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Dominican Republic Wind Energy Resource Atlas Development

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Dominican Republic Wind Energy Resource Atlas Development

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Introduction

A wind resource analysis and mapping study was conducted for the Dominican Republic. The purpose of this study was to identify most favorable wind resource areas and quantify the value of that resource within those areas. This was a major study and the first of its kind undertaken for the Dominican Republic. The key to the successful completion of the study was an automated wind resource mapping program recently developed at the National Renewable Energy Laboratory (NREL), a U. S. Department of Energy (DOE) national laboratory.

DOE and the U.S. Agency for International Development (USAID), in collaboration with Winrock International and the U.S. National Rural Electric Cooperative Association (NRECA), sponsored this study to facilitate and accelerate the large-scale use of wind energy technologies in the Dominican Republic.

NREL had the lead responsibility in administering and conducting this project and in collaborating with USAID, NRECA, and Winrock on project activities. The primary goal of the project was to develop detailed wind resource maps for all regions of the Dominican Republic and to produce a comprehensive wind resource atlas documenting the mapping results.

The *Wind Energy Resource Atlas of the Dominican Republic* (Elliott et al. in progress) presents the wind resource analysis and mapping results for the Dominican Republic. The wind resource maps were created using a program developed at NREL based on Geographic Information System (GIS) software. The mapping program combines high-resolution terrain data and formatted meteorological data and is designed to highlight the most favorable wind resource areas for wind energy projects based on the level of wind resource.

Mapping System and Methodology

NREL recently developed an automated wind resource mapping system to replace the manual analysis techniques employed in previous mapping efforts, such as the *Wind Energy Resource Atlas of the United States* (Elliott et al. 1987) and the *Wind Energy Resource Assessment of the Caribbean and Central America* (Elliott et al. 1987). The two primary inputs to NREL's wind mapping system are gridded terrain data with 1 km^2 resolution and formatted meteorological data. The meteorological data sources include surface (land and open-ocean) and upper-air data sets. These data are screened to select representative stations and data periods for use as input to the mapping system. The final meteorological inputs to the mapping system are vertical profiles of wind power density, wind power roses, which express the percentage of total potential power from the wind by direction sector, and the open-ocean wind power density where appropriate for coastal areas. The GIS determines any required adjustments to these composite distributions for each 1-km^2 grid cell. The factors that have the greatest influence on the adjustment for a particular grid cell are the topography in the vicinity of the grid cell and a combination of the absolute and relative elevation of the grid cell. The primary output of the mapping system is a color-coded map containing the estimated wind power density, and equivalent wind speed, for each individual grid cell.

To portray the mapping results, the Dominican Republic was divided into four regions—southwestern, northwestern, central, and eastern. Each region covered an area of approximately 160 km by 160 km. The regional divisions were determined principally by the geography of the country and the desire to maintain the same map scale for each region. Surface, satellite, and upper-air data were assembled, processed, and analyzed. These data sets included information provided by the Dominican Republic meteorological service (Oficina Nacional de Meteorologia), the Dominican Republic hydrological service (Instituto Nacional de Recursos Hidraulicos), USAID, U.S. National Climatic Data Center, U.S. National Center for Atmospheric Research, and other U.S. sources. The data from USAID's sites (Figure 1) were collected in collaboration with the NRECA and Winrock International/REGAE (Renewable Energy Growth Assistance Entity). The satellite data sets of calculated ocean wind speeds were extremely useful in this analysis due to the large expanse of ocean surrounding

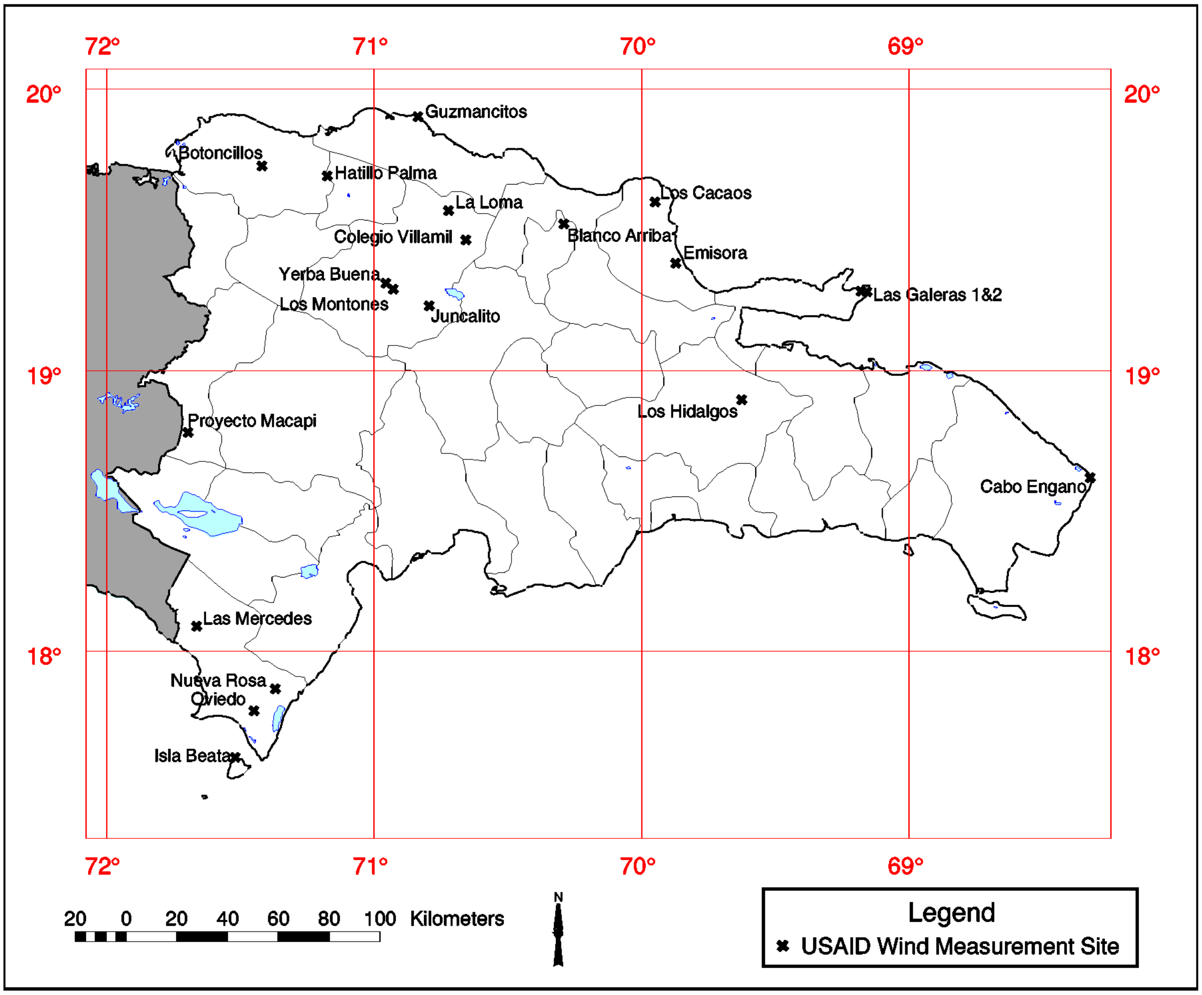

Figure 1. Dominican Republic: USAID wind measurement sites.

the Dominican Republic and the limited number and value of land-based observations. The mapping system generated a composite national wind resource map of the Dominican Republic and the four regional wind resource maps.

A combination of wind characteristics helps to determine the wind energy resource in a particular area. Factors such as the annual and monthly average wind speeds and the seasonal and diurnal wind patterns affect the suitability of an area for development. In general, locations with an annual average wind speed of 7 meters per second (m/s) or greater at turbine hub height are most suitable for utility grid-connected wind energy systems, and some locations with speeds between 6 and 7 m/s may be viable. Rural power applications are usually viable at lower wind speeds (5 to 6 m/s), in some cases at wind speeds as low as 4.5 m/s.

The average wind speed is not the best indicator of the resource. Instead, the level of the wind resource is often defined in terms of the wind power density value, expressed in watts per square meter (W/m^2). This incorporates the combined effects of the wind speed frequency distribution and the dependence of the wind power on air density and the cube of the wind speed. Thus, six wind power classifications, based on ranges of wind power density values, were established in each of two categories—one for utility scale applications, ranging from marginal to excellent, and one for rural power applications, ranging from moderate to excellent. This classification scheme is presented in Table 1.

Table 1. Wind Power Classification

Class	Resource Potential Utility	Rural	Wind Power Density (W/m²) @ 30 m asl	Wind Speed [(a)] (m/s @ 30 m asl)
1	Marginal	Moderate	100-200	4.9 – 6.1
2	Moderate	Good	200-300	6.1 – 7.0
3	Good	Excellent	300-400	7.0 – 7.7
4	Excellent	Excellent	400-600	7.7 – 8.9
5	Excellent	Excellent	600-800	8.9 – 9.8
6	Excellent	Excellent	800-1000	9.8 – 10.5

[(a)] Mean wind speed is estimated assuming a Weibull distribution of wind speeds with a shape factor (k) of 3.0 and standard sea-level air density. The actual mean wind speed may differ from these estimated values by as much as 20 percent, depending on the actual wind speed distribution (or Weibull k value) and elevation above sea level.

Wind Mapping Results

The wind resource in the Dominican Republic is strongly dependent on elevation and proximity to the coastline. In general, the wind resource is best on hilltops, ridge crests, and coastal locations that have excellent exposure to the prevailing winds from the east. The extreme southwestern and northwestern regions of the country are estimated to have the greatest number of areas with good-to-excellent wind resources for utility-scale applications, because the upper-air winds and ocean winds are greatest in these regions.

The wind mapping results (Figure 2) show many areas

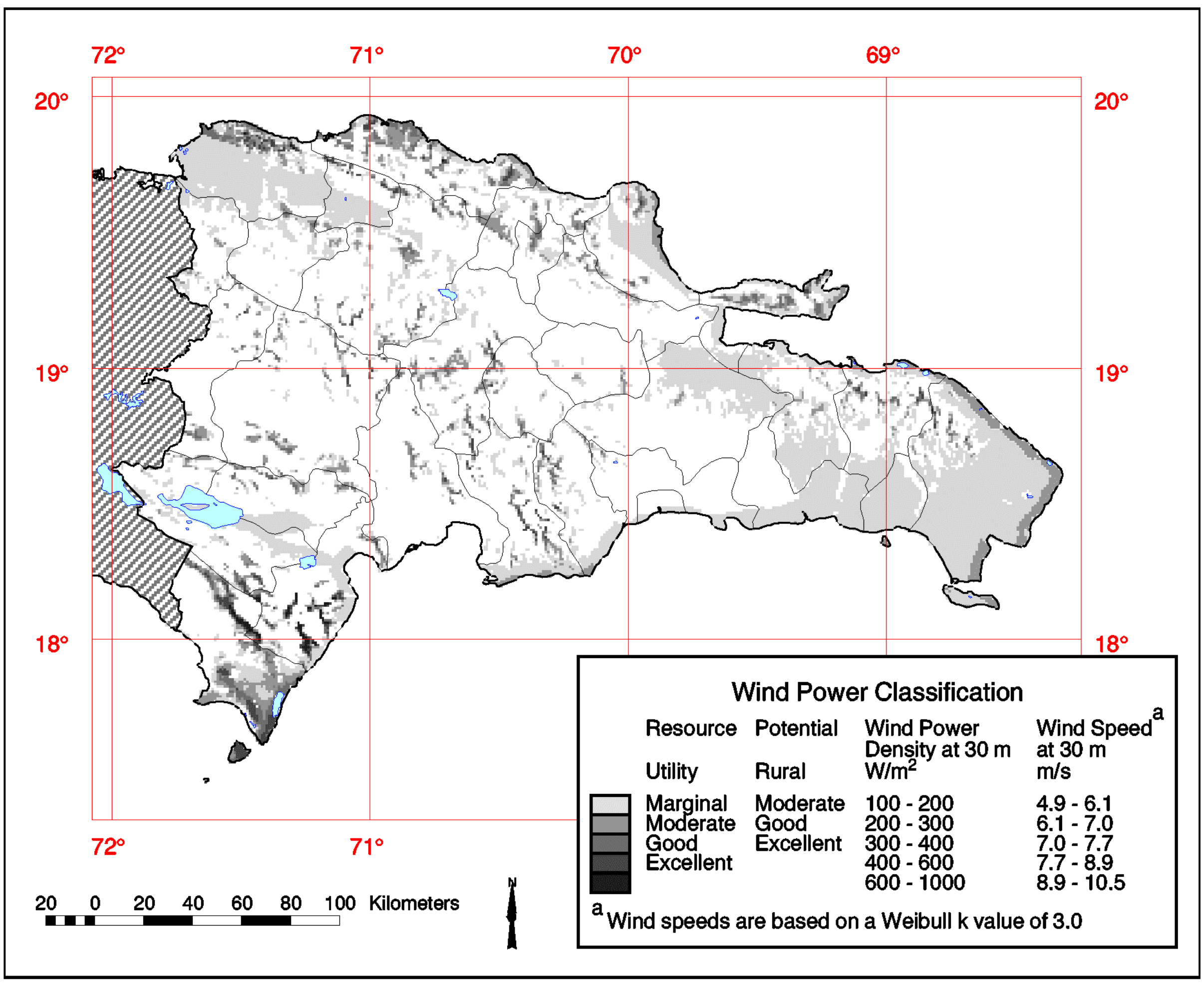

Figure 2. Dominican Republic: Most favorable wind resource areas.

of good-to-excellent wind resource for utility-scale applications or excellent wind resource for village power applications, particularly in the extreme southwestern and northwestern regions of the country. The best wind resources are found in the southwestern provinces of Pedernales and Barahona and the northwestern provinces of Puerto Plata and Monte Cristi. Significant areas of good-to-excellent wind resource can be found in many other locations, such as well-exposed hilltops and ridge crests of the Samana peninsula and other near-coastal locations throughout the Dominican Republic and the major mountain ranges including Cordillera Septentrional, Cordillera Oriental, Cordillera Central, and Sierra Neiba. The mapping results show many additional areas of moderate wind resource for utility-scale applications or good wind resource for village power applications, including many east-facing coastal locations along the eastern and northern coasts of the Dominican Republic.

Wind Electric Potential

The assumptions and methods for converting the wind resource to wind energy potential were based on those in the report *Renewable Energy Technology Characterizations* (DeMeo and Galdo 1997) and are listed at the bottom of Table 2. About 1500 km^2 of windy land areas have been estimated to exist with good-to-excellent wind resource potential. This windy land represents less than 3% of the total land area (48,442 km^2) of the Dominican Republic. Using conservative assumptions of about 7 MW per km^2, this windy land could support over 10,000 MW of potential installed capacity and potentially delivering over 24 billion kWh per year. Considering only these areas of good-to-excellent wind resource, there are 20 provinces in the Dominican Republic with at least 100 MW of wind potential and 3 provinces with at least 1000 MW of wind potential. However, additional studies are required to more accurately assess the wind electric potential, considering factors such as the existing transmission grid and accessibility.

If the additional areas with moderate wind resource potential (or good for rural power applications) are considered, the estimated total windy land area increases to more than 4400 km^2, or slightly more than 9% of the total land area of the Dominican Republic. This windy land could support more than 30,000 MW of installed capacity, delivering more than 60 billion kWh per year. There are 12 provinces with at least 1000 MW of wind potential and all except for three provinces have at least 100 MW of wind potential.

Table 2. Dominican Republic—Wind Electric Potential
Good-to-Excellent Wind Resource at 30 m (Utility Scale)

Wind Resource Utility Scale	Wind Power W/m^2	Wind Speed M/s*	Total Area km^2	Total Cap Installed MW	Total Power GWh/yr
Good	300 – 400	7.0 – 7.7	1,022	7,000	15,600
Excellent	400 – 600	7.7 – 8.9	377	2,600	7,100
Excellent	600 – 800	8.9 – 9.8	61	400	1,400
Excellent	800 – 1000	9.8 – 10.5	22	200	500
Total			1,482	10,200	24,600

* Wind speeds are based on a Weibull k value of 3.0

Assumptions
Turbine Size: 500 kW — Hub Height: 40m
Rotor Diameter: 38m — Turbine Spacing: 10D by 5D
Capacity/km^2: 6.9 MW

Wind Resource Characteristics

The seasonal and diurnal (time-of-day) variability of the wind resource depends on several factors including proximity to coastline and exposure to ocean winds, elevation above sea level and surrounding terrain, and geographic location. High ridge crests that have excellent exposure to the winds are expected to have the highest wind resource from June to August and December to February, with a maximum in July and a minimum in October. The diurnal pattern of wind speeds on exposed ridge crests tend to have the highest speeds during the night and early morning hours and lowest during mid-day.

At most inland locations, the wind resource is typically highest from June through August due to greater winds aloft and greater vertical mixing, with a secondary seasonal maximum from March through May. The wind resource at inland locations is usually lowest from October through December. The wind resource at inland locations is typically highest during late morning and afternoon and is lowest from late night to early morning. In most coastal areas where land-sea breeze effects and other land-based influences are prominent, the seasonal and diurnal variations of the wind resource are usually similar to those for inland areas.

Coastal points on capes and peninsulas that are well exposed to the ocean winds are expected to have the highest wind resource from June to August and December to February. Generally, these types of locations will exhibit very small diurnal variations in the wind resource and are not significantly influenced by land-sea breeze flows and other types of land-based effects on the wind flow.

Conclusions and Recommendations

The wind resource maps and other wind resource characteristic information in the Dominican Republic wind atlas will be useful for identifying prospective areas for wind energy applications. However, very limited data were available to validate the wind resource estimates. Therefore, it is strongly recommended that wind measurement programs be conducted to validate the resource estimates and refine the wind maps and assessment methods where necessary. A wind measurement program is underway by USAID in collaboration with NRECA and Winrock/REGAE, and it is hoped that this program can be improved and expanded to include additional locations that are particularly valuable in the validation of this wind mapping assessment.

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