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factsheets

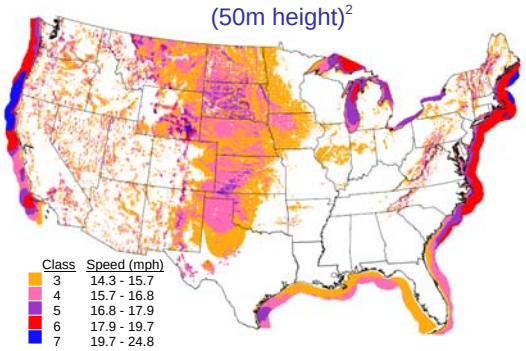
Wind Energy in the U.S.

The Wind Resource and its Potential

Approximately 2% of the solar energy striking the Earth's surface is converted to kinetic energy in wind.[1] The distribution of wind energy is heterogeneous, both across the surface of the Earth and vertically through the atmosphere. Wind turbines convert the wind's kinetic energy to electricity without emissions. Class 3 winds (annual average speed of 11.5 - 12.5 mph at 10m) are generally the minimum needed for a commercially viable project. Although only 2.3% of U.S. electricity was derived from wind energy in 2010[3], wind capacity is increasing rapidly.

- Wind power is proportional to the cube of wind speed.
- Because wind speeds are lower close to the earth's surface – a phenomenon called "wind shear" – more wind power is available higher off the surface. The hubs of most modern wind turbines are 70-100 meters off the ground.
- 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 2008 was about 17,400 TWh. Similarly, the U.S. annual potential of 68,000 TWh (lower 48 states) well exceeds annual U.S. electricity consumption of about 3,700 TWh (and growing).[3,4,5]
- A 2008 study found wind could feasibly provide 20% of U.S. electricity by 2030.[6]
- 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).[7]
- Detailed state wind maps can be found under the 'Maps & Data' at: http://www.windpoweringamerica.gov/

U.S. Wind Resources, Onshore and Offshore (50m height)[2]



Wind Energy Technology and Impacts

Horizontal Axis Wind Turbines

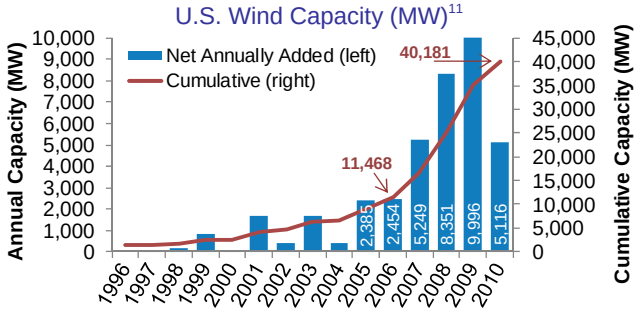
- This factsheet focuses on horizontal axis wind turbines (HAWT) because they are predominant.
- The HAWT rotor comprises blades (usually three) symmetrically mounted to a hub.
- The rotor is connected via a shaft to a gearbox, and the generator is housed within the turbine's nacelle.
- The nacelle is mounted atop a tower that is connected to the ground with a concrete foundation. 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 *capacity factor* of a wind turbine is its average power output divided by its maximum power capability. Capacity factor depends on the quality of the wind at the turbine. Higher capacity factors imply more energy generation.
- Most HAWT extract 40% or more of the energy from the wind that passes through the rotor area. The theoretical maximum efficiency of a HAWT is under 50%.[9]
- On land, capacity factors in the range of 0.25 to 0.40 are considered reasonable.[10]
- Offshore winds are generally stronger than on land, and capacity factors can exceed 0.50, but offshore wind farms are more expensive to develop and maintain. Most offshore turbines are currently placed in depths of 30m or less.

2.5MW Clipper, Medicine Bow, WY[8]

Installation, Manufacturing and Cost

- More than 35,000 utility-scale wind turbines are installed in the U.S.[11]
- U.S. installed wind capacity increased by 250% between 2006 and 2010; global installed capacity has grown 27% annually, on average, since 2000 and reached 197 GW in 2010.[11]
- U.S. average turbine size was 1.79 MW in 2010, up from 0.71 MW in 1999.[7]
- Average capacity factor has increased from 0.23 for projects installed before 1998 to around 0.30 for recent projects. Higher capacity factors tend to lower power prices.[7]
- Installed wind project costs declined by roughly $2,700/kW between the early 1980's and 2001.[12] By 2010, costs had slowly risen to $2,155/kW.[7]

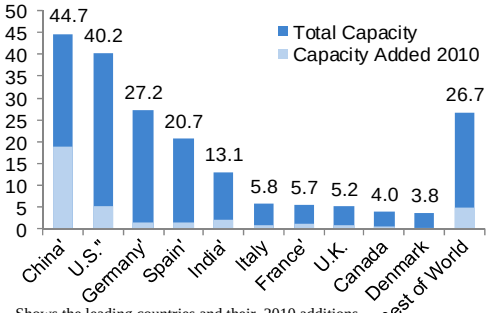
U.S. Wind Capacity (MW)[11]



- Since 2003, commercial wind energy has cost 3-5¢/kWh wholesale.[7] The 2010 average U.S. residential electricity price was 11.6¢/kWh.[13]
- A small (3-10 kW) turbine on an 80 ft. tower with an inverter and batteries would cost $15,000-$50,000 installed.[14]

- The leading wind states, by total capacity, are Texas (10,089 MW), Iowa (3,675 MW) and California (3,253 MW). Iowa generated the greatest percentage of electricity from wind – 15.4%.[7]
- Wind turbines and components are manufactured at more than 400 U.S. facilities.[11]
- In agricultural areas, annual lease payments provide a stable income to farmers of between $2,000 and $5,000/MW of installed wind turbine capacity (depending on the number of turbines on the farmer's property, the value of the power generated, and lease terms).[15] 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.[16]
- In a multi-turbine wind project, ≈60 acres of land are needed per MW of installed capacity, but 5% or less of this total area is actually occupied by roads, turbine foundations, or other equipment – 95% of this area is available for other uses.[17]

Global Wind Capacity, 2010 (GW)[18]



Shows the leading countries and their 2010 additions.
'FIT Incentive " PTC Incentive

Energy Performance and Environmental Impacts

- Wind turbines can reduce environmental impacts associated with electricity generation – 470 gal fresh water/MWh of electricity are evaporated by thermoelectric plants.[19] U.S. air pollutant emissions were 830.3 kg CO_2/MWh, 2.1 kg SO_2/MWh, and 0.8 kg NO_x/MWh, for the 2.72×10^9 MWh of electricity generated from fossil fuels in 2009.[3]
- According to a 2008 study, if 20% of U.S. electricity was wind-generated by 2030, annual CO_2 emissions would decrease by 825 billion kg, 7.6 trillion kg of CO_2 would be cumulatively avoided by 2030, and electricity generation-based water usage would decrease by 17%.[6]
- A 2005 study of two U.S. wind farms found net energy ratios (energy generated/energy invested) of 47 and 65.[20]
- Avian mortality due to collisions with wind turbines is much lower than for other human structures, but the best way to minimize mortality is careful siting – picking sites with low bird use.[21]
- Bat mortality due to wind turbines is less well studied and research is ongoing (as it is with avian issues). A large percentage of bat collisions occur during the fall migratory period.[22]
- Noise, in dB(A), from a typical wind farm at 350m is 35-45. For comparison, a quiet bedroom is 35; a 40 mph car 100 m away is 55.[23]

Solutions and Sustainable Actions

Policies Promoting Renewables

The price consumers pay for electricity generated with conventional fuels does not include externalities such as the cost of health effects from air pollution, environmental damage from resource extraction, or long-term nuclear waste storage. The following are examples of policies that support wind and other renewables and address these externalities.

- A *renewable portfolio standard* (RPS) schedules electricity providers to obtain a minimum fraction of their energy from renewable resources.
- *Capacity rebates* are one-time up-front payments for building renewable energy projects, based on the capacity (in watts) installed.
- *Feed-in tariffs* set a minimum per kWh price paid to renewable electricity generators by retail electricity distributors.
- *Production tax credit* (PTC)- the American Recovery and Reinvestment Act (2009) extended the federal PTC, which provides a 2.2¢/kWh benefit for the first ten years of a renewable energy facility's operation, through 2012 for wind. In addition, a *cash grant* of up to 30% of the property value is also offered for new facilities in lieu of a tax credit.[24]
- *Clean renewable energy bonds* are interest-free financing, for municipal and co-op utilities, that have no tax liability.[21]
- *Section 9006 of the Farm Bill* is the renewable energy and energy efficiency program that funds grants and loan guarantees for agricultural producers and rural small businesses.[25]
- *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.
- *Net metering*, offered in 43 states and DC,[26] requires retail utilities to credit customers who generate more electricity than they consume.
- For a listing of current U.S. policies by state, see the DSIRE database at http://www.dsireusa.org/

What Can You Do?

- Invest in non-fossil electricity generation infrastructure by purchasing "green power" from your utility.
- Buy Green Tags, also known as carbon offsets or Renewable Energy Certificates (RECs). A REC represents the environmental attributes – separate from the actual electrons – associated with a unit of electricity generated from renewable sources.[27]
- Consider installing your own wind system, especially if you live in a state that provides financial incentives or has a net metering policy.
- Visit the U.S. Department of Energy's small wind website at http://www.windpoweringamerica.gov/small_wind.asp

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[23] British Wind Energy Association (2000) *Noise from wind turbines. The facts.*
[24] U.S. DOE Database of State Incentives for Renewables & Efficiency (2011) Renewable Energy Production Tax Credit (PTC).
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[27] EPA's Green Power Network (2008) Renewable Energy Certificates.