WIND RESOURCE ASSESSMENT STATUS

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WIND RESOURCE ASSESSMENT STATUS ^(a)

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1. INTRODUCTION

The overall objective of the Federal Wind Energy Program is "...to accelerate the development, commercialization and utilization of reliable and economically viable wind energy systems" (1). To achieve this objective the program is organized into several elements. The Wind Characteristics Program Element (WCPE), managed for the Department of Energy by Pacific Northwest Laboratory, has the specific responsibility of providing the appropriate wind characteristics information to those involved in:

- energy program planning
- site selection for installing wind energy conversion systems (WECS)
- design and performance evaluations of WECS
- the operation of WECS (2).

Applied research and development activities within the WCPE are currently addressing four key issues:

- the wind energy resource
- effective siting technology
- economically effective energy conversion
- wind turbine operation in existing electrical networks.

The first of these issues will be discussed in this paper.

Often confused with siting activities, resource assessment, as addressed in the WCPE, refers to the large-scale analysis (i.e., the United States or a collection of several states) of the wind energy resource by producing an estimate of: 1) the wind energy potential of a given area, and 2) the distribution

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of the wind energy within that area. In siting, however, a small-scale area of about 100 km or less on a side is surveyed for the most favorable locations for wind energy extraction. The smaller area may be selected on the basis of a previous resource assessment. In the WCPE, work in resource assessment and the development of siting techniques are carried out simultaneously in two program areas as depicted in Figure 1.

2. NATIONAL ASSESSMENTS

Three national wind energy assessments were performed early in the Federal Wind Energy Program. The first assessment was published by Sandia Laboratories in 1975 (3). The other two assessments were performed as integral parts of separate mission analysis studies and were based on the same National Climatic Center data as the first assessment. Because of discrepancies in the amount and distribution of the wind power density in the three national assessments, a synthesis of these assessments was completed in 1977 (4). This synthesis was to analyze the causes of the discrepancies and to include the most plausible results in a single assessment (see Figure 2).

These initial assessments contributed to the preliminary wind energy scoping exercises; however, with increased interest in wind energy utilization, more refined and reliable assessments were required on a regional scale. For example, the wind power density values shown in Figure 2 are representative of terrain with good exposure to the wind. The amount of land in a given area with good exposure can vary from about 80% in flat terrain to less than 2% in mountainous terrain. This variation can produce unreliable estimates of wind power potential in given areas within a region.

3. TECHNIQUES FOR REGIONAL ASSESSMENTS

The first objective of the WCPE's regional assessment was to develop and test prototype techniques for the analysis of wind-energy potential and distribution over a large area (5). These techniques involved the utilization of a much larger data set, the application of meteorological and topographic factors in the analysis, and the use of indirect methods of wind power estimation in areas where no wind measurements existed. Five states in the Pacific Northwest were selected as a test of these techniques.

The wind data stations in the Northwest region that were used in the national assessments are shown in Figure 3a. These stations represent only half of the stations with summarized data available at the National Climatic Center (NCC). In Figure 3b, all stations with wind data in the Northwest region

are shown. For almost 60% of these stations the data is in unsummarized form, but screening techniques may be applied to effectively utilize the information. Data from the Fire Weather Stations of the U.S. Department of Agriculture are shown in Figure 3c. Only a small fraction of this data is useful, but the data that can be used is usually from stations located in areas where there is no other wind data. As a result, the wind data coverage for the Northwest region was increased from about 80 stations to about 350 stations.

The increase in data coverage of more than a factor of four certainly contributes to a more reliable analysis, but there are still many areas of the region without adequate data for wind energy estimates. In many of these areas combinations of meteorological and topographic features can be employed in the analysis to enhance the reliability of the overall assessment. A few features that indicate high wind energy potential are:

- gaps, passes and gorges in areas of frequent strong pressure gradients
- long valleys extending parallel to prevailing wind directions
- high elevation plains and plateaus
- exposed ridges and mountain summits in areas of strong geostrophic winds.

Some features that indicate low wind energy potential are:

- valleys perpendicular to the prevailing wind direction
- sheltered basins
- short and/or narrow valleys and canyons.

The features listed above can be located in a region by careful observation of relief maps and typical surface pressure maps.

Other indirect methods of estimating mean wind speeds involve observations of deformed vegetation (6) and landforms affected by the winds (7). These techniques were tested to a small degree in the Northwest region. The major portion of the assessment was accomplished with the enhanced data set and the topographic-meteorological analyses.

4. NORTHWEST REGIONAL ASSESSMENT

The wind power density was analyzed on a seasonal and annual average basis for each state in the region. The results of the analysis of annual average wind power for the Northwest

region are shown in Figure 4. The increase in resolution can be seen by comparing this analysis with the analysis for the five Northwest states in Figure 2. The effect of the analysis of meteorological and topographic features is particularly apparent in the long valley in southwestern Montana and the large east-west valley in central Washington.

As in the national analysis (see Figure 1), the stippled areas indicate that the wind power densities apply only for the well-exposed terrain. However, in the regional analysis there is significantly more definition in the number and distribution of the values shown in the stippled area than was possible to show in the national assessment.

An estimate of the total wind power potential for any portion of the region may be obtained by digitizing the power density values and the landform classifications for the region onto a grid consisting of grid blocks that are one-third degree longitude and one-fourth degree latitude. By assigning selected fractions on the power density to different percentages of the area in the block, according to the landform classification, the wind energy potential for the block can be estimated. The analysis can be performed for any collection of blocks within the region to determine the power available as a function of land area. The grid approach provides a convenient way to assess the effect of existing and proposed wilderness exclusion areas.

Other information provided in the assessment of the Northwest region was a series of graphical data presentations for 12 to 18 stations in each state, depending on the number of stations with time-series data available. These graphs depict such quantities as annual, monthly and diurnal variation of wind speed and power, as well as frequency and duration curves for wind speed and power. The information produced from this analysis is to be compiled into an atlas containing the maps, graphs, tables and descriptions designed to meet the needs of a wide range of wind energy planners.

5. OTHER REGIONAL ASSESSMENTS

The wind power atlas for the Northwest region will serve as a guide for the analyses of other regions of the country. The Department of Energy has released a request for proposals to conduct wind energy assessments for the eleven other regions, shown in Figure 5, which cover all the other states and territories of the United States. The present goal is to complete all the regional assessments by October 1980. In the process of completing these regional assessments, a wind energy data base will be established in a form for convenient updating as wind data becomes available.

6. SITING METHODOLOGIES

As indicated in Figure 1, the initial effort in this program area is the development of site-screening techniques. Several techniques have been developed to the point of needing verification and testing before any further developmental work is decided upon. Techniques that are candidates for verification are numerical modeling, physical modeling, and observation of deformed vegetation. A data set that includes wind measurements from a collection of stations in complex terrain has been prepared for testing the screening techniques using numerical models.

One of the most important aspects of the siting program area is appropriate documentation of the techniques for the various kinds of siting needs. In an effort to meet the needs of small WECS users, an interim handbook with a step-by-step description of a siting method has been prepared and distributed (8). This handbook is under revision on the basis of review comments on the interim handbook. A revised copy of the handbook has been used as a text in a trial presentation of a short course in siting small WECS. Both the handbook and short course are intended primarily for the layman interested in wind power for personal application.

A siting handbook for large WECS is being prepared for review. This document is aimed at a more technically oriented audience and is intended for use by utility companies and other potential users of large machines.

7. CONCLUSIONS

One of the primary concerns of the utility companies in the utilization of wind power is a reliable assessment of the resource. It has become apparent that the initial national assessments will not meet the needs expressed by the utilities and their representatives. The expressed needs have two conflicting criteria: one is that the assessment be as reliable as possible, and the other is that it be produced as soon as possible. Obviously the approach in the WCPE is to take a middle ground and produce an assessment as soon as possible with the capacity for being updated conveniently. This will mean that planners with urgent needs will have something to work with which has significantly better resolution and reliability than the national assessment. Planners who are more concerned with reliability will have something to work with which they can develop confidence in as they see it verified and upgraded by new data in their region of interest.

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DISCUSSION

Q. The next step would seem to be an attempt to correlate sites with high winds with other attributes such as land use and cost, population, wilderness, parks, forbidden zones (EM interference), etc., etc., etc. Are you planning to do this?

Wendell: We will be overlaying the power density maps and maps showing landform classifications with a grid that has a mesh size of approximately 15 x 15 miles. Estimates of wind power potential in each grid box can then be calculated as a function of land area. It will be relatively simple to define the land use classification in each grid box and calculate the effect of these "exclusion" areas on the wind power potential within a given area. At the present time we are planning to conduct work in this area.

WIND PROSPECTING

a) RESOURCE ASSESSMENT

b) WECS SITING

Figure 1. Sequence of activities for a) resource assessment and b) siting activities in the Wind Characteristics Program Element of the Federal Wind Energy Program

ANNUAL AVERAGE WIND POWER (WATTS/M²) AT 50 M

Figure 2. Annual mean wind power (W/m²) estimated at 50 m above exposed areas. The shaded areas indicate mountainous terrain in which the wind power estimates represent lower limits for exposed ridges and mountain tops (Elliott, 1977).

a) STATIONS IN U.S. ANALYSIS (NCC)

b) STATIONS WITH WIND DATA (NCC)

c) FIRE WEATHER STATIONS (USDA)

Figure 3. Locations of wind data in the Northwest.

Figure 4. Annual mean wind power at 10 m and 50 m above exposed areas. Shaded areas represent mountainous terrain (see Fig. 2 for detail).

**GEOGRAPHIC DIVISIONS FOR REGIONAL WIND ENERGY
RESOURCE ASSESSMENTS**

Figure 5. Geographic divisions for regional wind energy resource assessments.