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POTENTIAL ROLE OF RENEWABLE ENERGY IN ENERGY MIX TO OVERCOME ENERGY SHORTFALL IN NIGER

CASE OF SEKOUKOU VILLAGE

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DECLARATION

I, Claude Sara LEKOMBO, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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CERTIFICATION

I undersigned, Prof. Adamou Rabani Professor in Physico-Chemistry, in the speciality of Applied Photochemistry at Abdou Moumouni University in Niger and Director WASCAL (Climate Change and Energy) Climate Change and Energy Program, certify that Mrs. Claude Sara LEKOMBO conducted her Master's Thesis research under my supervision.

Signature Supervisor: Date: 30 August 2019

DEDICATION

I dedicate this master thesis dissertation to my dear mother.

ACKNOWLEDGMENT

To the Lord Almighty God who created me and gave me the strength and the courage to continue when discouragement was felt, to be eternally praised Amen! We give glory to GOD for his love, his fidelity, his breath of life, his intelligence, his wisdom manifested towards us.

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ABSTRACT

Energy access is closely linked to any development. The lack of access to energy is a major obstacle to the development and the improvement of living conditions for developing countries. The most West African developing countries are characterized by extreme poverty and energy insecurity, although their potential for renewable energy is considerable. The increase in the share of renewable energy in the national energy mix remains one of the main energy policy issues that the many stakeholders in developing countries like Niger are facing. This is often due to the lack of existing studies on the potential of its renewable energies.

This work trays to identify the potential of renewable energy and the role it plays in the Niger's national energy supply to overcome the energy deficit. During the study, the energy needs that were taken into account for households were mainly in electricity and cooking. The surveys were conducted on 60 households in Sekoukou's village with of nearly 70 households.

This study has made possible to identify the potential renewable energy sources in the village of Sékoukou and the estimation of their potential. Sékoukou village has a big energy potential consists of four energy source: sun, wind, wood and green wastes. The solar potential already exploited allows to Sékoukou's people to improve their living conditions. Indeed,the village does not have the forest (wood) potential, however a potential of argricultural and animal weste has been detected for biochar production. The integration of renewable energy in energy mix can accelerate the potential economic activity of Sékoukou.

Keywords: Renewable energy potential, Energy mix, Energy shortfall, Energy policies, Niger, Sékoukou

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LIST OF ABBREVIATIONS AND ACRONYMS

AfDB: Africa Development Bank

ANPER:National Agency of Lightning Promotion in Rural Area

C: carbon

CNES :National Agency of Energy Solar

CSP: Concentrated solar power

EC:European Commission

ECOWAS: Economic Community of West African States

ECSKC:Energy Charter Secretariat Knowledge Centre

EEEP:ECOWAS Energy Efficiency Policy

EREP:ECOWAS Renewable Energy Policy

ECREE:Efficiency Regional Centre for Renewable Energy and Energy

GESFORCOM : Gestion forestière communale et communautaire / Communal and community forest management

FCFA: franc CFA, currency of West Africa

FTCP:Formations of Cultivated Terroirs and Wood Parks

ICRISAT: International Crops Research Institute for the Semi-Arid Tropics

IEA: International Energy Agency

INS: National Institute of Statistics

IRENA: international Renewable Energy Agency

GDP:Gross Domestic Product

GHG: Greenhouse gas

Gj: gigajoule

GWh: Gigawatt hour

Kg: kilogram

Ktoe: kilo tons of oil equivalent

KW: Kilowatt

KWp: Kilowatt Peak

LPG: Liquefied petroleum gas

NIGELEC: Société Nigérienne d'Electricité, Nigerien Electricity Society

NESAP : Niger Solar Electricity Access Project

OECD: Organisation for Economic Co-operation and Development

PDE:Develop an Electrification Master Plan

PNE:National Program Electrification

RE: Renewable Energy

RES: Renewable Energy Source

SDACD:Supply Master Planin Domestic Fuels

SIE: Energy Information System

SNAE:National Electricity Access Strategy

SSA: Sub-Saharan Africa

Wascal: West African Center for Scientific Service on Climate Change and Land Use Adapted

I. INTRODUCTION

I. 1. Background

Access to modern energy is seen as a prerequisite for sustainable development, poverty reduction and the achievement of sustainable development goals (Ouedraogo, 2012). Energy is a very important element for all activities and plays a vital role in the economic development of any country. Most of the energy used in the world comes from fossil fuels. The depletion of these resources, price increases and concerns about environmental impact are forcing scientists and policymakers today to seek alternative forms of cleaner energy to integrate into the energy mix to meet steadily to the energy demand while preserving the environment. At the time of the energy transition, the use of renewable energy sources such as solar energy, wind power, hydroelectricity and biomass are one solution that attracts worldwide interest and reflection furthermore, with the advancements of technologies and its maturity, the cost of linking these sources of energy is becoming attractive.

In most developing countries such as Niger, access to energy remains a major challenge, especially for those living in rural areas. This situation is largely due to an energy sector heavily dependent on the outside   a bad balance in the energy mix. Indeed, the electricity sector in the Niger has a very bad balance of its energy mix and has a very low coverage percentage share in rural areas compared to urban areas. The national rate of access to electricity in Niger has increased from nearly 11% in 2015 to about 13% in 2018 (ANPER, 2019). This weak growth results from an energetic external dependency. It must also be recognized that the use of biomass remains dominant in energy consumption for cooking in Africa (Ouedraogo, 2017). In Niger, firewood accounts for 94.55% of final household energy consumption (SIE, 2018), it is the main source for cooking. Moreover, nearly 600,000 Africans die each year, most of whom are women and children, because of the pollution of the air due to the traditional use of firewood for cooking (AfDB, 2018). Despite the political efforts and strategies put in place by most governments, the extension of conventional grid electrification is considered too expensive for most rural areas in Africa (Karekezi and, 2002). However, to reach the goal of sustainable development by 2030, it would have to find clean and affordable solutions that respect the environment and culture in order to increase the rate of access to electricity in rural areas.

However, Niger has enormous potential in terms of energy resources, although conventional and renewable. Solar energy is the most popular renewable energy source in the whole country.

In addition, Niger currently has an unprecedented opportunity to accelerate economic development, reduce poverty and promote equitable prosperity by improving its energy situation through renewable energy technologies and public funds, ENCREE and other partners. The political will towards the sector continues to grow. Niger, according to its national electrification strategy, plans to reach 60% of access by 2027. The Nigerien government is making efforts to increase its electricity supply and encourage investment in the energy sector to stimulate the economy by creating income activities. It is a good thing that energy is the center of development, because it allows the development of all sectors. However, Niger's ability to meet this ambitious goal is limited by the challenges of the electricity sector. As a result, Niger is making great efforts to improve the regulatory sector of the energy market, in 2015, two authorities saw the creation of the Energy Sector Regulatory Authority (ESRA) to increase transparency and fair competition among the numerous actors in the energy sector and the Nigerien Rural Electrification Promotion Agency (ANPER), responsible for designing, implementing and monitoring rural electrification programs throughout the country. Other recent reforms also include a joint ministerial decree that removes taxes on solar power kits and wind equipment, reflects a political will to facilitate the integration of renewable energies into the energy mix and to allow a greater number of households to have access to electricity, and also a new electricity law that will allow the creation of IPP and ongoing avenues with consultants and the African Legal Support Facility to strengthen the legal and regulatory framework for renewable energies.

Despite the efforts made in this sector, the current weakness of the energy sector is a major barrier to the development of the sector and many others as well. Dependency is the biggest obstacle to economic development. Niger's energy dependence on the outside world is about 70% in terms of electricity and imports about 42% of the wood energy. A situation that weakens this sector, and which has impact in other sectors. It must be recognized, however, that this state of affairs is not only linked to a political will but also to the implementation of policies.

On the other hand, the use of Niger renewable energy potential that remains untapped but could help solve the energy shortfall and security problem. Renewable energy sources offer a unique opportunity to solve energy security problems and climate change and play a driving role in economic development.

This work aims to show that the integration of the Renewable Energy Source potential in the energy mix can impact or reduce the problem of energy deficit in Niger.

I. 2. Problem Analysis

Access to energy is a crucial element for the economic, social and political development of a country. Indeed, all communities need energy services to meet basic human needs and to foster transformation processes. Africa faces many challenges in terms of access to energy and water, and to this are added the constraints related to climate change that limit the quality of life of the African citizen, this lack of access to electricity is a barrier for economic development and poverty especially for remote areas, particularly in West Africa where energy poverty and security are of high importance for governments as it affects local economic growth and industrial development (ECREEE, 2012). For example Niger faces two big challenge energy security due to external dependence and supply deficit. Indeed Electricity situation in Niger is characterized by an insufficient supply and dependence from outside, low rates of access and coverage, inadequate and aging of facilities, transmission and distribution, poor service, price inadequacy, absence of regulation. For instance Niger depends on 70% of Nigeria in terms of imported energy (NIGELEC, 2015). In 2012, Niger's total primary energy supply was estimated at 2747 ktoe, of which more than 70% comes from biomass (Figure 1.1).

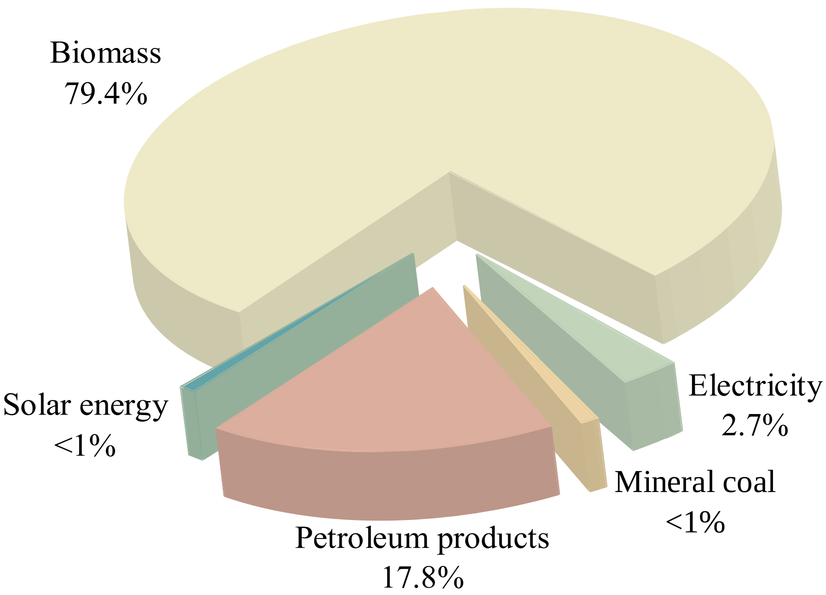


Figure 1 .1: Distribution of Final Primary Energy Consumption

Source: (ECSKC, 2015)

Moreover, Niger's final energy consumption is estimated at 0.15 toe per capita, one of the lowest in the world (ECSKC, 2015). This consumption is dominated by household, transportation and industries (Figure 1.2).

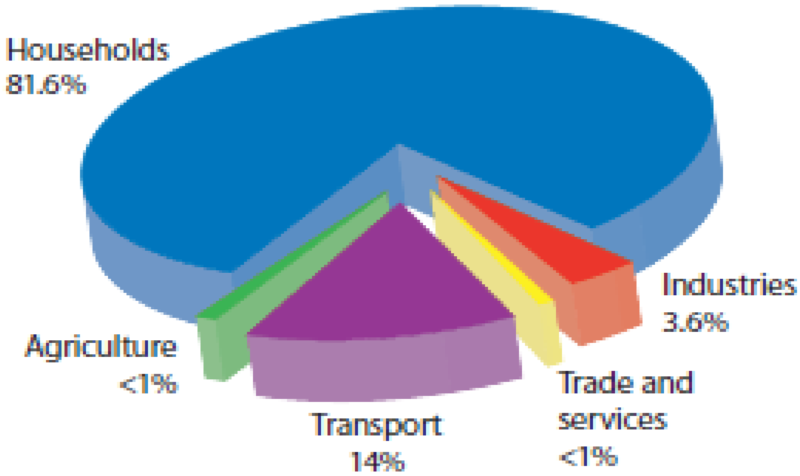


Figure 1. 2: Distribution of Final Energy Consumption by Use

Source: (ECSKC, 2015)

The country is characterized by a low access rate especially in rural areas. The current access rate is 12.93% of which % 0.93 in rural areas and 71.48 in urban areas (ANPER, 2019). This situation is largely due to the dependence of Nigeria which ensured Niger about 70% of its energy thanks to the 1972 agreement between the two countries ((NIGELEC, 2015).

This big dependence causes a major problem of supply deficit, which is especially noticeable during the period of heat when demand is particularly high. It should be remembered that the production capacity of Niger is 283 MW and it is 100% fossil energy.

In view of the increase in energy demand, the depletion of fossil fuels and concerns about the consequences or impact of major environmental disasters in the world, particularly in Africa, all these reasons justify the interest on renewable energies today. In addition, renewable energies are seen as a potentially important new source of jobs and rural growth, and a means to address environmental, energy access and security concerns the Organization for Economic Co-operation and Development (OECD, 2012).

Like most African countries, Niger face the challenge of access to energy and climate change. On the other hand, Niger is endowed with huge energy resources consisting of conventional and renewable energy sources. These resources are unequally distributed among the different regions and geological and metrological systems. Niger hardly benefits from these energy resources, namely renewable energy, which represents less than 1% of the energy mix. In addition to that, the use of the potential of its renewable resources could make it possible to remedy Niger's energy dependence and energy shortfall, but also promote the development of economic activities and improve the living conditions of rural populations.

Otherwise increasing the share of RE in a country or region's energy mix can improve energy security by providing greater diversity of supply (OECD, 2012).
Indeed, RE plays an important key role in projection for the future global energy provision particularly in the scenario which include measure to reduce emissions from energy production. It should be noted that the Nigerian Government is making efforts to promote REs to achieve SDG7. Indeed, Niger's government is working to expand its electricity supply and encourage investment in the energy sector to stimulate the economy. Niger is already taking critical steps to improve energy markets by creating, in 2015, a regulatory body ARSE (Autorité de Regulation du Secteur de l'Energie) to increase transparency and fair competition among numerous energy actors. The Government also created ANPER, which is mandated to design, implement, and monitor rural electrification programs throughout the country (Power Africa, 2018).
However, it should be remembered that there is still challenge to be raised, namely that of a plan for the integration of REs into the energy mix and the political will.
All that is involved in a panoply of questions concerns us: How the potential of REs can improve the energy shortfall of Niger. What a policy set up for their Integration in the energy mix?
This study seeks to harness the renewable energy potential of Niger to address the issue of the energy shortfall through the designing a policy for the integration of RE into energy mix.

I. 3. Research Gap

Renewable energy has been found to be a more economically viable alternative to fulfill the energy demands of numerous isolated consumers worldwide.
Indeed, like most of developing countries, Niger government was designed policy to increase the renewable energy contribution to the national energy balance from less than 0.1% in 2003 to 10% by 2020 by Creating the Stratégie Nationale sur les Énergies Renouvelables (SNER) and other policy to promote REs.
However, according to renewables readiness assessment by IRENA (2013), despite the efforts put in place by the Nigerien government, it lacks an effective policy to solve its energy problem and the lack of the real information on solar and wind is the barrier of the external investment. This study aims first to design an Integrated development planning of energy system to show how the integration of RE into the energy mix can help to overcome the energy shortfall in Niger.
Furthermore, papers reviewed in the areas discussed the techno-economic feasibility, the market and the reliability improvement of the Technologies. However, there is limited

discussion on the renewable energy policy action plan and the socioeconomic conditions at the government level that affects the expansion and the durability of the promoting of REs.
In that way, this work will try in another hand to discuss the general challenges of the integration of Res into the energy mix and renewable energy policy in the country.

I. 4. Objectives

I. 4.1. Main objective

The aim of this study is to determine renewable energy role in Niger energy mix to overcome energy shortfall in rural area and to deduce the strategies and mechanism to be adopted to accelerate the process of integration of renewable energies.

I. 4.2. Specific objectives

- To evaluate the RE potentials in Sekoukou village
- To analyse the energy demand and supply of Sekoukou village
- To identify the socio-economic activities in Sekoukou village
- To identify the instruments and strategies to facilitate the development of renewable energy in Niger.

I. 5. Structure of thesis

This study is structured as follows. It will begin with a general overview of renewable energy, its impacts and the energy situation in Niger, as well as policies. Subsequently, the methodology used to collect data for the village of Sékoukou was developed. Then the presentation of the results followed by the discussion. Finally, the proposal for policies for the integration of renewable energies.

II. LITERATURE REVIEW

In this section, we will give a general overview of renewable energies and their global impacts in the first part and then in the second we talk about the energy situation in general and existing policies in Niger.

II. 1. Empirical and theoretical review

II. 1.1. Evolution of renewable energy and energy security concepts

The concept of renewable energies and energy security has been the subject of particular and increasing attention in recent decades, in both in political and academic debates. There is a series of definitions of these concepts that are promoted by various international organizations as well as by individuals. The tables, Table II.1 and Table II.2, summarize some of definitions of the both concepts.

Despite the divergence of this concept, the following definitions have several points in common. The first is the emphasis on the availability and abundance of unlimited supply. The second concerns climate change due to the fact that they are clean energy sources with less impact on the environment and finally the third focuses on socially and economically sustainable development.

Of all this multiplicity of definitions, the definition of energy security can be summarized on three main points:

- autonomy (no risk of supply interruption due to socio-political, geopolitical, economic, technological and natural reasons),
- price (an affordable price balance, protection against inflation, no risk of influence on the price of oil),
- safety and security.

Table II.1: Definitions of renewable energy

Definitions	Sources
Renewable energy is relatively clean, widely available, and the supply is unlimited. Renewable energy is defined also as "fuels whose use today does not reduce the supply for tomorrow".	Komor, 2004
"Renewable energy is energy obtained from naturally repetitive and persistent flows of energy occurring in the local environment".	Twidell and Weir, 2015
"Renewable energy is a widely used term that describes certain types of energy production". In politics, business and academia, "renewable energy is often framed as the key solution to the global climate challenge".	Paehlke, 2005
"Renewable energy is at the centre of the transition to a less carbon-intensive and more sustainable energy system"	IAE, 2019
Renewable energy is considered also "to be in synergy with many aspects of sustainable development"	Inglesi-Lotz, 2016
"Renewable technologies are considered as clean sources of energy and optimal use of these resources minimize environmental impacts, produce minimum secondary wastes and are sustainable based on current and future economic and societal needs".	Panwar *et al.*, 2011

Table II.2: Definitions of energy security

Definitions	Source
Energy security is "the uninterrupted availability of energy sources at an affordable price. Energy security has many aspects: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance".	IEA, 2019
Energy security is defined as "the uninterrupted availability of energy sources at an affordable Price, can also profit from improved energy efficiency by decreasing the reliance on imported fossil fuels.	Ozturk, 2014
The Department of Energy and Climate Change defined Energy security as "secure energy means that the risks of interruption to energy supply, are low" (Department of Energy & Climate Change , 2009)	Lucas *et al.*, 2016
"Energy security is not only the ability of the energy systems to supply energy to consumers under reasonable conditions and acceptable prices, but also a system ability to resist potential disturbances arising due to technological, natural, economic, sociopolitical and geopolitical reasons.''	Juozas Augutis *et al.*, 2004

II. 1.2. Overview of renewable energy

Renewable energy (RE) is defined as energy that is generated from natural processes that are continuously replenished (Vasques, 2014). This includes sunlight, geothermal heat, wind, tides, hydropower, and various forms of biomass. This energy cannot be exhausted and is constantly renewed.

It should be noted that renewable energy sources have also been important for mankind since time immemorial, for example firewood and charcoal were used for heating, cooking and steam production; wind was used to move ships; hydropower and wind were used to power grain mills. Renewable energies have the potential to provide modern energy services with lower greenhouse gas emissions (Asif and Muneer, 2007). Renewable energy has grown rapidly in recent years, especially in the electricity sector, where evidence is important. The share of renewable energy in global energy demand is expected to increase by one-fifth over the next five years to reach 12.4% in 2023 (IRENA, 2018). Indeed, renewable energies should satisfy 30% of electricity demand in 2023 compared to 24% in 2017. During this period, renewable energies are expected to account for 70% of the global growth in electricity production driven by photovoltaics, wind, hydropower and finally bioenergy. Hydropower remains the most important source of renewable energy and will provide 16% of electricity demand in 2023, followed by wind power (6%), photovoltaics (4%) and bioenergy (3%) (IEA, 2018).

Despite the fact that the renewable energy sector is growing exponentially worldwide, the use of this energy source remains largely untapped in Africa. Modern renewable energies represent less than 2% of the energy mix in Sub-Saharan Africa (SSA) with the exception of solid biomass, which is traditionally used and represents more than 80% of the energy mix as shown in the (Figure 2.1), (AFDB, 2016). The implementation of some supportive policies and strategies have helped to encourage the modern renewable energy sector, but it is still in the process of being developed compared to amount of biomass (AFDB, 2016).

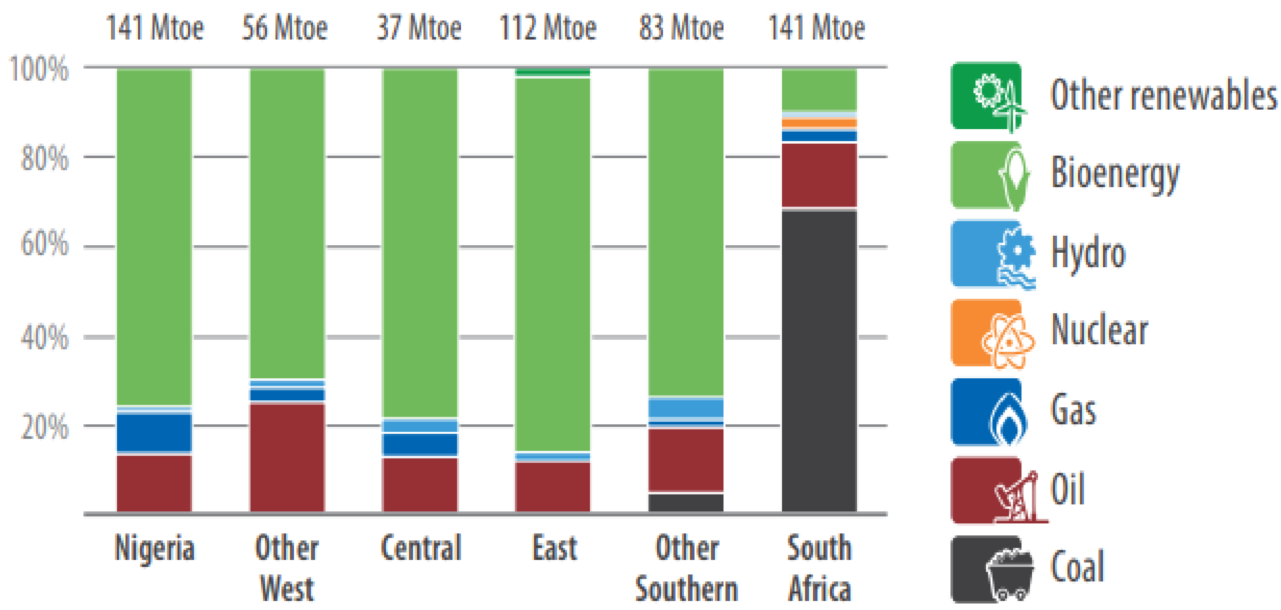


Figure 2.1: Sub-Saharan Africa primary energy mix by sub-region in 2012

Source: AFDB-Gender_and_Energy, 2016

Renewable energy sources have enormous potential and can play an important role in achieving universal access to energy by meeting current and future global energy demand, particularly in Africa or more than 645 million Africans do not have access to energy (AFDB, 2016).

The vast solar and hydroelectric potential, complemented by bioenergy resources, wind, geothermal and marine energy in parts of Africa can meet most of the current and future energy demand, both in concentrated high-demand in urban and in remote rural areas (IRENA, 2016). The technologies based on renewable energies represent today the most economical solution to answer the problem of access to energy and energy security of certain African country like Niger.

The potential of renewable energy in Niger, especially solar energy, can be a solution for the country to solve its energy deficit. However, the success of this cannot be achieved with awareness, willingness and effective policies (IEA, 2018).

II.1.2.1. Renewable energy link energy security, energy mix and climate change

Energy plays a vital role for human well-being and capital for the development of economic (Shahsavari and Akbari, 2018). Indeed, energy is at the heart of any production process and must be secure for the economic growth of the countries (Gökgöz and Güvercin, 2018). According to the International Energy Agency, energy security is defined as “the uninterrupted availability of affordable energy sources. Energy security offers two solutions: long-term, which consists mainly of investing in a timely manner to provide energy according to changing needs, and short-term, which focuses on the ability of the energy system to respond quickly to sudden changes in the balance between supply and demand." The IEA focuses on three important points in this definition on the consideration of long-term environmental and economic needs and on the permanent availability of supply in energy balance of short-term.

Indeed, the energy security of a country depends on a number of factors, these factors often interdependent (Augutis *et al*., 2015). For example it has been reported that the Economic Community of West African States region is facing the reality of energy vulnerability, instability of fuel prices and unreliability of the energy system, this situation is far from resolved (ECREEE, 2012). It should be added that this energy vulnerability is related to the dependence of fossil oil energy, 60% of the production of electricity comes from the diesel, to that must also add the imbalance at the level of supply and demand. However an adequate level of energy security is very important for the proper functioning of the economy and is one of the main guarantees to attract investors and national security (Augutis *et al*., 2015).

However, the use of renewable energy sources increases energy security and offers many socio-economic benefits to developing countries. Indeed, renewable energy sources and technologies have potential to provide solutions to the long-standing energy problems being faced by the developing countries. The renewable energy sources like wind energy, solar energy, geothermal energy, ocean energy, biomass energy and fuel cell technology can be used to overcome energy shortfull in a country (Kumar *et al*., 2010).

According to the OECD, Renewable Energy (RE) is being championed as a potentially significant new source of jobs and rural growth in OECD countries, and a means of addressing environmental and energy security concerns (OECD, 2012).

On the other hand, Inglesilotz (2015) has reported the importance of renewable energies in the energy mix at the international level are appreciated. Renewable Energy Development can help strengthen the security of energy supply and control their Greenhouse Gas (GHG) emissions. For example, the European Commission (EC) wants to increase the share of renewable energy sources to 20% of the energy mix by 2020 (EC).

It is in the same logic that Farooqui (2014) shows on the one hand that the penetration of renewable energies in the energy balance can allow Pakisan to answer their problem of independence and energy security and on the other hand it underlines many barriers such as political, fiscal, technological, market and social have delayed the effective penetration of renewable energy in the mix, indeed, it should be noted that some political and regulatory obstacles have been addressed over the past year with visible result for example a production of 900 MW from the combination of renewable energies. However there is still some effort to be made, a well-defined policy is the key to the country's exit from energy dependence.

II.1.2.2. Renewable energy and economy

Access to modern, clean and reliable energy services such as electricity and efficient fuel is cornerstone of the economic and social development of a community, as well as a nation (Tania and Anisuzzaman, 2016). Moreover, this shows that access to energy is a source of economic activities. Indeed, between energy consumption and economic growth there is an interdependence and complementary link. For example, an increase per capita real Gross Domestic Product (GDP) leads to an increase in energy consumption by short-term, which can increase production in sector and create new job (Ouedraogo, 2013).

However, more than half of the African population has not yet access to clean and reliable energy services. According to the African Development Bank, more than 645 million Africans do not have access to electricity. And some nearly 600,000 Africans die each year, most of whom are women and children, because of the pollution of the air due to the traditional use of firewood for cooking (AFDB, 2018). On the other hand, the continent is full of huge sources of renewable energy like solar, thermal, biomass, wind energy, which can be used to meet the challenges that Africa faces and limits its development. It should be noted the lack of access to affordable and reliable modern energy services constitute a fundamental obstacle to human, social, sustainable economic development and poverty reduction (Ouedraogo, 2013).

Indeed, the use of renewable energy potential can be an effective way to address the problem of energy shortfall on the continent. further promotes the integration of renewable energies into the energy mix through effective policies will not only bring about the further modernization of the energy sector, but also others sectors of countries as the economic sector (Inglesi-Lotz, 2015). Likewise, for OECD, renewable energies have proven significant importance in the creation of new job and economy growth in rural areas in the OECD countries policy (OECD, 2012). There is a positive relationship between real income per capita renewable energy consumption in remote areas as Lemaitre (2018), showed in its study.

In addition, access to energy services is necessary for the development of a country as it’s create jobs, develop industries, strengthen value-added economic activities, and support income-generating activities especially in rural areas. The use of efficient fuels is essential for health and many industrial activities. Electricity is an essential input to modern productive activities generating revenue (Kaygusuz, 2007).

According to OECD (2012), some of the case studies show the deployment of renewable energies can also offer some economic benefits to the communities, which can be listed as follows:

- new revenue sources. RE increases the tax base for improving service provision in rural communities. It can also be generating extra income for land owners and land-based activities. Indeed, farmers and forest owners who integrating renewable energy production into their activities have diversified, increased, and stabilized their income sources.
- new job and business opportunities, especially when a large number of actors is involved and when the RE activity is embedded in the local economy. Although RE tends to have a limited impact on local labor markets, it can create some valuable job opportunities for people in regions where there are otherwise limited employment opportunities. RE can create direct jobs, such as in operating and maintaining equipment. However, most long-term jobs are indirect, arising along the renewable energy supply-chain (manufacturing, specialized services), and by adapting existing expertise to the needs of renewable energy.

In fact, also Inglesi-Lotz (2015), its study shows that the influence of renewable energy consumption or its share to the total energy mix to economic growth is positive and statistically significant. From a policy point of view, promoting renewable energies bears benefits not only for the environment but also for the economic conditions of the countries.

II. 2. Niger energy sector

II.2.1. Background

The Republic of Niger is a member country of ECOWAS, with a area of 1,267,000 km^2, located between latitudes 11°37 and 24°33 north and longitudes 0°06 and 16°00 East. The capital of Niger is the city of Niamey. Niger is bordered on the north by Libya and Algeria, East by Chad, southern by Nigeria and Benin, and to the west with Burkina Faso and Mali (INS, 2016). The Nigerien population has more than doubled in 24 years, from 5,102,990 in 1977 to 11,066,291 in 2001 and then to 17,138,707 in 2012 (INS, 2012).

Niger is characterized by a Sahelian climate with a long dry season of eight to ten months and a short rainy season that lasts three to four months with a significant variation in the number of days of rain from north to south. There are four climatic zones:

- **the saharan zone**: covers 77% of the country, receives less than 100 - 150 mm per year. Apart from the Tenere, the valleys and oases of the Aïr and Kawar, forest vegetation almost does not exist. When it exists, it is a discontinuous steppe, generally present in depressions.

- **the sahel-Saharan zone**: covers about 12% of the country's surface area. It receives 150 mm at 350 mm of rain per year. It is characterized by herbaceous and shrubby steppe vegetation dominated by grasses (contracted or clear shrubby formations), which gives it an essentially pastoral vocation.
- **the sahel zone**: covers about 10% of the country's surface area, it receives 350 to 600 mm of rain per year. Characterized by a vegetation of wooded and shrubby steppes, it is an area with agricultural vocation. As a result, it is subject to intense demographic pressure.
- **the sahelo-sudanian zone**: this zone covers about 1% of the total area, receives 600 to 800 mm of rain per year. It is dominated by wooded and shrubby savannahs. With an agricultural vocation, it is densely populated and home to Park W. The woody stratum includes shrubs and trees capable of locally constitute closed stands. Vegetation is generally characterized by combrétacées and by the presence of other valuable species such as Butyrospermum parkii (shea), Parkia biglobosa (néré) etc.

Sahelian areas are characterized by vegetation that passes through contracted or clear shrubs in the north, to more diffuse and tree-lined formations in the south. These are steppe formations at Acacia raddiana and Aristida mutabilis on sandy substrates, Acacia senegal on sandy-clay soil and Acacia nilotica on the banks of ponds. On the lateral armour we find thickets with Combretaceae, Tiliaceae, Mimosae, constituting the bushes, called "tiger" or "stained". In the fossil valleys and large koris, develop formations at Acacia albida and Hyphaene thebaica, often promoted or built by man, in the form of agroforestry parks.

Finally, Sudanese areas include savannah vegetation characterized by an herbaceous stratum where perennial kids dominate and a woody stratum containing shrubs and trees. It includes meets open forests in Anogeissus leiocarpus or gallery forests in Mitragyna inermis. It includes also encounters large species such as shea butter, baobab, nere, Prosopis africana etc.

Figure 2.2: Photosat of Niger 2006

Source: PNED, 2015

The map on the figure shows the most covered areas of vegetation are in the Southwestern part of the country (Dry forests), and it also shows that we find in the alluvial valleys of the Centre-South (agroforestry parks) and in the depression of Lake Chad, at the extreme

According to Niger's SIE (Système information énergétique) in 2016 the energy supply in the energy mix was dominated by the biomass followed by the petroleum products. Indeed, the situation of Niger's energy mix doesn't know a big change: primary energy supply stands at around 2918 ktep in 2015 against3080 ktoe in 2016. In 2016, biomass represents 74.28% in the energy mix, followed by petroleum products (21.96%). The rest is composed of imports of electrical energy from Nigeria (2.17%) and mineral coal (1.58%) (SIE, 2018). The contribution of photovoltaic energy represents 0%.

Although in terms of evolution, the total supply of primary energy in the country has increased by 36% between 2010 and 2016, ie a consumption of 2269 ktoe in 2010 to 3079.59 ktoe in 2016, the biomass remains the source the more dominant in the mix.

II.2.2. Final energy consumption

II.2.2.1. Primary energy consumption

Niger's primary energy consumption is evaluate to 0.242 tep/inhabitant. This represents respectively 2.5 and 7 times less than that of Africa and global worldwide averages. Primary energy consumption in developed countries like France is more than 18 times higher than Niger (CDC, 2009).

II.2.2.2. Final energy consumption per capita

According to Niger's SIE report, in 2016, per capita final energy consumption was 0.146 toe. This consumption is very low, compared to the average of the African continent of 0.66 toe per capita and the world average of about 1.86 toe per capita (SIE, 2018).

This weakness could be explained mainly by a limited supply and deficit, a very strong demographic growth, an underdeveloped industrial sector and a very weak purchasing power. Indeed, it should be noted also rural population is dominant cause low energy consumption in the country.

II.2.2.3. Final energy consumption by product type

Total final energy consumption in Niger amounts to 2899 ktoe in 2016 compared to 2835 ktoe in 2015. Biomass remains the most dominant source of energy in Niger's energy mix, accounting for 80% of national consumption. Petroleum products are in second place, accounting for 17% of final consumption, and electricity is in third place, with 3%. Consumption of carbonized mineral coal and renewable energies is still marginal (SIE, 2018).

II.2.2.4. Energy consumption by sector

Households are leading the consumption with a percentage of 80.83% of total final consumption in 2016. The transport sector is in second place with 14.04%. Services, industry and agriculture account for 2.79% and 2.32% and 0.03% of this consumption respectively (SIE, 2018).

II.2.2.5. Distribution of final consumption in the household sector

According to SIE (2018), in 2016, fuelwood is the main source of energy for households (94.55% of consumption). Next come electricity with 2.06%, charcoal (1.62%), Liquid… (LPG) (0.69%) and the accumulation of agricultural residues and waste animals with 1.04%. Kerosene and carbonized mineral coal are marginal in this household consumption (SIE, 2018).

II.2.2.6. Evolution of final consumption by type of energy

The trend in final energy consumption in Niger has not improved significantly since 2010 to 2017 (SIE, 2018). As in most developing countries like Niger, biomass, mainly wood energy, is the most widely used source. Petroleum products are the second most important type of energy, with a share that varies from 15 to 20% depending. The share of electricity in this consumption is around 3%. Coal consumption carbonized mineral is very low with less than 0.03% while that of solar energy is very low despite the significant efforts made in this area.

II.2.2.7. Evolution of final energy consumption by sector

Households are at the forefront of energy consumption. Indeed, final energy consumption is very clearly dominated by household consumption, which explains the nature of the country's economy due to the predominance of wood energy in consumption. The share of household consumption is 80%. The transport sector is in second place with a share ranging from 12 to 15%. Next come the Industries and Services sectors with respective shares ranging from 2 to 4% and from 2 to 3%. The final consumption of the agricultural sector is very high negligible, not exceeding 0.04%.

II.2.2.8. Evolution of household final energy consumption

The breakdown of household consumption by product has changed slightly over the period 2010 to 2017. Biomass remains the most consumed source of energy consumption in this sector remains dominated by biomass, compared to a share of marginal to other forms of energy (figure2.3).

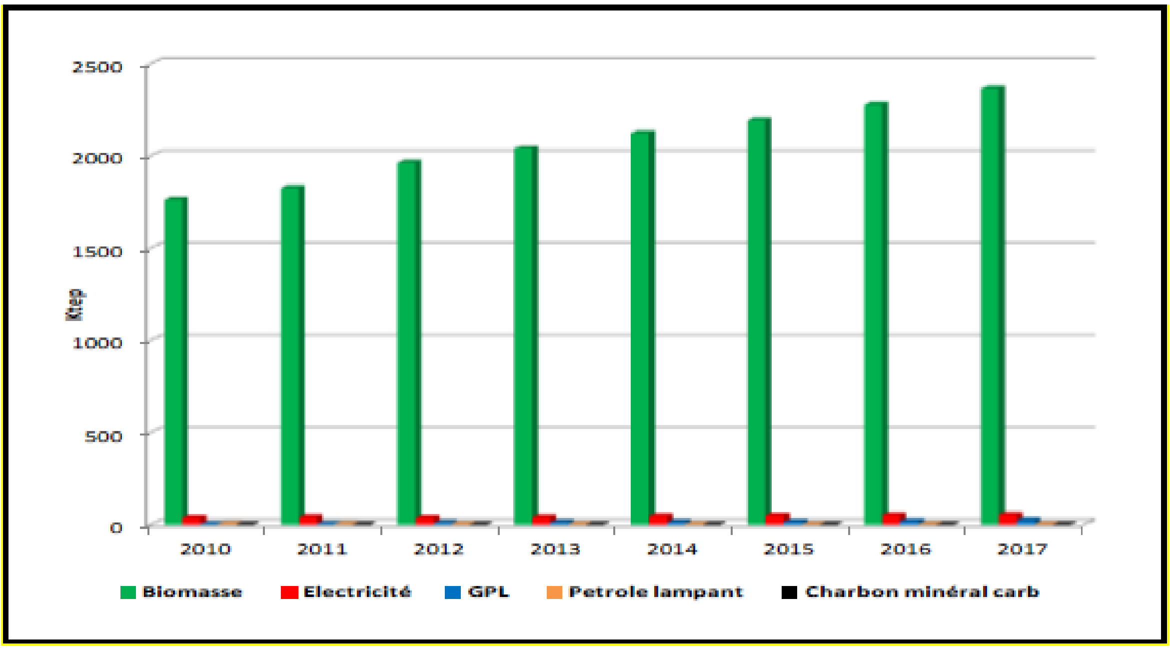


Figure .2.3: Evolution of household final energy consumption

Source: SIE, 2018

II.2.3. Evolution of the population and final energy consumption

The figure 2.4 shows that there is a strong link between consumption trends and population growth. Indeed, the population and final energy consumption are evolving at almost the same rate. However, final consumption in Niger is mainly dominated by wood and the population growth index in Niger is around 3.9%, which explains this relationship of consumption according to inhabitant.

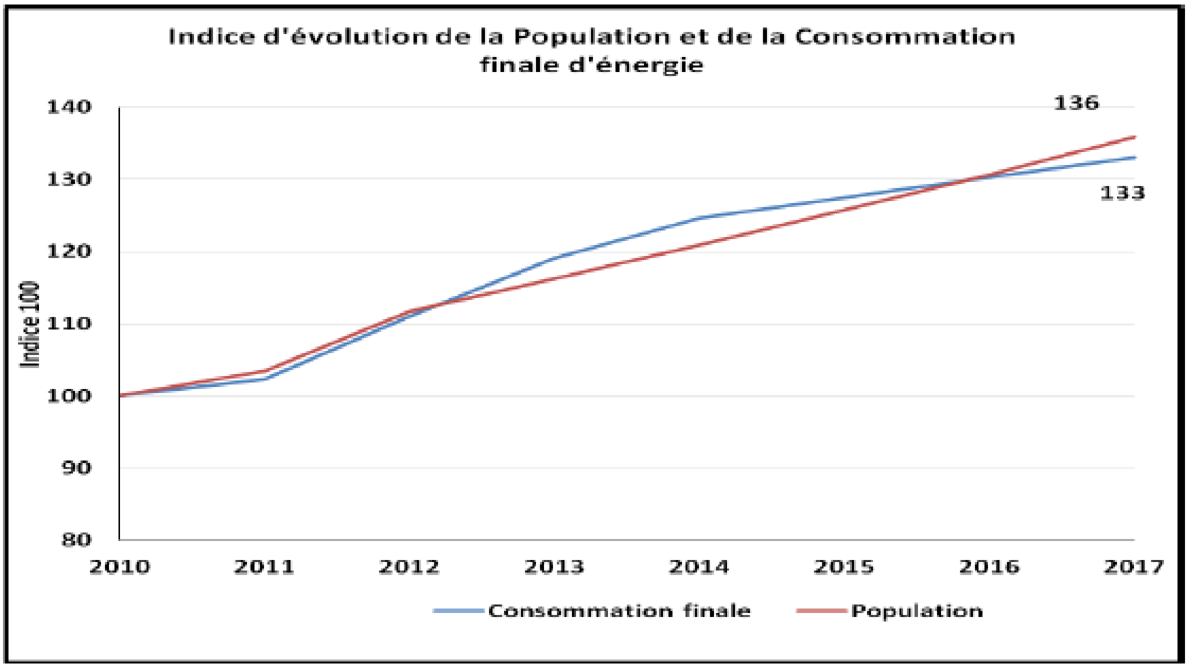


Figure2.4: Evolution of the population and final energy consumption

Source: SIE, 2018

II.2.4. Electricity situation

II.2.4.1. Distribution of final electricity consumption by sector

Final electricity consumption is dominated by households. This sector occupies the first place with 54%, followed by that of services with 24%. The industrial sector and the hydro-agricultural development represent respectively 21 and 1% (SIE, 2018).

II.2.4.2. Evolution of final electricity consumption by sector from 2010 to 2017

During the period from 2010 to 2017, the final consumption of electricity increased from 694 GWh in 2010 to 1066 GWh 2017, an average annual increase of 8%. The structure of electricity has not seen much improvement during this period. The structure remains dominated by households with a share of between 50 and 60% (SIE, 2018).

However, from 2013 the share of the industrial sector has varied from 19 to 26%, that of the service sector from 23 to 25% while that of the agricultural sector is around 1%.

II.2.4.3. Evolution of electricity supply from 2010 to 2017

The supply of electricity increased from 849.83 GWh in 2010 to 1396.82 GWh in 2017, an increase of around 39%. The import from Nigeria, which increased from 551.50 GWh in 2010 to 845.19 GWh in 2017, largely dominates supply by 55% to 65% despite a significant increase in domestic production, which went from 300.71 GWh in 2010 to a little over 845 GWh. This production is provided by the National Power Production Company (NIGELEC) and SONICHAR plants and some auto-producers (industrial units). It should also be noted that a small part of the import is reimported to Mallanville (Benin) until 2013.

TableII.3: Evolution of electricity supply from 2010 to 2017

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Generation (GWh)	300,71	323,58	382,85	507,49	511,12	495,67	564,37	551,63
Importation (GWh)	551,50	607,46	636,70	602,38	726,97	782,34	779,11	845,19
Exportation (GWh)	2,38	3,84	4,22	3,00	0,00	0,00	0,00	0,00
Supply (GWh)	**849,83**	**927,20**	**1015,33**	**1106,87**	**1238,10**	**1278,01**	**1343,48**	**1396,82**

II.2.4.4. Evolution of the access rate to electricity from 2010 to 2017

Between 2010 and 2017, the rate of household electricity access in Niger increased from 8.63% to 12.28%, i e an annual average of 0.52%. In rural and urban areas, these rates went from 0.6% in 2010 to 0.92% in 2017 and from 39.93% in 2010 to 63.88% in 2017 respectively (SIE, 2018). At the regional level, rates have not increased significantly despite efforts made in rural electrification. This could be explained by the rapid population growth of 3.9% according to the 2012 2012 General Population and Housing Census RGPH (SIE, 2018).

TableII.4: Evolution of the access rate to electricity from 2012 to 2017

Name of Region	2012			2013			2014		2015			2016			2017		
	Access rate in %			**Access rate in %**			**Access rate in %**		**Access rate in %**			**Access rate in %**			**Access rate in %**		
	Rural	**Urban**	**Regional**	**Rural**	**Urban**	**Regional**	**Rural**	**Urban**	**Rural**	**Urban**	**Regional**	**Rural**	**Urban**	**Regional**	**Rural**	**Urban**	**Regional**
Agadez	0.5	36.1	14.6	0.6	38.5	15.6	0.8	41.2	0.8	42.9	17.4	0.8	44.3	18.8	1.2	41.4	22
Diffa	1.7	40	7.2	2	40.1	7.4	2	43.1	0.2	44.9	8.1	1.9	46.5	8.6	1.6	44.2	8.9
Dosso	0.4	43.8	5.3	0.4	51.9	6.2	0.3	57.6	0.6	62.9	7.6	0.8	67.9	8.1	0.9	62.1	7.1
Maradi	0	32	5.3	0.1	37.6	6.3	0.1	41.1	0.1	43.3	7.3	0.2	45.3	7.7	0.2	39.6	6
Tahoua	0.3	41	4.3	0.4	45.7	4.8	0.4	48.8	1.2	46.5	5.6	2	44.4	6.1	1.7	56.7	7.7
Tillabery	0.3	44.9	4	0.3	48.7	4.3	0.4	57.7	0.8	60.1	5.8	1.1	62.3	6	1	61.6	5.4
Zinder	0.1	32.4	3.6	0.1	33.7	3.8	0.2	37.3	0.3	38.5	4.4	0.4	39.5	4.8	0.4	37	4.9
Niamey	0	63.6	58.6	0	68.9	63.4	0	71.8	0	81	74.6	0	89.6	79.4	0	98.5	93.7
National	0.3	46.3	8.7	0.3	50.5	9.4	0.3	54.4	0.6	58	11	0.84	61.6	11.8	**0.92**	**63.88**	**12.3**

II.2.4.5. Evolution of the electricity coverage rate from 2012 to 2017

The coverage rate at the national level increased from 22.65% in 2012 to 25% in 2017, representing an average growth of 0.34% per year. Only the Tahoua region experienced a significant evolution from 17% in 2012 to 24% in 2017 in the evolution of the coverage rate by region (SIE, 2018).

However, outside the Niamey region, the regions of Agadez and Diffa, which are desert and sparsely populated, have high coverage rates compared to other regions (SIE, 2018).

Table II.5: Evolution of the 2012 -2017 coverage rate (%)

Name of Region	2012	2013	2014	2015	2016	2017
Agadez	47,90	48,10	48,06	48,02	48,47	48,50
Diffa	26,82	27,03	27,34	27,65	28,21	28,59
Dosso	16,74	16,96	17,55	17,97	18,95	18,75
Maradi	17,27	17,34	17,37	17,85	18,37	18,57
Tahoua	17,31	18,67	19,68	22,02	22,77	24,26
Tillabery	15,05	15,44	15,77	16,08	16,90	17,13
Zinder	14,73	15,19	16,42	16,83	17,37	17,73
Niamey	96,59	95,89	95,25	94,60	94,41	94,26
National	**22,65**	**22,67**	**23,19**	**23,87**	**24,47**	**25,06**

II.2.4.6. Evolution of the number of localities electrified from 2010 to 2017

The electrification rate has changed in the different locality. The total number of electrified localities almost doubled between 2010 and 2017, from 344 to 660, an increase of 45 localities on average per year at the national level.

Table II.6: Evolution of the number of localities electrified from 2010 to 2017

Name of Region	2010	2011	2012	2013	2014	2015	2016	2017
Agadaez	11	11	11	11	11	11	13	13
Diffa	43	43	43	43	43	43	43	43
Dosso	40	42	50	53	60	70	86	86
Maradi	40	40	48	52	56	72	86	95
Tahoua	56	58	70	83	92	122	133	152
Tillabery	113	119	131	140	148	169	174	181
Zinder	40	40	49	56	66	74	81	86
Niamey	1	1	1	1	1	1	2	4
Total	**344**	**354**	**403**	**439**	**477**	**562**	**618**	**660**

The regions of Tahoua, Maradi, Zinder, Tillabéry and Dosso follow the same trend of growth, while the regions of Diffa and Agadez remain constant in evolution. This could be explained by the fact that these regions were already electrified before 2010.

II.2.4.7. Solar energy

Renewable energies constitute a considerable stake in the energy mix considering the national potential (an average radiation of 6 kWh/m^2/day with an average daily duration of 7 to 10 hours). The share of solar PV in Niger compared to conventional energy is very low in terms of installed capacity.

According to the report of SIE (2018) photovoltaic solar installations carried out by National Agency of Energy Solar (CNES) in collaboration with the Ministry of Energy in 2014, the total installed power is 5194.95 kWc. This power is mainly used by telecommunications with 38.93%, followed by pumping up to 27.17%, private installations with 15.21%, public lighting for 10.70%.

II.2.5. Situation of biomass

II.2.5.1. Firewood

According to the report of the SIE (2018), the demand for firewood was 4 356 000 tons in 2010 compared to 4 212 000 tons in 2009 and 3 909 000 tons in 2008, corresponding to growth rates of 3.4% and 7.8% relatively plausible relative to population growth. Based on the 2008 to 2010 demographic information, it can be deduced that the ratio used by the National Institute of Statistics (INS) is 0.78 kg wood/person/day.

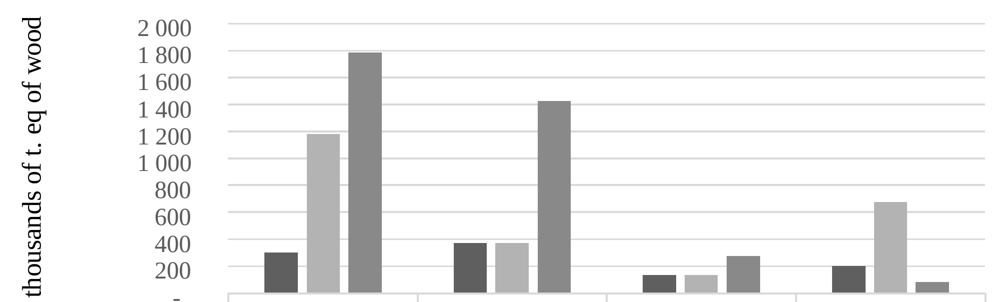
The wood consumption of the population in Niger was evaluated in total to 370 000 tons of wood in 1990- and 1 427 054-tons eq. wood in 2015 by rural populations is an increase of 5.5% per year (SDACD, 2017).

In 2015, rural wood fuel consumption accounted for 84% of the region's consumption. The consumption of Niamey represented only 16% (SDACD, 2017).

- **Evolution of the balance sheet resources-timber levels 1991 to 2015**

The figure below illustrates the increase in the demand for wood all over Niger, and in all the communes, on the attention that the consumption of the local populations is greater than the production of wood. Of the country's 54 municipalities, there are 48 municipalities whose consumption is not in surplus (SDACD, 2017).

There is an overexploitation of the woody resources of the terroirs, due to the demographic growth.



	Total Production	Rural wood Consumption	Urban wood Consumption	Balance sheet 1991-2015
1991	300	370	133	200
1991With FTCP	1 177	370	133	674
2015	1 786	1 427	278	82

1991 1991 With FTCP 2015

Figure 2.5: Evolution of the Balance Sheet Resources-Timber Levels 1991to 2015

Source: SDACD, 2017

Despite overexploitation of the land, the wood subsector is experiencing a deficit of 81660 t. eq of wood (Table I.7).

Table II.7: Balance sheet available resources

Description	Weight (t. eq.Wood)
Wood energy production (1)	1 786 218
Consumption of Niamey (2)	277 504
Consommation des zones rurales (3)	1 427 054
Deficit of Production –Total consumption	81 660

II.2.6. Energy potential

Niger has significant energy resources as shown in the following table.

Table II.8: Potential of energies resources

Energies resources	Energies Reserves	Energies Potential
Uranium	400 000 -500 000 tons	
Coal		
- **Anou Araren**	15 000 000 tons	
- **Salkadamna**	60 000 000 tons	
Oils		
- **Petroleum**	1 477 320 000 Barrel28	
- **gas**	10 000 000 000 m^3	
Hydropower		
- **Kandadji**		230 MW
- **Gambou**		122.5 MW
- **Mékrou**		26 MW
Solar		5 to 7 $kWh/m^2/day$
Wind		2.5 to 5 $m\ s^{-1}$

According to the Programmes National des Energies Domestique (PNED) report, in terms of domestic energies, solar energy is intended to produce electricity for lighting and medical refrigeration services in an isolated system and as a central part of the electricity grid. It is not

envisaged to consider the cooking uses by solar fireplaces or ovens whose availability is relatively limited. Wind potential can be used for water removal (PNED, 2015).
Thus, the sustainable supply of timber is estimated at 2 million tons per year, which means that the current overexploitation is taken from the stock.

II.2.7. Renewable Energy potential

A huge energy potential in renewable resources is available in Niger. According to the recent renewable energy assessment done by IRENA (2014), Niger has a potential of:

- 8,829 TWh/year of Concentrated Solar Power (CSP), taking into account all suitable areas,
- 15,669 TWh/year of PV, taking into account all suitable areas,
- 14,628 TWh/year of wind energy, if all areas have turbines with a capacity factor greater than 20%,
- 1,262 TWh/year of wind energy, if all areas have turbines with a capacity factor greater than 30%, and
- 55.8 TWh/year of wind energy, if all areas have turbines with a capacity factor greater than 40%.

However, energy consumption per capita is still low. It was only 54.17 kWh per capita in 2016, and energy insecurity level is very high because more than 70% of the electricity consumption in Niger comes from Nigeria sources (NIGELEC, 2016).

- **Solar energy**

Niger has a large and diverse renewable energy potential across different regions. Solar irradiation is abundant everywhere in the country and varies between 4 to 7.5 kWh/m^2/day, depending on the season. Thus, low radiations are observed during the cold season and high one in the hot season. Nonetheless, almost all the cities in the country receive an average irradiation of 5 to 7 kWh/m^2/day with an average sunshine duration of 7 to 10 hours per day.
However, the current applications of solar energy in Niger are mainly for domestic, agriculture usage, PV system supply for electrification and water pumping. As for the CSP, only fewer isolated applications are done in the country mainly for water heating, cooking and vegetables drying.

- **Wind power**

The theoretical potential for wind in Niger has yet to be considered by the National power production company, NIGELEC. Results of recent studies done in Africa proved that Niger has the highest wind resources in West Africa (Africa Roadmap 2030). The average wind speed of the country is about 2.5 - 6 m s^{-1} according to country wide data. The highest wind potential is observed in the northern part of the country (Tahoua and Agadez) with an average wind speed of 5 m s^{-1} while it is lower in the southern part (less than 4 m s^{-1}). The main applications of wind energy are mainly for water pumping for livelihoods, livestock and agriculture. Although wind installations have been among the oldest Renewable Energies Sources (RES) installed in the country by missionaries in the 1950's; the total installations are about 30 for water pumping and to date there is no application for electricity supply. However, this potential could be worth economically for the country (as the wind speed has to be a minimum of 5m/s). As previously the challenges are similar to that of solar system for instance the cost of wind turbine and implementation technology.

- **Hydropower**

Hydropower engineering refers to the processes and technology applied in converting the energy of the stream flow of a river into electrical energy. The Republic of Niger has a river called Niger River, which crosses the country along about 550 km and runs from Guinea Conakry to Nigeria. Thus, the above technique can be applied for power generation. The flow rate of Niger River presents a period of high flow between August and January and a period of low flow between February to July. The main driver is precipitation during the summer monsoon of West Africa.

The estimated hydropower potential it is at about 280 MW. According to IRENA (2013), the country hydropower potential can be up to 400 MW. Huge potential, but it is not fully exploited and Niger’s electricity supply system can be strengthened by hydropower generation.

- **Biomass**

Biomass energy dominates the sources of energy in Niger (MEP, 2015). It is the important source of energy for more than 97% of Nigerien households. This constitutes in terms of total energy consumption about 94% (MS/2000 energy balance). The traditional energy consumption way represents 67% and 37% in terms of total consumption respectively for m^3 wood and crop residues. The estimated biomass wood production is at about 0.1-1.5 /ha per annum (IRENA, 2013). The energy losses during traditional biomass utilization are very huge.

II.2.8. Political Framework

II.2.8.1. Domestic energy policies

- **Regional policies**

The regional white paper on access to modern energy services of ECOWAS29th January 12, 2006 during the Summit of the Conference of Heads of State and Government, the members of ECOWAS set themselves the global objective of increase access to energy services for rural and peri-urban populations in order to enable at least half of these populations to access modern energy services by 2015, including those related to cooking (improved cooking stoves and butane gas). This political decision was to translate into a fourfold increase in the number of people who had access to this type of service in 2015.

This policy had little effect on the domestic energy situation and the focus was on rural electrification and in some countries on multifunctional platforms.

- **Regional Policies of ECOWAS**

The ECOWAS Renewable Energy Policy (EREP) and the ECOWAS Energy Efficiency Policy (EEEP) were adopted by the ECOWAS Energy Ministers at the High-Level Energy Forum of the ECOWAS, held in Accra, Ghana from October 29 to 31, 2012. EREP advocates the ban of all inefficient cooking equipment from 2020 onwards. EEEP's goal for cooking is to achieve access safe, clean, affordable, efficient and sustainable cooking for the entire population of ECOWAS by 2030**.**

- **National policies**

To decipher the more precise orientations of Niger's domestic energy policy, it is necessary to return to the Declaration of Energy Policy (DPE) adopted by decree n° 2004-338/PRN/MME of 28 October 2004 and focused on four major points:

- increasing the accessibility of households to modern cooking fuels,
- the promotion of alternative energy to wood energy,
- securing energy supplies for cooking,
- the valorization of national energy resources for domestic purposes (mineral coal, gas, etc.).

- **Home Energy Strategy (SED)**

Developed since 1989 by the implementation of the Energy Project II (1989 - 1998) supply and demand components, and continued with ups and downs for the only component offered by the PED (2000 - 2002), the Natural Forest Management Project (PAFN 2002 -2006) and on a smaller scale by the GESFORCOM (Gestion forestière communale et communautaire /

Communal and community forest management) project (2007 - 2011), the Strategy for Domestic Energy Supply and Demand has never been formally adopted by a specific regulatory or legislative text. Only the supply side can present a legal framework through Decree 92-037 on the creation of rural markets and the implementation of an incentive tax system confirmed by Forest Law 2004-040. The decentralized forest control system conceptualized and tested by the GESFORCOM project from 2009 to 2011 remains a "project" experience.

II.2.8.2. Electrification Policies

- **The National Electricity Access Strategy (SNAE)**

The National Electricity Access Strategy (SNAE) addresses access to electricity for all Nigerien citizens by mobilizing the private sector through the electrification of the territory to electricity as the engine of sustainable development, also relying on adaptation and strengthening of the regulatory and institutional framework.

The definition of adapted access to SNAE is that of the SE4ALL initiative, which defines the access levels related to the use of electricity, detailing for each of these levels, the type of service, the maximum available capacity, the duration and the reliability expected by users.

This definition easily applies to the options or possibilities of electrification retained in the SNAE for connecting new households to access the electricity service. She takes account the level of continuous and continuous service stipulated in the Act Electricity. The provision of electricity is made by connection to the electricity network NIGELEC or to a decentralized network (mini-network) and individual systems (in particular solar kits).

Densification of the networks NIGELEC which concerns all the localities already electrified or 576 localities for a gross total of 1,857,923 inhabitants (base 2017); it will experience an average pace of 32 localities per year and will allow the connection of 311 654 new subscribers whose near of 92% in middle urban, for a cost way investment per subscriber of 188,151 FCFA.

Extension of NIGELEC networks, in 2 states including:

- the first so-called structuring phase, covering the period 2018-2024, takes into account the logistical and learning constraints, inherent to the start of implementation SNAE. Thus, the pace will gradually increase in power with a view to electrification with an average rate of the order of 300 poles/year, of all 2014 development poles not yet electrified (including the two poles of the Agadez region, namely Anney and Chimoundour, located more than 400km from the network NIGELEC the closest, who will benefit from mini-network).

- the second so-called mesh phase, over the period 2025-2035 that occurs after the climb cruise resulting from the structuring and which will maintain the course until 2035. The structuring network built in the first phase, will be densified for the connection of localities neighboring countries with more than 300 inhabitants and with the best present value net of the cost of the kWh. By 2035, 6,600 localities with 90% rural will be electrified.

Mini-networks, which will cover 1,898 localities almost exclusively in rural areas, with optimizing their diet by building clusters. These localities have more than 500 inhabitants and have not been taken into account previously in the extension phase of networks; they include the two poles of the Region Agadez. The cost way investment per capita covered (inhabitant of a locality electrified by mini-grid) is 208.374 FCFA, while the average cost per subscriber is 960.389 FCFA.

To reach an access of at least 80% in 2035, it is 142,872 connections that he Mini-grids will have to be carried out in the beneficiary localities.

Individual Systems or Distributed Solutions, which will be used to achieve the objectives access, by optimally supplementing, the densification, the extension of the networks and the development of mini-grids. They will concern some 1,757,408 people (basic 2017), residing in 12,297 localities with electricity by 2035, representing 53% of localities at the national level but less than 12% of the population. The development of the Plan Electrification director will have to confirm it. SNAE budget evaluations were conducted on a unit cost basis average of 300,000 FCFA / beneficiary and assuming a penetration of 70% horizon 2035 in the targeted localities.

SNAE Action Plan

SNAE takes into account the political objectives of access to electricity from DPNE and seven (07) identified priority activities, namely:

- Develop an Electrification Master Plan (PDE) and define a National Program Electrification (PNE);
- Ensure the establishment within the Ministry of Energy of a framework for planning and coordination of the implementation of SNAE;
- Ensure the mobilization of funding for the implementation of SNAE;
- Build the capacity of the actors involved in the implementation of SNAE;

- Ensure the appropriation and use of lean technologies for rural electrification and the connection of households;
- Develop and implement a strategy to support household connections, including including the most vulnerable;
- Ensure the implementation of the NPP and the monitoring and evaluation of the SNAE.

L´Agence Nigériénne de Promotion de l´Électrification en milieu Rural (ANPER) (National Agency of Lightning Promotion in Rural Area)

It is created under Law 2013-24 of May 6, 2013. ANPER is governed by the order number 86-001 of January 10, 1986 on the general scheme of the public establishment, a state-owned company. More details are given in the appendices (annexes

ANPER's mission is to develop rural electrification, especially throughout the national territory, and to train operators to operate the installed electricity infrastructure.

The table below shows the different project realization by ANPER

Table 1Table II.10: Different project realization by ANPER)

ranking	Locality supplied	Installed powe(kWp)	Region
1	Gorou	27.5	Tillabery
2	Bokki	28	Tillabery
3	Amaloul	42	Tahoua
4	Malmawa Kaka	40	Maradi
5	Gabouri	40	Maradi
6	Guidan Wari	40	Maradi
7	Maisou Same	40	Maradi
8	Gandou Goriba	40	Zinder
9	Yagagi	40	Zinder
10	Dinney	40	Zinder
11	Boucheri	40	Zinder
12	Ingouna	40	Zinder
13	Boure Sankin Arewa	40	Zinder

However, the pace of improvement of electricity in rural areas remains very slow as shown in the following table.

Table I.11: Niger's rate of access to electricity increases (source: ANPER)

Years	**2015**	**2016**	**2017**	**2018**
Rural access rate (%)	0,71	0,75	0,76	0,93
Urban access rate (%)	58,27	64,95	68,17	71,48
National access rate (%)	10,65	11,66	12,22	12,93

Thus, renewable energy technologies are above all the cleanest options for energy production and GHG removal. But there are many other benefits, such as energy, economic and environmental security, presented below (Kaygusuz, 2007; OECD, 2012):

In case of energy security, RETs can diversify the energy supply, thereby promoting energy security and price stability. For some nations, RETs can reduce dependence on imported fuels, an issue that is particularly important for developing countries. RETs can also promote energy security by decentralizing energy supplies with smaller, modular, and rapidly-deployable energy projects that are particularly suited to the electrification of rural communities in developing countries.

In case of economic security, RETs are often the most economical choice because of their scale. Their modular nature means they can be built (and paid for) as the demand for energy grows, and embedded within an existing network, if there is one. By contrast, large, centralized energy systems take much longer to build and are normally designed to supply a future demand that may not eventuate. The vulnerability of central power plants and transmission lines to power interruptions is also important. On the other hand, for developing countries, the energy security provided by RETs makes them attractive in rural areas, while simultaneously offering a clean "leap" over fossil fuels. The modular and distributed nature of RETs can also reduce the need for upgrading electricity distribution systems (Kaygusuz, 2007).

RETs can also provide regional and local job opportunities, particularly in rural areas. This can contribute to the stability of local communities, which then slows urbanization.

In addition, if energy is locally produced, money is invested in the local community and not exported, although RET products and services can be exported. All of these impacts can create an increase in local tax revenues, which can then create a more diversified tax base.

In addition to much lower greenhouse gas emissions, RETs offer other direct environmental benefits, particularly to developing countries. Improved air quality can be achieved through lower airborne emissions of pollutants compared to traditional fossil fuels. In particular, indoor air quality can be improved by substituting technologies such as photovoltaics (PVs) for lighting instead of burning kerosene. In many regions where a shortage of potable water damages human health, water supplies and water quality can be improved using small hydropower pumps. Solar pumps and small wind pumps can also be used to obtain water from underground sources. On the other hand, growing energy crops, such as fast-growing trees, can reduce soil erosion. Often, these energy crops require lower levels of agricultural chemicals and can be grown on land degraded by previous agricultural practices. This can help to improve soil conditions and enhance wildlife diversity.

In most African countries, the use of RETs is not yet fully integrated into the energy mix. In Niger, the share of traditional biomass remains the most dominant. REs represented less than 1% of the potential for RE. It should also be remembered that the country today suffers from an energy deficit in the two sub-sectors electricity and cooking (biomass).

III. METHODOLOGY

The methodology section located the field study by providing a brief overview of the village sanitary landfill site, including its geographical location, context and physical and socio-economic characteristics of the site, as well as how the data were collected, analyzed and interpreted. In addition, this section is the backbone of the study as it presents the methods used to achieve the objectives of this study.

III.1. Description of the study area

Sékoukou is a village in the department of Kollo, in the Tillaberi region of eastern Niger. Kollo is located about 144 km southeast of Tillaberi and 30 km southeast of Niamey, the capital of the Republic of Niger. The population of Kollo was estimated at 560762 inhabitants for the year 2017 (INS, 2018).

Sékoukou (13°16’25.49” N, 02°22’0.66” E) is located 40 km South-East of Niamey in Niger (Figure 3.1), with 650 inhabitants spread in more than 70 households, on the left bank of the Niger River. Only the Niger River crossing the region has a permanent flow.

The economy of this village is predominantly based on rainfed farming of millet, cowpea sorghum, rice, beans, off-season small-scale irrigation of potatoes and livestock breeding (e.g. sheep, cattle, etc.) and inter-village trading through weekly markets.

In this village, the farm animal heads are estimated to 500. The main language spoken is zarma. The renewable energy resources are various, namely: solar, wind, water, and biomass. The main energy source use is: solid biofuel (wood), solar energy, battery and human energy.

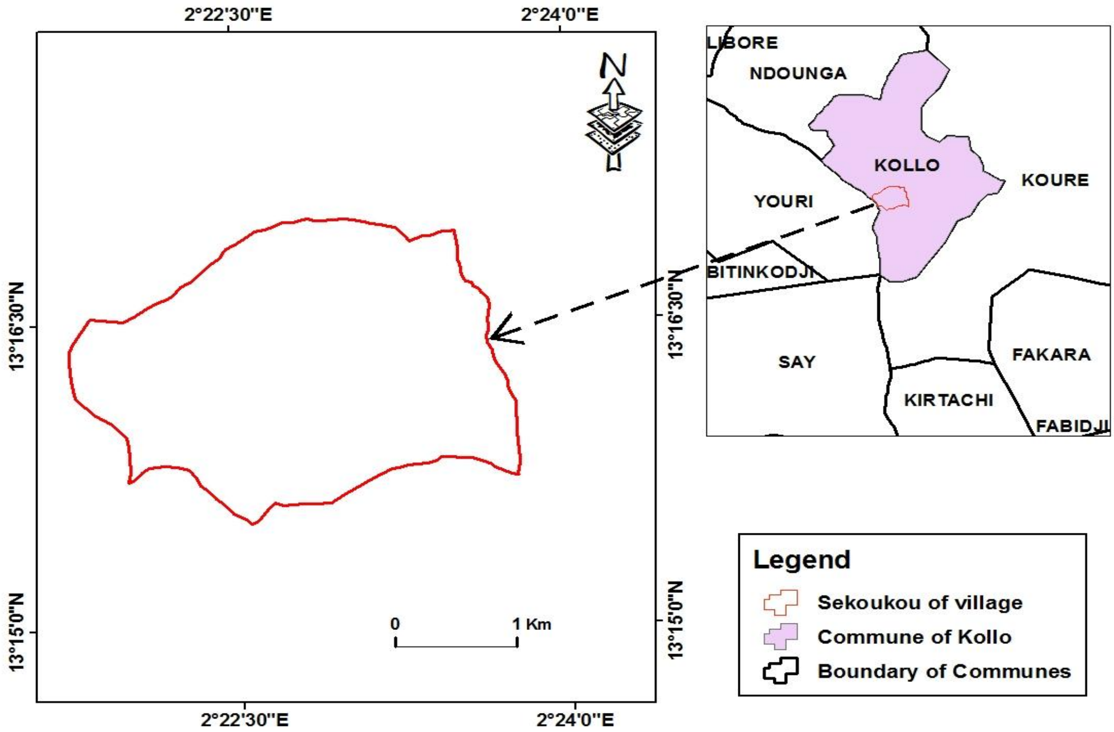


Figure 3.1 : Map of Sékoukou village location

III.3. Energy resources assessment

III.3.1. Solar energy potential of the Sékoulou village

The country receives an average irradiation of 5 to 7 kWh/day ((NREL, 2017). with average sunshine duration of 7 to 10 hours a day. Almost all over the country receives this energy. Energy received daily in Sékoukou village is given by:

$$E_{S1} = S * I_r$$

Where, S is the surface area in km^2 and Ir represents the irradiation.

Taking into account the most common polycrystalline silicon cell technology which only allows recovery of 13, 14 to 18% of this energy (Aye, 2011; Dualsun, 2019), the real energy is given by the following formula:

$$E_{S2} = E_{S1}\, r$$

The availability rate ***of solar energy*** is calculated by this method:

$$\mathbf{r = \frac{Power\ available}{Power\ installed} * 100}$$

III.3.2. Wind potential estimates

When the wind blows on a site, the mean theoretical power incident (P) per unit area, is given by:

$$p = \frac{1}{2}\rho\,\bar{V}^3$$

The recoverable energy potential after calculating the average cubic velocity by the Weibull distribution of the wind speed frequencies is therefore written:

$$P_2 = \frac{1}{2}\rho\,c\,\Gamma\,(1 + \frac{3}{k})$$

Where:

***P**$_1$*: is the theoretical power

***P**$_2$:* is the recoverable energy potential

ρ: represents the density of the air

c and k: both the parameters of Weibull characteristics of the place

Γ: is the Gamma function (the average speed in the case of this search)

III.3.3. Technology selection and assessment

After evaluating the resources, the electricity generation technologies were selected. With regard to solar energy, the technology of the mini photovoltaic solar power station was chosen instead of concentrated solar energy (CSP). This is due to the fact that the CSP technology is too expensive but also in relation to demand, in addition there is already the existence of photovoltaic technology based on a group of batteries on the Sékoukou site. For biomass, a pyrolysis oven for biochar and bio-digester were selected; this technology was still developing in the country. For water, tidal stream technology has been selected, although in order to extract usable energy from the Niger River, the Kandadji project must be completed and new data on river flow must be collected at the Sékoukou site.

III.4. Data collection

The data collected to answer this problem have been collected through different ways, the main ones are:

Literature review: The first element of data collection. It is a structured review of existing documents and literature on renewable energies and their impacts.

During this stage, an analysis of the literature, databases and other relevant elements (national action plans and renewable energy policies, articles, reports on the energy situation, etc.) have been made. This allowed an understanding of the situation through the information from this stage. The information decreed through the literary review has to make a preliminary description of the general situation then specific to the country.

Results obtained during qualitative interviews: The literature review has been completed by collected information through interviews with experts and actors in the field of energies. This interview study stage is intended to fill the gaps in information that could not be filled by the literature review, or lack of information through literature. In addition, the interviews helped to verify the preliminary findings. The intuitions were chosen on the basis of missing data interviews were conducted for this study with the staff of ANPER, DES, the stakeholder and other.

Quantitative survey: A survey was conducted in the village of Sekoukou. This survey was an addition to complete (improve) both volume and breadth perspectives to be addressed in the various tasks of the study this step of data collection was done in three parts:

- ***validation of the questionnaire:*** it consisted of visiting the village to do a general observation and then adopting the questionnaire in the context of the village. For this step we had worked with the members of the village solar project committee and the chief. This part of interviews was very enriched by the contribution and suggestion from the village chief and the committee for improvement and adapted the questionnaire in the context of the village of Sekoukou. It is after this that we started the investigation in the village
- ***interviews:*** the questions were closed and opened; we had a mixing of the type of questions. The questionnaire was also adapted to the according to the targeted response. The survey was conducted on almost the whole village, 60 households and 11 members of the committee. A total of 71 responses were received from both groups. The questionnaires were adapted according to the target group (household or management committee). In general, these questionnaires were described as follows: first, general information and lifestyle on the household was collected, second, socio-economic aspects of energy use and environmental aspects were addressed and third, the impact of migration on the village was the last part of the questionnaires.
- ***interview with the women of the village:*** This step was not included in the methodology at before, but during the survey, we found that most people (women) did not have enough knowledge and information about improve cookstove and effiency fuels. So it is with this in mind that we decided to meet all the women of the village to present these new technologies and their impact before continuing the investigation.

III.5. Data analysis

The GPS coordinates of the households surveyed and the outline of Sekoukou village were taken to the use of the GPS device. With these GPS coordinates, a map of the village of Sekoukou was designed and the village area was automatically calculated, by using the ArcGIS software. Excel was used to process the data and create the curves.

IV. RESULTS

After filtering, it is Sekoukou village that has been selected. The village of Sékoukou has a mini solar park. This solar park was installed by WASCAL in 2017.

IV.1. General Information on sekoukou's households

Figure 4.1 shows the gender distribution of the respondents to the questionnaire. Out of 100% of households surveyed, there is 85% (51) of households whom the person investigated were women and 15% men.

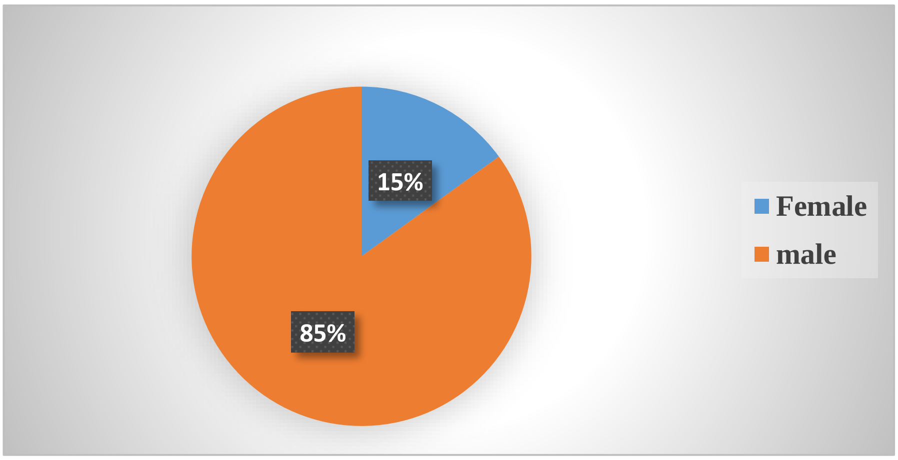


Figure 4.1: Gender of the person being investigated

The size of households in the village of Sékoukou varies (Figure 4.2). A distribution of the amount of people living in the households is shown in the following figure. Households with 5 to 10 people represent more than half (55%) of Sekoukou households. The category of households with 0 to 5 persons is the second largest in terms of household size with 22%. 10 to 15 people live in the same household in 15% of Sekoukou households. The smallest number of households (8%) are those with 15 to 20 people.

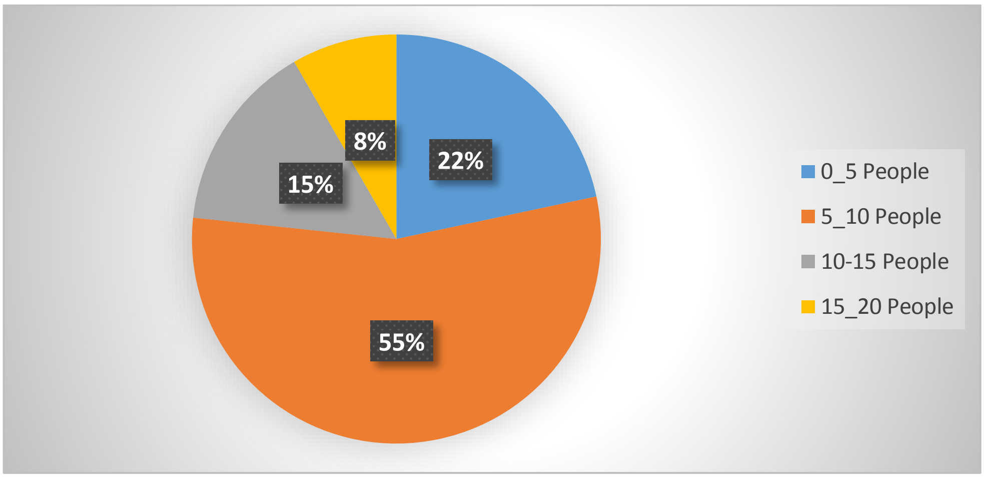


Figure 4.2: Distribution of Sékoukou village household size

IV.2. Utilization of wood

IV.2.1. Supply frequency

The main source of cooking in Sékoukou village is the wood that comes from the town of Kollo and the neighbor village located at 15 km from Sekoukou. 55% of households investigate weekly supplies for wood. This trend could be explained mainly by the limited supply of wood and distance on the one hand but the other part for the 45% of the households that stock up each day this choice could be explained by the lack of income.

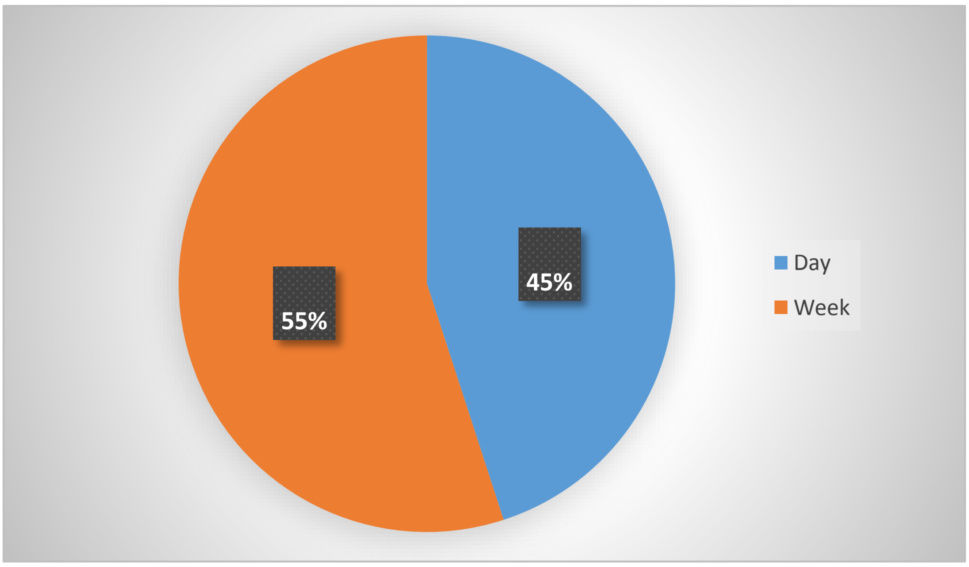


Figure 4.3: Distribution of wood supply frequency

IV.2.2. Frequency, amount and expenditures of wood Consumption

In the village of Sékoukou nearly households cook three times a day. The most households consume on average 1 to 2 bundles of 10 kg of wood per day for cooking (Figure 4.4). In this situation, the households have an average of 5 to 10 people. However, big families can use as much as three bundles of wood per day.

The bundle of 10 kg of wood costs 250 FCFA, the majority of households get supplies per week, with an expense ranging from 1750 to 5250 FCFA per week. The budget linked to the purchase of wood has risen to 7500 FCFA per month for the majority of the household, however there are households whose expenditures spend up to 22500 per month for the purchase of wood.

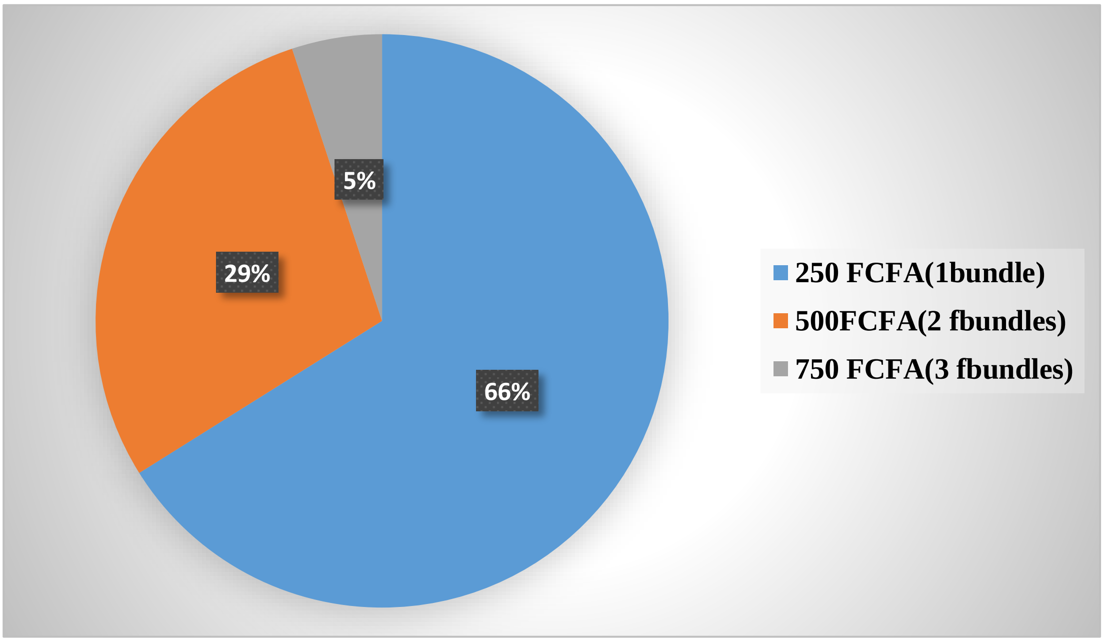


Figure 4.4: Distribution of wood consumption for cooking per household

IV.3. Potential of biochar fuel production

The following table shows the quantity of agricultural products produced.

Table IV.1: Amount of agricultural production

Produce	Mass in kg
Millet	73750
Rice	84400
Beans	16500
Sorghum	14300
Gombo	3950
Corn	600

Rice is first in agricultural production, this translates into a large amount of waste from this product, in addition to research shows research, it would take 205 kilos of rice husks to produce 75 kg of biochar fuel (fratmat.info). Thus, Sékoukou has a potential in terms of vegetable waste, in addition agriculture is not the only source of waste, it is necessary to add to this waste animal dejections. At least each household has at least ten of the chicken and at least two sheep.

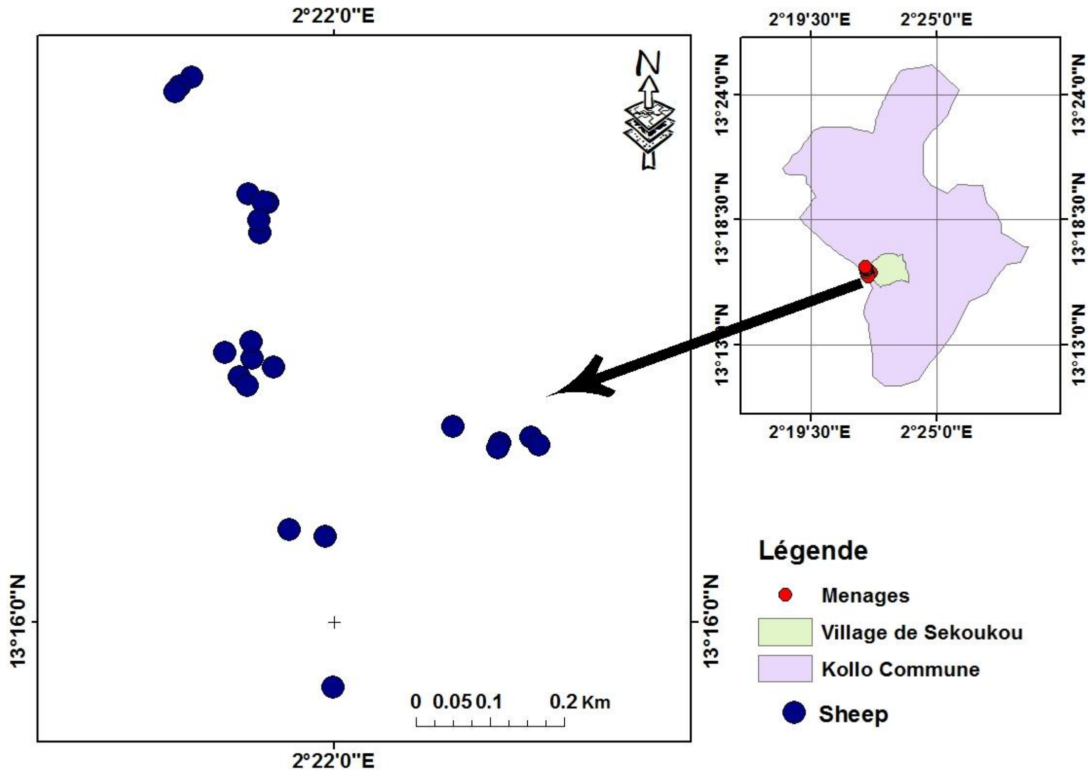


Figure 4.5: Map representing the number of households with sheep in Sékoukou

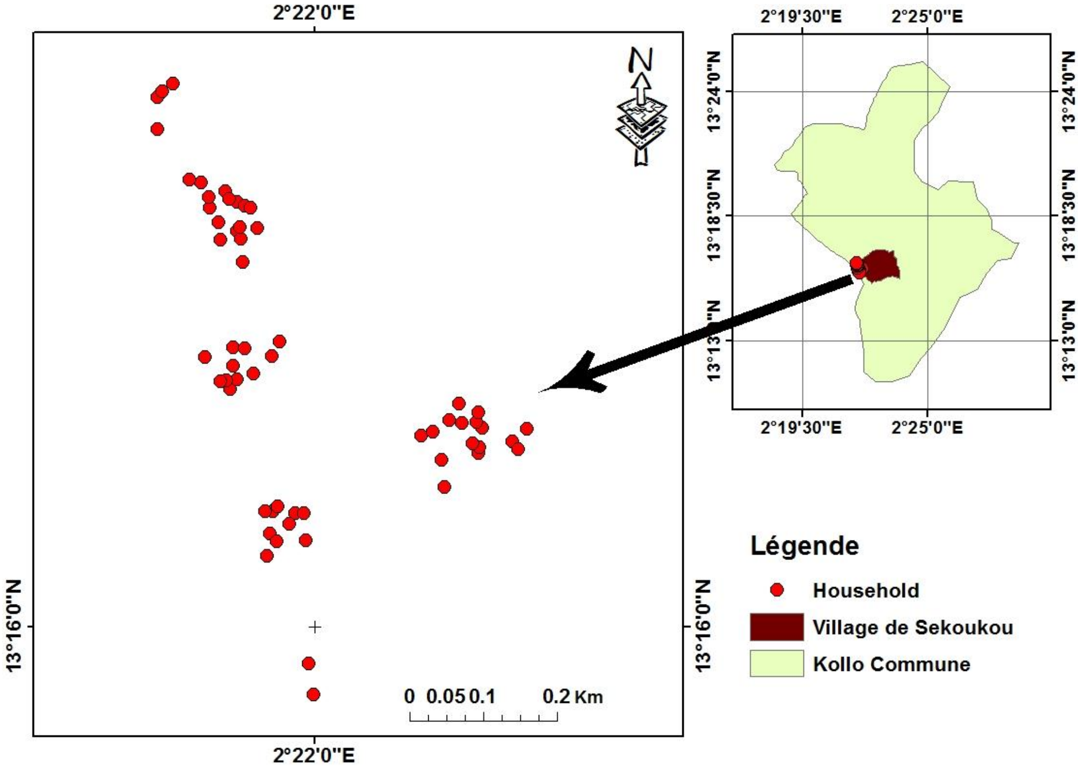


Figure 4.6: Map showing the number of households with chicken

IV.4. Energy sources of electricity

The survey shows there is a transition in the village towards renewable energies in the sub-sector of electricity, notably lighting. For nearly a year now that all households used at least solar energy for lighting and charging phones, however, despite this feat there is still household that used the battery powered lamps. Of the sixty (60) households surveyed, nineteen (19) still use batteries as a source of energy for lighting. Battery replacement is done for most households once a week.

On the question how do you use solar energy, them they answered as follows:

- 94% of the household use it for lighting
- 3% of households use this energy source for lighting and charging phones
- and the rest use it for lighting and education.

Currently two out of three houses use solar energy as an energy source for electricity. The use of solar energy has increased significantly in the village of Sékoukou. The figure below shows the evolution of the use of solar technology in the village. Five (5) households already had mini-photovoltaic installations before the mini-solar plant installed by WASCAL a year ago. The oldest facility is 10 years old.

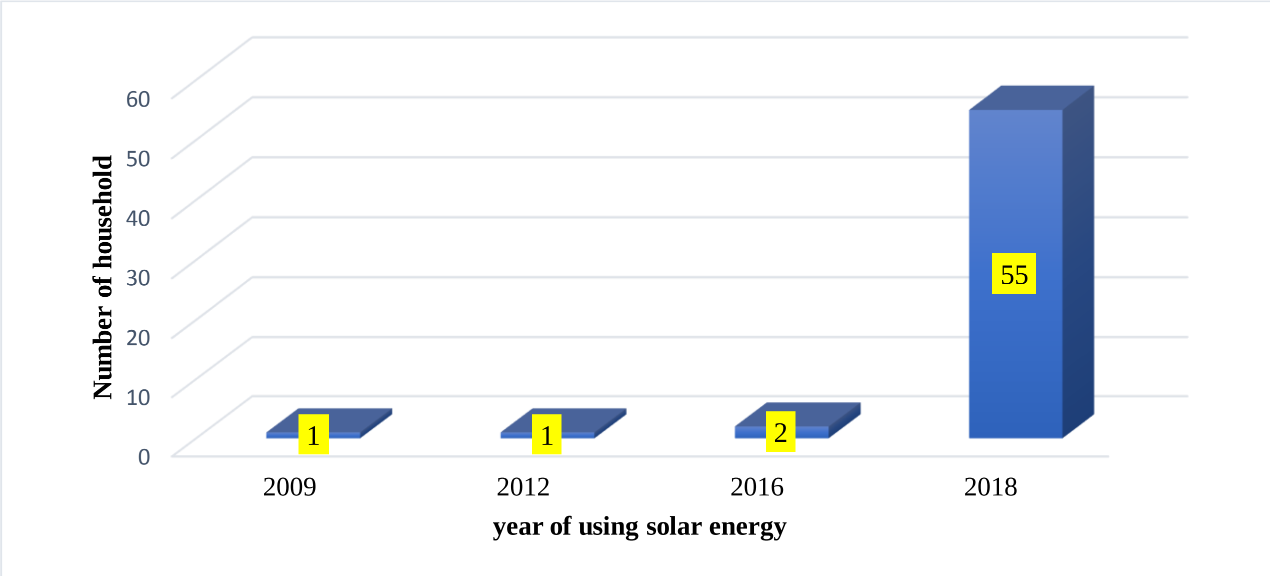


Figure 4.7: The evolution of using solar energy technology in Sékoukou village

IV.5. Energy utilization in households for electricity

IV.5.1. Household's lighting

Two energy sources (solar energy, use batteries) are used in the village for night lighting. The following figure illustrates the number of lamp use in household for household's lighting. To provide light at night, the majority (87%) of households has an average of 1 to 4 solar-powered lamps. Only 1/8 of Sékoukou households had more than 8 lamps for lighting. The lamps are recharged every 2 days, which represents three times the change of lamps per week.

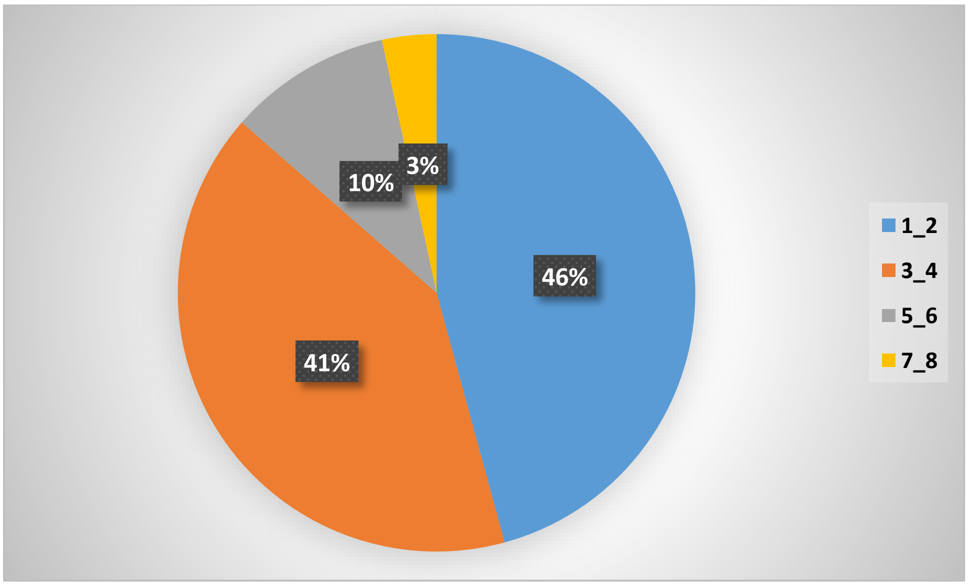


Figure 4.8.: Number of lamps in household

The distribution of expenditures of households that use solar energy for lighting is recorded in the following figure. The cost of buying fuel lamps varies between 500 and 7500 FCFA per month. Two thirds of households spend up to 2500 FCFA per month and the other third between 2500 and 7500 FCFA. Households that spend a budget of 1000 to 1500 FCFA per month for charging the lamps account for one-third. Almost a quarter of households estimate a budget between 2500 and 3000 FCFA. There are minority households that spend 5 times the majority.

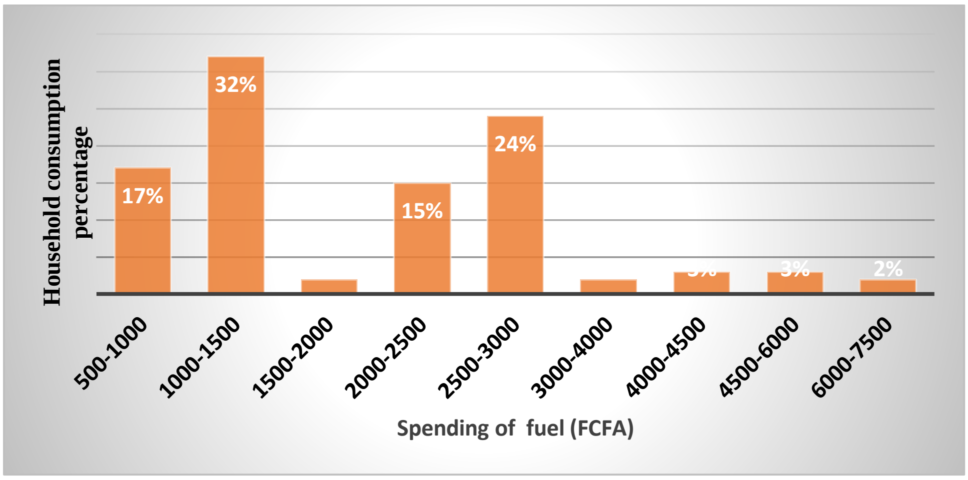


Figure 4.9: Distribution of the fuel spending for lamps per month

Table IV.2: Distribution of fuel purchase of lamps per month in Sékoukou village

Spending of fuel (FCFA)	Household	Parentage (%)
500-1000	10	17
1000-1500	19	32
1500-2000	1	2
2000-2500	9	15
2500-3000	14	24
3000-4000	1	2
4000-4500	2	3
4500-6000	2	3
6000-7500	1	2

IV.5.2. Charging phone in each household

The mini solar power plant installed in Sékoukou not only contributes to lighting but also to recharging the village population's phones. Figure X provides an overview of the telephone charging situation in households. 25% of households do not charge a phone (does not have a phone), however in the 75% of households with at least two phones in each household, the following figure shows the distribution of phones in households.

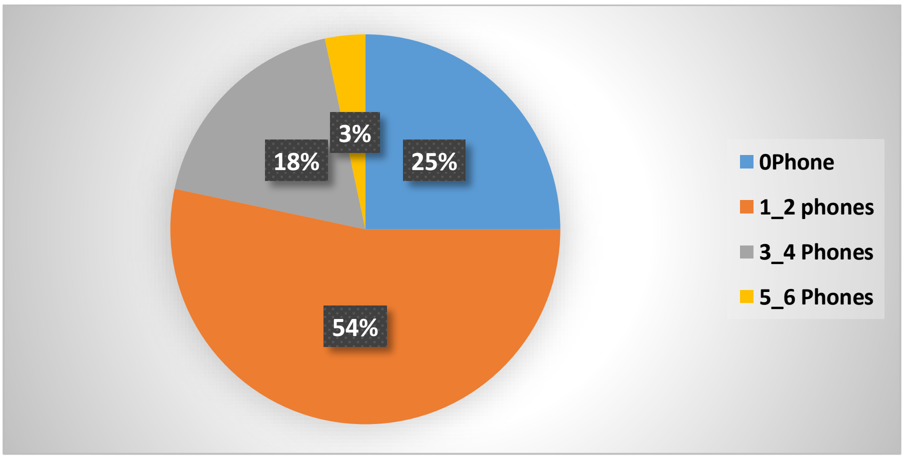


Figure 4.10: Distribution of phone in each household

The expenses related to the loading of the phones vary from 0 to 6000 CFA francs. Indeed, the results show nearly 13 households in does not spend for the charge, however there are 17 households that spend in the boarding school ranging from 500 to 1000 CFA F, followed by 16 households that are between 1000 to 1500.

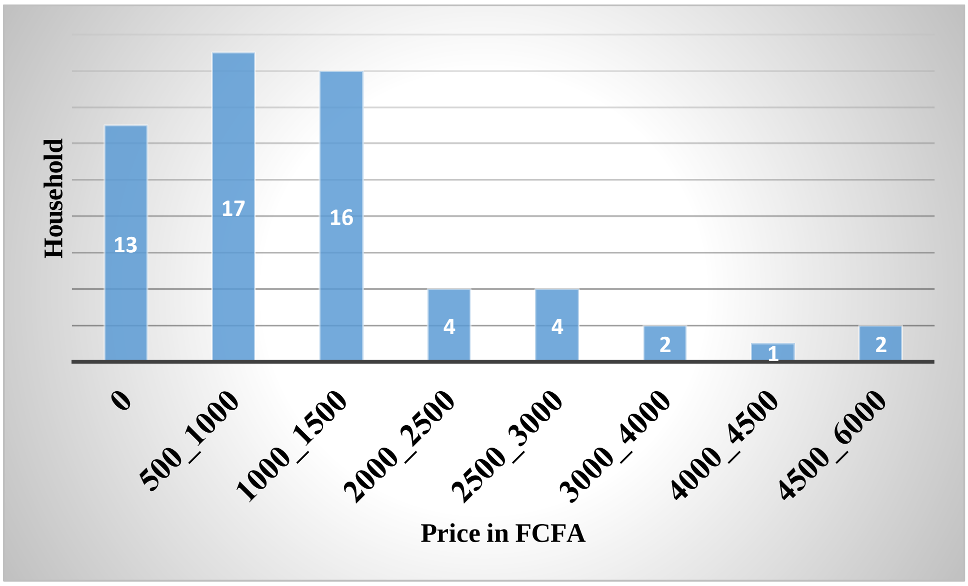


Figure 4.11: Distribution of charge phone payment

IV.6. Impacts of solar energy using

Thanks to the use of the solar park located in the village of Sékoukou, the population of this village records important impacts on its daily life. 88% of households have expressed interest in using renewable energy for the following reasons save money and save time, however just 3% of households use it to save money and 9% of households use this energy source to save money, save time and increase the success rate (Figure 4.12).

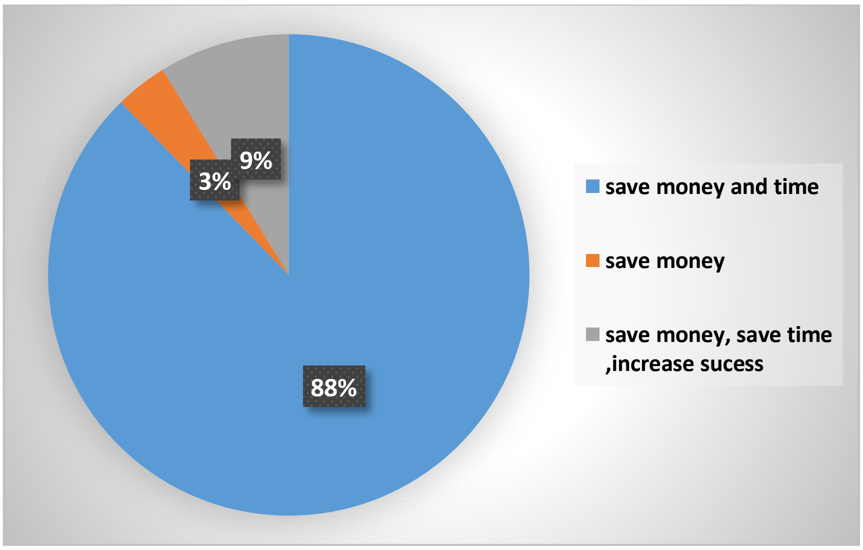


Figure 4.12: The reasons for the use of solar energy

When asked how the presence of solar energy in the village changes household life, the answers to this question show that the impacts of the use of this energy in the village have more positive social and environmental than economic impact and do not really create real economic value. The following figure presents the answers given for this question most of the answers show the impacts are linked much with changes in living conditions than on the creation of individual generating activity. 100% of households are willing to invest in renewable energies, more specifically in solar energy and clean and efficient fuels.

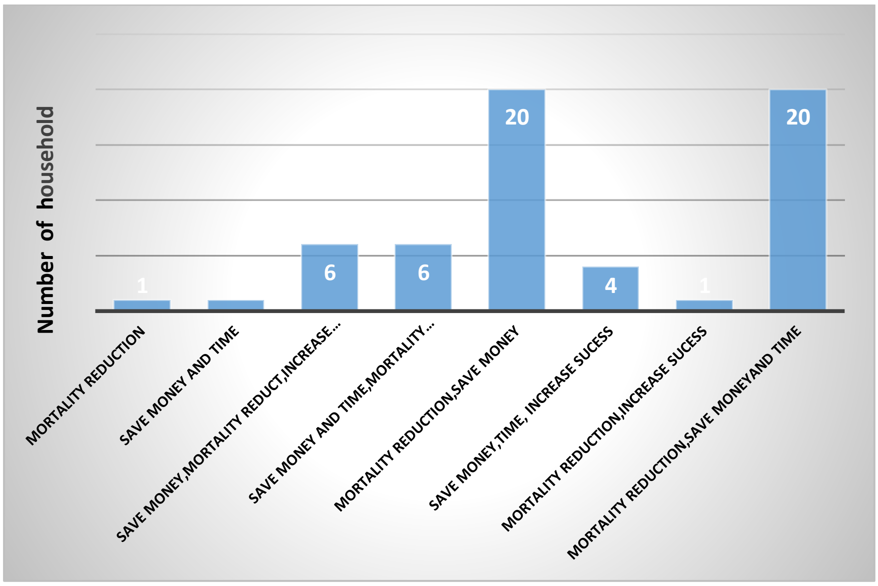


Figure 4.13: household responses on the impacts of PV use

IV.7. Socio-economic aspects

The long-term viability and extension of the solar park in the village of Sékoukou depends on the population's ability to manage the solar park.

IV.7.1. Ability to pay for the electricity bill

For this question: "Do you know how much the inhabitants of the city pay for their electricity? If not, guess the price" and "Would you pay the same price for access to electricity services", 75% of households guessed the price at 500O FCFA against 3 of the households that guessed a amount of more than 20000 CFA Franc. All these households responded favourably to pay the same price, in fact the majority of households are willing to pay a price between 0-5oooCFA Franc (Figure4.14).

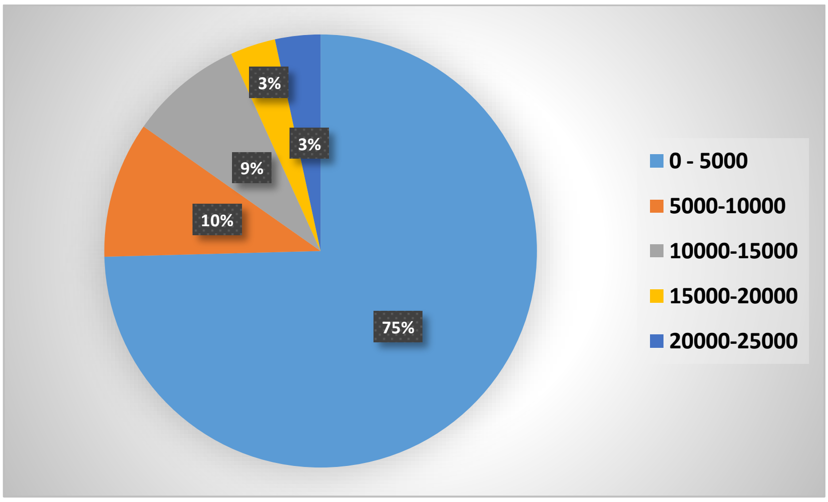


Figure 4.14: Ability to pay for the electricity bill

IV.7.2. Distribution of the different fees

56% of households have chosen the Indonesia rate of 67,787 per kWh as equitable to pay for their access to electricity, and if we take as a reference base that each consumption 1kWh per day or 30kWh per month as energy consumption. With this fee at least each household should pay 2034 FCFA per month. Indeed, the results also show that there are 24% of households that have preferred the Indian tariff, i.e. about 14 households are willing to pay 1295 FCFA per month for electricity, 20% of households chose the Japanese fee, i.e. a monthly expenditure of 3327,768 and finally none of the households chose the Denmark and Germany fees. The figure (4.15) illustrates the choice of households on the price that seems to be fair to them just for access to electricity.

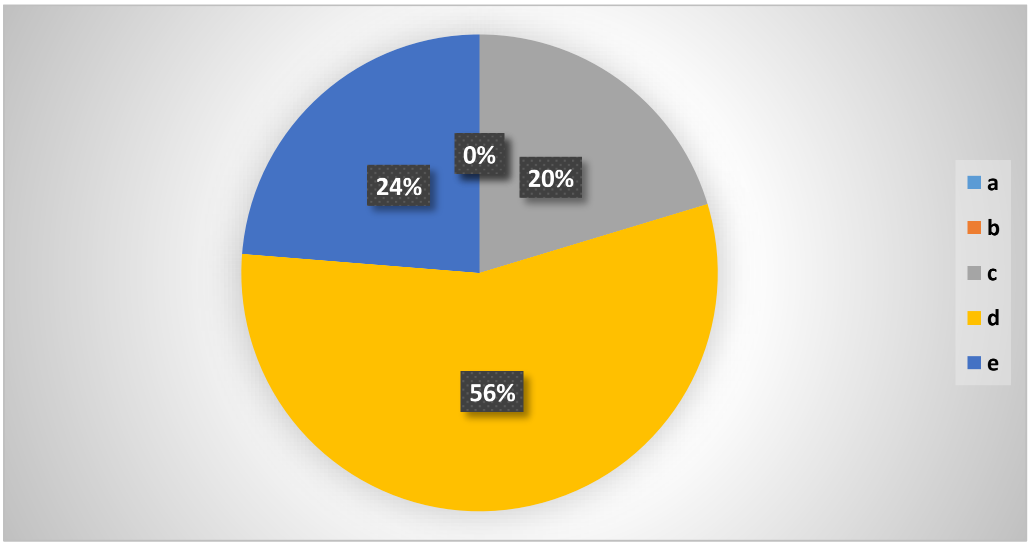


Figure 4.15: The distribution of the different fees

Where:

- a : represents the Denmark fees 0.309 $cent/kWh = 190.422 CFA/kWh (Av.Denmark 2016)
- b: 0.297 $cent/kWh = 183.027 CFA/kWh (Av. Germany 2016)
- c: 0.18 $cent/kWh = 110.9256 CFA/kWh (Av. Japan 2015)
- d: 0.11 $cent/kWh = 67.787 CFA/kWh (Av. Indonesia 2016)
- e: 0.07 $cent/kWh = 43.137 CFA/kWh (Av. India 2016)
-

IV.7.3. Fair price allocation ready to invest in clean and efficient fuels by households

Regarding the amount to be invested in clean and efficient fuel technologies, most households are ready to invest 5000 CFA Francs for the purchase of this technology.

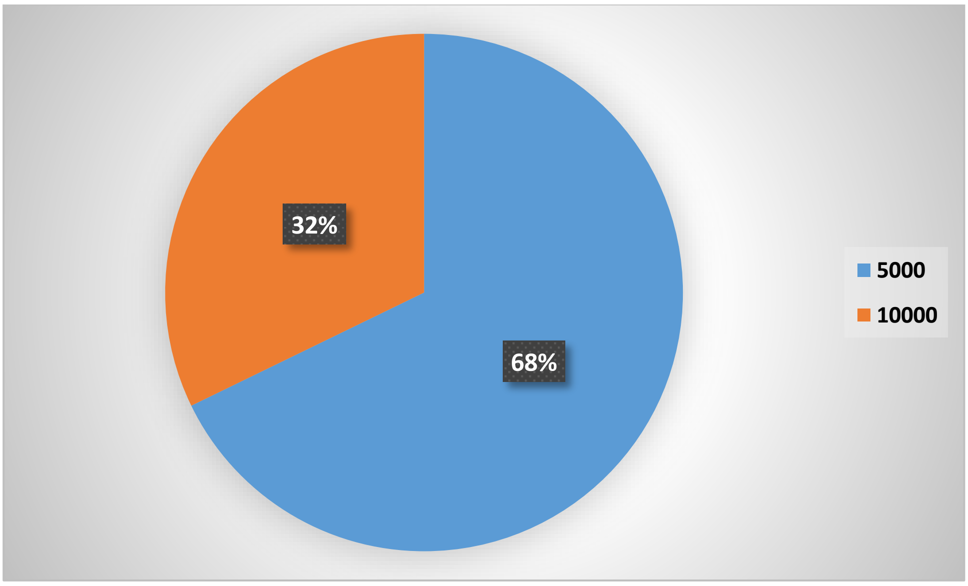


Figure 4.16: Fair price allocation ready to invest in clean and efficient fuels by households

IV.7.4. Distribution on financial assistance from outside

59% of households receive financial assistance from outside and 34% of households did not answer this question. The figure below gives more information on the distribution.

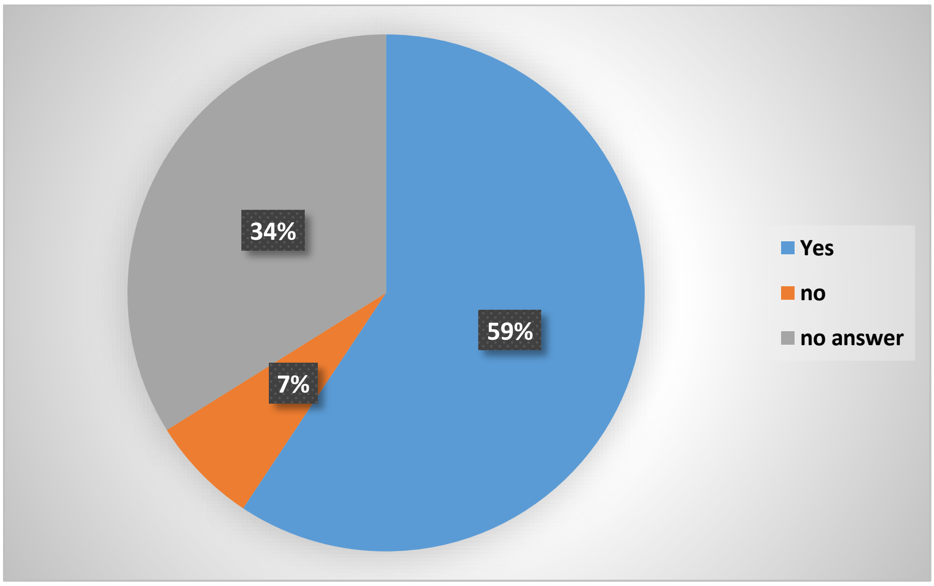


Figure 4.17: Distribution on financial assistance from outside

IV.7.5. Financial assistance amount received

In fact, most households receive this assistance once a year with a minimum amount of 5000 CFA francs. The following two figures illustrate the situation, the figure on the left represents the frequency with which households receive assistance and, on the right, shows the distribution.

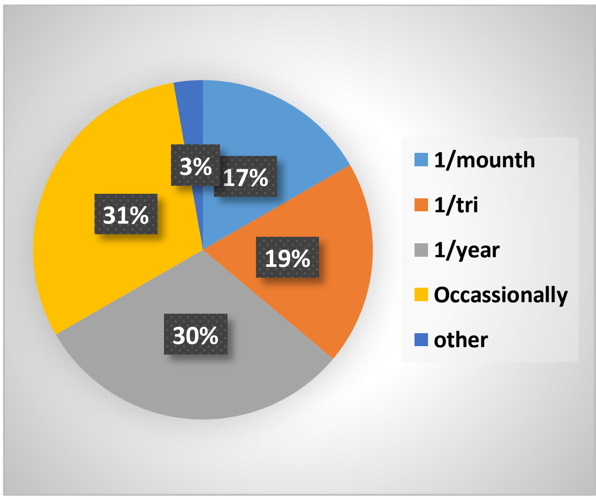


Figure 4.18: Frequency distribution

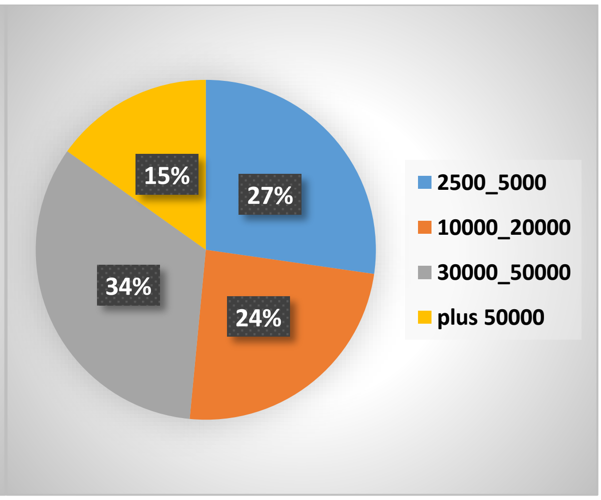


Figure 4.19: Distribution of amount outside of received financial assistance

IV.8. Solar energy potential of the Sékoulou village

The village area was automatically calculated by the ArcGIS with the GPS coordinates. This area is estimated to S = 6.92 km^2. The theoretical energy potential is: Es_1 = 41520000 kwh.

Taking into account the most common polycrystalline silicon cell technology which only allows recovery of 13, 14 to 18% of this energy (Fouad Aye, 2011; dualsun, 2019). The real energy is: Es_2 = 5397600 kwh.

The table III.3 summarizes the energy balance of Sékoukou in terms of lamps and phones.

Table IV.3: Energy balance of Sékoukou (in terms of lamps and phones)

Appliances	**Number**	**Power (W)**	**Total power (W)**	**Time (proximal per week) hour**	**Energy (kWh)**
Lamps	175	10	1750	8	14
Phones	120	33	3960	2	15.84

On the basis that most households charge their lamps twice a week, which is an average of 12 times a month, so energy consumption (for lamps) per month can be estimated at: 168 kWh. The loading of the phones was also considered also twice during the week for a period of 2 hours, so the consumption becomes then: 190.08 kWh. In summary, the current total consumption in terms of electrical energy of the village can be estimated at approximately: 358.08 kWh per month.

Compares this consumption with the available solar potential, we can see that solar energy could provide a thousand times more energy per day than the current demand. This shows that Sékoukou therefore has an enormous solar potential.

The total installed power for lighting and phone charging is about 14kWh, and it results, the availability rate is r = 38554285.72.

The village's wind potential is calculated by Weibull distribution of the measured wind speeds for Niamey 2015, with data provided by ICRISAT. Hence, the wind potential of Sékoukou village is P_2= 282.833 W. The data analysed shows that Sékoukou has a renewable energy potential, especially in terms of solar energy. Indeed, there is also a significant potential for aquatic plants, agricultural residues and animal ejection.

V. DISCUSSION

V.1. Energy potential of Sékoukou village

The different sources were analyzed to determine the potential and their integration into the energy mix. The technical analysis established that the village has an energy potential in terms of renewable energy. The potential in solar, wind and biomass (wood, solid waste, agricultural and animal residue) was well above the current and even future demand in terms of electrical energy and fuel for cooking, which shows that technically the village of Sékoukou has the energy potential to fill the energy shortfall.

V.1.1. Solar energy

In terms of photovoltaic (PV) solar energy, 1 hour of captured sunlight could supply a thousand times the Sékoukou village's current electricity needs. 5.4 GWh/day is estimated to be the technically exploitable solar potential. However, with the capacity currently installed in solar photovoltaic is 14 kWh, this is equivalent to an annual electricity production of 110040 kWh.

Photovoltaic solar energy could largely solve recurring problems in rural areas, such as access to modern energy services. Indeed, photovoltaic technology would be the best for the electricity sub-sector in the village of Sékoukou because of the acceptability but also because of the maturity of the technology and the limited number of entrepreneurs in this sector (NESAP, 2019).

The theoretical potential of wind energy in Niger has not yet been taken into account by the competent authorities in the energy sector and the electricity sub-sector. Recent studies on the African continent have shown that Niger has the most important wind resources in West Africa (Roadmap for Africa 2030, year). This was another asset for Niger's energy system. The average wind speed in the country is about 2.5 - 6 $m\ s^{-1}$ according to national data, and the highest wind potential is observed in the northern part of the country (Tahoua and Agadez) with an average wind speed of 5 $m\ s^{-1}$ while it is lower in the southern part less than 4 $m\ s^{-1}$ (ICRISAT). In fact, the main applications of wind energy in Niger are mainly pumping water for livelihood, livestock and agriculture.

Although wind farms were among the oldest RES installed in the country by missionaries in the 1950s, the total number of farms is about 30 for water pumping and to date, there is no demand for electricity supply (Wascal workshop, 2018). On the other hand, this potential could be economically interesting for the country because the wind speed must be at least 5 $m\ s^{-1}$.

According to the results of the analysis of the Sékoukou data taking into account the same Niamey meteorological parameter, the wind power obtained is estimated at **282.833 W**. Wind power to the potential that could contribute to electric power and other services in the village. However, it would therefore be necessary to carry out in-depth studies to better assess the wind capacity that could be installed by the village of Sékoukou and other villages in the country.

V.1.2. Wood energy

In Sékoukou village, the wood is the only source energy of cooking. This situation is general in Africa, according to the study conducted by FONABES as part of SDACD (Supply Master Plan in Domestic Fuels), (SDACD, 2017), in Africa wood energy is the main fuel used for cooking by more than 90% of households. Projections show that wood energy use will continue to be dominant, but is expected to compete in urban areas with butane gas and other so-called "modern" fuels. Fuelwood will remain the most widely used fuel in rural areas for many years to come, with a sharp increase in the use of charcoal. Estimates of the demand for fuelwood by 2030 indicate that if nothing is done to change the current trend, demand could increase by a factor of 4 to 10 for charcoal, double in the case of fuelwood and require the sustainable use of larger areas of forest formations than those available at present.

The total annual production of wood energy has been estimated at 1,786,218 t. eq. of wood energy at the national level (58% of annual productivity), which shows that Niger depends on neighboring countries for 42% of its wood energy (SDACD, 2017). It is also noted that the wood-energy consumption of rural populations represents 84% of the demand (1,427,054 t. eq. of wood per year), (SDACD, 2017).

V.1.3. Biofuel

Agricultural residues and aquatic plants such as water jacinth are the main biomass resource available in the village. There is also a large amount of animal waste, but so far there is no way to recycle this waste, but the potential of this waste can be used to produce a source of energy for cooking such as biogas and biochar.

Using a plant like the water jacinth will also contribute to the protection of the aquatic ecosystem and a human.

Indeed, it should be noted that ten water jyacinthe plants in 8 months can produce up to 655,330 individuals (Rabani *et al*, 2015). Moreover, water hyacinth is a very invasive plant, it causes eutrophication of water on certain stagnant portions, considerably reducing water quality... plus hyacinth mats also harbour vectors of diseases (bilharzia, cholera, malaria, filariasis, etc.). In addition, when it dies, in addition to contributing to the funding, it releases all toxic pollutants into the environment (Rabani *et al*, 2015).

Thus, the valorization of this resource will make it possible to reduce the proliferation of water jyacinth, thus protecting biodiversity, the supply of drinking water and the socio-economic activities of the populations living along the Niger River. The total organic carbon level is 1099 mg/kg/kg/ MS/ C in the water hyacinyh (Almoustapha *et al*, 2006), and in stable carbon sembe increase in pyrolysis temperatures (Masto *et al*, 2013).

A study by Eden (1994) evaluates the requirements for large-scale production of coal briquettes at from water hyacinth. He states that with an energy density of GJ m^{-3} they would be comparable to the coal energy density of 9.6GJ m^{-3}. However, for a plant to produce 40 tons of briquettes per day, an area of 12 hectares to dry water hyacinths, 1,300 tons of wet hyacinths per day and the climate should be dry and the temperatures relatively high (Practical Action).

Thus, the use of this plant as an energy source could be useful for the people of Sekoukou by helping to reduce the dependence on wood. In addition, studies have already been carried out to develop water hyacinth as an energy source, including:

Charcoal briquette in Kenya (Hill *et al.*,1997) Practical Action reported in its report that this idea emerged in Kenya in order to deal with hyacinth carpets of water that is rapidly spreading and evident in several parts of Lake Victoria. The is to develop a technology adapted to the briquetting of coal dust at from the pyrolysis of the water hyacinth. The project is still in its preliminary phase and both technical and socio-economic studies are planned to evaluate the prospects of such a project It is suggested that a small-scale water hyacinth charcoal briquetting industry could have several beneficial aspects for the lakeside communities:

- providing an alternative income
- providing an alternative source of biomass
- improvement of the lake shore environment through the removal of water hyacinth
- improved access to the lake and less risk to maritime transport
- reduced health risk associated with the presence of water hyacinth
- alleviation of pressure on other biomass fuel sources, such as wood, thereby
- reducing deforestation and associated soil erosion

Other studies have led to the national production of green charcoal.

Studies have been carried out for the possibilities to produce biogaz, primarily in India with quantities of up to 4000 liters of gas per ton of semi dried water hyacinth being produced with a methane content of up to 64% (Gopal, 1987). Most of the experiments have used a mixture of animal waste and water hyacinth. There is still no firm consensus on the design of an appropriate water hyacinth biogas digester. Also Almoustapha (2006) studied the possibility of biogas production from this plant for the sub-African zone.

V.2. Environmental and social impacts

The installation of solar energy has improved the quality of living conditions of the population in the village. The analyses of the results show that this photovoltaic parc has much more positive social and environmental impacts, on the social level because it has made it possible to reduce the rate of patients and infant mortality, improve living conditions, and on the environmental level to reduce the use of batteries.

The analysis of the results shows that wood is the only source of energy for cooking in the village of Sékoukou, as in many other villages as well. This excessive use of firewood for cooking can generate many consequences to the population particularly women and children through air pollution. Today, in Africa more than 600,000 Africans die each year (AFDB, 2018). Moreover, in addition to this health problem, the village of Sékoukou depends entirely on neighbouring villages to supply itself with firewood. With the population growth, this use accelerates of the forest degradation.

V.3. Limiting factors: cost

In Sékoukou, at least every household spends at least 90,000 Francs CFA francs each year to cover energy needs for cooking. What is worrying is that what they spend is huge for a source that is not reliable, affordable and clean in its use.

The expenses related to the energy needs for each can be estimated at least 100 000 FCFA each year.

The electricity price is still very high, for example the social price is 59.45/kWh. However, the largest number of households can earn at least 500 CFA francs per day. It shows financially that access to the energy connection remains a barrier. Especially since there is not yet also a tarrification for rural areas or for renewable energies.

Indeed, in terms of creating new income-generating activities at the individual level there is no impact, on the other hand the management committee tries to make money through the activities created around the project. Today the population does not benefit indivisibly from creating income-generating activities, however they do save on battery purchase expenses.

V.4. Viability of the project in the future

The technical parameters of the result have shown that technically Sékoukou had a huge renewable energy potential to overcome its energy needs.

The design of the integration of green biomass to be studied, indeed bio-coal would be the best short-term technology in the village than biogas. The potential of agricultural waste and water hyacinth are efficient sources for this technology. However, technical feasibility studies should be carried out. Nevertheless, the results showed a willingness and acceptance towards the transition of these energies by the population.

To continue to improve the living conditions, it is necessary to review the business around the other projects that will allow the creation of new income-generating activities.

Although the installation of solar energy has improved the quality of living conditions of the population in the village, it is necessary to review the business around the other projects that will allow the creation of new income-generating activities.

CONCLUSION AND RECOMMENDATION

The increase in the share of renewable energy in the national energy mix remains one of the main energy policy issues that the many stakeholders in developing countries are facing. Indeed, this is often due to the lack of existing data (studies) on the potential of its renewable energies.

This study has made possible to identify the potential renewable energy sources in the village of Sékoukou and the estimation of their potential. Sékoukou has an energy potential that can make up for the deficit in electrical energy. Four sources of energy have been identified in Sékoukou which are sun, wind, wood and green waste. The solar potential is already being exploited in the village for water pump and lighting even if it is not yet the 1/10th which is being exploited. For wind also an estimate has been made however, the same for the hydropower possibility but for a turbine this should be done. On the biomass side Sekoukou has agricultural residues and aquatic plants such as water hyacinth but also animal waste.

The half area of Sékoukou inhabited and the presence of groundwater allow to agricultural and herding people to exploit this great energy potential in order to produce more agricultural products in large quantities. Increased access to energy could boost activities also in livestock and fishing sector, and create other activities. The energy can accelerate the potential economic activity of Sékoukou.

The feasibility analysis of the integration of RE in energy mix was done and allowed the following recommendations to be made, taking into account what has already been done.

This study, thus, recommends the following:

- the implementation of an integrated development energy plan policy, it will allow to have an integrated resource plan that will allow to have an overview on the energy potential of each region.

Indeed, with this plan the priority is to the local resource for example the Direction of domestic energy wants to promote coal except because of the distance the product becomes more expensive, however through such a plan can know what is the potential of the village in terms of domestic energy (cooking) that can be developed locally before bringing another source, but it also allows all the private and local stakeholders to intervene in the process, moreover it can create a circular economy

- a reflection on a business model, for example in the case of Sékoukou we propose a payroll system as pay as you go adopted to the reality of the village and to enhance the value of the products. Indeed, the energy would be brought to the household according to their energy demand of their activities. This system also allows the household to improve their agricultural production. A quota is determined and imposed in terms of production, which will allow a percentage of money to be collected for energy to be provided.

To provide a legal framework to protect investors but also consumers and also a reflection on a support system to bring more efficiency to the installation projects

Finally, the continuation of this study should assess the integration of renewable energy potential across country and explore in detail the impacts of the full implementation of the integrated development plan for energy approach.

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APPENDIX

Appendix A: Interview and awareness session with women on new cookstove technologies

Figure A1 :

Figure A2 :

Figure A3 :

Figure A4 :

Figure A4 :

Appendix B: Different technology and source of energy used for lighting and cooking in the village of Sekoukou

Figure B1 :

Figure B2 :

Figure B3:

Figure B4:

Figure B5:

Figure B6:

Figure B7:

Figure B8:

Figure B9:

Figure B10:

Annex C: Questionnaire

Energy supply		
Electricity supply		
Q1	Is the household connected to the national grid?	Yes……………..…………………………….........1 No………………………………………………...3
Q2	What is the MAIN reason why your household is not connected to the grid? ***Record the MAIN reason.***	Grid is too far from household/not available…….....1 Cost of initial connection is too expensive…...........2 Monthly fee is too expensive………………………3 Satisfied with current energy solution……………...4. Renting, Landlord decision………………………...5. Service Unreliable……………………………….....6 Administrative procedure is too complicated………7 Submitted application and waiting for Connection...8 Company refused to connect the household……….9 Other, specify………………………………………10
Q3	Do you expect to get grid connection in the future?	Yes…………………………...…………………1 No……………………………..………………...2
Q4	When do you expect to get grid connection?	Month and Year Don't know………………………………………
Q5	are you ready to pay for a connection	yes………………. no …………………….
Q6	which system would you like to have : on grid or off grid	
Q7	Do you know how much people in the city pay for their electricity? If not, take a guess	
	Would you pay the same price if you had access to electric services?	
Q8	Please mark which of the following you think is a fair price for electricity access:	

	• 0.309 $cent/kWh = 190.422 CFA/kWh (Av. Denmark 2016) • 0.297 $cent/kWh = 183.027 CFA/kWh (Av. Germany 2016) • 0.18 $cent/kWh = 110.9256 CFA/kWh (Av. Japan 2015) • 0.11 $cent/kWh = 67.787 CFA/kWh (Av. Indonesia 2016) 0.07 $cent/kWh = 43.137 CFA/kWh (Av. India 2016	
Q9	Which payment model do you want (PAY AS YOU GO,CASH)	

Energy supply		
Electricity supply (Cont'd)		
Q10	How often do you/your household buy/s fuel for the lamps?	
Q11	How many lamps are in your home?	
Q12	How much do you/your household buy/s each time (of fuel for lamps)?	
Q13	How much do you/your household pay/s for said fuel	
Q14	How many appliances using electricity do have in your home?	
Q15	How much do you/your household pay for it	
Wood supply		
Q1	What (fuel) do you/your household use/s for cooking? (e.g. Wood)	
Q2	How many times per day do you/your household normally cook/s? And for how many people?	
Q3	How much wood on average do you/your household consume/s in a day? week? month?	
Q4	How often do you/your household get/s fuel for cooking?	
Q5	How much do you/your household buy/s (of fuel for cooking)?	
Q6	How much do you/your household pay/s for the wood?	
Q7	Do you or hear about clean and efficient cooking technologies and fuels?	
Q8	How much can you pay for it	

Appendix C:

ENERGY USER	**Responses/Options**						**Notes (surveyor)**
I. Background information							
I.1. Date of survey							
I.2. Interviewee code							
I.3. Garden code							
I.4. Village code							
I.5. Gender	**Male**		**Female**				
I.6. Size of household							
I.7. How old are you							
I.8. Position in the household	Head		Member		Other(Specify)		
I.9. Type of habitat							Observation
I.10. Level of education	**1.** Primary school	**2.** High school	**3.** University degree	**4.** Koranic education	**5.** Tertiary education	**6.** Illiterate	
I.11. Income Category (mean daily in F CFA)	100	≤500	500-1000	1000-2000	2000-5000	≥5000	

I. Background information (Cont'd)									Observation
I.12. Primary source of support for the household?	**1.** Farming	**2.** Breeding	**3.** Fishing	**4.** Business	**5.** Handicraft	**6.** Salaried	**7.** Housekeeper	**8.** Others	
I.13. What are secondary occupations in the household?	**1.** Farming	**2.** Breeding	**3.** Fishing	**4.** Business	**5.** Handicraft	**6.** Salaried	**7.** Housekeeper	**8.** Others	
I.14. What are sources of cash income for the interviewee?	**1.** Farming	**2.** Breeding	**3.** Fishing	**4.** Business	**5.** Handicraft	**6.** Salaried	**7.** Housekeeper	**8.** Others	
I.15. What are sources of cash income for other household members?	**1.** Farming	**2.** Breeding	**3.** Fishing	**4.** Business	**5.** Handicraft	**6.** Salaried	**7.** Housekeeper	**8.** Others	

II. Lifestyle (Cont'd)		Observation
II.1. What time do you normally wake up?		
II.6. If you had electricity, what time would you wake up at?		
II.2. At what time do you normally go outside your home?		
II.7. If you had electricity, what time do you think you would go to sleep at?		
II.3. What time do you normally return home?		
II.8. If you had access to electricity, do you think that would change? How?		
II.4. What time do you normally go to sleep?		
II.9 If you had access to cook stove, do you think that would change? How?		
II.5. List the 5 most important things you would like to have if you had access to electricity		

III. Social-Economic aspects of energy use			Observation
III.1. Do use electricity for your activity?	Yes	No	
III.2. Since when did you begin to use this electricity?			
III.3. What is your current energy situation	Deficit	Surplus	
III.4. Are you planning to increase your request for energy?	Yes / No		
III.5. Why?			

III.6. What is (are) the source(s) of the electricity used in your activity?	NIGELEC	Solar panels	Diesel Generator	Biofuel	Kerosene	Others (comment)	

III. Social-Economic aspects of energy use (Cont'd)							Observation
III.17. What are technologies using source of solar energy do you encounter in the village?							
III.18. How do you think this source of solar energy has changed people's lives around you?							
III.19. How has this source of solar energy changed your life?	Saving money	Saving time	Comfort	Increasing income	Rising yield	Increasing success rate	
	Death rates reduction	Protecting environment	Scholar enrollment	Drugs availability	Better healthcare	Others	

III. Social-Economic aspects of energy use (Cont'd)											Observation
III.7. How often do you use these sources of electricity?	NIGELEC	Solar panels	Diesel Generator	Biofuel	Kerosene	Others					
III.8. What do you use this electricity for?	Cooking	Lighting	Drinking water supply	Irrigati on	Heating water	Education	Business	Others			
III.9. Why do you use this (these) particular source(s) of electricity in your activity?	Saving money	Saving time	Comfort	Increasing income	Rising yield	Protecting environment	Scholar enrollment	Increasing success rate	Others		
III.10. How much did you pay to purchase and install this (these) source(s) of energy?											

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III. Social-Economic aspects of energy use (Cont'd)					Observation
III.11. How did you finance the purchase and installation? (Where did the money come from?)					
III.12. What expenses have you incurred after the installation?	Routine maintenance	Fuel supply	Purchase of spare materials	Others (Comment)	
III.13. Do you earn any money because you have installed this source of electricity, or has it helped you increase your income?	Yes, how so?		No, why?		

III. Social-Economic aspects of energy use (Cont'd)										Observation
III.14. What other sources of electricity have you used before in your activity/household?	NIGELEC	Solar panels		Diesel Generator		Biofuel	Kerosene		Others	
III.15. What differences do you see between these electricity sources?	Saving money	Saving time	Comfort	Increasing income	Rising yield	Protecting environment	Scholar enrollment	Increasing success rate	Others	
III.16. How has having this electricity source changed your life?										

IV. Environmental aspects **III. Social-Economic aspects of energy use (Cont'd)**							Observation
IV.1. Have you noticed any impacts on the environment with any sources of electricity you use now, or have used in the past?	Yes			No			
III.20. Which energy source are you used to supply in water?	NIGELEC	Solar panels	Diesel Generator	Biofuel	Kerosene	Others	
III.21. How often do you use these sources of energy?	NIGELEC	Solar panels	Diesel Generator	Biofuel	Kerosene	Others	
IV.2. If yes, which are these impacts?							
III.22. Do you pay to get water?	Yes		No (skip to **II.21.**)				
IV.3. How do you feel the sources of energy you have installed how impact the environment?							
III.23. If yes, why?	Fuel supply	Routine maintenance	Return of investment	To buy spare materiel		Others (Comment)	
III.24. How much are you paying per day?							
III.25. If no, why?	Subsidies		Cooperative	Insurance		Others (Comment)	

III. Social-Economic aspects of energy use (Cont'd)							Observation
III.26. If the village is supplied in water by solar panels do you know why this choice?	Saving time	Saving money	Comfort	Cheapness	Environmentally friendly	Others	
III.27. If one day the water pump stops operating, how will people feel?	Much better	Somewhat better	Stayed the same	Somewhat worse	Much worse	Don't know	
III.28. If you have the choice will you invest in solar energy?	Yes, why?			No, why?			

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V. Migration			Observation
V.1. Has anyone in the neighboring left because it did not have reliable sources of electricity?	Yes	No	
V.2. Is there any household’s member living outside village?	Yes	No	
Does he (she) send remittance back to your home?			
If yes, how often he (she) send money back home? *-One time per month* *2-Two times per month* *3-One time per quarter* *4-One time per year* *5-Occasionally* *6-Other…………*			

V. Migration (Cont'd)						Observation
What is your approximate total amount of remittance/ year?	………………. CFA					
V.3. Has installing new sources of electricity had impacted the migration of neighboring members?	Yes				No	
V.4. Does the use of solar panels impact migration rate?	Yes, how?				No, why?	
	Increase	Decrease	Don't know	No change	Don't know	
V.5. If yes, how many people in your household/neighboring migrate from (or to) the village each year?						

V. Migration (Cont'd)					Observation
V.6. Out of 10 households, how many people do you think migrate from (or to) the village?					
V.7. Has the frequency of emigration changed since the advent of solar panels in the village?	Never happened	No change	Decrease	Increase	