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Research Article

Energy Needs and Trends Assessment for the Urban Commune of N'zérékoré, Republic of Guinea

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Abstract

Nowadays, one of the major problems facing large cities is the adaptation of energy needs with their rapid demographic growth. In most cases, there is a disconnect between the rapid demographic increases and the updating of energy needs. The major cities of the Republic of Guinea are confronted to a significant challenge due to insufficient energy supply for their sustainable development, and the urban commune of N'zérékoré is a clear example of this. The city is experiencing substantial rapid demographic growth, which requires a long-term assessment of its energy needs for its sustainable development. In this paper, a model for projecting energy demand over 10 years for the urban commune of N'zérékoré taking into account its demographic evolution was developed. An estimate of energy needs was made based on the projected population growth from 2024 to 2060. The results show that the urban commune's current energy consumption is estimated at 53.89 MW, or 38.8 GWh per month, while the projected energy demand for the same year amounts to 51.6 GWh. Population growth continuously drives a strong increase in energy demand, if production remains unchanged, by 2060 the commune's energy need would reach 1,595.16 GWh, resulting in a deficit of 1,543.56 GWh.

Keywords

Republic of Guinea, N'zérékoré, Prevision, Energy Demand, Population

1. Introduction

Electrical energy is one of the key factors for the development of a nation or a city, as any surplus energy generated is difficult to store, making continuous production necessary. However, this production must match the demand; it sometimes happens that energy producers generate more than what is needed, leading to unnecessary costs and wear and tear on equipment. Conversely, production may also fall short of demand, which harms end consumers and negatively impacts economic growth and productivity.

The challenge of forecasting energy needs involves several factors, including population growth, technological advancement, economic performance, and energy consumption habits [1]. Several researches was carried out on assessment of energy consumption trends and forecasting in developed

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countries as in [2-5]

In developing countries, this challenge is exacerbated by the lack of reliable data, political influences, and the volatility of historical electricity demand due to macroeconomic or political instability [6-8]

In the Republic of Guinea, the city of N'zérékoré is undergoing significant demographic changes and diversifying human activities, all of which require substantial energy consumption. This situation necessitates an estimation of the city's overall energy needs in order to plan future electrical infrastructure.

In this context, the design of a hybrid energy system combining hydroelectric power and solar panels offers a long-term solution to meet the energy needs of N'zérékoré.

The urban commune of N'zérékoré currently receives electricity through an interconnection with the Republic of Ivory Coast, the maintenance of which is costly for the Guinean state and negatively impacts the financial support available for other sectors. Given the significant solar radiation and the presence of the Diani River, which has considerable hydroelectric potential, it would be prudent to implement a hybrid hydroelectric-photovoltaic system to sustainably meet the long-term energy needs of the urban commune of N'zérékoré.

This work is part of this effort and aims to estimate the energy needs and trends of the urban commune of N'zérékoré up to 2060, using a hybrid photovoltaic-hydroelectric energy system.

2. Materials and Methods

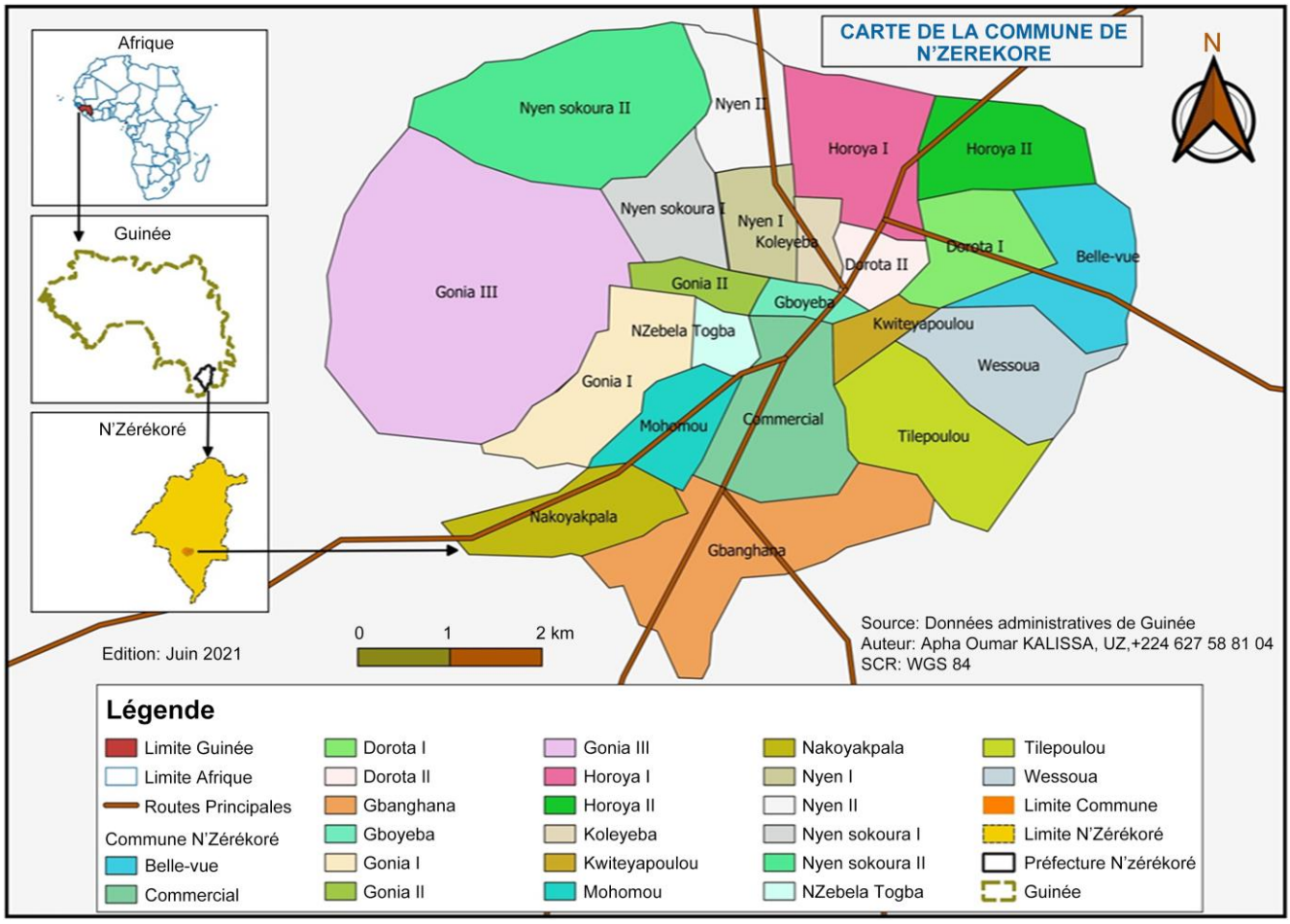


Figure 1. *Map of the urban commune of N'Zerekore.*

2.1. Study Area

The Prefecture of N'zérékoré is one of the 33 prefectures of Guinea. It is the largest city in Forested Guinea, a region in the southeast of the Republic of Guinea. The city is also the capital of the Forest region. It is located between 7°32 and 8°22 north latitude and 9°04 west longitude, extending over 47.3 km². The distances to neighboring prefectures are 39 km from N'zérékoré to Lola, 62 km from N'zérékoré to Yomou,

125 km from N'zérékoré to Beyla, and 135 km from N'zérékoré to Macenta. N'zérékoré is situated at an elevation of 480 meters, and its terrain is rugged. The plateau is dominated by hills, which are sometimes gneissic (Gonia) and sometimes quartzitic (Gboyéba). The city features three significant mountains: Götö (450 m), Hononye, and Kwéléyé (350 m). Nakoyakpala is one of the 22 neighborhoods of the urban commune of N'zérékoré, bordered to the east by the rural commune of Bounouma, to the west by the Tilé River and the Mohomou district, to the south by the Kérémé district, and to the north by the Gbangana district and the Tilé River.

2.2. Method Estimation Steps

For the estimation of energy needs and trends for the urban commune of N'zérékoré, we consider the following steps:

1. Constitution and population of the urban commune of N'zérékoré
2. Demographic data of the commune of N'zérékoré
3. Categories of electricity consumers

2.2.1. Constitution and Population of the Urban Commune of N'zerekore

The urban commune of N'Zerekore is made up of 22 districts which are: Commercial, Dorota I, Dorota 2, Gbangana, Nakoyakpala, Mohomou, N'yen I, N'yen II, Gonia I, Gonia II, Gonia III, Gboyeba, Horoya I, Horoya II, Belle vie, Tilepoulou, Wessoua, Sokoura I, Sokoura II, all these districts extend over an area of nearly 3,634 km^2.

2.2.2. Demographic Data of the Commune of N'Zerekore Population

The population census of the urban commune of N'zérékoré is conducted annually by administrative entity or subdivision. Table 1 presents the population for the last ten years, based on the annual reports provided by the housing service of the urban commune of N'zérékoré from 2015 to 2024.

Table 1. *Demographic data of the urban commune of N'Zérékoré over the last ten years [9].*

Year	population
2015	202 725
2016	202727
2017	214560
2018	220 659
2019	226 876
2020	233 213
2021	239 670
2023	252947
2024	259 769

2.2.3. Demographic Data of the Urban Commune of N'zerekore Population

According to the electricity company of Guinea EDG ~~[ref],~~ the classification of electricity consumers is as follows

1. Industrial consumers;
2. Semi-industrial consumers;
3. Tertiary consumers;
4. Residential consumers.

Industrial consumers

Industrial consumers are supplied with high voltage category B (HTB) and account for approximately 75% of total electricity production [14]. This study focuses on high voltage category A (HTA) consumers.

Semi-industrial consumers

Welding, pressing, carpentry, technical schools, workshops, laboratories, and mills are classified as semi-industrial consumers. Table 2 provides a census of semi-industrial consumers in the commune of N'zérékoré.

Table 2. *The census of semi-industrial consumers of the commune of N'zérékoré.*

N°	Semi-industrial consumers	Quantity
1	Welding	140
2	Carpentry	200
3	Pressing	10

Tertiary consumers

Tertiary consumers are supplied with high voltage category A (HTA) and significantly impact the overall electricity demand of the commune. The report in [10] presents the situation of tertiary consumers in the urban commune of N'zérékoré for the year 2024, as shown in Table 3.

Table 3. *Tertiary consumers recorded in the urban commune of N'zérékoré.*

N°	Tertiary consumers	Number
1	Shops	
2	Health establishment	30
3	Schools	120
4	Universities and higher institutes	3

Nº	Tertiary consumers	Number
5	Hotels with Restaurants	10
6	Restaurants	30
7	Social centers	1
8	Markets	10
9	Stadiums	3
10	Churchs	28
11	Mosques	70

Residential consumers

The number of households (customers) and the type of housing significantly affect electricity consumption, influenced by factors such as average household size, the number of rooms, and housing design. The number of households is directly proportional to the population size [2]. According to activities conducted by the census service as part of the fight against malaria in 2024, and an online survey, the average household size in the commune is estimated at five people per household.

Based on the literature [3], the number of households (customers) in the urban commune of N'zérékoré in 2024 was estimated at 51,954. The electrical appliances and equipment used by customers also play a crucial role in determining electricity consumption.

2.3. Energy Consumption of the Urban Commune of N'zérékoré

The EDG report [10] indicates that the urban commune of N'zérékoré is supplied by two feeders, allowing us to identify and define the distribution rate of installed power for each feeder in the commune, based on the installed power of the transformers (assumed to be operating at full capacity) supplied by the HTA line.

Equations (1), (2), and (3) are used to calculate the total energy consumption of the commune, determine the electrical power consumed, and calculate the distribution rate of electrical power for the urban commune of N'zérékoré.

$$P_f = \sum_{i=1}^{n} P_i \quad (1)$$

$$\Delta = \frac{P_t}{P_f} = \frac{\sum_{k=1}^{m} P_K}{\sum_{i=1}^{n} P_i} \times 100 \quad (2)$$

$$P_C = \sum_{j=1}^{2} P_j \times \Delta_j \quad (3)$$

Where,

P_f is the power supplied by the transformer, Δ the power distribution rate in the commune, P_c the power consumed by the commune with Pj the tip on the feeder. Table 4 gives installed power per Feeder, per zone and distribution rate.

Table 4. *Installed power per Feeder, per Zone and distribution rate.*

Post	Feeder	P_f	P_c	Δ(%)
Depature 1	Ossud	40	7	17.5
Departure 2	GouvernoraZao-Lola	40	7	17.5
Departure 3		40	7	17.5

Using the Bottom-up model developed here, we estimate the actual energy needs of the commune. For residential consumers, in-situ visits provided an overview of the types of devices used by households, user behaviors, and the frequency of use for each device.

The information was collected carefully and meticulously during these various in-situ visits. We assume that the model's input data considers all households to have the same characteristics, the devices to possess identical technological properties, and all users to exhibit similar behavior. Additionally, we take into account the usage coefficient (Ku), the usage time (Tu), and the device ownership rate per household (Tp).

2.3.1. Residential Consumer Model

Table 5 identifies the charges encountered in a typical household in the urban commune of NZerekore.

Table 5. *Estimation of household consumption.*

Device	Pa (W)	Nbr	Ku	Tu (h)	Pi (ti) Kwh	Tp	Pi (MW)
Heating	1000	1	1	1	1,00	56	27
Freezer	250	1	1	24	6,00	78,9	224
Ironing board	1300	1	1	1	1,30	96	59
hair dryer	1600	1	1	0,5	0,80	175	7
Water kettle	1500	1	1	0,5	0,75	56	20

Device	Pa (W)	Nbr	Ku	Tu (h)	Pi (ti) Kwh	Tp	Pi (MW)
Fan	60	1	1	3	0,18	36	3
Computers	45	2	1	3	0,27	88	11
Television	110	1	1	16	1,76	95	79
Water fountain	1000	1	1	5	0,5	43	10
Air conditioner	5000	2	1	2	20,00	53	50
Chargers	5	6	1	2	0,06	100	3
Energy saving lamp	12	6	1	24	1,73	80	66
Incandescent lamp	100	4	1	24	9,60	49,1	223
Electric hob	1500	1	1	4	6,00	68,4	194
Total household					49,9	Total	976

Where Pa, Pi (ti) and Pi in Table 5 represent respectively power of device, the energy consumed per unit of time and the energy consumed.

In this model, a household requires 49.95 kWh per day. To supply all households in the commune of N'zérékoré for one month, the estimated energy need is 29.29 GWh.

2.3.2. Tertiary Consumer Model

The urban commune census includes several tertiary consumers [4]. However, this model focuses on tertiary consumers that are considered more energy-intensive, as they primarily consume more than just lighting. These include schools, mosques, churches, shops, hotels, and restaurants. For the sake of clarity, we present the models of a school and a mosque as examples month, the estimated energy need is 29.29 GWh.

Model of a school

Table 6 presents the essential devices used in a school along with their respective usage times.

Table 6. *Estimation of household consumption.*

Devise	Pa (W)	Nber	Tu (h)	Ku	Pi (ti) Kwh	School Nber	Pi Mwh
Tube	40	205	18	1	147,6		
Computer	80	35	3	1	8,40		
Photocopier	200	5	1	1	1	359	
Printer	200	6	1	1	1,2		
Projector	1000	10	24	1	240		
Total school					398,2	Total	142,95

Table 7. *Estimation of a school's consumption.*

Device	Pa (W)	Nbre	Tu (h)	Ku	Pi (ti) Kwh	Mosque Number	Pi Mwh
Tube	40	100	24	1	96		
Micro	20	15	7	1	2,1	400	
Mixer	1200	2	7	1	16,8		
Amplifier	1500	2	7	1	21		

Device	Pa (W)	Nbre	Tu (h)	Ku	Pi (ti) Kwh	Mosque Number	Pi Mwh
affle	1000	5	7	1	35		
Fan	60	24	7	1	10,08		
Total Mosque					180,98	Total	72, 392

The daily consumption of the school is estimated at 398.2 kWh on a working day. Assuming that the schools operate five days a week, the monthly consumption for projectors is estimated at 2.58 GWh, while the consumption for other equipment is estimated at 1.25 GWh. This results in a total monthly consumption of 3.83 GWh for all schools in the urban commune.

Model of a Mosque

Table 7 presents the essential devices used in a church along with their respective usage times.

Mosques experience high energy consumption on Fridays during sermons, with an average consumption of around 180.98 kWh per mosque. Over the course of a month, lighting accounts for approximately 2.52 GWh, while other equipment consumes nearly 0.24 GWh. This results in an estimated total consumption of 2.76 GWh for all mosques in the commune during a month.

2.3.3. Semi-industrial Consumer

Among the semi-industrial consumers, we distinguish the following: carpentry, welding workshops, dry cleaners, and other entities that can be assimilated to these three types. Here, we present the model of a carpentry workshop.

Model of a carpentry

Table 8 gives the essential devices in a carpentry shop.

Table 8. *Estimation of the consumption of a carpentry shop.*

Device	Pa (W)	Nombre	Tu (h)	Ku	Pi (ti) Kwh	Carpentry Number	Pi Mwh
Jig saw	2300	2	8	O, 6	22,08		
Circular saw	750	2	8	0,6	7,20		
Spinning top	7000	2	7	0,75	73,5	30	
Band saw	11000	1	1	1	11,0		
Hand drill	700	3	2	0,6	2,52		
Angle grinder	2000	2	4	0,75	12,0		
Total carpentry shop					128,3	Total	3, 849

On a working day, the carpentry shop consumes approximately 128.3 kWh. Since carpentry shops do not operate on Fridays, the estimated monthly consumption for all carpentry shops in the commune is about 0.07 GWh.

2.4. Estimated Consumption

The consumption estimates categorized by type enable us to deduce the overall consumption of the urban commune of N'zérékoré. Table 9 presents the various consumption estimates by consumer category, as well as the total for the entire urban commune.

Table 9. *Estimated consumption by electricity consumer category for the entire commune.*

Urban commune of N'zérékoré		
Consumer	ENTITE	P/month (GWh)
Residual	Households	29,29
	Schools	3,83
	Mosques	2,76
Tertiary	Shops	8,63
	Hotels	1,25
	Restaurants	0,9

Urban commune of N'zérékoré		
	Carpentry	0,07
Semi-industria	Pressing	0,11
	Welding Equipment	0,07
Sector sum		46,91
Correction factor of 10 %		4,69
Total of the estimated consumption		51,6

2.5. Evaluation the Energy Deficit

The estimated consumption of the urban commune of N'zérékoré is 51.6 GWh per month, which includes 29.29 GWh for residential consumers - approximately 57% of the total consumption while other consumers account for 43.23%.

In designing the consumption charge models for tertiary and semi-industrial consumers, we did not consider entities such as health centers, depots, and transport agencies, as they are deemed less energy-intensive. To establish a more accurate consumption model for the urban commune, we made certain approximations based on observed realities, suggesting that these neglected sectors represent 10% of consumption in the tertiary and semi-industrial sectors. This assumption is justified by the fact that Guinea is a country in full expansion, making such a value plausible given the population growth observed in the commune. Using these assessment, we deduced that the trend of production and the power supplied to the commune is evaluated at 53.89 MW or 38.8 GWh during a month.

2.6. Energy Consumption Projection from 2024 to 2060

2.6.1. Demography Projection

The energy deficit, defined as the difference between the energy supplied to the commune and its energy needs, amounts to 51.6 GWh per month. For the commune of N'zérékoré, this deficit is assessed at 12.8 GWh, which represents 24.8% of the commune's total energy requirements.

An analysis of the reports provided by the statistical and housing service of N'zérékoré [11] indicates that the population of the commune evolves linearly. According to the literature [12], we can perform a projection based on the extrapolation of existing trends. The projected population is calculated using the following relation:

$$P_t = P_0 + \Delta t \quad (5)$$

$$\Delta = (P_0 - P_b)/y \quad (6)$$

Where

P_t, is the projected population

P_o, the starting population

P_b, initial population (base period)

y, Number of years in the base period

t, number of projection years (between start year and end year of projection). The overview of projection methods [13] allows us to determine at what rate the population has increased over the last ten years.

The parameters P_b, P_0, P_t, y and t are related by the following graphs (Figure 2):

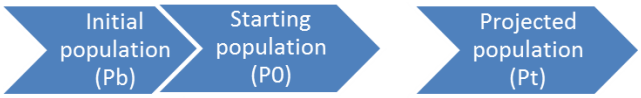


Figure 2. *Projected population calculation graph.*

Δ is calculated as following: $\Delta = \frac{P_0 - P_b}{y}$, AN: Δ=(259 769-202 725)/10 = 5704,4.

Table 10 illustrates the projected population over a span of 36 years.

Table 10. *Demographic projection of the urban commune of NZerekore from 2024 to 2060.*

t	Year	Pt
0	2024	259 769
1	2025	265473,4
2	2026	271 177,8
3	2027	276 882,2
4	2028	282 586,6
5	2029	288 291
6	2030	293 995,4
7	2031	299 699,8
8	2032	305 404,2
9	2033	311 108,6
10	2034	316 813
11	2035	322 517,4
12	2036	328 217
13	2037	333 926,2
14	2038	339 630,6
15	2039	345 335
16	2040	351 039,4
17	2041	356 743,8
18	2042	362 448,2
19	2043	368 152,6

t	Year	Pt
20	2044	373 857
21	2045	379 561,4
22	2046	385 265,8
23	2047	390 970,2
24	2048	396 674,6
25	2049	402 379
26	2050	408 083,4
27	2051	413 787,8
28	2052	419 492,2
29	2053	425 196,6
30	2054	430 901
31	2055	436 605,4
32	2056	442 309,8
33	2057	448 014,2
34	2058	453 718,6
35	2059	459 423
36	2060	465 127,4

2.6.2. Projection of Energy Consumption

The energy deficit, defined as the difference between the energy supplied to the commune and its energy needs, amounts to 51.6 GWh per month. For the commune of N'zérékoré, this deficit is assessed at 12.8 GWh, which represents 24.8% of the commune's total energy requirements.

An analysis of the reports provided by the statistical and housing service of N'zérékoré indicates that the population of the commune evolves linearly. According to the literature [5-6], we can perform a projection based on the extrapolation of existing trends. The projected population is calculated using the following relation.

Table 11. *Energy consumption projection of the urban commune of N'Zérékoré from 2024 to 2060.*

N	Mn	Pn (GWh)	Cn (GWh)	Sum (GWh)
2024	51 954	29,29	22,31	51,6
2025	53 094,68	32,219	24,541	56,76
2026	54 235,56	35,44	26,9951	62,4351
2027	55 376,44	38,985	29,6946	68,6796
2028	56 517,32	42,88	32,6641	75,5441
2029	57 658,2	47,172	35,93051	83,10251
2030	58 799,08	51,8892	39,52351	91,41271
2031	59 939,96	57,07812	43,47551	100,55363
2032	61080,84	62,78612	47,82351	110,60963
2033	62221,72	69,06512	52,60551	121,67063
2034	63362,6	75,97212	57,86651	133,83863
2035	64503,48	83,56912	63,65351	147,22263
2036	65643,4	91,92612	70,01851	161,94463
2037	66785,24	101,11912	77,02051	178,13963
2038	67926,12	111,23112	84,72251	195,95363
2039	69067	122,35412	93,19451	215,54863
2040	70 207,88	134,59412	102,51351	237,10763
2041	71 348,76	148,05412	112,76451	260,81863
2042	72 489,64	162,85912	124,04051	286,89963
2043	73 630,52	179,14512	136,44451	315,58963
2044	74 771,4	197,06012	150,08851	347,14863
2045	75 912,28	216,76612	165,09751	381,86363
2046	77 053,16	238,44612	181,60731	420,05343
2047	78 194,04	262,2861	199,76831	462,05441
2048	79 334,92	288,51612	219,74531	508,26143
2049	80 475,8	317,36612	241,72031	559,08643
2050	81 616,68	349,10612	265,89231	614,99843
2051	82 757,56	384,01712	292,48131	676,49843
2052	83 898,44	422,41912	321,72931	744,14843
2053	85 039,32	464,66112	353,90231	818,56343
2054	86 180,2	511,13112	389,29231	900,42343
2055	87 321,08	562,24412	428,22231	990,46643
2056	88 461,96	618,46812	471,04431	1 089,51243
2057	89 602,84	680,31812	518,14831	1 198,46643
2058	90 743,72	748,34992	569,96331	1 318,31323
2059	91 884,6	823,14812	626,95931	1 450,10743
2060	93 025,48	905,50	689,65531	1 595,15843

Where Mn, Pn and Cn in Table 11 are respectively the number of households in year n, the residual sector consumption in year n and tertiary and semi-industrial consumption in year n.

3. Results and Discussions

3.1. Estimation in 2024

First, we present in Figure 3 the population growth over the past ten years.

It can be observed that over the past ten years, the population of the commune of N'zérékoré has increased by approximately 21.96%. In 2024, it accounts for 49.2% of the total population of the forest region. Figure 2 illustrates the population growth of the urban commune of N'zérékoré over the last decade.

Figures 4 to 5 present the models for tertiary and semi-industrial consumers in the urban commune of N'zérékoré, indicating the types of devices used in each category.

Figure 6 shows the estimated electricity consumer category for the entire.

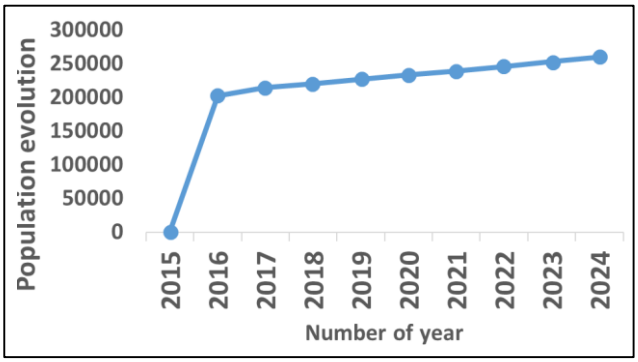
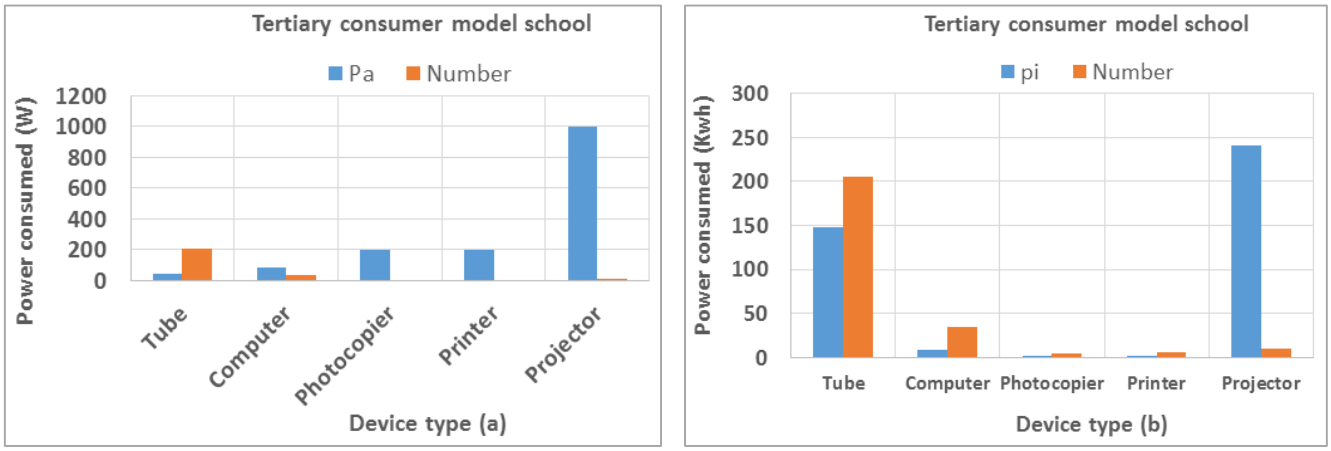
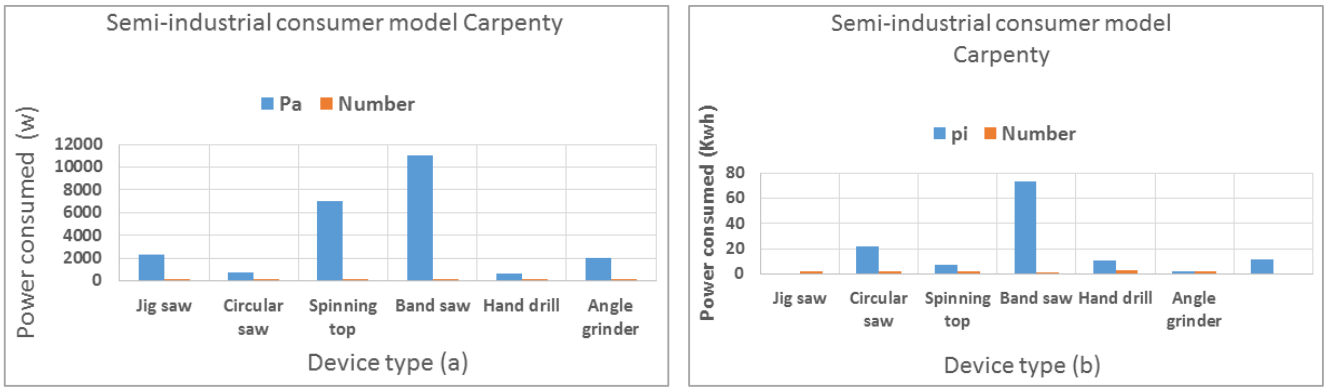


Figure 3. *Population evolution of the urban commune of N'zérékoré over the last ten years.*



(a) (b)

Figure 4. *Energy consumption by device for tertiary consumer model: a) apparent power, b) intern power.*



(a) (b)

Figure 5. *Energy consumption by device for semi-industrial consumer model: a) apparent power, b) intern power.*

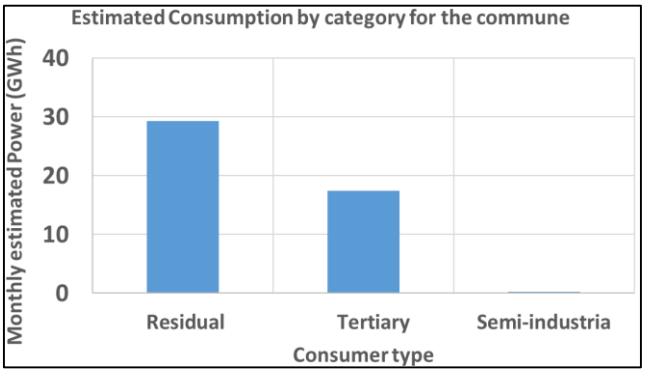


Figure 6. *Estimated electricity consumer category for the urban commune of Nzérékoré.*

3.2. Projection from 2024 to 2060

Figure 7 indicates the number of household's evolution from 2024 to 2060 in the urban commune of N'zérékoré.

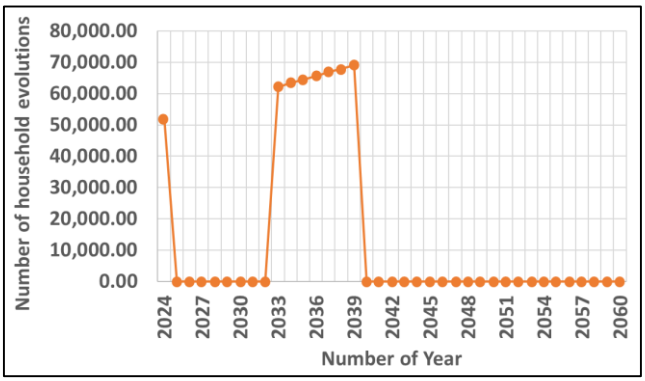


Figure 7. *Number of household's evolution from 2024 to 2060 in the urban commune of N'zérékoré.*

Finally, Figure 8 illustrates the demographic projection of the urban commune of N'zérékoré from 2024 to 2060.

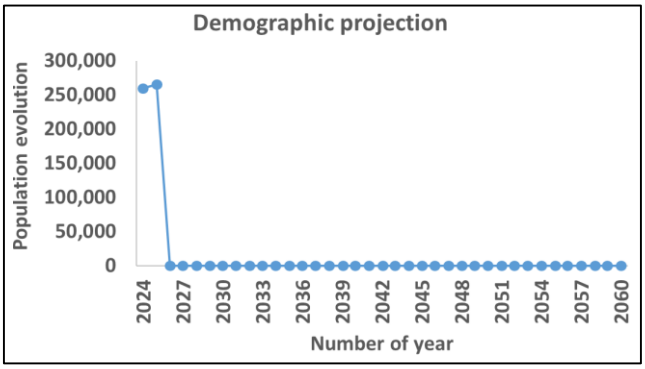


Figure 8. *Demographic projection of the urban commune of NZerekore from 2024 to 2060.*

Figure 9 presents the projected energy consumption of the urban commune from 2024 to 2060.

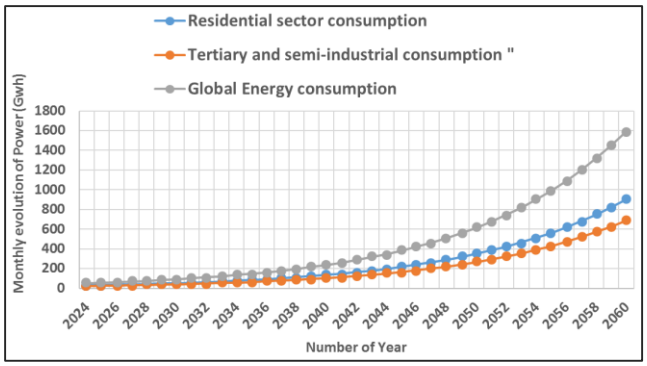


Figure 9. *Energy consumption projection of the urban commune of NZérékoré from 2024 to 2060.*

4. Conclusions

This research allowed designing an energy consumption projection model by 2060 for the urban commune of Nzérékoré. Doing that, the model took into account the different types of consumers-Industrial consumers; -semi-industrial consumers, -tertiary consumers and residential consumers. The energy need for the commune according to the number of population in 2024, the population and energy consumption of the urban commune of N'zérékoré were evaluated. Secondly, a projected population for 2060 was calculated, along with an energy consumption projection for the commune from 2024 to 2060.

Finally, it was found that the commune's consumption is 53.89 MW, or 38.8 GWh per month, while the estimated energy need for the same year amounts to 51.6 GWh. Population growth continues to increase energy demand year by year. If production remains static, by 2060 the commune's energy needs will reach 1,595.16 GWh, leading to a deficit of 1,543.56 GWh.

Abbreviations

HTB	High Voltage Category B
HTA	High Voltage Category A
$P_{f,}$	Power Supplied by the Transformer
Δ	Power Distribution Rate in the Commune
P_c	Power Consumed by the Commune with
Pj	The Tip on the Feeder
Ku	Usage Coefficient
Tu	Usage Time
Tp	Device Ownership Rate Per Household
Pa,	Power of Device
Pi (ti)	The Energy Consumed Per Unit of Time
Pi	The Projected Population
$P_{t,}$	The Starting Population

$P_{o,}$	Initial Population (Base Period)
P_b,	Number of Years in the Base Period
y,	Number of Projection Years (Between Start Year and End Year of Projection)
t,	Number of Households in Year n
Mn	The Residual Sector Consumption in Year n
Cn	Semi-industrial consumption in year
Pn	Tertiary consumption in year n

Author Contributions

Mamady Sangaré: Conceptualization, Resources, Conceptualization, Formal Analysis, Funding acquisition, Investigation

Oumar Keita: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing

Mohamed Rafi: Conceptualization, Investigation, Supervision, Formal Analysis, Investigation, Methodology, Validation

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Data Availability Statement

The data used or analyzed in this study can be available upon request. Contact the corresponding author if needed.

Conflicts of Interest

The authors declare no conflicts of interest.

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