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Energy Efficiency in Periods of Load Shedding and Detrimental Effects of Energy Dependence in the City of Maroua, Cameroon

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Abstract

During the years 2021 and 2022, the city of Maroua experienced repeated power blackouts. However, this locality has significant photovoltaic energy potential. Nevertheless, the evaluation of the electrical performance showed the dependence of the population on these fluctuations, which could be bypassed or suppressed. In most cases, the blackout occurs during high energy demand. In this paper, a method for evaluating electrical efficiency is proposed and its credibility has been demonstrated on the one hand, and on the other hand, a renewable energy production system is proposed. The Homer software has made possible the analysis of the proposed system and its impact on the environment has also been carried out. The techno-economic study of the system has proved that a solar photovoltaic farm associated with an energy storage system, with a capacity of 47 MW, can meet the energy demand of the town of Maroua. This alternative is profitable for this locality which lives in a precarious situation and a continuous need.

Keywords

Energy Efficiency, Load Shedding, Detrimental Effects, Maroua Cameroon

1. Introduction

The survey of electric power consumers in Maroua is the result of an investigation following several complaints. The use of diesel fuel is a source of significant losses for the government, which spends a lot of funds on the purchase of diesel fuel. In addition, diesel fuel is an important source of greenhouse gas production. Although the Lagdo dam produces energy, it does not meet the needs of all localities, especially Maroua, which has a high demography. This is why the energy company in Cameroon, ENEO, proceeds to temporary power outages, and many blackouts are also observed. However, based on statistical analysis, load shedding is beneficial to the provider while the consumer is penalised. The locality of Maroua has the potential for photovoltaic energy. Therefore, it is important to address these issues in this work, to avoid dependence on suffering and load shedding, and to propose an alternative [1]. Indeed, analysis of the sample meters showed that load shedding has perverse effects on the customer: it obliges the customer to consume almost the same amount at an imposed period and waste is recorded each time the power is restored in the absence of the customer. Appliances that remained connected are running all night while the offices are empty of occupants. From the studies and the collection of statistical data made from consumers and the electric energy provider in Cameroon named ENEO and based on energy efficiency, the data are as follows: 44.8% of customers have higher bills during load shedding while 1.5% of customers pay the amount. 53.7% of customers experience a slight decrease in the bill. This category of customers is made up of businesses where there is a constant human presence and an autonomous power source is available.

Load shedding is becoming a permanent reality in Cameroon [2] [3] [4] despite the increase in energy supply. Demand seems to be growing too fast [5]. Beyond the multiple harms that load shedding causes to customers, its overall impact is so immense and diverse. Curiously, there is little or no change in electricity bills. This means in effect that the energy supplier loses nothing by carrying out load shedding. On the contrary, it gains a great deal by avoiding the obligation to manage evening peaks. This seems to justify the systematic use of load shedding since only customers seem to suffer. This study is based on the observation that the amount of the monthly electric energy bill does not change despite load shedding. The first step is to collect data from the bills of a sample of subscribers and to proceed with the analysis of the sample in order to proceed with a comparative analysis. Since the observation made is very likely, the second part of the study will be devoted to the search for reasons that would justify this constant in energy consumption despite the load shedding whose monthly duration is close to half time. From the elements that explain the phenomenon, we will be able to identify tips to reduce the unnecessary consumption of electrical energy [6] in the context of load shedding.

It is obvious to make decisions on the choice of sources through two scenarios. The efficiency of each model is obtained through the study of economic [7] [8] [9], technical and environmental [10] aspects.

- Scenario 1:

  Depend on the energy company and expect satisfaction

- Scenario 2:

Seek an alternative to the national energy supplier, in order to satisfy the energy demand in households.

2. Materials and Methods

To confirm or refute the first research hypothesis, the bills of the sampled customers should be collected. Alternatively, collect initial and final meter readings from these customers for a 90-day period during the permanent supply period [11] and the same 90 days during the load shedding period.

A collection form (**Table 1**) designed for the purpose was used by the team members.

Let be IP_{0k} and IP_{1k} the start index (0) and the final index (1) taken during the permanent supply (*P*) on a meter *k*. We will note EP_k the energy consumed during the permanent supply period.

$$EP_k = IP_{1k} - IP_{0k} \tag{1}$$

The load shedding is evaluated using a rate defined by Equation (2).

$$\tau_d = \frac{T_0}{T} \tag{2}$$

where T is the load shedding period.

Let be ID_{0k} and ID_{1k} the start index (0) and final index (1) readings during the load shedding season (*D*) on the same *k* meter. We will also note ED_k is the energy consumed during the load shedding period. The Data collection sheet is presented in **Table 1**

$$ED_k = ID_{1k} - ID_{0k} \tag{3}$$

The difference ∂_k between the two variables represents the difference between the bill for permanent supply and the bill for interrupted supply or load shedding.

$$\partial_k = EP_k - ED_k = \left(IP_{1k} - IP_{0k}\right) - \left(ID_{1k} - ID_{0k}\right) \tag{4}$$

$$\partial_k = \left(IP_{1k} + ID_{0k}\right) - \left(ID_{1k} + IP_{0k}\right) \tag{5}$$

∂_k can be positive, zero or negative. Ideally, it should be positive and $\approx \tau EP_k$ where τ is the load shedding ratio; it is the ratio of the sum of the load shedding durations $\sum t_D$ over a period of time *T*. In this case, *T* represents 90 days.

$$\tau = \frac{\sum t_D}{T} \tag{6}$$

Table 1. Data collection sheet.

Power Meter	Location	**Type of Customer**	Normal Supply Period				Load Shedding Period			
			Start Index IP_0	Date of Index Score	Final Index IP_1	Date of Index Score	Start Index ID_0	Date of Index Score	Final Index ID_1	Date of Index Score

If ∂_k is close to zero, it is because load shedding only harms the customers, not the supplier. The case ∂_k where is negative is a catastrophic scenario. This would mean that the customer pays more when they are offloaded.

∂_k can take different values depending on the customer's behavior. To assess the overall impact of ∂_k, it must be evaluated on the sample of N counters or customers counted. Let ∂ be the overall difference between what the supplier charges in during load shedding and outside, so an estimate can be obtained by the following expressions:

$$\partial = \sum_{k=1}^{N} \partial_k = \sum_{k=1}^{N} EP_k - \sum_{k=1}^{N} ED_k \tag{7}$$

Equation (4) and Equation (5) allow us to write:

$$\partial_{kG} = \sum_{k=1}^{N} \left(IP_{1k} + ID_{0k}\right) - \sum_{k=1}^{N} \left(IP_{0k} + ID_{1k}\right) \tag{8}$$

∂_{kG} represents the overall difference.

This data can be inserted into an application so that the arithmetic operations related to Equations (1), (2), (3) and (5) are calculated automatically.

3. Results

The results obtained are extracted from the analysis of the customers using an on-site survey before being proven by an extrapolation of the electrical energy demand. The data collected is then implemented in HOMER for a technical, economic and environmental study.

3.1. Proposed System

The model of the system proposed as an alternative is presented in **Figure 1**. This system is formed with a photovoltaic source, a storage battery and an inverter.

3.2. Distribution According to the Sign of the Index ∂_k

After collecting the data (87 subscribers) and entering it into the table, the index is calculated and ranked in ascending order of index value ∂_k (**Table 2**). The customers can be divided into 3 groups according to **Table 3**.

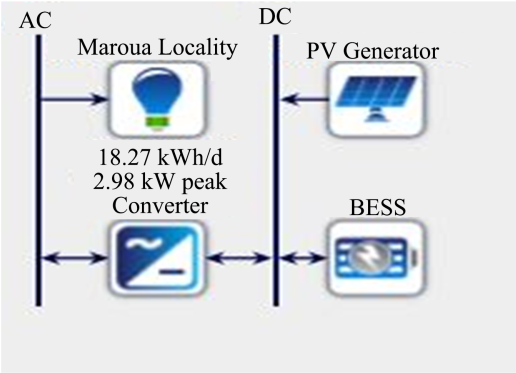

Figure 1. Model of proposed system.

Table 2. Index values.

N°	Customers	IP_{0k}	IP_{1k}	Ep_k	ID_{0k}	ID_{1k}	ED_k	∂_k
1	HOSPITAL	6587	7934	1347	9281	10,720	1439	−92
2	HOSPITAL	4200	5685	1485	7170	8742	1572	−87
3	HOUSEHOLD	4761	5028	267	5295	5643	348	−81
4	HOUSEHOLD	4258	4831	573	5404	6052	648	−75
5	MAYOR'S OFFICE	2830	4471	1641	6112	7816	1704	−63
6	DRINKING BAR	4890	5217	327	5544	5930	386	−59
7	TECHNICAL SCHOOL	4280	5726	1446	7172	8677	1505	−59
8	DELEGATE. DEPART.	6650	6944	294	7238	7589	351	−57
9	HOUSEHOLD	6360	6906	546	7452	8052	600	−54
10	HOUSEHOLD	1685	2336	651	2987	3690	703	−52
11	MAYOR'S OFFICE	4198	6061	1863	7924	9837	1913	−50
12	TECHNICAL SCHOOL	2925	4935	2010	6945	9001	2056	−46
13	FSEG-UMA	5020	6538	1518	8056	9612	1556	−38
14	DELEGATE. DEPART.	6276	6765	489	7254	7779	525	−36
15	MAYOR'S OFFICE	1177	2500	1323	3823	5178	1355	−32
16	RESTAURANT	1612	1957	345	2302	2670	368	−23
17	HOSPITAL	1386	3015	1629	4644	6295	1651	−22
18	RESTAURANT	417	729	312	1041	1375	334	−22
19	HOSPITAL	1597	3451	1854	5305	7180	1875	−21
20	DRINKING BAR	6266	6758	492	7250	7759	509	−17
21	GENERAL HIGH SCHOOL	5625	6840	1215	8055	9287	1232	−17
22	GENERAL HIGH SCHOOL	1823	3575	1752	5327	7095	1768	−16
23	TECHNICAL HIGH SCHOOL	740	2036	1296	3332	4644	1312	−16
24	FSEG-UMA	435	2526	2091	4617	6722	2105	−14
1	ENSPM	1248	3276	2028	5304	7342	2038	−10
2	SHOP	2018	2582	564	3146	3718	572	−8
3	FASHION	4819	5218	399	5617	6023	406	−7
4	DELEGAT. DEPART.	1795	2191	396	2587	2990	403	−7
5	FS-UMA	1751	3143	1392	4535	5934	1399	−7
6	DELEGAT. DEPART.	1606	1942	336	2278	2615	337	−1
7	SHOP	6278	6744	466	7110	7576	466	0
8	SHOP	1033	1525	492	2017	2507	490	2
9	PRIVATE COLLEGE	2140	2902	762	3664	4424	760	2

Continued

10	DELEGATE. DEPART.	6715	7324	609	7933	8540	607	2
11	HOUSEHOLD	3041	3347	306	3653	3957	304	2
12	ENSPM	6878	8867	1989	10856	12841	1985	4
13	WELDER	683	1118	435	1553	1983	430	5
14	HOME	2492	2960	468	3428	3890	462	6
15	PHARMACY	2443	4321	1878	6199	8071	1872	6
16	INFO SERVICE	4330	4765	435	5200	5629	429	6
17	WELDING	4143	5238	1095	6333	7419	1086	9
18	BAKERY	1218	1603	385	1948	2323	375	10
1	LIQUOR STORE	2157	2613	456	3069	3513	444	12
2	DRINKING ESTABLISHMENT	1109	1349	240	1589	1815	226	14
3	RESTAURANT	4258	4771	513	5284	5783	499	14
4	BAKERY	6950	7310	360	7670	8014	344	16
5	HOTEL	4025	5660	1635	7295	8912	1617	18
6	HOME	5434	5842	408	6250	6639	389	19
7	SAWMILL	4788	6072	1284	7356	8621	1265	19
8	HOME	6690	6939	249	7188	7417	229	20
9	PRIVATE COLLEGE	1790	2291	501	2792	3272	480	21
10	GENERAL HIGH SCHOOL	5491	7399	1908	9307	11,194	1887	21
11	SAWMILLS	3347	4220	873	5093	5943	850	23
12	MAIRIE	5127	6504	1377	7881	9229	1348	29
13	WELDING	4412	5114	702	5816	6485	669	33
14	SEWER	3819	4329	510	4839	5308	469	41
15	RESTAURANT	4828	5407	579	5986	6523	537	42
16	INFO SERVICE	4355	5243	888	6131	6977	846	42
17	INFO SERVICE	3339	4821	1482	6303	7740	1437	45
18	PRIVATE COLLEGE	6926	7478	552	8030	8535	505	47
19	COUTURE	3738	4242	504	4746	5202	456	48
20	SAWMILL	4182	5376	1194	6570	7710	1140	54
21	SHOP	1225	1719	494	2193	2626	433	61
22	PHARMACY	4956	6183	1227	7410	8576	1166	61
23	HOTEL	6626	8042	1416	9458	10,808	1350	66
24	HOTEL	1672	3394	1722	5116	6762	1646	76
25	PHARMACY	5435	7141	1706	8647	10,223	1576	130

Table 3. Distribution according to the sign of the index ∂_k.

Groups	∂_k	Number of subscribers	Fraction
1	Negative and <−10	24	35.82%
2	Null of nearer	18	26.87%
3	Positive and >10	25	37.32%
Total		67	100%

Figure 2 shows the fraction of energy consumed in households during load shedding periods. A fraction of 83.83% represents the dependence on energy during load shedding periods.

Figure 3 shows the behavior of households or inhabitants for one day. Two attitudes are presented: the behavior of households in normal times and in times of load shedding. This figure shows a high energy demand during load shedding.

The observation of customers classified in the different groups shows that customer behaviour towards load shedding varies according to whether they are:

1) Public utility;
2) Residential utility;
3) Manufacturing company;
4) Commercial utility.

It can also be seen that while some customers resign themselves to load shedding, others change their working habits and a certain minority acquire an alternative source of electricity, either for minimal service or for all loads.

3.3. Alternative against Energy Dependency

Figure 4 shows the possibility of energy production from a photovoltaic source. This photovoltaic generator associated with an energy storage system is capable of producing sufficient energy for the town of Maroua with a surplus of energy.

When we look at the different data provided during the year in **Figure 5**, we can see that the monthly power profile clearly shows that the photovoltaic energy deposit is sufficient to produce electricity. These values are provided by the Homer software that extracts the NASA meteorological data [11] for the locality of Maroua. The analysis of these data guarantees the feasibility and the economic and environmental impact.

Figure 6 shows the daily power profile as a function of sunlight availability in the city of Maroua.

The power profiles presented in **Figure 7** show us that the proposed system meets the energy demand. It is obvious from **Figure 4**, **Figure 5** and **Figure 7** that a photovoltaic source is an alternative with good energy efficiency.

Many solutions against load shedding are given in these last decades [12] [13] [14]. The use of a hybrid photovoltaic and wind power source is proposed as a solution [15] [16]. In the same way, integration of wind power plants into the electrical grid can be also a solution. When considering all of these works, the issue of load shedding is not considered as an important parameter of investigation. That is the reason why a specific area is selected to evaluate the energy efficiency.

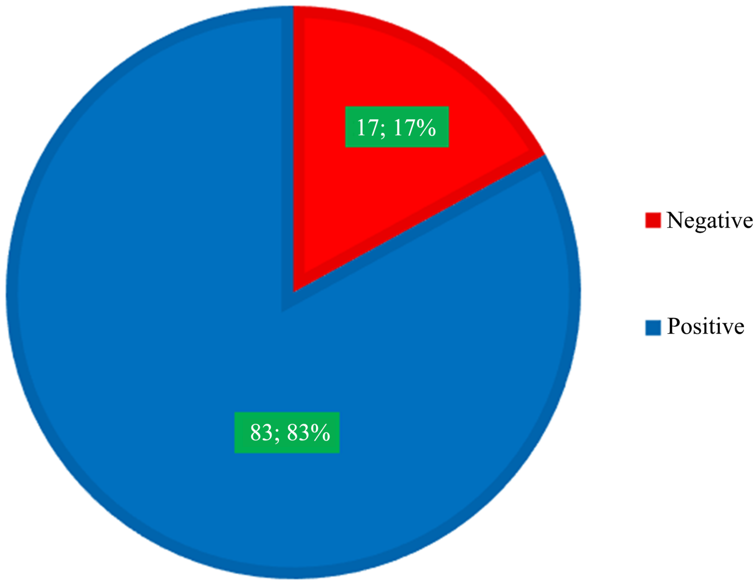

Figure 2. Fraction of energy for a month.

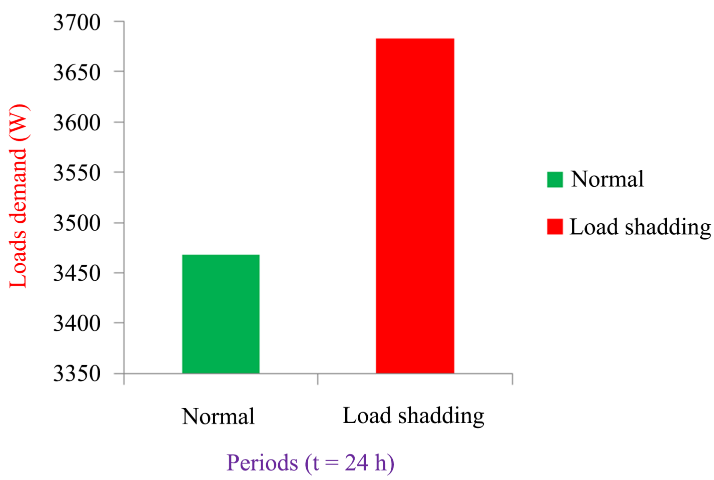

Figure 3. Households behavior.

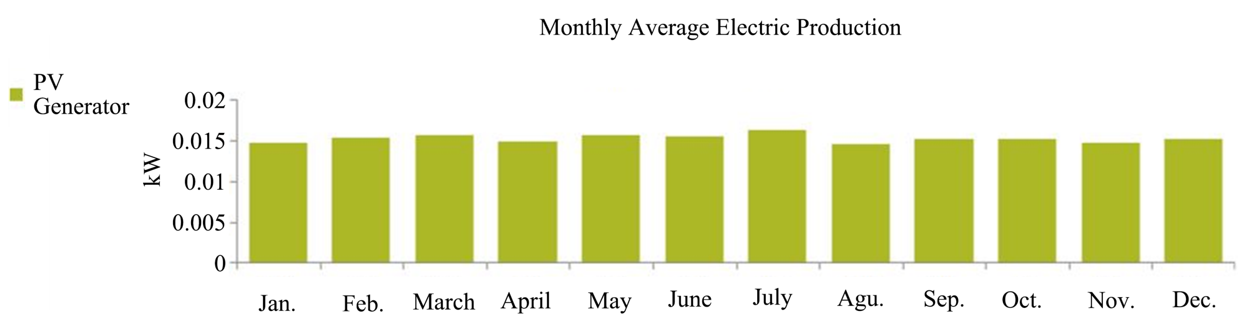

Figure 4. Power generated by the proposed system.

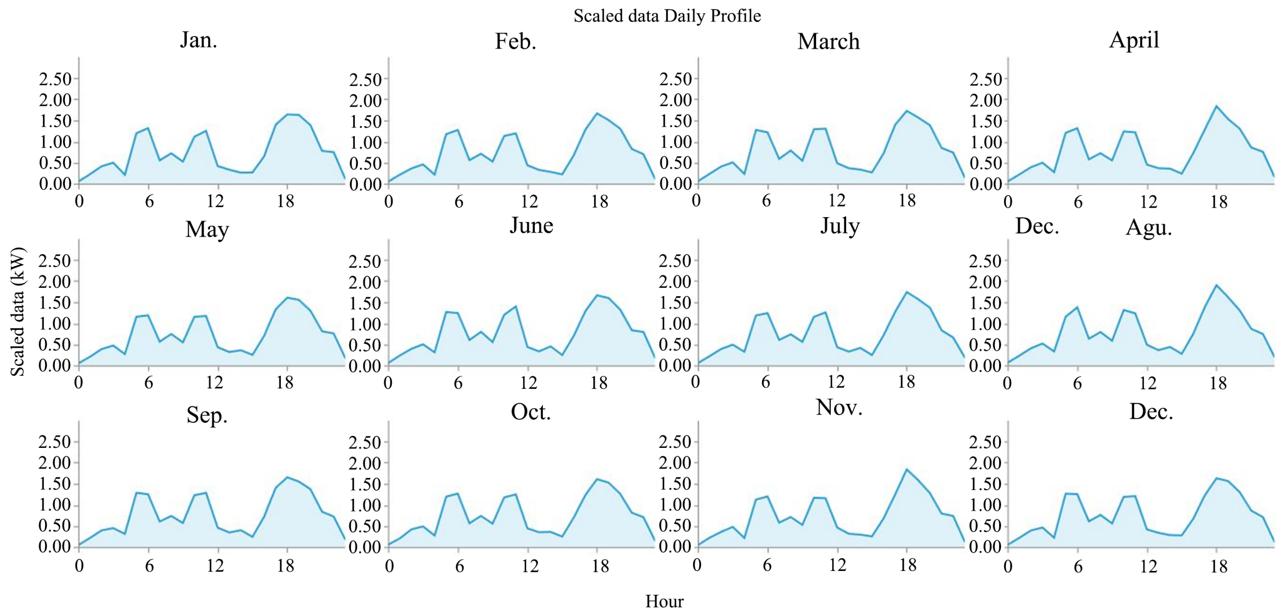

Figure 5. Daily power profile during a year.

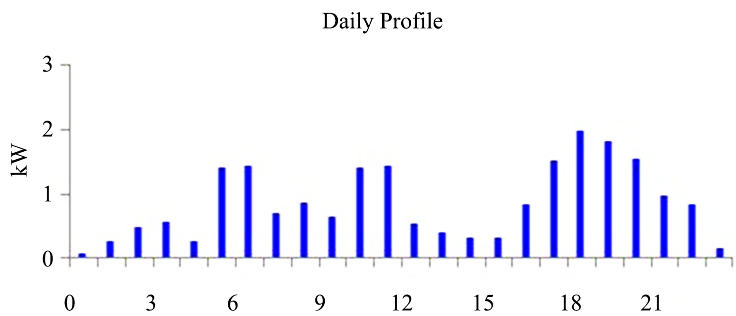

Figure 6. Daily power profile in Maroua locality.

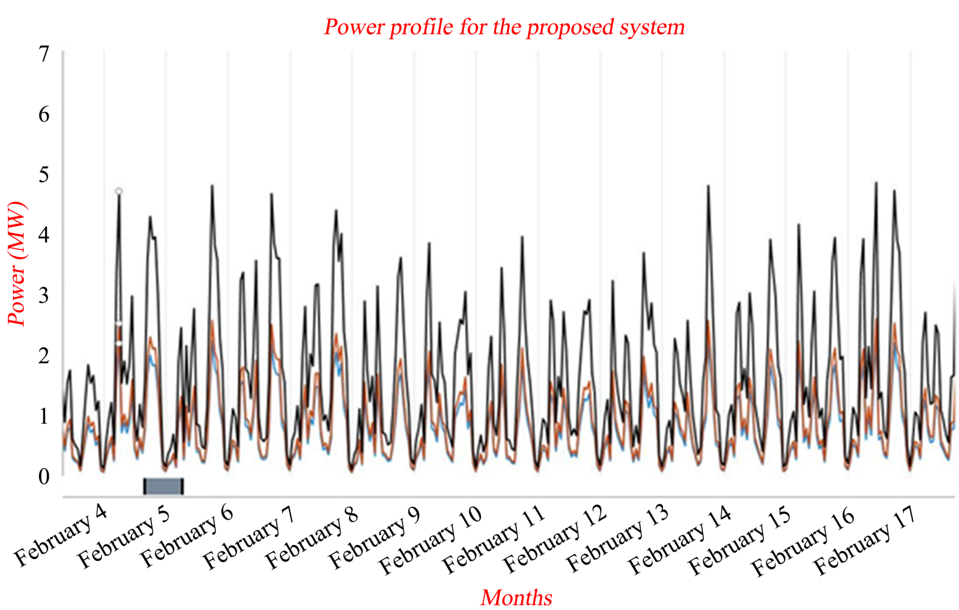

Figure 7. Power profile for Maroua locality.

4. Conclusion

Ultimately, it can be said that load shedding continues because the energy supplier gains more than it loses. Since peak load management involves a source of fuel expenditure, the customer and the national economy appear to be sacrificed economically. However, the use of a photovoltaic source with energy storage can satisfy the locality of Maroua for a capacity of 47 MW. Photovoltaic systems are not responsible for the production of carbon dioxide, unlike the use of thermal power plants. The maintenance of these systems is easy. The city of Maroua has a large amount of sunshine that can be exploited. This is why Scenario 1 is an alternative to be adopted.

Ethical Approval

The Manuscript is not submitted to any other journal, and it is not published in any previous paper.

Conflicts of Interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of Data and Materials

The data used during the current study are available from the corresponding author upon reasonable request.

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