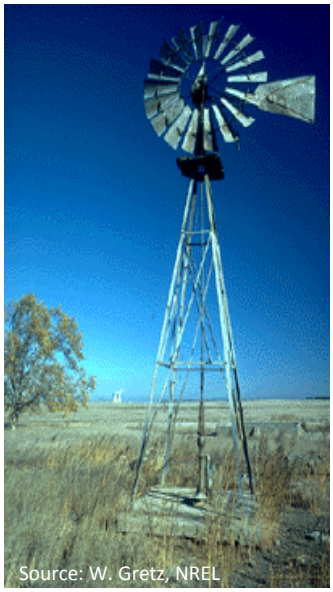
Energy Producing Systems: Wind Power


Source: W. Gretz, NREL

The power of the wind has been captured by humans for thousands of years. Wind powered sailing vessels allowed us to cross entire oceans on a routine basis. Windmills have been used to grind grains or pump water since at least 200 B.C. In the early 1900s it was common place in the United States to see windmill towers throughout the Midwest. Most often these individual wind towers were used to pump water for livestock. Some windmill designs were used to generate **electrical power** to operate lights and electric appliances in small rural homes. The construction of utility lines and the advent of **fossil fuel** use in the 1930s caused a rapid decline in the use of windmills in the United States.

Wind power is being rediscovered. Significant improvements in **wind power systems** have occurred during the last several years. As a result of our steadily increasing energy needs, wind power is now an attractive prospect. Wind is a **renewable energy source** that can be utilized on a local basis throughout the world. Wind power systems decrease dependence on imported energy fuels and aid in establishing stable, long-term energy supplies. Since 2000, wind power consumption has increased by over 3000% in the U.S (57 trillion BTU to 1,815 trillion BTU). Many projects are in service and other projects are underway to develop wind power In the United States. Wind was at one time the fastest growing energy resource in the U.S., but was surpassed by solar energy in recent years.

What Causes Wind?

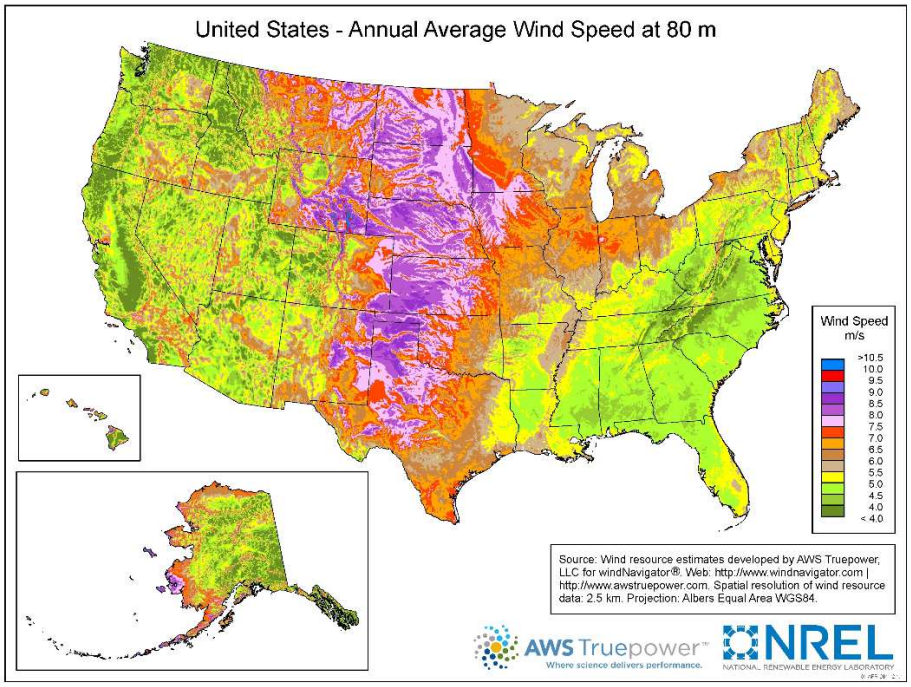
Wind is basically the movement of air over the Earth's surface. These air movements are the result of interactions that occur between the Sun's **radiant energy**, the surface of the planet and the atmosphere. A significant portion of the Sun's energy is converted to **thermal energy** following absorption by the Earth's surface. This absorption is not uniform and is highly dependent on the surface features of the planet. The surface of the Earth varies dramatically, with large areas of water, desert, forests, mountains and grasslands. Each type of feature absorbs different amounts of the Sun's energy. Additionally, the Sun's rays are more direct in the equatorial regions than they are in Polar regions. As a result of these factors there is significant variation in the heating of our planet's surface.

Air masses poised above the Earth's surface absorb a portion of the thermal energy associated with each location and this leads to variations in the temperature of the atmosphere from region to region. Warmer air masses tend to rise in the atmosphere as they gain in thermal energy. This warm air cools as it approaches the upper atmosphere and eventually sinks back towards the Earth's surface. These air movements create the flow that we commonly think of as wind.

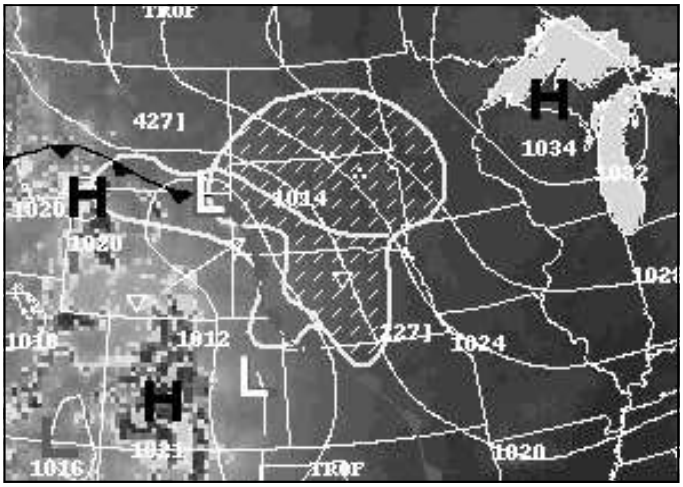
Where is the Wind?

The United States has substantial wind resources that could be harnessed to provide a significant portion of our nation's electrical power needs. Winds are typically characterized on a scale according to **wind power density** with class 1 being the lowest and class 7 being the highest. A class 4 or higher wind is usually required for large utility-scale power systems or so called wind farms. This roughly corresponds to an average wind speed in excess of 15 miles per hour (6.7 m/s as shown on the map). Wind resources in the U.S. are concentrated in the Western and Great Plains states and off of the coasts. States with high winds, listed in order of best potential are; Texas, Kansas, Montana, Nebraska, South Dakota, North Dakota, Iowa, Wyoming, Oklahoma, and New Mexico.

Air Pressure



When describing wind, meteorologists will often refer to areas of high and low pressure, as represented on weather maps with an **H** (high pressure) and an **L** (low pressure). Air pressure is the force of the atmosphere on the Earth's surface and it is related to the concentration of air molecules. The more air molecules present then the higher the pressure at the Earth's surface. When a section of the atmosphere gains in thermal energy, the air molecules begin to gain in **kinetic energy** (movement) and separate from each other. The air mass expands and thus decreases its density (mass per volume) reducing the surface pressure on the Earth.



(Source: National Weather Service)

In general warmer air masses will yield lower-pressure systems while cooler air masses result in higher-pressure systems. Areas of high pressure (cooler air) will tend to flow towards areas of low pressure (warmer air), sort of like toothpaste being squeezed from a tube. This creates "flows" of air at the Earth's surface and results in the formation of surface winds.

Such air movements are very common at the interface of land and water systems. The air over the land tends to warm up faster during the day, while the air over the ocean stays cooler. The resulting winds then tend to flow from the ocean (cooler: higher pressure) towards the land (warmer: lower pressure). This process reverses itself at night. The land rapidly looses its heat while the water retains its thermal energy and thus winds at night tend to flow from the now cooler land towards the warmer ocean air.

How is Energy Generated from Wind?

Historically wind power has been used to provide **mechanical energy** to propel boats, grind grain and to pump water. Modern wind power systems are predominantly used to convert wind to electrical power. This is accomplished in most cases by using a **turbine** system attached to a propeller-like blade. The turbine itself contains large magnetic coils and when they are rotated an electrical current is generated. Modern wind power systems look like large airplane propellers mounted on towers. Wind is used to force the propeller-like blades of the tower to rotate the attached turbine. The Earth's friction slows surface winds down and so in general the higher the tower, the better the wind speeds.

One type of wind power system involves wind farms designed to provide large quantities of power for use by municipal systems, cities and towns. These systems typically require a wind power rating of at least four or better. Site

selection is a major consideration in terms of wind speed, proximity to customers and energy storage options such as pumped hydroelectric storage. Another type of wind power application involves smaller home-use **distributed energy generation**. Such home or "village" systems do not require the strong winds required by utility systems and can be used to help offset home electrical needs in areas where wind power is moderate. These stand-alone units are especially appropriate for homes, farms or small communities that are located away from utility power line access.

Specific Characteristics of Wind Power

Wind power systems have several advantages over other energy sources. The wind is the product of natural global processes that are available worldwide. Wind is a renewable energy source and will not run out like fossil fuels, so investments in wind power can be made for the long term. Wind power systems are readily expandable by adding new towers to existing wind farms as energy demands grow. Wind farms do not dominate the land surface. The land below the towers can still be used for agricultural purposes, retaining the productivity of the land. Wind power is a clean source of power and operates without producing the air or water pollution associated with burning fossil fuels.


Source: W. Gretz, NREL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However, the wind does not blow all the time. Wind power systems are classified as intermittent power sources due to the occasional periods of minimal wind. In some locations the winds are far stronger during the day when the Sun's energy is fueling the formation of wind. During the night winds can drop dramatically. The strength of the wind resource can change dramatically with the seasons.

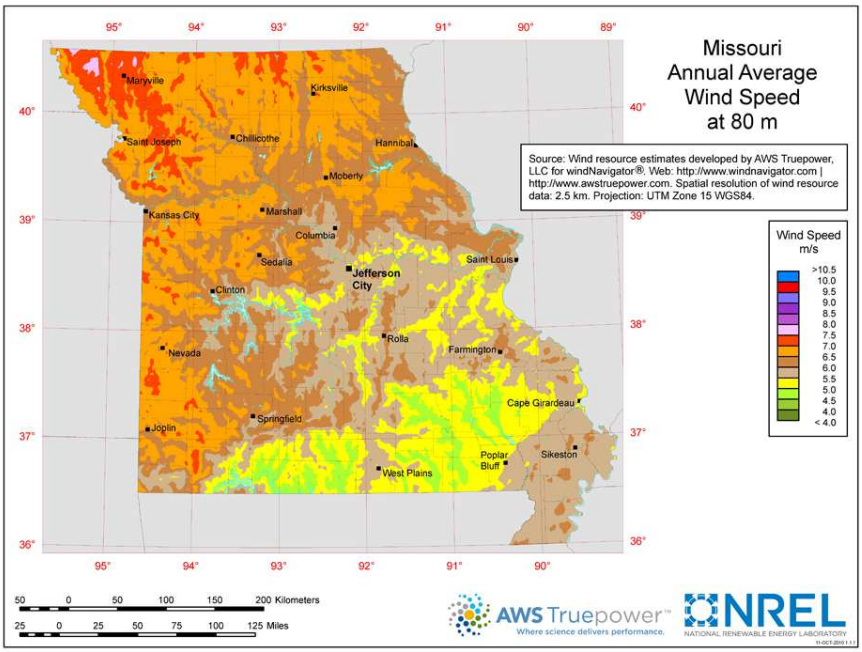
The intermittent characteristics of wind power can be solved using energy storage systems. For example, **pump storage hydropower systems** involve using the electricity generated during periods of high wind to pump water uphill to a large reservoir. The reservoir is then used as a conventional source of hydroelectric power during periods of low wind. Other systems have been designed that use the wind power to compress air in underground storage caverns. The high-pressure air is then in turn used to run turbines when wind availability is low.

Wind towers do have a visual impact and are not appropriate for installation in areas deemed to have a high aesthetic value. There have been issues in California with bird kills and wind towers. Studies have shown that this issue tends to be site specific and by carefully choosing a wind power site and using tower designs that do not promote bird roosting, these issues usually can be minimized.

Wind power decreased to all-time lows in the early-2000s, but then increased around 2008. However since 2008, the cost of capturing wind energy has again decreased to similar early-2000s prices and has become competitive with conventional energy systems. In locations with excellent wind resources, utility-scale wind power plants were found to provide wholesale power for as low as $0.02-0.04/kWh. This is similar to wholesale prices of electricity generated from **coal** or **natural gas** (around $0.03/kWh). In 2015 over 30 percent of Iowa's electricity was produced by wind power. Kansas and South Dakota both produced more than 20 percent of their electricity using wind power.

The Future of Wind Power in Missouri

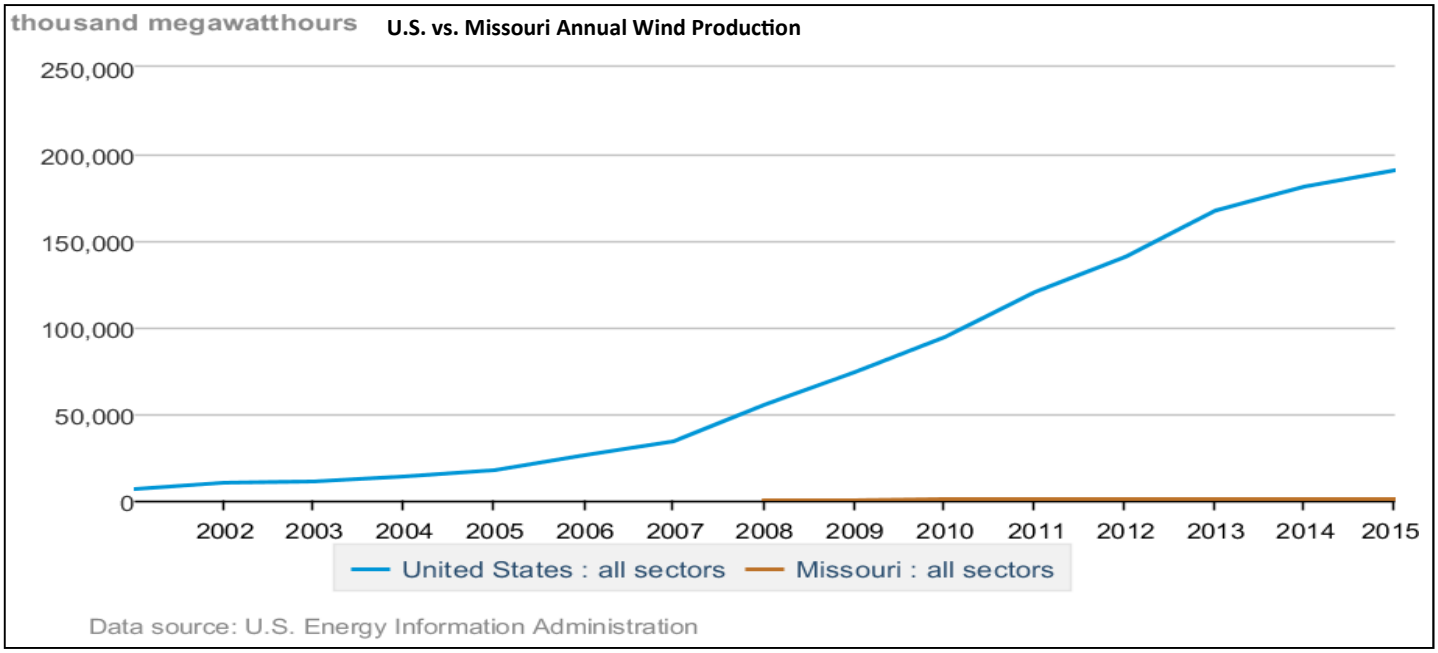
A map showing wind power possibilities for Missouri shows several locations that can expect utility grade wind class ratings of four (wind speeds higher than 6.5-7 m/s). Much of the state can expect wind class ratings of three, allowing the use of wind towers to provide supplementary power to homes, run water pumps and bring electrical power to remote locations.



Wind systems are ideal when used in conjunction with other power sources. Where wind power is plentiful, systems can serve as a preferred source of power and be backed up by conventional fossil fuel systems during times when winds are low. This strategy can be used to reduce current levels of fossil fuel use and conserve this finite resource while reducing the associated environmental issues inherent with fossil fuel systems. Where wind is not as prevalent (such as in Missouri) it can instead be used to supplement conventional electricity production.

In 2015 the state of Missouri derived 83% of electrical needs from burning coal. Missouri was the fifth-highest ranked coal receiver in 2014, getting 42.49 million short tons of coal. Coal importation cost Missouri $1.6 billion in 2013. For Missouri almost all of this coal is imported from other states. Further, Missouri produces more carbon dioxide emissions than all neighboring states, except for Illinois, as a result of a higher state population and heavy reliance on coal.

Currently, wind only accounts for 1.2 percent of Missouri's electricity generation. Wind is available in Missouri (see map below). Development of wind power would enable Missouri to retain a portion of the dollars sent to other states to purchase coal. If even a small fraction of that money was spent on locally produced energy sources, such as wind power, the benefit to Missouri's economy could be significant.



Glossary

Coal: A solid fossil fuel mined from the Earth's surface and underground which is often used to produce electricity through combustion. There are several different qualities of coal including anthracite, bituminous, and lignite

Distributed energy generation: The use of small localized power production systems to generate electrical power usually for a specific on-site application and sometimes to the larger electric grid. Solar photovoltaic systems and wind power systems are common distributed energy generation methods

Electrical power: Electrical energy used to conduct work; the measure of the rate of electrical energy used by a circuit. This is usually measured using a unit called a Watt (W)

Fossil fuels: Highly combustible substances generally found underground that were formed as the result of high levels of heat and pressure on decaying organic matter from millions of years ago. Fossil fuels include liquid oil, solid coal, and gaseous natural gas and are often burned to generate energy and power

Kinetic energy: Energy as the result of motion

Mechanical energy: The energy an object has from its motion or its potential for motion

Natural gas: A fossil fuel gas which can be recovered from underground and combusted as a fuel source. Increasingly used to generate electricity

Pump storage hydropower systems: A relatively new form of hydropower and energy storage in which excess electrical power during times of lower demand (often at night) is used to pump water from a lower reservoir into an upper reservoir. When demand is high and additional electrical power is needed, the water is released back into the lower reservoir operating **turbines** and generating electrical power

Radiant energy/Radiation: Transmission or emission of kinetic energy as waves through space. Light is one type of radiant energy. Electromagnetic radiation can be classified by the electromagnetic spectrum

Renewable energy source/fuel: Primary energy source that can be replenished at an equal or greater rate to its consumption; sustainable energy source

Thermal energy: Kinetic energy associated with the movement of molecules; commonly produced from combustion. Heat is the transfer of thermal energy from bodies of higher kinetic energy to lower kinetic energy

Turbine: A device which harnesses the kinetic energy of an incoming force (often steam, water, or air) to spin rotors and create mechanical power. In electrical power generation the spinning motion of turbine rotors is used to turn generators which use rotating magnets inside copper wire to create an electrical current

Wind power density: A classification system of wind speed at certain heights above the ground. Used to determine the feasibility of wind power systems at a certain location

Wind power systems: Technology which utilize the kinetic energy of moving wind to power turbines to generate electrical power

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