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How Sahara Contribute to Sustainable Energy Production? Sustainable development of Sahara countries, energy export and desert cultivation & repopulation

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Abstract. In the first party of this article, a particular attention is being given to first the Sahara in terms of solar potential capability in that it could capture enough solar energy to meet the entire world's electricity needs**,** second to its possibility of attracting inhabitant for accessing to a good quality life, agriculture and energy infrastructure.
This article also concerns the multidisciplinary project of developing and realising reference PV energy powered village in the Sahara of Algeria that would bridge the research and on site experiences. The project will be initiated on the same model of a huge laboratory regrouping several university researchers and research centres throughout Algeria. This will help training the population for using advance techniques that would help them in organising their new life. The project will also provide a research platform to demonstrate and optimize environmental technologies to enable restorative growth in desert areas in the Sahara and around the world. Crucial objectives are targeted at substantially increasing and enhancing the contribution of solar energy and favouring energy and food self-sufficiency. This pilot project implemented in the Sahara justifies the possibility to accelerate the use of indigenous solar energy resource, particularly for electricity supply, agriculture, architecture, civil and hydraulic engineering, biology…and the possibility of developing small businesses in areas of low economic development.

Keywords

Photovoltaic, solar, energy, Sustainable development, Sahara, sand.

1. Introduction

Around the world, governments and industries are now trying to keep pace with the new pacesetter in global clean energy development. Renewable energy (RE) generation, which will have to account for most energy production, can be implemented in different formats such as wind farm, hydro scheme, biomass, geothermal, and solar energy. Of all the RE sources now being fiercely debated, solar generation seems to be custom-tailored for Algeria being endowed with large reserves of solar energy source [1-3]. It is clean, efficient, freely available and now becoming more affordable. With almost 365 days of radiant sunshine a year, Algeria has the potential to be one of the major contributors in solar energy and become a role model to other countries in the world.

Should transform the Sahara on behalf of humanity? This question has been gnawing at the launch of major projects on RE in Algeria as the National Program on Renewable Energies (PNRE) with a capacity of 22 GW by 2030 or feasibility studies of projects SSB (Sahara Solar Breeder) or DESERTEC, a respective capacity of 100 GW and 470 GW by 2050. These projects can only harness the wide open spaces offered by the Sahara.

Sahara has its history, its people, its legend and its mysteries. It reduces man to his individuality, to the infinitely small. With a total area of 8.6 million km ², the Great Sahara is the largest desert in the world. It extends over 12 countries are Morocco, Mauritania, Mali, Algeria, Tunisia, Niger, Libya, Chad, Egypt, Sudan both, Sahara West.

It is hoped that this space becomes a haven of peace for future generations. Our first question is there any sense changing Sahara to a platform dedicated to RE for power generation, such as photovoltaic (PV) electricity. Sharing this energy should become the engine for sustainable energy guarantees a global future for all populations, the unbreakable link between the countries for a lasting world peace. At the end of oil, there will be sun and sand, the sand of the Sahara we want in this article to establish its potential in meeting increasing global energy needs.

2. Sahara Irradiation compared to World Energies

Total annual irradiation for all world deserts (31 deserts of 19 million km2), was calculated [4]. A summary of calculated results is presented in Table 1. It can be seen easily that the Sahara share of total irradiation of world deserts is nearly 49%. Compared to the primary energy consumption in the world at 2011 (12275 Mtoe [5]) the Sahara annual irradiation is nearly 140 times bigger (1701000 Mtoe /y).

Table 1: Annual irradiation at world deserts grouped by region

World region deserts		Area (km^2)	Annual irradiation (kWh/m^2)	Total annual irradiation		Share of total (%)
				(PWh)	(Mtoe)	
Africa	North africa (sahara)	8 600 000	2 300	19 780	1 701 080	48,79
	South africa (2)*	1 040 000	2 313	2 406	206 916	5,94
	Total africa (3)*	9 640 000	2 301	22 186	1 907 996	54,73
Asia	Middle east (6)*	3 052 400	2 137	6 524	561 052	16,09
	Central asia (5)*	2 420 000	1 661	4 019	345 634	9,91
	Total asia (11)*	5 472 400	1 927	10 543	906 686	26,01
Australia						
	Total australia (10)*	1 388 743	2 246	3 119	268 256	7,69
America	North america (5)*	1 664 000	2 188	3 641	313 126	8,98
	South america (2)*	813 000	1 289	1 048	90 154	2,59
	Total america (7)*	2 477 000	1 893	4 689	403 280	11,57
Total world deserts (31)*		**18 978 143**	**2 136**	**40 537**	**3 486 218**	**100**

* Deserts number

Unfortunately, it is impossible to use the total area of the Sahara for VLS-PV (Very Large Scale- Photovoltaic) system, because the Sahara offers contrasting landscapes: sand dunes, oasis, wadis (dry beds of rivers and streams) and mountains.

3. Sahara solar net energy potential using VLS-PV:

The suitable Sahara area for VLS-PV (The reg: Pebbles and gravel figure 1, and steppe figure 2) is 5132 000 km^2 using reference [4] and 5 330 000 km^2 using reference [6].Table 2 shows a rough calculation of PV capacity and annual power generation for the suitable Sahara area using VLS-PV based on a conceptual image of a one GW VLS-PV system [7].

A comparison with world primary energy consumption in the world at 2011 [5] allowed us to say that Sahara solar net annual energy potential using VLS-PV with buffer plant and with road is 2 times higher than world consumption in the world at 2011.

Figure 1: The reg: Pebbles and gravel

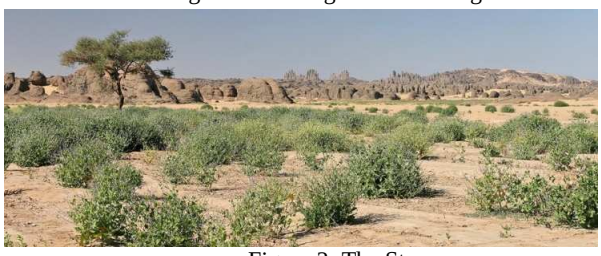

Figure 2: The Steppe

Table 2: PV capacity and Annual energy generation for all the Suitable Sahara area

PV Capacity and Energy generation using VLS-PV system	PV capacity (TW)	Annual generation (PWh)	Annual generation (Mtoe)	Annual generation to gross annual irradiation %
Without buffer plant and without road	**342**	**551**	**47 372**	**2,78**
Without buffer plant but with road	**257**	**413**	**35 529**	**2,09**
With buffer plant and with road	**171**	**275**	**23 686**	**1,39**

4. What can we do by this area or this energy?

Clean energy production for sustainable development of Sahara countries, clean energy production for export, desert cultivation & repopulation:

A. Clean energy production for sustainable development of Sahara countries

Table 3 shows calculation results of Sahara countries population in 2030, annual energy needs in 2030 (5toe/capita) and needed area to produce this quantity of energy. It can be seen that the needed area, of Sahara countries, to produce annual energy needs in 2030 is about 400 000 km^2 little than 8% of total Sahara's suitable area

Table 3: Area needed to produce energy for sustainable development of Sahara countries (2030)

Energy and area needed to countries consumption 2030	Utilisation d'énergie 2030		Area needed (km2)
	(Mtoe)	(PWh)	
	1 827,4	**21,2**	**395 943**

B. Clean energy production for export and desert cultivation & repopulation

Figure 3 shows the number of habitant and annual energy export according to used area for residence. The calculation was based on annual energy need by habitant in 2030 which amounts 5toe and the need of land per inhabitant for agriculture, building and green space purposes which is 1 hectare. If all the space used to produce energy for export, that is to say used area for residence = 0, we can export 250 PW. If, instead, the used area for energy exportation=0, it can accommodate more than 420 Million people. If we take an intermediate point, used two Million Km2 for residence, we can accommodate more than 170 million inhabitants and export 150 PWh.

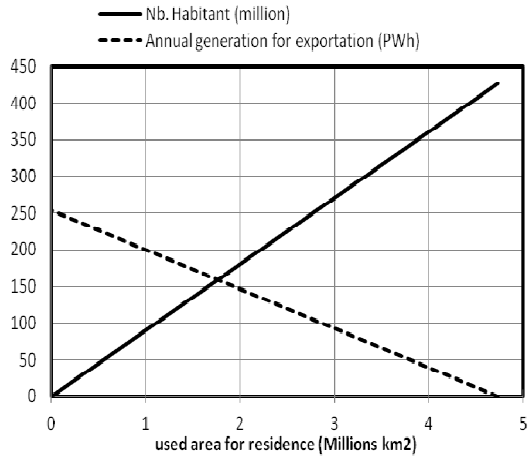

Figure 3: Number of habitant and annual energy exportation according to used area for residence

5. Silicon (Si) potential of the Sahara

VLS-PV needs an immense quantity of Si. Is the Si in the Sahara sand is enough to product 171 TW PV?

A calculating method was proposed to calculate Silicon (Si) potential of the Sahara according to sand dune area at Sahara S and the sand dune highs, h_{max} and h_{min} as shows on figure 4.

The volume of sand reserves V (m^3) is given by the proposed formula (1)

$$V = S.h_{min} + \frac{S}{3}(h_{max} - h_{min})$$

$$V = \frac{S}{3}(2h_{min} - h_{max}) \qquad (1)$$

S= Sand dune area at Sahara =1720000 (km²);

Taking h_{max} average= 100 m;

h_{min} average= 50 m;

$$V = \frac{1}{3} \times 1720 \times 10^9 (2 \times 50 + 100)$$

$$V = 115 \times 10^{12}\, m^3$$

While 1m3 =1850 kg , the weight of sand reserves (ton) W is given by formula (2)

$$W = V \times 1850 = 212 \times 10^{12}\ ton \qquad (2).$$

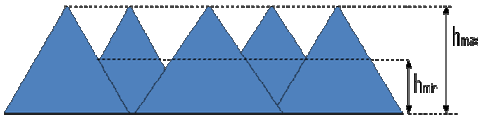

Figure 4: The volume of sand reserves

Taking the rate of Silica in the sand:
SiO_2 / Sand = 70% [8]

And the rate of Silicon in Silica:
Si / SiO_2 = 28/60

The rate of Silicon (Si) in the sand will be:
Si / Sand = 70x28/60= 32%

Taking extraction efficiency of Silicon =30% [8]
The Si extracting rate will be = 30%x32%= 10%
That mean 1 ton Si needs 10 tons Sand

The weight of Silicon reserves W_{si} is 10% of W

$$W_{Si} = W \times 10/100$$

$$W_{Si} = 21.2 \times 10^{12}\ ton$$

While 1MW PV needs 10 ton of Si (Silicon) [9] or 100 ton of sand, then 171 TW PV (total PV capacity, see table 2) needs 171x10^8 ton of sand.

The sand reserves which equal to $212x10^{12}$ ton is more than 12000 times the sand needs to product 171 TW PV.

6. Reference village project

Using solar energy and advance sciences will certainly achieve higher levels of economic development of a community by biological agriculture, integration of unit of desalination of briny water that would permit to irrigate thousands of hectares. It will also permit to solve the serious problem of treatment of waters that pollute the environment and caused the destruction of thousands of palm trees in the Sahara.

To realize or to achieve these objectives we have to do:

1. The transfer of appropriate technologies to the Sahara;
2. The domiciliation of these technologies (Apply, test, choosing the most suitable upgrade .... etc);
3. Training of the local community and new habitants to use these technologies and to adapt with.

These technologies are actually multidisciplinary; they primarily concern the following applications: housing and Planning; water pumping, desalination and treatment; organic agriculture: irrigation techniques and plants; bio fixing, bio washing …etc

Currently, these technologies and their applications are being developed in laboratories, research centers, manufactures, agencies, etc., separately, with respect to each other, separately from the users and sometimes separately from the destination sites.

We propose to combine the applications for the villages in a reference village, an experimental village, in a mother oasis. This reference village is directly linked to development centers by development engineers, researchers and trainers figure 5.

Figure 5: combine the applications for the villages in a reference village, and linked it to development centers by development engineers, researchers and trainers

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