An overview of different energy sources in Algeria

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Abstract

During the last few years, political support for renewable energies has been growing continuously both at the national and international level and most scientists now agree that the Middle East and North Africa are perfectly placed to play a leading role in the lucrative future solar and wind power industries. Algeria plays a very important role in world energy markets, both as a significant hydrocarbons producer and exporter, as well as a key participant in the renewable energy market. Due to its geographical location, Algeria has been considered as one of the best countries for exploiting solar energy. Algeria enjoys a relatively high abundance of sunshine, solar radiation, and moderate wind speeds, and biomass energy resources. An overview of the energy situation in Algeria is introduced with reference to the end uses and regional distribution. It also, discusses the present and future on solar and wind applications. The problem related to the use of renewable energy sources and polices to enhance the use of these sources are also analysed in this paper. In addition the technical know-how for each renewable energy sources technology is defined. The co-importance of both policy and technology investments for the future Algerian markets of RES and competitiveness of the solar/wind approach is emphasized. Some examples of policy significantly impacting Algerian markets are reviewed, and the intention of the new Algerian renewable energy sources initiative is discussed.

Key words: Solar, Wind, Hydro, Biomass and Geothermal

1. Introduction

Energy is recognized as a crucial element in a country development process. Energy produced and used in ways that support human development in all its social, economic and environmental dimensions is what is meant by sustainable energy [1]. The goals of energy policy towards sustainable development are founded on three pillars namely: energy security and economic growth (Profit), environmental protection (Planet) and social responsibility (People) [2]. Not surprisingly, the use of Renewable Energy Sources (RES) prolongs the lifetime of fossil energy sources, boosts employment, has a dampening effect on energy price, reduces local and regional pollution, cuts emission on climate-damaging CO_2 and increase security of supply. In order to balance between energy need, and environmental protection and economy, RES are the pivot for sustainable development. The important economical changes undertaken these last years on the national and the international levels, led Algeria to embark on structural reforms aiming to a progressive adaptation, notably in the energy sector (fossil and renewable energies), so as it will be comply with a free, open and competitive economy. In this perspective, the Algerian government intends to promote and speed up a greater and more diversified participation of the energy Private-sector for investments development, technologies acquisitions, know-how and access to foreign markets. This new policy required changes of the legal and institutional frameworks that the government has pursued, on both the global and sector-based levels to overcome challenges facing the efforts to increase renewable energy use, which have to be understood and properly translated into a comprehensive regulatory framework. The setting up of a specific and competitive energy tax system (for renewables), combined to the formulation of more inciting investment conditions, will give a new impulse to the energy sector activities development.

The law on Electricity n° 02-01, enacted on the 5th of February 2002 [3,4], devotes the liberalisation of the electricity sector with the opening of electricity production and distribution to competition and the non discriminatory access of a third part to the network, while reaffirming public service maintenance. The bill on hydrocarbons aims to developing sources of incomes, by improving the quantity and quality of products and energy services supplied to consumers and by developing the loyal competition in an open and non discriminatory framework.

2. Geographic location of Algeria

Algeria's geographic location has several advantages for extensive use of most of the RES (solar and wind). Algeria situated in the centre of North Africa between the 38°-35° of latitude north and 8°-12° longitude east, has an area of 2381741 km^2 and a population of 32.5 Millions of inhabitants (13.7 inhabitant/km^2) [5].

Administratively, Algeria is divided into 48 provinces and lies, in the north, on the coast of the Mediterranean Sea. The length of the coastline is 2400 km. In the west Algeria borders with Morocco, Mauritania and occidental Sahara, in the southwest with Mali, in the east with Tunisia and Libya, and in the southeast with Niger (figure 1).

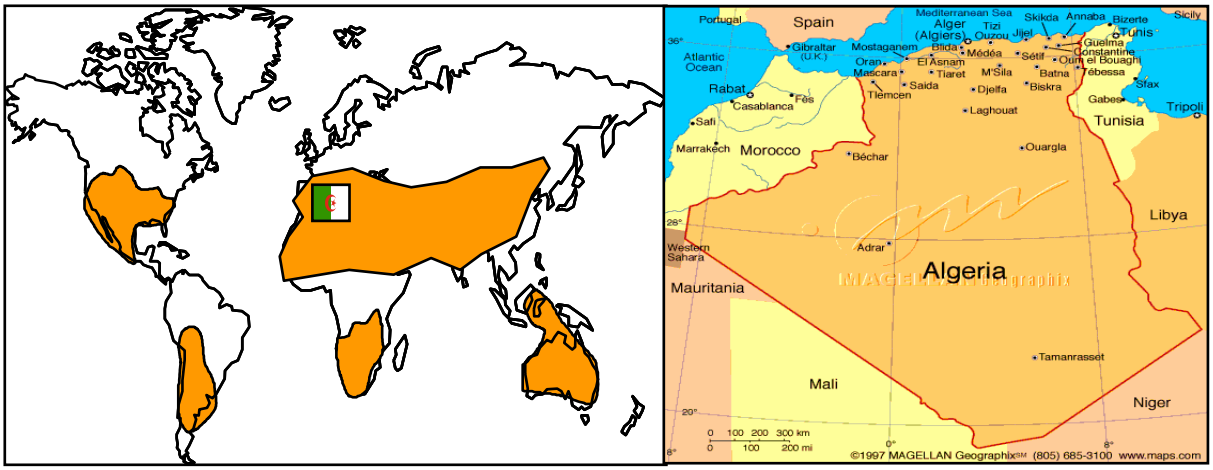

Figure 1: Solar suitable sites in the world and the Map of Algeria situated in the solar belt of the middle of the world

The climate is transitional between maritime (north) and semi-arid to arid (middle and south). The mean annual precipitation varies from 500 mm (in the north) to 150 mm (in the south). The average annual temperature is around 12 °C.

Three Ss should be the national energy policy drivers of Algeria namely: Solar, Sand and Space. The Sahara (south of Algeria) covers a total area of 2048297 km^2, approximately 86% of the total area of the whole country.

The geographic location of Algeria signifies that it is in a key position to play an important strategic role in the implementation of renewable energy technology in the north of Africa, as well as providing sufficient energy for its own needs and even exporting such projects to other countries of Europe.

3. Energy data for Algeria

Algeria plays a central role in the energy world, as it is a major producer and exporter of oil and natural gas. In 2008, Algeria produced approximately 1.4 million barrels per day (mbbl/d) of crude oil, of which 85% was exported, and 86.5 billion cubic meters (bcm) of natural gas, of which 70% was exported, mostly to Europe. Algeria was the fourth largest crude producer in Africa, and the sixth largest natural gas producer in the world. Oil and gas export revenues account for more than 95% of Algeria's total export revenues, around 70% of total fiscal revenues, and 40% of gross domestic product (GDP). Compared to other developing countries with a similar GDP, Algeria's energy consumption is high: 1.2 tons of oil equivalent (TOE) and 840 kWh of electricity per capita. However, these figures include self consumption and losses in the energy sector due to LNG (Liquefied Natural Gas) exports. The share of oil in the country's overall consumption fell from 40% in 1990 to 34% in 2007; the share of gas increased from 57% to 64%. In industry, gas accounts for nearly 53% of final consumption. Gas consumption also increased substantially in the residential sector, and in 2007 accounted for 46% of final energy consumption. This evolution shows the progressive adequacy of offer structure to the structure of our present reserves, richer in natural gas [6].

Primary energy production passed from 212 millions of tons oil equivalent (TOE) in 2003 to 260 millions of TOE in 2005. The primary energy production structure in 1980, made up of 87 % of oil and condensate, has considerably developed for natural gas' benefit, which now represents about 52 %. Algeria's revenues come mainly from exporting fossil fuels. In spite of a clear progression of national

consumption, exportations' share in energy commercial production remains determining (80 %). It has passed from 56 MTOE in 1980 to 133 MTOE in 2003.

Reserves of oil announced in Algeria are 4.5 billion of TOE. Estimates of natural gas reserves, in 2004, were around 4.52 10^{12} m^3, which implies a lifetime of 62.2 years compared with an expected 61.9 years globally [7].

As Algeria population grow many faster than the average 3%, the need for more and more energy is exacerbated. In Algeria, the consumption of energy at the national level is increasing year after year due to demographic and urban development, in addition to economic development in constant progression. As far as the resources are concerned, based essentially on oil and natural gas, they are not unlimited and are slowly being exhausted.

The national energy commercial consumption passed from 6 Million of TOE (MTOE) in 1970 to 32.7 MTOE in 2002, over 35.2 MTOE in 2003 and just under 40 MTOE in 2005 [8]. In unit terms, national consumption passed from 0.3 TOE/inhabitant in 1970 to 1 TOE/inhabitant in 2003 that is a tripling of the unit consumption in 30 years. The production of electricity in Algeria was 25.8 billion kWh in 2002 and 30.06 billion kWh in 2005 and the country consumption is between 25 and 30 TWh/year [8]. In a context of economic recovery, energy demand could double by the year 2020 (60 MTOE, even 70 million MTOE) by increasing uses of energy and economic activities.

4. Structure of power sector in Algeria

Algeria generated, Over the last five years, 185.8 10^9 kWh of electricity [9]. Conventional thermal sources of which natural gas accounted for 94.5%, contributed almost all of Algeria's electricity, supplemented by a small amount of hydroelectricity (5%) and solar photovoltaic/wind (0.5%). Algeria is now positively disposed to the promotion of RES and views renewables as a way of promoting the development of small and local businesses in selected areas and diversifying supply patterns at the regional level. Algeria has developed national programmes and set national indicative targets for renewables: to pursue the development of alternative electricity sources, including solar and wind to achieve a share of renewable energy sources in primary energy supply of 5% by 2015 and 10% by 2020. The Algerian energy sector is mainly operated by the following executing authorities: **SONATRACH SPA** (National Company of Hydrocarbons Research, Production, Transport, Transformation and Marketing); **SONELGAZ SPA** (Algerian Company of Electricity and Gas); **AEC SPA (**Algerian Energy Company) and **IAER** (Algerian Renewable Energy Institute)

The joint-stock company **NEAL** [10], created on the 28th of July 2002, is the first public-private partnership. Its registered capital of 200 Million Algerian Dinars (DA) is shared among Sonatrach 45 %, Sonelgaz 45 % and SIM 10 %. NEAL is a company developing projects in the production of electricity and heat from the renewable energies, which are the thermal solar, the photovoltaic solar, the wind, the geothermic and the biomass. It has also the dimension to fight against deforestation of the south of the country.

In 2003, the public authorities adopted the national energy efficiency policy by implementing the law of July 1999 relating to energy efficiency. The implementation mechanism for this strategy is composed of four instruments defined within the framework of this law, namely: **PNME** (National Energy Efficiency Programme); **FNME**, (National Energy Efficiency Fund); **CIME** (Inter-sector Energy Efficiency Committee) and **APRUE** (Algerian National Agency for the Promotion and Rationalisation of Energy Use).

The **CREG** (Commission of regulation of electricity and gas) is commissioned (art. 113 of the energy law) [3] to watch over the competitive and transparency functioning of the electricity market for the users and operator's interest. Its role is fundamental in the organisation and functioning of the electricity market, in general, and the renewable electricity, in particular. Article 128 of the law on electricity [3] imposes on the operators to lodge with the CREG sale and purchase contracts of electricity. This provision permits to know exactly the quantity and nature of the electricity sold within the market. For the renewable electricity, it is thus possible to know its origin: thermal or PV solar, wind, biomass or geothermal. The promotion of the renewable energies was thought with the objective to reinforce and favour the emergence of a local industry or a partnership in order to take a position in this market. In other word, the approach chosen by the sector of energy is based on the reform introduced by the law 02-01 of electricity and distribution of gas, which permitted, by exploiting the forces of the market, to promote the renewable energies in a long-lasting way.

The most important objectives of Algeria's energy policy and the portfolio of NEAL include: ensuring energy security of the country; more power for the remote area in the south; clean power to sustain the economical development; increasing the competitiveness of the economy and its energy efficiency;

protecting the environment from the negative effects of energy-related activities; four solar power plants in the south; four wind power plants in the south and achieving a solar hydrogen production.

Sonelgaz is responsible for the operation and maintenance of thermal, hydro power, solar and wind plants throughout Algeria. In addition to the production of energy, its activities also include the transport, transformation and distribution of electrical energy as well as the transport and distribution of natural gas and renewable energies. All of these structures and instruments mentioned above are under the supervision of the Ministry of Energy and Mines (MEM). Additionally, the MEM ordinance allows using renewable sources together with other fuels such as natural gas (co-firing). The total existing electrical exploitation installations capacity amounts the rate of 96%, more than 80% in the north of the country. The electricity market in Algeria is very important with a growth rate exceeding 6% [11].

5. Renewable energies potentials in Algeria

The interest for the development of renewable energies was perceived very early in Algeria with the creation of the solar energy institute as soon as 1962 (independence year). More than 2 million km^2 receive a yearly sunshine exposure equivalent to 2,500 kWh /m^2. The government seeks to create a solar-gas synergy; taking advantage of the country's abundant resources in both energies.

The assessed economic potentials, by the German Space Centre (DLR), of renewable energy sources in Algeria are [4]:

- Thermal solar : 169 440 TWh/year
- Photovoltaic : 13.9 TWh/year
- Wind energy : 35 TWh/year

Algeria is in urgent need of an adequate energy infrastructure so that it can achieve higher levels of economic development. This would allow all of its inhabitant's access to a quality energy supply, irrespective of their place of residence. Crucial objectives are targeted at substantially increasing and enhancing the contribution of renewable energies and favouring energy self-sufficiency. Pilot projects implemented in recent years justify the possibility to accelerate the use of indigenous energy resources, particularly for electricity supply. Algeria generated $25.8x10^9$ KWh of electricity in 2002 and $30.06x10^9$ KWh in 2005. The consumption of the country amounted to a value between 25 and 30 TWh/year. Conventional thermal sources of which natural gas accounted for 94.5%, contributed almost all of Algeria's electricity, supplemented by a small amount of hydroelectricity (5%) and solar photovoltaic/wind (0.5%). Algeria has an important potential for power generation from renewable sources, for the domestic market as well as for export to the European market. The current share of renewables is not very significant in the total energy balance, but an ambitious development program was set up, with a specific law in 2004, including incentives for electricity production from renewable, and the creation of a support fund and a renewable energy institute (IAER: Institut Algérien des Energies Renouvelables). Through a March 2004 decree, the government also introduced incentives for electricity production from renewable energy plants, including a feed-in tariff [12].

6. Solar energy

The history of using solar energy in Algeria backs to 1954 with the solar furnace built by the French for ceramic fabrication purpose [13]. The insulation time over the quasi-totality of the national territory exceeds 2000 hours annually and may reach 3900 hours (high plains and Sahara). The daily obtained energy on a horizontal surface of 1m² is of 5 KWh over the major part of the national territory, or about 1700 KWh/ m² / year for the North and 2263 KWh /m²/ year for the South of the country (table 1 and figure 2) [13].

Table 1: Solar potential in Algeria [13]

Areas	Coastal area	High plateau	Sahara
Surface (%)	4	10	86
Average duration of sunning (Hours/year)	2650	3000	3500
Received average energy (KWh/m^2/year)	1700	1900	2650

The solar deposit exceeds the 5 billion GWh.

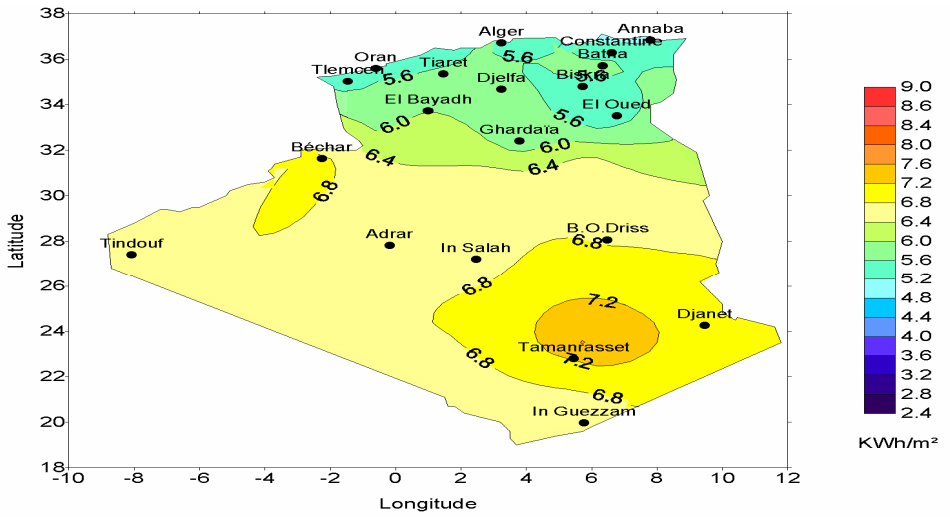

Figure 2: Potential sites for solar electricity supply and example of the overall daily exposure received (in KWh / m² / day) in Algeria [13]

The amount of solar radiation in Algeria means that it would be feasible to consider solar energy as a potential energy source for different applications in the form of individual photovoltaic solar panels or systems. Solar photovoltaic energy is being developed in Algeria mainly for six applications: domestic uses, water pumping, refrigeration, village electrification, lighting, and telecommunication. The development of solar energy plants is supported by the Ministry of Energy and Mines and realized mainly by Sonelgaz and other private installers companies. The solar energy is regarded as an important line of research within the structure of the Department of renewable energies of Sonelgaz. UDTS/CDTA (Silicon Technology Development Unit in collaboration with the Advanced Technology Development Centre), in Algiers, works on solar cells elaboration (clean room available) and with an encapsulation procedure workshop permits the production of 250 KW/year up to 500 KW/year [4]. A polycrystalline silicon growth oven having a capacity of 25 ingot /year, in the first phase, allows the elaboration of silicon ingot. Silicon ingot cutting facilities and electrical, optical and structural assessment equipment are also available. Manufacturing PV modules at ENIE (National Electronics Industry Company) [10] are limited in mono and polycrystalline silicon solar cell elaboration, assembly PV modules, and fabricating the support structure. UDES/CDER (Solar Equipment Development Unit in collaboration with the Renewable Energies Development Centre) ensures the development of solar thermal and photovoltaic equipment (domestic, industrial and agricultural), electronic, thermal and mechanical devices and systems involved in the application of solar energy. This means that the establishment of a silicon production industry is possible in Algeria to supply the local, MENA and European markets.

6.1. Rural electrification by solar photovoltaic energy

It relates to the electrification of eighteen (18) villages very far away from the networks existing and located primarily in the provinces of the great south (Adrar, Illizi, Tindouf and Tamanrasset). The number of rural hearths to be fed is 580. This program is financed entirely by the Special Funds for Development of the South Areas from the Ministry of Energy and Mines. The solar applications, by implanting photovoltaic power plants, are an extension of already existing diesel power stations in isolated areas and are limited to electrification, pumping, telecommunication, public lighting and small refrigeration systems. The photovoltaic installations used are of the semi-collective type. Sonelgaz have gone down the solar route for these 18 villages in the rural electrification programme with the aim of kick-starting the use of renewable and particularly photovoltaic energy (list of villages in table 2) [13].

Table 2: Installed power and daily home consumption (a), global installed power (b) and distribution per province of the PV installations (c)

(a)

Province	Village	Installed power (kW)	Consumption (kWh/day/home)
Tamanrasset	Moulay lahcen	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	Gara djebilet	33	1.47
	Daya el khadra	24	1.55
	Hassi mounir	21	1.68
Adrar	Hamou moussa	6	1.53
	Tala	16.5	1.61
Illizi	Imehrou	16.5	0.63
	Ifni	7.5	0.60
	Oued samen	15	0.68
	Tihahiout	12	0.57
	Tamadjart	24	0.80

(b)

	System (kWp)			Total
Power type	1.5	3	6	
Number of installed systems	10	50	48	108
Connection capacity in number of homes	30	300	576	906
Global installed power	453 kWp			

(c)

Province	Homes by unit	Power in (kWp)	Energy (kWh)	Stock (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

The concerned eighteen villages which have benefited from these installations have been selected according to their geographical location. These villages, situated in the South, with a small number of households, were typified by their isolation and their remoteness from any communications network. Supplying them by conventional methods (diesel, transmission grid), in addition to excessive start-up costs, would have posed the problem of trucking in the fuel, and in the case of the grid, of undoubted difficulties in constructing and maintaining the overhead lines.

One of the strengths of photovoltaics is to be found in its decentralised applications, cutting out the cost of transporting the energy produced. This is particularly true for supplying isolated consumers in areas of low population density, where the demand consists essentially in satisfying basic energy requirements (light, refrigeration, pumps, television and radio). Other notable characteristics of photovoltaics are: modular design enabling it to be extended according to need; the possibility of developing small businesses in areas of low economic development; protection of the environment and limited capital assets, capable of being used flexibly and in a decentralised way, and of being moved about over longer periods of time.

This developing strategy, by Sonelgaz, has been elaborated to promote the dissemination of renewable energies on sites where they are profitable compared to classical energies and to guide scientific research efforts in order to allow generalisation of renewable energy via mass production. The aims to be achieved consist of the contribution to a conservative policy for hydrocarbons both by increasing the renewable energy share within the national energy balance and by improving the living conditions of isolated communities. In the absence of any reference, this first operation led by Sonelgaz would allow on one hand to supply isolated area with electricity and on the other hand to collect information about: equipment behaviour in Saharan environment; matching the systems with the electricity supply; maintenance organization and management and technical -economic system optimization

The rural electrification second phase project will be approached with the same way as certain similar projects developed in the neighbouring countries. The role of NEAL would be in this case a provision of a financial engineering service. It is a question, for the populations non-connected to the network, of being able to profit from photovoltaic systems of production of electricity for the domestic needs and the pumping of water. The law on electricity offers the possibility to build the development of the production of electricity by concessions, which can be connected to private companies created around villages in the South for the benefit of local entrepreneurs. The Society of capital development (capital risk) being a privileged tool of financing in this case. Mono and multi - Crystalline Silicon modules are commercially available in Algeria and due to the interest given by the Algerian Government for developing remote areas as a socio-economic goal, the demand for more photovoltaic systems is expected to increase in the coming decade for more future solar energy production infrastructures.

7. Wind energy

Wind energy is the fastest growing energy source in the world and wind power is one of the most widely used alternative sources of energy today. The energy production in wind turbines depends mainly on wind speed in a place in which wind power plant is located (power curve). Depending on the wind velocity, it is possible to differentiate between four phases of operation:

- At very low wind speed, the wind energy is not sufficient to overcome the system's moments of friction and inertia, and the rotors remain stationary.
- Starting at a certain wind velocity, about 3 m/s, the wind turbine will turn. In this phase, the power output increases as a function of the wind speed to the power of 3 which means that twice the wind velocity produces 8 times the electrical power.
- If the wind velocity increases further, then the maximum capacity of the generator will be approached, and the energy generation has also reached its maximum.
- The surplus energy from a further increase in wind velocity must be bypassed. The maximum power of the system is thus determined by the flow over the rotor area, and does not depend on the number of rotor blades. During a gale-wind speed of about 24–26 m/s, the mechanical load on the rotors is too high. Pitch-controlled turbines and active-stall systems are then taken off the grid and the entire rotor is turned out of the wind to protect the overall turbine structure.

Wind energy can then be feasible where the average wind velocity is higher than 5–6 m/s. Algeria has a huge plan to develop wind energy. Studies of indigenous wind resources, performed by the CDER during recent years, show that the climatic conditions in Algeria are favourable for wind energy utilisation. The wind map of figure 3, established by the MEM [14], shows that 50% of the country surface presents a considerable average speed of the wind. The map also shows that the South-Western region experiences high wind speeds for a significant fraction of the year as seen in table 3 [15] showing the annual average wind velocities and power in the three sites of the South-West region of Algeria. This energy potential is ideal for the water pumping especially in the high plains.

The wind resource has also been assessed by the developer, Sonelgaz, and at present, there are six pilot projects for electrification and telecommunication which are identified and quantified. These are Adrar, Tindouf, bordj Badji Mokhtar, Bechar, Tamanrassat and Djanet.

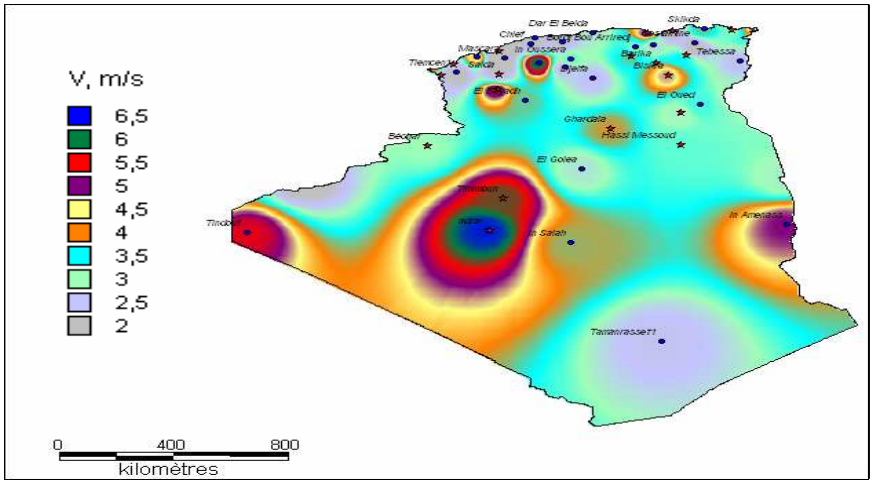

Figure 3: Wind chart of Algeria [14]

Table 4: The annual average wind velocities in the six identified places [15]

Sites	Adrar	Tindouf	Bordj Badji Mokhtar	Bechar	Tamanrassat	Djanet
Annual average speed (m/s)	6.3	5.1	4.6	4.4	3.7	3.3

The region of Adrar receives the most wind in the country judging from the results of the preliminary survey. Evaluations of powers recoverable at heights from 10 to 50 m could conclude in registering this region as a favourable site for the establishment of a windy farm. Other sites (North, High Plateaux) hide non-negligible energetic potentials (usable energy, figure 3). The installation, by Sonelgaz, of a 30 MW wind farm in Adrar region and the nine assessment stations in different regions of Algeria is seen as a second step in stimulating much faster the use of the wind power. The topography and terrain roughness of these prospective wind sites are also measured and quantified to better simulate and understand the wind flow.

8. Photovoltaic and wind installations throughout Algeria

The distribution per province of the photovoltaic and wind installations, the distribution of installed power per applications and the distribution of installed power per resources are respectively listed in table 5, 6 and 7 [4]. The overall installed power is 2.353 MW.

Table 5: Distribution per province of the photovoltaic/wind installations [4]

Provinces	**Resource**	**Installed Power (W)**	**Provinces**	**Resource**	**Installed Power (W)**
Algiers	Solar /Wind	46 610	Medea	Solar	5 000
Adrar	Solar	234 900	M'sila	Solar /Wind	45 500
Batna	Solar	7 500	Naama	Solar /Wind	88 400
Bechar	Solar	48 000	Ouargla	Solar	60 600
Biskra	Solar	5 000	Oum El Bouaghi	Solar	12 500
Blida	Solar	6 000	Saida	Solar	40 200
Bordj Bou Areridj	Solar	2 000	Setif	Solar	4 800
Bouira	Solar	3 000	Sidi Bel Abbes	Solar	39 000
Constantine	Solar	1 500	Souk Ahras	Solar	6 000
Djelfa	Solar /Wind	114 700	Tamanrassat	Solar	578 500
El-Bayad	Solar	78 500	Tebessa	Solar	64 000
El-oued	Solar /Wind	31 000	Tiaret	Solar /Wind	89 500
Ghardaia	Solar	32 750	Tindouf	Solar	96 150
Illizi	Solar	153 850	Tipaza	Solar	2 400
Khenchla	Solar	13 000	Tizi Ouzou	Solar	6 000

Laghouat	Solar /Wind	93 300	Tlemcen	Solar /Wind	54 500
Mascara	Solar	1 000	Other realizations	Solar	287 600
Total Solar /Wind : **2, 353, 260**					

Table 6: Distribution of installed power per applications [4]

Applications	**Installed power (W)**	**Percentage %**
Electrification	1352800	57
Pumping	288400	13
Public lighting	48430	2
Telecommunication	498000	21
Others	165630	7
Total	**2,353,260**	**100**

Table 7: Distribution of installed power per resources [4]

Resources	**Installed power (W)**	**Percentage %**
Solar	2279960	97
Wind	73300	3
Total	**2,353,260**	**100**

9. Hydroelectricity potential

Both the kinetic energy and the potential energy from flowing water can be converted into mechanical power by a turbine wheel, which in turn can drive machines or generators. Hydropower is a mature technology which, worldwide, generates the second largest share of energy from renewable sources, after the traditional use of biomass. 17% of the electricity consumed in the world today is generated by hydroelectric power stations. The overall flows falling over the Algerian territory are important and estimated to 65 billions m^3 but of little benefit to the country: restrained rainfall days, concentration on limited areas, high evaporation and quick evacuation to the sea. Schematically, the surface resources decrease from the North to the South. Currently the evaluation of useful and renewable energies is about 25 billion m^3, of which the 2/3 approximately is for the surface resources. 103 dam sites have been recorded. More than 50 dams are currently operational. The share of these small-sized production parks is about 5 % which supplements the natural gas production of electricity. The total capacity of 13 of them is 269.208 MW as shown in table 8 [4].

Hydraulic electricity represented, with 265 GWh in 2003, barely 1 % of the total electricity production. The electricity generation from hydropower is low due to the fact that the precipitation is low and unevenly distributed throughout the country.

Table 8: Hydroelectric production park [4]

Plant	Installed power (MW)	Plant	Installed power (MW)
Darguina	71.5	Ighzernchebel	2.712
Ighil Emda	24	Gouriet	6.425
Mansouria	100	Bouhanifia	5.700
Erraguene	16	Oued Fodda	15.600
Souk El Djemaa	8.085	Beni Behde	3.500
Tizi Meden	4.458	Tessala	4.228
Ghrib	7.000	Total	**269.208**

10. Geothermic energy

Geothermal energy is the energy derived from the heat of the earth's core. It is clean, abundant, and reliable. If properly developed, it can offer a renewable and sustainable energy source. People have used geothermal resources in many ways, including healing and physical therapy, cooking, space heating, and

other applications. One of the first known human uses of geothermal resources was more than 10,000 years ago with the settlement of Paleo-Indians at hot springs. Geothermal resources have since then been developed for many applications such as production of electricity, direct use of heat, geothermal heat pumps, etc.

Concerning the geothermic energy in Algeria, the geotectonic framework suggests that Algeria should not be lacking in commercially exploitable sources of geothermal energy. Geothermic is not to be excluded from the electric option of the renewable energies network. Some of these sources can be exploited for the purpose of renewable electricity production. This view is further strengthened by the presence of a fairly large number of hot springs in different parts of the country. More than 200 geothermal sources were counted by the CDER and are recorded of which one third's temperatures are superior to 45°C and where the highest temperatures registered are 98 °C in Hammam El Maskhoutin and 118°C in Biskra, in the western part of the country [13]. These hot springs are numerous but unfortunately not exploited for industrial ends.

11. Biomass energy

The oldest and simplest way of using energy is to burn the biomass. The generation of electricity and heat from biomass is a particularly attractive form of energy conversion from the climate point of view. The biomass in Algeria potentially offers great promises with bearing of 3.7 millions of TOE coming from forests and 1.33 million of TOE per year coming from agricultural and urban wastes (365 kg per Algerian as urban wastes); however this potential is not enhanced and consumed yet. A pre-survey showed the feasibility of production of electricity by modals of 2 MW that can reach a peak of 6 MW from the discharge of Oued Smar in Algiers. The study integrates the drainage of the site [16].

Regulations from the MEM which support using of biomass from energy crops rapidly caused an increase in interest for connection agriculture and energy sector. This is seen as a first step in stimulating much faster the use of biomass in Algeria.

Biogas is also considered to be an attractive and relatively cheap energy source. In addition, disposal of biogas by combustion is absolutely necessary to protect the environment; in particular, to protect the atmosphere against emission of unburned methane contained in biogas. A gradual growth of the use of biogas, particularly from landfills, has commenced at the UREERMS (Solar Equipment Experimentation Unit in the Sahara Area) which is seen as a step forward in the use of biogas in Algeria. A very promising alternative for burning is the gasification of biomass. Using gaseous biogenic fuels, it is possible to apply proven and efficient techniques like gas turbines and cogeneration units.

12. Solar Hydrogen

The solar-hydrogen energy system for Algeria would could extend the availability of fossil fuels resources, reduce pollution, and establish a permanent energy system. It could do so by solar production of hydrogen and then utilizing hydrogen as an energy carrier as well as exporting it to Europe. This would provide Algeria with a clean permanent energy system, and would enable it to maintain and improve its overall GNP, as well as improving its quality life. Algeria and the International Energy Agency agreed on technological cooperation in developing solar-hydrogen economy [17,18]. The Algerian Hydrogen Association (2AH) has been created in June 2005 during the hydrogen conference held in Algiers.

Initial work has already began in the areas of utilizing solar energy in producing hydrogen (CDER) for fuel cell but have not yet resulted in power generation and are rather in primary stages as compared with the work on solar and wind energy sources.

At the moment natural gas steam reforming is a likely initial source of hydrogen, due mainly to being a highly established process and having both natural gas distribution infrastructure and large scale hydrogen production facilities already in place.

NEAL tries achieving, in the near future, a solar hydrogen production as announced by the president of NEAL. Therefore, the sustainability for the environment is obvious. He also insists upon clean power to sustain the economical development of Algeria. In fact, there are several projects being qualified for application within Clean Development Mechanism (CDM) in different fields including:

- Renewable energy;
- Fuel switching for transportation (GPL fuel and the construction of a factory producing clean fuel, the GTL as reported by Oxford Business Group) [19];

- Industry (GGFR, Global Gas Flaring Reduction Partnership to reduce GHG emission at the Sonatrach's oil and gas plants) and
- National energy efficiency strategy (PNME, FNME, CIME and the APRUE) as listed above.

13. Technical know-how transfer and technical cooperation

The development of solar energy in Algeria is supported by the Plataforma Solar de Almerı´a (PSA), a division of the Centro de Investigaciones Energe´tica, Medioambientales y Tecnolo´gicas (CIEMAT). This is the largest research and development centre in Europe, devoted to high-concentration solar energy technologies. The PSA has been functioning since the 1980s, and is regarded as an important line of research within the structure of the Department of Renewable Energies of the CIEMAT.

A techno-pole has been created including Sonatrach-Sonelgaz and NEAL, CDER, Laghouat and Ghardaia universities and the Algerian Space Agency (ASAL). It also includes DLR and CIEMAT [13]. Additionally, technical cooperation is part of the CDER policy. This cooperation will assure a proper running of the centre. The technical cooperation as a scientific cooperation in research and development projects will incorporate the CDER's staff and laboratories into bilateral or international research activities of renowned worldwide institutes in the field of renewable energies such as:

- Cooperation with the European Union with the creation of the PIN (National Information Point) which aims the integration and Algerian participation in the European research programs on REs. By this means an intensive know how transfer is ensured.
- Cooperation with Spain in the field of solar water pumping systems, mini-central grid connected PV systems and electrification of the touristy region of Assekrem by means of PV energy.

In the frame of the SPP1 of Hassi R'mel and its know how transfer task, there are activities of training and technical cooperation with CIEMAT. These activities are performed initially in Spain and afterwards also in Algeria.

The international cooperation is an important activity for the agency because of its contribution in terms of international expertise and know-how. For this purpose, APRUE has developed cooperation relations both within the bilateral and multilateral framework. The stake in MEDENER, the association of Mediterranean energy efficiency agencies, enables APRUE to keep up to date with the programme, projects and actions in the region, but also to make itself known to the financial backers and promote both the Algerian energy efficiency market and the energy policy at the international level. Within the bilateral framework, APRUE has developed projects particularly with France and Spain.

The cooperation with France is of an institutional nature. This cooperation was formed, in 2003, through an agreement between APRUE and its counterpart the ADEME (the French Environment and Energy Management Agency). With regard to the cooperation with Spain, it has approached two sectors: industry and road transport.

At the multilateral level, APRUE has benefited from donations from the European Commission, from the GEF (via the World Bank and the UNDP) within the framework of projects in several sectors. APRUE intends to develop the cooperation at the international level even more. Negotiations are underway with the Italian and Quebecois partner, the GTZ of Germany, Afrec (African Energy Commission) and UNESCO to develop, with their support, energy efficiency projects in partnership with all consumption sectors. The actions planned for the years 2004 and 2005 had the objective of looking for and coordinating technical and financial international cooperation in order to support the national energy efficiency policy in Algeria, as well as to promote the Algerian energy efficiency market at the international level.

13.1 Available technical know how

Universities, UDTS/CDTA, UDES/CDER and their research units in Adrar, Ghardaia and Tlemcen, their equipments, staff and their know how can form a sound basis for a further successful dissemination of renewable energy technologies and applications in Algeria.

For the sustainable application of renewable energy systems in Algeria and their widespread practical use, suitable infrastructure of concerning expert exists and who can act as source of information about the renewable energy technologies for those people who will be interested on such energy supply as well as for a wider ranging distribution of knowledge and advantages of renewable energy systems. Parallel to this spread of information a build-up of opportunities for installation, maintenance and services, eventual repair and sale of system components and systems exist [20].

14. Total MENA-Europe HVDC Interconnections (by DLR)

Algeria is planning the realization of the projects of cables towards Europe. The concept of a MENA-Europe Link using High Voltage Direct Current power (required and to be supplied for different applications) transmission technology is summarized as follow (see also figure 4) [21]:

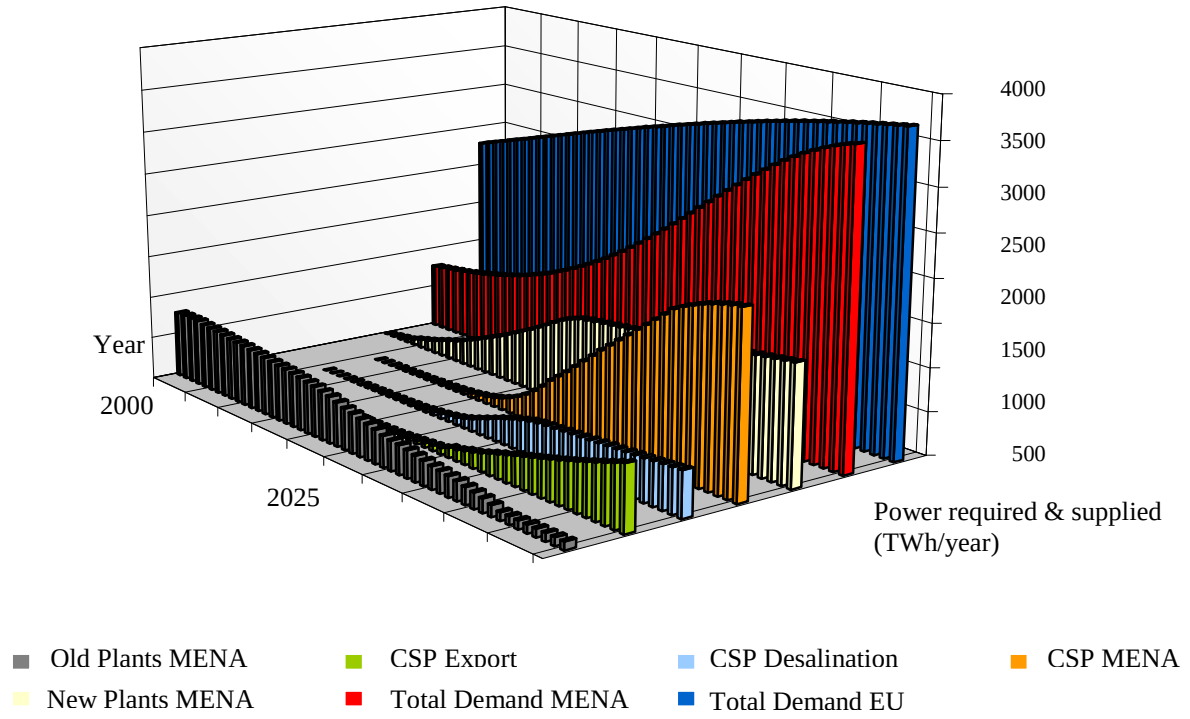

Figure 4: Interconnections MENA-Europe, power required & supplied for different applications [21]

15. Market, promotion and trend in the development of renewable energy sources in Algeria

The percentage of renewable energies in our national energy balance remains insignificant. But this situation cannot stay in an embryonic stage and the interest of introducing renewable energies in Algeria is becoming a declared desire of the public authorities; the results of the proposed actions will enable assessment and decision making elements to be given to the energy policy players. There is a market of electricity, which, at present time, is largely defined by the law 02-01 on electricity and distribution of gas which permitted, by exploiting the forces of the market, to promote the renewable energies in a long-lasting way. A statutory text or the decree on the costs of diversification aims at bringing the share of electricity produced by the renewable energies to 5 % of the total electricity to be produced by 2015, by introducing incentive measures for all the branches of energies used to produce electricity.

The action plans of the years 2004-2005 has particularly planed to make a clear diagnosis of the evaluation subsidiaries of this type of energy, to make the public authorities and the industrial players aware of this and to propose a national renewable energy development strategy. The promotion of solar energy is undergoing spectacular acceleration with, particularly, the launch of the important hybrid solar-gas power plant in Hassi R'mel, among many others that are eligible for the clean development mechanism's financing.

The setting up of a portfolio of projects will be based fundamentally upon an approach to the market. The local market will be stated now as the statutory texts and will be enforced such as the decree on the costs of diversification. The last meeting on energy, held in Roma between the Ministers of the European Union and the Maghreban countries (Morocco, Algeria, Tunisia and Libya), retained in its declaration the promotion of the production of electricity derived from renewable energies in the Maghreb region. The following objectives have been selected [22]:

- For the local market, the size should reach 500 MW by 2015.
- For exportation, the objective of the forthcoming five years remains the European market, which is able to absorb 1,000 MW by 2020 in renewable energy coming from Algeria.

The North Africa is perfectly placed to play a leading role in the lucrative future solar power industry, says a report released on October 2005 by Science and Development Network (SciDevNet). The report says that in 20 years, solar power could provide the same amount of electricity as 72 coal-fired power stations. This is enough to supply 100 million people, or the combined populations of Algeria, Morocco, Tunisia and Libya. By 2040, solar thermal power plants could supply five per cent of global electricity demand. Algeria is in urgent need of an adequate energy infrastructure so that it can achieve higher levels of economic development. This would allow all of its inhabitants access to a quality energy supply, irrespective of their place of residence. Crucial objectives are targeted at substantially increasing and enhancing the contribution of renewable energies and favouring energy self-sufficiency. The objectives established by NEAL are focused on raising renewable energy production to 1400 MW in 2020 and 7500 MW at the beginning of 2025. The electrical power will be obtained from solar power plants, which are exclusively solar, or from hybrid solar plants, which also use other forms of renewable or conventional energy, preferably natural gas. The Algerian Government has been promoting the use of renewable energy by means of a series of laws and official programmes already mentioned.

The objectives established by NEAL are focused on raising renewable energy production to 1400 MW in 2030 and 7500 MW at the beginning of 2050. The electrical power will be obtained from solar power plants, which are exclusively solar, or from hybrid solar plants, which also use other forms of renewable or conventional energy, preferably natural gas (table 9) [23].

NEAL has solicited several sources of funding and supporting its projects. On the one hand, the projected objectives is included within a solicited actions supported and financed by the world bank, IEA and the European bank of investment, whereas on the other, it also receives funds from the Algerian Government (Ministry of Energy and Mines).

Table 9: Total programme plans and objectives by NEAL [23]

Needs	Local (MW)	Export (MW)	Total (MW)
2015	500	75	**575**
2000	1000	400	**1400**
2050	1500	6000	**7500**

The Algerian Government has been promoting the use of renewable energy by means of a series of laws and official programmes already mentioned (table 10) [23].

Table 10: A total list of power production with renewable energy sources up to 2015 [23]

Project and place	Capacity (MW)	Bill-book	Cost ($\$x10^6$)	Observation
SPP1, Hassi R'mel	150	2008-2010	160	Hybrid, solar power plant-gas
SPP2, Naama	400	2010-2013	286	Solar power plant
SPP3, Megha	400	2012-2014	286+120	Solar power plant+ unsalted process
SPP4, Hassi R'mel	400	2012	286	Hybrid, solar power plant-gas
Total	**1350**		**1138**	
WPP1, Adrar	10	2010-2012	23	Wind power plant
WPP1, Tindouf	6	2012-2015	13	Wind power plant
WPP2, Tindouf	10	2012-2015	23	Wind power plant
WPP3, Timimoun	10	2012-2015	23	Wind power plant
WPP4, Bechar	10	2015	23	Wind power plant
Total	**36**		**82**	

By 2030, Algeria aims at generating 20% of its electricity from renewable sources, 70% of which from CSP, 20% from PV and 10% from wind. The country's strategy to develop renewable energy sources and

implement a low carbon economy fully supports its efforts to reduce vulnerability to oil prices and hydrocarbon exports. Algeria intends to become a leading nation in the renewable sector, including in manufacturing components, thanks to abundant domestic resources and targeted policies.

In view of the increasing energy intensity, the Government has emphasized energy efficiency and renewable energy options. The National Energy Efficiency Fund of Algeria (FNME) was created in 2000 (Decree no. 2000-116), with the objective of financing energy efficiency investments as well as the budget of the National Energy Efficiency Agency (APRUE) and the projects it manages under the National Energy Efficiency Program (PNME), FNME's annual budget is estimated at DA 500 million (Euro 57 million). The resources of the funds include taxes on natural gas (DA 0.00015/btu) and electricity (DA 0.02/kWh), and an initial government contribution of DA 100 million (Euro 1.15 million). Additional resources may include taxes on energy intensive equipments, penalties, loan reimbursements, and government or other contributions [12].

Algeria could one day be exporting solar energy to markets in Europe, as they will soon be connected to European energy networks. In fact, the Algerian Energy Company (AEC), Sonatrach and Sonelgaz in partnership with foreign companies (Spain and Germany) will realize, by 2015, a 2000 MW project of which a share of the production will be exported to Europe (4% of the projected power or 75 MW will be produced by a 150 MW concentrated solar-gas hybrid station in Hassi R'mel) [23]. Plans are underway for two undersea cables with capacity of 1.2 GW each from Algeria to Spain and Italy which represent the concept of a MENA-Europe Link using HVDC power transmission (figure 5) [24,25].

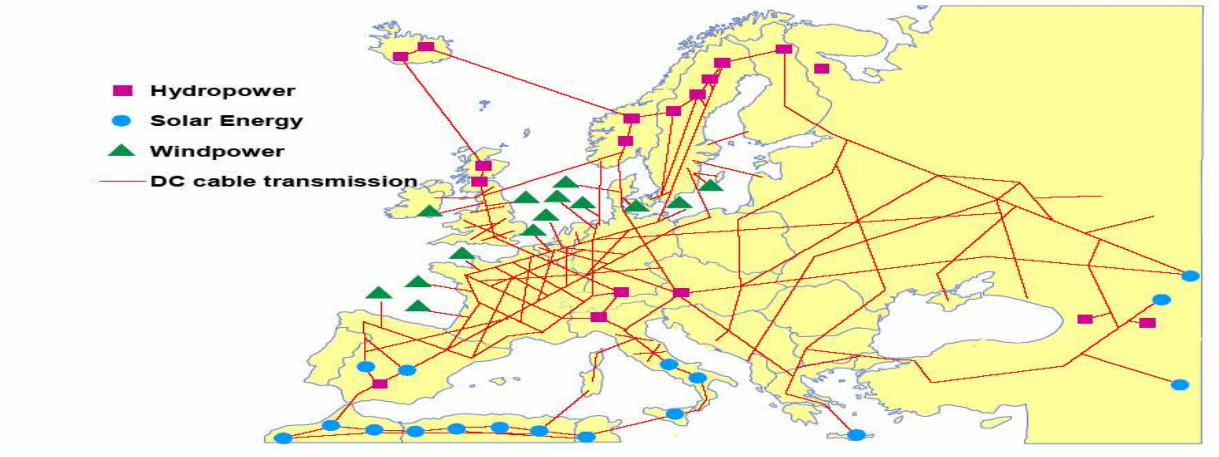

Figure 5: Interconnection North Africa-Europe trough the Mediterranean Sea [24, 25]

Conclusion

Algeria is endowed with large reserves of energy sources, mainly hydrocarbons and solar energy. Regarding the completed assessment work done by the DLR, it appears that there is a considerable potential for the utilization of renewable energy sources especially with respect to solar and wind power. However the level of development of such energy sources is rather primary, but efforts should increase because of the ever growing concern about the environment friendly sources of energy. It is now important in educating the public as well as introducing special energy legislation to increase the usage of this clean form of energy whether in private or public sectors and show the importance of energy efficiency and conservation. Renewable energies are now one of the major elements of Algeria's energy policy for many reasons:

- Due to its geographical location, Algeria holds one of the highest solar reservoirs in the world.
- Algeria plays a very important role in world energy markets, both as a significant hydrocarbons producer and exporter, as well as a key participant in the renewable energy market.
- The Government of Algeria has committed itself to develop solar energy as its largest renewable energy source, to cover 5% of the national electricity needs by 2015.
- In July 2002, Sonatrach, Sonelgaz and the private company SIM formed a joint venture, New Energy Algeria (NEAL), to pursue the development of alternative electricity sources, including solar, wind and biomass.

- Algeria's commitment to its National Rural Electrification Programme, which continues to provide solar power to villages in southern Algeria. Following a successful first phase, the second phase is now underway.

The production of electricity from renewable sources constitutes a real opportunity of investment in which economic viability is guaranteed by a contract of regulation. The multiplication of investments, the effects of competition and the experience curve will progressively reduce the costs of production. The quantities of renewable electricity for sale can be increased without any additional impact on the tariffs or the budget of the government. Moreover, the production of renewable electricity is well valorised when exported to Europe. The development of the production of renewable electricity will be self-sustained as it can provide electricity continuously without notable intervention of the public authorities. The PV, CSP and wind commodities have come into the market, and which is more and more popular by the common people. It is predicted that the solar/wind energy has a big potential in future Algeria.

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