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CASE STUDY

Moroccan National Energy Strategy reviewed from a meteorological perspective

Alaa Alhamwi*, David Kleinhans, Stefan Weitemeyer, Thomas Vogt

Next Energy—EWE Research Centre for Energy Technology at the University of Oldenburg, Carl-von-Ossietzky-Str.15, 26129 Oldenburg, Germany

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ABSTRACT

The National Energy Strategy (NES) in Morocco is one of the most ambitious and comprehensive renewable energy strategies in the Middle East and North Africa (MENA) region. Its intention is to establish 42% of total installed capacity from solar, wind and hydropower resources by 2020, with equal proportions of installed capacity for each resource. As an alternative approach, this paper aims to quantify the optimal combination of Renewable Energy Resources (RES) — wind, solar and hydropower generation — and to assess the NES power generation mix from a meteorological perspective. For the optimal mix analysis, a residual load modelling approach is adopted with the objective of minimising the effect of fluctuations of imbalance between renewable power generation and consumption. The model output provides material for discussion of the NES plan, and it lends support to the general strategy underlying the NES. Moreover, it highlights the importance of meteorological factors for the strategic consideration of future energy systems.

1. Introduction

One of the main objectives of Sustainable Energy for All (SE4ALL), an initiative launched by the United Nations, is to double the proportion of renewable energies in the global energy mix by 2030 [1]. Many governments around the world have oriented their transition strategies towards more sustainable and affordable energy systems. Recently, particular recognition and attention have been given to the transitional strategic options and scenarios of the MENA region [2]. In Morocco, energy security and the reduction of emissions and environmental pollution are considered to be the main driving forces for the transformation of the current power supply system towards a sustainable energy system based mainly on fluctuating RES. In addition to the National Strategy for Sustainable Development and Environment, which was adopted in 1995 [3], Morocco established the NES in 2008 with a key strategic objective being the promotion of renewable power production [4–7].

In general, governmental energy strategies are based on the results of projections or make use of traditional decision-making simulation tools such as cost-benefit analysis and the analytical hierarchy process [8,9]. Nowadays, there are well established energy economy models and methodologies, such as EXPANSE, PRIMES, Green-X lcpol and Green-X lcgen, for assessing the power generation mix from an economical perspective [10–12]. However, different results and projections are obtained for the power generation mixes that these models yield, especially for solar and wind energy resources [13].

Because of their dependency on weather conditions, methods of renewable power generation such as solar and wind resources have fluctuating and variable power outputs. There is therefore a need for energy storage and backup power in future energy systems in order to maintain a balance between renewable power supply and demand. This paper addresses the combination of different renewable power technologies on the basis of hourly weather and load data. It investigates the electricity mix proposed in the NES and compares it with the optimum combination from a meteorological point of view. For this purpose, two different approaches for the evaluation of residual loads are adapted from previous contributions [14,15].

Sections 2 and 3 give an overview of the power generation mix in Morocco and set out the opportunities and challenges presented by the NES. Section 4 presents the data sources and the collection methods, while Section 5 describes the model employed in this study. Section 6 discusses the model results for the power generation mix from

* Corresponding author.
E-mail address: alaa.alhamwi@next-energy.de (A. Alhamwi).

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renewable resources in Morocco. Section 7 discusses some implications for NES. Section 8 introduces several technical considerations and discusses the opportunities for Concentrated Solar Power (CSP)-integrated thermal storage in Morocco. The last section summarises the model output.

2. Morocco power generation mix

The current energy system infrastructure in Morocco depends primarily on hydrocarbons. About 70% of the total installed electricity capacity is powered by fossil fuels [6,16]. Coal and heavy oil are the main fuels in the electricity mix [5,6], representing 68% of the total current installed capacity (cf. Fig. 1). The long-term National Energy Strategy for 2020–2030 depends on commencing the use of nuclear energy and shale oil for powering some power plants [5]. Morocco is considered to be a net importer of hydrocarbons with 96% of its energy needs sourced externally [17,18]. The massive growth rate of electricity demand in Morocco (6%–8% per year) [7,19] and the increasing population [6] are putting more pressure on the energy supply system and forcing Morocco to import electricity from neighbouring countries such as Algeria and Spain. Approximately 18% (5659.6 GWh) of the total electricity demand in 2012 (31055.6 GWh) was imported, mainly from Spain since Morocco is interconnected to Spain by a 400 kV submarine cable across the Strait of Gibraltar [7,20].

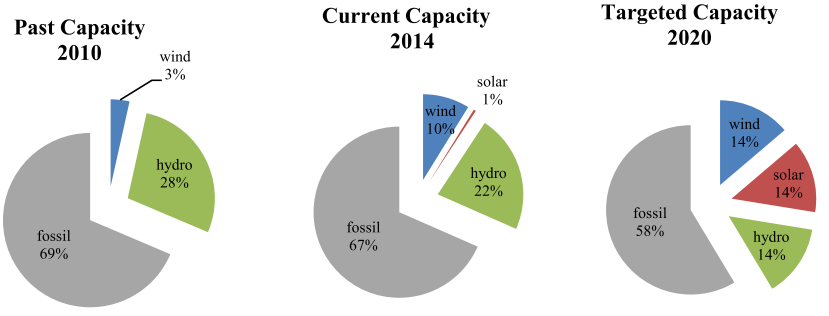
Morocco is, however, an attractive place for harnessing renewable energies such as solar, hydro and wind on large scales [20–22]. Morocco currently has wind turbines with an installed capacity of 780 MW [23]. In addition, the Tarfaya I (300 MW), Taza (150 MW) and Foum El Ouad wind farms (50 MW) are under construction [24] and are scheduled for completion by 2014. The Integrated Wind Programme plans to build 1000 MW of installed wind capacity on six qualified sites which are intended to be commissioned between 2014 and 2020 [7,25]. Morocco has 20 MW of installed capacity of concentrated solar power (CSP) in the municipality of Ain Beni Mathar and 160 MW (Noor I project) under construction at the Ouarzazate site [24,26]. Morocco also has about 15 MW of installed PV capacity in operation [6]. Furthermore, unlike most of the countries in the MENA region, significant hydropower potential will allow Morocco to install approximately 2.3 GW of hydropower by 2020 [27]. In addition, in September 2012 the United Nations highlighted Morocco as having promising potential for mini- and micro-hydropower plants, and the Electricity National Office (ONEE) has already identified 200 sites suitable for providing electricity from hydropower in rural areas [28,29].

The NES intends to maintain the use of coal as a main fuel with a share of 27% of the total installed capacity, together with 10% installed oil capacity, in the national electricity mix [4–6]. However, it aims to increase the proportion of gas and renewables to reach 21% and 42% respectively of the total installed capacity [4,6,26]. Electricity needs are expected to more than double by 2020 compared to 2014 [21,22,30], and the proportion of installed renewable power capacities is planned to increase to three times that of the total currently installed capacity [6,26] by 2020. Fig. 1 depicts the evolution of installed renewable capacity in Morocco between 2010, 2014 and 2020. The intention is to build 6 GW of installed renewables capacity by 2020, divided equally between wind, solar and hydropower (2 GW each) [7].

Figure 1 illustrates that, despite increasing electricity demand, the proportion of renewable energy in the Moroccan energy system is gradually increasing. In order to implement the NES targets, Morocco has passed some legislation and initiated national programmes to boost renewable energy production, e.g. the Moroccan Solar Plan (MSP) and the Integrated Wind Programme. However, assessing the NES from a technical perspective shows that the prospect of realising its targets by 2020 may be questionable. The NES's solar target seems unlikely to be achieved by 2020, given that only 35 MW of solar power plant (CSP + PV) capacity has been installed over the last four years. In addition to the Noor I project – 160 MW of CSP power plant under construction in Ouarzazate – Morocco would require an additional 1800 MW of installed solar capacity to be built during the coming six years in order to meet the NES target. The installed wind power capacity was 221 MW in 2010. Morocco currently has 780 MW of installed wind capacity, with 500 MW under construction and planned for completion by the end of 2014. This means that about 500 MW of wind power capacity needs to be installed during the coming six years in order to realise the wind target of 2000 MW by 2020. The hydropower goal seems to be achievable since Morocco has already installed 1770 MW and the remaining 230 MW could be realised by 2020.

3. NES opportunities and challenges

Many factors place Morocco in a good position to implement its energy strategy. Security and political stability constitute one of



	2010				2014				2020			
	wind	Solar	hydro	fossil	wind	solar	hydro	fossil	wind	solar	hydro	fossil
Installed capacity [MW]	221	0	1770	4352	780	35	1770	5392	2000	2000	2000	8500
Energy generated/ estimated [GWh]	659	0	3631	18410	2087	77*	3631	22804	5964	4380*	4103	35949
Share of total energy [%]	3	0	16	81	8.1	0.3	12.6	79	12	9	8	71

Fig. 1. Proportions of installed capacities in Morocco in 2010 [16] and 2014 [23,31] compared to the targets for 2020 set out in the NES [4,6,7]. The table lists the corresponding installed capacities and respective estimated generated energies [16]. The load factors for 2010 were used to estimate the generated energies in 2014 and 2020. *The solar load factor was not available from 2010 data. An estimated load factor of 25% was used here [32].