End-use Metering Campaign for Residential Houses in Nigeria

September 2013

Metering Campaign Report

DRAFT VERSION

Energy Commission of Nigeria
Federal Ministry of Environment
United Nations Development Programme
Global Environment Facility

Preface

For a population of over 160 million people in Nigeria, only about 50% of the population have access to electricity. The power (about 5,000 MW) currently generated in Nigeria is inadequate and unstable, forcing a large portion of the industry, businesses and households to rely on diesel and petrol generators as primary or back-up source of electricity, which can be expensive, polluting and a source of greenhouse gas emission. More also, a large part of the energy generated in Nigeria is wasted due to the wasteful behavior and the use of energy intensive and inefficient technologies.

The Nigerian government has put in place measures to increase electricity generation, which forms a major part of the policy objectives of previous and current administrations. The overall current electricity demand is estimated to be much higher than 10,000 MW. Much of government's focus is to generate electricity using gas powered thermal stations, which is non-renewable source and will result in the emission of greenhouse gases. With Nigeria having one of the largest gas reserve in the world and a large population, the high demand for electricity will force the government to invest and commission several more thermal stations to meet up with demand

Imbibing energy efficiency culture will help more people to have access to electricity. It also help to minimize the building of power stations, thus the money for building power stations will then be spent on other sectors of the economy. The promotion of large scale, concrete, national energy efficiency program is a critical demand-side initiative to help reduce the energy consumption of a series of major end-use appliances, in particular air-conditioners, refrigerators, electrical motorized equipment, heating equipment and lighting. The project will assist the Nigerian Government to increase access to electricity and at the same time mitigate the emission of greenhouse gases resulting from energy generation.

United Nations Development Programme (UNDP) with support from the Global Environment Facility (GEF) and in Collaboration with the Energy Commission of Nigeria, the Nigeria Federal Ministry of Environment (FME) and the National Centre for Energy Efficiency and Conservation (NCEEC) has started the implementation of a project to promote energy efficiency in Nigeria. The overall objective of the project is to improve the energy efficiency of series of end-use appliances (lighting, air conditioner, refrigerators, fans, heating equipment etc) used in Nigeria through policy and legislative instruments and demand-side management programme. The project aimed at reducing energy demand. The project will help to increase access to electricity in Nigeria and at the same time mitigate the emission of greenhouse gases resulting from energy generation.

Part of the activities to achieve the objective of the project will be to set minimum energy performance standards (MEPS) for end-use appliances notably lighting, air conditioners and refrigerators within the project life span. Setting standards for appliances will require an empirical approach. Before standards are set, it is imperative to understand current level of efficiency, which will guide the setting of MEPS. To gather baseline data that will help to set MEPS for selected appliances, the end-use monitoring study was carried out across the six geopolitical zones of Nigeria. The objectives of the study were to assess the current level of energy efficiency of some appliances (lighting, refrigerators and air conditioners) used in Nigeria in order to set minimum energy performance standard (MEPS) for these appliances. And the data will also serve as a tool to campaign among Nigerian policy makers and legislators to promote energy efficiency.

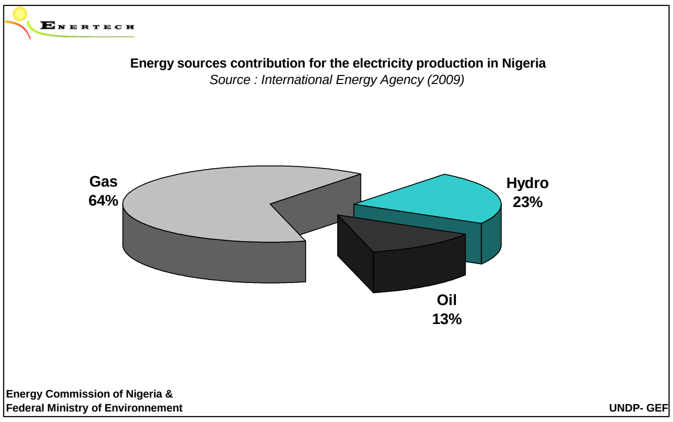
SUMMARY

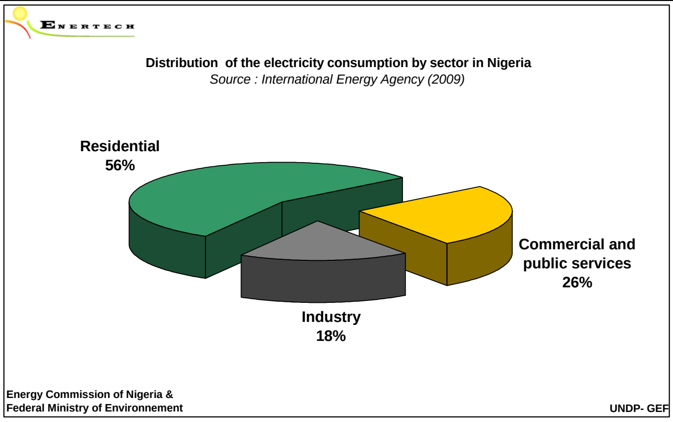
CHAPTER 1 : INTRODUCTION

1.1 STAKES AND OBJECTIVES

1.1.1 Context

Only 50% of the whole population of Nigeria (over 150 million people) have access to electricity, mostly the ones leaving in the urban areas. In the area connected to the electricity grid, consumers suffer from frequent power outages which can last for several hours. The power in Nigeria is unstable, forcing a large portion of the industry, businesses and households to rely on diesel and petrol generators as primary or back-up source of electricity. This solution is expensive and source of noise and air pollution. Furthermore, a large part of the generated energy is wasted due to the behaviour and technologies.





It has already been shown in different countries that household electricity consumption could be greatly reduced without any change in the rendered service, or in comfort. A first demonstration was done between 1995 and 1997 in France with the Ecodrome project, which was lead by « Cabinet O.SIDLER » (which later became ENERTECH) and financed by the European Community (contract number 4.1031/S/94-093) and ADEME (French Agency for Environment and Energy Management). The results of this project showed that we could save up to 40 % of the electricity-specific appliance consumption of the households by using efficient appliances. On a household scale, 1,200 kWh/year were saved. By extrapolating the French and European savings from this value, one found that 26 TWh/year could be saved in France and 180 TWh/year in Europe. The latter value represents the annual Italian electricity consumption.

1.1.2 Objectives of the project

The overall objective of the project is to improve the energy efficiency of end-use appliances used in Nigeria with the aim to reduce energy demand. The project will help to increase access to electricity in Nigeria and at the same time mitigate the emission of greenhouse gases resulting from energy generation

The objectives of the study are :

- to monitor the current level of total household electricity usage
- if possible, to assess energy efficiency of the main household electrical appliances (refrigerators, air conditioners and lighting appliances)

The result of study could be used to campaign among Nigerian policy makers and legislators on the need to promote energy efficiency. The study will also guide the development of Minimum Energy Performance Standard (MEPS) for Nigeria.

Indeed, one goal of the UNDP GEF Energy Efficiency Programme is to set MEPS for end-use appliances in Nigeria. It will focus on lighting, air conditioners and refrigerators. Before standards are set, it is imperative to monitor actual consumption of appliances. It will guide the setting of MEPS.

The first objective of this campaign is to describe the state and structure of the specific-electricity uses in the residential. This project will produce reference data that will allow research teams, and organisations that work in the modelling and forecasting of electrical consumptions, to base their works on reliable data and on sane basis. No pertinent action can save the cost of a sharp analysis of the initial situation. The descriptive approach is one of the most important contributions of this project.

1.1.3 Operationnal partners

Different partners were involved in this project :

- The ***United Nations Developpement Programme*** (UNDP) with support from the ***Global Environnement Facility*** (GEF) was the initiator and coordinator of the project.

- ***ENERTECH*** in France, because of its experience in the monitoring campaigns, was in charge of providing the monitoring equipment and analysing the data.

- ***Energy Commission of Nigeria*** and ***National Center for Energy Efficiency and Conservation*** was in charge of assembling a representative sample, installing and dismantling the monitoring equipment. ENERTECH provided a training session on the use and installation of monitoring equipment to four Nigerian engineers of this agency.

1.2 DESCRIPTION OF THE GENERAL METHODOLOGY

1.2.1 Generalities

The first part of the monitoring campaign, concerning the one month households, was initially scheduled from January 2012 to October 2012. However, due to problems in gathering a representative sample, the monitoring campaign finally lasted from march 2012 to march 2013 (see chapter : Feedback).

1.2.2 General characteristics of the measurement campaigns

The goal of the study was to monitor the household electrical consumptions for light, cold appliances and air conditioning in 230 households:

- 210 households were monitored for one month. The electrical appliances were monitored at a time step of 10 minutes. 6 sessions of 35 households were done in the 6 different geopolitical zones of Nigeria (see chapter: Description of the sample).

- 20 households are currently monitored for one year. This is the second part of the metering campaign The electrical appliances are also monitored at a time step of 10 minutes.

Table from figure 1.1 represents the forecasted monitoring plan.

Uses	Serial Wattmeter	Lampmeter	Wattmeter with ammeter pliers	Temperature sensor
General meter			1	
Air conditioning			1	
Cold appliances	2			
Lighting	1	5	4	
Miscellaneous	1			
Temperature				1
Total	**4**	**5**	**6**	**1**

Figure 1.1: forecasted monitoring equipment per household

The choice of the households was done by the Energy Commission of Nigeria and National Center for Energy Efficiency. The sample takes into account geographical and socio-economic criterions, representative of the different types of Nigerian households.

1.3 DESCRIPTION OF THE MONITORING EQUIPMENT

Several types of metering devices were used to achieve the monitoring campaign. They are described in this paragraph.

- Lampmeters were used to measure the consumption of the light sources that draw a constant electrical power (incandescent bulbs, CFL, etc.). All the light points with constant power were metered. The lampmeter measured the time during which the light source was switched on and the power was measured separately during the meter installation. From these two measurements, we were able to determine precisely the consumption's of each light point in the households. We used Wattmeters connected in series with the lamp to determine the consumption's of the halogen lights, for which the power drawn was not constant.

- The consumptions of the cold appliances (fridge, freezer, fridge-freezer) were monitored using Wattmeters connected in series with the appliances. The serial wattmeter was directly plugged into the wall sockets. The household appliance to be monitored was then connected in the trailing socket of the wattmeter.

- Some appliances (Air conditionning, Mains, Lights) were monitored directly from the main switchboard of the household. These measurements were done using the Multivoies system which was installed inside the breaker board (or fuse box).

- The inside temperature were monitored using thermometers.

1.3.1 The Multivoies system

The MULTIVOIES^{tm} system from the french ***OmégaWatt*** company is designed for the measurement of a large number of channels of power consumption and energies in electrical switch boxes. It includes a Din rail mounted concentrator to measure voltages and supply power to the system, and several modules equipped with current sensors.

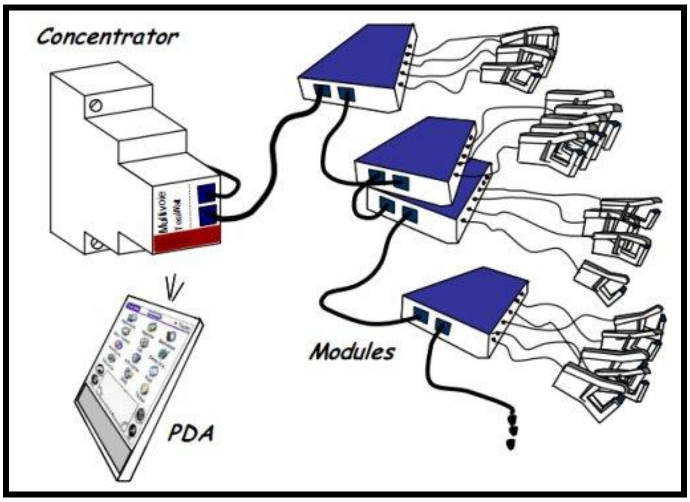


Figure 1.2 : Multivoies system overview

The system interfaces with the user thanks to a Personal Digital Assistant, using Infrared communication or low power radio (Bluetooth). The concentrator and the modules are connected to a high speed industrial data bus with factory assembled RJ11 connectors. The modules are fitted with standard closed miniature current transformers (0-45 Amps).

The main features include:

- Simultaneous measurement of electric power in tens of lines per switch box,
- Measurement of power ranging from 2 W to 230 kW per phase with a wide range of current sensors (Current jaws, miniatures current transformers, Rogowski coils). Typical accuracy: 2%.
- Recording of active energy and voltages with periods of 1 second to 60 minutes (5 month memory for 10 minutes period – independent on the number of current modules)
- Records power quality (voltage sags).

Figure 1.3 : Concentrator and Module for the multivoie system

1.3.2 The Serial wattmeter

The serial wattmeter developed by ENERTECH was designed with the aim of taking measurements of active energy and voltage for single-phase appliances with power level lower than 2,6 kW. Placed in serial between the standard socket-outlet 230 V~ and the plug of the appliance to be measured, it does not require any intervention on the distribution system.

The serial wattmeter is entirely autonomous and can be left in place several months according to the frequency of the selected data memorizing. At the end of the measurement period the stored data are read using the Oscar software which transfer them to a PC for analysis.

Figure 1.4 : Serial wattmeter overview

The features for the serial wattmeter includes:

- Voltage area: between 0 - 250 Vac (the power supply for the serial wattmeter is not taken on that entry - measurements continuous even in the absence of voltage sector)
- Maximum load: 12 amps
- Serial wattmeter power supply by standard batteries: 2 X LR6 (AA) 1.5V (autonomy: 400 days)
- Current measurement with two automatic gauges
- Resolution: 0.1 Wh - the resolution decrease with the power (progressive coding)
- Working Led: a short impulse every 4 seconds.
- Period of measurement: adjustable from 1 to 60 minutes
- The drift of the clock is of approximately 10 minutes per year
- 65 KB of memory: 1,3 year of autonomy in term of memory size for recordings at 10mn.

1.3.3 The Lampmeter

The lampmeter is an electronic recorder of reduced size. It can be installed in the immediate proximity of the appliance to evaluate, without requiring connection with the electrical supply network.

An optical sensor ensures the detection of the durations of lighting for the equipments. This allows a very fast assembly without intervention on the electric circuits. You just have to fix it near the lamp to be analyzed and to direct the sensor towards the source of light. A LED flickering indicates then if the sensor is correctly positioned.

Entirely autonomous, they can be left in place several months according to the frequency of selected data memorizing. At the end of the period of measurement the data is recovered using the Oscar software which transfer the data on to a PC where they will be analyzed.

Figure 1.6 : Lampmeter

The design features include:

- A micro controller with very low electric consumption,
- A nonvolatile memory of strong capacity (64Ko) allowing a recording going until 32000 events,
- A standard Lithium battery allowing an autonomy higher than 4 years
- An indicator of operating condition of the appliance. (The LED is active during 4 minutes after connection with the PC interface but it is not necessary to connect the interface to the PC.)
- Events recording (lightings and extensions):
    - Resolution for duration is one second.
    - Precision for the dating of the events is 4 seconds.

1.3.4 The Thermometer

The thermometer is an autonomous electronic data logger of reduced size provided with a temperature sensor. It takes regularly measurements and stores at selected time steps the average of several measurements (2 minutes interval between each measurement except at the time step of 1 minute) (ex: carry out the average of 5 measurements for a 10 minutes step).

The thermometer has a very broad range of measurements (-50°C to 120°C).

Figure 1.7 : Thermometer – Indoor and Outdoor models

The data are stored in a non volatile memory of strong capacity (64Ko) allowing a recording going up to 65000 measurements (1 byte per data, for an autonomy of approximately 1 year and 3 months for recordings at 10 minutes interval).

The recorder uses standard Lithium battery (standard CR 2032) allowing an autonomy equal to 2 years for a 10 minutes interval and one year for a one minute step.

1.4 ANALYSIS OF THE COLLECTED DATA

Once the data received by ***ENERTECH***, they were controlled by a software tool aimed at certifying the coherence of the transmitted records. This data was subsequently assembled in a database. The filtering and preparation work is very long and meticulous. But it is necessary to be sure that the data used is trustable. We decided to remove from the database any record that was doubtful or not reliable.

The data were stored in 1 database for a total of more than 14 million data.

1.5 DESCRIPTION OF THE SAMPLES

The monitoring campaign was split between 6 areas with 35 households per area. This will give us a good picture of the differences that can exist between the North and the South of the country, the major cities and the smaller one's, …

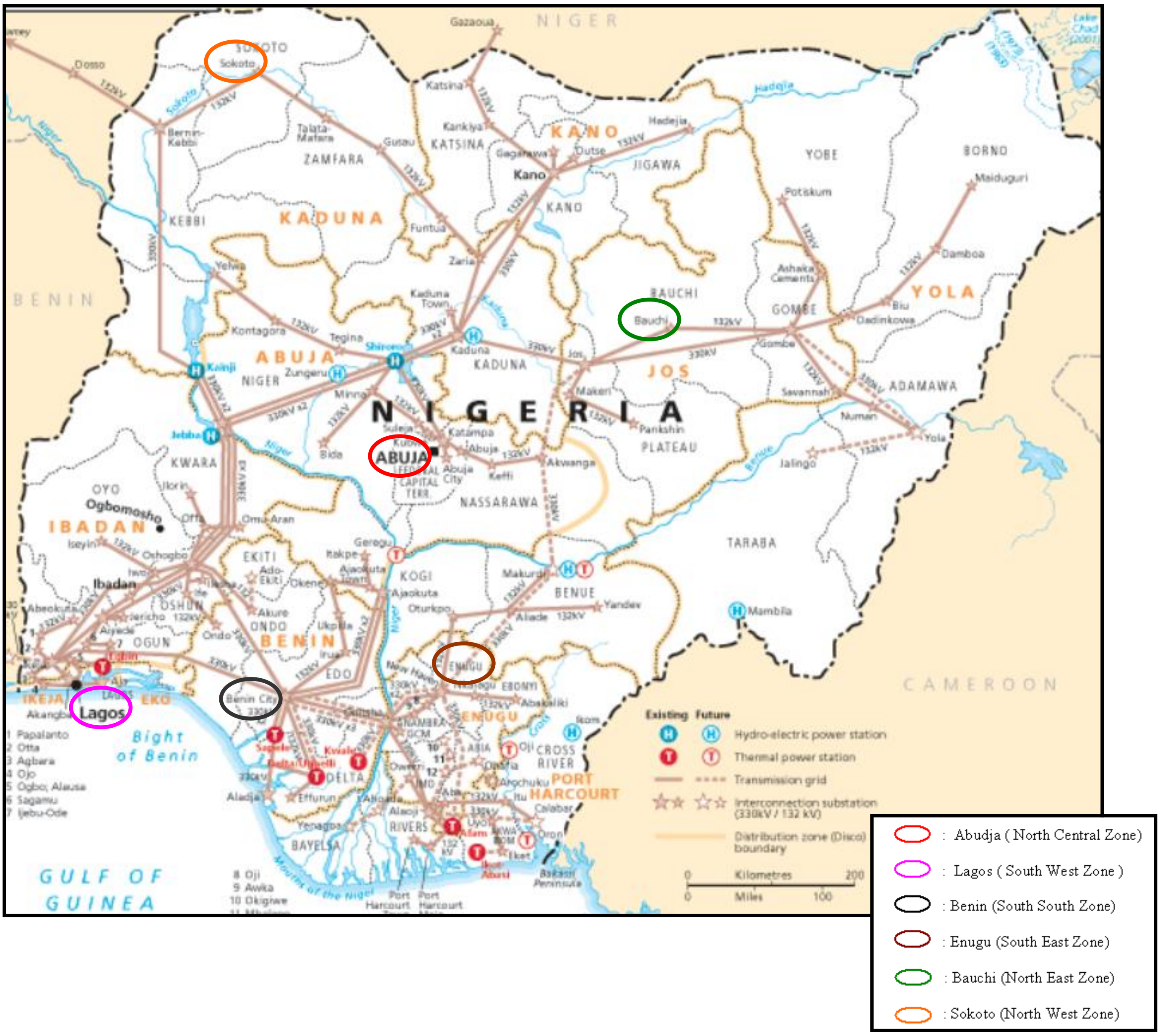


Figure 1.8 : The different areas for the monitoring campaign

1.6 INDOOR TEMPERATURE

The temperatures for the different areas were not monitored at the same period and the next graphs were not corrected using a seasonality factor. Therefore the conclusions has to be refined with the data issued from the one year households.

1.6.1 Indoor temperature daily curve

Figure 1.9 shows the indoor temperature daily average curve for each zone. A difference of 6-8°C can be found between the areas of Sokoto and Benin, located respectively in the north and the south of the country. The average indoor temperature in Nigeria turns around 29,5°C.

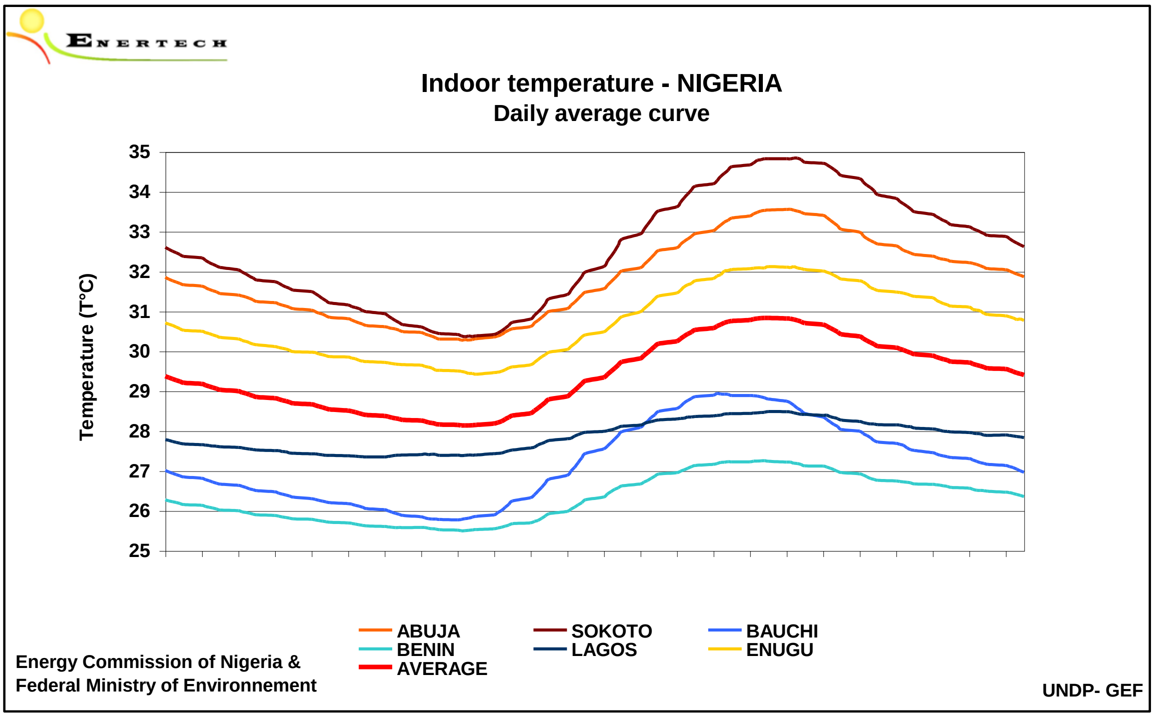


Figure 1.9 : Indoor temperature daily curve

1.6.2 Indoor temperature cumulative frequency

Figure 1.10 shows the cumulative frequency for the inside temperature per area. To get this kind of curve, we classified all the values from the max to the minimum. The difference of temperature between the north (Sokoto) and the south (Benin) of the country is also visible in that graph. We can see that 20% of the time, the temperatures are always higher than 27°C and 65% of the time, higher than 26°C.

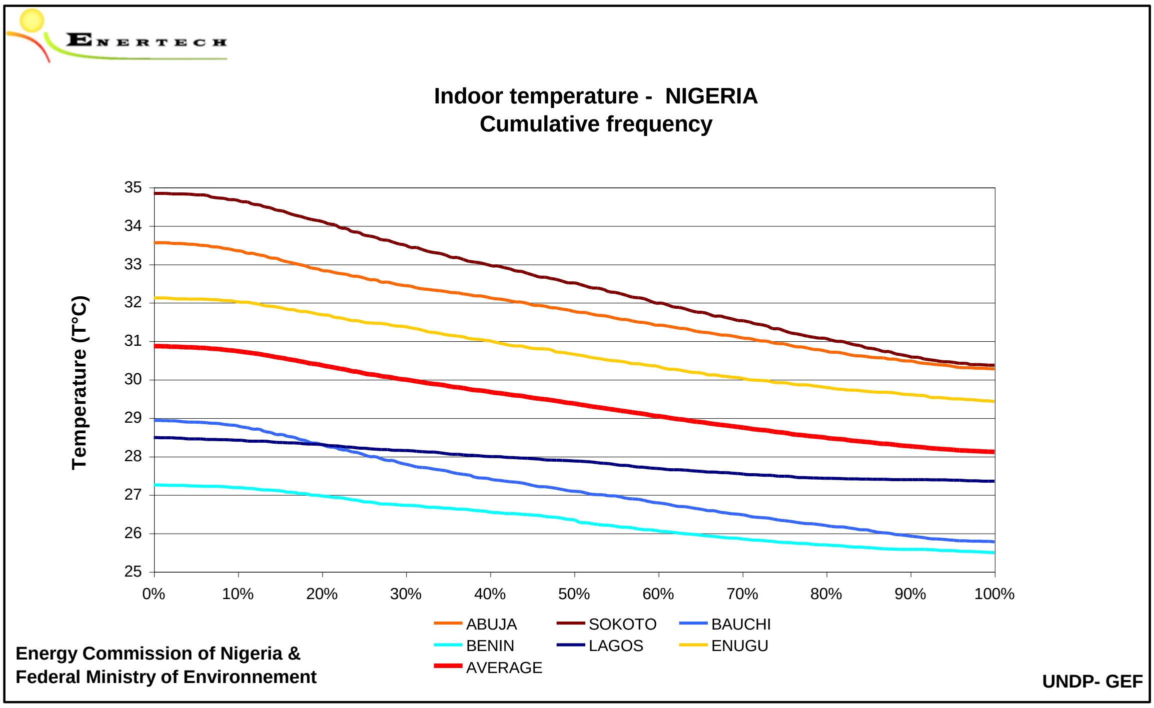


Figure 1.10 : Indoor temperature cumulative frequency

CHAPTER 2 : QUALITY AND STABILITY OF THE POWER GRID

2.1 Distribution of power access and power outages

The Nigerian power grid is not able to ensure a permanent supply of electricity. This unstable electricity supply varies, depending on the geographic situation. It was possible to record the average voltage per ten minutes with the multivoie system and therefore to detect the periods with/without power supply.

2.1.1 Distribution of power access and power outages for Nigerian Households

Figure 2.1 shows us the part of power access/ power outage during the monitoring campaign. This graph was done using the data from all the households for all the areas. The criteria used to sort the data between the two categories was the voltage. If V>0, we considered that we were in a "Power access" period, if V=0, we were in a "Power outage" period. We can see that the power outage periods represent 45% of the time. These periods will have a big influence in the rest of the report concerning the calculation of the average annual consumptions : an appliance that is off for half of the time because there is no power will certainly not consume the same as an appliance which will be on for the whole time.

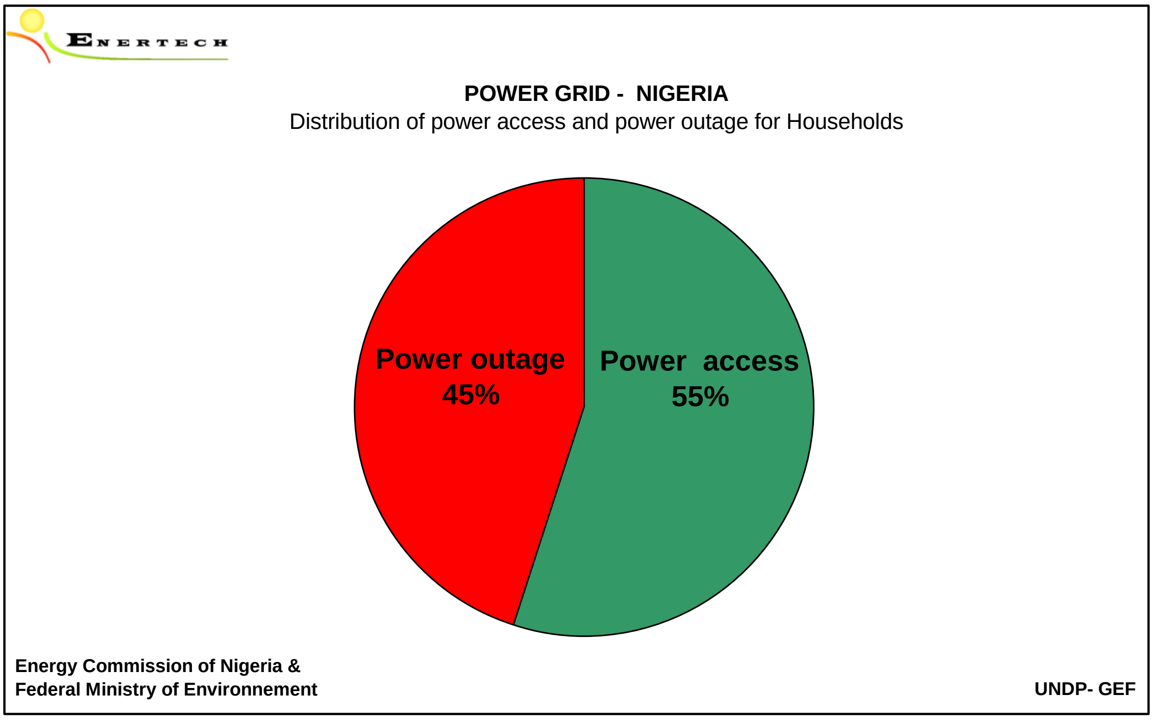


Figure 2.1 : Distribution of power access and power outages

2.1.2 Distribution of power access and power outage for each geopolitical zone

Figure 2.2 represents the part of power access/ power outage per monitoring area. The areas away from the power plants have more power outages : it varies from 34% for Lagos area to 61% for Bauchi and Sokoto areas.

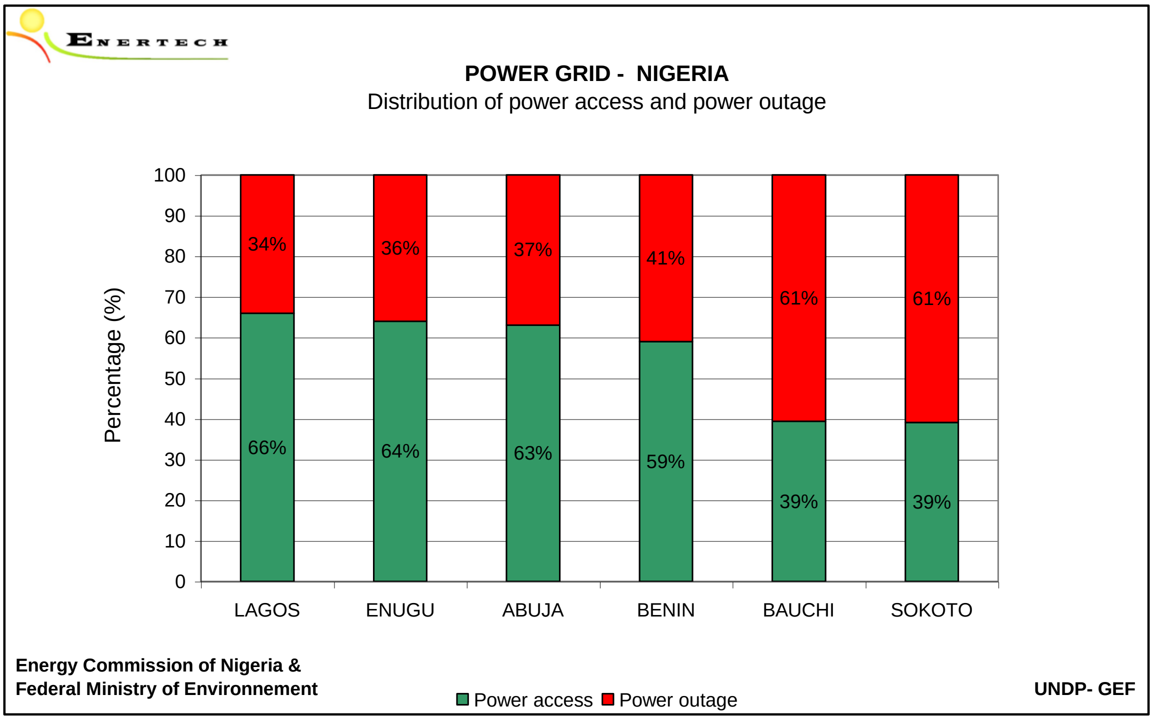


Figure 2.2 : Distribution of power access and power outage per zones

2.1.3 Daily curve of the part of power access

Figure 2.3 and 2.4 represent the average part of power access during a typical day for the different areas. Power outage are most likely to occur in the middle of the day, when the industries are also in need of energy. Figure 2.4 splits the area in four geopolitical zones. We can see that each zone has a slight variation in the pattern of the curve but for all, the power outage occurs most often during the day.

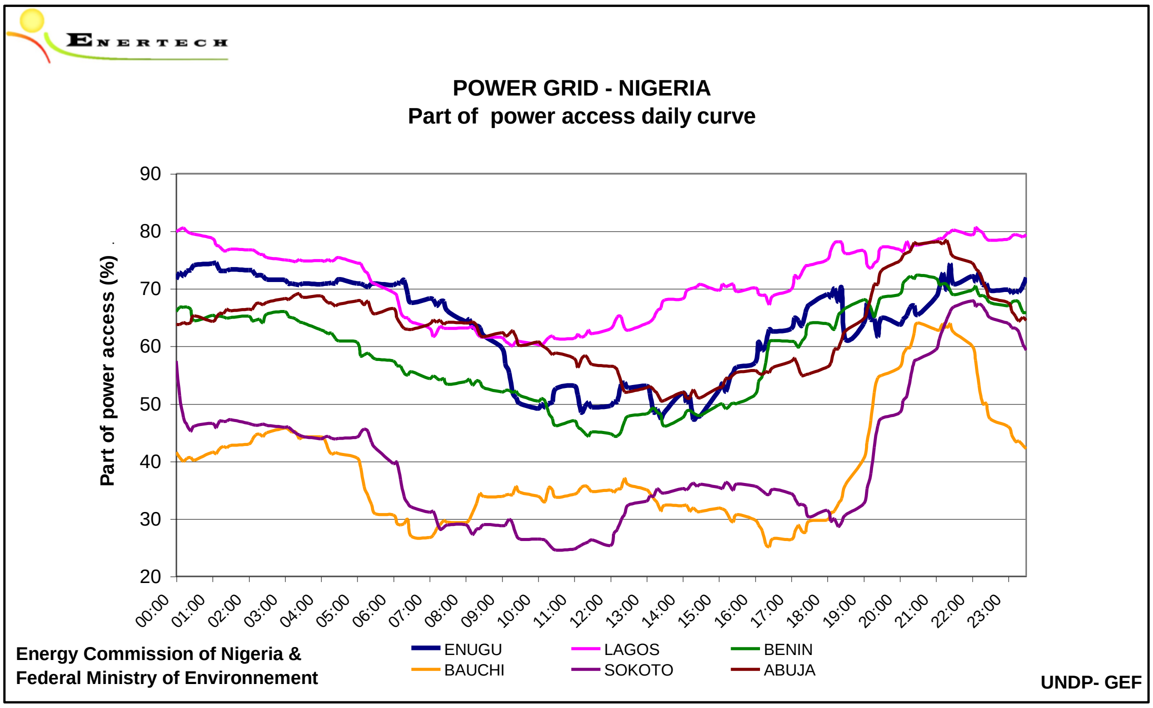
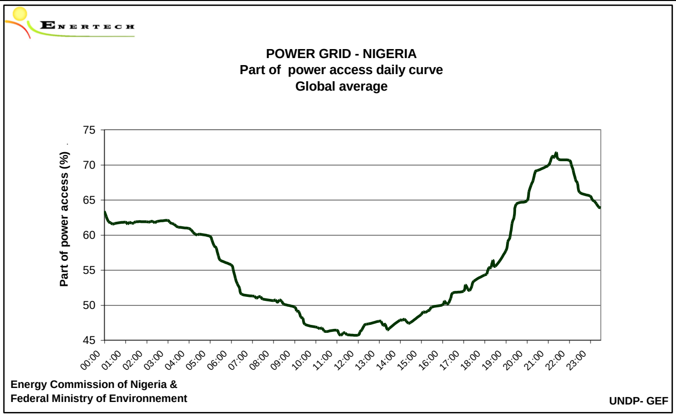
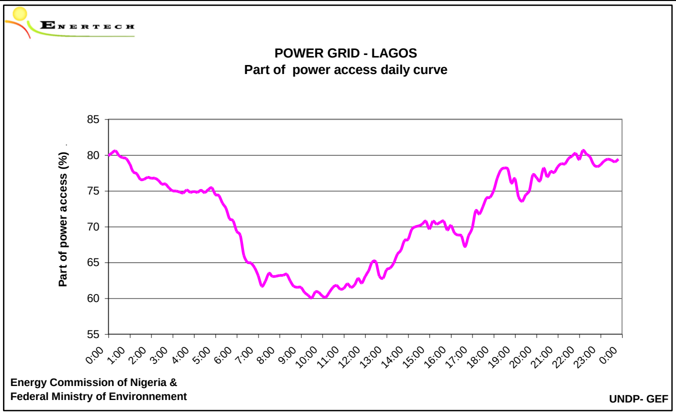


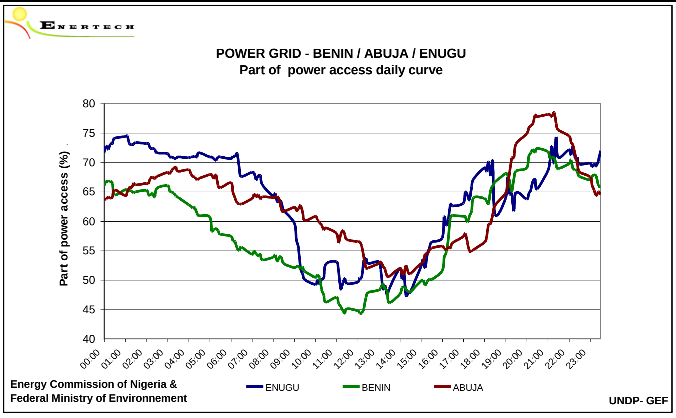
Figure 2.3 : Part of power access daily curve of each geopolitical zone



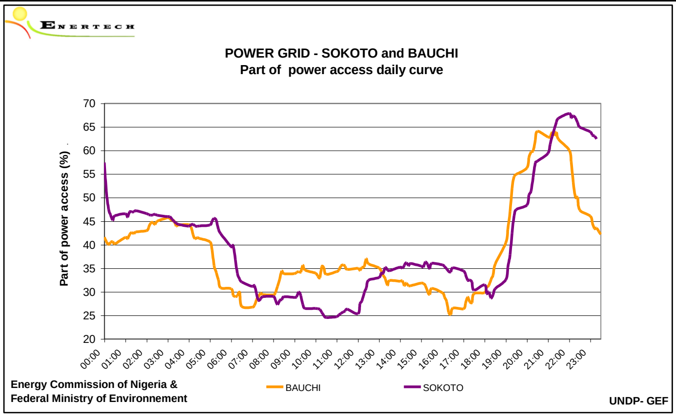
Part of power access daily curve in NIGERIA



Part of power access daily curve in LAGOS



Part of power access daily curve for ABUJA, BENIN and ENUGU



Part of power access daily curve for BAUCHI and SOKOTO

Figure 2.4 : Part of power access daily curve of each geopolitical zone

2.1.4 Average voltage during power access per Households

Figure 2.5 shows us the average voltage during power access per households. For each one, we calculated an average value using all the data for which the voltage was not zero. The results per household are between 160 and 240 Volts with an average at 205 Volts. An appliance connected to a 160 Volts power source will not have the same consumption and behaviour as the same appliance connected to a 240 Volts power source.

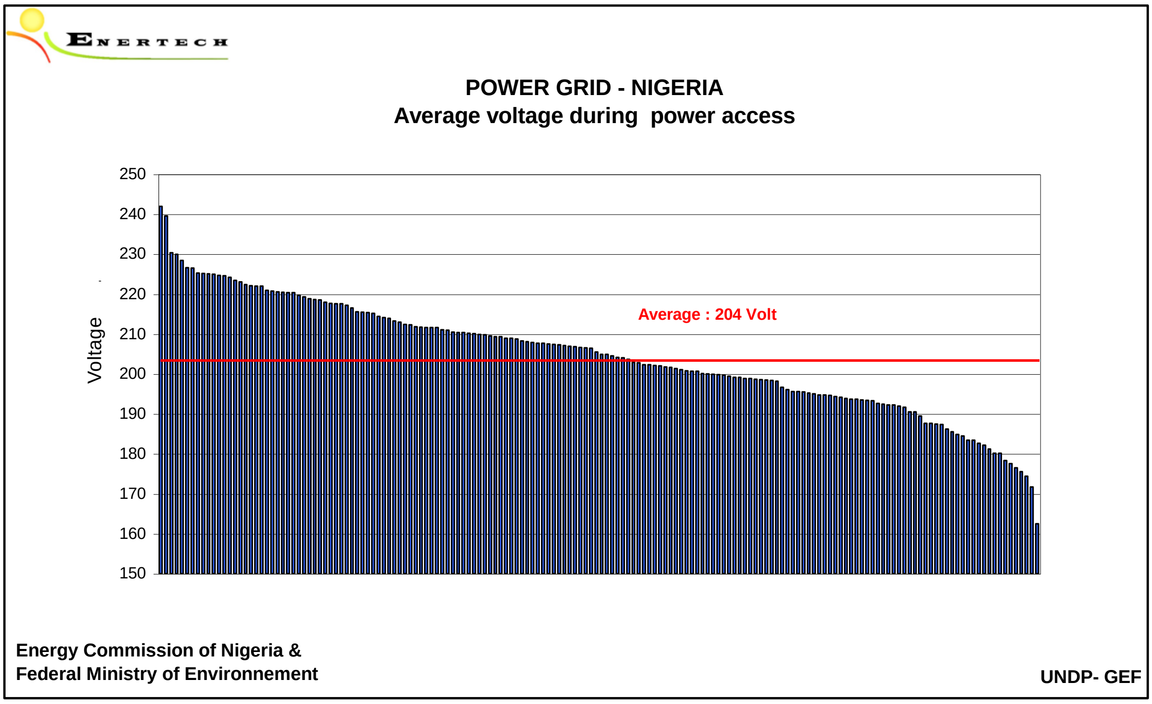


Figure 2.5 : Average voltage during power access

2.1.5 Average and extremum voltage during power access per geopolitical zone

Figure 2.6 shows us the average and extremum voltage for each geopolitical zone. Lagos is the city where the voltage is the most stable, with an average value at 211V. For that area, one household was monitored during the monitoring period with an average voltage at 228V, and one at 184V which represent the minimum. Benin is the area with the highest voltage variation between the households. The average voltage is very close for all the six areas and vary from 201 to 210 Volts.

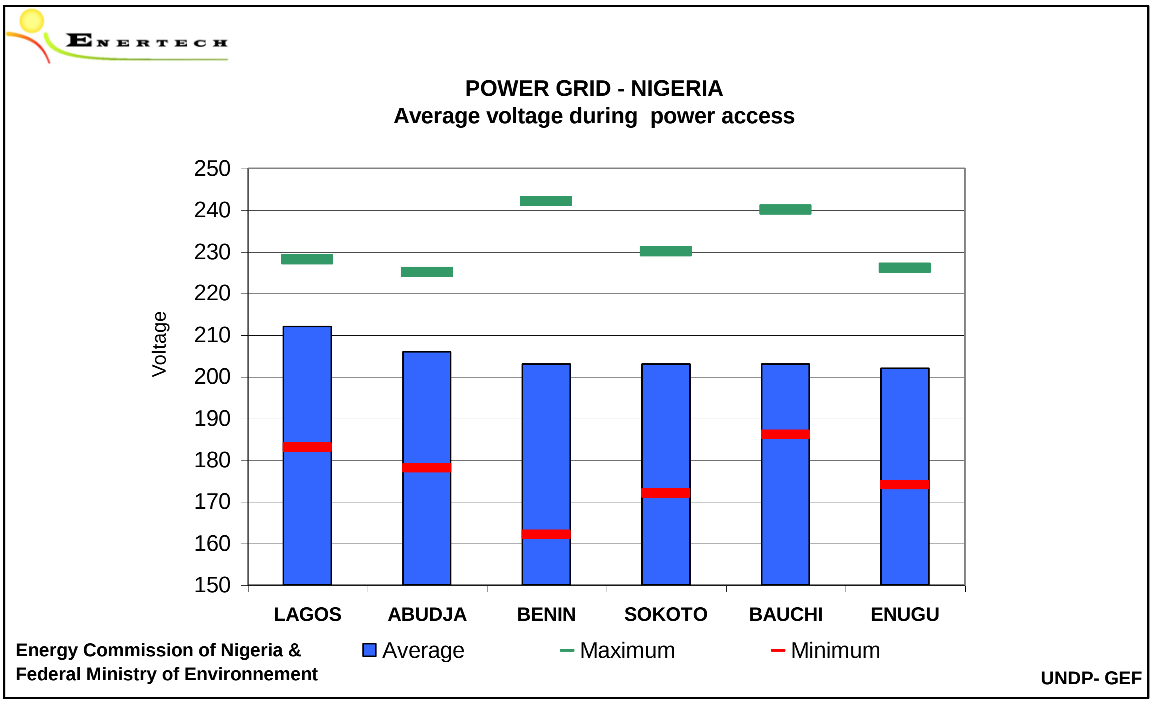


Figure 2.6 : Average and extremum voltage during power access

2.2 Daily number of hours of electricity access

2.2.1 Daily number of hours per household

Figure 2.7 shows the duration of electricity access per household. It varies from 2 to 24 hours with an average value at 13 hours.

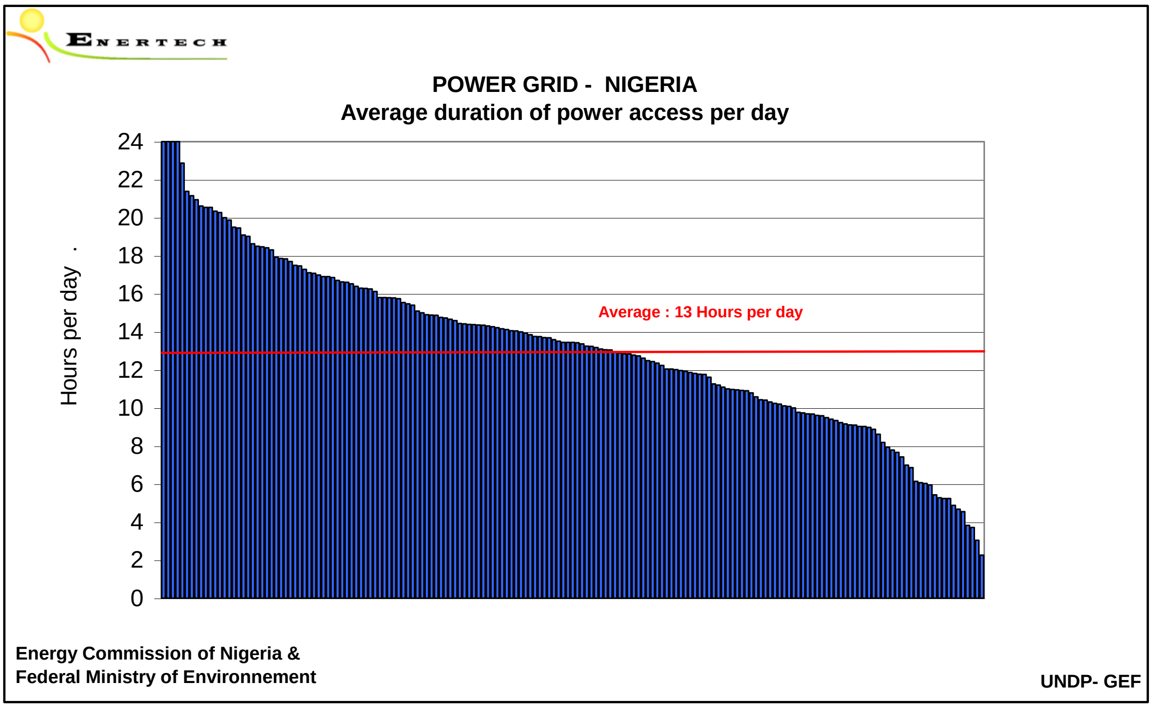


Figure 2.7 : Number of hours households get electricity per day

2.2.2 Daily average and extremum numbers for each Geopolitical zone

Figure 2.8 shows the average and extremum hours of electricity access per area. We can see that inside an area, the difference between the min and the max values are very high (more than 10 hours for all the areas).

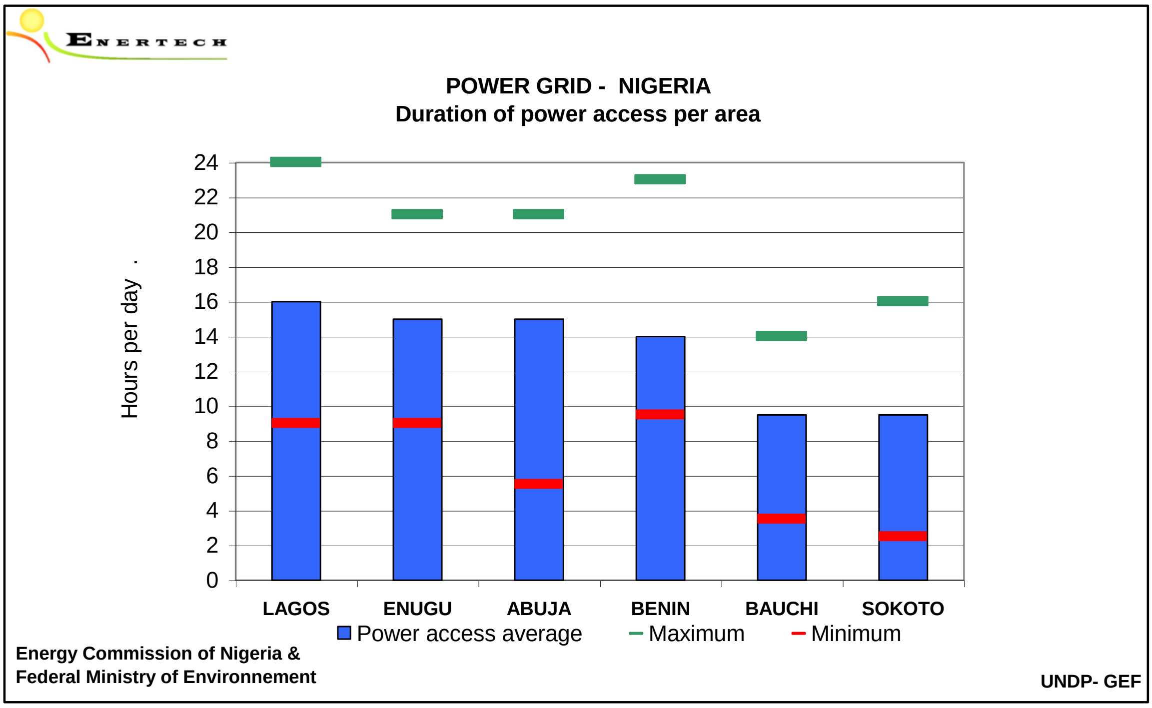


Figure 2.8 : Average and extremum number of hours households get electricity per day

2.3 Duration of the power outage cycles

2.3.1 Average duration of the power outage cycles per household

Using Figure 2.7, we can calculate that the daily average number of hours without power is 11 (24 hours minus the 13 hours with power access). But this value don't give us indication about the duration of the power outage cycles (one cycle of 11 hours or 11 cycles of one hour ?). Figure 2.9 helps us to respond to this question. The average value is 4 hours per power outage cycle. The difference between the households is very high and goes from 1 to 15 hours.

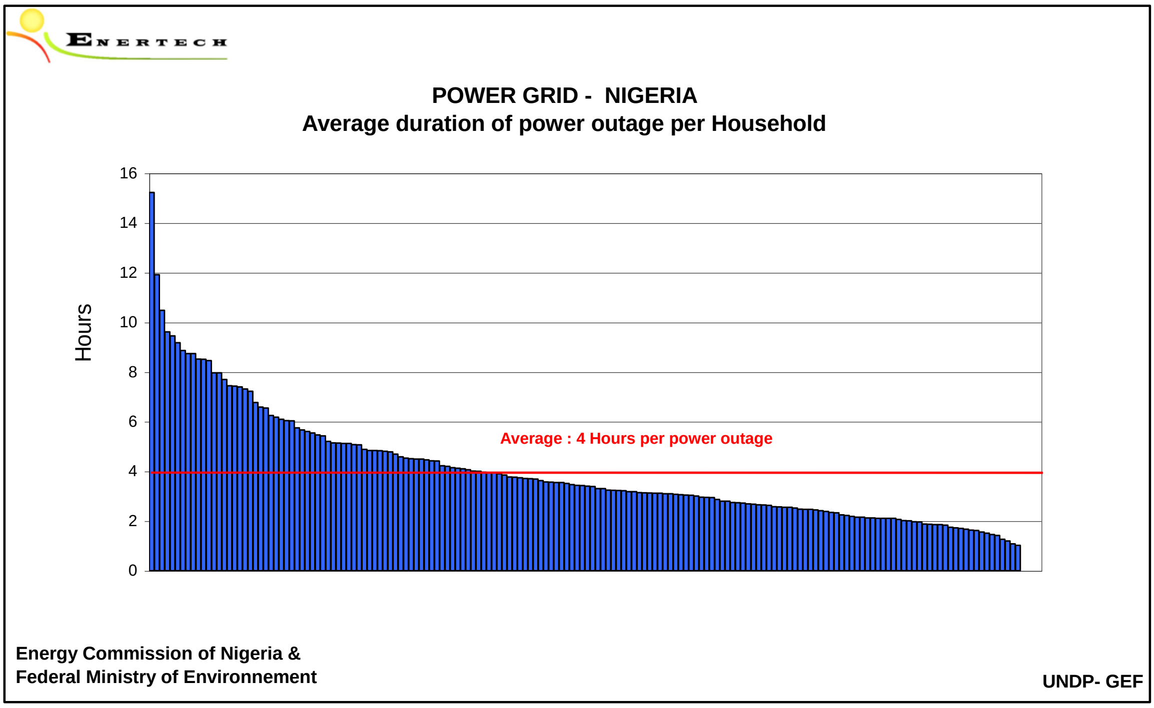


Figure 2.9 : Average duration of power outage

2.3.2 Average and extremum duration of power outage cycles per Geopolitical zone

Figure 2.10 shows the average and extremum durations of power outage cycles per areas.

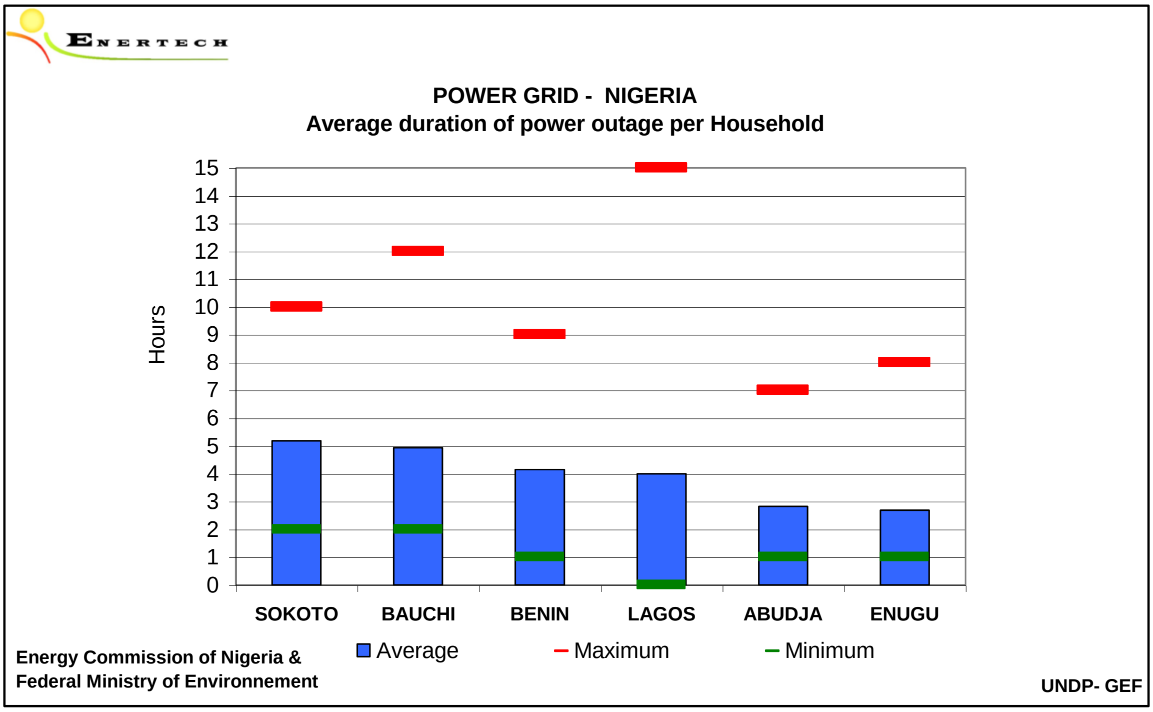


Figure 2.10 : Average and extremum duration of power outage

2.4 Duration of electricity access cycles

2.4.1 Average duration between two power outages per households

As for the power outage cycles, it could be interesting to know the duration of the power access cycles. Figure 2.11 shows the values per household with an average at 4,5 hours.

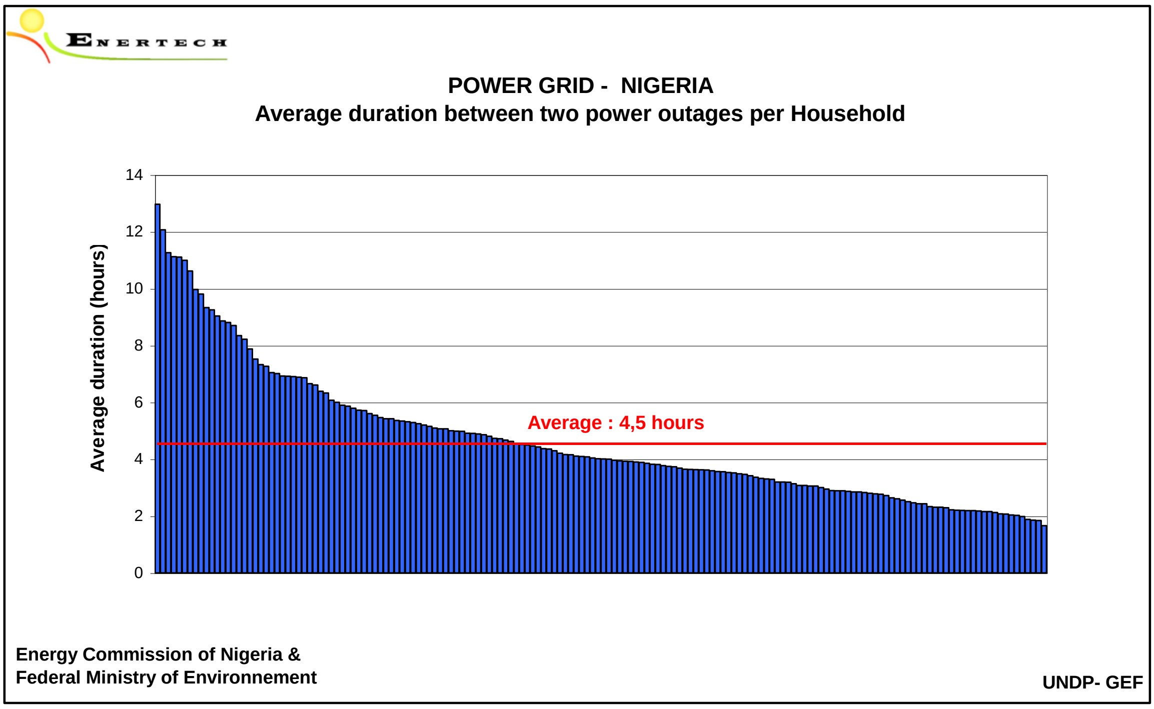


Figure 2.11 : Average duration between two power outages

2.4.2 Average and extremum duration between two power outages per geopolitical zone

Figure 2.12 shows the average and extremum durations per area. The Sokoto and Bauchi areas have the lowest difference between the minimum (2 hours) and maximum (5 hours) duration of the power access cycles. On the other side, the power access cycles for Abudja can vary from 2 to 13 hours.

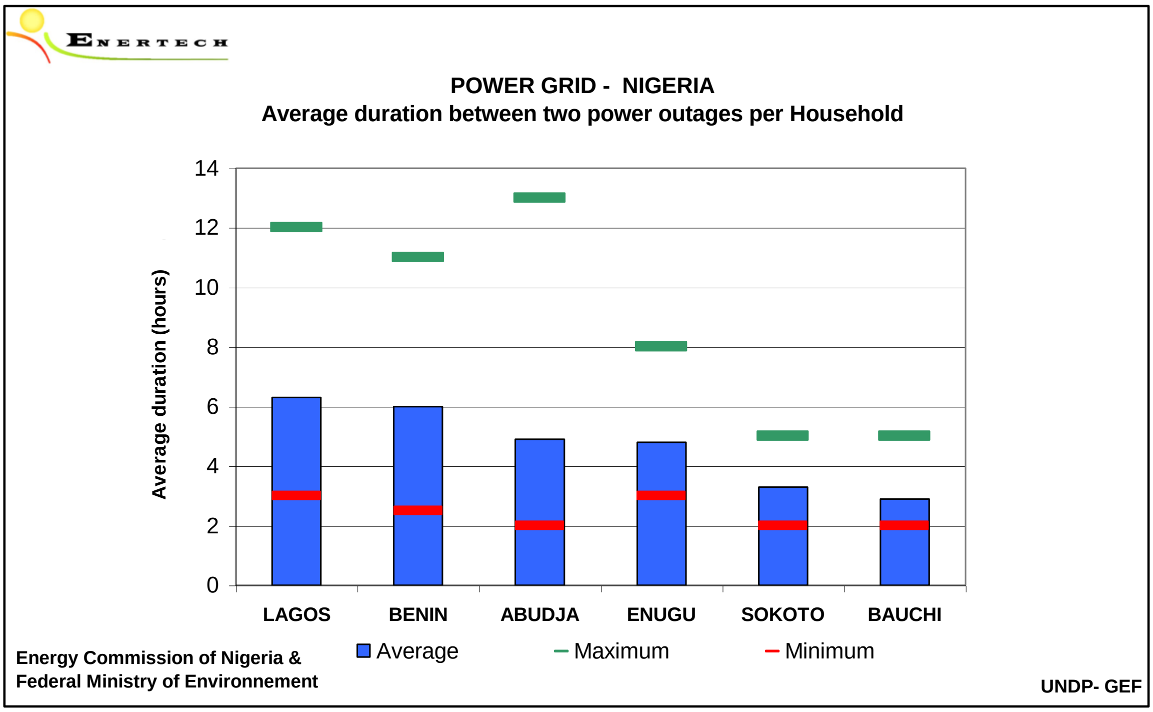


Figure 2.12 : Average and extremum duration between two power outages

2.4.3 Summary table relating to each graph from quality and stability of the power grid chapter

The table from figure 2.13 let us summarize the different results concerning power access.

		NIGERIA	Abuja	Sokoto	Benin	Bauchi	Lagos	Enugu
Part of power access		55%	63%	39%	59%	39%	66%	64%
Average Voltage during power access	Average	204V	206V	203V	172V	203V	212V	202V
	Minimum	172V	178V	172V	162V	186V	183V	174V
	Maximum	242V	225V	230V	242V	240V	228V	226V
Number of hours housholds get electricity per day	Average	13h/day	15h/day	9,5h/day	14h/day	9,5h/day	16h/day	15h/day
	Minimum	2,5h/day	5,5h/day	2,5h/day	9,5h/day	3,5h/day	9h/day	9h/day
	Maximum	24h/day	21h/day	16h/day	23h/day	14h/day	24h/day	21h/day
Average duration of power outage	Average	4h	3h	5h	4h	5h	4h	3h
	Minimum	0h	1h	2h	1h	2h	0h	1h
	Maximum	15h	7h	10h	9h	12h	15h	8h
Average duration of power access, between two power outage	Average	4,5h	5h	3h	6h	3h	6h	5h
	Minimum	2h	2h	2h	2h	2h	3h	3h
	Maximum	13h	13h	5h	11h	5h	12h	8h

Figure 2.13 : Summary table relating to the power grid chapter

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CHAPTER 3 : MAIN CONSUMPTION

3.1 Annualized consumption

3.1.1 Total annualized households electricity consumption

Figure 3.1 shows the annualized household electricity consumption. The total electricity consumption was always monitored for the household from the main electric switchboard and contains the specific consumption like cold appliances, lighting, audiovisual sites…
The average consumption of 3710 kWh/year was calculated with the power outage periods and therefore would be higher without this problems. The minimum to maximum ration is near 250. This indicates a great diversity in the type of households that were monitored (number of inhabitants and size of the household, number of appliances, duration of power access, …). In order to extract indicators from that values, it would be interesting to define different categories using socio-economic criteria's and then split the households between this categories.

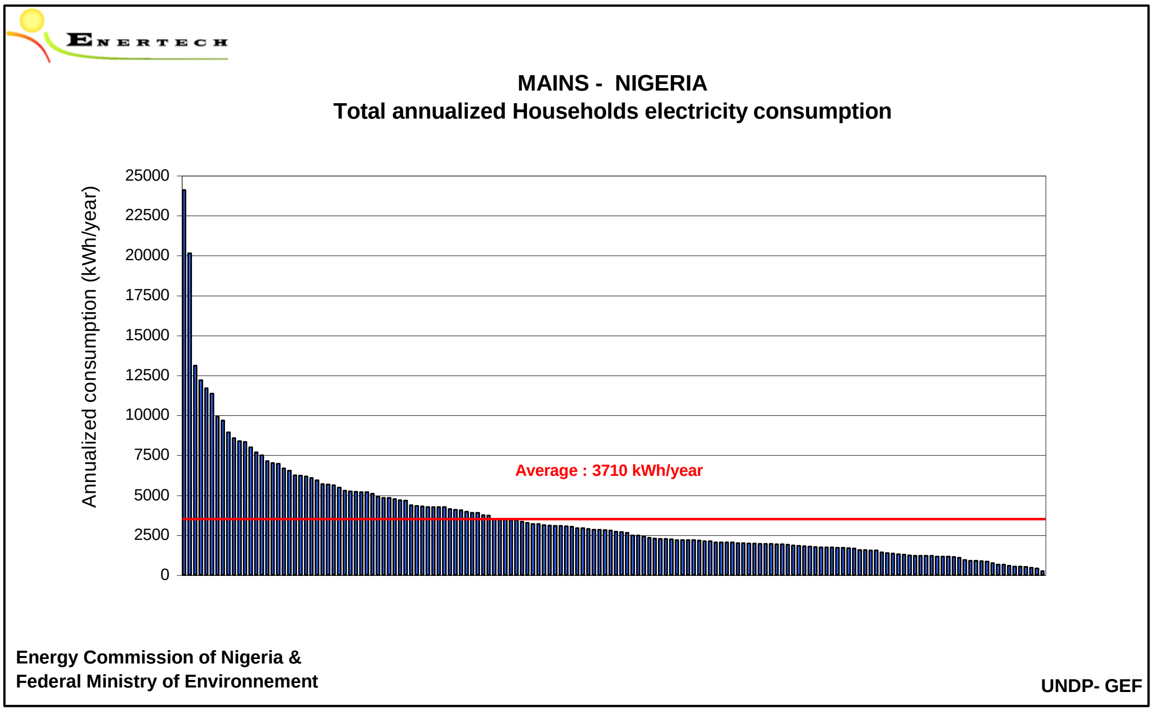


Figure 3.1 : Annualized electricity consumption

3.1.2 Average and extremum annualized households electricity consumption per Geopolitical zone

Figure 3.2 shows the average and extremum values for the annual consumption per area. There is a ratio of 2.5 between the Bauchi and the Lagos area, the two representing respectively the minimum and the maximum annual consumptions. If compared to graph 2.8 from previous chapter, we can note a correlation between the average duration of power access per day and the annual consumption : Lagos which has the highest duration of power access per day is also the area with the highest annual consumption. On the other side, Sokoto and Bauchi have the lowest duration of power access per day and also the lowest annual consumptions.

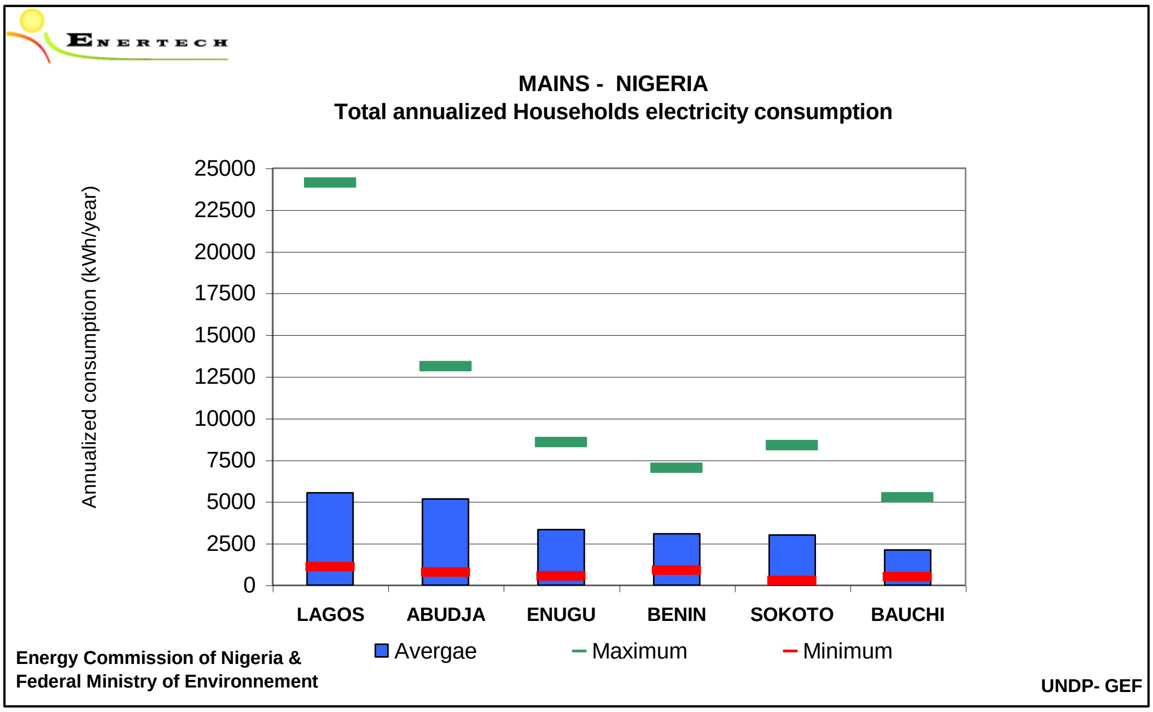


Figure 3.2 : Average and extremum annualized electricity consumption

3.1.3 Annual consumption versus power grid duration for each Households

Figure 3.3 tries to find a correlation between the annual consumption and the duration of electricity access per household. In paragraph 3.1.2, it was possible to find such a correlation for the six areas but analysing graph 3.3, we see that, on a household point of view, such a correlation is far from evident.

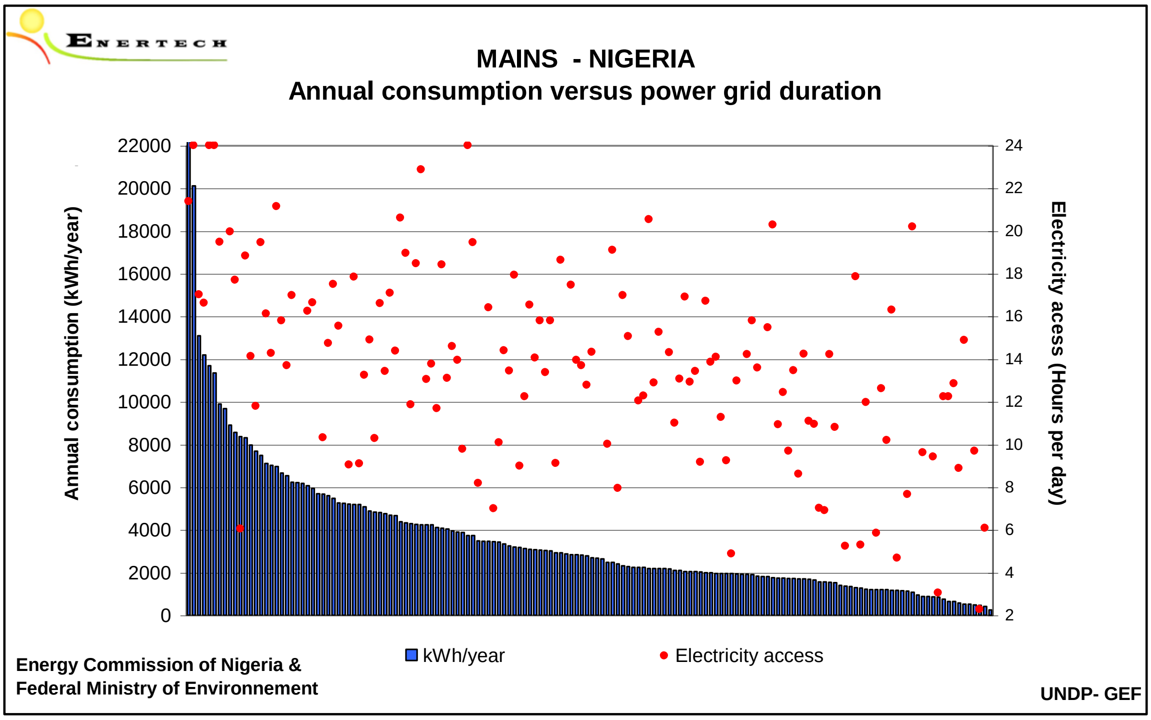


Figure 3.3 : Annual consumption versus power grid duration

3.1.4 Annual consumption versus power grid duration for each Households

Figure 3.4 is an other way to display the correlation between the annual consumption and the duration of power access. In that case too, it is not easy to find a way to link the two types of data together.

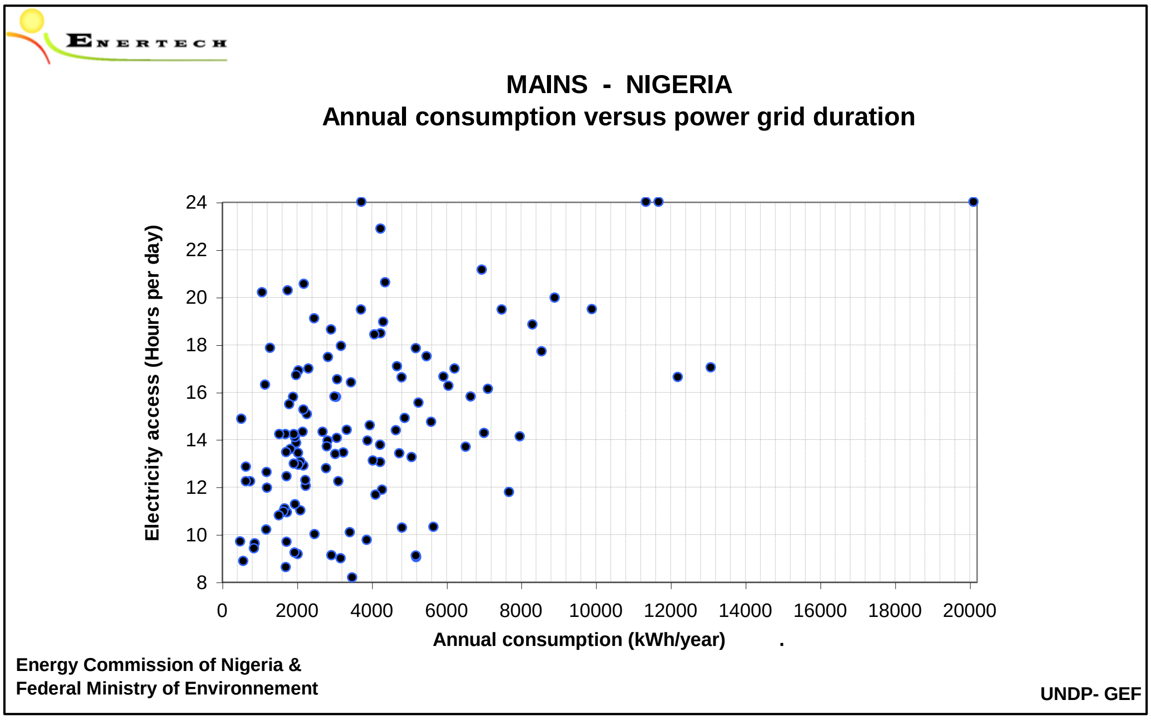


Figure 3.4 : Annual consumption versus power grid duration

3.2 Daily average load curve

3.2.1 Daily average load curve during power access for each geopolitical zone

Figure 3.5 shows, for the six different areas, the structure of the 'load curves', which shows the average hourly energy demand. These curves were calculated by averaging the individual load curves for each household using only the data for which the measured voltage value was greater than zero in order to use only the power access periods. The 10 minute values were merged per hour in order to obtain 24 values (one per hour) given in Watt.
This structure was obtained using the mains monitored from the main switchboard.
The six curves are very different in terms of power demand and profiles per area. For example, the Benin area has two peaks near 800 Watts at 07:00 in the morning and 19:00 in the evening while the Lagos area has only one peak in the evening but there power demand is always higher than for Benin.

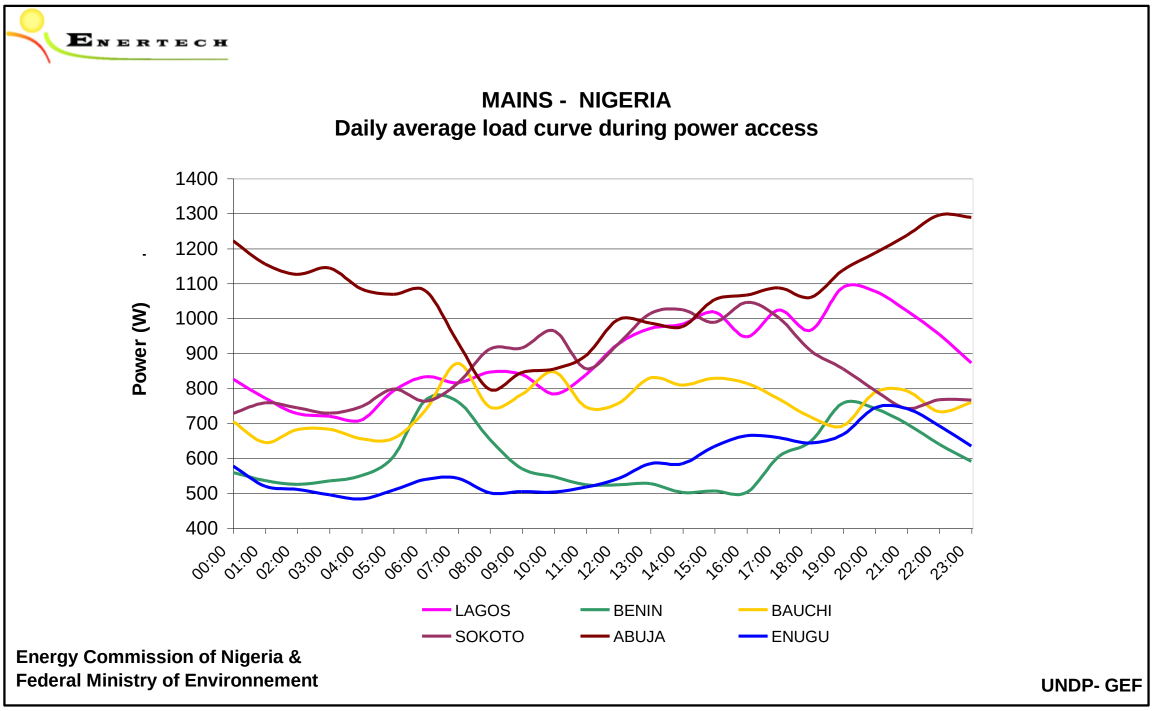


Figure 3.5 : Daily average load curve during power access per areas

3.2.2 Daily average load curve during power access, for all households

Figure 3.6 shows, for all the households merged, the structure of the 'load curve', which shows the average hourly energy demand. This curve was calculated by averaging the individual load curves for each household using only the data for which the measured voltage value was greater than zero in order to use only the power access periods. The 10 minute values were merged per hour in order to obtain 24 values (one per hour) given in Watt.

This structure was obtained using the mains monitored from the switchboard. The morning peak between 06:00 and 07:00 is clearly visible, the evening peak lays between 20:00 and 21:00.

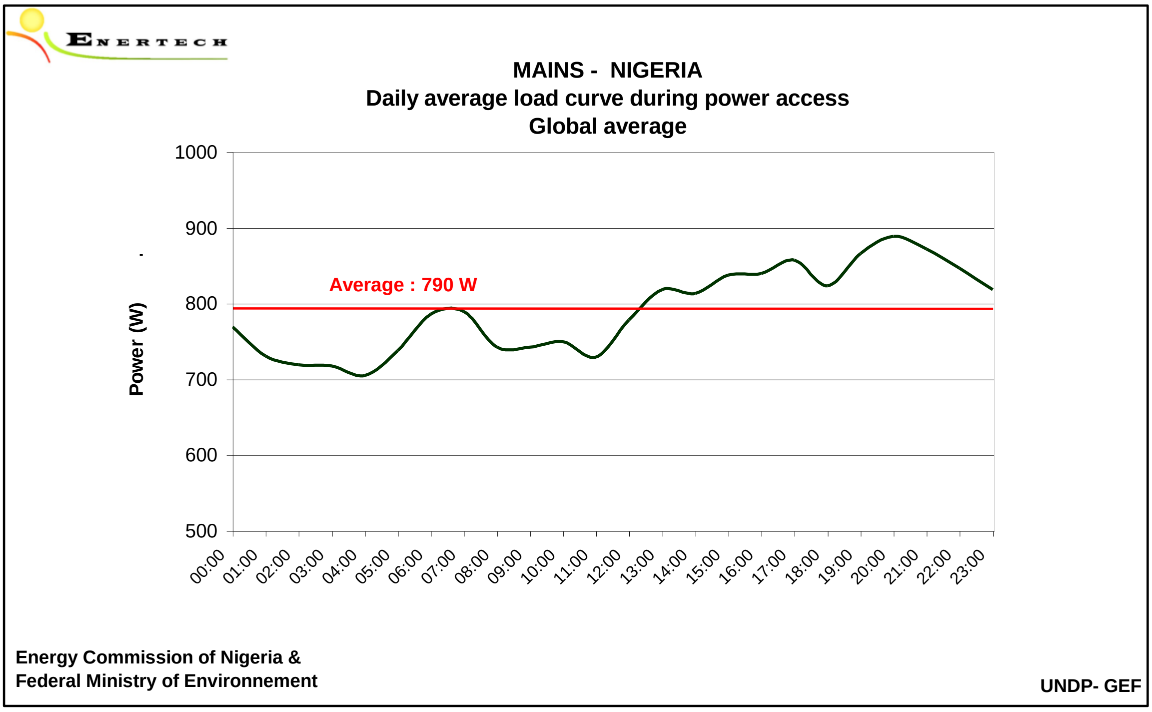


Figure 3.6 : Daily average load curve during power access

3.2.3 Daily average curve load curve during all the monitoring campaign, for each geopolitical zone

Figure 3.7 shows, for the six different areas, the structure of the 'load curves', which shows the average hourly energy demand. These curves were calculated by averaging the individual load curves for each household using all the data and not only the ones during the power access periods. The 10 minute values were merged per hour in order to obtain 24 values (one per hour) given in Watt.

This structure was obtained using the mains monitored from the main switchboard.

The six curves are this time very similar (in opposite to graph 3.5) in terms of profiles, the differences lying in the level of power demand.

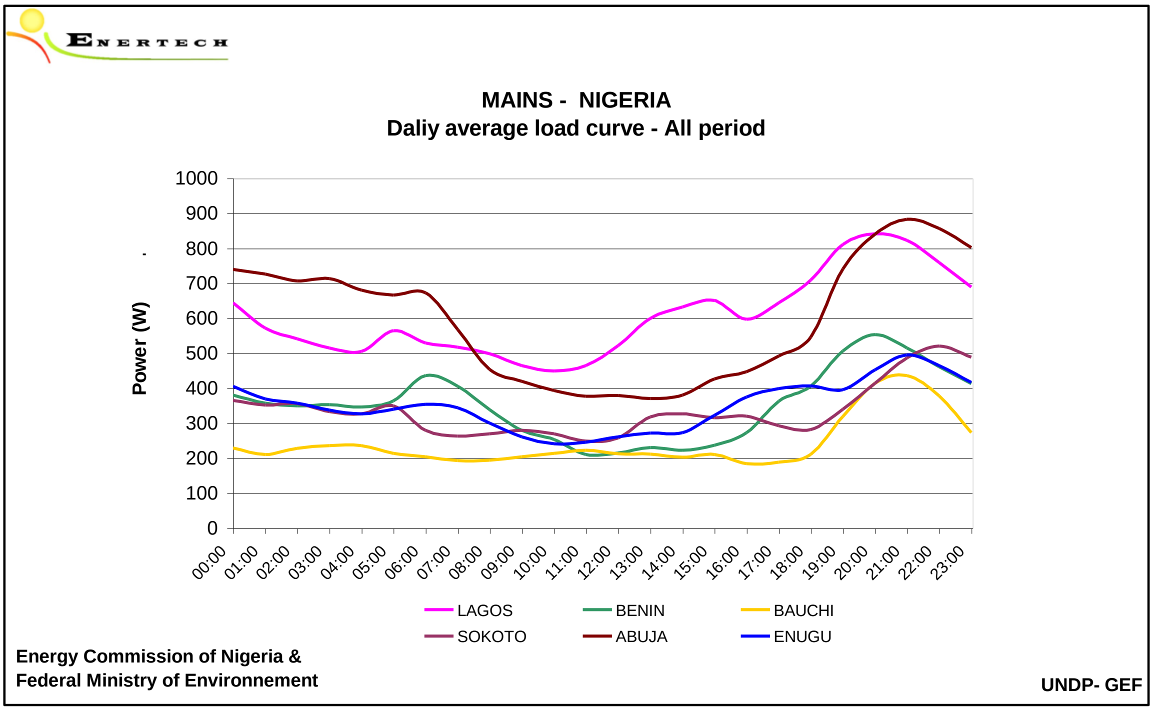


Figure 3.7 : Daily average load curve per area

3.2.4 Daily average load curve during all the monitoring campaign, for all households

Figure 3.8 shows, for all the households merged, the structure of the 'load curves', which shows the average hourly energy demand. This curve was calculated by averaging the individual load curves for each household using all the data and not only the ones during the power access periods. The 10 minute values were merged per hour in order to obtain 24 values (one per hour) given in Watt.

This structure was obtained using the mains monitored from the switchboard.

The curve shows a minimum during the day, comparable to the minimum observed in figure 2.3 concerning the daily curve of the part of power access.

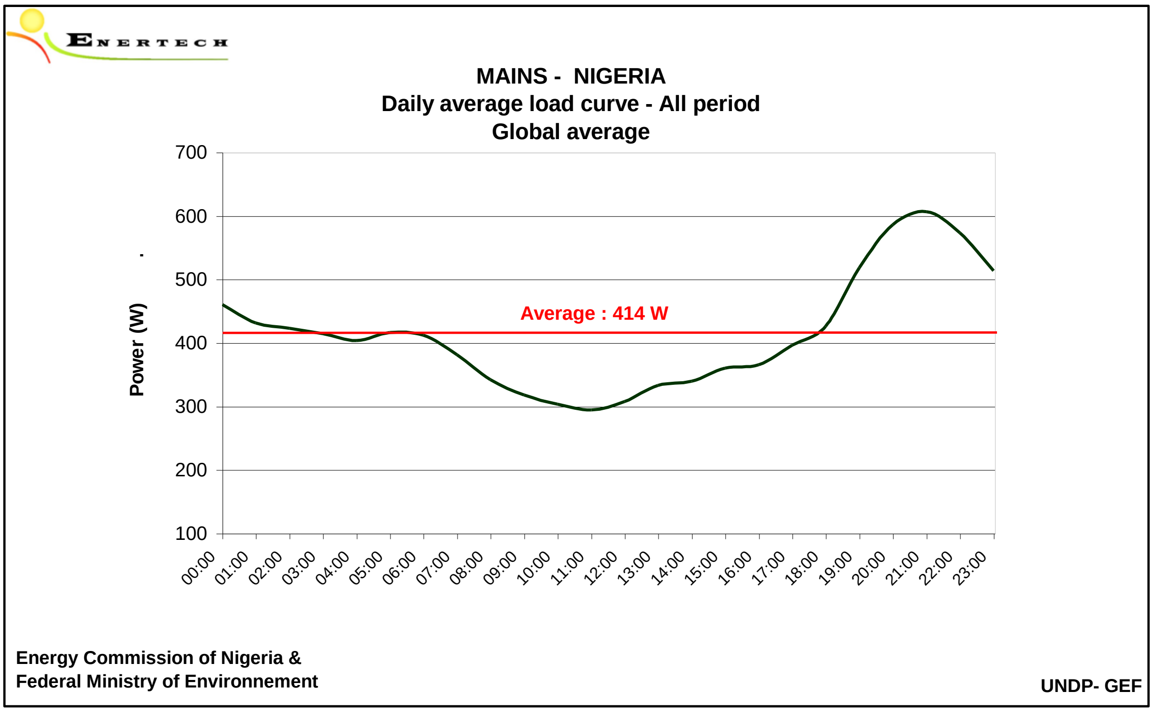


Figure 3.8 : Daily average load curve during all the monitoring campaign

3.2.5 Relative contribution from the different loads for each Households

Figure 3.9 shows the relative contribution from the different loads. This figure was calculated by merging the individual monitored devices per type of appliances (air conditioning, cold appliances, lighting, audiovisual sites, computer sites, cooking). The unknown part is the difference between the main consumption minus the sum of all the monitored appliances. It indicates the part not monitored with the dataloggers.

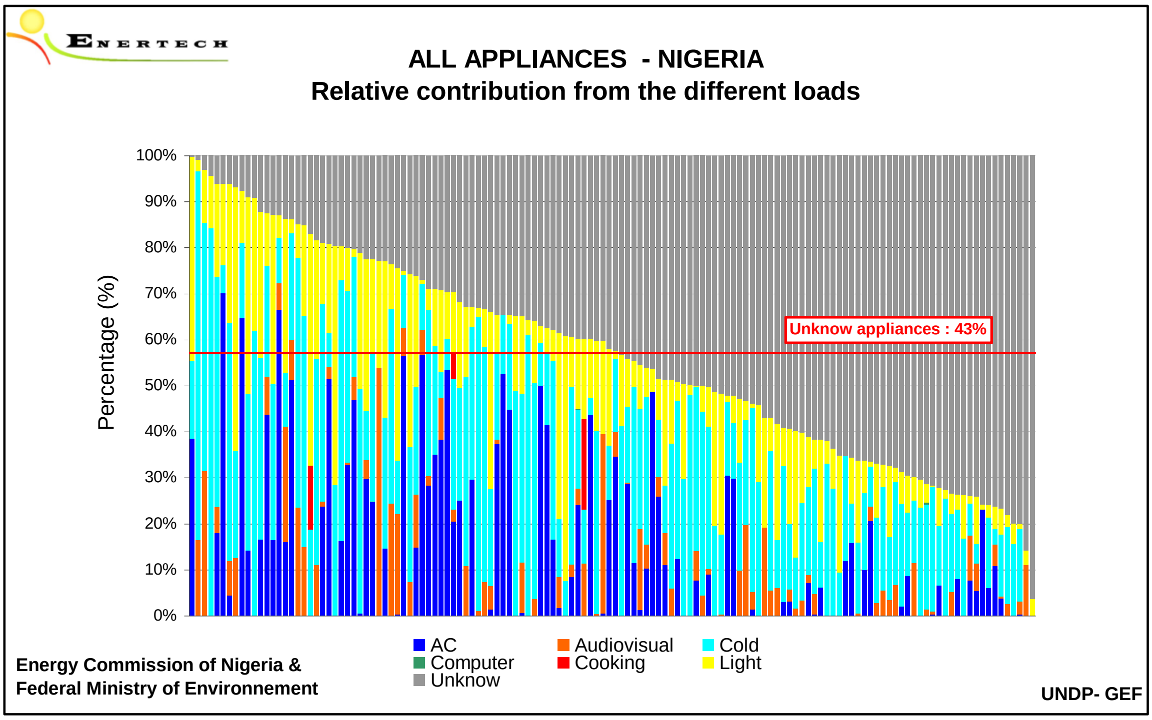


Figure 3.9 : Relative contribution from the different loads per Households

3.2.6 Relative contribution from the different loads per Geopolitical zone

Figure 3.10 shows the relative contribution from the different loads per area. This figure was calculated by averaging the individual consumption for each household per area. The individual monitored devices were merged per type of appliances (air conditioning, cold appliances, lighting, audiovisual sites, computer sites, cooking). The unknown part is the difference between the main consumption minus the sum of all the monitored appliances. It indicates the part not monitored with the dataloggers.

We can see for example that the cold appliances can represent up to 30% of the total consumption like in the Benin area or that the air conditioning consumption can more than double from one area to the other like between Benin and Abudja.

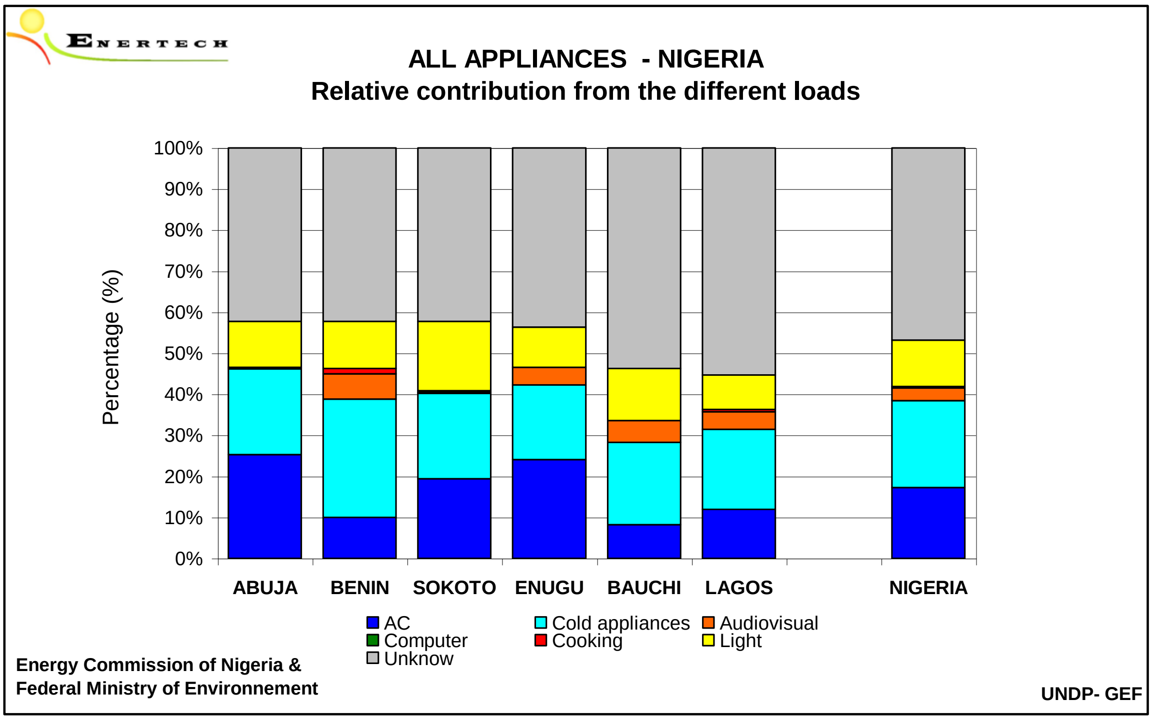


Figure 3.10 : Relative contribution from the different loads per zones

3.2.7 Daily average load curve with the relative contribution from the different loads

Figure 3.11 shows the structure of the 'load curve', giving us the average hourly energy demand. This curve was calculated by averaging the individual load curves for each household. The 10 minute values are merged per hour in order to obtain 24 values (one per hour) given in Watt.

This structure was obtained using all the monitored devices merged per type of appliance (cold appliances, lighting, audiovisual sites, computer sites, cooking, washing, heating etc.).

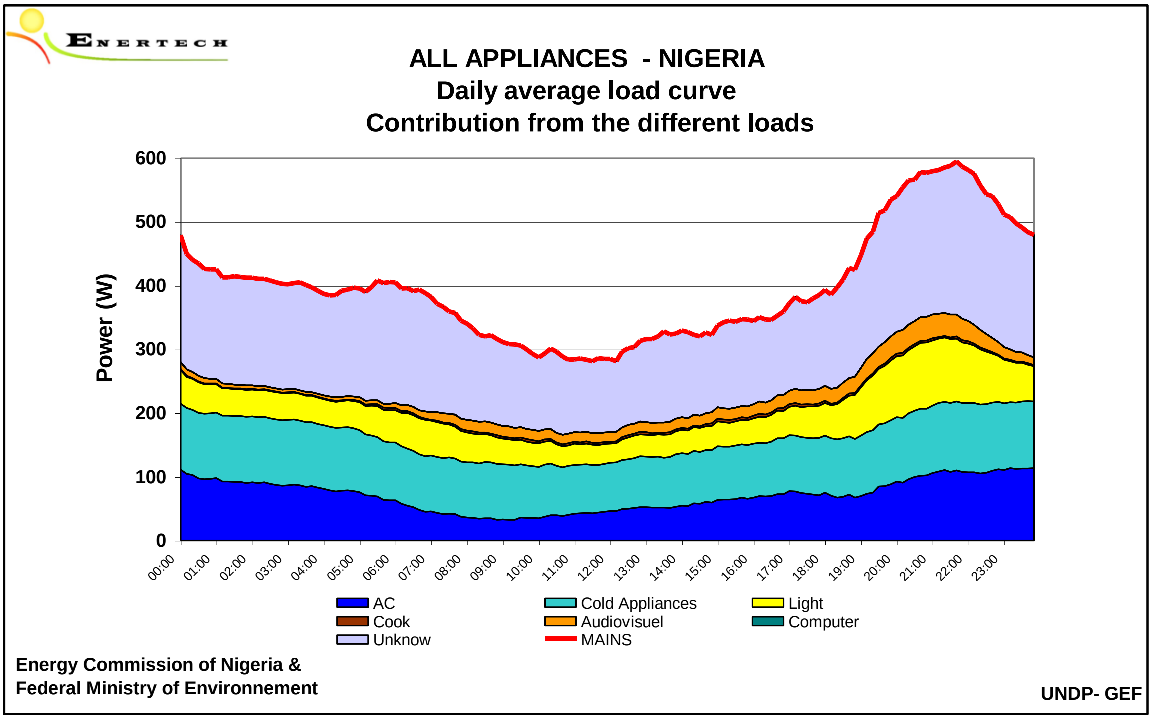


Figure 3.11 : Daily average load curve with the relative contribution from the different loads

3.2.8 Contribution from the different loads per Households

Figure 3.12 shows the contribution from the different loads for all the households. This figure was calculated by averaging the individual consumption for each household. The individual monitored devices were merged per type of appliances (cold appliances, lighting, audiovisual sites, computer sites, cooking, washing, heating etc.). We can see that the sum for air conditioning, lighting and cold appliances represent the half of the total consumption.

We can note that the total consumption for this graph differs slightly from the one found in graph 3.1 or given in table 3.13 (3710 kWh/year vs 3926 kWh/years). This is due to the fact that for graph 3.12, we used only the data from the households for which we were sure that the different loads were monitored with the best accuracy and that for graph 3.1, we had only to check the main consumption in order to include the household in our panel.

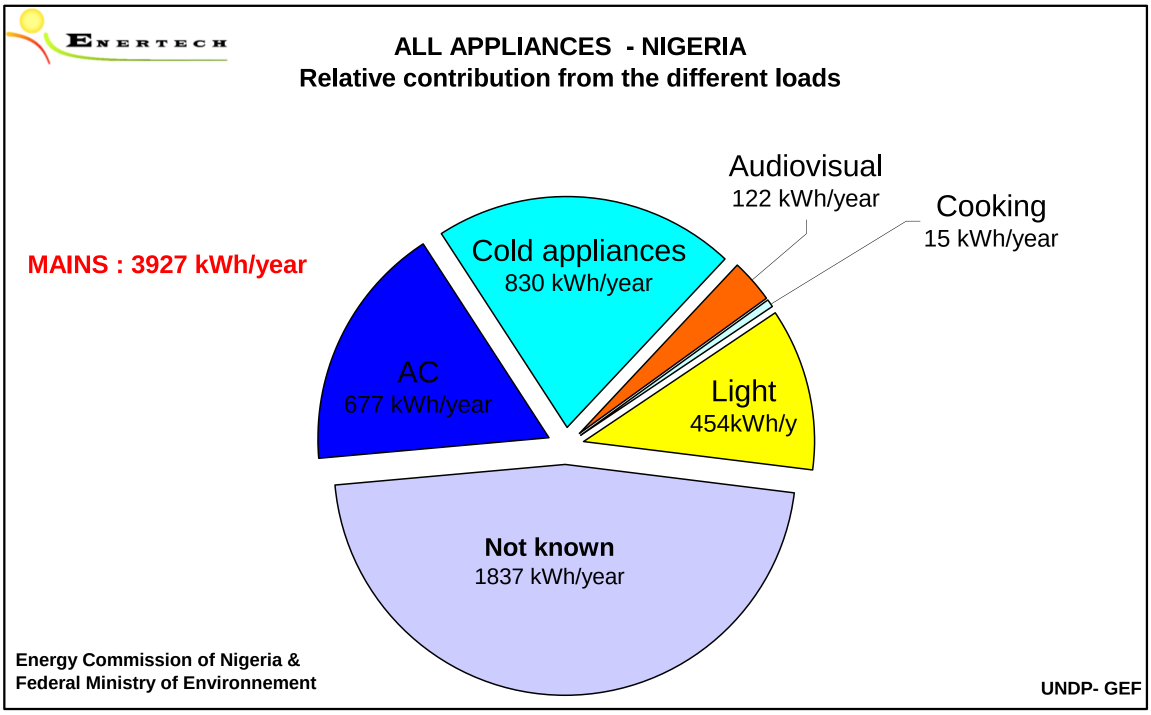


Figure 3.12 : Contribution from the different loads

3.2.9 Summary table relating to each graph from mains consumption chapter

The table from figure 3.13 shows the summary for all the results from chapter 3.

		NIGERIA	Abuja	Sokoto	Benin	Bauchi	Lagos	Enugu
Annualized consumption	Average	3710kWh/y	5175kWh/y	3000kWh/y	3090kWh/y	2124kWh/y	5544kWh/y	3330kWh/y
	Minimum	243kWh/y	754,5kWh/y	243kWh/y	878kWh/y	492kWh/y	1076kWh/y	521kWh/y
	Maximum	24098kWh/y	13089kWh/y	8367kWh/y	7016kWh/y	5241kWh/y	24098kWh/y	8558kWh/y
Average daily power demand during power access		790W	1065W	856W	599W	752W	889W	583W
Average load call during all the period		414W	595W	335W	243W	353W	606W	350W
Relative contribution from the different load on the global consumption	AC	17%	25%	19%	10%	8%	12%	24%
	Cold appliances	21%	21%	21%	29%	20%	20%	18%
	Audiovisual	3%	0%	0%	6%	5%	4%	4%
	Computer	0%	0%	0%	0%	0%	0%	0%
	Cooking	0%	0%	0%	1%	0%	1%	0%
	Light	11%	11%	17%	12%	13%	8%	10%
	Unknow	47%	42%	42%	42%	54%	55%	44%

Figure 3.13 : Summary table relating to the mains consumption chapter

CHAPTER 4 : AIR CONDITIONER

4.1.1 Annualized consumption

Figure 4.1 shows the annual consumption for the air conditioners. This graph include all the households from the monitoring campaign. You will find the results per area in the appendix at the end of the report.
There is a large gap between the air conditioners consumption. The consumptions per household goes from **0 kWh/year** to **3400 kWh/year** for an average value at **828 kWh/year.**
The only comparison can be given is the French Guiana monitoring campaign (11 households in Kourou - June 1998) with an average value of 2314kWh/year. It should be note that the Kourou's power grid is constant.

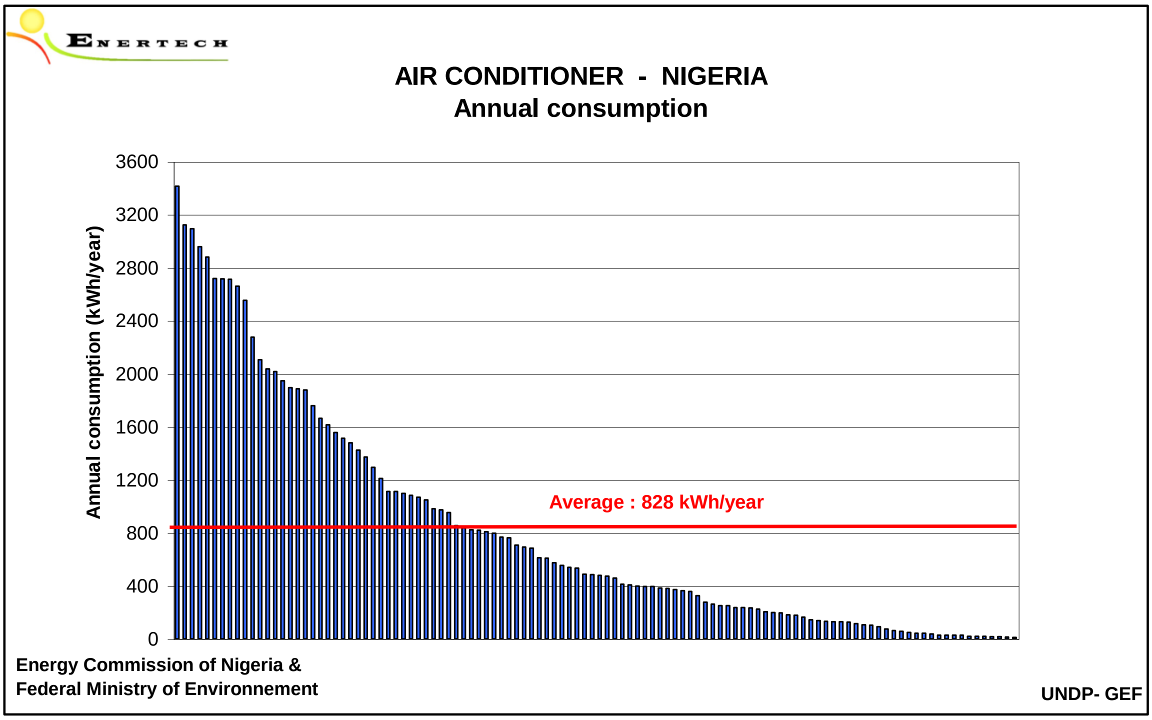


Figure 4.1 : Air conditioner annualized consumption

4.1.2 Functioning rates during the power access

Figure 4.2 shows the functioning rate during the power access. The values are in the range 0 (never used) - 100% (always on) for an average value at 22%. This indicates that this type of appliance is not always switched ON or that the temperature level in the households is not high enough to trigger it (but with an average temperature of 29.5°C found in §1.6.1, it is surprising not to have more power ON cycles).

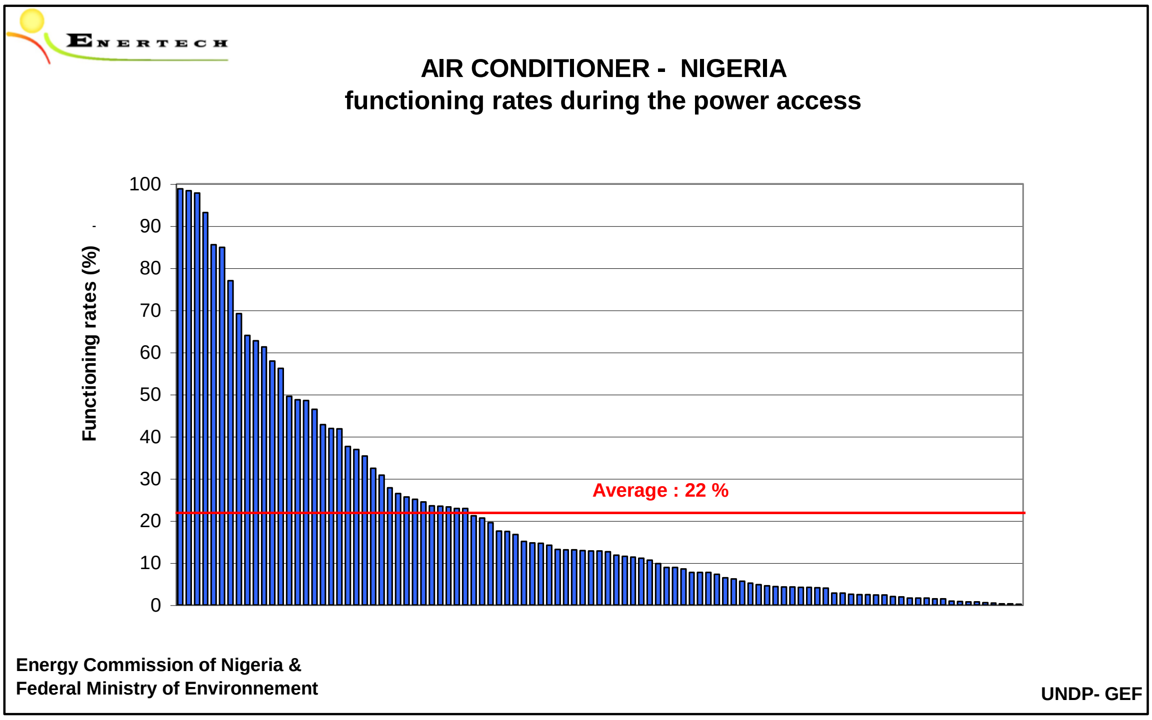


Figure 4.2 : Air conditioner functioning rates during the power access

4.1.3 Annualised consumption versus power grid

Figures 4.3 and 4.4 tries to find a correlation between the annual consumption and the duration of power access. But the differences between the functioning rates are too high to be able to find a simple relation between the two values.

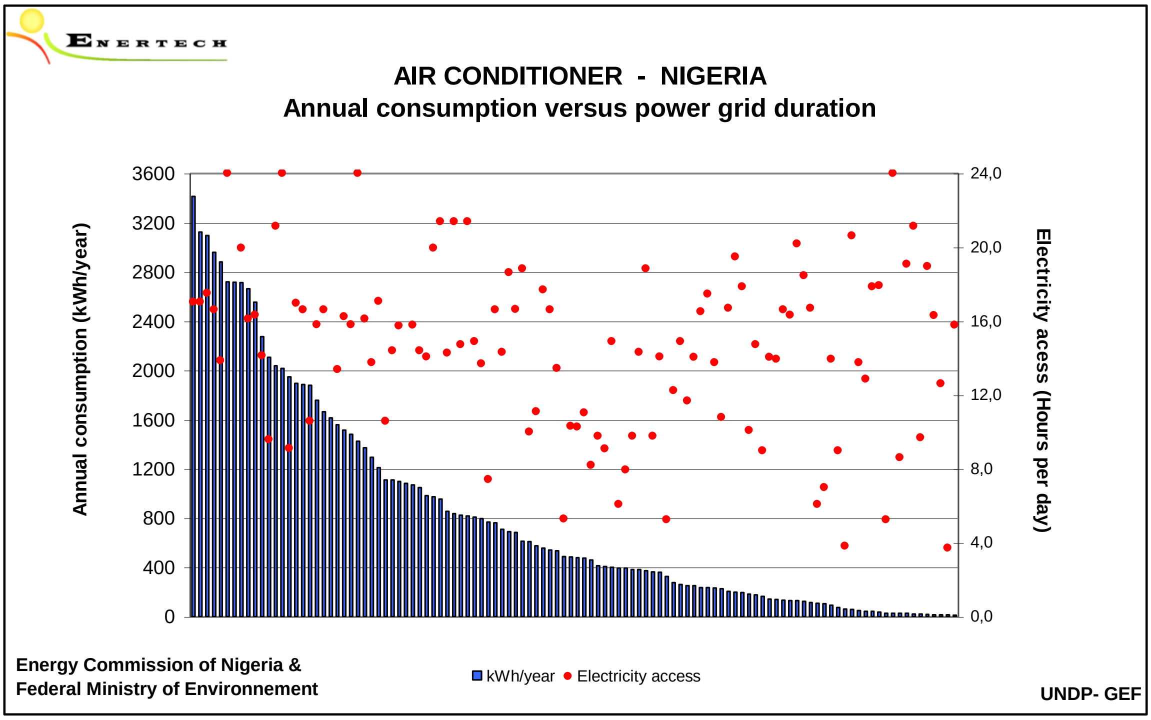


Figure 4.3 : Air conditioner – Annual consumption versus power grid duration

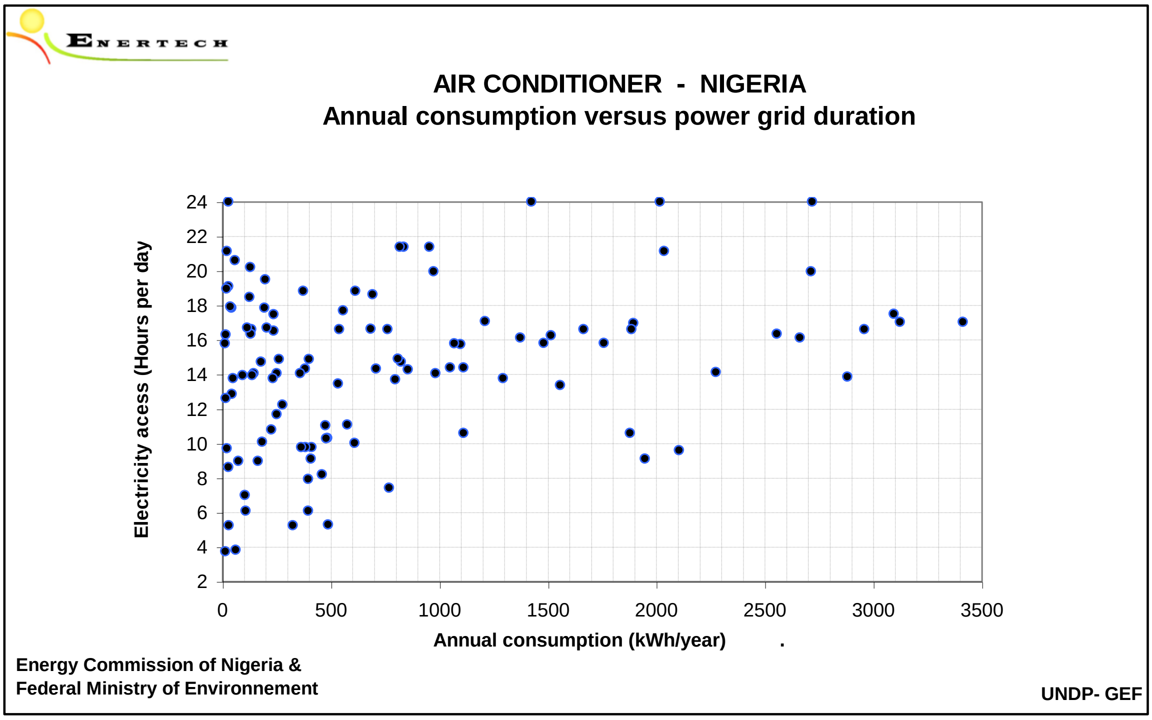


Figure 4.4 : Air conditioner – Annual consumption versus power grid duration

CHAPTER 5 : COLD APPLIANCES

5.1 GENERALITIES

The graphs from figure 5.1 show us two different consumption patterns for the **same fridge**. The difference lies in the power distribution conditions. When the appliance works in normal condition (without power outage), the compressor has ON/OFF cycles on a regular basis. On the opposite, with frequent power outage, the compressor is always ON to compensate the periods without electricity. This illustrates what we said at the beginning of the report, that the frequent power outage will influence the appliances consumptions. Therefore, it will be difficult to compare the results with results from other countries in order to determine the quality of the appliances

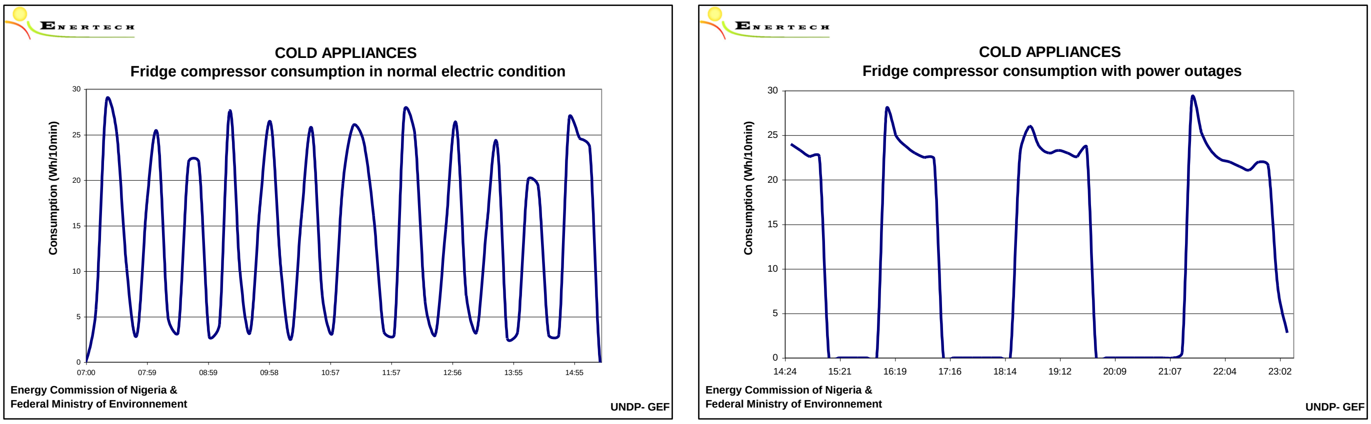


Figure 5.1 : Cold appliances – Compressor cycles vs power outage

5.1.1 Average possession of appliances

Figure 5.2 shows the average number of cold appliances per household. Fridge freezers and chest freezers are the most common appliances. The freezer category include the vertical freezers but also the appliances for which we didn't knew the type (vertical or chest).

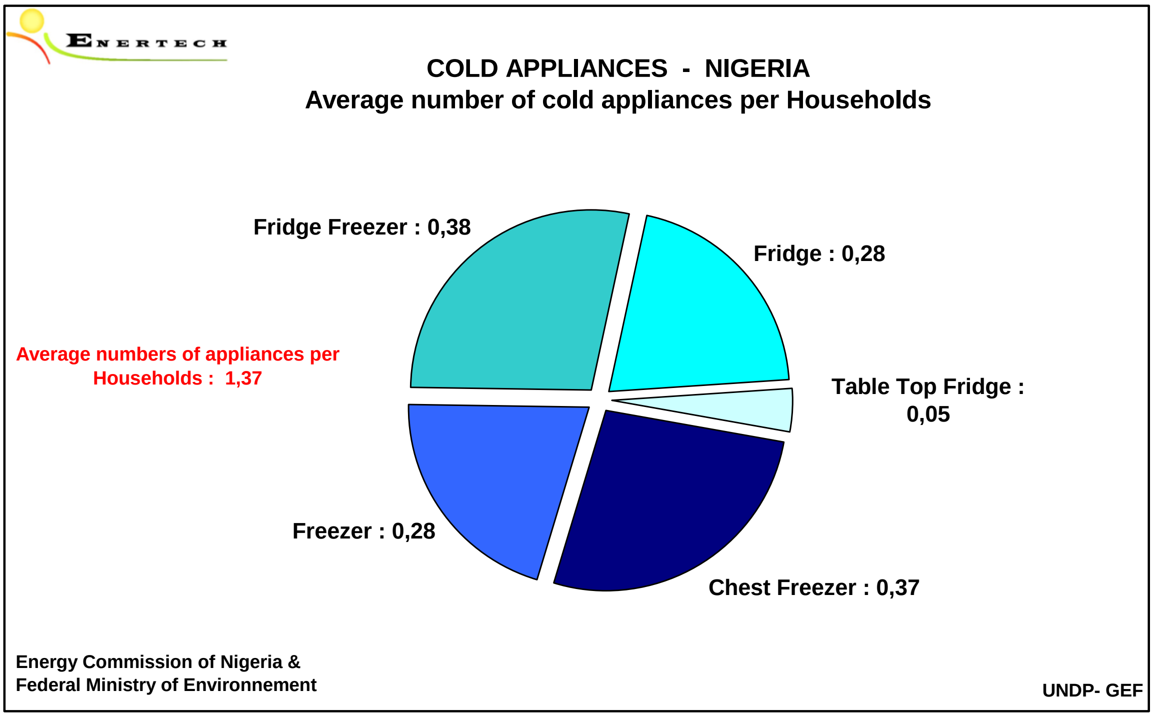


Figure 5.2 : Cold appliances – Average number of appliances per household

5.2 FRIDGE

5.2.1 Annualized fridge's consumption

Figure 5.3 shows the annual consumption for the fridges (or refrigerators). This graph include all the households from the monitoring campaign. You will find the results per area in the appendix at the end of the report.

The consumptions per household goes from less than **100 kWh/year** to **1000 kWh/year**. The average value of **425 kWh/year** can be compared to the 253 kWh/year found in France during the *Remodece+* project in 2007 or the 162 kWh/year found in England during the *UK240* project in 2010. In Sweden, the consumption went from 196 to 231 kWh/year.

All the parameters that can explain the differences in consumption, like the inside temperature of the different cold appliances, are not know. But it's sure that the inside temperature of the households and the frequent power outage will certainly play an important role in this high consumption.

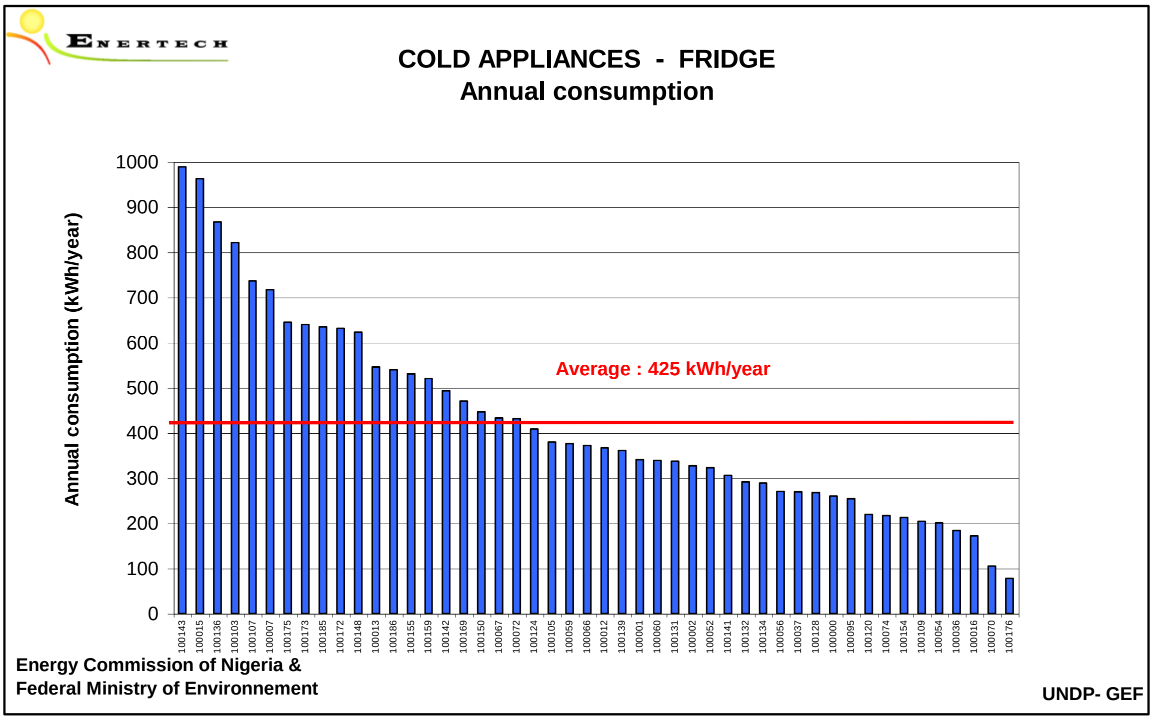


Figure 5.3 : Fridges – Annual consumption

5.2.2 Functioning rates during the power access

Figure 5.4 show the functioning rate during the power access. The values goes from 20 to 100% and the average value of 73% is very high for that type of equipment. This is explained by the frequent power outage that leads to very long compressor cycles.

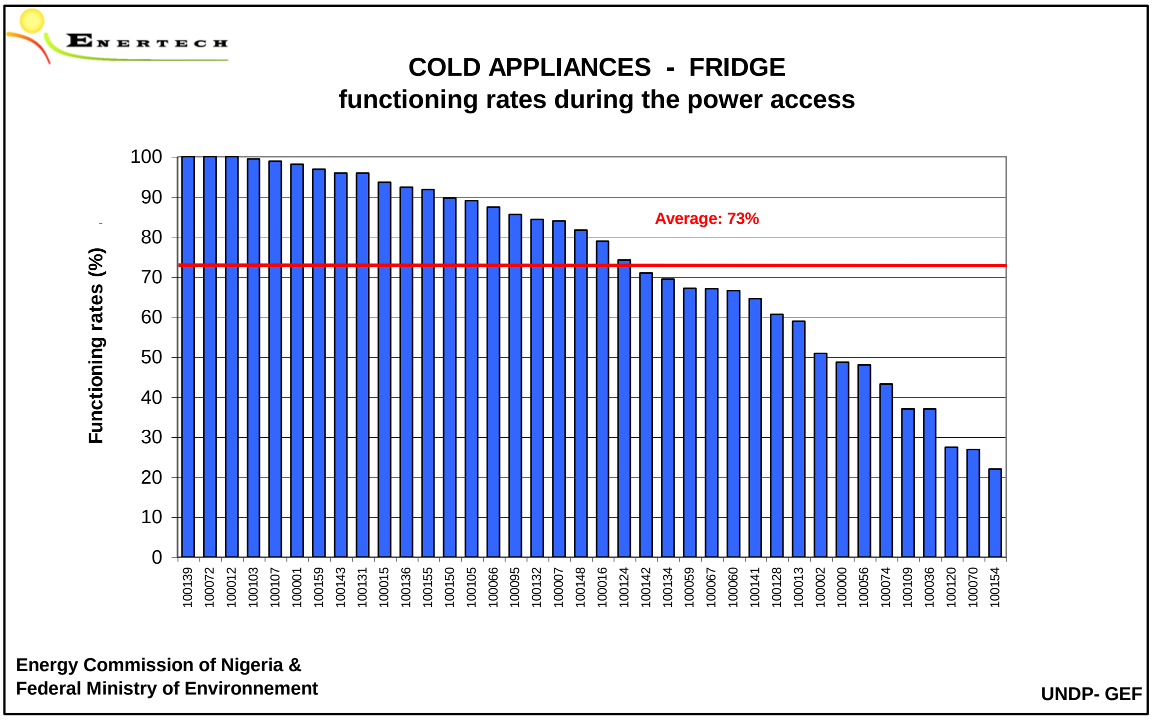


Figure 5.4 : Fridges – Functioning rates during the power access

5.2.3 Annualized fridge's consumption versus power grid duration

Figures 5.5 and 5.6 tries to find a correlation between the annual consumption and the duration of power access. We can see that there is no simple relation between the two data, the number of parameters is to important to be able to find a simple relation between the two values.

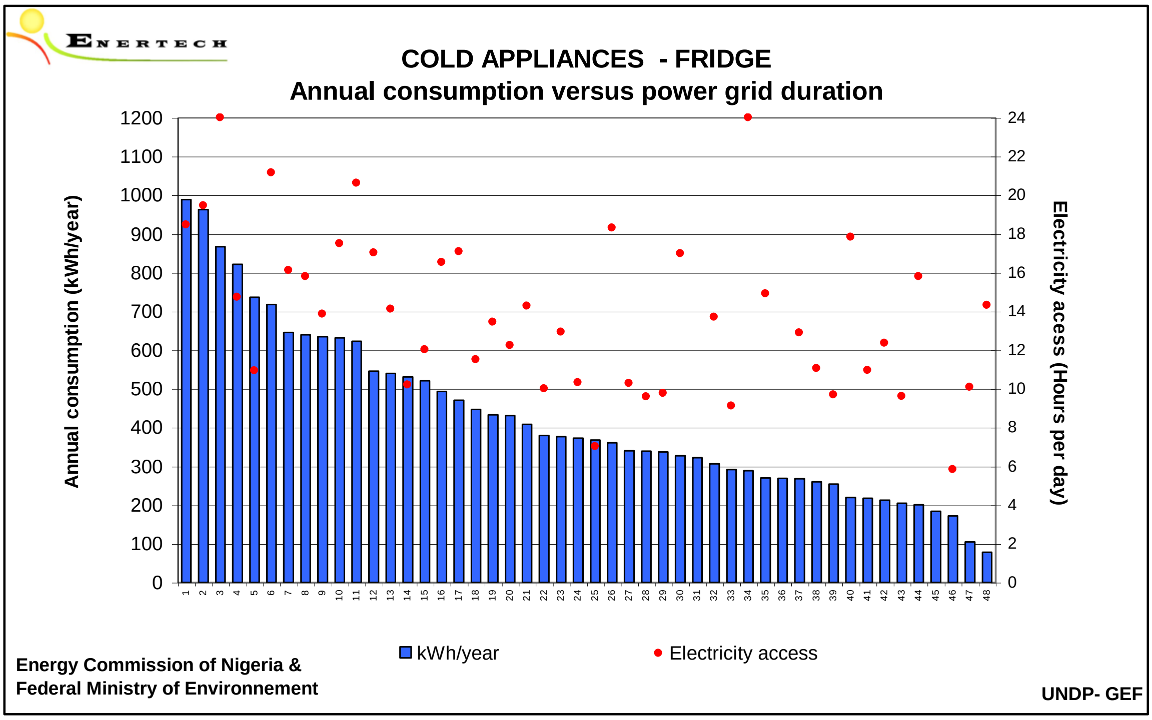


Figure 5.5 : Fridges – Annual consumption versus power grid duration

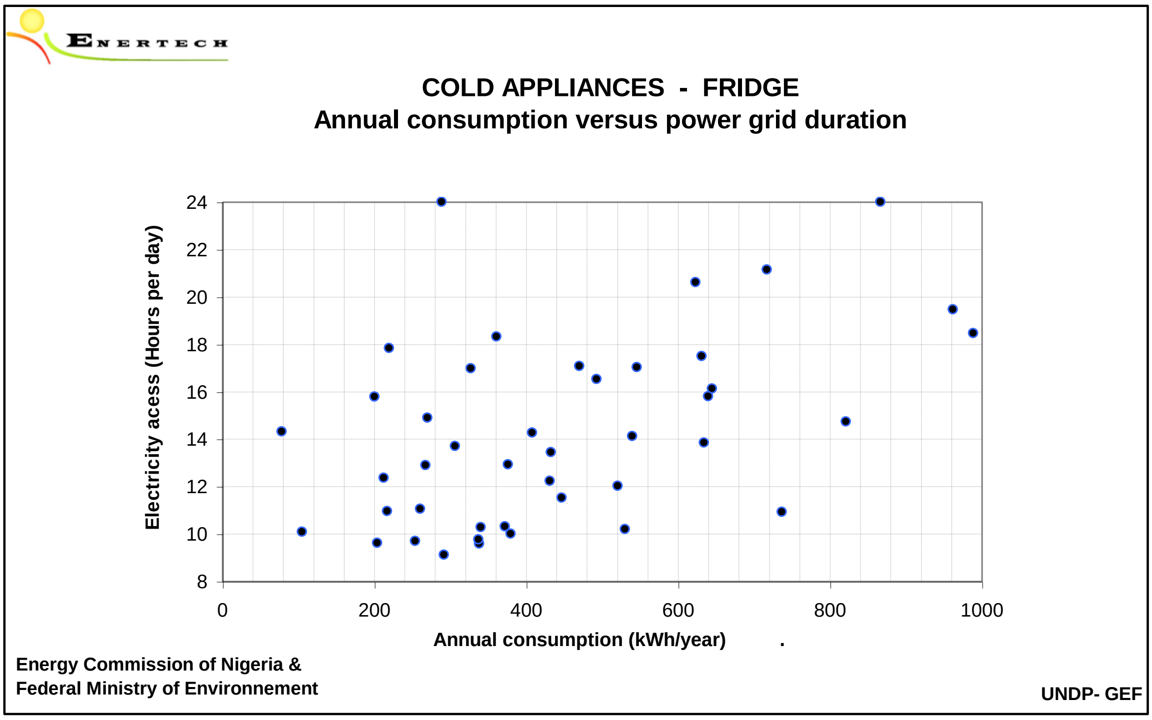


Figure 5.6 : Fridges – Annual consumption versus power grid duration

5.3 FREEZER

5.3.1 Annualized Freezer's consumption

Figure 5.7 shows the annual consumption for the freezers (or upright freezers). This graph include all the households from the monitoring campaign. You will find the results per area in the appendix at the end of the report.

The consumptions per household goes from less than **30 kWh/year to 1650 kWh/year**. The average value of **635 kWh/year** can be compared to the 556 kWh/year found in France during the Remodece+ project in 2007 or the 327 kWh/year found in England during the UK240 project in 2010. In Sweden, for the SWE400 project, the consumption went from 326 to 585 kWh/year.

All the parameters that can explain the differences in consumption, like the inside temperature of the different cold appliances, are not know. But it's sure that the inside temperature of the households and frequent power outage will certainly play an important role in this high consumption

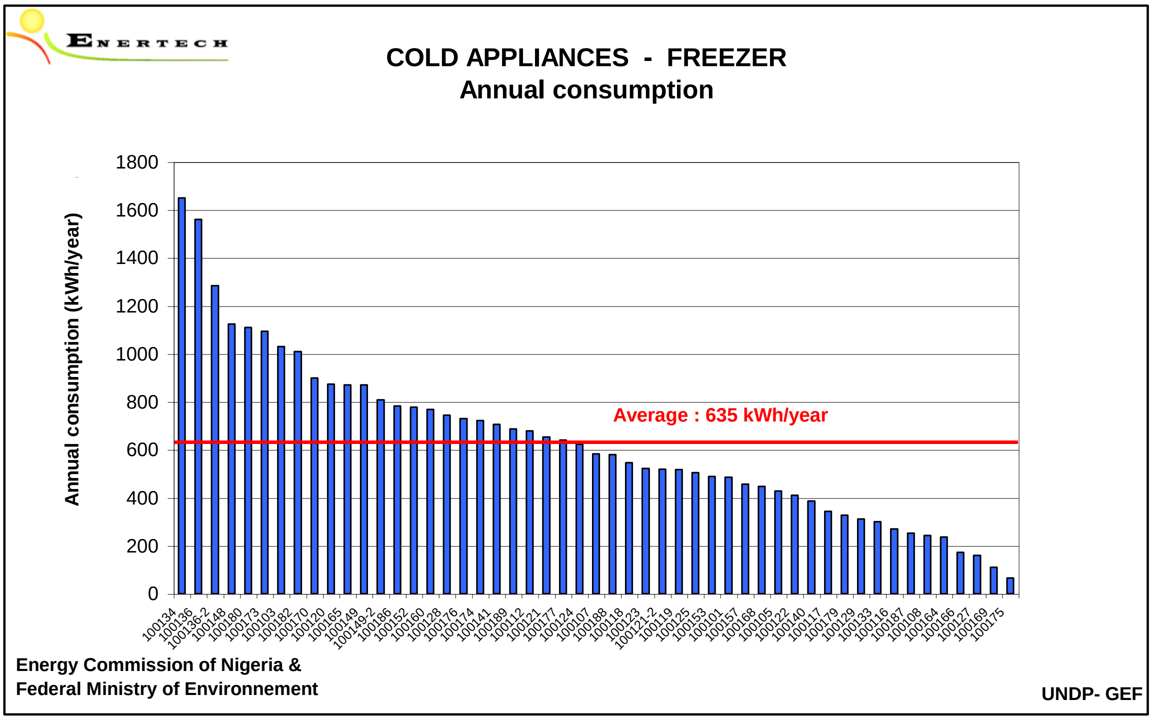


Figure 5.7 : Freezer – Annualized consumption

5.3.2 Functioning rates during the power access

Figure 5.8 show the functioning rate during the power access. The values goes from 28 to 100% and the average value of 78% is very high for that type of equipment. This is explained by the frequent power outage that leads to very long compressor cycles.

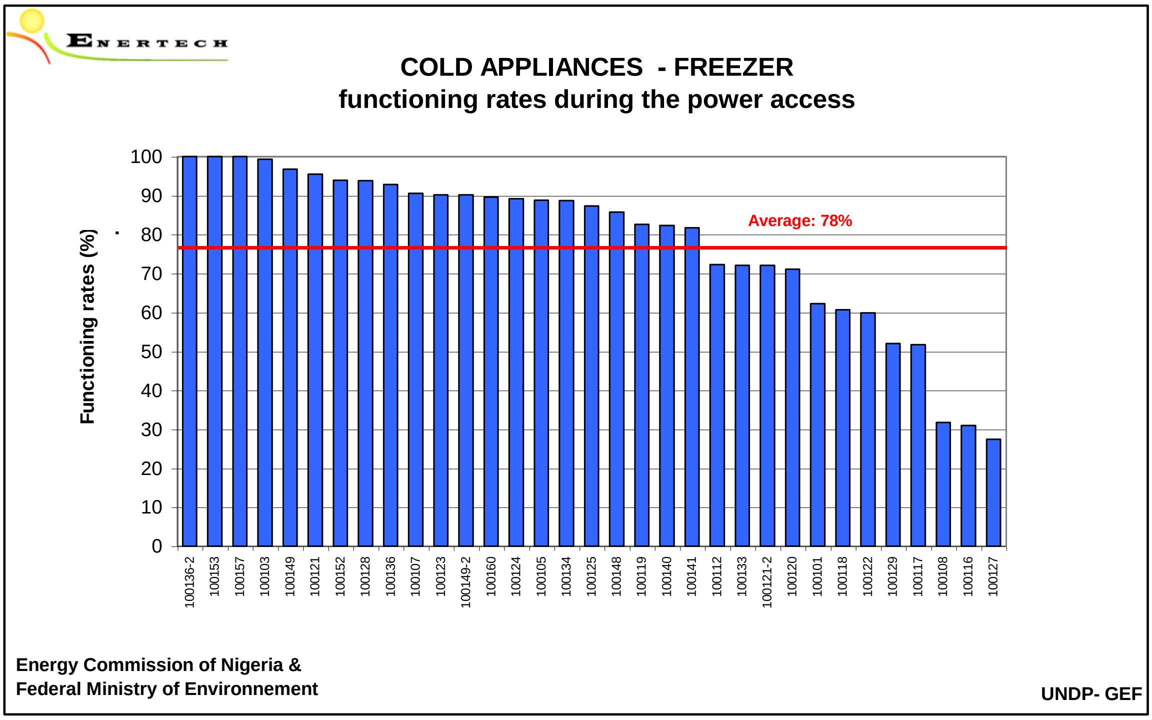


Figure 5.8 : Freezer – Functioning rates during the power access

5.3.3 Annualized Freezer's consumption versus power grid duration

Figures 5.9 and 5.10 tries to find a correlation between the annual consumption and the duration of power access. As for the fridges, we can see that there is no simple relation between the two data, the number of parameters is to important to be able to find a simple relation between the two values. We can however note that the three most consuming freezers are the one having access to electricity the whole day.

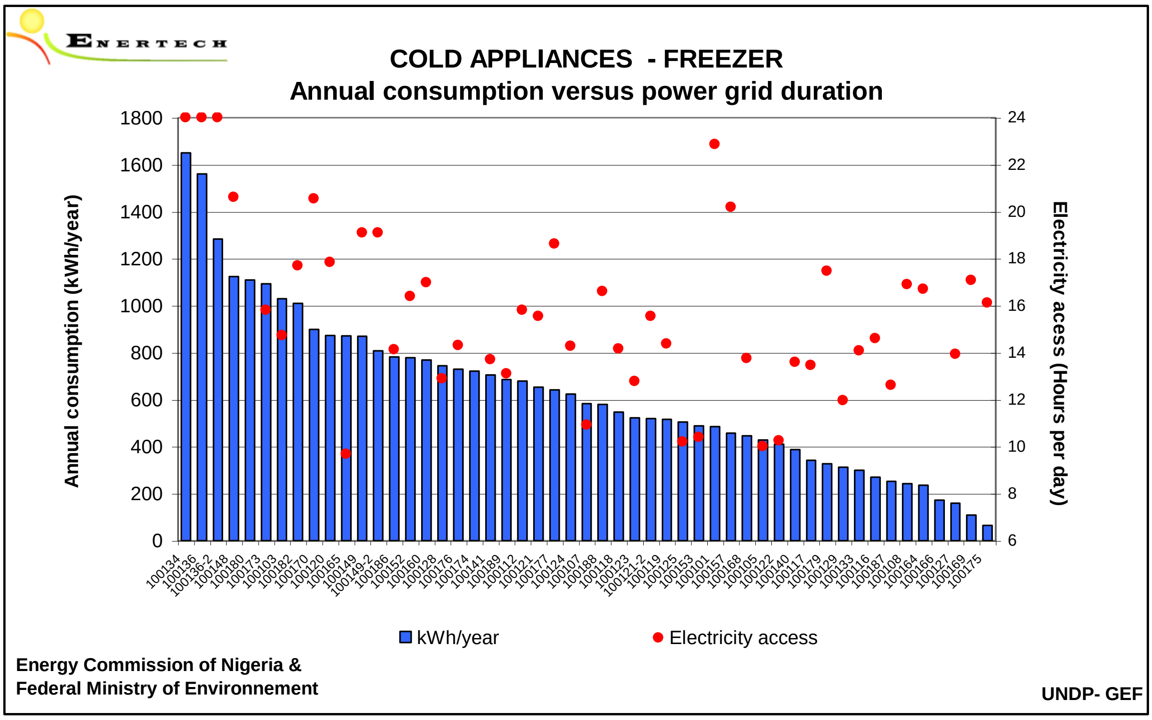


Figure 5.9 : Freezer – Annualized consumption vs power grid duration

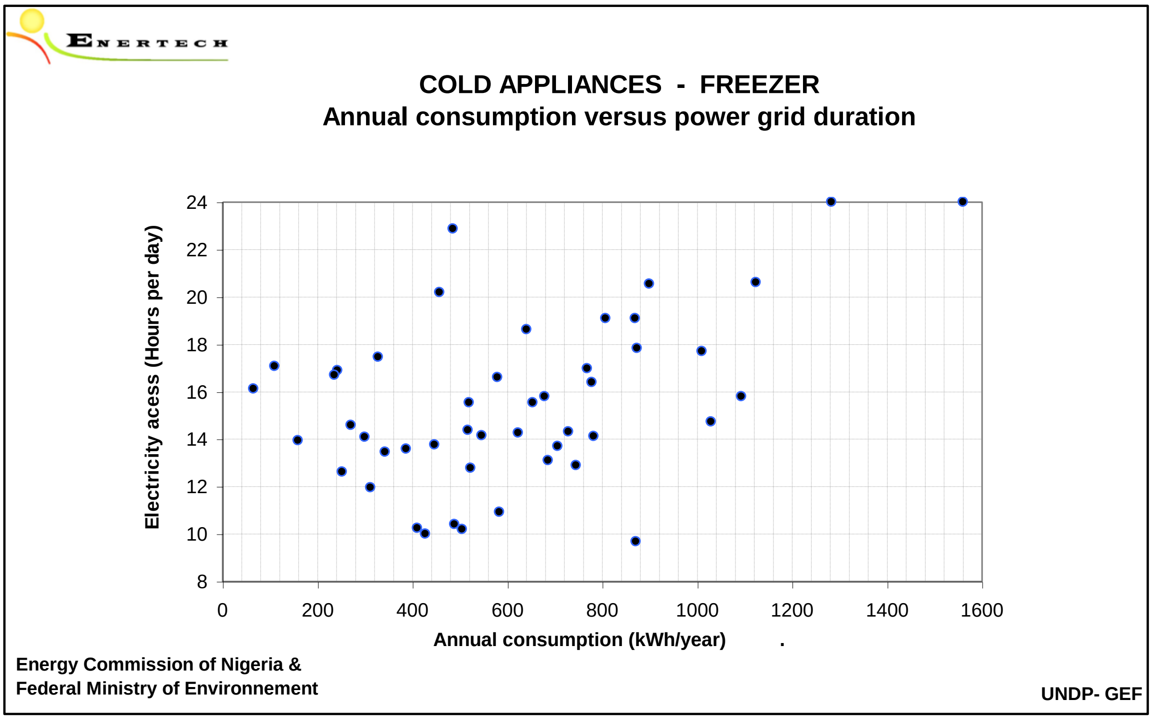


Figure 5.10 : Freezer – Annualized consumption versus power grid duration

5.4 FRIDGE FREEZER

5.4.1 Annualized Fridge freezer's consumption

Figure 5.11 shows the annual consumption for the fridge-freezers. This graph include all the households from the monitoring campaign. You will find the results per area in the appendix at the end of the report.

The consumptions per household goes from less than **100 kWh/year to 2000 kWh/year**. The average value of **496 kWh/year** can be compared to the 460 kWh/year found in France during the Remodece+ project in 2007 or the 427 kWh/year found in England during the UK240 project in 2010. In Sweden, for the SWE400 project, the consumption went from 413 to 525 kWh/year.

All the parameters that can explain the differences in consumption, like the inside temperature of the different cold appliances, are not know. But it's sure that the inside temperature of the households and frequent power outage will certainly play an important role in this high consumption

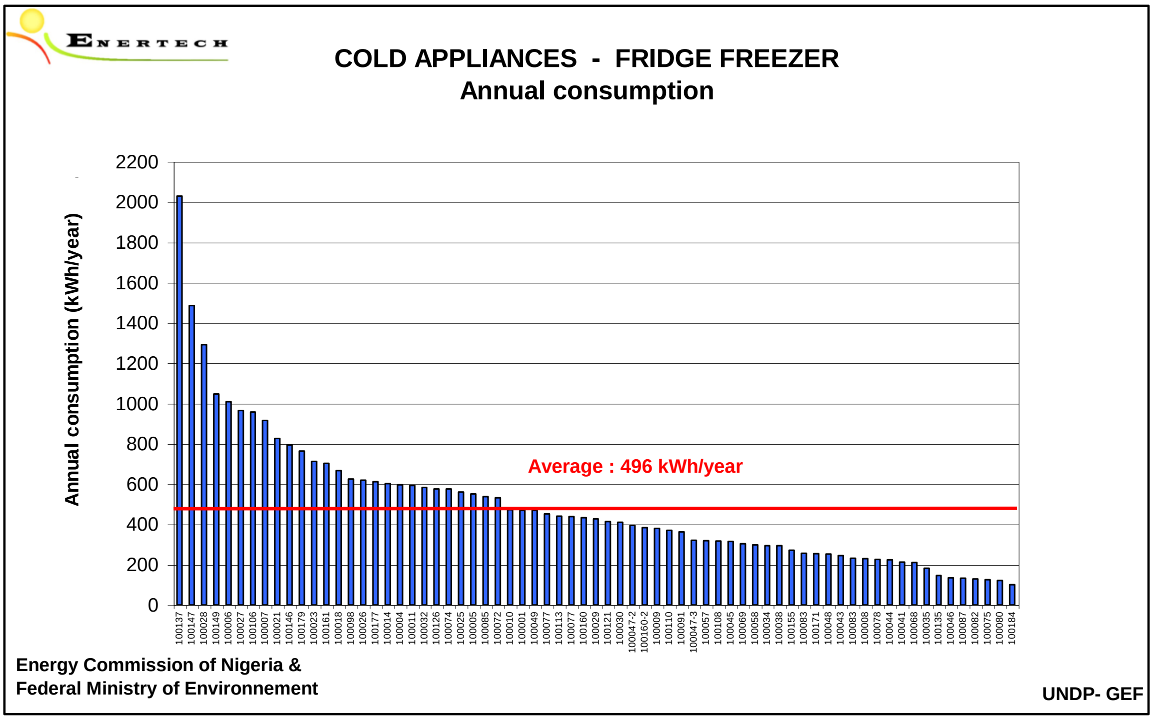


Figure 5.11 : Fridge freezer – Annualized consumption

5.4.2 Functioning rates during the power access

Figure 5.12 shows the functioning rate during the power access. The values goes from 31 to 100% and the average value of 82% is very high for that type of equipment. This is explained by the frequent power outage that leads to very long compressor cycles.

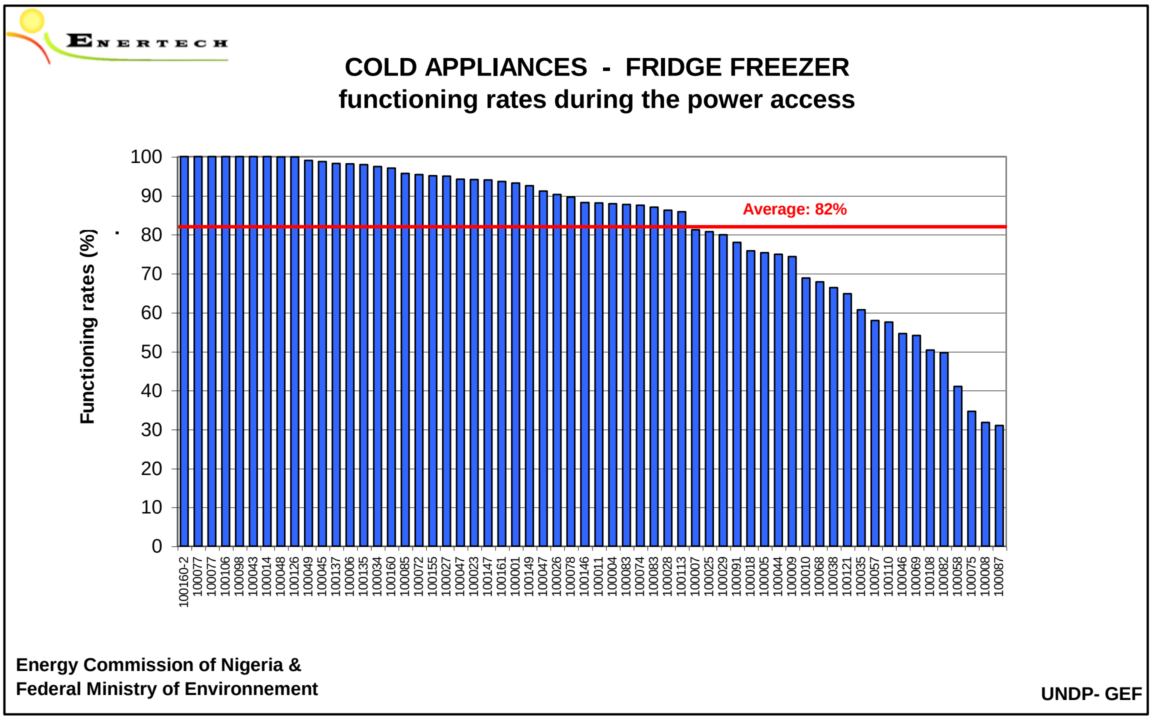


Figure 5.12 : Fridge freezer – functioning rates during the power access

5.4.3 Annualized Fridge freezer's consumption versus power grid duration

Figures 5.13 and 5.14 tries to find a correlation between the annual consumption and the duration of power access. There seems to be a better correlation than for the fridges or freezers.

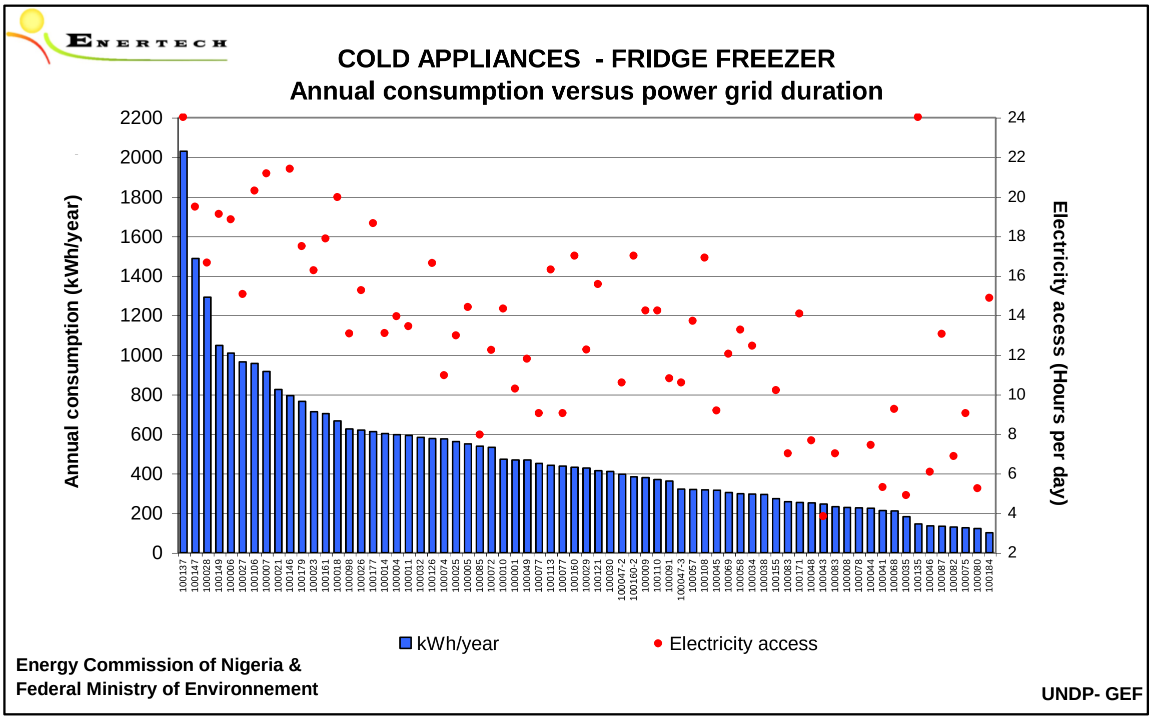


Figure 5.13 : Fridge freezer – Annualized consumption versus power grid duration

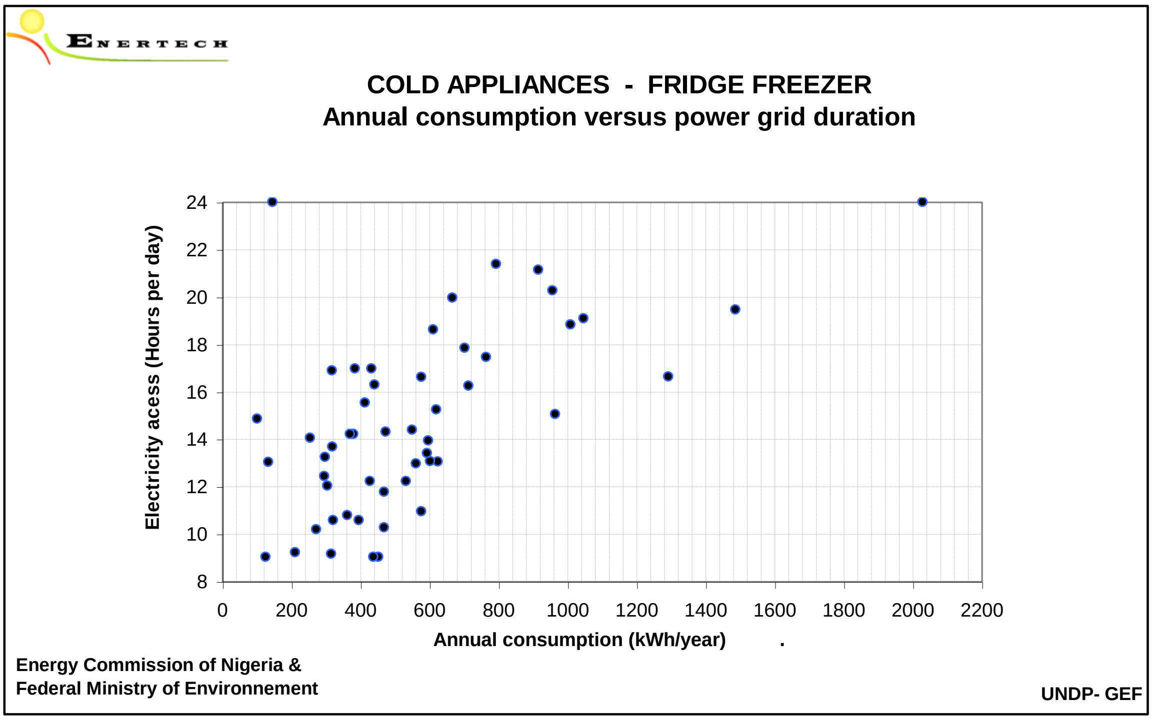


Figure 5.14 : Fridge freezer – Annualized consumption versus power grid duration

5.5 CHEST FREEZER

5.5.1 Annualized Chest freezer's consumption

Figure 5.15 show the annual consumption for the chest-freezers. This graph include all the households from the monitoring campaign. You will find the results per area in the appendix at the end of the report.

The consumptions per household goes from less than **75 kWh/year to 1400 kWh/year**. The average value of **572 kWh/year** can be compared to the 460 kWh/year found in France during the Remodece+ project in 2007 or the 362 kWh/year found in England during the UK240 project in 2010. In Sweden, for the SWE400 project, the consumption went from 242kWh/year (but with far less appliances to analyze).

All the parameters that can explain the differences in consumption, like the inside temperature of the different cold appliances, are not know. But it's sure that the inside temperature of the households and frequent power outage will certainly play an important role in this high consumption

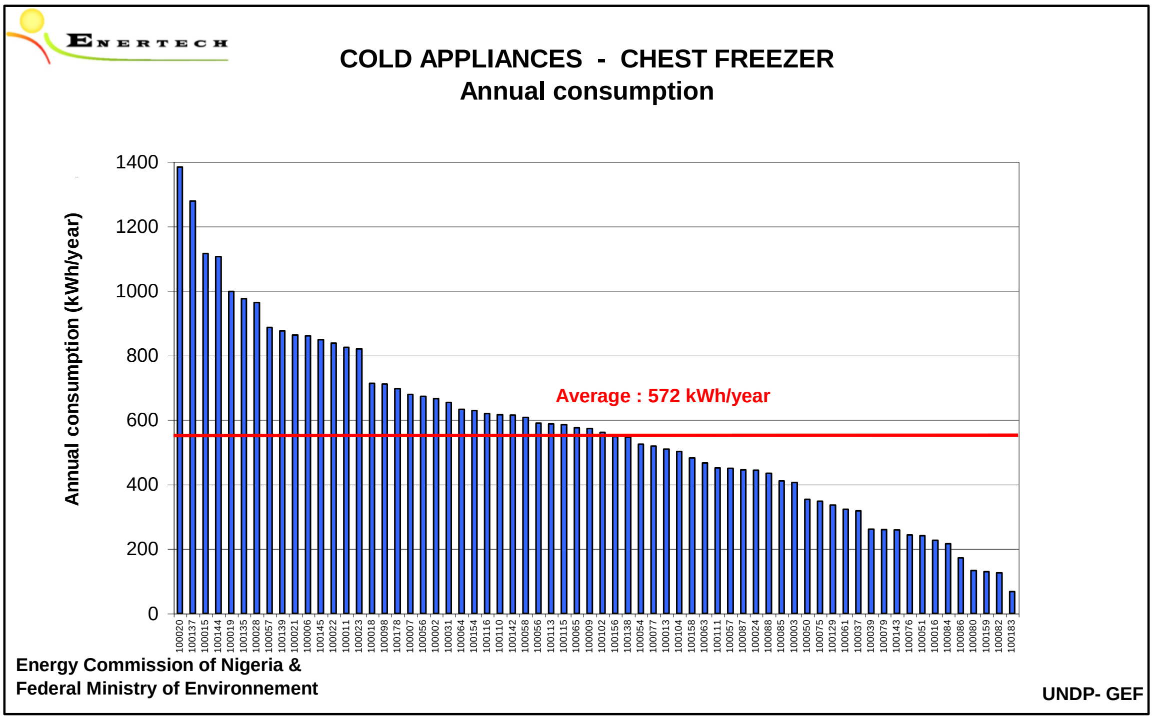


Figure 5.15 : Chest freezer – Annualized consumption

5.5.2 Functioning rates during the power access

Figure 5.16 show the functioning rate during the power access. The values goes from 30 to 100% and the average value of 79% is very high for that type of equipment. This is explained by the frequent power outage that leads to very long compressor cycles.

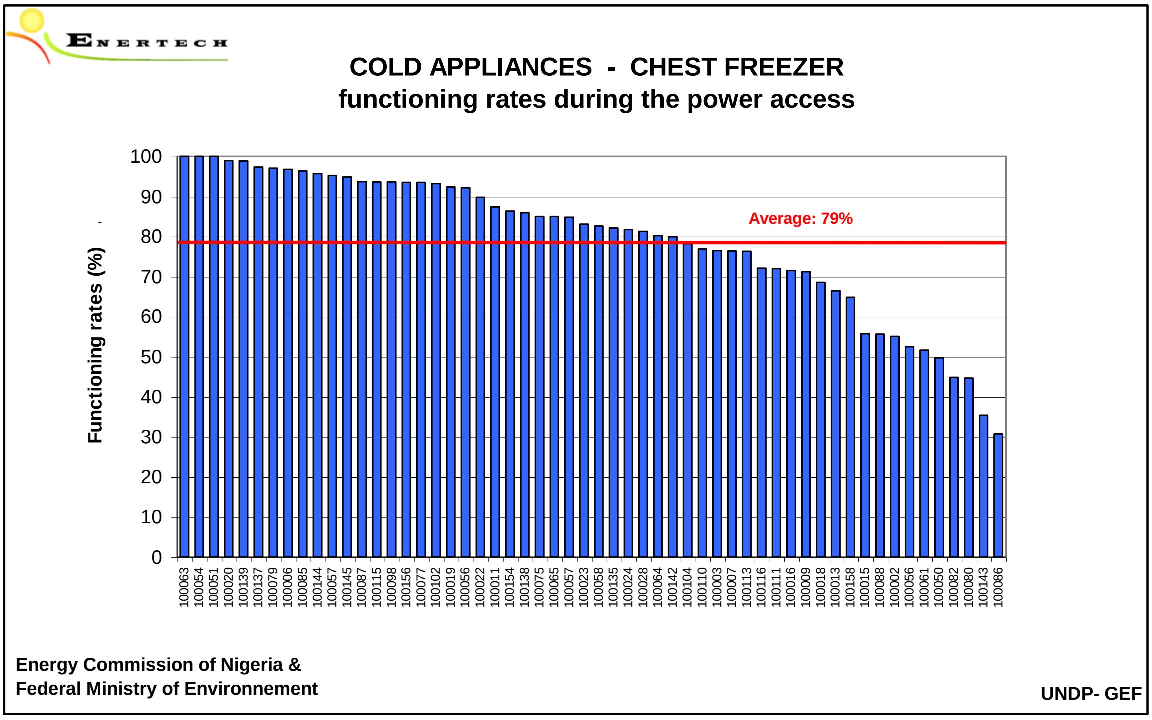


Figure 5.16 : Chest freezer – Functioning rates during the power access

5.5.3 Annualized Chest freezer's consumption versus power grid duration

Figures 5.17 and 5.18 tries to find a correlation between the annual consumption and the duration of power access. As for the fridge-freezers, there seems to be a correlation for that type of appliances.

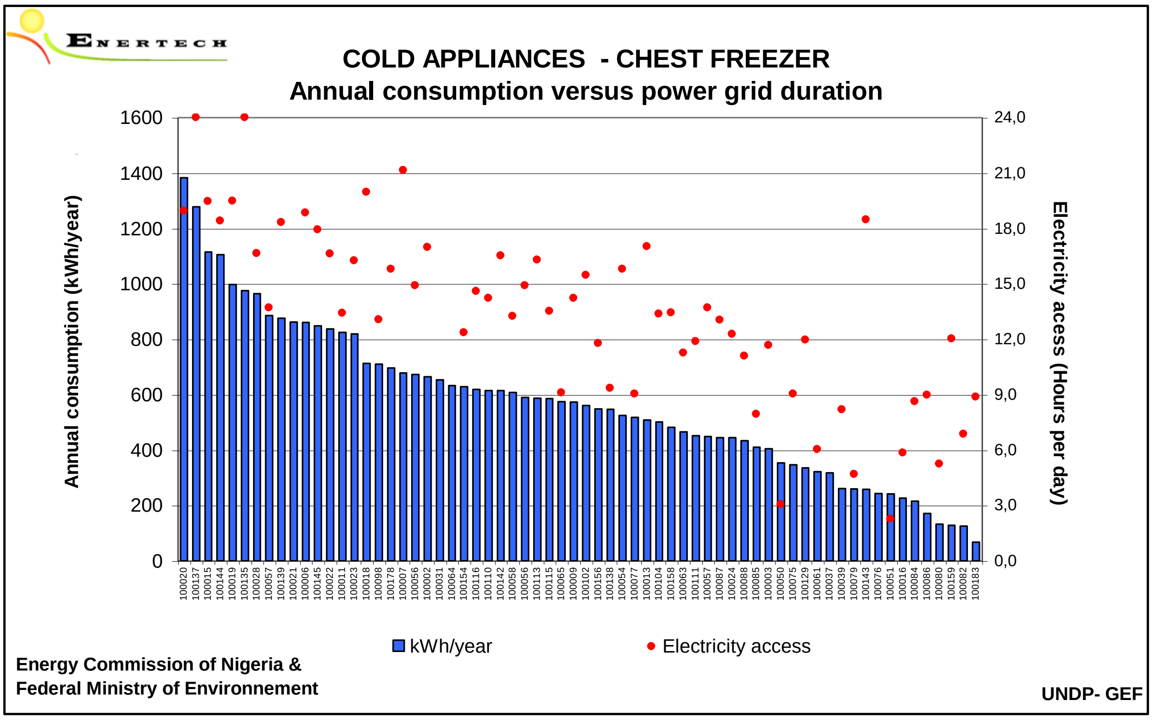


Figure 5.17 : Chest freezer – annualized consumption vs power grid

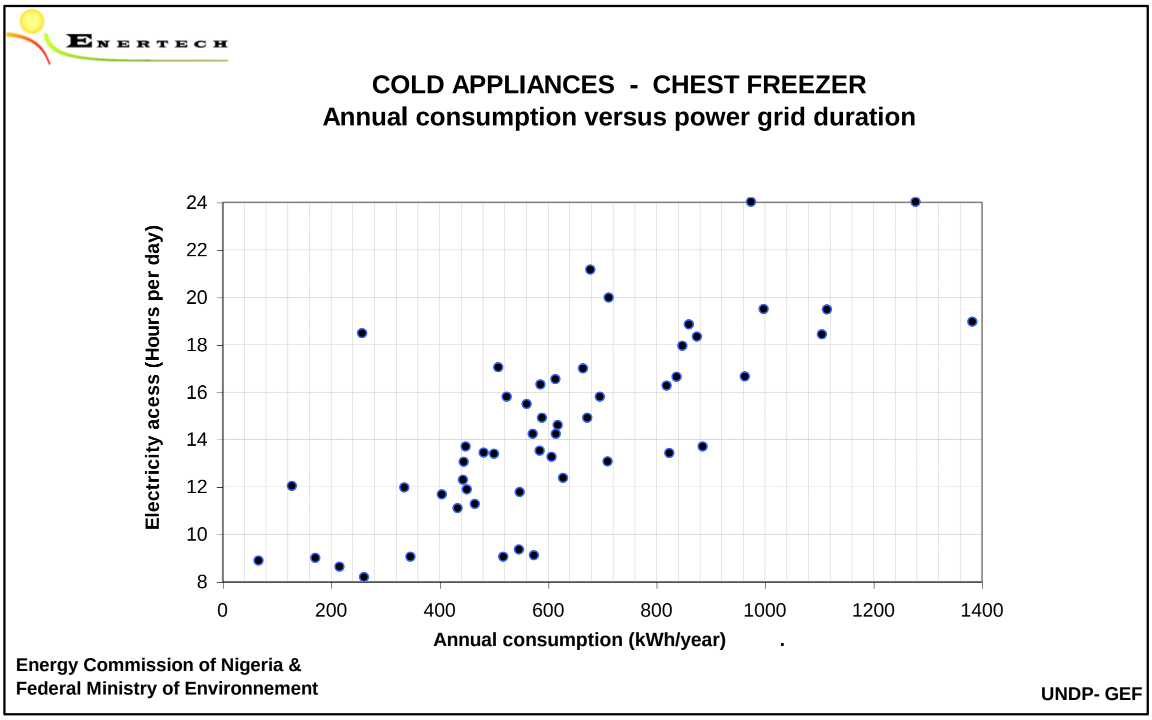


Figure 5.18 : Chest freezer – annualized consumption vs power grid

5.6 ALL COLD APPLIANCES

5.6.1 Annualized consumption

Figure 5.20 shows the annual consumption for all the cold appliances. The individual annual consumptions were aggregated per household.
The consumptions goes from less than **30 kWh/year to 2000 kWh/year** with an average value at **542 kWh/year** .

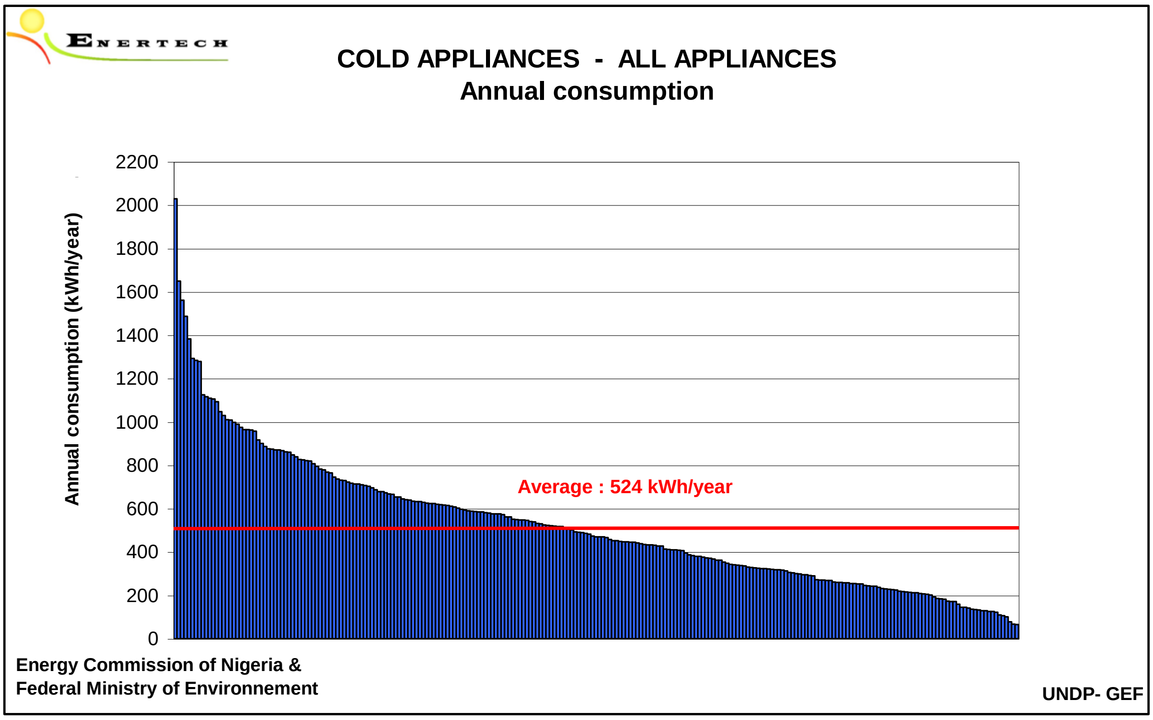


Figure 5.20 : All cold appliances – Annualized consumption

5.6.2 Functioning rates during the power access

Figure 5.21 show the functioning rate during the power access. The values goes from 20 to 100% and the average value of 78% is very high for that type of equipment. This is explained by the frequent power outage that leads to very long compressor cycles.

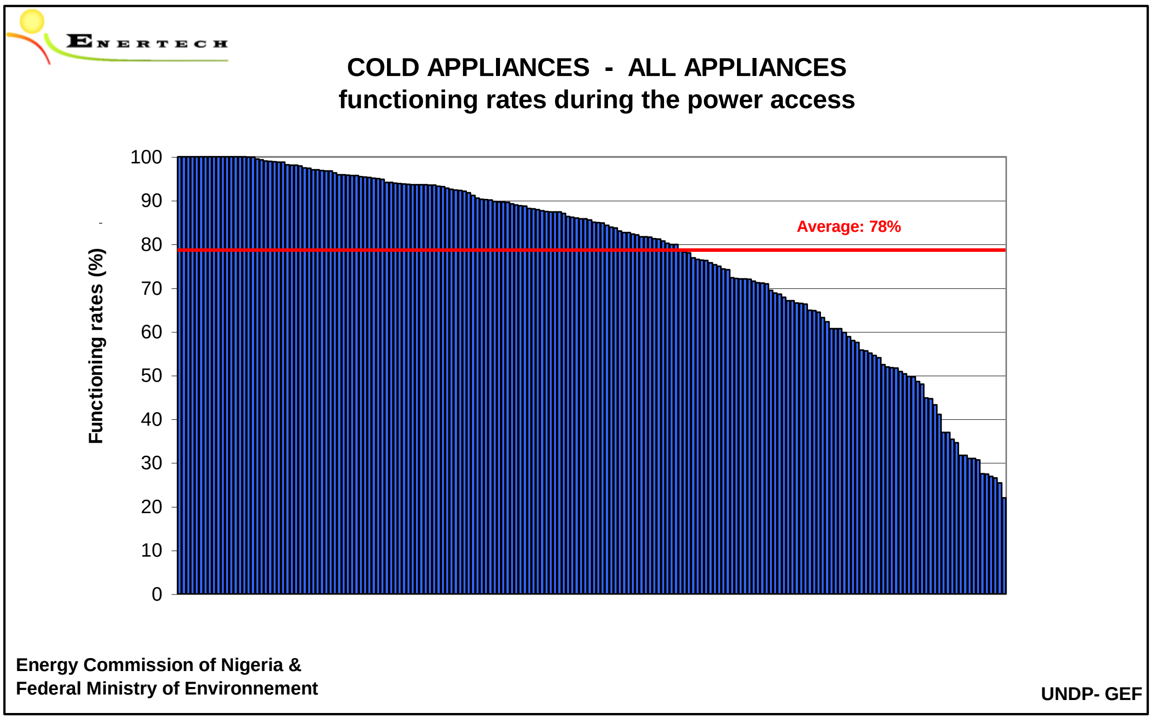


Figure 5.21 : All cold appliances – Functioning rates during the power access

5.6.3 Annualized consumption versus power grid duration

Figures 5.22 and 5.23 tries to find a correlation between the annual consumption and the duration of power access. On figure 5.23, we added the trend line in order to show the relation between the two values.

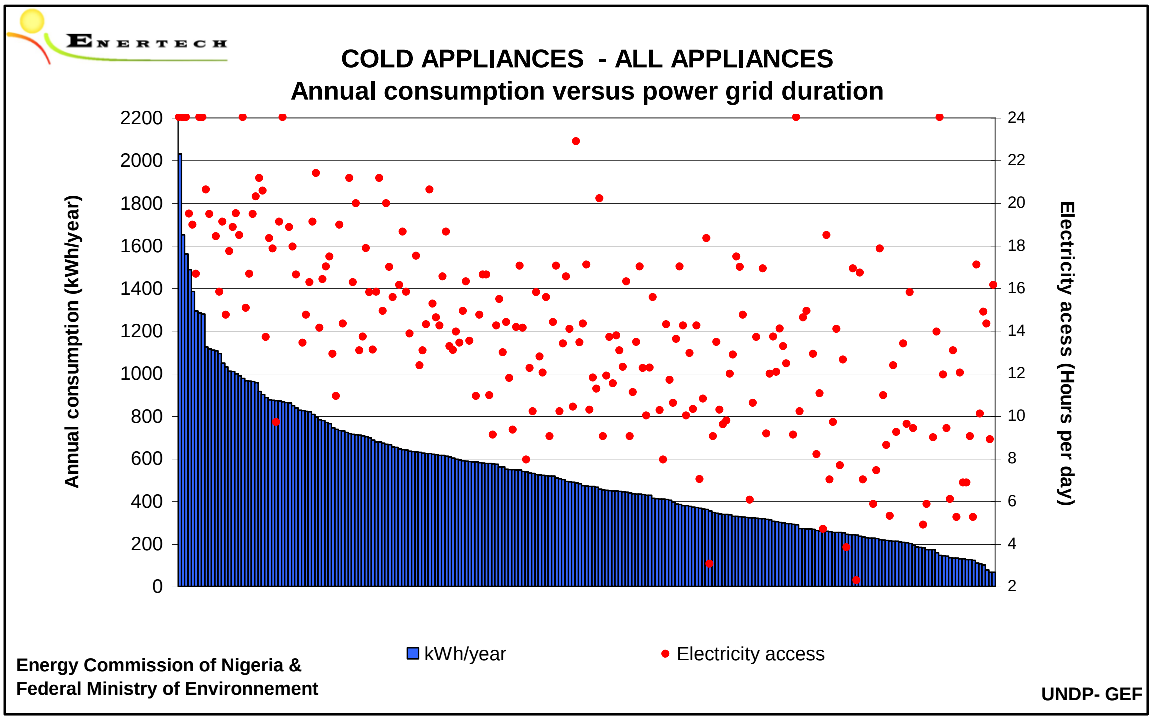


Figure 5.22 : All cold appliances –annualized consumption vs power grid

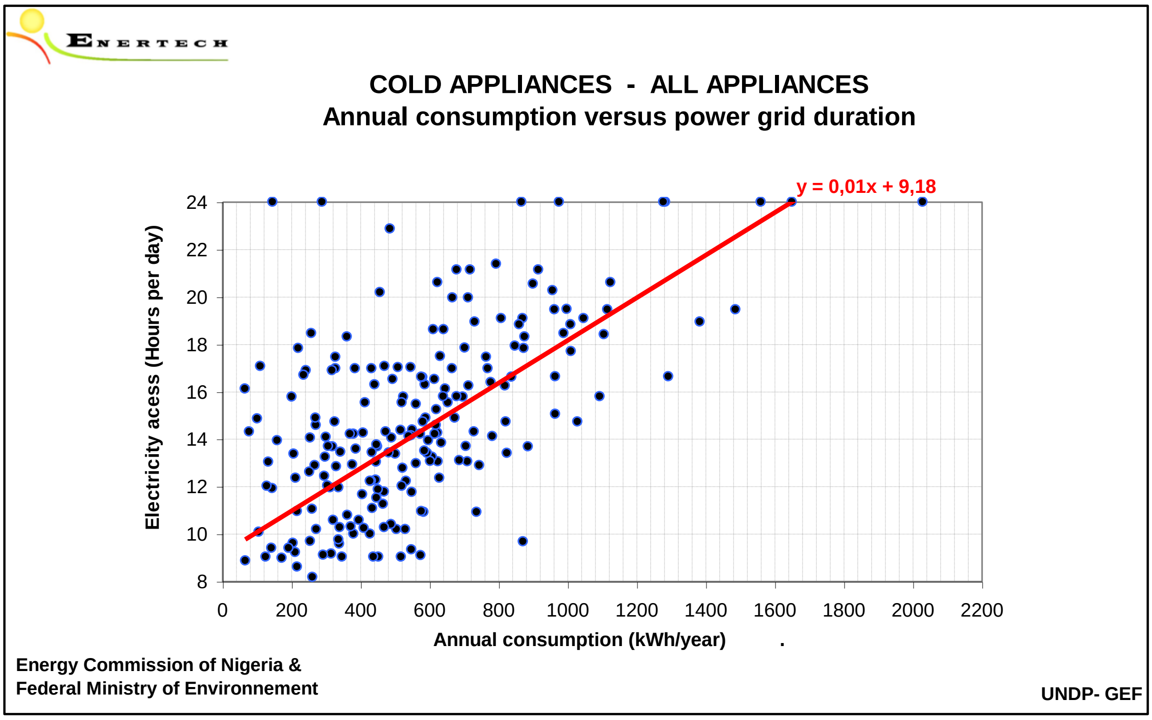


Figure 5.23 : All cold appliances –annualized consumption vs power grid

5.6.4 Summary table relating to each graph from mains cold appliances chapter

Table 5.24 lists all the results for the cold appliances from the previous graphs.

	COLD APPLIANCES	FRIDGE	FREEZER	FRIDGE FREEZER	CHEST FREEZER
Average number of appliances per Households	1,37	0,28	0,2	0,38	0,44
Annualized consumption	524kWh/y	425kWh/y	635kWh/y	496kWh/y	572kWh/y
Fonctioning rates during the power access	78%	73%	78%	82%	79%

Table 5.24 : cold appliances – Summary table

CHAPTER 6 : LIGHTING

For the first two areas (Abuja and Sokoto) most of the lighting consumption was monitored from the main switchboard using the multivoie system. This solution was problematic : contrary to the French switchboard with specific light departures, it is common to find several appliances per breaker inside a Nigerian switchboard (Cf Appendix – Chapter 2 : Feedback) This type of distribution complicates the electric measurements and the identification of the specific departures like the lighting.

In order to avoid this problem, we decided to use lampmeters to monitor the light consumption. But this solution brought another problem : the Nigerian teams were not always given full access to every room in the houses (especially in the Northern part of the country) and therefore it was not possible to monitor all the lights.

6.1.1 Installed wattage per type of bulbs

Figure 6.1 shows the power of each light source listed during the monitoring campaign. The average power of 37 Watts is comparable to the results from Sweden (38W) or England (41W) and lower than for France (56W).

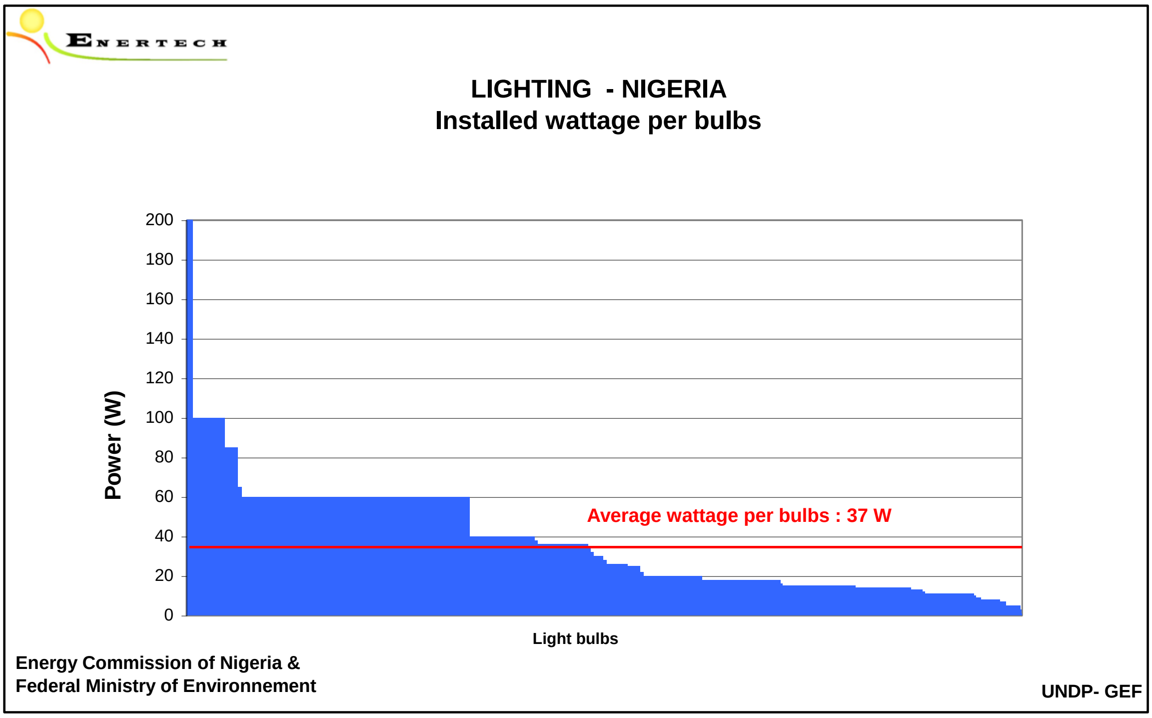


Figure 6.1 : Lighting - installed wattage per light bulb

6.1.2 Distribution of light bulbs per type of light sources

By light source, we mean any bulb, fluorescent strip lighting, low energy light bulb, LED or halogen spotlight. If a light fitting should comprise several sources (bulbs), each one of them is taken into account separately.
Figure 6.2 shows the part of each type of light source in the total installed light bulbs.
Over half of the light bulbs are Compact Fluorescent Lights (CFL) followed by the incandescent light bulbs. This two types together represent more than 90% of the total.

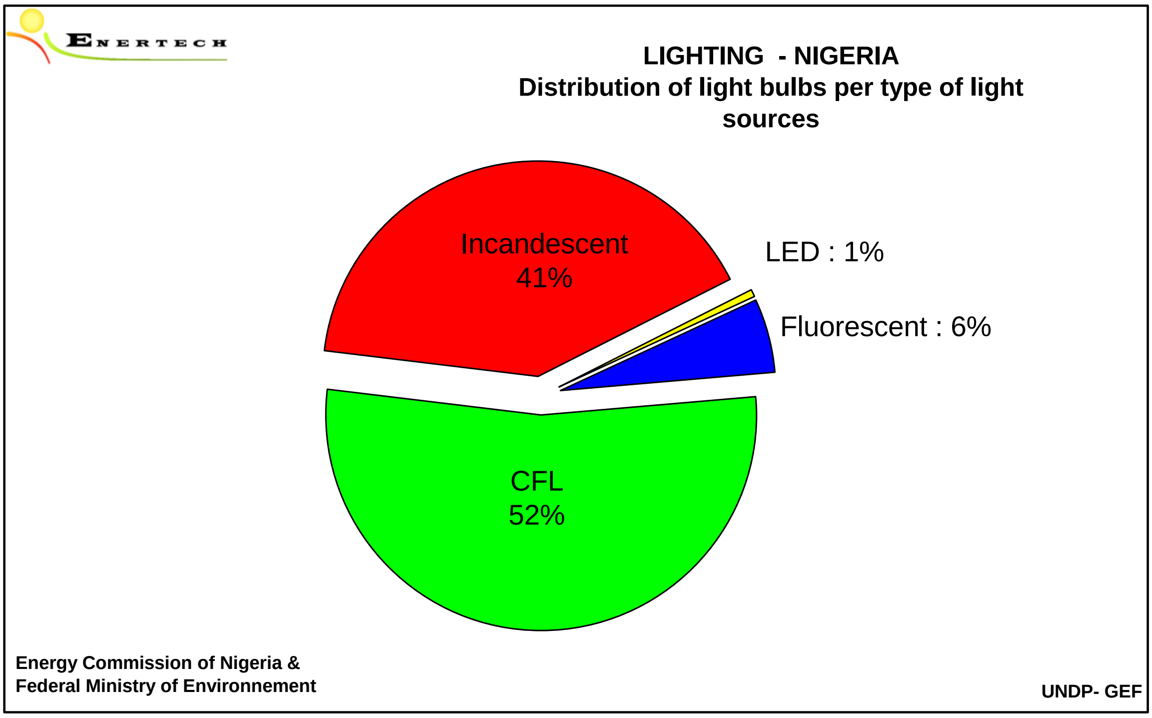


Figure 6.2 : Lighting – part of each type of light source

6.1.3 Installed wattage per type of room

Figure 6.3 shows the installed wattage per type of room. The living room and the kitchen are the places with the highest installed wattage. As the number of each type of rooms in a household can be greater than 1, it has to be noted that the addition of all these different wattages has no physical meaning at all, and will always be different from the household average installed wattage.
Finally, it should not be forgotten that some rooms were not monitored due to religious and traditional practises and therefore could not be integrate in the analysis.

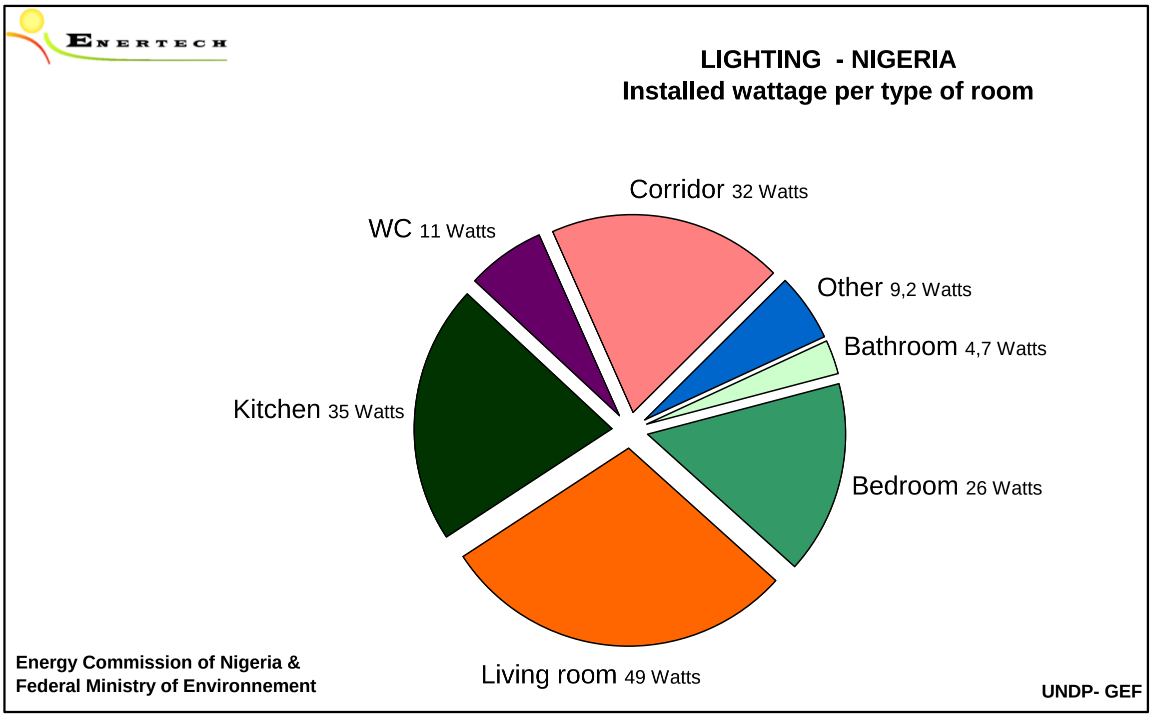


Figure 6.3 : Lighting - installed wattage per type of room

6.1.4 Distribution of the unit wattage of the bulbs, per type of light source

Figures 6.4 to 6.6 show the wattage distribution per type of light sources. A succinct analysis can be done for each type of light bulbs:

- the stock of fluorescent tube lights wattage is essentially 36 W (60 %),
- almost 68 % of the incandescent bulb wattage is 60 W,
- low energy light stock are between 11 and 20 Watts.

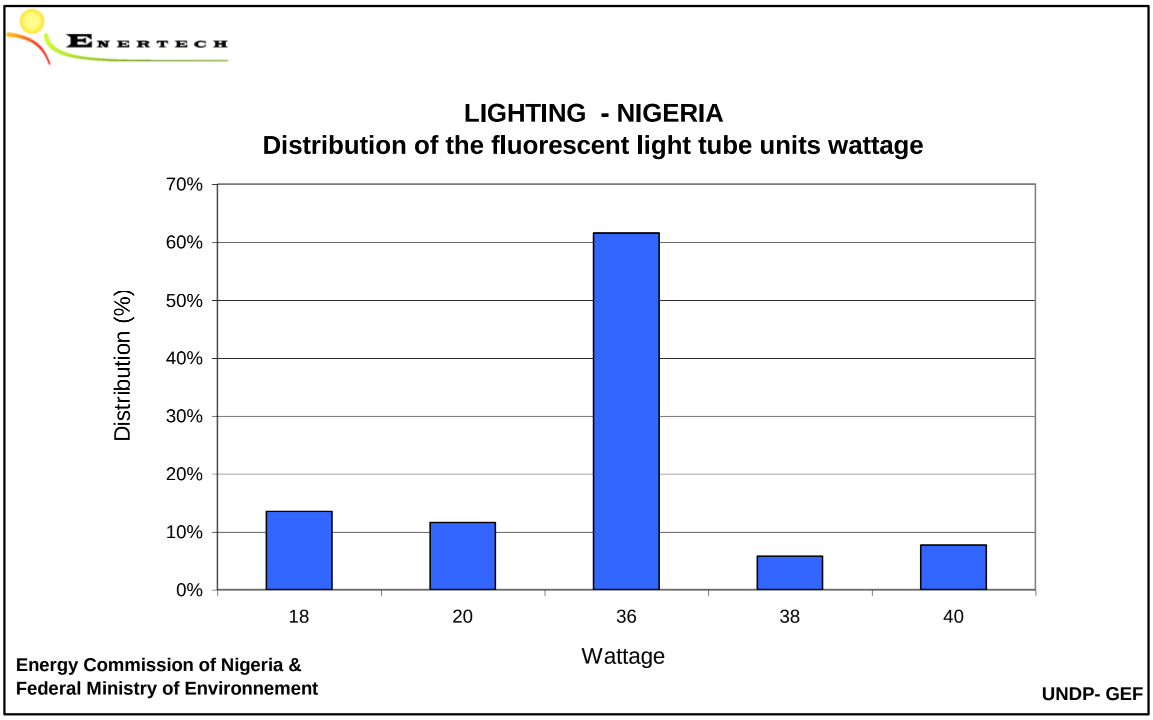


Figure 6.4 : Lighting – distribution of the fluorescent light tube units wattage

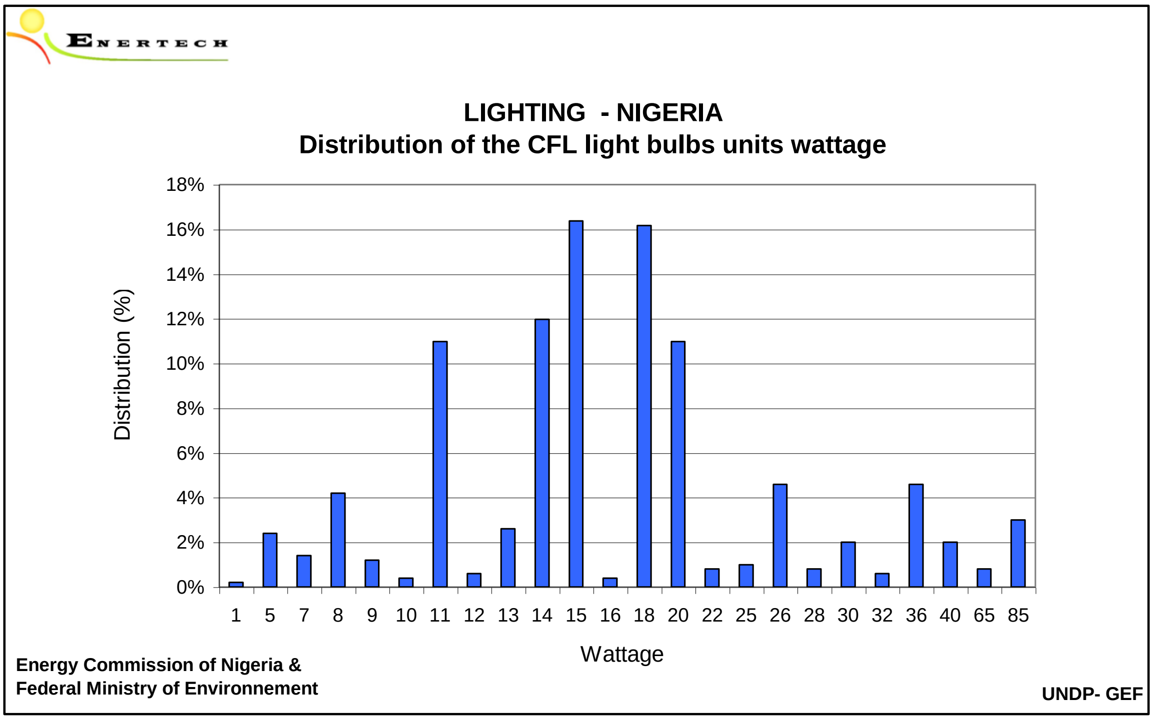


Figure 6.5 : Lighting – distribution of the CFL lights bulbs units wattage

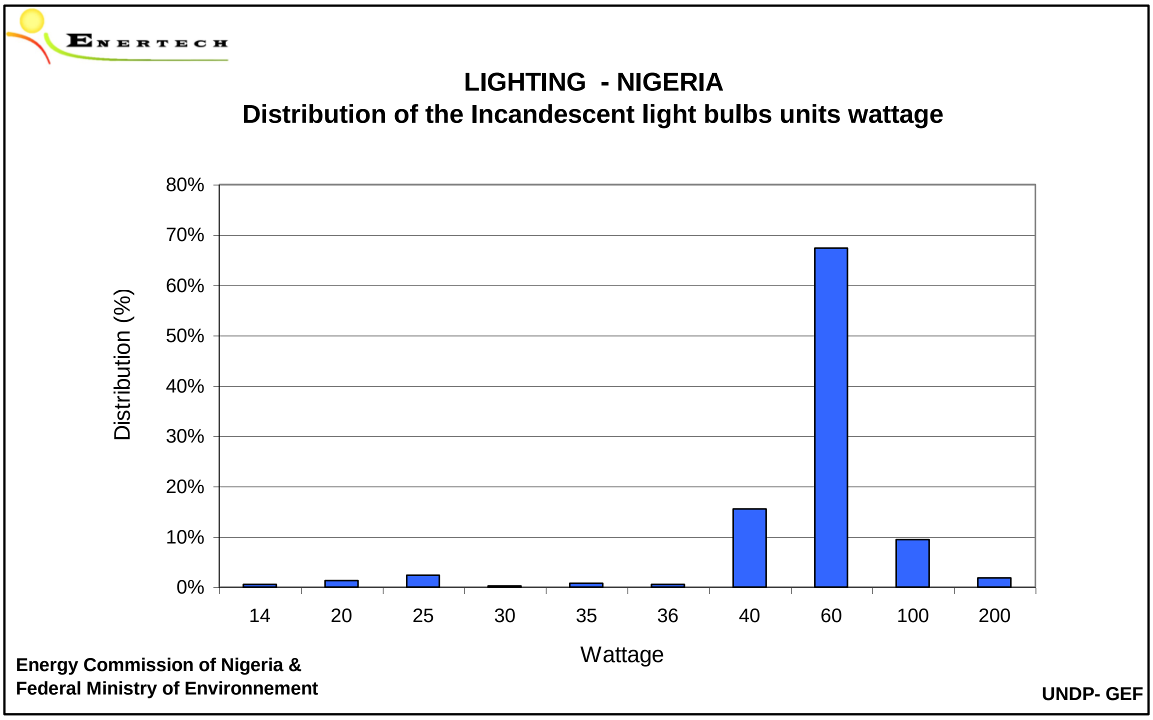


Figure 6.6 : Lighting – distribution of the incandescent light bulbs units wattage

6.1.5 Annualized lighting consumption per households

Figure 6.7 represent the annualized lighting consumption per household. This consumption goes from 25 to 3500 kWh/year with an average at **454 kWh/year**. This value is between the French consumption (354 kWh/year) and the English one (537 kWh/year).

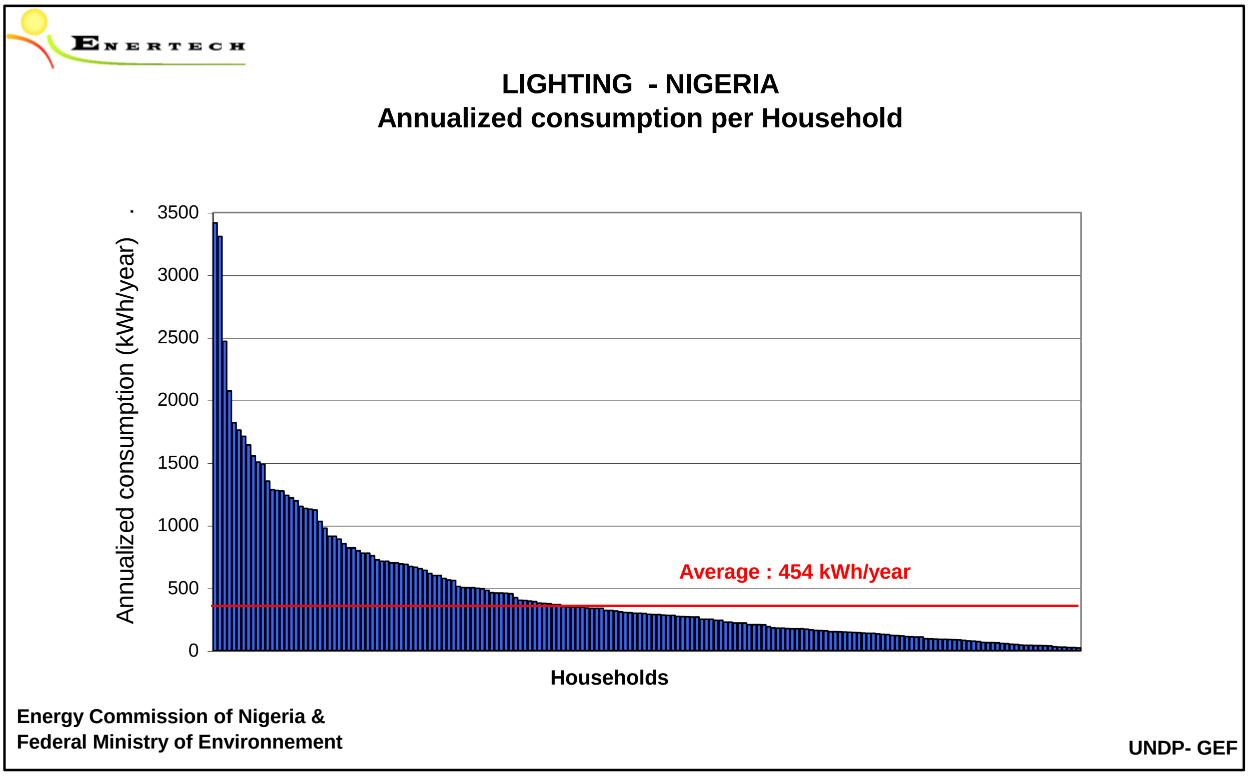


Figure 6.7 : Lighting – annualized consumption per households

6.1.6 Daily average load curve

Figures 6.8 represents the daily average daily load curve calculated for the whole monitoring period and only for the power access period. There are two main peaks, one in the morning at 06:00 and the highest one in the evening between 20:00 – 21:00. We can see that the light consumption during the night remains at an important level.

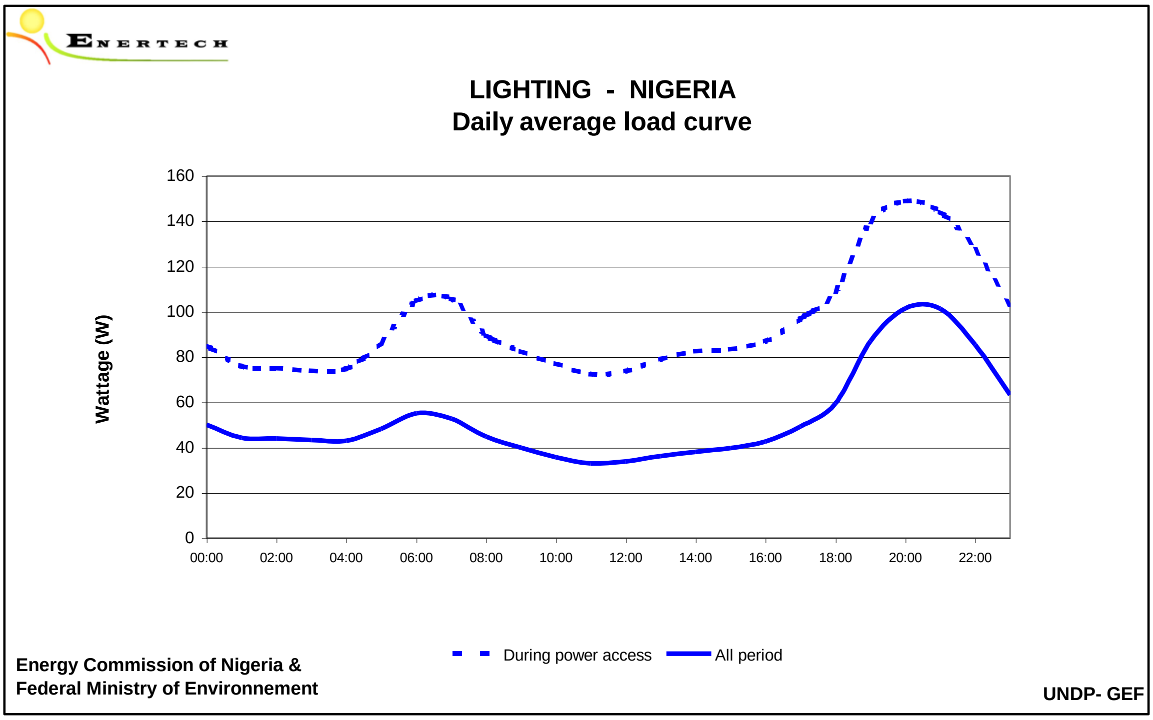


Figure 6.8 : Lighting – daily average load curve

Conclusion

This project represents the first measurement campaign ever made in Nigeria. By the number of households involved, this monitoring campaign can be compared to the one's achieved in several European countries (France, Sweden, England,…). The high number of households monitored for air conditioning, cold appliances and lighting lets us have a precise overview of the electrical consumption of this appliances but :

- The power outage periods, found in all the six areas where the campaign was conducted, has a big influence on the way the appliances works and therefore on the annual consumption,
- the power outage periods, which are unintended and semi-random in duration and frequency, prevents to calculate accurate annual savings per appliances,
- for the cold appliances, the ratio between the less and most consuming is always greater than 10 (from 30 to 1650 kWh/year for the freezers for example) and indicates the inefficiency in term of energy consumption of a part of the sample,
- with 56% of all the light bulbs installed corresponding to CFL light bulbs, Nigeria has a very high rate of low consumption light bulbs per households. It will be possible to further decrease the lighting consumption by replacing the 41% of incandescent light bulbs with high efficiency ones.

Reference

The Eureco project, End-use metering campaign in 400 households of the European Community, Assessment of the Potential Electricity Savings, Save project (N° 4.1031/Z/98-267)

The Remodece project, Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe, 2009, ISR-University of Coimbra, Dep. of Electrical Engineering, an EU, EACI project.

The SWE400 project, End-use metering campaign in 400 households in Sweden, Assessment of the Potential Electricity Savings, CONTRACT 17-05-2743

The UK240 project, End-use metering campaign in 240 households in England, Assessment of the Potential Electricity Savings,

Appendix

APPENDIX A : ANALYSIS PER AREAS

All the analysis done in the report were also applied to the six areas. The following paragraphs shows the results.

6.2 ABUJA

6.2.1 Indoor temperature

6.2.1.1 Temperature daily curve

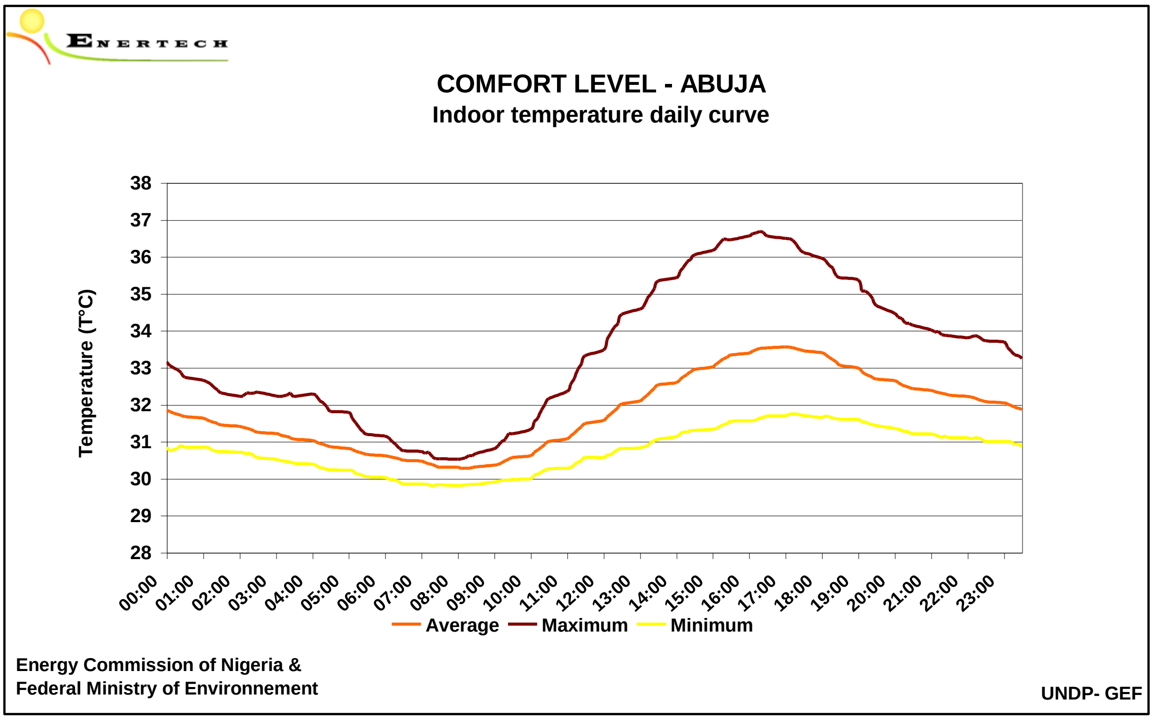


Figure 1.1 : Temperature Daily curve - Abuja

6.2.1.2 Temperature cumulative frequency

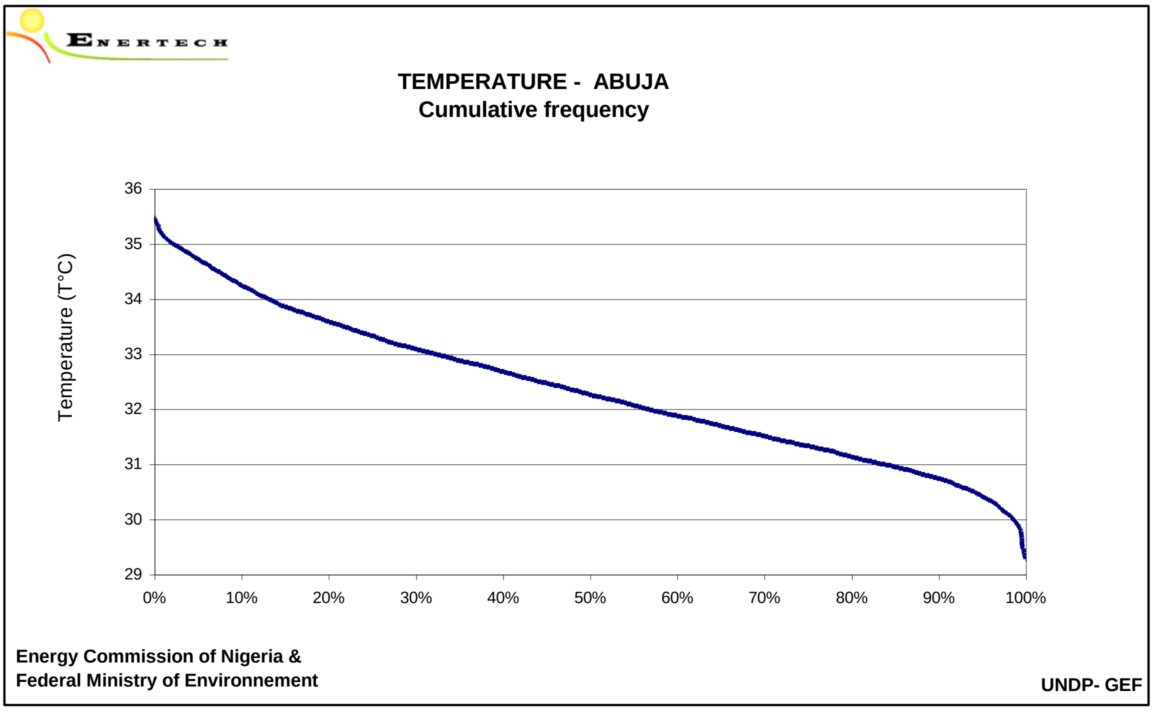


Figure 1.2 : Temperature cumulative frequency – Abuja

6.2.2 Power Grid

6.2.2.1 Distribution of power access and power outages

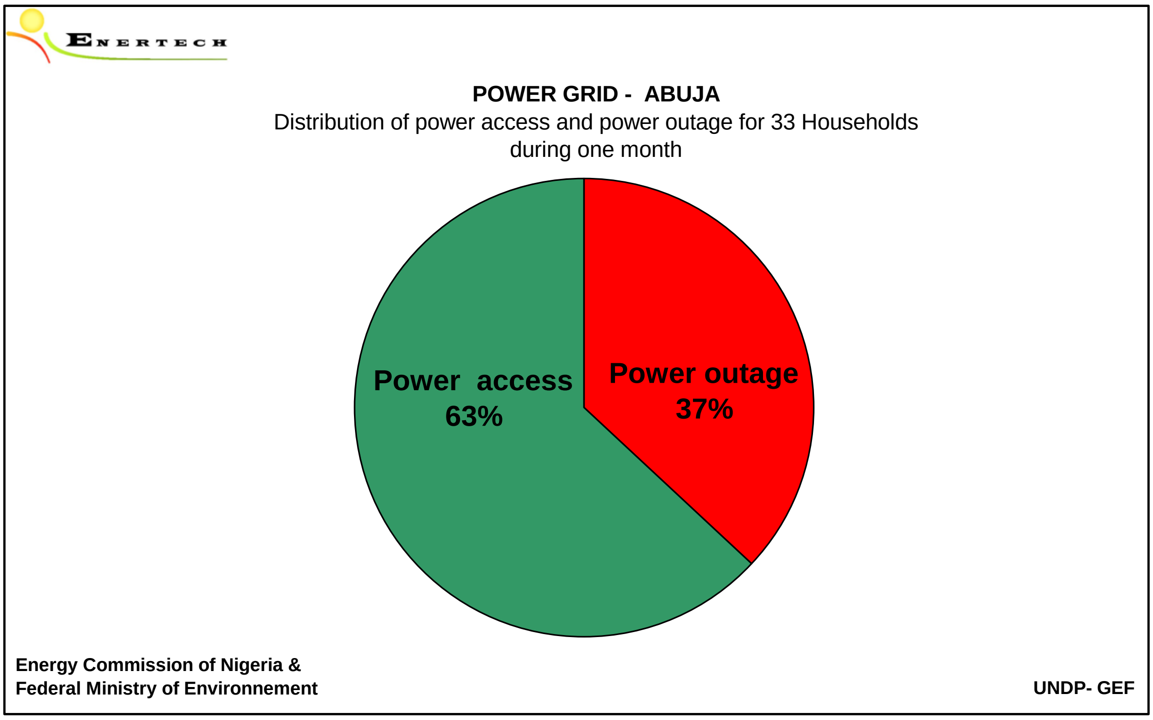


Figure 1.3 : Power access and power outages- Abuja

6.2.2.2 Average voltage during power access

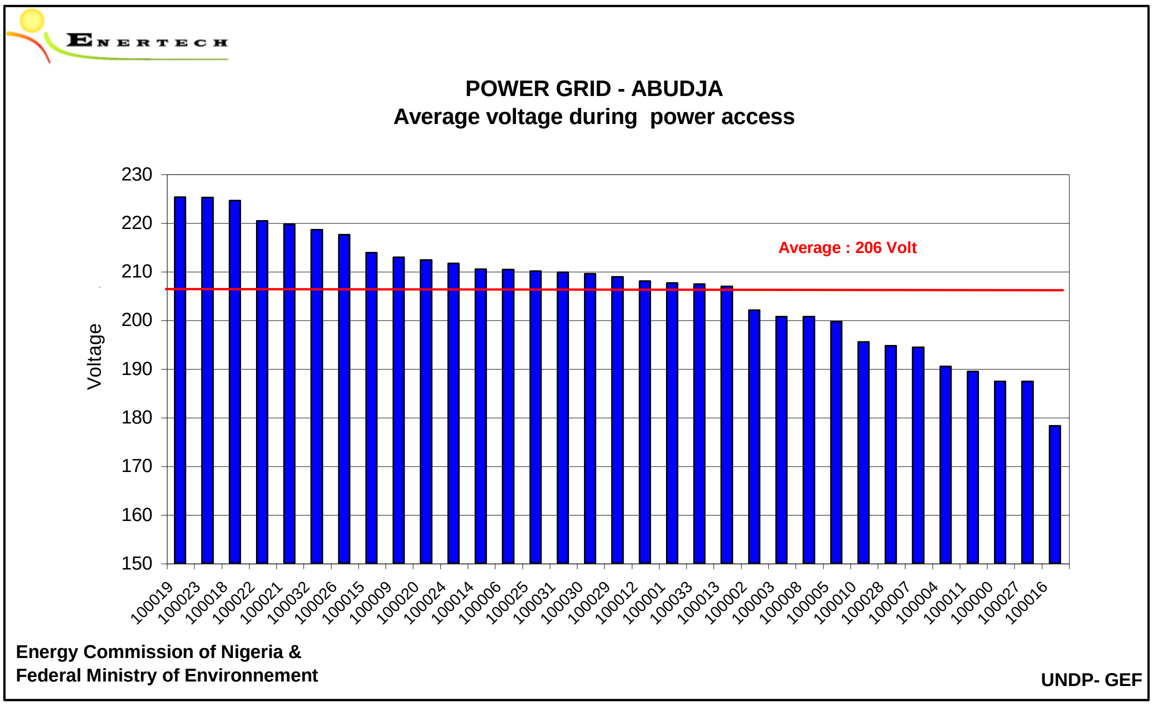


Figure 1.4 : Average voltage during power access - Abuja

6.2.2.3 Part of power access daily curve

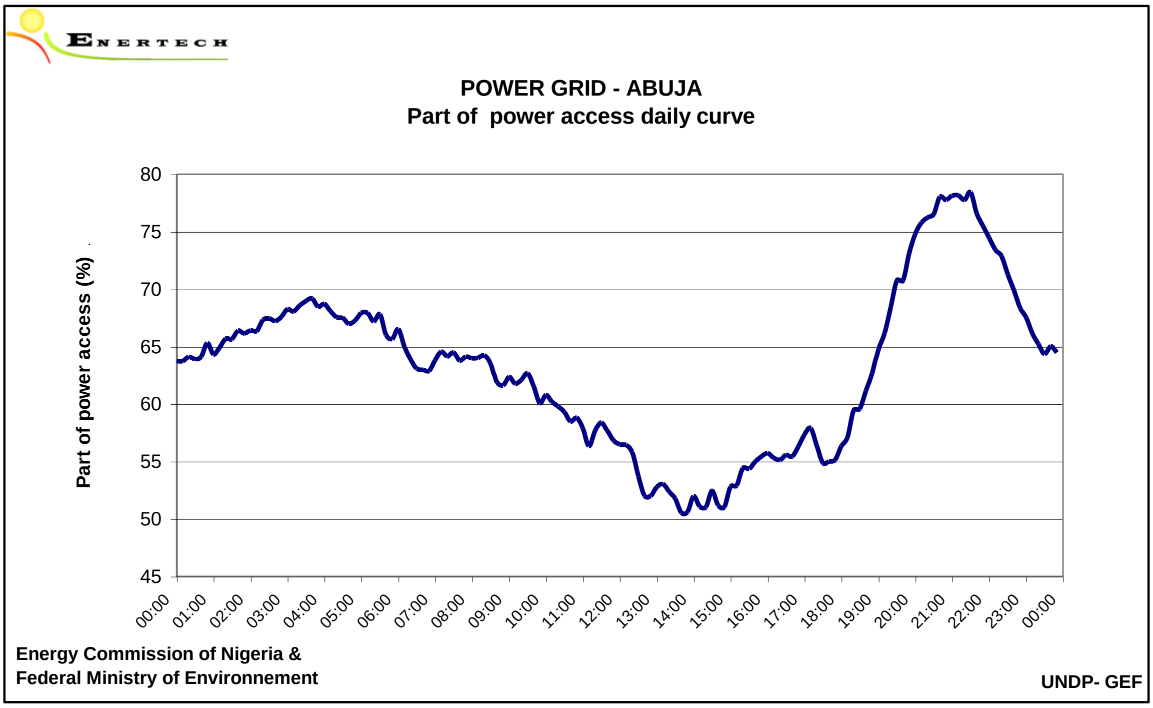


Figure 1.5 : Part of power access daily curve - Abuja

6.2.2.4 Numbers of hours per day of electricity access

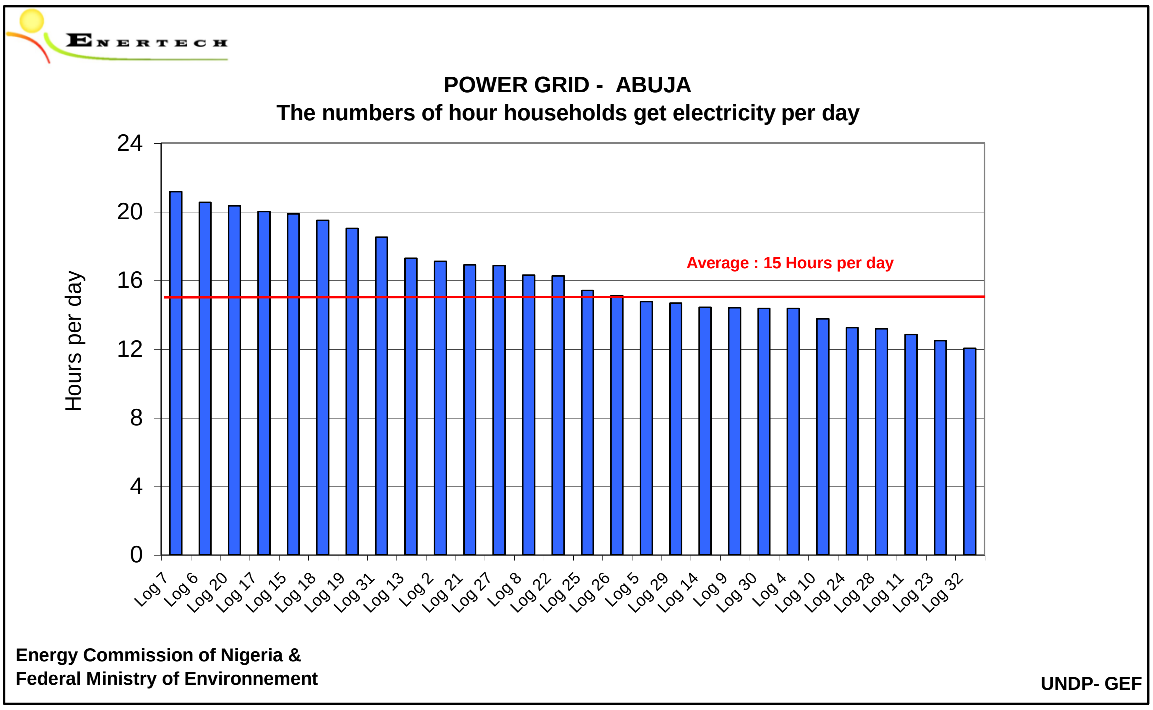


Figure 1.6 : Numbers of hours per day of electricity access - Abuja

6.2.2.5 Duration of power outages

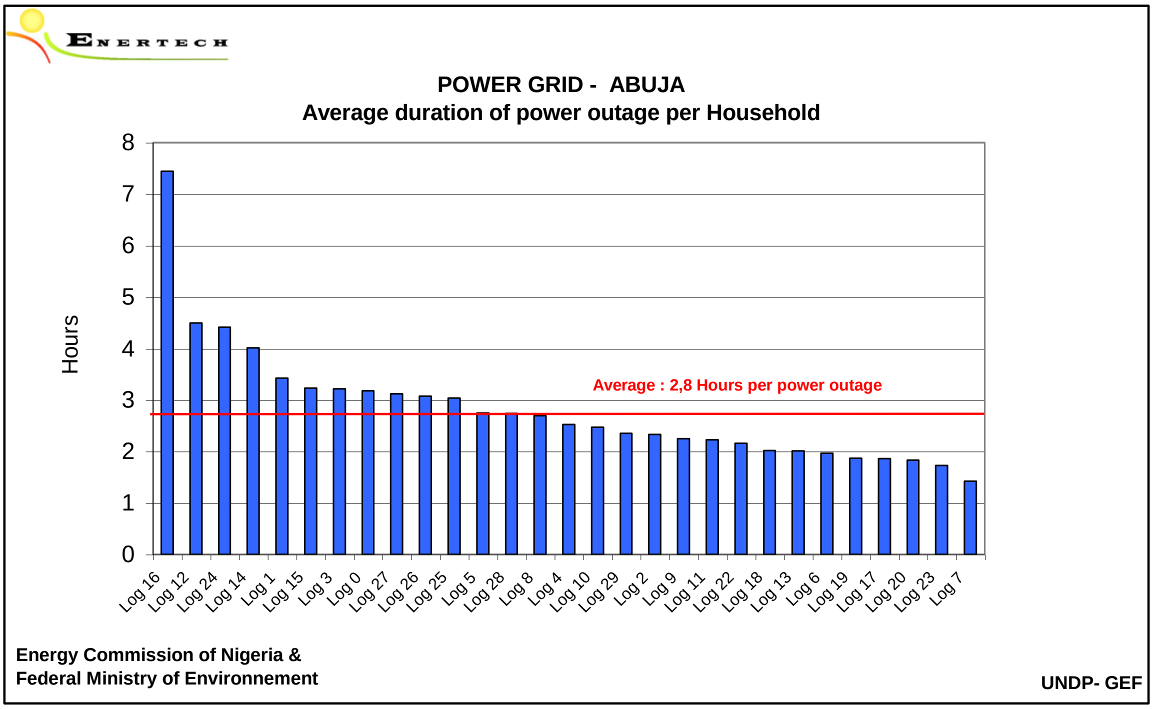


Figure 1.7 : Duration of power outages per Households - Abuja

6.2.2.6 Duration of electricity access

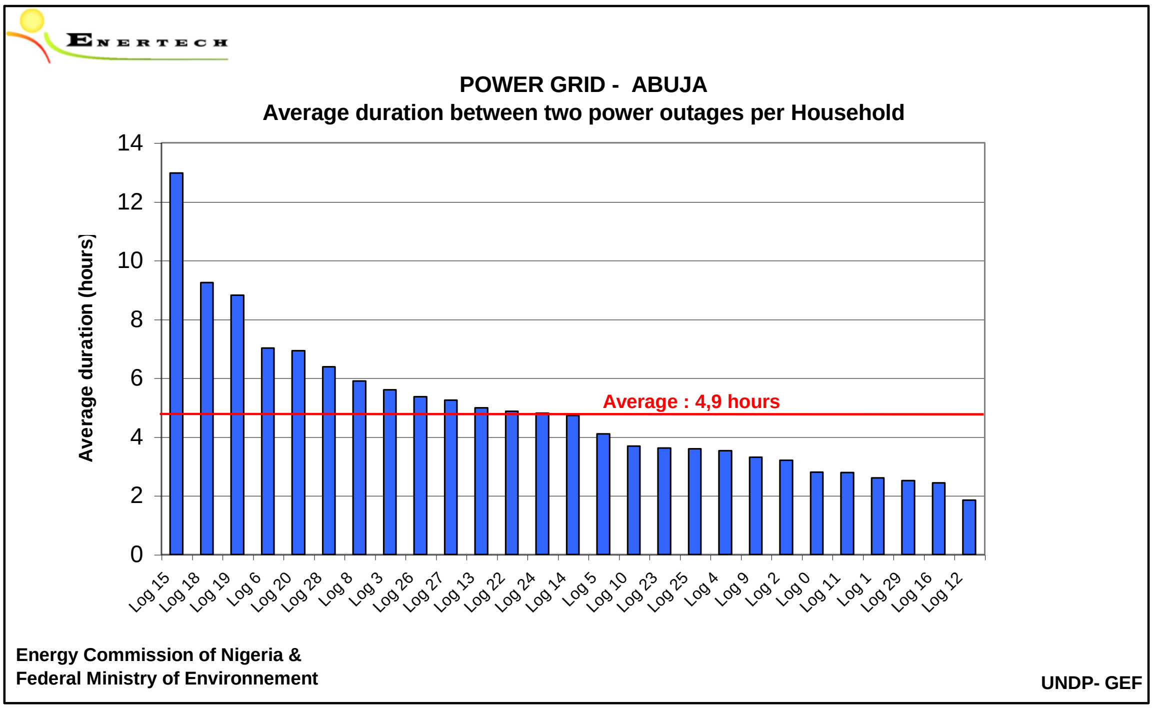


Figure 1.8 : Average duration of electricity access - Abuja

6.2.2.7 Annualized consumption

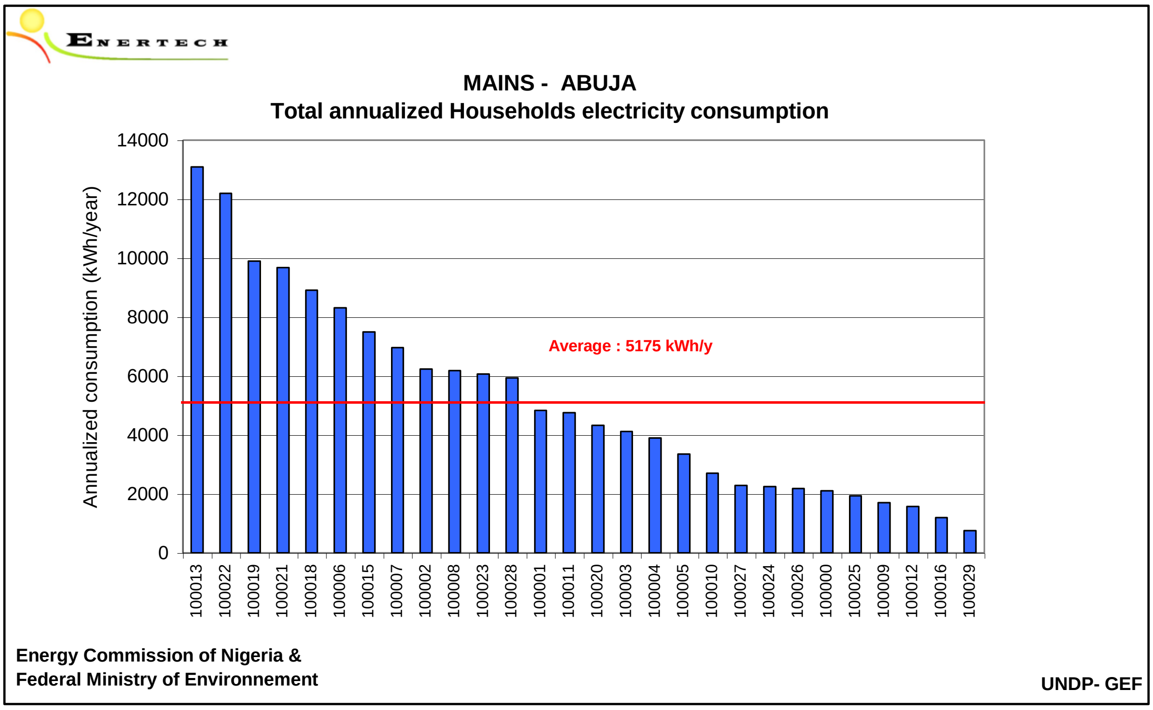


Figure 1.9 : Annualized Households electricity consumption - Abuja

6.2.2.8 Daily average load curve

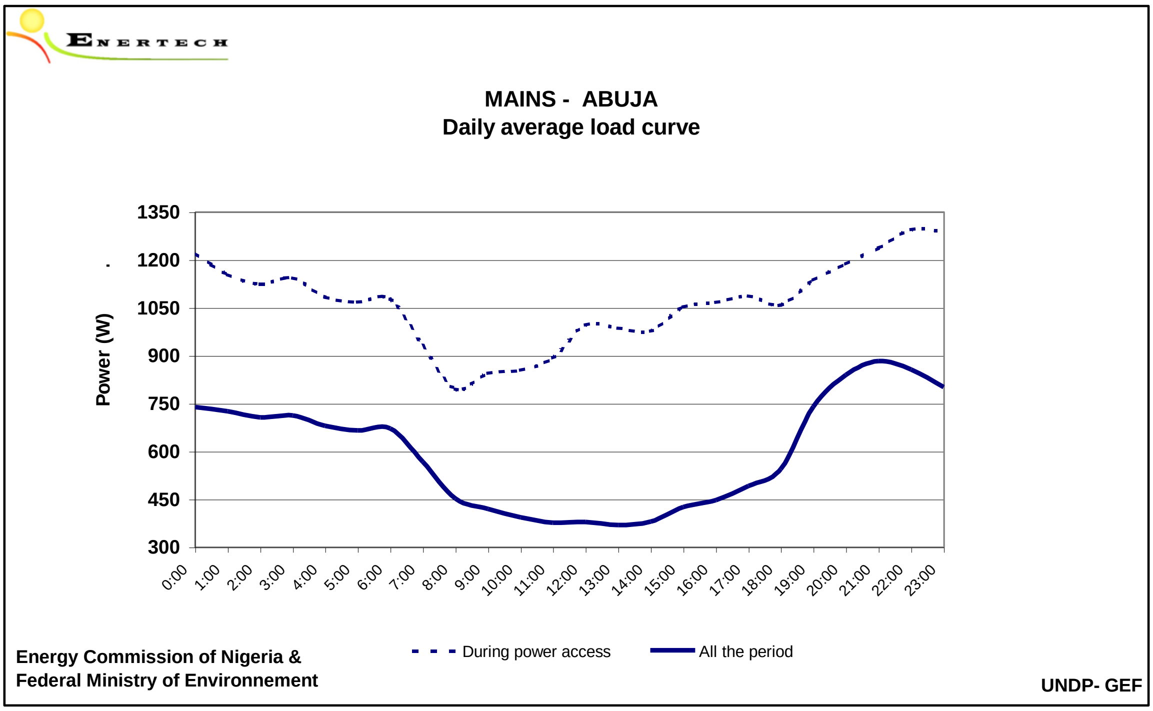


Figure 1.10 : Daily average load curve

6.2.2.9 Relative contribution from the different loads per households

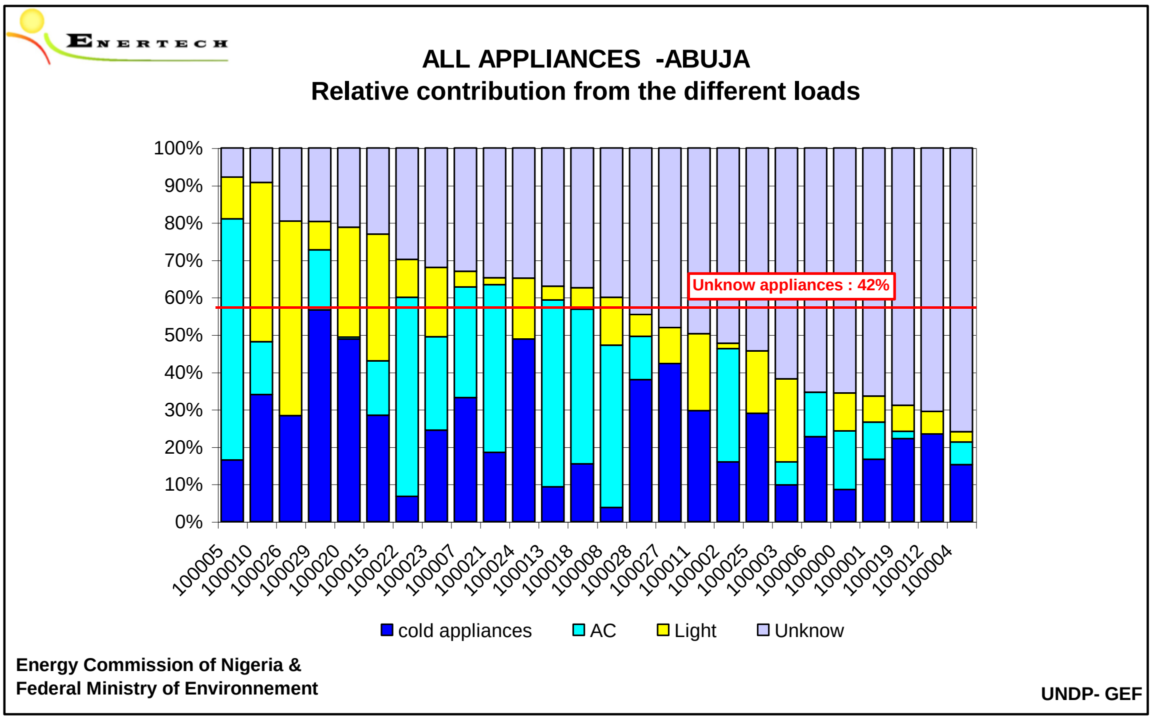


Figure 1.11 : Relative contribution from the different load per households - Abuja

6.2.2.10 Relative contribution from the different loads

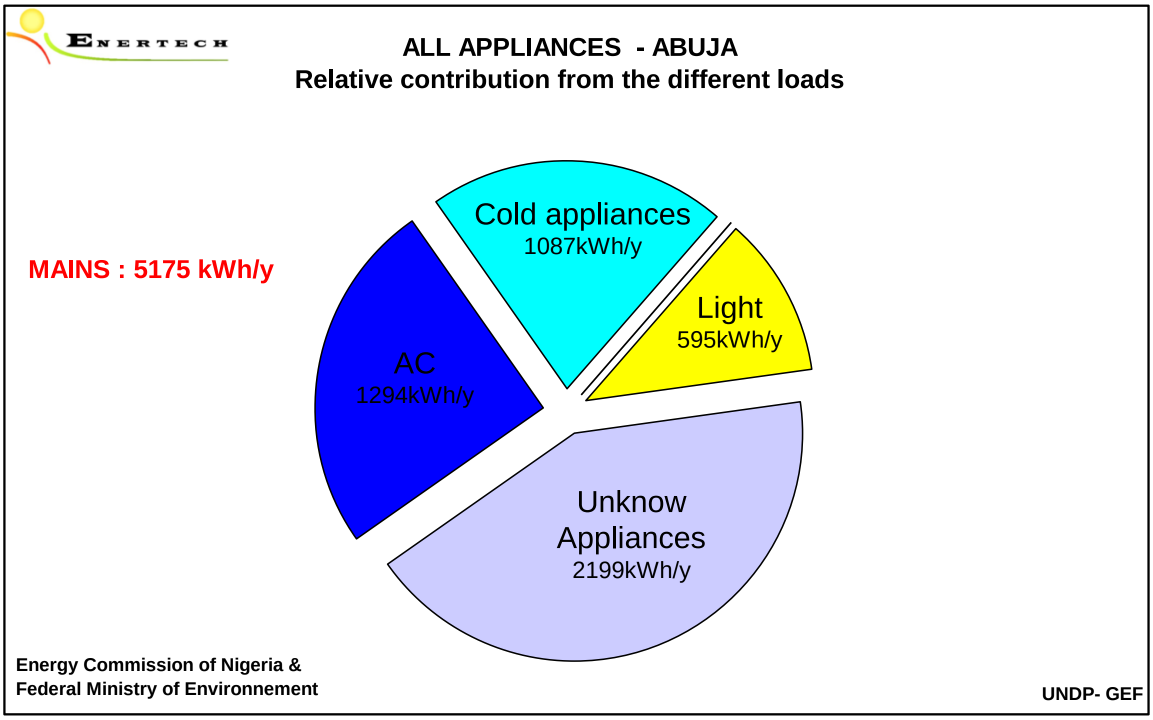


Figure 1.12 : Relative contribution from the different loads

6.2.3 Air conditioner

6.2.3.1 Annualized consumption

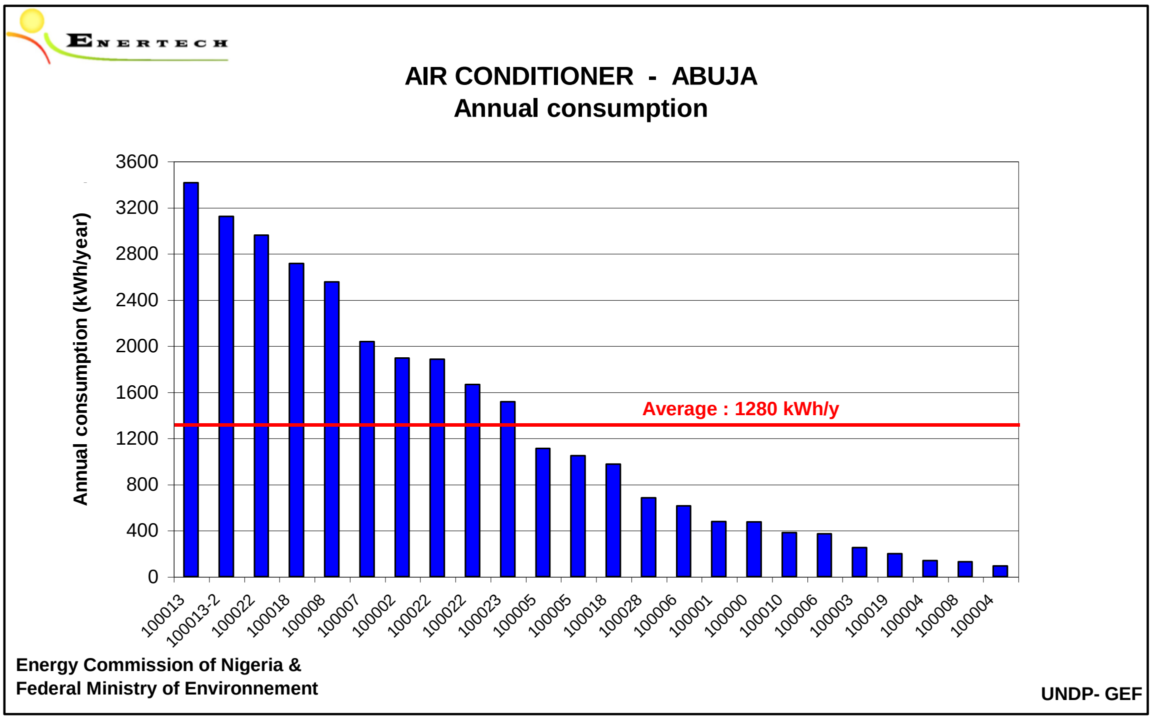


Figure 1.13 : AC annual consumption - Abuja

6.2.3.2 Functioning rates

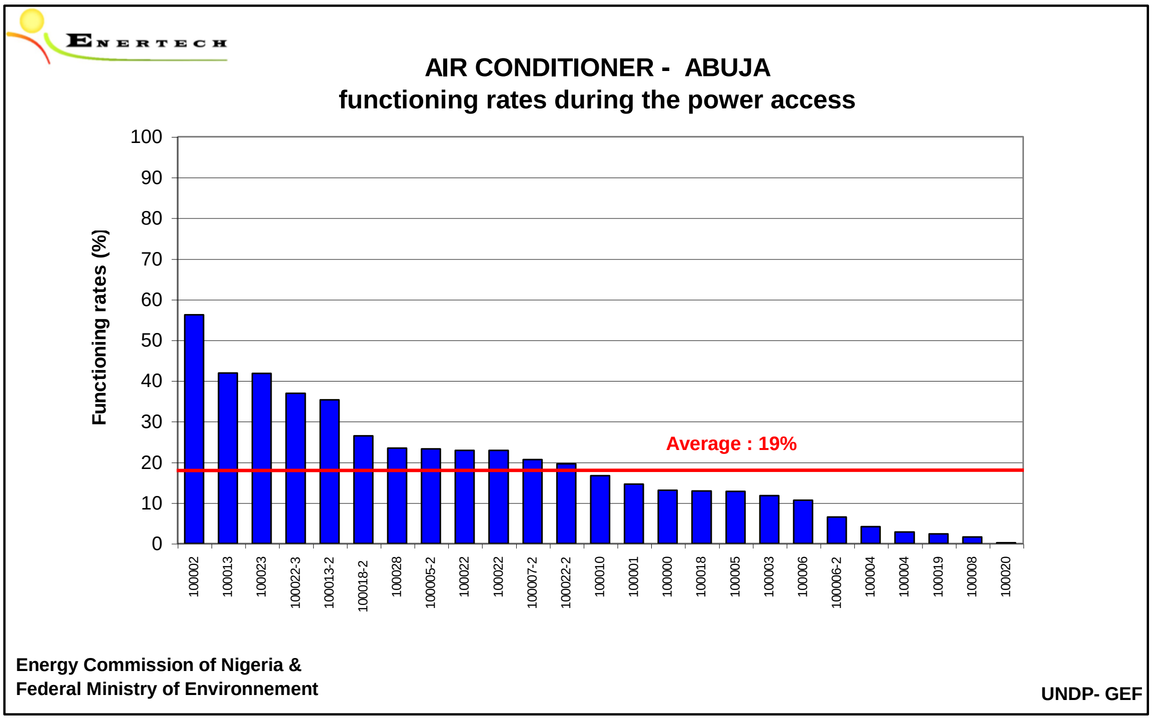


Figure 1.14 : AC functioning rates during power access - Abuja

6.2.3.3 Annual consumption versus power grid

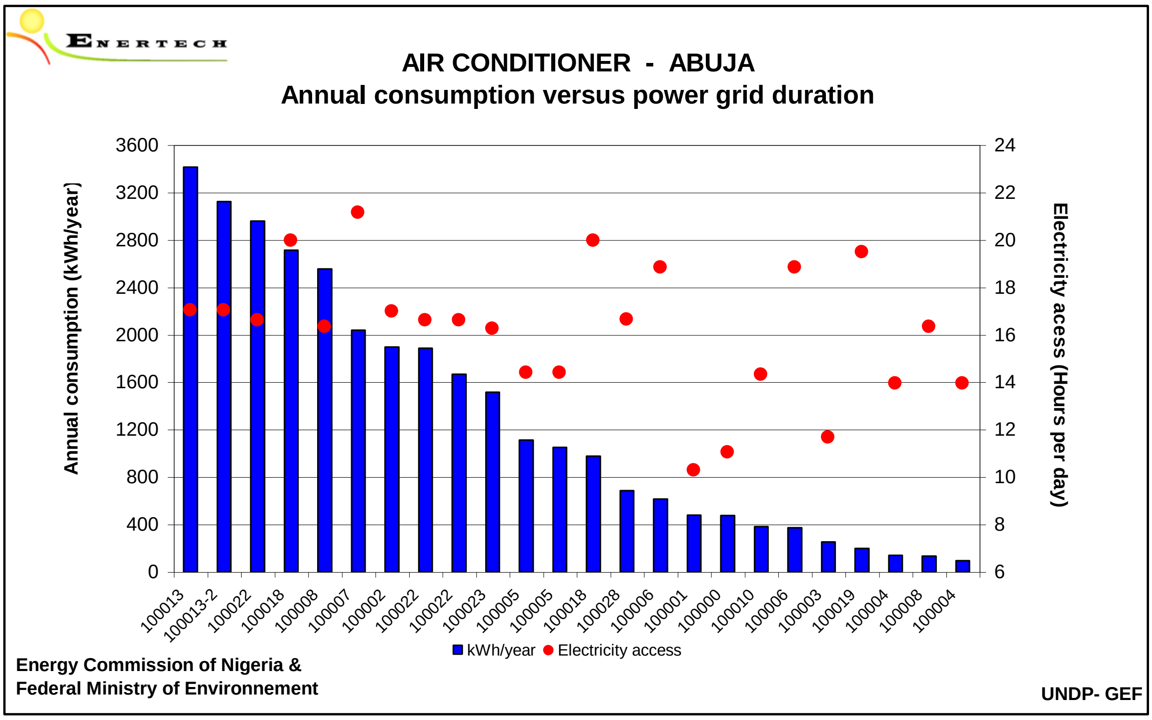


Figure 1.15 : AC annual consumption vs power grid - Abuja

6.2.4 Cold appliances

6.2.4.1 Average possession of appliances

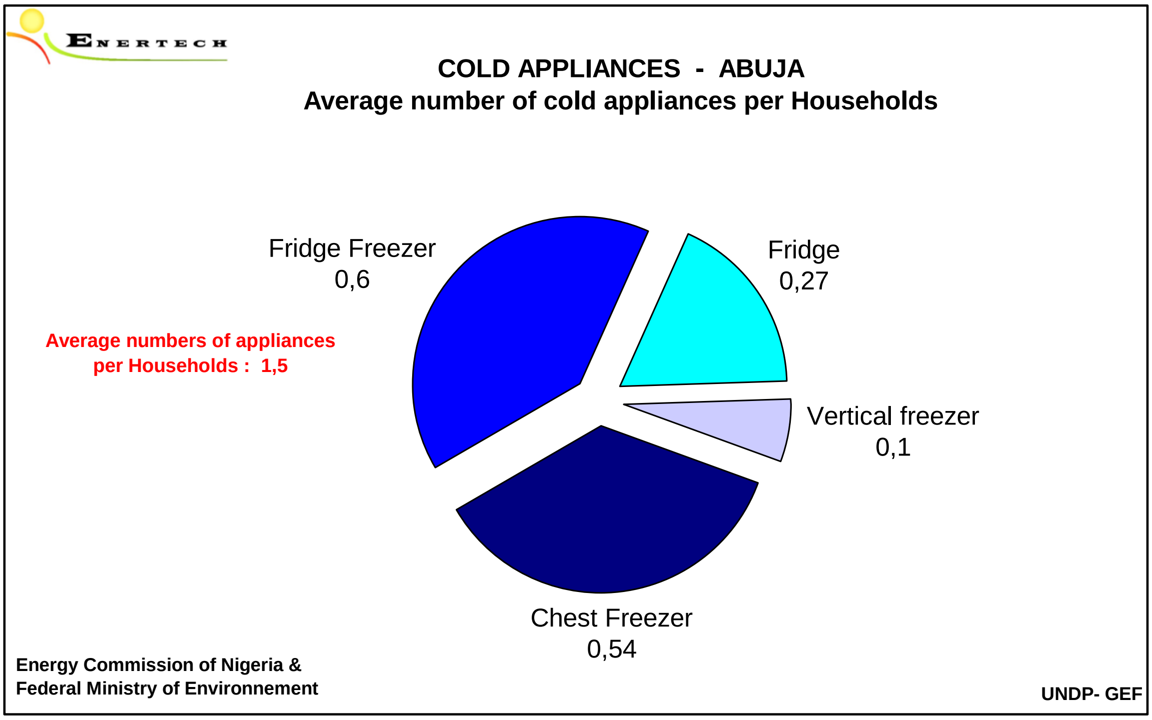


Figure 1.16 : Average possession of cold appliances - Abuja

6.2.4.2 Annualized consumption

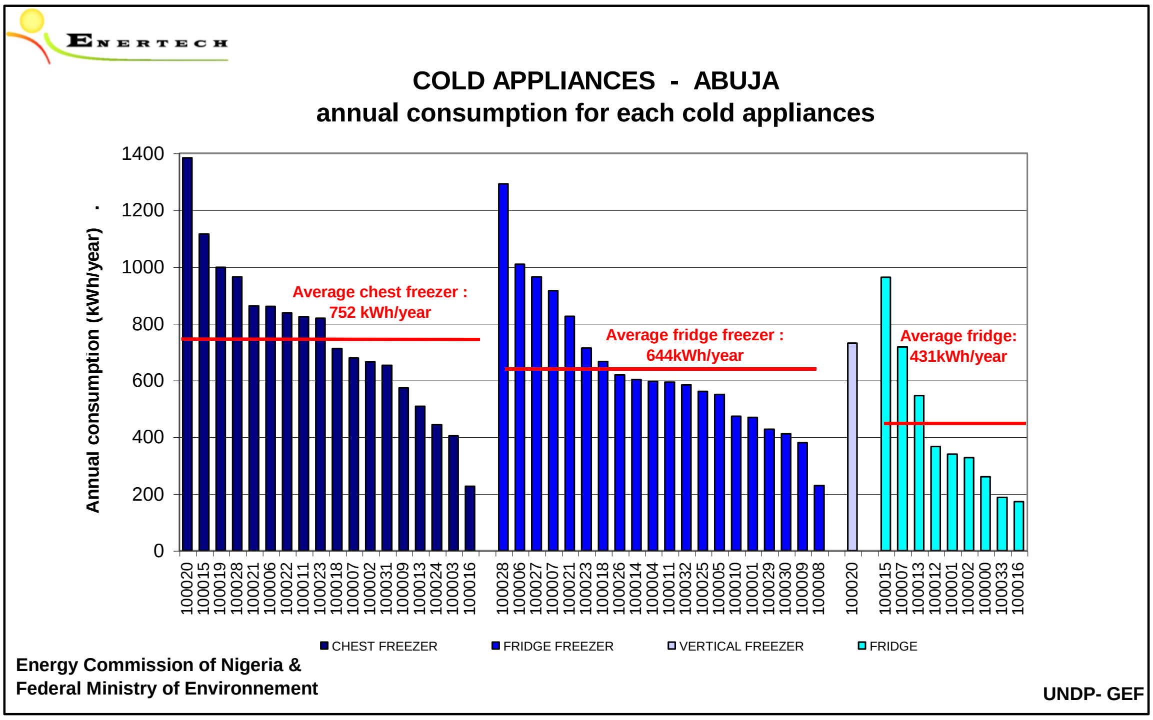


Figure 1.17 : Average possession of cold appliances - Abuja

6.2.4.3 *Functioning rates*

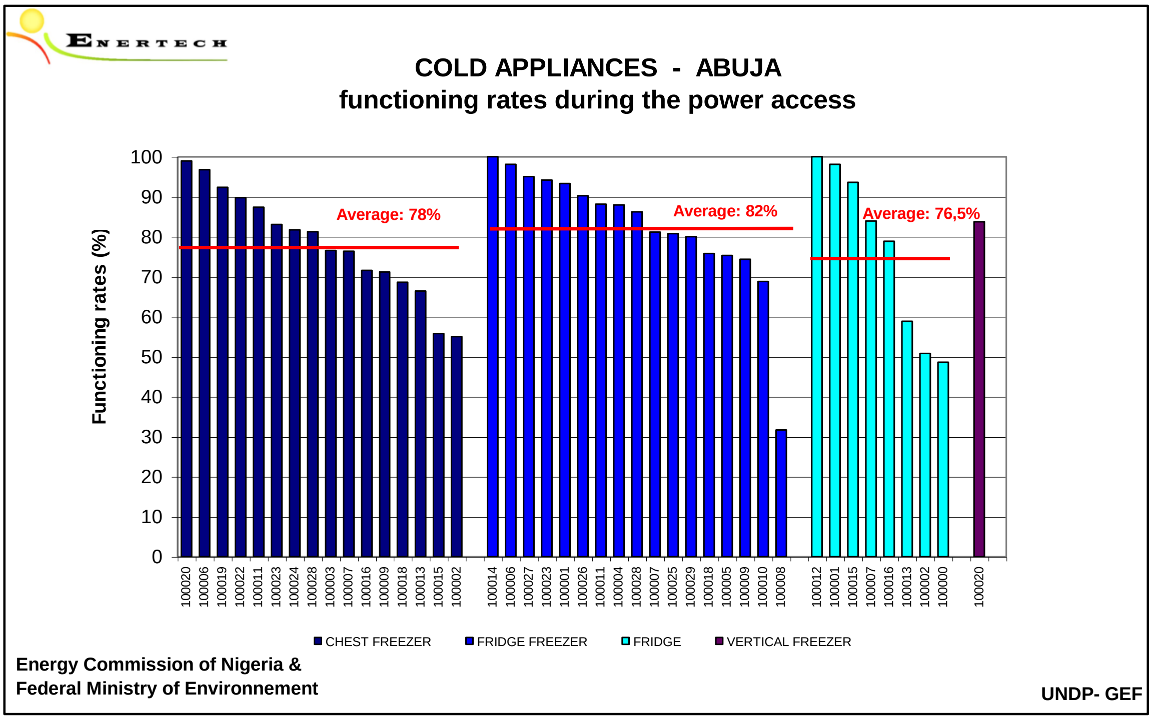


Figure 1.18: Cold appliances functioning rates during power access - Abuja

6.2.4.4 *Annual consumption versus power grid*

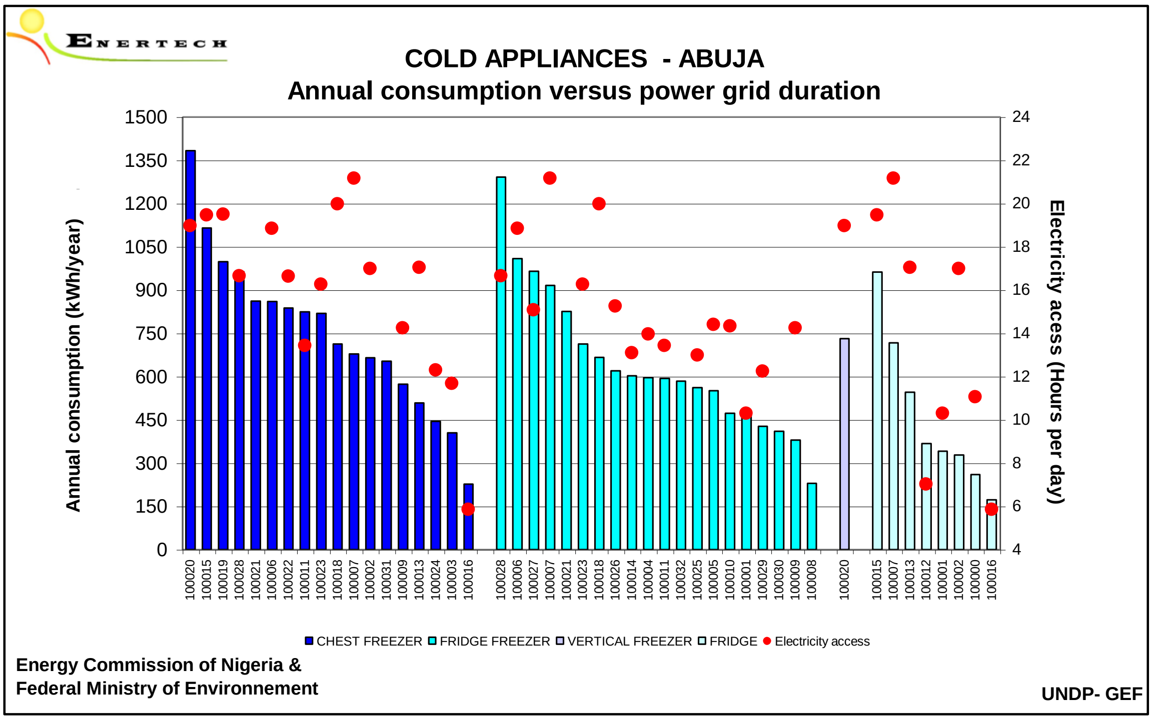


Figure 1.19 : Cold appliances annual consumption versus power access - Abuja

6.2.5 Lighting

6.2.5.1 Installed wattage per bulbs

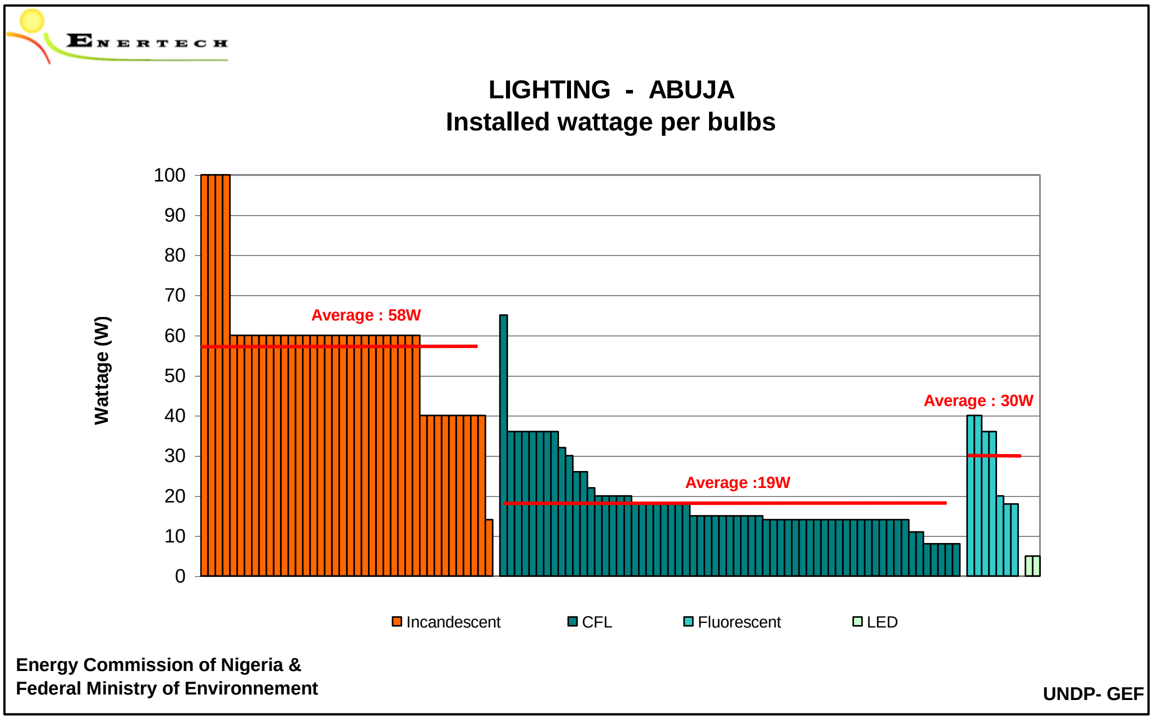


Figure 1.20 : Installed wattage per bulbs - Abuja

6.2.5.2 Part of each type of light source

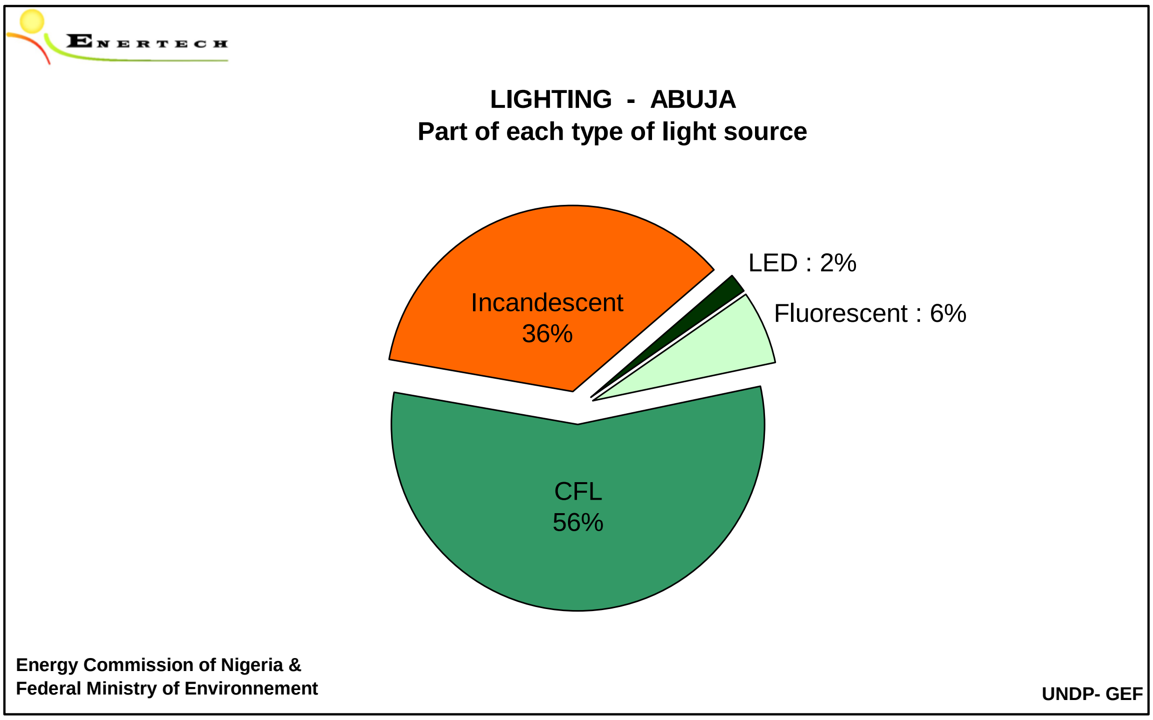


Figure 1.21 : Part of each type of light source - Abuja

6.2.5.3 Annualized consumption per Housholds

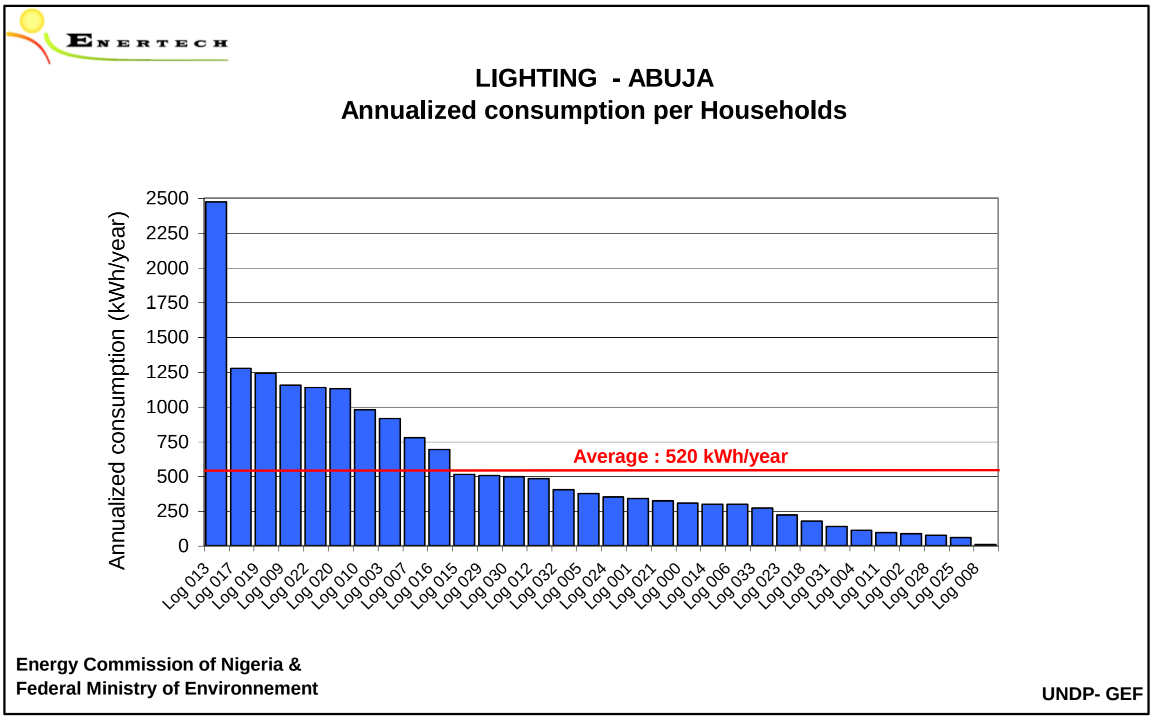


Figure 1.22 : Lighting annualized consumption per Households - Abuja

6.2.5.4 Daily average load curve

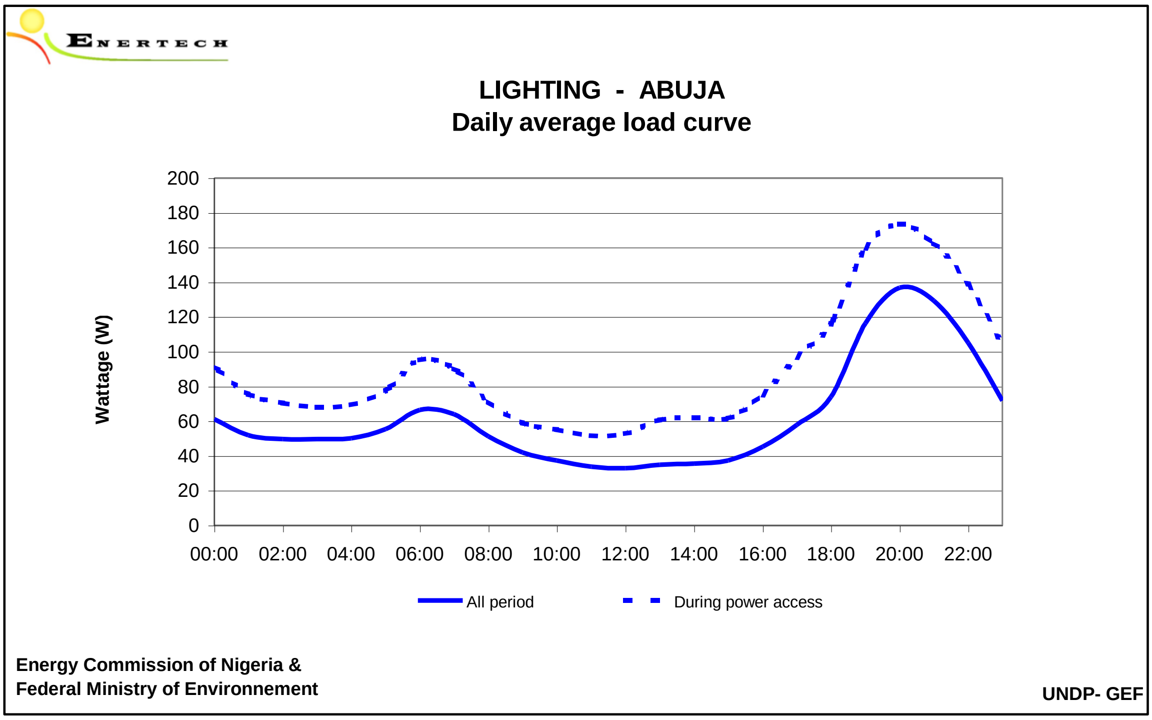


Figure 1.23 : Lighting daily average load curve – Abuja

6.3 SOKOTO

6.3.1 Indoor temperature

6.3.1.1 Temperature daily curve

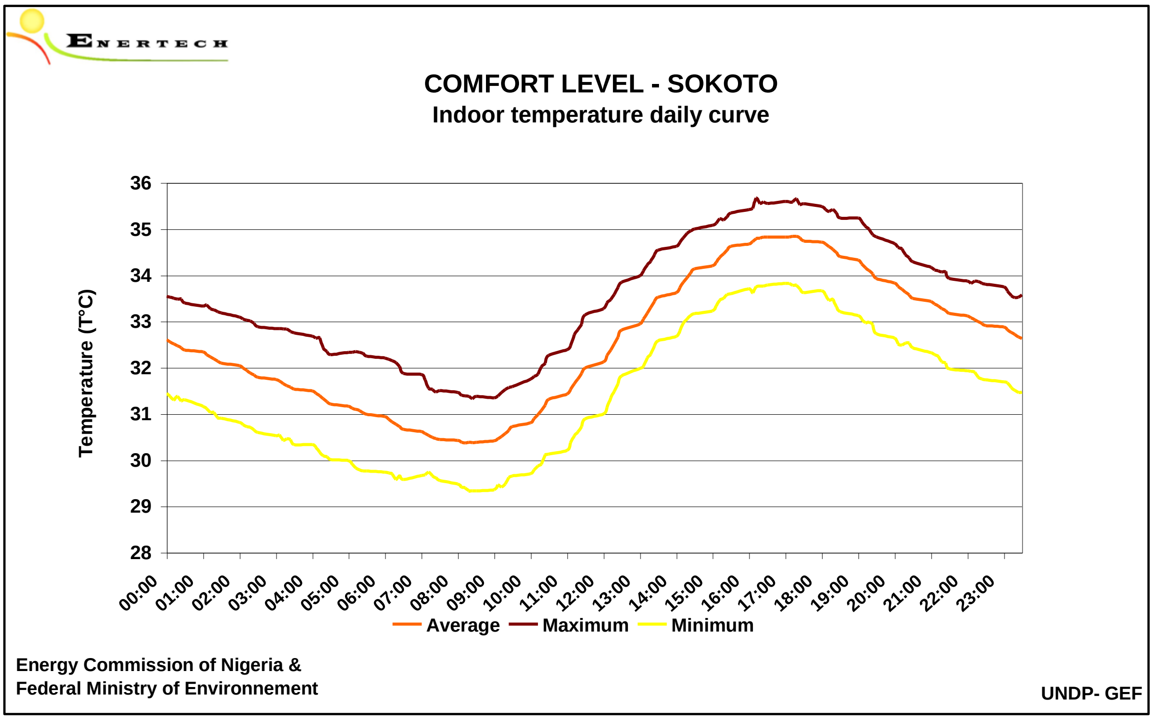


Figure 2.1 : Temperature daily curve - Sokoto

6.3.1.2 Temperature cumulative frequency

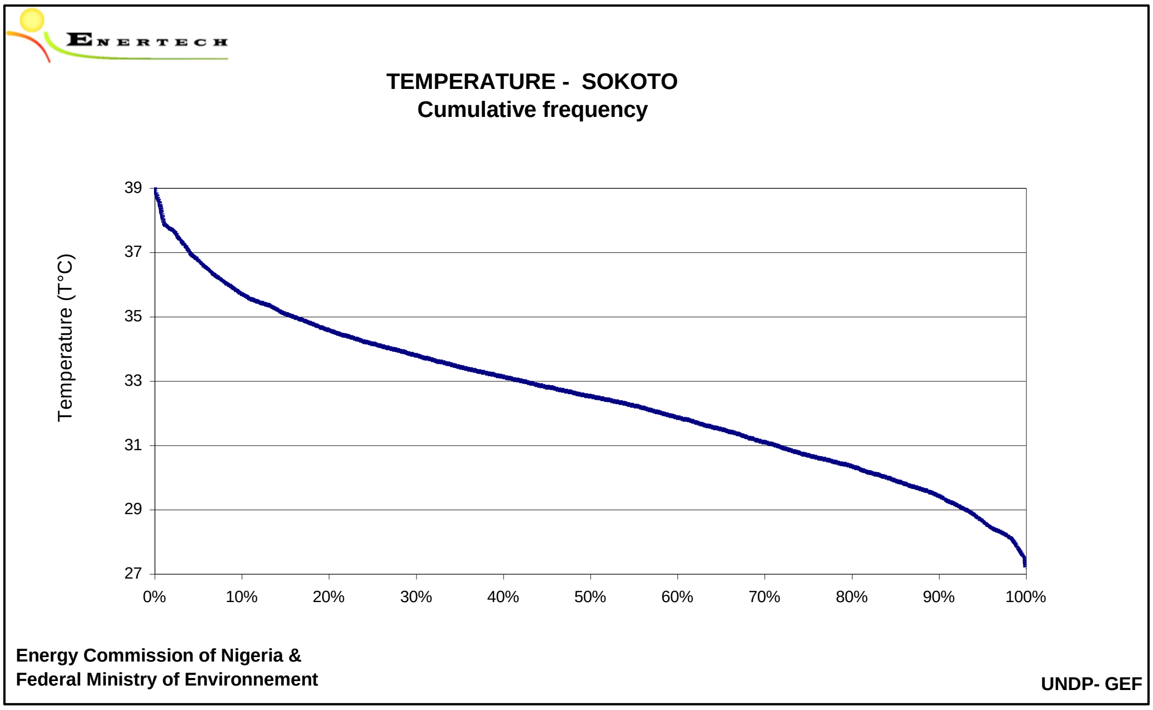


Figure 2.2 : Temperature cumulative frequency – Sokoto

6.3.2 Power Grid

6.3.2.1 Distribution of power access and power outages

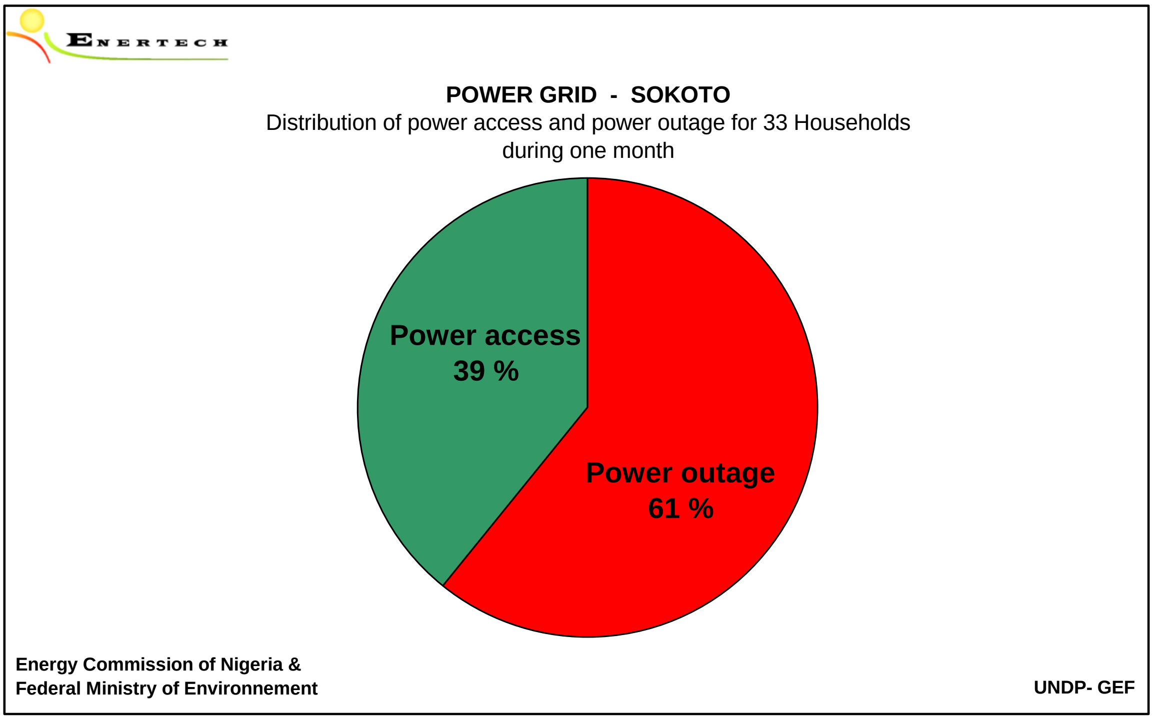


Figure 2.3 : Distribution of power access and power outages - Sokoto

6.3.2.2 Average voltage during power access

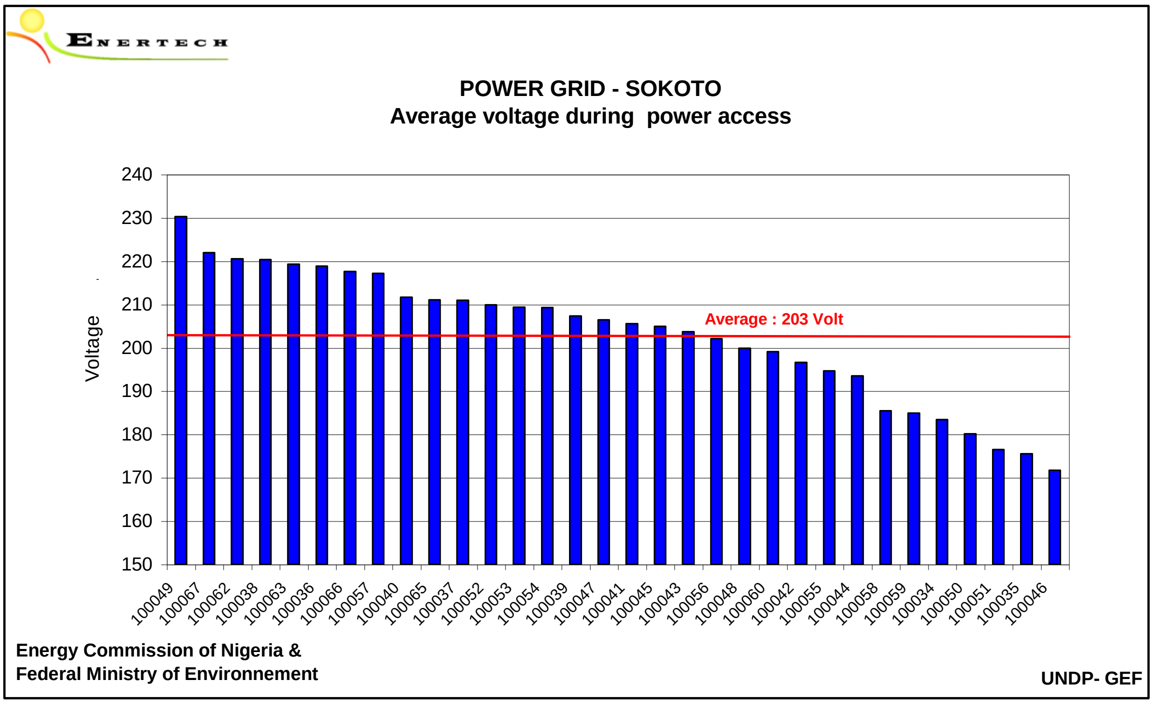


Figure 2.4 : Average voltage during power access - Sokoto

6.3.2.3 Part of power access daily curve

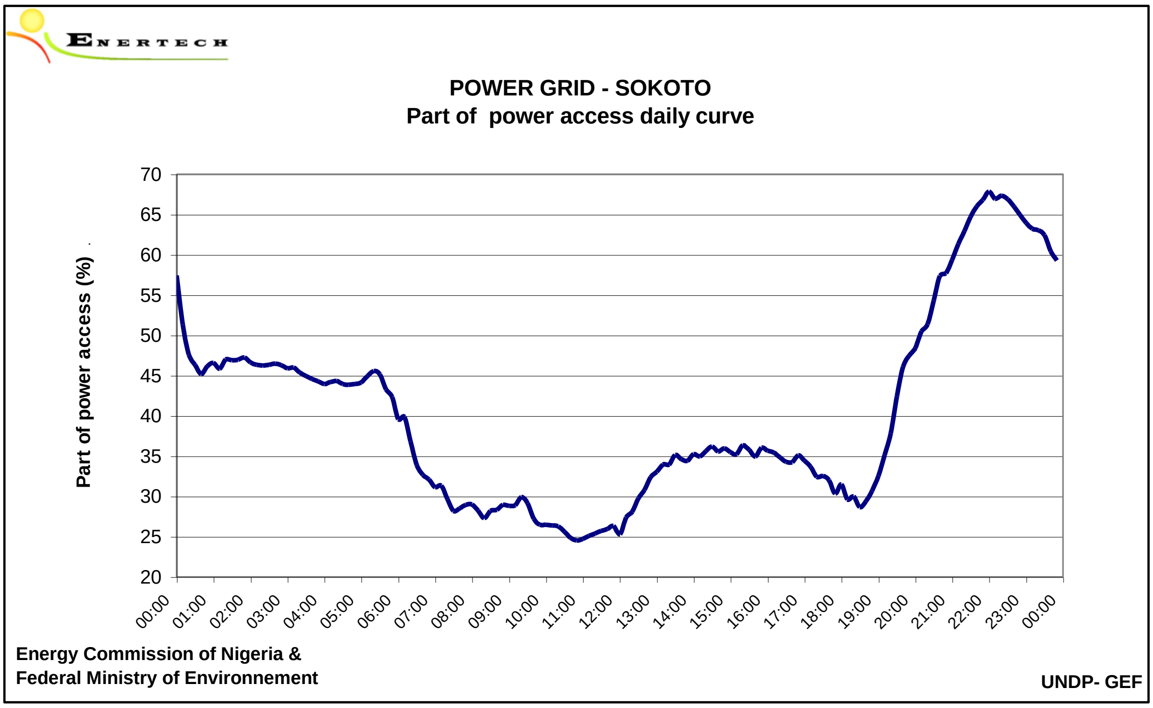


Figure 2.5 : Part of power access daily curve - Sokoto

6.3.2.4 Numbers of hours per day of electricity access

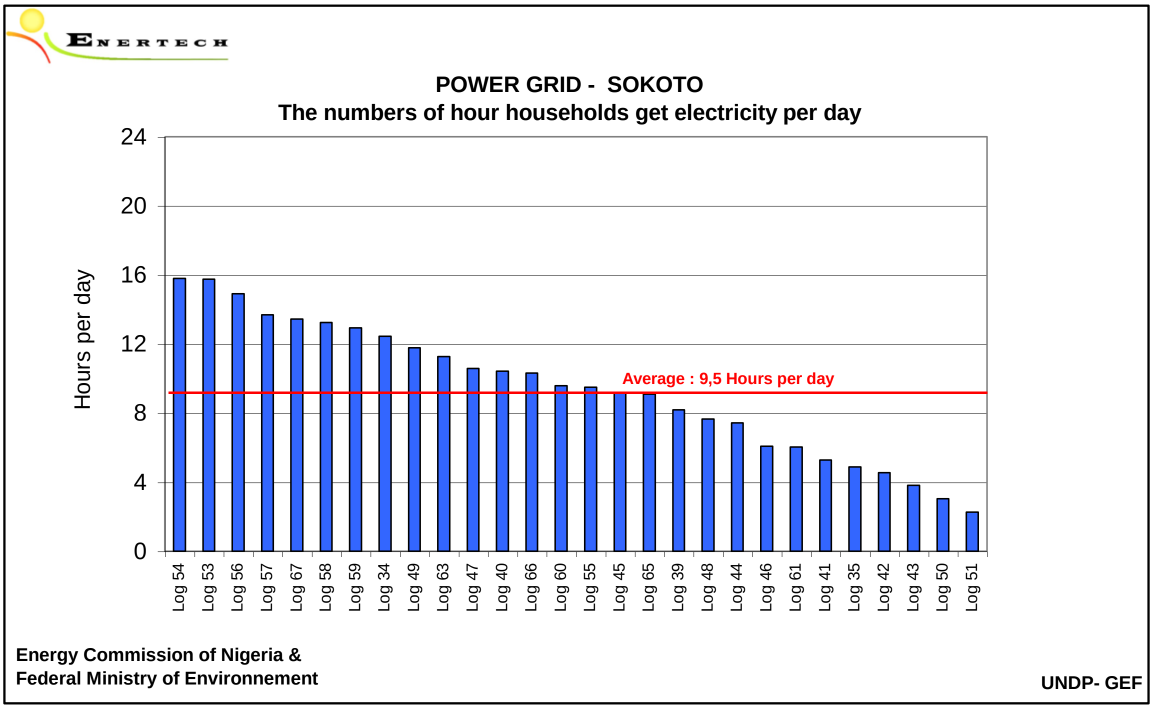


Figure 2.6 : Numbers of hours per day of electricity access - Sokoto

6.3.2.5 Duration of power outages

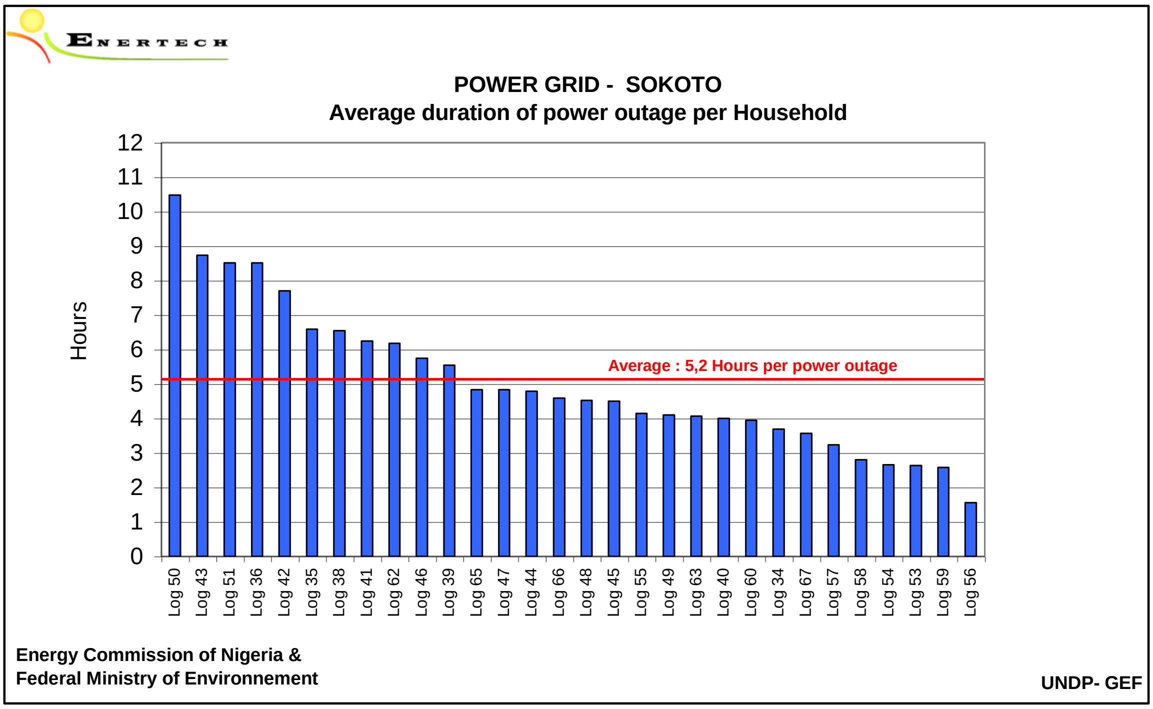


Figure 2.7 : Average duration of power outages - Sokoto

6.3.2.6 Duration of electricity access

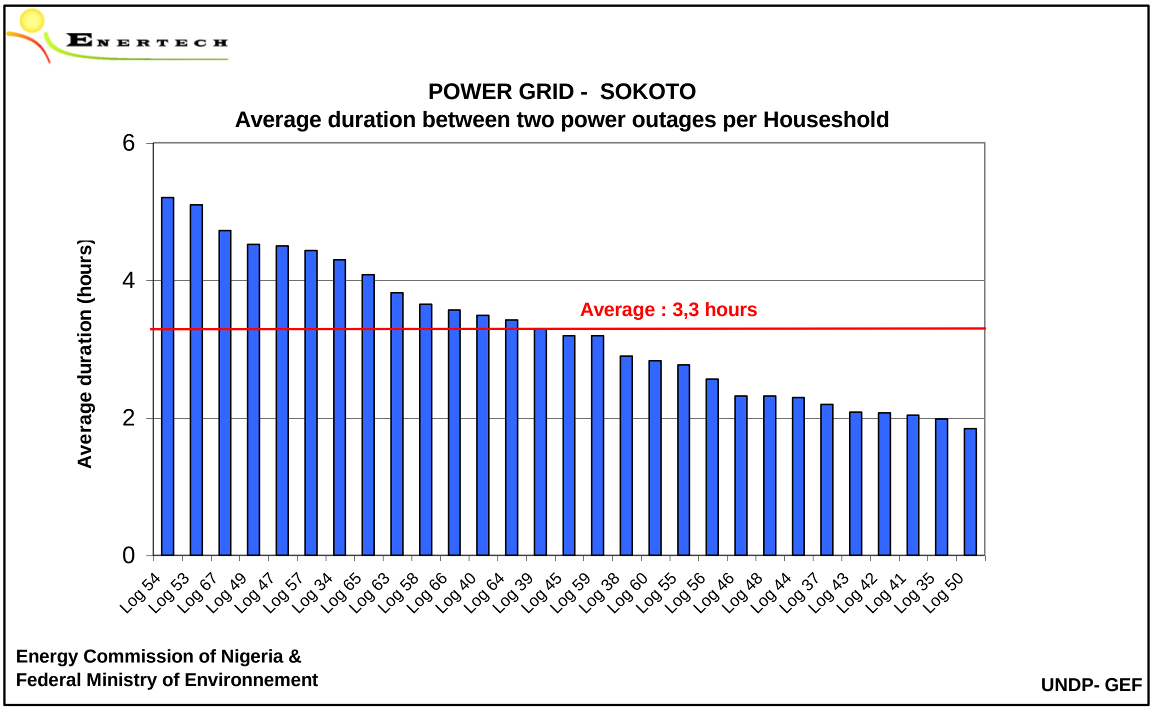


Figure 2.8 : Average duration of electricity access – Sokoto

6.3.2.7 Annualized consumption

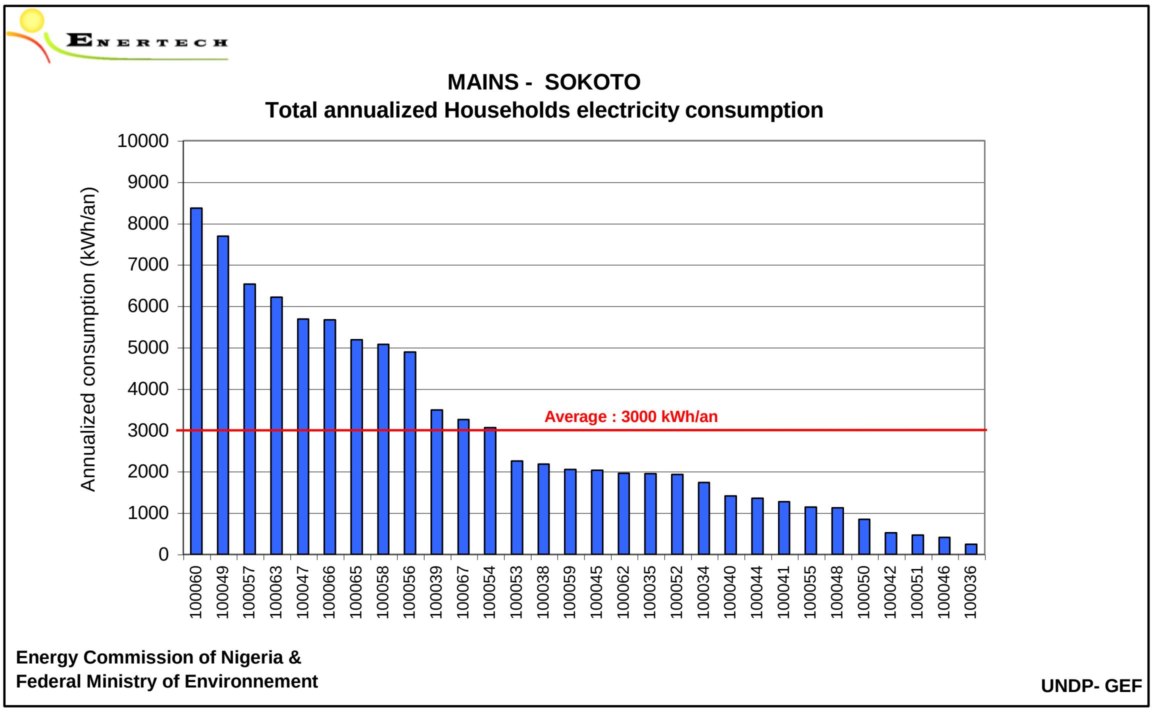


Figure 2.9 : Annualized households electricity consumption - Sokoto

6.3.2.8 Daily average load curve

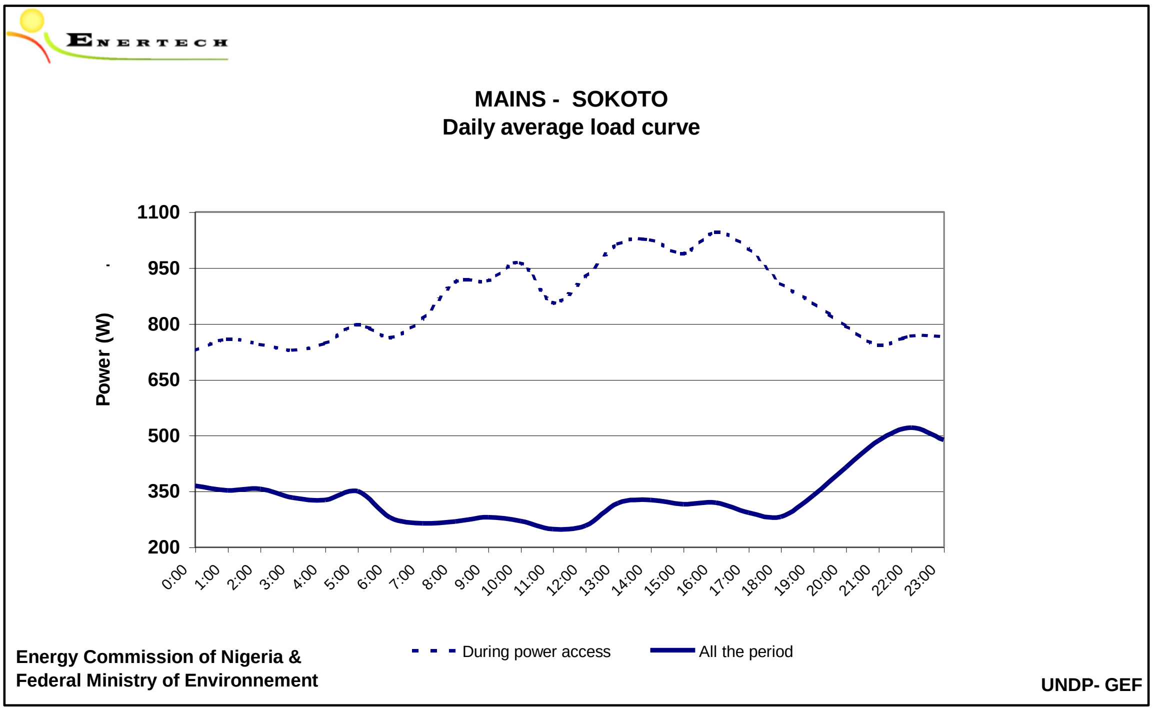


Figure 2.10 : Daily average load curve - Sokoto

6.3.2.9 Relative contribution from the different loads

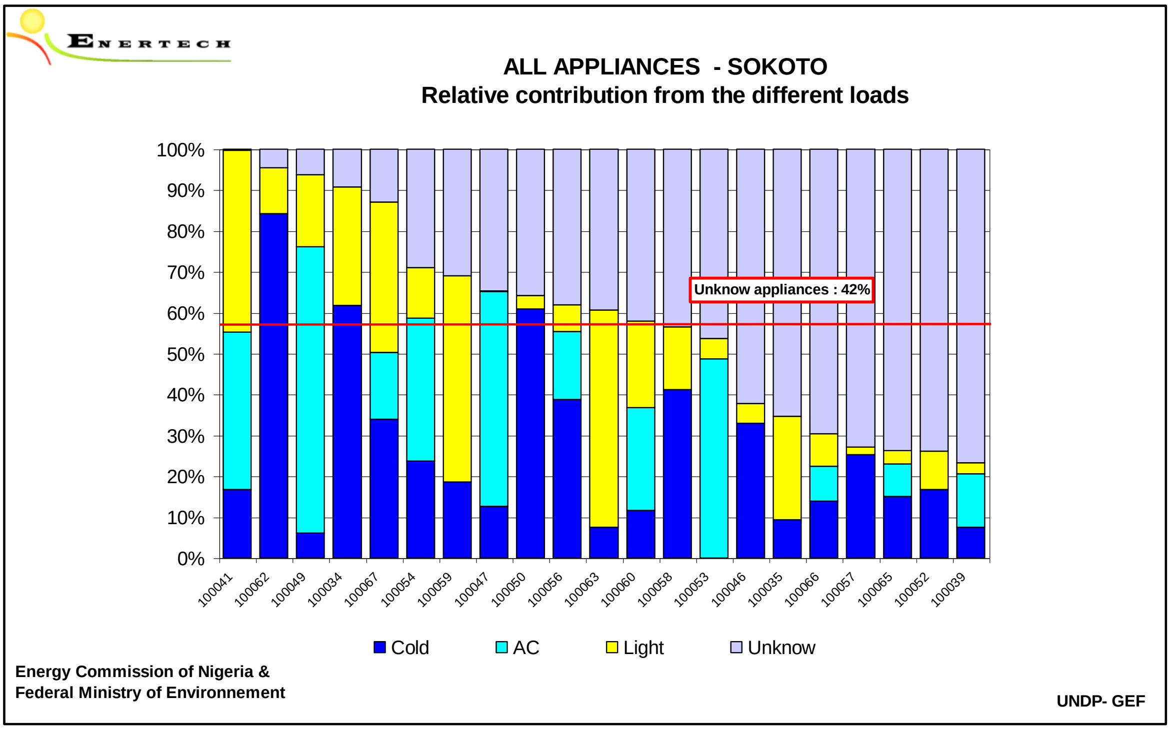


Figure 2.11 : Relative contribution from the different load per Households - Sokoto

6.3.2.10 Relative contribution from the different loads

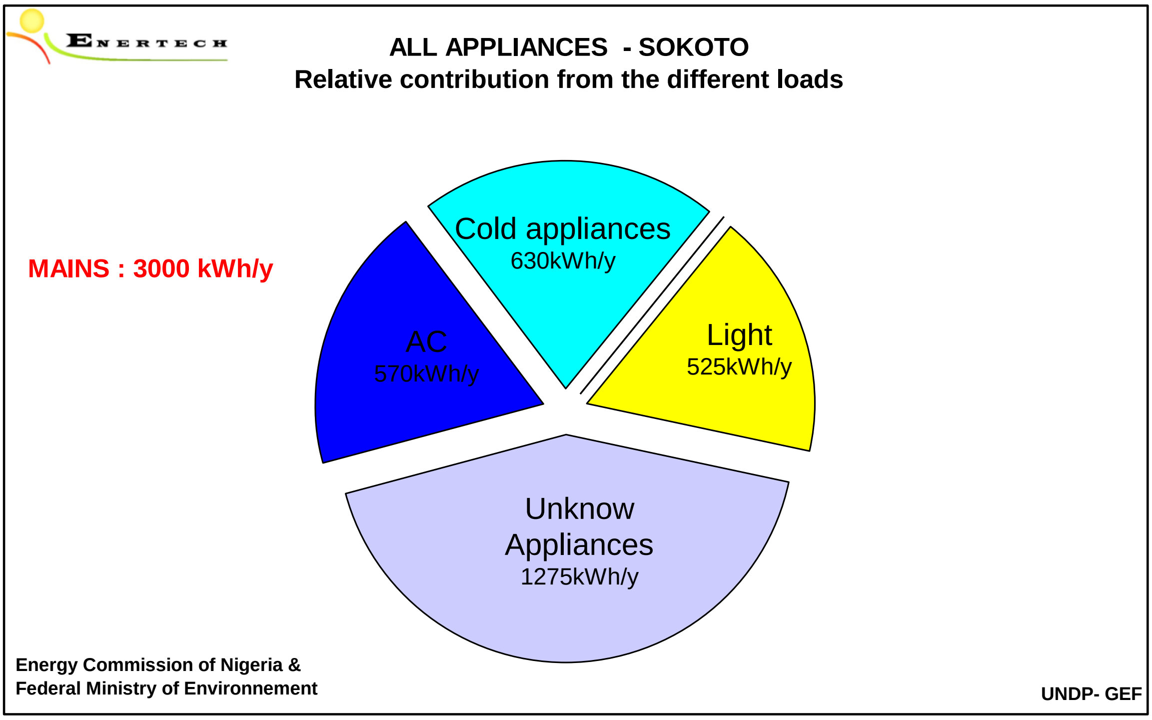


Figure 2.12 : Relative contribution from the different load - Sokoto

6.3.3 Air conditioner

6.3.3.1 Annualized consumption

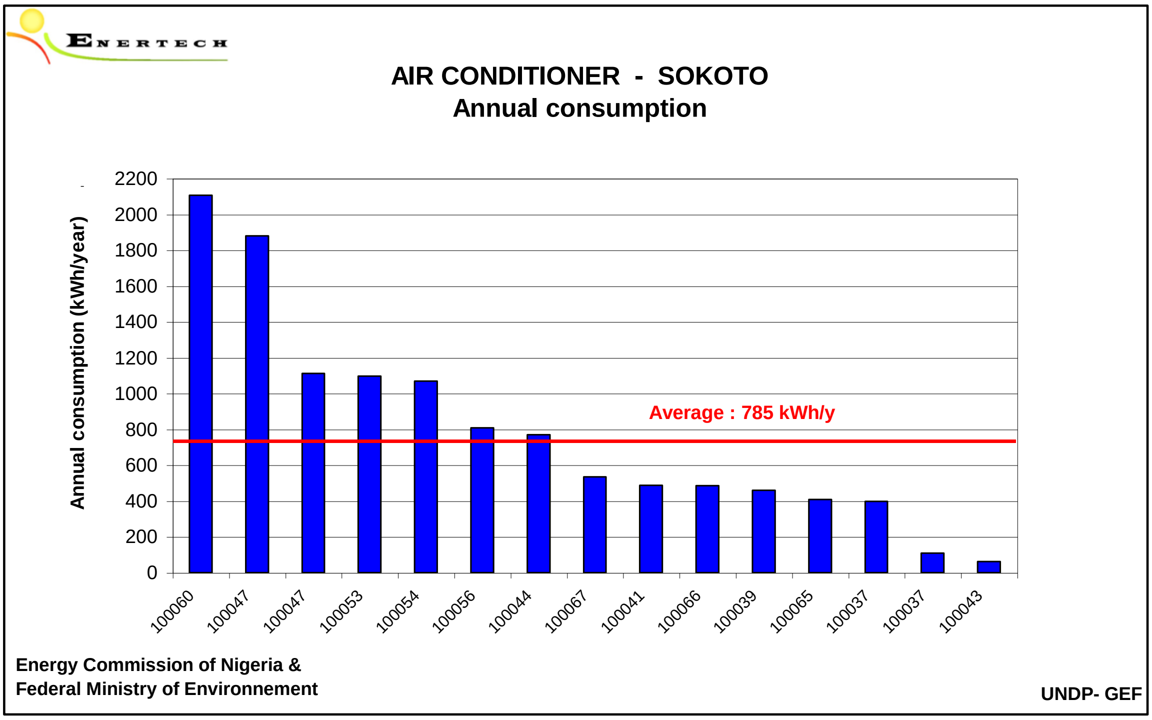


Figure 2.13 : AC annual consumption – Sokoto

6.3.3.2 Functioning rates

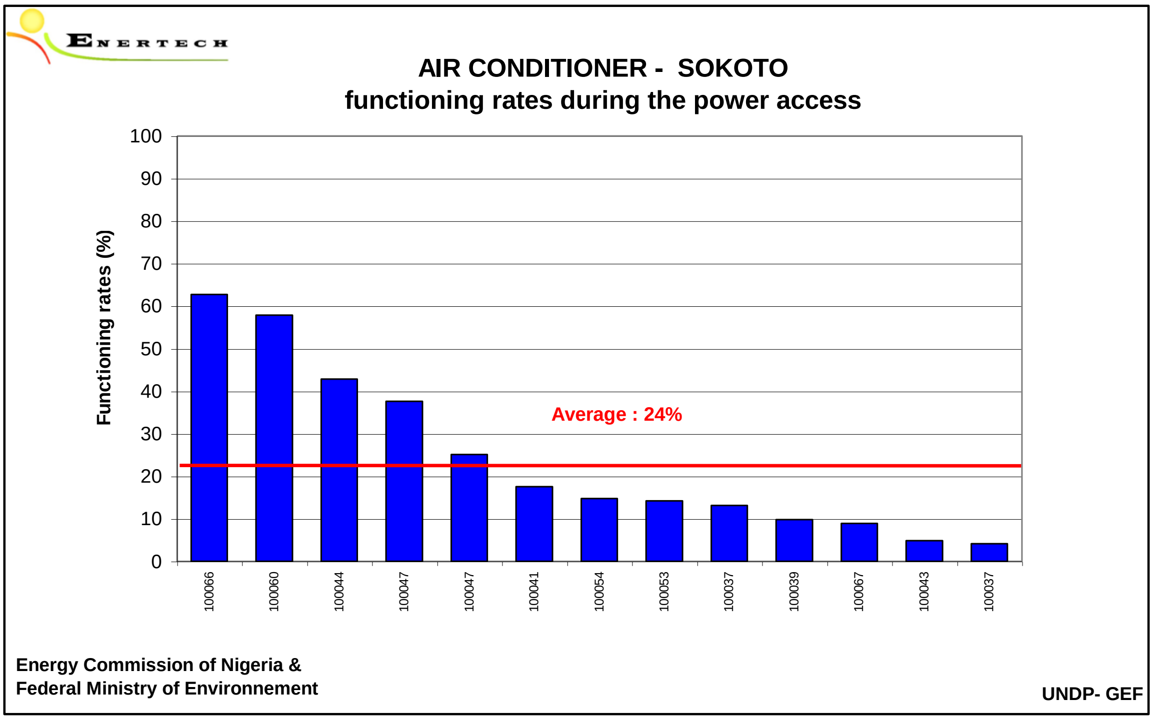


Figure 2.14 : AC functioning rates during power access - Sokoto

6.3.3.3 Annual consumption versus power grid

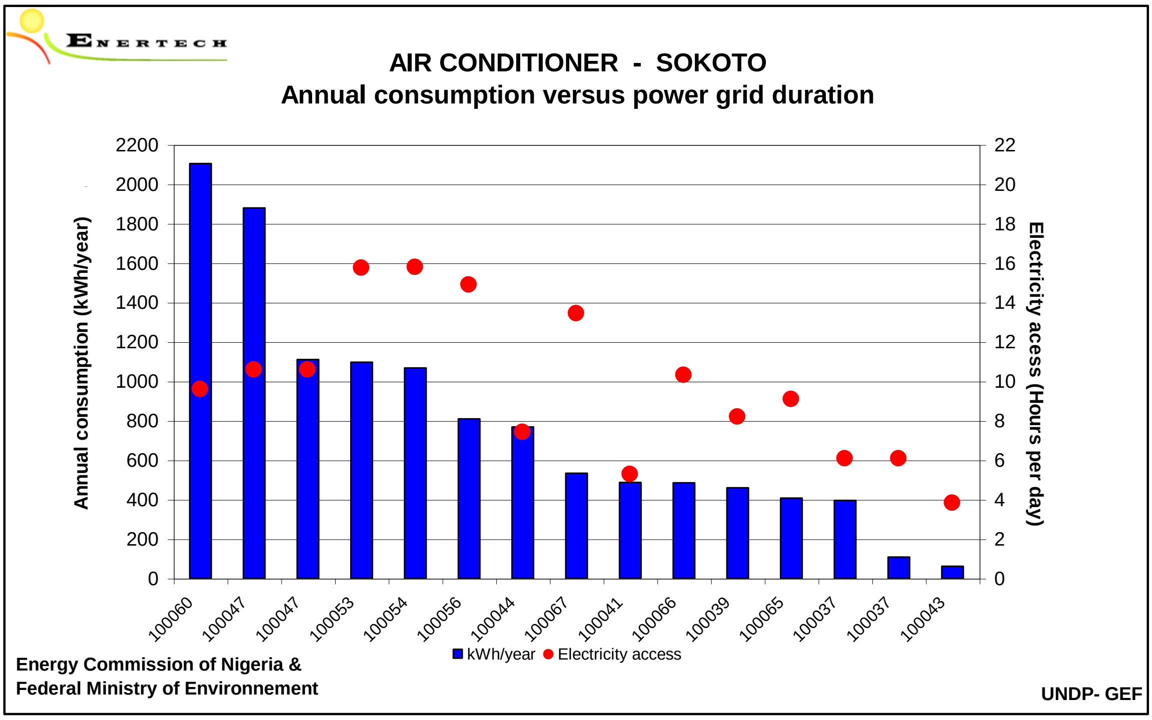


Figure 2.15 : AC annual consumption vs power grid - Sokoto

6.3.4 Cold appliances

6.3.4.1 Average possession of appliances

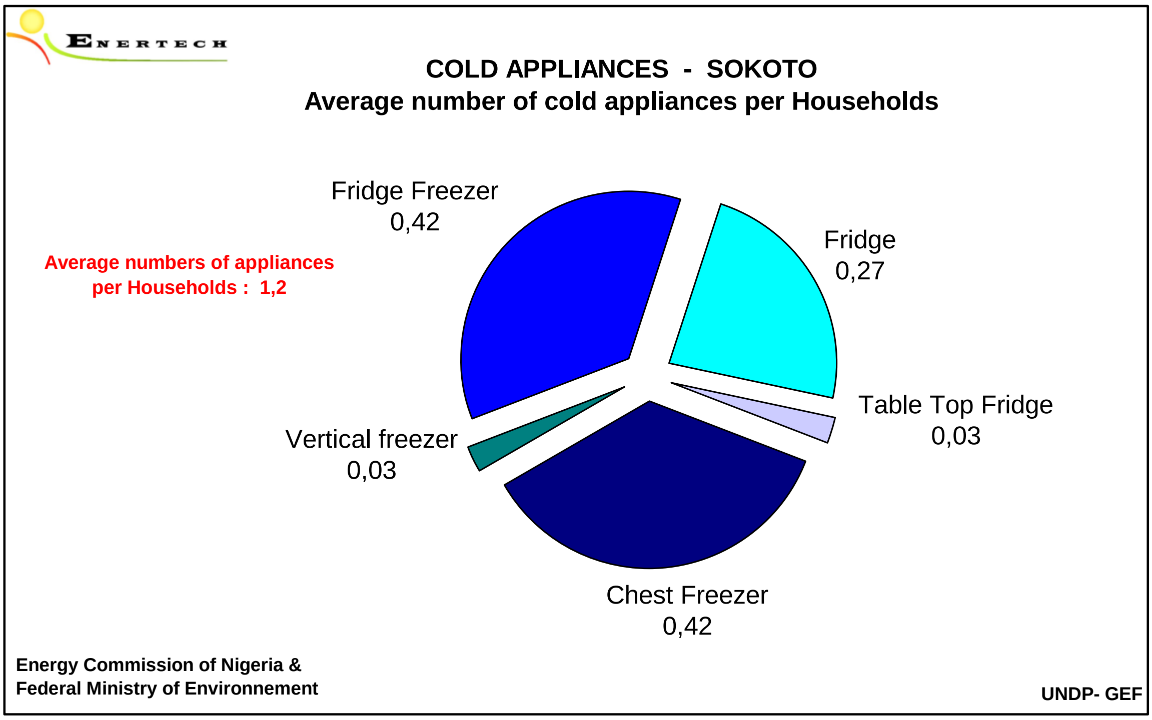


Figure 2.16 : Average possession of cold appliances - Sokoto

6.3.4.2 *Annualized consumption*

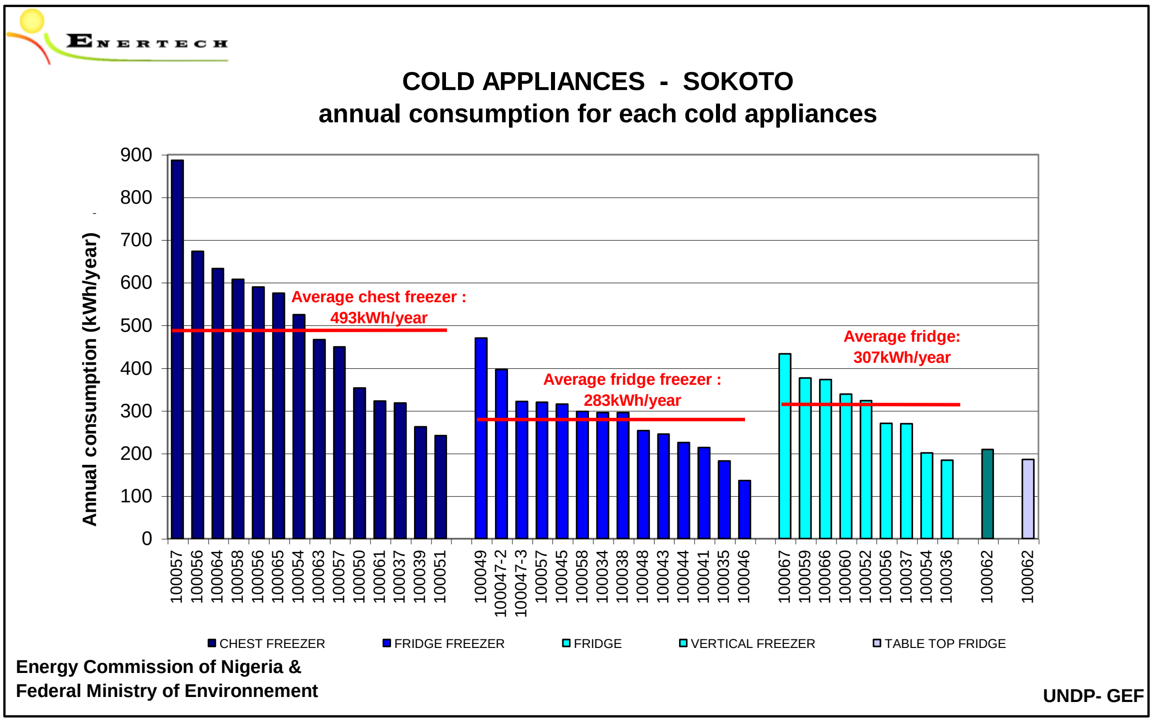


Figure 2.17 : Cold appliances annualized consumption - Sokoto

6.3.4.3 *Functioning rates*

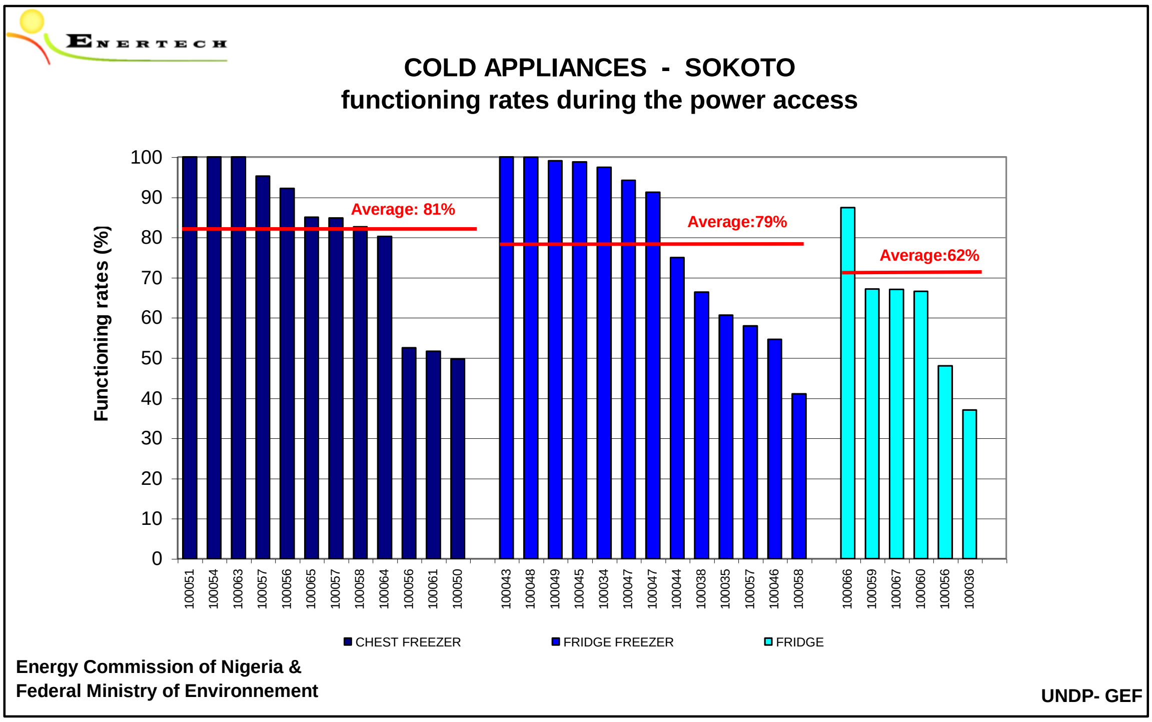


Figure 2.18 : Cold appliances functioning rates during power access- Sokoto

6.3.4.4 Annual consumption versus power grid

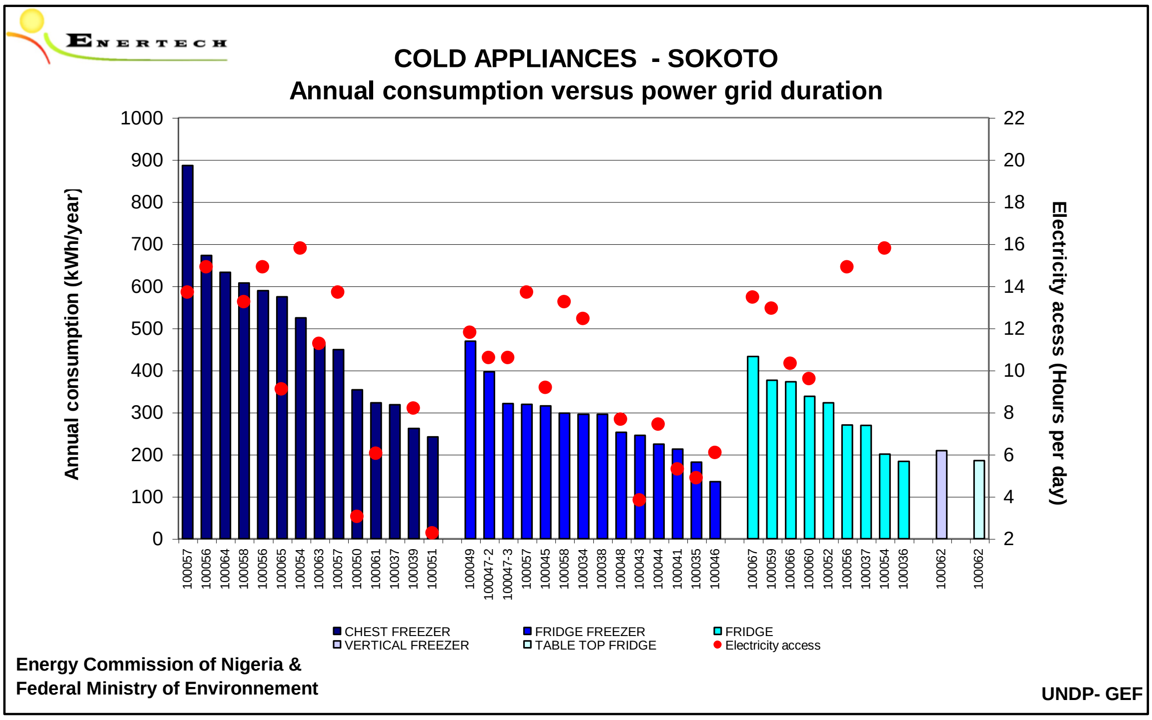


Figure 2.19 : Cold appliances annual consumption vs power grid - Sokoto

6.3.5 Lighting

6.3.5.1 Installed wattage per bulbs

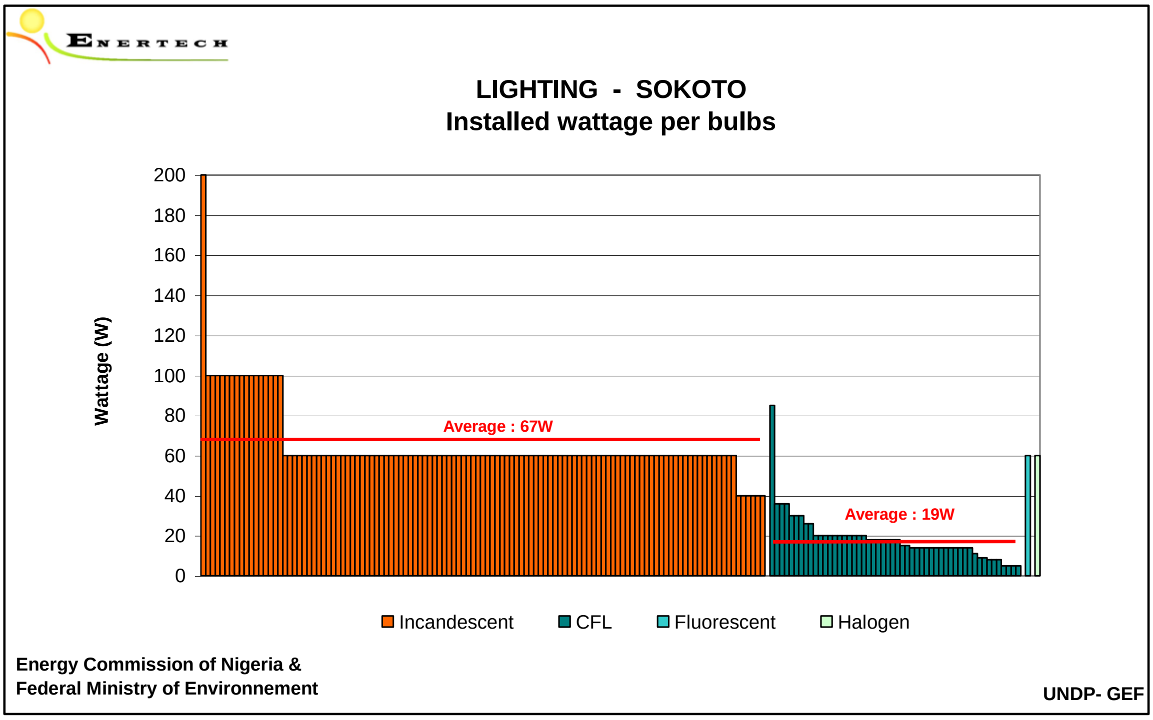


Figure 2.20 : Installed wattage per bulbs - Sokoto

6.3.5.2 Part of each type of light source

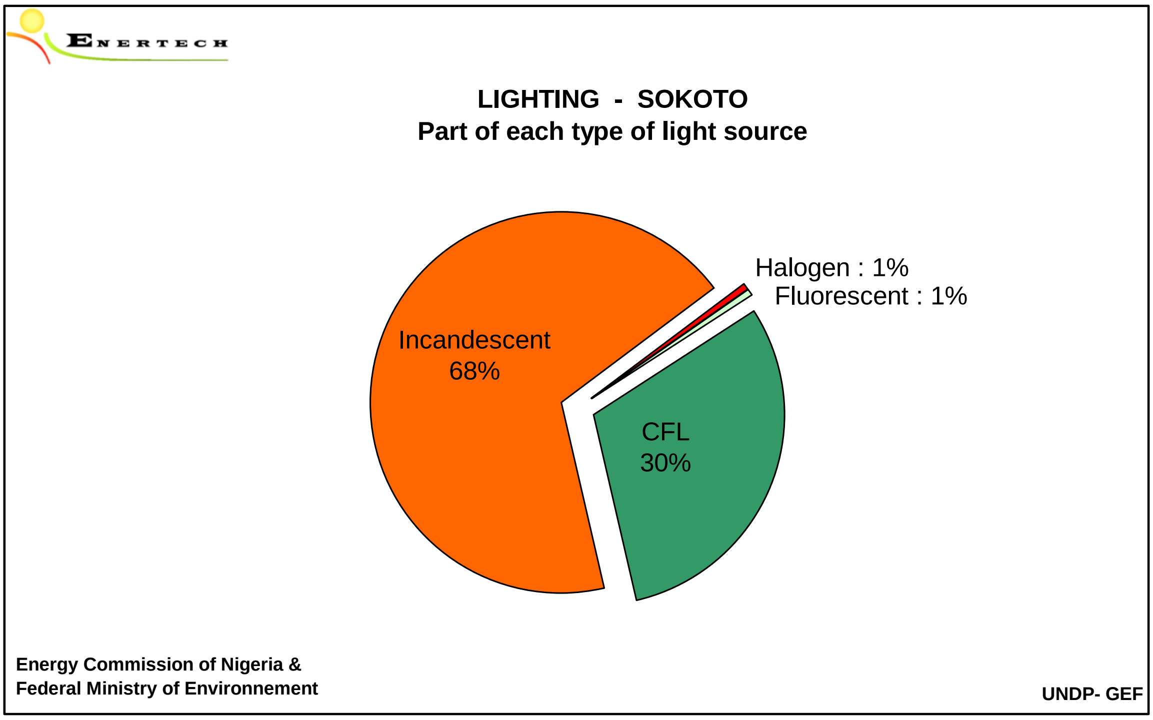


Figure 2.21 : Part of each type of light source - Sokoto

6.3.5.3 Annualized consumption per households

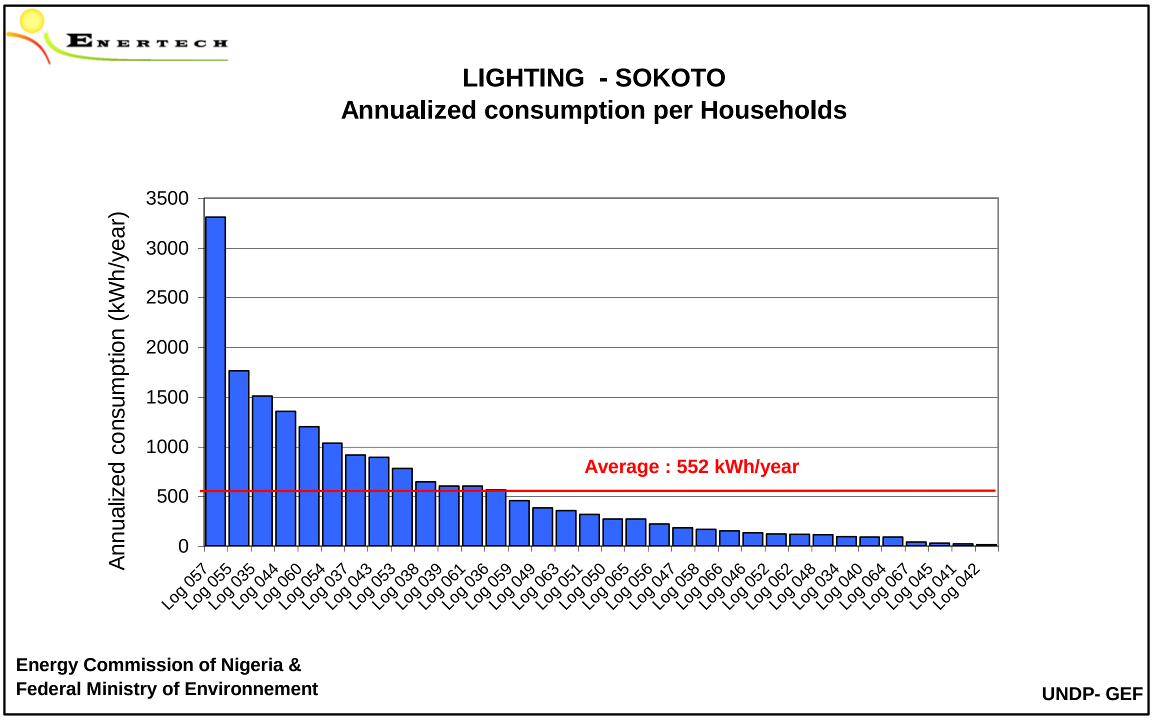


Figure 2.22 : Lighting annualized consumption - Sokoto

6.3.5.4 Daily average load curve

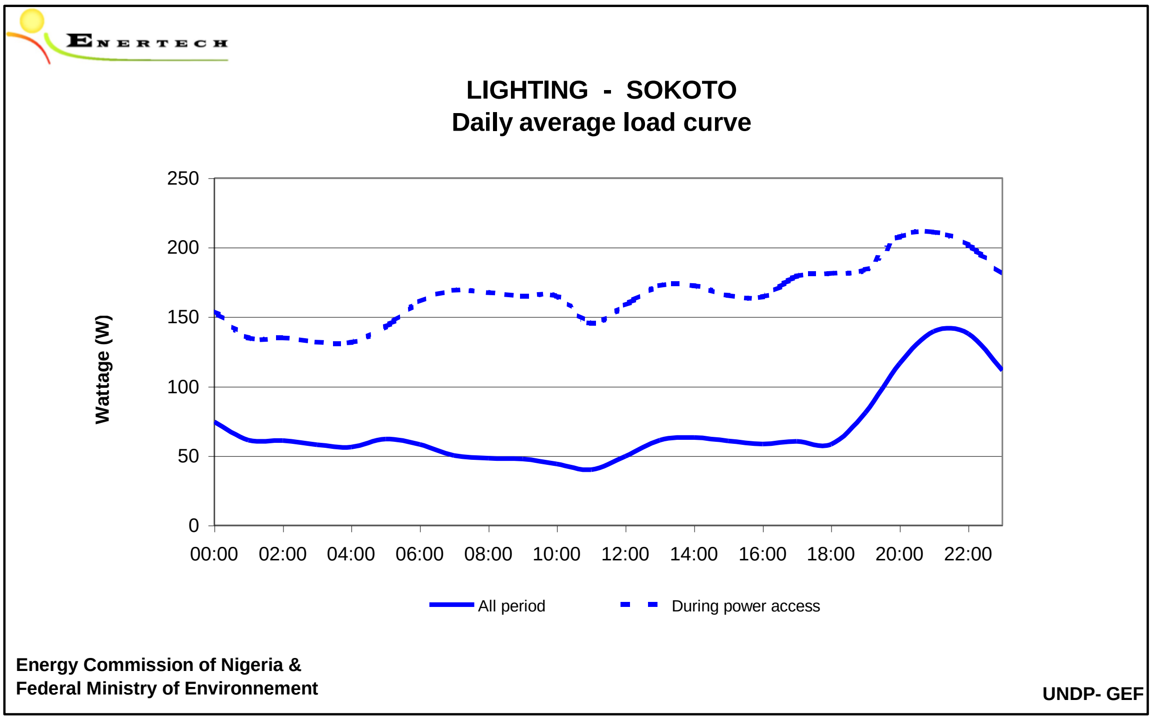


Figure 2.23 : Lighting daily average load curve - Sokoto

6.4 BAUCHI

6.4.1 Indoor temperature

6.4.1.1 Temperature daily curve

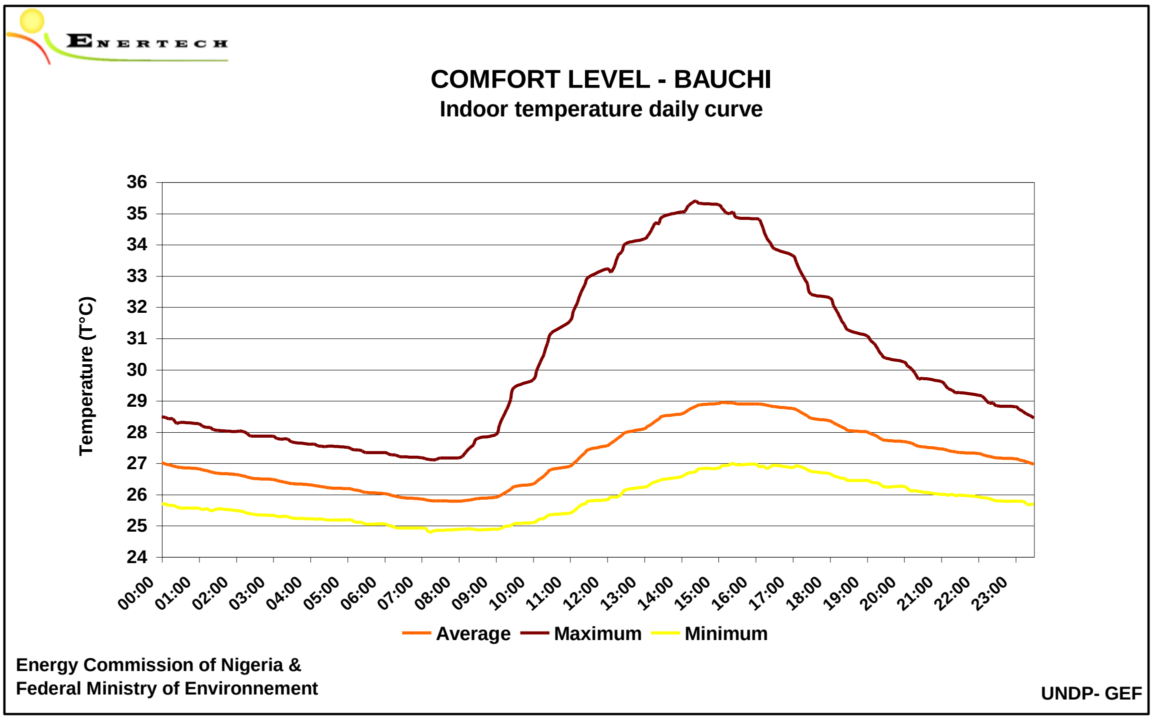


Figure 3.1 : Temperature daily curve – Bauchi

6.4.1.2 Temperature cumulative frequency

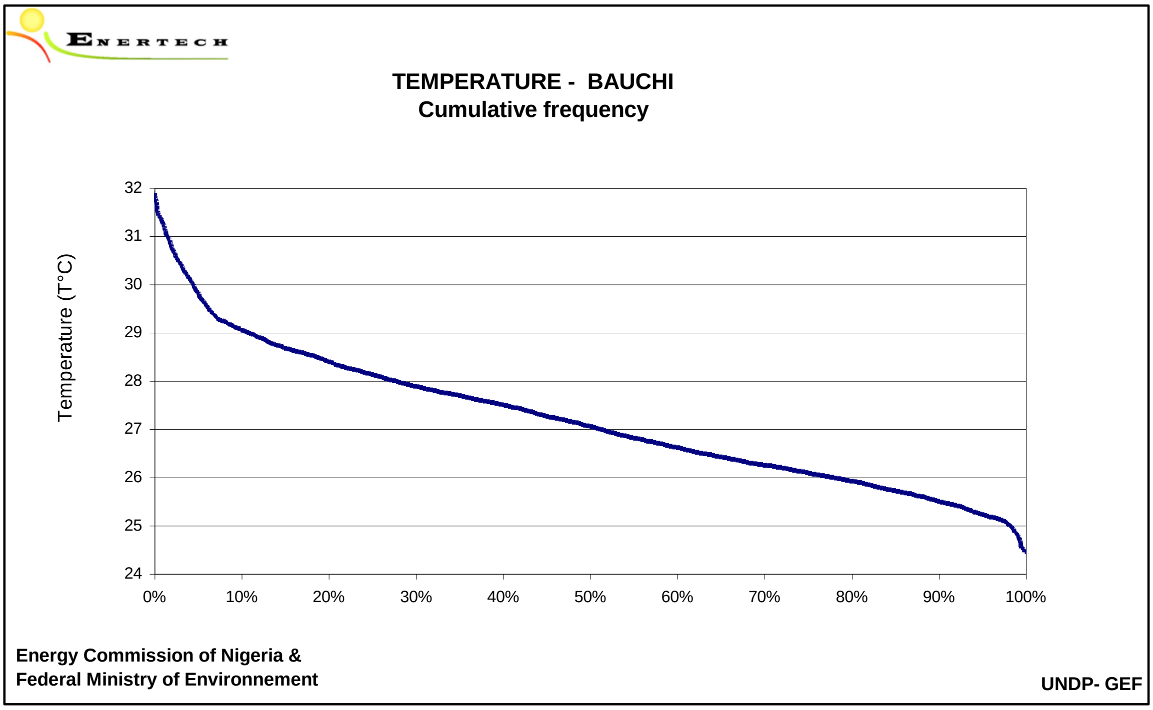


Figure 3.2 : Temperature cumulative frequency - Bauchi

6.4.2 Power Grid

6.4.2.1 Distribution of power access and power outages

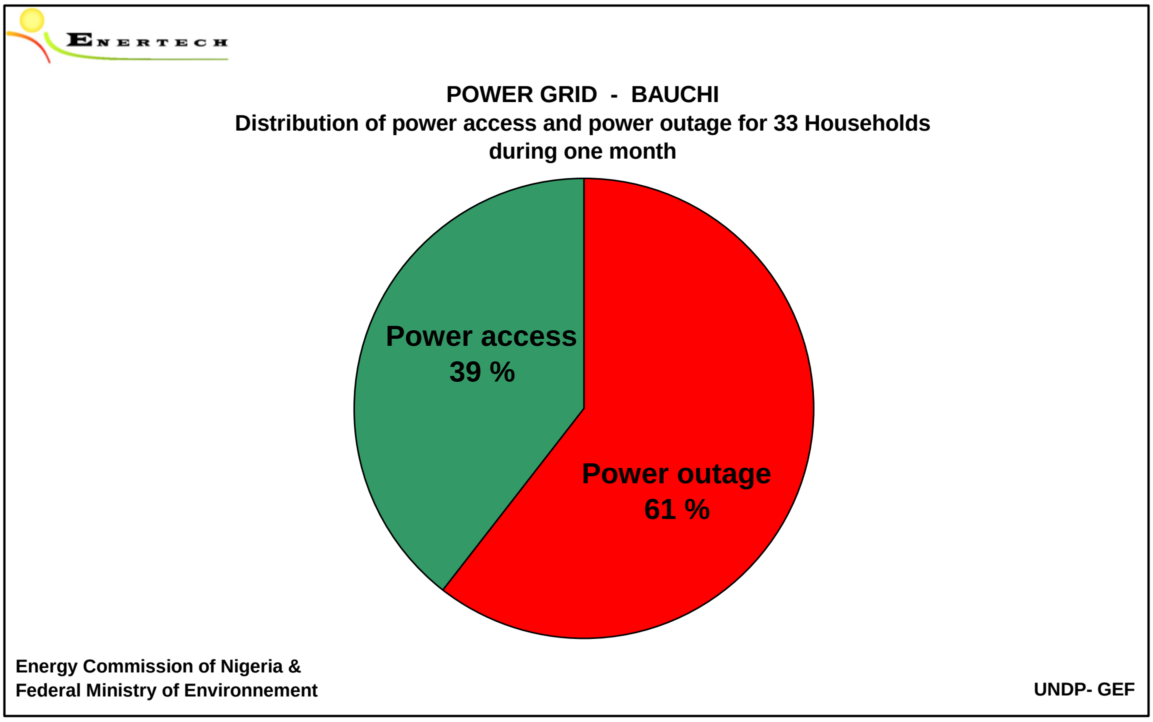


Figure 3.3 : Distribution of power access and power outages - Bauchi

6.4.2.2 Average voltage during power access

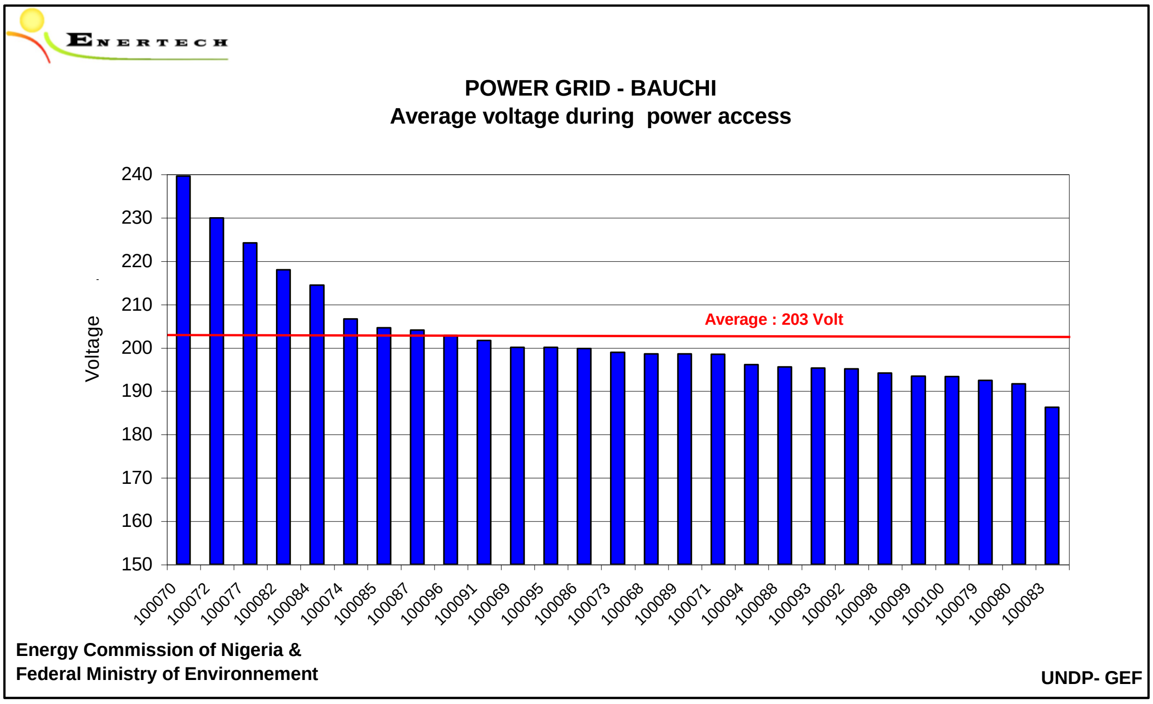


Figure 3.4 : Average voltage during power access - Bauchi

6.4.2.3 Part of power access daily curve

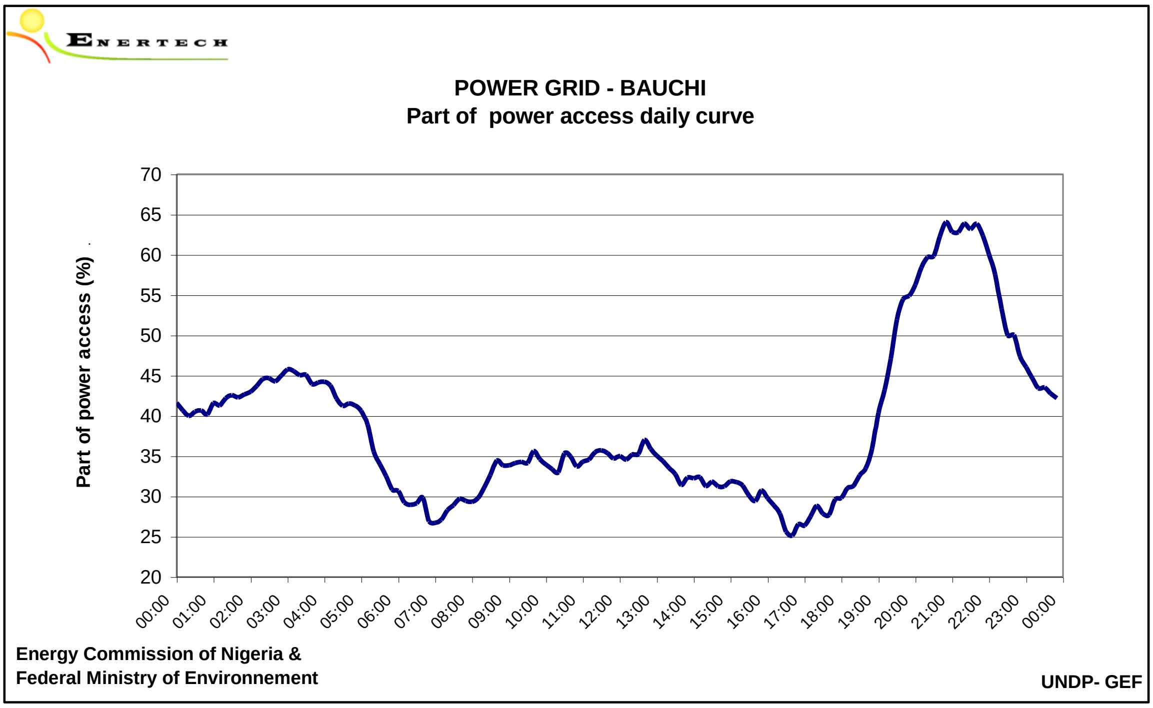


Figure 3.5 : Part of power access daily curve - Bauchi

6.4.2.4 Numbers of hours per day of electricity access

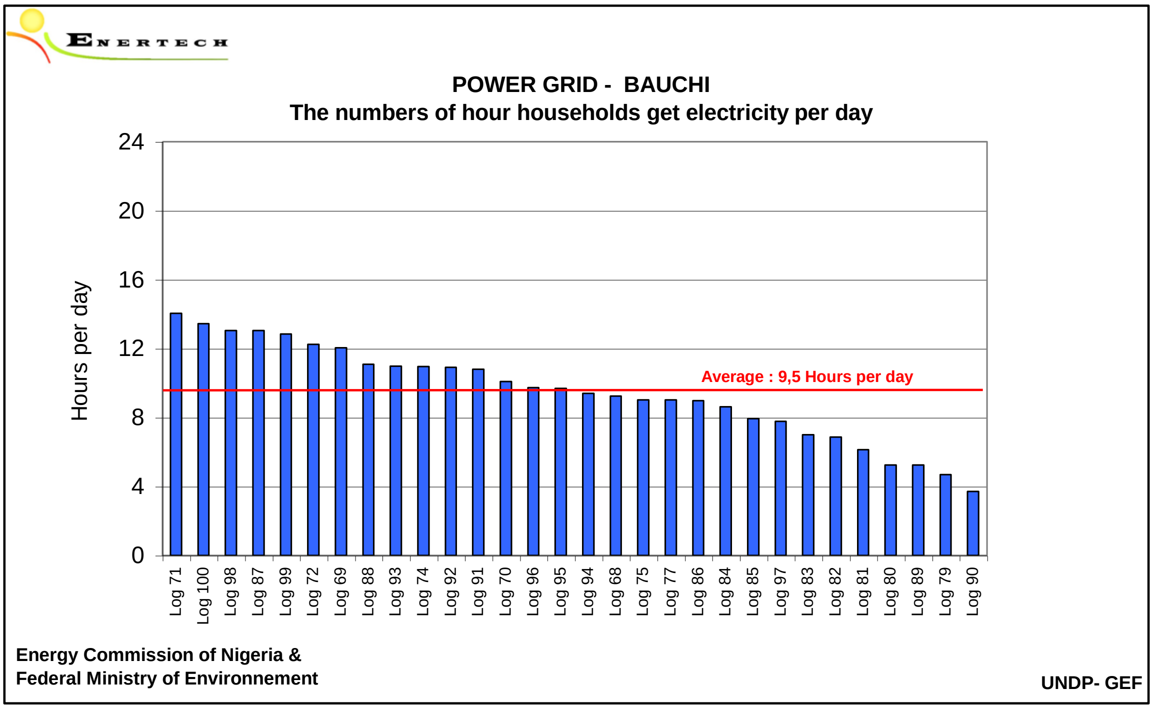


Figure 3.6 : Numbers of hours per day of electricity access - Bauchi

6.4.2.5 Duration of power outages

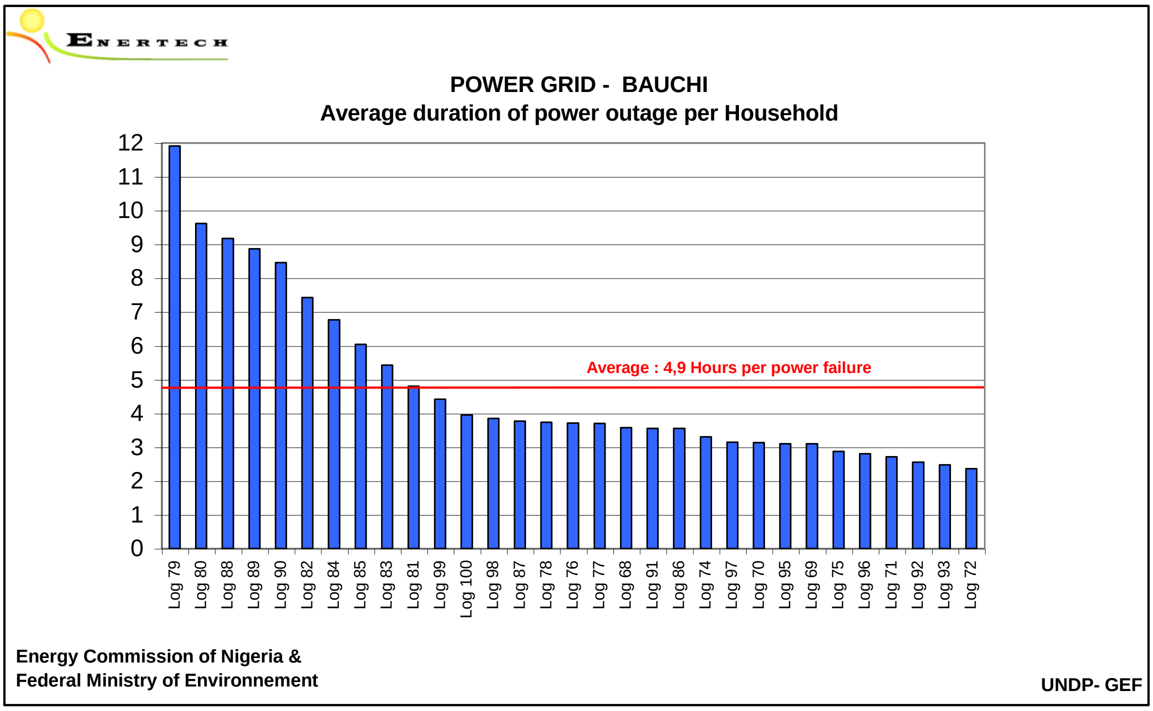


Figure 3.7 : Average duration of power access - Bauchi

6.4.2.6 Duration of electricity access

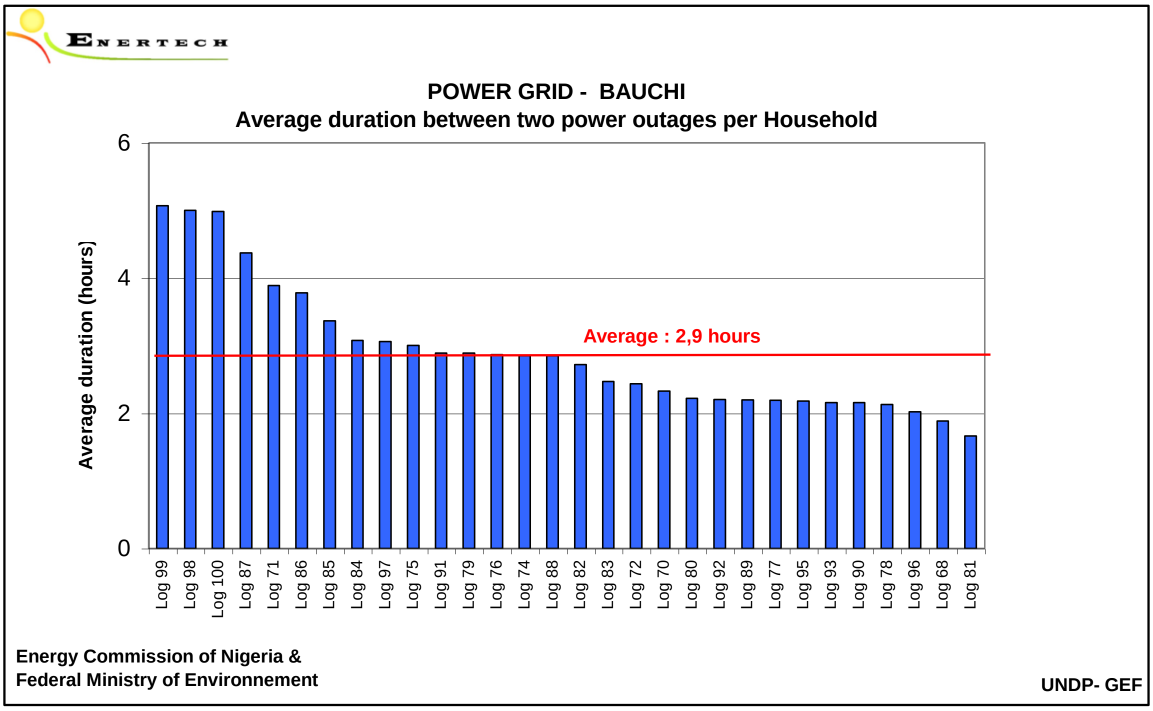


Figure 3.8 : Average duration of electricity access - Bauchi

6.4.2.7 Annualized consumption

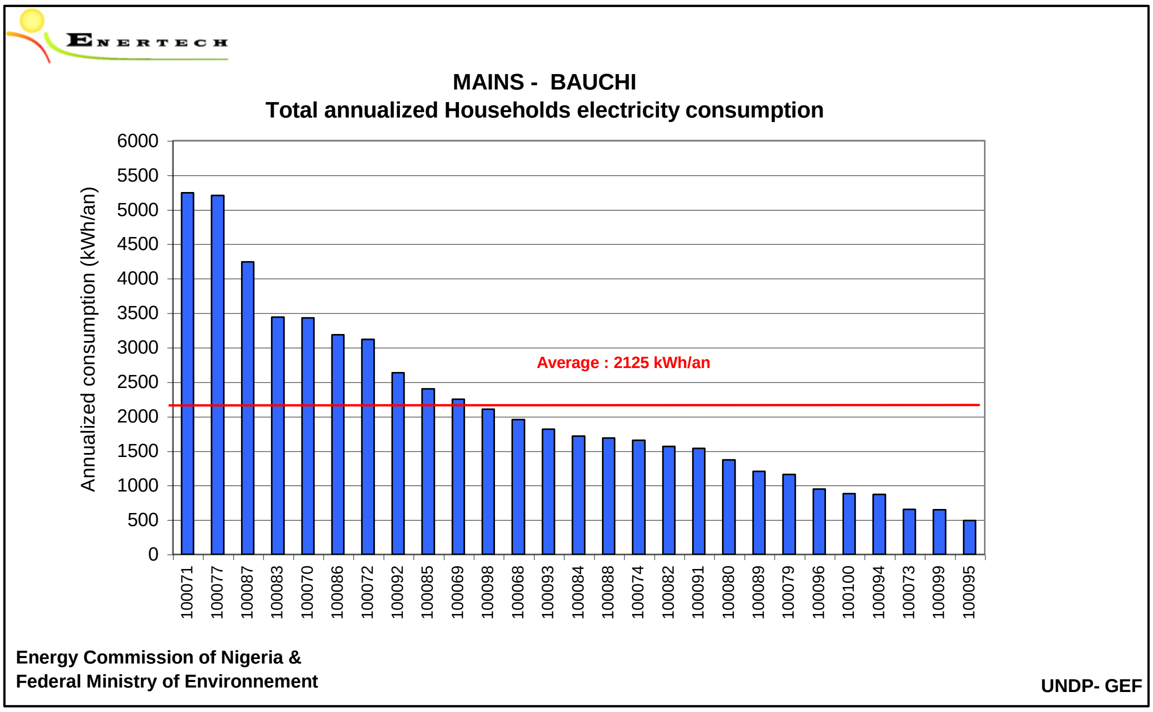


Figure 3.9 : Annualized households electricity consumption –Bauchi

6.4.2.8 Daily average load curve

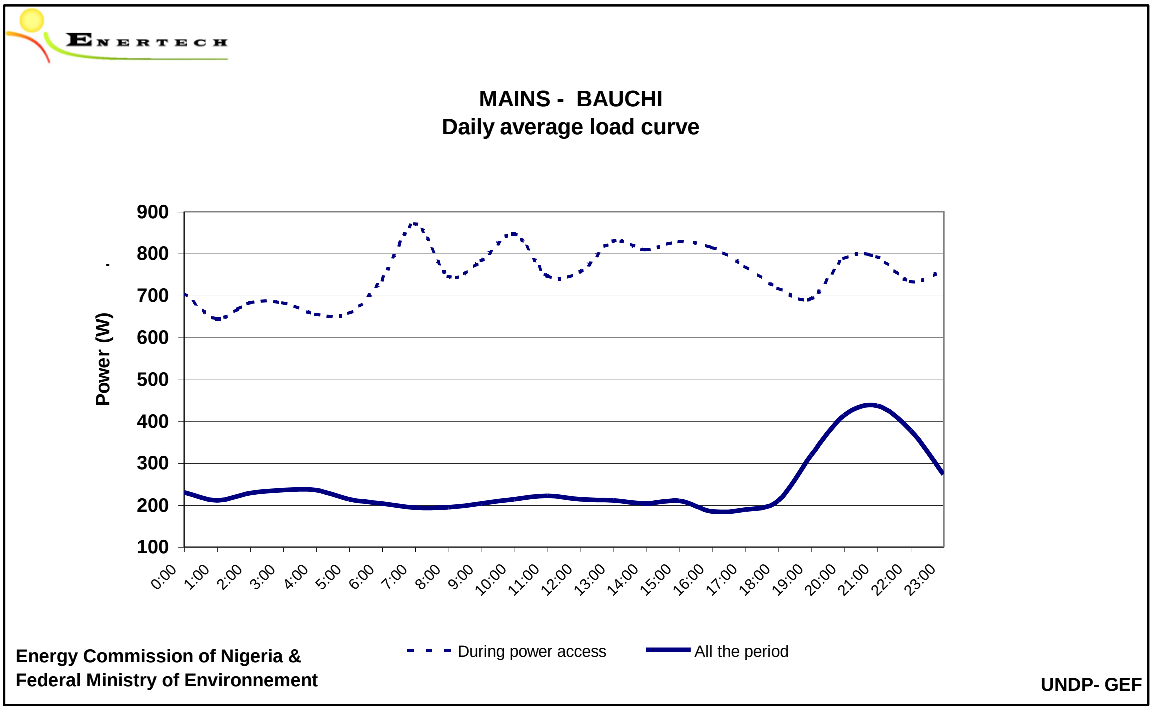


Figure 3.10 : Daily average load curve - Bauchi

6.4.2.9 Relative contribution from the different loads

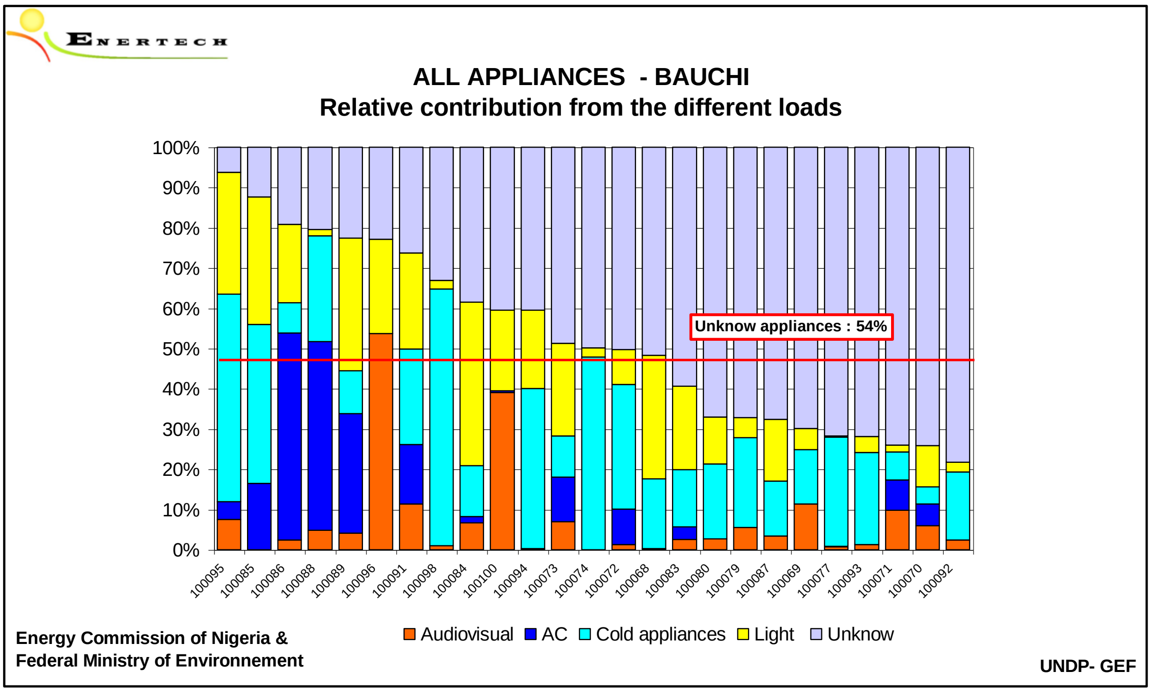


Figure 3.11 : Relative contribution from the different loads per households - Bauchi

6.4.2.10 Relative contribution from the different loads

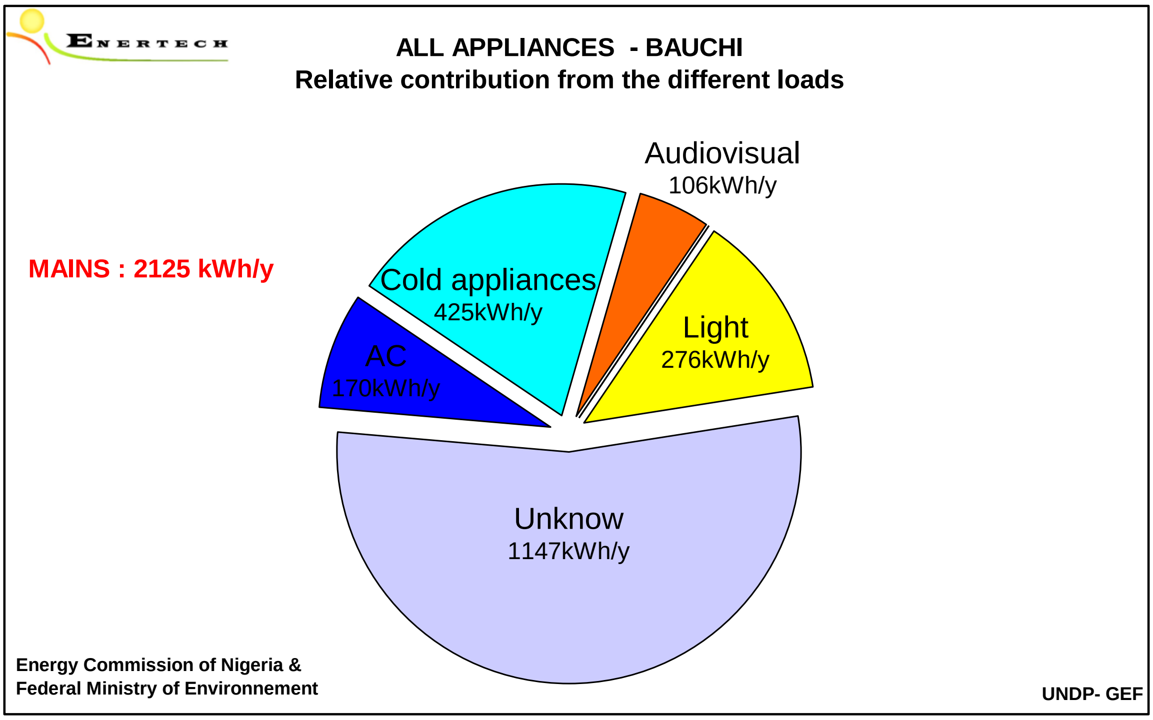


Figure 3.12 : Relative contribution from the different load

6.4.3 Air conditioner

6.4.3.1 Annualized consumption

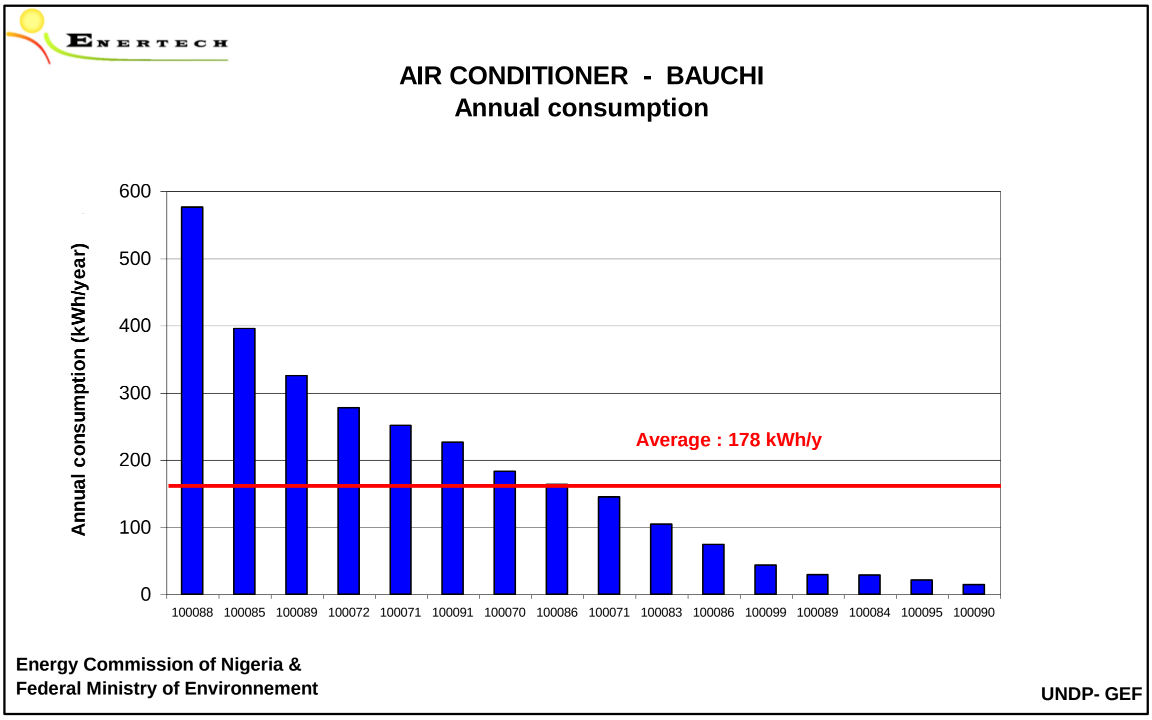


Figure 3.13 : AC annual consumption - Bauchi

6.4.3.2 Functioning rates

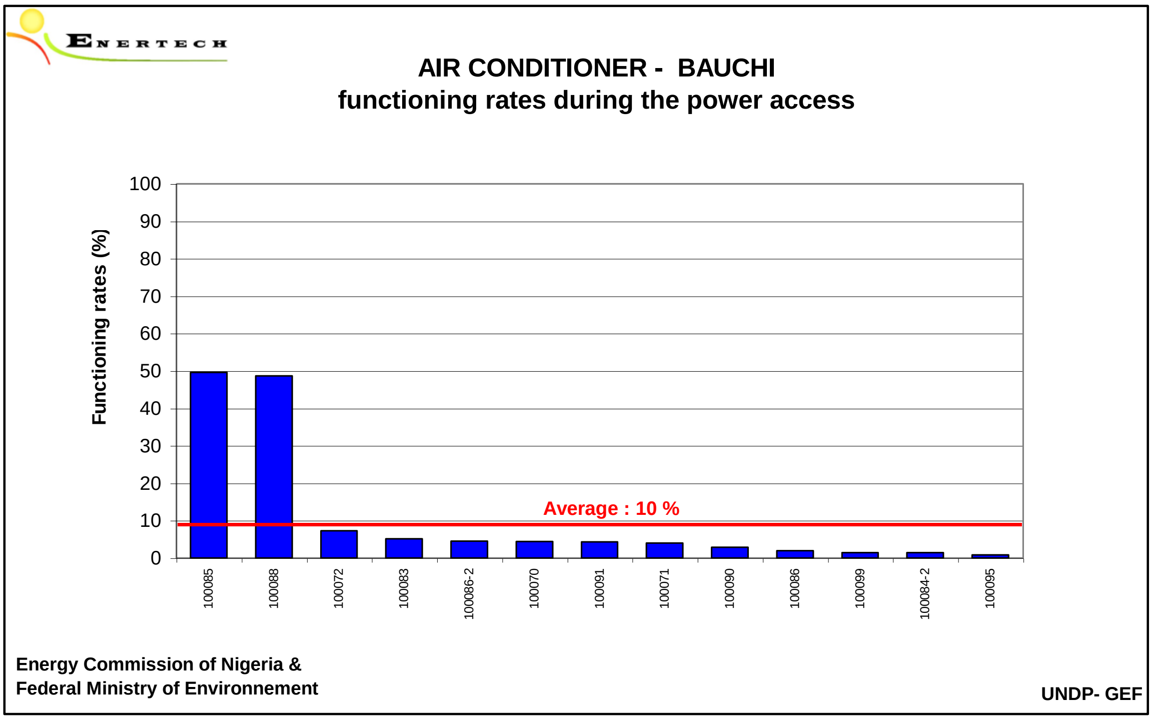


Figure 3.14 : AC functioning rates during the power access - Bauchi

6.4.3.3 *Annual consumption versus power grid*

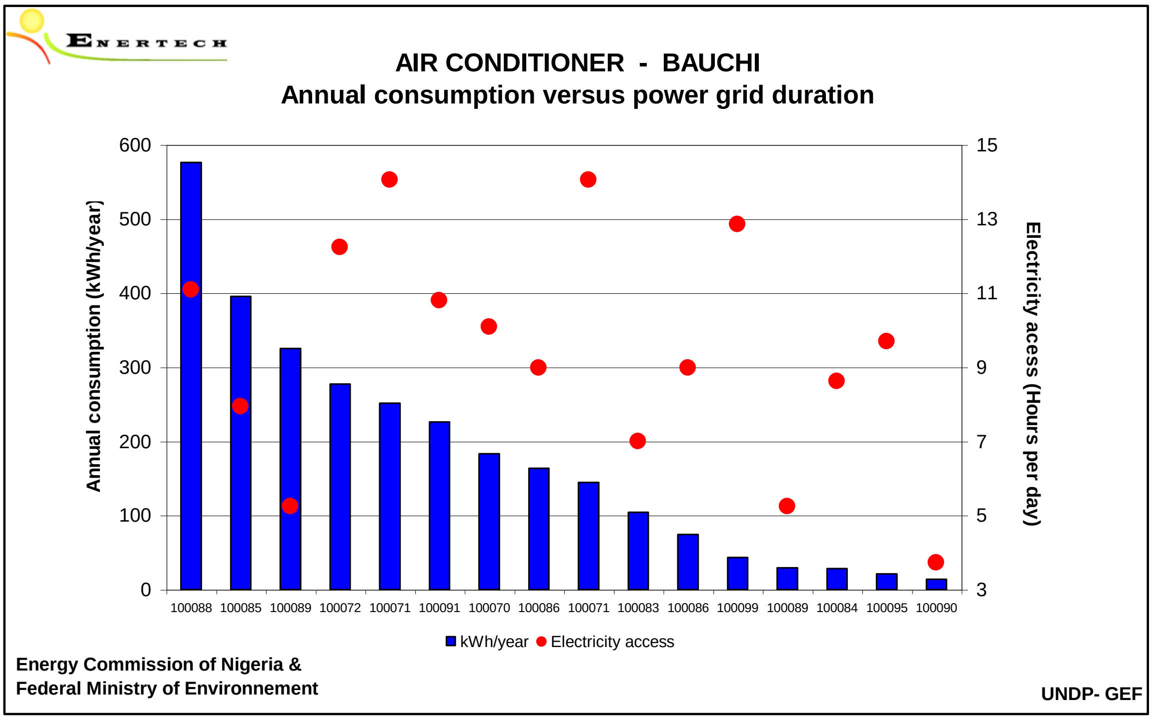


Figure 3.15 : AC annual consumption vs power grid - Bauchi

6.4.4 Cold appliances

6.4.4.1 *Average possession of appliances*

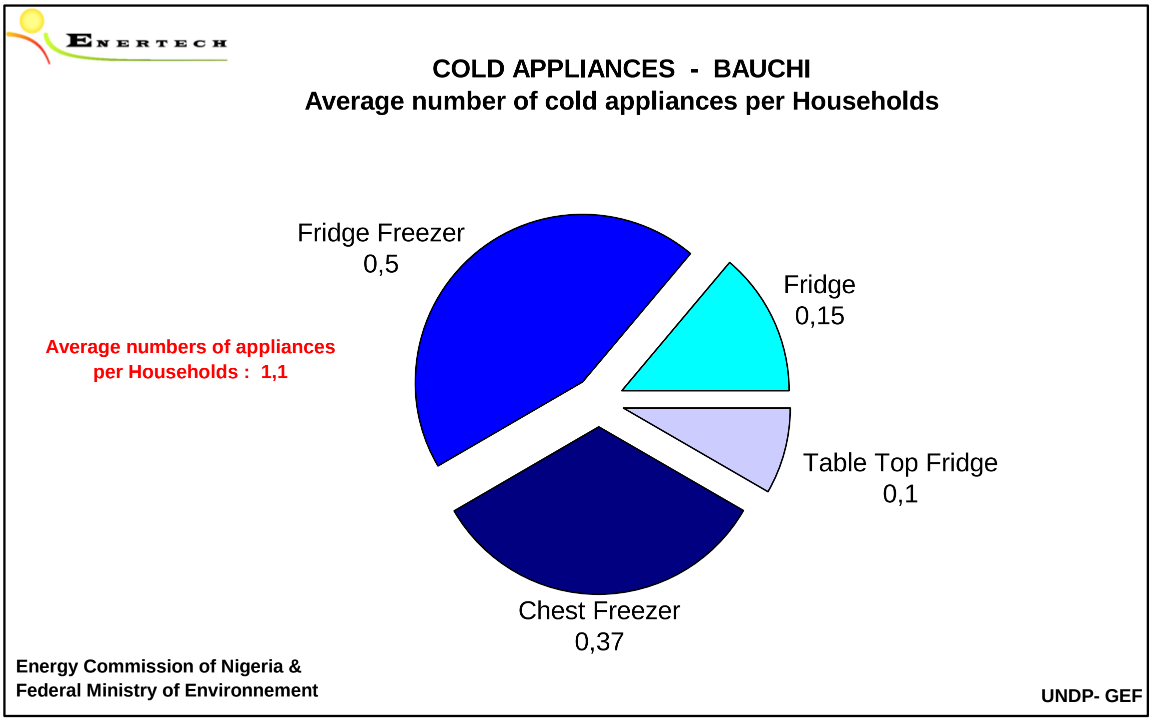


Figure 3.16 : Average possession of cold appliances - Bauchi

6.4.4.2 Annualized consumption

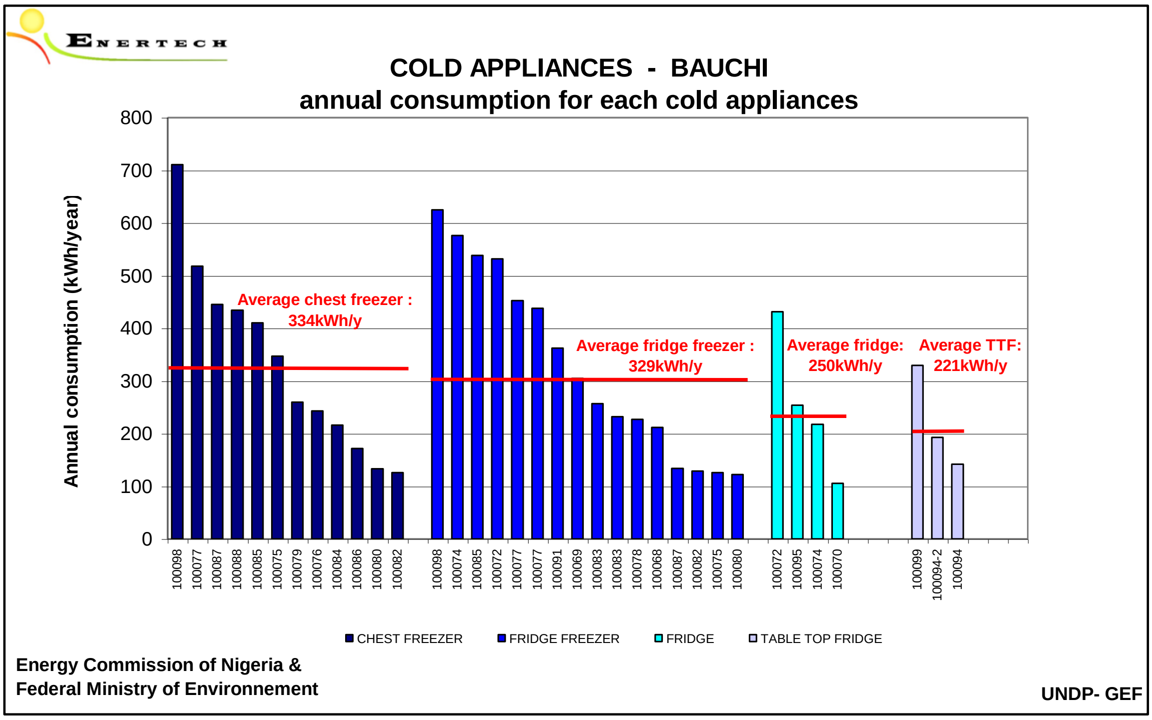


Figure 3.17 : Cold appliances annualized consumption - Bauchi

6.4.4.3 Functioning rates

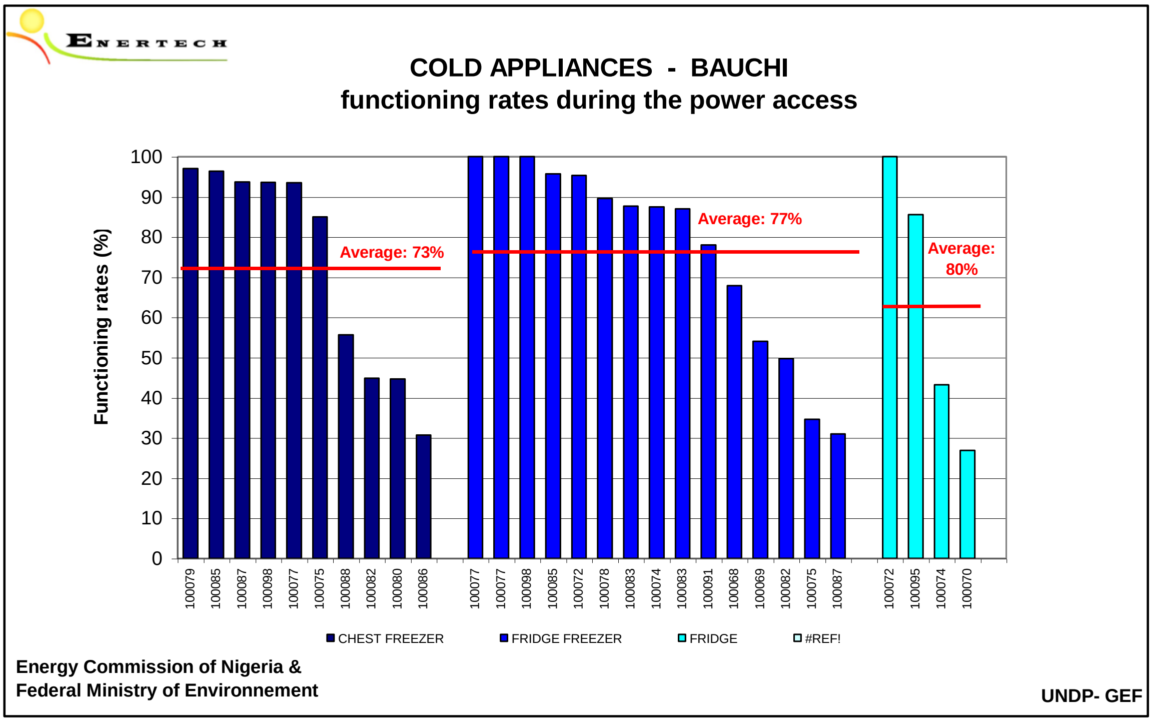


Figure 3.18 : Cold appliances functioning rates during power access - Bauchi

6.4.4.4 Annual consumption versus power grid

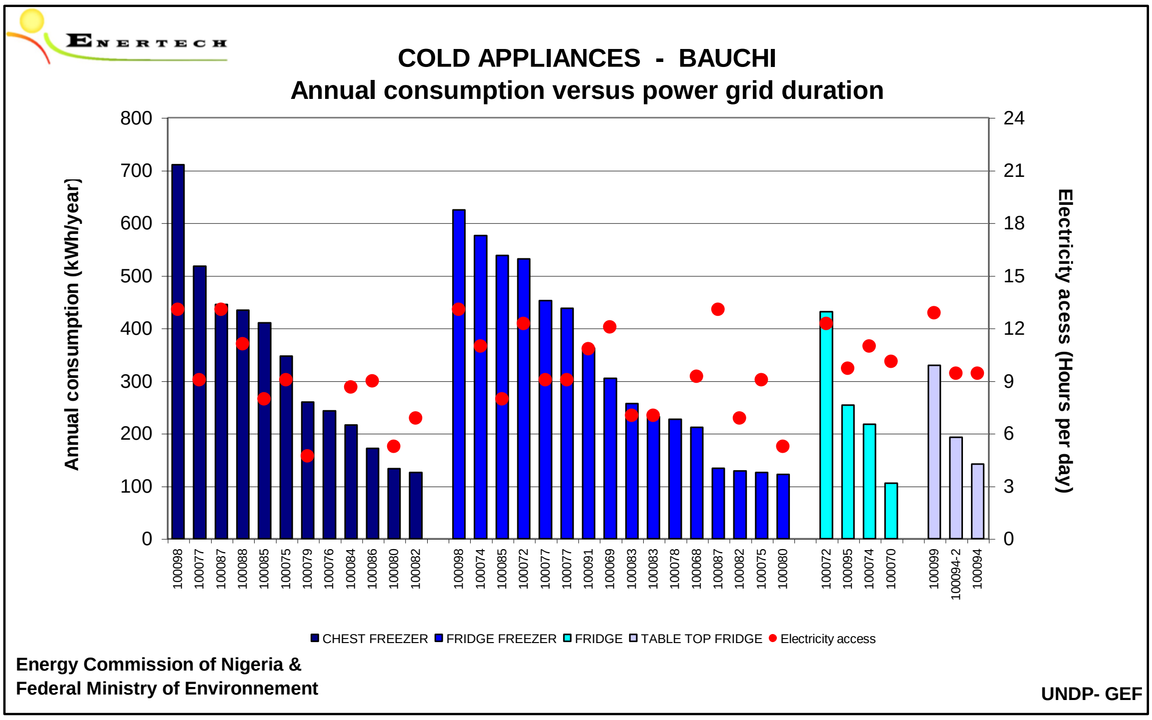


Figure 3.19 : Cold appliances annual consumption vs power grid – Bauchi

6.4.5 Lighting

6.4.5.1 Installed wattage per bulbs

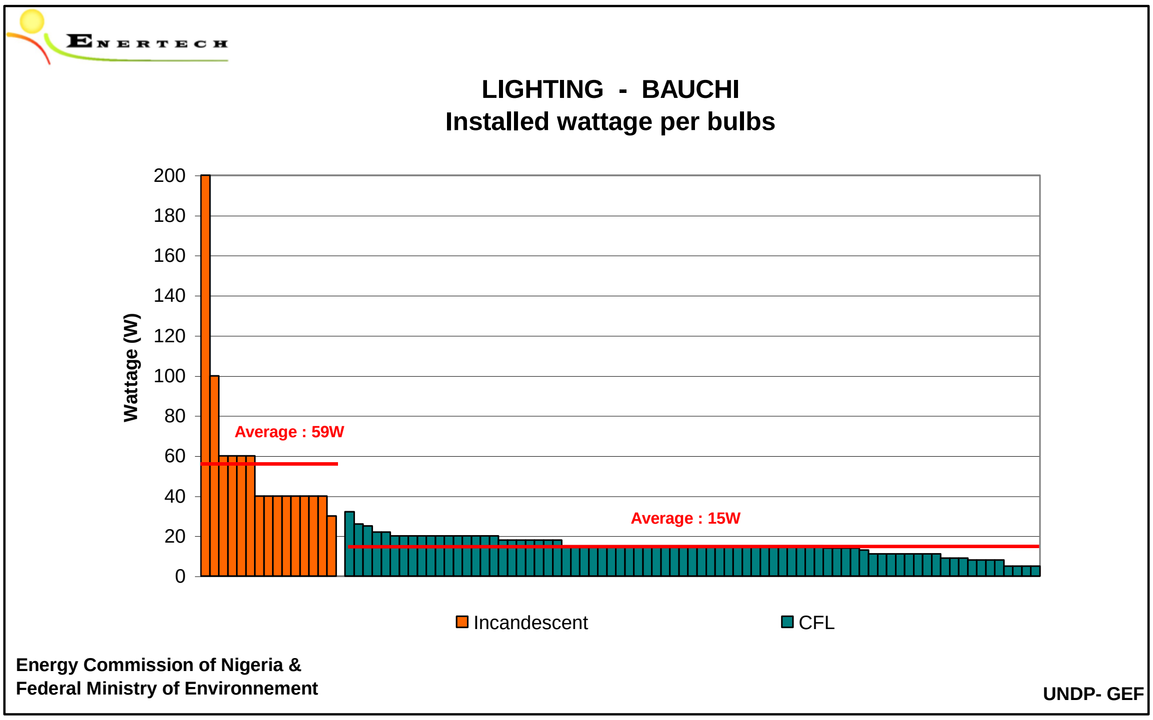


Figure 3.20 : Installed wattage per bulbs - Bauchi

6.4.5.2 Part of each type of light source

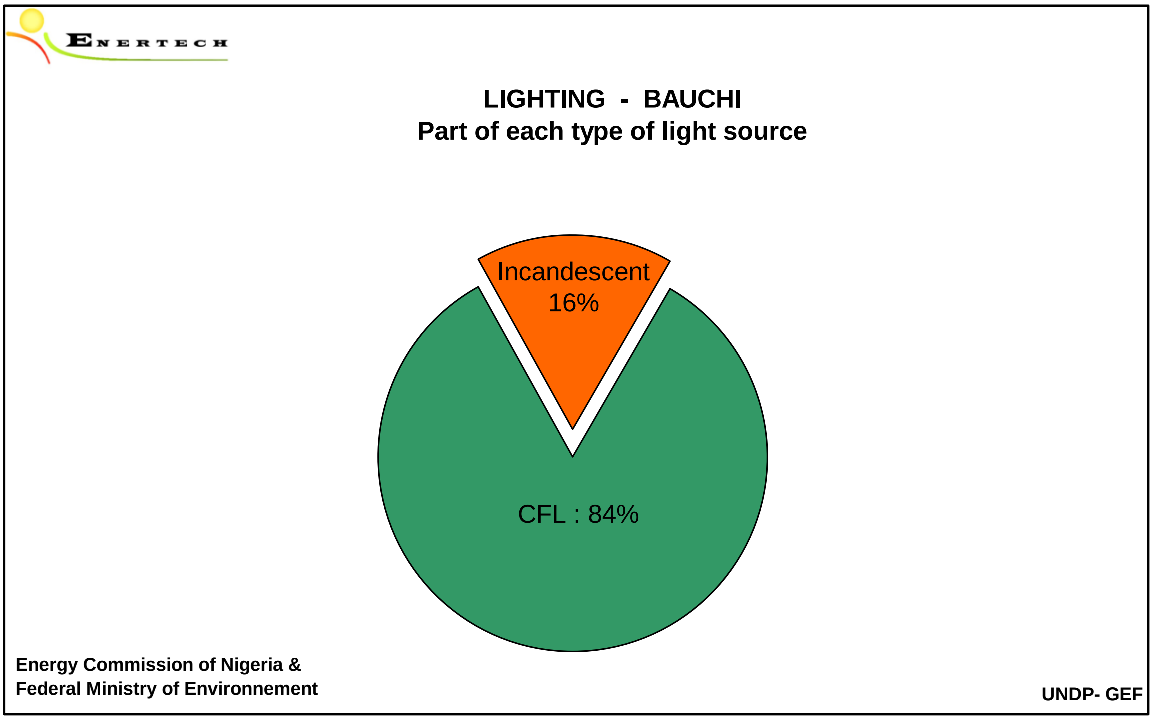


Figure 3.21 : Part of each type of light per bulbs - Bauchi

6.4.5.3 Annualized consumption per households

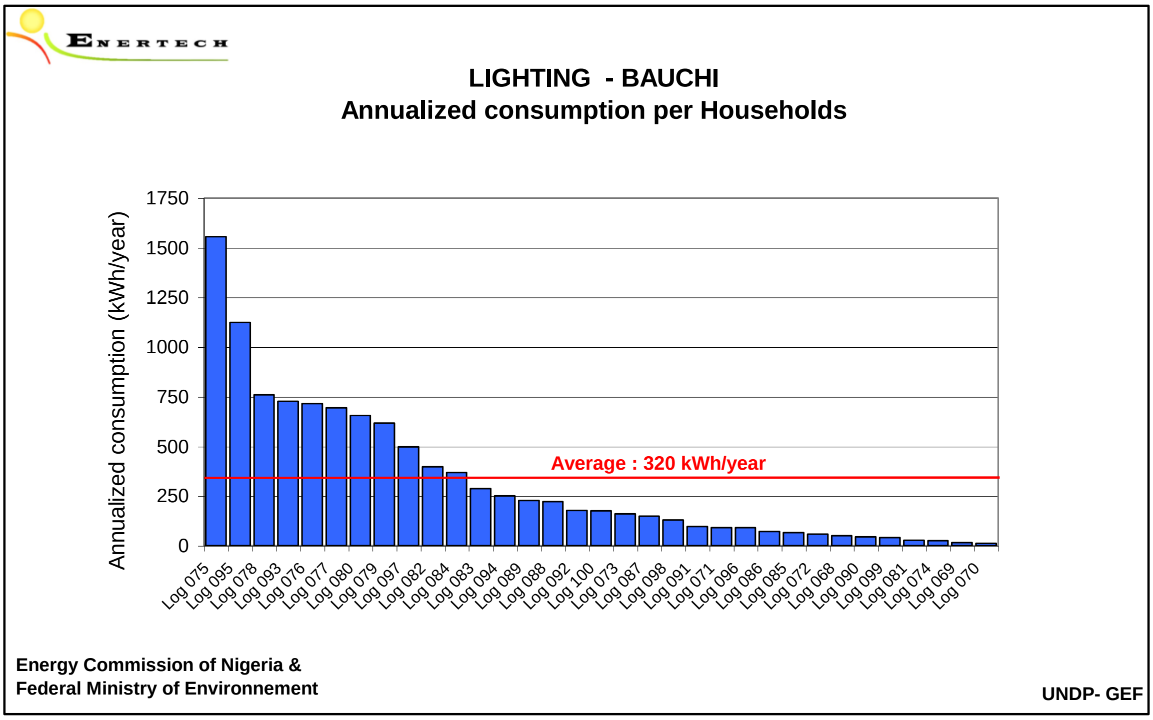


Figure 3.22 : Lighting annualized consumption - Bauchi

6.4.5.4 Daily average load curve

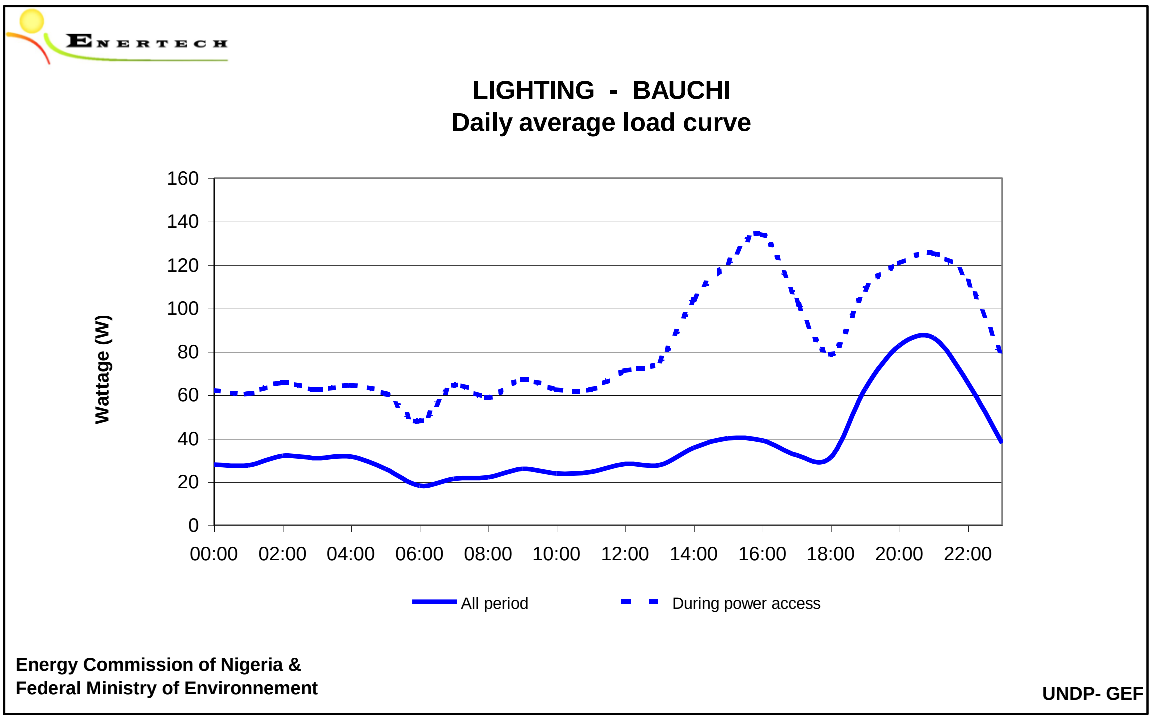


Figure 3.23 : Lighting daily average load curve - Bauchi

6.5 <u>BENIN</u>

6.5.1 Indoor temperature

6.5.1.1 Temperature daily curve

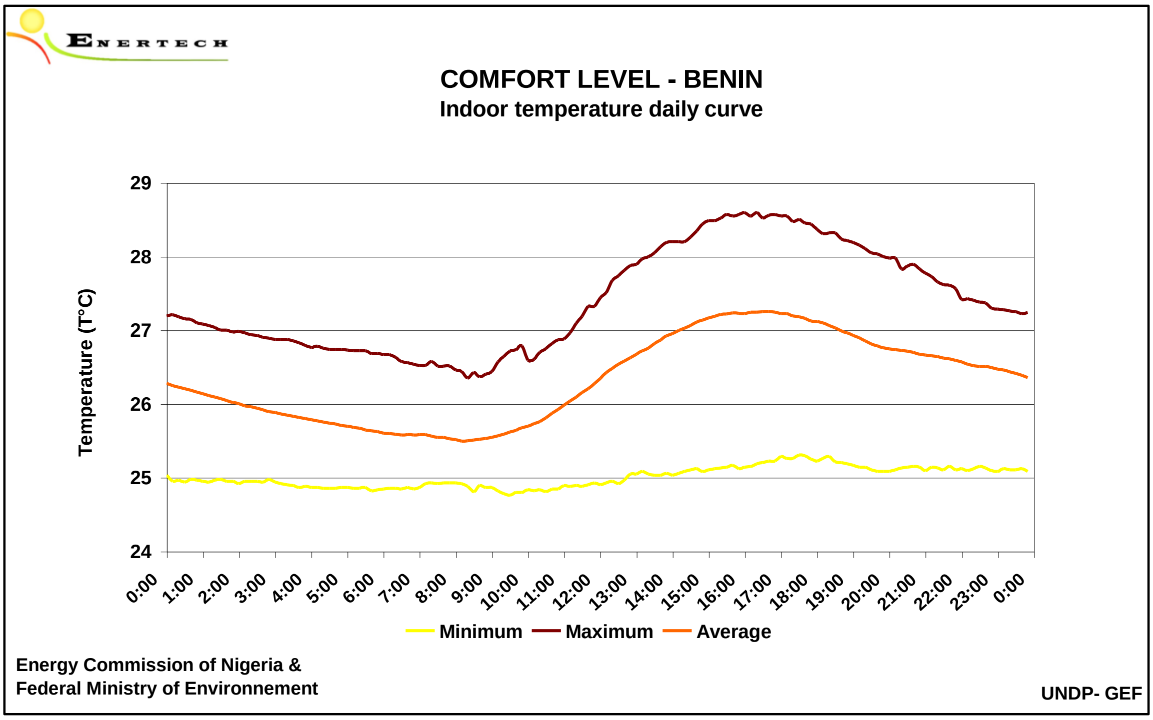


Figure 4.1 : Temperature daily curve - Benin

6.5.1.2 Temperature cumulative frequency

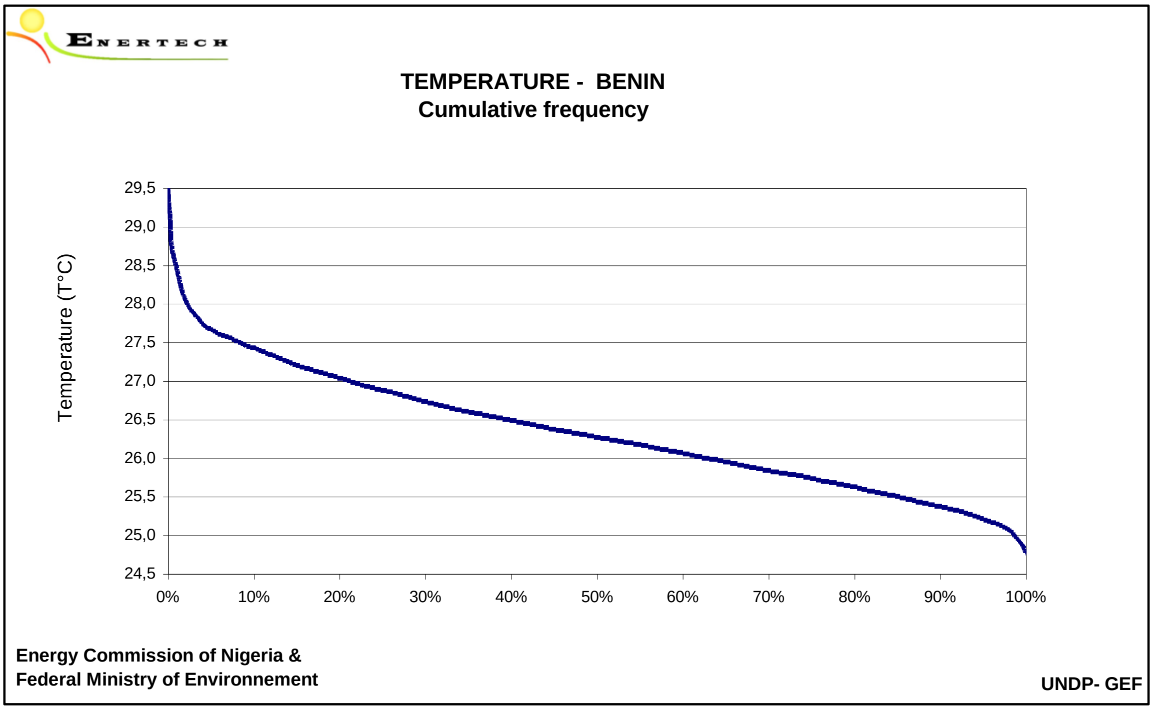


Figure 4.2 : Temperature cumulative frequency - Benin

6.5.2 Power Grid

6.5.2.1 Distribution of power access and power outages

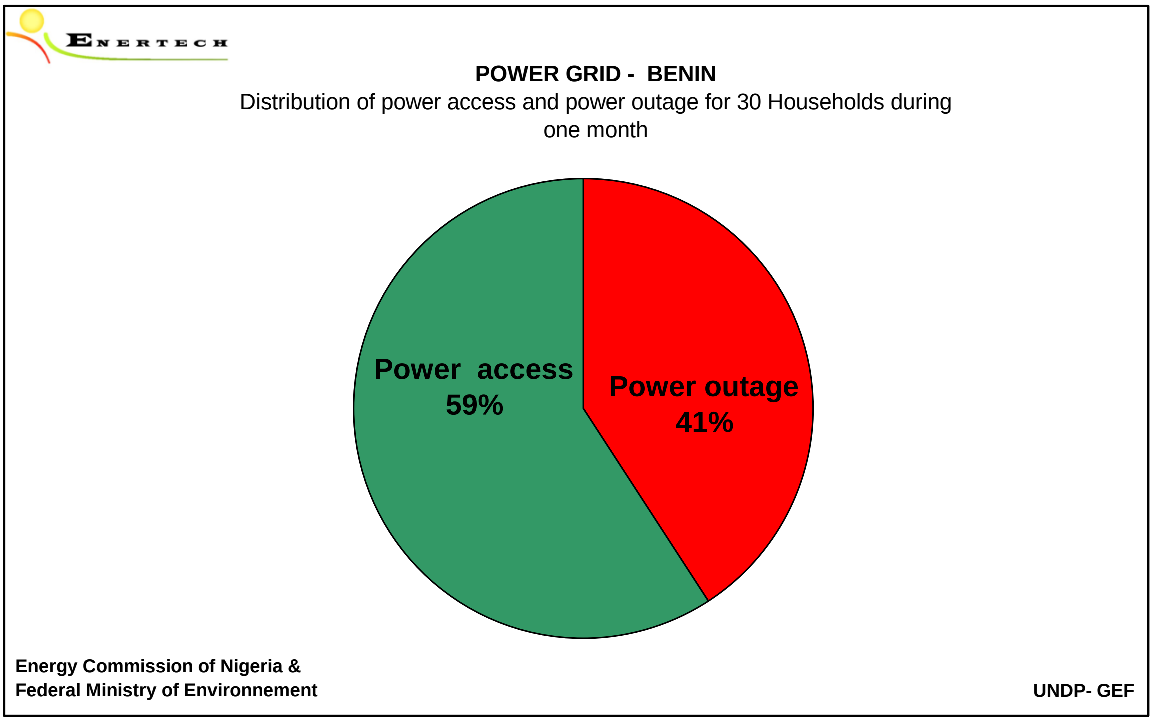


Figure 4.3 : Distribution o power access and power outages - Benin

6.5.2.2 Average voltage during power access

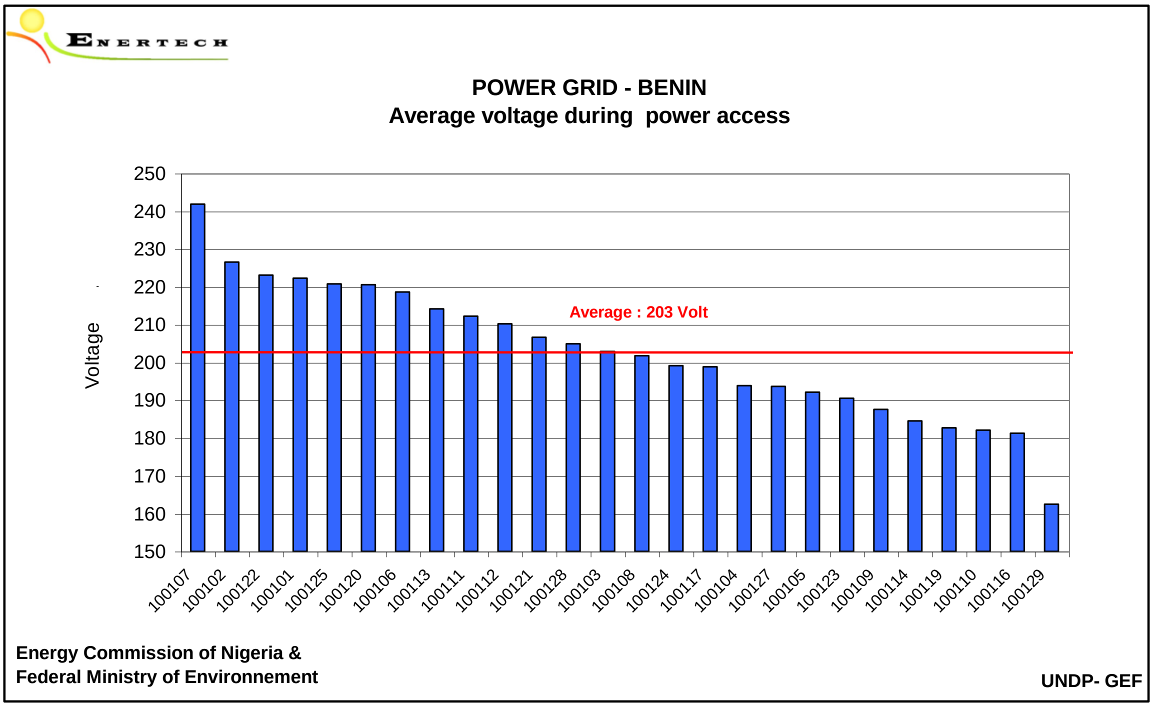


Figure 4.4 : Average voltage during power access - Benin

6.5.2.3 Part of power access daily curve

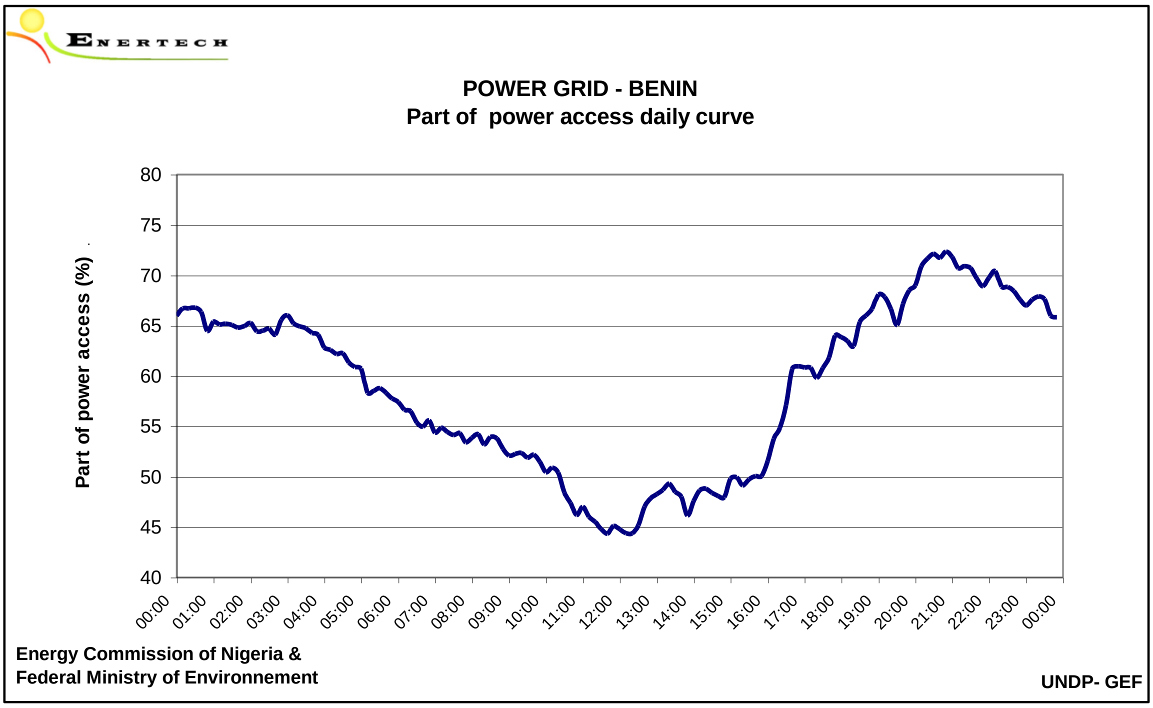


Figure 4.5 : Part of power access daily curve - Benin

6.5.2.4 Numbers of hours per day of electricity access

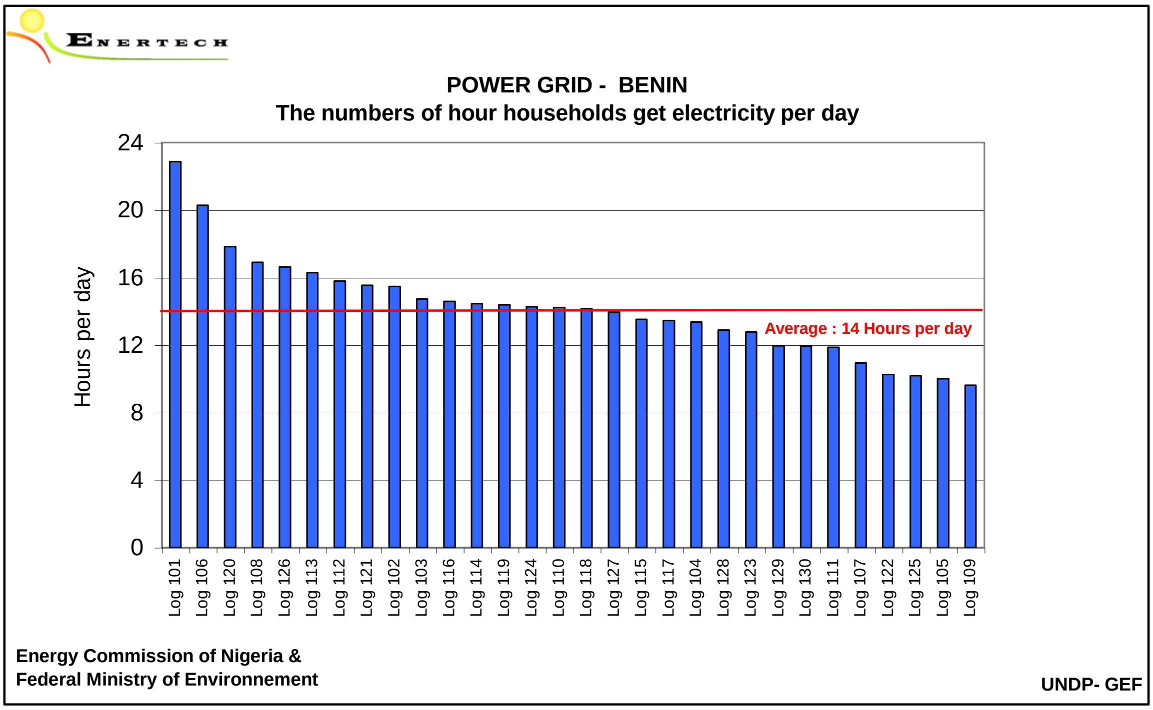


Figure 4.6 : Numbers of hours per day of electricity access - Benin

6.5.2.5 Duration of power outages

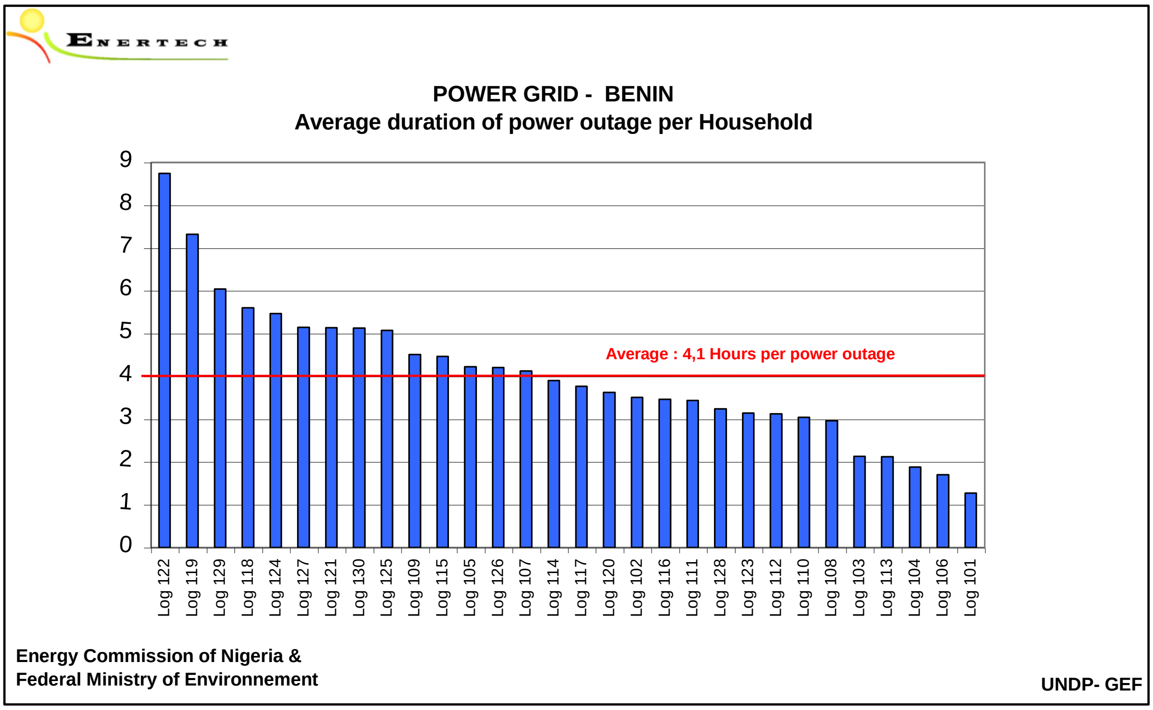


Figure 4.7 : Average duration of power outages - Benin

6.5.2.6 Duration of electricity access

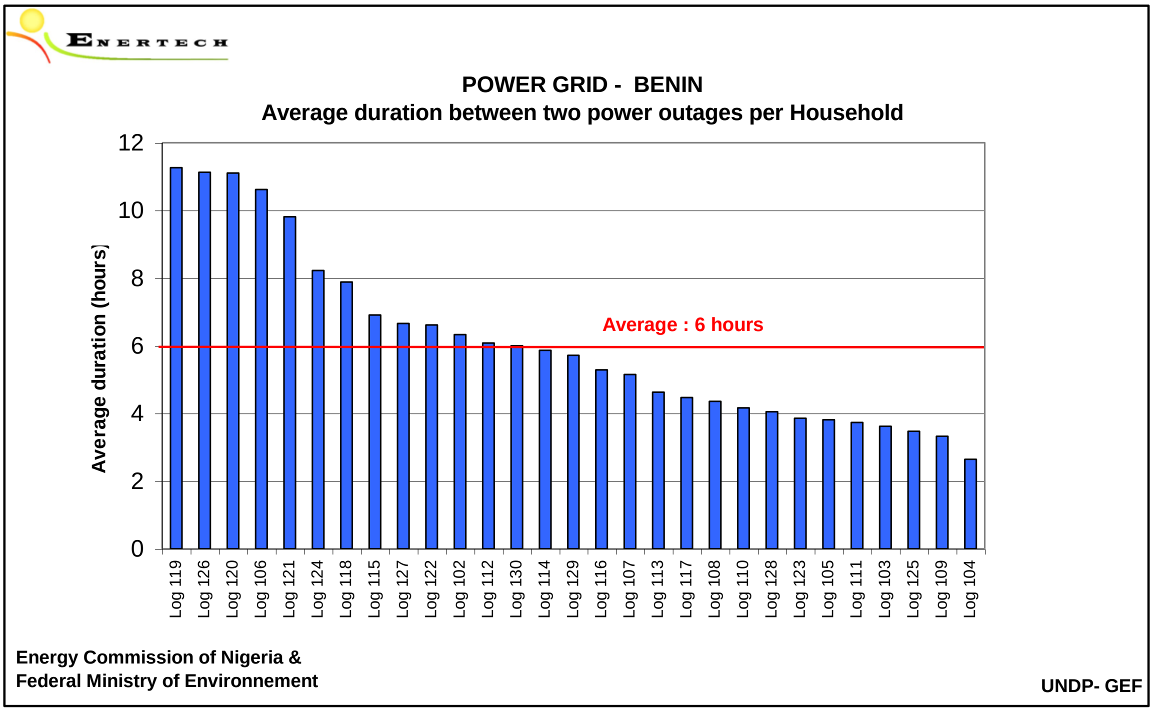


Figure 4.8 : Average duration of electricity access - Benin

6.5.2.7 Annualized consumption

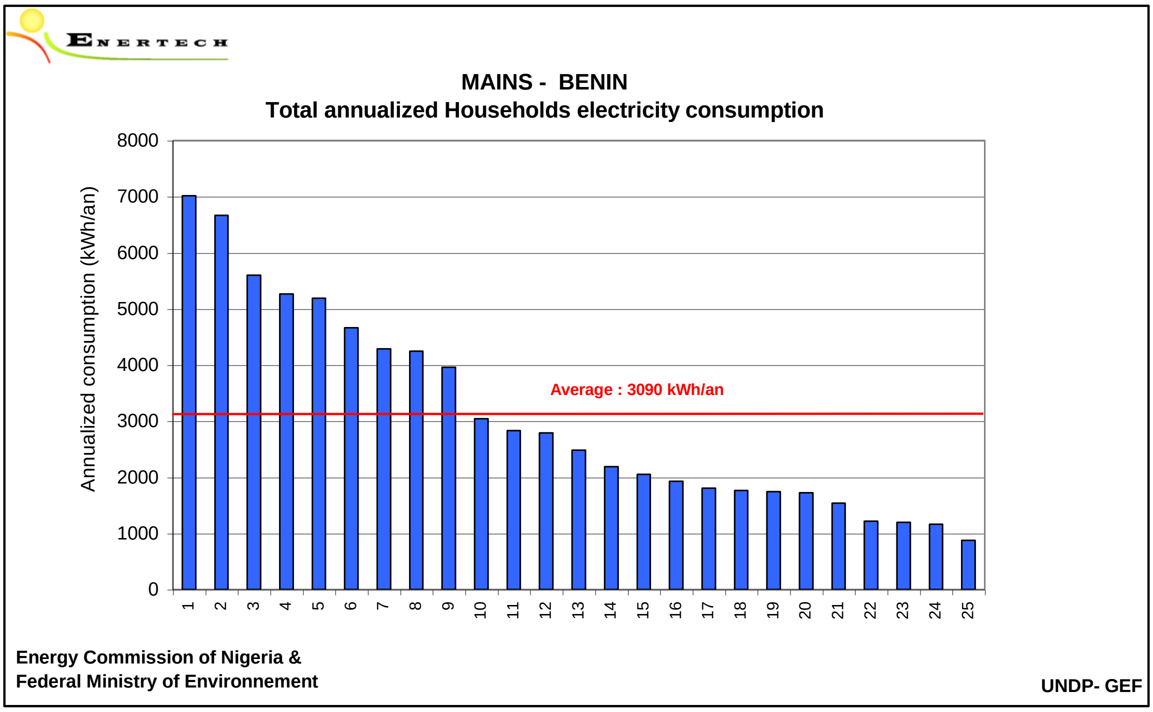


Figure 4.9 : Annualized households electricity consumption - Benin

6.5.2.8 Daily average load curve

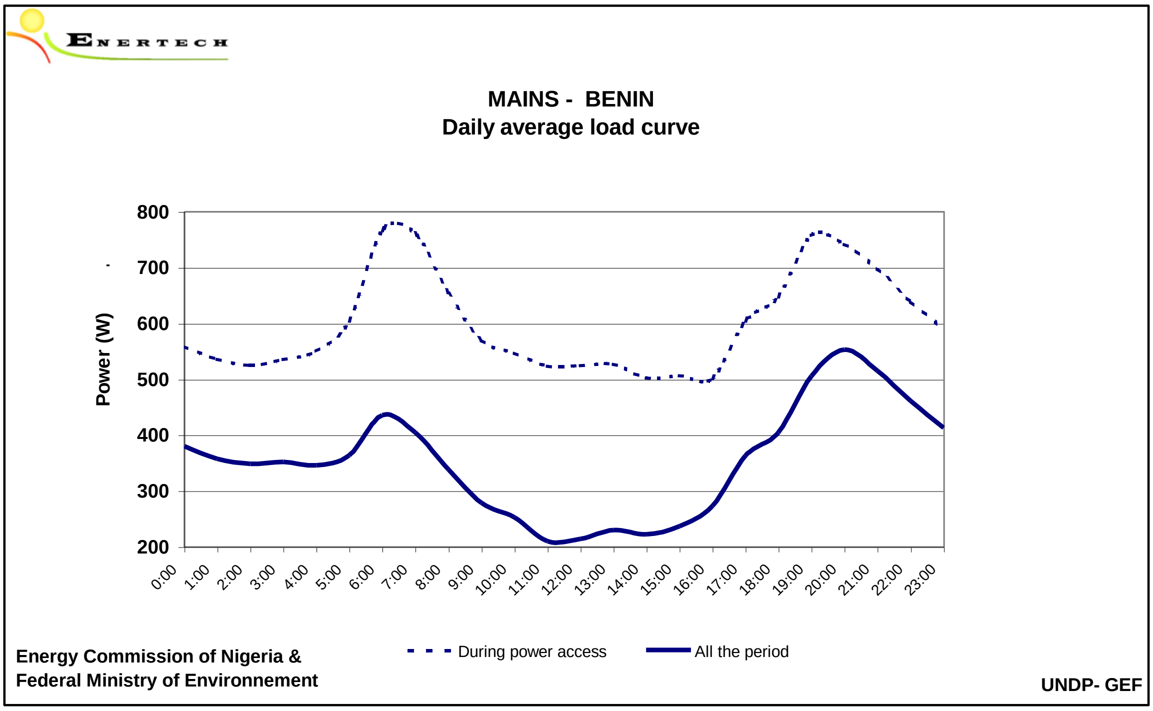


Figure 4.10 : Daily average load curve - Benin

6.5.2.9 Relative contribution from the different load

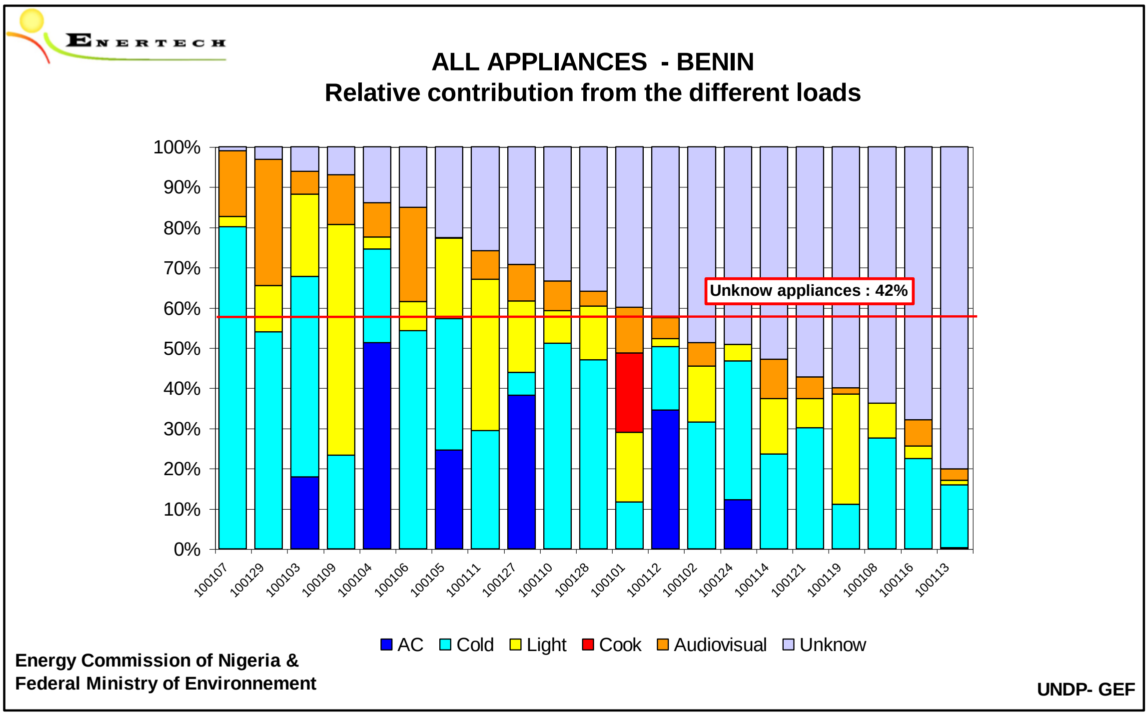


Figure 4.11 : Relative contribution from the different loads per Households - Benin

6.5.2.10 Relative contribution from the different loads

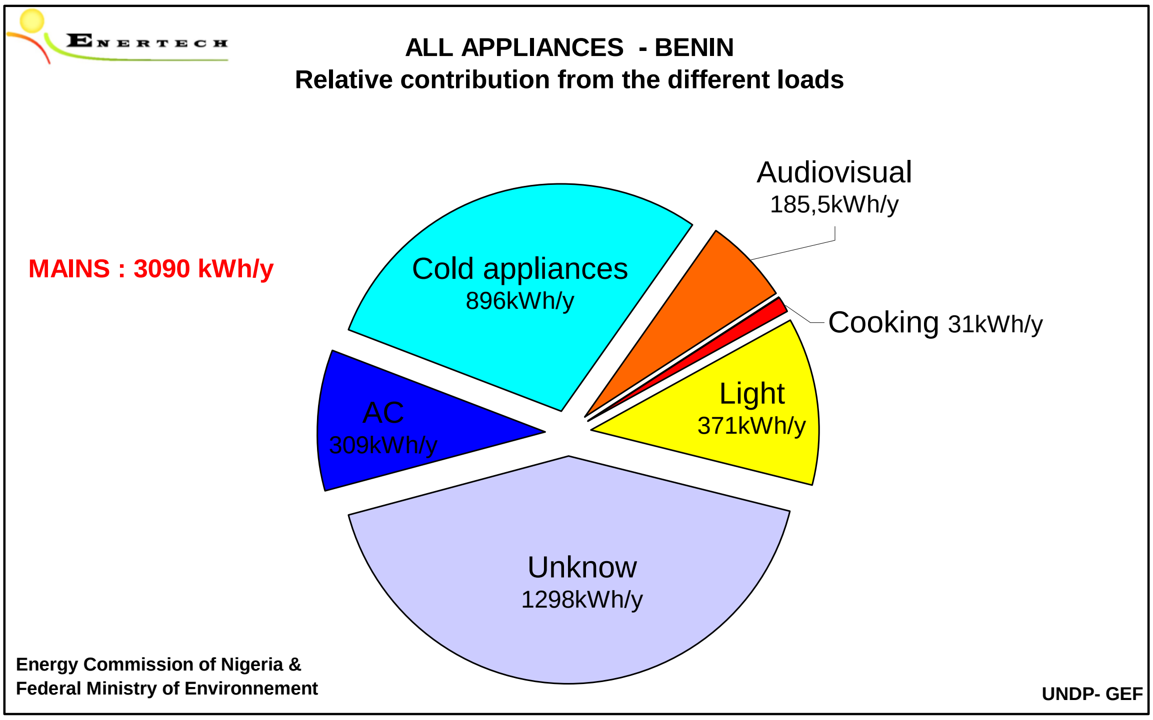


Figure 4.12 : Relative contribution from the different loads - Benin

6.5.3 Air conditioner

6.5.3.1 Annualized consumption

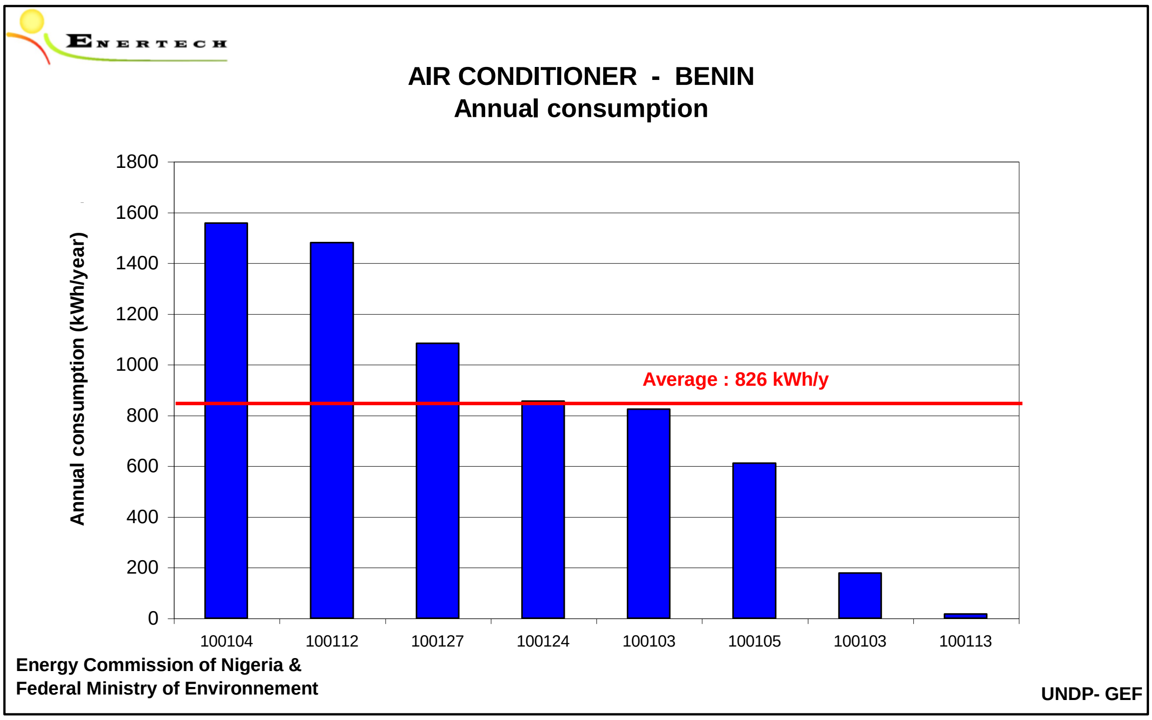


Figure 4.13 : AC annual consumption - Benin

6.5.3.2 Functioning rates

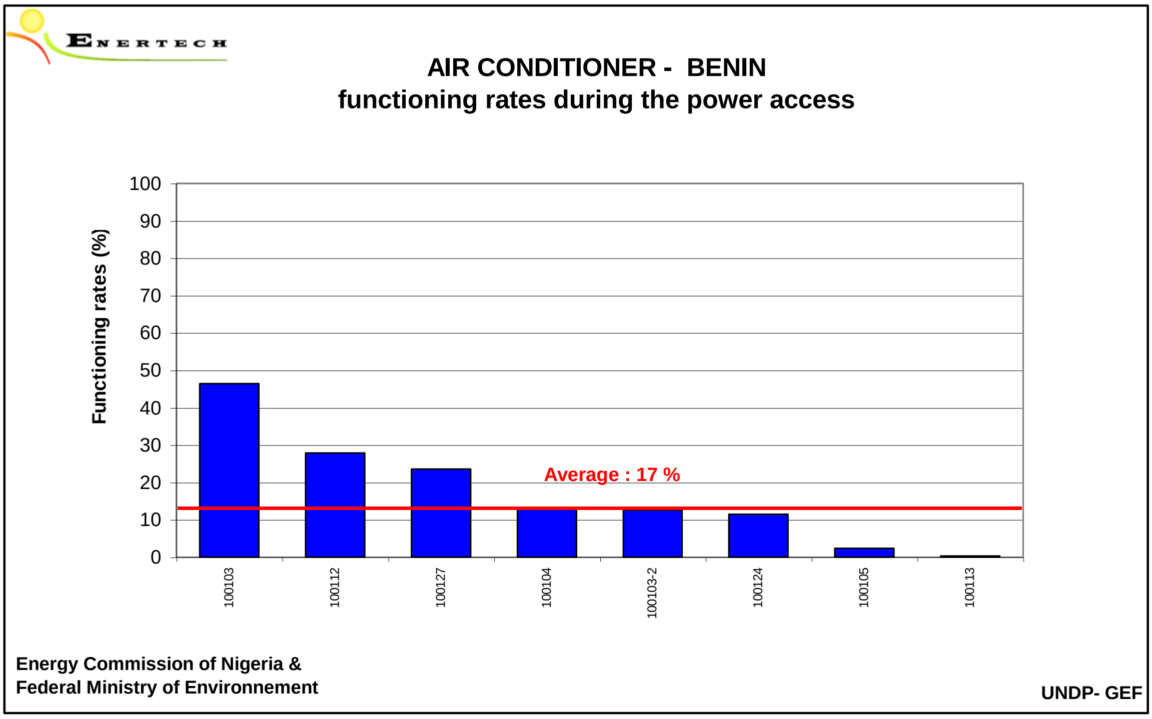


Figure 4.14 : AC functioning rates during power access - Benin

6.5.3.3 Annual consumption versus power grid

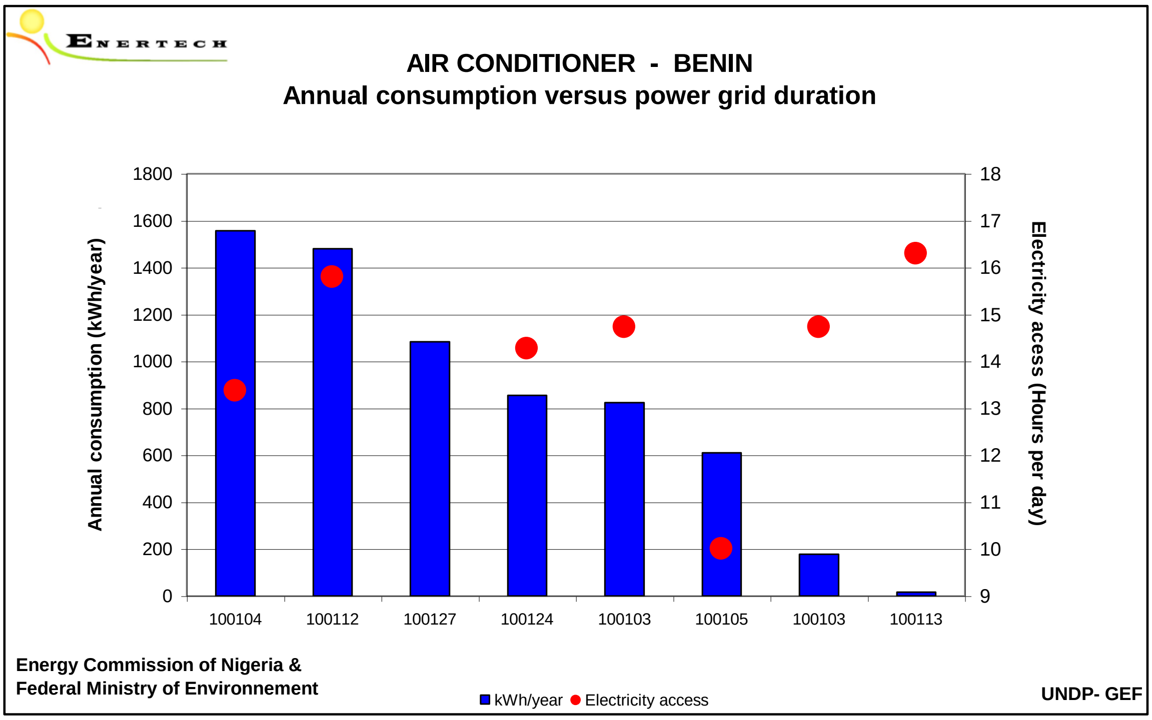


Figure 4.15 : AC annual consumption vs power grid - Benin

6.5.4 Cold appliances

6.5.4.1 Average possession of appliances

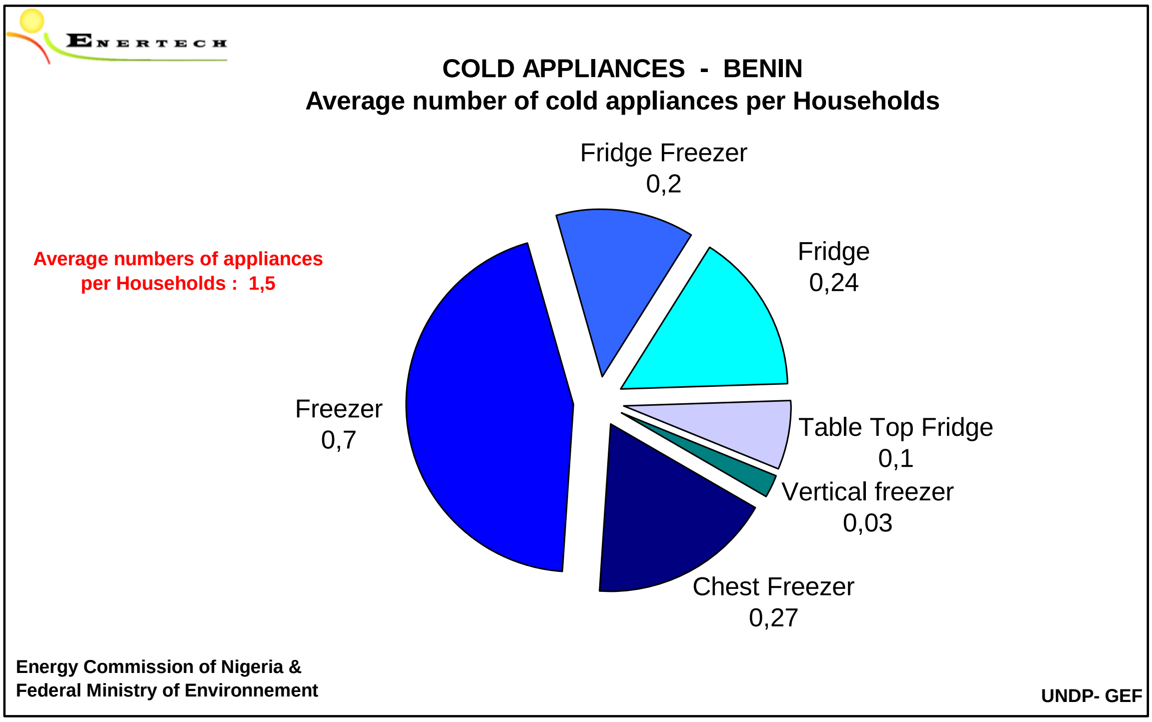


Figure 4.16 : Average possession of cold appliances - Benin

6.5.4.2 Annualized consumption

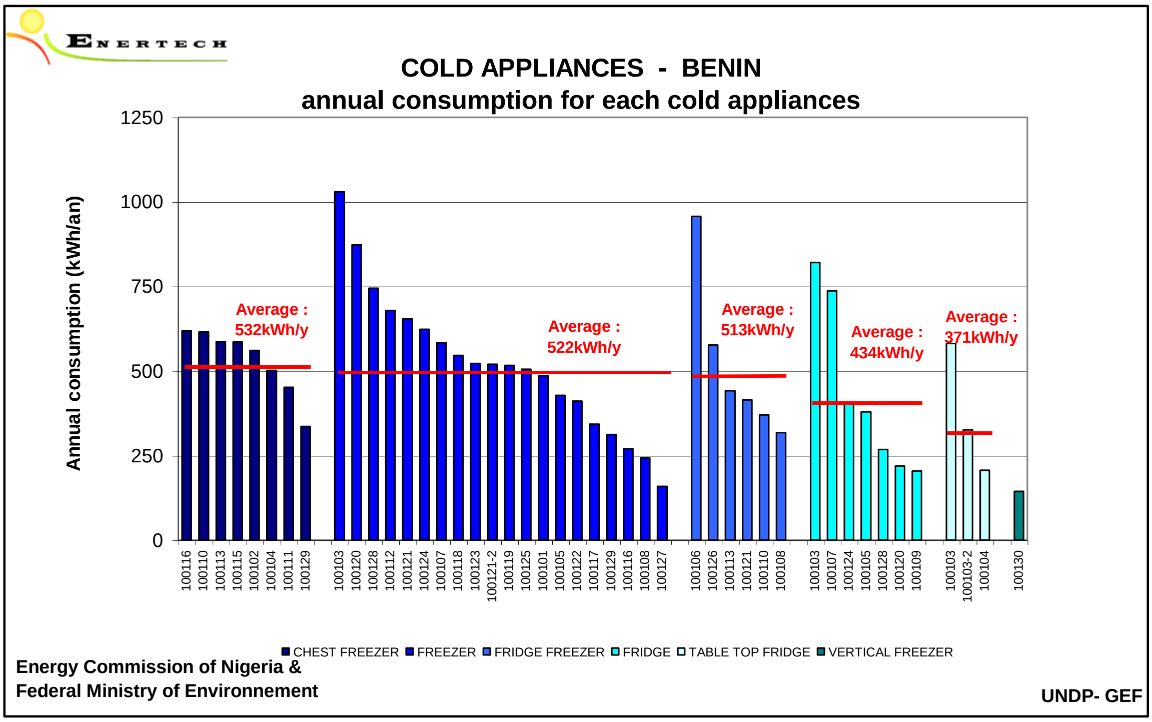


Figure 4.17 : Cold appliances annual consumption - Benin

6.5.4.3 Functioning rates

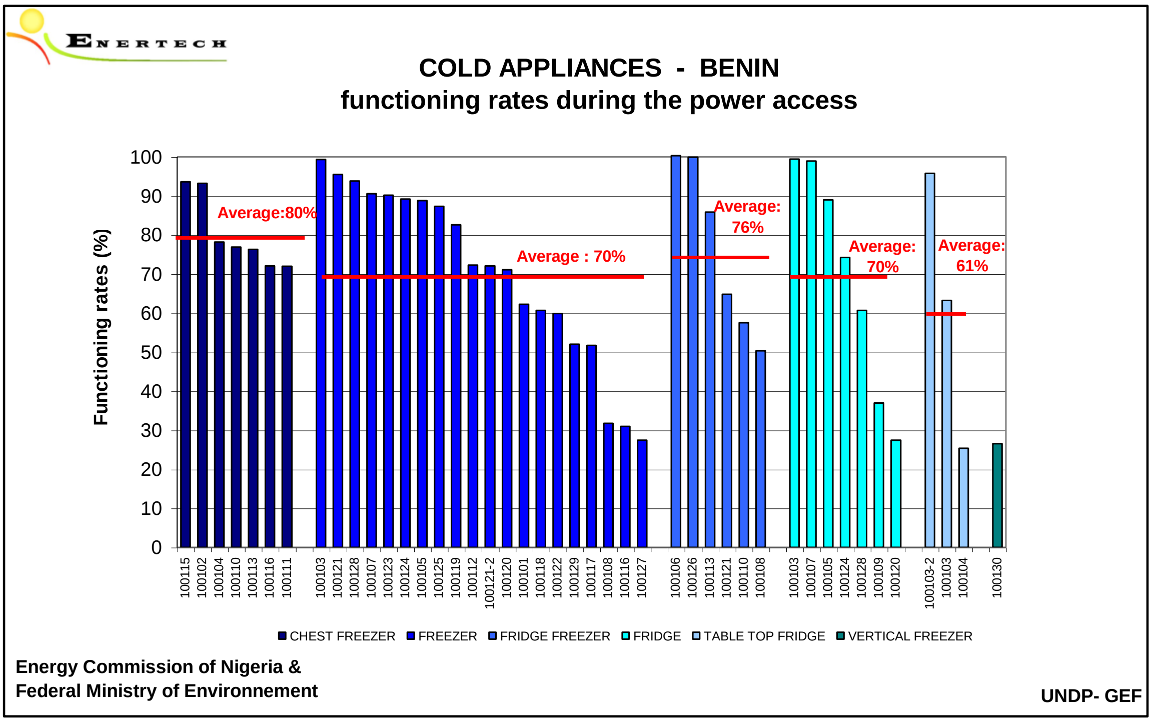


Figure 4.18 : Cold appliances functioning rates during power access - Benin

6.5.4.4 Annual consumption versus power grid

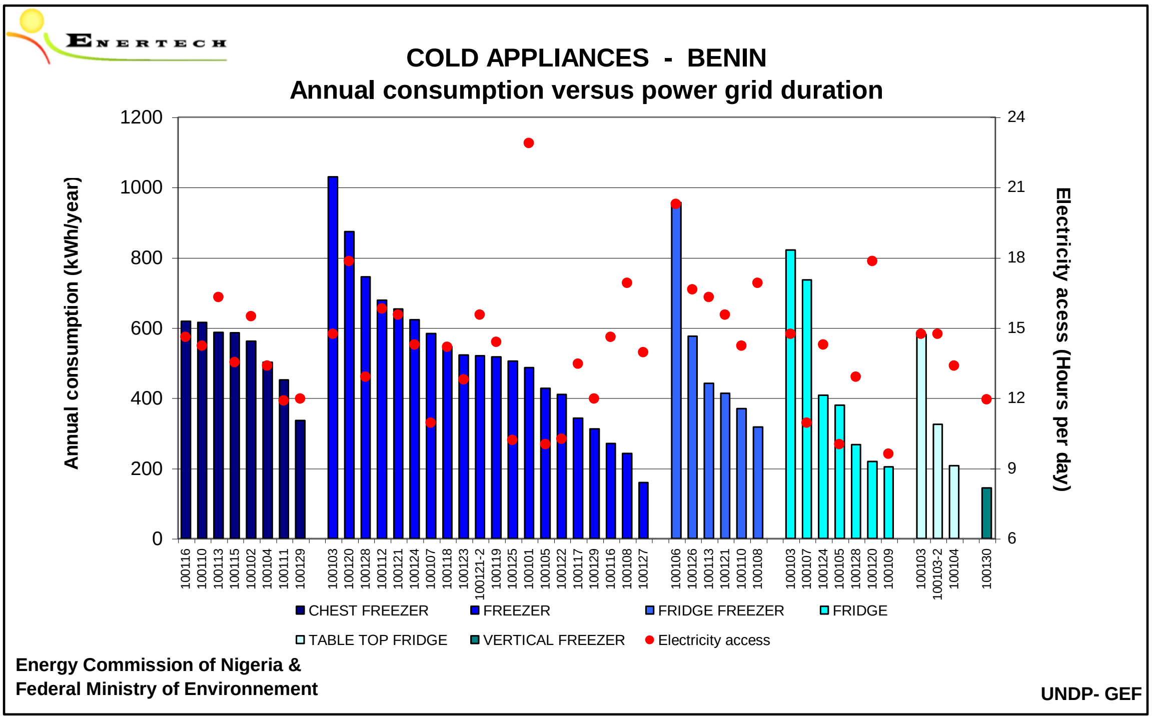


Figure 4.19 : Cold appliances annual consumption vs power grid - Benin

6.5.5 Lighting

6.5.5.1 Installed wattage per bulbs

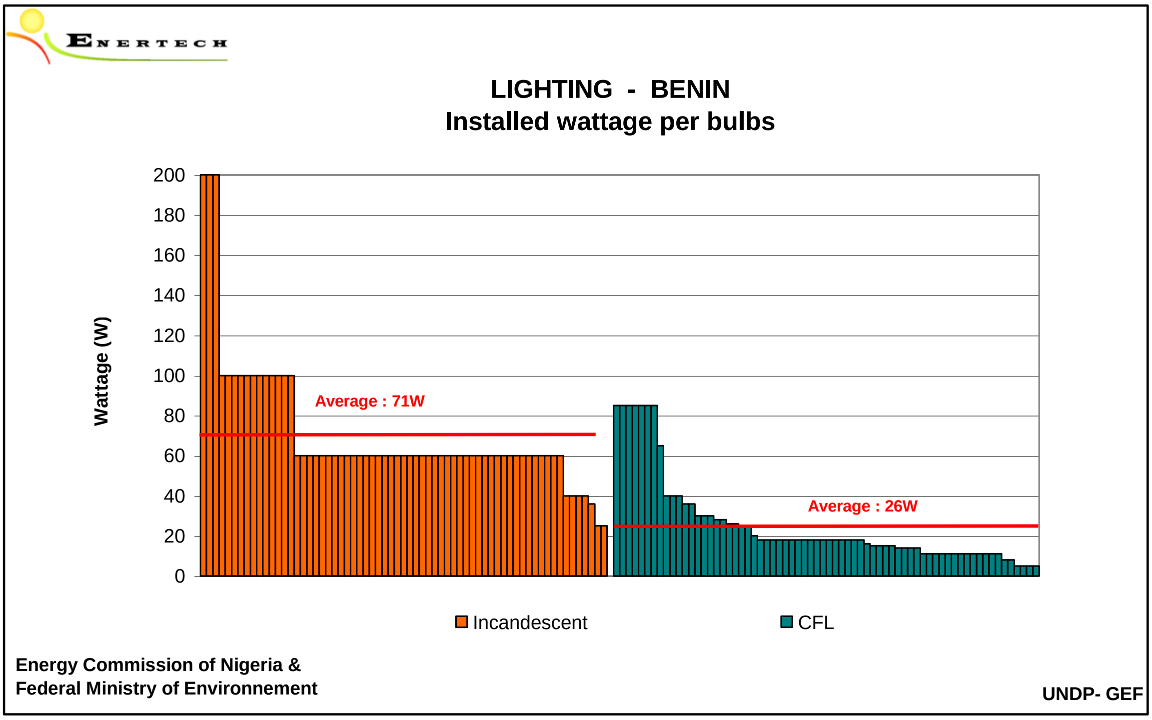


Figure 4.20 : Installed wattage per bulbs - Benin

6.5.5.2 Part of each type of light source

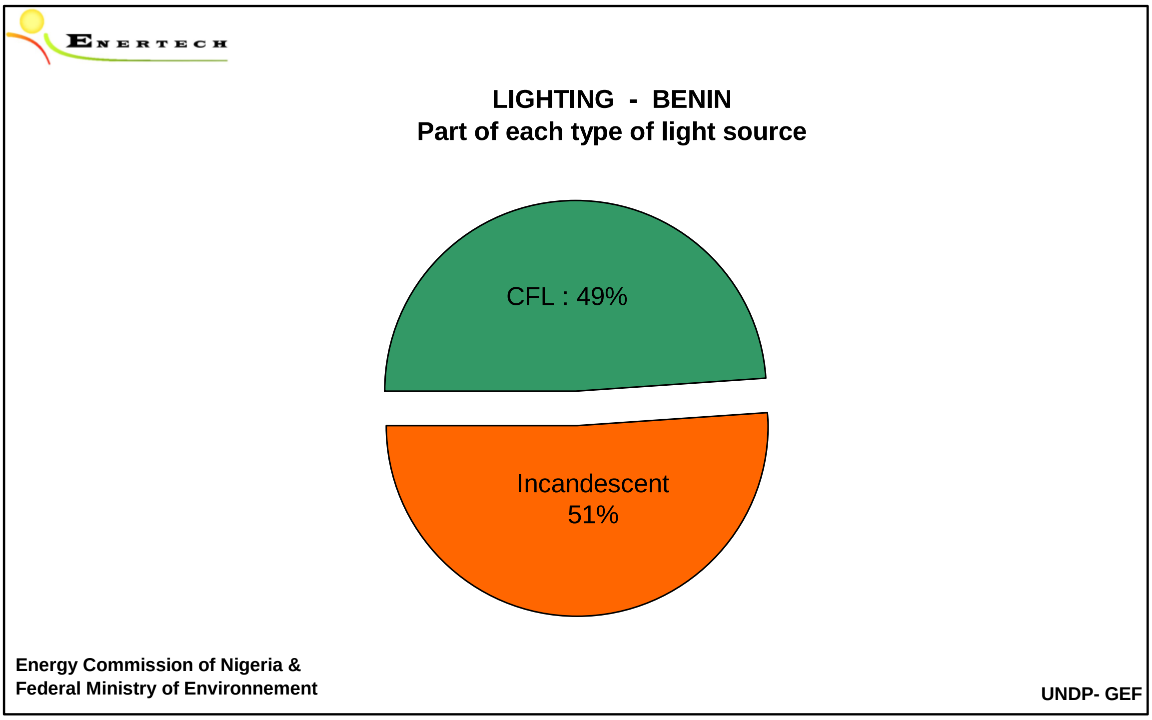


Figure 4.21 : Part of each type of light source - Benin

6.5.5.3 Annualized consumption per Households

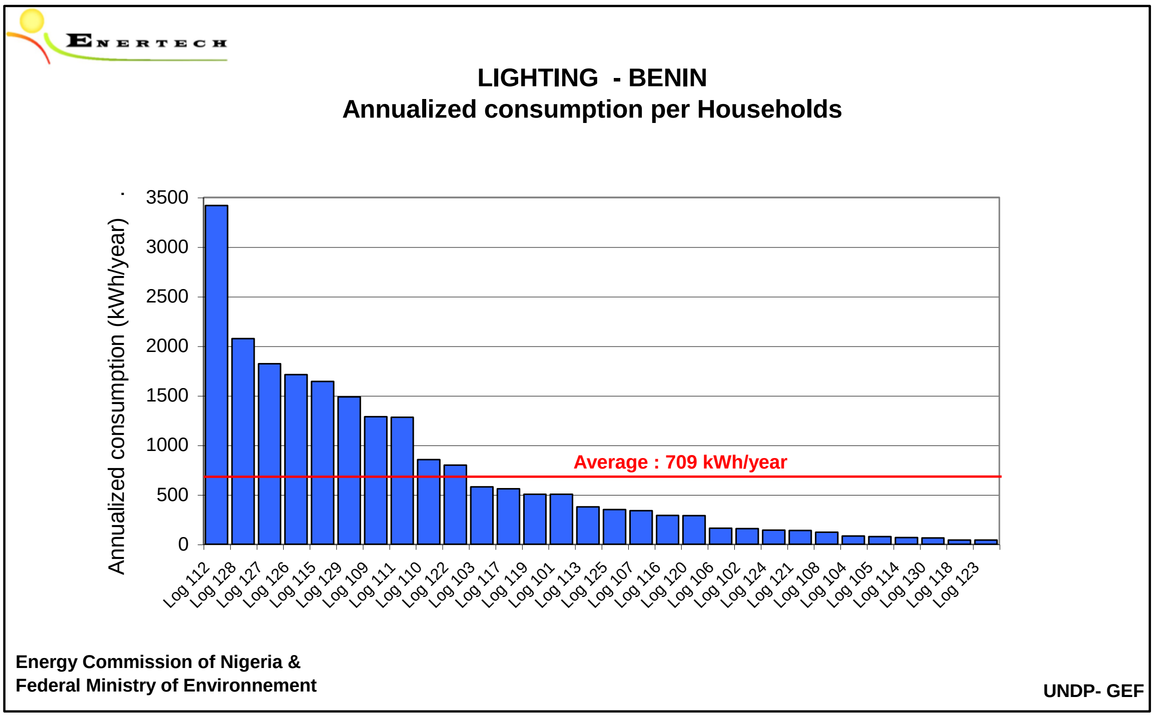


Figure 4.22 : Lighting annualized consumption – Benin

6.5.5.4 Daily average load curve

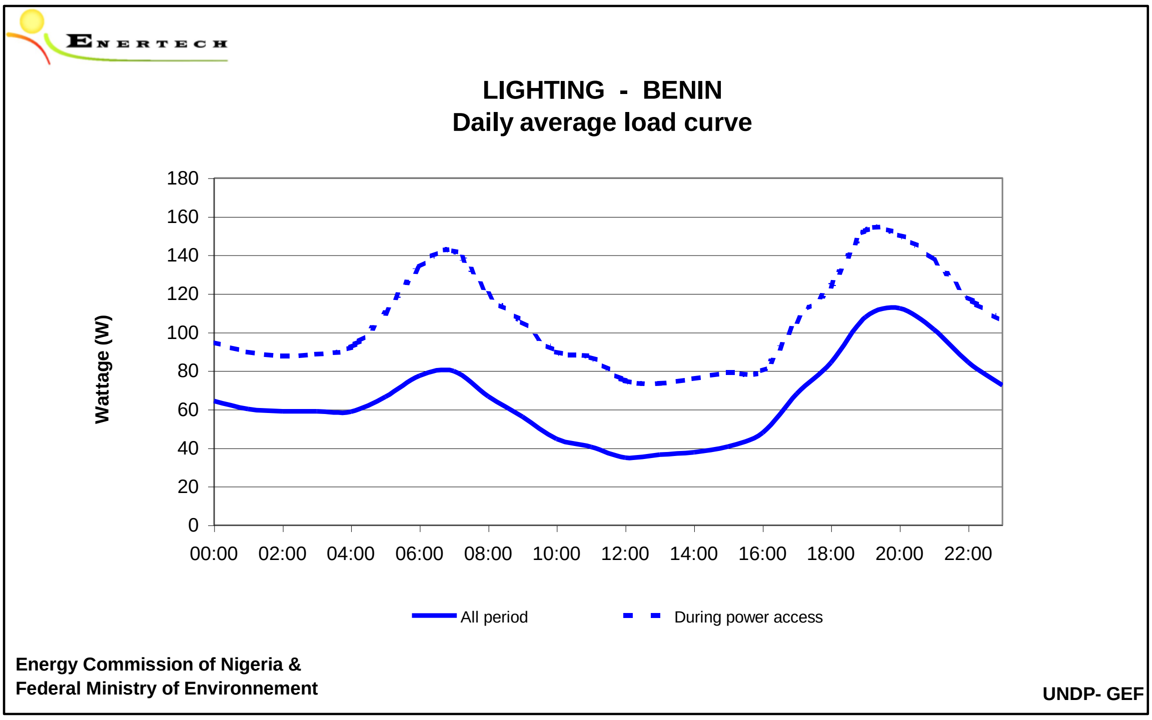


Figure 4.23 : Lighting daily average load curve - Benin

6.6 LAGOS

6.6.1 Indoor temperature

6.6.1.1 Temperature daily curve

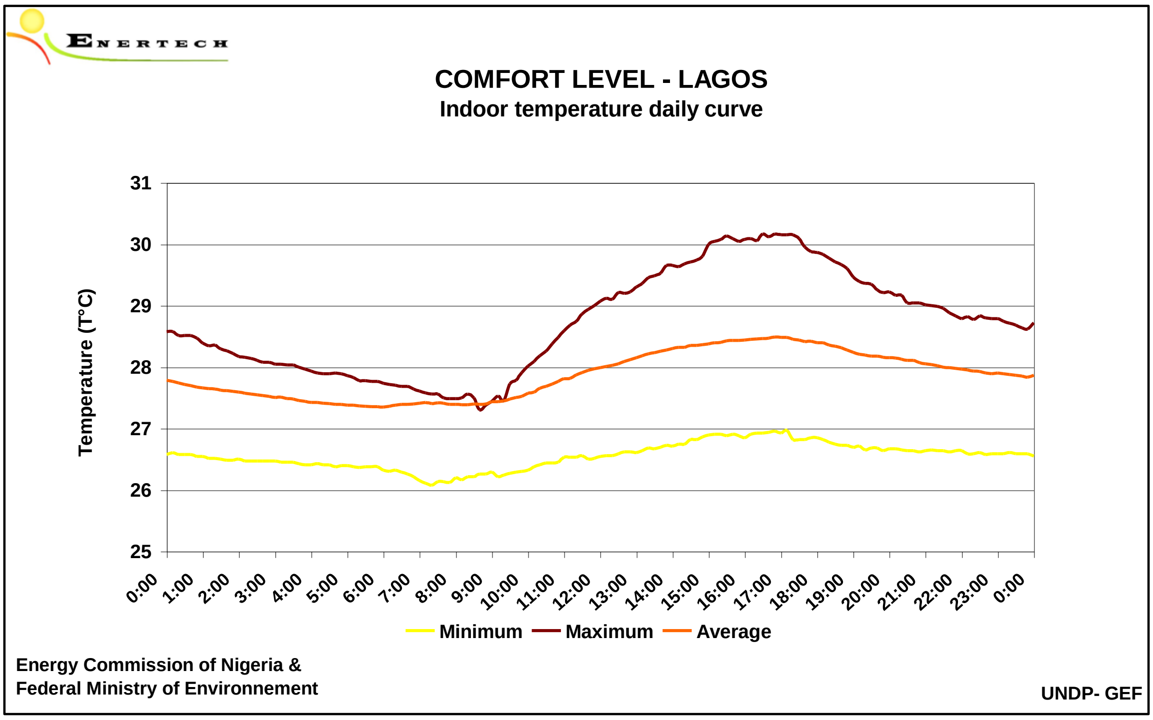


Figure 5.1 : Temperature daily curve - Lagos

6.6.1.2 Temperature cumulative frequency

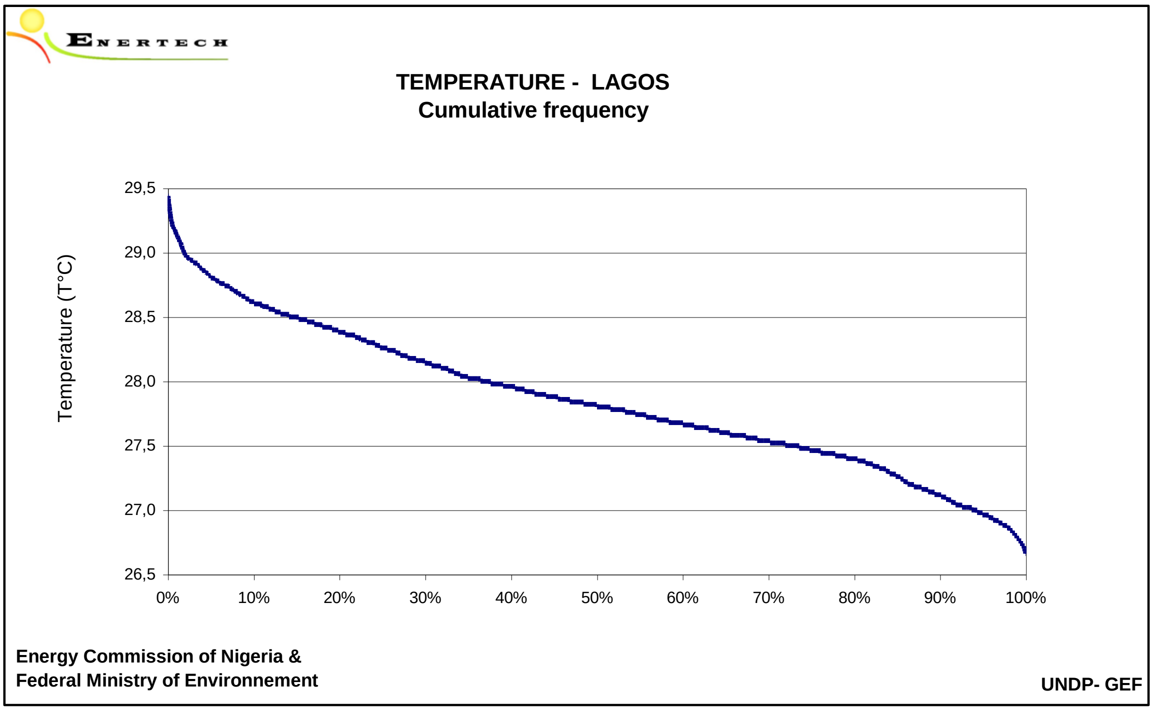


figure 5.2 : Temperature cumulative frequency - Lagos

6.6.2 Power Grid

6.6.2.1 Distribution of power access and power outages

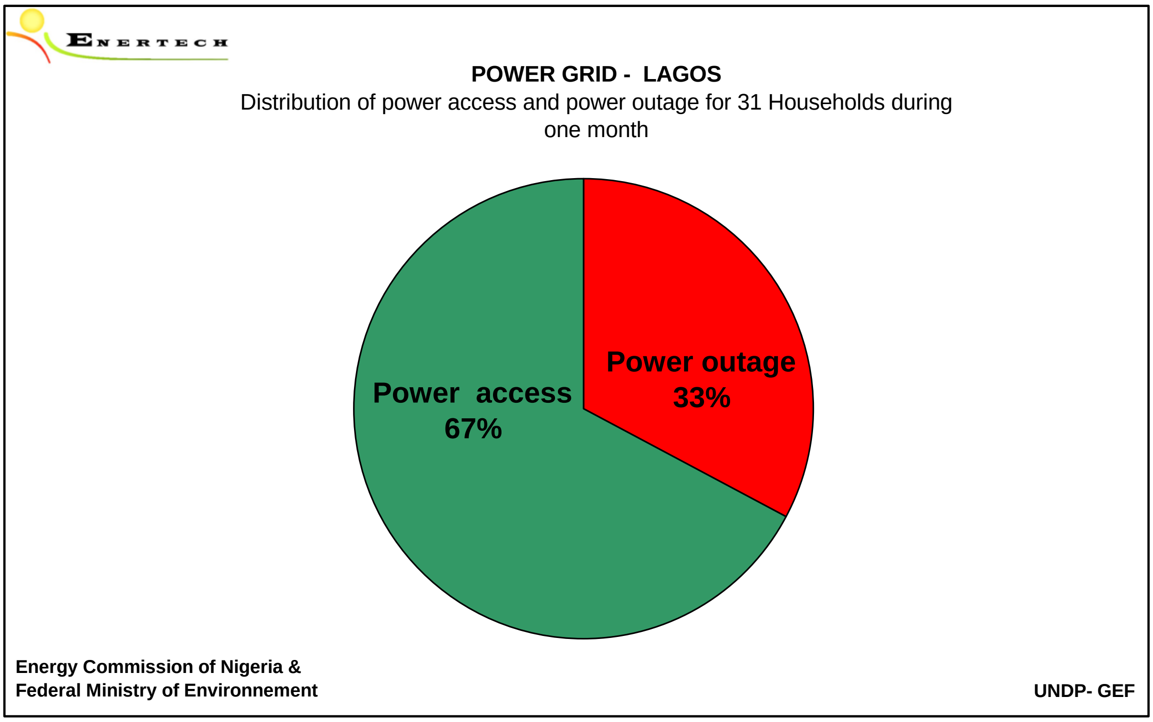


Figure 5.3 : Distribution of power access and power outages - Lagos

6.6.2.2 Average voltage during power access

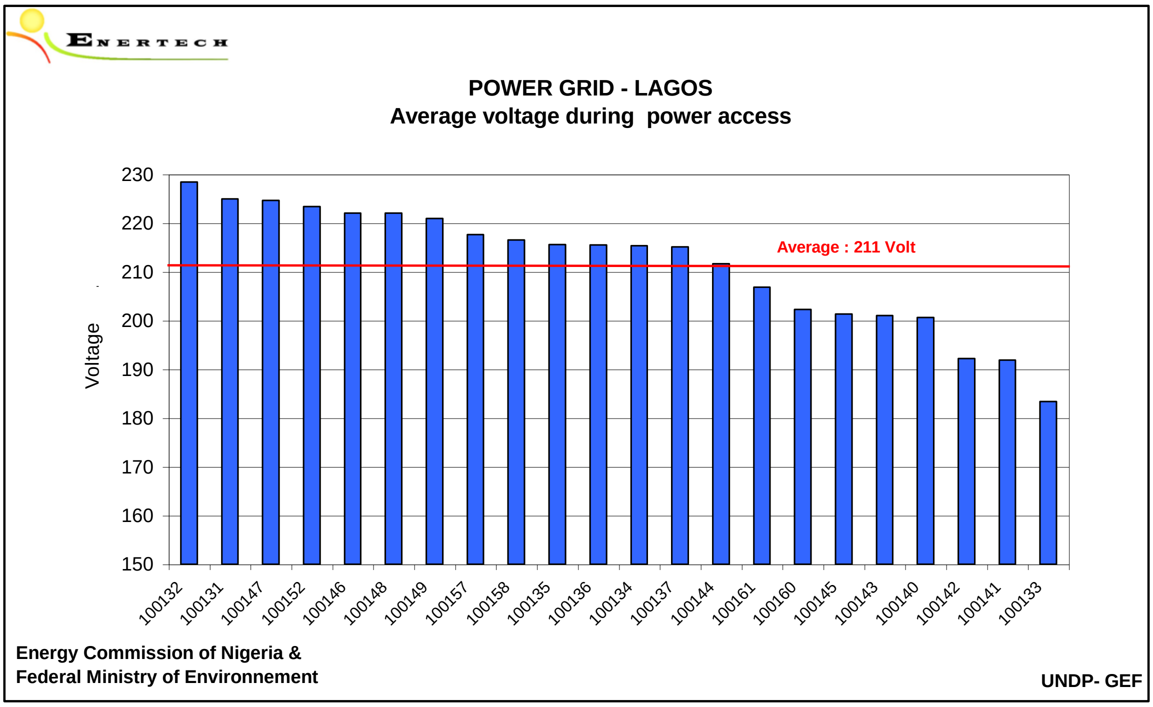


Figure 5.4 : Average voltage during power access - Lagos

6.6.2.3 Part of power access daily curve

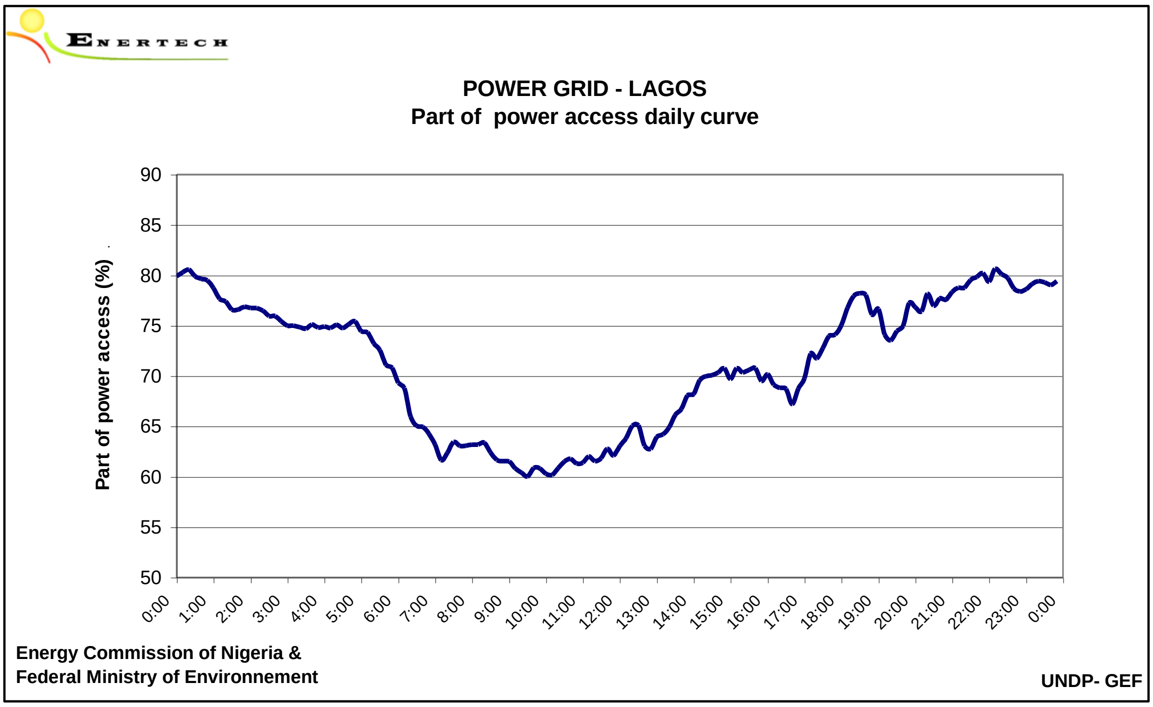


Figure 5.5 : Part of power access daily curve - Lagos

6.6.2.4 Numbers of hours per day of electricity access

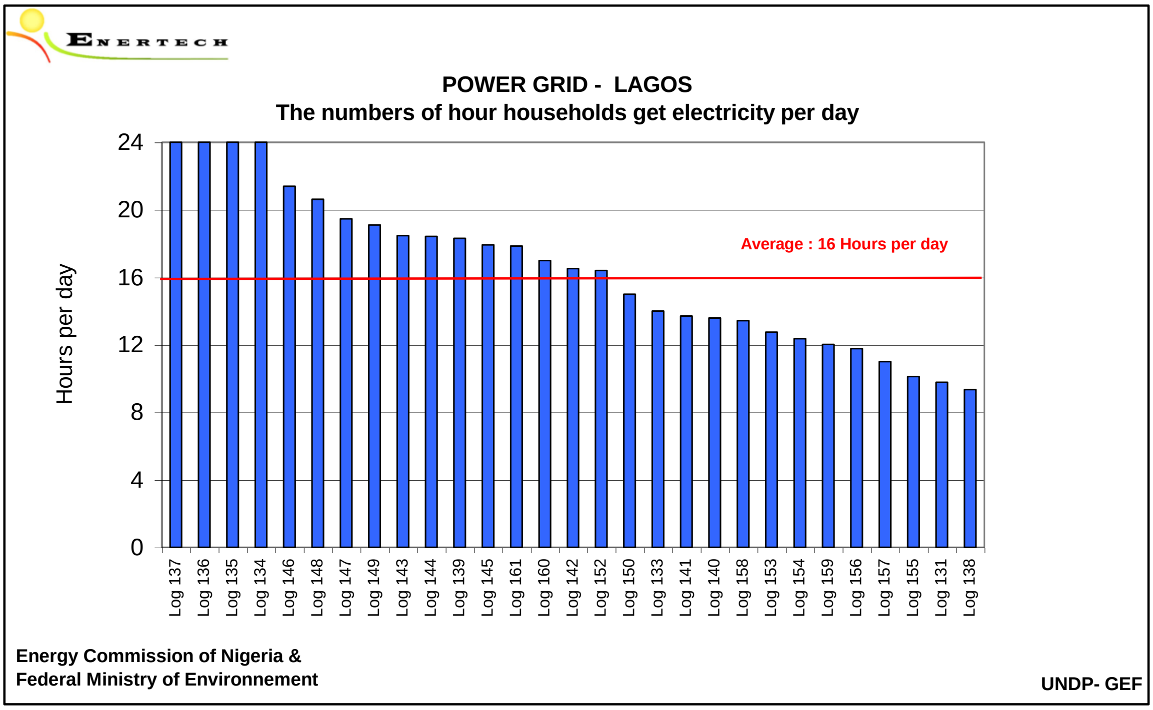


Figure 5.6 : Numbers of hours per day of electricity access - Lagos

6.6.2.5 Duration of power outages

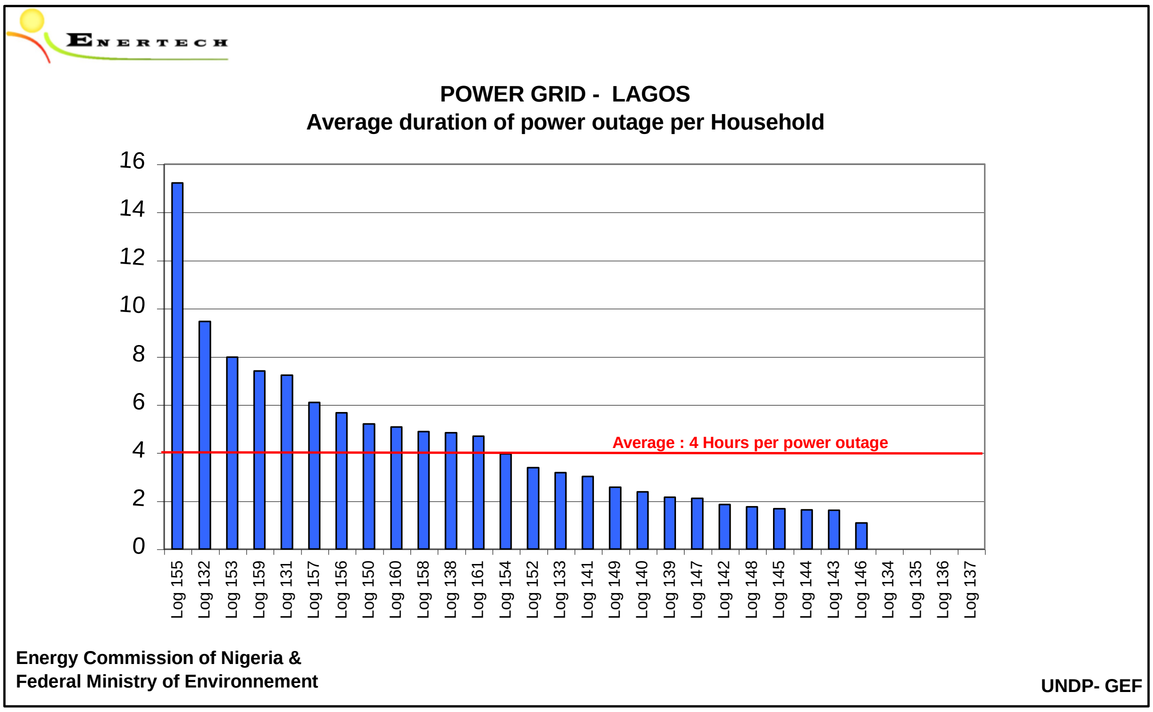


Figure 5.7 : Average duration of power outages - Lagos

6.6.2.6 Duration of electricity access

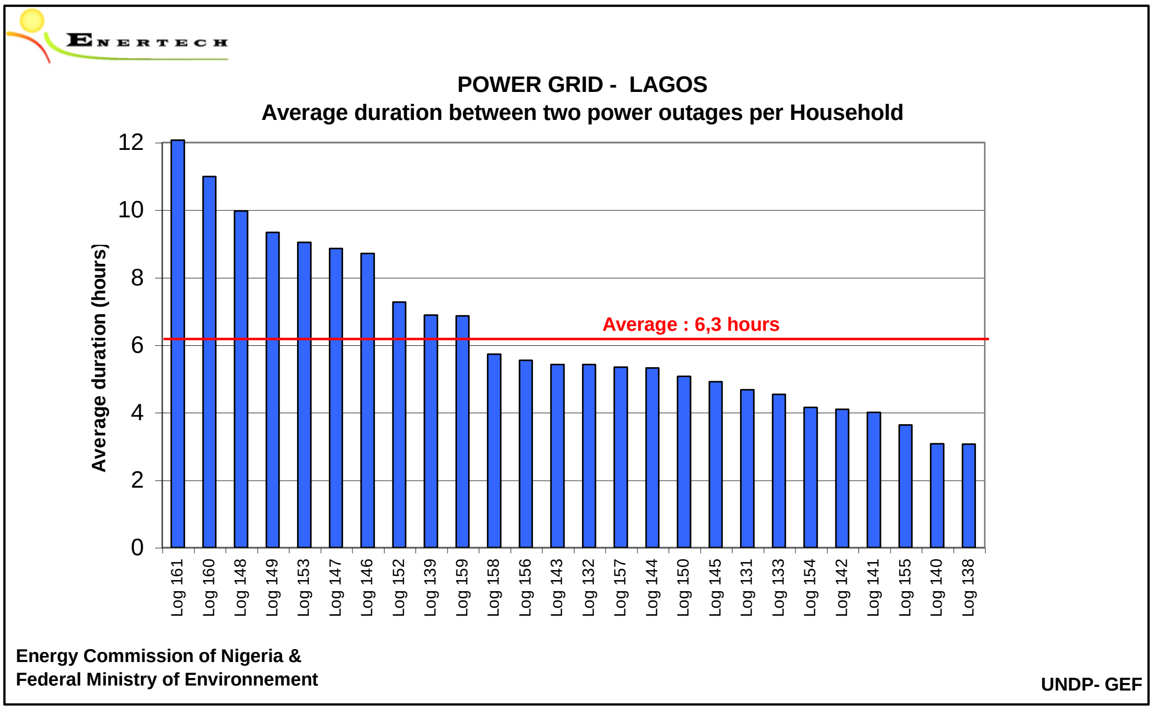


Figure 5.8 : Average duration of electricity access - Lagos

6.6.2.7 Annualized consumption

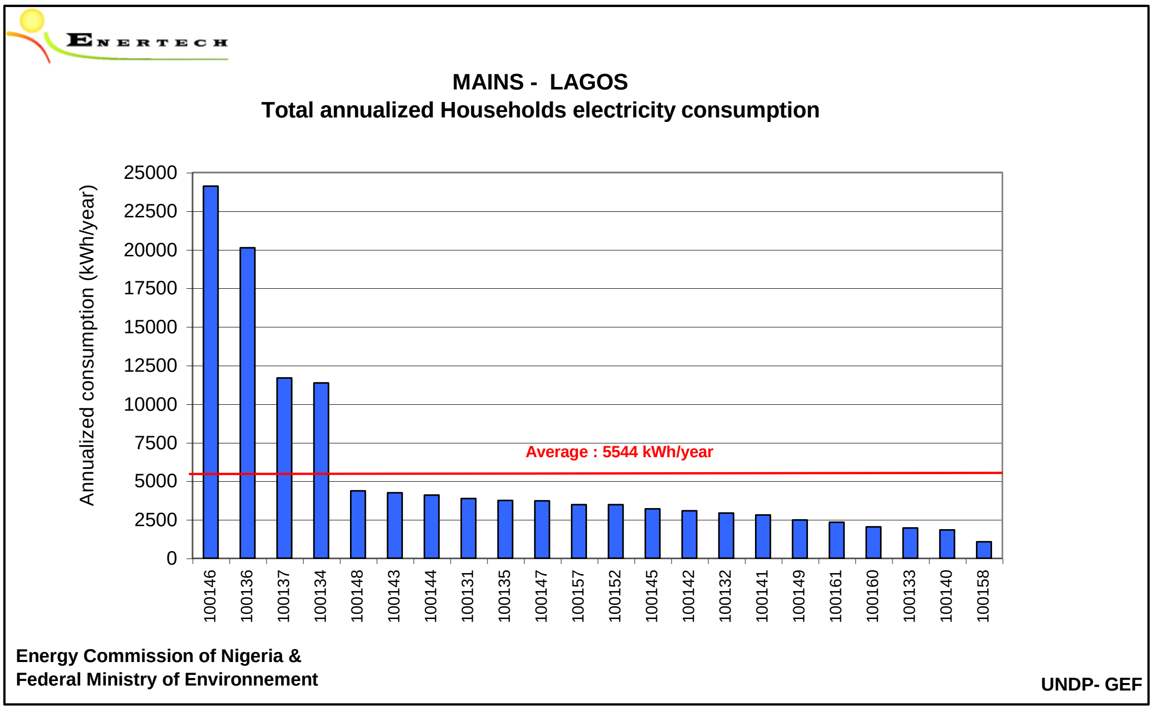


Figure 5.9 : Annualized households electricity consumption - Lagos

6.6.2.8 Daily average load curve

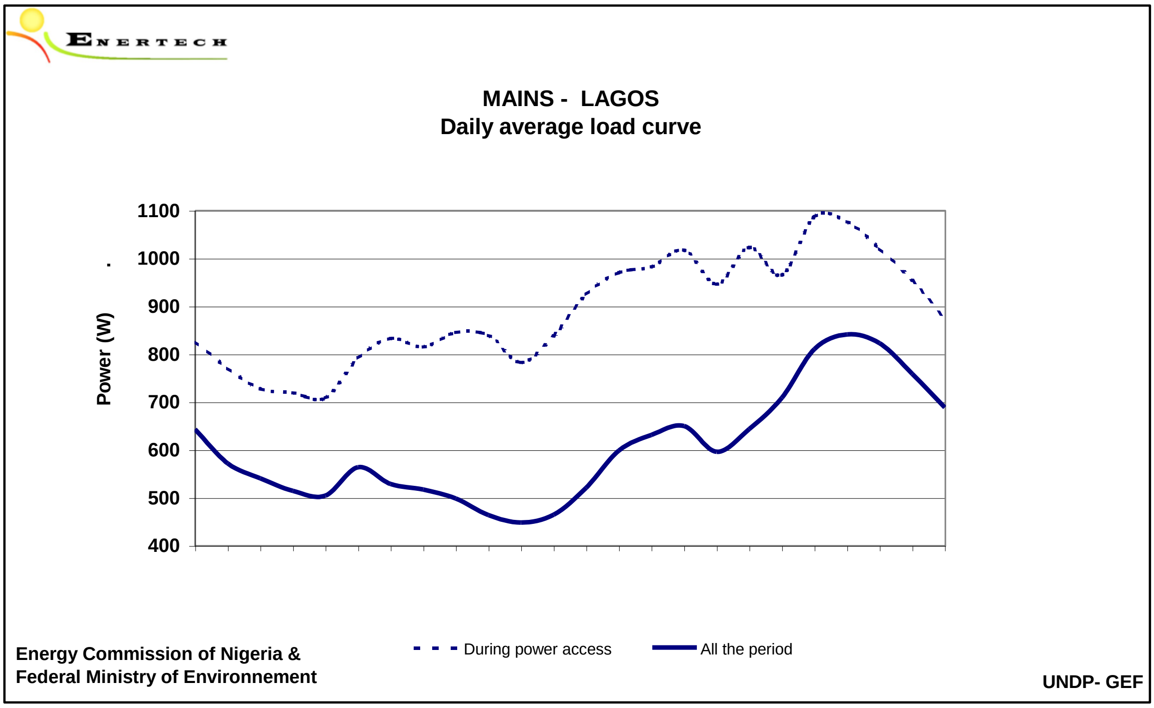


Figure 5.10 : Daily average load curve - Lagos

6.6.2.9 Relative contribution from the different loads

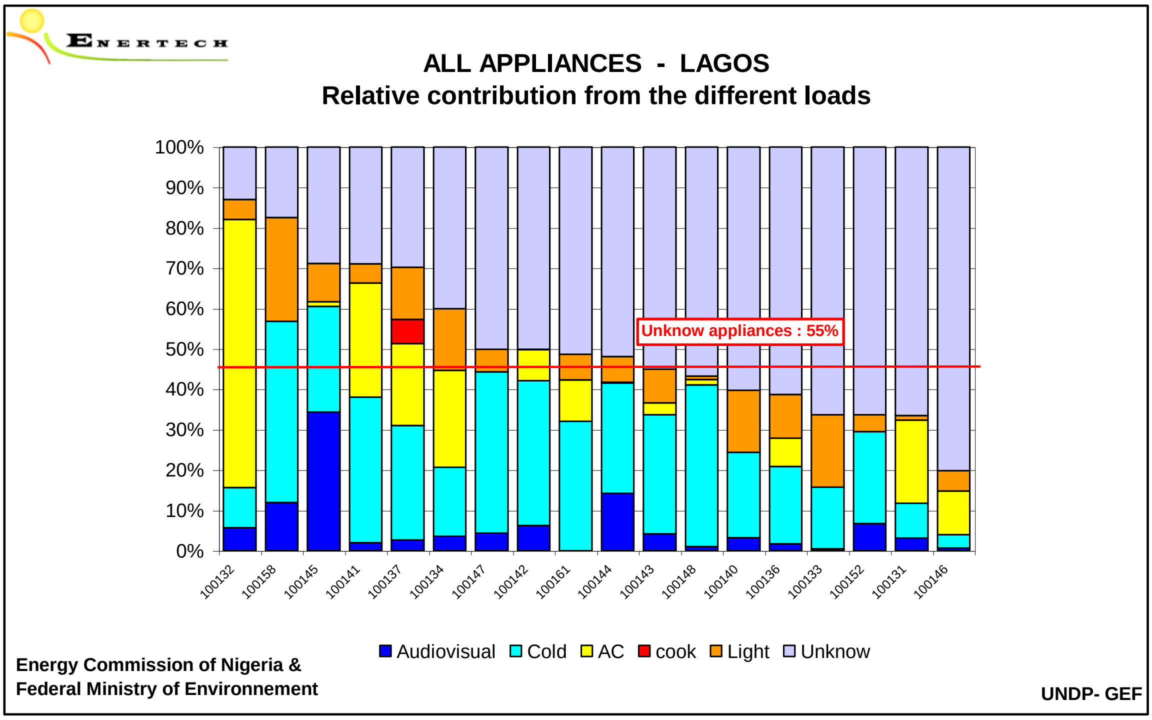


Figure 5.11 : Relative contribution from the different loads per Households - Lagos

6.6.2.10 Relative contribution from the different loads

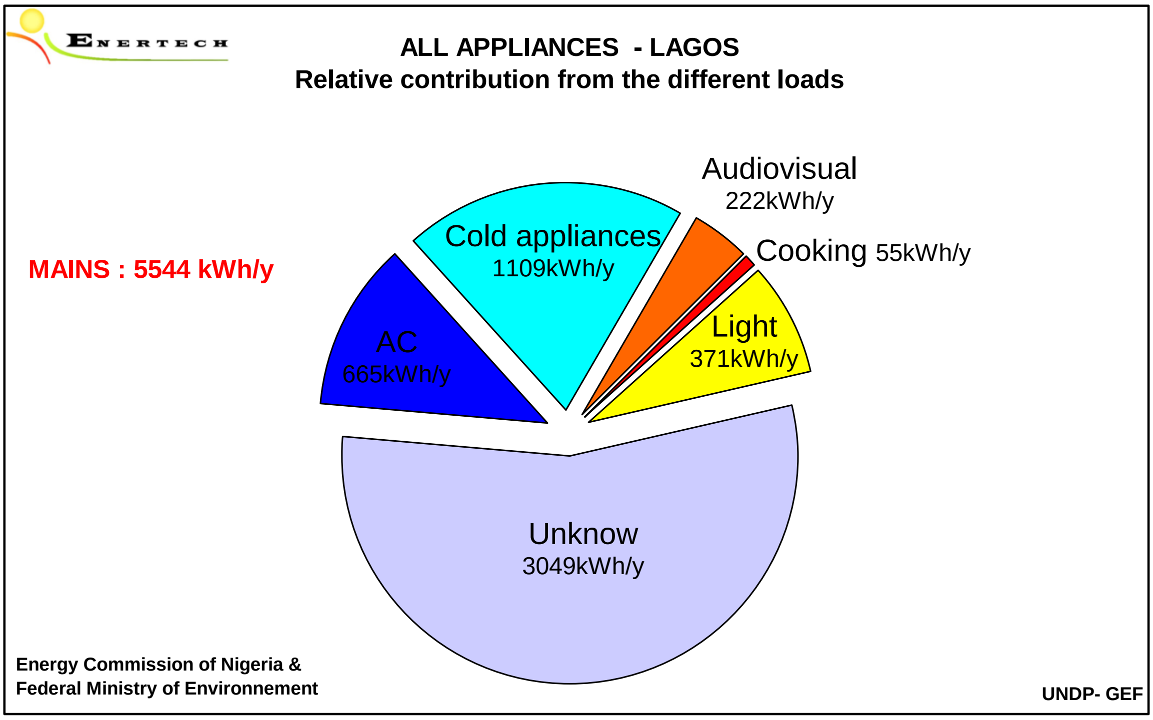


Figure 5.12 : Relative contribution from the different loads - Lagos

6.6.3 Air conditioner

6.6.3.1 Annualized consumption

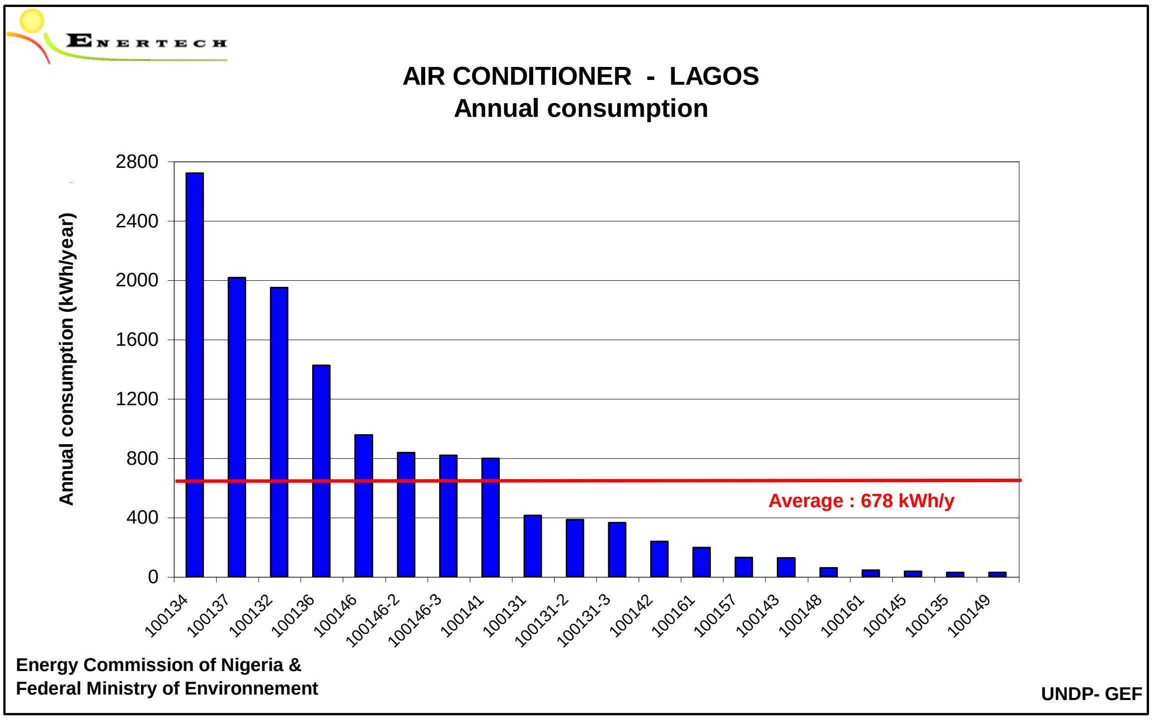


Figure 5.13 : AC annualized consumption - Lagos

6.6.3.2 Functioning rates

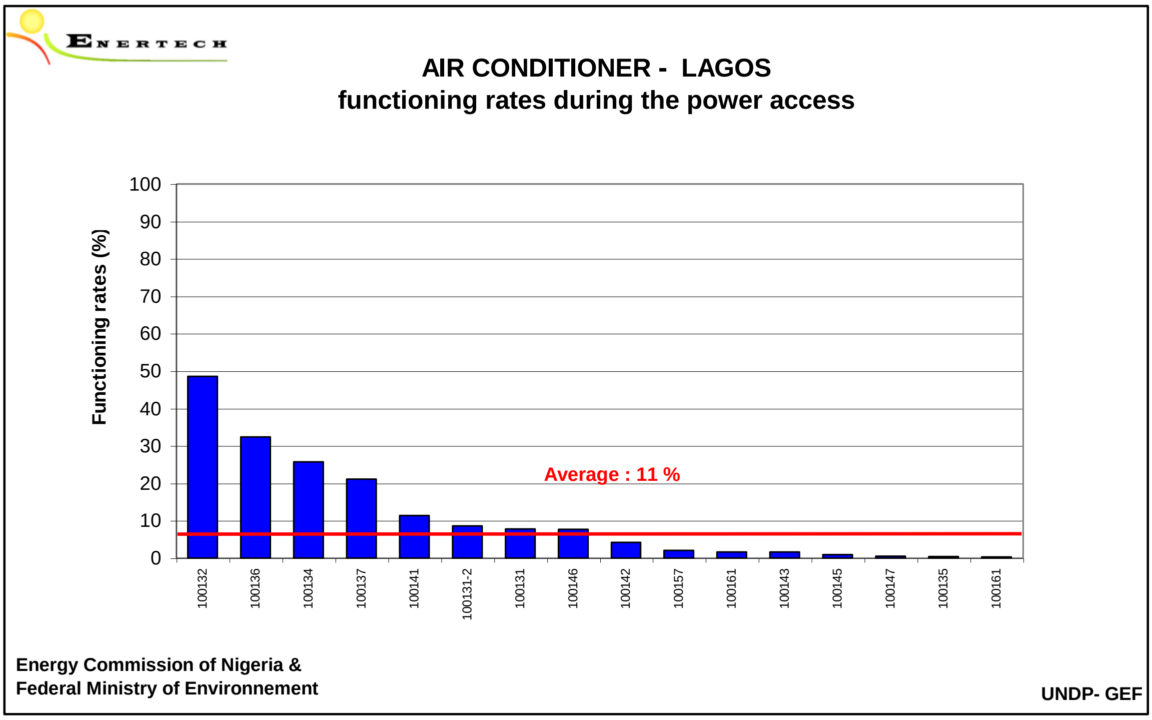


Figure 5.14 : AC functioning rates during power access - Lagos

6.6.3.3 Annual consumption versus power grid

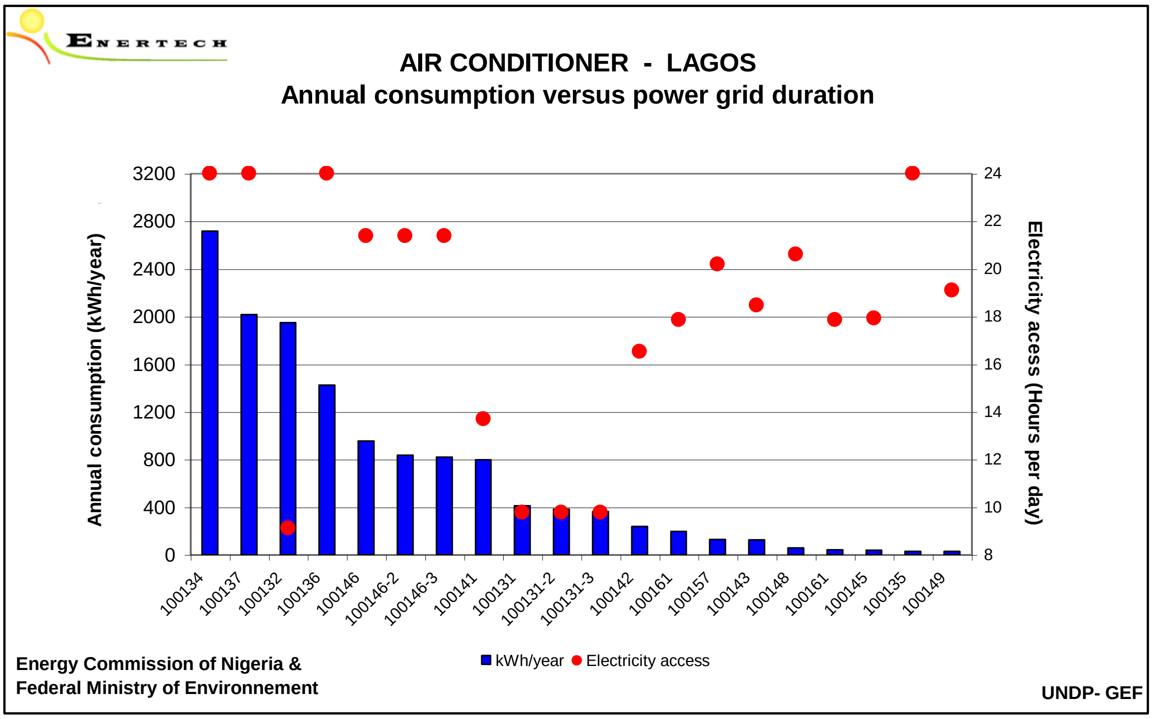


Figure 5.15 : AC annual consumption vs power grid - Lagos

6.6.4 Cold appliances

6.6.4.1 Average possession of appliances

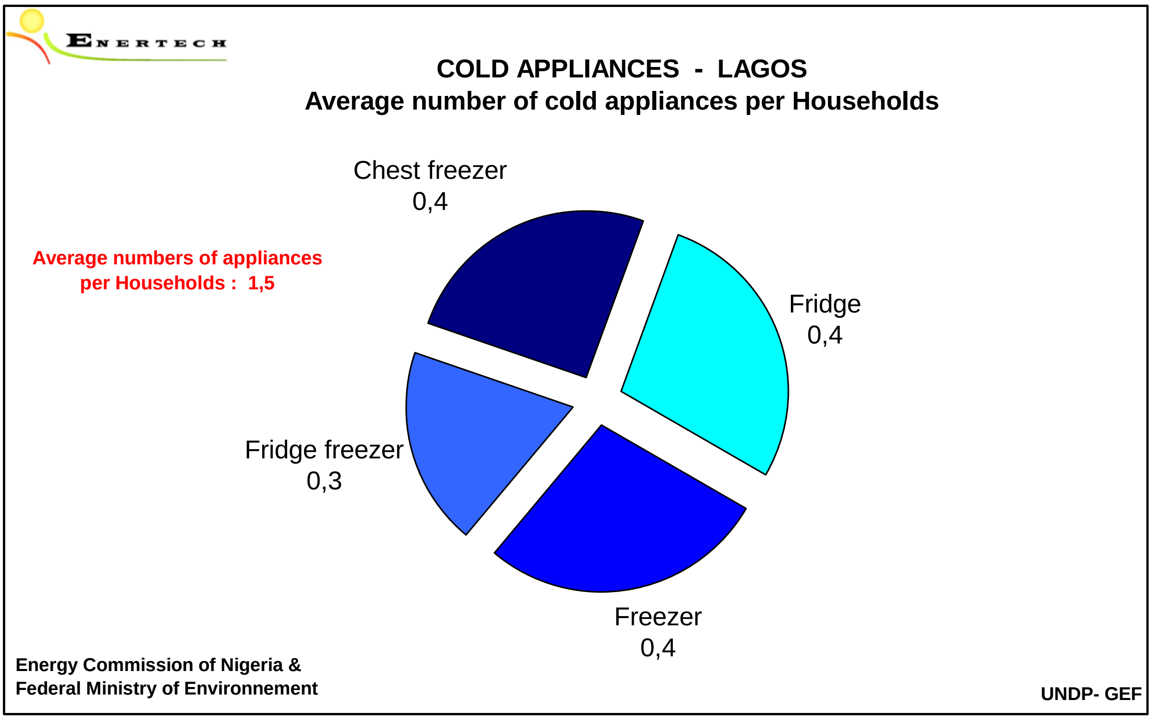


Figure 5.16 : Average possession of cold appliances - Lagos

6.6.4.2 Annualized consumption

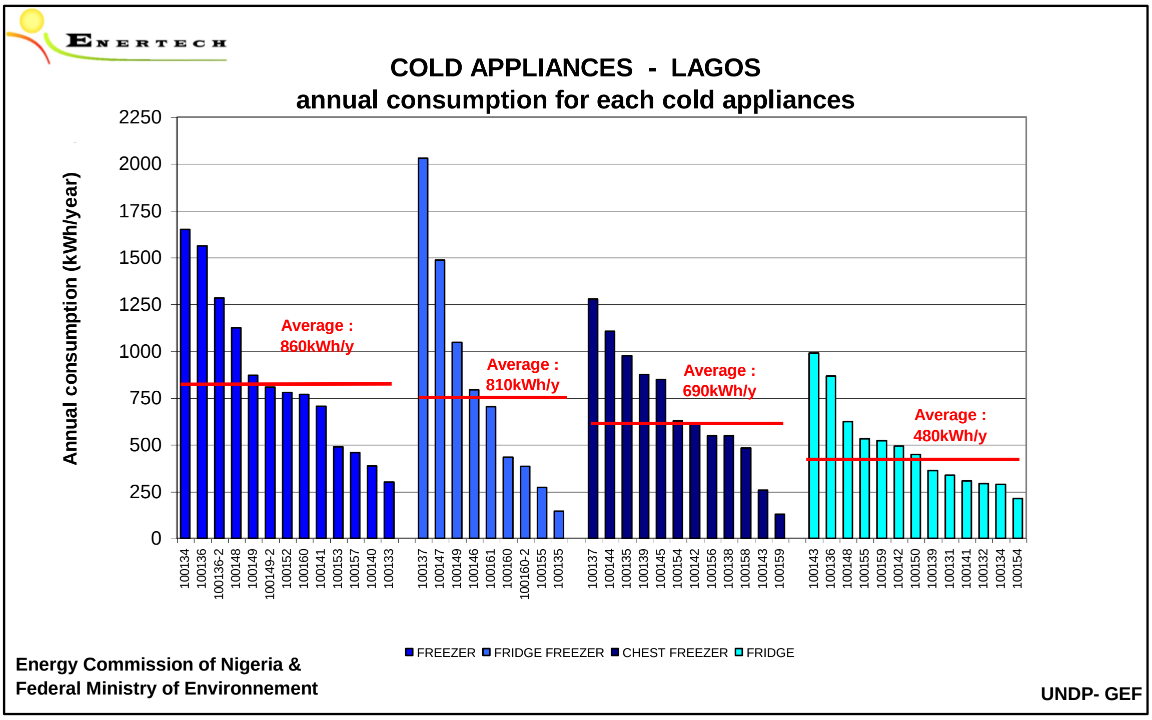


Figure 5.17 : Cold appliances annualized consumption - Lagos

6.6.4.3 Functioning rates

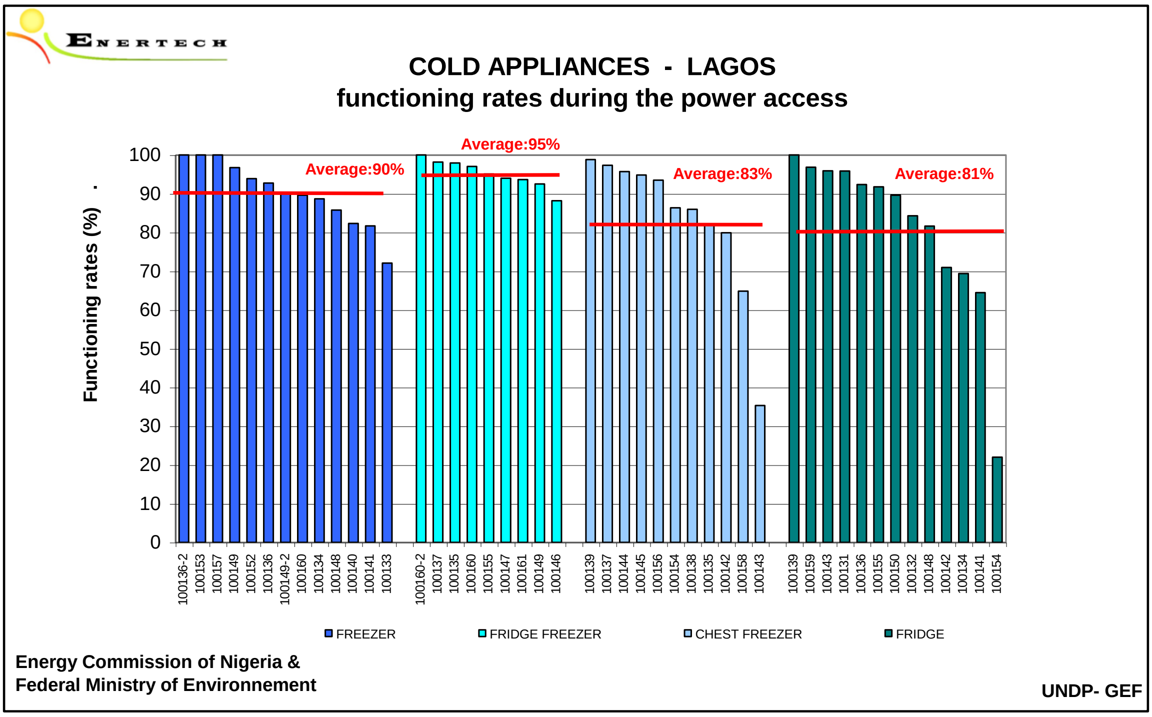


Figure 5.18 : Cold appliances functioning rates during power access - Lagos

6.6.4.4 Annual consumption versus power grid

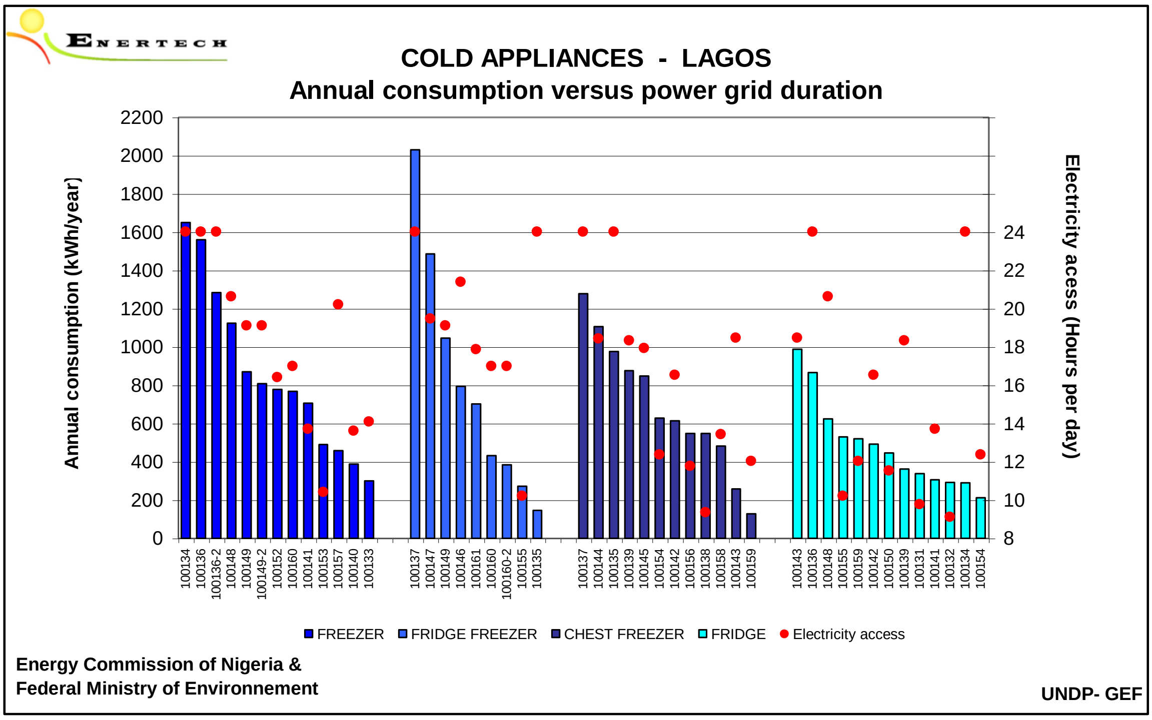


Figure 5.19 : Cold appliances annual consumption - Lagos

6.6.5 Lighting

6.6.5.1 Installed Wattage per bulbs

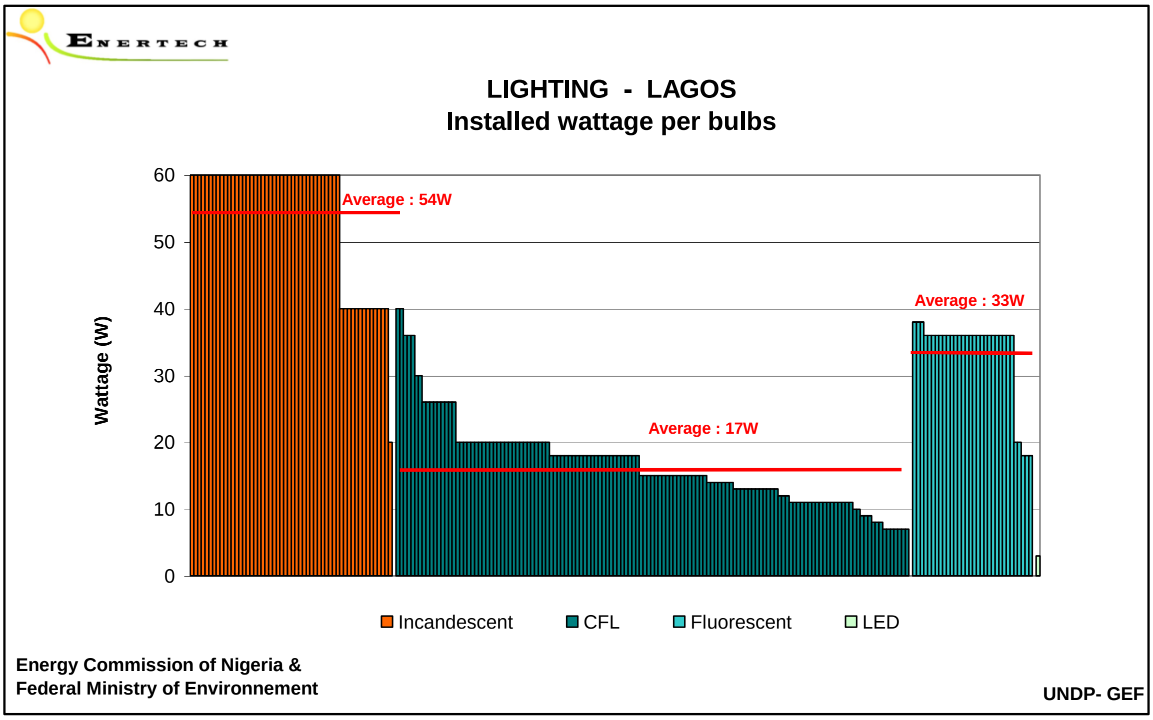


Figure 5.20 : Installed Wattage per bulbs - Lagos

6.6.5.2 Part of each type of light source

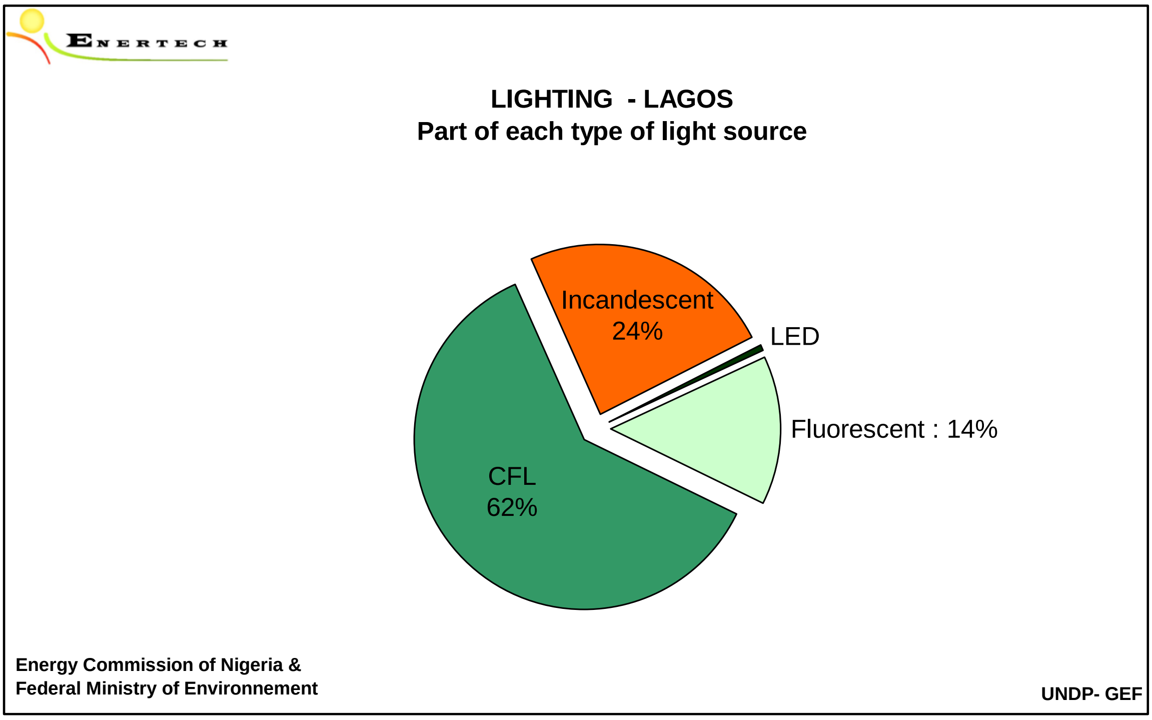


Figure 5.21 : Part of each type of light source - Lagos

6.6.5.3 Annualized consumption per Households

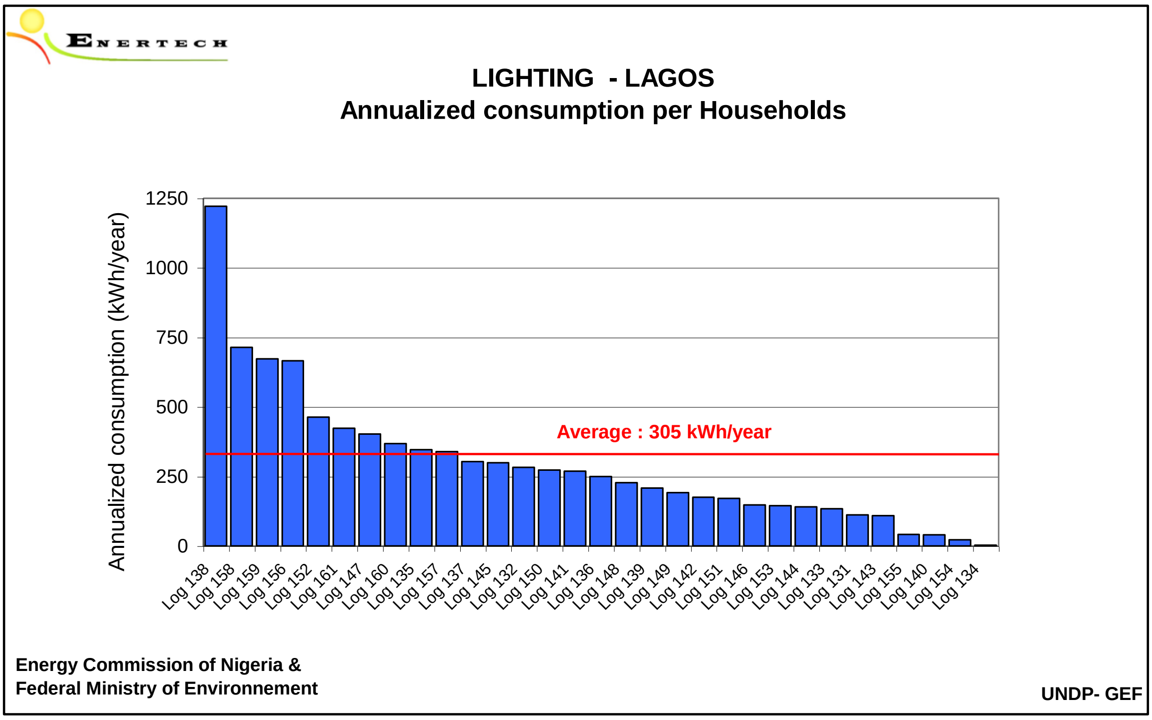


Figure 5.22 : Lighting annualized consumption - Lagos

6.6.5.4 Daily average load curve

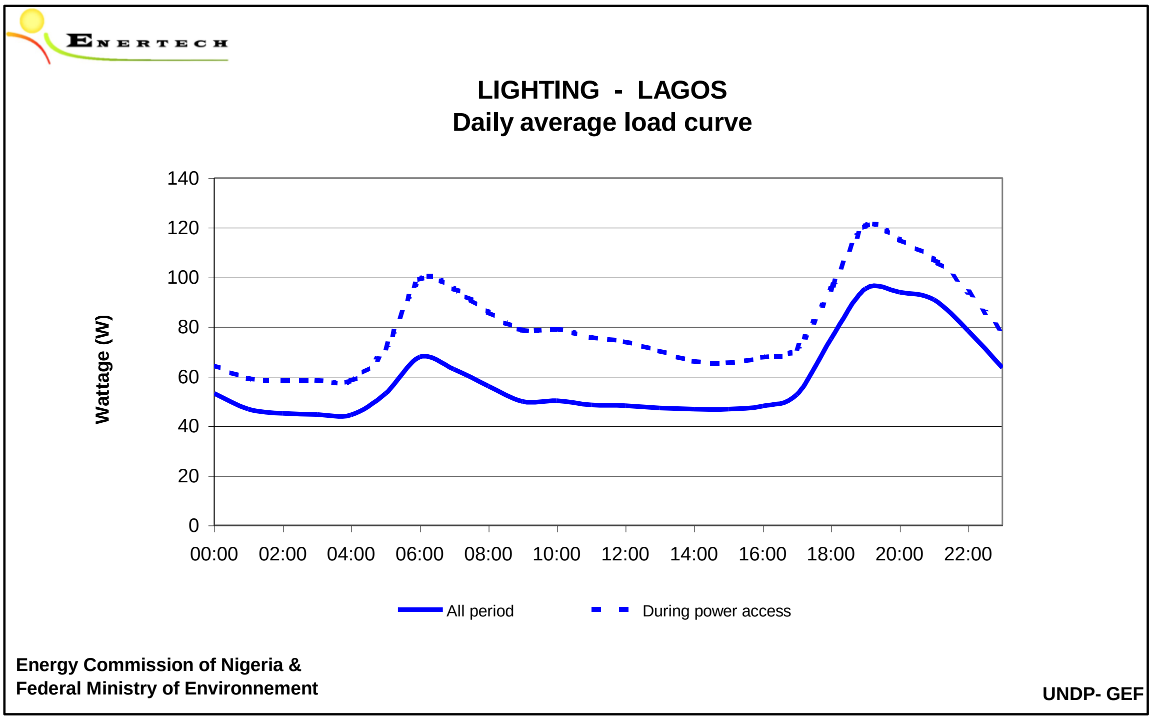


Figure 5.23 : Lighting daily average load curve - Lagos

6.7 ENUGU

6.7.1 Indoor temperature

6.7.1.1 Temperature daily curve

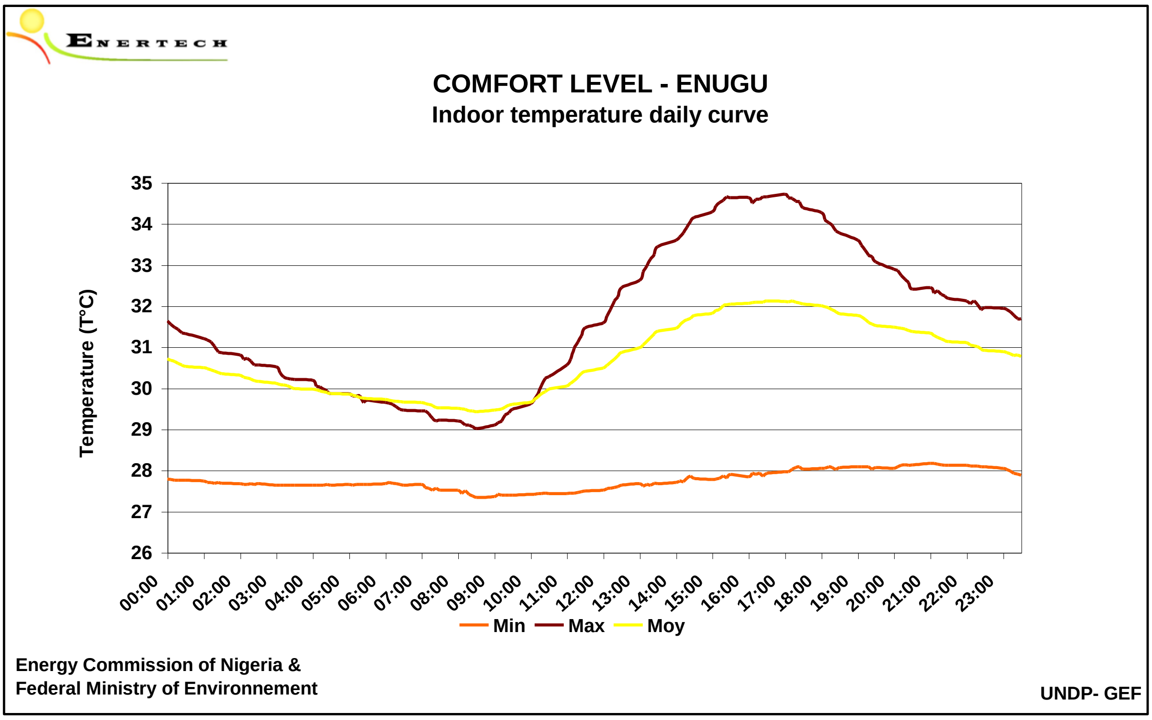


Figure 6.1 : Temperature daily curve - Enugu

6.7.1.2 Temperature cumulative frequency

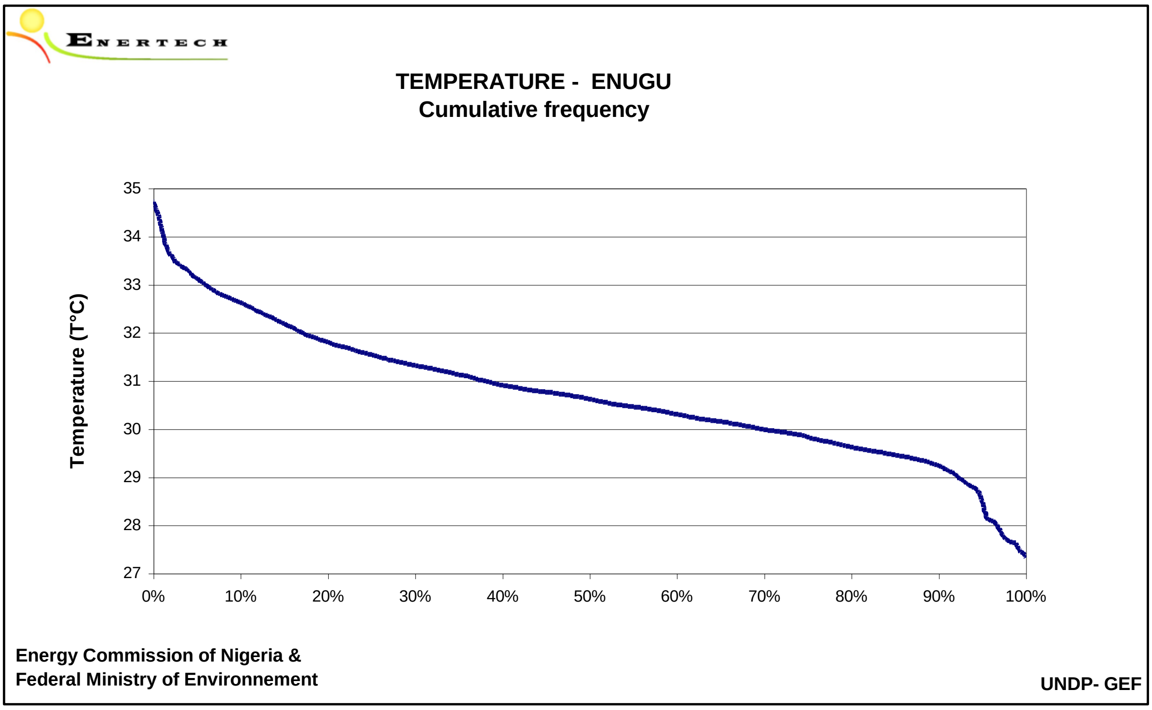


Figure 6.2 : Temperature daily curve - Enugu

6.7.2 Power Grid

6.7.2.1 Distribution of power access and power outages

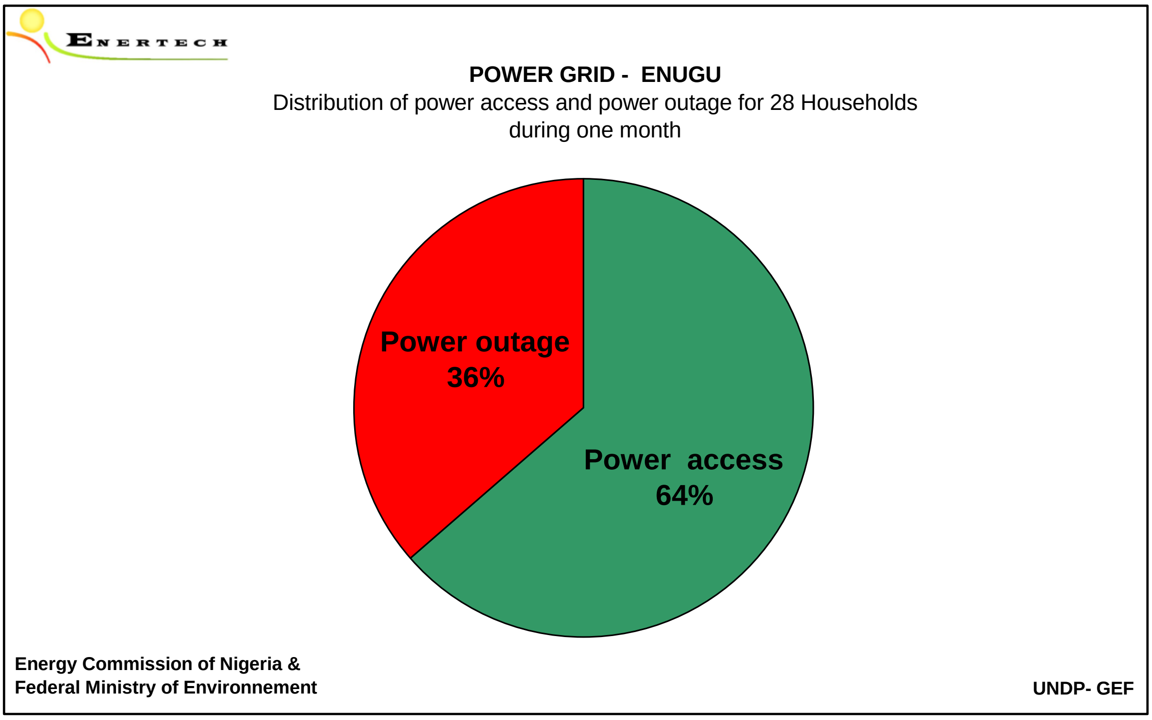


Figure 6.3 : Distribution of power grid access and power outage - Enugu

6.7.2.2 Average voltage during power access

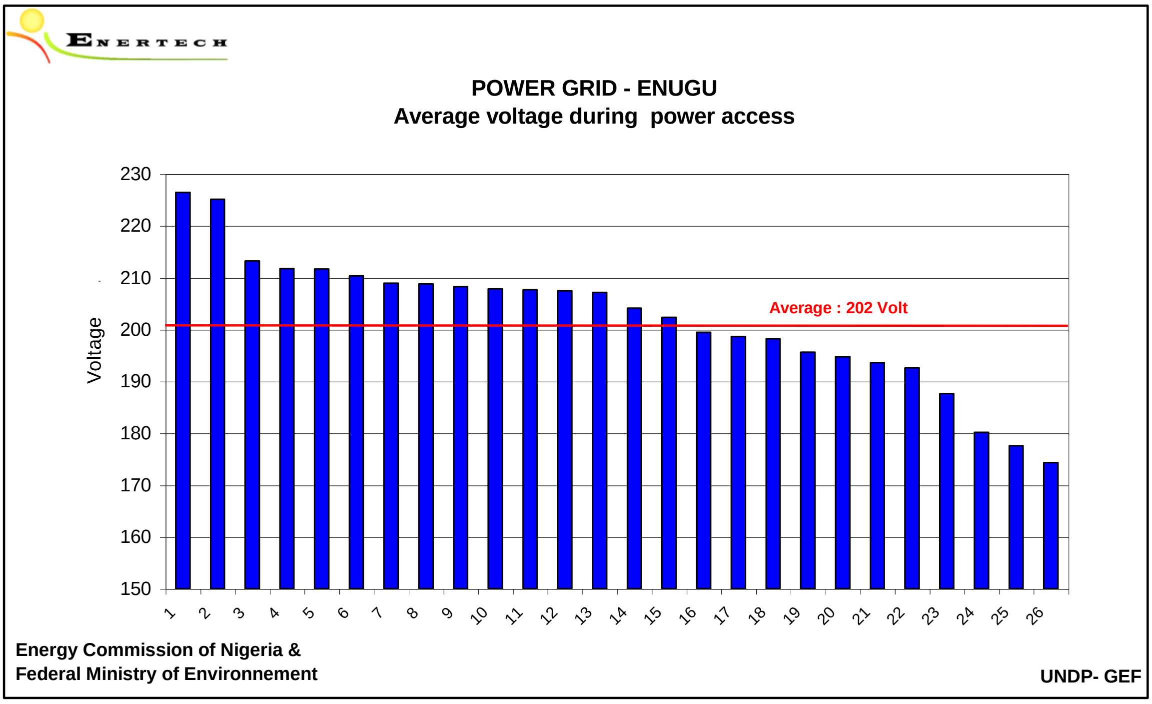


Figure 6.4 : Average voltage during power access - Enugu

6.7.2.3 Part of power access daily curve

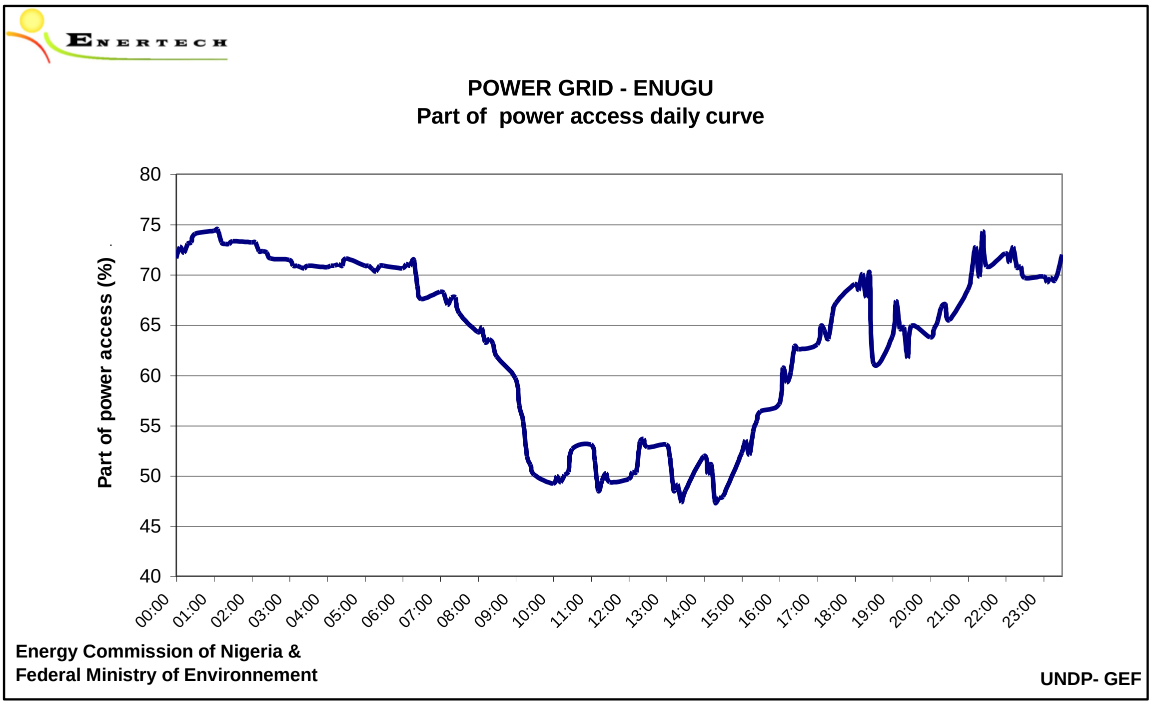


Figure 6.5 : Part of power access daily curve – Enugu

6.7.2.4 Numbers of hours per day of electricity access

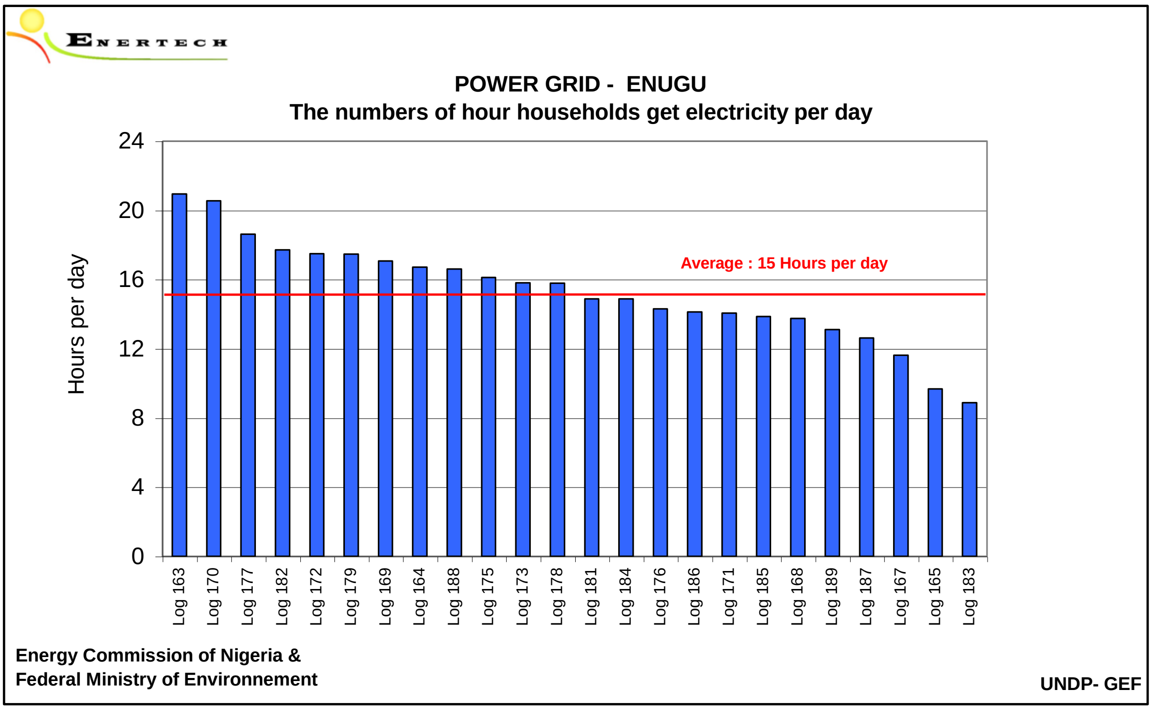


Figure 6.6 : Numbers of hours per day of electricity access - Enugu

6.7.2.5 Duration of power outages

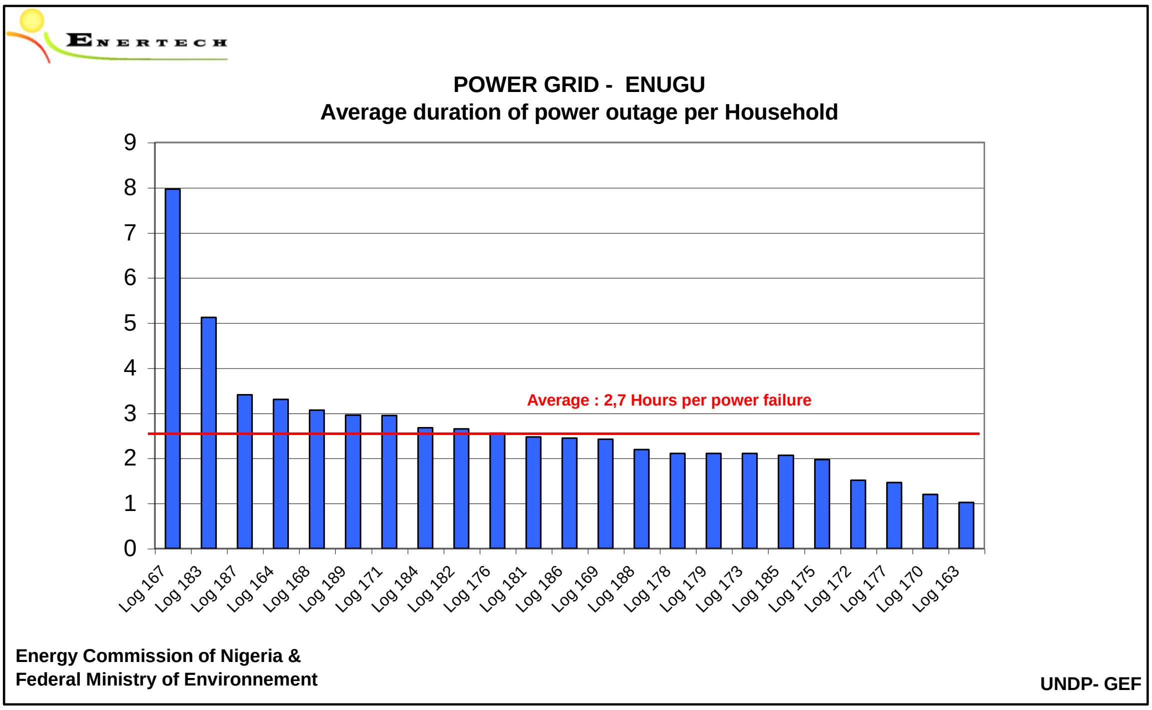


Figure 6.7 : Average duration of power outages - Enugu

6.7.2.6 Duration of electricity access

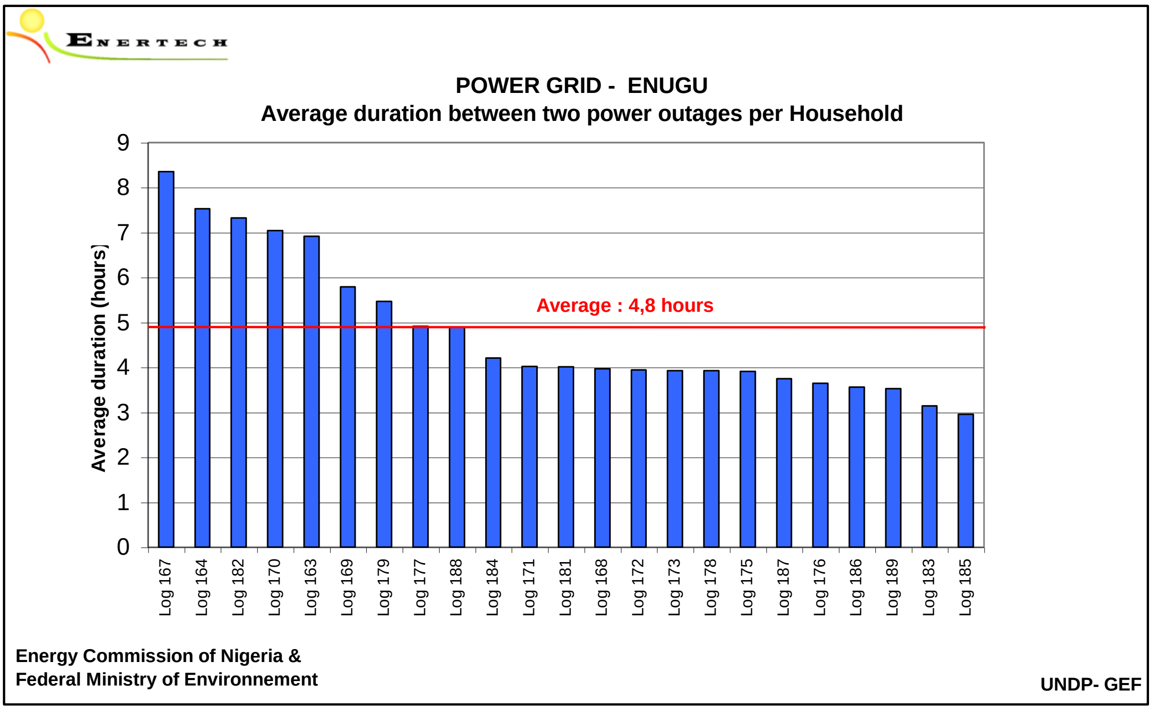


Figure 6.8 : Average duration of power access - Enugu

6.7.2.7 Annualized consumption

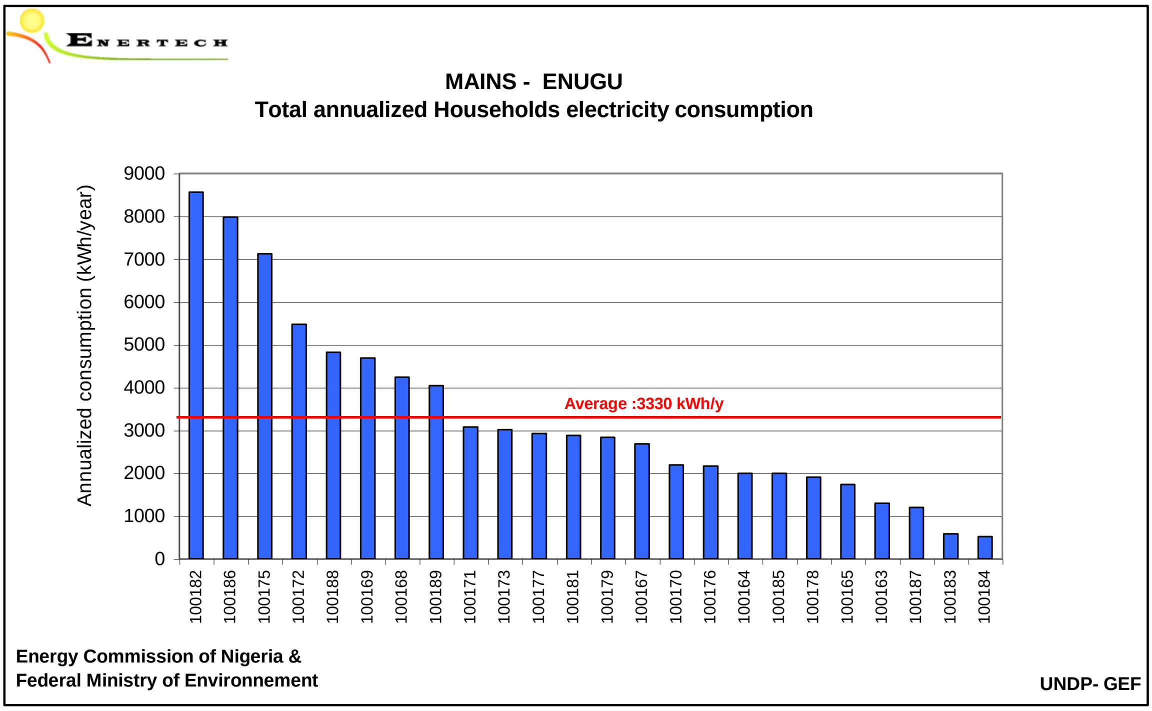


Figure 6.9 : Annualized households electricity consumption - Enugu

6.7.2.8 Daily average load curve

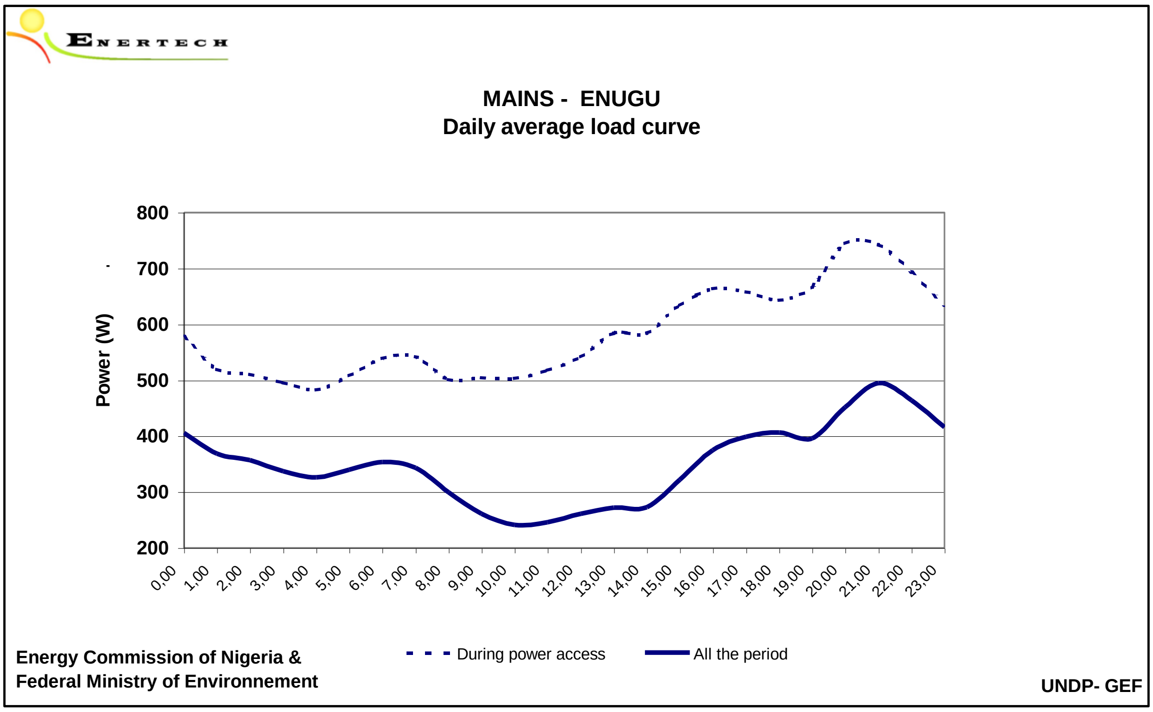


Figure 6.10 : Mains daily average load curve - Enugu

6.7.2.9 Relative contribution from the different loads

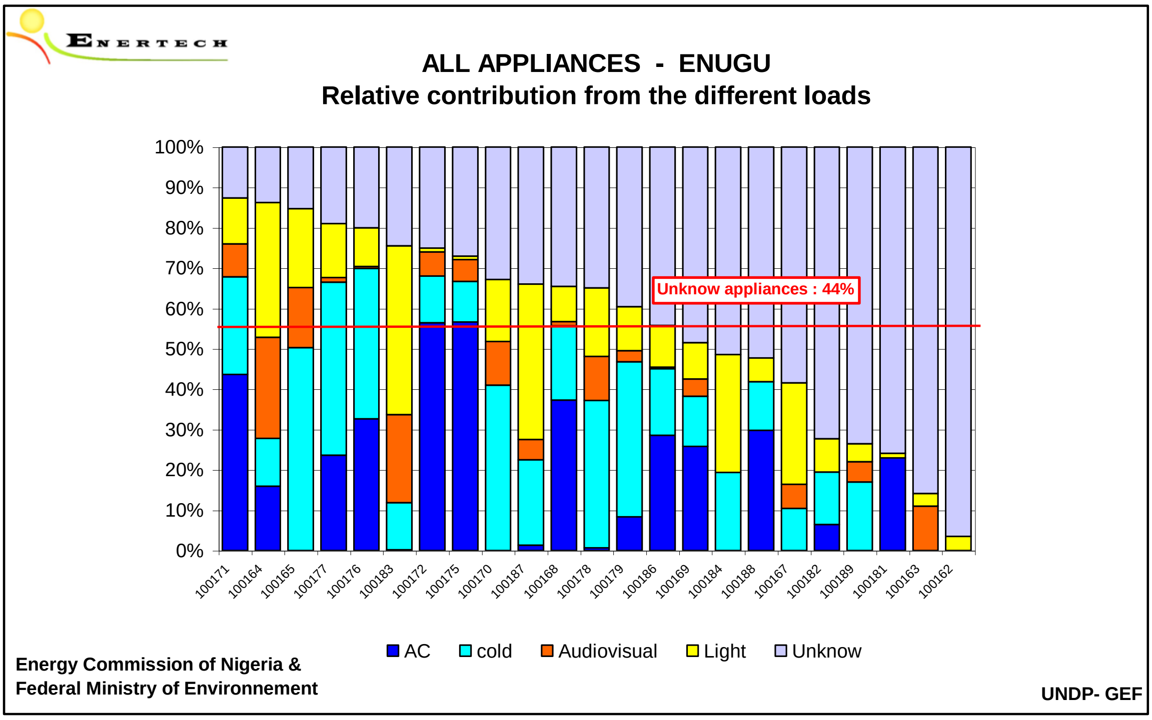


Figure 6.11 : Relative contribution from the different loads - Enugu

6.7.2.10 Relative contribution from the different loads

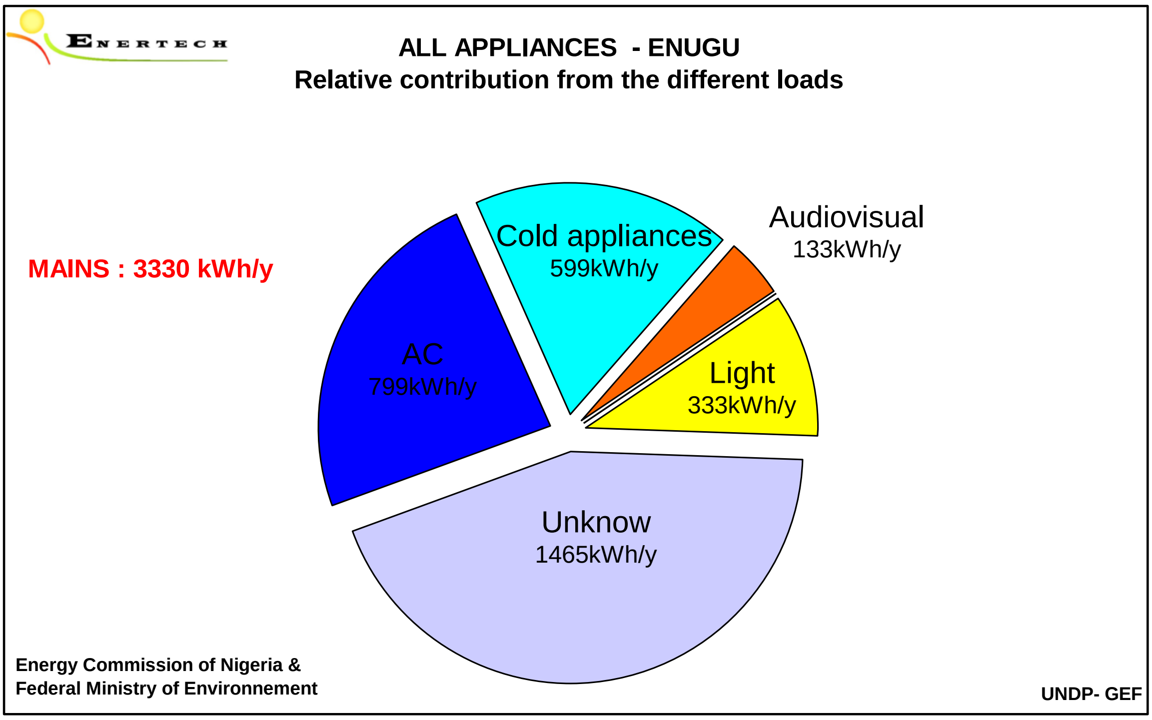


Figure 6.12 : Relative contribution from the different loads - Enugu

6.7.3 Air conditioner

6.7.3.1 Annualized consumption

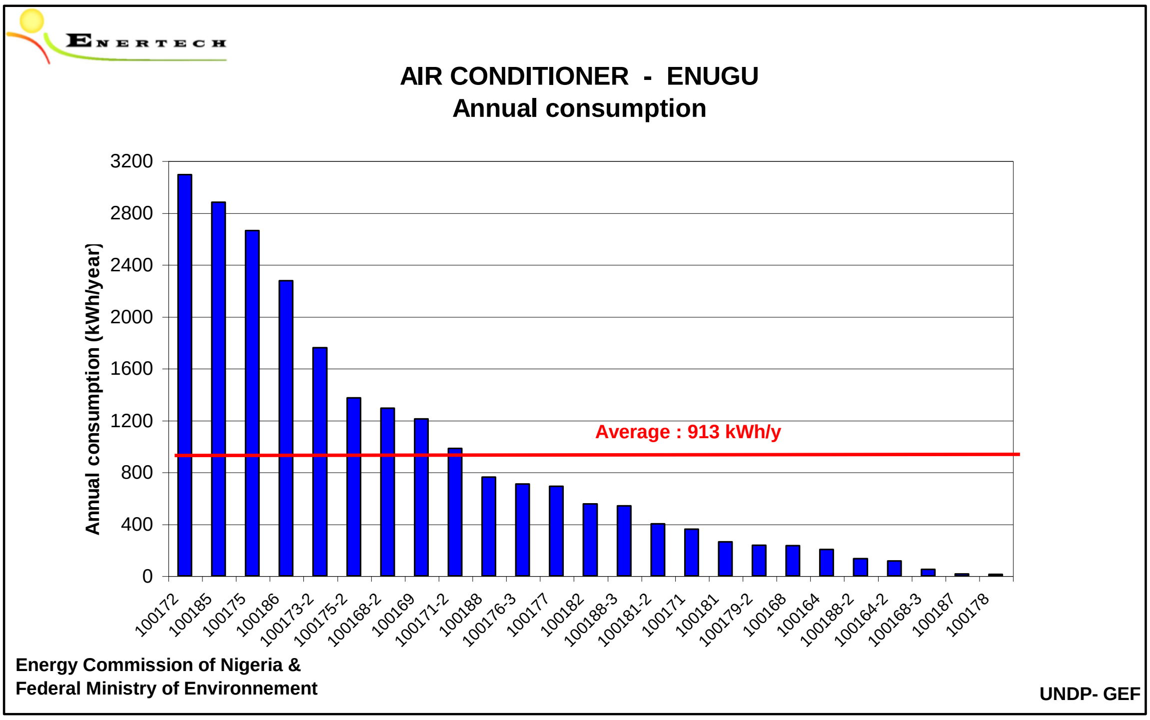


Figure 6.13 : AC annualized consumption - Enugu

6.7.3.2 Functioning rates

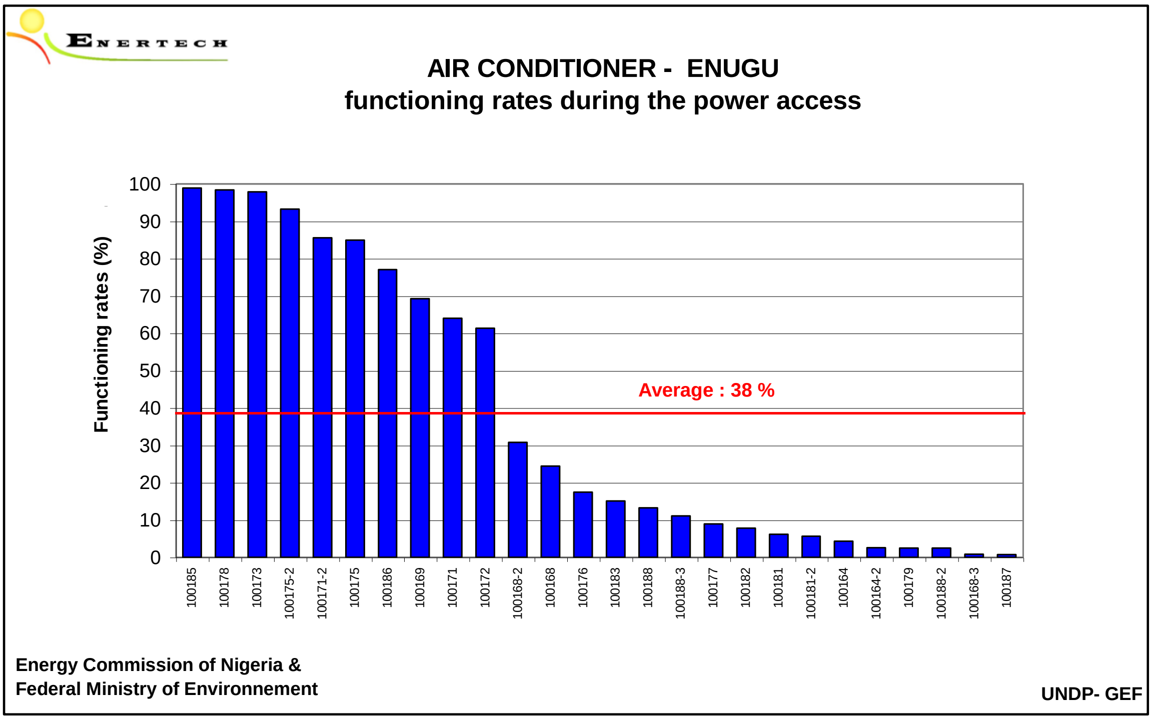


Figure 6.14 : AC functioning rates during the power access - Enugu

6.7.3.3 Annual consumption versus power grid

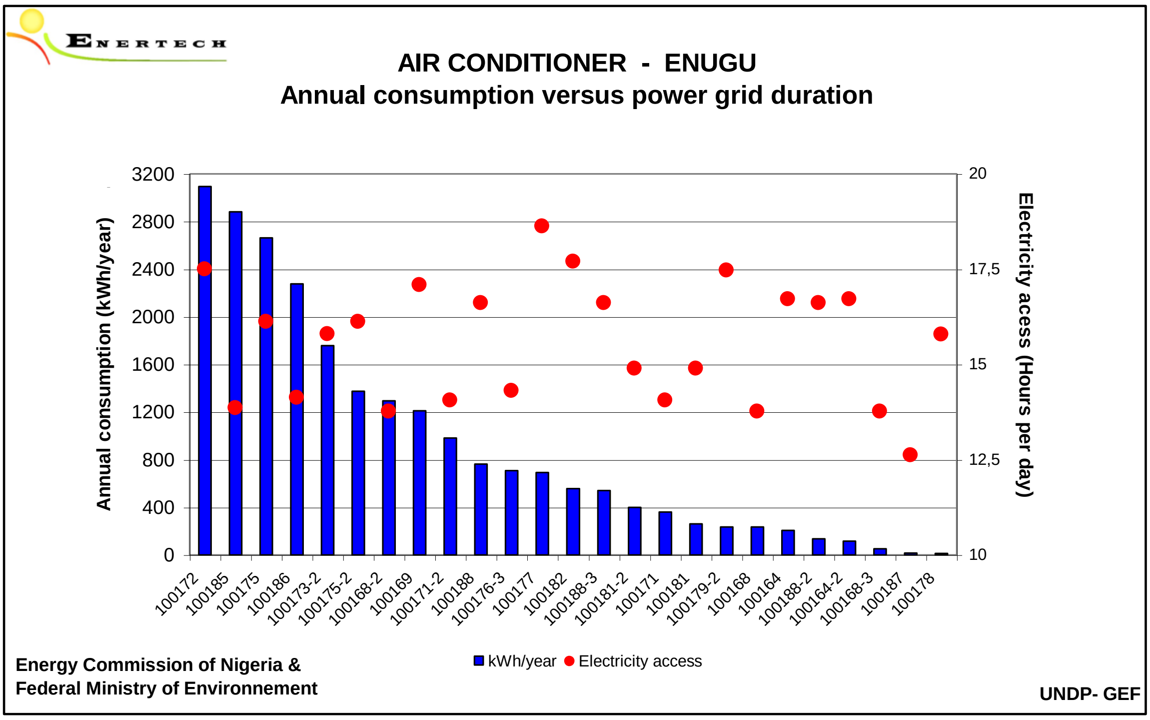


Figure 6.15 : AC annual consumption vs power grid - Enugu

6.7.4 Cold appliances

6.7.4.1 Average possession of appliances

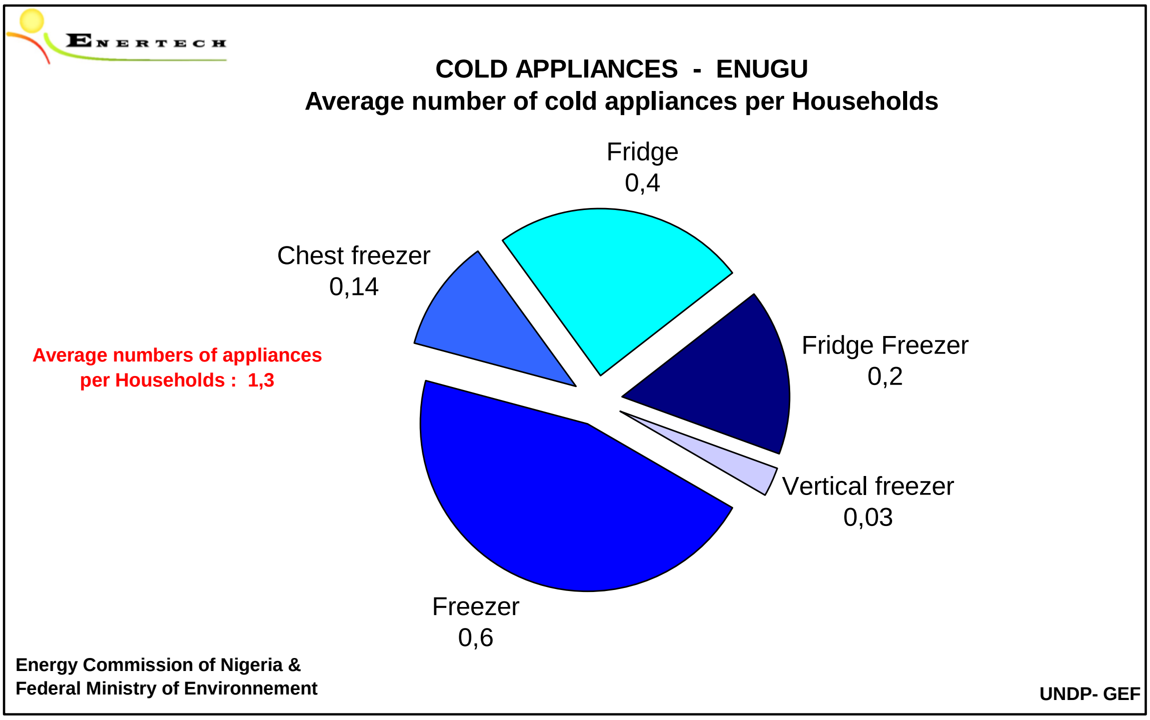


Figure 6.16 : Average possession of cold appliances – Enugu

6.7.4.2 Annualized consumption

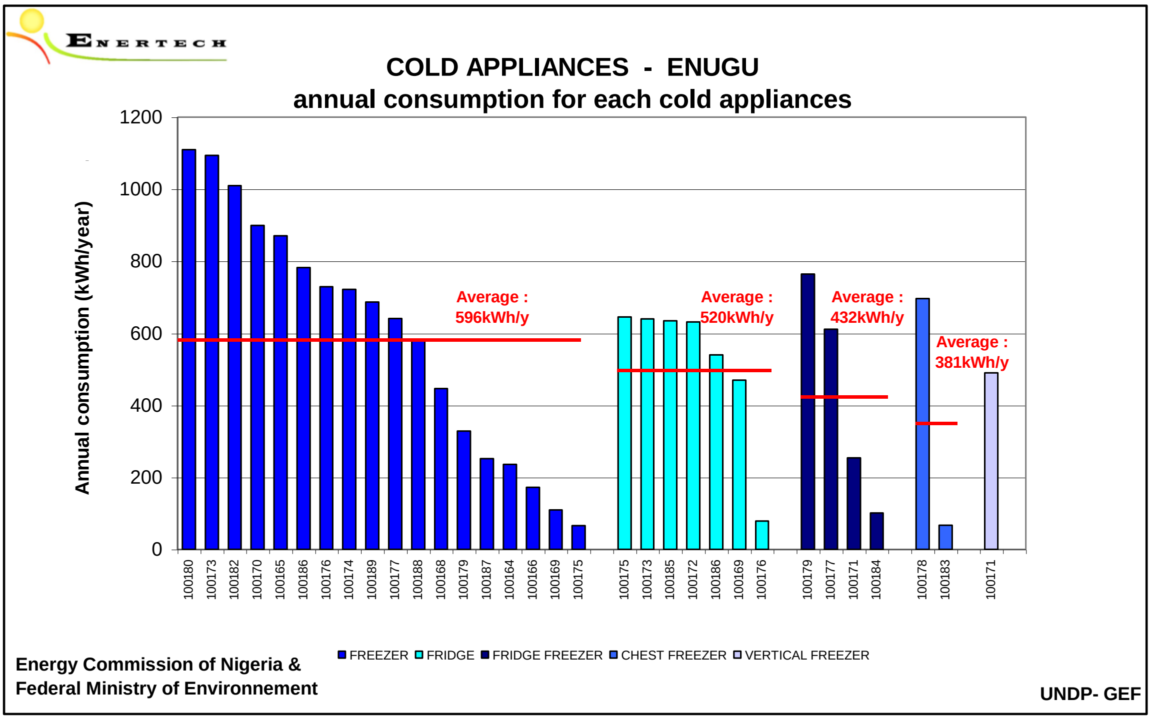


Figure 6.17 : Cold appliances annualized consumption - Enugu

6.7.4.3 Functioning rates

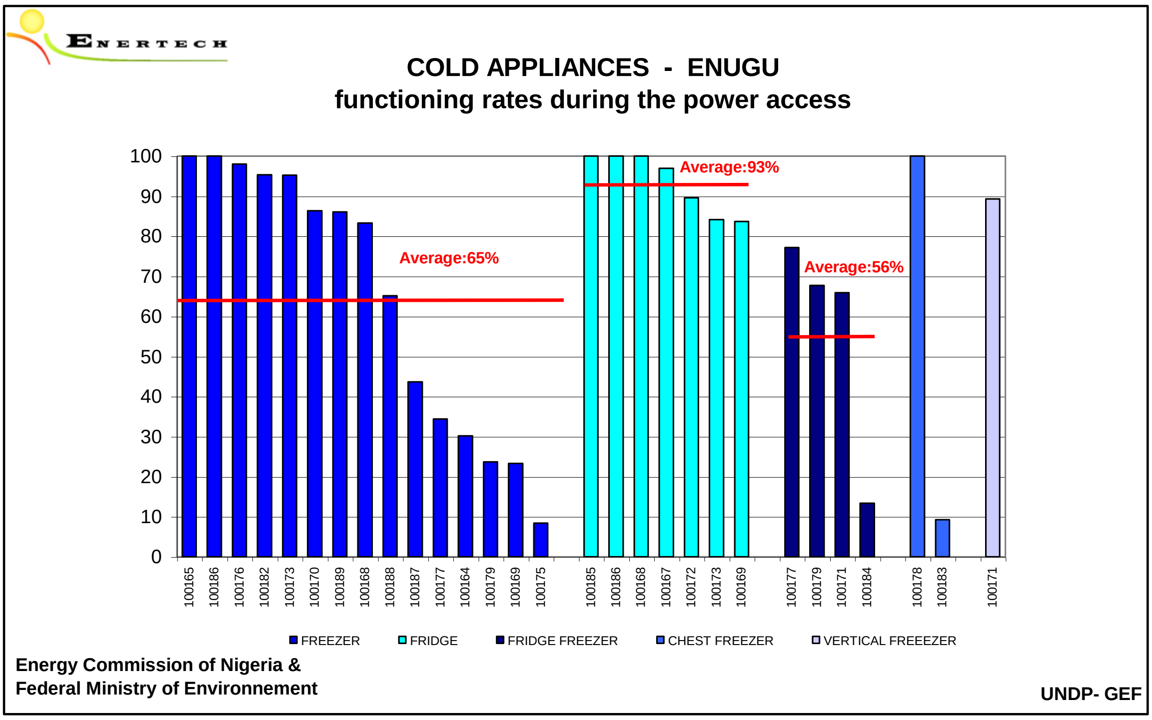


Figure 6.18 : Cld appliance functioning rates during the power access - Enugu

6.7.4.4 Annual consumption versus power grid

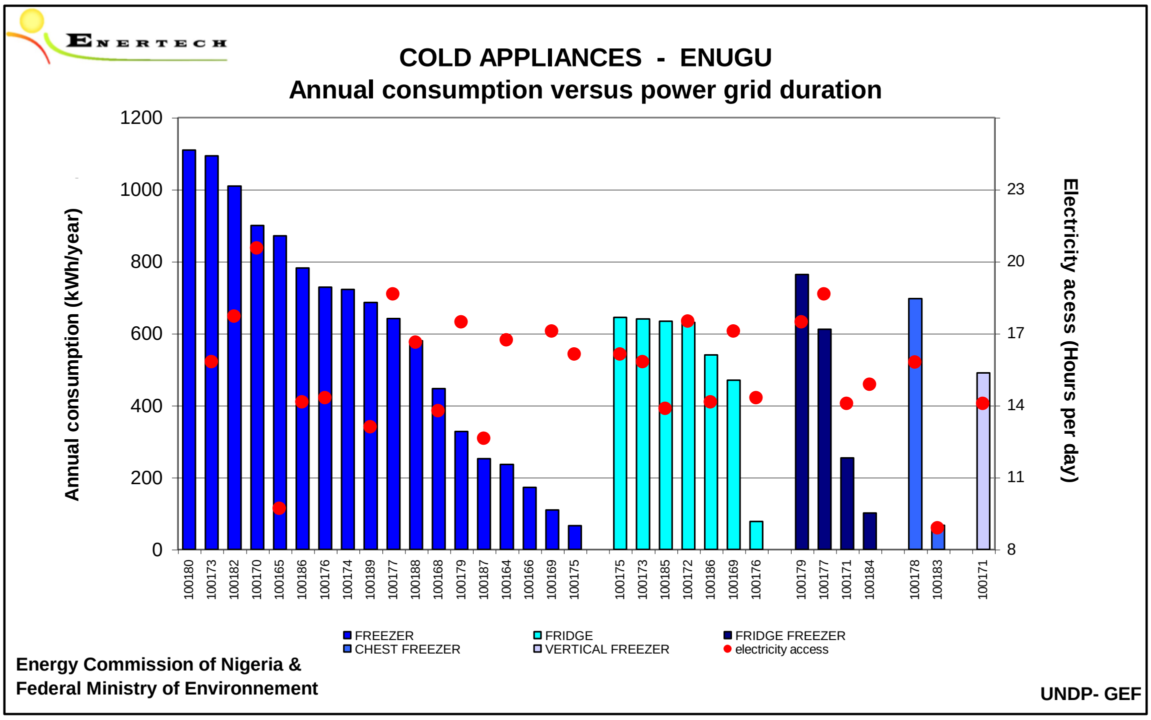


Figure 6.19 : Cold appliances annual consumption versus power grid duration - Enugu

6.7.5 Lighting

6.7.5.1 Installed wattage per bulbs

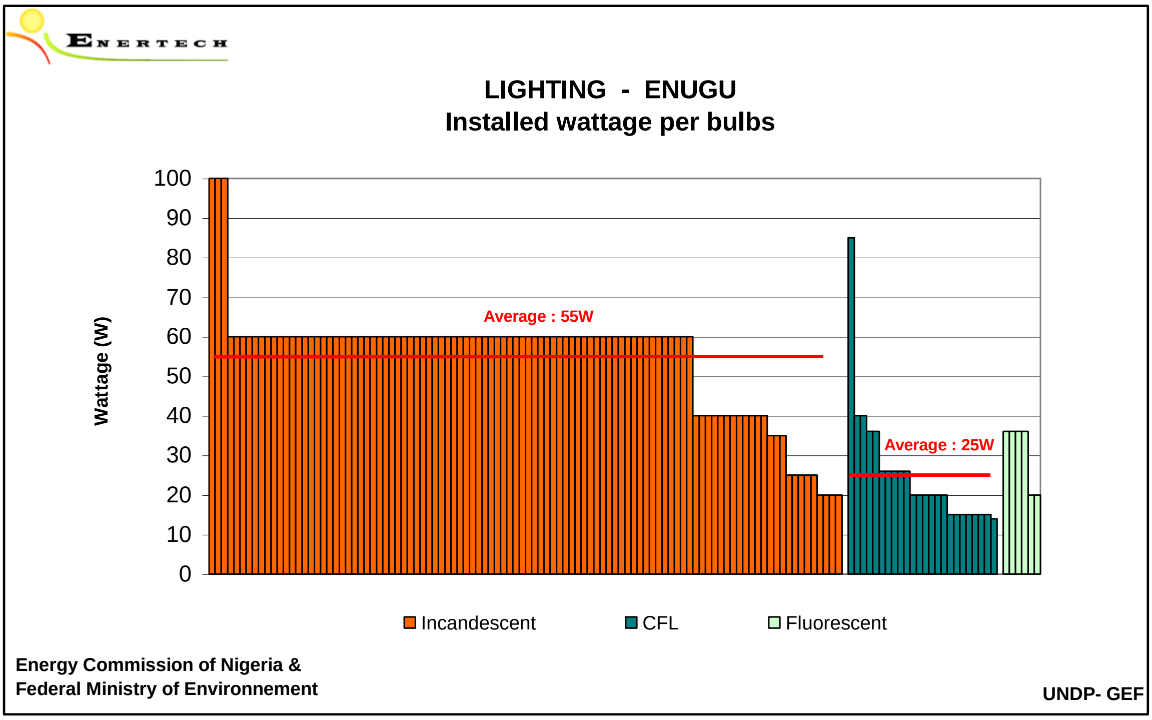


Figure 6.20 : Installed Wattage per bulbs - Enugu

6.7.5.2 Part of each type of light per bulbs

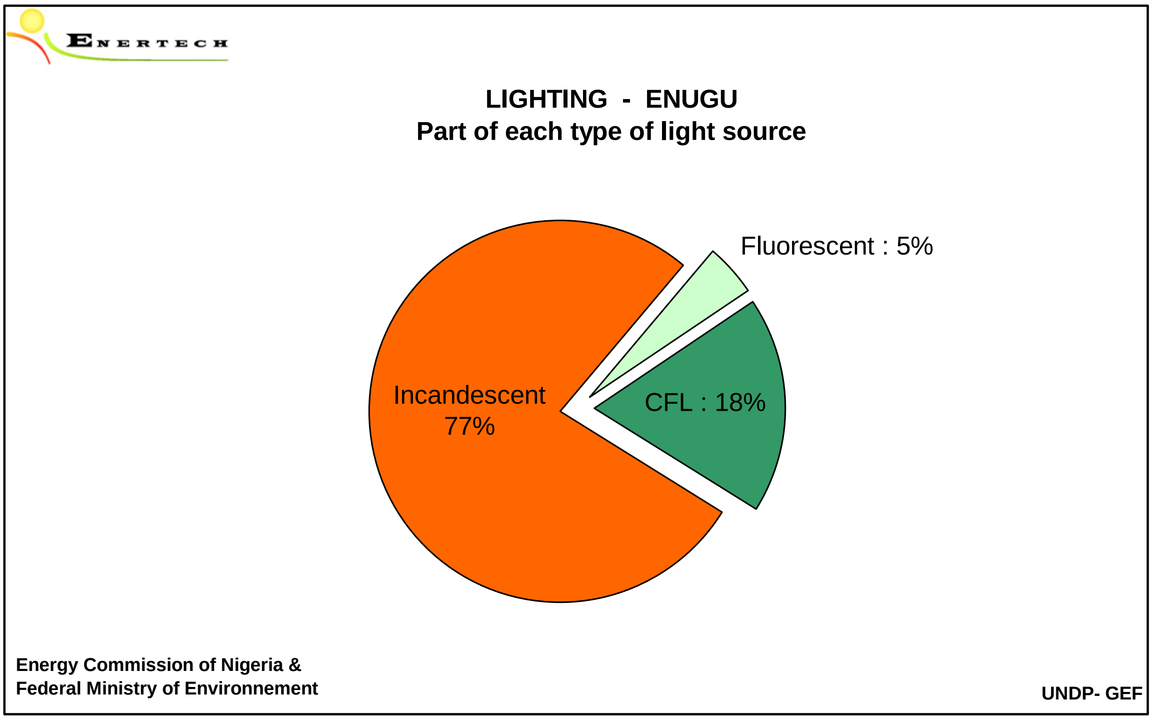


Figure 6.21 : Part of each type of light source - Enugu

6.7.5.3 *Annualized consumption per Households*

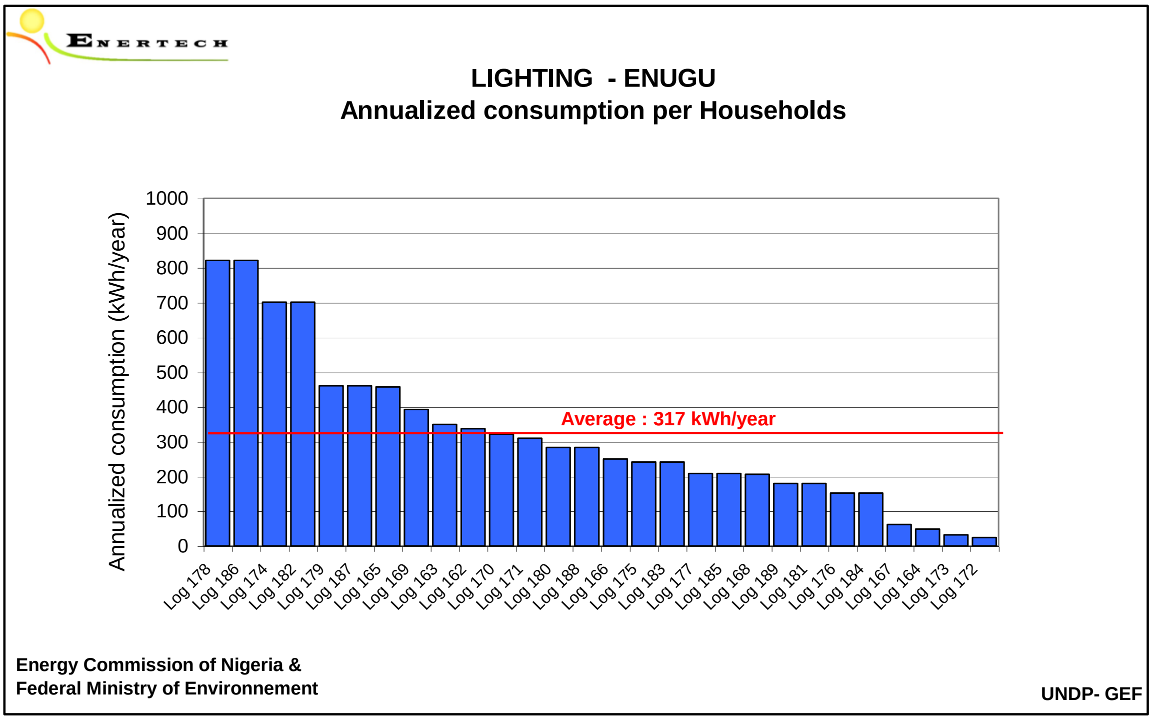


Figure 6.22 : Lighting annualized consumption - Enugu

6.7.5.4 *Daily average load curve*

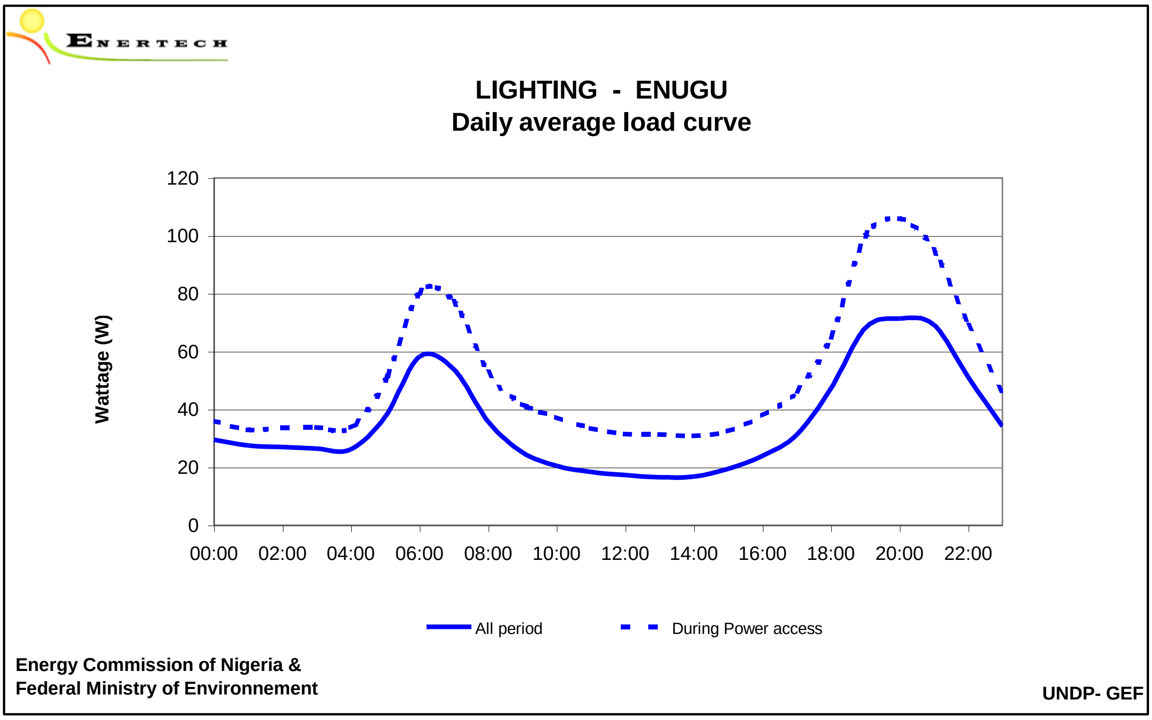


Figure 6.23 : Lighting daily average load curve - Enugu

APPENDIX B : FEEDBACK

6.8 Training of the Electricians by ENERTECH in France :

Four Nigerian engineers were trained in France by ENERTECH over four days with the following agenda:

- First day : Presentation of the data loggers. Generalities about the metering campaigns, procedures, goals. Presentation and use of the specific programming software tool for data loggers.
- Second and third days : On-field practical training. ENERTECH has organized an end-use metering campaign in French households for each Nigerian engineer, in order to practice the installation and the dismantling of data loggers according to the prescribed procedure.
- Fourth day : Assessment/reviewing about the practical training: extraction, reading and analysis of the data gathered during the on-field practical training. Preparation of the metering devices for the Nigerian metering campaign.

Training of the electricians at Felines sur Rimandoule

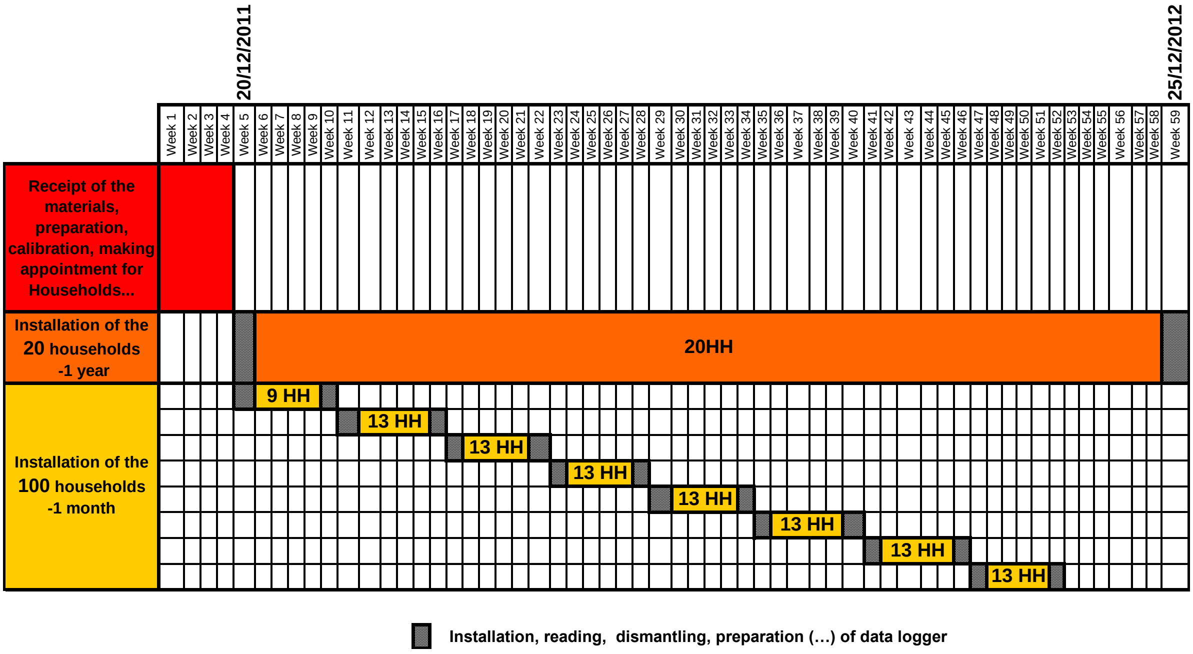
For safety reasons, engineers from Enertech were not able to go to Nigeria to conduct the training for the metering campaign. For the metering campaigns in Sweden, Greece, England, Portugal, Denmark or Italy, ENERTECH engineers provided in country training for local participants. It would have been more efficient if the training had been done in Nigeria because of the specific features (particularities of Nigerian switch board, power outages, specific electrical equipment…). They were not clearly identified before the training. So development of specific solutions and procedures was not anticipated.

6.9 Instrumentation : planning and organisation

Initial planning

The initial planning for this monitoring campaign was, after the training of the Nigerian engineers and the delivering of the 35 monitoring kits :

- To install the metering devices in 20 households monitored for one year,
- To install the metering devices in the first 9 single month households, then continuously install and dismantle the metering devices in 13 households every 1,5 months (one month metering and half month for dismantle and install the new sets).



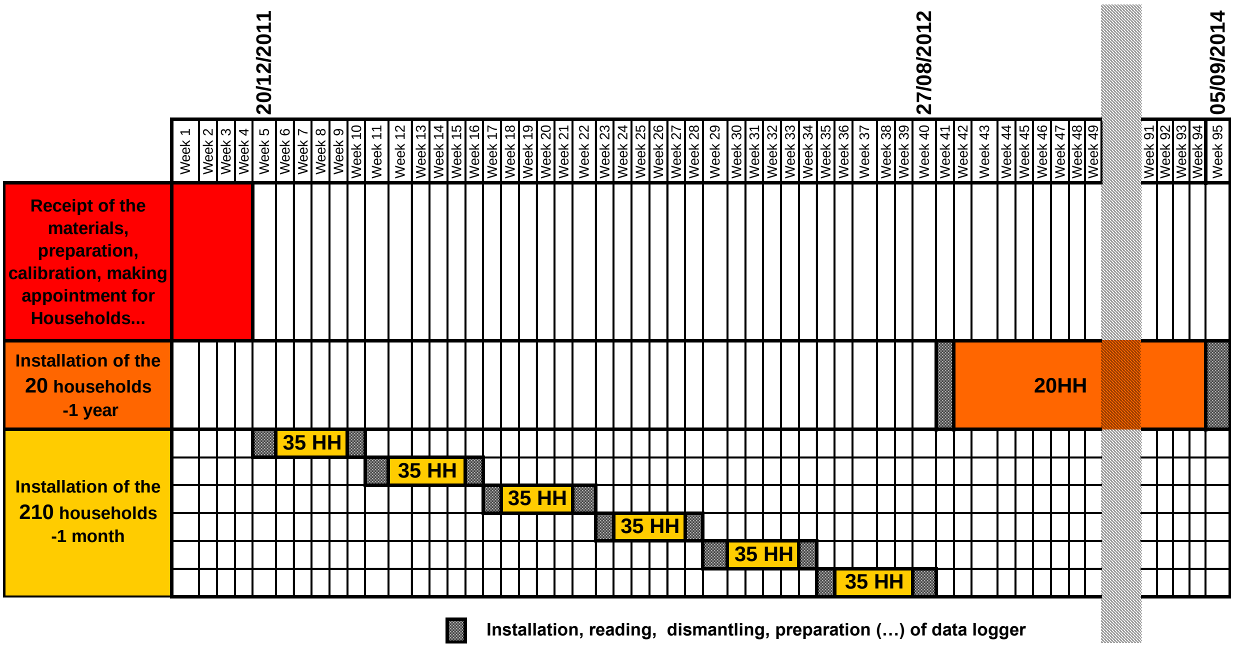
Modified planning

2 months after the installation of the first monitoring kits, the initial planning was changed, because "*stakeholders were of the opinion that one hundred household [was] too small for Nigeria with a population of over 160 million people*."

The new plan was :

- Installation of metering devices in **35 households** for **one months.**
- Installation of metering devices in **20 households** for **one year**, at the end of the "one month metering campaign".

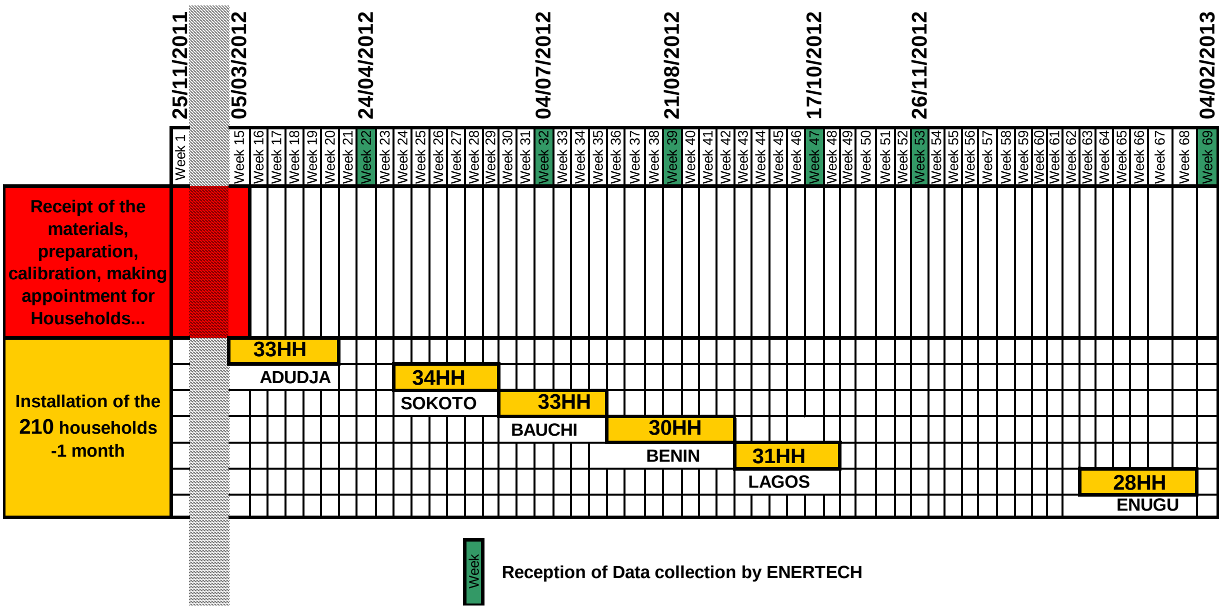
With this changes, 110 more households were monitored. It postponed the end of the monitoring campaign by 10 months.



Actual planning

This planning was delayed by 24 weeks. The main reasons of this slippage are the following :

- The delay between the training and the first installation of data logger :
  - **Finding households to be monitored** was difficult, as some households were suspicious and for safety reasons were not keen to participate,
  - The **metering devices transport** between France and Nigeria, with some Customs trouble…took longer than expected.
- The duration between two metering campaigns in two different geopolitical areas :
  - Due to **security issues and difficulties to travel** across these different geopolitical areas,
  - Some **adjustments** were necessary to improve data quality for the next session.



6.10 Installation and dismantlement of metering devices in the Nigerian Households

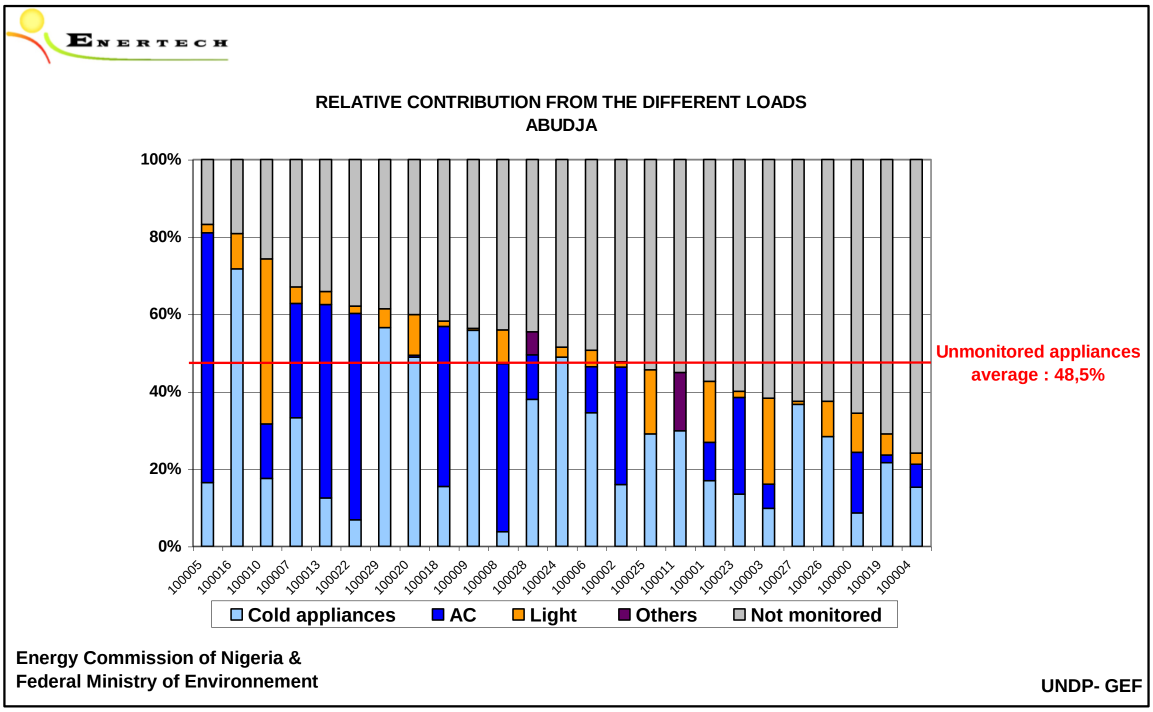
ZONE	Serial Wattmeter	Lampmeter	Wattmeter with ammeter pliers	Temperature Sensor	TOTAL
ABUDJA	53	108	182	33	**376**
SOKOTO	49	79	158	34	**320**
BAUCHI	95	110	169	33	**407**
BENIN	106	121	98	29	**354**
LAGOS	99	126	81	29	**335**
ENUGU	72	112	72	28	**284**
TOTAL	**474**	**656**	**760**	**186**	**2076**

	Serial Wattmeter	Lampmeter	Wattmeter with ammeter pliers	Temperature Sensor	TOTAL
Data loggers made available per zone	140	175	210	35	560
Data loggers installed (average per zone)	79	109	127	31	346
Using ratio of data loggers	56%	62%	60%	89%	**62%**

Only 62% of the data loggers were used during the metering campaign :

- The Nigerian team thought that the metering campaign was just for cold appliances, air conditioning and lights.
- Finding households to be monitored was very difficult so it would have been interesting to take the opportunity to monitor as many appliances (TV, HiFi, computer…) as possible by using all the data logger that were available.

The consequences are the we can’t explain, in average, half of the global Nigerian consumption.



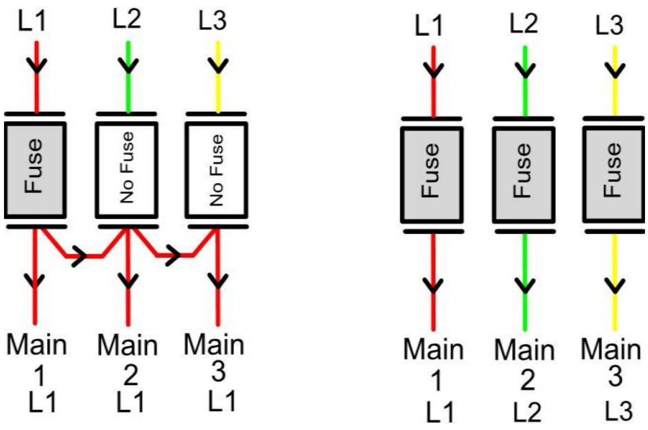
ENERTECH received the following feedbacks from the Nigerian Team about the difficulties encountered during the metering campaign :

- Problems due to security issues, religious and traditional practises in Nigeria : the Nigerian team were not given full access to every part of the house (especially in the Northern part of the country) during installation.

- Problems with the metering campaign methodology used, for the first time, by the group of Nigerian Team. During a metering campaign, we have many risks of errors between the configuration, the installation, the dismantling of data logger, etc… . Hence for the Nigerian campaign, about 20% of the data logger are unusable.

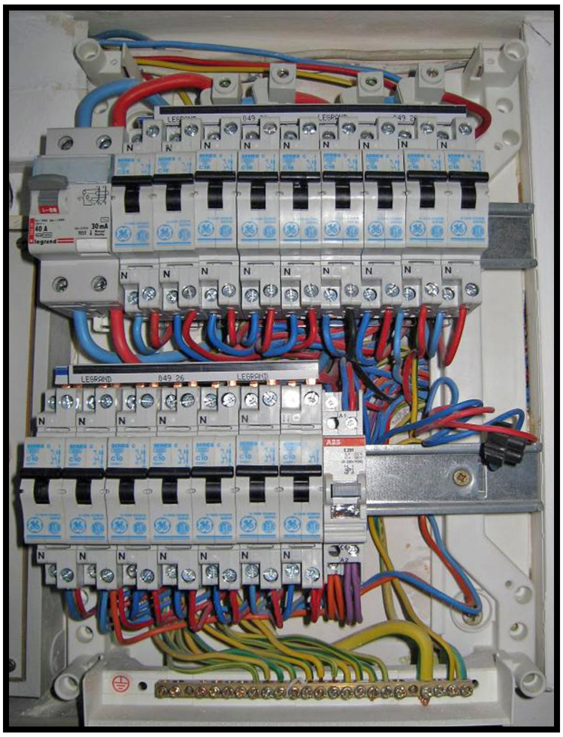
- Problems due to the wiring system : the distribution boards were complex and quite different (no labels on the different circuits, need to check manually all fuses). So in some cases it was quite difficult to fully identify all appliances connected to a specific electrical circuit.

Distribution Board looped from the mains as a single phase



Single phase with looping and three phase general principle

Most of the household have a three phases distribution board, but are usually looped from the mains as a single phase.



French household distribution board

Nigerian household distribution board

The French household distribution boards, in single phase, are composed of single-pole breaker. Each breaker correspond to a **specific departure** (washing machine socket, oven socket, light circuit 1, light circuit 2, air conditioner, …)
The French Electric Regulatory Restriction prohibit the use of several application per breaker (light + socket ; socket + air conditionner ; …)

The Nigerian household distribution boards are different, and we can find several appliances per breaker. This distribution complicates the electric measurement and the identification of the specific departures.

The use of the "Mulitvoies system" is a good solution to monitor the main consumption, but it is not appropriate to monitor the specific end-use consumptions. The Wattmeter which is directly connected to the equipment to monitor is, in this case, a better option.

6.11 Data transfer

The data files from the data loggers could be heavy (more than 25Mo). It was necessary, in this kind of transfer, to use a digital file delivery company. Trying to send the data to Enertech directly, some data were not received in time due to mail box problems.