GE Energy

GE Wind

Wind Energy Basics

GE imagination at work

REVISION HISTORY

Document	Rev.	Release Date (y/m/d)	Affected Pages	Change	Author
Wind Energy Basics	00	June 3, 2009	All	Original Issue	Siva Chockalingam

INTRODUCTION

This document is intended to provide general information on megawatt-scale wind turbines and the wind plant development process in North America. The guidance is general in nature, and is based on the published advice of recognized industry associations such as the American Wind Energy Association (AWEA). *It is essential for a prospective developer to retain the services of qualified professionals (consultants) for wind plant development.*

Intended Audience:
- Community Wind, Small Developers, Institutional (e.g. 1 – 6 units)
- Non-Utility Scale
- Non-Technical Audience

It is ultimately the responsibility of the owner and the developer to determine whether a wind plant can be developed at a particular site. The specific risk assessment required to make that determination will by necessity involve site-specific considerations that cannot be addressed in a document of this nature. The recommendations in this document should in no event be considered as professional, legal, or technical advice.

How much does a wind farm cost?

- The total cost will vary significantly based on site-specific conditions, permitting and construction requirements, and transportation constraints. In general wind power development can cost around $2 million per megawatt (MW) of generating capacity installed[1], including supporting infrastructure commonly referred to as Balance of Plant (BoP).
- The most economical application of wind turbines is usually in groups of turbines called "wind plants" that share common infrastructure such as electrical interconnection facilities and service roads. Wind plants can range in size from a few megawatts to hundreds of megawatts in capacity.

How big are wind turbines?

- The "tip height" of a GE 1.5 MW turbine is approximately 120 meters (394 feet), which represents the total height of tower plus a blade in its highest vertical position. Thus, the "tip height" of the turbine is roughly equivalent to the height of a 40-storey building. However, taller wind turbines with taller towers or longer blades may stand as high as 150 meters (492 feet) from ground level.
- 8 tractor-trailer loads may be necessary to bring equipment for a single turbine to the project site. Some of these will be over-sized or special-permit loads.

How much energy do wind turbines produce?

- At a good wind site each GE 1.5MW turbine can produce enough electricity to supply the annual energy needs of about 400 average US homes. The total energy output of a wind plant depends on the strength of the wind resource in which it operates.

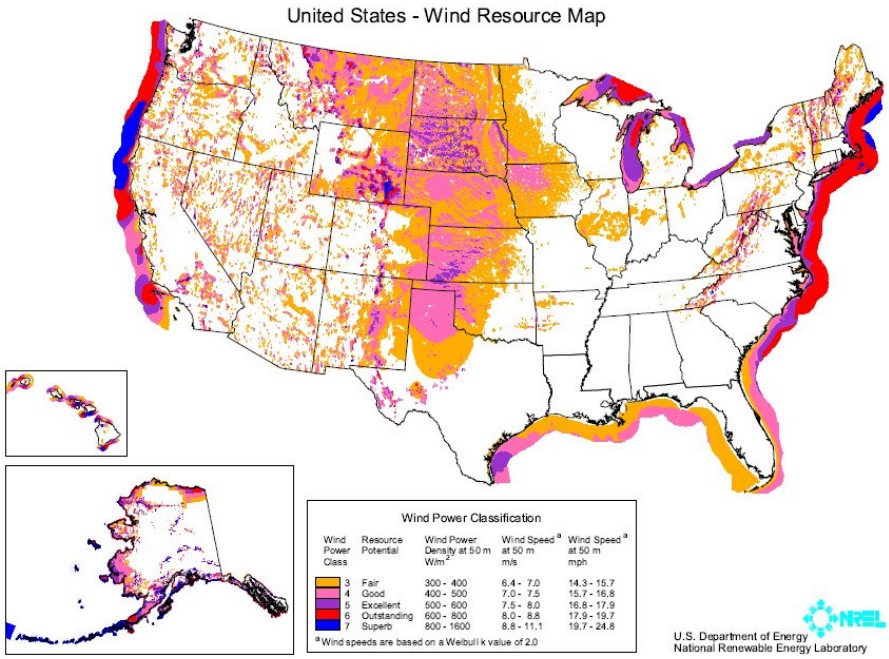
[1] American Wind Energy Association (AWEA) http://www.awea.org/

PROJECT FEASIBILITY CONSIDERATIONS – Can a wind farm be developed at a particular site?

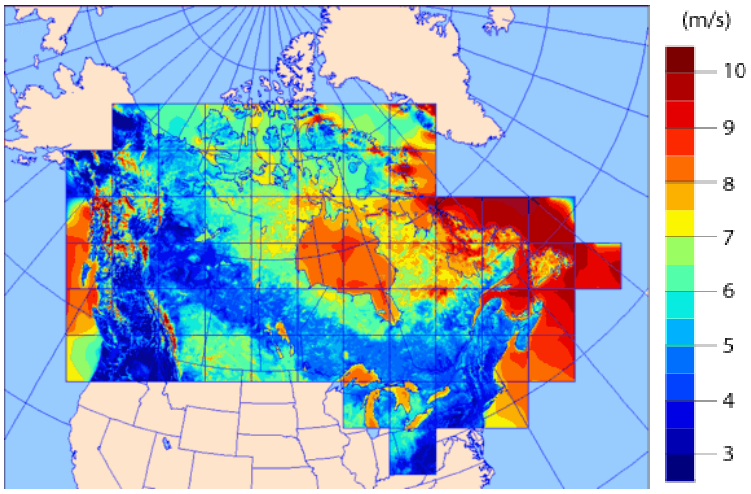
For detailed information on this topic, see the AWEA website[1].

Understanding your wind resource

- Simple resource classification provided by AWEA based on average wind speed:
  - **Moderate**: 6.4 - 7 m/s (14.3 - 15.6 mph) → IEC[3] Wind Turbine Class IV
  - **Good**: 7- 7.5 m/s (15.6 - 16.7 mph) → IEC Wind Turbine Class III
  - **Excellent**: >7.5 m/s (16.7 mph) → IEC Wind Turbine Class III, II or I



- Map showing annual mean wind speed in Canada at 50m height provided by Canadian Wind Energy Atlas (CWEA)[4]:



- See NREL[5] and CWEA[4] websites for the most up-to-date wind resource information.

[3] International Electrotechnical Commission (IEC) 61400-1: Wind Turbine Safety and Design
[4] Canadian Wind Energy Atlas: http://www.windatlas.ca/
[5] National Renewable Energy Laboratory: http://www.nrel.gov/

- Developer will need to undertake site-specific meteorological studies to evaluate economic feasibility of the project. This includes measuring wind speeds at the site for at least one year. The best way to measure wind speeds at a prospective site is to mount an anemometer on the top of a mast that has the same height as the expected hub height of the wind turbine to be used.

Siting considerations

- Siting wind turbines and assessing the feasibility of a proposed location must consider factors such as:
  - Wind resource characteristics, including extreme wind conditions
  - Setback requirements (distance to publicly accessible areas), and spacing between turbines
  - Proximity to existing infrastructure including transmission lines and roads with adequate capacity to serve the wind plant
  - Environmental impact, including avian, bat and other biological considerations
  - Seismic activity, noise constraints, altitude, corrosion, and extreme temperatures
  - Community acceptance and compatibility with adjacent land uses
- Depending on setback requirements tens of acres might be necessary to house a single GE 1.5MW turbine. Hence, megawatt-scale wind turbines cannot be located in densely populated areas.
- See *General Considerations for Wind Turbine Siting* published by GE Wind for additional information on this topic.

Determining interconnection to existing transmission lines

- A project developer should work with the interconnecting electric authority at an early stage to ensure that the planned project can be connected to the electric grid safely and reliably.
- Minimize the amount of transmission infrastructure, if possible – building high voltage lines can be very expensive.
- Wind plants in North America are predominantly connected to high voltage transmission system and the behavior of these systems have been well characterized, whereas interconnections of wind turbines to lower voltage distribution systems (< 56.2 kV) are much less common. If a distribution grid interconnection is necessary, the project developer/owner must work with local utilities and grid operators to establish appropriate schemes to avoid concerns associated with distribution grid connectivity.

Identifying reliable power purchaser

- Establishing a power purchase agreement is critical to the financial viability of the wind plant. Obtaining an adequately and stably priced power sales contract is often essential to receiving third party financing and being economically successful.
- Secure commitments from one or more buyers for the wind plant's output over 10 to 20 years of its operational lifetime[1]. Examples of power purchasers:
  - Utility, industry, cooperative, etc.
  - Private consumption

Wind farm construction

- Site-specific characteristics greatly influence the scope of construction.
- Engineering, Procurement and Construction (EPC) consideration include the following:
  - Wind turbine foundations
  - Wind turbine installation/erection
  - Balance of Plant (supporting infrastructure such as sub-station)
  - Offsite and onsite access roads capable of accommodating significant weight, including local county roads and highways

- Identification of environmental and seasonal construction limitations is essential; these are often contained in permit or approval conditions.

Regulatory Framework

- Permits, licenses and regulatory approvals are typically required at the Federal, State and Local levels
  - See AWEA Siting Handbook[2] for detailed information on this topic.
- Zoning and permitting expertise is essential
  - The developer would be well served to obtain the services of a professional (consultant) familiar with the regulatory environment surrounding wind plant development.

Securing access to land

- When a suitable site for the wind plant is identified, securing rights to the land is necessary and typically includes compensation to the landowner in the form of royalty or lease payments.

Ensuring access to capital

- Ownership structure and financing of the wind plant must be finalized before taking on significant capital commitments.

Establishing dialogue with turbine manufacturers

- Turbine configuration, mechanical suitability, and layout should be addressed early in the development process.
- Site-specific suitability of the turbine needs to be confirmed prior to procurement.

Securing agreement to address Operation and Maintenance (O&M) requirements

- Turbine availability and reliability are major factors in project success, and professional services for the operation and maintenance of the wind turbines can prove to be invaluable. GE offers a range of O&M services including remote monitoring.
- Financial planning should account for O&M expenses that will be incurred over the operational lifetime of the wind plant.

APPENDIX

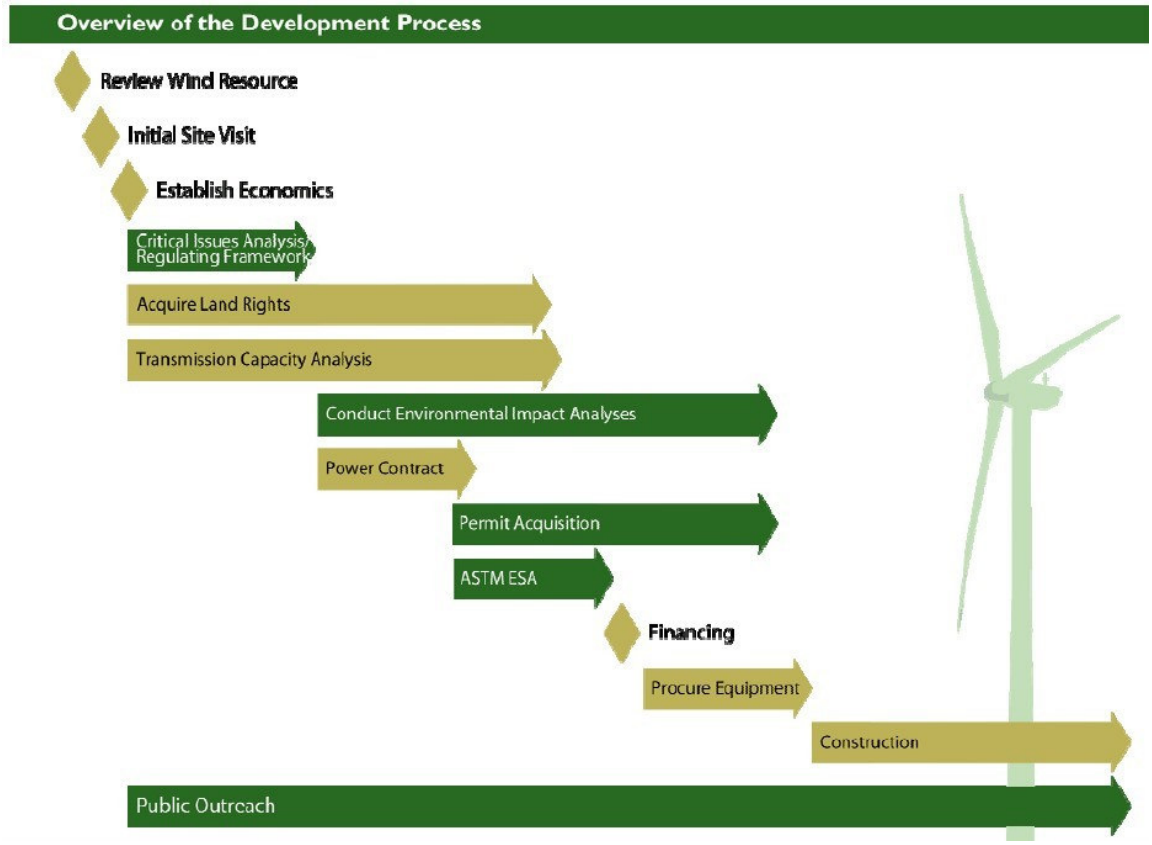
Wind Energy's Potential

- Wind power accounted for about 42% of all new power generating capacity added in the US in 2008, representing one of the largest components of new capacity addition.
- Wind energy could supply about 20% of America's electricity, according to Battelle Pacific Northwest Laboratory, a federal research lab. Wind energy resources useful for generating electricity can be found in nearly every state.
- Wind is projected to deliver 33% of all new electricity generation capacity and provide electricity for 86 million Europeans by 2010.

[2] AWEA Siting Handbook: http://www.awea.org/sitinghandbook/

Overview of the development process documented in the AWEA Siting Handbook[2]

(The actual development process for any given project will vary depending on project-specific requirements)



Useful Sources of Additional Information

- American Wind Energy Association: http://www.awea.org/
- Canadian Wind Energy Association: http://www.canwea.ca/
- DOE National Renewable Energy Laboratory: http://www.nrel.gov/wind
- New York State Energy Research and Development Authority: http://www.powernaturally.org/
- Danish Wind Industry Association: http://www.windpower.org/en/core.htm

[2] AWEA Siting Handbook: http://www.awea.org/sitinghandbook/