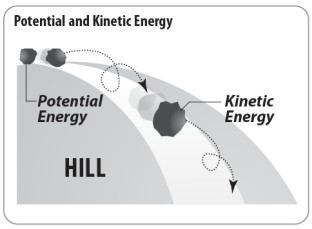
Background Information

Energy Leadership Summit Design Challenges

The Law of Conservation of Energy says, “Energy cannot be created nor destroyed; energy can only be transformed from one form to another.” When we use energy, it does not disappear. We change it from one from of energy into another. For example, a car engine burns gasoline, transforming the chemical energy in the gasoline into mechanical energy (motion.) Or solar panels transform radiant energy from the sun into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.



Energy is found in several different forms but can be categorized into two general categories: kinetic or potential. Potential energy is stored energy and the energy of position. In the diagram, the rock at the top of the hill is an example of gravitational potential energy. Another example of potential energy is chemical energy stored in the bonds of atoms and molecules that hold the particles together. Kinetic energy is motion--the motion of waves, electrons, atoms, molecules, substances and objects. In the diagram, kinetic energy is the rock as it is rolling down the hill. Electrical energy, or moving electrons, is another form of kinetic energy.

Wind is an example of kinetic energy we will be exploring through the design challenge by designing turbine blades. We will work as if we were engineers and focus our attention towards understanding, designing, experimenting and testing. The dynamic force of wind energy can be harnessed and used to do work. How? The wind's kinetic energy (*energy in motion*) can be captured and transformed into electricity (*electrical energy*) we can use to power our homes. Wind turbine technology can harness energy naturally provided by the wind to generate electricity.

What causes wind?

Wind is the movement of air relative to the surface of the Earth. Uneven heating of the atmosphere by the sun produces horizontal and vertical differences in atmospheric pressure, which in turn cause air to flow as wind. In this way, wind can be thought of as a by-product of solar energy. While only 2% of the solar energy reaching the Earth is converted into wind power, the total amount of energy is very large. The direction and strength of the wind are modified by the Earth's terrain, bodies of water and vegetative cover. Some locations consistently have strong winds from a particular direction, while other locations have erratic or little wind.

History of Wind Use

For thousands of years people have converted wind flow into energy to do work. Windmills have been used to convert the kinetic energy in the wind into mechanical energy for tasks such as pumping water or grinding grain. Modern wind turbines have generators that convert mechanical energy into electricity.

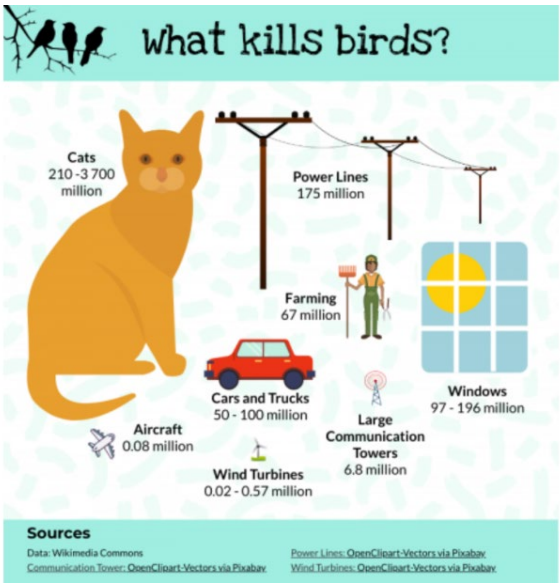
Sources: NEED ***Energy from the Wind*** (grades 6-8) and ***Exploring Wind Energy*** (grades 9-12)

Advantages of Wind Power

- *Wind power is cost-effective.* Land-based utility-scale wind is one of the lowest-priced energy sources available today.
- *Wind creates jobs.* The U.S. wind sector employs more than 100,000 workers, and wind turbine technician is one of the fastest growing American jobs. According to the *Wind Vision Report*, wind has the potential to support more than 600,000 jobs by 2050.
- *It is a clean fuel source.* Wind energy does not pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas. Wind turbines do not produce atmospheric emissions that cause acid rain, smog, or greenhouse gases.
- *Wind is a domestic source of energy.* The nation's wind supply is abundant and inexhaustible. Over the past 10 years, U.S. wind power capacity has grown 15% per year.
- *Wind is sustainable.* Winds are caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities. For as long as the sun shines and the wind blows, the energy produced can be harnessed to send power across the grid.
- *Wind turbines can be built on existing farms.* This benefits the economy in rural areas, where most of the best wind sites are found. Wind power plant owners make rent payments to the farmer for the use of the land, providing landowners with additional income.

Challenges of Wind Power

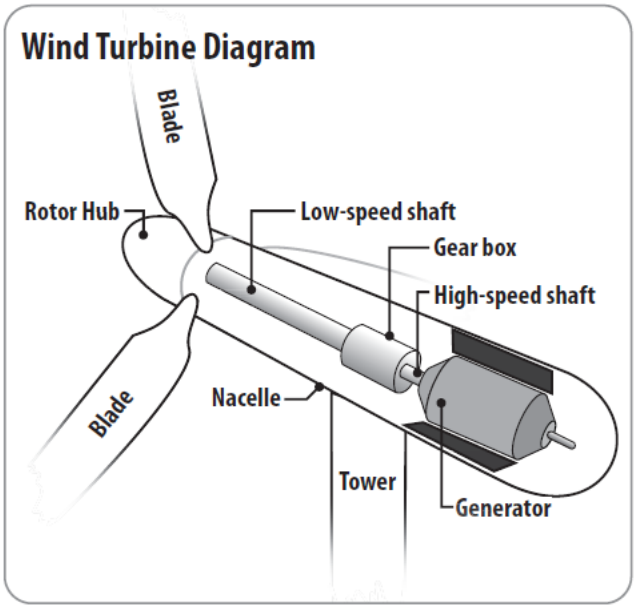
- *Wind power must still compete with conventional generation sources on a cost basis.* Even though the cost of wind power has decreased dramatically in the past several decades, wind projects must be able to compete economically with the lowest-cost source of electricity.
- *Good land-based wind sites are often located in remote locations, far from cities where the electricity is needed.* Transmission lines must be built to bring the electricity from the wind farm to the city. However, completing a few proposed transmission lines could significantly reduce the costs of expanding wind energy.
- *Turbines might cause noise and aesthetic pollution.* Although wind power plants have relatively little impact on the environment compared to conventional power plants, concern exists over the noise produced by the turbine blades and visual impacts to the landscape.
- *Wind plants can impact local wildlife.* Birds have been killed by flying into spinning turbine blades. Most of these problems have been resolved or greatly reduced through technology development or by properly siting wind plants. Bats have also been killed by turbine blades, and research is ongoing to develop and improve solutions to reduce the impact of wind turbines on these species.



Sources: [Office of Energy Efficiency & Renewable Energy] and [Let's Talk Science]

Wind Turbine Basics

To design and build a wind turbine, we must first understand its structure and the mechanics that control it. Most turbines have the same basic parts: blades, shafts, gear boxes, and a generator. The housing for this equipment is called the nacelle. These parts work together to convert the wind's mechanical energy into electricity.



The wind blows and pushes against the blades on top of the tower. The blades catch the wind and spin the rotor.

The rotor is connected to a low-speed shaft. When the rotor spins, the shaft turns. The shaft is connected to a gear box. The gears in the gear box increase the speed of the spinning motion on a high-speed shaft.

The high-speed shaft is connected to the generator. As the shaft turns inside the generator, it produces electricity.

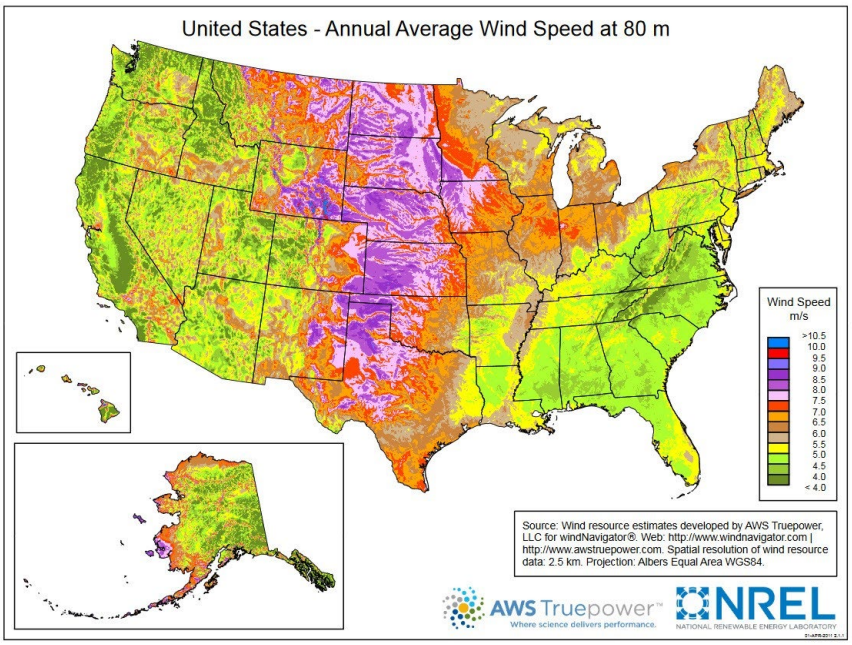
The electricity is sent through a cable down the turbine tower to a transformer and then to a transmission line.

The amount of electricity a turbine produces depends on its size and the speed of the wind. Wind turbines come in many different sizes. A small turbine may power one home. Very large wind turbines can produce enough electricity to power up to 1,000 homes. Wind power plants, or wind farms, are clusters of wind turbines grouped together to produce large amounts of electricity.

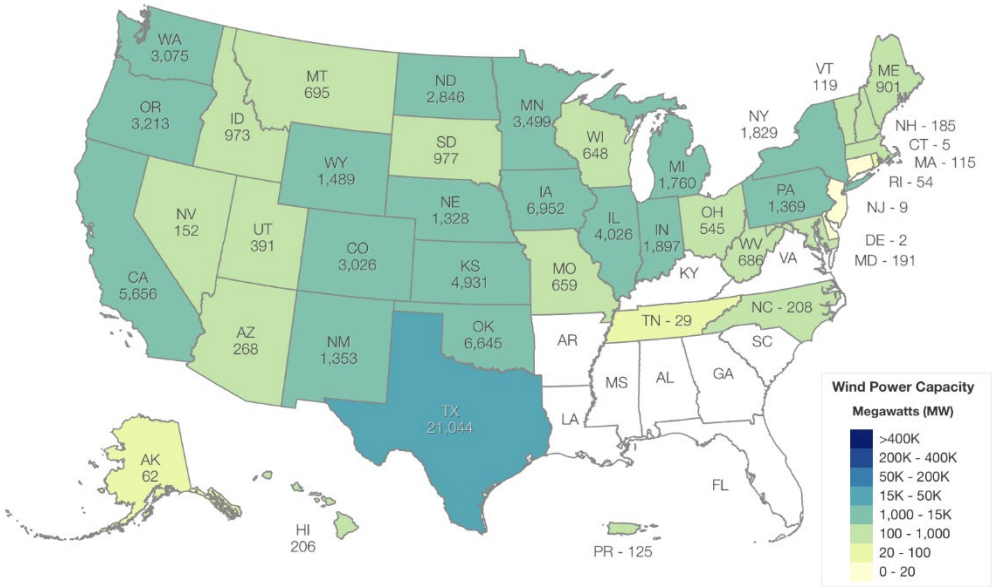
Timber Road Wind Farm in Paulding County, Ohio has 86 wind turbines with an installed capacity of 224 megawatts. That is enough electricity to power approximately 62,000 Ohio homes.

Wind in the United States

Before planning a wind farm, you must know if the wind resource in your location is adequate. From wind resource maps, you can determine if your area of interest should be further explored. The average wind speeds indicated on this map are model-derived estimates that may not represent the true wind resource at any given location. Small terrain features, vegetation, buildings, and atmospheric effects may cause the wind speed to depart from the map estimates.



Wind Power Capacity Measured in Megawatts *(updated June 30, 2020)*



Sources: **[National Renewable Energy Laboratory]**