EnerQuest Power Development Corporation
(EPDC)

Wind Power Development Project
(United States of America)

Request for Proposal

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Prepared by the Graduate Studies Program at
North Carolina Agricultural & Technical State University

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Project Scope

To consult, design, test and assemble a 30 MW wind power farm in a suitable area of the Western United States. The generated power will be sold to the USA electric grid, or to local consumers. This project will be executed as a joint venture with EnerQuest Power Development Corporation.

All proposals should emphasize those policy issues that would give the joint-venture best chances for approval (i.e.: new, inventive solutions, technology transfer, workers' training, alternative processes, local equipment procurement, export potential, etc.).

Project Background

Wind energy projects provide cost-effective and reliable energy in the United States and abroad. The U.S. wind industry currently generates about 3.5 billion kilowatt-hours of electricity each year--enough to meet the annual electricity needs of 1 million people. Wind energy installations are going up across the country as utilities realize the benefits of adding clean, low-cost, reliable wind energy to their resource portfolios.

The U.S. Department of Energy and NREL are helping bring wind energy, a clean, low-cost generation option, to the marketplace in the United States and abroad. Activities such as the Wind Energy Deployment Project, international cooperative projects and technical assistance, and standards development all help hasten the adoption of wind energy technology.

The electricity generated by wind turbines is used for many applications, from large, utility-scale power plants, to small, single turbines for home or village use. Wind energy's popularity is growing because of its many benefits: wind energy generates pollution-free electricity; the fuel source, wind, blows steadily in many areas; wind energy costs compete with conventional fossil-fueled power plants in some areas; and costs continue to drop as technology improves.

Environmental Issues

Wind energy is considered a green power technology because it has only minor impacts on the environment. Wind energy plants produce no air pollutants or greenhouse gases. However, any means of energy production impacts the environment in some way, and wind energy is no different.

Aesthetics and Visual Impacts: Elements that influence visual impacts include the spacing, design, and uniformity of the turbines.
Birds and Other Living Resources: Pre-construction surveys can indicate whether birds or other living resources are likely to be affected by wind turbines.
Global Warming: Wind energy can help fight global warming. Wind turbines produce no air emissions or greenhouse gases.
Lightning: Ongoing research and increased operator experience are improving the understanding of lightning and wind turbines.
Noise: Like all mechanical systems, wind turbines produce some noise when they operate. In recent years, engineers have made design changes to reduce the noise from wind turbines.
TV/Radio Interference: In the past, older turbines with metal blades caused television interference in areas near the turbine. Interference from modern turbines is unlikely because many components formerly made of metal are now made from composites.

Wind Resource

The wind is the fuel source for wind energy. The United States has many areas with abundant winds, particularly in the Midwest and Great Plains. Understanding the wind resource is a crucial step in planning a wind energy project. Detailed knowledge of the wind at a site is needed to estimate the performance of a wind energy project.

Wind energy is very abundant in many parts of the United States. Wind resources are characterized by wind-power density classes, ranging from class 1 (the lowest) to class 7 (the highest). Good wind resources (class 3 and above) which have an average annual wind speed of at least 13 miles per hour, are found along the east coast, the Appalachian Mountain chain, the Great Plains, the Pacific Northwest, and some other locations. North Dakota, alone, has enough energy from class 4 and higher winds to supply 36% of the electricity of the lower 48 states. Of course, it would be impractical to move electricity everywhere from North Dakota. Wind speed is a critical feature of wind resources, because the energy in wind is proportional to the cube of the wind speed. In other words, a stronger wind means a lot more power.

Political Issues:

Wind Project Siting Faces Unique Hurdles: Despite it s Status as the Fastest Growing Renewable Energy Source, Wind Power faces numerous obstacles in siting and permitting. This is true for both large projects being built to sell power to utilities and small projects being built for a single user. Regulations and laws governing power project siting are becoming ever more complex, and state and federal siting agencies are not as likely to approve power projects without extensive review. Various interest groups have become more involved in siting procedures as well. Large wind projects raise many of the same siting issues as other energy projects. There may be concern about truck traffic during construction, health effects of electromagnetic fields from transmission lines and social issues. Wind projects also face some unique challenges that require special consideration.

Land Use: Unlike most power plants, wind generation projects are not land intensive. On a MW output basis, the land required for a wind project exceeds the amount of land required for most other energy technology, but the physical project footprint covers only a small portion of that land. For example, a 50 MW wind facility may occupy a 1,500-acre site, but it will only use three to five percent of the total acreage, leaving the remainder available for other uses. Because wind generation is limited to areas with strong and fairly consistent wind resources, most wind generation is sited in rural and relatively open areas that are often already used for agriculture, grazing, recreation, forest management or seasonal flood storage. To ensure that a wind project is compatible with existing land uses, the layout and design of the wind project can be adjusted in a variety of ways, including:

- Selecting equipment with minimal guide wires
- Placing electrical collection lines underground

- Placing maintenance facilities off site
- Consolidating equipment on the turbine tower or foundation
- Consolidating structures within a selected area
- Using the most efficient or largest turbines to minimize the number of turbines required
- Increasing turbine spacing to reduce density of machines
- Using road-less construction and maintenance techniques, or using existing access roads.

Other land use strategies include using buffer zones and setbacks to separate wind projects from sensitive or incompatible land uses. Land use agencies in California have established setbacks ranging from two to four times the height of a turbine or a minimum of 500 to 1,200 feet from any residential area. Minnesota has established minimum setbacks of 500 feet from occupied dwellings.

What are the advantages of wind-generated electricity? Numerous public opinion surveys have consistently shown that the public prefers wind and other renewable energy forms to conventional sources of generation. Wind energy is a free, renewable resource, so no matter how much is used today, there will still be the same supply in the future. Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. In 1990, California's wind power plants offset the emission of more than 2.5 billion pounds of carbon dioxide, and 15 million pounds of other pollutants that would have otherwise been produced. It would take a forest of 90 million to 175 million trees to provide the same air quality.

What are the economic obstacles to greater wind power usage? Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil-fueled generators. Roughly 80% of the cost is the machinery, with the balance being the site preparation and installation. If wind-generating systems are compared with fossil-fueled systems on a "life-cycle" cost basis (counting fuel and operating expenses for the life of the generator), however, wind costs are more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses.

Are there other drawbacks to the use of wind energy? The major challenge to using wind as a source of power is that it is intermittent and it does not always blow when electricity is needed. Wind cannot be stored (unless batteries are used); and not all winds can be harnessed to meet the timing of electricity demands. Further, good wind sites are often located in remote locations far from areas of electric power demand (such as cities). Finally, wind resource development may compete with other uses for the land and those alternative uses may be more highly valued than electricity generation. However, wind turbines can be located on land that is also used for grazing or even farming.

Is the cost of wind power competitive with conventional power plants? New, utility-scale, wind projects are being built all around the United States today with energy costs ranging from 3.9 cents per kilowatt-hour (at very windy sites in Texas) to 5 cents or more (in the Pacific Northwest). These costs are competitive with the direct operating costs of many conventional forms of electricity generation now--and prices are expected to drop even further over the next 10 years. Since wind is an intermittent electricity generator and does not provide power on an "as needed" basis, it has to compare favorably with the costs saved on fuel from fossil generators.

Can homeowners sell excess electricity to the utility? Under the Public Utilities Regulatory Policy Act of 1978 (PURPA), any qualifying individual can install a wind generator and the local electric utility must pay for any excess power produced. PURPA was specifically intended to create a market for clean, renewable, electric-generating technologies by guaranteeing a buyer for the excess power. Prior to PURPA, selling power to the utility was an option but was the discretion of the utility. With PURPA, small power producers meeting specific criteria are guaranteed purchase and interconnection. Many states now permit "net metering," in which the utility must buy wind power generated by homeowners at the same retail rate the utility charges. This essentially allows the customer's meter to turn backward while wind energy is supplied to the grid by the customer's turbine.

Economic Issues

Although the Nation s wind potential is very large, only part of it can be exploited economically. The economic viability of wind power will vary from utility to utility. Important factors not addressed in this study that influence land availability and wind electric potential include production/demand match (seasonal and daily), transmission and access constraints, public acceptance, and other technological and institutional constraints.

To provide 20% of the Nation s electricity, only about 0.6% of the land of the lower 48 states would have to be developed with wind turbines. Furthermore, wind turbines, electrical equipment, and access roads would occupy less than 5% of this land. Most existing land use, such as farming and ranching, could remain as it is now.

Is wind energy good for the economy? Wind energy avoids the external or societal costs associated with conventional resources, namely, the trade deficit from importing foreign oil and other fuels, the health and environmental costs of pollution, and the cost of depleted resources. Wind energy is a domestic, reliable resource that provides more jobs per dollar invested than any other energy technology--more than five times that from coal or nuclear power. In 1994, wind turbine and component manufacturers contributed directly to the economies of 44 states, creating thousands of jobs for Americans.

The U.S. electric power industry is a combination of electric utilities (investor-owned, publicly owned, cooperatives, and Federal) and non-utility power producers. Investor-owned electric utilities account for over three-fourths of the sales of electricity and revenue in the industry. Historically, the investor-owned electric utilities served the large consolidated markets and operated in all States except Nebraska. Hawaii is the only State in which all electricity is supplied by investor-owned electric utilities.

Publicly owned electric utilities are nonprofit operations that have been established to serve their communities and nearby consumers at cost. The publicly owned electric utilities in this publication include municipals, public power districts, State authorities, irrigation districts, and other State organizations. Publicly owned electric utilities are exempt from taxes and can obtain new financing at lower rates than investor-owned electric utilities.

The publicly owned electric utilities are divided into generators and non-generators (in contrast, virtually all investor-owned electric utilities own and operate generating capacity). Generators are those electric utilities that have investment in electric utility plant and production to supply some or all of their consumer needs. However, many generators can supplement their demand by purchasing power. The non-generators cannot produce electric power for end use and rely exclusively on purchasing power. Their primary function is to transmit and distribute electricity to their consumers. The non-generators comprise over half of the total number of major publicly owned electric utilities.

Cooperative electric utilities are owned by their members and are established to provide electricity to those members. The Rural Electrification Administration (prior to the Rural Utilities Service), U.S. Department of Agriculture, was established under the Rural Electrification Act of 1936 with the purpose to extend electric service to small rural communities (usually under 1,500 consumers) and farms where it was more expensive to provide service. The National Rural Utilities Cooperative Finance Corporation, the Federal Financing Bank, and the Bank for Cooperatives are the most important sources of debt financing for Cooperatives. Cooperative borrowers (695 of 901 in 1999 total cooperatives) currently operate in 46 States. Financial data for the cooperative borrowers are found in the *Statistical Report, Rural Electric Borrowers* published by the Rural Utilities Service of the U.S. Department of Agriculture.

Federal electric utilities are also presented in this publication and include the four Federal power-marketing administrations, the Tennessee Valley Authority, and the U.S. Bureau of Indian Affairs. The four Federal power-marketing administrations are the Bonneville Power Administration, the Southeastern Power Administration, the Southwestern Power Administration, and the Western Area Power Administration. Primarily water resources generate electric power produced by Federal electric utilities. This power, which is not produced for profit, is primarily sold in the wholesale market to other electric utilities rather than being distributed to ultimate consumers. As required by law, publicly owned and cooperative electric utilities are given preference in the purchase of this less expensive power produced by the Federal electric utilities.

Industry Profile: Key facts of sales and revenues in 1999 are:

- The 2,008 publicly owned electric utilities, which accounted for close to two-thirds of all electric utilities, accounted for 14.6 percent of all revenues from sales to ultimate consumers and 18.3 percent of all revenues from sales for resale.

- The 900 cooperative electric utilities (more than a quarter of all electric utilities) accounted for 8.9 percent of all revenues from sales to ultimate consumers and 19.9 percent of all revenues from sales for resale.
- The 9 Federal electric utilities accounted for 0.6 percent of all revenues from sales to ultimate consumers and 14.7 percent of all revenues from sales for resale.
- The average ultimate consumers revenue per kilowatt-hour ranged from 2.4 to 6.8 cents depending on the type of electric utility servicing them. The overall average was 6.7 cents.
- The average sales for resale revenue per kilowatt-hour ranged from 3.5 to 4.9 cents, depending on the type of electric utility making the sale. The overall average was 4.3 cents.

Economic Context: Economic growth characterized 1999 with the real gross domestic product (GDP) growing by 4.0 percent, a slight decrease from 4.3 percent in 1998. Economic expansion maintained considerable momentum during 1999. This is the fourth year in a row in which the Federal Reserve used minimal intervention to stimulate the economy. Another sign of the sturdy economy was that industrial production indexes increased a robust 3.6 percent last year. The consumer price index (CPI) rose a slight 2.2 percent during 1999, up slightly from 1.6 percent in 1998. Capacity utilization was 80.7 percent for 1999. This represents the eighth year in a row where the measure of economic activity as a percent of capacity has been over 80 percent.

Generator Electric Utilities versus Non-generator Electric Utilities: The next section of the publication discusses generator and non-generator electric utilities separately. The two groups are distinct because of operational differences resulting in significantly different financial pro-files. For example, significant plant production expenses would not exist for non-generator electric utilities because existing production plant expenses are mainly maintenance costs for standby plants. It should be noted that both generator and non-generator electric utilities report according to varying fiscal years that are determined by their political localities.

Because non-generator electric utilities purchase all their power needs, they have less plant investment than generator electric utilities per dollar of revenue generated. In 1999, generator electric utilities had $3.71 of electric utility plant (without nuclear fuel) per dollar of electric utility operating revenue, com-pared with $1.22 for non-generator electric utilities.

Operation and maintenance (O&M) expenses represent very different costs between the two groups of electric utilities. Purchase power expenses, which comprise the majority of non-generators' O&M expenses, contain all the associated costs for the generating plants from which the power was purchased, including depreciation. This causes non-generators' O&M expenses to appear higher than generators' O&M expenses on a mills per kilowatt-hour basis. In 1999, non-generators' O&M expenses were 87.1 percent of revenues and depreciation was only 3.9 percent. For generators, depreciation of plant is shown directly, since all or their own plants meet some of their generating needs. Generators' O&M expenses represented only 63.8 percent of revenues, but depreciation was 12.1 percent of revenues.

Financing is also different for the two groups. Generator electric utilities, with their larger plant investments per dollar of revenue, have more debt per dollar of revenue than non-generator electric utilities. The large amount of debt creates greater interest expense. Interest expense represented 14.2 percent of revenues in 1999 for the generators versus just 1.2- percent of revenues for the non-generators (Tables 7 and 18).

Wind Power Incentives In The U.S.:

1. Provision for using renewable energy sources to provide electricity to 3 million un-electrified rural people.
2. Not yet implemented.
3. Not yet implemented.
4. 30% capital write-off per year on remaining balance of the investment.
5. Reduction of customs duty from 22% to 6%.
6. Not yet implemented but in the process of approval. All income tax paid by the wind farm operator will be returned.
7. The cost of grid connection is split between the wind turbine owners and the electric utilities.
8. Utilities receive US$0.015/kWh as a reimbursement of the general carbon tax.
9. 10% of annual electric consumption must come from renewable energy sources by 2005. 100 MW each year of wind power must be installed.
10. A grant that is limited to a maximum of 25% of the total investment costs.
11. About 1% below current commercial rates through Deutsche Ausgleichsbank/DtA. A grace period for first two years where no payments need to be made.
12. Subsidy of US$0.036-0.048/kWh, depending on whether the electricity is fed into the grid or being used by the turbine owner.
13. Electricity Feed Law guarantees at least 65-90% of the retail price for renewable energy.
14. Five-year tax holiday for wind power investments.
15. In the final stages of implementation.
16. 100% depreciation for wind investments in first year.
17. Wind generators are exempt from excise duty and sales tax. Some wind facility parts are exempt from customs duty while others enjoy a reduction in the customs duty.
18. IREDA provides credit to renewable energy projects which cover 70-80% of the project’s costs. Grace period of one year.
19. Directive No. 6 stipulates that US$0.104/kWh will be paid for the first eight years of operation of wind plant. US$0.05/kWh will be paid for the remaining life of the plant.
20. 77% depreciation of wind project during first year of operation.
21. 100% write-off of entire wind project investment within the first fiscal year.
22. Green electricity payments from pool of consumers’ voluntary payments.
23. Policy is still under consideration. There would be a removal of import taxes and duties on non-conventional technologies.
24. Payment of premium prices to priority technologies in remote areas, including US$ 0.08/kWh for wind and US$0.16/kWh for solar.

25. The federal policy was in effect from 1978-1985. There were two components: (1) 10% investment tax credit of the value of the installed wind energy equipment, (2) 15% energy investment tax credit. In California, there was also a 25% investment tax credit on the value of the installed equipment. California's ITC was in effect from 1978-1987.
26. US$0.015/kWh produced can be subtracted from income taxes. For non-taxpaying entities such as municipalities a direct cash payment of US$0.015/kWh is paid.
27. Green pricing programs are just beginning to be implemented as the country undergoes utility restructuring. Consumer disclosure will also be implemented as restructuring occurs.

About EnerQuest Power Development Corp. (EPDC)

EnerQuest Power Development Corporation has developed and owns more than 30 high-MW Wind Power farms. EnerQuest is one of the nation s leading independent developers of wind powered projects. We are dedicated to generating clean energy.

EnerQuest can provide turn-key services where we finance, construct, own, operate and sell power as we have done in California at our Green Peace I Facility, and in Japan at both of our Nataki and Asahi projects. EnerQuest s experienced team has developed and financed world-class wind power facilities representing an investment of approximately $2.3 billion. We can provide as much support as your project requires, or deliver reliable, high-availability wind technologies customized to meet the needs of alternative powered projects.

At EnerQuest, our team is committed to delivering continuously superior services to our highly valued customers. Our objective is to earn your respect and confidence, and become your long-term partner in wind power. Our uncompromising commitment to quality, and your satisfaction, is paramount.

We have a 5-member management team that continues to study various factors in such an ambitious project as this. These factors include, but are not limited to, the environment, politics, economics, marketing, technology, construction, and joint venture structure.

Brian Murphy *Business Development/Marketing Coordinator*
Generates project interest, Request for Proposal bid letting, to prospective client base.

Bryan K. Charles *Economic and Politics Professional*
Specializes in both political and economical issues relevant to this windmill energy generation project.

Gary Ajemian and Anthony Okeke *Technology Engineering*
Gathers information about the Technology Infrastructure and Specifications related to windmill energy systems.

Jacquelyn Barnett *Public Relations Officer*
Addresses correspondences from prospective bidders.

James D. Woodland *Joint Venture/Financial Specialist*
Coordinates the joint venture structure and financial aspect of Request for Proposal bid letting.

<u>**Joint Venture**</u>

Management

The J-V partnership will create a Board of Directors composed of experienced business professionals and academics with the primary mission of developing strategic planning and to oversee project operations. The Board of Directors should consist of:

- ♦ 3 EnerQuest executives (CEO, COO, a legal advisor)
- ♦ 1 EnerQuest environmental engineer
- ♦ 2 JV Partner engineers for operations management and plan review
- ♦ 1 JV Partner for technical consultation
- ♦ 1 JV Partner: production manager
- ♦ 1 government official from the Department of Energy (policy advisor)
- ♦ 1 university scholar specializing in wind powered projects in the United States
- ♦ 1 academic from a nationally recognized alternative energy research firm

Strategic Planning Goals

The principal objectives of the joint venture partnership with EnerQuest Power Development Corporation (EPDC) are to promote and develop alternative powered energy sources throughout the western region of the United States.

The joint venture goals and objectives for this project are:

- ♦ To establish a wind powered farm with a 30MW yield
- ♦ To locate viable markets for alternative energy consumption
- ♦ To provide a maintenance continuum to service the project
- ♦ To continuously provide jobs and encourage local business opportunities

The combined contributions of this joint effort will result in a powerfully dynamic and effective Board of Directors to provide a bold new vision to current and future enterprises within a framework to achieve excellence.

Contractor Qualifications

The joint venture partner shall contract for the assembly of a 30 MW wind powered farm in a given location in the western United States. The contractor shall be a reputable corporation with a proven record of expertise with wind powered energy systems. ISO 9000 and ISO 14000 certifications are required.

Financial Structure and Terms

EnerQuest shall have 60% ownership of the J-V, while the partner shall own 40% of the equity. Financing of the J-V shall be done through 60% debt and 40% equity. Please review table.

	ENERQUEST	JV PARTNER
EQUITY	60%	40%
CAPITAL	60%	40%

Capital investments will be estimated on the basis of the production of the generating farm for up to ten years after the J-V start. The ten-year life span of the J-V has been chosen in order to allow sufficient time for evaluation of technical, environmental, social, and political effects. After successfully addressing initial local goals, the progress of the J-V shall determine the pursuit of other domestic markets.

Technical Specifications

Overview

This project calls for the construction of a wind-powered electric generating facility. Nominal capacity is 30 Megawatts. On-line generation capability must be 90% of anticipated demand at all times and 95% of anticipated demand during peak periods.

The proposing joint venture partner will provide the lead position in project design and engineering, site selection, equipment acquisition and installation, and training including the development of local personnel to operate and maintain the facility.

Experience

The successful joint venture partner must demonstrate expertise and experience in the design, selection and construction of wind generation facilities.

Special Considerations

Special consideration will be given to proposals that include any or all of the following

1. Innovative designs in wind generation equipment
2. Integration of other non-fossil fuel electric generation technology with wind generation
3. Aesthetics and community acceptance

Proposal Specifications

1) Design and engineering

- a) Proposals shall include complete design plans and specifications on the following
  - i) Generation equipment
  - ii) Support systems
  - iii) Spare parts inventory

2) Durability and strength

- a) Life expectancy — the life expectancy of proposed generation equipment and systems is to be in excess of 25 years
- b) Storm Exposure — Equipment proposed should be able to withstand the elements to which it would be routinely exposed (based on site selection). Additionally, a description of the maximum conditions proposed equipment is designed to withstand and why that will be sufficient is also required.
  - i) Wind
  - ii) Rain/snow
  - iii) Hail

c) Earthquake — Equipment proposed should be designed to withstand moderate earthquake activity if required by site selection

3) Site selection and construction

a) Proposals must include an appropriate analysis of suitable sites and corresponding recommendations regarding facility location. Land needs and cost analysis is also required
b) Proposals shall include an assessment and provisions for the construction of
   i) Electric generation equipment
   ii) Connection to the electric grid
   iii) Facility infrastructure
   iv) Access roads
c) Site Preparation

4) **Staffing** — Operational and maintenance staff shall be hired from the local labor pool. Proposals must include

a) The number of staff required to operate and maintain the facility
b) Skills required to operate and maintain the facility
c) Training provided by the joint venture partner to achieve operational competency by staff.
d) Engineering support personnel provided by the joint venture partner

Specification Requirements

EnerQuest Power Development Corp. expects any potential partners in this or any Joint Venture to comply with any and all regulations. Whether those regulations stem from a federal, state or local mandate or are related to construction/engineering specifications. If however, the Joint Venture company can excede the following specifications, we at EnerQuest are opened to any changes do to technological advances.

The following specifications are to be used as guidelines in the design and selection of equipment for this project. Changes to required specifications must meet approval of EnerQuest before joint venture is granted.

Rated Output**:** Minimum 750 kW per tower

Annual Output: Minimum 20,000 megawatt hours per year

Turbine Design: Horizontal axis.

Designing a Brain for Tomorrow's Wind Turbines

In the past, turbine controls were used to solve particular problems: to slow or stop the rotor, to prevent wind gusts from suddenly producing too much power, to prevent the turbine from vibrating during operation, to mitigate damage from turbulent winds, and so on.
A better way to control a wind turbine is via an electronic brain, or smart controller, which can optimize every aspect of turbine operation. Smart controllers use miniature computers, called microprocessors, to continuously evaluate wind conditions and turbine operation at any given moment. The controller then adjusts turbine operation to maximize the amount of power it generates, to protect the machine from excessive wear and tear, and to ensure maximum service life, low energy costs, and safe operation. Such a controller will ensure the maximum benefit from using light, flexible rotors and custom generators.

Engineers at NREL and Sandia are working with university researchers to design a computerized control system for wind turbines. Starting with a computer model that includes control strategies to solve typical problems, they are programming it to systematically evaluate a particular strategy's costs and benefits under a variety of conditions. The smart control system will assess how a particular device such as a tip brake affects the entire wind turbine. It will decide whether using it makes more sense than another method for slowing the rotor.
In the future, system control specialists will work on designing new turbines from the beginning. Understanding how a wind turbine works, they will be able to design smart control systems as an integral feature of the next generation of utility wind turbines.

Tower Structure: Lattice configuration or tubular steel

Foundation: For lattice configuration - four (4) individually drilled caissons - diameter and depth to be determined by size of structure. For tubular steel design - concrete cylinder with depth and width to be determined by size of structure.

Footprint: For lattice configuration - square base - spaced 1 - 2,000 feet apart. For tubular steel design -circular base - spaced 1 - 2,000 feet apart. Footprint dimensions determined by size of structure.

Concrete: Amount to be determined by tower structure chosen and number of towers.

Steel Reinforcement: Contingent on type of tower chosen for project.

Height: Height from ground level to hub axis should exceed nearest vertical obstacle by 100 feet or more.

Taller Towers Reach for the Wind

Wind speed generally increases with height above the ground. Taller towers expose turbines to stronger winds, enabling them to produce more electricity. Until now, the value of the extra electricity has been nearly offset by the cost of materials to make the towers bigger, at least for traditional steel lattice or tube towers. However, innovative tower designs are allowing taller towers to be built at reduced cost. Consequently, average tower height should gradually increase from 100 feet to about 230 feet by about 2005.

Weight: To be determined by the tower structure chosen.

Blade Length: 24 - 34 meters (79 - 112 feet).

Rotor Diameter: 50 - 80 meters (165 - 263 feet).

Innovative Rotors Increase Energy Capture

Rotors are large, heavy, and crucial to capturing energy from the wind. Because improvements in rotor design have a great impact on energy costs, the National Renewable Energy Laboratory and Sandia National Laboratories have looked into new designs for airfoils; innovative hub attachments that allow rotors to be more flexible; and improved manufacturing processes for blades.

Airfoils specifically designed for turbine blades can greatly enhance turbine performance. Airfoils are the cross-sectional shapes on airplane wings or turbine blades that convert airflow into forces that can lift an airplane or turn a turbine rotor. Since 1984, NREL researchers have created seven "families" of airfoils for turbine blades of specific sizes. The new airfoils can increase energy capture by as much as 30% in constant-speed rotors. They are used on the Z-40, AWT-26, AWT-27, and AOC 15/50 wind turbines.

Turbine rotors with two blades capture about the same amount of energy as their three-bladed counterparts and are much less expensive to build. However, two-bladed rotors must be flexible enough to respond to wind gusts and dissipate forces in the wind that would otherwise impact the turbine. In 1994, NREL began a research project at the NWTC to study hub designs that allow such flexibility.

In 1997, researchers built a new research hub that will allow them to evaluate two key strategies for designing flexible, two-bladed rotors. In one approach, each blade will have a hinge at its base (root) that allows both blades to bend downwind in high winds. In the other strategy, the blades will be linked together and attached to the low-speed shaft by means of a single hinge. Researchers will install the hub on a research turbine, study both strategies, and determine which one works best. Their goal is to prepare for the development of a new class of lightweight, flexible wind turbines whose high-performance rotors will significantly lower the cost of energy production.

Sandia is also striving to lower the cost of turbine rotors by working with industry to improve manufacturing of turbine blades. By improving manufacturing processes, shortening the time it takes to cure the blades, and making other improvements, researchers hope to reduce the blade costs by as much as 25%. Sandia is also working with industry and academia to improve blade-manufacturing processes for fiberglass and plastic blades.

<u>Rotor Speed (Variable)</u>: 11 - 34 rpm

<u>Swept Area</u>: 20,000 - 50,000 square feet per turbine (65,840 - 164,600 square meters).

<u>Gearbox Type</u>: Integrated 2 stage with parallel shafts, or three-step planetary spur gear system.

<u>Generator Type</u>: Rotary current asynchronous.

Custom Generators Promise Better Performance

Today, most wind turbines use constant-speed generators to make electricity from the rotational energy produced when the wind turns the turbine rotor. These standard generators are widely available from industry. They are affordable but require costly transmissions and gears to operate. The gears increase the speed of the turbine rotor, which is 60 revolutions per minute (rpm) or less, to 1,800 rpm, the rotational speed required to operate a typical "off the shelf" generator.

The development of generators that work at low rotational speeds holds promise for better performance at lower cost. Because some generators can operate at the same rotational speeds as the turbine rotor, the expensive gearbox can be eliminated. Designing the generators is a major technical challenge, however. To work, low-speed generators require custom-made, high-efficiency, solid-state electronic converters, called power electronic converters, to generate 60-cycle alternating current and allow the generator to operate at variable speeds.

NREL researchers believe custom-made, low-speed generators with power electronics and variable-speed operation will be able to produce about 10% more electricity than

their constant-speed counterparts. Because they can respond to changes in the wind, variable-speed generators can keep the turbine operating at maximum efficiency. Plus, they are quieter and reduce wear and tear on the turbine. In a constant-speed machine, rotor speed must be held steady and cannot increase once the turbine is producing maximum power. In a variable-speed machine, the rotor can spin faster in response to increases in wind speed, thereby using more of the power in the wind to generate electricity.
Variable-speed generators should work well with both standard, three-bladed machines and two-bladed, flexible turbines. Designing custom generators and power electronics that both work efficiently at low wind speeds is essential, however. Otherwise, poor performance at low wind speeds will offset some of the gains in efficiency at higher wind speeds.

Inverter Type: IGBT-frequency inverter.

Braking Systems: Individual pitch regulation brake control system: fail-safe.

Yaw System: Motor driven with wind direction sensor and automatic cable unwind.

Control System: 32 bit microprocessor-based, embedded micro-controller, remote control operating system; microprocessor-based programmable logic controller (PLC); or equivalent.

Control Systems Improve Plant Efficiency

Computerized control systems can also help wind power plants run more efficiently. NREL's partner Second Wind Inc. <http://www.secondwind.com> developed a sophisticated wind power plant control system. The system can monitor each turbine's power output as well as current wind conditions. Power plant operators can use this information to adjust the operation of individual turbines to maximize power output or minimize wear and tear on the machine. A supervisory computer also allows operators to see the entire power plant at one time by displaying a map of the turbines, meteorological towers, and substations. DOE is using Second Wind's power plant control system to monitor turbine performance in new projects being developed under the Wind Turbine Verification Program. <weu.html>

Lightning Protection System: Lightning protection installed on blade tips, discharge inside the rotor blades along nacelle and tower.

Sound Proofing: Structure borne noise insulation of the tower, sound reduced gearbox, noise reduced nacelle.

The wind turbines should be certified to IEC Class II for a 30-year fatigue life. IEC Class II requires a wind turbine to withstand hurricane loads of up to 131.1 mph (211 km/hr) as a once in a 50-year occurrence, and 99.8 mph (161 km/hr) as a yearly occurrence.