RADHAKRISHNA INSTITUTE OF TECHNOLOGY AND ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

COURSE NAME : RENEWABLE POWER GENERATING SYSTEMS
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WIND ENERGY SYSTEM

Planning & Operating Electricity Network with Renewable Generation

3. Wind energy systems

CONTENTS

1-INTRODUCTION

Wind energy, the world's fastest growing energy source, is a clean and renewable source of energy that has been in use for centuries in Europe and more recently in the United States and other nations.

And todays world wind is one of the cheapest and cleanest energy source.

2-HISTORY of WIND MACHINES

- Throughout history people have harnessed the wind. Over 5,000 years ago, the ancient Egyptians used wind power to sail their ships on the Nile River. Later people built windmills to grind their grain. The earliest known windmills were in Persia (the area now occupied by Iran). The early windmills looked like large paddle wheels.
- Centuries later, the people in Holland improved the windmill. They gave it propeller-type blades and made it so it could be turned to face the wind. Windmills helped Holland become one of the world's most industrialized countries by the 17th century.
- American colonists used windmills to grind wheat and corn, to pump water, and to cut wood at sawmills.
- Last century, people used windmills to generate electricity in rural areas that did not have electric service. When power lines began to transport electricity to rural areas in the 1930s, the electric windmills were used less and less.
- Then in the early 1970s, oil shortages created an environment eager for alternative energy sources, paving the way for the re-entry of the electric windmill on the world landscape.

3-WIND RESOURCE

Where Wind Energy Comes From

All renewable energy (except tidal and geothermal power), and even the energy in fossil fuels, ultimately comes from the sun. The sun radiates of 1.74×10^{17} watts energy to the earth per hour.

About 1 to 2 per cent of the energy coming from the sun is converted into wind energy. That is about 50 to 100 times more than the energy converted into biomass by all plants on earth.

What Wind Is

Wind is simply air in motion. It is caused by the uneven heating of the earth's surface by the sun. Since the earth's surface is made up of land, desert, water, and forest areas, the surface absorbs the sun's radiation differently.

Wind Resources

- **Global winds**
- **Local Winds**
  - **Land Breezes and Sea Breezes**
  - **Mountain Breezes and Valley Breezes**

Global Winds

The wind rises from the equator and moves north and south in the higher layers of the atmosphere.

Around 30°; latitude in both hemispheres the Coriolis force prevents the air from moving much farther. At this latitude there is a high pressure area, as the air begins sinking down again.

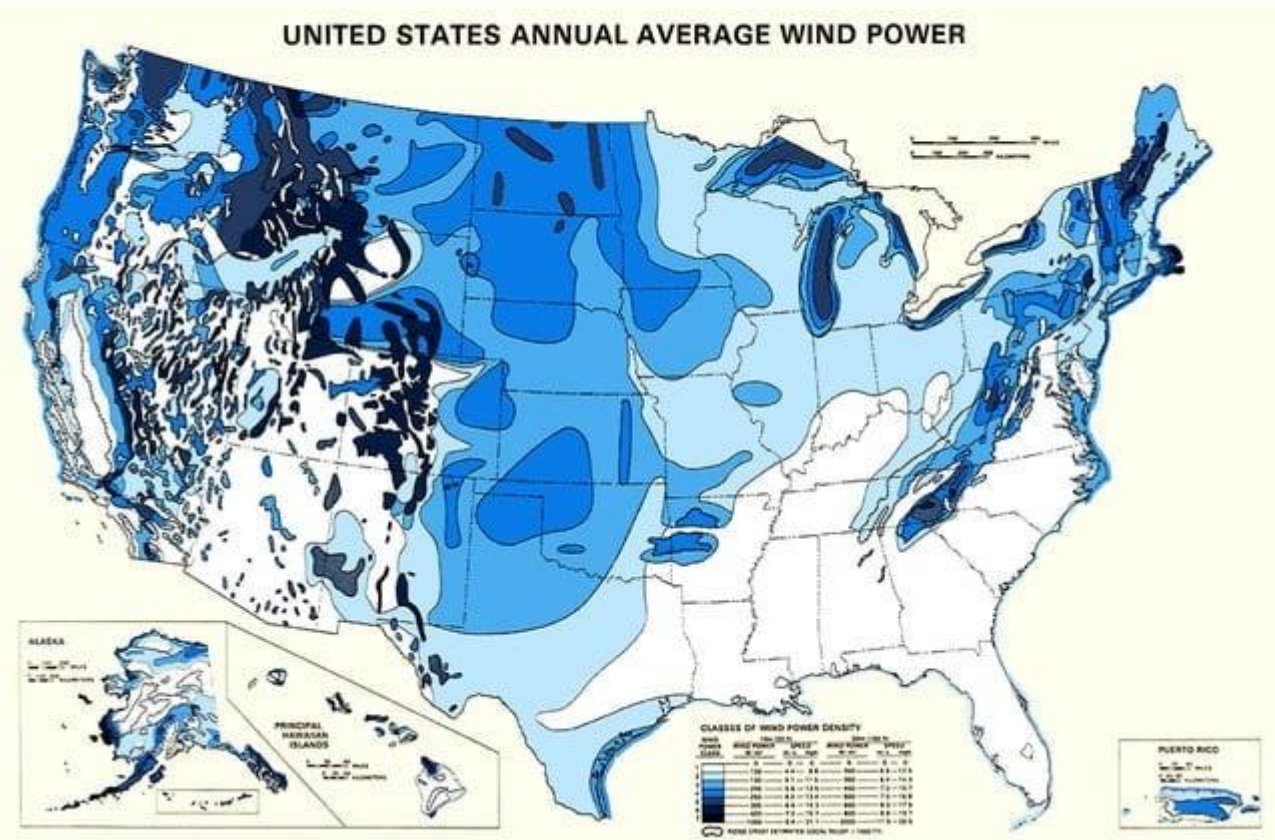
As the wind rises from the equator there will be a low pressure area close to ground level attracting winds from the North and South.

At the Poles, there will be high pressure due to the cooling of the air.

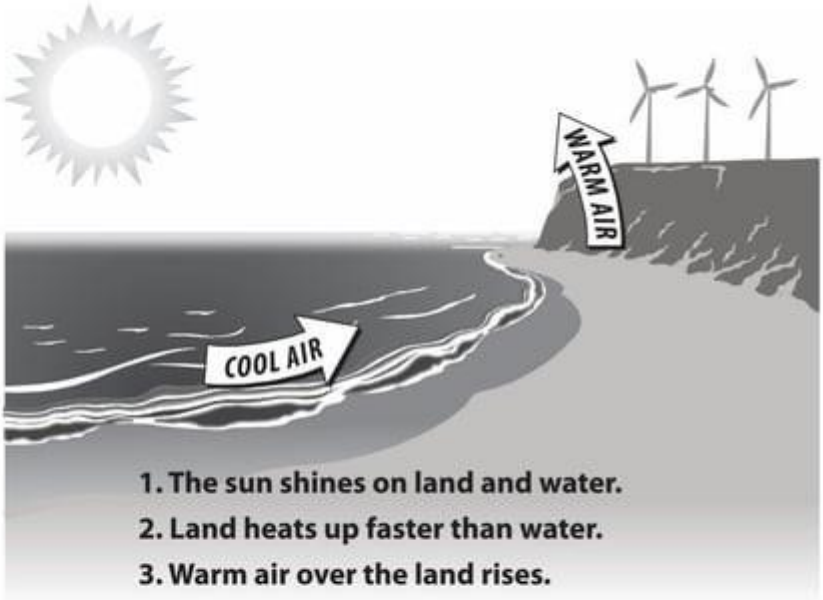
OBJECTIVES:

HOW TO MANIPULATE WIND ENERGY

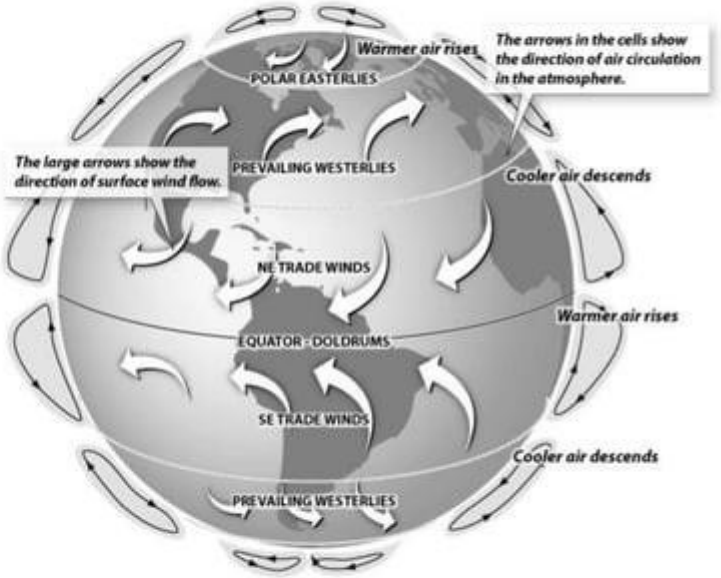
ANALYZING OUR SOURCE



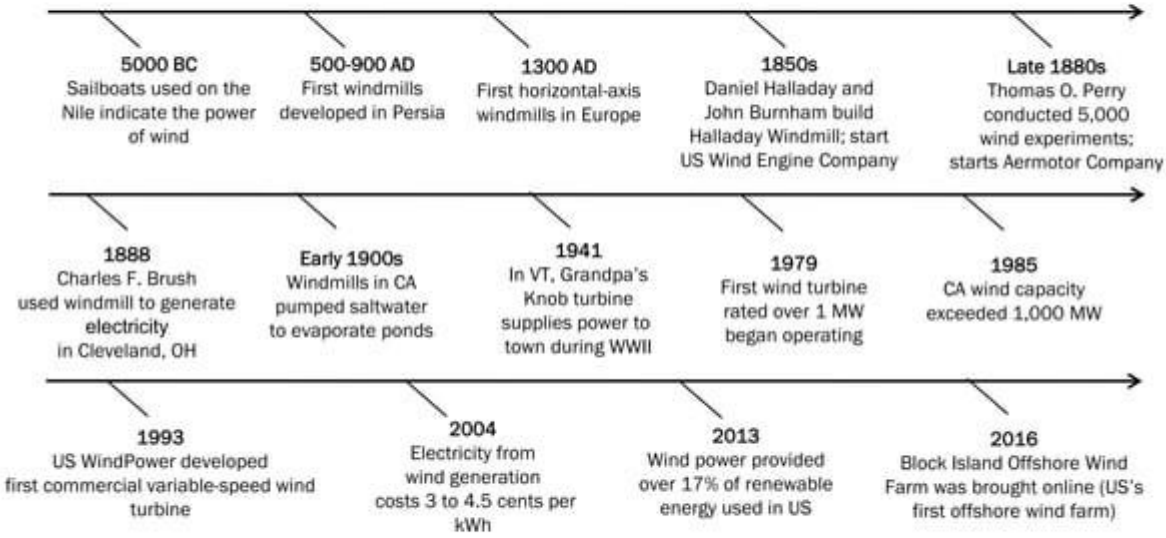
What Makes Wind



Global Wind Patterns



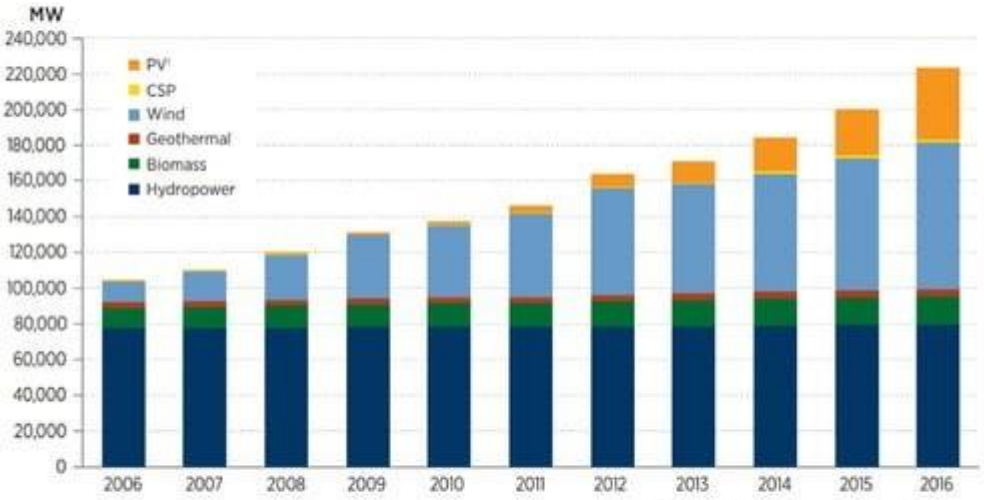
History of Wind Energy



Why Wind Energy?

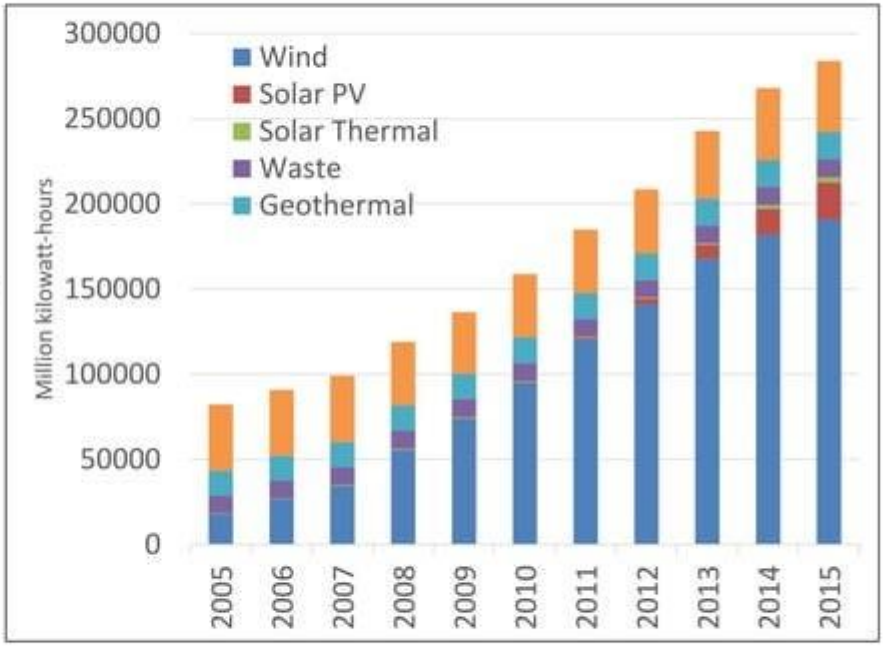
- Clean, zero emissions
  - NOx, SO2, CO, CO2
  - Air quality, water quality
  - Climate change
- Reduce fossil fuel dependence
  - Energy independence
  - Domestic energy—national security
- Renewable
  - No fuel-price volatility

Renewable Electric Capacity Worldwide



US DOE, EERE 2016 Renewable Energy Data Book

U.S. Electricity Generation from Non-Hydro Renewables



Why Such Growth? ...costs are low!

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements

1979
40
cents/kWh

2000
4 - 6 cents/kWh

2004
3 - 4.5 cents/kWh

2017
Less than 5 cents/kWh

Modern Wind Turbines

Turbines can be categorized into two classes based on the orientation of the rotor.

Vertical-Axis Turbines

Advantages

- Omni-directional
  - accepts wind from any direction
- Components can be mounted at ground level
  - ease of service
  - lighter weight towers
- Can theoretically use less materials to capture the same amount of wind

Disadvantages

- Rotors generally near ground where wind is poorer
- Centrifugal force stresses blades
- Poor self-starting capabilities
- Requires support at top of turbine rotor
- Requires entire rotor to be removed to replace bearings
- Overall poor performance and reliability

Horizontal-Axis Wind Turbines

Small (<10 kW)
- Homes
- Farms
- Remote Applications (e.g., water pumping, Telecom sites, ice making)

Intermediate(10-250 kW)
- Village Power
- Hybrid Systems
- Distributed Power

Large (250 kW-2+ MW)
- Central Station Wind Farms
- Distributed Power
- Schools

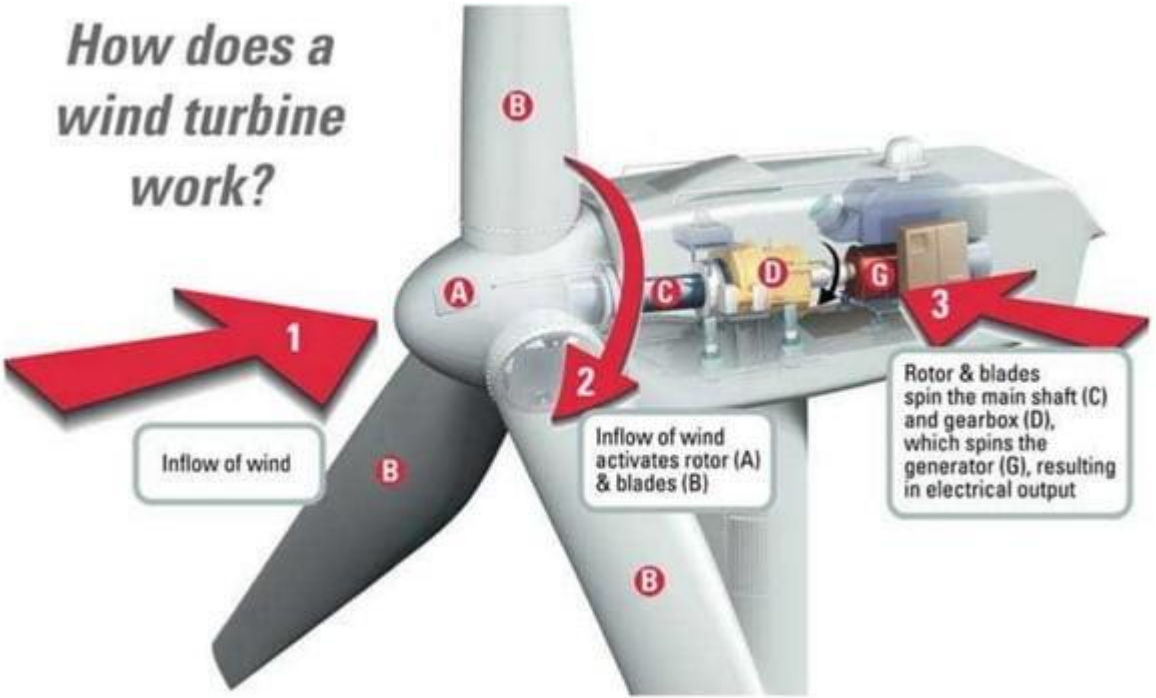
Large Wind Turbines

- Common Utility-Scale Turbines

- 328’ base to blade
- Each blade is 112’
- 200 tons total
- Foundation 20’ deep
- Rated at 1.5-2 megawatts
- Supply power to about 500 homes

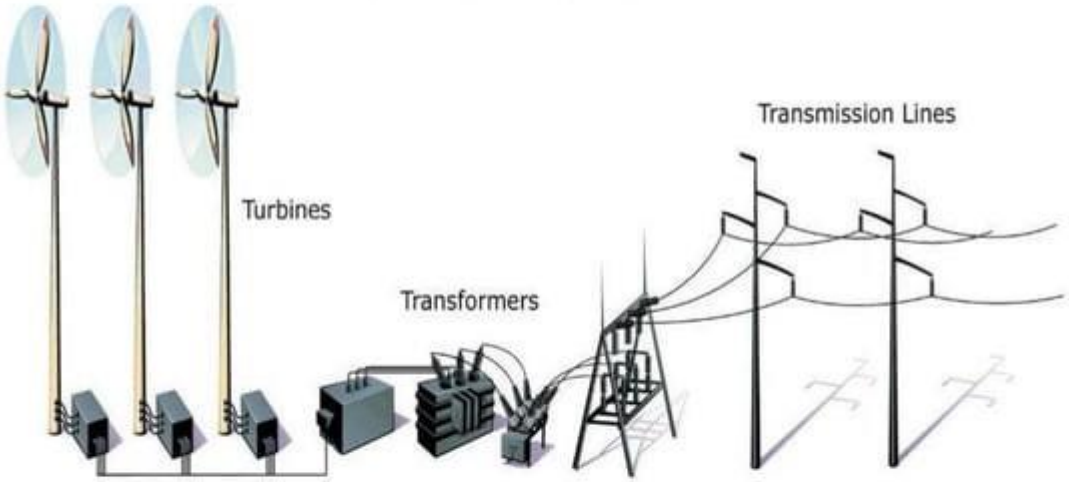

A
B
C
D
Turbine Components
A Blades
B Hub
C Nacelle
D Tower
• Wind Turbine Components

How does a wind turbine work?



Wind Turbine Perspective

Wind Farms

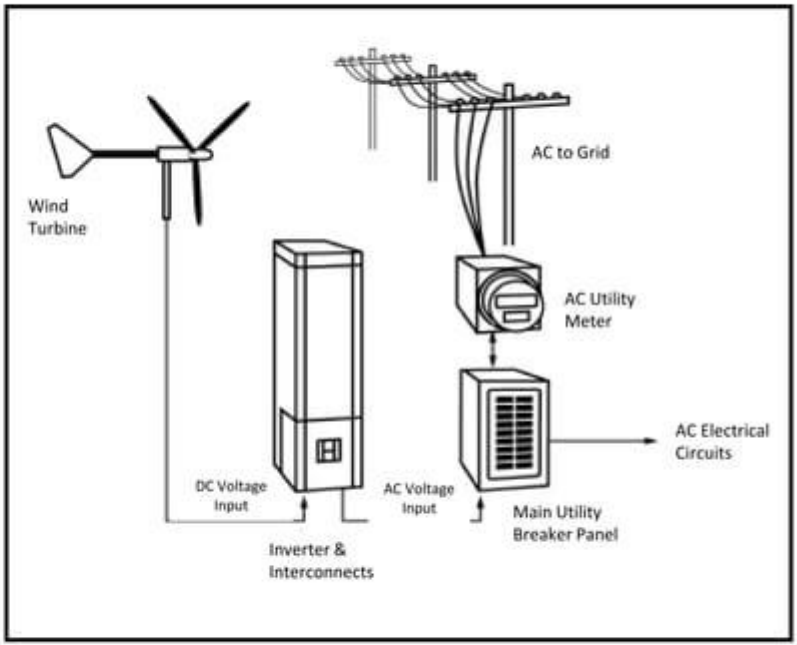


Offshore Wind Farms

Photo of Block Island Wind Farm

The first U.S. offshore wind farm is Block Island Wind Farm, located off the coast of Rhode Island. This five-turbine, 30 megawatt wind farm began operation in 2016.

Residential Wind Systems and Net Metering

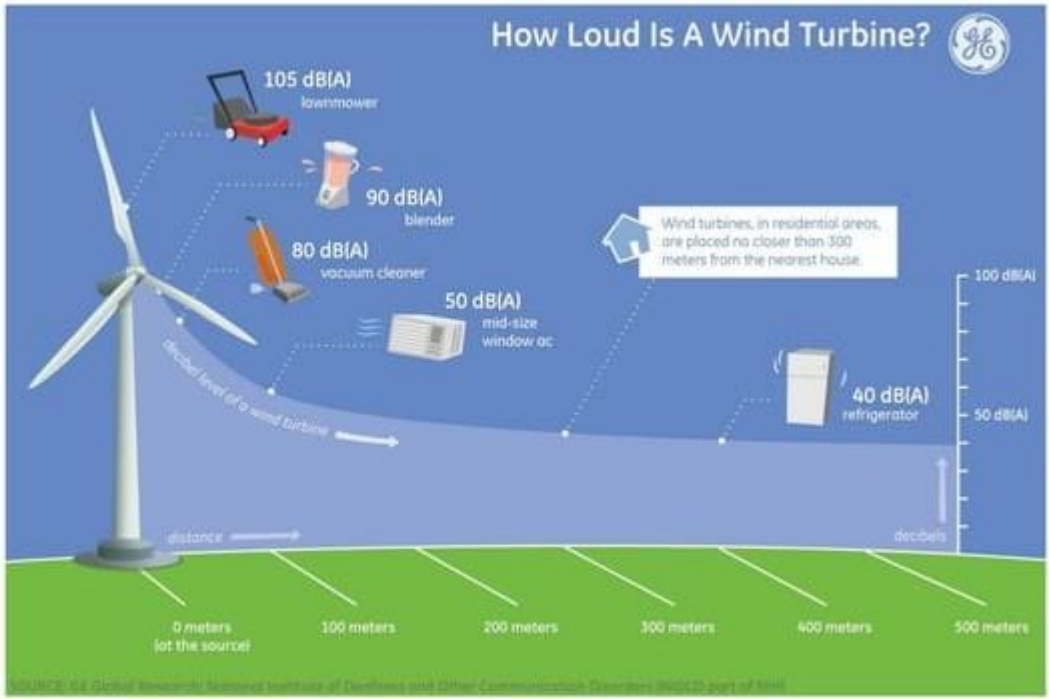


Potential Impacts and Issues

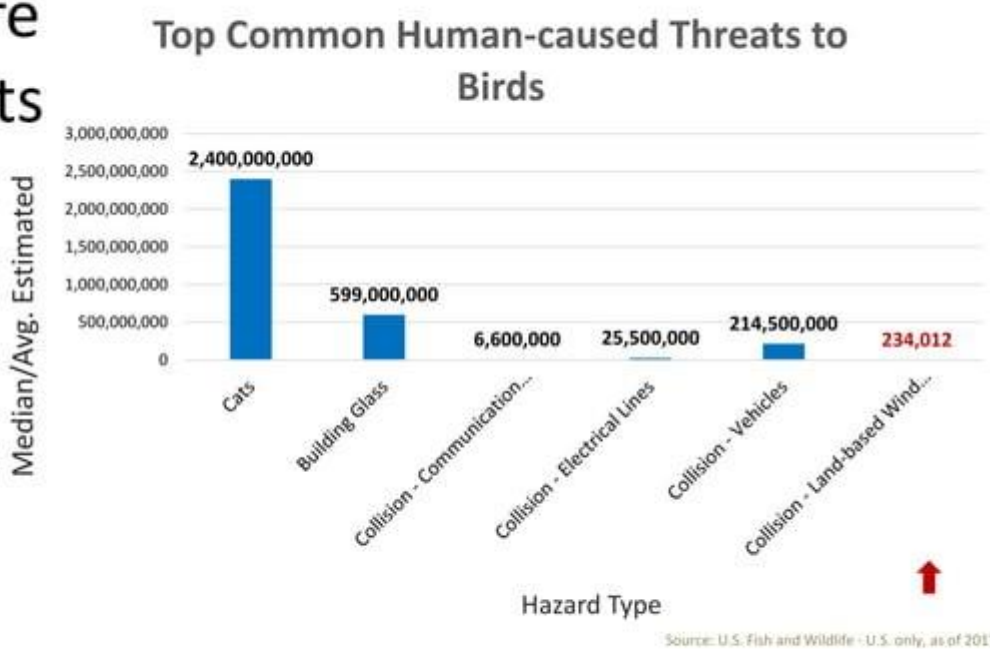
- Property Values
- Noise
- Visual Impact
- Land Use
- Wildlife Impact

Properly siting a wind turbine can mitigate many of these issues.

- **Impacts of Wind Power:** **Noise**



Wildlife Impacts



GENERATING WIND POWER

HORIZONTAL

Blades catch the wind and spin

1

2

Generator converts mechanical energy into electricity

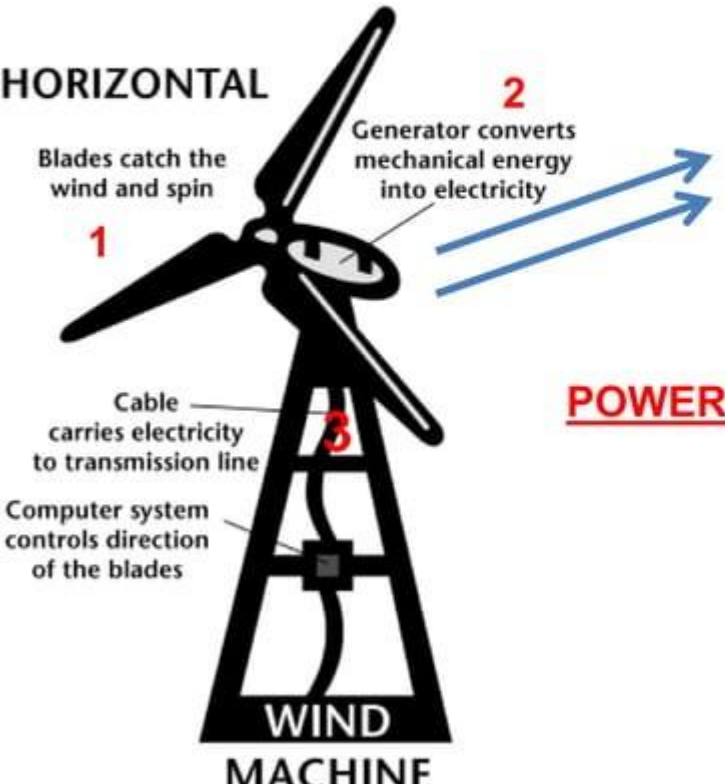
Cable carries electricity to transmission line

3

Computer system controls direction of the blades

WIND MACHINE

GENERATING WIND POWER



Attach a **voltage** probe

Attach a **current** probe

POWER = VOLTAGE x CURRENT

THINK OUTSIDE OF THE BOX

HIGHWAY WIND TURBINE

ROOFTOP WIND TURBINE

Local Winds

- **Land Breezes and Sea Breezes**

  Land masses are heated by the sun more quickly than the sea in the daytime. The air rises, flows out to the sea, and creates a low pressure at ground level which attracts the cool air from the sea. This is called a sea breeze. At nightfall there is often a period of calm when land and sea temperatures are equal.

  At night the wind blows in the opposite direction. The land breeze at night generally has lower wind speeds, because the temperature difference between land and sea is smaller at night.

- **Mountain Breezes** and **Valley Breezes**

  Mountain breezes and **valley breezes** are due to a combination of differential heating and geometry. When the sun rises, it is the tops of the mountain peaks which receive first light, and as the day progresses, the mountain slopes take on a greater heat load than the valleys. This results in a temperature inequity between the two, and as warm air rises off the slopes, cool air moves up out of the valleys to replace it. This upslope wind is called a *valley breeze*. The opposite effect takes place in the afternoon, as the valley radiates heat. The peaks, long since cooled, transport air into the valley in a process that is partly gravitational and partly convective and is called a *mountain breeze*.

4-WIND ENERGY TECHNOLOGY

- Horizontal Axis Turbine
- Vertical Axis Turbine
- Old-fashioned windmills

Horizontal Axis Wind Turbine

Most of the technology described in this project is related to horizontal axis wind turbines (HAWTs,) as shown in figure 2.

The reason is simple: All grid-connected commercial wind turbines today are built with a propeller-type rotor on a horizontal axis (i.e. a horizontal main shaft).

The purpose of the rotor, of course, is to convert the linear motion of the wind into rotational energy that can be used to drive a generator. The same basic principle is used in a modern water turbine, where the flow of water is parallel to the rotational axis of the turbine blades [5].

- Figure 2 Horizontal axis Turbine [6].

Vertical Axis Wind Turbine

- As you will probably recall, classical water wheels let the water arrive at a right angle (perpendicular) to the rotational axis (shaft) of the water wheel.
- Vertical axis wind turbines (VAWTs) are a bit like water wheels in that sense. (Some vertical axis turbine types could actually work with a horizontal axis as well, but they would hardly be able to beat the efficiency of a propeller-type turbine).

- The only vertical axis turbine which has ever been manufactured commercially at any volume is the Darrieus machine, named after the French engineer Georges Darrieus who patented the design in 1931. (It was manufactured by the U.S. company FloWind which went bankrupt in 1997). The Darrieus machine is characterized by its C-shaped rotor blades which make it look a bit like an eggbeater. It is normally built with two or three blades.

- Figure 3 Vertical axis wind turbine.

Advantages of VAWT's

1) You may place the generator, gearbox etc. on the ground, and you may not need a tower for the machine.

2) You do not need a yaw mechanism to turn the rotor against the wind.

Disadvantages of VAWT's

1) Wind speeds are very low close to ground level, so although you may save a tower, your wind speeds will be very low on the lower part of your rotor.

2) The overall efficiency of the vertical axis machines is not impressive.

3) The machine is not self-starting (e.g. a Darrieus machine will need a "push" before it starts. This is only a minor inconvenience for a grid.

Old-fashioned windmills

- Figure 4 Old-fashioned windmills.

Why turbines not look like old-fashioned windmills

The old-fashioned, as seen in figure 4, windmill is viewed with nostalgia, and some people prefer the look of them to that of their modern counterparts. Just because wind turbines are modern, it does not mean that they are less aesthetically pleasing. A modern wind turbine is simply an improved windmill. Every aspect of their design has been optimized, and they are hundreds of times more efficient than old-fashioned windmills. To make them look more old-fashioned would result in much more expensive electricity.

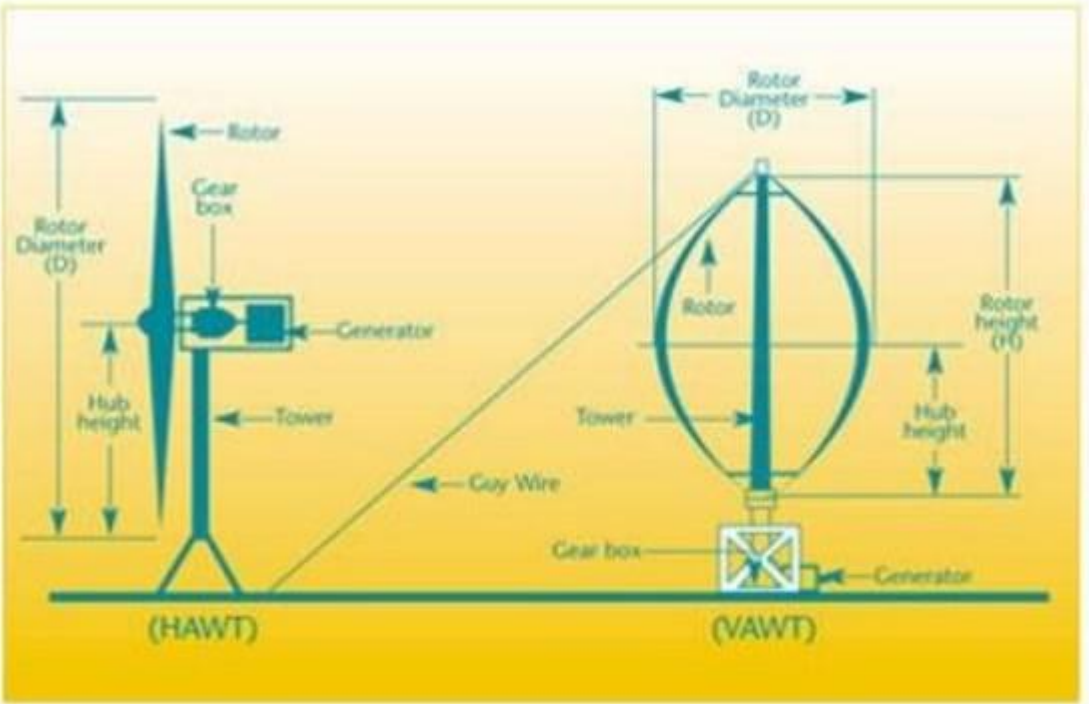
5-WIND TRIBUNE USE

- Electricity for homes and farms
- Electricity for communities
- Electricity in industry
- Supplying electricity for a nation
- Remote communities
- Energy to drive pumps

Electricity from turbines

As shown in figure 5 a wind turbine consists of six major components :

- A rotor that aerodynamically converts the wind energy into mechanical energy on a slowly turning shaft.
- A gearbox that increases the rotor-shaft speed for the generator. Some specially designed generators run at rotor-shaft speed and do not need a gearbox.
- A generator that produces electricity.
- A control and protection system that optimizes performance and keeps the machinery operating within safe limits.
- A tower that raises the rotor high off the ground where the wind speed is greater and the effects of local obstructions are less.
- A foundation that supports the wind turbine system, sometimes with the aid of guy wires.



- Figure 5 **Major components of horizontal and vertical axis wind turbines.**

- Wind turbine generators produce a range of electricity. Rotors that have diameters of about 1m produce a few hundred watts of electricity. Rotors that have diameters that approach 75 m can produce over one megawatt.

Electricity for Homes and Farms

Small and medium wind turbine generators at homes, farms or small industrial sites can be used with diesel generators or connected to the electrical supply grid. By connecting to the electrical grid, the user of the electrical supply pays only for the electricity they use from the electrical utility company.

Electricity For Communities

- Small numbers of medium/large wind turbine generators can be installed by groups of individuals wishing to contribute pollution-free energy to their electricity networks.

Electricity in Industry

Medium systems (10 to 100 kilowatts) can be used by large farms, process industries, and groups of individuals to offset costs of electricity from the grid network, or by remote communities to offset fuel costs and pollution of diesel power plants.

Large systems (100 kilowatts to 1 megawatt) can be used either individually or in small clusters to provide electricity to industries, large farms, or groups of dwellings. When used in arrays of multiple units, they can supply significant amounts of electricity to provincial or national networks.

Supplying Electricity For A Nation

Arrays of large wind turbine generators can be connected to electricity supply grids and can provide significant amounts of provincial and national electrical demand. In Denmark, for example, wind-generated electricity now provides about 10 % of national needs and is scheduled to provide 50 % of the need by 2030.

Remote Communities

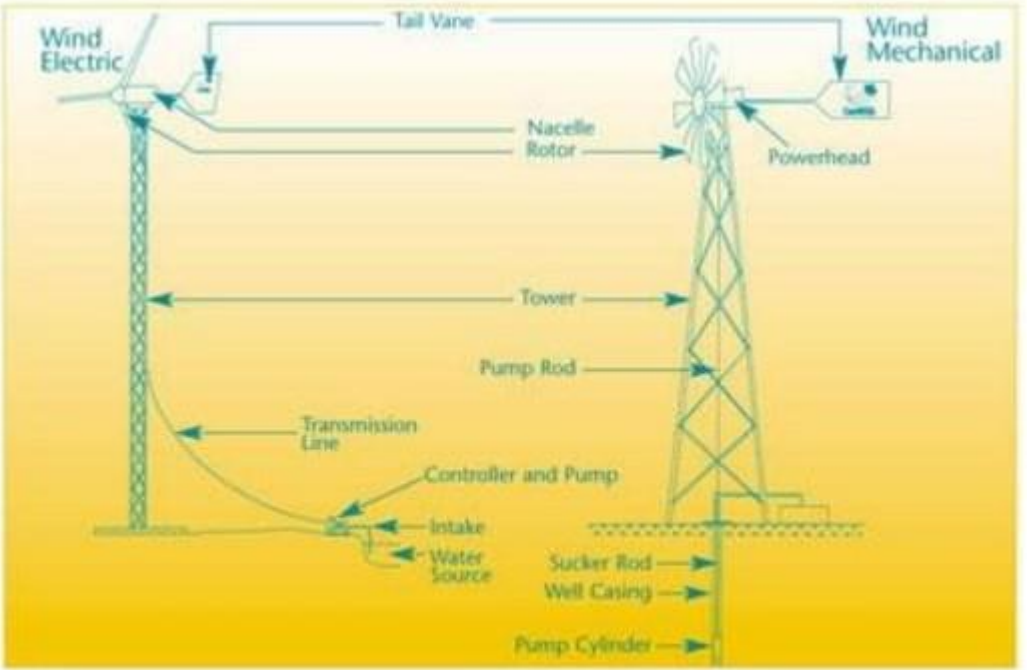
- Small wind turbine generators that are connected to batteries can provide sufficient electricity for rural dwellings, communications relay stations, navigational aids, and other needs in isolated areas. Small and medium wind turbines may also be used for pumping, either by direct drive or by powering electric pumps.

Energy To Drive Pumps

A wind turbine can be used to drive a rotating or reciprocating pump. Like a wind turbine, a wind pump has a rotor, a tower, and foundations. However, the hydraulic pump replaces the generator. Often, the rotor shaft drives the pump directly, which eliminates the need for a gearbox.

As shown in figure 6 the pump can be located in the following places:

- on top of the tower at the turbine rotor shaft
- at ground level, in which case shafting or pulleys are used
- at the bottom of the well, in which case a reciprocating pump with a long "dipper rod" is used.



- **Figure 6 Mechanical and wind-electric water-pumping wind systems.**

Modern Small Wind Turbines: High Tech, High Reliability, Low Maintenance

- Technically Advanced
- Only 2-3 Moving Parts
- Very Low Maintenance Requirements
- Proven: ~ 5,000 On-Grid
- American Companies are the Market and Technology Leaders

(Not to scale)

Off-Shore Wind Farms

CONCLUSION

This is true that today's world need more clean and more cheap energy. As I try to mentioned in this project wind energy is the one of the best way of clean and cheap energy. And also it is understood that in the future most of our energy source will based on wind energy.

- The costs for a utility scale wind turbine range from about **$1.3 million** to **$2.2 million** per MW of nameplate capacity installed. Most of the commercial-scale turbines installed today are 2 MW in size and cost roughly $3-$4 million installed

- According to the federal Energy Information Administration, the "levelized cost" of new wind power (including capital and operating costs) is **8.2 cents** per kWh. Advanced clean-coal plants cost about **11 cents** per kWh, the same as nuclear. But advanced natural gas-burning plants come in at just**6.3 cents** per kWh.

- Globally, onshore wind schemes are now costing an average of $0.06 per kilowatt hour (kWh), although some schemes are coming in at **$0.04** per KwH, while the cost of solar PV is down to $0.10 per KwH.

vg. US Installed Capital Costs - 2017 (NREL)	Cost Per Watt (DC)
Residential Rooftop	**$2.80**
Large Commercial	**$1.85**
Utility Scale (Fixed)	**$1.03**