CASE STUDY—WIND
the true cost of green energy

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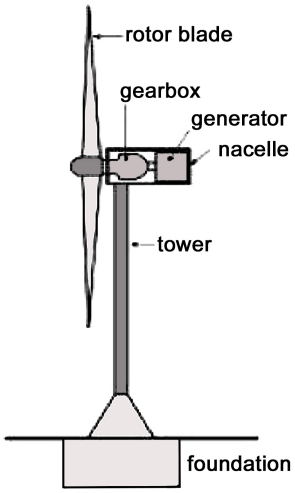
Wind turbines convert the "free" energy of the wind into electricity. What could be better? As it turns out—not much; but wind energy still has many external costs that are not fully addressed. These should be refined and included in the true economic valuation of wind energy. They must also be calculated more carefully for other energy sources.

At the end of 2016, there were more than 52,000 operating, commercial-scale, land-based wind turbines in the US. These wind farms also require balancing generating capacity from other sources for when the wind does not blow. These fossil-fueled facilities cause many impacts with significant costs and global climate change emissions in manufacturing and operation.

SOME BASICS

A typical wind turbine includes a massive concrete foundation, a tower, nacelle (to protect gearing and generator) and a 3 blade rotor. The rotors have been getting larger and larger over the years and some machines now approach a heigth of 400 feet. The wind turbine is likely to have a working life of 20-25 years if it is not blasted by lightning, broken in high winds, damaged by ice or simply breaks down early.



The foundation of concrete and steel has a relatively high energy cost. Two hundred cubic meters of concrete will weigh about 480 tons and cost 480 tons of carbon dioxide emissions to make. It will often be left in place after a turbine is decommissioned, but can be ground up and recycled (costly and usually only done in urban areas). The steel, aluminum and copper in the tower and nacelle also have high environmental costs for mining and processing, but can more easily be recycled.

The composite fiber blades are usually made with carbon, fiberglass, or e-glass reinforced plastics. The plastics are commonly polyester resins or epoxy. The production of these components can require a range of feedstocks and considerable energy. Most result in air and water pollution. The resins and epoxies can cause illness and injury if touched or inhaled. The fibers pose a risk for asthma, pneumonia and other lung disorders.

The remarkable annual creation of waste blades in Europe is estimated at about 50,000 tons per year. Recycling can be done, but so far is costly, dirty, energy intensive and the resulting fibers are down-cycled (shorter and not as strong as the original). Many blades are buried in land-fills or piling up in storage areas. Much research is currently underway to develop lower cost clearner recycling for blades. Use of alternative glues such as vitrimers may be the answer.

EXTERNAL ENVIRONMENTAL COSTS

The wind turbine has many associated environmental impacts. These start with the production of the raw materials, refining, processing, manufacturing and transporting them to the site. The site development will often include roads, pad clearing, and other impacts. These are almost certain to lead to wind and water erosion and the introduction of invasive species on equipment treads and tires. Some wildlife will be disturbed or killed during construction. The transmission lines and transformers also have many environmental impacts from construction through operation. Many larger birds are electrocuted in powerline contacts.

During operation the 3 blade rotors kill birds and bats. The question is how many birds and bats of what species will be killed? Some species are more vulnerable than others. Species like Red-tailed Hawks and Golden Eagles that forage for prey near turbines have increased fatalities. Ravens are smarter and appear able to avoid collisions. Rare and endangered species are a special concern. Many suspect wind turbines are killing condors. Tens of millions of dollars have been spent on the condor recovery program, now costing about $5 million a year. Based on the money spent and number of condors in the wild, one expert suggests each one should be valued at as much as $25 million.

The ultimate impact of the wind turbine or wind turbine farm will depend on the siting of the project and mitigation measures. The most critical issue is avoiding bird and bat migration corridors. These are not as well defined as wind farm builders might wish. During migration, mostly at night, the flights can be very dispersed. Wind turbines may need to be shut down during peak migration periods. These vary year to year, so monitoring and weather conditions must be carefully watched. Many of the weather radars can now detect birds and help with planning. Some turbines will be shut down when birds are detected.

Raptors (hawks, eagles, etc) appear to be particularly vulnerable but smaller bird remains may simply not been seen or counted. Every year, an estimated 75 to 110 Golden Eagles[1] are killed by the wind turbines in the Altamont Pass Wind Resource Area. Losses of these magnificent birds can be minimized by: siting turbines in areas of low prey density; protecting ground predators like bobcats and coyotes that will reduce the density of small mammal prey; and controlled burns and restoration of native vegetation.

The estimates for bird kills by wind turbines are very crude and based on limited surveys. The estimated number of birds killed is between 140,000-888,000 birds. The range of estimates suggests how little we know. We do know that we can reduce the bird kills significantly while the

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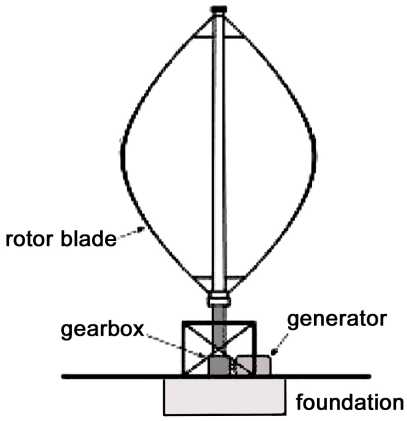
[1] Listed as endangered in parts of Canada and elsewhere in the world. US populations appear to be relatively table around 30,000 but still a cause for local and regional concern. Jason Tack and his colleagues used a life-stage simulation analysis to examine what life history characteristics most affected population growth of Golden Eagles. Their model indicated that breeding adult survival most affected population growth and that even small reductions in breeding adult survival (<4.5%) caused population declines. Moreover, they found Golden Eagles to be limited in their ability to offset these declines in survivorship by increasing reproductive output.

other dangers they face are more intractable. Collisions with windows kill 400,000 to a million birds a year. Vehicles kill perhaps 90,000-340,000 birds a year. Domestic and feral cats may kill 1-4 billion birds. A 2009 study using U.S. and European data concluded that wind facilities are responsible for between 0.3 and 0.4 bird fatalities per gigawatt-hour of electricity, while fossil-fuel power power plants are responsible for 5.2 fatalities per gigawatt-hour.

Some studies suggest that vertical axis turbines are safer for birds and less annoying for people but they have not penetrated the market to any extent. They produce less energy than horizontal axis turbines but can be installed in denser arrays. Since the generator is at the ground level they are much safer to maintain.



HUMAN EXTERNAL COSTS

Wind turbines also impact people (and wildlife) in other ways. This includes noise and low frequency sounds. The blades passing through the air can create noises ranging from a rhythmic whooshing noise to louder sounds. The equipment in the nacelle may generate mechanical noise. Residents whose homes are less than 2,640 feet from large wind turbines have complained of trouble living with the noise, especially at night. Lack of sleep can trigger a variety of health effects. Some EU countries require 1 mile separation between turbines and homes.

There are also some people who are affected by the movement of the blades. The impact will vary according to the wind energy technology (rotor size, speed, color, contrast, distance from the residences, shadow flickering) and the times when the turbine is either moving or stationary.

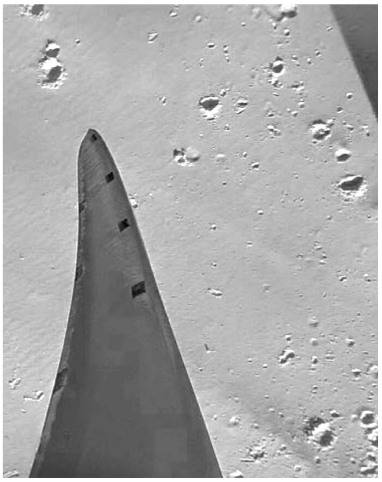
One study suggests that nearby wind turbines led to increases in suicide. The author considered the key factor was the role of low-frequency noise. The suicide effect was concentrated in the elderly, who are vulnerable to noise-induced illnesses. These sounds also impact wildlife.

These human annoyances can lead to a reduction in property value near wind turbines. A careful study in Europe found a decline in property value of 1.4% if machines were installed within 2 km. This may not sound like much, but the costs add up. If house prices are in the $400,000 range and 10 houses are affected it could amount to $60,000 dollars.

OTHER ISSUES

Wind turbines have control systems to prevent overspeed conditions in high winds. If these fail then the machine may self-destruct. A $3 million wind turbine was an unexpected casualty of an intense storm in Scotland. A 328-foot tall turbine burst into flames after a blade control failure and high winds caused the blades to turn too fast.

Rotor failure can result in blade toss. Pieces of blade weighing tons may be thrown 6 times the tower height and full blades may go 3 times the tower height. This could easily be 1,000 feet or more in the worst case with a runaway turbine in high winds.



Wind turbines can also be affected by ice buildup. Energy production can fall by as much as 50% when blades are iced. Operators may turn turbines off during ice-forming weather to prevent damage. Somtimes de-icers are used. The ice buildup puts stress on the blades and gear trains. Out of balance rotors may cause vibration in the machinery. Ice buildup can also result in ice toss as ice is thrown off the blade. Most falls near the tower, but very rarely large chunks have gone 1,000 feet or more and have damaged vehicles and facilities. The distribution of ice chunks can be seen as holes in the snow around the machine.

Some wind turbines have been placed too close to people, houses and facilities. Often this is done to highlight the "greenness" of the owner. But it can be dangerous and deadly. Set-backs should be carefully developed and observed.

THERE IS NO PERFECT ENERGY SOURCE

Wind energy generation has a variety of external costs, but is usually the best option when the wind speeds are appropriate and all accounts are considered. A 2017 study suggested that the cost per kwh of energy including some, but not all external costs, was 10¢ for wind including balancing facilities, 11.7¢ for photovoltaic arrays at utility scale, 12.7¢ for natural gas and 17¢ for coal. The energy from one of the solar power towers in Nevada was more than 30¢.

By including external costs that are now ignored true cost accounting can help ensure that the decisions made about funding and designing energy supply projects are more economical and sustainable. When true costs are counted the vertical axis wind turbines might turn out to be the preferred choice.