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Energy Consumption and Energy Saving Potential in the Tertiary Sector: Case Study

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Abstract The main objective of this work is to analyze the energy consumption and the Energy Saving Potential in a sector of the Beninese economy: Case study city of Porto Novo. To achieve this goal, this research relied on literature reviews and the energy audit that were carried out in the buildings of the city hall and the districts of Porto Novo. The energy audit revealed the following situations: the devices in the various buildings are very old and the buildings consume more electrical energy. Indeed, with a need of 313.219 kWh of energy per day, these buildings consume up to 502.06 kWh per day, causing a loss of 188.84 kWh of energy per day. To overcome these various problems, the local authorities of the city of Porto Novo were offered the use of LED lamps (street lights) or solar street lights for public lighting. A proposal that could lead them to make savings ranging from 163,476,000 F to 250,000,000 F per year on public lighting in the city with the possibility of using non-polluting energy and thus participate in reducing the production of greenhouse gas. In addition, at the level of the buildings under the responsibility of the city hall of Porto-Novo. It has recommended that some behaviors for the Eco-responsible use of electrical energy, the systematic replacement of old installations by economical devices. Finally, the implementation of a hybrid system is highly needed currently which will also reduce the costs of the city hall's electricity consumption. These actions resulted in huge energy savings and lowered the city hall's electricity bill.

Keywords Energy consumption, Energy audit, Energy Saving Potential, sustainable renovation

Introduction

Energy is a resource that contributes to the well-being of individuals and also to the creation of wealth [1]. As such, it participates in improving the living conditions of populations and changes in society. Access to energy is therefore at the heart of a country's development. However, many countries have great difficulty in gaining access to energy. For A. Baimey et al. (2016) this difficulty in accessing energy is often accompanied by poor energy management, leading to unnecessary and costly over-consumption for too vulnerable communities. Particularly with regard to electrical energy, indicated that electricity consumption continues to rise whether in developing countries or in developed countries[2]. Faced with this problem of unnecessary and costly over-consumption of energy, L. Fagbemi (2015) proposed energy efficiency, like many other authors. For the author, energy efficiency is a very important aspect in the fight against climate change, the reduction of energy consumption and the preservation of energy resources. In companies, energy savings not only quickly amortize the additional cost of investing in electrical equipment, but also ensure the competitiveness of the company [3].

The cost of electricity in many sectors ofeconomic activity represents a significant share of operating costs [4]. It is therefore recommended to implement a rational management approach for electricity consumption, monitoring overall consumption and implementing solutions allowing consumption optimization and better electrical power put into play [5]. For A. Boursas, (2013), the management and rationalization of the use of electrical energy also contributes to reducing the costs of services and improving competitiveness. The implementation of modern management concepts and the reliability of electrical power supplies are essential for the operational safety of installations and the performance of operations [6].

The aim of an energy efficiency policy is not to reduce access to electricity for consumers, but to improve its effects, thereby increasing their quality of life rather than reducing it. Many authors have pointed out the importance of saving energy when faced with an increase energy consumption. Energy efficiency ultimately appears to be a vital instrument to meet consumers demand for electricity in short and medium-term. This led Benin to accelerate its actions in energy efficiency from the beginning of 2004, by undertaking a diversification of its energy mix while creating structures specializing in energy management such as the Benin Agency of Rural Electrification and Energy Management (ABERME), the National Agency for the Development of Renewable Energies (ANADER) and the General Directorate of Energy Resources (DGRE) .With this in mind to make more optimal and efficient energy consumption in Benin several actions have been carried out. As an example, the Beninese government adopted in 2018, Decree No. 2018-563 of December 19, 2018, setting minimum energy performance standards and the energy labeling system for lamps and air conditioners in the Republic of Benin. Very recently, the Millennium Challenge Account-Benin II proceeded in March 2020, in collaboration with the entities implementing the Program which are: the Directorate General of Energy Resources (DGRE), the Beninese Agency for Rural Electrification and Maitrise d'Energie (ABERME), National Agency for Standardization, Metrology (ANM) and the Beninese Electricity Energy Company (SBEE). To sensitize around forty journalists on energy efficiency and the popularization of decree No.2018-593 of December, 2018. However, despite all these contributions for good energy efficiency in Benin, the observation of poor energy management in territorial administrations is bitter and growing, such as the case of the City hall of Porto-Novo. Public lighting which remains on even in broad day light, until now, the use of incandescent lamps as luminaries for public street lamps (red lamps) on one hand, and on the other hand, residential buildings with energy-consuming lamps, old air conditioners which are still turned on in offices in the absence of users, lighting at the expense of the city hall with zero compliance with efficiency standards. This continues to generate monthly electrical charges for the municipality which vary between 22,000,000 F and 90,000,000 F. This charge according to them, it seems fixed and weighs heavily on the city hall. Despite all the energy efficiency policies put in place by the government and the various contributions of specialists in the field, thus, it is essential to implement as soon as possible, a vigorous energy efficiency policy in the city hall of Porto-Novo. It can allow to reduce relatively short-term the pressure on the energy demand of buildings and public lighting at its expense in a relatively short-term. The problems mentioned above motivated us in the choice of this research topic, in order to assess the optimal consumption of the city hall, to analyze its energy situation to deduce the potential for possible energy savings following the various measures of energy efficiency. This work involves building a database of possible avenues that can make energy consumption in service buildings efficient and reduce the economic and environmental impact of energy consumption. To achieve this, a study of the Porto Novo city hall site and the buildings under its responsibility was initiated in order to stem the difficulties linked to the over consumption of energy. This paper is organized as follow: A research methodology has been defined, after, an energy audit of the various buildings at the expense of the city hall is carried out. Then an analysis of the results of the audit is made and at the end of the analysis, results are presented and recommendations are made.

Materials and Methods

Energy Saving

Energy economics is any policy leading to the succinct use of energy a consumption item, needs for the satisfaction of its services. It is more interested in consumers who are a key player in the energy saving process.

Energy savings are actions taken in order to limit energy consumption or avoid the loss of energy produced. Several researches have approached the subject from different angles. However, for the present study the ideas built around energy and economic theory, energy consumption and economic growth.

Energy and Economic Theory

The various problems in the field of energy efficiency in recent years have prompted energy economists to organize several meetings around four investigation topics [7]:

The reconstruction of the economy around a large public sector in charge of "public service" missions, first in a context of relative autarky, then openness to the outside world.

The search for a certain energy independence at the time of the oil shocks and increased awareness of the perishability of the dominant energy resources;

The search for better competitiveness as the internationalization of economies increases and the possibility for each consumer to one day have access to the supplier of his choice;

The more recent one is that of an awareness that "globalization" brings together all economies and that it requires at the same time to be concerned with "global environmental effects" such as the greenhouse effect, the inter-temporal management of nuclear waste, problems which must be raised from the outset on an international scale and in the interests of inter-generational equity.

The relationship that exists at a given time in a given country between the amount of primary energy consumed during the year and the gross domestic product is called "energy intensity of GDP". It is generally expressed in "tonnes-of-oil equivalent" per dollar, euro or franc. This ratio is varying, several factors influence it including: climate, technology, price, regulations, agent behavior. Numerous works by historians have looked at the evolution, and determinants of this energy intensity and on the best way to model energy demand in relation to the expected evolution of a particular economic indicator (GDP, industrial production, consumption). Some works are of an econometric type, others more of a technical-economic type. In the latter case, we speak of the useful energy apprehended at the level of the needs to be satisfied and, with assumptions on the penetration of available technologies, we deduce the amount of final energy and primary energy that will be required[8].

A famous theoretical controversy in the late 1970s opposed Berndt and Wood (1975) on one hand, and Gregory and Griffin (1976) on the other [7]. For the former, capital and energy are above all complementary, that is to say; energy is always consumed through equipment. For the latter, they are largely substitutable so we can save energy by making additional investments. This controversy has been fueled by multiple empirical verifications using mostly translog production functions W. Diewert (1974). An attempt at "reconciliation" was proposed by Berndt and Wood in 1979: energy and capital are crude substitutes in the "technical" sense but remain net complements in the "economic" sense [9]. The relations that exist within the KLEM production function between capital (K), labor (L), energy (E) and other raw materials (M) have largely diminished with the decrease in the number of prospective studies on the evolution of energy demand and supply. The decline in planning in favor of market regulation has relegated long-term forecasting models to a secondary position. The debates on the optimal organization of the energy sector and on the formation of energy prices have not lost any of its intensity. In France, for example, the share of total energy distributed through a meshed gas or electricity network is around 56%. The rest is made up of petroleum or charcoal products sometimes sold through a network of pipelines, for certain petroleum products, but most often routed by distributors located throughout the territory (service stations, resellers).

Energy consumption and economic growth

Many papers discuss the relationship between economic growth and energy consumption. This abundance of literature testifies the interest for both researchers and policy makers in understanding the correlation and causality between these two variables. If energy use and economic growth are linked, any shock or decision on one of these variables would have repercussions over time on the other. Economic theory therefore developed very quickly around the long-term relationships between energy, electricity and the economy. Engle & Newbold (1974) therefore looked at the analysis of co-integration, which is the statistical property of time series that are related in time. This work has been widely taken up by Engle & Granger (1983, 1987) as a new approach to econometric analysis.

Therefore, it is a matter of determining the relationship between independent and identically distributed random variables (iid) assumed to be linked in the long-term from an econometric point of view. The main methodologies studied by the authors, as well as the empirical examples of their applications are presented as follows: Let us suppose two variables Xt and Yt which are independent and identically distributed. We say that there is a co-integrating relation between Xt and Yt if there is a variable

$$Z_t = X_t - \alpha Y_t \quad (1)$$

which is the linear combination of Xt and Yt. However, several hypotheses must be verified on the variables Xt and Yt . First, Xt and Yt must be integrated in the same order, the degree of integration being the order of differentiation to apply to make Xt and Yt stationary; with Zt stationary. The definition of Angle and Granger (1987) implies that all variables have the same order of integration Most often, macroeconomic variables are of order 1, that is, not stationary in level but stationary after first order differentiation. The analysis of co-integration makes it possible to clearly identify the true relationship between two variables by investigating the existence of a vector of co-integration and eliminating its effect, if any. There are two methods of testing co-integration relations: the Angle & Granger procedure described above as well as the Johansen procedure.

All the methods described above and other more detailed methods have enabled economists over the past three decades to publish a multitude of works relating to energy consumption and economic growth. The methodology is based on five main methods: bi-variate analysis, multivariate analysis with error correction, multivariate analysis of panel data with error correction, ARDL and causality analysis. The choice of method depends on the data available and the interest of the study. In bi-variate analysis, the aim is to investigate specifically whether the two variables are related over time and what the direction of causality is. In the panel analysis, the objective is to identify whether countries have homogeneous specificities in terms of the long-term relationship that may exist between economic growth and energy consumption in sense of causality that links them. Tang (2008) points out that the literature is full of controversial results.

In the context of the USA, Kraft & Kraft (1978) determined a co-integration between economic growth and energy consumption over the period 1947-1974, with a causality in the direction of economic growth towards energy consumption. Yu & Hwang (1984), again in the context of the USA, concluded that there was no causal relationship between economic growth and energy consumption over the period 1947-1979. In the 2000s, Stern (2000), using the VECM (Vector Error Correction Model) method, found a causal relationship between energy consumption and economic growth. These three (3) results show the divergence of results at the country level, depending on the data used and the method. Beyond USA, Glasure (2002) through the VAR model finds no causal relationship for South Korea from 1961 to 1990. Zhang &Al (2017) applied the 04 methods that are "Auto Regressive Distributed Lag (ARDL)", "Value At Risk (VAR)", "Vector Error Correction (VEC), "Label Switch Router (LSR)" for China on data from 1978-2016. They found divergent results according to each of the applied methods despite the existence of a long-term relationship between the two variables. Soni & Al (2013) found a causal relationship from economic growth to energy consumption for India from 1981 to 2011. Regarding panel data, Narayan & Smith (2008) looked at the G7 countries (Germany, USA, France, UK, Italy, Japan, and Canada) from 1972 to 2002 using the VECM method. The results indicated that energy consumption and capital drive economic growth. That is, intensive use of energy and capital are the main causes of economic growth in the world's most industrialized countries. Lee, Chang & Al (2008) applied the same method for the 22 OECD countries and found a bidirectional causality between capital, economic growth and energy consumption.

In Africa, Rufael (2006) conducted a bivariate panel analysis of 17 countries to understand the relationship between electricity consumption and economic growth from 1971- 2001 using the ARDL method given a small sample size. It uses data on capital per capita and energy consumption per capita. Gabon, Ivory Coast, Nigeria and Sudan have a co-integrating relationship when capital per capita is used as the dependent variable. Algeria, DRC (Democratic Republic of Congo), Egypt and Ghana have the same result when energy consumption per capita is used as the dependent variable [10]. For the other 11 countries in the study, no long-run relationship is obtained in the bivariate analysis justifying the absence of co-integration. With respect to causal relationships, four categories of results are obtained: Algeria, DRC, Egypt, Ghana and Cote d'Ivoire have causality in the direction of capital per capita to energy consumption per capita; Cameroon, Morocco, Nigeria have unidirectional causality from energy consumption per capita to capital per capita; Zambia and Gabon have bidirectional causality and finally Benin, Kenya, Senegal, South Africa, Togo, Sudan, Tunisia, Zimbabwe and Congo do not have causality in the sense of Granger. This work has been revisited using a multivariate analysis, in this case considering capital per capita, energy consumption per capita, and capital formation per capita [11].

The results are inconsistent with the 2006 study because 9 countries (Republic of Congo, Gabon, Nigeria, South Africa, Zimbabwe, Benin, Cameroon, Morocco, and Zambia) have a long-term relationship between electricity consumption and economic growth.

Research methodology and energy audit of the Porto Novo city hall

In order to carry out a scientific study or the resolution of a scientific problem in a more efficient way, a methodology is used. The choice of the research methodology to be used in a scientific work is crucial for the possible conclusions of the studied phenomenon. The methodology adopted here is based on documentary research, field interviews and energy audit.

Research methodology

In order to achieve the objectives of our study, we must have a rigorous methodology and reliable analysis tools. These include practical data on electricity consumption through site surveys and actual consumption through invoices and energy audits. The data related to the consumption of all the sites was obtained from the "Société Béninoise d'Energie Electrique (SBEE)". The collection of essential data for this work was carried out on the basis of the audits performed. First, we recorded the number of different electrical equipment used and their characteristics (including types, and Power), the surfaces (including opaque walls, roofs, wooden doors and glassing) and the volume of different destinations in addition to the number of occupants per destination. Then, thanks to the interview, we collected information about the occupants' behaviors, such as the number of working days per week, the time of use of the equipment, forgetfulness, the standby mode towards the equipment.
The data campaign was carried out block by block, office by office and room by room. This step is critical because the relevance of the study depends on the reliability of the data obtained.

Calculation of energy consumption

The annual energy consumption calculated from the electric bills is called the real consumption E_r and the annual consumption estimated from the data of power and time of use is called the estimated consumption. E_e
The actual consumption is given by the equation:

$$E_r = \sum_{t+1}^{12} E_n \quad (2)$$

E_n: is the monthly energy consumed in kWh
n: is the number of months.
The estimated energy consumption has been calculated as the product of the power and the time of use. This formula is also applied to all the different energy consuming items within the sites.

$$E_g = \sum_{t=1}^{N} P_i T_i \quad (3)$$

P_i is the unit power in kW, T_i the usage time of an appliance in hours (h/year) and N: the number of appliances listed during the survey on a whole site.
The time of use was determined through the behavior of the users, the number of days per week and per month in order to determine the number of hours used to estimate the consumption over a year E_e.
In this calculation, it is assumed that a month has 30 days which is four weeks plus two days.

$$T_i = N_h + N_j + N_m \quad (4)$$

N_h;N_j etN_m represent the number of hours per day, the number of days per month and the number of months per year respectively.

Energy Consumption Analysis

The site's energy consumption was analyzed based on the estimated consumption (E_e); it's broken down into five (05) consumption items. The targeted consumption items are: air conditioning, lighting, ventilation or air circulation, office automation and miscellaneous.

Item 1(lighting): On this item, the energy efficiency analysis consisted in replacing the energy consuming bulbs by more economical ones. As a result, the wattage and types of bulbs were identified during the site survey.
Item 2(air conditioning): Efficiency in terms of consumption due to air-conditioning consists on the one hand of reducing the power of air-conditioners in case of over-sizing and on the other hand replacing air-conditioners with low cooling efficiency coefficient (EER).
In the present work, the EER (Energy Efficiency Ratio) was noted and the operating times were estimated during the site survey. In addition, a thermal balance was carried out in all air-conditioned premises of the Porto Novo city hall and districts, in order to detect cases of over-dimension and to remedy them appropriately
Item 3(Ventilation or air mixing): The analysis of the energy efficiency on this item consists in replacing the fans of low performance. Indeed, some fans are not efficient, so they can be replaced by more efficient fans.
Item 4 and 5(Office equipment and miscellaneous): These items consist of office equipment (photocopiers, printers, computers and fax machines) and other energy consuming devices (including coffee machine and electric heater).
The diagnosis of these items is mainly linked to the behavior of the users. The right location of the concerned devices in the premises can allow to reduce considerably the energy consumption.

Energy audit of the Porto Novo city hall and districts

The objective of the energy audit is to establish a strategic investment action plan that will generate energy and financial savings based on the evaluation of the building's energy performance. The audit covers the building envelope, heating system, air conditioning system, ventilation system, domestic hot water production, and lighting system.

Building Energy Audit

There are several types of energy audits: quick audit with site visit, energy cost analysis, standard energy audit, detailed energy audit. Performing an energy audit is more of an iterative process (an algorithmic process) than a linear one. However, a general procedure can be sufficient to outline the process for most buildings.

Building and Facility Data Analysis

The main objective of this step is to evaluate the characteristics of the building's energy systems and energy consumption profiles. Building characteristics can be gathered from architectural/mechanical/electrical drawings and/or from interviews with building operators. Energy consumption profiles can be obtained from a compilation of energy bills over several years. By analyzing the historical variation in energy bills, the auditor can determine if a season and weather have a strong influence on the buildings' energy consumption. The tasks to be performed in this step are presented below with key deliverables.

- Collect at least three years of energy data (to identify a historical energy profile)
- Identify the types of fuel used (electricity, natural gas, fuel oil, etc.) to determine the type of fuel that has the greatest influence on energy consumption.
- Determine fuel consumption profiles by fuel type (to identify peak consumption by fuel type)
- Establish the energy cost breakdown (power demand and consumption) to assess whether the building is penalized for power demand and whether a cheaper fuel can be substituted.
- Analyze the influence of climate on fuel consumption (this requires weather data for the years under consideration)
- Perform an analysis of electrical energy consumption by building type and size (the energy signature of the building can be determined, establish energy consumption ratios per unit area) to compare to typical ratios.

Site Survey

The results of this step will be used to determine if it is cost-effective to recommend more detailed energy audits. The tasks in this step are as follows.

- Identify the client's interests and needs.

- Verify existing operation and maintenance procedures.
- Determine the operating conditions of the main energy consuming items (lighting, HVAC, motors, etc.).
- Estimate, based on occupancy, the schedules of equipment and lighting needs

Building Energy Reference Model

The objective of this step is to develop a baseline model that simulates the existing energy consumption and operating conditions of this building. This model is used as a reference to estimate the energy savings for the different selected improvements. In this step, the main tasks to be performed are:

- Obtain and review architectural, electrical and fluid system, technical and control plans;
- Examine, test, and evaluate the efficiency and performance of the equipment;
- Obtain all occupancy schedules and equipment usage conditions (including lighting and air conditioning);
- Create a baseline model of the building's energy consumption;
- Calibrate the baseline model using energy data and/or survey data.

Evaluation of energy saving measures

In this step, a list of cost-effective measures is drawn up. For this purpose, the following tasks are recommended:

- Prepare a comprehensive list of energy reduction measures (using the information obtained from the site survey);
- Determine the gains resulting from the different relevant energy saving measures in the building using the baseline model developed in step 3;
- Estimate the capital costs of the solutions;
- Evaluate the cost-effectiveness of each energy efficiency improvement measure using an economic method (simple payback analysis or global discounted cost analysis).

The tables below summarize the recommended energy audit procedure for both commercial and industrial buildings. Energy audits for thermal and electrical systems are treated separately because the costs are different.

Energy audit of the Porto Novo city hall and district buildings

There are many electricity consumptions items within the service buildings. There are many possible ways to optimize consumption. They are all the very important since, according to a survey conducted at the Porto Novo City Hall, the city hall consumes an average of 15,000 kilowatt-hours per month for the offices and all related services, and a little over 210,000 kilowatt-hours for public lighting.

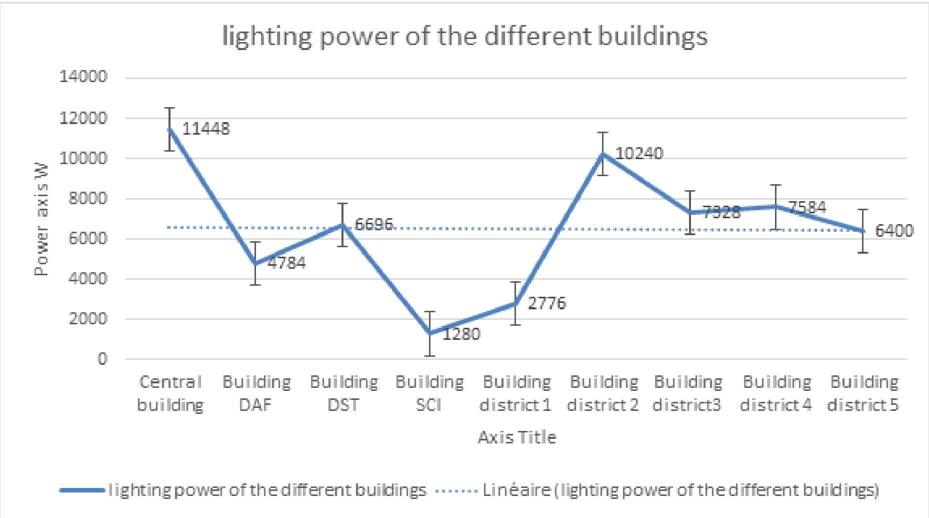


Figure 1: Typical bow arrangement

Energy demand for lighting in the various buildings

The distribution between natural and artificial lighting is not at all good in the offices, despite the presence of windows in almost all offices. Most of the light bulbs used need to be reviewed and replaced by energy saving lamps. The lighting equipment is very different in the different buildings and even offices. The lighting in the common areas is totally artificial because these areas do not face the outside. The improvement of natural lighting seems impossible due to the location of the common areas in the premises and the obsolescence of the installations. Figure 1 shows the variation in lighting consumption in the different buildings.

Energy demand of the computer park

Diverse are used in the office to accomplish tasks . These equipments takes a big share in the energy consumption of the city hall.

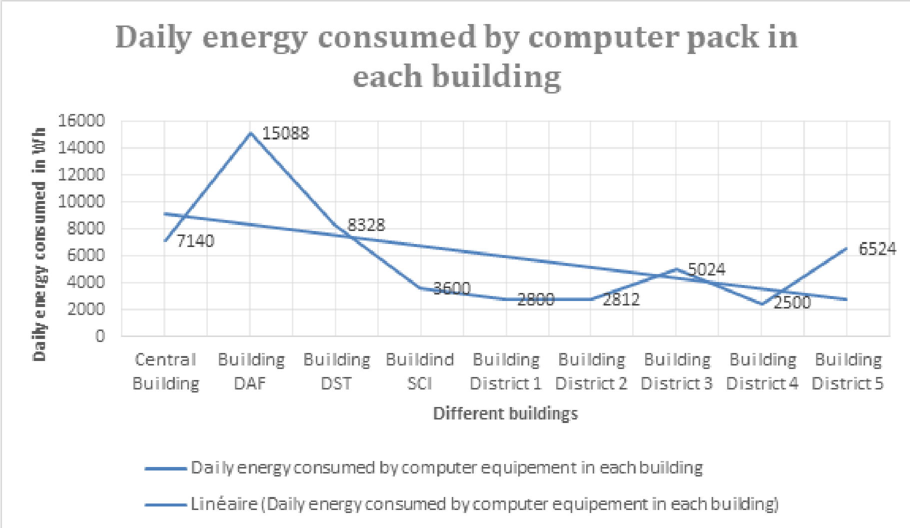


Figure 2: Energy consumption of the computer

Energy demand of air conditioning and ventilation

In the refrigeration sector, it should be noted that most of the equipment are no longer in good working condition. If the replacement of this equipment were to be considered, it would be very interesting to plan for low consumption equipment.

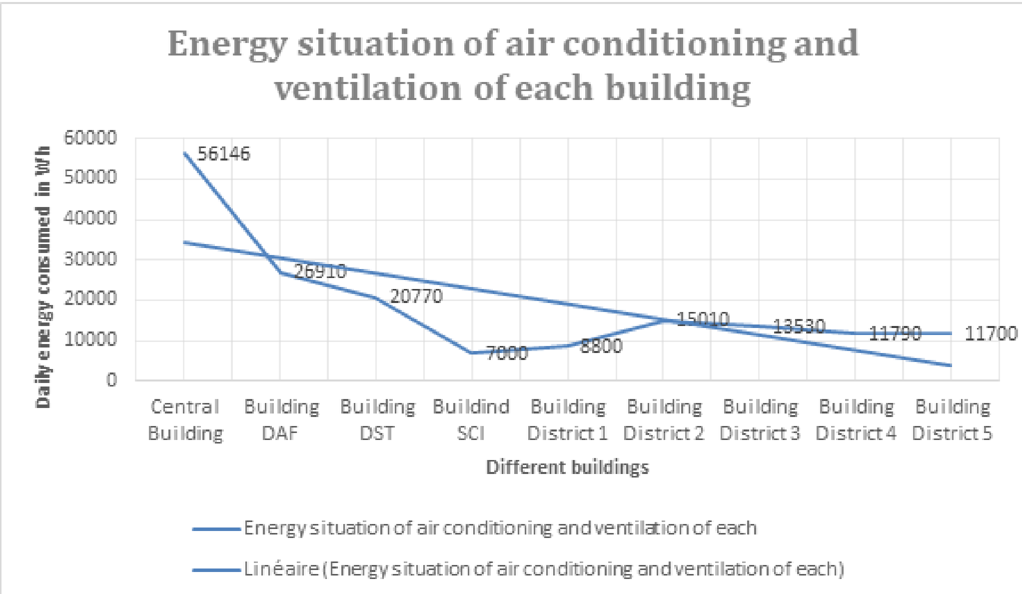


Figure 3: Energy situation of air conditioning and ventilation of each

Energy demand of refrigerators and electric pumps

It should be noted that here the number of these appliances are not very representative in the buildings and in other buildings these appliances are also dressed to the point where some of them do not even work

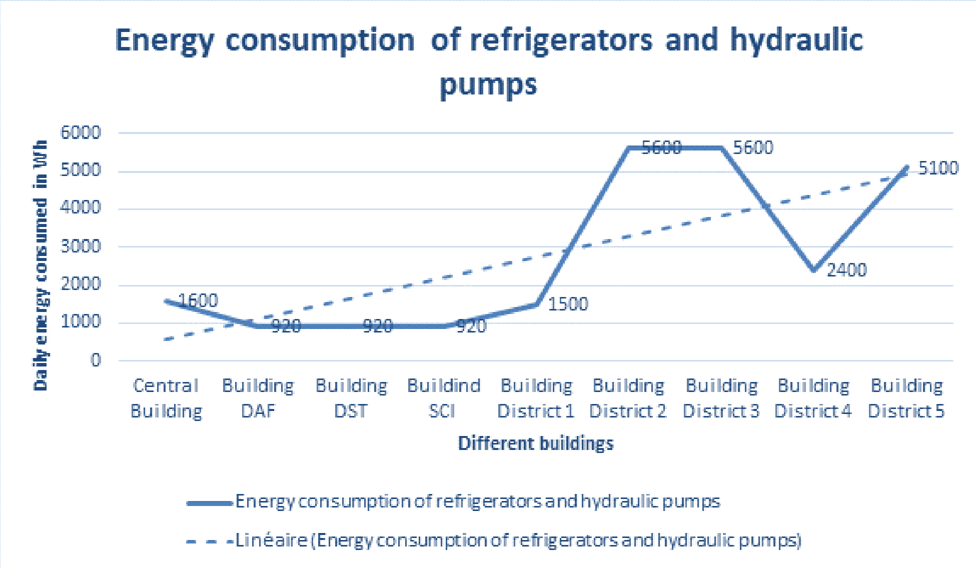


Figure 4: Energy consumption of refrigerators and hydraulic pumps

Summary for all consumption items and analysis

Figure 5 shows that the energy situation from one consumption item to another. This clearly shows that the air conditioning and ventilation weighs heavily in the consumption of buildings.

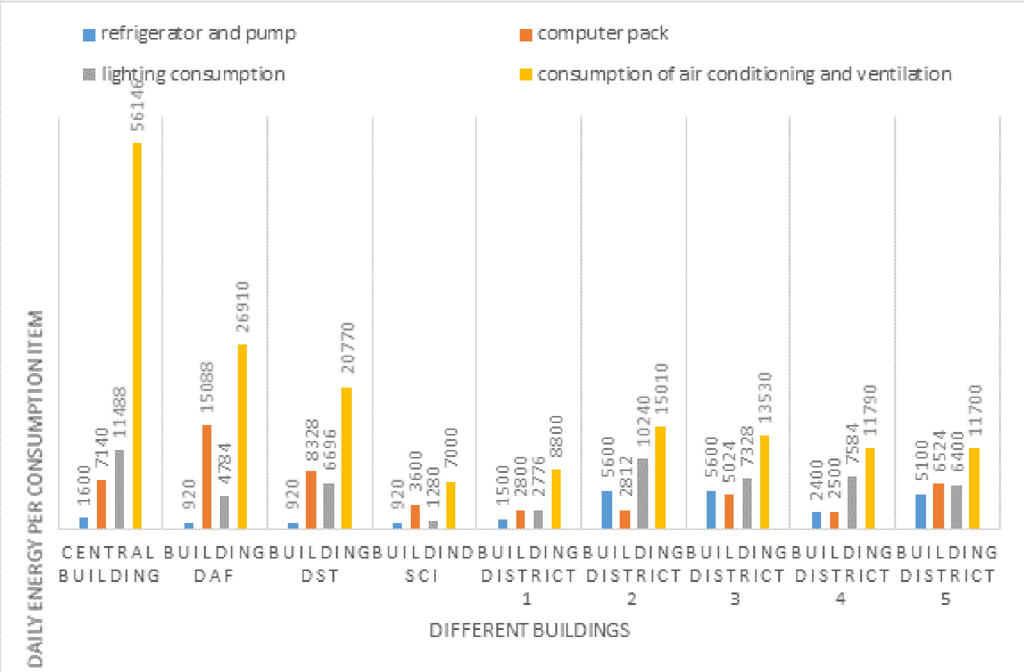
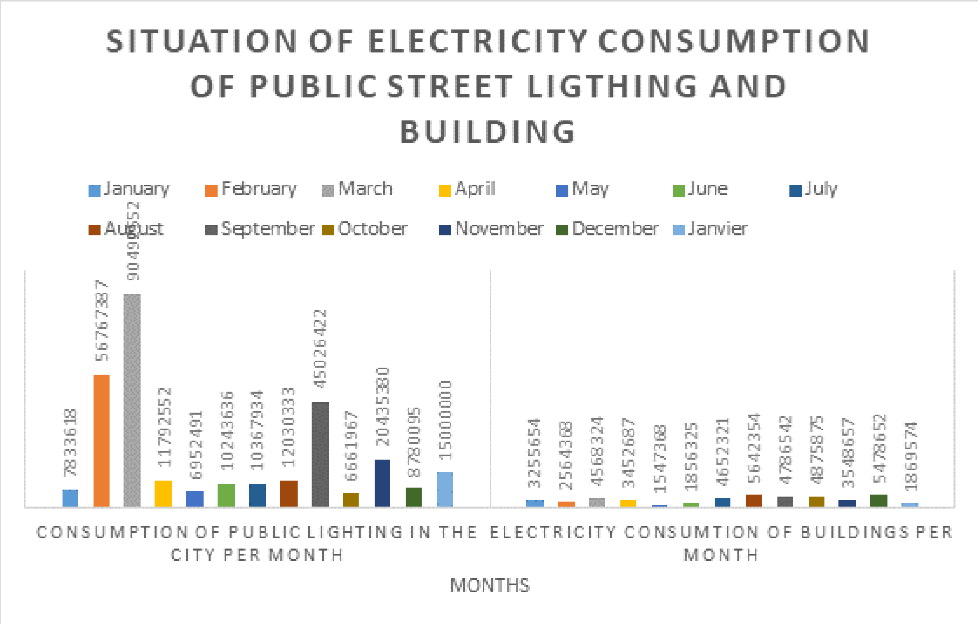


Figure 5: Variation in energy consumption per consumption item per building

Practical energy consumption of the city hall

Evaluation of the supplier's bills (SBEE)

The study of the electricity network bills sent by SBEE from January 2019 to January 2020 showed an average annual consumption of 205 MWh for the buildings under the responsibility of the city hall and about (2394 MWh) for public lighting. We can note a global average consumption of 2,599 MWh which is not negligible at all in the national energy balance. It has notice that that the consumptions increase in an inexplicable way at the level of public lighting and in the same way at the level of the residences. This is a major concern for the municipal authorities.



Street lighting: 92,11% Building consumption: 7,88%

Figure 6: Situation of electricity consumption of public lighting and building

It can be seen here that the consumption of the buildings and various residences of the city hall only represents 7.88% of the annual consumption of the city hall, whereas the PE represents the major part of the energy consumption, i.e., 92.11%.

Evaluation of the energy consumption of the generator

The importance of the continuity and quality of the power supply justifies the use of a generator on the site of the city hall. Within the framework of the activities of the city hall and its various services, in order to face any interruption and disturbance on the SBEE network, the city hall was equipped with an emergency generator. This generator consumes an average of 200L of diesel per month since there are not many disruptions or cuts in the SBEE network. This is estimated at an average of 120,000F per month.

Critical analysis of the practical energy situation of the city hall

The electricity bill provided by SBEE is estimated at an average of 3,699,900 francs per month, for a total monthly energy expenditure of 3,819,900 francs.

Figure 7: Share of consumption SBEE and generators

The main sources of consumption in our buildings are air conditioning/ventilation (31%), lighting (22%), IT equipment (12%) and cooling and electric pumps (2%). The time of the day is also crucial in the energy consumption of the city hall. Some studies have shown that depending on the number of people and services in the city hall, energy consumption can increase yearly. For example, it is higher between 7 am and 7 pm than between 7 pm and 7 am. The energy consumption per day can vary from 320 to 502 kWh, which is relatively consistent as consumption. This consumption, in 2014 was even higher than now with consumptions that went up to 700 kWh per day. The use of the offices has a huge influence on the energy consumption of the building. Occupant awareness is essential and can lead to significant savings. The replacement of air-conditioning units cannot be undertaken without a dimensioning to verify that the new ones do not unbalance the network (load losses or inadequate power). As far as ventilation is concerned, it is necessary to make the occupants aware of the impact of the obstruction of the air inlets or extractor vents.

Results & Discussion

The different results are presented and analyzed respectively on the installations of the Porto Novo City Hall, the installations in the districts, the power of the installations of the Porto-Novo city Hall, the energy to be consumed by the buildings and the cost of consumption, the theoretical study on the different measures taken during the site visits and finally the presentation of the results of the Network analyzer.

4.1 Facilities in the Porto Novo City Hall and districts

In the four buildings, namely the central building, the DST building, the DAF building and the Identity Card Service (SCI) building of the Porto-Novo City Hall, there are 151 appliances that consume electrical energy. These devices are among others: lamps, air conditioners, refrigerators, office computers, laptops, printers, brewers, photocopiers, inverters and regulators. Overall, 47% of these devices are in the central building, 24% in each of the DST and DAF buildings and 5% in the SCI building. We can also see that 45% of the electrical appliances in the City Hall are lamps, 14% are air conditioners, 11% desktop computers and 10% printers.

In the five districts of the Porto Novo council, we counted 217 electrical appliances. Lamps represent 55% of these appliances, followed by brewers 27% and computers 6%.

Power of the installations of the city hall and the districts of Porto Novo

Table 1 represents the total power of the installations of the four buildings of the city hall and the buildings of the districts of Porto Novo

Table 1: Specification of Models in stage

Buildings	**Total Power (in W)**	**Frequency in %**
Central building	21335	27.79
DST building	15842	20.63
SCI building	2510	3.27
DAF building	10596	13.8
District 1 building	3606	4.7
District 2 building	5558	7.24
District 3 building	6512	8.48
District 4 building	4663	6.07
District 5 building	6154	8.02
Total	76776	100

This table provides information on the total power of all the appliances installed in the city hall and borough buildings. With a total power of 76,776 W, the installations in these buildings have an average power of 8530.66W per building. The power of the installations in the Central Building of the City Hall represents 27.79% of the total power, 20% for the DST building and 13% for the DAF building. The five districts share 4.7%, 7.24%, 8.48%, 6.07% and 8.02% of the total power respectively.

Energy consumed by the buildings and cost of consumption

In terms of energy consumption, Table 2 gives an estimate per day, per month and per year of the energy required to operate these devices normally.

Table 2: Energy Consumption Needs

	Average	Standard deviation	Total
Energy consumption /day (in kWh)	34.80	22.69	313.21
Energy consumption /month (in kWh)	765.64	499.15	6890.82
Energy consumption /year (in kWh)	9045.66	5899.55	81410.94

According to Table 2, the appliances installed in the Porto Novo City Hall buildings and in the borough, buildings will require 313.21 kWh of electrical energy per day, 6890.82 kWh per month and 81,410.94 kWh per year. Each building will therefore need an average of 39.80 kWh of energy per day; 765.64 kWh of energy per month and 9045.66 kWh of energy per year.

Table 3: Energy Consumption Cost

	Average	Standard deviation	Total
Cost /day (in F CFA)	3967.44067	2586.51115	35706.966
Cost /month (in F CFA)	87283.6947	56903.2454	785553.252
Cost /year (in F CFA)	1031205.24	672549.309	9280847.16

From Table 3, shows that these facilities will cost a total of 35,706 CFA francs per day, 785,553 CFA francs per month and 9,280,847 CFA francs per year in terms of energy consumption costs for the territorial authorities of the Porto Novo council. This implies that the authorities will spend an average of 3,967 CFA francs per day, 87,283 CFA francs per month and 1,031,205 CFA francs per year on electricity consumption for each building.

Theoretical study on the different measures taken during the site visits

In order to know the actual electricity consumption of the buildings under the responsibility of the municipal authorities of the city of Porto Novo, the two slots have been considered. The first time slot is from 7 am to 7 pm and the second from 7 pm to 7 am. After the energy audit we had the results recorded in the following table:

Table 4: Effective electricity consumption per building

Electricity Consumption	07h à 19h (kWh)	19h à 07h (kWh)	Total /day (kWh)
Central building	100.5	33.2	133.7
DST building	45.9	10.3	56.2
SCI building	13.8	2.25	16.05
DAF building	66	15.6	81.6
District 1 building	19.76	4.25	24.01
District 2 building	36	7.5	43.5
District 3 building	41.9	10	51.9
District 4 building	35.4	12	47.4
District 5 building	38.7	9	47.7
Total	397.96	104.1	502.06

Source: Carried out from audit data

Table 4 shows that the buildings of the Porto Novo City Hall and the buildings of the five districts currently consume 502.06 kWh of electrical energy per day, divided into two tranches. In fact, for the first period from 7:00 am to 7:00 pm, these buildings consume 397.96 kWh of electrical energy and for the second period from 7:00 pm to 7:00 am, these buildings consume 104.1 kWh. Each building therefore consumes an average of 44.21 kWh of energy between 7am and 7pm; 11.57 kWh between 7pm and 7am and 55.78 kWh of energy per day.

Potential for energy savings in the Porto Novo City Hall

Our investigations in the different structures of the city hall of Porto Novo have shown us that there are two main sources of consumption at the expense of the city halls of our councils which are: Source 1: public lighting and Source 2: offices and residences. The statistics concerning the survey on the consumption in charge of the city hall of Porto Novo were examined in order to try to identify the causes of the over-consumption of the devices and the high cost of the bills of public lighting. First of all, we can note the obsolescence of the electrical installation in the majority of the offices and even of the used devices. Then the bad behaviors that generate huge losses of energy.

Starting with the latter, we note an important difference between the energy needed by the old electrical installations and the energy actually consumed.

Table 5: Comparison between energy required to consumed and effective theoretical energy

Buildings	Energy to be consumed /day (in kWh)	Effective theoretical energies /day (kWh)	Energy saving potential (kWh)
Central building	87.534	133.7	46.166
DST building	36.939	56.2	19.261
SCI building	11.88	16.05	4.17
DAF building	48.894	81.6	32.706
District 1 building	14.376	24.01	9.634
District 2 building	28.206	43.5	15.294
District 3 building	31.392	51.9	20.508
District 4 building	24.274	47.4	23.126
District 5 building	29.724	37.7	7.976
Total	313.219	502.06	188.841

The analysis of the above table shows us a clear and important difference between the energy actually consumed by the buildings and what they should consume normally. Indeed, the installations of the central building of the city hall, for example, consumes 133.7 kWh of energy per day instead of 87.534 kWh. That is a difference of 46.166 kWh of wasted energy. This implies that even if nothing is done in an extraordinary way, the adoption of good behaviors going in the direction of the reduction of electrical energy can contribute to save considerable energy at the city hall. So, the rational use of energy perceived as the set of actions that allow the reduction of the quantities of energy consumed for the production of a unit of a product or a service while preserving the quality, can contribute to save up to 188,841 kWh of electrical energy per day at the city hall of Porto Novo. These measures include: awareness; energy efficiency for lighting; energy efficiency for air conditioning and refrigeration.

In order to contribute to the rationalization of the consumption of electrical energy at the Porto Novo City Hall, our study proposes two avenues for local authorities: first, in a very practical way we propose some behaviors to adopt for more energy saving in the facilities and secondly, the implementation of a hybrid system. We have noted two main sources of electrical energy consumption in the city halls of our municipalities and the statistics show the following facts:

- **Source** 1: In the majority of cases, halogen lamps are still used for streetlights throughout the city. Let us note that the current street lamps consume an average of 199.5 MWh per month, i.e., 22,743,000 CFA francs, while LED lamps consume 80 MWh per month, i.e., 9,120,000 CFA francs, and solar street lamps are evaluated on their maintenance, which amounts to approximately 25,000,000 CFA francs every 5 years, i.e., approximately 500,000 CFA francs per month.
- **Source 2** (Offices and residence): Here lamps of 85W by place, 60W and 40W are used for lighting of offices of 4m², thus no harmonization at this time when we speak about energy efficiency. Here, we also noticed that the residences and offices in charge of the city hall consume nearly 80% of their daily energy between 07h and 19h.

These different results obtained thanks to the participation and collaboration of the users of the city hall are sufficient to make brief proposals for the energy optimization of the consumption of the electrical loads of the city hall.

In relation to source 1 two proposals are possible:

Proposal 1: Change the incandescent lamps by economical LED lamps

Proposal 2: Change the street lamps by solar street lamps.

Table 6: Comparison of average consumption costs of different types of street lights

Period	Average consumption cost of halogen lamps (street lights) in FCFA	Average consumption cost of LED lamps (street lights) in FCFA	Cost of maintenance of solar street lights (in FCFA)
Per month	22 743 000F	9 120 000F	500 000F
Per year	272 916 000F	109 440 000F	6 000 000F

From Table 6 we see that the transition from halogen lamps to LED lamps will result in a significant saving of 163,476,000 F per year on the city's public lighting.

A very important amount of money which will be used in several other fields. The transition to solar street lamps will make the city hall gain a huge amount of money (more than 250 000 000 F) with the possibility of using a nonpolluting energy and thus take part in the reduction of the production of greenhouse gases.

Besides the public lighting, we can also propose to the authorities the installation of economic devices in the offices; for example: lamps of 20w, ecological air-conditioners of less than 500W, televisions of 65W, office computers and laptops respectively of 75W and 50W, printers of 50W, brewers of 35W, economic photocopiers of power less than 100W, ecological fridges and solar pumps.

Hybrid Systems

The problem with the high cost of electrical energy in buildings in general and especially in city hotels, the varying and non-guaranteed power produced by the SBEE can be solved by coupling the sources of supply and forming a so-called hybrid system (HS). A hybrid electrical system is an electrical system, comprising of more than one power source. The hybrid system may include a storage device. From a more global point of view, the energy system of a given country can be considered as a hybrid system. Here we want to talk about the hybrid renewable photovoltaic power system (SHSERP) and the SBEE.

This type of hybrid system is very advantageous for buildings and especially for hotel buildings, since the majority of their consumption occurs between 07:00 and 19:00, which is more than 70% of the daily consumption of the buildings. In these cases, it is estimated that the conventional system can complete the less than 30% of the night. The objective of this system when they work in autonomous mode, is to feed without interruption the loads of these offices, administrative buildings. The photovoltaic system that we propose for tertiary buildings is without storage since these buildings consume the majority of their daily energy between 07h and 19h. Since energy storage is the real cause of the high cost of solar systems, this hybrid system is entirely profitable from the investment cost and its life span which is about 25 years. Most of the time, the office consumers require alternating current, so it is a special system that will be made with a network inverter that will transform the direct voltage received from the modules into alternating voltage in this special case with a frequency and a value equivalent to that of the network, which will feed the loads directly and can be supplemented by the network in case of insufficiency while being in phase with the latter and meeting a set of requirements and safety imperatives.

Conclusion

The research work presents a study on the consumption and the potential of energy saving in a tertiary sector of the Beninese economy. In this context, the adopted approach consisting in a first step to make documentary research on the concepts of consumption and potential of electrical energy saving in the second step to realize an energy audit of the buildings of the city hall of Porto Novo and of its districts allowing to detect the possibilities of optimization and improvement.

One of the findings is that, the obsolescence of the electrical installation in the majority of the offices and even of the appliances used on all the electrical installations. There are very old appliances. On the other hand, the energy audit reveals that all the installations of the buildings consume 502,06kwh/Day of energy instead of 313,219kWh/Day that is to say a loss of 188,841kWh per day of energy. This loss is due to the bad behavior of the users of these buildings. The local authorities pay more than 21,527 F per day for the over-consumption of energy by the various appliances, i.e., more than 5,500,000F per year of loss in the offices.

To overcome these problems, the research revealed a propose in a first analysis, the reduction of the cost of electrical energy consumed by energy efficiency measures. These measures are among others are: awareness; energy efficiency for lighting energy efficiency for air conditioning-refrigeration. It was proposed that the pure and simple replacement of appliances by new economic devices. For example, changing incandescent lamps to energy saving LED lamps, changing street lamps to solar street lamps. The transition from halogen to LED can save the city hall a significant amount of 163,476,000 F per year on the city's public lighting. And the transition to the solar street lamps can make the city hall gain a huge amount of money (more than 250 000 000 F) with the possibility of using a non-polluting energy and of participating so in the reduction of production of greenhouse gases. Very important amounts of money which can be used in several other fields. Finally, propose to the local authorities of the city of Porto Novo, a system including more than one energy source. It is a hybrid electrical system with renewable photovoltaic energy sources (SHSERP) and SBEE. It is a very profitable system that will save the authorities a lot of money.

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