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THE PROMOTION OF RENEWABLE ENERGIES: A SUSTAINABLE ANSWER TO THE ENERGY PROBLEMS OF THE RURAL HOUSEHOLDS IN CHAD

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ABSTRACT
The promotion of renewable energy is a hot topic around the world. Each country tries to provide solutions to its energy balance considering its settings called 3E (Energy-Economy-Environment). This research study emphasizes a scientific approach of renewable energy by applying it to the Chadian context. The purpose assigned to this paper is to highlight the magnitude of the Chadian natural legacy in renewable energy including biomass, wind, solar, etc. by conciliating it together with the new technology to meet the energy needs of households who not having access to the electricity. We will discuss this topic with a descriptive approach such as inventory of the energy situation in Chad, developing a map of potential renewable energy, environmental balance, survey of sites, etc. The outcomes of this study shows that country Chad has significant potential renewable energies, especially solar wind and biomass energies to which the rural population is approving to its development. The exploitation of this potential in renewable energy proved requires special effort from the government in its global energy policy in term of investment. The finding of this study can contribute to improve and increase the energy access rate to about 1.3%. Currently, the access rate to the energy in Chad is 3%.

Keywords: Access to energy; rural population; renewable energies, Chad.

1. INTRODUCTION

The energy is one of the bases of a nation economic development. Access to energy, and therefore an increase in energy service satisfactions is a consequence of the country development. In the scientific literature review dealing with the access issue to the energy in developing countries, several authors have studied the causal relationship between economic growth as measured by growth domestic product (GDP) and energy consumption. In a study done by (Fondja, 2013) in the case of Cameroon, the energy consumption of a country depends not only on the GDP but also on the price level of energy, climate and energy efficiency policies. Access to energy services impact on their socio-economic situation in four areas: education, environment, health and income (Kanagawa, 2007). But knowledge of this causal allows a country to improve the access to the energy services, reliability and availability of supply in environmental and social terms (Knight and Ouedraogo, 2011).

According to the International Energy Agency (IEA), the access to energy in a household is defined as "a household with reliable and inexpensive access to a clean cooking system, first connection to electricity with a minimum level of consumption, then a level of electrical consumption increasing over time to align with the regional average ". Access to energy is very unequal across the globe especially between industrialized and developing countries. The following statistical data are representative of these inequalities (IEA, 2006):

- 1.6 billion people -a quarter of the world's population- do not have access to electricity;
- 4 out of 5 people without electricity live in rural areas of developing countries, mainly in South Asia and Sub-Saharan Africa;
- 2.4 billion people use traditional biomass (wood, agricultural residues, manure) for heating and cooking;
- Most developing countries are net importers of electricity.

It should be recalled that 19% of the world's population does not have access to the electrical energy, of which 39% uses biomass (IEA, 2011). There are scenarios of an unfavorable situation in Sub-Saharan Africa areas, especially in Chad which is the scoop of our study. We assume the hypothesis that households surveyed in central African countries are pretty similar, in such way each country situation depicts exactly the situation of its neighboring countries. Subsequently, we will compare our study with the result of our neighboring countries such as Cameroon. Nkue and Njomo (2009) has studied the sustainability of the Cameroonian Energy System by comparing electricity supply and the demand. He concludes that the Cameroonian energy system is unsustainable because there is an inequality in services between urban and rural areas. In fact, there is a large use of wood energy in rural area that causes a reduction of forests (more than 100 000 hectare/year). As a solution to this problem, the authors proposed the development of

hydroelectric power. This conclusion follows the same direction as a study conducted by (Leopold and Ozer, 2005) where the use of biomass is causing degradation of the green cover (2% per year) in Sudano-Sahelian Africa. This study surveyed 7 countries (Mauritania, Senegal, Guinea Bissau, Mali, Burkina Faso, Niger and Chad which is our survey area). In Chad, there are very few studies devoted to the question of energy. We extended our study to neighboring countries like Cameroon because of the similarity between Cameroon and Chad: belonging to the same economic and financial union and having a similar climate. The issue of energy has been addressed by some authors as (Wirba et al., 2015**)** identifying the different potential renewable energies of Cameroon. They concluded that the use of renewable energy may improve the rate of access to electricity in Cameroon which is currently 10-14%.

Abanda et al. (2012) proposed that considering the hydroelectric potential of Cameroon, the exploitation of this energy would be a solution to the energy problem of this country. This is also recommended by (Williams and Simpson, 2009) suggesting that the installation of micro hydropower (5kW) is an adaptable solution to households in rural areas.

Some of these authors have addressed the issue of energy by proposing hydropower solutions, but the scope of their studies remains global and is limited to the supply of energy without studying the demand of households. Our work consists of studying the causes of the luck to energy access in rural areas in Chad and proposing solutions using the strong solar and wind energy capacities in the different environments surveyed. This study can contribute to improve and increase the energy access rate to about 1.3%. Currently, the access rate to the energy in Chad is 3%.

In the context of Chad, the energy balance shows the state of underdevelopment in terms of quantitative and qualitative energy consumption. According to a survey done by the Chadian National Institute of Statistics (INSEED), an Economic and Demographic Studies in 2011shows that the energy consumption is 493 kg of oil equivalent (KOE) per capita per year against 2,000 KOE per year on average of the world . The current production capacity in energy in Chad is 230 MW whose 178 MW are operational only, including that of Komé (oil production area) which is equivalent to 120 MW to which the surrounding population does not have access. Only 54 MW of installed capacity are insured by the National Electricity Society (SNE) monopolizing the national market and the services do not meet the expectation of consumers who faced the untimely blackouts. Unfortunately, it is normal to totalize several months of blackouts in some parts of N'Djamena, capital of Chad! And the situation is even worse in the provinces. This crisis is due to a lack of management: the electrical park is old existing back in colonization period. The electrical park's yield is only 40% due to lack of spare parts for maintenance and the expertise of the staff. One customer dominates the government who does not regularly pay their bills, while other customers use illegally power lines. This makes the power energy of Chad among the most expensive in the world; the average resale price of a KWH is 157 FCFA (around 0.32 USD) but it is sold at a loss because its average cost production is 226 FCFA (around 0.45 USD) which does not improve the electricity access to the population (only 4% of population has access). Over 88% of households use wood (biomass) as the main source of energy (INSEED, 2011).Now the country is full of important and diversified energy resources, namely fossil fuels (petroleum), uranium and renewable resources (solar, biomass, wind, geothermal, etc.). These resources are distributed across the regions, but the most important and better distributed are biomass and solar. According to the report of the Forum on Renewable Energies, held from 1st to 4th February 2012 in N'Djamena, the annual solar collection in the country is estimated at 2,850 hours and 3,750 hours from South to North. The sunshine makes an average radiation on a horizontal surface, from 4.5 to 6.5 kWh/m^2 per day (PVGIS). The exploitation of this source might solve recurrent country's energy crisis. It would be very ambitious to exploit solar in Chad, but there is lack of infrastructure and appropriate strategies. The recourse to the use of renewable sources, especially in the day, would it be a suitable alternative to the non-satisfied energy needs?

In this paper, we will discuss the following issues:
• what are the causes of energy problem in Chad?
• How to facilitate access to energy for unconnected households?
• What energy policy should be adopted if the country is to achieve the UN Sustainable Development Goals?
We start by giving an overview of the electrical energy supply in Chad, and then we will describe its various renewable energy resources. Finally, we will study the causes of the lack in energy access in the rural households in this country.

2. BACKGROUND

In Chad, the demand of energy is high but the offer is less. Furthermore, the cost of energy per kilowatt hour in the households in Chad is the most expensive in the World. Because of this problem, only 97% of households are not connected to electrical energy. Most of connected households to the electrical energy are from urban areas. Rural households are not connected due to non-accessibility to energy grid. Currently, most of rural households used wood energy except fewest that use own generators. The use of wood energy contributes to the desertification and the climate rise. The alternative solution can be the development and use of wind and solar energies.

Chad his sunshine country with high capacity of wind and solar energy production.

2.1. Production of electrical energy

The production of electrical energy is ensured by the National Company of Electricity in N'Djamena and in only 6 of 23 states of country (Abéché, Bongor, Doba, Faya, Moundou and Sarh) which is estimated to 54.1 MW as shown in Table 1.

Table 1 Production of the power stations of the National Company of Electricity in 2013 (ICR, 2013)

SITE	Power available (MW)	Gross output (MWh)	Delivered Production (MWh)
DJAMBAL BARH	11	6,600	6,336
FARCHA 1	14	8,400	8,064
FARCHA 2	16	9,600	9,216
STATES	13.1	7,860	7,546
TOTAL	54.1	32,460	31,162

To the National Company of Electricity production capacity, the power station of the Djarmaya refinery of 20 MW is added, which makes a total production capacity of 74.1 MW. Efforts are to be deployed by the government to increase the output of the power stations of Farcha 1 and Farcha 2 respectively to 14 MW and 60.2 MW, without forgetting the new auxiliary stations of V-POWER (20 MW) and AGGREKO (20 MW), which would bring back the power available of the capital to 144.2 MW.

In addition, some private groups like ZIZ (Zakaria Ibrahim Zakaria, a private operator supplying the cities like Mongo and Oum-Hadjer in the center of country), as certain towns of the country exploit the electric production centers whose production capacity is lower than that of the National Company of Electricity (Table 2).

Table 2 Production of the towns and private power stations (FITCHNER, 2012)

Commune	Working installed capacity (in MW)	Power available (in MW)	Current situation
Mongo	2	0.5	2×275 kVA
Oum-Hadjer	0.5	0.5	2×275 kVA; fuel: 10,000 l/an
Biltine	0.5	0.5	2×323 kVA; fuel: 5,100 l/an
Am-Timan	0.5	0.5	
Mao	0.5	0.5	
Bardaï	1	(not statement)	
Total	4,9	2.5	

Moreover, one can estimate the auto production of the industrialists (cement factory, oil mill, brewery, etc.) to 20 MW, without forgetting the power generating units of the private individuals whose capacity is difficult to quantify.

2.2. Production cost of the kilowatt-hour

The costs of production per unit of the SNE are relatively high ranging between 252 and 375 FCFA/kWh (around 0.51 and 0.75 USD/kWh). Consequently, the balanced average tariff does not cover the costs of exploitation. The SNE thus sold the kilowatt-hour at a loss. It is because to the government grants that SNE manages to cover the whole of its raw material charges and in wages of the personnel.

2.3. Renewable energy potential of Chad

2.3.1. Solar energy

Chad belongs to the area of higher sunning of Africa.Its solar potential is estimated between 2,850 hours in the South and 3,750 hours in North, with a radiant intensity from 4.5 to 6.5 kWh/m^2/day.A map extracted from PVGIS site, developed by the European Commission, which gives the solar energy in Europe and in Africa that illustrates this potential (Figure 1).The exploitation of this source will contribute to solve the energy crisis of the country. According to the estimation made by the support project to energy plan in Chad, 1 km^2 equipped with photovoltaic panels might produce 110 GWh per year, corresponding to a triple of the production output of the National Company of the Electricity (whose real capacity of production is 32.4 GWh).

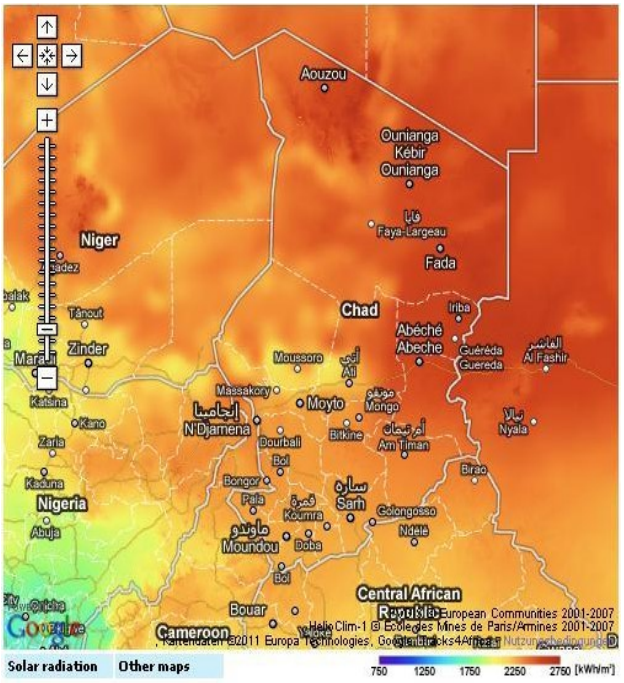

Figure 1 Map PVGIS of the solar layer of Chad (JRC, 2016)

By covering the main areas of Chad with photovoltaic panels, 500 cities might be sufficiently supplied that is equivalent to N'Djamena consumption in energy.Currently, 70 hydraulic sites are equipped and 43 new sites are in are in process to be equipped by the solar regional Program. It would be very ambitious to exploit the solar energy in Chad, but this requires infrastructures and strategies appropriate. Hope that our research project findings will help to clarify and sensitize the authorities in order to integrate the solar energy as priority on the energy plan in Chad.

2.3.2. Wind energy

It is difficult at the start to make a precise idea through data obtained by satellite on the wind potential of a given location, without making precise measurement series in the site over several months. The map below (Figure 2) locates the suitable states capable to be deeply studied to consider the exploitation of the wind energy.

However, the wind energy can be interesting in some areas of the extreme North (Borkou, Ennedi and Tibesti) where wind speeds are about 4 to 9 m/s. This speed can permit to install wind sites with average size of 50-200 kW against a large aero-generators requiring average velocity of more than 7 m/s and whose exploitation will be able to cover a large consumptions, but in the less populated states where it will be difficult to find potential consumers. Moreover, the wind energy requires regularly the maintenance, whereas in this part of the country there is a lack the qualified workers as well as difficult access to the areas.*2.3.3. Biomass energy*

It is difficult to obtain accurate data on green cover in Chad since the official studies of this potential are few, except for some Food and Agriculture Organization (FAO) reports in 1999, which produced a report that states the following conclusions:

- 40,000 hectares would be lost each year because of the human activities (agriculture, breeding, bush fires);
- the vegetation covers 23,450,000 hectares with a rate of deforestation of 0.6% per year;
- rough volume rises to 304,000,000 m^3 and exploitable volume is 5,600,000 m^3.

This vegetable hedging is dense from South to North, according to the climatic subdivision of the country in three zones: the Desert zone in North covers a surface of 600,370 km^2, where the vegetable hedging is almost non-existent; Sahelian zone in the center covers a surface of 553,590 km^2 and has a vegetable hedging of about 10,172,000 hectares, finally, the Sudanese zone covers an area of 130,040 km^2 and has a vegetable hedging of around 13,258,000 hectares.

The wood sector contributes to over 97% in household energy demands, especially for cooking (FAO, 2002). But it leads to increase the deforestation and soil degradation, especially in rural areas, because the alternative to wood is easier in urban than rural areas. With this deforestation rate of 0.6% per year mentioned by FAO, forest area in 2020 would be approximately 20,391,807 hectares or 8.85% less than the current covered. A more recent study confirms a deforestation of 2% per year. It is globally serious and alarming than the FAO official data (Leopold and Ozer, 2005).

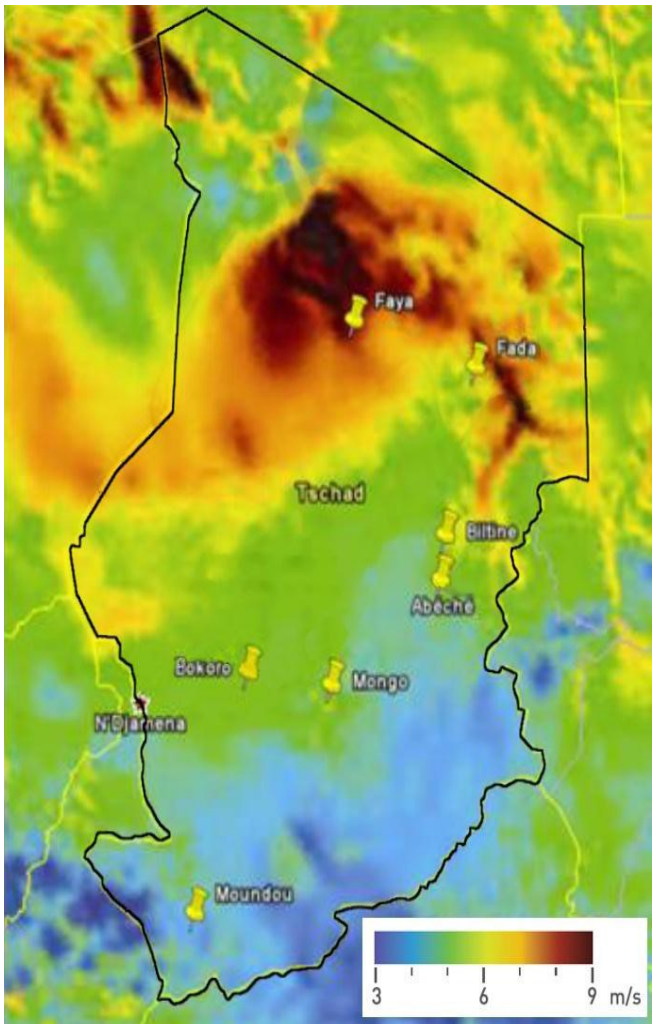

Figure 2Map of the wind potential in Chad (Chad, 2016)

However, this sector has to be replaced by other proper green sources in order to preserve the vegetable cover of the country. The other forms of biomass (household rejection, waste of the animals, etc.) can be considered for the heat production. For example the incineration or fermentation to obtain biogas process. The case of the sugar cane-trash is a unique case in Chad. It is developed by the Sugar Company of Chad (CST) to meet its needs in electricity. A campaign of the Agency for Domestic Energy and Environment (AEDE) encourages the use of produced biogas from cane-trash, but that is considered to be expensive.

2.3.4. Hydroelectricity

The main hydraulic site is unique Gauthiot falls in Mayo-Kebbi, which could produce 15 MW of electricity, but this capacity is reduced to 3 MW according to research conducted in the 1970s by the United Nations Development Program (UNDP). The profitability of the project is challenging due to the lack of local markets can consume this low production capacity and expected population resistance to its use, because it considers the site as a ritual and sacred place. In addition, we must enhance the natural elevation by a dam to increase production, which will increase the cost of kilowatt-hour production.

2.3.5. Geothermic energy

Chad has a geothermic potential of small scale to 50 km in the South-west of Bardaï in the montain of Tibesti and in the South of Baïbakoum close to the Central African Republic border. But in the current state, the exploitation of this resource is not possible because of lack of reliable studies on this resource.

3. METHODOLOGY

Our methodology is based on a questionnaire survey of households. The purpose of the survey is to identify the problem of access to energy in rural areas on a sample of households in the states of Guera, Kanem and Ouaddai. We based our investigation on a random selected households in the three states selected to interview 118 households divided as follows: 53 households in Mongo, 43 households in Mao and 22 households in Abéché. This sample is summarized in the below Table 3. The range 118 households is statistically acceptable to produce reliable data. The revenue and energy need of households in the 3 states selected are similar so the different sizes of the sample in the 3 states are not affecting the results.

Table 3 Sample of the investigation

States	Number of Households
Mongo	53
Mao	43
Abéché	22
Total	118

Data from this study were obtained through a questionnaire with three parts: the first part covers information on the households surveyed (subscription to a network, electricity supply difficulties, etc.); Part II provides an assessment based on alternative sources used by household interviewed and their expenses and the possibility of recourse by households to renewable energy to meet their electricity needs, the price per kilowatt-hour that consumers are willing to pay is collected in the third part.

The conduct of the investigation was done by a shift in situ, with an interview. The results are analyzed with a specialized software SPSS (Statistical Package for Social Sciences), suitable for a quantitative and qualitative approach. This will help to analyze the following results.

4. RESULTS AND DISCUSSION

4.1. Access to an electrical supply network of the surveyed households

The aim of our study is to find out why the access to energy rate is weak? The answers are presented in Table 4.

Table 4 Rate of connection of the households to a network

States	YES (connection)	Frequency %	NO (no connection)	Frequency %	Total
Abéché	18	82	4	18%	22
Mao	29	67	14	33%	43
Mongo	19	36	34	64%	53
Total	66	56	52	44%	118

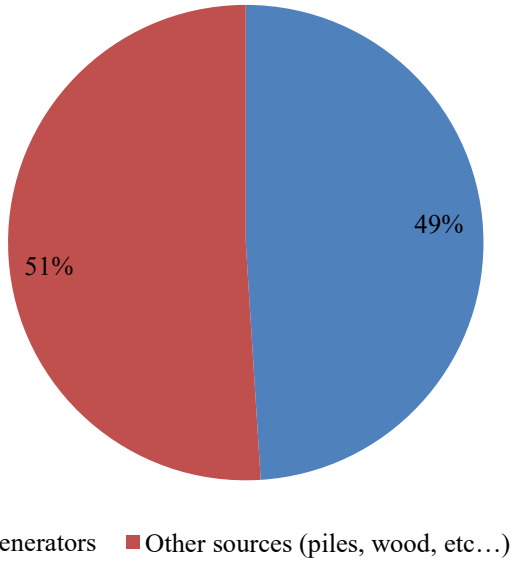

Figure 3 Utilization ratios of various alternative sources

The big difficulty encountered by users (connected and unconnected) is the untimely blackouts due to lack of fuel and spare parts for maintenance. These parts are, for the most of times ordered outside of the country especially in Europe. To meet their energy needs, households use

alternative sources (generators, kerosene lamps or batteries and solar panels) and especially wood energy as illustrated in Figure 3**.** As for the cooking, the energy used is wood (Table 5). Cooking equipment used by majority of households is the traditional three-stone fire. The charcoal is sold per bag (around 42 kg) at 20,000 F CFA (40 USD) and sometimes piles of 1 kg at 500 FCFA (1 USD) from the ban to use it in 2008 by a law, for which offenders are liable to a fine of 500,000 F CFA (1,000 USD).

Although this government law was taken in the interest of preservation of vegetation cover, it was unfortunately not followed by support measures, hence the use of firewood. Wood is sold by lot at 1$ US (equivalent to about 3.8 kg per lot) about 0.27$ US/kg. The average consumption of wood energy per household is 11.8 kg per day. It differs from one state to another depending on the number of people per household. But in Chad, a household has 5.6 people in average. And this size may vary according to state habitations: 5.1 persons in average in Abéché, 5 in Mao and around 5.8 persons per household in Mongo (Table 6)

4.2. Will of renewable energy utilization

A near-majority of 95% responded favorably to the exploitation of the solar energy. But the cost of one kilowatt-hour has to be at more reasonable price than the marginal price around 350 FCFA (0.70 USD). The results of this survey are shown in Table 7 below.

Table 5 Alternative source of energies used by the surveyed households

Connection to electrical supply network	Generators	Frequency (%)	Other sources	Frequency (%)	Total
YES	33	50%	33	50%	66
NOT	25	48%	27	52%	52
Total	**58**	**49%**	**60**	**51%**	**118**

Table 6 Consumption of wood-energy by household in the sites studied

States	Number of people by household	Consumption in kg/ person / day	Consumption in kg/ household /day	Spend day laborer by household (USD)	Consumption In kg/ person/ an	Annual expenditure by households (USD)
Abéché	5.1	2.31	11.78	3.11	843	1,136
Mao	5.0	2.36	11.80	3.12	861	1,138
Mongo	5.8	2.03	11.77	3.10	741	1,135
Average	5.6	2.11	11.80	3.12	770	1,138

Table 7 Rate of opinion favorable to the utilization of renewable energies

States	YES	Frequency (%)	NO	Frequency (%)	Total
Abéché	20	91%	2	9%	22
Mao	40	93%	3	7%	43
Mongo	52	98%	1	2%	53
Total	112	95%	6	5%	118

From all people interviewed during the survey, 56% of them are connected to the electric network, while 44% do not have access. These results show that the majority of surveyed households are located in urban areas where there is a strong connection rate to the network of SNE. This is not the case in rural areas where the rate is lower as shown by the results obtained from the diagnostic energy survey in Chad, conducted by FICHTNER consulting in 2012: total of 101, 210 households surveyed across the country, only 8.2% are connected to the electric network against 91.8% of households without electric network. Non connection rate is slightly higher in case of FICHTNER study than the results obtained in three states surveyed in case of this study: 68% in Abéché, Mao 87.9% and 73.7% in Mongo. According to the data collected from operators, there are 4,267 subscribers in Abéché (3.1%), 780 subscribers Mao (0.6%) and only 500 subscribers in Mongo (a rate of 0.7%) (FICHTNER, 2012).

All these results show that we are far from the average in Africa (25%) and the global average (92%) to the electricity access rates. This study can contribute to improve and increase the energy access rate to about 1.3%. Currently, the access rate to the energy in Chad is 3%. But the purchase of fuel is expensive for non-connected households who spend a daily average from 1,000 FCFA (2 USD) to 80,000 FCFA (160 USD) per month for the light and appliances. Hence, the recourse wood utilization as an

energy source. The daily utilization of wood energy sequence is three times per day for a total duration of 6 hours of time (average of 2 hours per meal). It is noted that household consumption is around the average of 11.8 kg of wood. Therefore, there is no difference in demand for wood energy in the three regions selected. However, the impact of deforestation is more visible in Mao as compared to the two other states due to dryness, low rainfall and soil erosion. The use of renewable energy including photovoltaic is an alternative for the households surveyed. That is why big majority of households are favorable to the solar energy development but the Chadian government does not dedicate adequate investment.

5. CONCLUSION

The problems and constraints of access to electricity in Chad for households are mainly:

- Maintenance of the existing equipment: failure of the generating sets of the SNE due to lack of revision, know-how, oil supply deficiency, spare parts, safety parts, lack of highly qualified staff to maintain modern high-tech generators;
- Logistical dysfunction: some spare parts take 1 year before arriving;
- Insufficient fuel storage capacity in some plants;
- Scheduled and occasional releases to encourage self-production which results in a loss of earnings for the SNE;
- Concentration of the network in urban areas;
- Decay and incoherent network energy distribution;
- High cost of energy.

With regard to biomass, the country harbors significant sources estimated in the 1970s at 312 million hectares, but nowadays the area has decreased considerably in the order of 23 million hectares and Continue to fall by 0.6%, due in particular to uncontrolled and abusive exploitation combined with repeated droughts. As for solar energy, Chad is among the sunniest countries in the World with an annual sunshine of 2,850 hours in the South at 3,750 hours in the North. The overall radiation intensity varies on average from 4.5 to 6.5 kWh / m² / day. As for wind energy, the average speed of calm winds ranges from 4 m/s to 9 m/s from South to North.

From our study, about 44% of the population does not have access to electricity. The survey for this study covered only 3 states out of 23 in Chad. According to the official statistics, around 97% of the Chadian population does not have access to electricity. Because of the lack of scientific work on energy in Chad, we compared our results with those in the countries of Central Africa especially Cameroon. These studies show that the rate of access to energy in Chad is among the lowest (3%). For the rest of our research, we will extend the characterization of the energy demand profiles of a specific village and study solar photovoltaic techniques in order to consider decentralized rural electrification (micro-grid) as a solution to the energy problem of Groups of households studied.

The survey covered 3 states and the results are promising. It would be good to further study to a large number of the states and households in Chad. The survey methodologies for this study are based on questionary that is more statistical and reliable. Furthermore, it can suggest pursuing the work based on econometric modeling.

To promote renewable energy in Chad, the forum formulated to the public authorities the following recommendations to:

- Develop a national strategy for the development of renewable energies (REN);
- Adopt a framework law on renewable energies;
- Establish a Renewable Energy Agency, responsible for ensuring the implementation of the framework law and the REN development strategy, and to regulate the sector;
- Establish an incentive tax and financial framework;
- Establish a fund dedicated to the development of this sector;
- Develop a training program capable of supporting the development of the whole sector;
- Strengthen the capacity of national structures to allow better access to the opportunities that are the Clean Development Mechanism and Carbon funds.

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