Sahara potentials and sustainable development of Algeria

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***Abstract*—Taking Algeria as an example, our first question finds there, all it sense, making Sahara a dedicated platform to RE for power generation, such as photovoltaic (PV) electricity, and agriculture as the engine of sustainable development. Energy input to modern and sustainable agricultural production and processing systems is a key factor in moving beyond subsistence farming towards food security, added value in rural areas and Green Dam region of Algerian desert and its expansion into new agricultural markets. Sharing this strategy should become the engine for sustainable energy which guarantees for Algeria a future for all population. At first we present a rough calculation of PV capacity and annual power generation potential for all the suitable area of Algeria desert using a Very Large Scale-Photovoltaic system (VLS-PV). The obtained value is more than the half of world primary energy consumption in 2030.**

Currently the rate of primary energy consumption in Algeria per capita is up to 1.15 toe (tons of oil equivalent) per person per year. We estimate that this value will be around 2 tons in 2030. Considering this rate the needed energy, of Algeria population in 2030 will be about 88 Mtoe which amount the value of 1.6 % of total Sahara potential, 1.6 % of Sahara clean energy potential is sufficient for sustainable development of Algeria

We examine the feasibility of desert greening, cultivation and repopulation through the study of the needs of the village of 500 hectares area on the steppes land in the north of the Sahara, inhabited by 500 residents in 100 families. Noting that half of this area is agricultural land. After we specify all needs, we calculate the energy required to meet them, using modern, economical and clean techniques. The applications, taken in consideration are: Drip irrigation; Desalination using reverse osmosis; Wastewater treatment; Pumping over sun; Domestic and commercial used; Public needs (Administrative, Service, School, Mosque, Post office, Polyclinic); Divers (Transformation industries, handicrafts, Livestock breeding). The first results show that the PV generator that satisfies the needs of the village should have approximately 5 MW (10 kW per Habitat) occupying an area of 10 hectares, which presents 2% of the entire area of the village. These results are very important because they show that the necessary power can be generated in a small surface.

At last we study the advantages of combining Sahara cultivation and repopulation to Algeria Green Dam project. The Algerian Green Dam (AGD) which launched in 1974 to stop the advancing desert was intended to reforest an area of 3 million hectares from east to west of Algeria, over a length of 1,200 km and a width varying from 5 to 20 km.

***Keywords*— Photovoltaic; Solar energy; Sustainable development; Sahara; Sand.**

I. INTRODUCTION

The desert is a beautiful but barren wide land of pebbles, gravel, sand dunes, a sun shining bluntly during long hours, a rare water, and difficult lonesome life. Human abandoned the desert, no human remain except in some scattered oases. The desertification propagates severely in all directions, turning the plains to a barren land. The question that may be asked is: How to stop the advance of drought, and how restore the life in the deserts? Are we able to overcome the challenge, and turn the scorching sun which expanse the desertification, the drought and the ruin, to a great and nice landscape: restore the energy source, the vegetable life and populate the steppes. In other words turn the desert creep to vegetables creep and populated area. Is this possible? Or it is a daydream weaving of the concentrated peoples in the small and large oases. This is what we will try to answer in this paper taking Algeria as an example, which can be generalized to a lot of desert countries.

In order to achieve this dream, we need to:

- Usable clean energy: it is available as a raw natural form in the blazing sun in large quantities in our country, particular in our deserts. It is able to be converted into usable clean energy, as heating and electric forms,
- Large areas of land: which are available in abundance but they need special attention in order to become suitable for agriculture and creep vegetables. Yes human of ancient civilizations did the same thing, reclaimed land and extended water channels, for a change and make it Eden Garden.
- Large amounts of fresh water: This fresh water is not available in large quantities, if any, is subject to high salinity making it unusable. But with the help of solar energy and modern techniques we can provide fresh water in large quantities by desalination of desert salty and briny water.
- The person who is determined to win the Challenge need to innovate and develop modern technologies; as did the men of ancient civilizations;
- Civil and government agencies that adopt this strategic project shall promote it and provide it with the terms of the social, economic and political success.

II. ALGERIA DESERT IRRADIATION

Total annual irradiation for all world deserts (31 deserts of 19 million km2), was calculated [1-3]. A summary of calculated results is depicted in Tables 1. It can be seen easily that Algeria desert has an 11.4 % share of the total irradiation of world deserts. The Algeria desert annual irradiation (395600 Mtoe/y) is more than 26 times higher the primary energy consumption of the world in 2030 (15000 Mtoe [4]

TABLE 1: ALGERIAN DESERT IRRADIATION COMPARED TO WORLD ENERGIES

WORLD REGION DESERTS	Area (km²)	Annual irradiation (kWh/m²)	Total annual irradiation (PWh)	Total annual irradiation (Mtoe)	Share of total annual irradiation (%)
TOTAL WORLD DESERTS (31 deserts)	**18 978 143**	**2 136**	**40 537**	**3 486 218**	**100**
North Africa (NA)	**8 600 000**	**2300**	**19 780**	**1 701 080**	**49**
Middle East (ME)	**3 052 400**	**2137**	**6 524**	**561 052**	**16**
Algeria	**2 000 000**	**2300**	**4 600**	**395 600**	**11,4**

III. ALGERIA DESERT SOLAR NET ENERGY POTENTIAL USING VLS-PV

A. *Suitable area for VLS-PV system*

The deserts offer contrasting landscapes: sand dunes, oasis, wades (dry beds of rivers and streams), mountains, Reg (composed of pebbles and gravel) and steppe. It is impossible to use the total area of the deserts for VLS-PV system; the suitable area for this kind of systems is the Regs and the steppes only. Table 2 shows a rough calculation of the different areas of Algeria desert; it can be seen that the suitable area for VLS-PV is about 1 200 000 km2.

B. *The range of VLS-PV system*

The size of a Very Large Scale- Photovoltaic system may range from 10 MW to 1 or several GW, consisting of one plant, or an aggregation of plural units [5]. Figure1 shows a conceptual image of a one GW system [5,6], occupying 30 km2 (15 km x 2 km) of land, taking into account PV collectors, buffer plant, roods and transmission lines.

C. *PV capacity and annual power generation*

Table 3 shows a rough calculation of PV capacity and annual power generation for all the suitable area of Algeria desert using VLS-PV based on a conceptual image of a one GW system of figure 1. A comparison with world primary energy consumption [4] allowed us to conclude that Algeria solar net annual energy potential using VLS-PV without buffer plants (8100 Mtoe) is more than the half of world consumption in 2030 (15000 Mtoe).

TABLE 2: DIFFERENT AREAS OF ALGERIA DESERT

Total area (km²)	Sand dune area (km²) 20%	Oasis area (km²)	Mountain area (km²) 18%	Reg and Steppe area (km²)
2 000 000	**400 000**	**40 000**	**360 000**	**1 200 000**

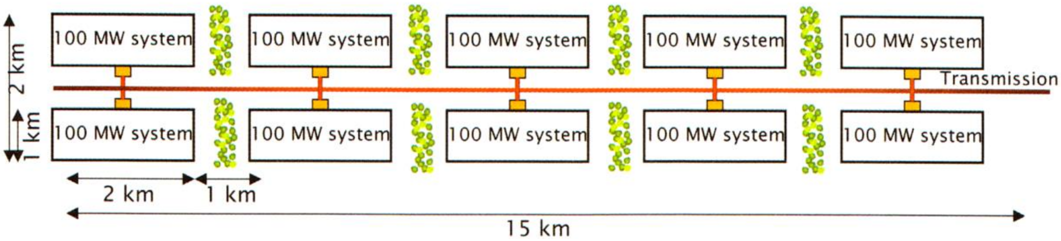

Fig 1. A conceptual image of a one GW [5,6]

TABLE 3: PV CAPACITY AND ANNUAL ENERGY GENERATION FOR ALL THE SUITABLE DESERTS AREA OF ALGERIA

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	**60**	**95**	**8 100**	**2,1**
With buffer plant	**40**	**63**	**5 500**	**1,4**

IV. SILICON (SI) POTENTIAL OF ALGERIA DESERT

VLS-PV needs a huge quantity of Silicon (Si). Is the Si present in Algeria desert sand enough to produce 60 TW PV? A calculation method [1,3] was proposed to assess Si potential of Algeria desert . Table 4 shows a rough calculation of sand and Silicon potential of Algeria desert.

While 1MW PV needs 10 tons of Si [7] or 100 tons of sand, then 60 TW PV (total PV capacity, see table 3) will be needing 60x108 tons of sands. The sand reserves which equal to $48,6x10^{12}$ tons is more than 8000 times the sand needs to produce 60 TW PV energy.

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V. WHAT CAN WE DO USING ALGERIAN SOLAR NET ENERGY POTENTIAL?

Many purposes can be achieved using this clean energy in that:

a. Sustainable development of Algeria;
b. Desert greening, cultivation & repopulation;
c. Export to Europe countries.

In this part of our paper we will try to study the possibility of achieving first and second objectives in Algeria in terms of needs assessment, energy potential, and space needed for photovoltaic generators.

A. *Clean energy production for sustainable development of Algeria*

Currently the rate of primary energy consumption in Algeria per capita is up to 1.15 tons of oil equivalent per person per year. We estimate that this value will be around 2 tons in 2030. To meet this amount of energy we need a photovoltaic generator in the middle of the desert of 20 kW per person. Our following calculations will be carried out using these rates.

Table 5 shows calculation results of Algeria population, and annual energy needs in 2030. It can be seen that the needed energy, of Algeria in 2030 will be about 88 Mtoe, which amounts the value of 1.6% (88/5500) of total Algeria potential. The needed area to produce 88 Mtoe is equal to 20 000 km2 with buffer plants or 13 500 km2 without buffer plants. Knowing that the width of north Algeria, from Morocco to Tunisia (Figure 2), is equal to 1200 km, the above needed Area is equal to the surface of a strip along the north of the desert in the steppe area of 17 km or 11 km, depending on the situation of with or without buffer plants, respectively.

Table 4: A rough calculation of sand and Silicon potential of Algeria desert

Sand dune area (km²)	Volume of sand potential (m³)	Weight of sand potential (ton)	Weight of Si potential (ton)
400 000	$26,7 \times 10^{12}$	$48,6 \, x \, 10^{12}$	$4,86 \times 10^{12}$

Table 5: Algeria annual primary energy needs in 2030

Population 2010 Million	Growth rate	Population 2030 Million	Energy use per capita 2009 (toe)	Energy use per capita 2030 (toe)	annual energy needs 2030 (Mtoe)	Area needs with buffer (km²)	Area needs without buffer (km²)
35	1.19	44	1.138	2	88	20 000	13 500

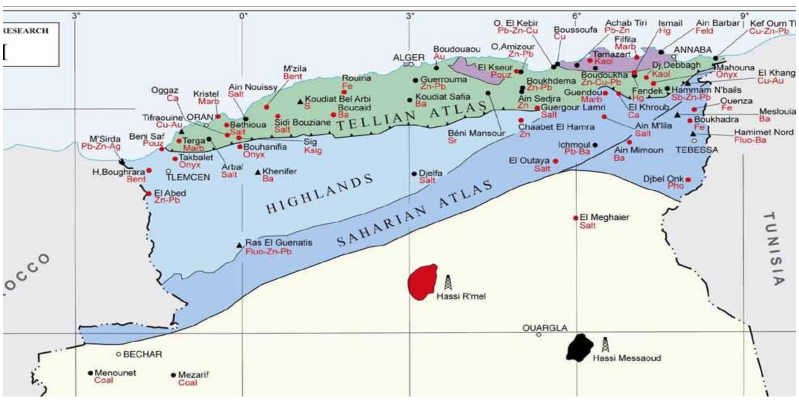

Fig. 2. North of Algeria region

B. Clean energy production for desert greening, cultivation & repopulation

a. A village of 500 Habitats & 500 Hectares

We examine the feasibility of desert greening, cultivation and repopulation through the study of the needs of the village of 500 hectares area on the steppes land in the north of the Sahara, inhabited by 500 residents in 100 families. Noting that half of this area is agricultural land

After we specify all needs, we calculate the energy required to meet them, using modern, economical and clean techniques. Each one of the solar energy applications of the village has its dimensioning method. The estimated results of this study will allow us to decide on the feasibility of these ideas. The applications taken in consideration are (figure3): Drip irrigation; Desalination using reverse osmosis; Wastewater treatment; Pumping over sun; Domestic and commercial uses; Public needs (Administrative, Service, School, Mosque, Post office, Polyclinic); Divers (Transformation industries, handicrafts, Livestock breeding).

The first results show that the PV generator that satisfies the needs of the village should have approximately **5 MW (10 kW per capita)** occupying an area of **10 hectares**, which presents **2%** of the entire area of the village. This result is very important because it shows that the necessary power can be generated in a small area, and equivalent to almost one ton of oil equivalent per person per year, a half of the amount in our study which we estimate to feed Algeria 2030.

To optimize the batteries and energy production we can connect village's autonomy systems to the national grid as show in figure 4, in order to obtain an annual exchange balance, in energy, between village and grid equal to zero.

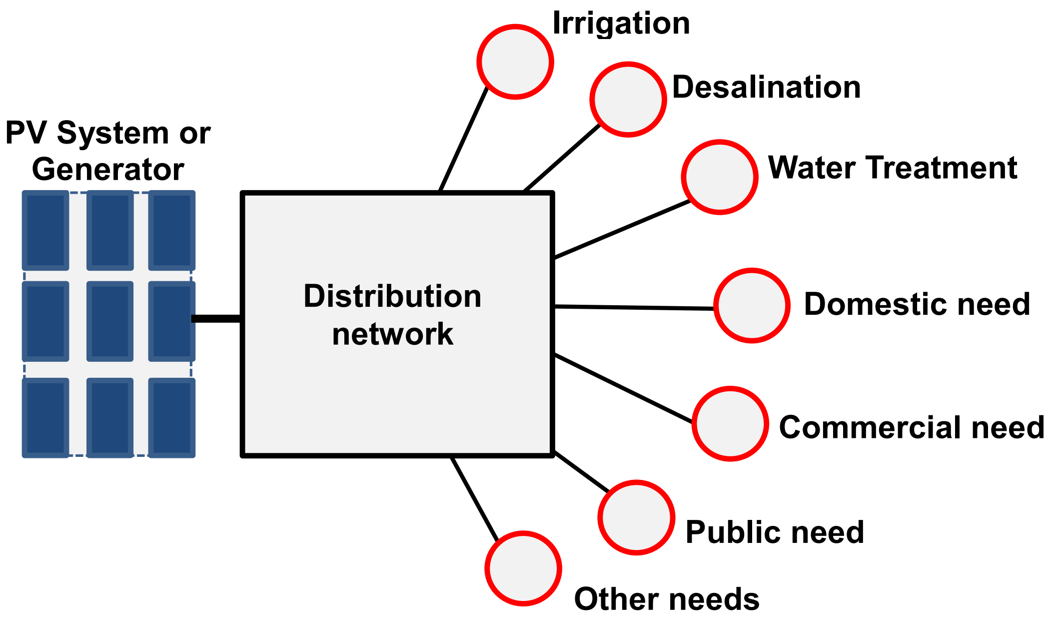

Fig 3: PV village's applications

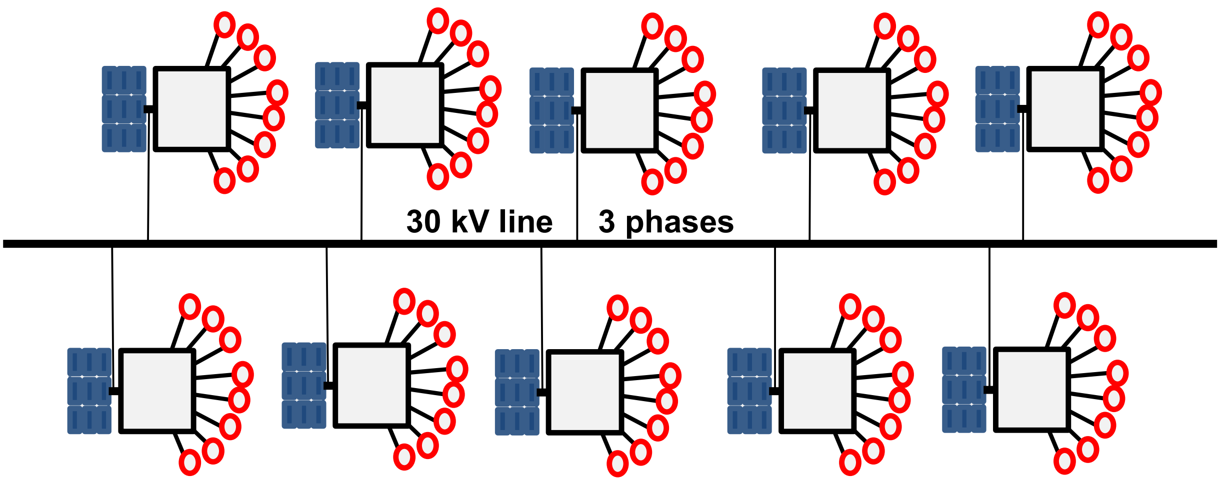

Fig 4: village's autonomy systems connected by the national grid

b. *Combined Sahara cultivation & repopulation to Algeria Green Dam:*

The Algerian Green Dam (AGD) which was launched in 1974 to stop the advancing desert was intended to reforest an area of 3 million hectares from east to west of Algeria, over a length of 1,200 km and a width varying from 5 to 20 km (figure 5a and 5b). The full consequences of dysfunction relating to the project emerged in the 1980s

Why it is necessary to combine?

- To optimize the area of VLS-PV System;
- To solve the problem of the GD by providing its needs in water;
- To build a news village in the steeps near the GD and VLS-PV,
- To export electrical energy to the north of Algeria & Europe. The distance 100 to 400 km, with 6 kWh/m2/day

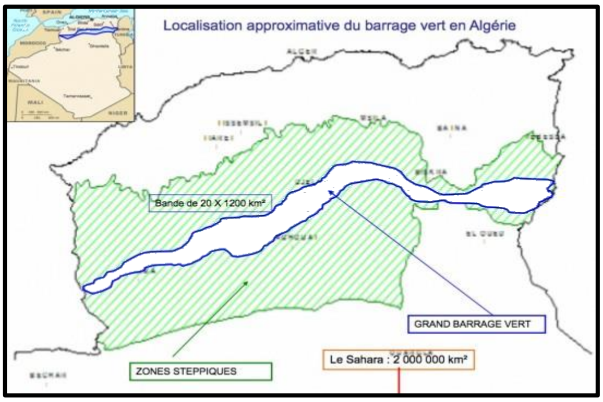

Fig 5 a: Algerian Green Dam map [8]

Fig 5 b: Algerian Green Dam photo [9]

VI. CONCLUSIONS

Algeria has one natural resource, which so far has received scant attention, despite an abundance that has few parallels around the world: Solar Energy and Silicon, which can participate in solving the energy and climate problems for a world in a sustainable way. Calculation results allowed us to conclude that Algeria solar net annual energy potential using VLS-PV with buffer plants and roads (5500 Mtoe) is more than Europe primary energy consumption in 2030 (4600 Mtoe), And even a small fraction of this solar potential: 1.6% would already be sufficient to meet Algeria annual energy needs in 2030 which will be about 88 Mtoe

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 and solve the serious problem of treatment of waters that pollute the environment and caused the destruction of thousands of palm trees in the deserts. It will also permit to desert cultivation and repopulation.

Combined Sahara cultivation & repopulation to Algeria Green Dam project to optimize the area of VLS-PV System and to solve the problem of the GD by providing its needs in water.

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