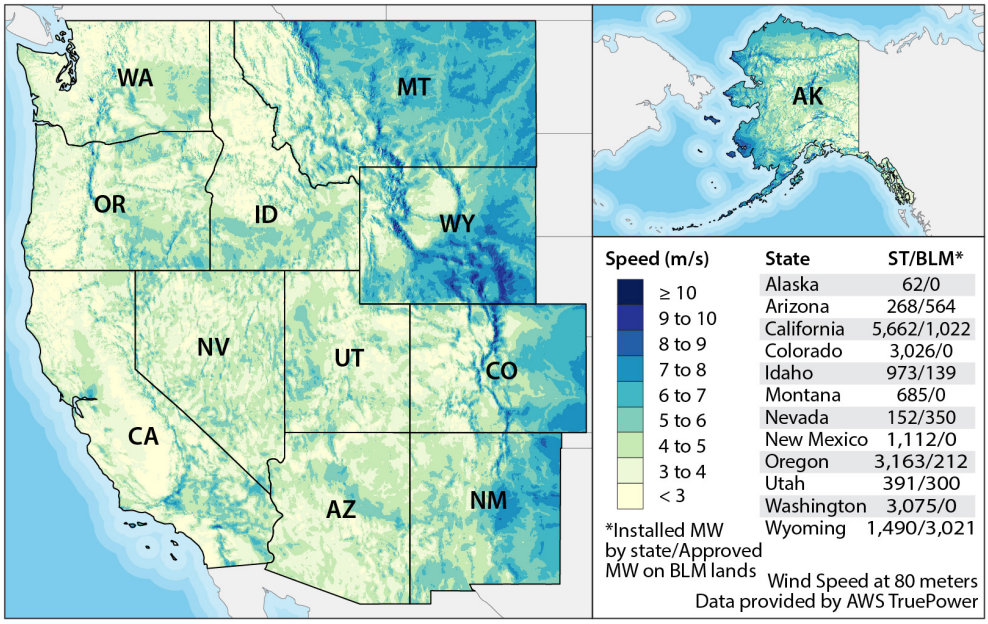
Wind Energy



Market Outlook

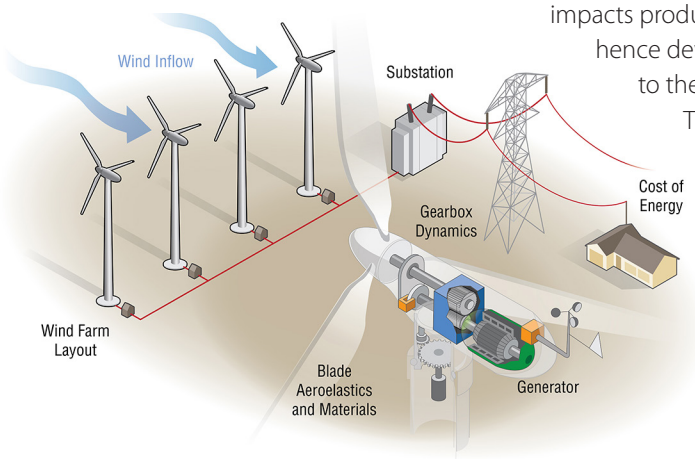
Land-based wind capacity growth has been steady in past years due to a long-term PTC extension and falling costs. The five year extension of the tax credit will likely encourage sustained growth through 2020. Levelized wind energy costs have continued to decline, and in certain regions, wind energy has already reached cost parity. Wind energy technology continues to trend towards larger rotor diameters (80-100 m), resulting in larger capacity sizes for individual wind turbine generators. Due to the remoteness of many high quality resource areas, proximity and capacity availability of the transmission grid are often key siting criteria.

Key U.S. Technology Statistics

- Total Wind Capacity: **82 GW**[3]
- 2015 utility-scale capacity factor: **37.4%** (100MW≈284,700MWh/yr)[4]
- PPA price range: ($20-50/MWh)[2]
- PTC Extended (remaining % of PTC rate, subject to IRS inflation adjustment factor)
  - 2017: **80%**
  - 2018: **60%**
  - 2019: **40%**
  - 2020 onward: expired
- Total installed cost/kW reduction of **26.4%** since 2009[2]
- BLM Project Pipeline:
  - Approved: **5,608 MW**
  - In Operation: **1,171 MW**

Technology Basics

A horizontal axis wind turbine generator consists of a tall tower, a nacelle mounted on top connected to a two- or three-bladed rotor. When sustained wind blows between ~4-25 m/s (~9-56 mph), a yaw mechanism in the nacelle turns the nacelle/rotor to face into the wind. The blades are then pitched (angled) to an optimum angle based on wind speed and turn a low-speed shaft. This shaft is either directly connected to a low speed generator (direct drive) or indirectly connected (via a gearbox) to a high speed generator. AC power is sent down the tower where it is converted to DC then to grid-quality AC power. A collection system delivers the power to a wind farm substation where it is stepped up to transmission voltage for delivery onto the grid. Although vertical axis turbines do exist, horizontal axis turbines are the only type of turbines used in wind farms. Siting wind farms and individual turbines in the windiest possible locations positively impacts production and economics, hence developers' desire for access to these sites whenever possible. Turbine spacing varies significantly with the available land shape/size, topography, wind regime, and other factors. However, there is a calculated average capacity density of 19–145 acres/MW in an NREL land use study.[5]



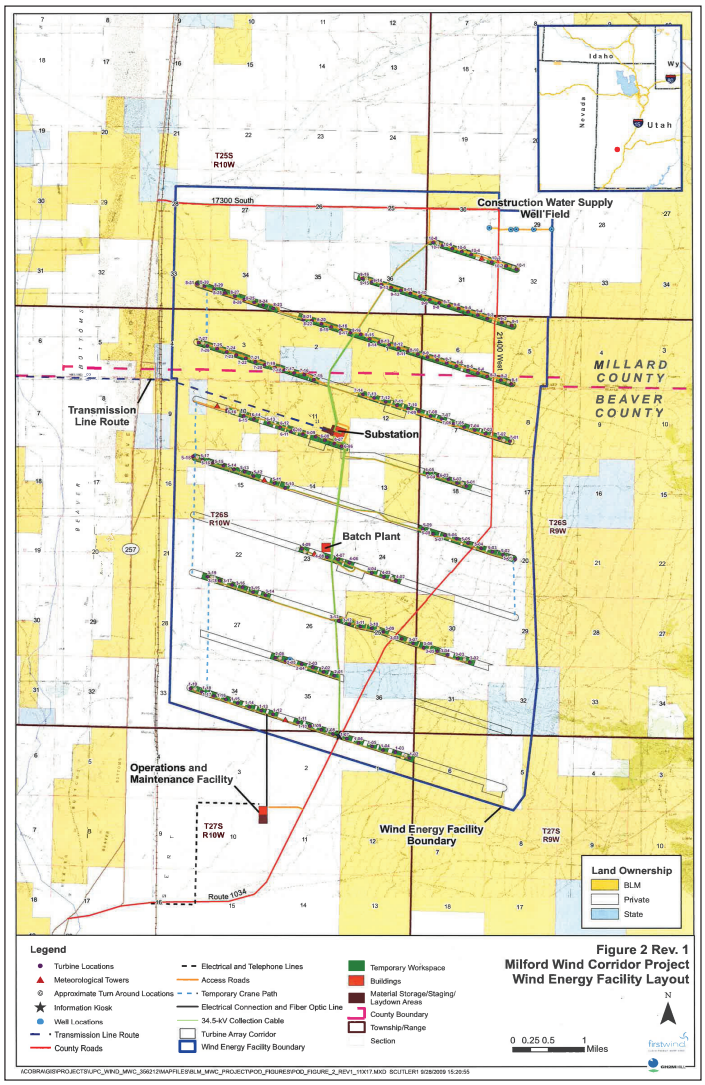
Simplified schematic of a Wind Turbine Generator. Illustration by Alfred Hicks, NREL

Typical Project Requirements & Specifications

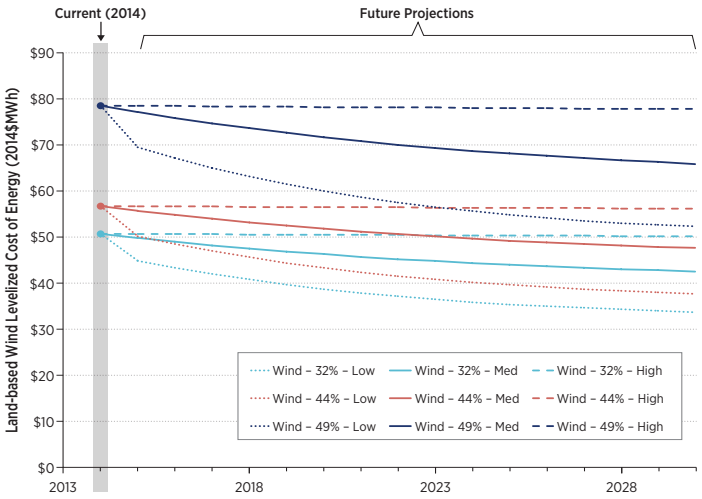
Site Requirements	
Land Slope	<20%
Water Use	None
Average Land Use	19-145 acres/MW[6] (~4-34 MW/mi^2)
Interconnection proximity	1-30 mi. (Dependent on resource strength)
Contiguous Land needed?	No, but easements for interconnection needed
O&M Cost[1]	$51/kW/yr
Met Tower Land Use	2.5 acres/met (land use per met); 5K-30K acres/met (assessment range)
Potential future site impacts due to technology change	Re-power with larger, higher efficiency turbines
Setback distance	County dependent: Roads, property lines, electric lines: at least 1.1 x structure height – Other wind parcels: 5x rotor diameter
Turbine Cut-in/Cut-out Wind Speeds	Cut-in: 6.7-9 mph / Cut-out: 45-56 mph

Development Considerations	
Assessment	3-10 met towers (60-80m tall), often augmented by SODAR or LIDAR. Measurement period – minimum for financing is 1 year. Reasonable assessment period for a wind farm is 2-4 years of wind measurement.
Roads/ Laydown	**Roads:** Improved & widened (16-30 ft during construction, 12-16 ft post-construction). **Laydown/staging:** (150-250 ft diameter circle around turbine pad).
Water Use	Dust mitigation can account for 60-75% of water use (~19.5 mil gal of 27.3 mil gal total) at BLM Mojave Wind Project. Cement production can account for 15-20% (4.9 mil gal at this site).
Electrical	Collection system is often buried along roads and combines wind farm output at a substation for transmission to the grid.

Milford Wind Farm Site Layout



Technology LCOE Cost Curve



Depicts the impact on LCOE at various capacity factors (32-49%) and cost reduction trajectories (Low-High)[1]

Resources:

1. NREL Draft ATB 2016. *http://www.nrel.gov/analysis/data_tech_baseline.html?print*
2. Bolinger, M., Wiser, R. "2015 Wind Market Technologies Report" LBNL. August, 2016. *https://www4.eere.energy.gov/wind/resource_center/resource/2015-wind-technologies-market-report*
3. American Wind Energy Association. "U.S. Wind Industry Fourth Quarter 2016 Market Report". January 26, 2017. *http://www.awea.org/2016-market-reports*
4. US Energy Information Administration. "Electric Power Monthly: Data for February 2016". 4/28/2016. *https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b*
5. Denholm et al. "Land-Use Requirements of Modern Wind Power Plants in the United States". August 2009. *http://www.nrel.gov/docs/fy09osti/45834.pdf*

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