New Mexico Wind Development Handbook

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Purpose

The purpose of this handbook is to provide an overview of the development process for large wind turbine projects (projects consisting of one or more wind turbines rated at 600 kW or higher) and the key factors that would indicate whether or not a site may be suitable for large-scale wind development.[1] The document also provides a framework for identifying conditions that may preclude project development (i.e., "fatal flaws"), or that may need to be mitigated, resulting in additional costs during the construction phase of the project. The handbook concludes with a discussion of the critical success factors that lead to a financeable wind project.

The Development Process

Figure 1 shows the steps involved in the wind plant development process.[2] This handbook will discuss Site Identification and On-Site Wind Resource Assessment, and briefly introduce the reader to next-level site pre-development activities. Financial analysis of the proposed investment is beyond the scope of this handbook.

The steps shown in Figure 1 are used for illustration and discussion purposes. The wind project development process has also been described as consisting of the following steps:[3]

- Site Selection
- Land Agreements
- Wind Assessment
- Environmental Review
- Economic Modeling
- Interconnection Studies
- Permitting
- Sales Agreements
- Financing
- Turbine Procurement
- Construction Contracting
- Operations & Maintenance

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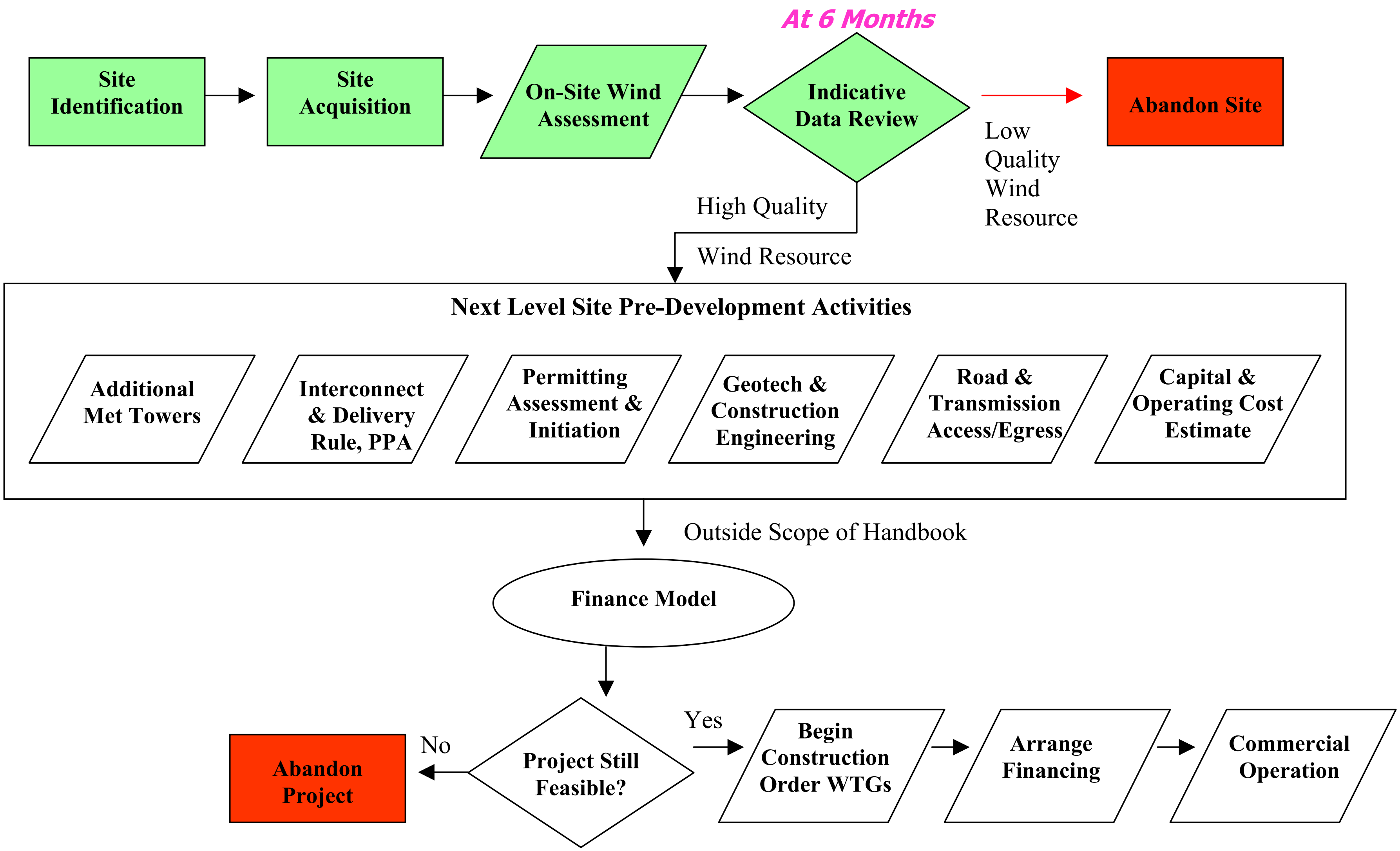
[1] For a discussion of small (≤100 kW) home/farm-based wind energy systems, refer to the publication ***A U.S. Consumer's Guide to Small Wind Electric Systems*** available from the National Renewable Energy Laboratory, Golden, CO (www.nrel.gov).
[2] Darin Huseby, SeaWest WindPower, *Colorado Wind & Distributed Energy Workshop, April 2002*
[3] Dale Osborn, Distributed Generation Systems, Inc., *September 1998*

Figure 1. Wind Plant Development Process



Is There Enough Wind?

People often say, “The wind always blows at my place” or “I live on the highest hill in the county.” But these observations are overly simplistic. The key question is, “Does the wind blow hard and consistent enough to make wind project development economical.”

Estimates of the wind resource are expressed in wind power classes ranging from Class 1 to Class 7, with each class representing a range of *mean wind power* density or equivalent mean wind speed at specified heights above ground level.[4] Table 1 defines the wind power classes in terms of mean wind power density and mean wind speed at 30 m (98 ft) and 50 m (164 ft) above ground level.

Table 1. Wind Power Classes

	30 m		50 m	
Wind Power Class	Wind Power Density (W/m^2)	Wind Speed m/s (mph)	Wind Power Density (W/m^2)	Wind Speed m/s (mph)
1	≤160	≤5.1 (11.4)	≤200	≤5.6 (12.5)
2	≤240	≤5.9 (13.2)	≤300	≤6.4 (14.3)
3	≤320	≤6.5 (14.6)	≤400	≤7.0 (15.7)
4	≤400	≤7.0 (15.7)	≤500	≤7.5 (16.8)
5	≤480	≤7.4 (16.6)	≤600	≤8.0 (17.9)
6	≤640	≤8.2 (18.3)	≤800	≤8.8 (19.7)
7	≤1600	≤11.0 (24.7)	≤2000	≤11.9 (26.6)

Areas designated as Class 4 or higher are generally considered to be suitable for most wind turbine applications. Class 3 areas may be suitable for wind energy development using tall (e.g., 70-80 m hub height) towers.

Since the wind resource can vary significantly over an area due to local terrain influences on the wind flow, there are steps you can take to answer the question of whether or not there is enough wind at your location or site.

As a first step, wind resource maps such as the one shown in Figure 2 can be used to estimate the wind resource in your area.[5] As Figure 2 makes clear, the greatest wind potential is in the eastern half of the state. Additional wind resource information can be found at the National Renewable Energy Laboratory’s (NREL) web site (www.nrel.gov) and the U.S. Department of Energy’s Wind Powering America web site (www.eren.doe.gov/windpoweringamerica).

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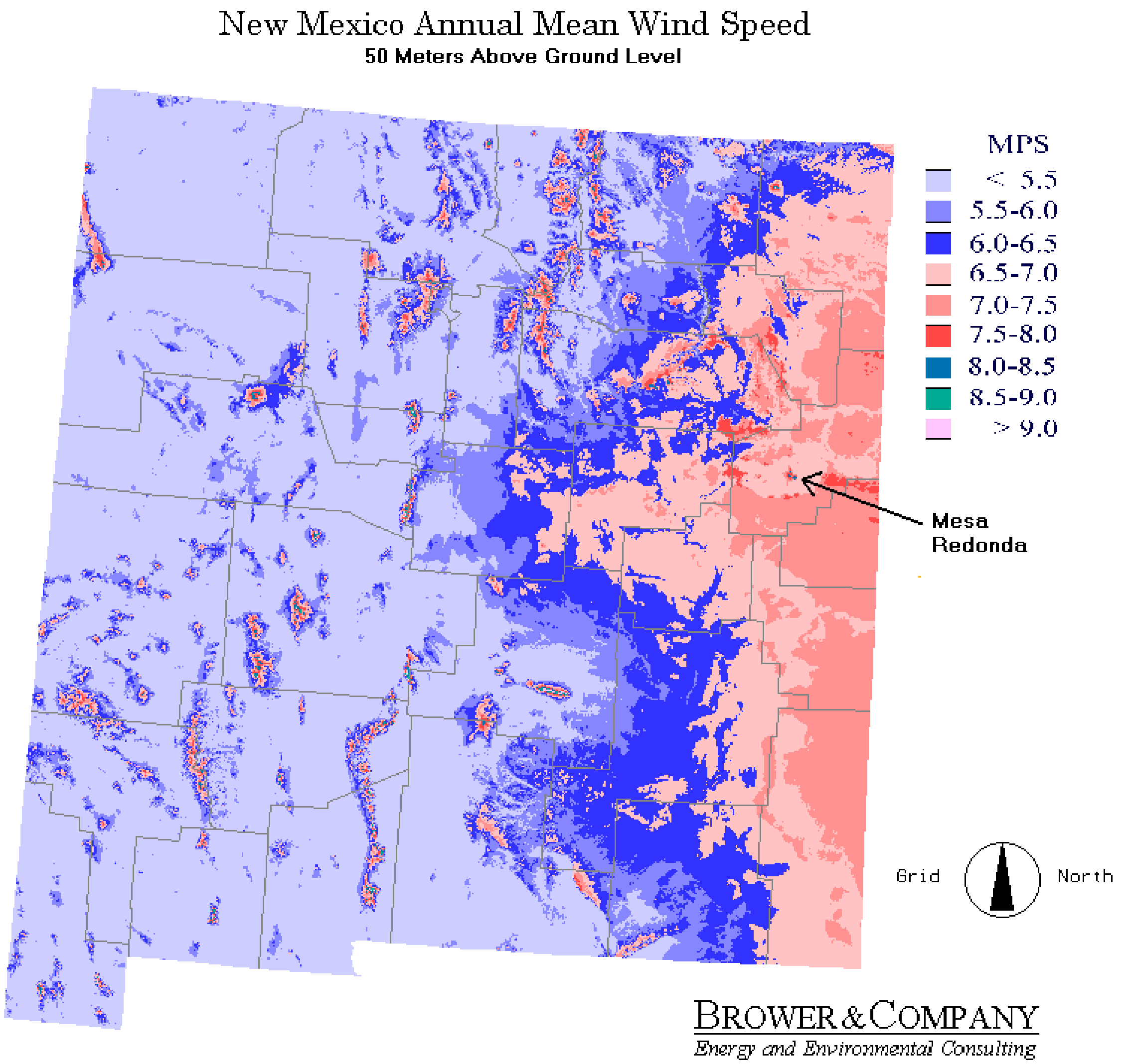
[4] *Wind Resource Assessment Handbook: Fundamentals for Conducting a Successful Monitoring Program*, AWS Scientific, Inc.

[5] Brower and Company

Figure 2. Wind Resource Map of New Mexico



Another valuable source of information at the early stage of the siting process can be existing wind data, such as that obtained for a nearby airport. Caution should be used however, because the majority of this data was not collected for wind energy assessment program purposes. Thus the results often reflect the mean conditions near population centers in relatively flat terrain, or in low elevation areas. Local terrain influences and other factors (e.g., trees or other obstructions) may also cause the wind speeds measured at airports to differ significantly from your location.[6] As the power available in the wind increases as a function of the cube (v^3) of the wind speed, even small differences in the assumed wind resource can significantly affect the overall economy of a wind project.

[6] In order to achieve reasonable accuracy, the distance from the measurement location to the potenial wind farm site must be less than 15 miles (Source: Vestas – American Wind Technology, Inc.)

Airport wind measurements are also generally measured at heights between 6 and 10 m (20-33 ft) above ground level. Since wind speed increases with height, average wind speeds at typical wind turbine hub heights are usually much higher than measurements taken the 6-10 m level. The approximate increase in wind speed for different types of ground cover can be calculated using the following formula:

$$V_2 = V_1 \text{ x } (h_2 / h_1)^n$$

where V_1 is the wind speed at the reference (e.g., airport station) or measured height h_1 above ground level, V_2 is the wind speed at the assumed hub height of the turbine h_2, and n is the exponent determining the change in wind speed (wind shear).[7] The wind shear exponent is often assigned a value of 0.143, known as the 1/7th Power Law, to predict wind profiles in a well-mixed atmosphere over flat, open terrain. Other values for n are given in Table 2 for different types of ground cover.

Table 2. Exponent Values for Different Types of Ground Cover

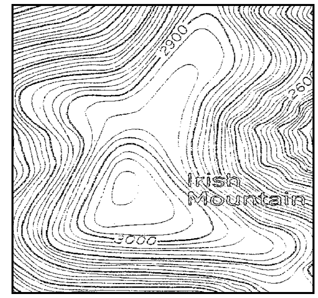
Ground Cover Description	n
Smooth surface (e.g., ocean, sand)	.10
Low grass on fallow ground	.16
High grass or low row crops	.18
Tall row crops or low woods	.20
High woods with many trees	.30

The primary benefit of this data therefore, is to provide a general description of the wind resource within the area of interest, and not to pinpoint the windiest locales. Common sources of wind information include the National Climatic Data Center (which archives weather data from all National Weather Service stations), universities, air quality monitoring networks, electric utilities, the U.S. Forest Service, and various other government and private organizations. Wind information from many of these sources has been synthesized by the Pacific Northwest Laboratory on behalf of the U.S. Department of Energy. Several potential data sources should be contacted since no one particular organization is likely to possess full data coverage for the area(s) of interest or provide all the statistics used in the wind resource characterization. For example, wind shear data are generally not available from National Weather Service stations because these stations do not use multi-level towers. A better source of information in this instance may be a utility's air quality monitoring tower if it is in a representative location.

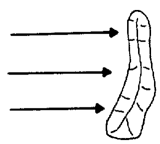
Another useful indirect measurement of the wind resource is the observation of an area's vegetation. Trees or brush can be permanently deformed by strong winds, also known as "flagging." For more information on the use of flagging, you may want to obtain *A Siting Handbook for Small Wind Energy Conversion Systems*, available from the National Technical Information Service (www.ntis.gov/ordering.htm).

[7] *New York State Wind Energy Handbook*, New York State Energy Office

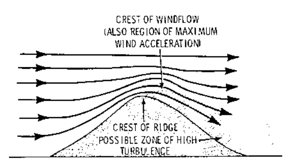
The analysis of topographic maps is an effective means of streamlining the siting process. Maps on a 1:24,000 scale (1 in = 2,000 ft) available from the U.S. Geological Survey (USGS) are the best source of information for identifying suitable terrain features. The topographic screening should attempt to identify features that are likely to experience a greater mean wind speed than the general surroundings. This process is especially important for areas containing little or no relevant historical wind speed data. Features that are likely to be windier include:



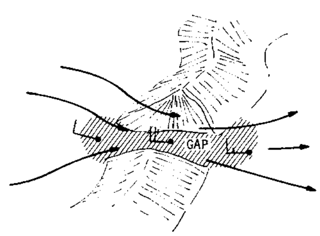
- Ridges oriented perpendicular to the prevailing wind direction



- Highest elevations within a given area



- Locations where local winds are channeled.



Features to be avoided include areas immediately upwind and downwind of higher terrain, the lee side of ridges, and excessively sloped terrain. In each of these situations, increased turbulence may occur.

Topographic maps can also provide a preliminary look at other attributes of a site important to wind development, such as:

- The available land area[8],
- Positions of existing roads (accessibility) and dwellings (obstructions),
- Land cover (e.g., forests),
- Political boundaries, and

[8] A rough rule of thumb is 40 acres/ 1.5 MW of installed capacity.

- State and National Parks, or other sensitive environmental areas (e.g., wetlands)
- Proximity to transmission lines.

While wind turbines are increasingly becoming an accepted part of the landscape, the issue of aesthetics can still present a real obstacle to any project. There is no universal or consistent view of what is or is not pleasing to the eye, so you must rely on your own judgment based on the character of the land and the proximity of public viewing areas. It is in the project's best interests to investigate this topic in-depth early in the site evaluation process by discussing proposed development with neighbors and the local communities likely to be affected by any subsequent installation.

On-Site Wind Assessment

There is however, no substitute for on-site wind data collected using industry-accepted equipment and practices to provide a clear picture of the available wind resource. In fact, a minimum of one year of on-site wind data is typically required by financial institutions in order to obtain project financing. A good overall guide on this subject is the *Wind Resource Assessment Handbook* prepared by AWS Scientific, Inc. and available electronically in NREL's publications database at www.nrel.gov/publications.

This publication provides valuable guidance on all aspects of a successful wind measurement plan, including:

- Measurement parameters
- Equipment type and quality
- Number and location of monitoring stations
- Sensor measurement heights
- Minimum measurement accuracy, duration, and data recovery
- Data sampling and recording intervals
- Data storage format
- Data handling and processing procedures
- Quality control measures
- Format of data reports.

Wind measurement systems (50 m) cost around $10,500. Including installation, data collection, and analysis, the cost of a one-year monitoring program can be in the neighborhood of $25,000.

The ultimate success of a wind resource assessment program rests on the quality of the program's assembled assets—sound siting and measurement techniques, trained staff, quality equipment, and thorough data analysis techniques. The objectives of an on-site wind measurement program are:

- To determine or verify whether sufficient wind resources exist within the area to justify further site-specific investigations,

- To obtain representative data for estimating the performance and/or the economic viability of selected wind turbines, and
- To screen for potential wind turbine installation sites.

When a field survey is made, you should also check cellular phone service reliability for data transfers, and determine soil conditions so that the proper type of anchor can be chosen if a guyed meteorological tower is used.

Because of the complexities of siting and monitoring, it is advised that you consult with a person with field measurement experience.[9] Data analysis, interpretation, and computer skills are also necessary assets. High standards of data accuracy and completeness require an appropriate investment in quality equipment and tools, personnel, prompt responsiveness to unscheduled events (e.g., equipment outages), access to spare parts, and frequent review of the collected data. Furthermore, financial institutions generally require that wind study documentation be prepared by a recognized professional independent meteorologist prior to closing a finance agreement.

Data quality is usually measured in terms of representativeness, accuracy, and completeness. A *quality assurance plan* should be developed to minimize the uncertainties that unavoidably enter into every step of the siting and measurement processes. No site perfectly represents the entire area it describes, no sensor measures perfectly, and no data gathered over an extended measurement period perfectly reflect all future wind conditions a wind plant will experience during its 20-year lifetime. However, if the magnitude of these uncertainties is understood and controlled through a concerted quality assurance plan, the conclusions can be properly qualified to provide useful information.

The minimum monitoring duration should be one year, but two or more years will produce more reliable results. One year is usually sufficient to determine the diurnal and seasonal variability of the wind. With the aid of a well-correlated long-term reference station such as an airport, the inter-annual variability of the wind can also be estimated. The data recovery for all measured parameters should be at least 90% over the program's duration, with any data gaps kept to a minimum (less than a week).

Two important guidelines should be followed when choosing an exact location for the monitoring tower:

- Place the tower as far away as possible from local obstructions to the wind[10]
- Select a location that is representative of the majority of the site.

Inquiries must always be made to determine whether any permits are required before a tower is installed. Tilt-up towers usually fall into the category of temporary structures, so permitting requirements are generally minimal, or non-existent. Some jurisdictions may

[9] The wind flow over hills, mountain ridges, and mesas can be very complex, thereby affecting the energy production and lifetime of such projects significantly. (Source: Vestas – American Wind Technology, Inc.)
[10] As a rule, if sensors must be near an obstruction, they should be located at a horizontal distance no closer than 10 times the height of the obstruction in the prevailing wind direction.

require a standard building permit, which should be displayed at the site during the installation period. Building permits can be acquired from the town clerk or directly from the town building inspector. These fees are usually $10-$100 range.

Other Siting Considerations

The main objective of a siting program is to identify potentially windy areas that also possess other desirable qualities of a wind energy development site. These other attributes include:

- Proximity to transmission
- Permittability
- Constructability
- Financability

In general, the site should be located <10 miles from transmission (or distribution) lines with the capability to deliver the output of the wind project to the demand center(s) with minimal constraints. Right-of-way access to transmission (or distribution) lines should be identified, along with property owners and jurisdictional authorities for all considered alternatives. Permitting considerations include potential avian (bird) impacts, interference with aviation, and land use conflicts. Constuctability issues include the steepness of the proposed terrain, land cover, and geotechnical (soil stability) considerations. Financabilty considerations include the successful negotiation of a power purchase agreement with a credit-worthy buyer and the ability to take advantage of available State and Federal production tax credits.

Fatal Flaw Analysis

A "fatal flaw" analysis should be undertaken as early as possible during the development process. The purpose of this analysis is to quickly identify any environmental, archeological, or sociological impacts of the project that would preclude its construction or operation. Moreover, the analysis defines impacts that require more in-depth investigation and/or design of mitigation measures. For example, a site with a known population of threatened or endangered species, or a site with significant historical, cultural, or archaeological significance may be extremely problematic, if not impossible, to develop.

The analysis follows general National Environmental Protection Act (NEPA) guidelines for site permitting. However, since this is not a NEPA study, an environmental assessment and/or environmental impact statement prepared by a qualified environmental consultant may be needed prior to any proposed development or permitting. Information relevant to site conditions or environmental concerns may be obtained from preliminary site reconnaissance and a review of existing reports or data.

Geology and Geotechnical Issues

Identify existing geological conditions and possible geotechnical issues associated with the development of the project. Typical elements may include:

- Geological age and type of formation(s) present
- Seismic conditions and known active faults in the area
- Types of soils present and deleterious properties, if any (e.g. collapsible, heaving, etc.)
- Corrosive soil characteristics
- Typical groundwater conditions and potential problems
- Geotechnical construction related issues (foundation installation, material reuse, seismic design, slope stability, groundwater problems)
- Potential impacts and mitigation measures necessary for development of the site

Visual Aesthetics
Identify potential visual impacts and required mitigation measures associated with the project.

Vegetation
Identify existing vegetation present at the proposed site and adjoining properties.

Wildlife
Identify existing wildlife known or expected to habitat at the proposed site and surrounding areas. Additionally, anticipated impacts to wildlife and possible mitigation processes should be noted.

Avian Species and Migratory Birds
Identify avian species that live and/or migrate within the project area. Potential impacts to avian species within the area and migratory birds should be identified and possible mitigation measures noted.

Threatened and Endangered Species
Following the preliminary cataloging of known species (vegetation, wildlife, and avian), a review of the Federal and Local Threatened and Endangered (T/E) Species list should be conducted. Presence of T/E species could curtail further site development.

Wetlands
Perform a survey and catalog identifiable wetlands within the proposed development area and adjacent lands. Identify expected impacts to the wetlands due to the development and anticipated mitigation measures.

Drainage

Identify impacts to drainage conditions due to the proposed development and anticipated mitigation measures.

Floodplains

Review available Federal Emergency Management Agency Flood Insurance Maps or similar documentation to identify any known floodplains within the proposed development area. Identify expected impacts to known floodplains and anticipated mitigation measures that may be required.

Cultural Resources

Review Federal, State, Tribal and local records of archeological sites of historic cultural significance within the proposed development area. Include anticipated impacts to publicly owned parks, recreation areas, wildlife and waterfowl refuges, and Native American sacred or religious lands.

Land Use

Identify current land uses of the proposed development area such as grazing, farming, recreational, hunting, fishing, etc. Identify expected impacts to these uses resulting from the development and any anticipated mitigation measures that may be necessary.

Noise

Current noise conditions within the project area should be evaluated considering the potential impacts associated with any proposed development. Identify possible noise mitigation measures that may be required to develop the site.

Hazardous Materials

Identify known hazardous materials on, or adjacent to, the site and any hazardous materials that would be brought to the site associated with the development (construction and operation).

Construction

Consider the cost and feasibility of the following construction related elements:

- Are resources available locally (e.g., cranes)?
- Site access – Rugged? Remote?
- Estimated construction duration – seasonal impacts?
- Impact of construction on adjacent property – availability of easements, loss of lateral support?

A fatal flaw analysis should be completed in a relatively short period of time (< 2 months). Consequently, data for the analysis comes from an investigation of the site coupled with searches of relevant databases and interviews with representatives of Federal, State and County agencies that would have jurisdiction over the proposed project. For example, the New Mexico Department of Game & Fish, Department of Environment, Department of Energy Minerals and Natural Resources, Regulation and Licensing Department, Construction Industries Division, and County governments will no doubt need to be consulted. Other government agencies and organizations that may need to be contacted prior to development include the:

- U.S. Army Corps of Engineers (USCOE)
- State and Local Building Permit Offices (Building Regulations)
- Bureau of Indian Affairs (Tribal Lands)
- U.S Fish and Wildlife (Game and Endangered Species)
- U.S. Forestry Service (National Forests)
- Bureau of Land Management (Public Lands)
- U.S. Environmental Protection Agency (known Hazmat Sites)
- State Historic Preservation office and Archeological Division (known Historic or Archeological Sites)
- State and Federal Highway Divisions (Roadways)
- Public Utilities Commission (Regulations, Right-of Way and Permitting)
- Local Audubon Society (Avian Issues)

Assuming that the analysis reveals no "fatal flaws," the resulting investigation will serve as a blueprint for activities that must be performed to comply with all applicable requirements of the entities governing the construction and operation of the project.[11]

Critical Success Factors

Economic performance is the most important issue regarding wind project development. By focusing on the economics of a project, the developer is naturally led to optimize each of the critical success factors (including land lease payments[12]). There may however, be political realities or mitigation measures that must be taken that degrade economic performance.

The critical success factors in our opinion are:

1. Site Selection

[11] Note: Lenders and investors may have additional requirements that are over and above those required by the jurisdictional agencies.
[12] Typical land lease payments may be on the order of $2,500-3,000 per MW.

2. The Sales Agreement
3. Interconnection Requirements, Transmission Charges
4. Equipment Costs
5. Construction Costs (including access)
6. Operation and Maintenance Costs

All of these factors contribute to the economic conclusion that results in a financeable project. Financeability means that the project's economics can provide competitive rates of return for equity investors and that debt service coverage ratios are sufficient.

Site Selection

While the terms (including the electricity sales price) associated with the Sales Agreement will be negotiated and ultimately be the basis on which financing is obtained, strategic site selection represents a major opportunity to improve the economics of the project. The cost of construction, interconnection to the transmission/distribution utility, permitting, taxes, and landowner payments can all be heavily impacted by the site selection process.

Wind projects have a visual impact on the area in which they are deployed, and therefore remote locations are preferred. Private land is preferred to public land because public lands usually are governed by more stringent environmental study requirements and review than projects on private land. Locations with known environmental issues should also be avoided. The permitting of sensitive sites can be extremely costly and extend the development cycle dramatically.

The wind resource should be excellent and the principal factor in screening potential project locations. Assuming the project site has an economically developable wind resource, the next step is a cursory review of the transmission and distribution facilities in close proximity to the proposed location (preferably <10 miles). Access to the property compatible with the use of heavy equipment is essential (paved roads within 1 mile of the construction location), and ease of access in the event of inclement weather is also important.

Sales Agreement

The sales agreement is the most important of all project assets. It is the agreement that creates revenue, and therefore the cash flow that is necessary to attract investors. One result of utility restructuring and deregulation has been that rating agencies have treated *long-term* power purchase agreements like potentially stranded assets. This has put pressure on the term of such agreements.

The sales or *power purchase agreement (PPA)* is between the owners of the project and the purchaser of the wholesale energy produced by the project. The key elements of this agreement are price and term. A nominal levelized price results from a fixed price per kWh of energy generated by the project in a given year, or blocks of years, and may change over the life of the agreement. The price during the early years of the agreement (while the project debt is being payed off) is usually higher than the price during latter years of the agreement, thereby creating better cash flow to maintain minimum debt service coverage ratios in the early years. This is an important factor in obtaining debt for the project.

The term of the agreement is longer than the full term of the loan provided by the financial institution. The shorter the term of the PPA, the shorter the period in which to pay off the loan, resulting in the need for a higher price to generate the necessary cash flow.

Interconnection Requirements, Transmission Charges

Interconnection to transmission facilities rated 115 kV and above requires a substation with a step-up transformer. Generally, such a substation costs in excess of $1,500,000. Only large projects can typically absorb such a cost. Interconnection costs to sub-transmission or distribution facilities (rated at or below 69 kV) are generally in the range of $500,000-$1,000,000 and can be absorbed by a smaller project. Proximity to transmission or distribution lines or existing substations is also critical because the cost to build several miles of new line, acquire the necessary right-of-way, and permit the facility can become cost prohibitive. Wheeling the power from a project to the point of consumption is usually not the developer's responsibility, but the cost of wheeling the power is usually born by the project and should be considered when examining the project's economics.

Equipment Costs

The market for wind turbine equipment is a competitive one, which keeps pressure on prices charged by equipment suppliers. Negotiation and selection of a turbine supplier usually occurs late in the development process. The selection of wind turbine suppliers is a technical (matching the right turbine configuration with the available wind resource) and economic one, with a focus on system performance and economics (including maintenance costs) over the life of the project. Warranties may also be a differentiating factor.

Construction Costs

Construction costs are heavily dependent on soil conditions (foundations) and access/proximity to good roads. Access roads may need to be engineered if the terrain (slope) is difficult. Clearing land of foliage may require special permits in some locations, and the density of the foliage may add significantly to the cost (large-scale clear cutting is usually not a good idea!). The cost of construction is also closely tied to the length of the construction schedule.

Operation and Maintenance (O&M) Costs

Financial institutions generally require that the turbine supplier stay involved with the project for a certain length of time (2-3 years) through operation and maintenance support contracts. O&M costs should be controllable if systems are designed and constructed properly.

Financing

A discussion of financing is beyond the scope of this document. However, financing small projects may be more difficult than financing a large project. The low overall cost of small projects may make it difficult to attract the attention of large institutional investors. Also, the transaction costs associated with such an investment can also get prohibitive and must be managed carefully.

For More Information

Books

A Siting Handbook for Small Wind Energy Conversion Systems, H. Wegley, J.Ramsdell, M. Orgill and R. Drake, Report No. PNL-2521 Rev.1, 1980; available from the National Technical information Service, 5285 Port Royal Rd., Springfield, VA 22151 (800) 553-8647. http://www.ntis.gov/ordering.htm

Small Wind Electric Systems: A U.S. Consumer's Guide, Produced for the U.S. Department of Energy by the National Renewable Energy Laboratory, Report No. DOE/GO-102001-1293, May 2001. http://www.nrel.gov/publications

Wind Energy Resource Atlas of the United States, D. Elliott et al.; available from the American Wind Energy Association, 122 C. Street N.W., Washington, D.C. 20001. http://rredc.nrel.gov/wind/pubs/atlas

Wind Resource Assessment Handbook: Fundamentals for Conducting a Successful Monitoring Program, AWS Scientific, Inc.; http://www.nrel.gov/publications

Government Agencies

National Climatic Data Center, Federal Building, 151 Patton Avenue, Asheville, NC 28801-5001. (828) 271-4800. Fax (828) 271-4876. http://www.ncdc.noaa.gov

New Mexico Energy, Minerals and Natural Resources Department, 1220 South Saint Francis Drive, Santa Fe, NM 87505. (505) 476-3319. Fax (505) 476-3322. http://www.emnrd.state.nm.us/

Non-Governmental Organizations

American Wind Energy Association, 122 C. Street N.W., Washington, D.C. 20001. (202) 383-2500. http://www.awea.org

Web Sites

Database of State Incentives for Renewable Energy. http://www.dcs.ncsu.edu/solar/dsire/dsire.html