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For a better installation of thermal solar collectors in Cameroon

Pour une meilleure installation des collecteurs solaires thermiques au Cameroun

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ABSTRACT:

The sun is the most accessible source of energy on earth. For the development of solar energy in Cameroon, knowledge on solar potential and solar technologies is indispensable. In this work, the average of the solar radiation received annually by various cities (head-quarters of the ten Regions) of Cameroon has been evaluated using the RETScreen software, then the data obtained are used to find out the optimal tilt angle of a thermal solar collector in each region of Cameroon. The results show that in Cameroon, the annual average of insolation varies between 4.43 kWh/m^2/day and 5.88 kWh/m^2/day for an ideal efficiency of the thermal solar collector, the optimal tilt angle would be chosen between 2.5° and 20° depending on the Region.

Keywords: Solar potential, Optimal tilt angle, Thermal solar collector, Cameroon.

RÉSUMÉ :

Le soleil est la source d'énergie la plus accessible sur terre. Pour le développement de l'énergie solaire au Cameroun, la connaissance du potentiel solaire et des technologies solaires est indispensable. Dans ce travail, la moyenne du rayonnement solaire reçu annuellement par différentes villes (siège des dix Régions) du Cameroun a été évaluée à l'aide du logiciel RETScreen, puis les données obtenues ont été utilisées pour connaître l'angle d'inclinaison optimal d'un capteur thermique solaire dans chaque région du Cameroun. Les résultats montrent qu'au Cameroun, la moyenne annuelle d'insolation varie entre 4,43 kWh / m^2 / jour et 5,88 kWh / m^2 / jour pour un rendement idéal du capteur solaire thermique, l'angle d'inclinaison optimal serait choisi entre 2,5° et 20° selon les régions.

Mots clés : Potentiel solaire, Angle d'inclinaison optimal, Capteur solaire thermique, Cameroun.

1. INTRODUCTION

Energy is regarded today as a force of development due to the increasingly important role it played in worldwide economic progress and industrialization. In view of the world's depleting fossil fuel reserves, which provide the major source of energy, the development of non-conventional renewable energy sources has received impetus. Amongst the renewable sources of energy, the sun is the most accessible and available source on the earth (Bennamoun, 2001; Funk, 2010). Everywhere on the planet, the exploitation of the sun has seen a true revolution. The simplest and the most efficient way to utilize solar energy is to convert it into thermal energy for heating application using solar collectors (Aloyem, 2011). Thermal performance of solar collectors depends on the value of solar radiation intercepted. Hence, the installation of the solar collectors should therefore be executed with the objective of intercepting a maximum solar radiation by using adequate orientation and tilt angles. Research on solar thermic has shown that the optimal orientation in any case is the full southern orientation but the tilt angle varies according to the latitude of the place considered. Thus, the main objective of this work is to contribute to a better installation of solar collectors in Cameroon. Specifically, it aims to assess the solar potential in each of the ten Regions of Cameroon by taking the head-quarters as reference area and use the data obtained to find out the optimal tilt angle of thermal solar collectors in each Region. In order to obtain reliable data, a reference year is defined for each locality.

2. MATERIAL AND METHODS

2.1. Case study

Cameroon is a country located at the center of Africa and at the North of the equator (figure 1). It is bounded to the North by Tchad, to the East by Central African Republic, to the South by Congo, Gabon and Equatorial Guinea and to the West by Nigeria. It extends in latitude between 1°40' and 13° (north) and in longitude between 8°80' and 16°10' (west) with a total surface area of 475,440 km^2 carrying a population of about 24 million inhabitants. It is subdivided in ten administrative units as presented on figure 1 called Regions each headed by a Governor, created by the decree of the 12/11/2008**.** Each Region is also divided in to Divisions headed by a Senior Divisional Officer.

	Region	Head-quater
1	Adamawa	Ngaoundere
2	Centre	Yaoundé
3	East	Bertoua
4	Extreme-North	Maroua
5	Littoral	Douala
6	North	Garoua
7	North-West	Bamenda
8	West	Bafoussam
9	South	Ebolowa
10	South-west	Buea

Figure 1 : Administrative Units of Cameroon

2.2. Assessment of solar energy

The estimation of the solar potential is made through RETScreen software by defining for each city, a reference year based on the weather conditions as follows:

- Data collection for 10 consecutive years (2009 to 2018);
- For each month, the average temperature for the 10 years is calculated;
- Whatever the year, the month which the average temperature approaching most the general average over the 10 years is selected. This logic is the same as the one used for the energy diagnostic software of the Mechanical Building Firms CETIM-INERG (Nadeau, 1992).

2.3. Model of hourly solar density

Three models which make it possible to simulate the hourly solar density were found in the literature. They are Yves Jannot's model, Perrin de Brichambaut and Liu's model then Jordan' s model. The model of Yves Jannot which seemed simpler and besides is revealed powerful was considered within the framework of this work because the variations obtained through this model are close to the real variations.

2.4. Tools and conditions of simulation

MATLABR2014a software and EXCEL were used for simulations. The influence of the tilt angle of the solar collector on the received power was simulated for two standard days in each city: the least sunny and the sunniest. The data are presented in Table 1.

Table 1: Simulation Conditions for the determination of the optimum tilt angle

Ville	Latitude (°)	Value of radiation ($kWh/m^2/day$)	Corresponding day	Observations
Maroua	10.6	7.6	96	Sunniest
		1,21	214	Least sunny
Garoua	9.3	7.33	76	Sunniest
		1.8	205	Least sunny
Ngaoundere	7.3	7.46	82	Sunniest
		1,64	198	Least sunny
Bertoua	4.6	7.05	82	Sunniest
		1,49	187	Least sunny
Yaounde	3.9	6.23	49	Sunniest
		2,33	233	Least sunny
Douala	4.1	6.94	85	Sunniest
		0.82	242	Least sunny
Ebolowa	2.93	6.1	49	Sunniest
		1.92	233	Least sunny
Bafoussam	5.48	7.16	87	Sunniest
		2,35	242	Least sunny
Bamenda	6.0	7.08	82	Sunniest
		2.35	242	Least sunny
Buea	4.15	6.94	85	Sunniest
		0.82	242	Least sunny

3. RESULTS

3.1. Solar Potential

Figure 2 gives the daily average of the solar radiation in each city. The analysis of this graph shows that the average radiation is 5.03 $kWh/m^2/day$ in Cameroon with a minimum of 4.43 $kWh/m^2/day$ in the South-west Region (Buea) and a maximum of 5.88 $kWh/m^2/day$ in the Extreme-North Region (Maroua). The Extreme-North Region is thus the sunniest. The Littoral and South-west Regions are the least sunny with a daily average radiation of 4. 44 $kWh/m^2/day$ and 4. 43 $kWh/m^2/day$ respectively. Similar results were reported by Njomo (1988), Nkue and Njomo (2009) and Goron (2015).

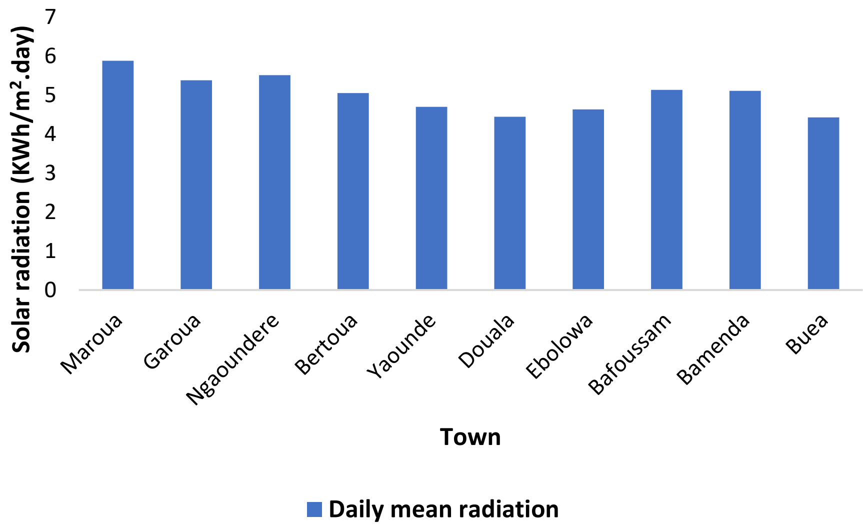

Figure 2: Daily average of the solar radiation and temperature in some cities of Cameroon

The monthly average of solar radiation is shown in figure 3. It is noted that the maximum values of the radiation are registered in February, march and April and the minimum values are registered in July, august and September.

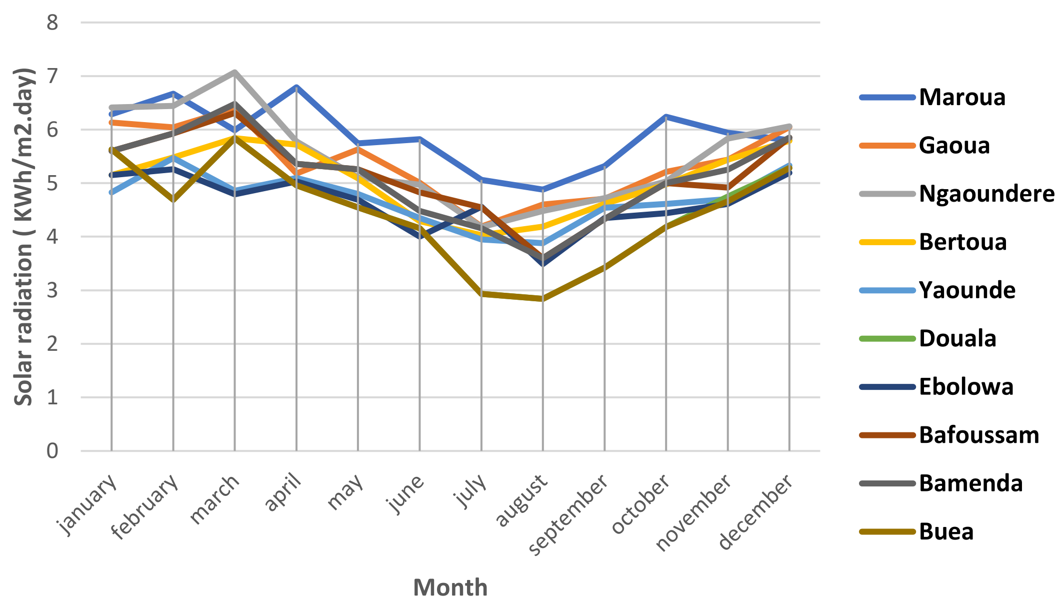

Figure 3: Monthly average of the solar radiation and temperature in some cities of Cameroon

Annually, the average sunning on a horizontal surface of one square meter varies between 1600 kWh and 2200 kWh. These data obtained made it possible to draw a map Cameroon in which four zones of sunning are delimitated as presented in figure 4. A thermal solar collector of approximately 5 m^2 area should provide an average per annum between 28,800 MJ and 39,600 MJ of heat.

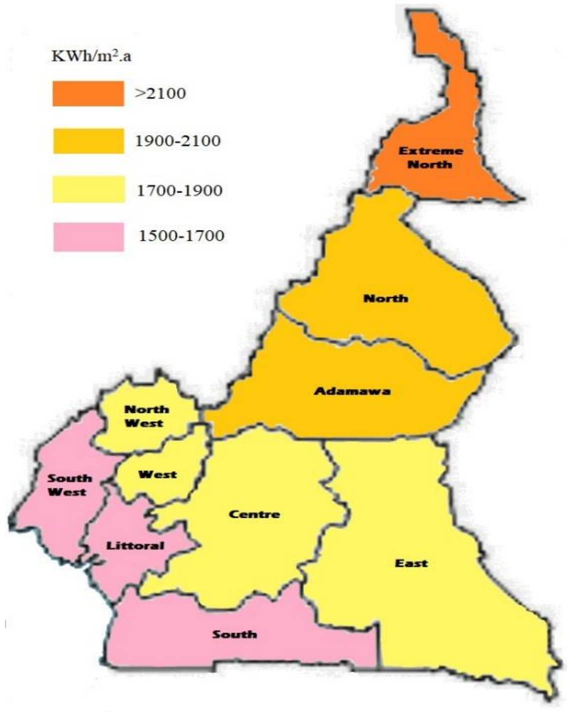

Figure 4: Cameroon's solar radiation area

By making a comparison of the average solar energy received annually by the various cities of Cameroon, Spain, China, Germany, France and Canada as presented in table 2, it is noted that Cameroon has a potential much more interesting than the countries which are recognized as being leaders in the field of solar energy.

Table 2: Average of the solar energy received annually on an area of one square meter in the cities of Cameroon and abroad.

In Cameroon		**Abroad**	
Maroua	2146.2 kWh	**Barcelone**	1540 kWh
Garoua	1963.7 kWh	**Shanghai**	1510 kWh
Ngaoundéré	2011.15 kWh	**Berlin**	1110 kWh
Bertoua	1843.25 kWh	**Toulouse**	1450 kWh
Yaoundé	1715.5 kWh	**Québec**	1580 kWh
Douala	1620.6 kWh	**Lille**	990 kWh
Ebolowa	1689.95 kWh		
Bafoussam	1872.45 kWh		
Bamenda	1865.15 kWh		
Buea	1616.95 kWh		

The great but still unexploited potential of solar energy constitutes an exceptional opportunity for Cameroon. The growth of its exploitation would generate positive effects on the environment, the economy and social since energy constitutes an essential element for the development of societies.

3.2. Power received by thermal solar collector in the ten Regions of Cameroon

The figure 5 below illustrates the theoretical variation of the direct, diffuse and reflected components of the solar radiation as well as the total radiation for a zero value of **i** and **γ** during the sunniest day in each locality. It is noted that the light intensities increase gradually until they reach their maximum theoretical value at 12 P.M True Solar Time (1 P.M local time), then fall and reach a zero value around 7 P.M True Solar Time. Similar evolutions were revealed by Benlahmidi (2013), Djebnoun (2012) and Chalal (2007).

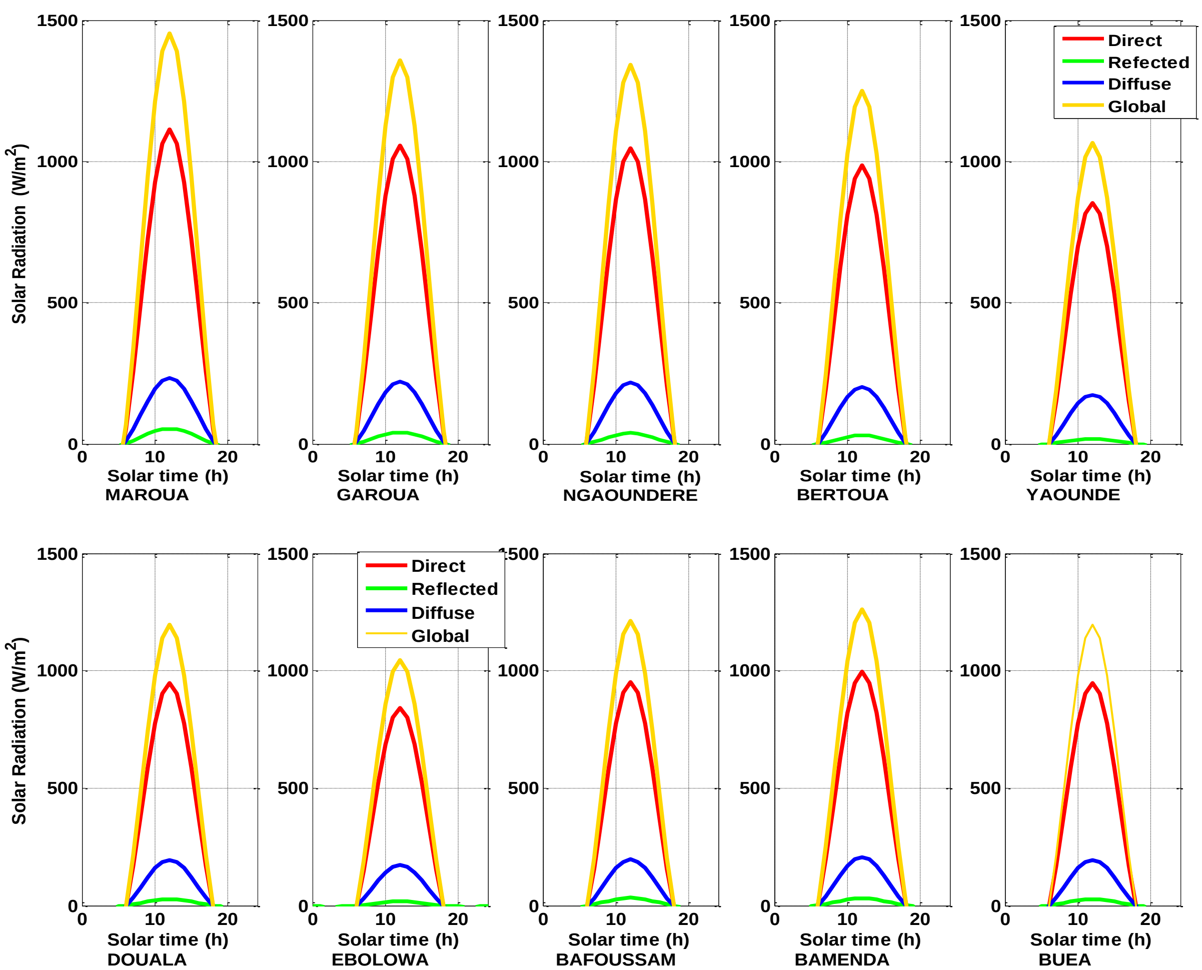

Figure 16: Solar power on a horizontal level during the sunniest day in the headquarter of each Region of Cameroon.

The maximum Global instantaneous powers reached in each area are tabulated in Table 3.

Table 3: Instantaneous maximum power attacks on a horizontal level during the sunniest days.

	Maroua	Garoua	Ngaoundéré	Bertoua	Yaounde	Douala	Ebolowa	Bafoussam	Bamenda	Buea
Latitude	10.6	9.3	7.3	4.6	3.9	4.1	2.93	5.48	6.0	4.15
Radiation ($KWh/m^2/day$)	7.6	7.33	7.46	7.05	6.23	6.94	6.1	7.16	7.08	6.94
Maximum Power (W/m^2)	1454	1359	1342	1249	1067	1195	1047	1214	1262	1195

3.3. Influence of the tilt angle on the solar power

By considering the maximum $\mathbf{R_{max}}$ and minimum $\mathbf{R_{min}}$ values of radiation during the year for each reference city and $\boldsymbol{\gamma}$ equals to zero, the evolution of the instantaneous power according to the tilt was found while varying the tilt angle $\boldsymbol{i}$ from 0° to 45° according to cases. Table 4 gives the summary of the maximum tilt angle in both cases of a thermal solar collector for each region in Cameroon.

Tableau 4: Optimal tilt angle of a solar collector in the ten Regions of Cameroon

Town	Latitude	i_{op} (R_{max})	I_{op} (R_{min})	Med (i_{op})
Maroua	10.6°	10°	30°	20°
Garoua	9.3°	10°	10°	10°
Ngaoundere	7.3°	5°	10°	7.5°
Bertoua	4.6	5°	0°	2.5°
Yaounde	3.9°	10°	20°	15°
Douala	4.1°	10°	0°	5°
Ebolowa	2.93°	10°	20°	15°
Bafoussam	5.48°	20°	0°	10°
Bamenda	6.0°	5°	0°	2.5°
Buea	4.15°	10°	0°	5°

In both cases, the optimal tilt angle $\mathbf{i_{op}}$ does not exceed 45°, which is in conformity with the recommendations of Zeghmati (1979) and Forson et al..(2007) according to which it is necessary to choose the tilt angle close to the latitude of the place considered but not exceeding 45° in any case. For each Region, the tilt angle of a thermal solar collector would be chosen between the two values obtained but, for an ideal efficiency, the median value of "imax " could be considered as optimum while installing solar sensors.

4. CONCLUSION

In this work, the solar potential in the headquarters of the ten Regions of Cameroon has been evaluated as well as the performances of a plane air solar collector. For this to be done, the climatic data were obtained through the RETScreen software. These climatic data made it possible to assess the solar potential after having defined a reference year for each case. It arises from the exploitation of the data that solar potential is sufficiently large in Cameroun to justify its exploitation on a large scale:

- Daily solar radiation varies between 4,43 kWh/m^2 (Buea) and 5,88 kWh/m^2 (Maroua) according to areas in Cameroon ;
- Cameroon is subdivided in four zones of sunning and disposes a potential more important than those countries leaders in solar energy ;
- The Region of extreme-North is the sunniest;
- The optimum positioning of a thermal solar collector is a full southern orientation with a tilt angle varying between 2.5° and 20° according to Regions.

With the challenges of sustainable development, it is necessary to master very well the judicious usage of solar energy in Cameroon.

5. CONFLICT OF INTEREST DECLARATION

The authors declare that there is no conflict of interest.

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