Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 12, Issue, 04, pp.11056-11065, April, 2020

DOI: https://doi.org/10.24941/ijcr.38297.04.2020

ISSN: 0975-833X

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

MEASURING HOUSEHOLD ENERGY POVERTY IN BENIN USING BOARDMAN'S ECONOMIC APPROACH

Latif Adéniyi Fagbemi[1], Evrard Karol Ekouedjen[1,*] Yvette Onibon Doubogan[3], Gildas Farid Adamon[2], Stephen Junior Zannou-Tchoko[1] and Laurent Jodoin[4]

[1]Laboratory of Energetics and Applied Mechanics (LEMA),Doctoral School of Engineering Sciences, Abomey-Calavi Polytechnic School, University of Abomey-Calavi, Benin
[2]National University of Technical Sciences Engineering and Mathematics of Abomey, Benin
[3]Faculty of Letters, Arts and Human Sciences of the University of Parakou
[4]Inter-University Research Centre for Science and Technology (CIRST), Quebec University, Directorate of Environmental Studies and Sustainable Development Faculty of Arts and Science University of Montreal Canada

ARTICLE INFO

Article History:
Received 09th January, 2020
Received in revised form
25th February, 2020
Accepted 28th March, 2020
Published online 30th April, 2020

Key Words:
energy poverty, Boardman's economic approach, survey, households, energy source, health problems

ABSTRACT

In this paper, energy poverty is measured on households in Benin using Boardman's economic approach. The survey covered a sample of 640 households selected by simple random probability sampling. The households are mainly located in rural and peri-urban areas. The results indicate that out of all the households surveyed, 506 households or 79.06% are in energy poverty. The study also reveals that households living in energy poverty mainly use firewood (76.48%) followed by charcoal (18.18%) as a source of cooking energy. These sources are combined with inefficient or poorly efficient cooking stoves and poorly efficient and expensive lighting energy sources. In fact, the majority of these households use three-stone stoves (67.19%), followed by woodlouse stoves (16.40%). Dry cell flashlights (34.78%) are the main source of energy for lighting, followed by kerosene lamps (24.70%). All these factors combined with the high cost of improved households and low income justify the energy poverty status of households. Household members found to be energy poor report suffering from respiratory health problems (46.05%) and 50% of them suffer from visual health problems.

Citation: ***Latif Adéniyi Fagbemi, Evrard Karol Ekouedjen, Yvette Onibon Doubogan, Gildas Farid Adamon, Stephen Junior Zannou-Tchoko and Laurent Jodoin. 2020.*** "Measuring household energy poverty in Benin using Boardman's economic approach", *International Journal of Current Research*, 12, (04), 11056-11065.

INTRODUCTION

Access to clean and sustainable energy is crucial to the emancipation of peoples. This importance is embodied in Goal 7 of the Sustainable Development Goals (SDGs) to ensure access to reliable, sustainable and modern energy services for all at an affordable cost (United Nations, 2015). The availability of energy makes it possible to improve the local economy by promoting the development of the activities of craftsmen and small producers. Because of its multidimensionality, access to energy makes it possible to contribute greatly to the achievement of many Millennium Development Goals, including MDG3, which aims to promote gender equality and the empowerment of women. The importance of access to energy is not limited to this, energy is also crucial for the achievement of many other MDGs, notably those concerning gender equality, poverty reduction and improved health, etc. (International Energy Agency, 2017). However, despite all the efforts made by the international community to improve access to energy, a large part of the world's population remains without access to modern energy sources.

***Corresponding author:* Evrard Karol Ekouedjen,**
Laboratory of Energetics and Applied Mechanics (LEMA),Doctoral School of Engineering Sciences, Abomey-Calavi Polytechnic School, University of Abomey-Calavi, Benin

By 2016, there will be nearly 1.1 billion people without access to electricity. This compares with 1.7 billion in 2000 (International Energy Agency, 2017). Most of these people depend on traditional biomass sources to meet their basic energy needs (cooking, heating, cooling and lighting) (International Energy Agency, 2017). According to the same source, about 2.8 billion people still do not have access to clean cooking energy. Lack of access to clean energy sources negatively affects human health. Exposure to fumes, use of kerosene lamps and other types of lamps that do not provide visual comfort cause health problems for the households concerned later on. Households that depend on biomass for cooking spend about 1.4 hours per day collecting firewood and several hours per day cooking with inefficient stoves, this burden is mostly borne by women. This time could be redirected to other activities to generate income or learn new skills. In sub-Saharan Africa, more than 90 million primary school-age children attend school without electricity, hindering their education and future economic prospects (International Energy Agency, 2017). According to the same source, an estimated 2.8 million premature deaths per year are caused by the use of solid biomass and coal for cooking and the use of candles, kerosene and other polluting fuels for lighting, often used in enclosed spaces and without proper ventilation. All of this raises the issue of energy poverty, which affects many people around the world. Energy poverty is a multi-dimensional phenomenon that mainly affects developing countries located in sub-Saharan Africa, Asia and South America. Today, there are 588 million people without electricity in Sub-Saharan Africa and nearly 107 million in Asia (International Energy Agency, 2017). Due to its multidimensional nature, energy poverty has no standard definition. Several approaches exist. Some authors approach energy poverty as a lack of access to modern energy sources, others use engineering calculations to define an energy poverty line below which a person would be considered energy poor, and still others use economic approaches and define the threshold of 10% of income spent on household energy needs (Pachauri et al., 2004; Nussbaumer, Bazilian and Modi, 2012). Increasingly, energy poverty is being addressed through access to modern energy sources. However, in rural areas, this indicator does not seem very relevant. Several other works based on engineering calculations to define the basic energy needs that constitute the threshold below which any individual would be considered energy poor (Goldemberg, 1990; Johansson, 2015; Barnes, Khandker and Samad, 2011; Goldemberg, 1983). Thus, several categories of indicators for measuring energy poverty are available. In this sense, a distinction is made between one-dimensional indices, batteries of one-dimensional indices and composite indices (Nussbaumer, Bazilian and Modi, 2012). Each category of indicators has strengths and weaknesses. One-dimensional indices allow analysis in a specific direction but do not capture the multidimensional aspect of energy poverty. One-dimensional sets of indicators allow the phenomenon to be appreciated in all its dimensions and give a complete representation of the phenomenon; however, this type of indicators is complex to manipulate and does not allow the different parameters to be tracked over time.

The last category of indicators is that of composite indices, which are a compromise between the last two categories of indicators. Indeed, composite indices make it possible to describe the multidimensional nature of energy poverty while retaining the simplicity and flexibility of one-dimensional indices (Nussbaumer, Bazilian and Modi, 2012). The final approach used to define energy poverty is the economic approach based on the 10% household income principle. The idea of energy poverty in the economic approach was coined by Boardman (1991) cited in several works including (Khanna et al., 2019; Pachauri et al., 2004; Herrero, 2017), who proposed a single indicator approach, whereby if energy expenditure represents more than 10% of household income, the household is said to be energy poor. This latter approach is interesting because it allows energy-poor households to be identified on the basis of the share of income spent on energy expenditure. It is a fairly simple and flexible approach that allows for relevant analysis. However, it should be noted that it has some limitations because a high share of income devoted to energy expenditure can be linked to the size of the household and inefficient equipment. Nevertheless, in the context of this work, we use this approach to measure the poverty level of the households surveyed in Benin. Indeed, to our knowledge, there are no previous studies that have used Boardman's economic approach to assess energy poverty in Benin. This paper aims to measure the energy poverty of a number of households in Benin using the economic approach proposed by Boardman. The aim is to define poor households firstly on the basis of Boardman's approach, and secondly to identify the reasons and causes that could underlie or explain the energy poverty situation of these households. This paper is subdivided into four parts. The first presents the context and situates the topic in the literature, the second part describes the methodology adopted as well as the study framework and materials used. The third part sets out the results obtained and presents the discussions and the last part concludes the study and announces the perspectives.

METHODOLOGY

As part of this research, a survey is being organized over the entire national territory (Benin). Due to the limited financial resources of the project, only about six hundred and forty (640) households are surveyed and distributed in twenty-two (22) of the 77 communes in Benin and more than one hundred and twenty (120) villages or city neighborhoods, all chosen in a simple random manner. Table A in the appendices and Figure 1 below present the different areas surveyed in detail. The questionnaire used is structured in four sections. The first section presents the socio-demographic characteristics of the household surveyed. The second section describes access to electricity, access to domestic lighting, access to cooking energy and cooking stoves. The third section presents the energy policy aspect and the last section deals with gender issues. Questions relating to personal household information are optional and households that do not wish to answer them are not obliged to do so. The surveys carried out take into account both the quantitative and qualitative aspects. The quantitative component consisted of administering the questionnaire described above to households, while the qualitative component consisted of interviews with households, village groups, cooperatives and focus groups. The results of the qualitative component allow us to better explain the quantitative data collected.

Definition of the target population: The target population for this research is households only. Both rural and urban households are concerned, but priority is given to rural areas that are more affected by the lack of access to modern energy. According to the Larousse dictionary, a household from a statistical point of view is an elementary statistical unit of population, made up of one or more persons (single, family, community) who, whatever the ties that unite them, occupy the same dwelling as their main residence, and considered in its economic function of consumption. In our context, single-member households or households without children are not taken into account.

Sampling: In this study, 640 households were surveyed. The choice of villages to be surveyed was made on the basis of the 640 households. The probability sampling method was used so that the results of the study could be used to estimate the entire Beninese population. The sample was selected in several stages:

- **Step 1:** Three regions are considered, namely the northern region, the central region and the southern region.
- **Step 2:** In each region, evaluate the percentages of non-access to energy starting from that of the constituent departments.

- **Step 3:** On the basis of these average percentages of non-access to energy in each region, calculate the proportion of households to be surveyed per region.
- **Step 4:** Once the number of households to be surveyed per region is known, the number of villages to be surveyed per region must be determined, with a minimum of ten (10) households per village, i.e. a total of at least sixty (60) villages at the national level.
- **Step 5:** Next, it is necessary to proceed in a simple random way to the choice of the different villages to be surveyed per region, while respecting the proportion that belongs to each region.
- **Step 6:** Once the villages have been chosen, the respective districts, communes and departments are identified for all the villages chosen.

Selection of villages: As explained above, the villages or city districts are selected directly in a simple random manner in order to obtain the required number per region. This choice is made from the complete list of villages in Benin proposed by National Institute of Statistics and Economic Analysis (INSAE). Table A in the appendix summarizes the different villages and city districts selected as well as their districts and communes of origin. These villages are distributed in twenty communes of the country. The villages or city districts selected are mostly located in rural areas (73% or 16 communes), only a few are located in urban areas (27% or 6 communes) as shown in Figure 1.

Boardman's economic approach: To identify energy-poor households out of the 640 households surveyed, we use Boardman's economic approach. This approach stipulates that a household is considered energy poor if it spends more than 10% of its income on energy needs. To implement this approach, we compare affordability (the percentage of household income spent on energy expenditures, including energy supply costs) to the 10% of household income threshold. Affordability therefore includes household expenditure on transport and the supply of cooking energy, electricity and energy for lighting. Energy expenditure and income are monthly.

$$Affordability = \sum_{i=1}^{3} (Supply + Transportation\ costs)_i \quad (01)$$

i represents the heading (cooking, electricity, lighting) and therefore varies from 1 to 3.

RESULTS AND DISCUSSION

RESULTS

To successfully identify energy-poor households out of the 640 households surveyed, we compare the share of income spent on energy expenditure to 10% of income. Energy expenditure represents the total amount of household expenditure attributable to the supply of energy sources for lighting, cooking and electricity (purchase of dry batteries, purchase of oil, purchase of wood and/or charcoal, recharging of batteries, cost of transport etc.). The two curves are drawn in the same plot (Figure 2). Figure 2 below shows the energy expenditure in blue compared to the 10% income threshold in red. For a better reading of the results obtained, the curves in Figure 2 are presented in Figure 3, but presented in four zones for ease of reading. Thus, Figures 2 and 3 present the same jump result as the details are more perceptible in Figure 3. When we analyse these results we notice that at several points in Figure 3 the blue curve is above the red curve. In clearer terms, the analysis of the curves indicates the existence of several points where energy expenditure is higher than 10% of household income. This indicates the existence of energy poor households in the sense of Boardman's approach. Numerically, there are 506 households whose energy expenditure is higher than 10% of income. In other words, there are 506 energy poor households in the Boardman sense out of the 640 households surveyed in the study. This means that about 79.06% of the households surveyed are energy poor according to Boardman's economic approach.

DISCUSSION

When we look at the households that were found to be energy poor according to the approach used, we notice that the majority of them are farmers (60.10%) as shown in the following Figure 4. 19.40% of them are traders and the rest have various professional occupations. This information allows us to highlight the socio-economic factors that favour their state of energy poverty. Indeed, farmers or herders have an ease in using wood as their main source of cooking energy due to the distance of the electricity grid and Liquefied Petroleum Gas (LPG) supply points from agricultural (rural) areas, due to the high cost of subscription to the national grid, the high cost of the first domestic gas recharge and due to the availability of wood in rural areas. Most of the time this wood is obtained during the preparation of the field for agriculture. Some households, however, buy the wood. However, even if the wood is collected, it costs money to transport and deliver it to the place of use. Some herders or farmers, depending on the time of year and the distance between them and the fields, are obliged to buy the wood. Figure 5 below shows that energy-poor households rely mainly on wood for about 76.48% and charcoal for 18.18% as their main source of cooking energy. Dependence on traditional solid fuels is higher in rural areas (Das, Pradhan and Nonhebel, 2019) and is a physical sign of lack of access to modern energy sources.

The use of these energy sources predisposes households to energy poverty. Inefficient and abusive use of wood leads to ever-increasing anthropogenic pressures on forest cover. Charcoal is generally produced by the traditional millstone technique with low yields generally below 15% (Institut de la Francophonie pour le développement durable (IFDD), 2007). All these factors contribute to global warming. Wood is generally used with inefficient fireplaces, as will be seen below. The use of traditional solid fuels negatively affects human health and hinders socio-economic development(International Energy Agency, 2017). In the search for possible explanations for the energy poverty status of the households surveyed, it is found that these households use inefficient or low energy-efficient cooking stoves. The analyses show that three-stone cookstoves are mostly used by energy-poor households (67.19%), followed by woodlouse stoves (16.40%) and traditional ceramic stoves (10.47%) as shown in Figure 6. However, the use of inefficient or low energy efficiency equipment is a factor that promotes energy poverty or predisposes households to suffer from energy poverty. Improved households account for a total of 3.76% of households used by energy poor households. Several studies (Nussbaumer, Bazilian and Modi, 2012 ; Boemi and Papadopoulos, 2020 ; International Energy Agency, 2017) indicate that low income, low or inefficient energy use and high energy costs are the main causes of energy poverty. This can be easily seen from the results obtained in this study.

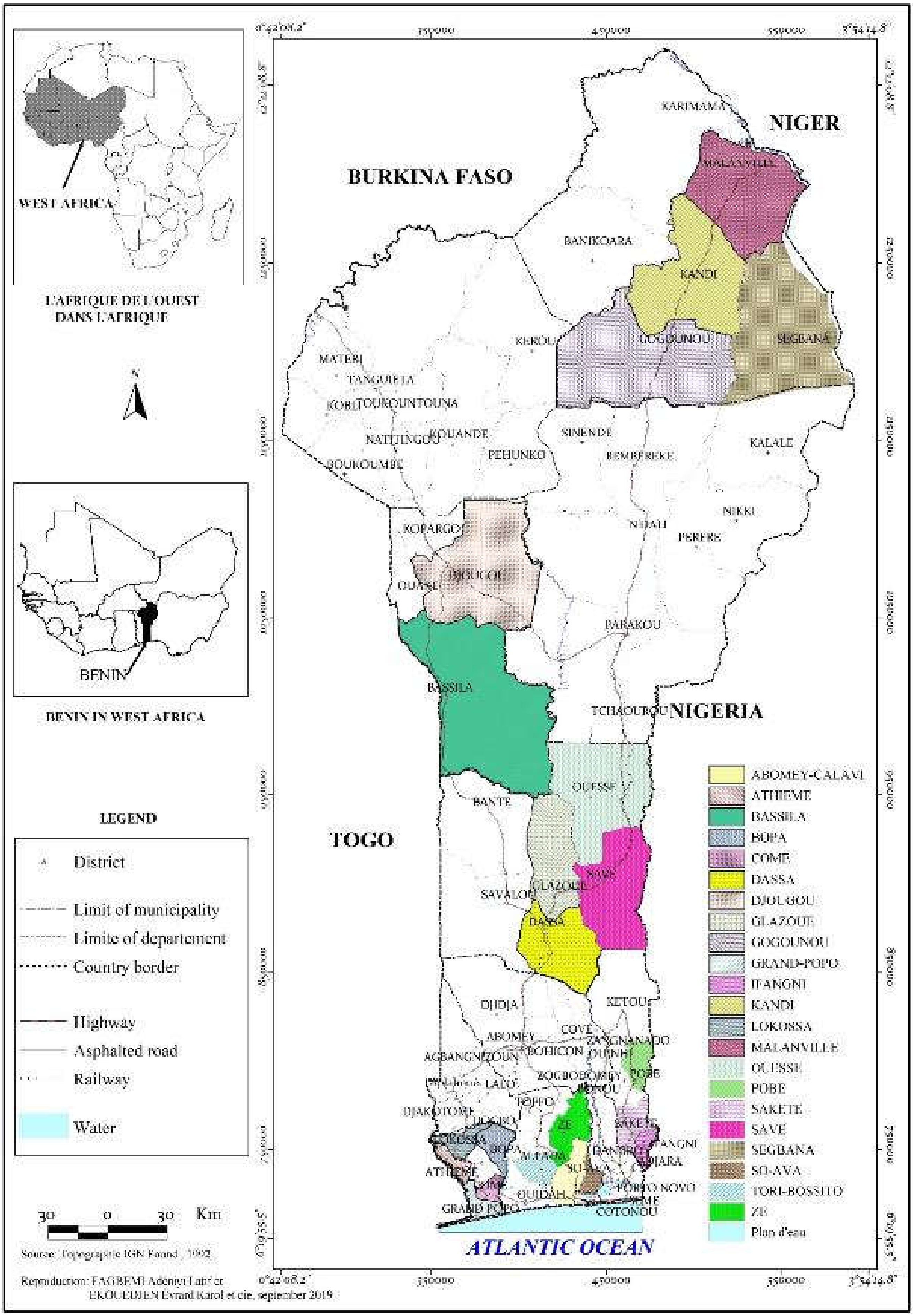

Figure 1. Presentation of the study area

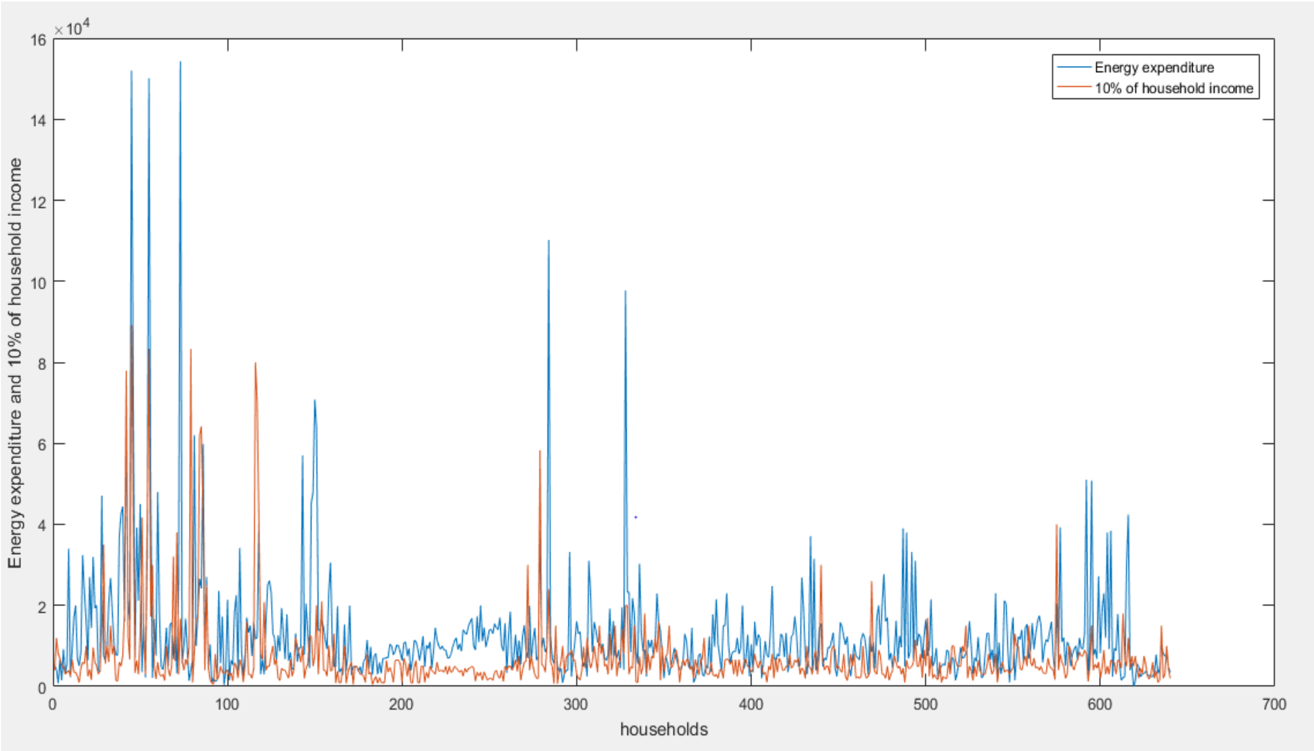

Figure 2. Comparative curve of household energy expenditure and the 10% household income threshold

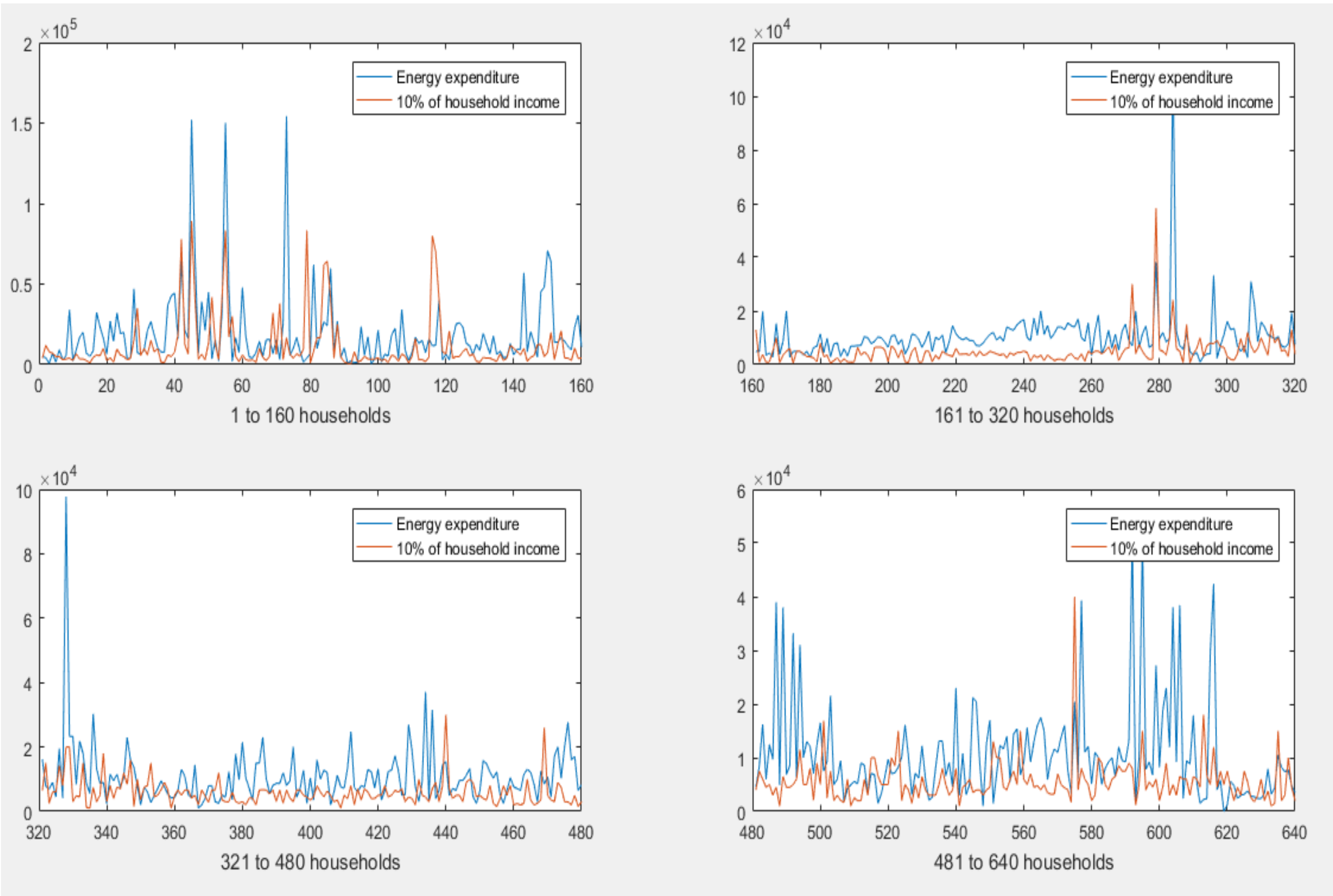

Figure 3. Comparative curve of household energy expenditure and the 10% household income threshold by zone

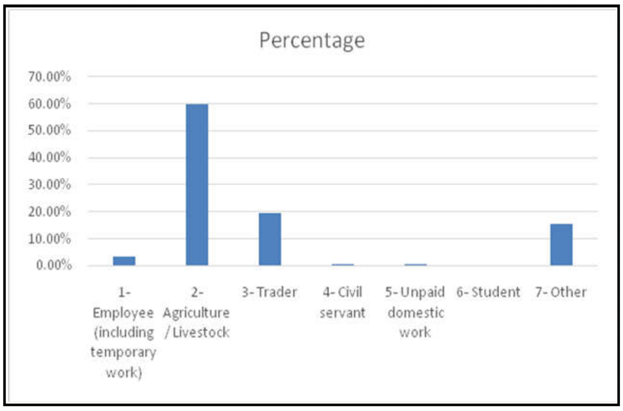

Figure 4. Occupations of energy-poor households surveyed

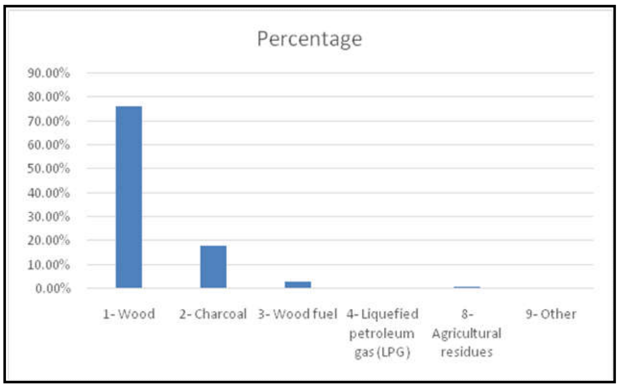

Figure 5 Main source of cooking energy used by energy-poor households

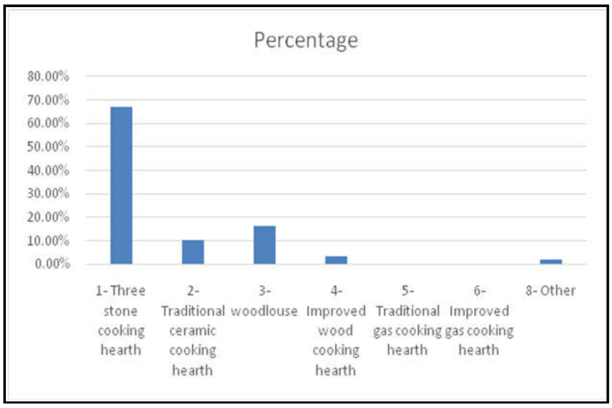

Figure 6. Main cooking stoves used by energy-poor households surveyed

The use of improved cooking stoves and better energy efficiency and affordable and low-cost energy sources would therefore reduce the measure of energy poverty. However, the effect of the high cost of improved cookstoves combined with low household income does not facilitate household access to efficient improved cookstoves should not be overlooked. This is because improved cooking stoves and improved energy efficiency are expensive and this makes it difficult for low-income households, especially small farmers, pastoralists and small traders, to afford them. According to a study[1] carried out by the Directorate General of Energy in 2010, conventional stoves induce thermal losses of about 50% of the initial energy. Improved stoves can reduce energy consumption by 25% to 40%, thus reducing the amount of fuel to be used and preserving forests.

[1] Study entitled "Summary Cost-Benefit Analyses of Possible Strategies in the Domestic Fuel Sector".

Figure 7.Young Man Carrying Wood in Rural Benin

Table 1. Energy Indicators

Energy Indicator	Field Survey Results 2019
National electrification rate	19%
Rural electrification rate	10,21%
Urban electrification rate	33,62%
National rate of access to electricity	36%

The main barrier remains the price of the fireplace, which is four times higher than that of conventional stoves. But the multiple advantages they offer allow a rapid return on investment. The energy authorities therefore need to find ways to popularize improved cook stoves and encourage households to move towards the mass use of improved cookstoves. The central government could subsidise improved cookstoves to reduce the purchase price, for example, which is the first barrier for low-income households. In addition, the massive use of three-stone stoves by energy-poor households raises environmental, socio-economic and health issues. Three-stone cooking hearth use fuelwood as fuel. This fuelwood is collected in the fields and/or sometimes in the forests in an informal way. This, combined with the fact that three-stone stoves are inefficient in terms of energy and responsible for a significant loss of energy, leads to an abundant use of firewood, especially in rural and peri-urban areas, thus creating excessive anthropogenic pressure on Benin's forests. The environmental problem thus posed contributes to global warming. The other aspect that should not be overlooked is that the time spent collecting firewood is wasted time that could be used for other income-generating activities. Better still, school children sometimes participate in the collection of firewood and this considerably reduces their school performance as stated by the International Energy Agency (International Energy Agency, 2017). Surveys conducted in Benin indicate that about 10.78% of children participate extensively in the collection of energy sources and 45.15% of children who participate little in this collection. Figure 7 illustrates the involvement of school-age children in wood collection. Exposure to combustion fumes negatively affects human health (International Energy Agency, 2017), mostly women and children, and all this combined is a brake on the country's economic development. In addition to the use of inefficient or ineffective cooking stoves, energy-poor

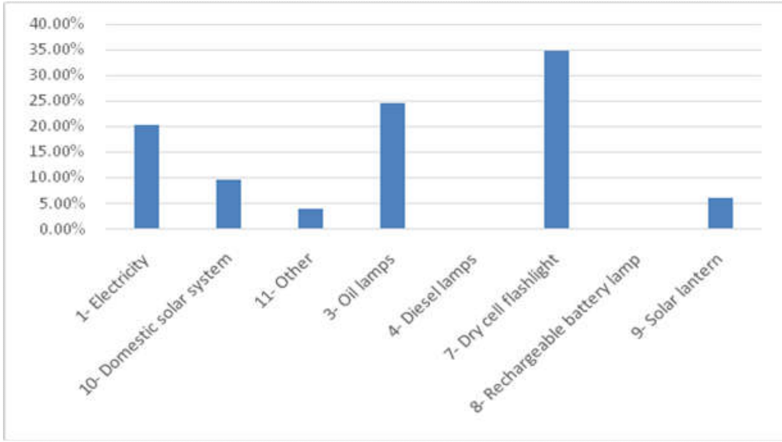

Figure 8 **Main energy sources for lighting in the energy-poor households surveyed**

Figure 9(1) oil lamps; (2) dry cell flashlights; (3) fireplace woodlouse; (4) three-stone cooking hearth

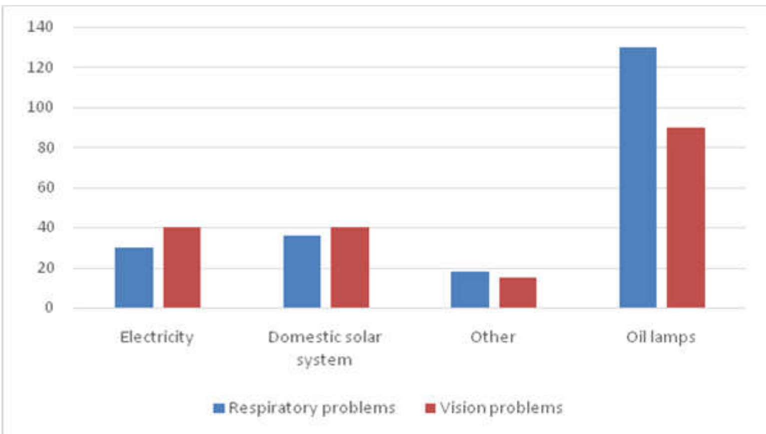

Figure 10. Link between cooking energy sources and the health problems of members of energy-poor households

households are also characterized by the use of poorly modern and expensive lighting sources due to lack of access to electricity. Indeed, the study reveals that energy poor households use mainly dry cell flashlights (34.78%) as the main source of energy for lighting, followed by kerosene lamps (24.70%) and electricity (20.36%) as shown in Figure 8 below. Indeed, households without access to the electricity distribution network are obliged to find alternative solutions to provide lighting for their homes. In fact, electricity needs are mainly covered by non-rechargeable dry batteries (52%) and individual solar installations (16%). Table 1 below presents the energy indicators from the surveys. In In this context, energy-poor households use dry cell flashlights and kerosene lamps mainly because these sources of energy for lighting are available in their environments. This result is corroborated by several previous studies that show that the poorest households generally depend on inefficient energy sources (Pachauri et al., 2004). These solutions are not the most economically advantageous and the use of oil and exposure to combustion fumes could lead to risks to human health. The management of non-rechargeable dry batteries after use is a real concern for communities and creates environmental problems. The toxic content of many dry cell batteries and their accumulation can have negative impacts on health and the environment (Bensch, Peters and Sievert, 2017). Kerosene lamps and flashlights do not provide good light output and visual comfort, which exposes those using them (especially learners) to the risk of developing vision-related health problems later on.

Lack of adequate and constant lighting has a negative impact on the general well-being of poor households and for the children of these households who attend school (Sharma et al., 2019). Lack of adequate lighting leads to difficulties in studying after dark, lower school performance, and increased drop-out rates due to poor school performance (Sharma et al., 2019). Exposure to harmful emissions from kerosene lamps damages the health of these households. The following Figure 9 shows, by way of illustration, images of the main energy sources for lighting and the main cooking stoves used by energy-poor households.

The different energy sources used by households that are found to be energy poor negatively impact the health of household members. Indeed, 46.05% of the members of energy poor households report suffering from respiratory health problems and 50% of them suffer from visual health problems. The different health problems reported by members of energy poor households could be closely related to the type of energy source used. For example, Figure 10 presents a cross-analysis between the cooking energy sources used by energy poor households and the health status of the members of these households. The analysis of this graph shows that wood use is largely associated with vision and respiratory health problems among members of energy-poor households. The graph indicates that there are more people with respiratory problems using wood than people with vision problems. It is also noted that the use of charcoal could also cause the same health problems as wood but to a lesser extent. LPG and other energy sources do not cause health problems. This could be justified by the fact that LPG is a clean energy. Indeed, these results are consistent with studies (Silwal and Mckay, 2016) that indicate that people living in households that cook with firewood have 9.4% less lung capacity than people who cook with cleaner fuels. This impact is greater for women and children than for men. Figure 11 shows the link between the type of energy used for lighting and the health problems of members of energy-poor households. There are more people with vision problems than people with respiratory problems who share the use of dry cell flashlights. Overall, dry battery flashlights affect sight much more than lung health in households. Kerosene lamps, on the other hand, affect household respiratory health much more than vision. This is justified by the fact that burning kerosene initially produces flue gases that are harmful to respiratory health, and the person who uses this energy source is in close proximity and therefore inhales these gases. On the other hand, kerosene lamps have poor light output, which later leads to problems of sight for the users. Numerous studies (Mills and Ph, 2012) confirm the close link between off-grid lighting sources and health problems among household members. The inequity of fuel-based lighting, which is expensive and of poor quality, is compounded by adverse health and safety risks including burns, indoor air pollution, poisoning from accidental kerosene ingestion by children, compromised visual health, maternal health problems and reduced services in health facilities lit only or sporadically with fuel-based lighting (Mills, 2016). In summary it can be said that the energy efficiency of the equipment used, income, the high cost of energy, cooking stoves and the nature of the energy source used are the main factors influencing the measurement of household energy poverty. The use of non-recommended (not modern or clean) energy sources for lighting and cooking promotes the perception of energy poverty and negatively impacts household health and the environment. If efforts are to be made to reduce this scourge then it is in these key factors that energy should be concentrated.

Conclusion

From all the above, it emerges that out of the 640 Beninese households surveyed, about 79.06% of them are in energy poverty according to Boardman's economic approach. The study also revealed that the majority of households revealed to be energy poor depend on traditional energy sources (wood and charcoal) for cooking energy needs and use inefficient or poorly energy-efficient cooking stoves. Energy-poor households also depend on energy sources for unsavoury lighting such as dry cell flashlights and kerosene lamps. Energy efficiency or inefficiency, high cost of energy and lack of access to the electricity grid therefore appear to be determining factors in the measurement of household energy poverty. It should also be noted that the sources of energy used by these households for lighting are inefficient or ineffective and expensive. The negative effects on health, education and the environment of inefficient household use and the use of inconvenient lighting sources were addressed in this study and it was found that almost half of the members of energy poor households complain of health problems (mainly respiratory and vision problems). All these findings coupled with the high cost of improved households, low income and lack of access to electricity contribute to the observed situation of energy poverty. It is therefore necessary for the political authorities in charge of energy to find accompanying measures to reduce the purchase price of improved stoves in order to encourage their use by low-income households. It is also necessary to work to put in place off-grid electrification measures in order to enable households located in regions very far from the national electricity grid to have access to electricity. All this will have the advantage of contributing to the preservation of the environment and human health and thus promote local development. The next steps in this study will be the development of an energy poverty index that takes into account the influence of the energy efficiency of the equipment used.

Acknowledgment

This study is funded by International Development Research Center (IDRC) through the project Number 6156 entitled Optimal energy efficiency strategies to promote energy justice and low carbon development executed by Econoler in Benin, Senegal and Togo.

Conflict of Interest: Authors declare ‘’No conflict of Interst’’

REFERENCES

Beguerie, V. 2015. ‘Impact de l’ accès à l ’énergie sur les conditions de vie des femmes et des enfants en milieu rural : analyse d’impact du programme des plate-formes multifonctionnelles au Burkina Faso To cite this version : HAL Id : tel-01168754 Impact de l ’ accès à’.

Bensch, G., Peters, J. and Sievert, M. 2017. ‘Energy for Sustainable Development The lighting transition in rural Africa — From kerosene to battery-powered LED and the emerging disposal problem ☆’, *Energy for Sustainable Development*. International Energy Initiative, 39, pp. 13–20. doi: 10.1016/j.esd.2017.03.004.

Boemi, S. and Papadopoulos, A. M. 2020. ‘Energy & Buildings Energy poverty and energy efficiency improvements : A longitudinal approach of the Hellenic households’, *Energy & Buildings*. Elsevier B.V., 197(2019), pp. 242–250. doi: 10.1016/j.enbuild.2019.05.027.

Das, K., Pradhan, G. and Nonhebel, S. 2019. ‘Human energy and time spent by women using cooking energy systems : A case study of Nepal’, *Energy*. Elsevier Ltd, 182, pp. 493–501. doi: 10.1016/j.energy.2019.06.074.

Goldemberg, J. (1990) ‘One kilowatt per capita’, 3402(1990). doi: 10.1080/00963402.1990.11459775.

Institut de la Francophonie pour le développement durable (IFDD) 2007. *La carbonisation efficace en Afrique de l’Ouest*.

International Energy Agency 2017. ‘WEO-2017 Special Report: Energy Access Outlook’.

Khanna, R. A. *et al.* 2019. ‘Comprehensive energy poverty index : Measuring energy poverty and identifying micro-level solutions in South and Southeast Asia’, *Energy Policy*. Elsevier Ltd, 132(November 2018), pp. 379–391. doi: 10.1016/j.enpol.2019.05.034.

Mills, E. 2016. ‘Energy for Sustainable Development Identifying and reducing the health and safety impacts of fuel-based lighting’, 30(1), pp. 39–50.

Mills, E. and Ph, D. (2012) *Health Impacts of Fuel- - based Lighting*.

Nussbaumer, P., Bazilian, M. and Modi, V. 2012. ‘Measuring energy poverty : Focusing on what matters’, *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, 16(1), pp. 231–243. doi: 10.1016/j.rser.2011.07.150.

Pachauri, S. *et al.* 2004. ‘On measuring energy poverty in Indian households’, *World Development*, 32(12), pp. 2083–2104. doi: 10.1016/j.worlddev.2004.08.005.

Sharma, R. *et al.* 2019. ‘Energy for Sustainable Development Do solar study lamps help children study at night ? Evidence from rural India’, *Energy for Sustainable Development*. International Energy Initiative, 50. doi: 10.1016/j.esd.2019.03.005.

Silwal, A. R. and Mckay, A. 2016. ‘The Impact of Cooking with Firewood on Respiratory Health : Evidence from Indonesia The Impact of Cooking with Firewood on Respiratory Health : Evidence from Indonesia’, 0388(February). doi: 10.1080/00220388.2015.1056784.

United Nations 2015. ‘Sustainable Development Goals’.

Appendices

Table A : Summary of selected villages and city districts

N°	Selected Villages	Borough of belonging	Commune of belonging
NORTH REGION			
ALIBORI			
ALI-01	KOSSENIN	GOGOUNOU	GOGOUNOU
ALI-02	BANIGOURE	BAGOU	
ALI-03	OUESSENE PEULH	SORI	
ALI-04	GANDO-DUNKASSA	LOUGOU	SEGBANAN
ALI-05	GBARANA	SOKOTINDJI	
ALI-06	SEREKIBE	SOKOTINDJI	
ALI-07	PIAMI	SEGBANAN	
ALI-08	PEGON	KASSAKOU	KANDI
ALI-09	ALFAKOARA	ANGARADEBOU	
ALI-10	GOGBEDE	BENSEKOU	
ALI-11	GAROU II	GAROU	MALANVILLE
ALI-12	BOIFFO	GUENE	
ALI-13	SENDE	MADECALI	
ALI-14	ZENON	TOMBOUTOU	
DONGA			
DON-01	BANDETCHOURI	BAREI	DJOUGOU
DON-02	TOSSAHOU	BARIENOU	
DON-03	KPANDOUGA	BOUGOU	
DON-04	KOLOKONDE	KOLOKONDE	
DON-05	VANHOUI	PATARGO	
DON-06	SASSIROU	DJOUGOU I	
DON-07	FIRIHOUN	BASSILA	BASSILA
DON-08	AKARADE	ALEDJO	
DON-09	BAYAKOU	PENESSOULOU	
DON-10	BASSILA 1	BASSILA	
CENTRE REGION			
COLLINES			

COL-01	KPINGNIN	KPINGNIN	DASSA-ZOUME
COL-02	GBEDAVO	PAOUIGNAN	
COL-03	OUISSI		
COL-04	LEMA-TRE	TRE	
COL-05	ADJOKAN		
COL-06	ESSEKPERE	DASSA II	
COL-07	AGBEGBE	DASSA I	
COL-08	IGOHO	KERE	
COL-09	ASSANTE	ASSANTE	GLAZOUE
COL-10	KPOTA	OUEDEME	
COL-11	HOKO	THIO	
COL-12	OROKOTO	GLAZOUE	
COL-13	OGUIRIN	MAGOUMI	
COL-14	AWO SERIKI	BONI	SAVE
COL-15	GOBE	OFFE	
COL-16	ISSALE-OTOUN	ADIDO	
COL-17	MONKA	OKPARA	
COL-18	KPASSA	LAMINOU	OUESSE
COL-19	TOUI-GARE	TOUI	
COL-20	ODOUGOU	OUESSE	
COL-21	IDADJO	GBANLIN	
SOUTH REGION			
ATLANTIQUE			
ATL-01	HOUEDAGA	TORI-CADA	TORI-BOSSITO
ATL-02	HOUETA	ADJAN	ZE
ATL-03	AIFA	KOUNDOKPOE	
ATL-04	WAGNIZOUN	KPANROUN	ABOMEY-CALAVI
ATL-05	DOSSOU GAO	GANVIE II	SO-AVA
MONO			
MON-01	TOGUIDO	ADOHOUN	ATHIEME
MON-02	HONVE COME	COME	COME
MON-03	AYIGUINNOU	AGOUE	GRAND-POPO
MON-04	HOUIN TOKPA	HOUIN	LOKOSSA
MON-05	LOBOGO GBEDE COME	LOBOGO	BOPA
PLATEAU			
PLA-01	KO-AYIDJEDO	KO-KOUMOLO	IFANGNIN
PLA-02	BANIGBE NAGOT	BANIGBE	
PLA-03	OKEITA	AHOYEYE	POBE
PLA-04	AKPATE	IGANA	
PLA-05	IDJIGBORO	AGUIDI	SAKETE

****