

IRENA CASE STUDY 2013
MOROCCO WIND ATLAS



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I. NATIONAL CONTEXT

The Kingdom of Morocco is the only North African country with no natural oil resources and is the largest energy importer in the region with 96% of its energy needs being sourced externally. The leading supplier of Morocco's energy requirements is Saudi Arabia at 48%. By 2011 Morocco's energy bill had reached MAD 86 billion (approximately USD 10 billion); electricity demand in the country is projected to quadruple by 2030.

Morocco is situated in a key geographical position that enables it to act as a regional hub and with an electricity network that is inter-connected with Spain and Algeria.

Morocco has small quantities of gas in the areas between Rabat and Meknes. Morocco also has large reserves of oil shale and has signed partnership agreements with global energy companies to test the oil shale. However, in the absence of a proven specific industrial process that can produce oil and gas from this unconventional source, Morocco has turned to implementing a number of strategies that promote renewable energy and energy efficiency.

Morocco has far reaching ambitions for the renewable energy sector. With domestic demand for power rising steadily and power generation fuelled by imported fossil fuels, investment in developing energy from renewable sources is critical.

The Kingdom has achieved significant progress and has taken important steps to reform the policy and regulatory framework. It now boasts one of the most de-regulated electricity sectors in the Middle East and North Africa (MENA) region.

In 2008 Morocco launched the National Energy Strategy, with Renewable Energy and Energy Efficiency Plan as the main pillars, which aims to develop renewable energy to meet 20% of the country's domestic energy needs and increase the use of energy efficiency to meet 12% by 2020 and 15% by 2030.

Morocco has one of the most ambitious renewable energy programme in the MENA region. It expects 42% (equivalent to about 6,000 MW) of its total energy mix to come from solar, wind and hydroelectric sources by 2020. It has planned more wind and solar projects than any other country in the region.

Morocco developed a track record in successfully implementing renewable energy schemes. However historically, inadequate regulatory framework, a lack of finance

and a piecemeal approach to renewables have all hindered the sector's development.

In recent years the Moroccan Government made significant efforts to strengthen the legal and regulatory framework required to facilitate the development of the renewable energy sector and the energy efficiency measures through out the country.

This ambitious goal is achievable as it is recognised that Morocco has a huge potential in solar and wind power and a strategic position in the heart of the Euro-Mediterranean energy hub; including the regional projects facilitating synergy, for example, the Mediterranean Solar Plan, Desertec Initiative and Project MedGrid with which Morocco adheres.

Based on 20 years of data collection, the "Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique¹" (ADEREE) developed the first wind digital atlas for 2.5 km² resolution at 60 metres (m), 80 m and 100 m.

ADEREE also publishes solar potential maps at the national and regional levels for global solar radiations at 12x12 km resolution, to be refined at 4x4 km.

The approximate cost of installing wind measurement installation is around EUR 70,000, including equipment, collection, monitoring and recording for one year. The costs of solar measurement installation are lower at EUR 40,000, including the equipment, collection and monitoring for one year.

II. MEASUREMENT CAMPAIGN(S) AND CREATION OF THE NATIONAL ATLAS

The Centre de Développement des Energies Renouvelables (CDER)² created in 1982 and transformed in June 2011 to the national agency ADEREE, exerted significant efforts to identify and characterise the national renewable energy resources. Data gathered for the solar and wind energy evaluation programme of ADEREE, confirms that Morocco has several areas with excellent wind energy potential and a large potential of solar resources.

In 1990, ADEREE launched a programme that evaluated wind energy resources. The first phase of the programme (1991 - 1994) was devoted to the assessment of wind resources at the Coastal areas of Dakhla, Tangier and Tetouan. In March 1994, ADEREE published the "Second wind atlas in Morocco". This document contained data from 17 stations of the Agency. The second phase (1995 - 2000) targeted the North Eastern provinces (Taza and

1. National Agency for Development of Renewable Energy and Energy Efficiency

2. Centre de Développement des Energies Renouvelables, CDER for Renewable Energy Development



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Nador), provinces of Essaouira and those in the south of Morocco (Tarfaya and Laayoune).

The wind energy measurements at several stations in the provinces of Tangier and Tetouan were very promising, having an average of 8 m/s to 11 m/s, thereby favouring the installation of wind farms that could then be connected to national grid.

The third phase (2001 - 2010) focused on the south Atlantic coast and the mountains of the Atlas and Rif. ADEREE installed eight monitoring stations and 20 wind measurement stations at 60 m in favourable sites, with the aim of putting in place large wind farms that connect to the national grid. The measurements constitute a portfolio of projects aimed at facilitating wind energy investment in Morocco.

Data analysis used an approved method that included the software ALWIN, designed for wind energy applications. ALWIN connects the site wind potential with technical data of a selected wind turbine (mainly height and the power curve of the selected wind turbine) and establishes the expected annual energy yield of a wind turbine based on wind resource assessment

According to a study prepared by ADEREE and the German Co-operation Agency (GTZ), presented at a workshop in 2007, the technical wind energy potential estimated for Morocco was 4 896 TWh/year, which equates to 2 645 GW of installed power. The achievable potential is estimated at 3 200 MW by 2020, this was

estimated according to the total power capacity of all power plants that are to be installed in Morocco in 2020.

The ADEREE initiated a study to identify potential opportunities for enhancement of low-power wind energy for localised applications (smart grid).

For the wind atlas simulations, ADEREE used data from a variety of sources; ADEREE installed 60 measurement stations at 10m, 40m, 60m, 80m and 100m; certified 10 wind stations; used satellite data; and 20 years of collected data.

For solar energy resources, ADEREE has undertaken the characterisation measurements of solar radiation in different areas of Morocco, these are additional measurements to those that have already been made by the National Directorate for Meteorology since 1957. This work was recently completed with the mapping of Morocco's climate, in which six climatic regions were identified that were characterised by their average temperature; degree-days for heating; and degree days for cooling. These are the main technical specifications used for establishing the Moroccan thermal building regulation.

These studies prove the abundance of the solar resources (more than 3 000 hours of sunshine per year and 5 kWh/m²/day, in terms of energy received) and helped initiating a process of development for the two largest solar industries, namely:



- ♦ Solar photovoltaic applications for decentralised rural electrification, water pumping and telecommunications
- ♦ Solar thermal for low-pressure applications, like sanitary water heating.

According to the ADEREE/GIZ study, PV technologies have considerable advantages for rooftop applications and solar PV plants; the technical and achievable potentials are estimated respectively at 10 829 MW and more than 2 018 MW by 2020, and these correspond to an energy production of about 13 000 TWh/year and 3.3 GWh/year respectively.

ADEREE's current solar atlas programme for Morocco is based on three components:

- ♦ Assessment of the regional resource (Regional Atlas for: solar, wind and biomass Master Plan), evaluation of potential energy efficiency in the building industry, financial and technical support
- ♦ Identification and promotion of development projects and investment in renewable energy and energy efficiency
- ♦ Creating a cluster of skills in renewable energy and energy efficiency, capacity building, strengthening the commercial circuit and local services.

This regional dynamics are expected to be extended to other territories of the country.

Regarding the direct solar radiation (DNI) required for concentrating solar power (CSP) (includes both CSP and

CPV projects), DNI data from 5 locations were identified on the basis of satellite and calculated data in the following locations:

Ouarzazate	DNI of 2 635 kWh/m ² /yr
Ain Beni Mathar	DNI of 2 290 kWh/m ² /yr
Foum Al Ouad Laâyoune	DNI of 2 628 kWh/m ² /yr
Boujdour	DNI of 2 642 kWh/m ² /yr
Sebkhath Tah/ Tarfaya	DNI of 2 140 kWh/m ² /yr

Today, ADEREE, is developing a certification for the measurement sites, which is needed by investors. There are 20 wind locations and 10 solar locations that are under certification, in accordance with international standards.

Additionally, ADEREE in partnership with international partners has implemented a national renewable energy (wind, solar, biomass) mapping tool, which will be available online with a high resolution focus on the region of Guelmim Es-Semara. The solar atlas will provide solar radiation data at 12x12 km resolution, to be refined at 4x4 km.

III. IMPACT OF THE MEASUREMENT PROGRAMME

Based on the measurement and identified locations made by ADEREE, the National Electricity Office (ONEE) has launched a wind farm programme called EnergiPro (a 1000 MW private initiative), in addition to the ONEE public programme of 1 000 MW. A database of the potential wind locations in the North and South of the country has been developed. Furthermore, the framework for grid connection



has been studied and to simplify procedures, an Energie Pro-team was established to act as interface between project developers and the employees responsible for grid connection within ONEE. The EnergiPro programme supports the national aim to increase the share of renewable energies by 2020. Today, more than 15 projects have applied for this 1 000 MW initiative. Although, a number of private developers applied to set up a wind farm, information from ONEE indicates that the existing grid cannot support any additional capacity.

Morocco has been a priority partner country of GTZ (currently Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), since 1961. Today, co-operation is also targeted at the energy sector (in particular wind and solar energy). Since February 2008, GIZ has been advising ADEREE and Ministry of Energy, Mines, Water and Environment in developing policies that support the implementation of renewable energies and energy efficiency. Between 1997 and 2000, the GIZ's TERNA Wind Energy programme carried out wind measurements at three different sites that have led to concrete investment projects. The Kreditanstalt für Wiederaufbau (KfW)³ has been active in various wind farm projects. The KfW's Tangier wind farm project with a capacity of 3.5 MW, commissioned in 2001, was the first

donor-financed wind energy scheme in Morocco. The KfW has also supported the Essaouira wind farm with a capacity of 60 MW, commissioned in 2007, and is currently engaged in a second wind farm in the Tangier region (140 MW).

The KfW also promoted PV projects locally to increase rural electrification, this involved private companies at an early stage of the project in order to maintain these systems. Other international organisations are also active in Morocco. The World Bank, for example, is promoting modernisation of the energy sector with a loan of USD 100 million. The World Bank together with the African Development Bank, European Investment Bank, and the French Development Agency are also involved in the financing of a solar thermal power plant and other wind farms, based on measurements made by ADEREE described earlier.

The work prepared by ADEREE over the past three decades, the identification, mapping and evaluation of national renewable energy resources, have allowed Morocco to gradually launch major initiatives to develop renewable energy in country. The Moroccan solar programme is the result of technical efforts and raising awareness at all government decision levels, which allows Morocco to decide its national projects for CSP and wind:

- ◆ The PV rural electrification programme (PERG); the decentralised programme that incorporated from 1997 PV projects into its facilities and thanks to these efforts, more than 60 000 households have been equipped with solar home PV systems.
- ◆ Integrated Projects for Solar and Wind Energy, to reach 2 000 MW each by 2020, were launched on the 2 November 2009 and 28 June 2010, respectively under the chairmanship of His Majesty King Mohammed VI. This illustrates the outcome from a perspective of proactive policy when National priority is given to renewable energy targets.
- ◆ The integrated solar CSP plans programme aims to build five plants as follows: 500 MW in Ouarzazate to be brought into production by 2015; 400 MW in Ain Beni Mathar near Oujda; 500 MW in Tah Sebkhah; 500 MW in Fom El Oued; and 100 MW in Boujdour.
- ◆ The integrated solar programme mobilised an estimated investment of USD 9 billion, allowed annual savings of 1 million ton oil equivalent (toe) and avoids 3.7 million tonnes of CO₂ per year from the use of fossil fuels.
- ◆ In addition to the success of the Moroccan Solar Programme, the development of wind energy has been accelerated in accordance with the High Royal Directives, through the implementation of the Moroccan Integrated Wind Power Generation Programme reaching a capacity of 2000 MW to be completed by 2020.
- ◆ In this context, 286 MW of wind power are already in production and five other sites are under development at: Taza 150 MW, Tangier2 150 MW, Koudia El Baida 300



MW, Tiskrad 300 MW and Boujdour 100 MW. This integrated project totalling 1000 MW is to be rolled out across five new sites. Beside this public programme of 1000 MW, ONEE launched in 2010 EnergiPro initiative for private investments totalling 1000MW that was described earlier.

This programme will allow annual wind energy production of 6 600 GWh, and will mobilise an estimated investment of USD 3.5 billion in addition to annual savings of USD 1.5 million and avoided emissions of 5.6 million tonnes of CO₂ per year.

- ♦ In the development of solar water heaters, ADEREE, in line with the national energy strategy launched the Shemsi programme, which aims to achieve 1.7 million m² by 2020.
- ♦ The large scale PV programme connected to the grid, is today under development. Regulatory framework is also under preparation, with the preferred option being net metering as a mechanism for trading green electricity.

IV. POLICY AND REGULATORY FRAMEWORK

The Moroccan Government has been praised for the substantial efforts that it has made in recent years to

strengthen the legal and regulatory framework for developing renewables. Significant legal reforms in 2010 and 2011 were enacted by four laws:

Decree 1-06-15 of 2006 obliges public institutions to employ competitive calls for tender in awarding projects. The law applies for example to municipalities that may wish to contract wind farms or other sources of electricity from renewable energy.

Law 16-08 voted in 2008, raised the ceiling for self-generation by industrial sites from 10 MW to 50 MW. The Law was conceived principally to support wind power, but applies equally to other technologies. This Law amends the 1963 Decree from which created ONEE and attributes to ONEE a monopoly of production above 10 MW

Law 13-09 promotes renewable energy development and provides a framework for developers and investors in clean energy projects. The new law does not put a limit on the installed capacity for each project or the type of energy. The electricity produced can be supplied to the local market and/or exported by access to the national grid and interconnections with other countries, if necessary, with the availability of hotlines for export.



Law 47-09 on energy efficiency recently promulgated, detailed in particular, the obligation to perform an assessment of the energy impact of any project or programme planning, or any proposed building construction programme. Thresholds for specific consumption of thermal or electrical energy shall be determined through regulations. This confirms Morocco's ambition and shows its commitment to the development of renewable energy, energy efficiency and the fight against climate change.

Law 16-09 provides the establishment of The Moroccan Agency for Development of Renewable Energy and Energy Efficiency (ADEREE), as a public agency,

Law 57-09 provides the establishment of the Moroccan Agency for Solar Energy (MASEN), as a Public Private Partnership (PPP)

Other regulatory provisions have been published or are in the process of being adopted, such as the ministerial decree on locations/zones of wind development. To support the development of these renewable programmes, accompanying measures have been implemented, these include: the establishment of the Energy Development and Energy Investment Company, SIE (Société d'In-vestissements Energétiques), a reference investor in the energy strategy of Morocco, was founded in February 2010 in accordance with the guidelines of the national energy strategy aimed at the diversification of resources, promotion of renewable energy and energy efficiency, and the creation in 2009 of Research institute on Renewable Energy- IRESEN, to be the linkage between private sector and research institutions



V. CORE BUSINESS OF ADEREE

ADEREE is a public institution with both commercial and industrial activities, it is attached to the Ministry of Energy, Mines, Water and Environment and contributes at a national and regional level to the development of Renewable Energies and Energy Efficiency in aiming to reduce energy dependence and preserve the environment. The ADEREE develops its multi-faceted activities, including technology adaptation, publications, awareness campaigns, training courses, conception and execution of demonstration, and pilot projects. It provides technical expertise and assistance for the realisation of technical, economic and financial feasibility studies, *inter alia*:

- ◆ Proposals for the Moroccan government with regard to laws and regulations related to the development of renewable energy and energy efficiency initiatives.
- ◆ Design and implement development programmes in the areas of renewable energy and energy efficiency, as well as environmental protection programmes related to energy activities.
- ◆ Submit to the Moroccan government a national plan and sectoral plans for development of renewable energy and energy efficiency.
- ◆ Proposals for the state administration measures and incentives for the development of renewable energy and the enhancement of energy efficiency.
- ◆ Provide and disseminate standards and labels, equipment and devices that produce and use electrical energy and/or thermal energy.
- ◆ Communicate and educate renewable energy and energy efficiency through technical, economic and social demonstrations as well as through the use of environmental interest.
- ◆ Contribute to human capacity development through training in the field of renewable energy and energy efficiency.
- ◆ Identify, assess and carry out the mapping of renewable energy resources and energy efficiency potential.

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