Wind Energy

Wind Resource and Potential

Approximately 2% of the solar energy striking the Earth’s surface is converted to kinetic energy in wind.1 Wind turbines convert the wind’s kinetic energy to electricity without emissions. The distribution of wind energy is heterogeneous, both across the surface of the Earth and vertically through the atmosphere. Class 3 winds (annual average speed of 14.3 to 15.7 mph at 30m) are the minimum needed for a commercially viable project.2 Only 2% of U.S. electricity was derived from wind energy in 2014, but wind capacity is increasing rapidly.4

- Wind power is proportional to the cube of wind speed.
- Due to a phenomenon called “wind shear,” wind speeds are lower close to the Earth’s surface and more wind power is available at higher altitudes. The average hub height of most modern wind turbines is 80 meters off the ground.5
- Potentially, global onshore and offshore wind power at commercial turbine hub heights could provide 840,000 TWh of electricity each year, while total global electricity consumption from all sources in 2012 was about 19,710 TWh.6,7 Similarly, the U.S. annual wind potential of 68,000 TWh (lower 48 states) well exceeds annual U.S. electricity consumption of about 3,700 TWh.4,8
- A 2015 study by the U.S. Department of Energy found wind could feasibly provide 20% of U.S. electricity by 2030 and 35% by 2050.9
- Many studies have shown wind’s variability would increase the cost to operate the grid by less than 0.7¢/kWh of electricity (for up to 40% electricity from wind).5

Wind Technology and Impacts

Horizontal Axis Wind Turbines

- Horizontal axis wind turbines (HAWT) are the predominant turbine design in use today. The HAWT rotor is comprised of blades (usually two or three) symmetrically mounted to a hub. The rotor is connected via a shaft to a gearbox, and the generator is housed within the nacelle. The nacelle is mounted atop a tower connected to the ground with a concrete foundation.9
- HAWT come in a variety of sizes, ranging from 2.5 meters in diameter and 1 kW for residential applications up to 100+ meters in diameter and over 3.5 MW for offshore applications. The theoretical maximum efficiency of a HAWT is ~59%, also known as the Betz Limit. Most HAWT extract about 50% of the energy from the wind that passes through the rotor area.9
- The capacity factor of a wind turbine is its average power output divided by its maximum power capability. Capacity factors depend on the quality of wind at the turbine. Higher capacity factors imply more energy generation.8 On land, capacity factors range from 0.30 to 0.32.10
- Offshore winds are generally stronger than on land, and capacity factors are higher on average, but offshore wind farms are more expensive to develop and maintain.10 Offshore turbines are currently placed in depths of 30m (about 98ft) or less.11

Installation, Manufacturing, and Cost

- More than 48,000 utility-scale wind turbines are installed in the U.S., with a cumulative capacity of 66 GW.13 U.S. installed wind capacity increased by 294% between 2007 and 2014, a 22% average annual increase.13,14 Global installed capacity increased by 22% annually, on average, from 2007 to 2014, reaching 170 GW in 2014.16
- U.S. average turbine size was 1.87 MW in 2013, up from 0.89 MW in 2000.5,17
- Average capacity factor has increased from 0.25 for projects installed through 1998 to around 0.32 for projects in recent years. Higher capacity factors tend to lower power prices.5
- Installed wind project costs declined by roughly $2,700 per kW between the early 1990s and 2001.18 In 2013, costs were $1,630/kW.5
- The installed cost of a small (<100 kW) turbine is approximately $7,000 per kW, on average.19
- Currently, commercial wind energy costs 3-7¢/kWh wholesale.5 The 2014 average U.S. residential electricity price was 12.5¢/kWh.4
- Texas (14,098 MW), California (5,917 MW), and Iowa (5,688 MW) are the leading states in total installed wind capacity.13 Iowa generated the highest percentage of electricity from wind with over 28%.20
- Wind turbines and components are manufactured at more than 560 U.S. facilities.13
- In 2014, an estimated 73,000 full-time workers were employed in the U.S. wind industry.21
- Large (>20 MW) wind projects require roughly 85 acres of land area per MW of installed capacity, but 1% or less of this total area is directly impacted by roads, turbine foundations, or other equipment; the remainder of this area is available for other uses.22
- For farmers, annual lease payments provide a stable income of around $5,000/MW of turbine capacity, depending on the number of turbines on the farmer’s property, the value of the power generated, and lease terms.8 For a 250-acre farm, with income from wind at about $55 an acre, the annual income from a wind lease could be $14,000.23

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Energy Performance and Environmental Impacts

- Wind turbines can reduce the impacts associated with electricity generation; for example, thermoelectric plants use an average of 19 gallons of water to produce one kWh of electricity.24 U.S. air pollutant emissions were 744.7 kg CO2/MWh for the 2.74×107 MWh of electricity generated from fossil fuels in 2014.25
- Each year, the current U.S. wind capacity of 61 GW will avoid an estimated 96 million metric tons of carbon dioxide emissions and conserve about 37 billion gallons of water that would have otherwise been consumed in conventional power plants.26
- According to a 2015 study, if 20% of U.S. electricity was wind-generated by 2030, 16% of electric sector GHG emissions would be reduced, 380 billion kg of CO2 emissions annually, or 3.3 trillion kg cumulatively, and electricity generation-based water usage would decrease by 4%.27
- A 2005 study of two U.S. wind farms found life cycle net energy ratios (energy generated/energy invested) of 47 and 65.28
- Annual avian mortality from collisions with turbines is 200,000 which is much lower than mortalities due to power lines (130 million) or buildings (100-1000 million). The best way to minimize mortality is careful siting in areas with low bird use.29 Bat mortality due to wind turbines is less well studied, but research shows that a large percentage of bat collisions occur in summer and fall months, during low-wind periods, when bats are most active.30 The wind industry has been testing methods that potentially reduce bat mortality by more than 50%.31
- Noise from a typical wind farm at 350m away is 35-45 dB(A). To compare, a quiet bedroom is 35 dB(A); a 40 mph car 100m away is 55 dB(A).32
- As of 2013, several studies have conclusively determined that sound generated by wind turbines have no impact on human health.33

Solutions and Sustainable Actions

Policies Promoting Renewables

Policies that support wind and other renewables can address the externalities associated with conventional electricity, such as health effects from pollution, environmental damage from resource extraction, and long-term nuclear waste storage.

- A Renewable Portfolio Standard (RPS) requires electricity providers to obtain a minimum fraction of their energy from renewable resources.26
- Feed-in tariffs set a minimum per kWh price paid to renewable electricity generators by retail electricity distributors.28
- Net metering - offered in 44 states, D.C., and four U.S. territories - allows customers to sell excess generated electricity back to the grid.28
- Capacity rebates are one-time, up-front payments for building renewable energy projects, based on the capacity (in watts) installed.
- The federal production tax credit (PTC) provides a 2.3c/kWh benefit for the first ten years of a wind energy facility’s operation, for projects started by the end of 2014. It has not been renewed. Small (<100 kW) wind installations can receive tax credits for up to 30% of the purchase and installation cost.30
- Qualified Energy Conservation Bonds (QECBs) are interest-free financing options for state and local government renewable energy projects.31
- Section 9006 of the Farm Bill is the Rural Energy for America Program (REAP) that funds grants and loan guarantees for agricultural producers and rural small businesses to purchase and install renewable energy systems.32
- System benefits charges are paid by all utility customers and create a fund for low-income support, renewables, efficiency, and R&D projects that are unlikely to be provided by a competitive market.33

What You Can Do

- Invest in non-fossil electricity generation infrastructure by purchasing “green power” from your utility.
- Buy Renewable Energy Certificates (RECs), also known as green tags or green energy certificates. RECs are sold by renewable energy producers and are used to purchase and install renewable energy systems.
- Consider installing your own wind system, especially if you live in a state that provides financial incentives or has a net metering policy.

32. NCSC, IREC (2013) “USDA - Rural Energy for America Program (REAP) Loan Guarantees.” DSIRE.
33. NCSC, IREC (2013) “Glossary.” DSIRE.