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Research Article

A Breakthrough for Photovoltaic Solar Energy in the Energy Mix: The Case of Rural Electrification in the Northern Part of Cameroon

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Abstract

Many countries in sub-Saharan Africa, such as Cameroon, face major challenges in terms of access to electricity, particularly in rural areas. A large proportion of the rural population does not have access to a reliable source of energy, which limits the economic and social development of these regions. Existing conventional energy sources, such as hydropower or oil-fired power plants, are often unsuitable for remote areas due to high transport and infrastructure costs. Cameroon enjoys abundant sunshine throughout the year. The government of Cameroon has therefore identified solar PV as a promising option for the rural electrification of 1,000 villages. Of the 350 solar power plants already delivered, the North of Cameroon has received 92 plants, representing 72% (38341.8 kWp) of the country's solar installations and 20% of the region's electricity supply in its energy mix, if we include the 2 large solar power plants in Guider and Maroua, each with a capacity of 15 MWp. Approximately 2,21712 rural households could therefore have access to electricity, with an average per capita energy supply of between 431 and 578 kWh/inhabitant/year in the rural areas benefiting from the first and second phase installations, compared to an estimated national average consumption of 280 kWh/inhabitant/year.

Keywords

Rural Electrification, Photovoltaic Solar Energy, Electricity Access Rate, Coverage Rate

1. Introduction

Rural electrification is defined as the percentage of the rural population with access to electricity, which promotes the socio-economic, environmental and health development of the locality [1-4]. Access to electricity in rural areas is generally limited in developing countries, where sustainable development strategies should be based on rural electrification [5, 6]. 70% of people in sub-Saharan Africa do not have access to electricity, and the number is increasing as electrification efforts continue to follow the rhythm of population growth [7]. However, the importance of access to electricity is recognised in Goal 7 of the Sustainable Development Goals, which aims to ensure that everyone has access to reliable, modern and affordable energy services by 2030. There is therefore an urgent need to find an effective and sustainable rural electrification model for Africa. The infrastructure to be deployed requires significant funding and large-scale planning capacity in rural areas, which are sometimes far from the national grid and have low population densities that under-

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mine the economic viability of these projects [8].

Cameroon launched a national thermal emergency program in 2010 to address recurrent load shedding. The Cameroon Rural Electrification Agency (REA), the public institution responsible for promoting and developing rural electrification throughout the country, is now considering dismantling the thermal power plants installed in certain localities and replacing them with solar power plants. The reasons for this planned change are complaints from the electricity supplier *The energy of Cameroon* (Eneo) about the cost and pollution of the fuel [9]. The running costs of the thermal power plants installed in the northern regions of Cameroon, for example, cost CFA francs (CFAF) 13 billion per year [10]. In this context, the development of decentralised solutions for access to electricity could include the use of renewable energy, particularly solar energy, given its abundance and availability. The government of Cameroon understands this so well that in 2017 it launched a major project to electrify 1,000 rural communities across the country using solar energy. We'll take stock of phases 1 and 2 of this project, which have already been completed.

2. Materials and Methods

2.1. Study Area

The northern part of Cameroon extends between the latitude 6˚N and 13˚N and between longitude 11˚E and 16˚E and includes the Adamawa, North and Far North administrative regions. Its area is approximately 164,037 km^2, or 34.5% of the total national territory. It shares its boundaries with Nigeria, Central African Republic and Chad Republic (Figure 1) [11, 12]. Data for this study was provided by the Rural Electrification Agency of Cameroon.

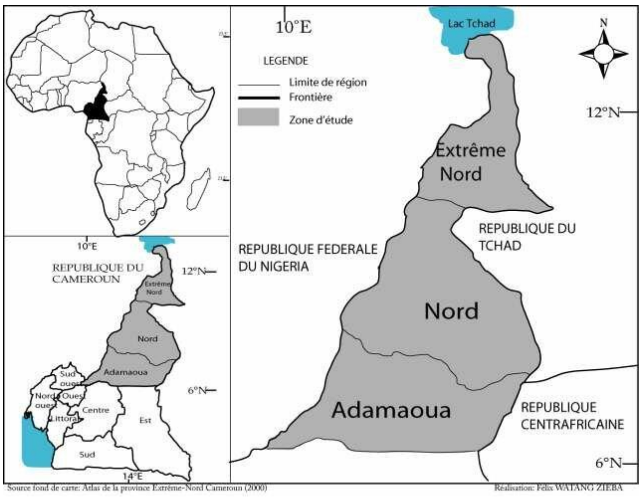

Figure 1. Geographic card of the Northern part of Cameroon [13].

2.2. The Rural Electrification Situation in Cameroon [14]

The current state of rural electrification in Cameroon has indeed been presented through the main indicators selected which are:

1) Coverage rate = Number of electrified localities / Total number of localities
2) Rate of access to electricity = population living in electrified localities / total population.

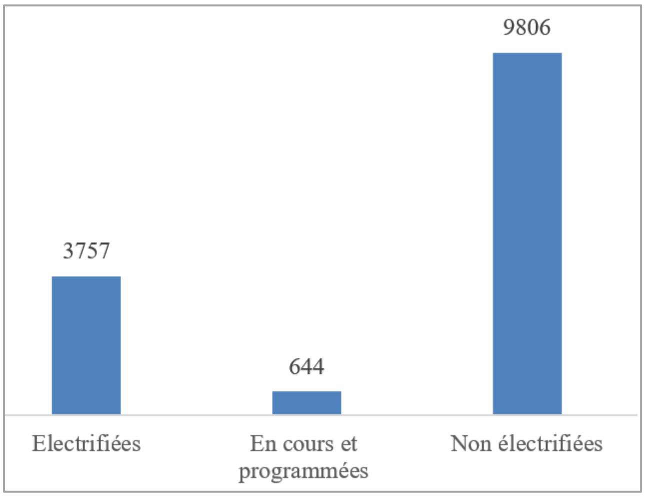

Figure 2. Electric state of 14207 rural localities in Cameroun in 2015 [14].

Of the 14207 rural localities listed in 2015 (Figure 2), 9806 localities are not electrified, a non-coverage rate of 69%.

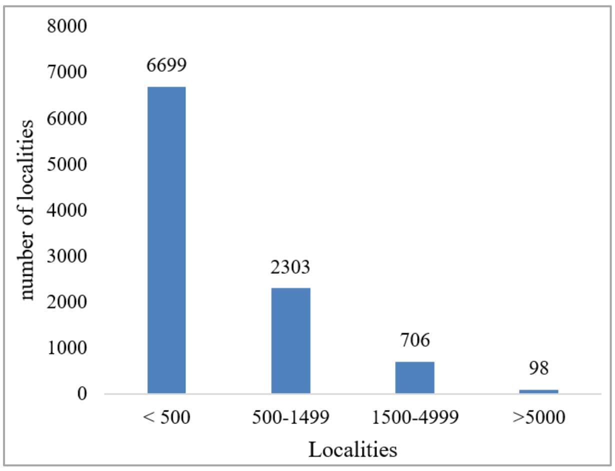

Figure 3. Granulometry of 9806 non-electrified localities (number of localities).

Figure 3 shows that of the 9,806 non-electrified localities with a population of 5.8 million, almost 70% (6,699) are localities with less than 500 inhabitants. They accommodate a population of about 1.4 million and the average size of these localities is 209 inhabitants (Figure 4).

2,303 localities with 1.9 million inhabitants are between 500 and 1,500 inhabitants in size. Their average size is 828 inhabitants.

706 localities with 1.7 million inhabitants are between 1,500 and 5,000 inhabitants, with an average size of 2,397 inhabitants.

Finally, there are only 98 localities with a size of more than 5,000 inhabitants. Their average population is 8,215 out of a total population of 805,000.

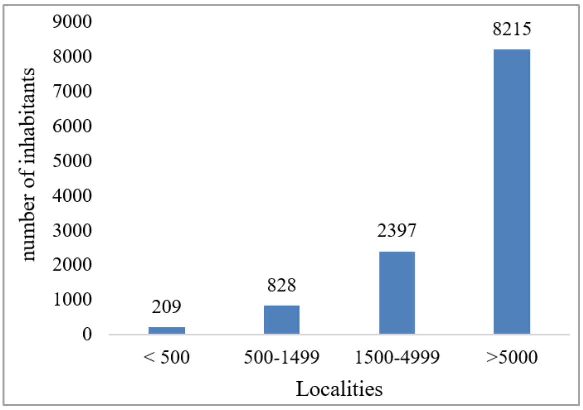

Figure 4. *The average size of 9806 non-electrified localities (number of inhabitants).*

In terms of regional distribution (Figure 5), more than 4 million people without access to electricity live in rural areas in the northern part of the country (Adamawa, North and Far North).

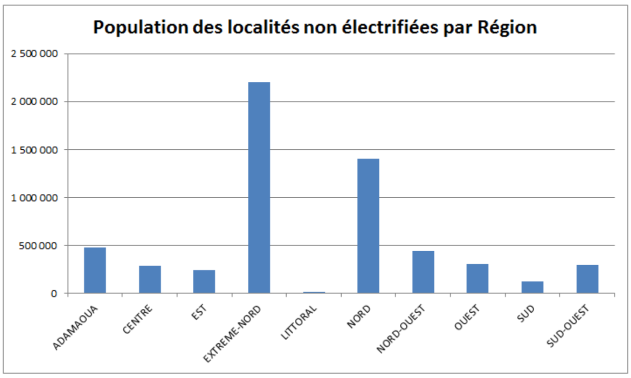

Figure 5. *Populations of the non-electrified localities by region [14].*

2.3. Solar Potential in the North of Cameroon

All regions of Cameroon benefit from significant average annual insolation (Figure 6). It varies from 4.9 kWh/m2/day in the south to 5.8 kWh/m2/day in the northern part of the country, which are characterized by dry and sunny climatic conditions [15-20]. Specifically, Global solar radiation averages 6 kWh/m2/day in the Far North region, 5.8 kWh/m2/day in the Northern region and 5,6 kWh/m2/day in the Adamawa region.

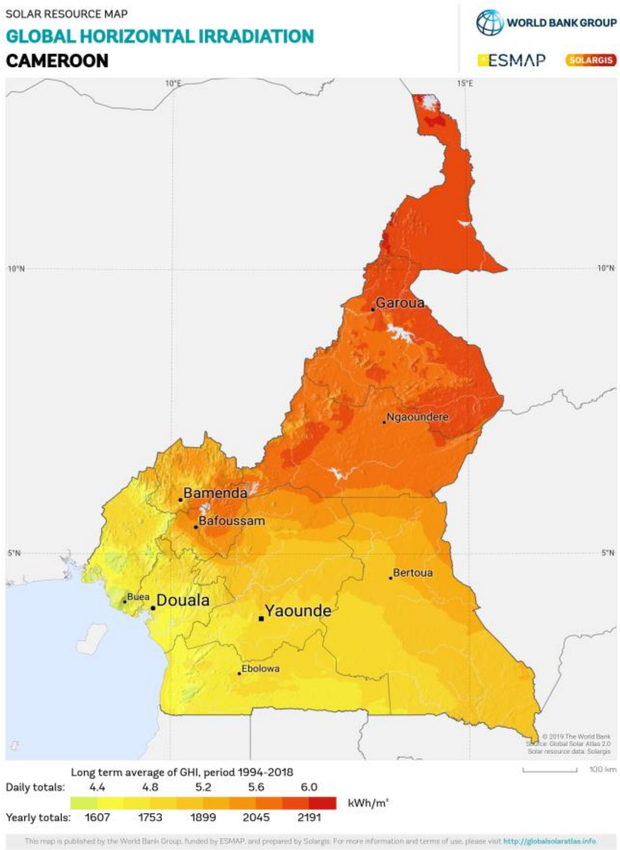

Figure 6. *Solar map of Cameroon [17].*

3. Results

In Phase 1, which started in 2018, the government of Cameroon installed PV solar power plants in 166 villages with a total capacity of 9,940 kWp [21] (Figure 7), with a total annual energy production of around 87 GWh/year. The average energy supply per inhabitant in these villages is therefore 431 kWh/inhabitant per year. It should be noted that only the Far North region was not affected by this phase due to terrorist instability. The Centre region has the largest number of power plants (47) with a cumulative capacity of 2505 kwp (Figure 7).

In Phase 2, 184 villages received the PV solar power systems, with a total installed capacity of 13,003.2 kWp [21] and a total annual energy production of 114 GWh/year (Figure 7). The annual energy supply per inhabitant in these villages is estimated at 578 kWh/inhabitant/year.

The accumulation of the two phases shows that the northern part (consisting of the Adamawa, North and Far North regions) has an installed capacity of 8,341.8 kWp, or 15.75% of the national installed capacity of 22,943.2 kWp (Figure 7).

If we add the two PV solar power plants of Guider in the North Region and Maroua in the Far North Region, each with a capacity of 15 MWp, we end up with an installed capacity of 38341.8 kWp in the northern part of Cameroon, or about 72% of the solar national park's estimated 52943.2 kWp (Figure 8).

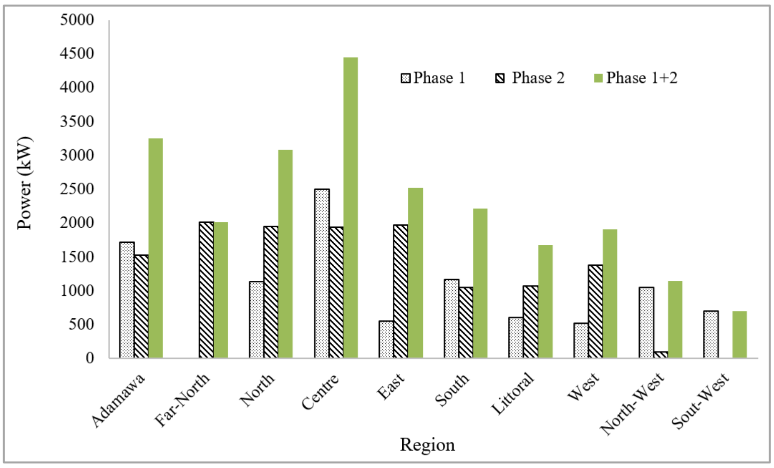

Figure 7. *Installed peak power of PV power plants in rural areas of Cameroon.*

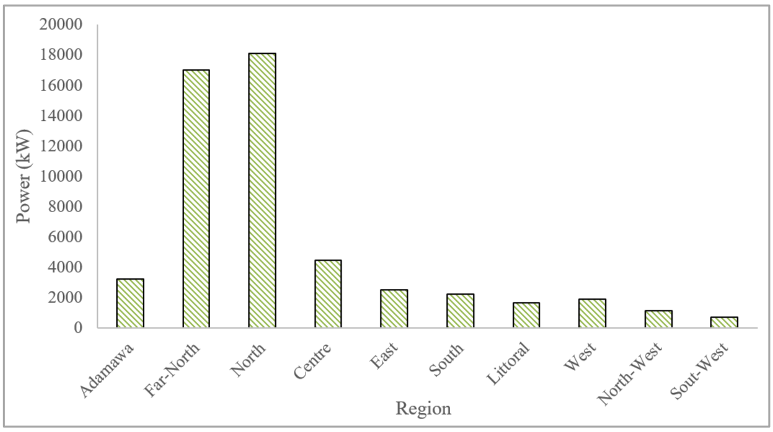

Figure 8. *Installed peak powers of PV power plants in Cameroon.*

The energy balance of the various power plants installed in the northern region shows that The fuel thermal power plants (Banyo, Tibati, Tignère, Ngaoundal, Mbakaou, Ngaoundere, Poli, Touboro, Ndjamboutou, Garoua, Guider, Maroua Aggreko, Maroua Eneo and Kousseri) have an output of 82080 W. The fuel thermal power plants in Banyo, Poli and Touboro should already be hybridized on solar energy by 2022. [9, 22]. The Lagdo and Mbakaou hydroelectric plants have an installed capacity of 73,400 kW.

We therefore note that solar PV accounts for 20% of the electricity park installed in the northern region (Figure 9), while the share of renewable energy in the energy mix in sub-Saharan Africa is 2% [8].

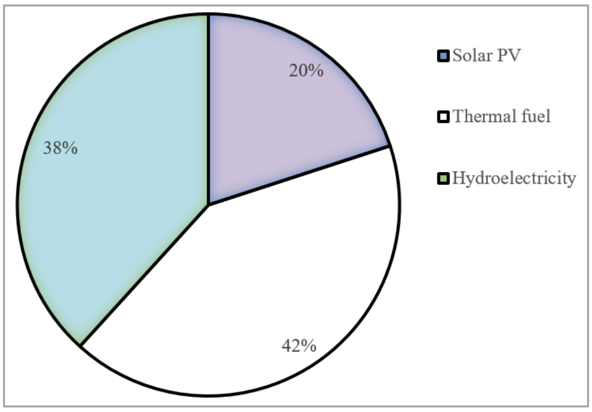

Figure 9. *Electricity balance sheet for the Northern Region of Cameroon.*

Of the 350 solar power plants installed throughout Cameroon in the first two phases of the 1000 villages electrification project, the Northern part received 92 plants (43 in Adamawa, 26 in the North and 18 in the Far North) with a total installed capacity of 8,377.8 kW, of which 3,284.2 kWp in Adamawa, 3,084.8 kWp in the North and 2008.8 kWp in the Far North. The population served is about 173,712 out of 5,683,940 inhabitants living in rural areas: about 6.61% (58,528 inhabitants) of the rural population in the Adamawa region have access to electricity, compared to 4.88% (82,424 inhabitants) in the North region and 1.05% in the Far North region (32,760 inhabitants) (Table 1).

Localities with fewer than 500 inhabitants are not suitable for conventional grid electrification because demand is not high enough to justify the investment in infrastructure. Solar energy is therefore an effective response to this problem, providing access to electricity for around 625 households or 5,000 inhabitants in 13 beneficiary localities (5 in the Adamaoua region, 3 in the North and 5 in the Far North) (Figure 10).

30 localities with a population of between 500 and 1,500 have benefited from solar installations, enabling around 3,765 households, or 3,120 inhabitants, to access the energy services provided by the solar power plants. Agricultural activities are the main characteristic of the rural population living in this class of localities. Access to energy will therefore facilitate their access to certain modern energy services for the promotion and processing of agricultural products, saving time that can be devoted to other activities.

52 localities with a population of between 1,500 and 5,000 benefited from the solar installations, which means that some 15,856 households, or 12,848 inhabitants, will have access to the energy services provided by the solar power plant. These localities are potentially centres of economic activity linked to the rural world, with access to basic education and health care.

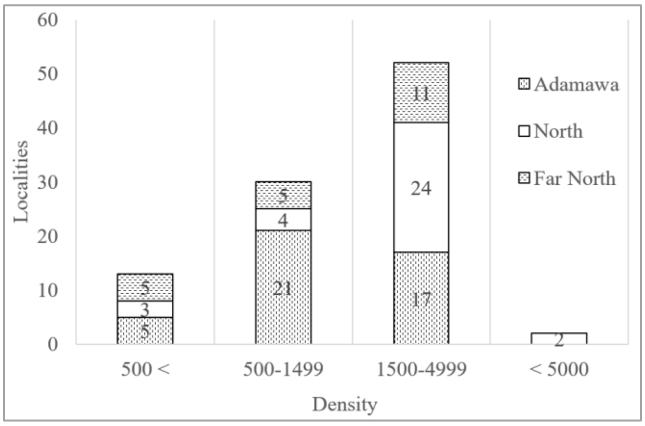

Figure 10. *Number of localities electrified by solar energy in the North of Cameroon.*

Table 1. *Situation of mini-solar power plants installed in rural areas in the North of Cameroon.*

Region	Number of power station	power installed (kWp)	population served	Population in rural area	Percentage of population served (%)
Adamawa	43	3284.2	58528	884289	6.61
North	26	3084.8	82424	1687859	4.88
Far North	18	2008.8	32760	3111792	1.05

In most cases, they host a weekly market, making them focal points on which the surrounding villages depend. Electricity will therefore allow them to have access to modern, affordable and reliable services, which are necessary to boost economic activities, strengthen the health centre and contribute more to children's education.

02 villages with more than 5,000 inhabitants have also benefited from a solar installation, giving around 1,668 households or 1,344 inhabitants access to the energy services provided by these solar power plants. These are relay centres that provide an interface with border towns and a large market. Although they are candidates for conventional electrification, these two localities are far from the conventional electricity grid: the arrival of electricity will enable this class of localities to prosper economically.

The energy map of solar photovoltaic installations in rural areas in the Adamaoua, North and Far North regions of Cameroon is therefore shown in Figure 11.

In contrast to previous studies, which provide a global overview of the solar and photovoltaic potential in a given region, we have presented here an explicit overview of the solar power plants installed in rural areas in the northern part of Cameroon, their share in the energy mix of the northern interconnected grid and the number of people served.

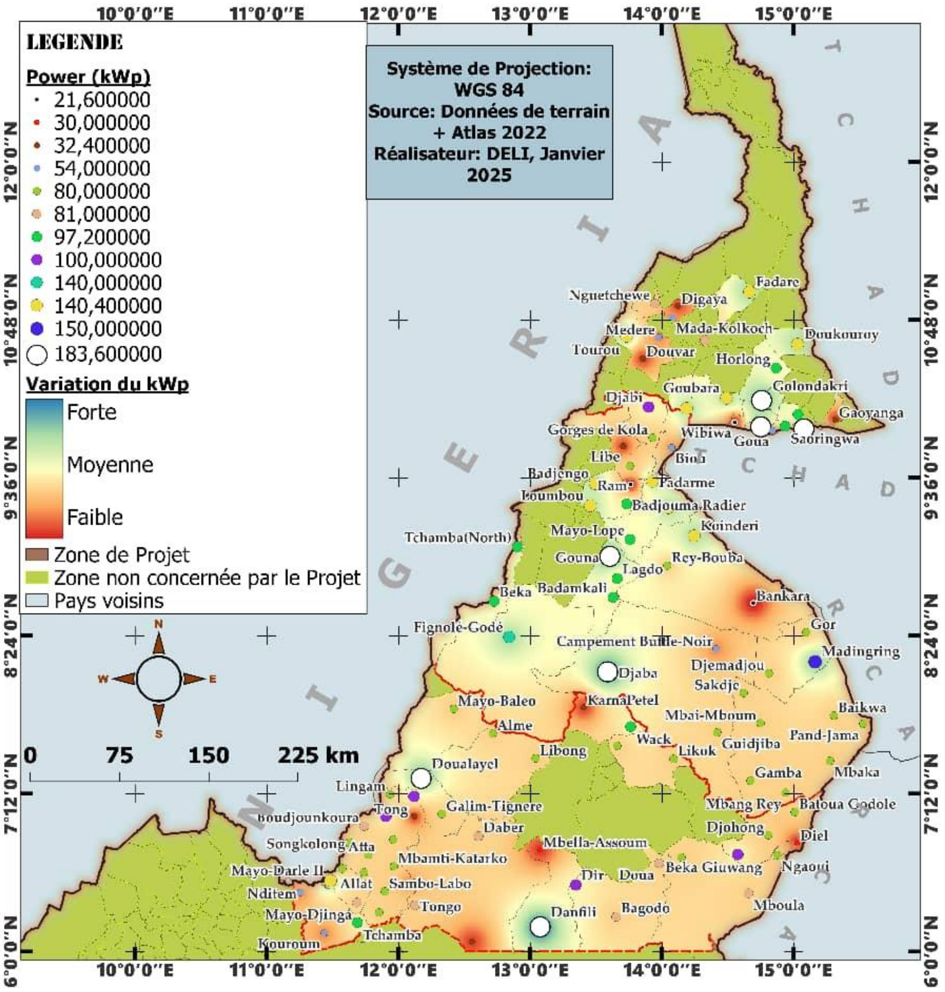

Figure 11. *Energy map of photovoltaic solar installations in rural areas in the Adamawa, North and Far North regions of Cameroon.*

4. Conclusions

The aim of this work was to make an inventory of installed and operational solar power systems in rural areas in the North, Adamawa and Far North regions, which make up the northern part of Cameroon. It seems that:

1) PV solar production covers 20% of the electric park installed in the northern region;
2) The average energy supply per inhabitant is 431 kWh/inhabitant/year in the rural areas that benefited from the installations during the first phase, compared with 578 kWh/inhabitant/year for a national average consumption estimated at 280 kWh/inhabitant/year;
3) The northern region of the country accounts for 72% of the national PV solar installations, estimated at 52,943.2 kWp;
4) Photovoltaic solar production accounts for 20% of the electricity installed in the northern region;
5) Approximately 2,21712 households living in rural areas could have access to electricity supplied by the 92 photovoltaic solar systems installed in the Adamaoua, North and Far North regions of Cameroon.

These results show that there has been a remarkable breakthrough for photovoltaic solar in the energy mix in this part of the country. However, a more in-depth and nationwide study is planned on the installation of the 1,000 solar power plants in the various rural localities and their involvement in social, economic and environmental development. A study will also be carried out on the management of energy supply and demand for these different solar power plants throughout their lifetime, in order to determine whether they are correctly sized.

Abbreviations

Eneo	The Energy of Cameroon
REA	The Cameroon Rural Electrification Agency
CFAF	CFA Francs
kWp	Kilowatt Peak
kWh	Kilowatt Hour
MWh	Megawatt Hour
GWh	Gigawatt Hour

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Author Contributions

Deli Goron is the sole author. The author read and approved the final manuscript.

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

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Biography

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Research Field

Deli Goron: Photovoltaic solar energy, Photovoltaic module shading modelling, Therman solar energy, Flat plate collectors, hydropower, Energy Demand and Supply Study.