Overview of Solar Potential, State of the Art and Future of Photovoltaic Installations in Algeria

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Abstract-Solar Energy, found everywhere on Earth, represents an attractive alternative for electricity production thanks to photovoltaic technology (PV). Thereby, not only it decreases the dependence to fossil fuels, but it also protects the environment. Algeria, which has the most important solar potential of the Mediterranean sea (169440 TWh/year), is an ideal candidate for large-scale exploitation of solar energy. In this context, we propose in our work a balance sheet of general energy consumption and production in Algeria as well as a summary of the most important realized or currently planned projects for the exploitation of photovoltaic in this country.

Keywords-Algeria, solar energy, photovoltaic, environment, energy production.

1. Introduction

For a century, the mastery of energy resources such as coal, petroleum, natural gas and to some extent, nuclear energy, has allowed a raise in the standard of living of the world's population, especially in developed countries [1].

However, the abrupt increase in the petroleum prices that occurred in 1973 caused Man's interest in other energy resources [2]. In Algeria, even if the opinions currently differ around a precise date, everyone is unanimous in saying that there will come a day when the depletion of fossil fuels will be inevitable [3].

To address these concerns, the use of renewable resources sounds like the best solution because they are:

- Endless on a temporal human scale.
- Harmless to the environment (less CO_2 releases).

Among these renewable resources, solar energy, which is available anywhere on earth, represents theoretically 900 times the global demand in energy [1]. Because of its location, Algeria has one of the most important solar potential in the world (an average insolation of more than 3000 hours/year) [4], which makes it suitable for the implantation of solar energy conversion systems, in particular photovoltaic systems.

In this context, we will, through this work, explore the situation of energy production in Algeria and make a balance sheet, an overview, of the developed programs in order to encourage and multiply the use of photovoltaic energy in this country.

2. Energy Situation in Algeria

The economic sector of energy in Algeria includes local production and importation of primary energy, their eventual transformation into secondary energy carriers, transport of these agents and their final consumption, as well as the flow of imports and exports of energy [5].

According to the national energy balance sheet of 2013, established by the Algerian Energy Ministry [6], the national energy production has reached 154.6Mtep which 5.9 Mtep are for importations (a decrease of 3.8% compared to 2012) [7].

This production was used for internal supply of about 52.7 Mtep, and exports of around 101.8 Mtep.

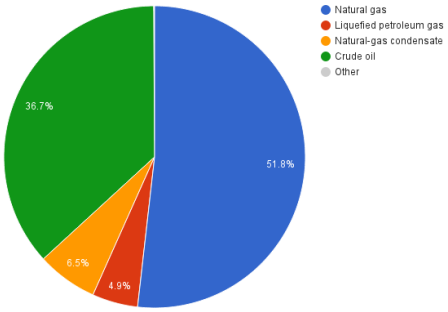

Fig. 1. Structure of primary energy production.

In Fig.1, we can see that the primary energy production is dominated by natural gas (51.8%) followed by crude oil (36.7%). For derived energy, petroleum products dominate this sector (Fig.2)

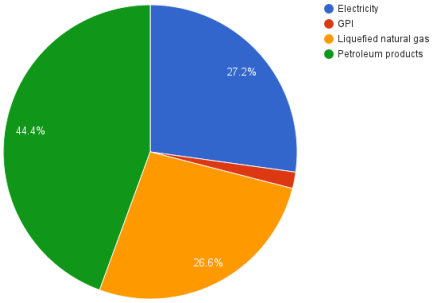

Fig. 2. Structure of derived energy production.

Figure 3 shows that 50.8% of the produced electricity comes from combined cycle. This rate is the highest concerning the production means of electric energy in Algeria. Electricity from hydro and solar constitutes only 0.2%

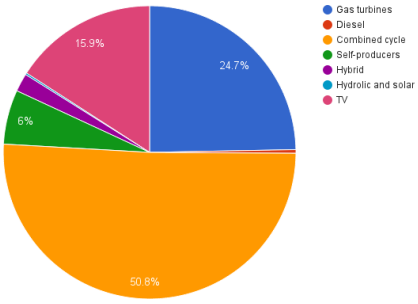

Fig. 3. Structure of the electricity generation.

Energy consumption has reached 53.3 Mtep in 2013. It is dominated by natural gas (35%), followed by oil (30%) and electricity (28%) (Fig.4).

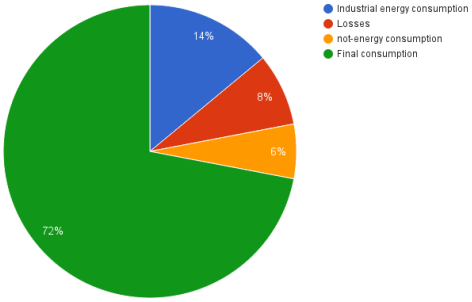

Fig. 4. Structure of the energy consumption.

3. National Development Program for Renewable Energy

The renewable energy development program [8] adopted by the Algerian government in 2011 was updated in February 2015. This program, which experienced a first phase dedicated to pilot projects and tests of the various available technologies, now he bets mainly on large-scale development of photovoltaic and wind power over 15 years (2015-2020-2030).

Table 1. Algerian program of renewable energy.

Technology	First phase [MW]	Second phase [MW]
PV	3000	10575
Wind	1000	4000
CSP	-	2000
Cogeneration	150	250
Biomass	360	650
Geothermal	05	10

This program focuses on the production of 22000 MW of which 13575 MW of solar photovoltaic according to data provided by theRenewable Energy Development Center[9]. By 2020, the Algerian government has set a target of achieving 4500 MW of the program (3000 MW will be produced by photovoltaic).

4. Solar Potential of Algeria

Solar potential is the total amount of solar radiation energy (kWh) received on a given surface area (m^2) during a given time (year) in specific location [10]. On Fig.5 we can notice that the available energy in a year is sufficient to cover all the energetic needs of the world during the same period.

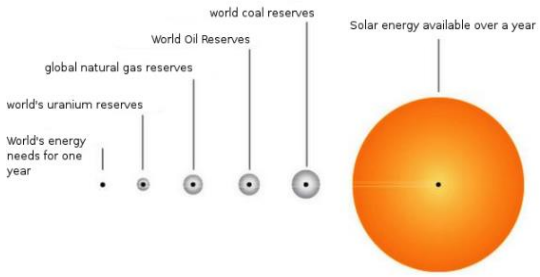

Fig. 5. Solar energy vs. other energy sources.

Algeria receives an average of 3000 hours/year of solar radiation; it has the most important solar potential of the Mediterranean basin (169440 TWh/year). The average of the received solar energy in coastal regions is 1700 kWh/m²/year while it is 1900 kWh/m²/year on highlands and 2650 kWh/m²/year in the Sahara [3] (see table 2). It has been proved that alone, the solar potential of the Sahara could cover all the needs of energy in the world if we put the necessary amount of investments in this field [11].

Table 2. Solar potential of Algeria.

Region	Coastal regions	Highlands	Sahara
Surface %	4	10	86
Average sunshine duration (hours/year)	2650	3000	3500
Average energy (kWh/m²/year)	1700	1900	2650

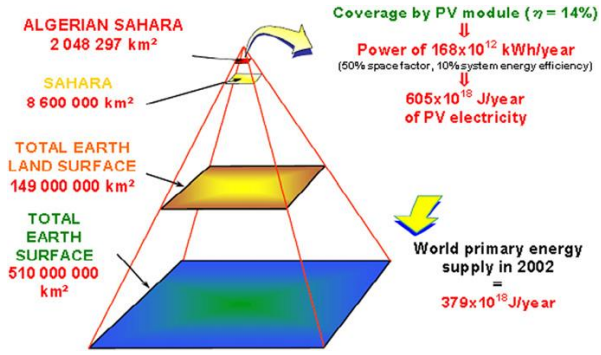

Fig. 6. Solar pyramid [12].

Following the model of the solar pyramid proposed by Kurokawa for the Gobi desert in Asia, if applied to the Algerian Sahara with 50% of the space factor, 10% of the system energy efficiency and a 14% PV module coverage, the amount of solar electricity produced exceeds 605.10^{18}J/year [12] (see Fig.6).

5. Photovoltaic Technology

5.1.Solar Photovoltaic

Solar photovoltaic energy is a technology used to convert sunlight into electricity using photovoltaic cells, which compose solar panels. Photovoltaic cell is composed of semiconductor material that can set electrons free under the influence of an external energy. When talking about photovoltaic, this energy is brought by the photons contained in sunlight.

5.2.Photovoltaic Systems

In the chain that represents the photovoltaic system, the panel on its own cannot do much. To cover some specific needs, it is primordial to link it to other components of the system that can be variable depending on the application. For example:

- Solar trackers.
- Electricity storage elements.
- Regulators and power convertors.
- External power generators bearing the random nature of the sun.
- DC or AC load lines.

Photovoltaic systems are divided essentially into two categories:

- Stand-alone PV systems.
- Grid-connected systems.

6. Photovoltaic Systems Installed in Algeria

6.1.Isolated Sites

Algeria, with an area of 2.3 million km² (10th largest country in the world) of which more than 80% goes to the Sahara desert, is the home of many big isolated localities where the extension of the electric power transmission network is impossible or way too expensive to be thought of.

According to the Ministry of Energy, there are over 260000 villages not connected to the general electricity network [13].Thereby, isolated houses tend to use engine-generators to cover their essential need in electricity. These engine-generators mainly use Diesel fuel to produce electrical energy that does not only have a bad effect on the environment, but it also costs a lot in means of transport.

Therefore, solar photovoltaic energy represents a very attractive alternative instead of engine-generators. It has manifold assets, among which:

- No gas releases nor greenhouse effect.

- Free energy source for everyone.

- Modular design adaptable to all needs.

Sonelgaz (The National Gas and Electricity Society), gives its contribution to the rural electrification of Algeria for years by deploying solar photovoltaic kits all over isolated villages which contain a limited number of houses. These villages (about 906 houses), arecalled "Solar Villages" and are mostly located in the south of Algeria [14,15].

A total electricity consumption estimated between 1.5 kWh/day and 2 kWh/day represents [14]:

- 5 lamps.

- 1 refrigerator.

- 1 TV/Radio.

- 1 fan.

The regions affected by this program (first phase) were Tindouf (three villages), Adrar (two villages), Illizi (five villages), andTamanrasset (eight villages) [14] (see table 3). In its second phase [13], which started in 2010, rural electrification aims to deploy solar photovoltaic kits in 16 other isolated villages (table 4).

Table 3. First phase of rural electrification [13].

Province	Village	Installed power (kW)	Consumption (kWh/day/home)
Tamanrasset	Moulaylahcen	9	1.48
	In Delagh	15	0.92
	Tahifet	61.5	1.30
	Arak	61.5	1
	Amguid	51	1.60
	Tahernenet	30	1.13
	Tin Tarabin	34.5	1.44
	In Blel	15	1.38
Tindouf	Garadjebilet	33	1.47
	Daya el Khadra	24	1.55
	Hassimounir	21	1.68
Adrar	Hammoumoussa	6	1.53
	Tala	16.5	1.61
Illizi	Imenhou	16.5	0.63
	Ifni	7.5	0.60
	OuedSamen	15	0.68
	Tihahiout	12	0.57
	Tamadjart	24	0.80

Table 4. Second phase of rural electrification [13]

Province	Village	Homes by unit	Distance from the grid [km]
Tamanrasset	Abdnizi	3	270
	Ait Ouklan	20	150

	In Azarou	26	90
	Tigannouine	70	70
	Idikel	25	50
	Tit Loukten	15	44
	Ilamane	20	25
	Tensou	20	120
El-Oued	El Ghanemi	40	45
	El Maklia	60	40
M'sila	Zbiret	100	50
Illizi	IkabrenTarat	20	70
	Arrikine	25	140
	Issendiline	12	90
	Dider	20	50
Ghardaia	HassiGhanem	72	60

Still in the south of Algeria, cooperation between The Renewable Energy Development Center (CDER), the "InstitutCataläd'Energia" (ICAEN) and the region of Tamanrasset gave birth to a project that allowed the electrification of a refuge at "Assekrem" by solar energy. Note that this refuge has also a Diesel engine-generator [16]. In steppes such as M'sila, about 444 solar panels were distributed in 2014 to supply houses that are away from electric networks. Furthermore, at El Bayadh, after a first satisfying operation, a second one has been launched in 2012 to supply 540 nomad families with photovoltaic kits [17].

Table 5. Distribution per province of the PV systems [13].

Province	Homes by unit	Power (kWp)	Energy (kWh)	Additional available energy (kWh)
Tamanrasset	555	277.5	1665	4026
Illizi	150	75	450	1100
Tindouf	156	78	468	1144
Adrar	45	22.5	135	330
Total	906	453	2718	6600

In Naama, during the period from 2003 to 2013, no fewer than 848 families living in remote areas have received, free of charge, solar kits.

Fig. 7. Bedouin using solar panels.

In addition to the electrification of houses financed by the state in its rural electrification plan, Sonatrach (National Society for the research, production, transportation, processing and marketing of hydrocarbons) also has benefited from solar energy by using photovoltaic power for telemetry systems and cathode protection of pipelines transporting hydrocarbons [15,17].

Finally, as last example, we can cite the road monitoring stations (gendarmerie) and more than 100 telecommunications sites until now who have not less than 700 kWp of energy produced via PV panels [17,18].

6.2.Photovoltaic Power Plants

Many photovoltaic power plants have been installed, and more are planned in the country. A photovoltaic plant was inaugurated in "Bousmail", region of Tipaza, in the unit development of solar equipment (UDES) (2012) [14,17].

For the south of the province of Sidi Bel-Abbes, in the town of "Dhaya", a photovoltaic power plant with a capacity of 15 MW has been included in the program of the achievements of 2014. Just as the west, east, more precisely the city of "Ain Azel" has benefited from a project of a solar plant power of 150 MW at the end of 2013 [17].

In the town of "Ain El Melh", located in the steppe zone, a photovoltaic plant with a capacity of 20 MW was achieved in 2014.

Fig. 8. Pilot plant in Gherdaia.

In 2015, the South Korean company "Hanwha Engineering" will deliver a power of 450 MW in the region of Biskra. In "Ras El Oued", in the region of BordjBouArreridj, the Chinese company Sino-Hydro installed a power of 20 MW photovoltaic power at the end of 2014 [17].

At Ghardaia, south of Algeria, a photovoltaic plant power of 1.1 MW (Fig.8)was put into operation for the experiment of the four existing solar cell technologies (table 6) [4,17,19]. Always in this region, the first mini photovoltaic solar power plant connected to the network and using micro amorphous panels with a capacity of 28 kilowatts was put into operation. This achievement is within the scope of research activities of the Unit for Applied Renewable Energy (URAER).

Table 6. Cell types used in the plant of Gherdaia [19]

Technology	Power [kWc]	Surface [m²]	Energy [MWh/year]
Si mono fixed 1	252	1661	464.7
Si mono fixed 2	100	684	188.3
Si mono motorized	100	684	250.2
Si poly fixed 1	252	1791	272.1
Si poly fixed 2	100	684	177.1
Si poly motorized	100	684	235.4
Amorphous Si	100	1409	187.1
CdTe	100	907	193.6

At Adrar and In Salah, seven photovoltaic plants were planned for the fourth quarter of 2014 [17]. In Sebdou, a plant with a capacity of 10-20 M.VA (million volt-ampere) will inject energy into the national electricity grid.

Fig. 9.PV panels in the roof of CDER.

At CDER, Algiers, the electricity produced by 90 photovoltaic modules is injected directly into the network (Fig.9). A hybrid solarpower station (photovoltaic/diesel) of 13 kW is located at Illizi, beaconing of 2300 km of roads [18]

6.3.Various

In Algeria, the PV energy is not only present in the isolated localities. Indeed, as the city of Oran who decided to go green, the town of Sidi Bel-Abbes has been given a budget of 150 million Algerian Dinars (DA) for the installation of a public lighting system alimented by solar energy.

Fig. 10. Proposal for the roof of the future Oran airport [17].

The new terminal "Ahmed Ben Bella" of Oran, whose reception is scheduled for late 2015, will benefit from the installation of photovoltaic panels that will save nearly 50 million DA/year in terms of electric power consumption. In the capital, Algiers, the new Olympic Museum will also be provided with a facade of photovoltaic cells to reduce energy consumption by about 60% [17].

Finally, to finish with these examples, it is important to mention the agreement between the UDES (unit development of solar equipment) and NAFTAL in 2012 to equip, initially, about 42 service stations by photovoltaic panels and solar water heaters. These stations are mostly located along the east-west highway.

7. Research, Development and Photovoltaic Market

In the field of research and development, many Algerian organizations operate in the photovoltaic field. Indeed, several research projects have been launched to acquire the necessary knowledge to fully master this field. We can cite a few examples of organizations [9,20]:

- CDER: Renewable Energy Development Center.
- UDES: unit development of solar equipment.
- URAER: unit for applied research in renewableenergy.
- URERMS: research unit of renewable energy in theSaharan environnement.
- CRDEG: centre for research and development ofelectricity and gas.

In the university sector, we can cite examples of research laboratories:

- Research unit of material and renewable energy, university of Tlemcen.
- Semiconductor research laboratory, university of Annaba.
- Laboratory of applied physical energy, university of Batna.
- Laboratory of development of new and renewable energy in the Saharan arid areas, University of Ouargla.

For the photovoltaic market in Algeria, it is still in its infancy. This is mainly because there is no yet photovoltaic industry in this country, and the only companies that produce PV panels ("Condor" and "ALPV" for example) do, in fact, assembly. In other words, the basic components, solar cells, are imported from abroad so that the cost of photovoltaic panels on the national market is expensive [20,21].

However, an ambitious project that involves the construction of a factory for the manufacture of solar cells, in Algiers (Rouiba) could finally lower the price of photovoltaic panels. This plant, which was supposed to be completed in 2013, is delayed.

Areas that may be most attracted to a local industry and photovoltaic panels marketing at low prices [22]:

- Agriculture.
- Telecommunications.
- Transport.
- Housing.
- Health.
- Etc...

For the purchase prices of photovoltaic, in 2014 feed-in tariffs for electricity generated from the photovoltaic and the conditions of their application have been fixed by a ministerial decree published in [23].

Article 4 of the decree states that the purchase contract is concluded for a period of twenty years from the date of connection of commissioning. During this period, the producer receives in a first phase, which corresponds to the first five years of this period, the single purchase price set and calculated based on a reference potential estimated at 1500 hours of full load operation. In a second phase, and for the remaining term of the contract, flat rate will be adjusted depending on the real potential of the site.

Table 7. PV ground installation with a capacity from 1 to 5 MWC [23]

Regulatory limit of adjustment	Hours of operation per year	Guaranteed purchase price(Algerian dinars/kWh)	
		Phase 1	Phase 2
- 15%	1275-1349	15.94	20.08
	1350 - 1424		18.83
	1425 - 1575		17.45
Reference	1500 - 1574		15.94
+ 15%	1575 - 1649		14.43
	1650 - 1724		13.06
	> 1725		11.80

Article 5 of the decree states that the producer must send to the commission of regulation of electricity and gas data of measurements of the potential of the site for the past year. The commission of regulation notify the manufacturer, if any, during the fourth quarter of the fourth first years, the guaranteed purchase price that will be applicable to him during the second phase.

Table 8. PV ground installation with a capacity greater than 5 MWC [23]

Regulatory limit of adjustment	Hours of operation per year	Guaranteed purchase price (Algerian dinars/kWh)	
		Phase 1	Phase 2
- 15%	1275-1349	12.75	16.06
	1350 - 1424		15.06
	1425 - 1575		13.96
Reference	1500 - 1574		12.75

+ 15%	1575 - 1649		11.54
	1650 - 1724		10.44
	> 1725		9.44

Finally, we should note that other components of photovoltaic systems, such as batteries and other metallic structures to support these systems are manufactured in Algeria.

7. Conclusion

In recent years, the photovoltaic field in Algeria had known an important development. This growth is mainly because experts in this field are beginning to realize that available fossil fuels in the country, which are the mainstay of its economy, beginning to run out, hence the search for alternatives for the future.

Thus, the Algerian government is stepping up efforts to regulate and encourage the development of renewable energies in Algeria, particularly photovoltaic. These efforts are felt particularly in large rural electrification projects by solar kits, where the distribution of electricity is non-existent.

On industry, Algeria is still lagging behind. This delay is compensated by the many research projects that are conducted to find solutions and control the best use of solar energy in Algeria.

Finally, with its huge solar potential, Algeria has to gain by developing a local photovoltaic industry, and increasing efforts to spread this technology to all corners of the country to reduce its dependence on fossil fuels.

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