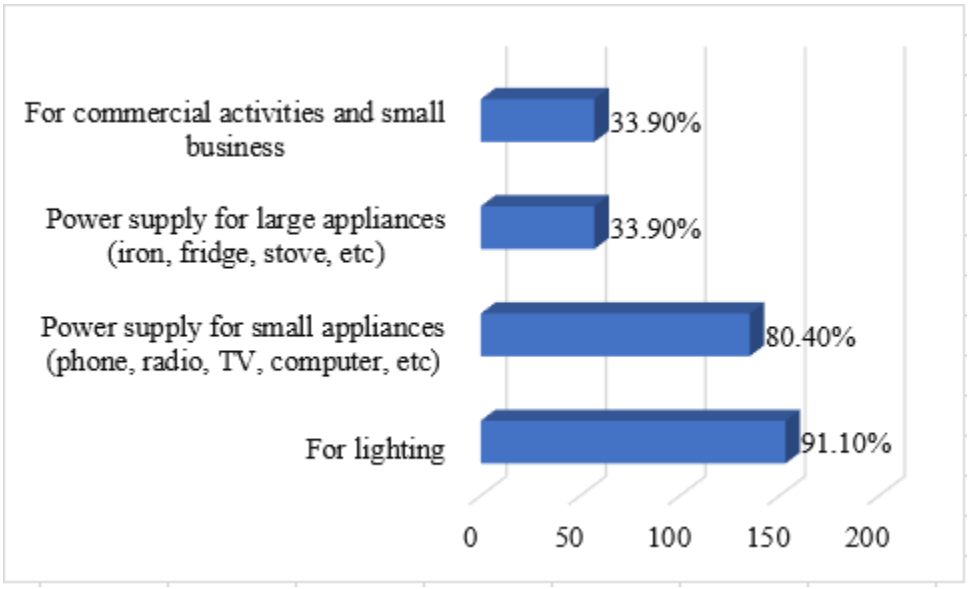


Figure 4. 17: potential loads of respondents

According to the results obtained and presented in Figure 4.17, 91.1% of respondents stated that they use energy from the mini grid for lighting needs, 80.4% of respondents admitted that they usually connect small appliances that do not consume much power such as television, telephones, computers, etc. 33.9% of the respondents said that they use appliances with high power consumption such as irons, fridges, stoves, etc. In addition, 33.9% of the respondents indicated that this energy helps them to run their small businesses such as mills, hairdressing salons, welding shops, dry cleaning, car washes, sewing shops, internet cafes, etc. as well as commercial activities.

In the light of these results, it can be understood that the energy of the NURU mini solar network meets a real need and contributes to the development of the community.

4.4.3 Quality, Regularity and Billing of electricity

The third section of the questionnaire was concerned with the evaluation of the quality and availability of energy supplied by NURU and the assessment of customer satisfaction with the price of energy. The aim was to see what proportion of NURU's energy was appreciated by the users. Customers were asked to evaluate these three aspects on a scale of 1 to 5 provided as 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree as shown in Figure 4.18 below.

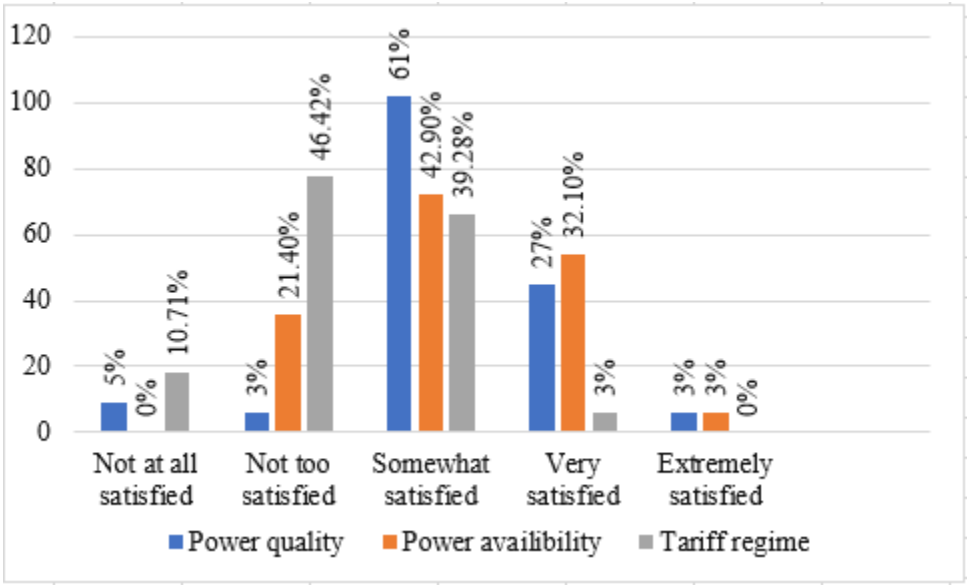


Figure 4. 18: Assessment of power quality, power availability and tariff regime

Regarding the quality of energy, 61% of the respondents remained neutral on the question, so it can be understood that they are moderately satisfied with the quality of energy provided by the NURU solar mini grid. 27% of the respondents said they were very satisfied with the quality of energy. Note that there were 5% of respondents who were not at all satisfied with the quality of energy. From our interviews, we found that some customers had machines that at some times the networks could not cope with. In general, we find that satisfaction is just a little above average.

Concerning the regularity of energy, 42.9% of the respondents are somewhat satisfied and 32.1% are very satisfied, these percentages sufficiently prove how positively the respondents' satisfaction is tending. But we cannot remain silent in front of the 21.4% who were not satisfied

with the regulation. This can be explained by the fact that during failures, it is difficult for NURU to satisfy everyone.

Speaking of energy pricing, 46.42% of the respondents were not satisfied at all, i.e. they found the energy expensive. And it is only 39.28% who are somewhat satisfied and so it is clear that the majority of respondents find NURU's energy expensive.

4.4.4 Consumers satisfaction

The last section of the questionnaire addressed three other issues. Firstly, on a scale of 1 to 5 provided as 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree, respondents were asked to establish their level of acceptance with the statement that: the use of NURU energy would have improved their quality of life. Secondly, if the services they have received so far meet their initial expectations about their energy supplier and thirdly, if Nuru solar mini grid is competitive with other energy suppliers in the region. The results are presented here below on Figure 4.19.

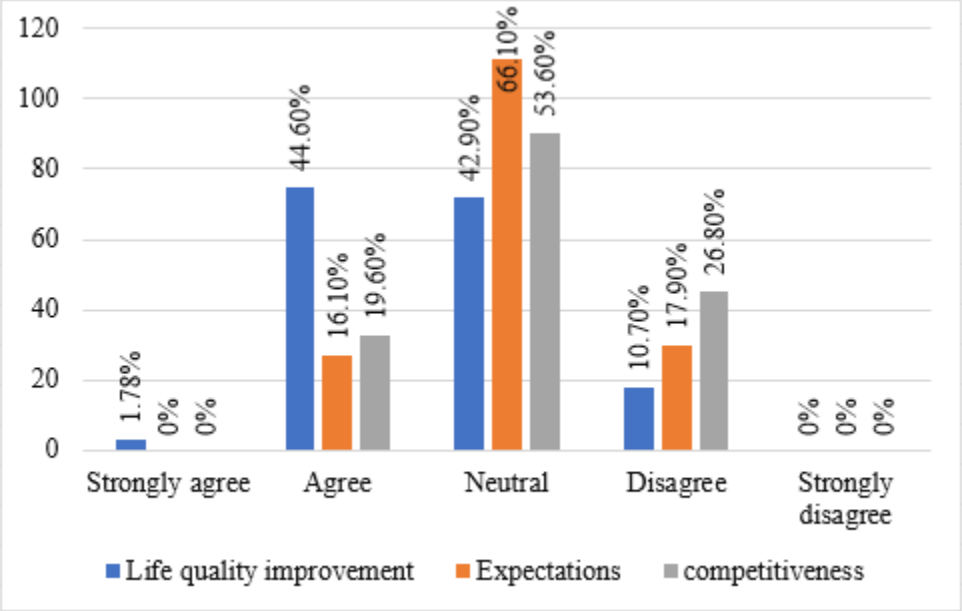


Figure 4. 19: Assessment of life quality improvement, expectations and competitiveness

From the study, the most of interviewees affirmed that the quality of their lives have been improved by the use of the solar mini-grid energy as shown by 44.6% of agreement and the neutrality of 42.9%.

On the other hand there was neutrality on that the expectations of respondents were met by the services provided by the solar min-grid as shown by the score of 66.1%.

About the competitiveness of the solar mini-grid with other hydro power plant which supplied power in the same city, we observed neutrality of 53.6% of respondents.

4.4.5 Conclusion

This study aimed to identify the prospects for solar mini grids deployment in North Kivu. We interviewed 168 NURU mini grid customers in the city of Goma. According to the results obtained, we can say that the energy supplied by the NURU solar mini grid is mainly used at more than 80% for lighting needs and to power household appliances that do not consume much energy. It is also used at 33.9% to power large appliances and small businesses. We also found that this energy is of moderately good quality and availability (over 50%). On the other hand, this energy was found to be expensive by more than 60% of respondents.

In terms of customer satisfaction, the results revealed that the use of Nuru's electricity has raised the clients' standard of living, the services obtained have met the expectations of more than 50% of the subscribers, and the subscribers think that the mini grid can be competitive.

CHAPTER FIVE

CONCLUSIONS AND RECOMMANDATIONS

5.1 Introduction

This chapter summarizes the entire studies and includes a list of the key conclusions, recommendations, and findings. The chapter aims to summarize and draw honorable conclusions from the study's objectives. As a result of the analysis in chapter four, the study's findings led to suggestions and conclusions. The chapter ends with suggestions for future investigations.

5.2 Summary of Findings

The first study was on identifying the barriers to the deployment of solar mini grids in North Kivu, Democratic Republic of the Congo. Thus, a questionnaire with 23 potential barriers was provided to the experts' expertise in order to gather information from 17 experts of 7 solar enterprises. Notably, 18 barriers were recognized and validated by at least 30% of experts as obstacles to the deployment of solar mini grids in North Kivu, DRC. Those barriers are listed below: Political instability and Political interference, Lack of regulatory framework, Ineffective licensing & permitting regime, Unfavourable fiscal regime, Ineffective institutional arrangements, Security instability, Access to finance, Lack of viable business models, Limited paying capacity, Lack of validated resource data, Poor maintenance and technical support culture, Lack of monitoring systems, Inadequate community engagement, Limited political leverage in remote areas, Lack of stakeholder coordination, Land disputes, Lack of programs for electronic waste management, and Lack of recognition of environmental benefits of renewable mini-grids.

The second study was focused on prioritization for the 18 barriers validated by experts in the previous study according to their categories. The results were obtained after processing the data by the "*SpiceLogic Analytic Hierarchy Process software*".

For the Political & regulatory Category, with the consistency ration (C.R.) of 0.0022, the combined preferences of all experts showed that "Ineffective institutional arrangements" is the most important barrier with 20.61%. This is followed by "Ineffective licensing & permitting regime" with 18.22%, "Political instability and Political interference" with 17.81%, "Lack of

regulatory framework" with 16.11%, "Security instability" with 13.69% and the least important of all is "Unfavourable fiscal regime" with 13.54%.

In the Economic & finance Category, the combined preferences of all experts demonstrated that "Access to finance" is the most significant barrier with 57.06%. "Limited paying capacity" with 23.8% is the second one and the last one is "Lack of viable business models" with 19.14% with a consistency ration (C.R.) calculated as 0.0048.

For the Technical Category, the most important technical barrier to deployment of solar mini-grids with 44.76% is "Poor maintenance and technical support culture". This is followed by "Lack of monitoring systems" (29.71%) and "Lack of validated resource data" (25.54%), with a consistency ration (C.R.) of 0.0015.

In the Socio-cultural Category, the combined preferences of all experts appointed the "Land disputes" as the most significant barrier with 37.24%. This is followed by "Lack of stakeholder coordination" (26.36%), "Limited political leverage in remote areas" (20.3%) and the "Inadequate community engagement" with 16.1%. These are well illustrated in the figure 4.13 as following. Notice that the consistency ration (C.R.) was of 0.0058.

For the Environmental Category, "Lack of recognition of environmental benefits of renewable mini-grids" is the top priority barrier with 68.05%. This is followed by "Lack of programs for electronic waste management" with 31.95%.

The last study aimed to identify the prospects for the deployment of solar mini grids in North Kivu. We interviewed 168 NURU solar mini grid customers in the city of Goma who constitute 54.1% of our sample. The study showed that the energy supplied by the NURU solar mini grid is mainly used at more than 80% for lighting needs and to power household appliances that do not consume much energy. In addition, 33.9% of respondents used to power large appliances and run their small businesses using NURU energy. The study established that this energy is of moderately good quality and availability (over 50%) and it is considered to be expensive by more than 60% of respondents.

Finally, the results revealed that the use of Nuru's electricity has raised the standard of living of the customers, the services obtained have met the expectations of more than 50% of the subscribers, and the subscribers think that the mini grid can be competitive.

5.3 Conclusions

At the end of this thesis, it is shown that the objectives have been achieved. In this study, the barriers to the deployment of solar mini-grids in North Kivu/DRC were examined in order to explore how solar mini-grids can be promoted to better participate in the electrification of the DRC. First, the most potent barriers to mini-grids deployment were identified and prioritized. Second, the assessment of prospects to solar mini-grids deployment in North-Kivu/DRC shown that solar energy sector is promising.

5.4 Recommendations

In the future, we hope that the Congolese government and investors will focus on the deployment of several solar mini grids in North Kivu and elsewhere in the DRC. Because we have shown that this energy has a good future perspective and is competitive with energy from other resources.

We recommend that the Congolese government to consider the possibility of tackling the political barriers rose in this work, as it is its duty to do so in order to facilitate the task of investors. It should discourage administrative burdens and facilitate access to exploitation permits in a fair manner. It should also look at mechanisms to facilitate investors' access to long-term loans and subsidies to enable them to stabilize and provide energy at an affordable price.

We recommend that investors promote regular maintenance of equipment and the installation of fault detection systems to ensure the smooth running of the mini grids and to avoid untimely outages that discredit them in the eyes of customers. We also recommend them to involve customers and new operators in the ACERD for participation of all as well as sensitize the population on the environmental benefits of solar mini grids.

The study suggests conducting additional research to delve thoroughly into this topic across the country and to perform a depth analysis of barriers identified.

APPENDIX A: QUESTIONNAIRE SURVEY (PHASE 1)

Dear Experts,

As part of our Master's thesis on "**Barriers and Prospects of Solar Mini-Grid Deployment in North-Kivu/DRC,** we would like to ask for your contribution by answering this questionnaire survey.

In the interests of confidentiality, we assure you that the data from this work will be used for research purposes only. Your responses will be anonymous, as our aim is to identify trends in responses. We thank you for your availability.

I. Identification of the respondent

- Gender: Male ☐ Female ☐
- Level of education: Bachelor's degree ☐ Postgraduate ☐
- Company you work for: .....
- Working Experience: 0-2years ☐ 3-4years ☐ 5 and over ☐

II. Questionnaire itself

In this part, you have to tick all the boxes of the barriers that you recognize as being part of the barriers to the deployment of solar mini grid in North-Kivu/DRC and to add others barriers that you consider missing to the list according to categories below.

A. Political & regulatory Category

☐ Political instability and Political interference

☐ Lack of regulatory framework

☐ Ineffective licensing & permitting regime

☐ Unattractive tariff regime

☐ Unfavourable fiscal regime

☐ Ineffective institutional arrangements

☐ Security instability

Others: ……

……

B. Economic & finance Category

☐ Access to finance

☐ Currency and inflation risk

☐ Lack of viable business models

☐ Limited paying capacity

Others: ……

……

C. Technical Category

☐ Lack of validated resource data

☐ Poor maintenance and technical support culture

☐ Lack of monitoring systems

☐ Low productive use

Others: ……

……

D. Socio-cultural Category

☐ Inadequate community engagement

☐ Limited political leverage in remote areas

☐ Lack of stakeholder coordination

☐ Land disputes

☐ Ethnic/language difference

Others: ……

……

E. Environmental Category

☐ Lack of programs for electronic waste management

☐ Use of mini-grids to power environmentally detrimental activities

☐ Lack of recognition of environmental benefits of renewable mini-grids

Others: ……

……

Thanks

APPENDIX B: QUESTIONNAIRE SURVEY (PHASE 2)

Dear Experts,

As part of our Master's thesis on "**Barriers and Prospects of Solar Mini-Grids Deployment in North-Kivu/DRC,** we would like to ask for your contribution by answering this questionnaire survey.

In the interests of confidentiality, we assure you that the data from this work will be used for research purposes only. Your responses will be anonymous, as our aim is to identify trends in responses. We thank you for your availability.

I. Identification of the respondent

- Gender: Male☐ Female☐
- Level of education: Bachelor's degree☐ Postgraduate ☐
- Company you work for: .....
- Working Experience: 0-2years ☐ 3-4years☐ 5 and over ☐

II. Questionnaire itself

In this part, you have to make a pairwise comparison of barriers in the same category where they are scored using the importance scale as following: 1. Equal importance, 3. Moderate importance, 5. Strong importance, 7. Very strong importance, 9. Extreme importance.

A. Political & regulatory Category

	9	7	5	3	1	3	5	7	9	
Political instability and Political interference										Security instability
Political instability and Political interference										Unfavourable fiscal regime
Political instability and Political interference										Ineffective institutional arrangements
Political instability and Political interference										Lack of regulatory framework
Political instability and Political interference										Ineffective licensing & permitting regime
Security instability										Unfavourable fiscal regime
Security instability										Ineffective institutional arrangements
Security instability										Lack of regulatory framework

Security instability										Ineffective licensing & permitting regime
Unfavourable fiscal regime										Ineffective institutional arrangements
Unfavourable fiscal regime										Lack of regulatory framework
Unfavourable fiscal regime										Ineffective licensing & permitting regime
Ineffective institutional arrangements										Lack of regulatory framework
Ineffective institutional arrangements										Ineffective licensing & permitting regime
Lack of regulatory framework										Ineffective licensing & permitting regime

B. Economic & finance Category

	9	7	5	3	1	3	5	7	9	
Access to finance										Lack of viable business models
Access to finance										Limited paying capacity
Lack of viable business models										Limited paying capacity

C. Technical Category

	9	7	5	3	1	3	5	7	9	
Poor maintenance and technical support culture										Lack of validated resource data
Poor maintenance and technical support culture										Lack of monitoring systems
Lack of validated resource data										Lack of monitoring systems

D. Socio-cultural Category

	9	7	5	3	1	3	5	7	9	
Limited political leverage in remote areas										Inadequate community engagement
Limited political leverage in remote areas										Lack of stakeholder coordination
Limited political leverage in remote areas										Land disputes
Inadequate community engagement										Lack of stakeholder coordination
Inadequate community engagement										Land disputes
Lack of stakeholder coordination										Land disputes

E. Environmental Category

	9	7	5	3	1	3	5	7	9	
Lack of programs for electronic waste management										Lack of recognition of environmental benefits of renewable mini-grids

Thanks

APPENDIX C: QUESTIONNAIRE SURVEY (PHASE 3)

Madam, Sir

In the realization of our master's thesis which is entitled "**Barriers and Prospects of Solar Mini-Grids Deployment in North-Kivu/DRC,** we solicit your availability in order to contribute to the accomplishment of this research by answering freely to this questionnaire which concern particularly customers of Nuru solar mini grids in the city of Goma.

While reassuring you that the answers you give will be used only for scientific purposes and guaranteeing you discretion, please accept, Sir, Madam, our sincere thanks in advance.

I. Identification of the respondent

- Gender: Male☐ Female☐
- How old are you? 20-25years☐ 26-35years☐ 36-45years☐
  46-55years ☐ 56 and over ☐
- What is your level of education?
  a. Did not go to school☐ b. Primary☐ c. Secondary ☐
  c. Bachelor's degree ☐ d. Postgraduate ☐
- What is your profession?
  a. Trader☐ b. Employee☐ c. Entrepreneur ☐
  d. Other: ……

II. Theme 1: Use of electricity

Q1. What uses do you have for electrical energy?

a. For lighting ☐

b. Power supply for small appliances (phone, radio, TV, computer, etc) ☐

c. Power supply for large appliances (iron, fridge, stove, etc) ☐

d. For commercial activities and small industry ☐

e. Other: ……

II. Theme 2: Power Quality, Power availability and Tariff regime

Q2. At which level are you satisfied by the quality of the energy supplied by Nuru solar mini grid?

1. Not at all satisfied☐ 2. Not too satisfied☐ 3. Somewhat satisfied☐
4. Very satisfied☐ 5. Extremely satisfied ☐

Q2. At which level are you satisfied by the power availability of the energy supplied by Nuru solar mini grid?

1. Not at all satisfied ☐ 2. Not too satisfied ☐ 3. Somewhat satisfied ☐
4. Very satisfied ☐ 5. Extremely satisfied ☐

Q3. At which level are you satisfied by tariff regime of the energy supplied by Nuru solar mini grid?

1. Not at all satisfied ☐ 2. Not too satisfied ☐ 3. Somewhat satisfied ☐
4. Very satisfied ☐ 5. Extremely satisfied ☐

III. Theme 3: Consumer Satisfaction

Q5. What is your level of agreement with this statement: Using Nuru energy improved your quality of life.

1. Strongly Disagree ☐
2. Disagree ☐
3. Neutral ☐
4. Agree ☐
5. Strongly agree ☐

Q6. What is your level of agreement with this statement: the services you have received so far meet your initial expectations about of your energy supplier.

1. Strongly Disagree ☐
2. Disagree ☐
3. Neutral ☐
4. Agree ☐
5. Strongly agree ☐

Q7. What is your level of agreement with this statement: Nuru solar mini grid is competitive with competition.

1. Strongly Disagree ☐
2. Disagree ☐
3. Neutral ☐
4. Agree ☐
5. Strongly agree ☐

Thanks!

APPENDIX D: BARRIERS OF SOLAR MINI GRIDS DEPLOYMENT IN NORTH KIVU/RDC

Categories and barriers	Descriptions
Political& regulatory	
Political instability and Political interference,	Obstacle arising from political manipulation when dealing with energy-related issues
Lack of regulatory framework,	barrier due to lack of regulation for solar mini grids
Ineffective licensing & permitting regime,	Obstacle resulting from unnecessary bureaucracy in the public administration when providing permits and licenses for mini-grids.
Unfavourable fiscal regime,	Difficulties related to unfavourable fiscal measures (VAT, import duties, corporate tax, etc.) for solar mini-grids
Ineffective institutional arrangements,	Difficulties arising from unimportant bureaucracies and duplication of functions by the relevant sectoral agencies
Security instability.	Difficulties related to the inaccessibility of certain areas due to armed rebel groups
Economic & finance	
Access to finance,	Barrier related to the difficulty of obtaining access to funds (debt and equity) at national and international level.
Lack of viable business models,	Barrier resulting from the lack of viable business models for solar mini-grids.
Limited paying capacity.	Obstacle related to the inability of end-users to purchase the necessary energy on a regular basis.
Technical	
Lack of validated resource data,	Obstacle related to the lack of viable data on the different sites to be operated.
Poor maintenance and technical support culture,	Obstacle linked to Poor maintenance culture leading to untimely outages.
Lack of monitoring systems,	Barrier related to the inability to remotely monitor and detect system failures in order to proactively repair and avoid interruptions, as well as to monitor systems for demand-side management purposes.
Socio-cultural	
Inadequate community engagement,	Barrier resulting from limited understanding of consumer needs and budgets for sustainability of solar mini-grids.
Limited political leverage in remote areas,	Barrier resulting from lack of interest of political leaders in local populations in remote areas.
Lack of stakeholder coordination,	Barrier due to lack of coordination of the different actors in the sector
Land disputes,	Obstacle resulting from the difficulty of having a large plot of land without resistance or

	incomprehension between owners
Environmental Lack of programs for electronic waste management, Lack of recognition of environmental benefits of renewable mini-grids	Barrier related to inappropriate disposal of e-waste from batteries, solar models, etc. of solar mini-grids. Barrier of not considering the environmental benefits of solar mini-grids.

REFERENCES

[1] R. M. Elavarasan, G. M. Shafiullah, N. M. Kumar, and S. Padmanaban, "A state-of-the-art review on the drive of renewables in Gujarat, State of India: Present situation, barriers and future initiatives," *Energies*, vol. 13, no. 1, Dec. 2019, doi: 10.3390/en13010040.

[2] L. Cozzi *et al.*, "World Energy Outlook 2020," 2020. [Online]. Available: https://www.oecd-ilibrary.org/energy/world-energy-outlook-2020_557a761b-en

[3] IEA;IRENA;UNSD;WB;WHO, "TRACKING SDG7 : The Energy Progress Report 2021," Washington DC,USA, 2021. [Online]. Available: www.worldbank.org

[4] ANAPI, *Cahier Sectoriel: INVESTIR DANS LE SOUS-SECTEUR DE L'ELECTRICITE*, Mediaspaul. Kinshasa, 2020. [Online]. Available: www.investindrc.cd

[5] IEA;IRENA;UNSD;WB;WHO, "TRACKING SDG7: The Emergy Progress Report," pp. 1–176, 2019.

[6] K. Kusakana, "A Review of Energy in the Democratic Republic of Congo," *Conf. ICDRE*, vol. 10, no. 6, pp. 1–11, 2016, [Online]. Available: https://www.researchgate.net/profile/Kanzumba-Kusakana/publication/306380971_A_Review_of_Energy_in_the_Democratic_Republic_of_Congo/links/57bc3edf08ae9fdf82f14b35/A-Review-of-Energy-in-the-Democratic-Republic-of-Congo.pdf

[7] P. Yadav, P. J. Davies, and S. A. Sarkodie, "The prospects of decentralised solar energy home systems in rural communities: User experience, determinants, and impact of free solar power on the energy poverty cycle," *Energy Strateg. Rev.*, vol. 26, 2019, doi: 10.1016/j.esr.2019.100424.

[8] IRENA, *Renewable capacity statistics 2019*. Abu Dhabi, 2019. [Online]. Available: https://www.irena.org/publications/2019/Mar/Renewable-Capacity-Statistics-2019

[9] ANSER, "Plans locaux d'electrification approche 145 territoires horizon 2021-2030," *ANSER*, 2022. https://www.anser.gouv.cd/Bibliotheque.php

[10] J. Peters, M. Sievert, and M. A. Toman, "Rural electrification through mini-grids: Challenges ahead," *Energy Policy*, vol. 132, pp. 27–31, Sep. 2019, doi: 10.1016/j.enpol.2019.05.016.

[11] D. Bukari, F. Kemausuor, D. A. Quansah, and M. S. Adaramola, "Towards accelerating the deployment of decentralised renewable energy mini-grids in Ghana: Review and analysis of barriers," *Renew. Sustain. Energy Rev.*, vol. 135, no. November 2019, 2021, doi: 10.1016/j.rser.2020.110408.

[12] V. Gambino, R. Del Citto, P. Cherubini, C. Tacconelli, A. Micangeli, and R. Giglioli, "Methodology for the energy need assessment to effectively design and deploy mini-grids for rural electrification," *Energies*, vol. 12, no. 3, pp. 1–27, 2019, doi: 10.3390/en12030574.

[13] J. T. Nuru, “Assessing Benefits and Barriers to Deployment of Solar Mini Grids in Ghanaian Rural Island Communities,” Antioch University New England, 2020.

[14] M. Numata, M. Sugiyama, and G. Mogi, “Barrier analysis for the deployment of renewable-based mini-grids in Myanmar using the analytic hierarchy process (AHP),” *Energies*, vol. 16, no. 3, 2020, doi: 10.3390/en13061400.

[15] USAID and Power Africa, “Off-Grid Solar Market Assessment of Democratic Republic of the Congo,” 2019.

[16] USAID, “DRC POWER SECTOR REFORM PROJECT,” 2019.

[17] C. R. KOTHARI, *Research methodology : methods and techniques*. New Delhi: New Age International, 2004.

[18] J. P. Painuly, “Barriers to renewable energy penetration; a framework for analysis,” *Renew. Energy*, vol. 24, pp. 73–89, 2001.

[19] G. Odhiambo Ponde, E. NSM Kahiu, R. Kinyua, and C. Author, “Factors Affecting Sustainability of Mini-Grid Energy in Kenyan Rural Areas: A Case of KISII County,” *IOSR J. Environ. Sci.*, vol. 13, no. 3, pp. 19–61, 2019, doi: 10.9790/2402-1303011961.

[20] D. Bhattacharyya, S.C.; Palit, *Mini-Grids for Rural Electrification of Developing Countries: Technical Aspects of Mini-Grids for Rural Electrification*, 1st ed. Berlin, Germany: Springer Cham, 2014. doi: https://doi.org/10.1007/978-3-319-04816-1.

[21] Saaty, T.L, “How to make a decision: The analytic hierarchy process.” Eur. J. Oper. Res, pp. 74, 426–447, 1994.

[22] Saaty, T.L.; Kearns and K.P, “Analytical Planning,The Organization of System.” Pergamon Press, New York, NY, USA, 1985.

[23] A. R. Keeley and K. Matsumoto, “Relative significance of determinants of foreign direct investment in wind and solar energy in developing countries – AHP analysis,” *Energy Policy*, vol. 123, pp. 337–348, 2018.

[24] N. S. Ouedraogo, “Opportunities, Barriers and Issues with Renewable Energy Development in Africa: a Comprehensible Review,” *Curr. Sustain. Energy Reports*, vol. 6, no. 2, pp. 52–60, 2019, doi: 10.1007/s40518-019-00130-7.

[25] World Bank, “Increasing Access to Electricity in the Democratic Republic of Congo,” *World Bank*, p. 88, 2020, doi: 10.1596/33593.

[26] D. Akinyele, J. Belikov, and Y. Levron, “Challenges of microgrids in remote communities: A STEEP model application,” *Energies*, vol. 11, no. 2, pp. 1–35, 2018, doi: 10.3390/en11020432.

[27] A. Eales and B. Unyolo, “Renewable energy mini-grids in Malawi : status, barriers and opportunities,” 2018, [Online]. Available: https://pure.strath.ac.uk/ws/portalfiles/portal/82159440/

Eales_Unyolo_2018_Renewable_Energy_Mini_grids_in_Malawi.pdf.