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SOCIOECONOMIC IMPACT ASSESSMENT OF DECENTRALIZED HYBRID (PHOTOVOLTAIC & GENSET) TECHNOLOGY IN RURAL AREAS OF WEST AFRICA CASE STUDY: BURKINA FASO

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Declaration

I am KOUAKOU Gnamien Constant, 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.

Acknowledgement

I wish above all to thank God the Almighty for this strength and the health he grants during the period of my Master thesis. Then, thank the members who will accept to read and judge this work. Their criticism and advice will undoubtedly improve it.

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List of abbreviations

ACP-EU:	African, Caribbean and Pacific Group of States- European Union
AIDS:	Acquired Immune Deficiency Syndrome
ARSE:	Electricity Sector Regulatory Authority
AU:	African Union
CH4:	Butane
CO:	Carbon Monoxide
DES:	Decentralized Energy Systems
DFID:	British Agency for International Development
DM:	Dry Matter
DNM:	Department of National Meteorology
ECOWAS:	Economic Community of West African States
EDF:	France Electricity
ESMAP:	Energy Sector Management Assistance Program
FCFA:	Franc from the African Financial Community
FDE:	Electrification Development Fund
GDP:	Gross Domestic Product
GMO:	Genetically modified organism
HDI:	Human Development Index
HIV:	Human Immunodeficiency Virus
IEA:	International Energy Agency
IRSAT:	Institute for Research in Applied Sciences and Technology
KVA:	kilovolt Ampere
KWh:	Kilowatt Hour
KWp:	Kilowatt peak
m2:	Square meter
MDG:	Millennium Development Goal
MNVOC:	Greenhouse Gas
MW:	Megawatt
N_2O:	Nitrous Oxide

NOx:	Oxides of Nitrogen
PN-PTFM:	National Multifunctional Platforms Program
PRSP:	Poverty Reduction Strategy Paper
SE4ALL:	Stainable Energy for All
SONABEL:	National Company of Electricity of Burkina Faso
SSA:	Sub-Saharan Africa
TFP:	Technical and Financial Partners
UEMOA:	West African Economic and Monetary Union
UN:	United Nation
UNCED:	United Nations Conference on Environment and Development
UNDP:	United Nations Development Programme
UNIDO:	United Nations Industrial Development Organization
USD:	United States Dollar
WHO:	World Health Organization

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Abstract

Access to electricity is the key and driving force of all economic and social development of populations. Access to electricity is a collective supply that modernizes rural areas. It favours quantitative and qualitative development building of the villages. The present study was to assess socio-economic impact of decentralized energy system in Bilgo located in Burkina Faso. This assessment was based on two levels; household and community levels. In carrying out the research, a survey was conducted by administering questionnaires to the community residents and data collection from some international institutions. Access to electricity and its impact on the two levels was assessed. The obtained results from this study shows that in the community, access to electricity has led to an increase of 47 % in girl's school attendance, enabled opening of 18 economic activities and increased the number of equipment in Bilgo health center. At household level, the opinions of the respondents are differently shared. It indicates that electrification increased comfort by 50 %, contributed to better well-being by 30 % and provided a better means of security for the remaining 20 % of the population between 12 and 19. It also resulted in better health services and opening of more businesses. As regards access to information, electrification resulted in an increase in acquisition of mobile phones by 38 %, radio by 22 % and TV by 13.3 %. Domestic lighting increases the time for activities and leisure. This is explained by the fact that for the surveyed population, the hours of dinners vary between 7 and 8 pm and washing of dishes occurs from 9 to10 pm. Access to electricity brought about economic supplies in Bilgo village. Access to electricity also facilitates comfort, security, well-being, education of the rural population. It is supply which brings about economic activities that help rural population by creating opportunities and conducive business environment. This kind of trade is the most beneficial economic activity in Bilgo population.

Résumé

L'accès à l'électricité est la clef et le moteur de tout développement économique et social des populations. L'accès à l'électricité est une offre collective qui modernise les zones rurales. Il favorise le développement quantitatif et qualitatif des villages. La présente étude a consisté à évaluer l'impact socio-économique du système énergétique décentralisé à Bilgo, situé au Burkina Faso. Cette évaluation était basée sur deux niveaux : le niveau des ménages et le niveau communautaire. Dans la réalisation de la recherche, une enquête a été mené par l'administration de questionnaires aux résidents de la communauté et la collecte de données auprès de certaines institutions internationales. L'accès à l'électricité et son impact sur les deux niveaux ont été évalués. Les résultats obtenus de cette étude montrent que dans la communauté, l'accès à l'électricité a entraîné une augmentation de 47 % de la scolarisation des filles, a permis l'ouverture de 18 activités économiques et augmenté le nombre de matériel dans le centre de santé de Bilgo. Au niveau des ménages, les opinions des répondants sont partagées différemment. Il indique que l'électrification a augmenté le confort de 50 %, a contribué à un meilleur bien-être de 30 % et a fourni un meilleur moyen de sécurité pour les 20 % restants de la population entre 12 et 19. Il a également permis de meilleurs services de santé et l'ouverture de plus entreprises. En ce qui concerne l'accès à l'information, l'électrification a entraîné une augmentation de l'acquisition de téléphones mobiles de 38 %, de la radio de 22 % et de la télévision de 133 %. L'éclairage domestique augmente le temps pour les activités et les loisirs. Cela s'explique par le fait que, pour la population interrogée, les heures de dîner varient entre 7 h et 8 h et le lavage des vaisselles se déroule de 9 h à 10 h. L'accès à l'électricité a entraîné des approvisionnements économiques dans le village de Bilgo. L'accès à l'électricité facilite également le confort, la sécurité, le bien-être, l'éducation de la population rurale. C'est une offre qui apporte des activités économiques qui aident la population rurale en créant des opportunités et dans un environnement commercial propice. Ce type de commerce est l'activité économique la plus avantageuse de la population de Bilgo.

Chapter I:
GENERAL INTRODUCTION

1.1 Background

At the beginning of the 1990s, the international community considered energy essentially as a means of action for the protection of the environment and the fight against climate change. At the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992 (better known as the Rio Earth Summit), which highlighted the importance of linkages between environment and economic development, the energy problems mentioned were mainly oriented towards climate change. For example, the Action Plan adopted following this Conference (Agenda 21) focuses on renewable energies and energy efficiency, which are seen as a means of protecting the atmosphere (Cecelski, 2000a). However, the document does not focus on access to energy. As Clancy (1999) points out, energy has never been seen as a basic need such as water or food. According to the Larousse definition, energy "is manifested by the production of heat, work or radiation. Since he has domesticated fire, man uses raw materials (wood, coal, oil, uranium, etc.) and natural phenomena (wind, solar radiation, tides, etc.) to derive energy". The role of energy in development issues began to evolve in the late 1990s and more precisely in 1997 at the 19th Special Session of the United Nations General Assembly, organized to draw up a five-year review After the Earth Summit in Rio. At this conference, the relationship between energy and development was clearly presented (UNDP, 1997), and a specific chapter on energy was Program for the continuation of Agenda 21. Awareness of the preponderant role of energy in poverty reduction is reinforced at the World Summit on Sustainable Development, held in Johannesburg in 2002. One of the commitments of the Report of the World Summit on Sustainable Development (2002) states: " To act jointly and redouble efforts to work together at all levels to increase access to reliable and affordable energy services to facilitate the achievement of the Millennium Development Goals, Half the proportion of people living in poverty by 2015, because access to energy facilitates the elimination of poverty, enabling the production of other important services ". While there is no Energy Millennium Development Goal (MDG), access to energy is now seen by the international community as a necessary condition for achieving the Millennium Development Goals Poverty and hunger, health, gender equality and education (UN-Energy, 2005). Jeffrey Sachs goes so far as to say in 2005 that: "In the absence of increased investment in the energy sector, the MDGs will not be reached in the poorest countries" (Foreword in Modi et al., 2005). The British Agency for International Development (DFID) presented in a matrix the relationship between energy and the MDGs (DFID, 2002). This

matrix, included *in the White Paper for a Regional Policy, on access to energy services for rural and peri-urban populations to achieve the MDGs of ECOWAS* and UEMOA in 2006, can be summarized as follows

Table 1.1: Summary of links between energy and MDGs

	Objective	Importance of energy to achieve these goals:
1	**Eradicate extreme poverty and hunger**	• Access to reliable and affordable energy services enables business development. • Lighting can extend commercial activity beyond the hours of the day. • The use of machines improves productivity. • Clean and efficient fuels reduce the Households spent on cooking, lighting and heating. • Post-harvest losses are reduced by better conservation • Energy for irrigation improves food production and access to better nutrition.
2	**Achieve universal primary education**	• Energy provides access to water, hygiene, lighting and heated / temperate areas, contributing to the reduction of absenteeism and abandonment rates by creating a better environment for children. • Electricity provides access to schools and homes for the media for communication and education. • Electricity provides access to schools and homes for the media for communication and education. • Quality lighting helps study at home as well as attendance at evening classes.
3	**Promote gender equality and empower women**	• The availability of modern energy services frees girls and young women from the time allotted to survival activities (collection of firewood, water, inefficient cooking, manual harvesting, etc.). • Affordable, high-quality energy services pave the way for business female
4	**Reduce child mortality**	• Clean cooking equipment reduces exposure to air pollution in homes and improves health. • Modern energy is safer, and can reduce accidents (burns, fires, etc.). • Electricity can pump clean, pure water. • Refrigeration allows vaccination of young children. • Energy services are required to provide access to better services medicines for mothers (refrigeration of medicines, sterilization of equipment and operating theaters)
5	**Improve maternal health**	• Excessive workloads and heavy manual work can damage the overall health of a pregnant woman.
6	**Combat HIV / AIDS, malaria and other diseases**	• The electricity in the dispensaries allows the opening at night, to retain the personnel qualified, and the use of special equipment. • Access to energy services, through its multiple aspects (lighting, communication, driving force, pumping, cooking, etc.), makes a great contribution to achieving the MDGs

Faced with the new challenge and challenge facing the world today, UN has drafted the Agenda 2030 and approved 17 Sustainable Development Goals (SDGs) listed below with the figure 1. In these Goals and targets, UN are setting out a supremely ambitious and transformational vision and envisages a world free from poverty, hunger, disease and will, where all life can prosper. Each goal has specific targets to be achieved over the next 15 years. The UN is considering a world free of fear and violence. A world with universal literacy. A world with equitable and universal access to quality education at all levels, health care and social protection, where physical, mental and social well-being is ensured. A world in which we reaffirm our human rights commitments to safe drinking water and sanitation and to improving hygiene; And where food is sufficient, safe, affordable and nutritious. A world where human habitats are safe, resilient and sustainable, and where universal access to affordable, reliable and sustainable energy.

Sustainable Development Goals

Goal 1. End poverty in all its forms everywhere

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3. Ensure healthy lives and promote well-being for all at all ages

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5. Achieve gender equality and empower all women and girls

Goal 6. Ensure availability and sustainable management of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Goal 10. Reduce inequality within and among countries

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12. Ensure sustainable consumption and production patterns

Goal 13. Take urgent action to combat climate change and its impacts

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice

for all and build effective, accountable and inclusive institutions at all levels

Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Figure 1-1 Sustainable Development Goals(UNFCCC, 2017)

Even today, energy challenges remain enormous, especially in sub-Saharan Africa (SSA). If electricity is considered, according to world Bank, in 2013, 1.2 billion people did not have access to it (World Bank, 2013). Regarding Africa, more than 620 million Africans today live without electricity and the continent has the lowest average electrification rate among developing regions (42%). This average rate masks wide disparities across the continent: the electrification rate is indeed much lower in sub-Saharan Africa, where it falls below 10%

(Energy for Africa, 2015) . There are also large disparities between urban and rural areas. Indeed, in 2012, the International Energy Agency (IEA) estimated that the rural electrification rate in SSA was 12.9% against 64.2% in urban areas. Energy from renewable raw materials (wood, charcoal) and agricultural by-products is therefore still predominant in rural areas but the rate of exploitation is very low. Regarding Burkina Faso, electrification rate in Burkina Faso is 16.4% (IEA, 2014), either the 12th position in the ECOWAS Member States (Figure 0.2). Only 112 departments have access to electricity on a total of 350 in the country and the supply of electrified localities is therefore very uncertain, especially during the period April-June. There is a significant gap between rural and urban areas in terms of access to modern energies (electricity and petroleum products); thus the rate of access to electricity in rural areas is only 2.2% compared to 54.0% in urban areas (Figure 0.2). SONABEL, whose mission is the electrification of the country, ensures the production and distribution of electrical energy in Burkina Faso from 24 thermal power stations and 4 hydroelectric power stations1. The production of these plants is complemented by imports of electricity from neighbouring countries Ghana, Côte d'Ivoire and Togo. For example, in 2014, the total supply of the country was 1,359 GWh, of which 64% of local production (thermal power plants: 57%, hydropower stations: 7%) and 36% of imports (Figure 0.3). The total installed capacity is 285 MW with more than 252 MW in thermal (SONABEL, 2015). The supply of electricity to the country remains insufficient because there is no balance between supply and demand. To mitigate the disparity of electricity between the urban and rural area through new production technologies of electricity from a decentralized energy system (DES). It is in this vision that International Institute for Water and Environmental Engineering (2iE) has developed since 2009 the concept of solar hybrid solar photovoltaic / generators, called the "Flexy Energy" concept. This hybrid plant concept was implemented at Bilgo. After years of operation of the power plant, this study is to assess the linked socio-economic impacts to the electricity availability on the well-being of Bilgo population.

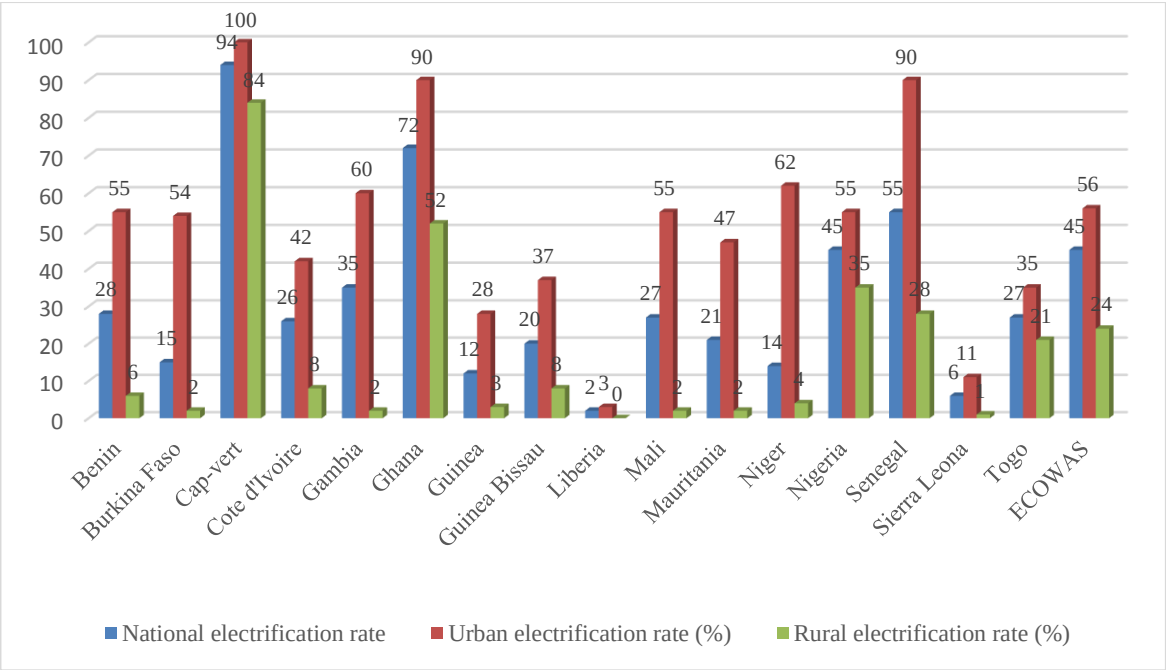


Figure 1-2: Electrification rate of ECOWAS member states in 2012. Source of data: IEA, World Energy Outlook 2014

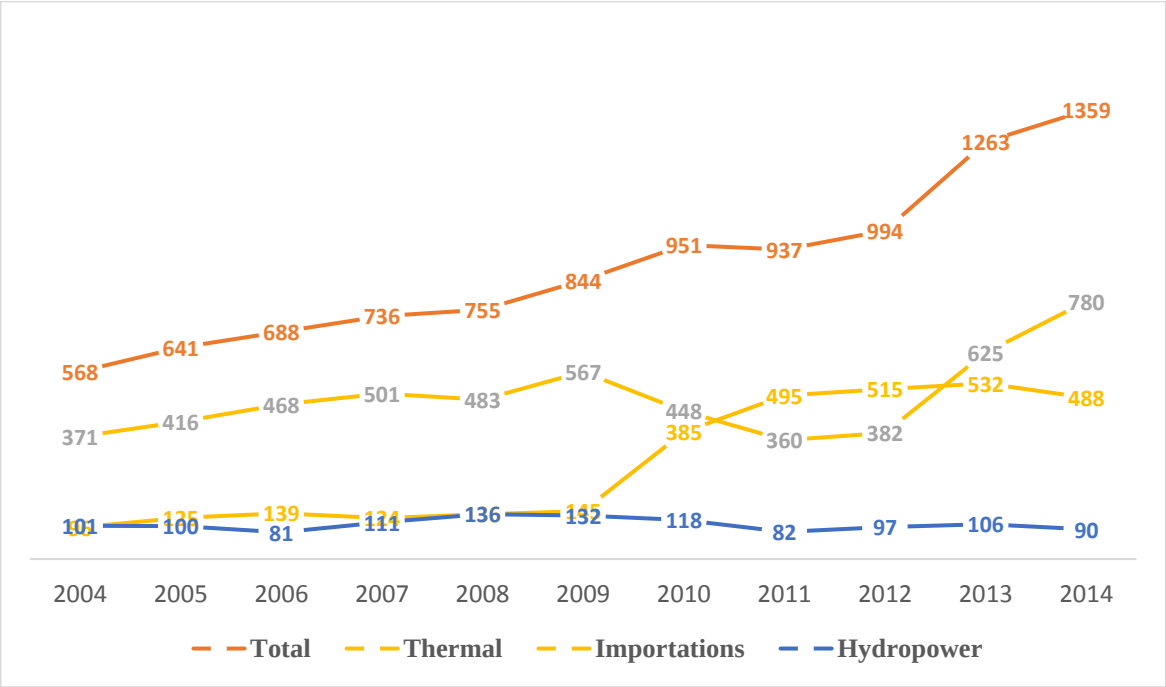


Figure 1-3: Electricity supply in MWh in Burkina Faso according to the origins from 2004 to 2014. Source of data: Reports of activities of SONABEL 2013 and 2014

1.2 Problem statement

Like access to water, access to energy by the predominantly rural populations is almost impossible. In Burkina Faso, the rate of electrification in rural areas is below 5 %. The energy gap is high between rural and urban or semi-urban areas. To offset this energy deficit,

the Government of Burkina Faso, through funding from the ACP-EU Energy Facility, has built a hybrid power plant with a capacity of 30 kilowatt peak (kWp) of solar and 77 KVA as genset capacity in the region of Kadiogo precisely in Bilgo. Bilgo is a county located in the region of Kadiogo in the center of Burkina Faso at 25 km from Ouagadougou. The population of Bilgo is estimated at around 2003 inhabitants. Inaugurated on March 31, 2016, this powerhouse has for objective to power more than 300 households of the locality infirmary, maternity center, schools and trade points in Bilgo.

Access to clean, reliable and sustainable energy is one of the main goals of the SDGs of all member states of the West African Economic and Monetary Union (UEMOA). One of necessary conditions for economic development of a rural area can be explained by its energy accessibility. It is very important to have a positive impact through access to energy on the development of the economic and social activities of the populations living in the villages of Bilgo.

1.3 Justification of study

This study is done to provide a clear and detailed report to decision markers, government or investors in order to improve assessing methods of future projects aiming to improve energy access, as well as improving accountability of energy providers and policy- makers in the project funding, by providing recommendations to improve the electricity network, expand the energy project and improve project design.

1.4 Purpose of the Study

The purpose of this study was to know which improvement access to electricity brought in the population well-being.

1.5 Objectives of the Study

The objectives are subdivided on two mains objectives as described below.

1. General objective

The main objective of this study is to assess the socio-economic impacts generated by decentralized rural electrification using hybrid systems namely (photovoltaic and Genset) at Bilgo. This hybrid system is implemented in Bilgo village in Burkina-Faso. The capacity of solar plant is 30 KWp and for the genset is 77 KVA as shown in the figure below. The main partners in this project are Energy facility ACP- EU, the International Institute for Water and Environment (2iE), SONABEL (National company of electricity of Burkina), which will be the beneficiaries of the plant and will be responsible for its operations and

management. For this purpose, the study assesses the impact of energy access on human development of that county. The HDI is used as a quantitative measure of human development. The different levels considered for the impact assessment of energy access on human development in Bilgo area are: household level and community level.

Figure 1-4: Bilgo power plant(lefaso, 2017)

2. Specific objective

The specific objective of this study is to know the impacts of electricity availability on the vital services of the Bilgo population. The indicators used on the both level of assessment are:

- Household level: Comfort, well-being and security; access to information; contribute education improvement; time flexibility for domestic and productive tasks.
- Community level: Spatial extension and evolution of housing; health, education and economic activities.

1.6 Research Questions

From the above objectives, the study sought to answer the following question: to what extent did the decentralized renewable energy interventions in Bilgo impact the socio-economic profile of households, businesses and community institutions?

1.7 Scope and Limitation

The scope of my study is focused on changing of Bilgo with electricity supply. The study focuses on household and community level thus industrial users are not included. The accuracy of the survey depends on ability of the surveyors to accurately translate and ask questions in native language.

1.8 Research Background

Energy is the foundation of modern economies, the central need for modern life though the relationship between energy access and poverty indicators. In addition, there is the causality relationship between energy consumption as well as electricity consumption and the HDI (human development index) using as a proxy of human well-being as described by figure 2. It means that Energy influences socio-economic condition of developing countries as shown in Figure 3. Energy is prerequisite for economic growth, improving living conditions and alleviating poverty. Access to energy is defined as "the ability to avail energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy & safe, for all required energy services across household, business and community uses" (ESMAP, 2014). Secondly, access to energy is considered an important goal including in the 17 Sustainable Development Goals (SDGs) (SDGs and the UN agenda for 2030). However, obstacles such as high energy costs, unaffordable energy grid infrastructure and disperse population makes providing access to a majority of the world's population in developing countries a daunting task. Meanwhile, decentralized renewable energy technologies offer a unique opportunity to provide affordable and sustainable energy to millions of people. Decentralized renewable energy technologies, in particular, offer diverse and economically attractive options for rural electrification.

The gap in the electrification rate between urban and rural areas is generated by the high cost of electricity transmission and the enormous losses generated by transmission lines in the electricity grid. In rural areas, habitat dispersal is an important decision-making factor for decentralized electrification solutions: the more remote the dwellings are, the higher the costs of distributing from a central source, therefore decentralized solutions are more efficient.

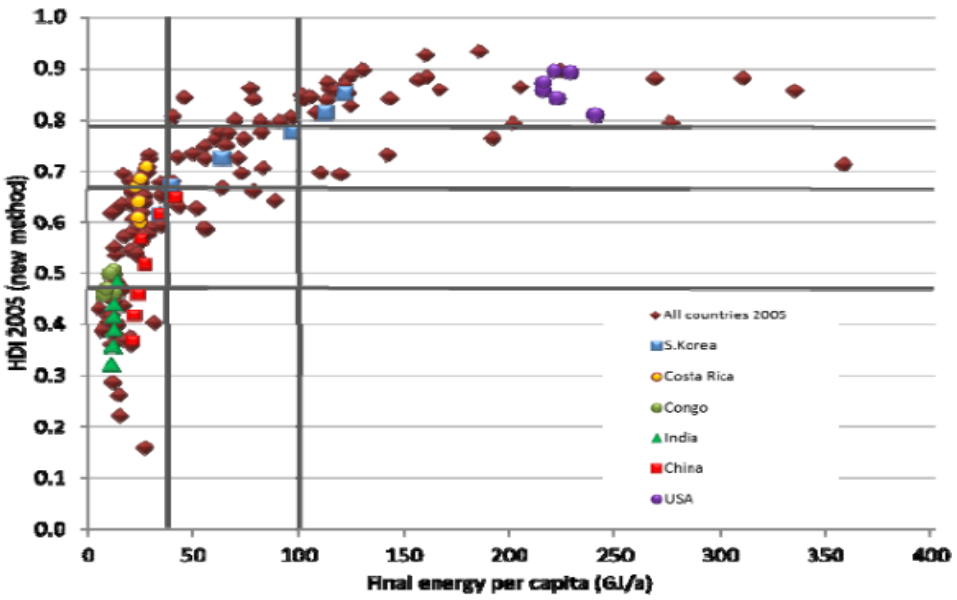


Figure 1-5: Causality relationship between energy and the HDI (Steckel et al. 2013)

In particular, access to energy is a key step in alleviating poverty and improving living conditions in sub-Saharan Africa. The electrification rate of sub-Saharan countries is the lowest among developing countries with over 620 million people having no access to electricity (Energy for Africa, 2015). This has left many countries in the region to struggle with extreme poverty. The case has not been any different for Burkina Faso, a country with a population of 15 million inhabitants and a population growth rate of 2.9%. The majority of the population in Burkina Faso, over 90%, does not have access to modern cooking fuels. Actual rate of access to electricity was 13.54% in 2010(…)

Introduction of such infrastructures in rural areas serves two purposes: first; it reduces the disparity between urban and rural areas and also satisfies the legitimate aspiration of the rural population to life comparable to that of city dwellers. Secondly, it contributes to the improvement of living conditions, human development and increases the rate of access to reliable, affordable and sustainable energy.

Regarding advantages of DES, it has been recognized worldwide that decentralized electricity generation can reduce capital investment significantly by avoiding transmission and distribution losses. Decentralized electricity system with renewable sources could provide reliable, affordable, environmentally sustainable electricity in rural areas (R.B. Hiremath 2009). In addition to that decentralized electricity generation can reduce cost of electricity per unit, it is a clean form of energy resulting in reduced pollution, emission of greenhouse gases, vulnerability to extreme weather events (WADE, 2003). From this perspective, Burkina government doesn't represent an exception. A policy has been put in

place on the issue of renewable energies and energy efficiency with clear relevant objectives that will increase the penetration of renewable energies into the energy mix and the adoption of energy efficient technologies. For this fact, some projects are already under way such as the construction of the Zina Solar Power Station in the Boucle du Mouhoun, with a capacity of 20 Mgw. The plant will provide access to electricity for nearly 20,000 inhabitants, 13 schools, 40 health centers and financial support for 250 groups to carry out income-generating activities for the benefit of local populations. (Government of Burkina Faso, 2016) and the Zagtouli solar power plant: 30 MW. (Regulator of the electricity subsector, 2016)

This research assesses the socioeconomic impact of decentralized hybrid systems in Burkina Faso rural areas (Bilgo). The methodology of the study and the data collection process is described below.

Chapter II

LITERATURE REVIEW

Study examined some similar studies conducted to evaluate socioeconomic benefits of access to energy from decentralized energy systems. Opinion-based studies are the primarily sources as the literature review is intended to provide a background to introduce the findings of the paper. The literature on rural electrification encompasses issues on access and affordability; success stories and problems; institutional dimensions; subsidies; social, economic and environmental impacts; project planning, design and implementation; and more recently on the energy, poverty and gender nexus. This chapter highlights some of the important issues discussed in various international papers, journals and books that the author finds relevant to this study to reduce the gaps, (Bhandari, 2006).

Some of these concepts (Multi-tier framework) enable to better understand the dimensions of energy access. Whilst the underlying principles of energy access, for example affordability or safety, may be universal, the ways in which we define or measure these may vary across different regions. It is in this context, the world Bank's Energy Sector Management Assistance Program (ESMAP) under support of multiple international organizations, including GIZ and Endev team, came up with a Global Tracking Framework (GTF) made up of various Multi-Tier framework to understand the dimensions of energy access on the well-being of the population. The MTF is an approach that provides a great insight into access to energy. In fact, it assesses access to energy according to several attributes, i.e. to what extent energy is adequate in quantity, available when needed, good quality, reliable, practical, affordable, legal, healthy and safe. Each of the attributes is measured on a continuum of improvement, from level 0 (poor performance - energy poverty) to level 5 (good performance - good access to energy), either by binary indicators or by a graduated scale. Each attribute receives a level score based on its performance. The combination of attribute scores determines the assignment at a specific level, which reflects the level of access to energy, the overall level score is calculated by applying the lower level score in all attributes.

2.1 Consequences access to electricity

Makoto Kanagawa and Toshihiko Nakata researched to reveal relations between access to electricity and advancement in a socio-economic condition in rural areas of developing countries. The objective was to understand the technological potential that reveals the links between access to energy, improvement and eradication of poverty through access to energy in rural areas. For this purpose, four studies have been carried out. These studies include: 1)

Energy and health; 2) energy and education; 3) energy and income; 4) energy and environment. Figure.1 below shows the different relationships. These studies were focused on analysis of un-electrified rural areas in Assam state, India. They have developed an energy-economic model in order to analyse the possibility of electrification through dissemination of electric lighting appliances as well as applied multiple regression analysis to estimate the socioeconomic condition, a literacy rate above 6 years old, in the areas. As a result of the case study, the household electrification rate, the 1000 km^2 road density, and sex ratio had been chosen as the explanatory variables of the literacy rate.

Moreover, the model analysis shows that complete household electrification will be achieved by the year 2012. In combination with the multiple regression and model analysis, the literacy rate in Assam may increase to 74.4% from 63.3%. In sum up, after studies, they revealed that socio-economic factors such as health and education could improve with access to energy. In addition, it has significant effects on other factors, such as the economy, gender equality, the environment, etc., in rural areas of developing countries. With these socio-economic factors, it could contribute to the eradication of poverty and lead developing countries towards sustainable development.

Del Rio and Burguillo (2009) researched the socioeconomic benefits of community, household and business based decentralized energy systems (DES) by conducting three case studies in Spain. These cases included biofuel, solar and wind energy projects and used empirical methods to collect data. The aim was to identify the contribution of community, household and business levels based decentralized energy systems (DES) to local sustainability including: 1) social; 2) economic; and 3) environmental. The objective was to understand the perception of socioeconomic benefits of DES by the recipient community, households and businesses. It does this by conducting a stakeholder analysis and a perception survey of the communities, households and businesses. In this context, eleven indices were used including: impact on education, employment, income generation, demographic impacts, energy accessibility, social cohesion and human development, tourism and use of indigenous resources. The paper concluded that the impacts on employment of the DESs are positive. Although direct employment is relatively modest, the indirect contribution to employment creation is large compared to size of the community. While solar power had the lowest number of jobs created, the biofuel projects have created the most number of direct and indirect jobs. In one case, a biofuel project created 200 (i.e.

direct and indirect) jobs in a community of ten thousand people. The projects have also lead to diversification of employment and income sources as well as creation of temporary jobs (Rio and Burguillo 2009).

The study further found negligible impacts on demographic (i.e. flow of people in the town), educational impacts and cheaper energy supply. It also finds the impacts on tourism to be rather small. However, the study concludes that DESs impact on improving standard of living, human development and social cohesion is significant. DESs have also provided an alternative to farming by providing a source of employment. Significantly, the author finds that environmental benefits from these projects have been rather negative for the local population due to negative externalities. These included noise, occupation of land by projects, replacement of vegetation by crops used for energy production in case of biofuel and visual intrusion. The paper concluded that, although DESs had positive socioeconomic impacts on the communities, households and business, they cannot be the only solution to sustainability and had to be treated as a part of the solution rather than the whole.

The total population of the Economic Community of West African States (ECOWAS) was estimated to 362,807,215 inhabitants in 2016, representing 30 % of the total of Africa population. (Populationpyramid, 2016) The energy access situation in the ECOWAS region is characterized by a very low energy consumption level. This reflects the insufficient access to modern energy services, including electricity and modern fuels, which are crucial for developing economic activities and reducing poverty levels. Some researchers (e.g. Pirlogea, 2012; Yakunina and Bychkov, 2015) have provided evidence on the role of energy in human development. The human development index (HDI) is used as a quantitative measure of human development (Sen, 1992). The HDI computes human development by considering issues such as school enrolment and literacy rates as measure of education, gross domestic product per capital as a measure of quality of life, and life expectancy as a measure of health care. The HDI is an average of three component indices: the education level index, life expectancy index, and gross domestic product per capital index. Countries are ranked from the highest development index to the lowest. Table 2 shows the overview of the electricity access in West Africa and the human development index (HDI) ranking.

From table 2, the study suggests that the key challenge faced by policy makers in West Africa is expanding energy access especially in the rural areas which plays a key role in achieving economic and social development. Wide gaps exist between the access rates in urban areas and rural ones, as well as between different countries. Only Cape Verde and

Ghana have a high rural electrification rate in the region, with countries such as Burkina Faso, the Gambia and Sierra Leone having low electrification rate. Furthermore, according to the human development index (HDI), only Caper Verde and Ghana are classified as medium human development areas whereas the rest of the countries in the ECOWAS region are classified in the low human development. Providing energy access is further complicated by both unstable power supply and inadequate financing to build appropriate infrastructure to create the market for modern energy services. For example, in Ghana, despite the high urban electrification rate, the country still experiences unreliable power supply. Most of the policies in the ECOWAS region focus on the supply side with emphasis on extending on the demand side, which deals with issues such as households access, and ease of use energy services. A missing component of the policy analysis on energy access in the ECOWAS region is the inadequate incentives to create a supply chain in the energy business that can support peri-urban and rural areas.

The conceptual framework of the relationship between energy access and poverty indicators used in this study is presented in Figure 2-1 below. Energy access has positive effects on socio-economic development, this is reflected in the improvement of certain such as education, health, gender, shelter and food security, access to information, Improvement of the living environment. These dimensions of development are directly connected to one another (Kanagawa. M. and Nakata, 2006). The Energy and Mining Group of the World Bank established the connection between economic prosperity, sustainable income, health, education, women and children (Kanagawa. M. and Nakata, 2006). The study is framed on four key indicators that are linked to energy access. The indicators refer to the following dimensions:

- Health
- Education
- Income
- Environment

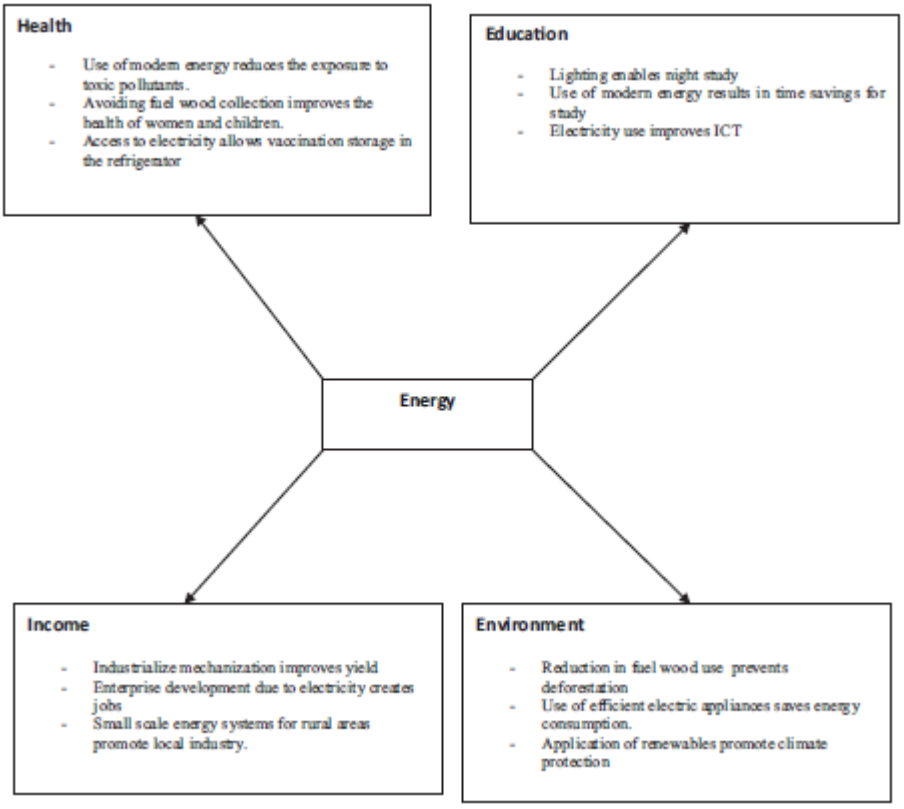


Figure 2-1: Linking energy with the key indicators(V Kanagawa and Nakata,2006)

The main focus of this framework is that there is a direct link between access to energy and economic development as the inadequacy of modern fuels and electricity in most developing countries creates poverty and limits the delivery of social services as well as the opportunities for women. This paper aims to use the framework to analyses the situation in the ECOWAS region and provides inputs to policy makers to make informed decisions with regards to energy access-poverty indicators.

Table 2: Electricity access in West Africa 2013

Country	Population without electricity (millions)	National electrification rate %	Urban electrification rate %	Rural electrification rate %	GDP per capita Estimated at 2013 (USD/PPP)	HDI rank 2013 ranking
Benin	7	29%	57%	9%	1600	166
Burkina Faso	14	17%	56%	1%	1500	183
Cabo Verde	0	94%	100%	84%	4400	122
Cote d'Ivoire	15	26%	42%	8%	1800	172
Gambia	1	36%	60%	2%	2000	175
Ghana	7	72%	92%	50%	3500	140
Guinea	9	26%	53%	11%	1100	182
Guinea-Bissau	1	21%	37%	6%	1200	178
Liberia	4	10%	17%	3%	700	177
Mali	11	26%	53%	9%	1100	179
Niger	15	15%	62%	4%	800	188
Nigeria	96	45%	55%	37%	2800	152
Senegal	6	55%	90%	28%	2100	170
Sierra Leone	6	5%	11%	1%	1400	181
Togo	5	27%	35%	21%	1100	162

Source: *Kanagawa and Nakata,2006*

2.2 Energy Access and Heath

According to the United Nations, SDG 3 indicates reduction in child mortality, improvement in maternal health and fight against HIV/AIDS, malaria and other diseases. Many foods need cooking and the application of modern cooking facilities reduces significantly in-door air pollution, therefore limiting respiratory and other lung diseases. Access to modern energy services enables households to heat water, thus reducing waterborne infections. Sustainable energy access supports the running of medical facilities such as hospitals and clinics (IEA, UNDP and UNIDO, 2010). In addition, access to energy enables medical facilities to serve the people after dark, to power the communications gadgets and retrieve clients' information. Energy access crises therefore has caused public health alarms, due mainly to inhaling of pollutants during indoor cooking, injury during fuel wood gathering, lack of safe storage of medication (refrigeration) and electricity access for medical facilities (Sovacool, 2012a). Improved energy access will thus improve health delivery and medication storage. The ECOWAS region has recognized that insufficient access to energy has an impact on the social development. Women in particular bear the hardship of collecting fuel and water on a daily basis, leaving less time to access health or

education services. According to estimates, more than 257.8 million people (nearly three-fourths of the region's population) in the ECOWAS region are affected by air pollution from indoor smoke, small particle pollution, carbon monoxide, and nitrogen oxides, predominantly as a result of cooking and heating with solid fuels. Energy services are vital for providing safe, affordable and effective health services. The challenges in the ECOWAS region are how to improve maternal and children's health, expand the number of doctors and health facilities, which can be achieved if access to energy is considered as part of the solutions.

2.3 Energy Access and Education

Limited access to energy has adverse effects on educational chances to humanity, both for adults and children. These effects include irregular school attendance due to sickness. Many medical researchers have established links between air pollution mainly due to ineffective indoor cooking stoves and severe respiratory problems amongst children. Achieving universal primary education is the SDG 2 of the United Nations. Children in poor rural areas spend the majority of their time fetching firewood and water. Access to modern energy services will facilitate cooking and allow time for school. Electricity is crucial for education since it improves communication and information sharing. It also enables lighting thereby allowing students study during the night. It also allows communities to organize literacy lessons for adults, thereby improving their reading skills. It is also worth noticing that household electricity is important to education, by expanding total hours available for work, chores and study - enabled by electric light compared to fuel-based lighting. Also, it is much easier to recruit and retain teachers in the rural areas if the schools are well-equipped and well-maintained and have access to electricity, clean water, and sanitation facilities. For example, the non-formal education system in Ghana where those without formal education are trained to read through evening classes can be improved with access to electricity. In Guinea only 2% of schools are electrified (UNESCO,2012), and education explains the gender inequality in Burkina Faso. Ninety percent of children in sub-Saharan Africa go to primary schools that do not have access to electricity or any form of energy services, hampering their chances of receiving adequate and quality education. There is a clear linkage between energy poverty and education.

2.4 Energy Access and the Environment

The environmental effects of limited energy access include destroying forest zones, changing the landscape and greenhouse pollutants. The World Health Organization (WHO,2014) projected that about 2 billion people are dependent upon the traditional biomass for space heating and cooking, and burn about 2 million tons of biomass daily. Whereas the wood is in limited supply, the population grow is high and the rate of replenishing the trees is slow, thereby resulting in the deforestation and affecting the environment (Sovacool,2012a). The connection between firewood fetching and deforestation is not true for all nations. A study revealed that many times, people fetch firewood not from the forest reserves but from the "invisible trees" (Sovacool,2012a). Sovacool (2012b) further suggested that only in Africa - including the ECOWAS - region fetching firewood significantly results into deforestation. Firewood is one of the main sources of cooking in the ECOWAS region. With regards to access to modern cooking facilities, the access situation is worse than that of electricity access. In the ECOWAS region, Nigeria only has over 100 million people without access to clean cooking facilities. Within fifteen ECOWAS member countries, where more than 60% of the population relies on traditional fuels for cooking, it is estimated that in 2015 more than 200 million people were without modern cooking facilities

2.5 Energy access and economic growth (Income)

Modern energy services help to increase income earning activities and can significantly support poverty alleviating methods. A world-wide assessment showed that between 20% and 30% of the yearly incomes of poor people is used on energy band an additional 20–40% is remotely used on the use of the energy (Sovacool, 2012a). A reliable supply of efficient heating, lighting, cooking and transportation is vital and modern energy sources are the key to that need. Researchers, academics and practitioners have accepted the strong bidirectional relations between access to energy and income levels. It is evident that nations with poor population also have less access to modern energy sources (PracticalAction,2013). An increased income is mostly accompanied by increased access to modern energy services. However, electricity access is not only the outcome of economic development; it contributes significantly to the economic development (Practical Action, 2013). According to Jones (1989) and Lee (2005) urbanization leads to increased energy consumption and energy use also increases GDP growth. Rural electricity consumption equally increases agricultural growth (Fan, S., Nyange, D., Rao, N, 2005). It is therefore important that for countries to

develop, every effort must be made to increase access to not only electricity but modern energy facilities. In making an effort to increase access to electricity and modern energy, attention must be given to the quality, reliability, quantity and sustainability of modern energy sources. GDP per capita in the ECOWAS countries ranges from USD 800 in Niger to USD 4400 in Cape Verde. Most ECOWAS countries rank among the poorest in the world, with 13 Member States classified as having "Low Human Development" by the United Nations.

2.6 Electricity Situation in Africa

The issue of electricity access, particularly, in Sub-Saharan African needs urgent attention, especially with regards to rural electrification, to ensure any significant success in the future. According to World Energy Outlook report (2012), the trend in electricity access in other regions such as developing Asia has high potential to improve remarkably. The region is likely to reduce electricity poverty from about 630 million people without electricity in 2010 to about 335 million in 2030, which would be about 50% improvement. The situation is, however, different in Sub-Saharan Africa. Even though Sub-Saharan Africa was ranked highest with record of 589 million people without electricity access in 2010, projections indicate that the situation could exacerbate to about 655 million people in 2030 due to fragility of intervening actions. The situation is even alarming in the rural areas where most of the people have never had access to electricity. According to UNEP (2012), rural electricity access rate in the sub-region is only 8 per cent, whereas 85 per cent of the population rely on biomass for energy (UNEP, 2012; World Energy Outlook, 2012).

The good news, however, is that Africa and the Sub-Saharan Regions have abundant resources of renewable energy, which studies have shown that, they are the most plausible forms of energy for rural electrification, particularly with respect to solar and wind. Recent studies also show that the attempt to increase the share of renewable energy is very high on the policy agenda of most leaders in developing countries, including Sub-Saharan Africa (Gómez et al., 2010; Javadi et al., 2013; Lahimer et al., 2013; UNEP, 2012;).

2.7 Uses of Electricity in Rural Areas

Most impact studies have shown a discrepancy between theoretical justifications for projects and the measurable impact once those projects have been carried out. Fluitman (1983) argued that most of the existing impact studies were of a descriptive nature and he concluded "costs it appears, becomes trivial compared to the happiness of a villager who can see (an

electric) light at the end of the poverty tunnel". Gaunt's (2003) says that with the ethics behind international aid only social objectives are valid to carry out rural electrification in developing countries. Scholars Cecelski (2003) and Zomers (2003) find it difficult to quantify and isolate the improvement in the well-being of the people as a consequence of electrification. For a particular case of Bangladesh, Zomers (2001) and Barkat (2002) agree that, where, in addition to electrification, other infrastructure such as roads, health services and educational facilities are developed, the economic effects are greater. Ranganathan (1993) has pointed out that post electrification studies have criticized rural electrification programmes for not meeting its anticipated effects, for over-emphasizing the social benefits and for being too expensive. He considers rural electrification to be a merit good where the positive externalities are not internalized as part of an infrastructure besides being a commodity and a production input. As such the return on investment criterion may not be appropriate to be the only yardstick in judging a rural electrification programme's success. He states that the developing countries' governments want to subsidize rural electrification at the utilities' costs. He rightly argues that electricity cannot cause development unless it is used and that there are corresponding inputs as well. In Thailand, Yang (2003) the net present value of rural electrification projects financial analysis was negative but its economic analysis showed an internal rate of return of 12.5%.

2.8 Social Effects of Rural Electrification

Most scholars agree that rural electrification has positive bearings on health and education. Barnes (2004) reports that in Costa Rica after the electrification of rural areas, significant social improvements took place: the number of education institutions with lighting and night classes increased considerably, new hospitals were set up and the number of health centres increased.

Spalding-Fecher (2005) suggests the inclusion of avoided health costs of fuel in cost-benefit analysis of energy projects. He classifies health impacts into morbidity and mortality and suggests evaluating both of them based on willingness to pay within which the mortality could be based on value of statistical life (VOSL) or to the value of lost years (VOLY). It is expected that with electricity, the extended evenings would be spent in socially and economically productive ways. Most impact studies agree that there have been positive changes with family spending more time together and the introduction or expansion of the small local / cottage industries. For example, (Djeflat, 1985) one of the findings is that the

many households have changed their way of spending the evening after electrification. Lim (1984) concludes that electricity had not given rise to important changes in the life-style of Malaysian villagers. His study finds that electricity was hardly used for new or better income generation purposes.

Energy is one area that does not have appropriate gender-analytic tools according to Skutch (2005). In one paper she discusses some approaches that could be used for energy projects arguing that there are differences in energy demand between men and women. Instead of the common demand driven energy projects, the author suggests an approach of "need" driven projects. She recommends including women in different phases of the project. The implications to gender, especially empowerment, have received more attention UNDP (2005); Madon (2003); Masse (2003); World Bank, (2003) in recent papers. Lack of access of electricity is one of the major impediments to growth and development in rural economies in developing countries. That is why access to modern energy, in particular to electricity has been one of the priority themes of many countries. A few countries are considered, that is, India, Bangladesh, Phillipines and Zimbabwe. The cases of the social effects globally point to how rural electrification has transformed lives.

India has experienced rapid economic growth over the past decade, with an expanding middle class larger than the population of the United States. In 2000, the population grew at a rate of over 6 per cent, which required a rate of 9 per cent of energy growth. In the past 20 years alone, urbanization has driven a 208% growth in India's energy consumption. Under these conditions, it is imperative that India meets its growing energy necessities in a self-reliant, sustainable manner. However, providing 1 billion plus people with a constant energy supply is very difficult, especially for a developing country facing rising gas prices. Inclusive growth starts with providing energy access to the most disadvantaged and remote communities.

More than 18,000 villages live without electricity in India; according to the International Energy Agency, 404.5 million people do not have access to power. Many who do receive electricity face constant blackouts and uncertainties of a steady energy supply from their utility companies. Erratic voltage levels and an unreliable power supply are major problems, due to the inadequate energy supply and ageing transmission leading to power cuts. Rural areas face serious problems with the reliability of power supply. India's climatic conditions make it a very suitable place to rely on renewable energy, with very high solar irradiation levels and 45,000 megavolts megawatts (MWV) of possible wind capacity, renewable

energy business growth has much potential. The Indian economy also depends heavily on agricultural production, and the livelihood for a majority of the population is farming. Installing renewable energy for rural agricultural purposes is necessary to make a significant impact.

India is an agricultural nation, yet the farmers and the rural poor remain the underserved. The benefits of renewable energy in rural Indian communities are tremendous, renewable energy not only expands energy generation and greenhouse gas mitigation, but also contributes to improvements in local environment, drought control, energy conservation, employment generation, health and hygiene, social welfare, security of drinking water, and increased agricultural yield. Implementing wind farms and solar power in villages brings development in the form of infrastructure, efficient agriculture, and an overall better quality of life for the rural people. Thus, the broader developmental goals, such as poverty alleviation, sustainable development and employment generation should be integrated into the rural electrification programmes while seeking direct support under bilateral and multilateral cooperation. The government of India, NGOs, the international community, private businesses, and the villagers themselves all have a significant part to play in creating this better life, and must work together in order to do so.

After the independence of Bangladesh in 1971, the first major initiative to extend grid electricity in rural areas was taken in 1975 under a scheme called ‘Total Electrification Programme. This programme looked beyond grid connectivity towards development of the basic distribution facilities for effective delivery of power to rural areas by 1978. At around the same time, establishing an institutional structure was considered, which would develop the technical, economic, financial and social analysis, and organizational requirements for a rural electrification project in Bangladesh. Then at the request of the Bangladesh Government Rural Electrification Project Committee, a decision was taken for the establishment of a new national agency under the Power Ministry to develop and administer a rural electrification programme. Accordingly, Rural Electrification Board (REB) was established on 29 October, 1977 and started functioning on 1 January, 1978 with following basic objectives; to provide reliable, sustainable and affordable electricity to rural people, to help improve the economic condition of rural people by providing electricity for agriculture and small industries, help improve the living condition of rural people, expand

electrification to entire rural Bangladesh and to ensure consumer participation in policy-making.

The REB programme operates through locally organized rural electric associations called *Palli Bidyut Samity* (PBS). The concept of PBS is based on the model of Rural Electric Cooperatives in USA, which operates with cooperatives and ownership of consumers. A PBS is an autonomous organization registered with REB, and it owns, operates and manages a rural distribution system within its area of jurisdiction. Its members are its consumers, who participate in its policy-making through elected representatives in its governing body. REB's role is to provide PBS with assistance in initial organizational activities, training, operational and management activities, procurement of funds, and providing liaison between PBS and the bulk power suppliers like Bangladesh Power Development Board (PDB), Dhaka Electric Supply Authority (DESA), and other concerned Government and Non-Government agencies. The area coverage of one PBS is usually 5-10 *thanas* (sub-locations) with a geographic expanse of 600-700 sq. miles.

The first PBS was established in 1980 to operate in Dhaka, and as of 2007 a total of 70 PBSs are working in some 46,000 villages in 61 locations and serving more than 7 million rural customers all over Bangladesh (REB 2007). Since the inception of REB, rural electrification has grown significantly – starting from less than 10 percent connectivity in 1977, about 61 percent villages have received electricity by 2007.2 Under REB's programme, about 800,000 new rural customers get electricity every year, which is phenomenal for a poor country like Bangladesh. The REB consumers are mostly domestic users of electricity (85 percent), although industrial and commercial customers are also served, including those needing connection for irrigation pumps. REB plans to cover 75,000 villages of Bangladesh by the year 2020. The rural electrification programme of REB is often viewed as one of the most successful government programmes in Bangladesh.

2.9 Economic Effects of Rural Electrification

Empirical studies and intuitive appeal highlight the role of energy in economic development. The International Energy Agency has underscored the high correlation between access to energy and development (Silva and Nakata, 2009). Over 2 billion people all over the world live with no electricity and they continue to subsist below the poverty line (UNDP cited in Haayika, 2006). In cognizance of this, rural electrification has been a government priority for two decades so much so that the Philippines has finally achieved 100% electrification of

the 41,980 barangays or villages in 2009. To accomplish this, the government has had to mobilize a lot of multi and bilateral support as well as programmes from the major IPPs operating in the Philippines (Anonuevo, 2009).

According to the National Electrification Authority, the government has spent pp (Philippine peso) 49.3 billion (US$ 1 billion) or pp2 million for each barangay from 2001 to 2009. Of that amount, 37.64 billion came from loans and pp11.68 billion from subsidies (Anonuevo, 2009).

Historically, a great majority of the new barangays were connected via line extensions from the existing distribution network. Under this approach, last mile connections became harder and harder to reach. Moreover, as the lines became extended longer and longer, quality became problematic. Increasing losses and subsidies limited what could be achieved. Under this metric, only the existence of a tapping point within the barangay was recorded, while utilization and the number of actual household connections were ignored.

Similar to the dissonance noted in the impressive GDP growth, full electrification of the barangays did not impact on poverty incidence mitigation. Clearly, a more pro-active stance on providing electricity is needed. In 2003, ADB commissioned a study to find out why some "New and Renewable Energy" (NRE) projects failed to achieve their desired objectives. Among the areas that need attention include lack of stakeholder mobilization and beneficiary participation, institutional problems, including unsuitable management practices, technical problems, including lack of spare parts for operation and maintenance and use of obsolete technologies, financial problems, such as high initial and maintenance costs, or high tariffs for consumers.

Asian Development Bank (ADB) notes that it is important to ensure installed NRE systems are sustainable in the long-term, it is important to also develop renewable energy-based livelihood opportunities." Sample of these undertakings could be rice mills and mini-ice plants for cold storage of fish. Provision of skills and training for operation, maintenance skills and market access are also important components of these projects.

In 2009, the WB approved a US$40 MM loan to the Development Bank of the Philippines for the Rural Power Project (RPP) aimed at reducing poverty and improving the quality of life of 10,000 rural households in hard-to-reach, isolated and poorest areas of the country, particularly in Mindanao. The RPP will target households, use more public-private sector partnerships, emphasize rural electric cooperatives and upgrade these distributors to become financially viable and operationally efficient (US Fed News). At this point, one may ask if perhaps this is the key to coupling provision of electricity with poverty alleviation.

Certainly, it would provide sustainability of the projects financed by these loans. Moreover, areas with high poverty can be identified and focused on. It would also be useful to rethink the nature of the problem at hand.

The Population of Zimbabwe is approximately thirteen million and an area of 398 000 sq. km. This country was under the Colonial rule from 1890 to 1980 when it attained independence. The thrust to electrify all rural growth points & service centres started in the early 1980's. The RE Masterplan Study (ADB-funded) of 1995, was approved by Cabinet in 1997. In 2002 the new Electricity Act passed initiated the privatization of electricity utility (ZESA), setting up of RE Agency with own board having majority of Provincial Administrators. RE Agency embarked on the Expanded RE Programme, funded by levy on electricity tariffs (rose 1%-6% in last 5 years) and additional government allocations. The approach to rural grid extension in Zimbabwe was focused on unelectrified rural centres. These are rural centres where local government infrastructure such as police stations, agriculture extension and health services are located. Government houses and premises are connected free. Household connections for the general rural public are not subsidized. Rural electrification has continued but at a very slow pace.

Lim (1984) argues that the poor economic returns of rural electrification in Malaysia could possibly improve when other socio-economic inputs to rural development were also provided. In USA, rural electrification in the 1930's was expected to improve the economic competitiveness of farm families, but unfortunately it was not enough (Yang, 2003). Fluitman (1983) mentions that the benefits of extending the grid tend to be overestimated and the costs understated. His study did not find much evidence to suggest that electricity, which could be used for productive purposes, had any major beneficial impact on the income generation or employment of the rural poor. On the contrary, with the "partial and patchy empirical evidence", he says that, there is some indication of net job losses and of worsening income distribution as a result of rural electrification. This, it is further stated, is not to suggest that rural electrification should not be promoted but that there is a need for a more judicious planning and evaluation of such programmes.

Rural electrification may not gap the income disparity if most of the people cannot afford to use it. Only as income rises, the type of fuel used also shifts towards electricity. A survey conducted in South Africa deduces that the energy transition theory is mostly driven by income rather than the access to electricity (David, 1998). Fuel switching towards

electricity, the study found out, was evident in a substantial way in wealthier households and electricity substituted other fuels in only a few households. In the middle and low income households, electricity appeared to be more of an additional energy source rather than a replacement for other fuels.

Barnes (2004) suggests additional intervention to assist the rural people gain the benefits by helping them consume more energy. He tries to explore ways and means by which the viability of rural electrification could be enhanced. Costs of wiring, lack of credit were some reasons why households in electrified villages remained un-electrified. He suggests introducing credit and loan promotion schemes as part of the rural electrification project. Other areas to enhance the impact is to introduce social infrastructure and community street lighting, electrifying public buildings, functions like vocational training, adult literacy campaigns.

Zomers (2003) points out those criteria for decision making as to whether a rural electrification project should be implemented have changed. He says that growing environmental concerns are also playing key roles in rural electrification decisions. Fluitman (1983) concluded that the economic and environmental benefits of rural electrification tend to be overestimated and the costs understated. Many other studies (World Bank, 2003; DFID, 2002) express the need to assess the externalities in rural electrification programmes. There are other issues that are directly not reflected in common socio-economic impact studies. Davidson and Mwakasonda (2004) say that "strong institutions are the backbone of an efficient and effective energy sector". They point out that countries similar in political and social setup may still require different policies to create the right enabling environment. Foley (1992), unlike most papers on Rural Electrification, narrate some of the important institutional concerns and options to carry out rural electrification works. Several options other than having the rural electrification programme implemented under the central utility's direct control are suggested with examples of their usage in different countries. The strength and weaknesses of each of the different institutional setups are mentioned. He mentions that the institutional aspects of rural electrification programmes need as much attention as the technical aspects for successful implementation. Barnes (2005) agrees. His study shows that "a variety of approaches have been successful" and factors such as autonomy and accountability, amongst others, were common in the successful rural electrification projects.

2.10 Impact of electrification on rural development

Samanta and Sundaram (1983) did a study on socio-economic impact of rural electrification in India. The study addressed the following questions: Does rural electrification increase productivity, income, and employment and bring structural change in rural areas? Does rural electrification reduce excessive migration to urban areas? How does rural electrification fit into the broad strategy of rural development? What complementary conditions make for success in rural electrification schemes? How does rural electrification affect the roles of women and children? The analysis is based on primary data collected by the Operations Research Group (ORG) in 132 villages in four states Andhn'a Pradesh, Maharashtra, Punjab, and West Bengal. Data were collected a-both the village and household levels, and from State Electricity Board and research and manufacturing enterprises in the sample villages. For 108 of the 132 villages, these data were supplemented by a baseline 1966 survey of agricultural innovation. The ORG study finds that rural electrification has made a major contribution to rural development. It is found to be positively associated with the two most critical inputs--irrigation and innovation--in the agricultural sector. It is also found to have positive effects on development of rural industry and services. In the social sectors, the effects were less pronounced though still consequential.

2.11 Impact of electrification on rural economy

Khandker et al. (2008) examined the welfare impacts of households' rural electrification based on panel surveys conducted in 2002 and 2005 for some 1,100 households in rural Vietnam. The findings indicated that grid electrification has been both extensive (connecting all surveyed communes by 2005) and intensive (connecting almost 80 percent of the surveyed households by 2005). Vietnam is fairly unique in that once electricity is locally available, both rich and poor households are equally likely to get the connection. The econometric estimations suggest that grid electrification has significant positive impacts on households 'cash income, expenditure and educational outcomes. The benefits, however, reach a saturation point after prolonged exposure to electricity. Finally, this study recommends investigating long-term benefits of rural electrification – not just for households, but for rural economy as a whole. Studies have shown that in electrified homes, energy consumption constitutes, on average, 4% of the household budget, while, in non-electrified homes, 15% of the household budget is spent on energy (MRC 1998). Other studies indicate that, apart from self-collected wood at no financial cost, electricity is the

most cost effective energy source for cooking. The relatively low cost of electricity, coupled with the access programmes for the rural areas, has resulted in a much higher proportion of households using electricity for cooking in South Africa than in many other African countries. However, when considering simultaneous cooking and space heating, coal and wood burning stoves appear to be more cost effective than electricity in the higher regions of the country (Graham and Dutkiewicz 1998).

Electricity serves a heterogeneous population, which includes: industrial, commercial and domestic users and each is services under different costs and unit supply. For a variety of reasons, electricity use is cross subsidized among the various categories and there are subsidy differentials for the different types of users. The SONABEL (National Electricity Company of Burkina Faso) tariff schedules distinguish five classes of tariff rates: A (ordinary domestic consumers and small commercial), B (medium commercial and industrial consumers), C (large consumers and industrial consumers), D (interruptible off-peak supplies to ordinary consumers) and E (street lighting). The commercial and industrial consumers are the major users of electricity for economic production and consume 75.5% of the total of the distributed electricity, whereas the domestic class or residential users consume only 23% (KPLC, 2006). The residential group is often considered less important, because of their low consumption rates and low contribution to the economic output.

There has been progress in reducing the costs for both grid and off-grid services, but the biggest hurdles are the initial connection fees and monthly consumption costs for low-income households (Townsend, 2000). In order to assess the affordability for connection to electricity services, it is necessary to compare household income with connection cost. Affordability refers to the actual ability of a household to pay for goods/ services and it can be distinguished between the affordability for access and the affordability for consumption (Estache et al., 2002), which are a key determinant in this study.

Chapter III:

MATERIALS AND METHODS

3.1 Study Area

For this study, Bilgo was considered as a case study. The village of Bilgo is located in the commune of Pabré, 30 Km from the city of Ouagadougou. The population of Bilgo is estimated to be about 2000 inhabitants in 2009. Local population's livelihood mainly relies on agriculture and livestock. (2iE foundation, 2016)

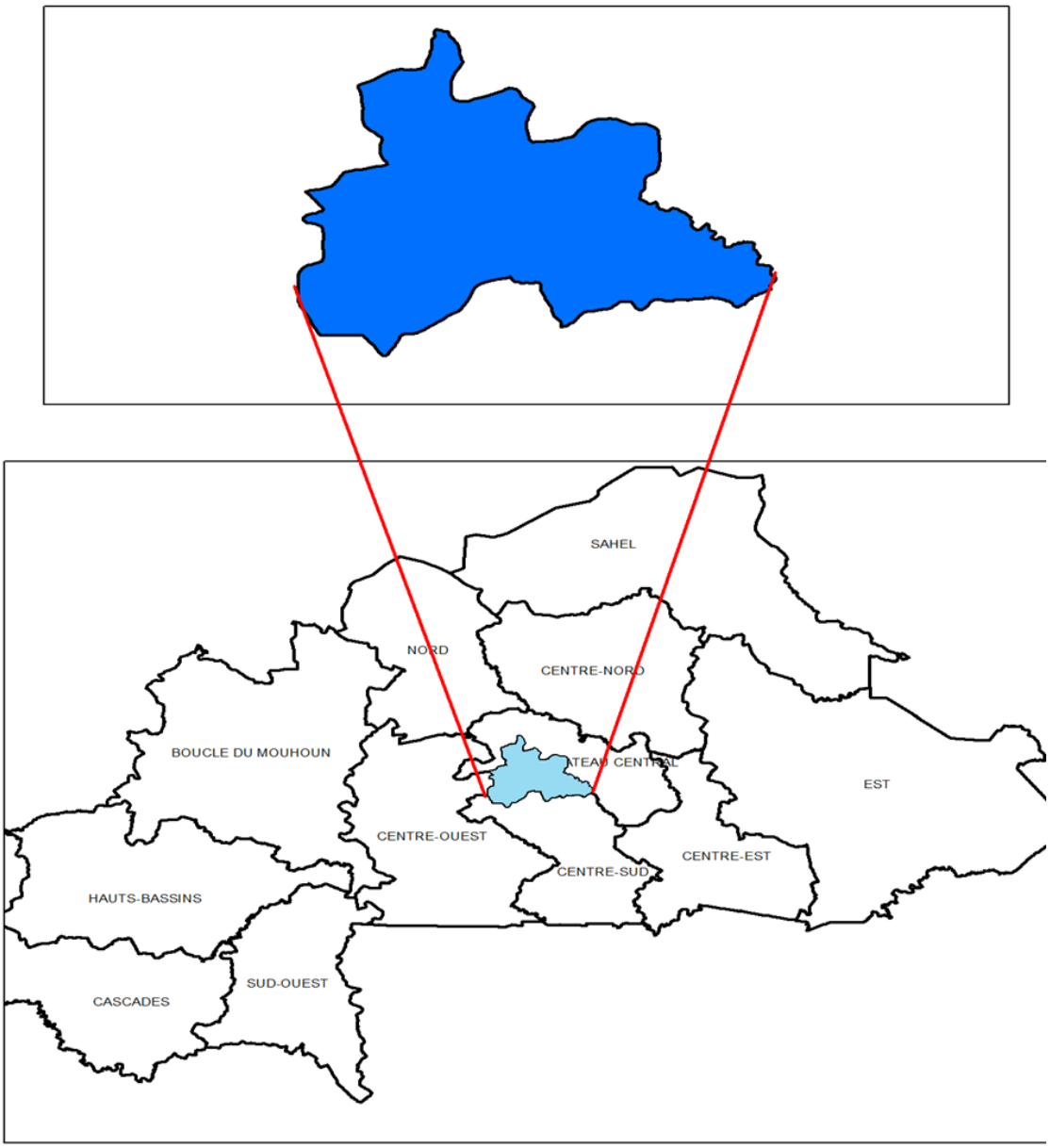


Figure 3-1: Location of the study Area (Draw with ArcMap)

3.2 Detailed explanation of research methodology

The methodology used in this study involved a two-phase approach. Phase 1 involved assessment of existing literature and technologies as will be described in the literature review. Phase 2 included collecting data that involved questionnaires design, interview, data

collection from some international institutions and data analysis. The collected data was based on two (02) levels such as household level and access to energy for community level.

Indicators shown in flow chart 1 and 2 are used in order to measure the socioeconomic impacts from energy access respectively at the household and community levels. These indicators were chosen from previous similar studies and will adjust to the socioeconomic profile of the selected communities. A questionnaire was developed to measure these indicators based on the perception of the recipient community.

A representative sample has been interviewed in the locality. The sample in Bilgo was included 100 respondents, representing 0.05% of the population. The main aim of this study is to analyse the impact of electrification in rural areas, that is to say, the decisive influence of electrification on the development of rural localities. We are based on the method known as the "double difference method". This approach makes it possible to compare situations before and after electrification. The power plant of Bilgo has started to operate in 2015. In this study, expression “Before electrification” refers to 2 years before operation of the power plant and expression “After electrification” refers to 2 years after operation of the power plant. Years considered are respectively 2013 and 2014 for before power plant operation and 2016 and 2017 after power plant operation. These indicators are based on immediate effect, indirect effect and long term effect.

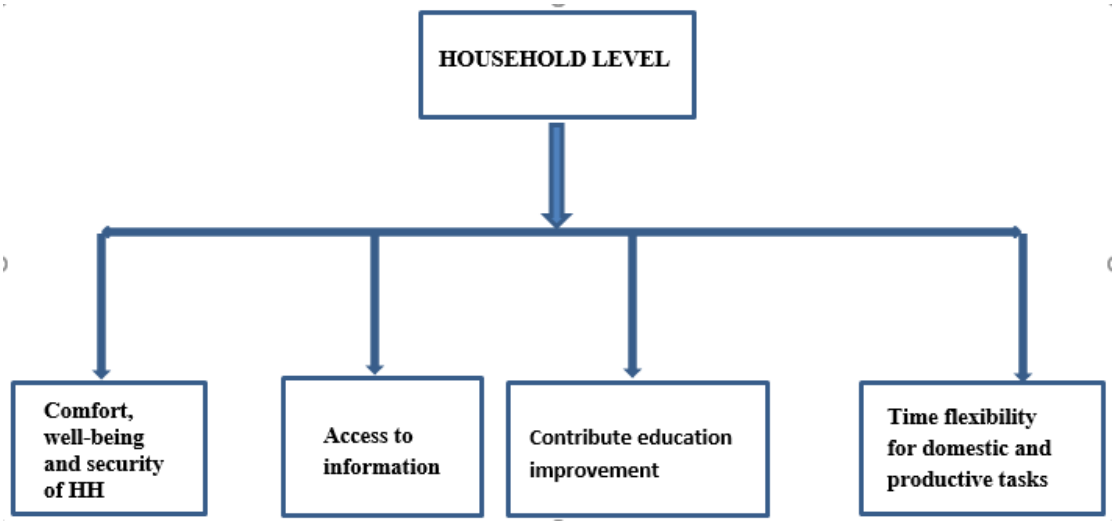
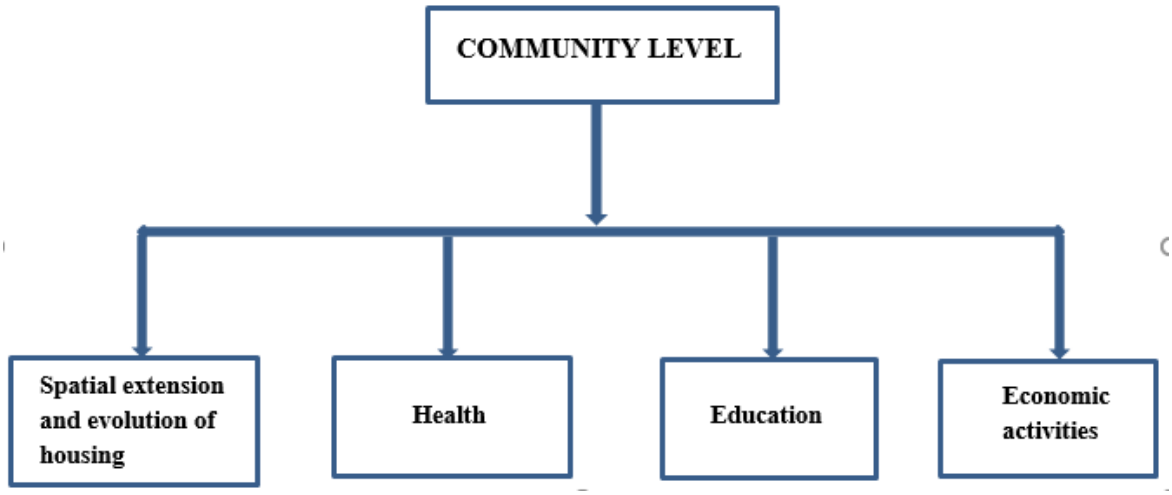


Figure 3-2: Flow chart at household level



3. **Figure 3-3: Flow chart at community level**

In order to analyse the spatial and socio-economic changes caused by electrification in rural Burkina Faso, we used the village of Bilgo, a village in the town of Pabre in the province of Kadiogo, Central region of Burkina Faso. This location was selected based on a number of criteria: geographic location, date of commissioning of the village's hybrid power plant, demographic size and accessibility.

In terms of demographic size, we used the results of the last census of population and housing in 2016.

3.3 Data Collection Process and Data Processing

The data collection process took place in Bilgo for three (03) days. Prior to the process, we are assured that the weather conditions were good enough for the data collection exercises to proceed in good conditions. My team for data collection consisted of three people with a local language translator (Mossi) included. Beforehand, a meeting between the team and the customary chiefs was carried out for authorization and facilitated access to households and existing local institutions in the village of Bilgo. At the meeting, a presentation of the study was made by the team to members of local associations. At the end of this presentation, a selection of households was made in a jumble. As a result of the data collection process, my team independently interviewed the heads of the health center, the principal of the primary school, the director of the Bilgo village savings bank to collect information about the community On the various key dimensions linked to the development of the locality: education, public health, the economic returns of the rural population and spatial development and the evolution of modern habitat. Then, a survey of a sample of 100 people, either 0.05% of the target population, was conducted. The choice of these persons was made

on the basis of the quota method. An inventory of housing, infrastructure, equipment and economic activities was done. The results of this study are summarized in the following table. All the participants expressed satisfaction with rural electrification from the decentralized hybrid system in the Bilgo area; However, when posed specific questions, their answers were mixed. In general, the participants perceived that project as a positive development in their communities.

The qualitative data collected were grouped according to the nature of the response and recorded. Then, the quantitative data obtained were entered and processed using the Microsoft Office Excel 2014 software.

3.4 Geographic and Demographic Framework

Burkina Faso also called Burkina formerly Republic of Upper Volta, is located in the heart of West Africa in a transition zone between the Sudano-Guinean region and the Sahel and extends over 274,200 km2. Burkina Faso is bordered by Mali to the north and west, Niger to the east, Benin to the southeast, Togo and Ghana to the south and Côte d'Ivoire to the south-west. The capital Ouagadougou is located in the centre of the country. Burkina Faso is a member of the African Union (AU) and the Economic Community of West African States (ECOWAS). Its climate is tropical Sudanian type characterized by a long dry season from October to April and a short rainy season from May to September. Precipitation ranges from less than 500 mm per year in the northern part to nearly 1,100 mm per year in the western and southern regions. These very large rainfall variations make it possible to distinguish three main climatic zones:

- The southern Sudanian zone between the 900- and 1,100-mm isohyets, occupied by the dry forest, wooded savanna and gallery forests, and contains about 38% of agricultural land;
- The north-Sudanian zone between the isohyets 700 and 900 mm is the domain of the shrub and tree savanna;
- The Sahelian zone with less than 500 mm of rain per year is covered by the steppe with thorny shrubs with a grassy carpet in tufts.

The population of Burkina Faso was estimated in 2016 at 19,034,397 inhabitants distributed as follows:

- Urban Population: 5 826 443 inhabitants;

- Rural Population: 13 686 091 inhabitants

The average density is 70.30 inhabitants per km2. According to the 2015 demographic surveys, the urban population is growing at an average annual rate of 5.5% while that of the rural population is around 2%. (World Bank, 2017)

3.5 Socio-economic Context

This section contains two sub sections covering the economic aspects and social aspects.

4. Economic aspects

The economy of Burkina Faso is strongly influenced by the socio-economic and climatic environment at both the international and continental levels. The rise in oil prices, the decline in repatriation of savings, the massive return of emigrants to Burkina Faso and poor rainfall were all factors that weighed more heavily on the economy of Burkina Faso for the period 2000 -2002. The year 2016 was marked by a gradual return to economic growth through the introduction of new industrial mines combined with a modest recovery in gold and cotton prices and a rise in cereal production to The result of the relative good rainfall. The real GDP growth rate was 5.4% in 2016, well above the 4.3% of 2014 and 2015 with a GDP per capita of $ 613 in 2015. (World Bank, 2017)

The tertiary sector, which is very dynamic, contributes the most to the formation of GDP (about 43.4%). It is strongly dominated by commercial activities and, more particularly, informal trade, which occupies the majority of urban populations. In the budgetary field, recovery efforts and tax reforms have enabled a steady increase in revenue. But fiscal pressure (10.6% on average of GDP) is still low compared to the Community norm (17%). In addition, the current revenue structure highlights the importance of imposition on domestic revenues. This is due to the narrow tax base and some collection difficulties. Budgetary savings have deteriorated over the years (40.4 billion FCFA in 2000 to 22.4 billion FCFA in 2002), indicating a more rapid increase in current expenditure (12.1% per year) compared to current revenue (6.8%). However, efforts have been made to maintain the ratio "Capital-financed investments on tax revenues" at a level above about 13 percentage points of the Community standard which is at 20% minimum. (World Bank, 2017)

The primary sector in Burkina is dominated by the agricultural sector which accounts for 35% of GDP and employs 82% of the working population. (agriculture ministry of Burkina Faso, 2012) Cereals (millet, sorghum, maize, rice, fonio) are the main crops in Burkina Faso. According to the latest general census of agriculture (RGA 2008), they were practiced on 4,190,344 ha in 2008. Millet, sorghum and maize represent respectively 29%, 35% and 11% of the cereal areas, the rice covering only 1%. On average, 4.2 million tons of cereals have been produced per year over the past five years, thus covering the country's food needs globally. Other food crops (cowpeas, yams, sweet potatoes, voandzou) account for 3% of the total area planted. Cash crops (cotton, sesame, peanut, soybean) are grown on about 19% of the total area planted. Cereal production in 2013-2014 is estimated at 4.9 Mt, a figure comparable to that of the 2012-2013 season. This value represents an increase of 15.3% compared to the average of the last five years. Production of other food crops is estimated at 915,485t. Cash crops (cotton, sesame, peanut, soybean) are grown on about 19% of the total area planted. A major production of fruits and vegetables, the main ones being mango, banana, papaya, cashew nut and citrus, is also worth noting. As for market gardening, it is dominated by tomatoes, onions, potatoes and cabbages. Production of food crops is estimated at 0.9 Mt for 2013-2014. Main cash crop, cotton is grown on about 586000ha, mainly cotton (genetically modified variety) and accounts for about 60% of the country's export earnings. Cotton production for the 2013-2014 season is estimated at 0.76 Mt, an increase of 22.2% compared to the 2012-2013 season. The purchase price of seed cotton amounts to € 0.37 / kg. Net receipts paid to producers amount to € 144.4 million. For the 2014-2015 season, the Inter-Professional Cotton Association of Burkina Faso has set a production target of 800,000 tons of seed cotton. With 500,000 ha of genetically modified crops, Burkina Faso is the second country in Africa in terms of areas dedicated to GMOs. (agriculture ministry of Burkina Faso, 2012)

The secondary sector is underdeveloped and occupies only 2% of the working population. It is characterized by a very limited export potential of industries. The low competitiveness of manufacturing firms is explained by very high production and operating costs. The sector's share of GDP rose slightly from 20.6% in 1995 to 23.4% in 2002. The geographical location of companies is particularly unbalanced. Of the 100 industrial units, Ouagadougou concentrates 71% of the companies, whereas Bobo-Dioulasso counts only 18%. The remainder is spread over isolated "mono-industrial" centres such as Banfora and Koudougou.

Manufacturing is light. These are mainly the agro-food and textile factories, which are the spearhead of the sector. In addition, a wide variety of industrial units oriented towards mechanics, chemistry, building and civil engineering, leather processing completes the industrial park in Burkina Faso.

On the overall political and macroeconomic level, Burkina Faso has asserted since 1991 its option for a market economy based on the principles of free enterprise. This is reflected in the following actions:

- Completion of economic and structural reform measures to create an enabling environment for business, competition and private investment. To this end, the Government has implemented the "Contract of Objectives" initiative with private sector operators;
- Increased mobilization and more efficient and effective use of financial resources. As regards resource mobilization, dialogue with the Technical and Financial Partners (TFP) in the spirit of Rome on harmonization of procedures has been strengthened with a view to broad participation in budget support. On the one hand, the efforts to improve the collection of tax revenues are being pursued at the domestic level. Regarding the efficiency of resource use, in addition to strengthening budgetary management, consideration was given to the constraints and limits of economic growth with the objective of make it more intensive;
- Better refocusing and accelerating reforms in the social sectors. The latest survey on household living conditions further highlighted the crucial role of the social sectors in the evolution of poverty. Indeed, it can be seen that these sectors, in particular education and health, have significant resources. But it is also in these sectors that progress is slow. The persistence and accentuation of the social deficit partly explains the current state of poverty. The redefinition of the concept of basic education, the compulsory and free provision of such education and the improvement of health services delivery and the strengthening of the fight against HIV / AIDS remain the main and constant concerns of the Government;
- A more explicit partnership with civil society organizations.

In terms of the country's long-term development, the government has set itself the following broad orientations:

- Strengthen actions to reduce the state of poverty and vulnerability of populations and the different disparities;
- Pursue high-quality macroeconomic policies to achieve strong, sustainable and better-distributed growth;
- Accelerate and strengthen the process of decentralization and modernization of public administration;
- Successfully integrate the country into the process of globalization and reorganization.

It is in this context of dynamization of the economy and the axes of development of the country that Burkina Faso as the other countries of the ECOWAS area elaborated in 2000 the Poverty Reduction Strategy Paper (PRSPs) whose major quantitative objectives are:

- Reducing the incidence of poverty from 46.4% to less than 35% by 2015;
- Increasing per capita GDP by at least 4% per year from 2004;
- Increasing life expectancy to at least 60 years by 2015.

It should be recalled that these quantitative targets are in line with the achievement of the SDGs and those pursued by the New Partnership for Africa's Development.

5. Social aspect

Burkina Faso has an area of 277,200 km2 and a population of 17.2 million, which is growing at a rate of 3.1% percent or an average of 6.2children per woman of reproductive age (CIA, 2012). Population growth of this magnitude has created an overwhelmingly young population with 59.1% of the population under the age of 20 (IMF, 2012). Eighty percent of the population relies on subsistence agriculture, which contributes to the persistence of the country’s severe poverty and poor education (State Dept., 2012). The population is an ethnically integrated country, split between two major West African groups, the Voltaic and the Mande. The population is 60.5% Muslim,19% Christian, and 21% other religions (CIA, 2012). Despite consistent growth, Burkina Faso remains one of the poorest countries in the world, ranking 181 out of 187 on the 2011 United Nations Development Programme

(UNDP) Human Development Index. In 2011, rising government discontent and deep social malaise led to country-wide protests resulting in vandalism, destruction, and riots. The protests ended shortly thereafter and the country is undergoing major political reforms with some success. The major priorities for human development are increasing access to proper healthcare and sanitation, reforming the education system to reduce dropouts and increase participation by women, and introducing contraceptives to rural populations to reduce the country's high population growth rate. While the vast majority of population in Burkina Faso remains rural, urbanization rates have risen as people migrate from drought-plagued regions in search of job opportunities and food security in cities. The droughts affecting the country since the 1970s and 1980s have led the poor and vulnerable populations to migrate into the valleys and the small basins of the rivers, which in turn aggravates the effect flooding events, particularly in the outskirts of cities that are in the flood plain. Currently, 20% of Burkinabés are urban dwellers, with the percentage on the rise since 2005.

3.6 Energy Scenarios in Burkina Faso

6. Energy potential

- **Wood energy**

An estimate established in 1998 showed a forest potential of 191,902,451.69 m3. As for the biodegradable biomass potential, a study carried out by GERED in 1997 estimated it to be 24 million Dry Matter (DM).

- **Hydrocarbon**

No hydrocarbon resources have been identified and the geological structures do not seem favorable to the existence of such a deposit.

- **Hydroelectricity**

The overall potential of the country in hydroelectricity was estimated in 1998 at 150 MW or 600 Mwh2 of productive energy.

- **Renewable energy**

For renewable energies, wind energy is very little used, wind speeds being very low. As for solar energy, according to a study carried out by the Institute for Research in Applied Sciences and Technology (IRSAT) and the Department of National Meteorology (DNM), the solar radiation received daily on the ground varies between 2,142 KWh and 7,801 KWh

because of regional disparities. However, the average potential for sunshine is estimated at 5.5KWh / m2 / day for 3000 to 3500 hours per year. It can therefore be said that in this area, Burkina has a great potential.

7. Supply, demand and access to modern energies

- **Wood energy**

According to the energy balance of 2002, the supply of wood energy increased to 2242 Ktoe of which 98% comes from wood. The final consumption for the same year was 1924 Ktoe, representing 89% of household consumption

- **Petroleum products**

Burkina Faso imports more than 500,000 tons of petroleum products per year, accounting for 40% of the country's total imports. Petroleum products contribute 16% of final energy consumption.

The chart below shows the demand for the main sectors of activity.

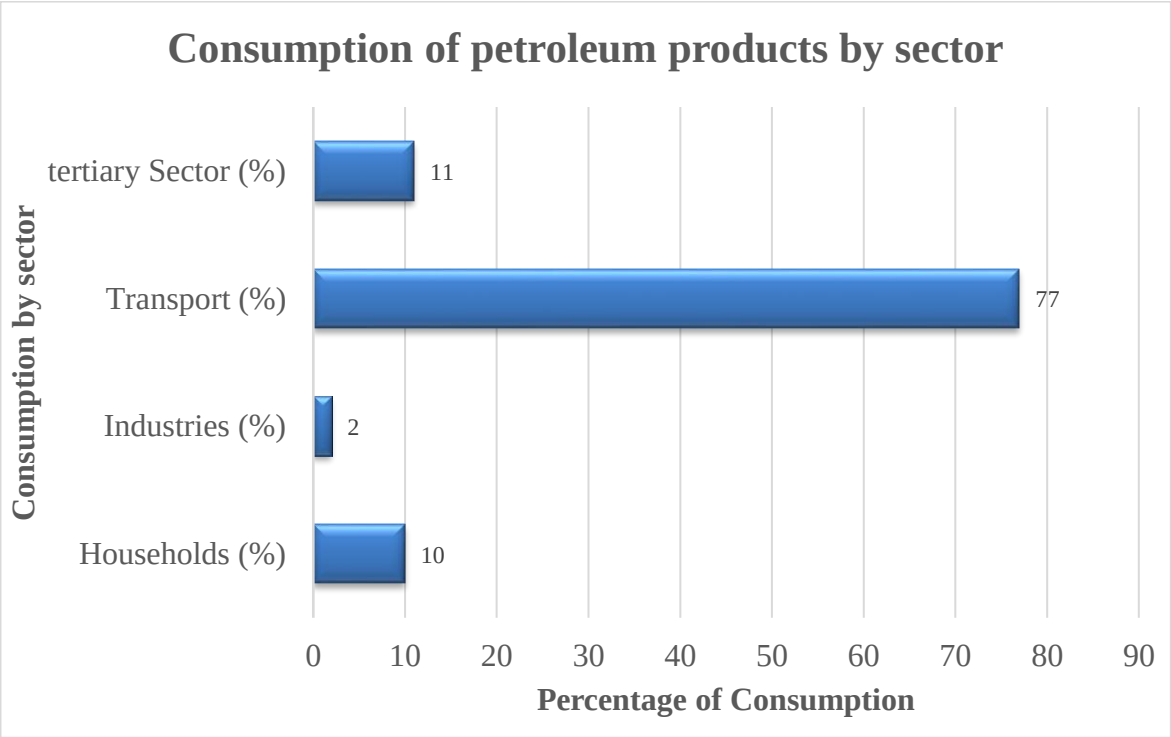


Figure 3-4: Consumption of petroleum products by sector (HELIO, 2009)

The transportation sector consumes most of the hydrocarbons (77%), followed by the tertiary sector (11%), households (10%) and industry (2%).

Demand for electricity in Burkina Faso, as shown in the figure below, shows the quasi-identical share between industry and household sectors.

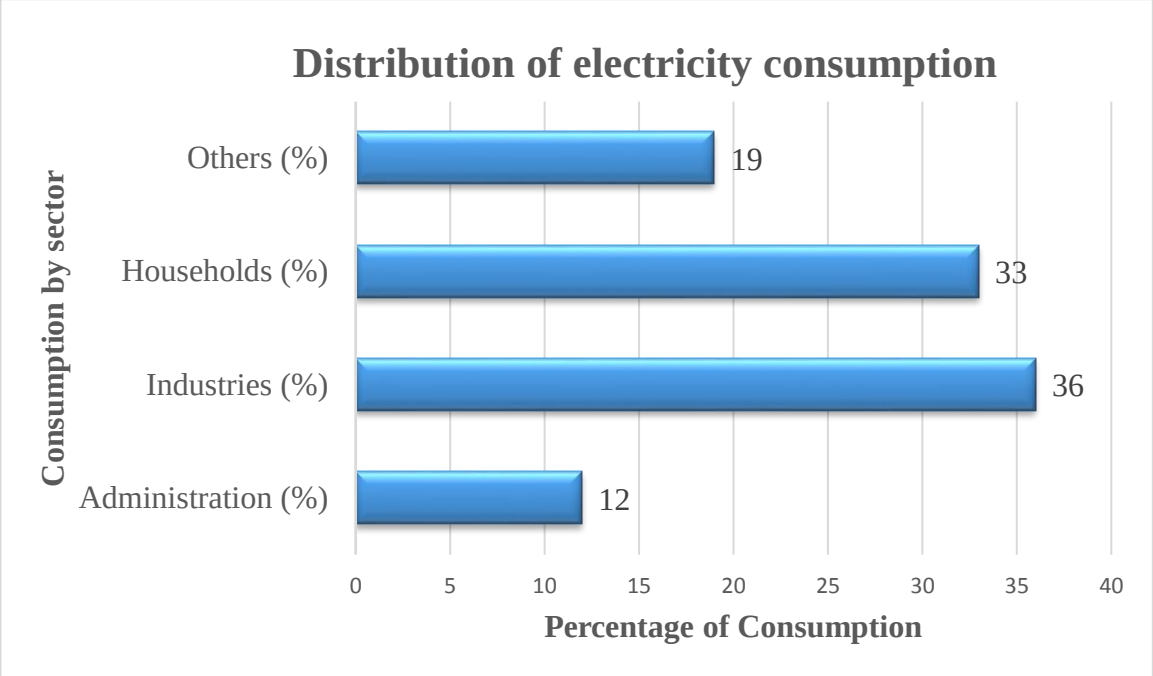


Figure 3-5: Distribution of electricity consumption, 2008 (HELIO, 2009)

- **Electricity production**

The electricity produced in Burkina Faso is of thermal and hydroelectric origin. Its production and distribution are provided by the National Electricity Company of Burkina Faso (SONABEL), a state-owned industrial and commercial company. The total production capacity has an installed capacity of 250 MW, of which 32 MW for hydroelectric power stations and 218 MW for thermal power stations (3 MW for electricity cooperatives and private developers).

3.7 Climate change (CC) and activities of the clean development mechanism (CDM)

The methodology for the development of greenhouse gas inventories applies to the energy, industrial processes, solvents, agriculture, land use, and forestry and waste sectors. It requires enormous data which have not always been available or accessible, which sometimes necessitates the use of extrapolation and approximation in order to enable it to function.

In the absence of national scientific information on coefficients and parameters used in the emission calculations, the technical recommendations related to the inventory model were applied Within the framework of ONUDI program. The year 1994 was chosen as the

reference year that is to stay years Year of beginning of data collection, information and calculations. The following results reflect the state of emissions and sinks of greenhouse gases in Burkina Faso.

8. Energy sector

The energy sector is the most incriminated area in the inventory studies because of the discharges due to the burning of fossil fuels. In Burkina Faso, emissions from this sector are quite significant, with a contribution of 902 Gg of carbon dioxide (Mamadou Honadia, 2010). Transport is the most polluting sub-sector with 322 Gg of which 309 Gg is for road transport, dominated by two-wheel drive engines consuming a mixture of fuel oil for their operation.

Manufacturing industries dominated by agro-food and electricity plants rank second and third respectively in the polluting sub-sectors. As for other sectors, including the residential sector (releases of 46 Gg due to the use of kerosene), their level of emissions of 81 Gg of carbon dioxide is not negligible. Figure 6 shows the responsibility for emissions.

Other trace gases are also emitted during the incomplete combustion of fuels. The emission levels are aggregated and show the following results:

N_2O: 0.01 Gg CO: 29 Gg MNVOC: 5 Gg

NOx: 4.26 Gg CH4: 0.14 Gg

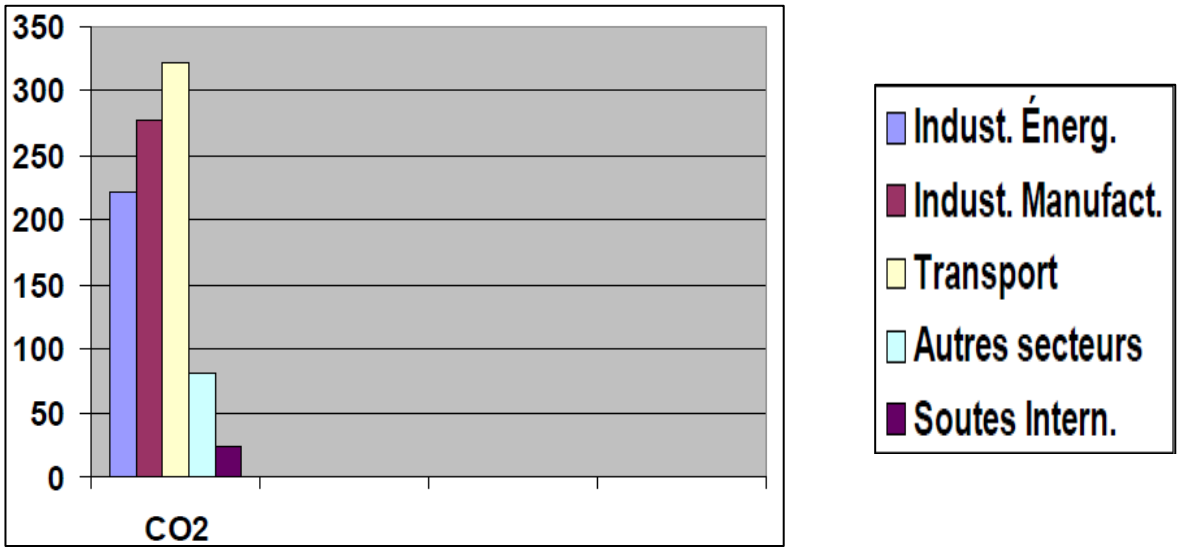


Figure 3-6: CO2 only emissions in the energy sector (UNIDO program, 2010)

9. Emission mitigation analysis in the energy sector

They have for objective is to develop a scenario for the mitigation of GHG emissions in the energy sector and the corresponding financial assessment. Energy consumption is undoubtedly the second largest source of greenhouse gas emissions in Burkina Faso. However, it is technically possible to achieve significant greenhouse gas emission reductions in accordance with the timetable for renewal of used or obsolete infrastructure and equipment. Mitigation measures in the field of energy are diverse. These include the more efficient conversion of fossil fuels, the use of low-carbon hydrocarbons, the application of energy efficiency measures in various sectors (industrial, tertiary, building, households), and the promotion of renewable energies, among others.

3.8 Governance in the field of energy: the institution (s) in charge of the energy

The institutions in charge of energy in Burkina Faso are numerous. These are mainly: The Ministry of Mines and Energy (MME); The Ministry of Industry, Trade and Handicraft (MICA), the Ministry of Environment and Sustainable Development (MEDD) and the Ministry of Economy and Finance.

The first institution of the sector is the Ministry of Mines and Energy (MME) created by decree n ° 95-278 / PRES / PM of 14/07/95. It ensures the implementation and monitoring of the Government's policy on mines, quarries and energy. It is responsible for energy: (i) the development and application of legislation and regulations in the fields of energy research, production, supply and distribution; (Ii) the creation, equipping and control of energy infrastructure; (Iii) control of the production, supply and distribution of conventional energy in relation to the Ministers responsible for the environment and water; (Iv) the promotion of new and renewable energies; And (v) the promotion of energy savings.

The Direction General of Energy (DGE) within the MME is the mainstay of the implementation and monitoring of energy policy. Its main tasks are: (i) to propose administrative, financial and technical measures to ensure the coverage of the national territory in electrical energy; (Ii) to define a national electrification plan for the country; (Iii) to develop and enforce regulations on production, supply and distribution of electrical energy; (Iv) to monitor the implementation of the electrification policy of the country of thermal and hydraulic origin in collaboration with the departments of the ministries concerned; (V) develop and monitor the implementation of any interconnection policy; (Vi) to determine, in relation to the relevant departments of the ministries concerned, the fixing of electricity tariffs.

The Ministry of Industry, Trade and Handicraft (MICA) sets the prices of electricity for consumption on the proposal of the commission for the approval of electricity prices. In the field of hydrocarbons, MICA mainly deals with the commercial aspects of prices, quality, metrology and imports. With regard to biomass, the ministry is responsible for making regulatory texts in the field of timber marketing and allocating the funds generated by marketing to the state budget.

The Ministry of the Environment and Sustainable Development (MEDD) was created by Decree N ° 2011-329 / PRES / PM / DGG-CM of 6 June 2011. Its mission is to ensure the implementation and Followed by the Government's policy on the environment and the improvement of the living environment. In this capacity, the department is responsible for the implementation of the government's environmental actions; Forests, wildlife and fishery resources; And sustainable development. It administers programs for the sustainable management of biomass in relation to the MME.

The Ministry of the Economy and Finance implements the government's fiscal, monetary, financial and budgetary policy. It ensures the financial control of public expenditure as well as the financial supervision of the various public establishments and state-owned companies in the energy sector. It also intervenes in the mobilization of resources to finance development plans for access to energy services.

3.9 The objectives of the National Economic and Social Development Plan (PNDES) for energy in Burkina Faso

The Ministry of Energy, Mines and Quarries held its first Ministerial Sector Council (CASEM) on 19 and 20 January for the year 2017 on the theme: "Reforms in Energy and mining sectors: what is at stake in achieving the objectives of the National Plan for Economic and Social Development (NPESD) ".

In view of the expected high contributions in the energy sector for the efficient and effective implementation of the objectives of the National Economic and Social Development Plan (NPDES), institutional, legislative and regulatory reforms have been initiated by the Ministry in charge of Energy and mining sectors. It is essentially the creation of the Directorate-General for Renewable Energy (DGER), the Directorate-General for Energy Efficiency (DGEE) and the Directorate General for Conventional Energies (DGEC). Particular emphasis is placed on increasing renewable energy sources in the energy mix and promoting energy efficiency.

Another institutional reform was the creation and adoption of the statutes of the National Agency for Renewable Energies and Energy Efficiency (ANEREE), responsible for stimulating, facilitating, coordinating, facilitating and carrying out any operation Having for object the development of renewable energies. Through these reforms, the government aims to increase national electricity coverage to 80% and national electrification to 45% in 2020, with rates of 33.32% and 18.83% respectively in 2015. (FasoZine, 2017)

The government also aims to improve the quality, reliability and accessibility of infrastructure to facilitate the structural transformation of the economy by increasing installed capacity to 1,000 megawatts in 2020 compared to 325 megawatts by 2015 and reducing Cost of KWh of electricity from high voltages of 25 FCFA to 2020. (FasoZine, 2017)

10. Thermal Energy for households

- **Relevant objectives, policies, strategies and plans**

The targets for access to thermal energy for households are:

- Reaching to 60% improvement in the penetration rate of urban wood and charcoal improved stoves by 2017 for all cities in Burkina Faso, whether 1.1 million improved stove to diffuse;
- Reaching 367 000 rural households with improved stoves adapted to the needs of rural populations in the Sudano-Sahelian zone by 2017;
- Reaching a butane gas penetration rate of 40% in urban areas and 10% in rural areas by 2020;
- Promote the combined use of wood energy and solar energy for community amenities (mixed kitchen for rural schools, hospitals, etc.);
- Installing 25,000 biogas plants in 2015 and more than 100,000 in 2030;

11. Electric sector

Burkina Faso's objective in the field of electric power is:

- Reaching 60% electrification rate in 2015 and 100% in urban areas and 49% in rural areas by 2020;
- Achieving interconnection with Nigeria via Niger by 2020;
- Achieving interconnection with Han – Bobo Dioulasso by 2017;
- Installation of a 72.5 MW thermal power plant in Komsilga;
- Installation of a 20 MW thermal power station in Bobo Dioulasso;
- Installation of four (4) hydroelectric power stations (Noumbiel 60 MW, Samandéni 2 MW, Ouessa 21 MW, Downstream 14 MW) total power 97 MW;
- Installing three 41.5 MW solar power plants by 2015;
- Installing a 50 MW Solar thermal power plant;
- Distributing 2,000 individual solar kits.

- **Institutions and national's capacities**

In addition to the institutions cited in Section 18, namely the Ministries of Mines and Energy; The Directorate-General for Energy; The Ministry of Industry, Trade and Handicrafts and the Ministry of Finance; A regulating authority for the electricity subsector (ARSE) was created by decree 27 DECREE N ° 2008-369 / PRES / PM / MCE / MEF / MCPEA of 24 June 2008. The ARSE is responsible for regulation Production, operation, transport, distribution, sale, export and import of electricity throughout the national territory.

Its mission is to: (i) ensure the application of laws and regulations governing the electricity subsector under objective conditions of transparency and non-discriminatory; (Ii) protect the interests of consumers and operators by taking all appropriate measures to ensure that sound and fair competition in the subsector is ensured, in accordance with the legal and regulatory provisions in force; (Iii) to promote the effective development of the subsector by, inter alia, ensuring economic and financial equilibrium and preserving the economic conditions necessary for its sustainability; (Iv) determine electricity tariffs to ensure the financial equilibrium of the sub-sector after advice from the Ministries of Energy, Finance and Trade; (V) Implement the user / consumer and operator consultation mechanisms provided for by laws and regulations; (Vi) order the measures necessary to ensure the continuity, quality and safety of the public electricity sector.

The electricity sub-sector in Burkina Faso is managed by two entities: The National Electricity Company of Burkina Faso (SONABEL) and the Electrification Development Fund (FDE). SONABEL is a state-owned company with a monopoly over the production, transmission and distribution of electricity throughout Burkina Faso. The liberalization of the electricity sub-sector took place in 2007. However, SONABEL still has a monopoly on the transmission of electricity over the territory of Burkina Faso.

The Electrification Development Fund (EDF) was created by Decree No. 2003089 / PRES / PM / MCE of 19 February 2003 as a body for the facilitation and financing of electrification policy. It is responsible for the implementation of the rural electrification policy in Burkina Faso and the promotion of renewable energy technologies. The objectives assigned to the EDF are: (i) to promote equitable coverage of the national territory in electrical energy by developing rural electrification; (Ii) contribute to the implementation of the national electrification plan for rural areas; (Iii) support the development of rural electrification pilot projects that contribute to the development of electrification in the country; (Iv) to facilitate

rural access to electricity by serving as a guarantee fund and by providing subsidies for investments or in support of studies; (V) ensure the recovery of loans to promoters; (Vi) to seek financing from the Technical and Financial Partners to achieve the targets set for rural electrification rates; (Vii) ensure close regulation of rural electrification tariffs; And (viii) prepare an annual report to the Electricity Sector Regulatory Authority (ARSE) on rural electrification activities.

12. Modern energy for the productive sectors

- **Relevant Objectives**

The objectives of Burkina Faso on access to modern energy for productive uses are:

- Substituting 3% of diesel in the biodiesel transportation sector;
- Establishing an anhydrous bioethanol production unit before 2020 for the substitution of gasoline

- **Institutions and capacities**

The dissemination of 1,300 new PTFMs in Burkina Faso is managed by the National Multifunctional Platforms Program (PN-PTFM), which because of its cross-cutting impact is placed under the technical and financial supervision of the Ministry of Economy and Finance. This institutional choice also aims at maintaining and reinforcing the synergies already developed with the other priority sectors (hydraulics, electrification, health, etc.), this in the implementation of development policies. From the institutional point of view, the development of biofuels, biodiesel and bioethanol in Burkina Faso is supported by the Biofuels Development Policy in Burkina Faso. The Ministries of Energy, Agriculture, Environment, Economy and Finance, Trade and Justice are the institutional actors that carry the National Biofuels Policy. Their role is to define a regulatory and fiscal framework that ensures the safety of investments of actors working in the production, processing and distribution or marketing of biofuels. They will therefore put in place standards that guarantee the quality of products at the level of users or consumers.

3.10 Brief overview of ongoing energy programs in Burkina Faso

In the field of energy production in Burkina Faso, some projects are in the works such as:

- Feasibility studies and detailed preliminary design of the downstream Bagre hydroelectric dam.
- Solar power plant of Zagtouli: 30 MWc

At the level of the Electrification Development Fund (EDF), some rural electrification projects are in the works, such as:

- Electrification of twenty (20) localities financed by the Electrification Development Tax (TDE) started in November 2012: Kononga, Ronga in the North, Taaga in the Hauts-basins; Nyorida, Sidtenga, Zangogho, Lilgom in the South Central; Birou and Loaga in the Center-North; Ekoulkoala, Poun and Tialgo in the Center-West, Pounkouyan in the Central South, Gon, Moaga in the Center-East, Lorgho, Boulyhaoguin in the East; Kampala in the Central South, Tanghin in the Central Plateau; Tioma in the Boucle du Mouhoun.
- Electrification of 15 localities financed by the FDE-TDE 2013 budget to be executed by the ASE / MI Group for 277,000,000 CFA francs, including VAT, NATOBE Sarl for 37,000,000 CFA francs and SATEL for 111,000,000 CFA francs TTC: Mikeledougou, Nafona II, Kossara in the Cascades; Bandoukou and Toussiamasso in the Hauts-basins; Boudougou, Boudieri and Komandougou in the East; Gorbillin, (Gorkassin and Konlastenga) and Sabtenga in the Central-East, Lebda in the Center-North; Zincko, Central West; Kanrin in the Center-East.
- Electrification project by supplying and installing photovoltaic solar kits for twenty (20) localities. Yalka, Gossere, Loubre, Nimpouya, Namsiguia, Lilboure tougue-yarce in the north; Gatougou in the Sahel; Tentenga, Kogoli, Tatiangou, Nadiabonli, Gandeogo-bogdin, Tawari, Bartiebougou to the east; Kirio in the loop of the mouhoun; Kilsio in the center-west; Dapola, Saala, Tangsebla
- Project to electrify thirty-six (36) localities under the Energy Facility II. Arba-Débéré, Dalla, Ouilao, Pem, Sirgne, Babanga, Bognori, Botontonga, Mansila, Pontitiaga, Hamdalaye, Aliakoum, Gagara, Kel-equief, Lilingo, Ounaré-Mallebé, Tandiolel, Hoka, Diguel, Gankouna, Maty, Nianguel, Ouaguéssé, Sibé, Tongomael, Waguessi, Tin-Akoff, Oursi, Kelbo and Solhan.

Chapter IV: RESULTS AND DISCUSSION

4.1 Community level

a) Spatial extension and change of habitat expansion

One of the visible indicators of the impact of electrification in rural areas is the formal aspect. It is reflected in the spatial extension and evolution of modern habitat (urbanization). In total, about 25 hectare of parcel been parcelled.

The situation concerning the life of the village of Bilgo before the intervention of the electrification was dominated by the constructions of traditional type (46 %). This type of dwelling was followed by modern houses (30 %) and evolutionary (24 %). After the announcement of the project of construction of the power station in 2011, Bilgo village began to extend in surface area. What made, after electrification, there is a slight evolution of modern buildings (32 %) on all dwellings. Also, in the rural landscape, there is a remarkable breakthrough in evolutionary houses (28 %) after the electrification of localities to the detriment of traditional houses (40 %) as shown in the table 2.

Table 4.1 evolution of traditional housing

	Before electrification (%)	After electrification (%)
Traditional constructions	46	40
Modern houses	30	32
Evolutionary houses	24	28

Source: *Town hall of Pabre*

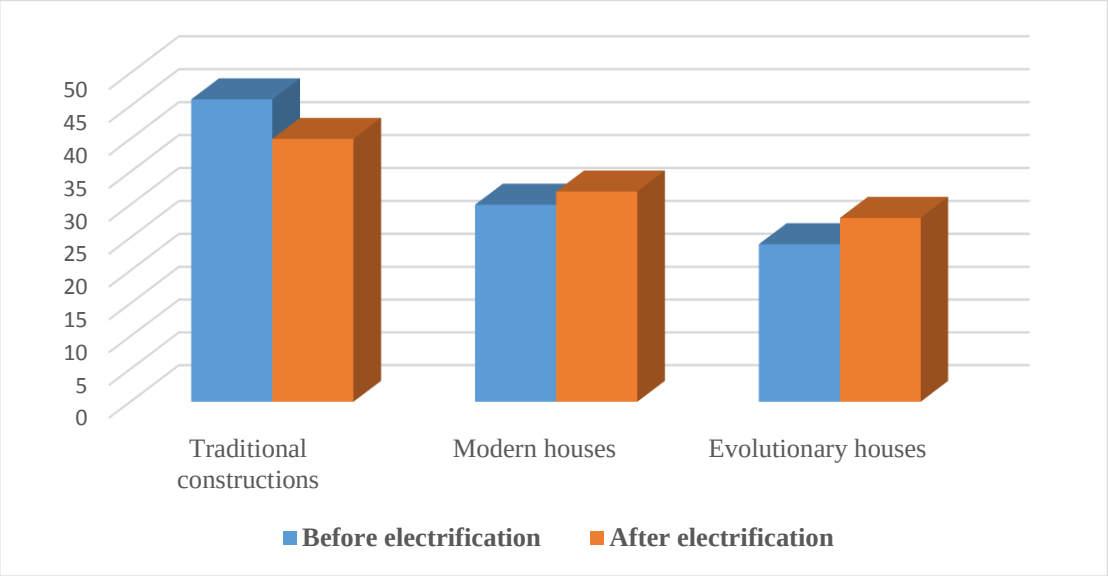


Figure 4-1: Evolution of habitat expansion

b) Health

Impact of access to electricity on population health, as far as the health centres are concerned, the village of Bilgo has a dispensary (public health center). The attendance rate of the Health Center, nocturnal consultation and hospitalization over a period of two years before and after the power plant are given in the table below. is 73.82% against 15.60% of nocturnal consultation and 10% of hospitalizations. And the infant mortality rate in Bilgo village in the table.

Table 4.2: Population attendance in health center

	Before electrification		Average	After electrification		Average
Years	**2013**	**2014**		**2016**	**2017**	
Attendance rate	29	31	**30**	38	40	**39**
Nocturnal consultation	4	5	**4.5**	13	15	**14**
Hospitalization	2	4	**3**	8	10	**9**

Source: *Our survey from June to July*

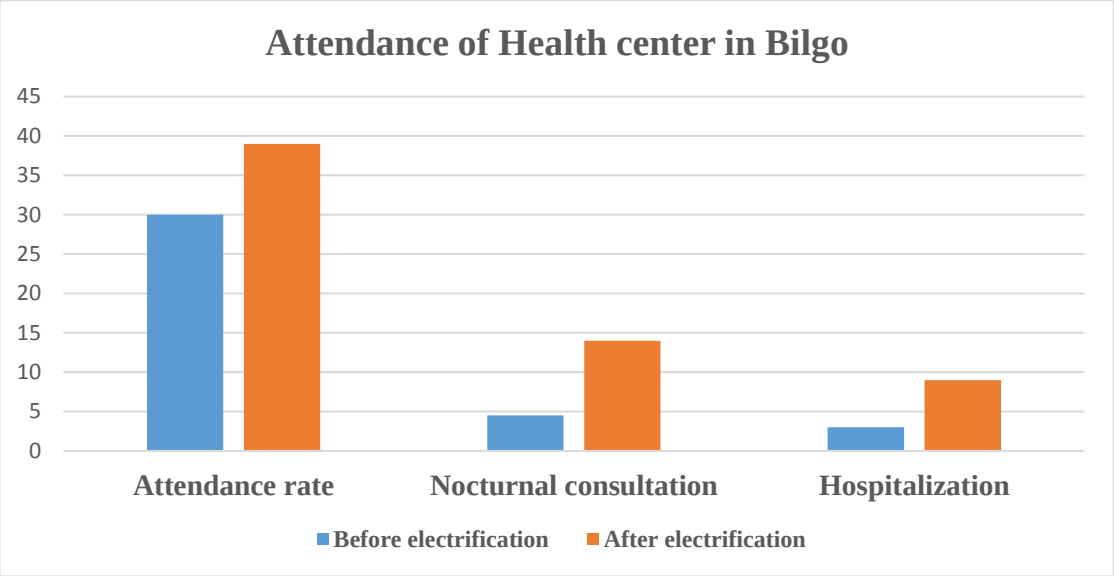


Figure 4-2 Our Survey from June to July

The equipment bought as a result of the availability of electricity are two (02) refrigerators for the storage of vaccines and serums, 1 TV and lighting inside and outside of health center. Lighting of the health center to play enormously in reducing its rate of infantile mortality. In 2013 to 2014, in average, 2 child born died on 10 birth. In 2016, 0 infant deaths were recorded. Table below summaries data of infant deaths.

Table 4.3: Rate of infant deaths

Years	Rate of infant deaths
Between 2013 to 2014	2 over 10
From 2016 to 2017	0 over 10

Source: *Our survey from June to July*

c) Education

Regarding to education, the rate of attendance for girls in primary school increase with electrification. In the table below, is summarized the rate of girl attendance.

Table 4.4 Rate of girls school attendance

School years	Rate of girls attendance
2011-2012	26
2012-2013	28
2013-2014	27
2016-2017	47

Source: *our survey June-July*

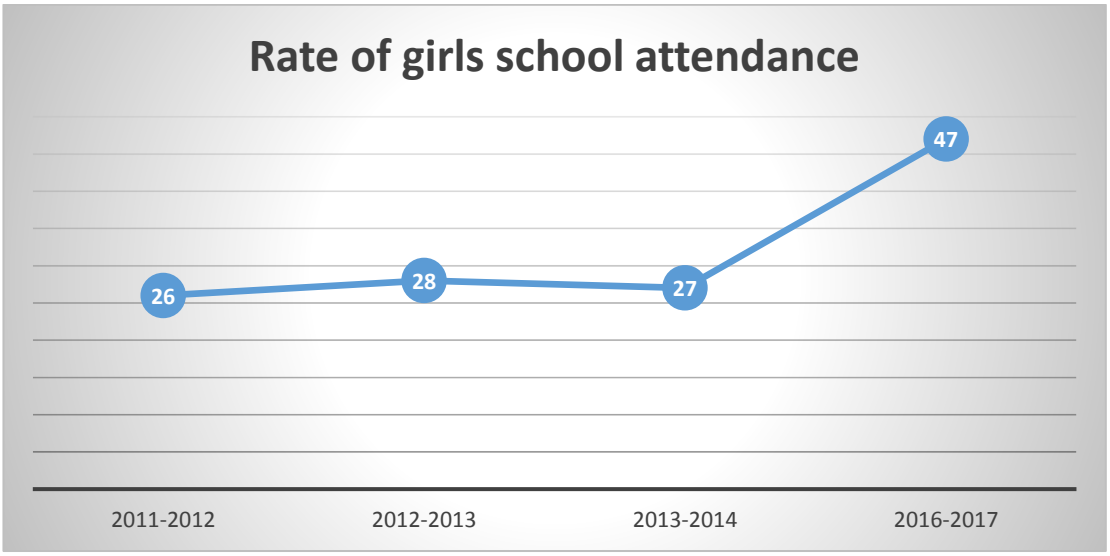


Figure 4-3 Rate of girls school attendance

Bilgo village has a college and three school groups. The results in the secondary school at the 1st cycle study certificate (BEPC) is 51 % For the school year (2016-2017). The average success rate for the Certificate of Primary and Elementary Study is 46 %. Of the 100 people interviewed in this village on the influence of electricity on the work of their offspring, 74.00 % said they had seen good results from their children, 12.50 % were undecided and 3 % abstained.

d) Economic activities

The great impact of rural electricity access on the living population is the improvement of its standard of living. It is generating an increasing number of economic activities.

These activities provide the rural population with considerable additional monetary income.

Table 4.5: Declaration of monthly turnover of rural traders

Types of economic activities	People surveyed	Average turnover (F.CFA)	Activities opened before electricity availability	Activities opened with electricity availability
Small Trade	**18**	**196,500**	**5**	**13**
Restaurant, Refreshment room	4	100,500	2	2
Phone booth	6	50,000	0	6
Video club	2	6,000	1	1
Coffee shop	2	25,000	1	1
Sale of juice, syrup	4	15,000	1	3
Service Crafts	**6**	**110,000**	**1**	**1**
Hairdressing salon (Male)	2	32,000	1	1
Repair of bicycle and motorcycle	3	45,000	3	0
Sewing	1	33,000	1	0
Formal Activities	**4**	**115,000**	**2**	**2**
Shops	4	115,000	2	2
TOTAL	**28**	**421,500**	**10**	**18**

Source: *Our surveys June-July 2017*

In the table below is summarized activities opened before and after electricity supply.

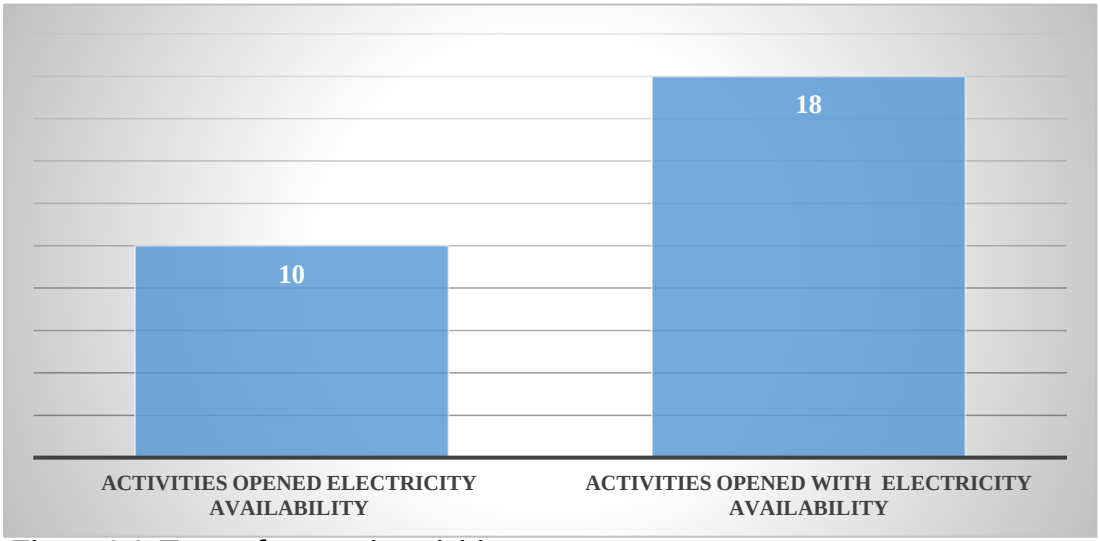


Figure 4-4: Types of economic activities

4.2 Households level

Access to electricity in households influences some indicators at the household level. In our study, the indicators surveyed are described below from the results of our survey.

a) Comfort, well-being and security of HH

The availability of electricity facilitates access to domestic equipment. These facilities participate in the animation of the village of Bilgo. It changes the habits of rural people. Thus, rural people in the village of Bilgo make electrification a factor of social advancement. This idea is variously shared by 100 individuals surveyed according to their age. 50 % of those surveyed whose age is between 12 and 19 years old declares finding comfort in the electrification. 30 % of this age group finds it as a contribution to well-being. The remaining 20 % say it is a means of security. In addition to comfort (40 %), 30 % of age group 20-24 years old consider electrification as a means of safety. 20 % of this age group say that electrification brings well-being, while another 10 % say they have not seen change. Unlike the previous group, people between the ages of 24 and 34 years old say that after comfort (41 %), electrification brings more well-being (22 %) than security (19 %). While for those aged between 35 and 45 years, it is not only the comfort that electrification brings, it provides more security (24 %) than well-being (18 %). For people aged 45 and over, well-being is the most significant contribution (48 %). Then come comfort (33 %) and safety (15 %).

b) Access to information

HH lighting provides access to information for living populations through the use of HH appliances such as telephone, radio and television. The survey shows that 50 % of the people own a mobile phone, 40 % own a radio and only 10 % own a television set.

Table 4.6: HH appliances surveyed

Typology of household appliances	Number of people surveyed	Appliances got before electricity availability	Appliances got after electricity availability	Percentage increase in appliances (%)	Proportion (%)
Phone	50	21	29	38	50
Radio	40	18	22	22	40
Television	10	3	7	133	10
Total	**100**	**42**	**58**	**38**	**100**

Source: *our survey from June to July*

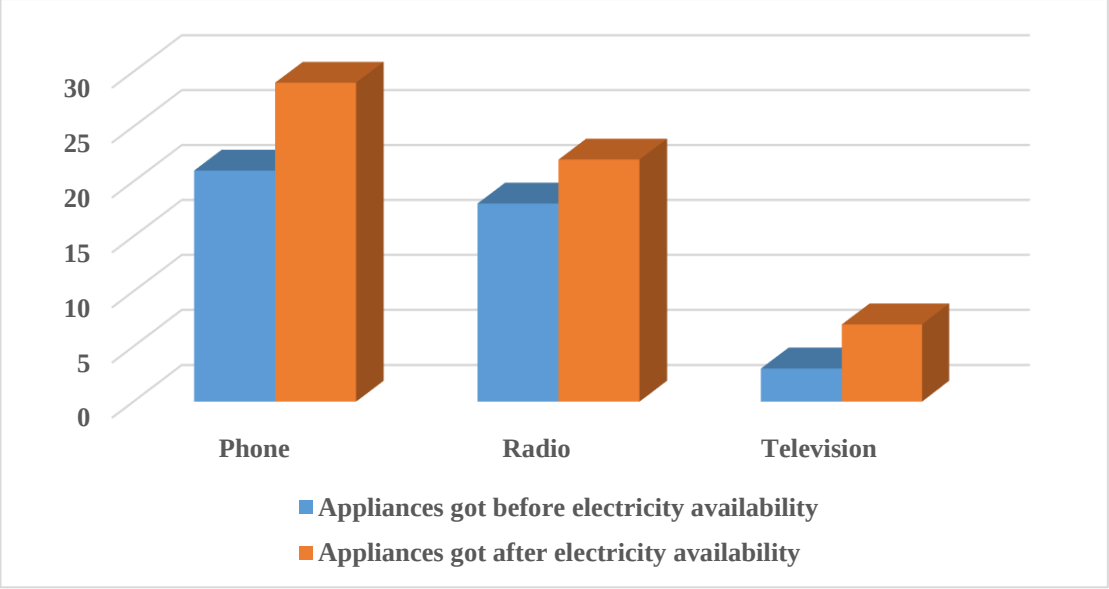


Figure 4-5: HH appliances surveyed

c) Contribute to education improvement

With HH lighting, the study time of elementary and secondary students has increased. Study time goes from 5:30 pm after the closing of the classes at 8 pm for the young people from 6 to 15 years old. From 16 to 19 years old the study time is between 5:30 pm and 10 pm. From 5:30 pm to 11 pm for young people aged 20-year-old and over.

Figure 4-6 : Before electricity intervention

Figure 4-7 : After electricity intervention

Previously, the lack of lighting forced the rural population to go to bed at 7 pm.

d) Time flexibility for domestic and productive tasks

The working time of the rural population extends with electrification. The leisure time is from 10 to 11 pm. Electrification allows some household chores to be performed at night such as cooking food, washing dishes. However, the time to do the activities from 7 pm to 10 pm is 3 hours more. Previously, in the absence of lighting, the rural population went to bed at 7 pm, so there was not enough time to cooking foods and

doing the crockery. As a result, this led to indigestion and certain diseases related to the hygienic condition.

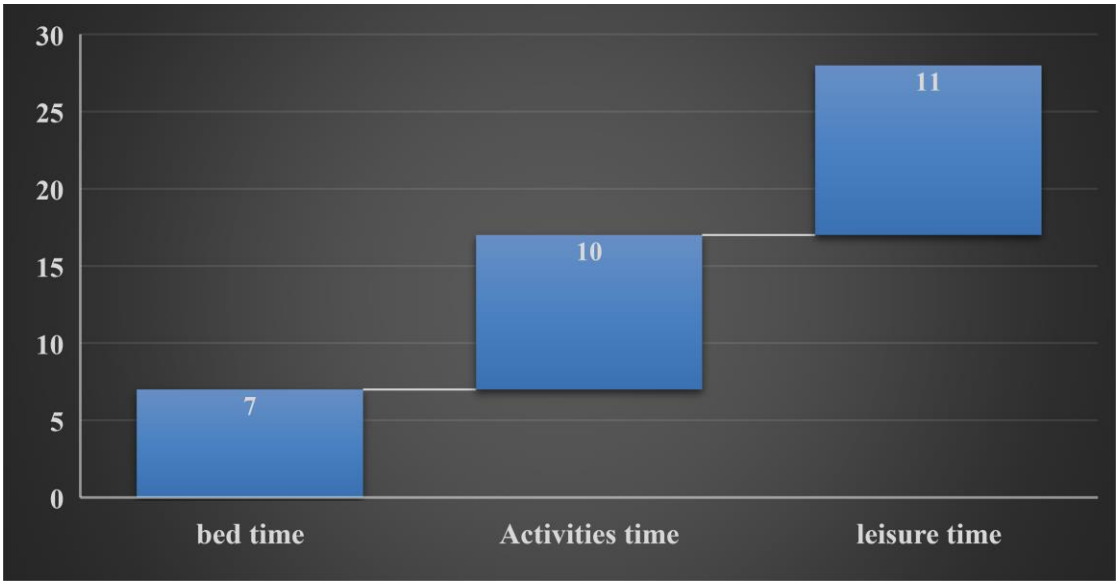


Figure 4-8: Time flexibility for domestic and productive tasks

4.3 Discussion

The method of data collection and the criteria used for this study make it possible to measure the impact of electrification in rural areas. This study was based on data collected through a survey. This survey by opinion was necessary to better understand the decisive effects of electricity on the framework and the conditions at the community level and to manage living populations in the village of Bilgo. A sample of 100 people, or 0.05 of the target population, is representative for an opinion survey because the responses of the surveyed population are relatively the same. The opinion survey based on the following indicators: spatial extension and evolution of housing, health, education, economic activities, comfort, well-being and security of HH, access to information, contribute to education improvement, time flexibility for domestic and productive tasks is the most appropriate method for this study. It makes it possible to better know all the mutations induced by the electrification.

13. Community level

Bilgo village endowed its plan of subdivision during the period of 2011. The subdivision of the localities and the density of the population are criteria of eligibility to the electrification. These criteria are essential for the choice of the areas to be electrified. After the subdivision of Bilgo, the village began to expand some socio-collective and economic infrastructures such as shops, modern and evolutionary houses,

hairdresser and other small space arranged for economic activities. On the basis of all the above, I assert that the high spatial coverage of the rural environment is explained by the way in which the environment is developed. The spatial dynamics of the village take place over time. The dynamic of the village is explained by the dynamics of its population and especially of certain cadres (native of the village) who invest in real estate. Indeed, Bilgo has a positive annual growth rate. This positive rate is linked to the socio-collective facilities and infrastructures (school), health center and especially to its electrification. The proportion of some traditional dwellings and especially of semi-hard dwellings (evolutionary houses) is evolving in this environment in such a way that a gradual disappearance of the traditional dwelling. The dynamism of modern and semi-hard (evolutionary) housing is explained by the exclusion of traditional houses for connection to the electricity grid. This is why we see the presence of modern houses before the electrification of these localities. The presence of this type of construction is one of the essential conditions for the electrification of a village.

The impact of electrification on health structures in rural areas is very enormous. Indeed, according to the staff of the healthcare facilities (dispensary, maternity and pharmaceutical depot), electricity makes operational any medical electrical equipment and thus improves the diagnosis and the care. It makes it easy to carry out nocturnal interventions (surgical operations, deliveries) by a better level of lighting. The two refrigerators allow to keep the sera, vaccines and other pharmaceuticals requiring conservation at low temperature. Lighting availability in the health center facilities childbirth nocturnal. According to our survey, most of death infantile was due to lack of lighting in health center because it was very difficult for nurse to help women in the good condition. The nightly attendance in rate of the health center is an indicator of improvement in the working conditions of the staff.

Regarding to girl's school attendance, the rate is higher in school years 2016-2017 with 47 % of girl's attendance. This rate increased with electricity availability because the girls spend less time dong household tasks. The high rate of successful of education is linked to public lighting and schools. With public lighting and school, the working conditions of students and teachers improve. Access to electricity increases the level of training, education and access to information and training. Our survey showed that 74 % of the respondents found good results in their offspring. However, average rate of success to CEPE (Certificate of Primary and Elementary Study) in Bilgo from 2016

to 2017 in our study area (61 %) is less than national success rate which is 81,13 % (Alice L, 2017). For these people, this low success rate is not related to electricity but rather due to the broadcasts on television. These broadcasts have a negative influence on student achievement.

Availability of electricity has a positive impact on economic activities in rural area. Regarding to Bilgo village, in total 18 economic activities opened with availability of electricity. These activities are possible with electricity supply. For example, for phone booth, managers use electricity to charge their phone battery and used the lighting to work in night what is not possible before electricity supply. Lighting increases, the time for activities and leisure in place of activities such as video club, restaurant, hair dress and coffee shop. Also, electricity availability reduces spending linked to fuel using for supply electricity.

14. Household Level

On the domestic level, access to electricity enables it possible to fight effectively against insecurity through lighting. On this point, the opinions of the respondents are differently shared. Indeed, 50 % of those surveyed whose age is between 12 and 19 years declares to find comfort in the electrification. 30 % of this age group finds it as a contribution to well-being. The remaining 20 % say it is a means of security. The study shows that this age group focuses more on comfort and well-being. For comfort, is explained by the use of a number of household appliances that gives them the same sensations as that of the city. Security is explained by the domestic and public lighting that allows them to play games (lady, card) and to go out at night. For the 20-24 age group, the people surveyed consider electrification as a means of security. These people feel safe from reptiles and other nasty beasts (scorpion, wild spider, ant, snake etc.) that can slip into their room. 20.00 % of this age group assert that electrification brings well-being. Unlike the previous group, people between the ages of 24 and 34 say that after comfort (41 %), electrification brings more well-being (22 %) than security (19 %). Whereas people in the age range of 35 to 45 believe that, in addition to the comfort provided by electrification, it provides more security (24 %) than well-being (18 %). For these people, electrification first gives an agreeable disposition of body and mind. Then come comfort and safety. With even public lighting, the haunted places disappear. Even those from households not connected to the electricity grid can benefit from the help of their neighbours or street lights to study.

As regards access to information, 29 of the respondents have got a mobile phone after the electricity supply. The high mobile phone rate recorded during our survey can be explained by the facility of owner to charge their phone battery with availability of electricity. So, they don't cover the long distance to charge their mobile phone and don't pay money to charge them. A total of 22 respondents and 7 respondents have got respectively a radio and TV after electricity supply. They should spend a lot of money to buy battery and fuel. Now, with electricity availability is very easy for them to use information appliances because they don't spend a lot money for battery or fuel.

With the electrification of households, students no longer need to study under the storm lamp. Lighting allows longer times to revise their courses as this allows them to study even after sunset. What was not possible before the intervention of electricity. Even those from households not connected to the electricity grid, benefit from the help of their neighbours or streetlights to study. Teachers are more at ease in the preparation of the teaching sheets.

Domestic lighting increases the time for activities and leisure. It allows the majority of rural people to go to bed at midnight and sometimes beyond to the delight of small traders. In our study, the categories of people who sleep beyond midnight hours are mostly young people and especially vacationers. These organize games (scrabble, checkerboard etc…) during the nights. Regarding, household chores, lighting makes it possible to cook, dishes at night. This is explained by the fact that the hours of dinners vary between 7 and 8 pm for the persons surveyed. The hours for the dishes in the night varied between 9 and 10 pm.

Chapter V:

CONCLUSION AND RECOMMENDATION

At the community and household level, electrification is an equipment that modernizes the environment and living conditions of rural people in time and space. It gives villages a living environment that meets urban standards and brings comfort, well-being and safety. It generates income-generating activities. But, this assessment study didn't take into account some problems related to the quality of electricity supply. This quality assessment of electricity supply should be based on the indicators listed below and access to energy for clean cooking facilities:

- **Availability**: Need to be a technical possibility to use it
- **Affordability:** A price that is not prohibitive
- **Adequacy:** Sufficient supply and a supply that is easy to use (and pay for) including being located nearby
- **Convenience:** desired hours of the day and safe to use
- **Voltage level:** Importantly, the supply must be of the right quality
- **Reliability:** Be usable for most of the time

5.1 Recommendation

As recommendation, this study suggests:

- An extension of the network to increase access to electricity for many households. It should be noted that only 300 households have access to electricity.
- Strengthen the network to avoid the use of genset during the long time.

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