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Presented by

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TITLE: WATER-ENERGY-FOOD NEXUS RESEARCH: ASSESSMENT OF HOUSEHOLD INDICATORS IN DRC

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By my signature below, I, **Douswe Gamaidandi,** declare that this thesis is my work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis and completion of this thesis. I have given all the scientific material recognition through accurate citations and references. I affirm that I have cited and referenced all sources used in this paper. I have made every effort to avoid plagiarism.

I am submitting this document in partial fulfilment of the requirements for a degree from Pan African University and declare that I have not submitted this document to any other institution for the award of an academic degree, diploma or certificate

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DEDICATION

I dedicate this work to the **GAMAIDANDI family**, in particular to my deceased father **Gamaidandi Tokne**, my mother **Akefter Abkréo** and my elder brother **Pahlé Gamaidandi**, without forgetting the other members of the large family and the friends who supported me throughout my studies.

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Abstract

The DRC is one of the top 20 countries in the world in terms of energy deficiency, with only 19% of the population having access to electrification while access to clean cooking solutions is only 4% nationally. Already **characterized** by high levels of social vulnerability, including food insecurity, high levels of poverty, undernourishment and very low levels of access to clean water, climate projections suggest that extreme events will become more frequent in parts of the DRC, potentially worsening the situation.

The present work in a Nexus approach focuses on the assessment of household indicators with regard to access to water, energy and food in the DRC. The study mobilised and adapted tools such as the ESMAP Multi-tier framework, the United Nations Joint Monitoring Programme (JMP) Framework for Measuring Access to Water and Sanitation and the Food and Agriculture Organization of the United Nations (FAO) Food Insecurity Experiences Scale (FIES) to conduct an in-depth assessment of access to water, energy and food in the Mwenga Territory of South Kivu in eastern DRC. The core of the work was a household survey, which captured the reality of access to water, energy and food in Mwenga, which is characterised by almost no access to adequate electricity, limited access to improved water sources and severe food insecurity.

Keys words: Water-Energy-Food Nexus, Water access, Access to clean water, Multi-Tier Framework, Electricity access, cooking solution, Food security, Food insecurity.

Résumé

La RDC est l'un des 20 premiers pays au monde en termes de carence énergétique, avec seulement 19% de la population ayant accès à l'électrification, tandis que l'accès à des solutions de cuisson propres n'est que de 4% au niveau national. Déjà caractérisée par des niveaux élevés de vulnérabilité sociale, y compris l'insécurité alimentaire, des niveaux élevés de pauvreté, la sous-alimentation et des niveaux très bas d'accès à l'eau potable, les projections climatiques suggèrent que les événements extrêmes deviendront plus fréquents dans certaines parties de la RDC, aggravant potentiellement la situation.

Le présent travail, dans une approche Nexus, se concentre sur l'évaluation des indicateurs des ménages en matière d'accès à l'eau, à l'énergie et à la nourriture en RDC. L'étude a mobilisé et adapté des outils tels que le cadre multi-niveaux d'ESMAP, le cadre de mesure de l'accès à l'eau et à l'assainissement du Programme commun de surveillance des Nations Unies (JMP) et l'échelle d'expérience de l'insécurité alimentaire (FIES) de l'Organisation des Nations Unies pour l'alimentation et l'agriculture (FAO), afin de réaliser une évaluation approfondie de l'accès à l'eau, à l'énergie et à la nourriture dans le territoire de Mwenga, au Sud-Kivu, dans l'est de la RDC. L'essentiel du travail a consisté en une enquête auprès des ménages, qui a permis de saisir la réalité de l'accès à l'eau, à l'énergie et à la nourriture sur le territoire de Mwenga, qui se caractérise par un accès quasi nul à une électricité suffisante, un accès sommaire à des sources d'eau améliorées et une grave insécurité alimentaire.

Mots clefs : Nexus Eau-Energie-Alimentation, Accès à l'eau, Accès à l'eau potable, Cadre multi-niveaux, Accès à l'électricité, Solution de cuisson, Sécurité alimentaire, Insécurité alimentaire.

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ABBREVIATIONS AND ACRONYMS

IRENA	International Renewable Energy Agency
USAID	United States Agency for International Development
DRC	Democratic Republic of Congo
ESMAP	Energy Sector Management Assistance Program
WASH	Water, Sanitation and Hygiene
WEFN	Water-Energy-Food Nexus
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
SEI	Stockholm Environment Institute
ARCOS	the Albertine Rift Conservation Society
FAO	Food and Agriculture Organization
SADC	Southern African Development Community
CDC	Centers for Disease Control and Prevention
JMP	Joint Monitoring Programme
WHO	World Health Organization
UNICEF	United Nations Children's Fund
SDG	Sustainable Development Goals
JPM	Joint Monitoring Programme
FIES	Food Insecurity Experience Scale
SHS	solar home system
MTF	Multi-Level Framework
PMURR	Projet Multisectoriel d'Urgence de Réhabilitation et de Reconstruction
EIA	Energy Information Administration
CGEA	Commissariat Général à l'Energie Atomique
IAEA	International Atomic Energy Agency
SNEL	Société nationale d'électricité
EDC	Electricité du Congo
NEPAD	New Partnership for Africa's Development
SAPP	Southern African Power Pool
PNUD	Programme des Nations unies pour le développement
GDP	Gross domestic product
QUIBB	Enquête avec questionnaire unifié à indicateurs de base de bien être
CDF	Congolese franc
IPC	Integrated Food Security Phase Classification
CSC	Climate Service Center
AMCOW	African Ministers' Council on Water
DSCRP	DRC's Growth and Poverty Reduction Strategies
CNAEA	DRC's National Water and Sanitation Committee

REGIDESO	Régie de distribution d'eau
UWS	Urban Water Supply
SNHR	National Rural Hydraulics Service
MEDD	Ministère de l'Environnement et Développement Durable
DRE	Directorate of Water Resources
MRHE	Ministère des Ressources Hydrauliques et Electricité
PNSPE	Politique Nationale du Service Public de l'Eau
MECNT	Ministry of Environment, Nature Conservation and Tourism
FONEL	National Electrification Fund
AGENA	National Electrification Agency
CNE	National Energy Commission
CATE	Cellule d'Appui Technique à l'Energie
MDR	Ministry of Rural Development
SENEN	National Service for New Energies
ECCAS	Economic Community of Central African States
PEAC	Central African Power Pool
CEPGL	Economic Community of the Great Lakes Countries
EGL	Energy of the Great Lakes Countries
CICOS	International Commission of the Congo-Oubangui-Sangha Basin
MERH	Ministry of Energy and Hydraulic Resources
INERA	National Institute for Agricultural Studies and Research
NAP	National Action Plan
PNSAN	National Food and Nutritional Security Policy
SSADR	Sectoral Strategy for Agriculture and Rural Development
MINAGRI	Ministère de l'Agriculture
NAIP	National Agricultural Investment Plan
PNIA	National Agricultural Investment Programme

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General introduction

1.1 Background

The United Nations Sustainable Development Goals (SDGs) condense the main challenges facing human society into 17 Sustainable Development Goals and 169 associated goals that are integrated and indivisible (Johnston 2016), with the core of these goals being the basic human needs of energy, water and food. Ambitious targets for 2030 have been set by the United Nations in each of these areas. The challenge is particularly great as the world's population continues to grow and is expected to reach 8.5 billion by 2030. More than half of the projected world population growth between 2017 and 2050 is expected to occur in Africa. Of the 2.2 billion additional people that could be added between 2017 and 2050, 1.3 billion will be in Africa (United Nations, Department of Economic and Social Affairs 2017). Furthermore, half of the world's population growth is expected to be concentrated in only nine countries, of which five (5) are on the African continent: India, Nigeria, the Democratic Republic of Congo, Pakistan, Ethiopia, the United Republic of Tanzania, the United States of America, Uganda and Indonesia (United Nations, Department of Economic and Social Affairs 2017).

This rapid increase in world population will logically have an impact on global demand for water, energy and food, and it is estimated that by 2050 global energy demand will almost double, while demand for water and food is projected to increase by more than 50% (IRENA 2015). Meeting this increase in demand is therefore a considerable challenge, given the competing needs for limited resources in a context of worsening climate change impacts. According to (IRENA 2015) in order to overcome the growing constraints, the world is facing, it is necessary to substantially rethink the way it is produced and consumed energy in relation to the water and food demand. Meeting this requirement is challenging by the fact that these three resources are strongly intertwined (Schlör, Venghaus, and Hake 2018). Their interactions are called the energy-water-food nexus (EWF) (Bieber et al. 2018).

This research will focus on the question on how to identify, track and monitor the needs of these interrelated areas at household level.

1.2 Basic concepts

- **Energy access:** The ability of the end user to utilize energy supply that is usable for the desired energy services. Improvement in energy access is achieved through enhancement of the usability of the energy supply with improvement in attributes. Energy access can be defined either inclusive or exclusive of use of appliances. When defined inclusive of appliances, it is called access to energy services, and when defined exclusive of appliances, it is called access to energy supply.
- **Energy poverty:** The state of being deprived of certain energy services or not being able to use them in a healthy, convenient, and efficient manner, resulting in a level of energy consumption that is insufficient to support social and economic development. Although energy poverty can be measured using binary indicators (by specifying a minimum package of energy services or minimum amount of energy use), it is in reality a continuous variable encompassing deprivation on a range of energy services.
- **Energy services:** Amenities that are delivered through the use of energy when converted into light, sound, heat (or cold), motion, signal, etc. Energy services encompass lighting, cooking, air circulation, refrigeration, air conditioning, heating, communication, entertainment, computation, motive power, etc.
- **Energy supply:** The provision of energy regardless of the availability of end-use equipment.
- **Food Access:** Determined among consumers by the spatial accessibility and affordability of food retailers - in particular factors such as travel time to shop, availability of healthy foods and food prices - in relation to transport access and the socio-economic resources of food shoppers.
- **Food Security:** "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life. Commonly, the concept of food security is defined as including both physical and economic access to food that meets people's dietary needs as well as their food preferences"(FAO 1996).
- **Water access:** is defined as having a source of safe water within 1 kilometre of the dwelling (Jamie Bartram 2010).

1.3 Problem statement and motivation of the study

According to USAID, regions of the DRC are already characterized by significant social vulnerability, including food insecurity, high levels of poverty and undernourishment. Dependence on rain-fed agriculture dominates and current climate variability is already having a negative impact on crop productivity through flooding, erosion and heavy rains. Rising temperatures and increased rainfall are changing the distribution and range of insect pests, weeds and pathogens and damaging already limited transport networks. Climate projections suggest that these extreme events will become more frequent in the target regions. Investments in these regions will therefore need to be adapted to these changing conditions in order to reduce the risks posed by climate variability and change (USAID 2017).

The Democratic Republic of Congo (DRC) has one of the lowest rates of electrification and energy consumption in the world. Those who do have access often face erratic and irregular supply service. Most are powered by diesel generators that they use themselves or that belong to their neighbours, an expensive, high-maintenance, unreliable and unclean source of energy (seforall 2019). With only 19% (ESMAP 2018) of the population having access to electrification while access to clean cooking solutions is nationally only 4% (SEforALL 2021), the DRC is one of the top 20 energy-deficient countries in the world (ESMAP 2020). According to Tracking SDG7: The Energy Progress Report 2018 (World Bank 2018) many households and businesses are too far away to be connected to an adequate power supply. The energy infrastructure needed to provide the power facility is often dilapidated and poorly managed. There is also a lack of local technical capacity and training opportunities to support a growing renewable energy sector. The country has an estimated unmet energy demand of 2,929 megawatts (MW). Despite this energy deficiency, the DRC has the capacity to generate an estimated 70 gigawatts (GW) of power from solar photovoltaic systems. Off-grid solar power has a potentially huge role to play in providing energy to communities (seforall 2019).

The challenge is to measure the relevance in the local context of the standard indicators for energy, water, sanitation and hygiene (WASH) and food security in order to facilitate progress towards these three basic needs through the water-energy-food nexus approach.

1.4 Objectives

1.4.1 Main objective

The main objective of this work is to understand the relevance and dependence of impact indicators for energy access, water access (WASH), and food security.

1.4.2 Specific objectives

- Overview recent policies addressing the nexus in the considered area
- Perform household and community interviews (in partnership with local HEDERA partners)
- Statistical analysis of the results taking into account social and demographics variables

1.5 Research questions

- What is the relevance in the local context of standard frameworks for WASH, Energy, Food?
- What are the challenges of implementing these frameworks in local contexts?
- What is the current level of access in the considered region? Is it possible to relate the results with vulnerability indices (e.g., climate change)?
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1.6 Scope of the study

The scope of the thesis is to analyse the relevance of modern indicators for the three areas (access to clean water, access to energy, food security) at the household and community level in Eastern DRC, combining household interviews, community leader interviews, and focus group discussions.

1.7 Relevance of the study

This work will contribute to progress towards energy, water and food security in Africa through the water-energy-food nexus approach (SDG2, SDG6 and SDG7). This study will contribute to the agenda 2030 SDGs as well as the action plan of Agenda 2063 in Africa especially in Aspiration 1: "A prosperous Africa based on inclusive growth and sustainable development"; That are the benefits intended to be achieved by this research in connection to the sustainable development Goals (SDGs).

The main focus of analysing the NEXUS approach lies in the improvement of household access to basic services. Understanding the needs of the population, beyond national statistics or studies focusing on population samples, is crucial to achieving sustainable development without leaving anyone behind. Despite the growing awareness of sustainable development topics, the monitoring of progress at the household level remains a major challenge for the research, public, and private (investors, NGOs, financial institutions, and small and medium enterprises) sectors.

Tentative thesis chapter outline

This study consists of the following chapters:

Chapter 1 Introduction

This consists of presenting the background information, problem statement, knowledge gaps, objectives, research questions, scope and importance of the work.

Chapter 2 Literature review

This chapter will present the literature review which will include an overview of the frameworks for Energy access, WASH, food Access Assessment, Vulnerability Indices and Indicators (Poverty, Climate Change, Climate Risk) as well as an in-depth description of existing WEF Nexus studies (focusing on DRC and East Africa).

Chapter 3 Methodology and description of case study areas

The third chapter will briefly describe the materials and methods used to carry out the study and an overview of the existing situation in the study area will be explored to give a better understanding of the actual situation on the ground.

Chapter 4 Results and discussions

To present the main results from the site and online data collection.

Chapter 5 Conclusions and Recommendation

Highlight the main findings of this study in relation to the overall problems, research and questions.

2 Literature review

2.1 Defining the nexus approach

2.1.1 Emergence and Drivers behind the nexus Approach

Every conceivable human activity and technology requires either water, energy, food or a combination of all three. We use water to grow our food and run the turbines that produce our electricity. Energy is needed to transport and purify water, and it is also needed to produce fertilizers, harvest crops and cook our food. In turn, energy can be produced from crops such as maize and sugar cane as biofuels. Also, it is important to remember that we all individually consume water, energy and food every day. It is clear that these three sectors depend on each other and are all highly interconnected and this phenomenon is known as the "Water-Energy-Food Nexus" (WEFN) (Garcia and You 2016).(Keskinen et al. 2016a) says that the idea of examining the three aspects and their links is not new. In fact, he says that it can even be argued that scientists, public officers and other practitioners have all been well aware of these interactions for many decades, it is just that the specific term 'nexus' has not been used. He finds two reasons for the increase in nexus-related literature since 2011. The first is the growing awareness of the economic risks involved in the nexus. The second is a desire to promote the nexus as a new framework for global policy debate on the links between resource use and development and, indeed, on how to facilitate sustainable development.

According to (Zhang et al. 2018) The popularity of the nexus could be traced back to the 2008 World Economic Forum, where global challenges related to economic development were recognized in terms of the nexus between water, energy and food. Academic and public interest in the water, energy and food nexus has increased significantly in recent years, following the publication of a World Economic Forum report in January 2011 and the gathering of academics and practitioners at an international conference on the nexus in 2011 (Wichelns 2017). In fact, the Global Risks 2011, Sixth Edition of the World Economic Forum provides a comprehensive overview of 37 selected global risks, as perceived by members of the World Economic Forum's Global Agenda Councils and confirmed by a survey of 580 leaders and decision-makers from

around the world. Among these 37 risks, the report identifies the risks related to the Water-Energy-Food Nexus, but also points to a set of elements that are common drivers of the risks related to the Water-Energy-Food Nexus. These include economic growth and population growth, as well as the fact that improved living conditions in emerging economies are resulting in more resource-intensive consumption patterns (World Economic Forum 2011a).

(Hoff 2011) in a paper for the Bonn 2011 conference in preparation for the Rio+20 summit, demonstrates that water, energy and food security can be improved by adopting a nexus approach, i.e., an approach that includes management and governance across sectors and scales. It highlights that the nexus approach can also support the transition to a green economy, which aims, among other things, at resource efficiency and greater policy coherence. Given the increasing interconnection between sectors and across space and time, mitigating negative economic, environmental and social externalities can increase overall resource efficiency, bring additional benefits and secure human rights to water and food.

(Al-Saidi and Elagib 2017) says that the literature on the Water-Energy-Food Nexus (WEF) reveals three lines of justification for the need for the debate on the WEF Nexus. Firstly, the increasing interconnection of resources due to their growing scarcity, secondly the recent resource supply crises, and thirdly the failures of sectoral management strategies. These are the driving forces behind the emergence of reflection on the Nexus. The argument is that internal factors, such as economic and demographic changes, are leading to an increasing demand for water, energy and land. Combined with external factors such as climate change and variability, these changes lead to risks to resource security. These notions of increasing degradation, risk and insecurity are at the heart of the arguments of the World Economic Forums in 2008 and 2011 and the Bonn conference in 2011 (World Economic Forum 2011b).

(Botai et al. 2021) in a Review of research on the water-energy-food nexus in Africa shows that research on the WEF nexus has gained traction in Africa since 2013. This was mainly driven by the need to sustainably manage the water, energy and food resources that are under pressure on the African continent. In Central and East Africa, the transboundary basin of Lake Kivu and the Ruzizi River, which are shared by the Democratic Republic of Congo (DRC), Rwanda and Burundi, provides a variety of ecosystem services. Research work in the Lake Kivu and Ruzizi River basin by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) gmbH has

focused on understanding the trade-offs between competing users of water, land and energy, improving the efficiency of natural resources to support people's livelihoods and the integrity of the basin ecosystem using the WEF Nexus approach (nexus 2020). Or the research undertaken by Stockholm Environment Institute (SEI) as part of a project led by the Albertine Rift Conservation Society (ARCOS), which examined how the water-energy-food security nexus approach can help promote climate-resilient decision-making and model actions in the three selected landscapes along the Akagera basin (Oliver W. Johnson Mbeo Ogeya , Tom Ogol , Taylor Binnington , Francisco Flores, Louise Karlberg 2019).

Yet, despite several publications related to water-energy-food nexus, there is no general agreement on what nexus is and what a "nexus approach" means and requires(Keskinen et al. 2016b).

2.1.2 Definitions of nexus Approach

According to (Keskinen et al. 2016a), no common definition or conceptual framework for the Nexus has emerged and, as a result, different organizations and different authors intentionally or unintentionally interpret the essence of the nexus in very different ways. Even the name of the approach is varying, with the three sectors of the nexus being written in a different order and the term 'security' being both included and excluded from the term. The actual number of nexus sectors also differs, sometimes extending to other sectors such as climate change (World Economic Forum 2011b), ecosystems (De Strasser et al. 2016) and livelihoods (Biggs et al. 2015) or focusing on only two sectors Energy-Water Nexus (Hussey and Pittock 2012; Kouangpalath and Meijer 2016). Terms also change, for example, food is sometimes replaced by land (Howells et al. 2013).

However, for (Zhang et al. 2018) in general, there are two categories of Nexus definitions.

In the first category, Nexus is interpreted as the interactions between the different sectors within the Nexus system. For example, for (Liu et al. 2016) the water-energy Nexus can be presented as the interdependencies between energy and water, as they are coupled in their supply, treatment, distribution and use. Similarly, when the system boundary is extended to a water-energy-food system, the Nexus can be defined as the interconnection between water, energy and Food supply. Water is needed during the processes of energy and food production. Energy is needed for the collection, distribution and treatment of water. On the other hand, food can also be used to produce

energy in the form of biofuels. Thus for (Gulati et al. 2013) the water-energy-food relationship goes beyond simply calculating the water footprint of food production, calculating the carbon footprint of water supply chains, or analyzing new energy supplies and climate adaptation strategies in relation to water for consumption or its impact on land availability and thus food prices. But at the heart of this relationship is the interdependence of these resources, how the demand for one resource can drive the demand for another, and similarly how the cost of one resource can determine the efficiency of production of others. Also for (Lawford et al. 2013) the Water-Energy-Food nexus describes the interactions between the water, energy and food sectors.

In the second, more widespread category, Nexus is presented as an analytical approach to quantify the links between the nodes of the link (i.e., water, energy and food) (Zhang et al. 2018). This approach is not always uniform, homogenous and subject to many interpretations. This is why (Keskinen et al. 2016b) after analysis considered that the content of the nexus approach could be interpreted from a triple perspective which complemented each other:

- **Firstly, he saw the nexus as a method of analysis:** a systematic approach that explicitly includes the consideration of water, energy, food and other related sectors, in quantitative or qualitative terms, in order to better understand their interrelationships and thus provide more integrated information for planning and decision-making in these sectors.
- **secondly as a tool for governance:** A tool that specifically focuses on the linkages between the water, energy, food and related sectors, and their actors, in order to strengthen cross-sectoral collaboration and policy coherence, and ultimately to promote sustainability and efficiency in resource use.
- **thirdly as an emerging discipline:** which emphasises the trade-offs and synergies between the water-energy-food nexus and encourages actors to cross sectoral and disciplinary boundaries and adopt a cross-sectoral and transdisciplinary approach to water, energy and food issues.

For (FAO 2014), in the context of increasing demand for water, energy and food, leading to increased competition for water and land resources worldwide, the water-energy-food nexus is a useful concept to describe and address the complex and interdependent nature of our global resource systems on which we depend to achieve various social, economic and environmental goals. In simple terms, it is a conceptual approach to better understand and systematically analyse

the interactions between the natural environment and human activities, and to work towards a more coordinated management and use of natural resources in all sectors and at all scales. Or for (Kurian 2017), the nexus approach represents a multidimensional, scientific means of inquiry that attempts to describe the complexity and non-linearity of human-environment interactions while allowing a holistic understanding of the unintended consequences of policies, practices and technologies.

2.2 Nexus Approach and Climate Change.

In Africa, climate change and variability are likely to impose additional pressures on water availability, accessibility and demand, and will also affect the health, agriculture and energy sectors (Kibreab 2010). As a complex and cross-cutting issue, climate change requires an integrated and transformative systems approach to address the challenge, whereas current sectoral approaches to climate change adaptation initiatives often lead to unbalanced and delayed sustainable development, according to (Mpandeli et al. 2018). The "nexus" approach could thus help to better understand the interdependence of the water, energy and food security sectors and to strengthen coordination between them. However, it needs a major change in the decision-making process to adopt a holistic vision and to develop institutional mechanisms to coordinate the actions of the various actors and to enhance complementarities and synergies between the three sectors (Mabhaudhi et al. 2016) .

As (Rasul and Sharma 2016) points out, developing countries face the difficult challenge of meeting the growing demand for food, water and energy, which is further aggravated by climate change. They point out from the case of South Asia that the policy process in developing countries generally follows a sectoral approach that does not take into account the interconnections and interdependence between these three sectors. Using the Himalayan region of the Hindu Kush as an example, they seek to better understand the linkages between water, energy and food, explain why it is important to consider this linkage in the context of adaptation responses, and argue that focusing on trade-offs and synergies using a nexus approach could facilitate better adaptation to climate change and help ensure food, water and energy security by improving resource use efficiency and promoting greater policy coherence. They conclude that a nexus-based approach to

adaptation which integrates a nexus perspective into climate change adaptation plans and an adaptation perspective into development plans is crucial for effective adaptation.

In a study on climate risks and opportunities in Southern Africa, where they explore the opportunities of the WEF link in promoting cross-sectoral policy linkages between the water, energy and food sectors at a regional level to achieve regional integration and sustainable development, (Nhamo et al. 2018) point out that climate change projections indicate that the most significant climate change impacts for the SADC region will be on water resources, which could severely affect food and energy production. They also point out that by 2080, annual rainfall in the region is expected to decrease by 20%, which could exacerbate food and water insecurity problems, particularly in countries that are already facing resource shortages. These already evident stressors have a negative impact on energy production and supply, as well as food and water security, which affects the region's development objectives. Thus, the WEF nexus represents an opportunity for coordinated management of resources for sustainable development, fostering regional cooperation, assuring regional security and reducing regional vulnerabilities to climate change

According to (Mabhaudhi et al. 2019), the largest number of populations vulnerable to the hazards of climate change are on the African continent, where chronic water, food and energy insecurity and malnutrition remain endemic. Variability in precipitation threatens the production of more than 80% of the continent's agricultural land, where agriculture is predominantly rainfall-based. Southern Africa is particularly sensitive to climate change and variability due to multiple factors, such as dependence on climate-sensitive agriculture and fisheries, lack of resources for adaptation, poor infrastructure and institutional arrangements, and low capacity to adapt. Water, energy and food are projected to be sectors most impacted by climate variability and change in the region. Faced with these possible impacts of climate change, an adapted response is needed. The WEF nexus approach could thus be a decision support tool that will improve rural livelihoods through integrated resource distribution, planning and management, and ensure inclusive socio-economic transformation and development (Mabhaudhi et al. 2019).

2.3 Measuring de nexus

2.3.1 Assessing Access to Water

Access to safe drinking water and hygienic sanitation is used by many international institutions to measure progress in the fight against poverty, disease and death. access to these services is now considered not a privilege but a human right, for every man, woman and child (CDC 2017). To this end, the Joint Monitoring Programme (JMP), led by WHO/UNICEF and affiliated with UN-Water, established in 1990, assesses progress in household drinking water, sanitation and hygiene. Its objectives are to provide regular global reports on drinking water and sanitation coverage to facilitate sector planning and management, to support countries in their efforts to improve their monitoring systems and to provide information for advocacy(UNICEF and WHO 2021).

2.3.1.1 Joint Monitoring Programme (JMP) water access and sanitation (WASH) assessment methods.

2.3.1.1.1 JMP definitions

Using relevant data from official national sources, populations using different types of drinking water and sanitation facilities, the JMP classifies households as using water access facilities from improved, unimproved or no sources. Thus, improved drinking water sources are those that have the potential to provide safe water by design and construction, while improved sanitation facilities are those that are designed to hygienically separate excreta from human contact (JMP 2020). The use of "improved" drinking water sources has served as the main indicator for the MDGs on drinking water and is the basis for the new SDG indicators on drinking water (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018).

Table 1: JMP classification of improved and unimproved facility types

TYPES	DRINKING WATER	SANITATION
IMPROVED FACILITIES	**Piped supplies** • Tap water in the dwelling, yard or plot, including piped to a neighbour • Public taps or standpipes • Non-piped supplies • Boreholes/tube wells • Protected wells and springs • Rainwater • Packaged water, including bottled water and sachet water • Delivered water, including tanker trucks and small carts/tanks/drums • Water kiosks	**Networked sanitation** • Flush and pour-flush toilets connected to sewers • On-site sanitation • Flush and pour-flush toilets or latrines connected to septic tanks or pits • Ventilated improved pit (VIP) latrines • Pit latrines with slabs (constructed from materials that are durable and easy to clean) • Composting toilets, including twin pit latrines with slabs and container-based systems
UNIMPROVED FACILITIES	**Non-piped supplies** • Unprotected wells and springs	**Networked sanitation** • Flush and pour-flush toilets flushed to an open drain or elsewhere **On-site sanitation** • Pit latrines without slabs • Open pits • Hanging toilets/latrines • Bucket latrines, including pans, trays or other unsealed containers
NO FACILITY	**Surface water** • Open water sources located above ground, including rivers, lakes, ponds, streams, canals, reservoirs or irrigation channels	**Open defecation** • Defecation in the bush, fields or ditches • Defecation into surface water, including beaches, rivers, streams, the sea, or drainage channels

Source: (JMP 2020)

Table 2:Classification of drinking water technologies

First level classification	Second level classification	Improved	Unimproved
Tap water	Piped water into dwelling	X	
	Piped water to yard/plot	X	
	Public tap, standpipe	X	
	Other	X	
Ground water	Tube well, borehole	X	
	Protected well	X	
	Protected spring	X	
	Unprotected well		X
	Unprotected spring		X
Rainwater	Covered cistern/tank	X	
	Uncovered cistern/tank	X	
Packaged water	Bottled water	X	
	Sachet water	X	
Delivered water	Cart with small tank/ drum	X	
	Tanker truck provided	X	
Surface water	River		X
	Lake		X
	Dam		X
	Pond		X
	Stream		X
	Irrigation channel		X
Other	Other improved	X	
	Other unimproved		X

Source:(WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018)

Table 3:Classification of sanitation technologies

First level classification	Second level classification	Improved	Unimproved
Flush toilets	to piped sewer system	X	
	to septic tank	X	
	to unknown place/not sure/DK	X	
	to open drain		X
	to elsewhere		X
Pour flush latrines	to piped sewer system	X	
	to septic tank	X	
	to pit	X	
	to unknown place/not sure/DK	X	
	to elsewhere		X
Dry latrines	Ventilated Improved Pit latrine	X	
	Composting toilets	X	
	Pit latrine with slab	X	
	Pit latrine without slab/ open pit		X
	Hanging toilet/hanging latrine		X
	Bucket latrine		X
No facility	Bush, field		X
Other	Other improved	X	
	Other unimproved		X
DK/Missing			X

Source: (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018)

2.3.1.1.2 JMP Water Service level classifications (Drinking water ladder)

The JMP also assesses the level of service access to water sources based on a set of criteria. These service level criteria are derived from the human right to safe water and include (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018):

- **accessibility within 30 minutes:**

Here, the question is how long it usually takes to collect water from the household. Thus, household surveys and some censuses collect data on the typical time taken to collect water. The survey questions should therefore specify the time taken for each round trip (i.e., from the dwelling to the water collection point, queuing for water, filling the containers and returning to the dwelling). Time spent socialising (outside the queue) should not be included in the total number of minutes. Surveys can record the number of minutes reported as a number, or record ranges (for

example, 0-30 minutes). When a number is recorded, households using improved sources and reporting collection times of 0-30 minutes (inclusive) are classified as having a source of drinking water within 30 minutes. When ranges are reported, all ranges with an upper limit of 30 minutes or less are counted(WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018).

- **on premises:**

A water supply is considered to be on premises when the water is collected from a point within the house, plot or yard. While piped water is usually available on the premises, other types of water supply may also be located on the premises**.** in surveys that collect data on water collection times, households reporting a collection time of zero minutes are classified as having water on site (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018).

- **availability when needed:**

The human right to safe drinking water states that water should be *"available continuously and in a sufficient quantity to meet the requirements of drinking and personal hygiene, as well as of further personal and domestic uses, such as cooking and food preparation, dish and laundry washing and cleaning. […] Supply needs to be continuous enough to allow for the collection of sufficient amounts to satisfy all needs, without compromising the quality of water"*(United Nations Human Rights Council 2009).

To assess the availability of water when needed, the JMP uses data from population-based sources from various questions included in national household surveys. In cases where surveyed households report having access to sufficient water when needed, or having water available at least 50% of the time, i.e., at least 12 hours a day or 4 days a week, the JMP classifies them as having drinking water services available when needed. and in the absence of population-based data, data from administrative sources have also been used or can be used. In this case piped water systems that provide water for at least 12 hours a day or 4 days a week are classified by the JMP as "available when needed", although it is recognized that this may fall short of the full realization of the human right. (WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018).

- **quality:**

The JPM assesses the quality of the water and it should be "free of contamination", i.e., the drinking water should meet microbiological and chemical priority quality standards. For microbiological testing, the standard applied is that no E. coli should be detected in a 100 ml sample. Thermotolerant coliforms are another commonly used faecal indicator and are considered an acceptable alternative to E. coli. For chemical testing at the global level, the priority chemical contaminants are arsenic and fluoride. The JMP thus collects data on compliance with relevant national standards and, where possible, uses compliance with WHO guideline values (10 µg/L and 1.5 mg/L, respectively)(WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply 2018; World Health Organization 2011).

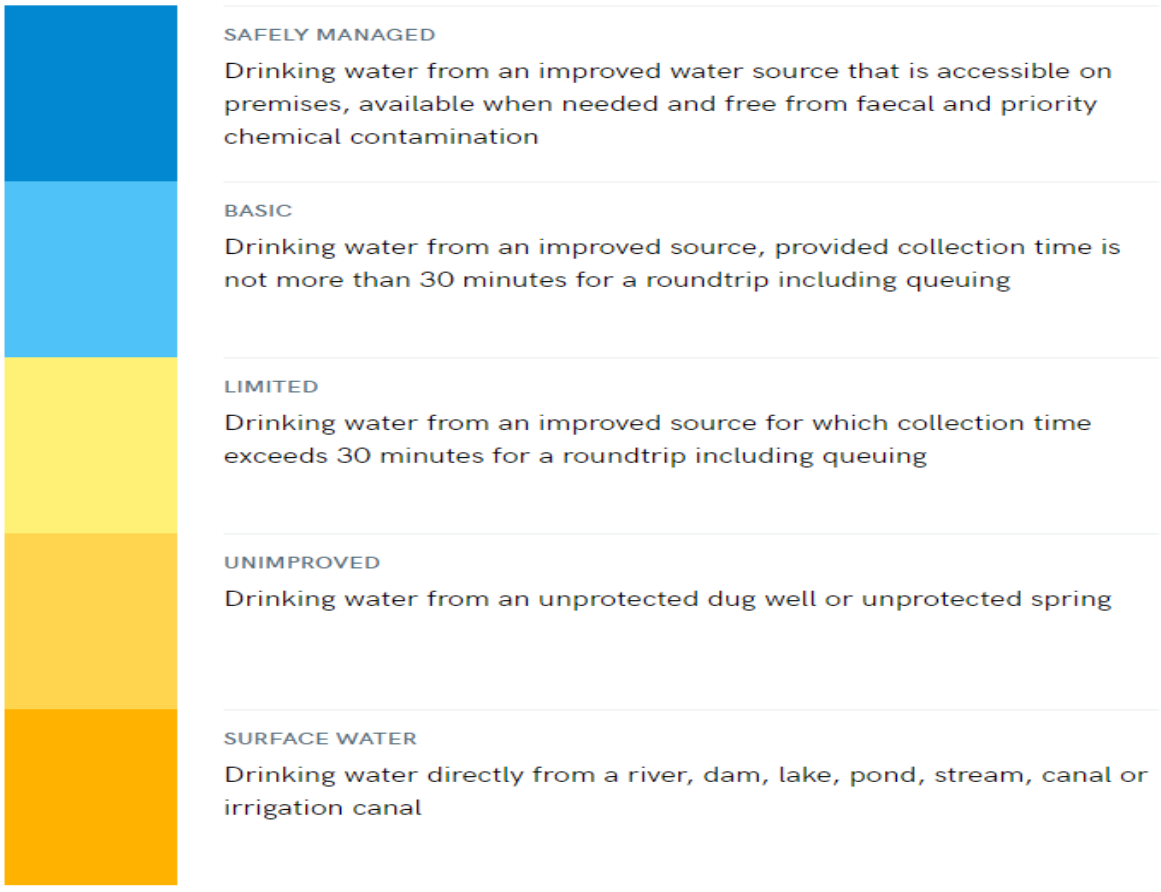

Figure 1:Drinking water ladder

Source: Drinking water | JMP (washdata.org)

2.3.1.1.3 JMP Sanitation service level classifications (Sanitation ladder)

The JMP introduces a set of globally comparable sanitation service levels, including service indicators, into its analysis and methodology. For the JMP a sanitation service is assessed according to the extent to which the elements of the sanitation chain address the issues of: containment, emptying, transport, treatment, and reuse or final disposal(Potter, Uandela, and Naafs 2011). To do this, the following elements are studied:

- **Not shared with other households**

Household surveys here may ask respondents whether the sanitation facility used by household members is shared with other households.

- **Containment**

The question is to what extent the sanitation facilities used by people ensure that excreta are safely separated from human contact at household and community level.

- **Emptying of on-site storage facilities**

What is sought here is data on the proportion of people using on-site storage facilities such as septic tanks or latrines that have never been emptied.

- **Treatment and disposal of excreta from on-site storage facilities**

This involves investigating the proportion of excreta emptied from on-site storage facilities such as septic tanks or latrines that are either buried on-site, transported, usually by cart, truck or tanker, and delivered to treatment plants (whatever the type of treatment plant) or discharged into sewerage systems.

- **Wastewater transported to treatment**

Here we are looking at the proportion of excreta discharged into sewerage systems that is transported with the wastewater to treatment plants regardless of the type of treatment plant.

- **Wastewater treated**

It's about the proportion of wastewater reaching treatment plants that receives at least secondary (biological) treatment.

Figure 2:Sanitation ladder

Source: [Sanitation | JMP (washdata.org)]

2.3.2 Food Access assessment

2.3.2.1 Definition of Food security

(Maxwell and Frankenberger 1992) in the 1990s counted about 200 definitions of food security in the published literature. All these efforts to define the concept rightly testify to its flexibility.

It was in the context of discussions on international food issues in the mid-1970s that the concept of food security emerged. The issues of food supply, availability and price stability monopolised attention. However, the 1974 World Food Conference provided a new vision of the issue of food security, creating a new set of institutional arrangements covering information, resources for the promotion of food security(United Nations 1974). Above all, it was explicitly recognised for the first time at this conference that this issue concerns the whole of humanity (Napoli, Muro, and Mazziotta 2011).

"Every man, woman and child has the inalienable right to be free from hunger and malnutrition in order to develop fully and maintain their physical and mental faculties. Society today already possesses sufficient resources, organizational ability and technology and hence the competence to achieve this objective. Accordingly, the eradication of hunger is a common objective of all the countries of the international community, especially of the developed countries and others in a position to help"(United Nations 1975).

Although the definition of the concept has evolved and diversified since the 1974 Rome conference, the most widely accepted definition is that of the World Food Summit (WFS) in November 1996:

"*Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"*(FAO 1996).

Four main dimensions of food security can be identified from this definition, and according to (EC-FAO Food Security Programme;Agriculture and Economic Development Analysis Division 2008) for food security objectives to be achieved, all four dimensions need to be fulfilled simultaneously.

Table 4:four main dimensions of food security.

Physical **AVAILABILITY** of food	Food availability addresses the "supply side" of food security and is determined by the level of food production, stock levels and net trade.
Economic and physical **ACCESS** to food	An adequate supply of food at the national or international level does not in itself guarantee household level food security. Concerns about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets and prices in achieving food security objectives.
Food **UTILIZATION**	Utilization is commonly understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals are the result of good care and feeding practices, food preparation, diversity of the diet and intra-household distribution of food. Combined with good biological utilization of food consumed, this determines the nutritional status of individuals.
STABILITY of the other three dimensions over time	Even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status.

Source: (EC-FAO Food Security Programme;Agriculture and Economic Development Analysis Division 2008).

2.3.2.2 Definition of Food insecurity

FAO defines food insecurity as: *"A situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life. It may be caused by the unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate use of food at the household level. Food insecurity, poor conditions of health and sanitation, and inappropriate care and feeding practices are the major causes of poor nutritional status. Food insecurity may be chronic, seasonal or transitory"*(FAO et al. 2020).

In general, the FAO defines two types of food insecurity.

Table 5:General types of food insecurity.

	CHRONIC FOOD INSECURITY	TRANSITORY FOOD INSECURITY
is...	long-term or persistent.	short-term and temporary.
occurs when...	people are unable to meet their minimum food requirements over a sustained period of time.	short-term and temporary. there is a sudden drop in the ability to produce or access enough food to maintain a good nutritional status.
results from... can	extended periods of poverty, lack of assets and inadequate access to productive or financial resources.	short-term shocks and fluctuations in food availability and food access, including year-to-year variations in domestic food production, food prices and household incomes.
can be overcome with...	typical long term development measures also used to address poverty, such as education or access to productive resources, such as credit. They may also need more direct access to food to enable them to raise their productive capacity.	transitory food insecurity is relatively unpredictable and can emerge suddenly. This makes planning and programming more difficult and requires different capacities and types of intervention, including early warning capacity and safety net programmes.

Source:(EC-FAO Food Security Programme;Agriculture and Economic Development Analysis Division 2008)

2.3.2.3 The FAO Food Insecurity Experience Scale (FIES)

Developed by FAO in 2013 as part of the Voices of the Hungry Project, the Food Insecurity Experience Scale (FIES) is a tool that provides information on the adequacy of people's access to food by asking them directly about their experiences. It is an experience-based measure of food insecurity that provides a global benchmark against which to compare measures from different parts of the world and in different contexts (FAO 2016).

The FIES is calculated from data on people's direct responses to questions about their access to food of adequate quality and quantity. What the FIES measures is therefore fully consistent with the idea that the main characteristic of food security is "secure access to sufficient food at all times(FAO 2016; Maxwell and Frankenberger 1992).

As the FIES measures the ability to access food at the household or individual level, it is structured around eight questions on food-related behaviours and experiences that reflect increasing levels of severity as food resources become more limited: these are questions on:

- Uncertainty and anxiety about access to food;
- changes in diet quality as the situation worsens, such as a less balanced and more monotonous diet;
- and a decrease in the amount of food consumed when portion sizes are reduced or meals are skipped.

The food insecurity status of each respondent can be placed on a severity scale based on the number of behaviours or experiences reported. Depending on their position on the severity scale, respondents are classified as moderately or severely food insecure. In this manner, the FIES gives a population estimate of the prevalence of food insecurity at different levels of severity(FAO 2016).

Figure 3: Food Scale of Severity.

Table 6:Questions in the Food Insecurity Experience Scale.

	During the last 12 MONTHS, was there a time when? Because of lack of money or other resources	LABEL
Q1	you were worried you would not have enough food to eat because?	**WORRIED**
Q2	you were unable to eat healthy and nutritious food?	**HEALTHY**
Q3	you ate only a few kinds of foods because?	**FEWFOODS**
Q4	you had to skip a meal?	**SKIPPED**
Q5	you ate less than you thought you should	**ATELESS**
Q6	your household ran out of food	**RANOUT**
Q7	you were hungry but did not eat	**HUNGRY**
Q8	you went without eating for a whole day	**WHLDAY**

2.3.2.4 The Integrated Food Security Phase Classification (IPC)

As a result of a collaboration between various organisations at global, regional and national levels that are committed to ensuring the development and maintenance of the highest possible quality in food security and nutrition analysis, the Integrated Food Security Phase Classification (IPC) is a common global scale for classifying the severity and extent of food insecurity and malnutrition (IPC Global Partners 2019). The IPC classification is intended to provide information that is routinely needed by stakeholders around the world to make strategic decisions. The IPC assesses the number of people experiencing varying degrees of food insecurity and malnutrition, and reports on the main drivers and characteristics of the situation, thus provide decision-makers with key information to support response planning (IPC Global Partners 2019). To this end, the IPC distinguishes between three types of food insecurity:

- acute food insecurity
- chronic food insecurity and
- acute malnutrition

Table 7: The three IPC scales

IPC Scale	Identifies areas and populations with:	Identify the need for urgent action to:
Acute Food Insecurity	food deprivation that threatens lives or livelihoods, regardless of the causes, context or duration.	decrease food gaps and protect lives and livelihoods.
Chronic Food Insecurity	persistent or seasonal inability to consume adequate diets for a healthy and active life, mainly due to structural causes.	address underlying factors and potentially implement safety net programmes.
Acute Malnutrition	a high prevalence of acute malnutrition accompanied by high or increasing levels of morbidity or individual food consumption gaps.	scale up acute malnutrition treatment and prevention for affected populations.

Source:(IPC Global Partners 2019), www.ipcinfo.org

Table 8:Key characteristics of the three IPC Scales

	Acute Food Insecurity	Chronic Food Insecurity	Acute Malnutrition
IPC definitions of food insecurity and malnutrition	Food insecurity found at a specific point in time and of a severity that threatens lives or livelihoods, or both, regardless of the causes, context or duration.	Food insecurity that persists over time mainly due to structural causes, including intra-annual seasonal food insecurity.	Global Acute Malnutrition (GAM) as expressed by thinness of individuals or presence of oedema.
Informs action with specific strategic objectives	Short-term objectives to prevent or decrease severe food insecurity that threatens lives or livelihoods.	Medium- and long-term improvement of the quality and quantity of food consumption for an active and healthy life.	Short- and long-term objectives to prevent or decrease high levels of acute malnutrition.
Severity categories	5 Severity Phases: 1. Minimal/None 2. Stressed 3. Crisis 4. Emergency 5. Catastrophe/Famine	4 Severity Levels: 1. Minimal/None 2. Mild 3. Moderate 4. Severe	5 Severity Phases: 1. Acceptable 2. Alert 3. Serious 4. Critical 5. Extremely Critical
Analytical focus	Identifying areas with a large proportion of households with significant food energy gaps or livelihood change strategies that can endanger lives or livelihoods.	Identifying areas with a large proportion of households that have long-term inability to aquire adequate food requirements both in terms of macro- and micronutrients.	Identifying areas with a large proportion of children wasted or with oedema.

Source: (IPC Global Partners 2019), www.ipcinfo.org

2.3.3 The Multi-Tier Framework: A multi-dimensional approach to energy access assessment

2.3.3.1 A new way of defining Energy access

According to (Lighting Africa and World Bank Group 2016) "*traditionally, energy-access measurements have been split into the 'haves' and the 'have-nots.' In other words, a household either had a connection to grid-electricity and was considered as having 'access,' or it did not*". However, this binary view did not take into account the reliability of energy services or off-grid sources. For example, a household using a solar home system (SHS) would not be considered "connected" even though a critical set of basic energy needs are met, while a household connected to the grid would be considered to have access to energy even if outages are frequent enough to make the grid unreliable or if the cost of electricity makes it unaffordable to use (Lighting Africa and World Bank Group 2016).

(Seforall 2016) also states that the traditional approach to measuring access looks at whether households 'have an electricity connection' and 'have access to non-solid fuels', but does not provide information on the energy services provided by other alternative technologies such as solar lanterns for electricity and improved biomass stoves for cooking. It also does not provide any information on the affordability or reliability of the service provided to the 'connected' household. Thus the Multi-Tier Framework for tracking energy access - both electricity and modern cooking solutions aims to improve on traditional measurement approaches (Seforall 2016).

The Multi-Level Framework (MTF) was developed by ESMAP in 2015 as part of the SE4ALL initiative, in consultation with multiple development partners, to monitor and evaluate energy access using a multidimensional approach. It's redefines energy access from the traditional binary count to a multi-dimensional definition as *"the ability to avail energy that is adequate, available when needed, reliable, of good quality, convenient, affordable, legal, healthy and safe for all required energy services"*(Mikul Bhatia and Nicolina Angelou 2015). The framework provides information on the quality of service received by households, including its adequacy and availability, reliability, affordability, safety and impact on user health. The framework recognizes that improving access to energy involves a continuum of improvements and provides a methodology for measuring access across a multi-level spectrum - from level 0 (no access) to level 5 (the highest level of access).

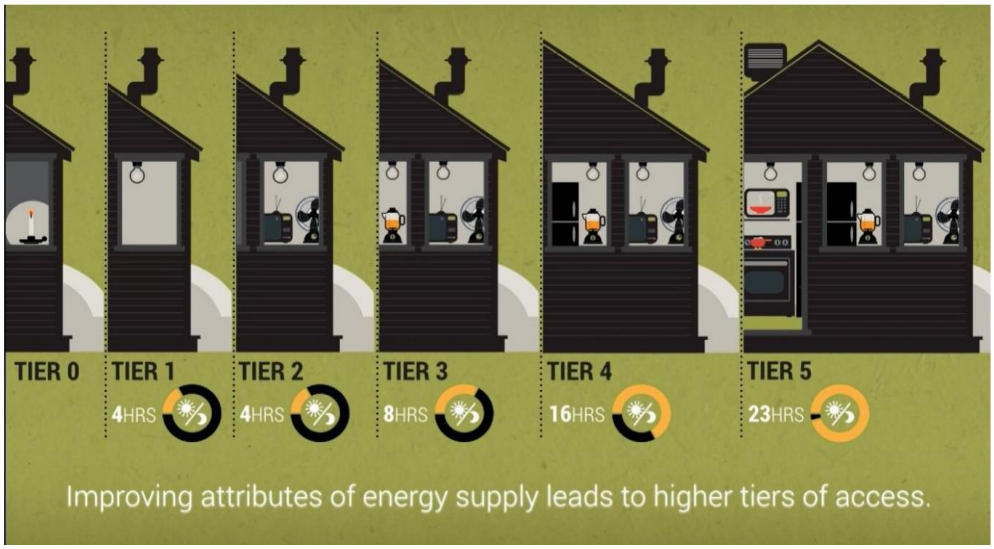

Figure 4: The Tiers of the Access of MTF (Rysankova, Portale, and Carletto 2016)

2.3.3.2 Multi-tier Matrix for Measuring Access to Household Electricity Supply

The Multi-Tier Matrix is designed to be technology and fuel neutral when assessing electricity supply performance. Access to electricity is thus measured on the basis of a combination of seven energy attributes across six levels of electricity supply, starting with limited access to small amounts of electricity for a few hours per day and gradually increasing to unlimited supply. Each attribute is assessed separately, and the overall level of household electricity access is calculated by applying the lowest level obtained in any of the attributes(Bhatia and Angelou 2015). The relevant attributes for evaluating household access to electricity supply are:

- **Capacity:** What appliances does the household use?
- **Duration** (including daily supply and nighttime supply): Is electricity available when the household needs it?
- **Reliability:** Are there frequent interruptions in electricity supply?
- **Quality:** Do voltage fluctuations damage the appliances?
- **Affordability:** Can the household afford to buy the minimum required amount of electricity?

- **Legality:** Is the service provided formally or informally?
- **Health and Safety:** Is it safe to use the electricity service, or are the household members risking their health & safety if they use it?

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3[b]	TIER 4	TIER 5
Capacity	Power capacity ratings (W or daily Wh)	Less than 3 W	At least 3 W	At least 50 W	At least 200 W	At least 800 W	At least 2 kW
		Less than 12 Wh	At least 12 Wh	At least 200 Wh	At least 1 kWh	At least 3.4 kWh	At least 8.2 kWh
	Services		Lighting of 1,000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability[a]	Daily Availability	Less than 4 hours	At least 4 hours		At least 8 hours	At least 16 hours	At least 23 hours
	Evening Availability	Less than 1 hour	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability		More than 14 disruptions per week			At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours[c]	(> 3 to 14 disruptions / week) or ≤ 3 disruptions / week with > 2 hours of outage	At most 3 disruptions per week with total duration of less than 2 hours
Quality		Household experiences voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability		Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		No bill payments made for the use of electricity				Bill is paid to the utility, prepaid card seller, or authorized representative	
Health and Safety		Serious or fatal accidents due to electricity connection				Absence of past accidents	

Figure 5: Multi-tier Matrix for Measuring Access to Household Electricity Supply (Bhatia and Angelou 2015)

2.3.3.3 Multi-tier Matrix for Measuring Access to Cooking Solutions

Household cooking solutions are assessed according to the combination of seven energy attributes over six tiers (tiers 0 to 5), starting with access to rudimentary solutions and gradually increasing to modern cooking solutions that perform best on all attributes. Health, convenience, safety and efficiency are the main concerns at the lower levels (levels 1 to 3), as households are likely to experience high levels of pollution and suffer from insecure solutions. This reflects the fact that the choice of inferior solutions for these attributes is usually a consequence of difficulties with affordability or availability attributes. At higher levels (levels 4 and 5), affordability, availability and quality requirements are also imposed to provide a complete cooking experience. Access to cooking solutions is assessed taking into account all relevant energy attributes that influence the user experience. Primarily focused on health and safety attributes, the approach progressively integrates the other attributes as access improves, to ensure that health effects are observed and users benefit from improved cooking activities. The final multilevel metric represents access at the household level, considering not only the primary cooking solution but also the secondary solutions(Bhatia and Angelou 2015). The relevant attributes for evaluating household access to Cooking Solutions are:

- **Health (based on indoor air pollution):** The health aspect of energy for cooking is directly related to the indoor air quality of the kitchen. What is the impact of household air pollution from cooking activities on the health of women and children?

- **Convenience (based on fuel collection time and stove preparation time):** How long does it take the household to get and prepare fuel for cooking before a person in the household can cook?
- **Safety:** Is it safe to use the kitchen, or is the concerned person exposed to potential safety risks? Have accidents occurred in the past due to the use of cooking fuel?
- **Affordability (including expenditure on stoves and fuel):** Can the household pay for both the cooking equipment and fuel.
- **Efficiency:** Efficiency is assessed on the basis of laboratory measurement of cookstove performance under standard conditions or in the field under real conditions. Is the combination of combustion and heat-transfer efficiency (World Bank 2020b).

- **Quality:** Does the quality of the fuel affect cooking?
- **Availability**: Is the cooking fuel available when the household needs it?

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cooking Exposure [a]	Emission: Fuel	Firewood, dung, twigs, leaves, rice husks, processed biomass pellets or briquette, charcoal, kerosene				Biogas, ethanol, high quality processed biomass pellets or briquettes	Electricity, solar, LPG
	Emission: Stove Design	Three-stone fire, tripod, flat mud ring, traditional charcoal stove	Conventional or old generation ICS	ICS+ chimney, rocket stove or ICS + insulation	Rocket stove with high insulation or with chimney, advanced insulation charcoal stoves	Rocket stove with chimney (well sealed), Rocket Stove gasifier, Advanced secondary air charcoal stove, forced air	
	Ventilation: Volume of Kitchen [b]	Less than 5 m^3	More than 5 m^3	More than 10 m^3	More than 20 m^3	More than 40 m^3	Open air
	Ventilation: Structure	No opening except for the door	1 window	More than 1 window	Significant openings (large openings below or above height of the door)	Veranda or a hood is used to extract the smoke	Open air
	Ventilation Level	Bad			Average	Good	
	Contact Time [c]	More than 7.5 hours	Less than 7.5 hours	Less than 6 hours	Less than 4.5 hours	Less than 3 hours	Less than 1.5 hours
		Bad			Average	Good	
Cookstove Efficiency	ISO's Voluntary Performance Targets (TBC)	Less than 10%	More than 10%	More than 20%	More than 30%	More than 40%	More than 50%
Convenience	Fuel acquisition (through collection or purchase) and preparation time (hours per week)	More than 7 hours		Less than 7 hours	Less than 3 hours	Less than 1.5 hours	Less than 0.5 hour
	Stove preparation time (minutes per meal)	More than 15 minutes		Less than 15 minutes	Less than 10 minutes	Less than 5 minutes	Less than 2 minutes
Safety of Primary Cookstove		*Serious accidents over the past 12 months*				No serious accidents over the past year	
Affordability [d]		Levelized cost of cooking solution (fuel) more than 5% of household income				Levelized cost of cooking solution (fuel) less than 5% of household income	
Fuel Availability		*Primary fuel available less than 80% of the year*				Primary fuel is readily available 80% of the year.	Primary fuel is readily available throughout the year

Figure 6: Multi-tier Matrix for Measuring Access to Cooking Solutions

2.4 WEF Resources Endowment in the SADC Region

2.4.1 Water Resources and Availability

The Democratic Republic of Congo (DRC), the second largest country in Africa, is endowed with large amounts of fresh water. Its hydrographic network covers about 77,810 km² and is made up of rivers (the Congo River) as well as lakes and rivers and has about 52% of the total surface area of the African continent's water reserves (Agence Nationale pour la Promotion des Investissements 2021).However, water security is low due to economic and governance constraints. Economic growth is negative in real terms, limiting government investment in and maintenance of basic infrastructure. Limited policy space for civil society activity and limited social accountability, particularly with regard to investment in water and sanitation, further constrain service delivery. As a result, currently only 52% of the population has access to basic water and 29% to sanitation. Lack of access to water and sanitation, combined with poor hygiene behaviors, is among the top five risk factors associated with death and disability in the country. (Kabemba 2005).

- **Surface water resources**

Surface water resources are very abundant. They consist of the waters of the Congo Basin and the Nile Basin. They are characterized by a very dense hydrological network and a series of transboundary and inland lakes (TSHIBAMBA 2005). The hydrographic network of the Congo Basin includes the Congo River and the following main tributaries:

- Left: Lubudi, Lomami, Lulonga, Ruki and Kasai;
- Right: Lufira, Luvua, Lukunga, Luama, Elila, Ulindi, Lowa, Maïko, Lindi, Itimbiri, Mongala, Ubangi and Uele.

The Congo River is the country's most important surface water resource. At 4,700 km in length, the Congo River is the second longest river in Africa after the Nile. Together with its tributaries, it irrigates the second largest tropical rainforest in the world. The Congo River is one of the most regular rivers in the world in terms of its hydrological regime. The regularity of its regime results from the mixing of the hydrological regimes of its tributaries of the so-called "northern" system, which drains more or less 1/3 of the basin and is located in the northern hemisphere, where the Ubangi is a major tributary. And those of the so-called "southern" system, which drains 2/3 of the basin and is located in the southern hemisphere with the Kasai as a major outlet; as well as those

of the so-called "composite" system of the areas located along the equator (Bureau d'Etudes Industrielles Energies Renouvelables et Environnement 2009).

Figure 7: Congo River.

Source:https://www.routard.com/photos/republique_congo/79714-l_imposant_fleuve_congo.htm

The two important inland lakes of the DRC are Lake Tumba and Lake Maï-ndombe, which together cover an area ranging from 2,302km² to more than 7,000km² from the dry season to the heavy rainy season.

- With a surface area of between 500km² and 765km² depending on the seasons, Lake Tumba or Ntumba is a lake in the Equateur province of the Democratic Republic of Congo, located halfway between Mbandaka and Lake Mai-Ndombe. The main town on its shores is Bikoro. The lake empties into the Congo River through the Tumba-Irebu canal (WWF - World Wide Fund For Nature 2020) .
- Lake Mai-Ndombe (formerly Lake Leopold II) is a lake in Bandundu, Democratic Republic of Congo. It feeds the Fimi River, a tributary of the Congo River. Lake Leopold II was renamed Lake Mai-Ndombe in 1972. Mai Ndombe means "black water" in Lingala. The size of the lake varies with the rains and can double or triple in size depending on the rainy season. The lake remains navigable all year round. Its shores are lined with dense forest in the north and a mixture of forest and savannah in the south. Its ports are Inongo and Ndonges (Encyclopaedia Britannica 2015).

The transboundary lakes that the DRC shares with its neighbors consist of the large eastern lakes that belong to the African Rift, which are:

Table 9:DRC transboundary lake

Name	length & depth	Sharing countries
Lake Tanganyika	148,000 km² of which 32,000 km² in the DRC with a depth of 772 m	DRC Tanzania, Zambia, Burundi
lake Albert	5270 km² of which 2420 km² in DRC with 618 m depth	DRC, Uganda
lake Kivu	2700 km² of which 1700 km² in DRC with 460 m depth	DRC, Rwanda
lake Edouard	5600 km² of which 1630 km² in DRC with 912 m depth	DRC, Uganda
lake Moëro	5100 km² of which 1950 km² in DRC with 927 m depth	DRC Zambia

- **Groundwater resources**

Although surface water is abundant, the vast majority of the Congolese population relies on groundwater and springs for their drinking water. It is estimated that groundwater accounts for almost 47 per cent (421 km3 /year) of the DRC's renewable water resources. water resources in the DRC (Partow 2011).

The key hydrogeological units in the DRC are:

- The highly productive continuous aquifer rocks of the Cuvette Centrale and Oubangui are composed of large alluvial sediments up to 120 meters thick. Recharge comes directly from rainwater and the fluvial system. Libenge and the alluvial plain between the N'Djili River and Ngaliema Bay in Kinshasa province are areas with significant potential (Partow 2011).
- A tertiary-quaternary aquifer with low potential underlying the Batékés Plateau and South East Kasai. It consists mainly of a semi-continuous sandy marl and soft sandstone, up to 100m thick in some areas. The aquifer feeds numerous tributaries and is mainly rain-fed, with relatively little indirect recharge from streams(Partow 2011).
- The Mesozoic (Karroo) sandstone and limestone aquifers that surround large parts of the Cuvette Centrale, around Gemena, Kisangani and northern Kasai. This region is

characterised by rapid recharge and low to moderate productivity. In some areas, fracturing has led to the development of karst systems (Partow 2011).

- A sedimentary limestone-dolomitic complex with a high yield constituting an important aquifer in southern Katanga (Lubumbashi dolomites). Lubumbashi). This system is characterised by heterogeneous faulted aquifers(Partow 2011).
- The crystalline and fractured Precambrian basement rocks (basalt and granite) forming the mountainous terrain along the Great Rift Valley from Lake Tanganyika to Lake Edouard, as well as the Bas-Congo south of Kinshasa, contain discontinuous aquifers, but with a high potential (Partow 2011).

2.4.2 The access to drinking water situation in the DRC

Despite its potential to hold more than 50% of Africa's water reserves, an estimated 33 million rural people do not have access to good quality water. No more than 52% of the DRC's population has access to an improved water source and 29% to improved sanitation facilities (UNICEF 2020).

The rapid and growing urban expansion of the DRC's population is outstripping the country's ability to provide infrastructure that would provide safe drinking water to this population. In contrast to the urban areas, in the more rural communities, water production infrastructure is almost non-existent, exposing the population to a high risk of consuming contaminated drinking water, especially in recent years due to mining activities. Most people living in these rural areas use water from local streams and rivers, unaware that this water source can be contaminated upstream by chemicals, bacteria and parasites(THE BORGEN PROJECT 2016) .

2.4.3 Energy Resources and Potential

- **Main sources of renewable energy in DRC**
- **Hydropower**

The main energy resource of the Democratic Republic of Congo (DRC) is hydroelectricity. With a potential of 100,000 MW, the DRC is ranked first among African countries and has nearly 13% of the world's hydroelectric power potential (Amadou. and Joottun. 2019). 44% of this potential, which represents more than one third of the total African hydroelectric potential, is concentrated at the Inga site(Esseqqat 2011). However, only 2.5% of the DRC's hydroelectric capacity has been developed (World Bank Group 2014). The total installed capacity is 2516MW with an average possible production of 14500 GWH (Mbay 2011).

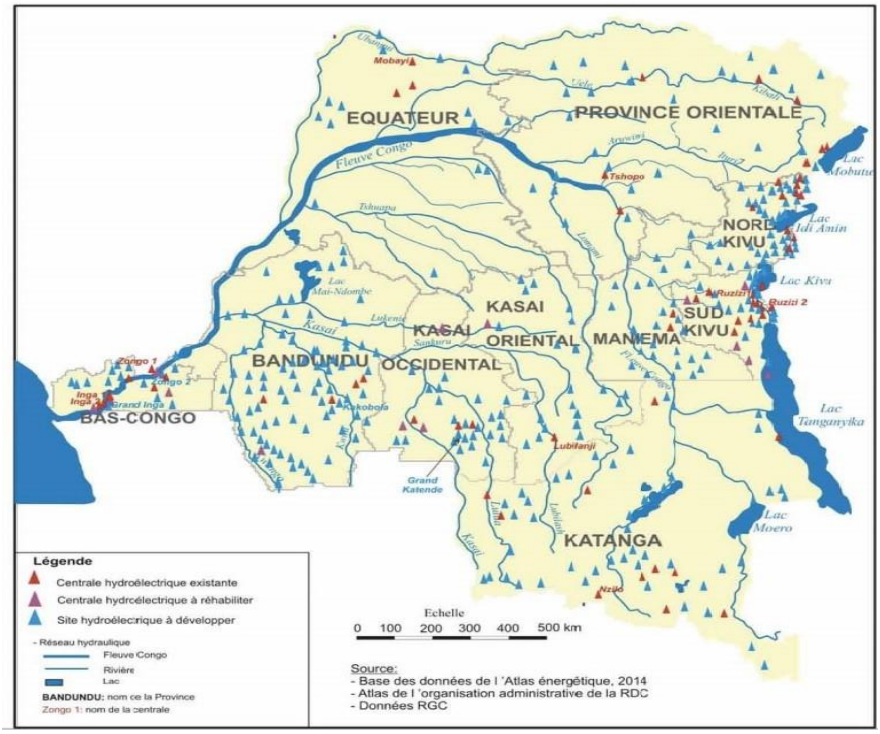

Figure 8: Hydraulic potential and hydroelectricity production in the DRC.

Source: (MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014)

The Atlas of Renewable Energy in the DRC identified nearly 780 hydroelectric sites in 2014. This Atlas shows how the country's overall hydroelectric potential (the 100,000 MW) is distributed

across the national territory of the DRC. While it was known that the INGA hydroelectric site alone concentrates an estimated 44,000 MW of potential, there was no indication of the breakdown of the rest of the DRC's hydroelectric potential. Thus with the Atlas, it is realized that an estimated potential of around 10,000 MW is largely decentralised and offers the DRC the possibility of developing other mini or small hydroelectric power plants (between 1 and 10 MW) but also hydroelectric applications even better adapted to the structure of the local market (micro and pico hydroelectric which are below the megawatt level) throughout its 145 territories (MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014).

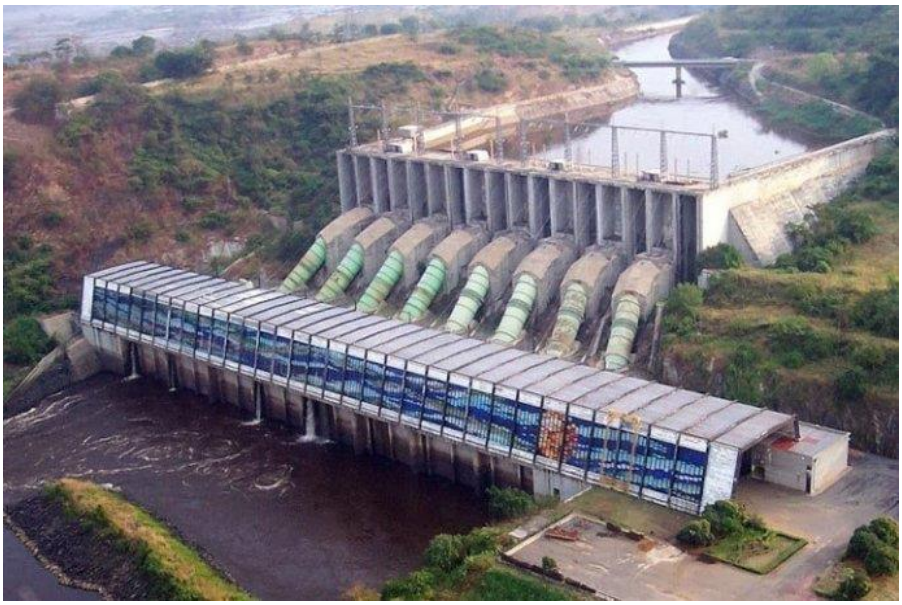

Figure 9:Inga Dam.

Source: https://afrique.lalibre.be/42696/rdc-le-projet-de-mega-barrage-dinga-iii-bloque-par-la-discorde-sino-espagnole/

Solar Energy

The DRC is located in a very sunny region with radiation levels ranging from 3.25 to 6.0kWh/m2/day, making the implementation of photovoltaic systems, as well as solar heating systems, viable throughout the country (Kusakana 2016). Between 1970 and 1990, more than 3,000 solar panel installations with a total peak power of 500 kW were present in the DRC(Esseqqat 2011). Currently, there are more than 800 solar systems installed, with a total capacity of 83 kW. They are located respectively in Equateur (167), Katanga (159), North Kivu

(170), the two Kasai provinces (170) and Bas-Congo (170). The Caritas network also has 148 installations with a total capacity of 6.31 kW(Clean Energy Information Portal (reegle) 2016).

Figure 10:DRC Solar Potential.

Source:(MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014)

- **Wind**

On a national scale, wind speeds tend to be low, with an average of 1.4 m/s (Clean Energy Information Portal (reegle) 2016). However, in some regions wind speeds of up to 6.6 m/s have been measured (see Table 10). The wind energy potential is about 77,380 MW (REEEP 2012).

Table 10:Wind energy potential in some provinces in DRC.

Province	Wind Power Potential					
	m/s					
	J	A	JJ	O	Averages	Potential
KASAI OCCIDENTAL						
Kasai	< 5	< 5	< 5	5	< 5	Low
Lulua	< 5	5	6	6	5.5	High
KASAI ORIENTAL						
Sankuru	< 5	< 5	< 5	< 5	< 5	Low
Tshilinge	< 5	5	6	6	5.5	High
Kabinda	< 5	5	6.5	6.5	6	Very High
KATANGA						
Tanganika	< 5	5	6.5	6.5	6	Very High
Haut Lomami	< 5	< 5	5.5	5.5	5	Normal
Lualaba	< 5	5	5	5	5	Normal
Kolwezi	< 5	< 5	< 5	< 5	< 5	Low
Haut katanga	< 5	< 5	5	6	5	Normal

Source : Projet Multisectoriel d'Urgence de Réhabilitation et de Reconstruction (PMURR), Etude d'électrification rurale, octobre 2007, page 96.

- **Geothermal**

The eastern part of the DRC has enormous geothermal potential but has not been exploited so far. Several geothermal sources are found in this part of the DRC belonging to the western branch of the East African Rift. The provinces of the DRC concerned by this type of energy are North Kivu, South Kivu, the former Katanga, the former Oriantale and Kongo Cetrale provinces (Mbamba Kilenda, Matamba kanzi and Nkukutu). Nkukutu) (Makuku 2019; Syakengwa 2021) .

- **Biomass**

The forest covers 1,232,000 km2 of the 2,344,885 km2 of the DRC's total area. The forest covers 52.54% of the Congolese territory. With its 125 million hectares or 70 million tons of oil equivalent, the dense and humid forest of the DRC represents 47% of the tropical forest of the African continent and 6% of the world's tropical forests (Esseqqat 2011).

Table 11:The most wooded provinces of DRC.

PROVINCES	SURFACE AREA in (Km2) and % wooded		
	Total	Forest	% Wooded
Bandundu	295.658	190.000	41
Bas-Congo	53.920	10.000	19
Equateur	403.193	402.000	99
Katanga	496.965	10.000	2
Kasaï - Occidental	156.967	40.000	25
Kasaï - Oriental	168.216	100.000	59
Kinshasa	9.965	-	
Province orientale	256.662	180.000	70
Kivu	503.239	310.000	74

Source: Directorate of Forest Management, Ministry of Environment, Water, Forests and Nature Conservation, quoted by (Esseqqat 2011).

- **Main sources of non-renewable energy in DRC**

- **Oil**

The country has oil reserves in the Western Coastal Basin (offshore and onshore) and in two virtually unexplored sedimentary basins. In 2016, the country's crude oil reserves of about 180 million barrels were the second largest in Southern Africa after Angola and 58th largest in the world (Worldometer 2016). Although the DRC has significant crude oil production capacity, the country has no refineries and must therefore export all production and import refined products such as petrol, jet fuel, paraffin, aviation gas, fuel oil and liquefied petroleum gas for local use. The DR Congo has proven reserves equivalent to 23.5 times its annual consumption. This means that, without net exports, there would be about 23 years of oil left (at current consumption levels and excluding unproven reserves) (Kusakana 2016).

- **Natural gas**

The proven gas reserves so far are those of Lake Kivu (which is shared with Rwanda) which contain methane gas reserves of nearly 65 billion m^3, the equivalent of 50 million tons of oil, which are found at depths of over 300 meters, and which remain untapped. Lake Kivu's methane gas reserve is the only case of gas dissolved in water in the world. Studies on Lake Kivu have shown that the amount of methane gas at the bottom of the lake has increased by 30% over the past 30 years due to volcanic activity in the region, as well as the introduction of sardines into the lake (Kusakana 2016; Worldometer 2016) .

- **Coal**

The DRC is estimated to hold 97 million tons (MMst) of proven coal reserves in 2019, ranking 60th in the world (EIA 2019). Domestic coal production and consumption in 2016 amounted to 0.145 million and 0.397 million short tons, respectively. This means that the DRC imports coal from other countries to meet its local energy needs (Kusakana 2016).

- **Nuclear Energy**

The DRC has a reserve of approximately 1,800 tons of high concentration uranium deposits distributed mainly around seven sites in the southern region of Katanga province (Shinkolobwe, Kalongwe, Lwambo, Mindigi, Kalongwe, Kasompi and Samboa) which are not exploited. Nuclear energy in the DRC is managed by the Commissariat Général à l'Energie Atomique (CGEA), which has a mandate to develop the country's uranium sector by exploring and exploiting uranium deposits. However, the current activities of the CGEA are limited to research, control and regulation. Two research reactors were built in 1958 and 1972 (Centre for Atomic Energy), but were shut down in 1998 at the demand of the International Atomic Energy Agency (IAEA) for safety and security reasons (Kusakana 2016).

2.4.4 The DRC Energy Balance Sheet

- **Situation of the energy offer**

- **About electricity:**

About 2.3% of the electricity supply is covered by imports (notably from Zambia) and 97.7% by local production from 108 power stations including 62 hydroelectric power stations and 46 thermal power stations (SNEL and private). According to the World Bank, SNEL's power generation facilities consist of 15 hydroelectric plants representing 2,579 MW of installed capacity and 33 thermal units with an installed capacity of 318 MW and a 1 MW solar plant in Manono (commissioned in March 2018). The Zongo 2 hydropower plant added 150 MW to installed capacity in 2018, but is currently limited in output. The INGA dam currently comprises two power stations with a total capacity of 1,775 MW (Inga 1 with 6 groups totalling 351 MW and Inga 2 with its 8 groups totalling 1,424 MW) (World Bank 2020a).

Several mini-grids based on hydroelectricity exist. These include the Electricité du Congo (EDC) grid in the town of Tshikapa (1.5 MW), the Virunga SARL grids in Mutwanga (0.4 MW) and Matebe (12.6 MW), the Société d'énergie de Kasaï (Enerka) grid in Mbuji-Mayi (17.48 MW) and the Société des Mines d'Or de Kilo-Moto (SOKIMO) grid in Bunia and Mongbwalu (11 MW). The three new hydroelectric power station projects currently under construction could significantly improve the country's share of hydroelectricity in the energy balance: Zongo II (installed capacity: 150 MW); Grand Katende (installed capacity: 64 MW); and Kakobola (installed capacity: 9.3 MW). The Grand Inga project could produce up to 40,000 MW of electricity, more than twice the power output of China's Three Gorges Dam, and more than a third of the total electricity currently produced in Africa. The Grand Inga is a series of dams that are proposed on the lower Congo River in the Democratic Republic of Congo (DRC). Grand Inga will be built in seven phases, of which the Inga 3 BC dam is the first phase. The project is already being touted as a way to "light up Africa" by the companies that plan to benefit from it and the governments that hope to receive electricity from it. Grand Inga is listed as a priority project of the Southern African Development Community (SADC), the New Partnership for Africa's Development (NEPAD), the Southern African Power Pool (SAPP) and the World Energy Council (International Rivers 2021).

- **About Oil and Gas**

The DRC's oil production per day is estimated at around 20,000 barrels, which places it 70th in the world, far behind its neighbors such as Angola, Congo-Brazzaville and South Sudan. All production is located in Central Kongo, onshore and offshore fields in the Muanda basin, operated by the Anglo-French company Perenco, which exports all extracted crude oil from its floating terminal in Kalamu (Respaut 2016).

With regard to the gas sector in Congo, it is still in its infancy despite the large reserves, as fields with high gas potential are not yet exploited. Most of the production is gas associated with oil. More than 55 billion cubic meters of dissolved methane gas are found in the deep waters of Lake Kivu, which could power a 200 MW power plant for 100 years. Several agreements between the DRC and Rwanda for the joint exploitation of these hydrocarbons remain unfulfilled due to political disputes between the two countries (Respaut 2016).

- **About solar and wind energy**

According to a study by International Rivers, the DRC has abundant, inexpensive and accessible wind and solar potential that could not only replace, but significantly exceed the energy that would be provided by the proposed Inga 3 dam project, with a generation potential of about 70 GW for solar PV and 15 GW for wind power(Deshmukh, Mileva, and Wu 2017). However, until recently, the only offer came from the private sector. SODETAP, a private company under Congolese law and a partner of PHOTALIA (a French company of the Vergnet Group), has installed solar-powered fridge kits for vaccines and blood banks in health centers. But this situation is about to change because in 2020, the Congolese President, Félix Tshisekedi, launched the construction of a 1000-megawatt solar power plant, called "Kinshasa Solar City", in order to remedy the energy deficit in Kinshasa, the capital of the Democratic Republic of Congo (DRC). The plant is being built by the company "The Sandi Group" (TSG) Global, the initiator of this project, in the locality of Menkao in Maluku, a large commune located on the outskirts of Kinshasa. (Mulegwa 2020).

- **Final energy consumption and demand situation.**

Total final energy consumption is estimated at 22 611 ktoe, i.e., an average of 0.31 toe/capita. This level of consumption is lower than the African (0.66 toe/capita/year) and world (1.82 toe/capita/year) average. In the DRC, the structure of energy demand is composed of biomass, hydroelectricity, petroleum products and gas. The demand situation is calculated on the basis of standards of average annual energy consumption by an African citizen. Taking into account the current population of about 84,000,000, the demand is estimated at 42,000,000 toe/year, divided into three main energy market segments: private (households), industrial - SME/SMI, transport, agriculture and government (PNUD 2013).

Table 12:DRC's energy situation by province.

Provinces	Energy situation
Kinshasa	• Solar potential: average solar radiation varies between 3.22 and 4.89 kWh/m2/d; • Wind potential: the average annual wind speed measured at a height of 10 m is 1.3 m/s; • Electrification rate: 44.1%.
Ex. Katanga	• Solar potential: 6.5 kWh/m²/d • Wind potential: average wind speed of more than 5m/sec; • Installed capacity is 567 MW, while current demand is estimated at nearly 900 MW (of which 600 MW is for the mining sector alone).
Kongo-Central	• The hydroelectric potential is estimated at 64,000 MW (560,640 GWh) per year; • The Inga site alone accounts for 69% of the potential (44,000 MW).
Ex. Province Orientale	• The overall potential of the currently identified sites is estimated at 7200MW; • The electrification rate: 3.6%.
Kasaï Oriental	• The province's electrification rate is very low (0.5%); • Energy needs (2012) are estimated at 264.774 MW against an insignificant current installed capacity (2012) of 1.94 MW, thus highlighting a very large gap that is a burden on all sectors; • Solar potential: 4.4 and 5.14 kWh/m2/d.
Kasaï Occidental	• The hydroelectric potential is 103 MW; • The rate of electrification is very low: 1% with a non-existent motive power; • The overall installed capacity is 31.7 MW, of which 20.7 MW are at a standstill, representing 65.2% of installed capacity; • The solar potential varies between 5.16 kWh/m2/d and 5.26 kWh/m2/d.
North-Kivu	• The current electrification rate is estimated at 3.1%; • Installable power can reach 240.3 MW; • Biomass potential: annual energy production can reach 76,583.74 MWh; • Solar potential: average sunshine varies between 4 and 5.5 kWh/m2/d; • Natural gas: the potential could reach 57.00 billion Nm3.
South Kivu	• Hydroelectric potential: the installable power can reach 1050.00 MW; • Biomass potential: the annual producible energy can reach 109 878,88 MWh/year; • Solar potential: average sunshine reaches 5 kWh/m2/d; • Wind potential: the average annual wind speed is less than 5 m/s; • Natural gas: the potential could reach 57.00 billion Nm3; • Annual electrification rate: 7.9%.
Maniema	• The electrification rate is very low 3.0%; • Solar potential: located in a band between 3.5 and 6.75 kWh/m2/d); • Available production is: 2.1MW.
Kwilu, Kwango and Maindombe	• Hydroelectric potential estimated at 104 MW; • Solar potential: sunshine varying between 4.5 and 7 kWh/m2/day; • The electrification rate is 0.6%, second lowest in the country; • The province has a huge gap of around 408.35 MW between supply and demand: the installed capacity of existing infrastructure is 22.66 MW, compared to 431.01 MW to cover current energy needs.
North Ubangi, South Ubangi and Equator	• Electrification rate: very low ≈1.4% although the province has several sites identified in its northern part; • High biomass potential (about 40,000,000 hectares of forest out of the 86 million in the DRC; • The province's energy needs (2012) are estimated at 426,085 MW (all the territories of Equateur), compared to an availability of around 26,770MW (2010); • Good level of sunshine with values between 5 and 5.5 kWh /m²/d.

Source: (Agence Nationale pour la Promotion des Investissements 2020; MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014).

2.4.5 DRC's agricultural production potential.

With a population of nearly 98 million people, about 70% of whom live in rural areas and nearly 85% of whom derive their livelihoods from agricultural activity (THE BORGEN PROJECT 2018). The agricultural sector contributes about 18% of the DRC's GDP and accounts for about 60% of the labour force, but it still fails to ensure food security and create sufficient sustainable income and employment. Almost half of the country's population lives below the poverty level and the country has to import more than 70% of the food it consumes (THE BORGEN PROJECT 2018). According to vulnerability assessments, about 27.3 million people are acutely food insecure, which represents about 28% of the rural population, or about 60.7 million people (IPC 2021).

According to the DRC's Ministry of Agriculture, the country has an agricultural production potential of nearly 80 million hectares of arable land, natural pastures that can support up to 40 million head of cattle. The DRC also has a dense hydrographic network spread throughout the country, a fisheries potential of nearly 707,000 tones, 4 million irrigable hectares, an immense phylogenetic diversity and a diversity of agro-climatic conditions favorable to a wide variety of crops. The Democratic Republic of Congo therefore has an agricultural production potential estimated to feed nearly 3 billion people annually (MINISTERE DE L'AGRICULTURE 2019). However, only less than 10% of the land is exploited (Financial Afrik 2019). The DRC also has a variety of soil types, the main ones being ferrosols, sandy-clay soils with patches of clay, sandy soils, recent volcanic soils, alluvial plain soils, ancient rock soils, areno-ferrous soils and hydro-kaolisols. This variety of soil types allows for many different types of crops, the main ones being cassava, plantain, maize, peanuts/tobacco, coffee, sugar cane, cocoa and rice. Rubber is also extracted from rubber trees and palm oil from palm trees (Embassy of the Democratic Republic of Congo 2021).

2.4.6 General overview of agricultural production and food security in the DRC.

According to the report of the joint mission to monitor the 2017/2018 agricultural season (MINISTERE DE L'AGRICULTURE 2018), the results of the QUIBB survey of (INSTITUT NATIONAL DE LA STATISTIQUE (INS) 2018) or the integrated analysis of food and nutritional security conducted in June 2018, the agricultural and food situation of the DRC is as follows:

- The DRC's gross cereal production is estimated at 3.2 million tonnes for the 2017/2018 consumption year. This includes 2.4 million tons of maize, 0.6 million tons of rice, 0.085 million tons of sorghum, 0.016 million tons of millet. Compared to the 2013-2016 average, maize production fell from 2.8 million tons to 2.4 million tonnes, a drop of around -15%;
- Also, the total production of rice fell from 1.8 million tonnes to 0.6 million tonnes, i.e., a drop in production of -64%. Gross cassava production fell from 29.8 million tons to 18.5 million tonnes, a drop of 37%;
- The country's food deficit is estimated at 6.9 million tonnes, or -22% of national food needs. The country has a large cereal deficit (-10.7 million tonnes, or 83%)
- Cereal and food balance sheets confirm that food insecurity is more a problem of access than availability;
- National livestock production is in decline due to looting and recurrent zoo-pathologies. Cattle farming is concentrated in the provinces of South Kivu, Haut-Uélé, Kwango, Kwilu and Central Kongo, while pig production is predominant in the provinces of Central Kongo, Tshopo and Kwilu. The provinces of Kongo Central and Kwilu are the two main areas for sheep and goat farming;
- According to UNICEF, global acute malnutrition affects 8% of children under the age of five. The indicators observed show that around 43% of children under five suffer from malnutrition and that six provinces out of 26 have a prevalence of over 50%, which is considered an emergency threshold;
- A review of the cost of hunger shows that the total losses associated with undernutrition are estimated at CDF 1,636.9 billion or US$ 1,771 million for the year 2014. These losses correspond to 4.56% of GDP for the same year and the most important driver of these costs is the loss of potential productivity due to mortality associated with undernutrition;

- About two out of three households have a low diversity of food consumption and remain restricted to three food groups, including tubers (or cereals), vegetables (cassava leaves, sweet potato) and palm oil and that more than 15 million people are in food crisis according to the preliminary results of the 16th round of the IPC; compared to June 2017, the number of people in food crisis has increased from 7.7 million to 15.6 million, an increase of more than 100%.

2.5 Climate Change Impacts on WEF Resources in DRC

It is generally acknowledged that climate change will have significant impacts in Africa and this is particularly true for the Democratic Republic of Congo, where climate change will have a significant impact, as evidenced by its climate risk profile (USIAD 2018a). Climate variability and change are likely to exacerbate the current situations of social vulnerability, political instability, food insecurity and high poverty rates, especially as the majority of agricultural production is rain-fed (and provides a livelihood for the majority of the population), and climate-sensitive diseases such as malaria are likely to spread to new areas (Burton, LeRoux-Rutledge, and Godfrey 2010; USIAD 2018b). (USIAD 2018a) classifies these climate impacts into four categories as shown in Figure 11 below.

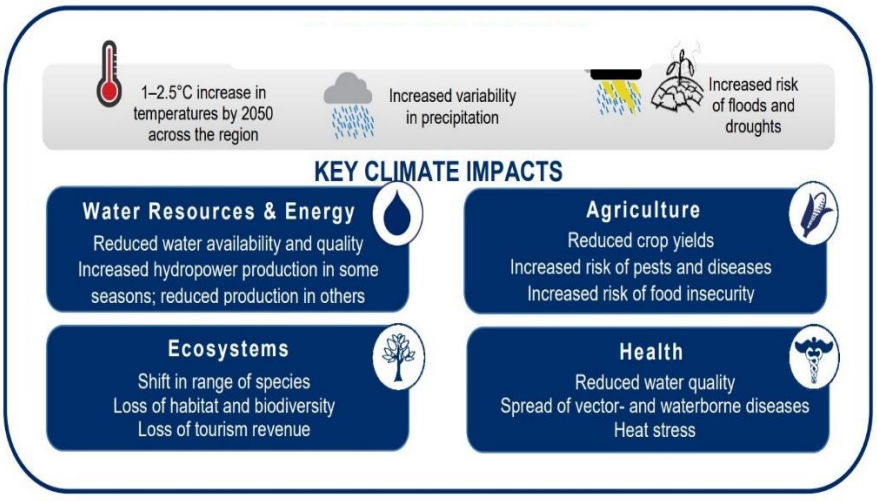

Figure 11: DRC's Climate projection

2.5.1 Climate Change Impacts on Water Resources

The DRC is projected to experience substantially more drought and significant drought severity, which is projected to increase pressure on the country's and the region's water resources by mid- to late-century (The World Bank Group 2021). In additional to water supply, more frequent and intensive rainfall may also increase the risk of flooding of rivers, streams and drainage ditches, which impacts on water quality, particularly in urban areas where open sewage, waste and activities of local businesses such as farms, sand and gravel quarries regularly pollute the water sources (USIAD 2018b) (Politiques, Higher, and Laws 2019).

Table 13:Climate Stressors and Climate Risks on Water Resources

Climate Stressors and Climate Risks WATER RESOURCES	
Stressors	**Risks**
Rising Temperatures	Increased sedimentation; reduced Temperatures surface water quality
Increased frequency of intense rainfall	Reduced water quantity and quality in shallow wells and springs due to increased rates of evaporation
Decreased dry season rainfall	Increased damage to water infrastructure

Source: (USIAD 2018b)

2.5.2 Climate Change Impacts on Agriculture

The agricultural sector is a key sector of the DRC's economy and food security and is considered one of the most vulnerable to projected climate change. Agriculture is the source of livelihood for most Congolese, and is estimated to account for about 40% of the national gross domestic product (GDP) and to employ about 70% of the DRC's population (The World Bank Group 2021). The country's national economic development plan focuses on promoting agricultural development. However, DRC's agricultural activities, which are mainly rain-fed and subsistence, could be impacted by climate change. Increased precipitation intensity damages crop and erodes fertile soils, which may lead to an increase in crop diseases. Longer periods of drought and increasing temperatures are stressing plants and reducing yields, leading farmers to extend their cultivated land into the surrounding forests. Climatic variability and climate change can shift key seasons of activities, which impacts on crop productivity and changes the selection of crops and the production and processing practices of farmers. For instance, in comparison to potatoes, which are

highly tolerant to a wide variety of meteorological conditions, insect and disease pests, dried bean production is more susceptible to heat stress, and farmers have little means to control climate-sensitive diseases such as bean root rot. On the other hand, yields of rice in the Kivus could be increased. Higher temperatures will also change the dynamics of pests and pathogens, including diseases such as cassava mosaic virus and coffee rust, which have damaged crops in recent years (CSC 2013; The World Bank Group 2021; USIAD 2018b).

Table 14:Climate Stressors and Climate Risks on Agriculture

Climate Stressors and Climate Risks AGRICULTURE	
Stressors	**Risks**
Rising temperatures	Changes in soil fertility and crop yield: potential increases in selected crops (e.g., maize in Bandundu and Kasai-Occidental); reductions or failure/loss in others
More variable rainfall	Increased pests/pathogens, such as cassava mosaic, leaf rust, coffee rust, berry borer, potato taste defect and brown rot disease
Prolonged dry Spells	Increased postharvest losses; spoilage of animal products
	Shifts in timing of planting/harvesting
Increased extreme weather and floods	Increased food insecurity and/or hunger
	Damage to road networks (decreasing access to markets)

Source: (USIAD 2018a)

2.5.3 Climate Change Impacts on the Energy Sector

Extreme weather events such as heavy rains can damage infrastructure, roads and communication networks, and disrupt supply lines. Given that the majority of DRC's electricity generation comes from hydropower, an increase in the frequency and intensity of heavy rains and flooding is likely to impact on already fragile infrastructure systems and disrupt river flows, which could affect hydropower generation (The World Bank Group 2021; USIAD 2018b).

Table 15:Climate Stressors and Climate Risks on Energy

Climate Stressors and Climate Risks ENERGY	
Stressors	**Risks**
Rising temperatures	Possible increased hydroelectricity production potential but also greater unreliability
Increased rainfall variability	

Source: (USIAD 2018b)

2.6 DRC Institutions and Policies Related to the WEF Nexus

2.6.1 Governance of the water sector

2.6.1.1 The Institutional framework

The governance of the water sector in the DRC is currently divided between several ministries and organisations. This makes it difficult today to identify the entity in charge of coordinating national water sector policies. This multiplicity of public actors and the absence of a central entity able to articulate a coherent vision and unite the actors in the sector is one of the factors hindering the development of the sector (AMCOW 2015). These institutions include

- **The Ministry of Planning (Ministère du Plan) :** responsible for the elaboration and monitoring of the DRC's Growth and Poverty Reduction Strategies (DSCRP I (2007-09), and the DSCRP II (2010-13)) In addition to its role in overall development planning, the Ministry of Planning is involved in the water supply and sanitation sector through its National Water and Sanitation Committee (CNAEA), which has a wide mandate for both policy development, programming and monitoring, as well as coordination at inter-ministerial level and with development partners;
- **Ministry of State Portfolio (Ministère du Portfeuille):** Is responsible for the administrative and financial supervision of REGIDESO;
- **Ministry of Water Resources and Electricity (Ministère des Ressources Hydrauliques et Electricité)** : Provides technical supervision of REGIDESO, and is responsible for water supply policies in urban areas (UWS);
- **REGIDESO (Régie de distribution d'eau):** created in 1939, it is a limited liability company whose main shareholder is the Congolese state. It is responsible for the distribution of drinking water throughout the Congolese national territory. It is under the supervision of the Ministry of Water Resources and Electricity and the Ministry of the Portfolio.
- **National Rural Hydraulics Service (Service National d'Hydraulique Rurale, SNHR):** Attached to the Ministry of Rural Development, this structure is in charge of formulating and implementing projects for access to drinking water in rural and peri-urban areas of the DRC since its creation in 1983.

- **The Ministry of the Environment and Sustainable Development (MEDD):** Through its **Directorate of Water Resources (DRE)** is responsible for ensuring the sustainable management of the DRC's continental, maritime and transboundary water resources.

Generally speaking, the two main ministries leading the water sector are the Ministry of Environment and Sustainable Development (MEDD) and the Ministry of Water Resources and Electricity (MRHE). The management of water as a natural resource is the responsibility of the MEDD's Directorate of Water Resources, while MRHE supervises REGIDESO (Partow 2011). It should be noted that the multiplicity of actors in the water sector makes it difficult to clearly identify the responsibility of each actor, sometimes leading to overlapping responsibilities and possible conflicts.

2.6.1.2 Policies and Strategies

The documents outlining the DRC's water sector policies and strategy are in particular:

- **The Second Poverty Reduction and Growth Strategy 2011–15 (DSCRP II):**

It is a reference document outlining the DRC government's overall growth strategy, even though it is now slightly outdated. Water and sanitation are part of the five pillars, namely pillar 3 and entitled "Improving access to basic social services and strengthening human capital". It plans to reform the water sector, including the restructuring of the sector's legal and institutional frameworks, notably by:

- the promulgation of the Water Code;
- the development and implementation of national policies for public water and sanitation services
- the reorganisation of the structures involved in the drinking water sub-sector in urban and rural areas as well as the sanitation sub-sector, and
- the promotion of partnership with the private sector in order to ensure increased access to drinking water and sanitation.

The GPRSP II has set both specific targets for the urban and rural water sector.

- For the urban drinking water sub-sector, it was a question of increasing access to drinking water in urban centres through vast infrastructure rehabilitation and extension programmes

as well as the construction of new systems. it was also a question of the transformation and reorganisation of REGIDESO in accordance with the laws on decentralisation and the disengagement of the State.

- For rural areas, it was a question of strengthening the territorial sanitation brigades and the nationwide implementation of the "sanitised village and school" programmes, consisting of improving access to drinking water by developing springs and digging wells and boreholes.

National Water Utility Policy (Politique Nationale du Service Public de l'Eau (PNSPE))

The national water policy was developed under the leadership of the Ministry of Energy and Water Resources and had two main objectives:

- The first objective was to place all responsibilities related to drinking water supply and resource management under the authority of a single ministry. It also provided for the decentralisation of water services, giving the provinces and the ETDs responsibility for the production, distribution and marketing of drinking water, as well as for the financing of new waterworks (Frédéric and Lucrezia 2014).
- The second major objective was to separate the responsibilities of project ownership from those of service management and operation (Frédéric and Lucrezia 2014).

2.6.2 Energy governance

2.6.2.1 The institutional framework

2.6.2.1.1 National institutional framework of the energy sector

The national institutional framework of the energy sector in the DRC is made up of several actors who are among others:

- Ministerial departments: the Ministry in charge of electricity (MRHE) and its various technical services/structures, the Ministry of Environment, Nature Conservation and Tourism (MECNT), Ministry of Hydrocarbons, Ministry of Rural Development.
- Orientation, control, execution or financing institutions (National Electrification Fund (FONEL), National Electrification Agency (AGENA), National Regulatory Authority for the Electricity Sector, Steering Committee for the Reform of Public Enterprises.
- It should also be noted that the national institutions involved in the exploitation and development of RE are: the MRHE (through its technical services: the National Energy Commission (CNE) and the Technical Support Unit for Energy (CATE)) and the MDR (via the National Service for New Energies (SENEN))

2.6.2.1.2 Regional and international institutional framework

The DRC is a member of several regional and international institutions.

The Economic Community of Central African States (ECCAS);

- The Central African Power Pool (PEAC);
- The Economic Community of the Great Lakes Countries (CEPGL);
- The Energy of the Great Lakes Countries (EGL);
- The International Commission of the Congo-Oubangui-Sangha Basin (CICOS);
- The Southern African Development Community (SADC);
- The South Africa Power Tool (SAPP);
- The International Renewable Energy Agency (IRENA).

It should also be noted that at the international level, three main interconnection projects are being implemented to enable the DRC to export its electricity.

The projects are as follows

- Northern axis: DRC - North Africa (Libya - Egypt)
- Western axis: DRC - Gabon - Cameroon - Nigeria
- Southern axis: DRC - Angola - Namibia - Republic of South Africa

Table 16:Institutional framework of the DRC's energy sector

Policy and legal framework	Legal framework		
	National	Regional	International
DRC Electricity Sector Policy Document the DRC - **Strategies:** **1.** Reform of the legal/constitutional, regulatory and institutional framework 2. Creation of the Electricity Sector Regulatory Authority, the Rural Electrification Agency and the Rural Electrification Fund Electrification Fund) Reform of the SNEL (National Electricity Company) 3. Development of different energy sources 4. Promotion of cross-border solidarity and regional regional integration - Draft law on the Electricity Code in the DRC - Growth and Poverty Reduction Strategies Reduction (GPRSP1 2006-2010)	**Key agencies:** - Ministry in charge of electricity - National Energy Commission (CNE) - Service National des Energies Nouvelles (SENEN) within the Ministry of Rural Development - National Regulatory Authority for the electricity sector - National Electrification Agency (AGENA) - National Electrification Fund (FONEL)	**Regional Communities:** - The Economic Community of Central African States of Central Africa (ECCAS) - The Central African Power Pool Africa (PEAC) - The Economic Community of Great Lakes Countries (CEPGL) - The Energy of the Great Lakes Countries (EGL) - The International Commission of the Congo-Oubangui-Sangha Basin (CICOS) - The Southern African Development Community Development Community (SADC) - The South Africa Power Tool (SAPP) - The International Renewable Energy Agency (IRENA) Energy Agency (IRENA)	Three interconnection axes: - Northern axis: DRC - North Africa (Libya - Egypt) - Western axis: DRC - Gabon - Cameroon - Nigeria - Southern axis: DRC - Angola - Namibia - Republic of South Africa

Source: (MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014)

In general, the energy sector in the DRC still lacks clarity, particularly in terms of identifying the roles of different institutions and communicating with stakeholders. This lack of clarity is an obstacle for the DRC both in the development of the energy sector and in the framework of a well-regulated regional energy market.

2.6.2.2 Policies and Strategies

For a long time, the governance of the DRC's energy sector was based essentially on instruments dating from the colonial period (MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014). However, recently a set of policy and legislative instruments have been adopted to regulate the energy sector. The first of these is the Growth and Poverty Reduction Strategy Paper (GPRSP 1 and 2) adopted (in 2006 and 2012 respectively) by the Government, which emphasizes the importance of the energy sector in the industrial, social and economic development of the country. This document includes increasing electricity production and improving access to electricity for the population as strategic pillars of the poverty reduction strategy (Ministère du Plan 2011). A "Five-Year Action Plan 2007 - 2011" has been developed by the Ministry of Water Resources and Electricity for this purpose and a process of formulating and establishing an energy policy and a new regulatory framework to facilitate faster access to energy services for the entire population is being implemented. This will result in particular in:

- **A Policy Paper**

articulated around the following main aspects:

- opening up to private capital and the option of market liberalisation as a guarantee of better efficiency and performance of the electricity sector;
- the institutional reform of the energy sector through a progressive disengagement of public authorities from operational activities and a redefinition of the roles and responsibilities of each of the stakeholders in the electricity sector
- the reform of SNEL and the presence of other actors in the electricity sector
- the creation of a National Electrification Agency (AGENA);
- the creation of a regulatory authority for the electricity sector
- the creation of a National Electrification Fund (FONEL) and a project management and contracting unit (MINISTERE DES RESSOURCES HYDRAULIQUES ET ELECTRICITE 2014; Ministère du Plan 2011).

- **Law n° 14/011 of 17 June 2014 aimed to regulate the energy sector in the DRC (Assemblée Nationale 2014):**

this law:

- Ended SNEL's monopoly on the electricity sector, opening the market to independent electricity producers.
- reorganised the energy sector, making the Ministry of Energy and Hydraulic Resources (MERH) responsible for the national energy strategy and for monitoring the development of water and electricity production and distribution infrastructure.
- The promotion and harmonious development of electricity supply in urban, peri-urban and rural areas;
- The coverage of the electricity needs of all categories by quality supplies in compliance with safety and environmental standards;
- The creation of an institutional framework and economic conditions allowing the realisation, security and profitability of investments in the electricity sector as well as the emergence of national energy in a public-private partnership mode;
- The guarantee of fair competition between operators and the rights of users. rights of users.

- **an "Electrification Strategy for the Hinterland of the DRC" document**

2.6.3 Governance of the agricultural sector and food security.

2.6.3.1 the institutional framework.

The development of the agricultural sector, and issues related to food security, involves several ministerial actors each with a specific mission.

- **The Prime Minister's Office**:
  - The institutional coordination of Food and Nutritional Security (FNS) at the central level is placed under the direct authority of the Prime Minister.
- **the Ministry of Agriculture:**
  - Planning of national production objectives in the fields of agriculture and agroforestry;
  - Design, implementation, monitoring and evaluation of agricultural development programs and projects;
  - Promotion of agricultural products for domestic food, national industry and export;
  - Orientation and support of economic operators interested in investing in the agricultural sectors towards sites with high production potential, so as to minimise operating costs;
- **the Ministry of Fisheries and Livestock:**
  - responsible for the formulation, development, management and implementation, monitoring and evaluation of public policies on fisheries and livestock**.**
- **the Ministry of Environment and Sustainable Development:**
  - Hunting and fishing regulations in collaboration with the Ministry of Fisheries and Livestock
- **the Ministry of Rural Development:**
  - To contribute to the achievement of food security and the sustainable and effective improvement of the living conditions of rural populations.

All these institutions have specialized services and supervise a range of actors involved in the agricultural and food security sector. However, other ministries are directly or indirectly involved in supporting agricultural production and food security. The Ministry of Higher Education, Universities and Scientific Research, through the National Institute for Agricultural Studies and Research (INERA). Other Ministries also have specific attributions that directly affect the

operators of the agricultural sub-sectors: Plan and Follow-up of the Implementation of the Modernity Revolution; Economy and Trade (12 DRC NAP 2014 – 2020); Finance; Public Health; Land Affairs; Gender, Family and Children; Land Use Planning, Urbanism, Housing, Infrastructure, Public Works and Reconstruction, and Primary, Secondary and Vocational Education .

2.6.3.2 Policies and Strategies

The DRC government has formulated a set of policies, programmes and strategies to develop and ensure the food security of the Congolese. it is mainly about:

- **The National Food and Nutritional Security Policy (PNSAN, 2016**), which integrates in its formulation the commitments of the 2030 Agenda and the vision expressed in the DRC's National Strategic Development Plan to 2030, namely "a middle-income country, free from hunger and malnutrition where all Congolese, including vulnerable people, have a good food and nutritional status enabling them to enjoy optimal physical, intellectual and psycho-affective capacities and to lead active and productive lives"(Taskforce RDC - UNFSS 2021).
- **The Agricultural Policy and Rural Development Note formulated in September 2009** whose overall objective is to contribute to the achievement of food security and which was complemented by a Sectoral Strategy for Agriculture and Rural Development (SSADR) in April 2010 (MINAGRI 2009).
- **National Agricultural Investment Plan (NAIP) 2014 - 2020** which has the overall objective of stimulating a sustained annual growth of the agricultural sector of more than 6%, which is essential for reducing poverty, ensuring food and nutritional security for the Congolese and nutritional security of the Congolese population and to generate sustainable employment and income (Ministère De L'agriculture Et Du Développement Rural 2013).
- The strategy to revive the agro-industry in May 2015 through the National Agricultural Investment Programme (PNIA).
- The National Food Security Programme (PNSA) of the Ministry of Agriculture.
- At the level of the Ministry of Health, the national nutrition policy was revised in 2013 to make it multisectoral; and the multisectoral national nutrition strategic plan and its operational plan were developed in 2016.

3 Methodology

3.1 Area of the study.

The territory of Mwenga is one of the eight territories of the Province of South Kivu. Located in the heart of the Province, the territory of Mwenga was created by order n°62/142 of 15/08/1949 of the Governor General of the Belgian Congo, now the Democratic Republic of Congo. It has an area of 11,172 km² and an estimated population of 843,636. It is divided into six collectivises, namely Itombwe, Wamuzimu, Basile, Lwindi, Luhwinja and Burhinyi. It is limited to the:

- North by the territory of Walungu,
- To the South by the territories of Shabunda and Fizi,
- to the East by the territories of Uvira and Fizi and
- to the West by the territory of Shabunda.

It is located between 28°25'29" east longitude and 3°03,16'05" South latitude. Its altitude varies between 1,500 and 1,800 m in the north-east. In the centre and south, it is around 670m. In the East, it is more or less 200m and in the West more or less 670m (Cellule d'Analyse des Indicateurs de Développement (CAID). 2021).

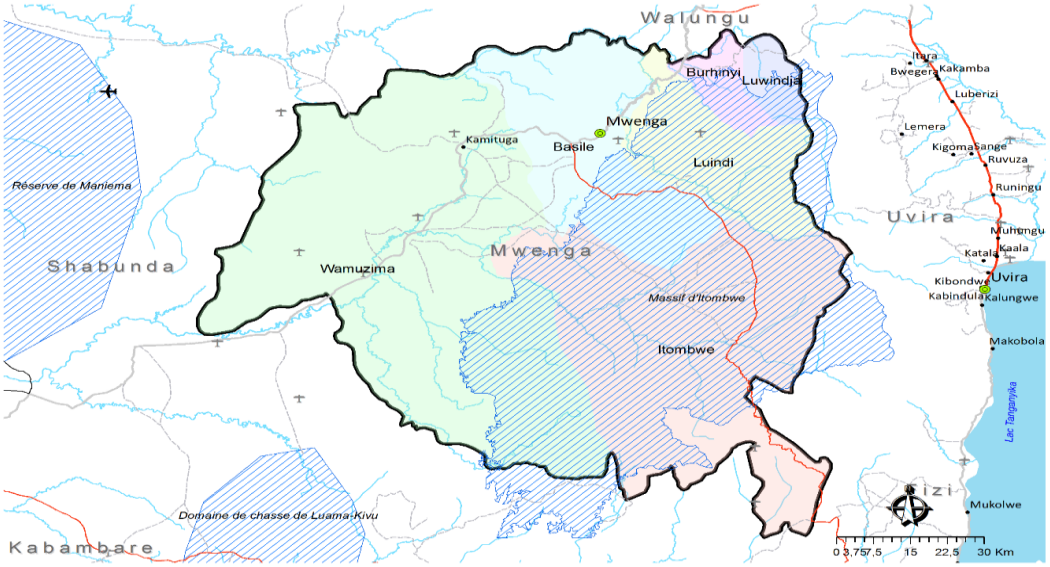

Figure 12:Administrative map of Mwenga territory

Source: https://www.caid.cd/index.php/donnees-par-province-administrative/province-de-sud-kivu/territoire-de-mwenga/?secteur=fiche

It has a humid tropical climate with two seasons: the dry season from June to September and the rainy season from September to May. The dry season which runs from June to September and the rainy season which runs from September to May. Its hydrography is abundant with two tributaries of the Congo River; the Elila and Ulindi Rivers which drain all the rivers except the Lwiko River which flows into the Lwama. The temperature varies between 21 and 37° C in most of the territory and is low in the Itombwe sector due to the high altitude, which goes up to more than 2000m. As for the relief, there are the mountains of Burhinyi, Luhwinja, Basile and the Itombwe sector; the Itombwe plateaus and finally the alluvial plain of the Elila basin. The vegetation is mainly dense forest and savannah. The vegetation is mainly dense forest and savannah. The fauna is rich, the soil is clay and sand. The forest is home to the Itombwe Nature Reserve. The subsoil is very rich and includes minerals such as gold, cassiterite, coltan and wolframite (Cellule d'Analyse des Indicateurs de Développement (CAID). 2021).

3.2 Socio-Economic activities

the main socio-economic activities in the territory of Mwenga are agriculture, livestock small-scale trade artisanal mineral exploitation hunting and logging. Artisanal mineral exploitation is the main activity in the chiefdoms of Wamuzimu and Basile. There is a multitude of economic operators in the territory of Mwenga. More than half of these economic operators are located in Kamituga. The main activities of these companies are the trade in manufactured goods (clothes, loincloths, plastic materials, cooking pots, household appliances....) from Bukavu. The economic activities of the Mwenga territory are concentrated in Kamituga (Cellule d'Analyse des Indicateurs de Développement (CAID). 2021).

3.3 Study population

This study focused on four localities in Mwenga territory, namely Kitutu and Kamituga in Wamuzimu chiefdom, Mwenga in Basile chiefdom and Kasika-Chidasa in Lwendi chiefdom. The data was collected in these localities. The results obtained were generalised to represent the entire Mwenga territory.

3.4 Sampling method

For the selection of the locations to be studied in the Mwenga territory the study adopted non-probability and purposive sampling. Thus Kitutu, Kamituga, Mwenga Centre and Kasika-Chidasa were represented in the whole Mwenga territory. Also, the targeting of households in the selected localities was done in a random way. The sample size was determined using a sample calculation formula known as the Andrew Fisher formula.

$$\mathbf{SS} = (\text{Z-score})^2 * p*(1-p) / (\text{margin of error})^2 \quad (1)$$

For a known population it is still possible to adjust:

$$\mathbf{SS\ adj} = (SS) / 1 + [(SS - 1) / \text{population}] \quad (2)$$

Where,

SS = sample size

p = proportion (if not known take 0.50)

Z-score = confidence level. For a 95% confidence level the Z-score = 1.96

margin of error = 0.05

Hence ,

$$SS = (1.96)^2 * 0.50*(1-0.50) / (0.05)^2 \quad (3)$$

$$\mathbf{SS=384.16} \quad (4)$$

As the population of Mwenga is 843 636

$$SS\ adj = (384) / 1 + [(384 - 1) / 843{,}636] \quad (5)$$

$$\mathbf{SS\ adj: 384} \quad (6)$$

This means that the number of people to be interviewed is 384.

3.5 Data Collection

We adopted both a qualitative and a quantitative approach to conduct this study. The first phase consisted of a documentation on the country's water, energy and food access situation. The second phase consisted of a direct household survey that provided quality data. A detailed questionnaire from the Multilevel Framework (ESMAP, 2015), the United Nations Joint Monitoring Programme (JMP) and the Food and Agriculture Organization (FAO) has been adapted and prepared with several questions to assess energy, water and food security. A multiple-choice format was used to answer some of the questions. Household characteristics such as number of children, elderly, adult men and women, household type and monthly income were studied as control variables.

The data collection tool that has been used is an android application called ODK Collect available on Google Play store. This application has been downloaded in android phones, where the questionnaire prepared by the HEDERA team has been loaded.

3.6 Data analysis

The data collected were analysed using mainly Python and Jupyter Book with the support of the HEDERA technical team. This allowed us to generate graphs and data tables allowing a better visualization and interpretation of the data collected from the households.

4 Results and Discussion

4.1 Collection overview

The study included 333 household interviews, conducted in four different localities in the territory of Mwenga in the Province of South Kivu in the East of the Democratic Republic of Congo (DRC). These included the locality of Mwenga Centre (Basile chiefdom) where 81 households were interviewed; the locality of Kamituga where 86 households were interviewed; the locality of Kitutu (Wamuzimu chiefdom) where 113 households were interviewed and the locality of Kasika-Chidasa (Lwindi chiefdom).

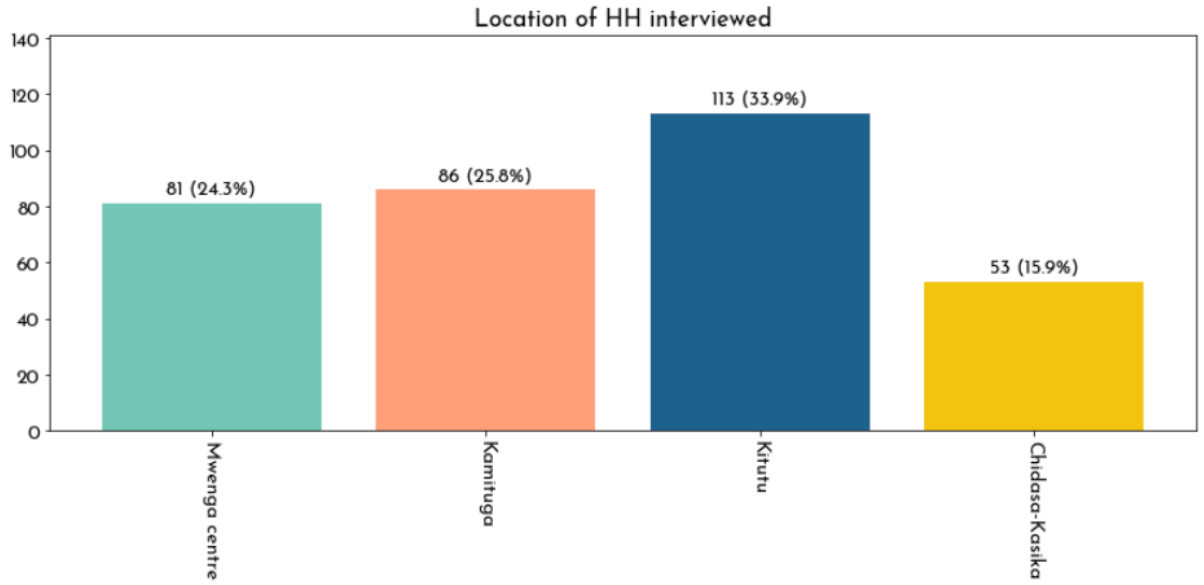

Figure 13:Data collection overview in Mwenga territory

4.2 Access to clean water

While approximately 52% of the population of the DRC have access to improved water points, in South Kivu province access to improved water points is between 40 and 45% of the population. In addition, there are disparities between urban and rural areas (Radio Okapi 2021). While urban areas have a much better rate of access to improved water points, rural areas sometimes remain at a much more precarious level (World Bank 2017). The territory of Mwenga being rural and difficult to access, and due to the near absence of state services, there are no statistics giving a general overview of the situation of access to drinking water in this region. the few sanitation facilities and drinking water points built, most of which are the work of NGOs working in the area.

Figure 14:A water hydrant built by OXFAM in Kitutu locality.

4.2.1 Water service ladder

Based on the scales using the JMP's established classification of improved/unimproved facility types, it was found that in general people in Mwenga territory have basic access to improved water sources. Meaning that they have access to drinking water from an improved source even though a large proportion still have limited access to improved water sources. However, as shown in Figure 15 , there are households in Mwenga Centre and Kitutu that do not have access to improved water source services.

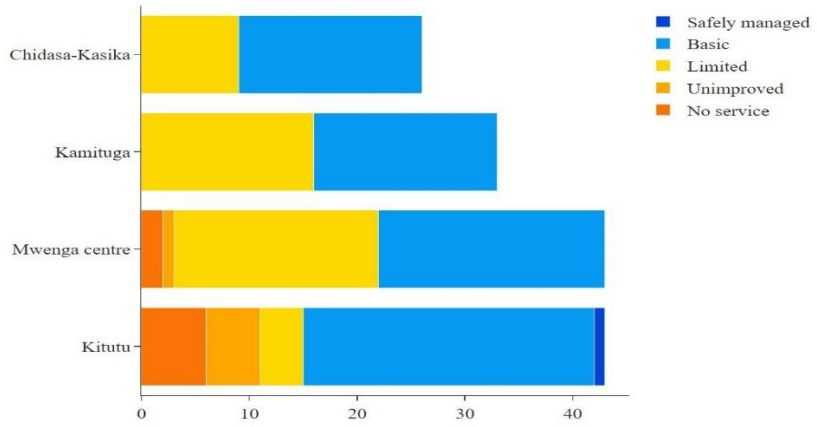

Figure 15: Water service ladder

4.2.2 Drinking water sources

The survey shows that the main sources of drinking water in Mwenga territory are boreholes, public taps, and dug wells. Since there is almost no piped water distribution system to households except in a few places in Kamituga households get their water from boreholes and public taps. Observing Figure 16 and Figure 17, it appears that the main source of drinking water for the Kasika-Chidasa locality are boreholes or tube wells, followed by public taps, for the Mwenga Centre and Kitutu localities it is also the same thing, but for the Kamituga locality public taps are the main source of drinking water.

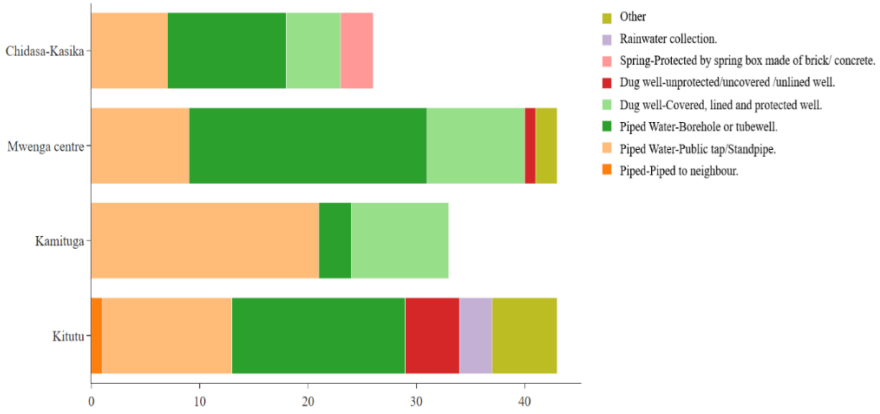

Figure 16:Main source of drinking water

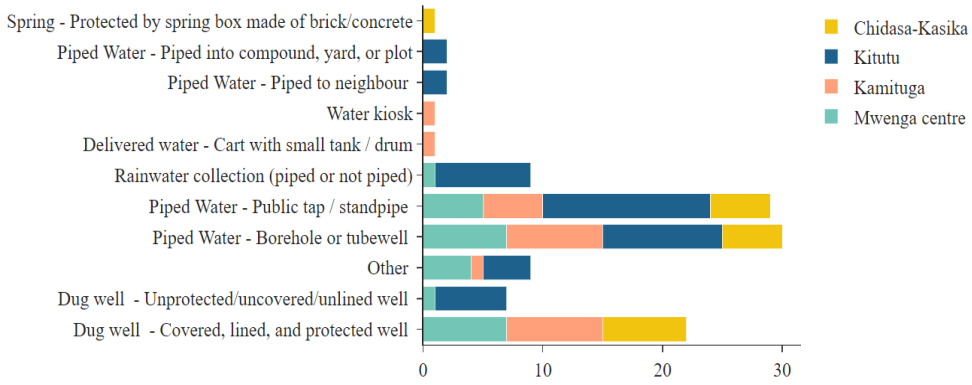

Figure 17:Additional sources of drinking water

4.2.3 Water Availability

To assess water availability, households were asked where they collected water to meet their water needs. To this question most households in Mwenga-Centre and Kasika-Chidasa answer elsewhere than in their plots, as they get their water from public taps. But in Kitutu, because of the poor quality of the water, many households have dug wells in their houses.

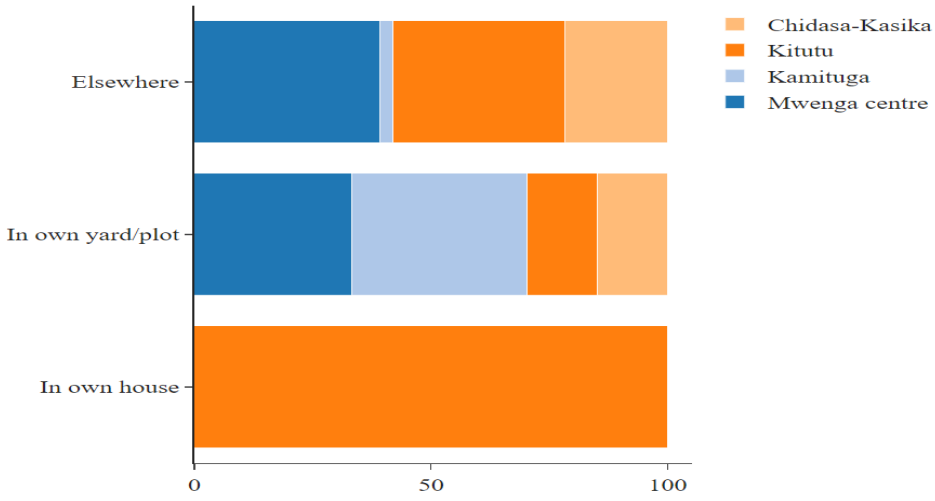

Figure 18:Water Availability

4.2.4 Quality of water

Here is an assessment of water quality based on household experience. Households were asked two main questions, namely whether the water supplied by their main source is generally acceptable in terms of quality and also whether the water is treated before consumption. As shown in Figure 19 and Figure 20, most households find the water unacceptable in terms of quality, and most do not treat it before consumption.

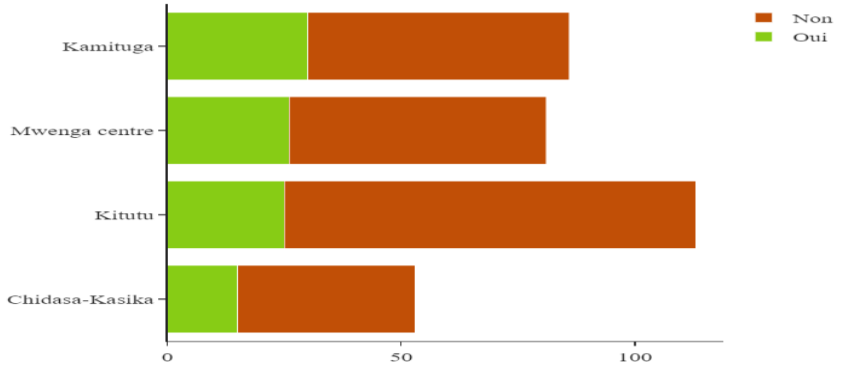

Figure 19:is quality of the water acceptable?

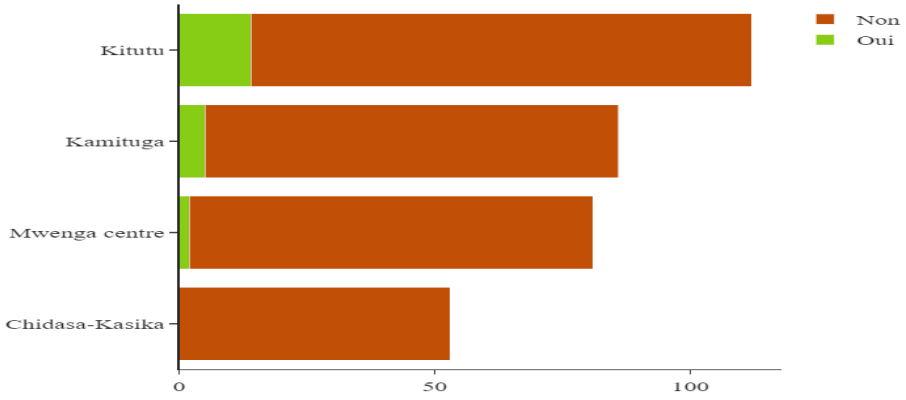

Figure 20:Is the water treated before drinking?

Water quality is the main concern of the local authorities in Mwenga territory. Indeed, due to the multiplication of mining operations (mainly gold mining by Chinese and Congolese companies)

in the territory, there has been a significant pollution of the watercourses and rivers in the territory in recent years. According to the authorities of the Wamuzimu and Basile chiefdoms, several cases of cholera and typhoid have been reported in recent years due to the pollution of the territory's rivers and streams.

4.2.5 Storage of water

As there is no piped water system in the households, households were asked if they use a storage tank**.** In general, households do not use water storage tanks, mainly due to lack of funds to purchase water. However, the few households that do use a storage system generally only use 20, 10 and 5 litre containers.

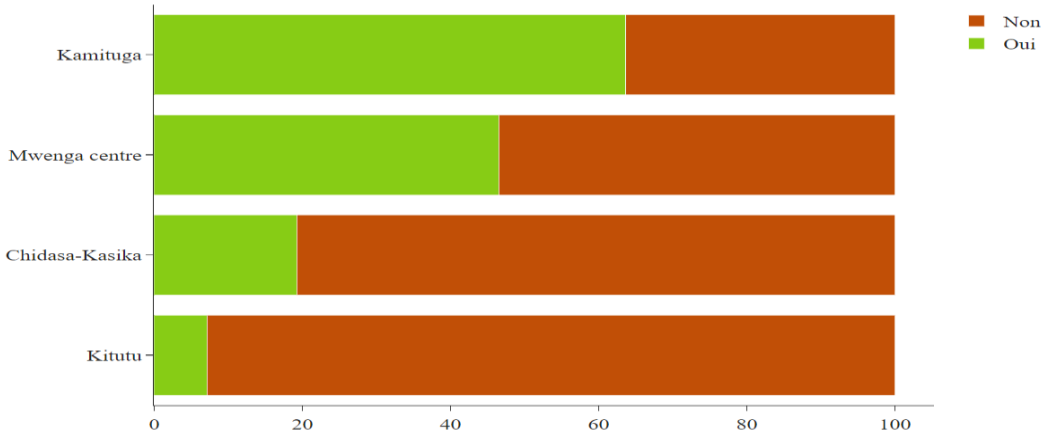

Figure 21:household use storage tank

4.3 Energy Access

The ESMAP Multi-Tier Framework (MTF) was used to assess access to energy in Mwenga territory. Both **access to electricity,** and **to cooking solutions** were assessed. As mentioned earlier, the ESMAP Multi-Tier Framework (MTF) provides a multidimensional definition of access to energy, breaking with the traditional binary definition (connected or not connected, cooking with firewood or not) of energy access.

4.3.1 Access to Electricity

The province of South Kivu despite its huge hydroelectric and natural gas potential (the potential could reach 57.00 billion Nm3), remains with an electrification rate of about 7.9%, which is very low considering its potential. Concerning the situation in the territory of Mwenga, there is no electricity network except in the locality of Kamituga, where the Mungombe hydroelectric dam on the Zizi River provides electricity to the town.

4.3.1.1 Attributes describing electricity access

The MTF Access to Electricity Supply Ranking Matrix provides a broader view of access to electricity based on a set of attributes. From the Matrix it was found that electricity capacity does not meet the needs of households according to the appliances owned. Even though most households have affordable electricity service, as shown in the Matrix (Figure 22), the source of electricity is not always available (availability). It should also be noted that households report that the quality of the source of electricity is not good, even though its use does not cause major problems (is safe). However, most of the households interviewed would like to change their electricity source, but due to lack of financial means are forced to use low quality solar kites.

Also, after each attribute is assessed separately by assigning it a Tier (level) from 0 to 5, then the MTF index for access to electricity is defined as the minimum among all attributes for each household. Thus, as shown in Figure 23, the MTF index for all intervening households is between tier 0-2. This situation corresponds concretely to households that use solar kits or candle and fuel lamps that do not allow for certain electricity services such as phone recharging.

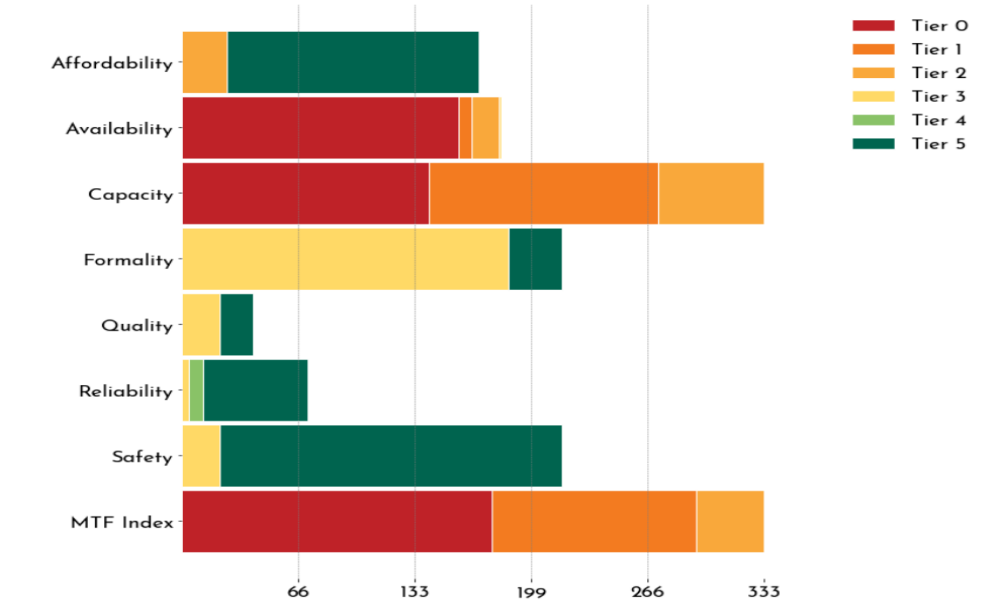

Figure 22: Attributes describing electricity access

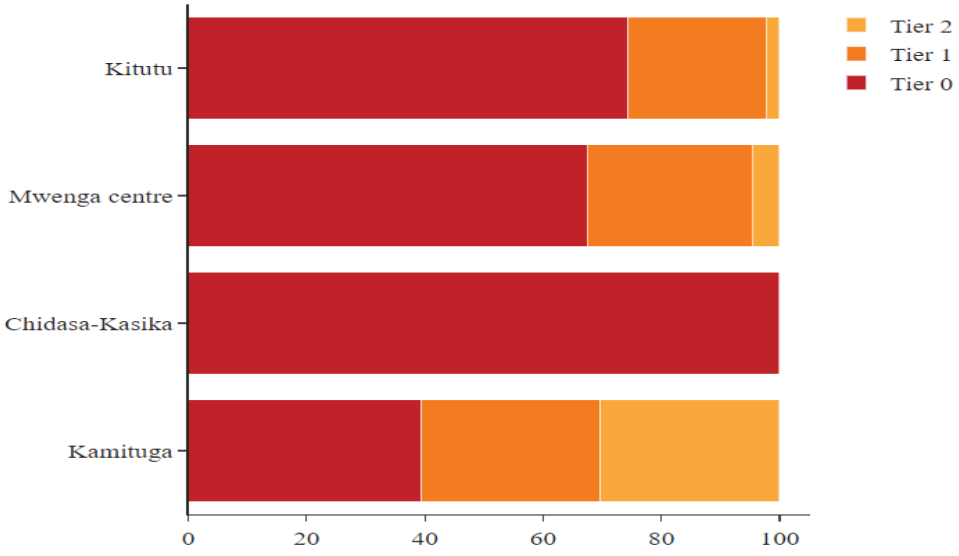

Figure 23:MTF Index (Access to electricity): Analysis per locality

4.3.1.2 Power sources

When asked what is the primary source of electricity for your household, most households answered none. Only the locality of Kamituga, as mentioned above, is served by a mini-electricity network. On the other hand, a proportion of households in the localities of Mwenga centre, Kitutu and Kasika-Chidasa have either solar lighting systems or portable solar lanterns. Since most of them only have basic solar systems as their power source, their use of household appliances is generally limited to telephones and radios (Figure 25).

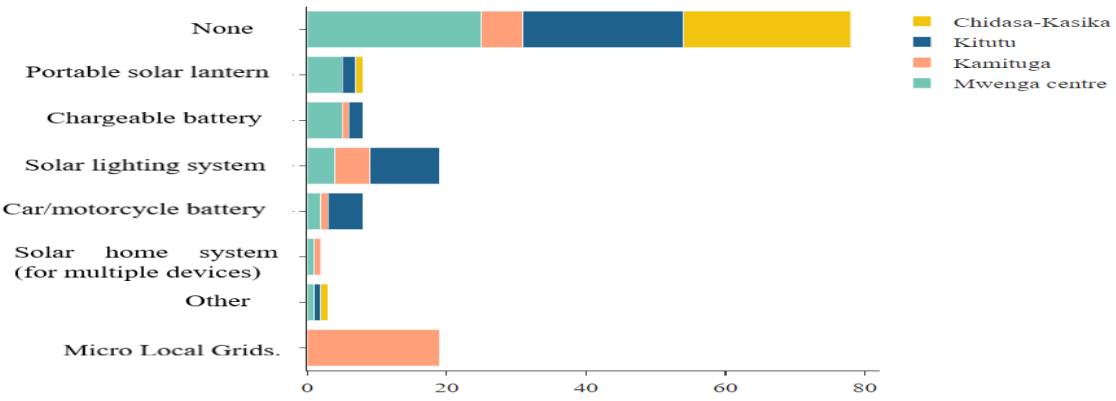

Figure 24:Primary electricity source

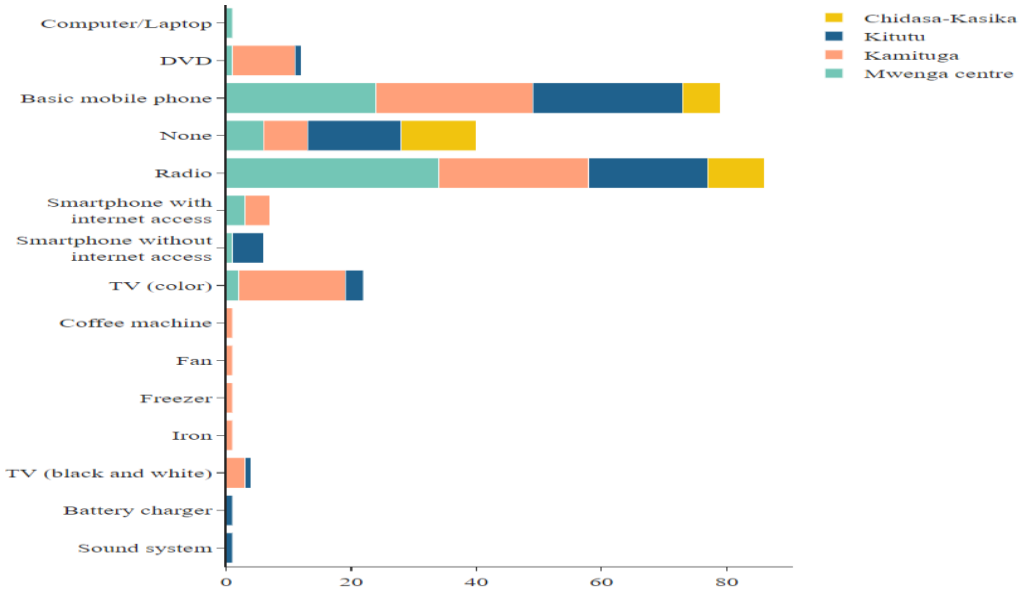

Figure 25:Household Appliances

4.3.2 Cooking Solutions

4.3.2.1 Attributes describing access to cooking solutions

As shown in the Access to Cooking Solutions Ranking Matrix below (Figure 26), most of the households interviewed find energy sources for cooking affordable, available, and consider their cookstoves safe. This is mainly due to the fact that most use wood as their main source of cooking energy and this wood is not being paid for.

However, the MTF index for each household, which is given by the minimum ranking among all attributes, places all interviewed households between tier 0-2 (see Figure 27). Firewood, which is the main cooking fuel in the region, was found to be both inconvenient due to the time required to collect and prepare the wood, as well as unclean for cooking due to the smoke produced when it is used.

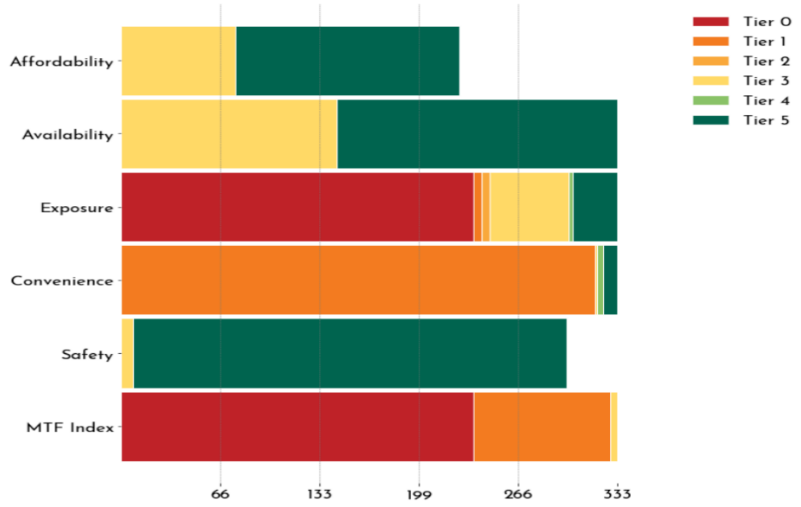

Figure 26:Attributes describing access to cooking solutions

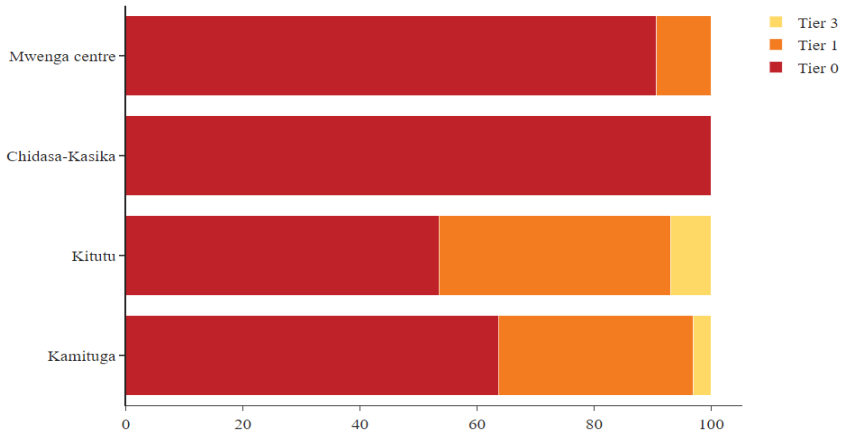

Figure 27:MTF index (cooking solution): Analysis per locality

4.3.2.2 Cookstove

The main cookstoves used in the interviewed households are the traditional three-stone stove and the traditional home-made stove.

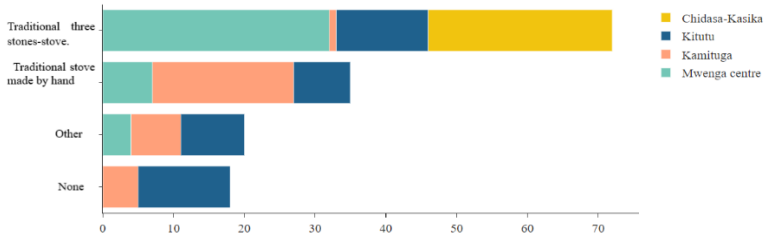

Figure 28:main cookstove

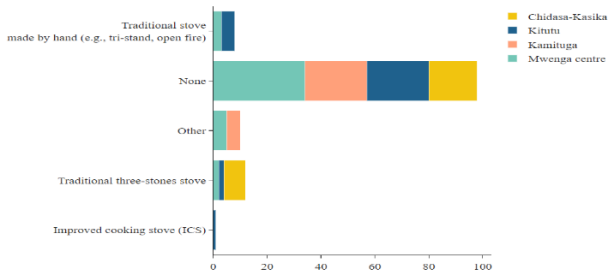

Figure 29:Secondary stoves

4.3.2.3 Primary Cooking fuels

The primary cooking fuel in Mwenga territory is mainly wood, followed by charcoal which is used in some prefabricated cookstoves (see Figure 30 and Figure 31).

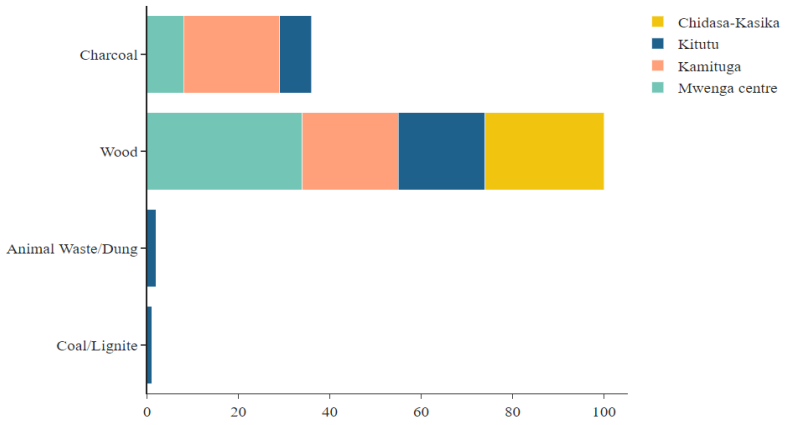

Figure 30:Solid fuels used in the hand made stove

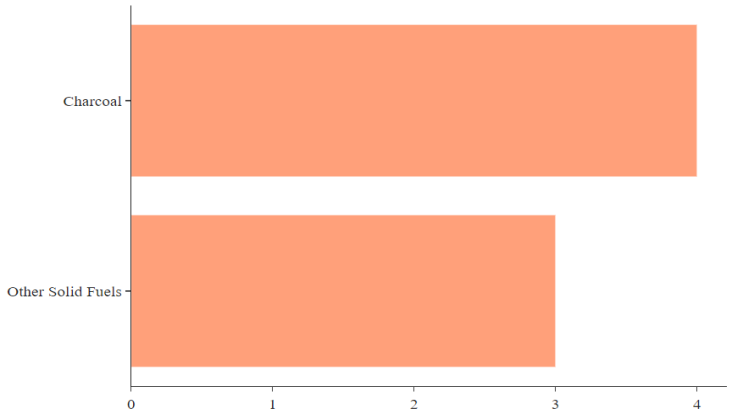

Figure 31:Solid fuels used in the prefabricated stove

4.4 Food Access

To assess food access, we considered two survey modules.

- Food Insecurity Experience Scale (FIES): 8 questions developed for the assessment of food insecurity at the individual level.
- Household Dietary Score: a series of questions to characterise food availability and variability.

This framework allowed us to assess food insecurity on the basis of personal experience, and to determine the severity of food insecurity by asking households about their access to adequate food.

4.4.1 Food Insecurity Experience Scale (FIES)

To determine the Food Insecurity Experience Scale, these 8 questions were asked of households.

Table 17:Food Insecurity Experience Scale Questions

During the last 12 months, was there a time when, because of lack of money or other resources:	
• you were worried you would not have enough food to eat?	**(WORRIED)**
• You were unable to eat healthy and nutritious food?	**(HEALTHY)**
• You ate only a few kinds of foods?	**(FEWFOOD)**
• You had to skip a meal?	**(SKIPPED)**
• You ate less than you thought you should?	**(ATELESS)**
• Your household ran out of food?	**(RUNOUT)**
• You were hungry but did not eat?	**(HUNGRY)**
• You went without eating for a whole day?	**(WHLDAY)**

Thus, based on the household responses, we were able to determine the household's food situation. As shown in Figure 32 , most households have answered **yes in the last months** and **yes in the last years** to the questions. What this means in concrete terms is that in the last 12 months, due to lack of money or other resources, most of the households interviewed said they were afraid of not having enough to eat, lacked healthy and nutritious food, ate only one or a few types of food most of the time, had to skip meals, ate less than they thought they would, sometimes lacked more food,

did not eat when they were hungry. In conclusion, according to the Food Insecurity Experience Scale, most of the households interviewed are severely food insecure.

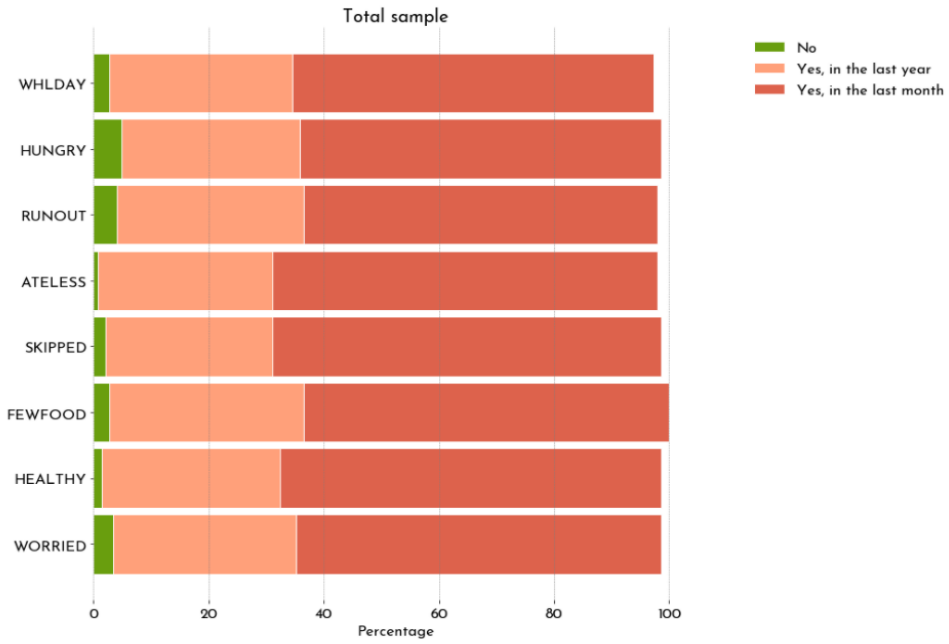

Figure 32:Households Food Insecurity Experience Scale

4.4.2 Household Dietary Score

Since dietary diversity is a qualitative measure of food consumption that captures the variety of foods that households have access to, the survey asked a series of questions about the foods and beverages that household members had consumed in recent days. These questions aimed to characterise food availability and diversity in the household. Based on the FAO's Guide to Measuring Dietary Diversity at the Household and Individual Level, the questions covered the following food groups: Cereals, white roots and tubers, vitamin A-rich vegetables and tubers, dark green leafy vegetables, other vegetables, vitamin A-rich fruits, other fruits, offal, meat (muscle), eggs, fish and seafood, pulses, nuts and seeds, milk and dairy products, oils and fats, sweets, spices, condiments, beverages (Kennedy, Ballard, and Dop 2013) .

The dominant crop and staple food in Mwenga territory is cassava, both the tuber and the leaves. In recent years, due to mining activities, many households have abandoned agricultural activities in preference to artisanal mining. This has led to a significant drop in agricultural production in the region and many problems in the diversification of the household dietary needs. As a result, the household dietary pattern in Mwenga territory remains relatively undiversified (see Figure 33).

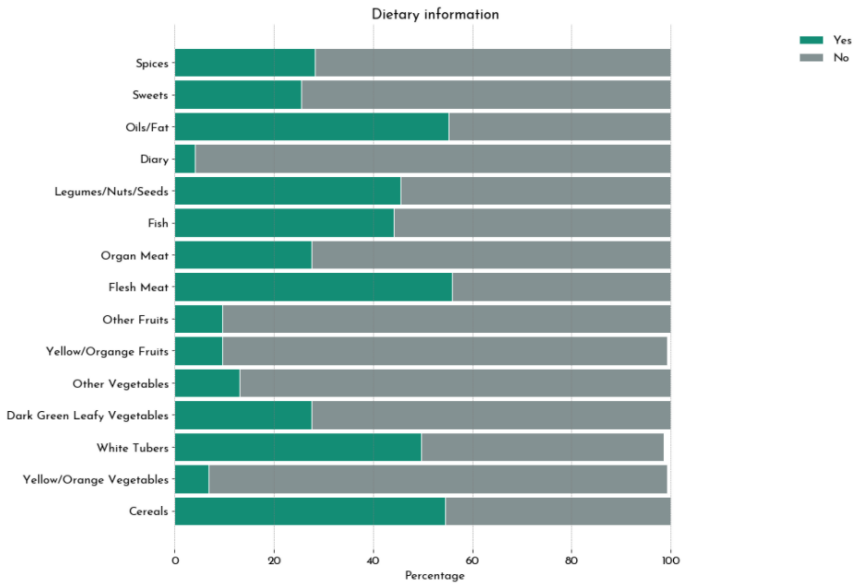

Figure 33:Household Dietary Module

5 Conclusions, and Recommendations

5.1 Conclusion

The main objective of the study was to understand the relevance and dependence of impact indicators for energy access, water access (WASH) and food security in the Mwenga territory in South Kivu, Eastern Democratic Republic of Congo. To do this, four (4) localities in the territory of Mwenga were chosen to conduct the survey where 333 households were surveyed. These were Kitutu and Kamituga in the Wamuzimu chiefdom, Mwenga centre in the Basile chiefdom and Kasika-Chidasa in the Lwindi chiefdom. The survey consisted of a set of questionnaires on access to water, energy and food. Using a digital application, the survey consisted of a set of questionnaires on access to water, energy and food.

With only 19% of the population having access to electrification while access to clean cooking solutions is only 4% nationally, DRC is one of the 20 most energy-deficient countries in the world (SEforALL 2021),. The same is true for access to water, as only about 52% of the DRC's population has access to improved water points. This situation is worse in South Kivu province, where access to improved water points is between 40 and 45% of the population. It is even worse in the territory of Mwenga, with a quasi-absence of state services. There is no water distribution network to households, nor an electricity network except in Kamituga which is served by the Mungombe hydroelectric dam on the Zizi River. In addition to this, there is the pollution of waterways and rivers by mining activities in the territory.

With regard to access to water, the study found that the majority of the main sources of drinking water in Mwenga territory are boreholes, public taps and dug wells. However, this basic access should be taken with great caution, as according to the households interviewed and the local authorities, the water drawn from these sources is not of good quality, as cases of water-related diseases have been reported in the area.

With regard to access to energy, the MTF index for access to electricity and access to cooking solutions, which is defined as the minimum among all attributes for each household, places almost all of the intervening households between Tier 0-2. Because the main sources of electricity for households are solar kits, which are generally of poor quality even though they are usually affordable. Also, the main source of energy for cooking is wood which is inconvenient especially

as it is used on traditional stoves which are not efficient, thus exposing households to smoke related problems.

Access to food is also an issue, as the study found through the Food Insecurity Experience Scale that most of the households surveyed are severely food insecure. The household food supply is generally made up of cassava, of which both the leaves and the tuber are consumed.

5.2 Recommendation

As the study has highlighted a range of problems related to access to water, energy and food, we can make the following recommendations to help improve the situation.

1. More massive deployment of state services in the field of water, sanitation and electricity.
2. Non-governmental and international organisations operating in the region should integrate a nexus approach into their development programmes.
3. Regulation and supervision of mining activities in the area in order to reduce the pollution of the region's rivers and streams.
4. Raising the awareness of local people to return to agricultural activities.
5. Setting up agricultural cooperatives by providing them with mechanical means to increase agricultural production in the region.
6. Introduction of new crops in the region to allow diversification of household food dietary.

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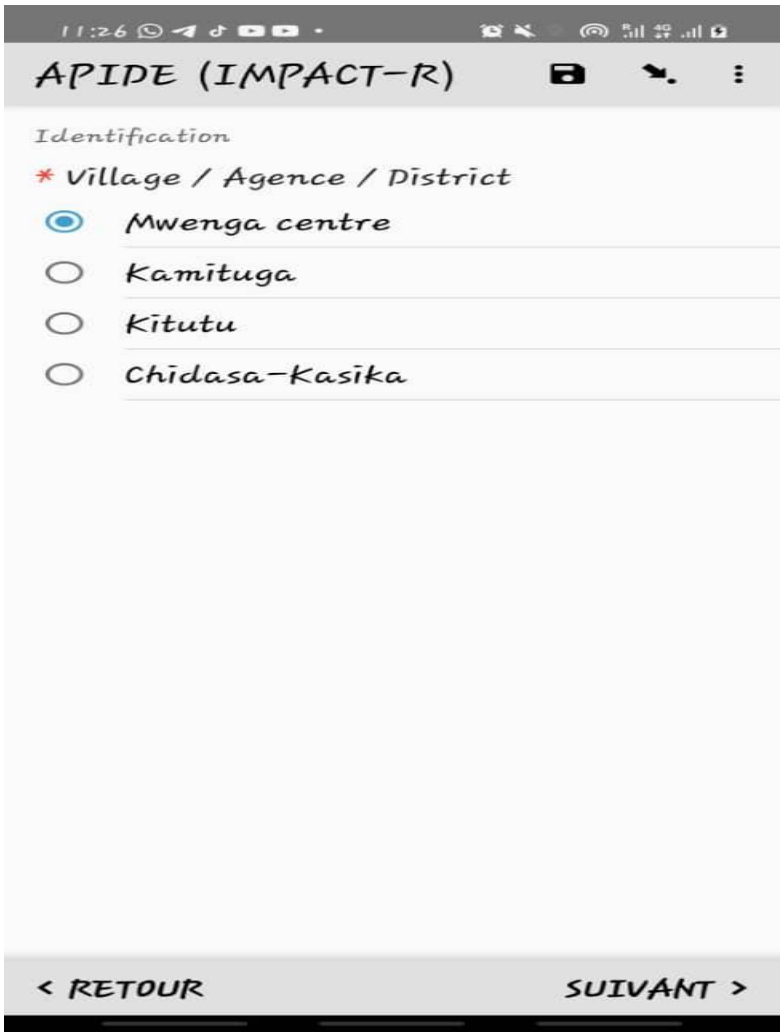
Appendix

Equations:

ODK Collect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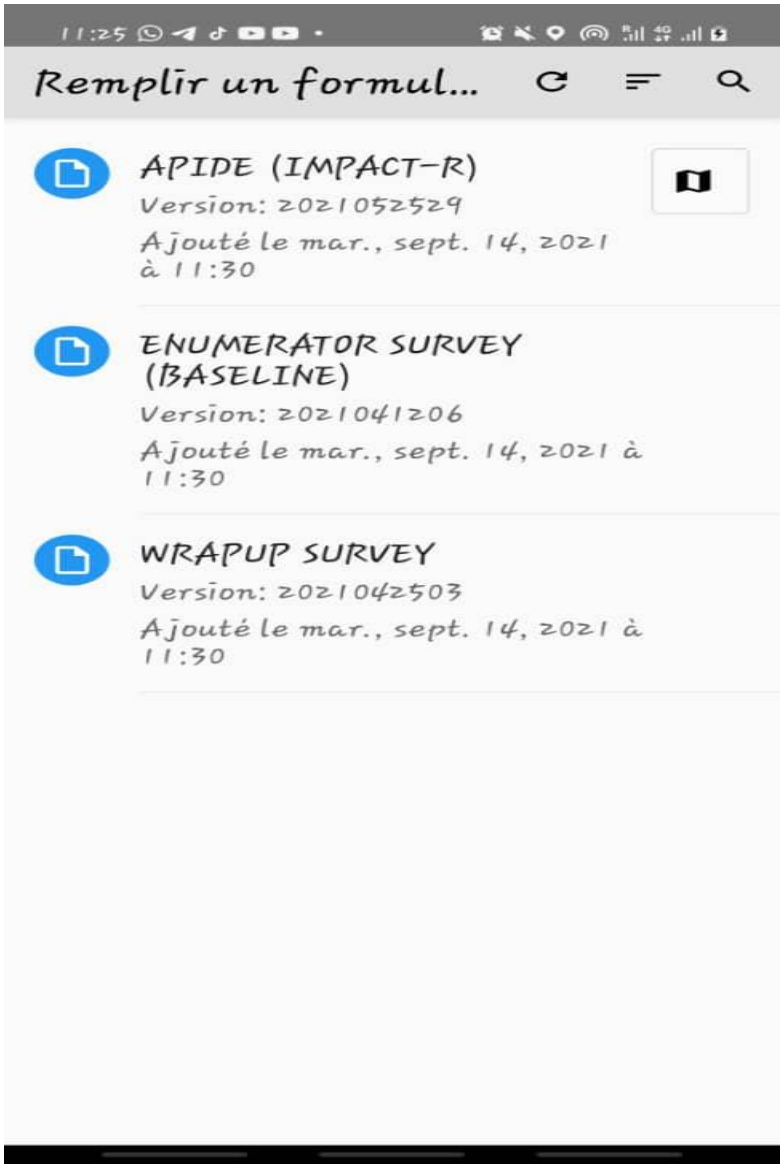
Mwenga centre
Kamituga
Kitutu
Chidasa-Kasika
< RETOUR
SUIVANT >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ENUMERATOR SURVEY (BASELINE)
Version: 2021041206
Ajouté le mar., sept. 14, 2021 à 11:30
WRAPUP SURVEY
Version: 2021042503
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