WindWise Education Curriculum

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From the KidWind Project and Pandion Systems, Inc.

Developed with funding from the New York State Energy Research and Development Authority (NYSERDA)

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Foreward

WindWise Education is a comprehensive curriculum and teacher training program that explores the dynamic field of wind energy. WindWise Education gives teachers the tools to teach 6-12 grade students about this timely and critical energy resource. It is an advanced, interdisciplinary wind energy curriculum that can be incorporated in a wide range of subjects. The lessons use real, unbiased scientific data and real-life scenarios to help students learn to think critically so they can make informed decisions about wind energy in the future.

As interest in green, renewable energy has increased, the demand for and investment in wind energy has risen. In 2008, the United States became the largest producer of wind power in the world. Currently, there is enough wind energy generated in the United States to power 14 million homes. As wind energy becomes more widespread, many communities are learning about wind energy for the first time in their own backyards. WindWise Education provides students with the opportunity to ask key questions such as where are the best locations for wind farms? how are birds impacted by wind turbines? and how can I build a better turbine? Through hands-on lessons, students learn and discuss the role that wind energy plays in their communities and the country.

Every lesson has an inquiry-based introduction to encourage creative thinking and a hands-on activity to develop analytical skills. Case studies and profiles of professionals are featured to provide students with real-life examples from the wind energy sector. Through these lessons, WindWise Education engages students in thoughtful, real-world dialogue about the future of wind energy.

Core Curriculum

The core curriculum includes 15 lessons each framed around a key question related to wind energy. The curriculum package includes:

- Inquiry-based approach to encourage critical thinking skills
- Standards-based lessons for middle and high school students in areas of physics, biology, technology, earth science, environmental science, math, geography, language arts, economics, and social studies
- Ready-made lab and activity kits for educators
- Data and maps
- Case studies
- Profiles of professionals
- Reading passages
- Answer worksheets for teachers
- Assessment tools for each activity that measure comprehension

Each lesson is laid out in an easy-to-use format including pages for teachers (in color) and students (in black and white). Teacher pages provide background information, lists of materials, standards, assessment questions, and tips. Student pages include reading passages, case studies, professional profiles, and worksheets.

WindWise Materials Kits

Ready-made educational kits enable teachers to quickly implement the lessons in the classroom without extensive preparation. Kits are designed to make learning not only more fun, but also more constructive. Students who participate in hands-on activities are more likely to retain key concepts and show enthusiasm for a subject. WindWise Education kits enable students to see science in action. The WindWise Shop at WindWiseEducation.org provides a quick and easy online ordering system for all kits.

Teacher Training

WindWise is most effective when it is paired with teacher training. Expert instructors provide one-day hands-on trainings in the WindWise curriculum nationwide. Workshop participants get to

- Explore the basic principles behind wind energy
- Learn how to implement WindWise lessons with students
- Experience WindWise through interactive activities and sessions

Advanced workshops provide detailed training on specific lessons and opportunities for using lab kits in greater detail. Participants receive a comprehensive curriculum package upon completion of the workshop.

Lesson	Lesson Title	Grade	Subject	Key Concept
Unit 1: Energy Creation and Choices				
1	How is Energy Converted to Electricity?	6-8 9-12	Physical Science Mathematics	Students will learn that energy conversion and transfer is an important part of electricity generation. That causes energy to be lost.
2	What is the Cost of Inefficiency?	6-8 9-12	Physical Science Technology Mathematics Environmental Science	Students will learn the difference between energy and power and the role that efficiency plays in reducing energy costs and carbon dioxide emissions.
Unit 2: Where is the Wind and How Does it Work?				
3	What Causes Wind?	6-8	Physical Science Social Studies Earth Science	Students will learn about the forces that cause wind and the ways in which these forces are measured.
4	Where is it Windy?	6-8 9-12	Earth Science Social Studies	Students will learn how topography and elevation affect wind speeds and will identify optimal locations for wind farms based on wind speed.
5	Can Wind Power Your Classroom?	6-8 9-12	Physical Science Technology/ Engineering Mathematics	Students will conduct a simple energy audit for the classroom and estimate what size wind turbine could power their classroom under local wind conditions.

Lesson	Lesson Title	Grade	Subject	Key Concept
Unit 3: Experiments With Turbines				
6	How Does a Windmill Work?	6-8 9-12	Physical Science Technology/ Engineering	Students will learn the fundamental parts of a windmill, how different rotor designs affect performance, and how energy is transferred from wind into usable mechanical energy.
7	How Does a Generator Work?	6-8 9-12	Technology/ Engineering Physical Science	Students will learn how electricity is generated and how design variables affect electricity production.
8	Which Blades are Best?	6-8 9-12	Physics Technology/ Engineering Mathematics	Students will learn through experimentation how different blade designs are more efficient at harnessing the energy of the wind.
9	How Can I Design Better Blades?	6-8 9-12	Physical Science Technology/ Engineering Mathematics	Students will learn how to design and construct different turbine blades to maximize the power output of a wind turbine.
Unit 4: Wind Energy and Wildlife				
10	How Does Energy Affect Wildlife	9-12	Living Environment Earth Science Environmental Science	Students will learn that different electricity generation sources have very different effects and risks to wildlife.
11	What is Wind's Risk to Birds?	6-8 9-12	Technology Mathematics Living Environments	Learn how bird behavior and ecology are related to avian impacts from wind turbines and how scientists study these impacts.
12	Can We Reduce Risk to Bats?	6-8 9-12	Living Environments Technology	Students will analyze bat behaviors and propose a wind farm operational plan that could reduce the risk of bat mortality.
Unit 5: Siting Wind Energy Facilities				
13	How do People Feel About Wind?	6-8 9-12	Language Arts Social Studies	Students will explore what effects media can have on people's perception of wind energy.
14	Where Do You Put a Wind Farm?	6-8 9-12	Social Studies Environmental Studies Earth Science Mathematics	Students will learn how to analyze data (maps, tables, and written information) to compare and contrast two potential sites for a wind farm.
15	When is a Wind Farm a Good Investment?	6-8 9-12	Economics Social Studies Earth Science Mathematics	Students will learn what factors impact the economics of a wind farm and compare and contrast two potential sites.

ACKNOWLEDGMENTS

KidWind and Pandion have been dreaming up ideas for a more advanced wind energy education program for a couple of years. We just felt there was a need for a comprehensive curriculum that touched on all aspects of wind—from science and technology to economics and biology. Our companies met at a wind conference and quickly realized we were the perfect match. KidWind is the original wind energy K-12 education and turbine kit company Pandion designs curriculum and teacher training programs in addition to conducting wildlife studies for wind energy. It was meant to be.

We were thrilled when the New York Energy Research and Development Authority (NYSERDA) gave us the opportunity to design WindWise Education for New York State teachers. Thanks to NYSERDA we have put our ideas into action and created an innovative curriculum along with supporting materials such as a website and other teaching tools. We are truly grateful for NYSERDA's support.

In early 2009 we launched WindWise with an online survey about wind energy education. More than 400 of you told us what you did and did not want in a curriculum. You also gave us good ideas on how we could make this curriculum as useful as possible. We have drawn from the expertise of a fantastic team of teachers and wind energy professionals we call the CAB (Curriculum Advisory Board). The CAB has tested these activities and given us their guidance throughout the development of WindWise. We are hugely grateful for their assistance and input.

Thank you for taking the time to explore the curriculum. We hope you enjoy using it in your classroom. If you have feedback, ideas, suggestions, or just want to talk more about wind, feel free to contact us. We always enjoy hearing from you.

—KidWind and Pandion WindWise Education Team

KidWind PROJECT®

PANDION

WindWise is a production of KidWind Project and Pandion Systems, Inc.

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For more information on the program, visit our website:
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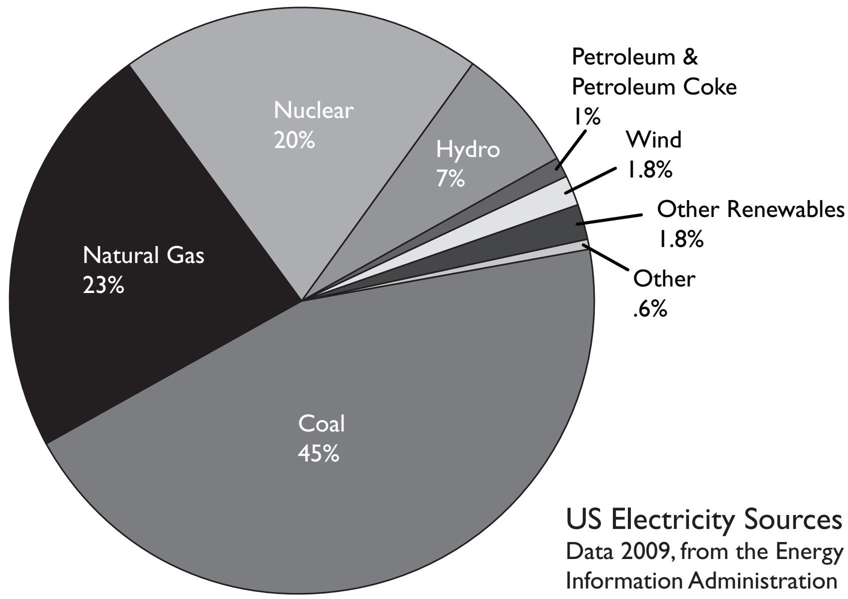
Introduction

WHY WIND?

We tend to take for granted where our electricity comes from. We expect that when we flick the switch, the lights will come on. Behind that switch are billions of dollars of investment and thousands of people making sure that it is just as simple as that—flicking the switch.

In 2009, wind power comprised 39% of all new energy installations in the US. As investors and power producers look to build new power infrastructure they are looking to build wind farms at an increasing rate.



US Electricity Sources
Data 2009, from the Energy Information Administration

Of our current generation mix, about 2% of our energy is generated by the wind. That is double what we had three years ago: approximately 20,000 wind towers.

The current US wind power capacity of 35,600 MW is capable of generating enough to power for close to 10 million US homes! Some industry leaders believe that by the year 2030 we will get 15-20% of our energy from the wind. Reaching this goal will take great effort and lots of scientists, engineers and technicians.

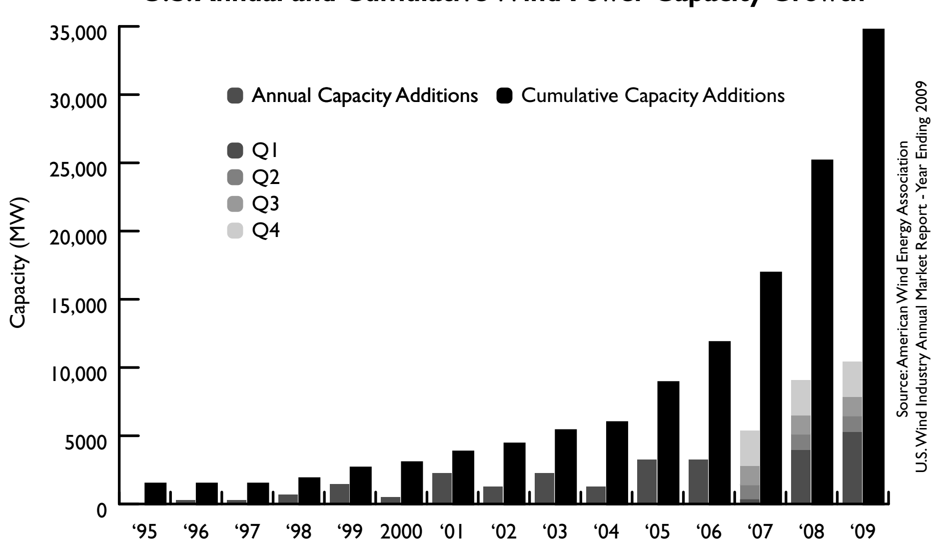
Why are we seeing more wind?

Per-capita average consumption of electricity in 2008 was seven times higher than in 1949. Predictions are that US consumption will increase 1-2% a year for the next 20 years due to population and consumption changes (DOE).

In many states there is a drive to meet this increasing consumption by reducing overall demand (efficiency and conservation) and by generating electricity using cleaner technologies like wind, solar, and biomass.

Why this push for renewable sources of electricity? States and local governments are reacting to public pressure to reduce negative environmental impacts to air, water and wildlife from coal, nuclear and large hydropower generation. Based on data from the Intergovernmental Panel on Climate Change (IPCC) many state and regional governments are convinced that they need to significantly reduce the amount of carbon that is being pumped into the atmosphere. If they do not make radical changes, they feel that their constituents will be adversely impacted by climatic change.

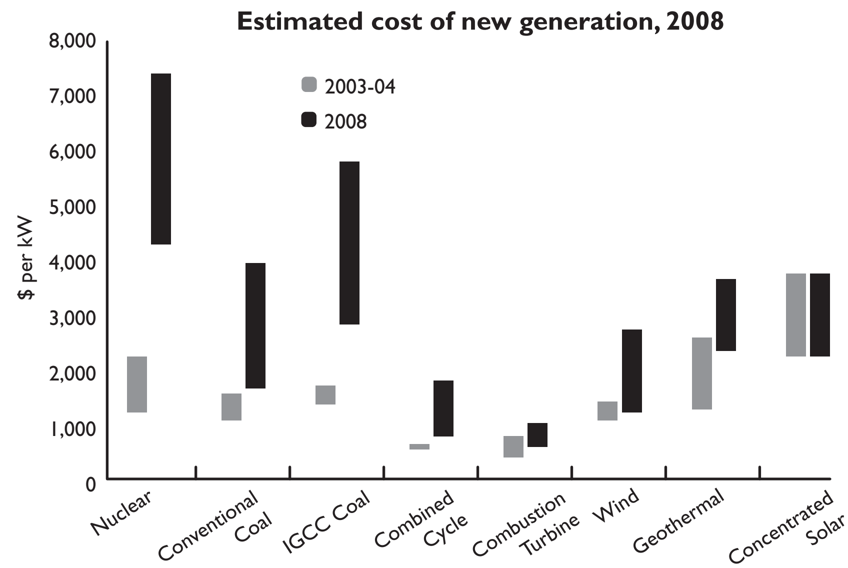
U.S. Annual and Cumulative Wind Power Capacity Growth



To convince power producers to build renewable energy facilities, over 30 states have enacted Renewable Portfolio Standard (RPS) legislation. These laws mandate that a specific percentage of electricity must come from renewable resources by a specific date. For example in New York, the RPS mandates that 29% must come from renewable sources by 2015. These mandates are creating a huge market for renewable clean energy in the states where they have been enacted. Currently there is no national level RPS legislation, but there is a push to make that a reality.

Decreasing Wind Energy Costs

As investors seek to build new renewable energy infrastructure they look for the cheapest option. As of right now the cheapest, most mature utility scale option is wind energy. As you can see from the charts, in 2008, wind energy was the most affordable renewable energy option with a low carbon footprint.



The reduction in the cost of wind energy production is significant and has been realized through investment advances in wind energy technology. Investment returns in large wind farms have also been helped by significant government financial incentives to help offset the high initial capital cost of a wind farms.

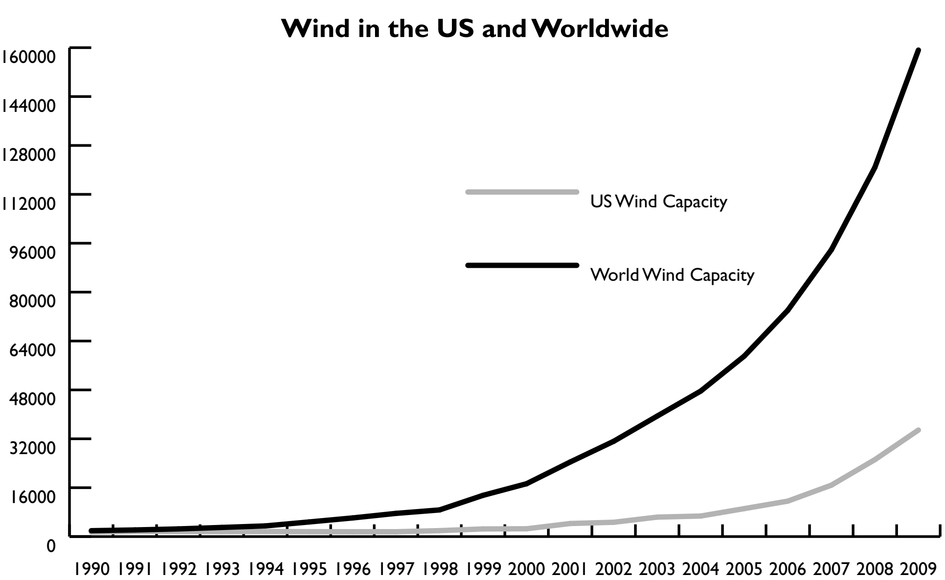
Wind energy is not free—a large wind farm may cost $200 million to build, but the fuel is free. In a world where fuel prices have only one direction to go, wind is pretty interesting to investors and consumers.

Over the next 5-10 years we are going to see many more wind turbines on the landscape. How dramatically this impacts the reliability and cost of electricity will depend on a variety of factors. The next few sections will help you understand the promise and challenges that face wind energy today.

Wind in the US and Worldwide

Wind power has seen rapid growth over the past 20 years. In 1990, wind energy had the capacity to produce 1,930 MW worldwide. About 76% of this installed capacity was located in the United States (1,484 MW). The vast majority of these wind turbines were located in California. By the beginning of 2010, installed wind capacity world wide had multiplied 82 times, reaching 159,213 MW.

In addition to the US, other countries at the forefront of wind energy installations include: Germany, Spain, China and India. At certain times of the day, Denmark can get more than 50% of its electrical energy from wind power.



For many years, Europe led the development of wind farms and manufacturing of wind turbine components. More recently, however, the wind industry has spread globally. Many of the top 10 wind turbine manufacturers are still based in Europe: Vestas (Denmark), Enercon (Germany), Gamesa (Spain), GE Energy (United States), Siemens (Denmark/Germany), Suzlon (India), Nordex (Germany), Acciona (Spain), Repower (Germany), Goldwind (China). Of these 10 manufacturers, 7 have now opened manufacturing facilities in the US.

Today there are hundreds of companies producing components for wind turbines: gearboxes, turbine blades, braking systems, bearings, towers, and more. These companies are based all over the world. It has been estimated that the global wind industry employs approximately 550,000 workers today.

Turbines are also getting much larger and more efficient. The average turbine in 1990 stood only 54 meters tall and produced a maximum of 500 kW (0.5 MW). Most turbines today stand 80-100 meters tall and produce 1.5-2.5 MW. Some turbines built today are rated at 5 MW or more.

HARNESSING WIND POWER

Basic Concepts of Wind Power

Windmills have been used for centuries to pump water or move heavy rocks to grind seeds into grain. A wind turbine is the modern advancement of the windmill, instead using the wind to turn an electrical generator.

The force of the wind on the blades causes them to move. As the rotor turns, it spins a driveshaft which is connected to a generator. The spinning generator converts mechanical (rotational) energy into the electrical energy we use every day. Large wind turbines often have a gearbox between the rotor and the generator so that the generator can spin much faster than the blades are spinning.

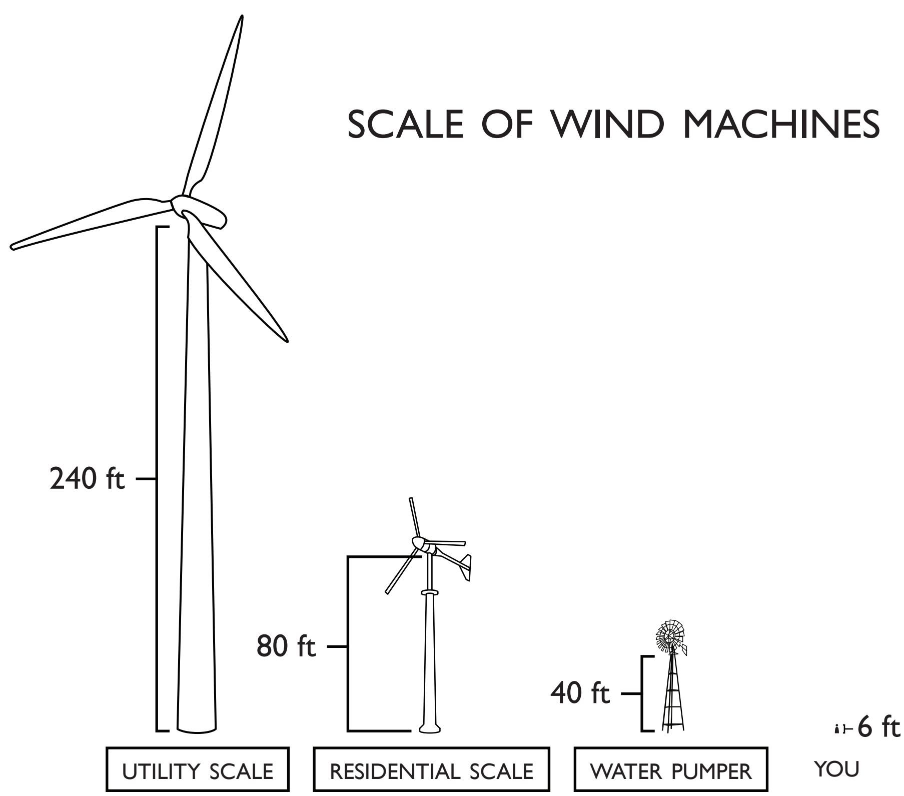
The amount of electricity a wind turbine is able to produce depends on several variables: wind speed, the diameter (size) of the rotor, the density of the air, and the efficiency of the turbine. Wind speed, or velocity, dramatically affects how much power is available in the wind. As wind speed doubles, the power available in that wind is multiplied eight times!

Large wind turbines are often built in clusters called wind farms. A wind farm may have just a few turbines or several hundred. Wind farms act just like other power plants—feeding electricity directly into the power grid.

Small vs. Large Wind Turbines

Wind turbines come in all shapes and sizes. The smallest wind turbines produced have a rotor diameter of 1 meter and only produce enough power to charge a few 12 volt batteries—or about 100 watts. A wind turbine that could power your whole house is still considered "small." This wind turbine might have a rotor diameter of 7 meters and could produce 10 kW (10,000 watts).

A typical "large" or utility scale wind turbine has a rotor diameter of 80 meters and stands on a tower 80-100 meters tall. This wind turbine could produce 1.5 MW (1,500,000 watts)—enough electricity for about 400 American homes. Utility scale turbines are getting bigger and bigger. Some turbines today can produce over 5 MW and have a rotor diameter of 126 meters!



Where are Wind Farms?

Since wind velocity greatly affects the power in the wind, it makes sense to build wind farms in places that are very windy. Look at the wind speed map of the United States. Where would you put a wind farm? The windiest places in the US are the Great Plains (the "wind belt"), mountainous areas, and coastal areas. Currently, the majority of wind turbines installed in the US are in the Great Plains from Texas to North Dakota.

In Europe, many wind farms have been built out in the sea—miles from land. Consistent, fast, and smooth offshore wind means that these wind farms can make a lot of power. It is safe to assume that there will be many offshore wind farms built around the US in coming years.

WIND ENERGY CHALLENGES

Humans have harnessed wind power for thousands of years using windmills, sailboats and other processes. The current versions of residential and utility sized turbines are young, with designs less than 20 years old. How long have we been burning coal or other fuels—thousands of years? Will there be problems? Yes, but with continued investment wind turbine technology is going to become more efficient, longer lasting and more economical. The question is will we make those investments and have some patience?

Technological Hurdles

The industry continues to learn how to make wind turbines larger, cheaper, last longer and connect to the grid more reliably. This process is accelerating as the market grows and more companies try to make money in a rapidly growing industry.

Major research is currently taking place on improving, or removing gearboxes from large turbines, squeezing more electricity from generators, enhancing blade performance and programming control systems that automate wind turbine response and performance.

Variable Production

One major complaint is that wind energy is not reliable since we cannot predict when the wind will blow. Not exactly true—there is a huge amount of research taking place to more accurately predict when the wind will blow, how fast it will blow, and for how long. The better the wind industry gets at predicting the wind resource, the more wind farms will become like other power plants—it is all about prediction. As they say in the industry "the wind is always blowing somewhere." We just need to quantify and predict.

Do we need resources when the wind does not blow? Yes. Do we need a 100% backup for wind farms? No! Some studies have shown that the amount of reserve power to cover variable wind production could be in the 8-10% range, others put it higher at 20-40%. The actual ratio depends heavily on proximity of wind generation to load, other generators on the system, overall system load (both forecasted and real time), planned outages of generators and transmission lines, and other reliability criteria.

Currently we do not store wind energy, as it is produced it goes right onto the grid. This may change in the future; storage options are being explored in compressed air, pumped water and hydrogen technology systems.

Transmission

Some consider transmission to be the single biggest hurdle facing wind energy development. Moving wind generated power from rural locations to urban centers is going to require a great deal of infrastructure. This will be costly and not without controversy—people do not like high voltage power lines in their neighborhood. Some claim we should distribute the turbines more evenly and generate power closer to the cities and urban locales. The problem with this is that often the wind resource is not as good and you lose some economies of scale of having a large farm.

Cost is a huge issue. Who pays the billions in upgrade costs to get the power where it needs to go? Is it a cost that is spread out across everyone who uses the grid? Is it a cost that generators will pay? Is it a cost that transmission owning companies will pay? These questions are still being played out.

Offshore wind power is very promising as 48% of our population lives within 50 miles of the ocean. The concept would be to build large wind farms in the ocean or great lakes and run cables many miles back to shore. In 2010 Cape Wind started construction of the first offshore wind farm in the US.

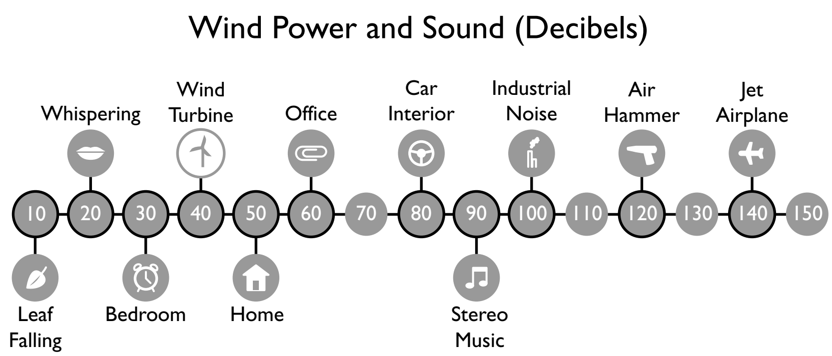
Ecological Factors

Compared to other energy generation sources, wind energy has very low impacts on the environment and wildlife. A wind farm requires many studies before construction begins to determine whether ecosystems or wildlife will be impacted during construction and operation. These studies look at the location and type of natural areas at the site, wildlife species present, potential placement of turbines, placement of power lines, and the location of maintenance roads and structures. Wind energy has a small physical "footprint," meaning that the space the turbines, roads, and buildings take up is small. Wind farm infrastructure generally takes up only about 2-5% of a wind farm's land. Wind farm developers must consider the potential impacts to wildlife, especially birds and bats, when they are deciding where to place their turbines.

Birds and bats can be impacted by wind turbines in three main ways: they can be killed by the blades when they are flying, they can be displaced from their normal habitat by the presence of the turbines, and their habitat can be impacted by the construction of turbines and wind farm infrastructure. Although birds do collide with turbines, turbine collisions are a very small risk to birds in general and are only a minor contributor (less than 1%) to human caused bird fatalities nationwide. Nevertheless, bird impacts from turbines are continually monitored and studied by scientists and regulators. Bats have recently become a major concern for developers and scientists. Bats can be killed by collisions with turbines or by "barotrauma" when they suffer a sudden drop in pressure if they fly too close to a spinning turbine blade. There is uncertainty about the amount of impact turbines have on bat populations. Scientists, developers, and regulators are working together to learn more about and minimize the impact that wind farms have on bats.

Sound

Recently there have been complaints about adverse impacts related to the sound that turbines produce. A number of individuals living near wind farms have made the claim that their health has been negatively impacted by the sound and infrasound produced by turbines. The industry has produced studies that declare this is not supported by medical fact. This problem will definitely be explored more deeply in the next few years to determine appropriate setbacks for wind turbines from peoples' homes and businesses.



Landscape Impact & Public Perceptions of Wind

While a large majority of Americans support the production of wind energy as a concept, there can be resistance to the siting of wind turbines in rural communities. While local concerns often relate to sound, health and wildlife issues, residents are also very concerned about how these new technologies will impact landscape values and local economies.

In some locations around the US, wind projects are creating bitter local politics where neighbors are being pitted against one another. Active oppositional campaigns are politically challenging new projects. While some landowners are benefiting from lease payments, their neighbors often claim that viewsheds impacts are significantly affecting entire communities and this may result in lower property values and erode the historic qualities of small towns. Local planners and elected officials often have to balance these concerns with the new jobs and tax base the wind farm may provide.

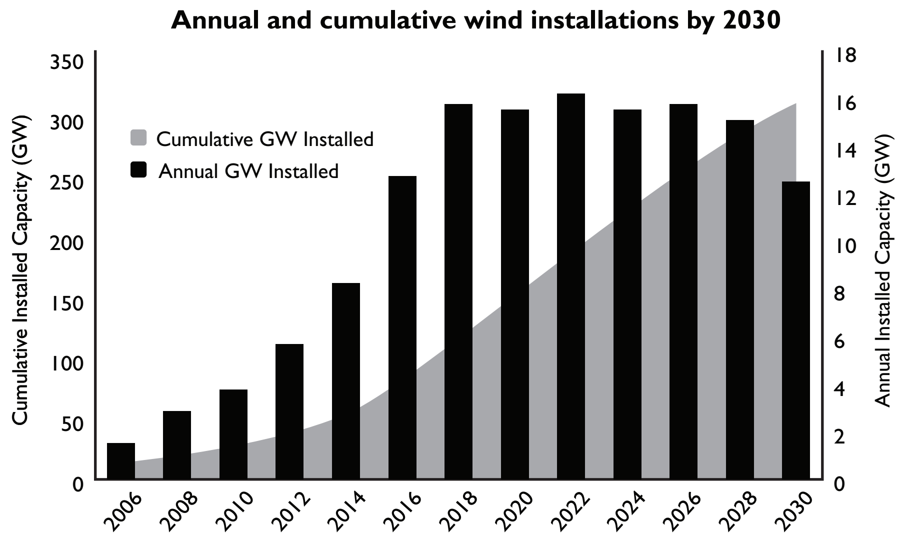
Many communities feel the solution to these conflicts is more transparency and democracy in the process of building a wind farm. The industry counters that they have the most open process of any energy generation source currently being constructed.

Cheap Fossil Fuel Prices

If natural gas and coal remain very cheap it makes it harder for wind energy to compete for capital and makes the cost of wind energy more expensive compared to those sources. One thing that may change is that in the next 5-10 years we could see a tax on carbon. This would add an additional cost to coal and natural gas generation and make wind a more attractive option. At this point a "carbon tax" is a very controversial proposition in US politics.

Future of Wind

It is clear that we are going to see more electricity from wind energy in the future. How much will depend on the variety of factors that we have previously discussed. A recent Department of Energy report predicts that we will get about 5% of our electricity from wind in 2020.



20% Wind Energy by 2030 DOE Report (2007)

Another report was released in 2008 indicating that with aggressive public policy and private investment, the US could produce 20% of our electricity from wind by 2030. That would be a colossal program. There is currently 35 GW (1GW=1000MW) of wind power capacity installed in the US. To get to 20% we need 305GW! That's a lot of turbines.

Would this be challenging? Definitely! Is it possible? Based on this study, we have the technology, materials and skills to do this. What we need is the will.

The benefits of this kind of widespread clean energy development would be monumental. By 2030, in this scenario we would reduce the cumulative amount of CO_2 being put in the atmosphere by 7600 metric tons. Close to 200,000 jobs would be created to manufacture, install and maintain these devices. Additionally, in this plan we would see huge reductions in water use for power and negative health impacts from other pollutants. If done properly, we would see little or no increase in the cost of electricity and no decrease in reliability.

One of the major findings of the 20% by 2030 report was that a major hurdle to reaching this goal was that in the US there is a predicted decrease in the number of trained engineers and scientists who could do the research required to improve the turbine technology. What this means is that we would be importing much of this new technology, not inventing or designing it ourselves. That is a problem that WindWise seeks to address.

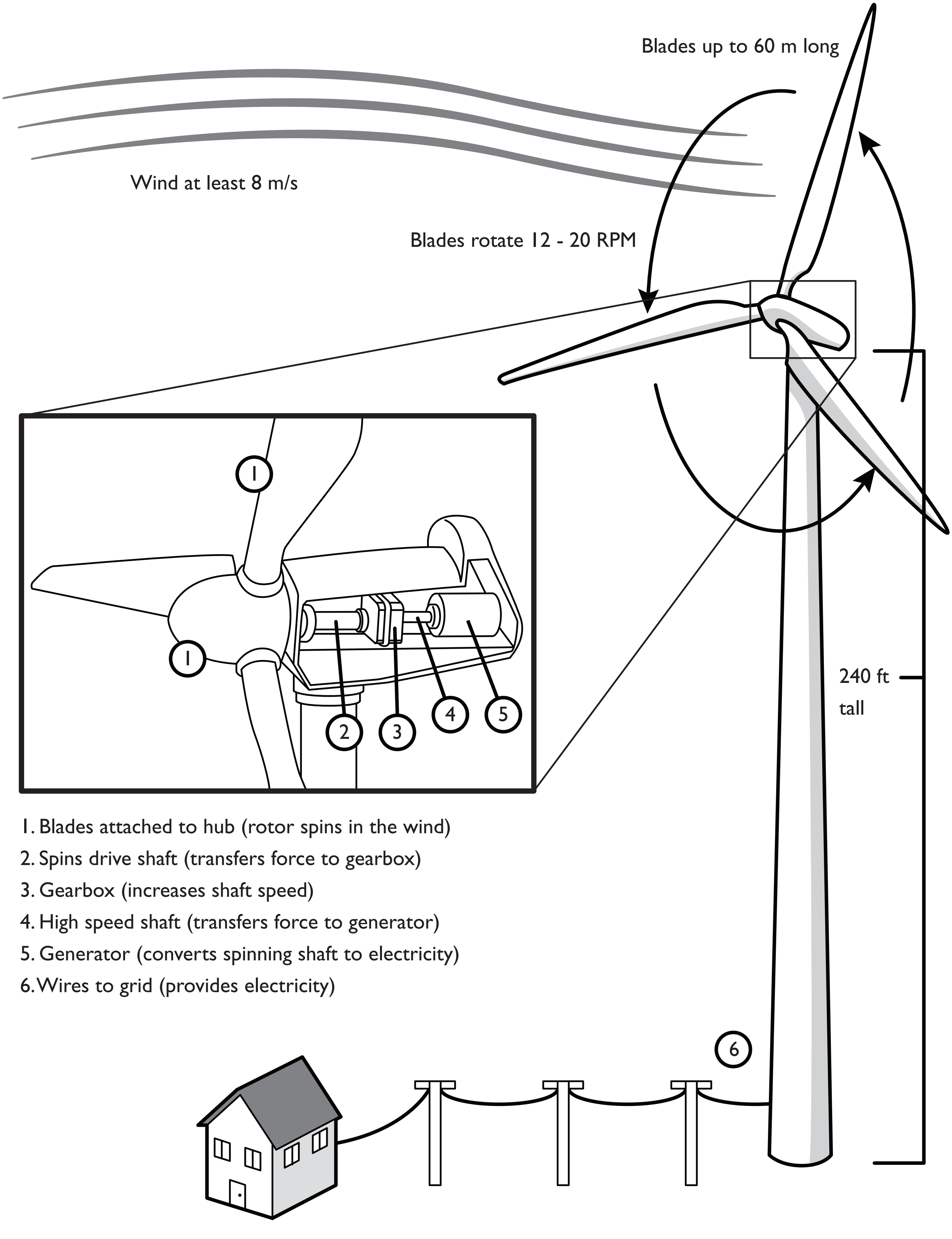
There is a great deal of work to be done and this is a start. WindWise is designed to start students down a road where they understand the limits and promise of wind energy and see it as a career choice in the future.

Off we go!

A QUICK HISTORY OF WIND ENERGY TECHNOLOGY

3,500 BC	Egyptians made the earliest known sailboats, using the wind to propel boats.
200 BC	Windmills are used to pump water in China.
600 AD	The Persians of present day Iran used windmills to grind grain into flour.
1100 AD	Wind power appears in Europe during the medieval period. Windmills were used to grind grain.
1300 AD	The first horizontal-axis windmills appear in Western Europe to drain fields in the Netherlands and to move water for irrigation in France.
1800's	American settlers use windmills to pump water along the western frontier. By the late 1880's, six million windmills had sprung up across America. Steel blades for windmills improve efficiency.
1887	The first windmill for electricity production is built by Professor James Blyth in Glasgow, Scotland.
Early 1900's	Electric wind turbines appear all over Europe and are used to power rural homes and farms in America.
1920's	French inventor G.J.M. Darrieus develops a vertical axis turbine shaped like an eggbeater.
1931	100 kW wind turbine built in the former USSR. This is a precursor to the modern wind turbine.
1941	Large wind turbine (1,250 kW) is constructed in Vermont in response to fuel shortages. This supplied power for several years during World War II.
1956	200 kW, three-bladed turbine is invented by Johannes Juul in Denmark. This turbine inspired many later turbine designs.
1973	OPEC oil embargo causes oil prices to rise dramatically. High oil prices increase interest and research in alternative energy sources.
1977–1981	The US designs several two-bladed turbine prototypes. One prototype, called the MOD-1, had a 2 megawatt capacity.
1985	California wind capacity exceeds 1,000 megawatts, enough to power 250,000 homes. Wind turbines were still very inefficient at this time.
1990's	Growing public concerns about environmental issues such as air pollution and global warming encourage interest in renewable energy.
1991	The world's first offshore wind farm begins operating off the coast of Denmark.
1999	The US Department of Energy began the Wind Powering America (WPA) Program
2001	Wind energy capacity reaches 24,800 megawatts. The global wind power industry generates about $7 billion in business.
2004	The cost of electricity from wind generation was competitive with fossil fuel generation.
2009	Global wind energy production exceeds 159,000 megawatts, employing 550,000 people and generating $65 billion in business.

ENERGY TRANSFERS AND CONVERSIONS IN A TURBINE



1. Blades attached to hub (rotor spins in the wind)
2. Spins drive shaft (transfers force to gearbox)
3. Gearbox (increases shaft speed)
4. High speed shaft (transfers force to generator)
5. Generator (converts spinning shaft to electricity)
6. Wires to grid (provides electricity)