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Wind energy resource in Northern Mexico

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ABSTRACT

Mexico has installed less wind power compared to the other North American countries. Renewable energy sources only account for 3% of the energy mix in Mexico. The U.S. states bordering Mexico, namely Texas, New Mexico, Arizona, and California, have good wind power resources. Among them, Texas has the highest installed wind power capacity of 10.34 GW. The wind resources in these bordering states indicate that the wind energy resource in Northern Mexico must be assessed; thus, the spatial and temporal information about the wind energy resource was studied. The daily pattern of the wind speed, one per state studied, was obtained. The wind speed was found to exhibit a pattern; it increases from 4 pm until 6 am the following day. The main conclusions are that the state of Tamaulipas has the highest Wind Power Density (WPD) of 1000 W/m^2 during September and October, but the north of Nuevo Leon has, in a large part of its territory, an annual WPD greater than 103 W/m^2; each state has 1700 useful hours of wind speed above 3 m/s. Northern Mexico has some zones with excellent wind speed as well; the states of Chihuahua, Coahuila, Nuevo Leon and Tamaulipas have a wind speed of over 4.51 m/s across nearly their entire territories. Because Mexico in recent years has been starting to exploit renewable energy sources, the government has mandated energy reform, which improves the conditions for investment in wind energy in Mexico.

Contents

1. Introduction

Energy is a vital input for social and economic development [1]. As a result of the globalisation of human activities, the demand for energy has increased remarkably, especially in emergent

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Nomenclature

SMN	Servicio Meteorológico Nacional
AMS	Automatic Meteorological Stations
INIFAP	Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias
SMSEN	Surface Meteorology and Solar Energy of National
ASDC	Atmospheric Science Data Center
NASA	National Aeronautics and Space Administration
NREL	National Renewable Energy Laboratory
LCE	Life Cycle Environmental
WRA	Wind Resource Assessment
OK	Ordinary Kriging
UK	Universal Kriging
ρ	Correlation coefficient (Pearson)
σ_{ij}	Covariance between series i and j
σ_i	Standard deviations of series i
WPD	Wind Power Density
P	Wind Power Density (Eq. 2)
$\overline{P}$	Wind power density Average
P_W	Power output
PDF	Probability Density Function
d	Air density (1.225 kg/m^3)
v	Wind speed (m/s).

countries due to their industrial growth. Because the fossil fuel resources required for the generation of energy are becoming scarce and the carbon emissions to the atmosphere from the burning of such fossil fuel resources is related to climate change, the interest in energy savings and environmental protection has increased [2]. Experts predict that the world will require 30 TW of energy resources by the year 2050 to maintain the current economic growth [3]. One strategy to reduce the dependence on fossil fuel resources involves using renewable energy sources [4], not only for large-scale energy production but also for stand-alone systems [5]; wind power has the potential to satisfy both types of systems [6].

Renewable energy can contribute to social and economic development, energy access, energy security, energy independency and the reduction of the negative impacts on the environment and health of fossil fuel-based energy [7]. Renewable energy policy and research worldwide have driven the growth of these technologies with good results [8], e.g., in the European Union (EU) [9], the United States of America (USA) and China [10].

According to the report of the International Energy Agency (IEA) [11], the distribution of global electricity generation in terms of resource utilisation is petroleum products 5.6%, natural gas 20.9%, coal 41.5%, nuclear power 13.8%, hydraulic power 15.6%, and other resources 2.6%.

Deployment of a 100% renewable energy system is expected to be technically and economically feasible in the future [12]. Some agencies (European Wind Energy Association and the German Aerospace Center) have proposed scenarios that have renewable energy sources, including wind farms, supplying 80% of Europe's entire electricity demand by 2050. The National Renewable Energy Laboratory in the USA assessed how wind could supply 20% of the entire US electricity demand by 2030 [13]. Another study [14] demonstrated that the wind electricity potential in Canada is many times the current total electricity demand.

North American countries currently have the following wind power installed capacity: USA (47 GW), Canada (5.27 GW), and Mexico (0.57 GW) [7]. The USA states bordering Mexico are Texas, New Mexico, Arizona and California. Among all of the US states, Texas has the highest installed capacity of 10.34 GW, followed by Iowa (4.32 GW) and California (3.93 GW). Lesser installed capacities are in New Mexico (750 MW) and Arizona (138 MW). During 2003, in the state of Arizona, a set of high-resolution wind energy maps were produced for evaluating the most promising sites for wind development [15].

In Mexico, a total energy production of 257.9 TW/h has been determined, which is distributed as follows: 205.1 fossil fuels, 35.8 hydroelectric, 10.1 nuclear, 6.5 geothermal, and 0.4 wind [16]. The new law of Mexico mandates that CO_2 emissions must be reduced by 30% from business-as-usual levels by 2020 and by 50% by 2050 from the year 2000 levels [15]. Mexico has many forms of renewable energy resources: ocean energy [17], hydroelectric [18], geothermal [19], biomass [20], wind [21,22] and solar [23]. Renewable energy projects have enormous potential to satisfy the energy consumption in Mexico, not only because of the abundant renewable resources but also because of the emission reduction opportunities that could be realised through industrial projects, similar to those projects that have been successful in Asia [24].

The first step for wind power implementation is performing a wind resource assessment (WRA), both spatially and temporally throughout the day and months of at least two years. Much information exists regarding WRA in the literature: Khalid Farooq and Kumar [25] estimated the current and future potential of renewable energy sources for power generation by employing new technologies; Millward-Hopkins [26] developed an analytical methodology for predicting above-roof mean wind speeds in urban areas and used the methodology to map wind speeds over four different UK cities; Wu et al. [27] used statistical methods involving three probability density functions, i.e., two-parameter Weibull, Logistic and Lognormal, to perform wind speed distribution modelling using data measured at a typical site in Inner Mongolia, China; Saleh et al. [28] assessed the wind resource using different methods to estimate the Weibull distribution parameters for the wind speed; Durisic and Mikulovic [29] analysed data, wind speed and direction, average wind speed and power density, and Weibull distribution parameters (c and k) to perform a WRA; Gormally et al. [30] used GIS-based techniques to develop a methodology that assesses the regional-scale potential for community-based renewable electricity; Lee et al. [31] assessed the potential of offshore wind power generation at Younggwang in Korea, which is a candidate site of the offshore wind farm planned to be completed in 2019; in Masdar City, the wind speed was assessed by Isam et al. [32] using the inferred vertical wind profile, which was adequately fitted with a power law profile; Girard et al. [33] quantified the impact on market revenue of the predictability and the capacity factor of a wind farm or a cluster of wind farms. WRA has been useful to determine the techno-economic potential of wind turbine generator sites in Malaysia with light winds, as reported by Nor et al. [34].

Regarding the life cycle environmental (LCE) impacts of wind power, Arvensen and Hertwich [35] indicated that the current body of LCE impacts of wind power provides a fairly good overall understanding of fossil energy use and its associated pollution. WRA has been used to assess electricity options: Stamford and Azapagic [36] used an LCE impact assessment to identify the most sustainable options and to inform policy; Sungmoon et al. [37] proposed a new Bayesian approach to estimate the annual energy production (AEP) of a site, for which construction of wind turbines is considered. However, wind discontinuity is one of the factors that significantly affects the installation of wind farms. Several studies indicate how the interconnection of large, geographically