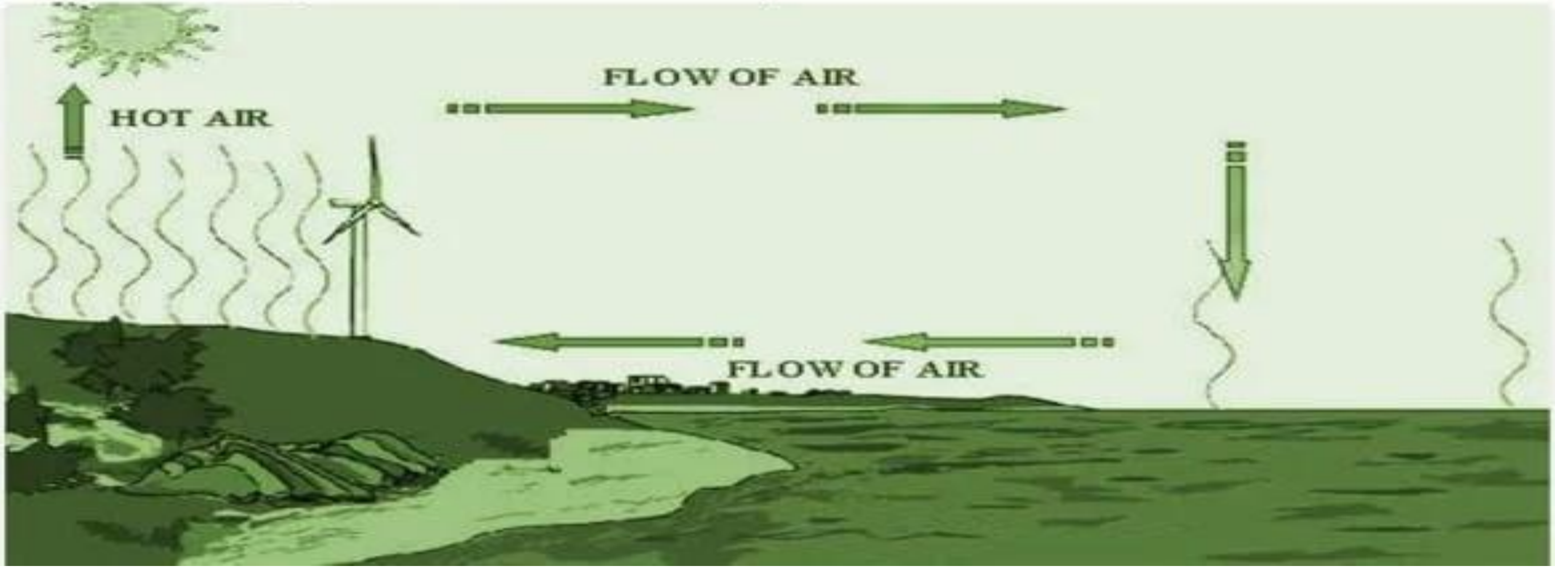
Introduction to wind energy

Wind is simply defined as moving air. When the earth heats up from sunrays it releases wind, this is a balanced reaction meant to cool the earth. The sun heat is felt more on dry land than on the sea. The air expands and easily reaches maximum high altitudes, then cool air drops down and moves as wind.



How do you convert wind into electricity???

Wind turbines convert **the kinetic energy** in the wind into **mechanical power.**
This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

A wind turbine works the opposite of a fan.
Instead of using electricity to make wind, like a fan, wind turbines use **wind to make electricity**. The wind turns the blades, which spin a shaft, which connects to a generator and makes elec

The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.
Wind turbines are mounted on a tower to capture the most energy. At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind.

Basic Principles of Wind Energy Conversion

1. The Nature of Wind

The circulation of air in the atmosphere is caused by the non-uniform heating of the earth's surface by the sun. The air immediately above a warm area expands, it is forced upward by cool, denser air which flows in from surrounding areas causing wind.

The nature of the terrain, the degree of cloud and the angle of the sun in the sky are all factors which influences this process.

In general, during the day the air above the land mass tends to heat up more rapidly than the air over water. In coastal regions this manifests itself in a strong onshore wind. At night the process is reversed because the air cools down more rapidly over the land and the breeze therefore blows off shore.

Despite the wind's intermittent nature, wind patterns at any particular site remain remarkably constant year by year. Average wind speeds are greater in hilly and costal area than they are well inland. The winds also tend to blow more consistently and with greater strength over the surface of the water where there is a less surface drag.

2. The Power in Wind

Wind possesses energy by virtue of its motion. Any device capable of slowing down the mass of moving air, like a sail or propeller, can extract part of the energy and convert is into useful work.

There are three factors determine the output power generated from the wind mill, they are

(1) The wind speed
(2) The cross section of wind swept by rotor, and
(3) The overall conversion efficiency of rotor, transmission system and generator or pump.

No device, however well-designed, can extract all of the wind's energy because the wind would have to be brought to a halt and this would prevent the passage of more air through the rotor. The most that is possible is for the rotor to decelerate to whole horizontal column of intercepted air to about one-third of its free velocity.

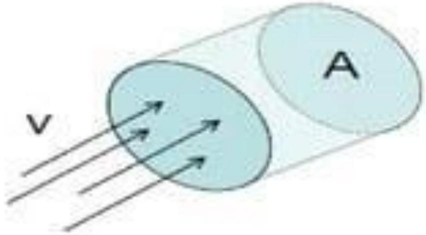
A 100% efficient aerogenerator would therefore only be able to convert up to a maximum of around 60% of the available energy in wind into mechanical energy.

Power in the Wind

Fundamental Equation of Wind Power

- Wind Power depends on:
  - amount of air (volume)
  - speed of air (velocity)
  - mass of air (density)

  flowing through the area of interest (flux)



$\dot{m} = \frac{dm}{dt}$ mass flux

- **Kinetic Energy** definition:
  - $KE = \frac{1}{2} * m * v^2$
- Power is KE per unit time:
  - $P = \frac{1}{2} * \dot{m} * v^2$
- Fluid mechanics gives **mass flow rate** (density * volume flux):
  - $dm/dt = \rho * A * v$
- Thus:
  - $\boxed{P = \frac{1}{2} * \rho * A * v^3}$ $\Rightarrow$

- Power ~ cube of velocity
- Power ~ air density
- Power ~ rotor swept area $A = \pi r^2$

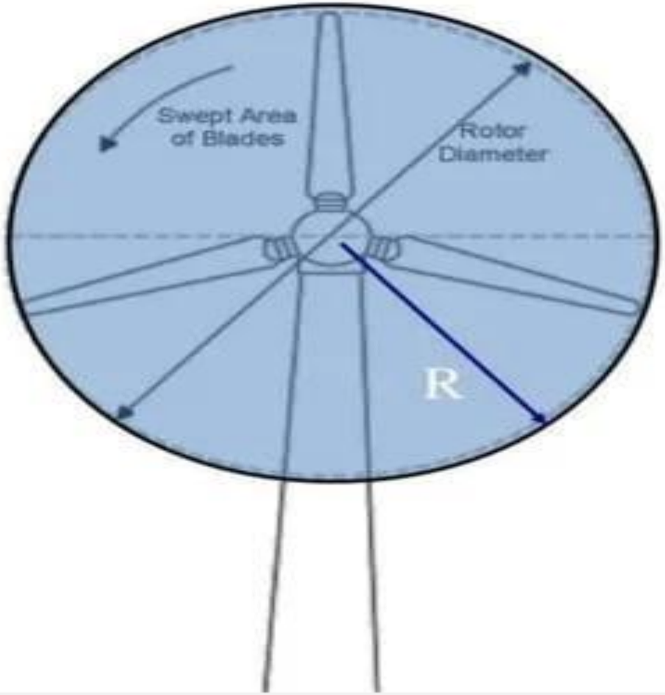
POWER IN WIND

- Wind mill works on the principle of converting kinetic energy of the wind to mechanical energy.
- Kinetic energy = $\frac{1}{2}\rho AV^3$ watts

  Which gives us the maximum wind available.
- This equation also tells us that power available is proportional to air density.
- It may vary 10-15 percent during the year because of P and T change.
- Available wind power $P_a = \frac{1}{8}\rho\pi D^2V^3$

Power in the Wind = $\frac{1}{2}\rho A V^3$

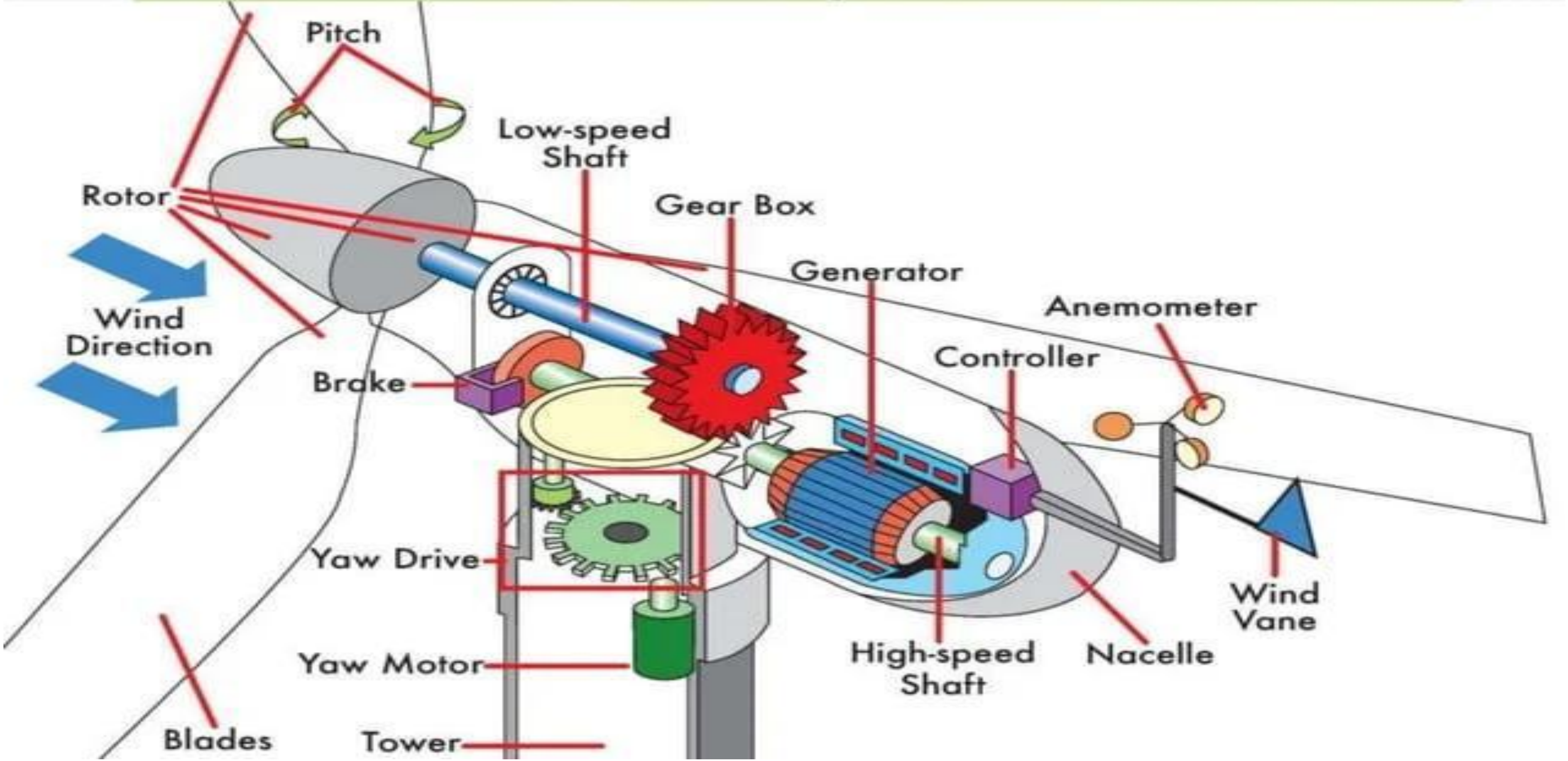
- Effect of swept area, A
- Effect of wind speed, V
- Effect of air density, ρ



Swept Area: $A = \pi R^2$ Area of the circle swept by the rotor (m^2).

Components of wind turbine

Main components



The tower

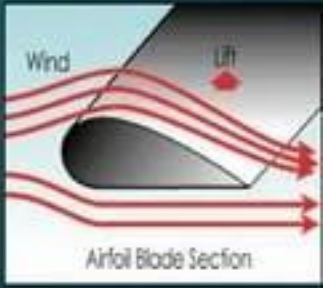
- The most common tower design is a white steel cylinder, about 150 to 200 feet (45 to 60 m) tall and 10 feet (3 m) in diameter.
- Some turbines use a lattice tower, like the Eiffel tower.
- Towers have a ladder running up the inside and a hoist for tools and equipment.

The blades

The blades of the wind turbines are designed in two different ways:

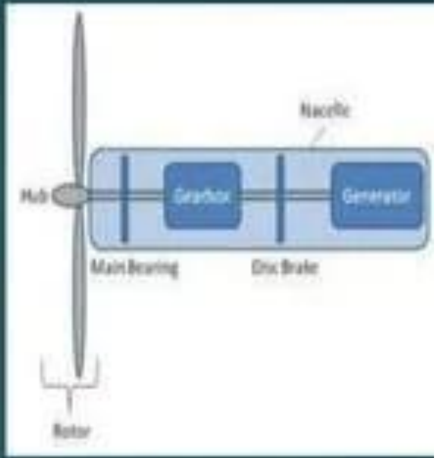
Drag type: The wind literally pushes the blades out of the way. Slower rotational speeds and high torque capabilities. Useful for providing mechanical work (water pumping).

Lift type: Most modern HAWT use this design.
Both sides of the blade has air blown across it resulting in the air taking longer to travel across the edges.
In this way lower air pressure is created on the leading edge of the blade, and higher air pressure created on the tail edge.
Because of this pressure difference the blade is pushed and pulled around, creating a higher rotational speed that is needed for generating electricity.



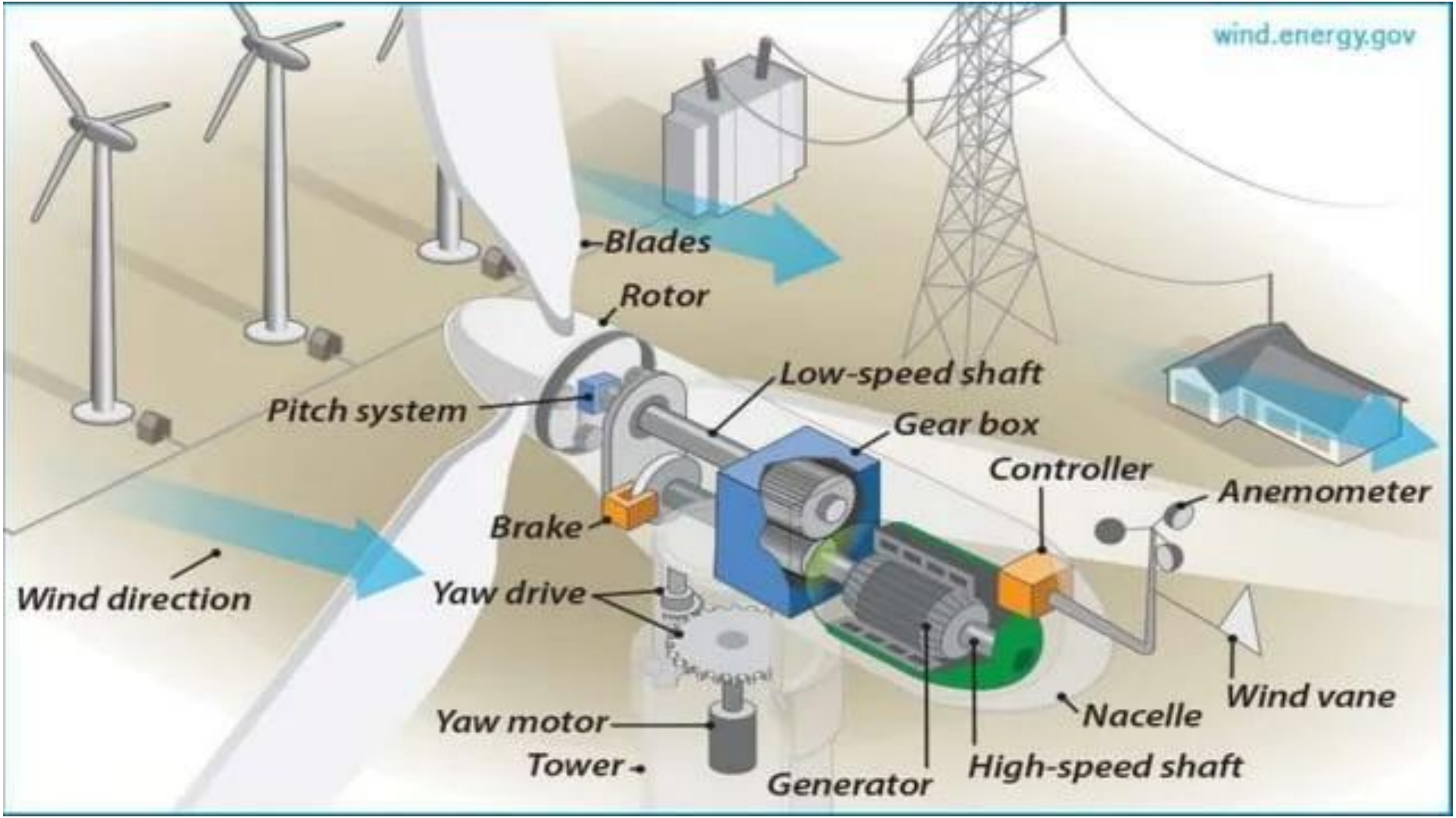
The nacelle

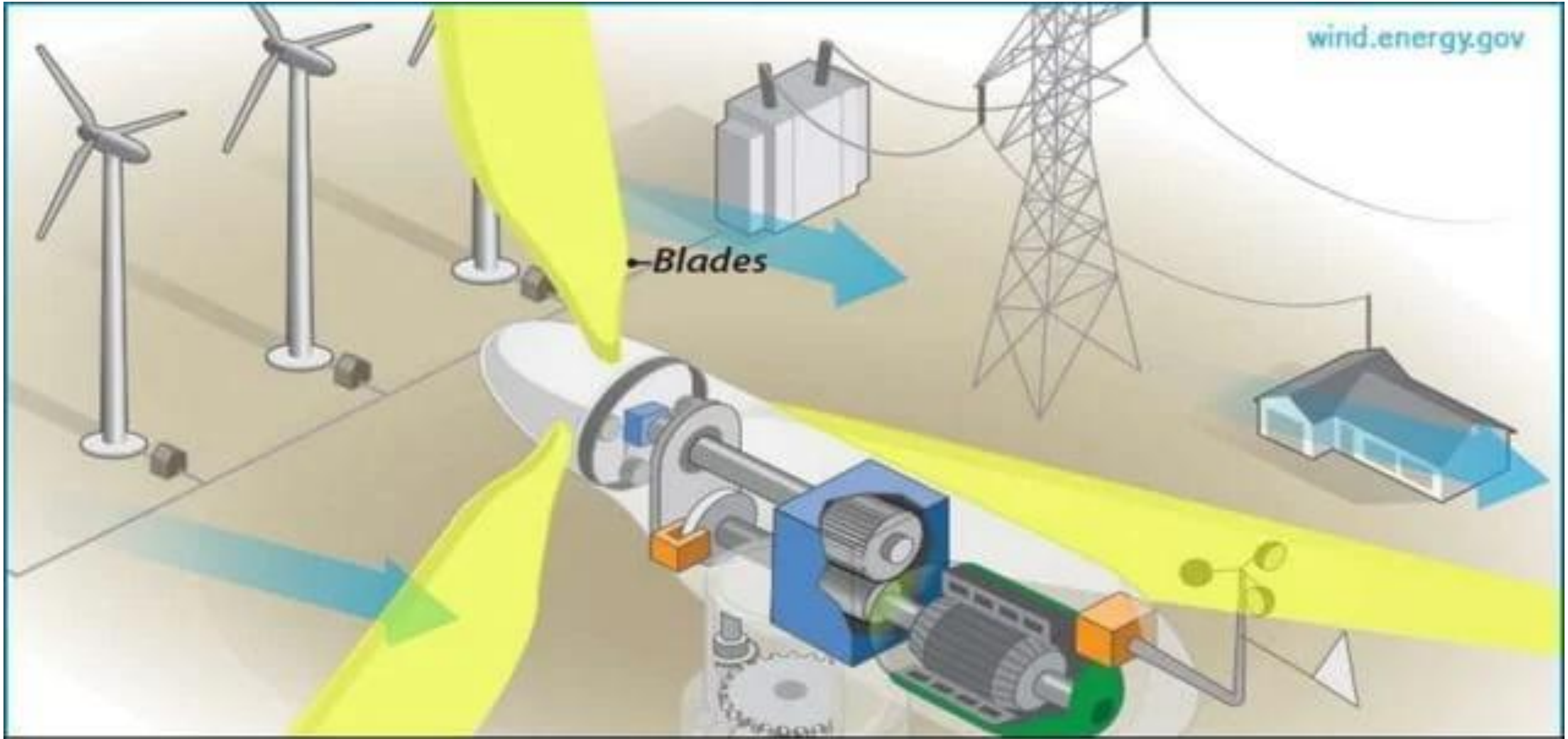
- The nacelle houses a generator and gearbox.
- The spinning blades are attached to the generator through a series of gears.
- The gears increase the rotational speed of the blades to the generator speed of over 1,500 RPM.
- As the generator spins, electricity is produced.
- Generators can be either variable or fixed speed:



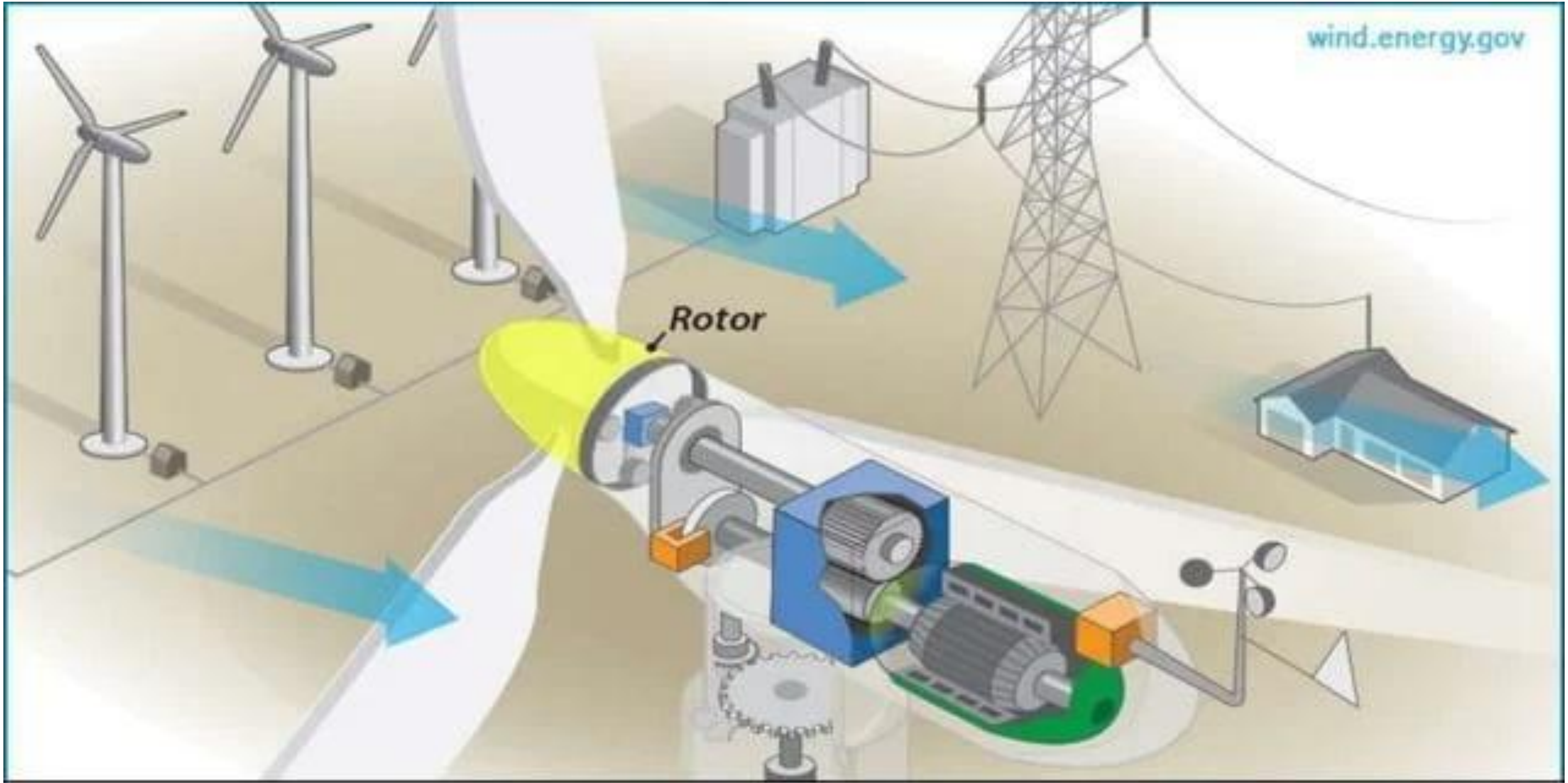

SIEMENS

Inside the tower

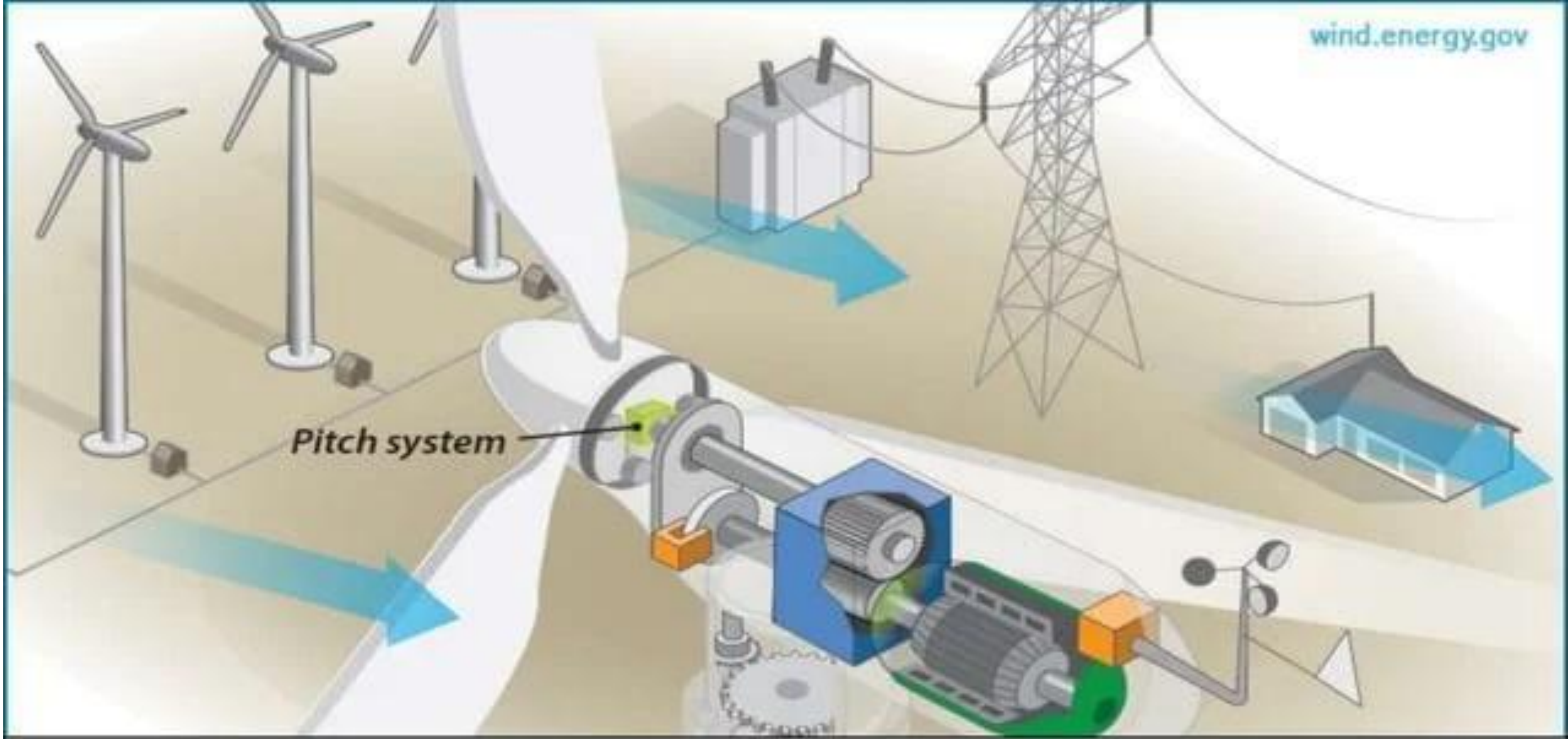

wind.energy.gov
Blades
Rotor
Low-speed shaft
Pitch system
Gear box
Controller
Anemometer
Brake
Wind direction
Yaw drive
Yaw motor
Tower
Generator
High-speed shaft
Nacelle
Wind vane



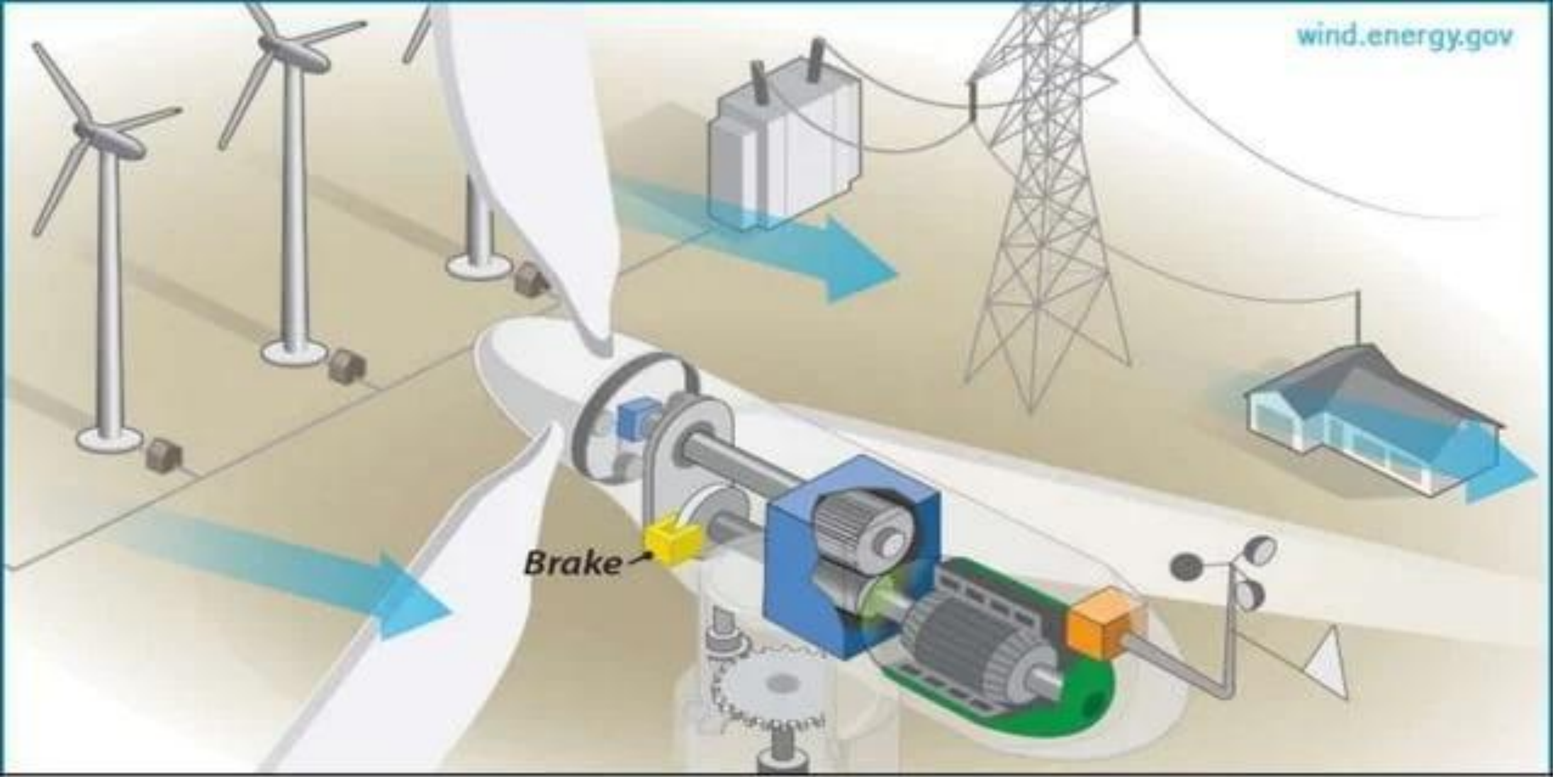
Blades:
Lifts and rotates when wind is blown over them, causing the rotor to spin. Most turbines have either two or three blades.



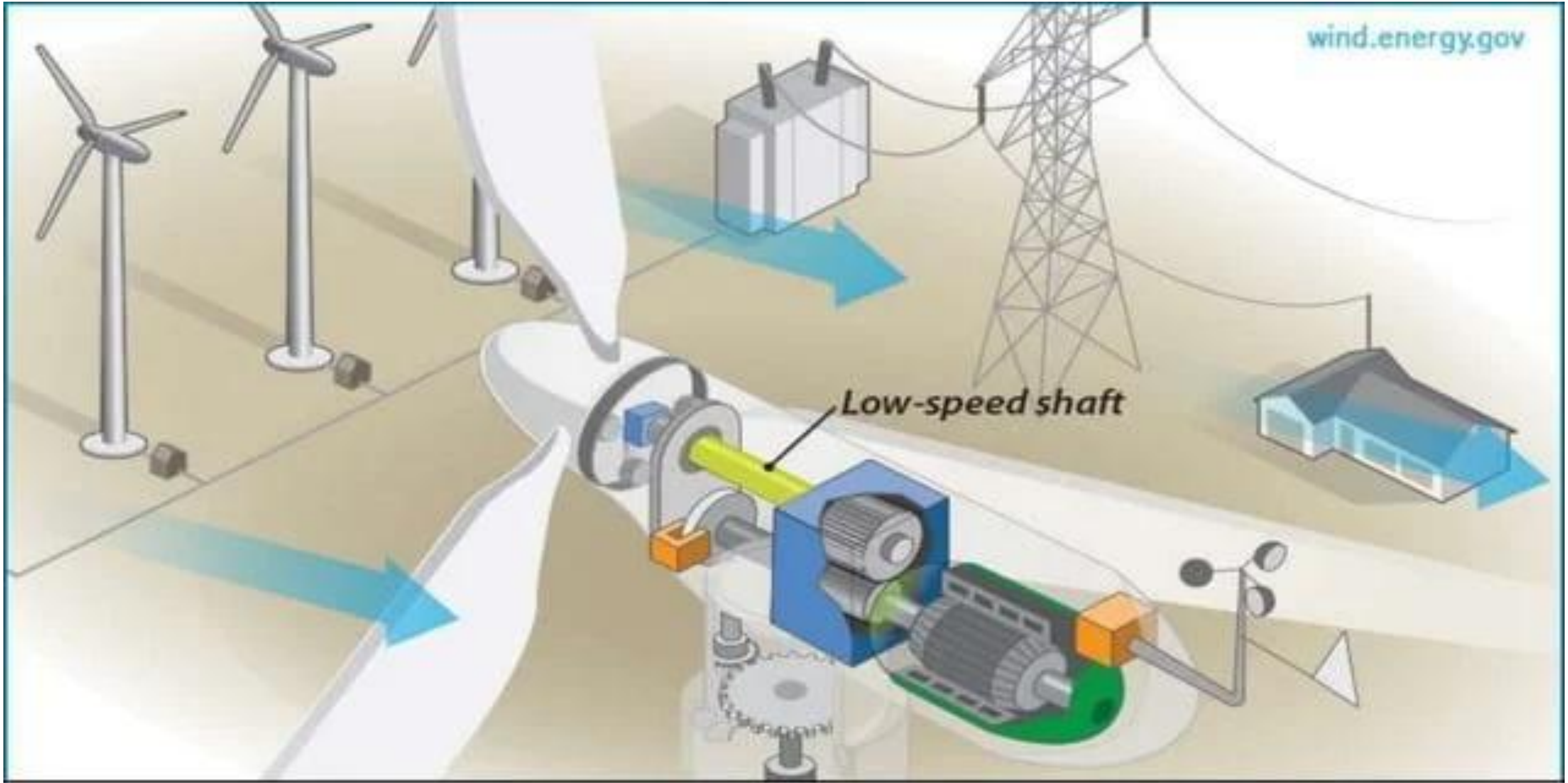
Rotor:
Blades and hub together form the rotor.



Pitch:
Turns (or pitches) blades out of the wind to control the rotor speed, and to keep the rotor from turning in winds that are too high or too low to produce electricity.

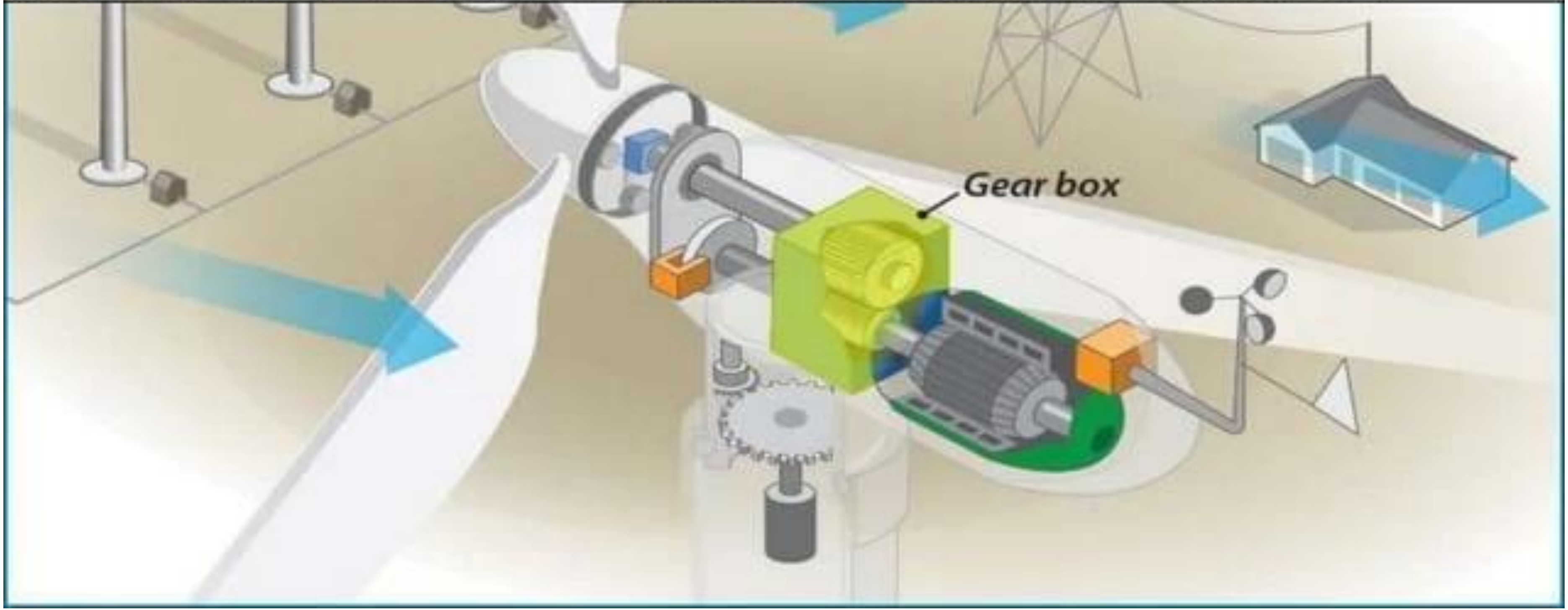


Brake:
Stops the rotor mechanically, electrically, or hydraulically, in emergencies.

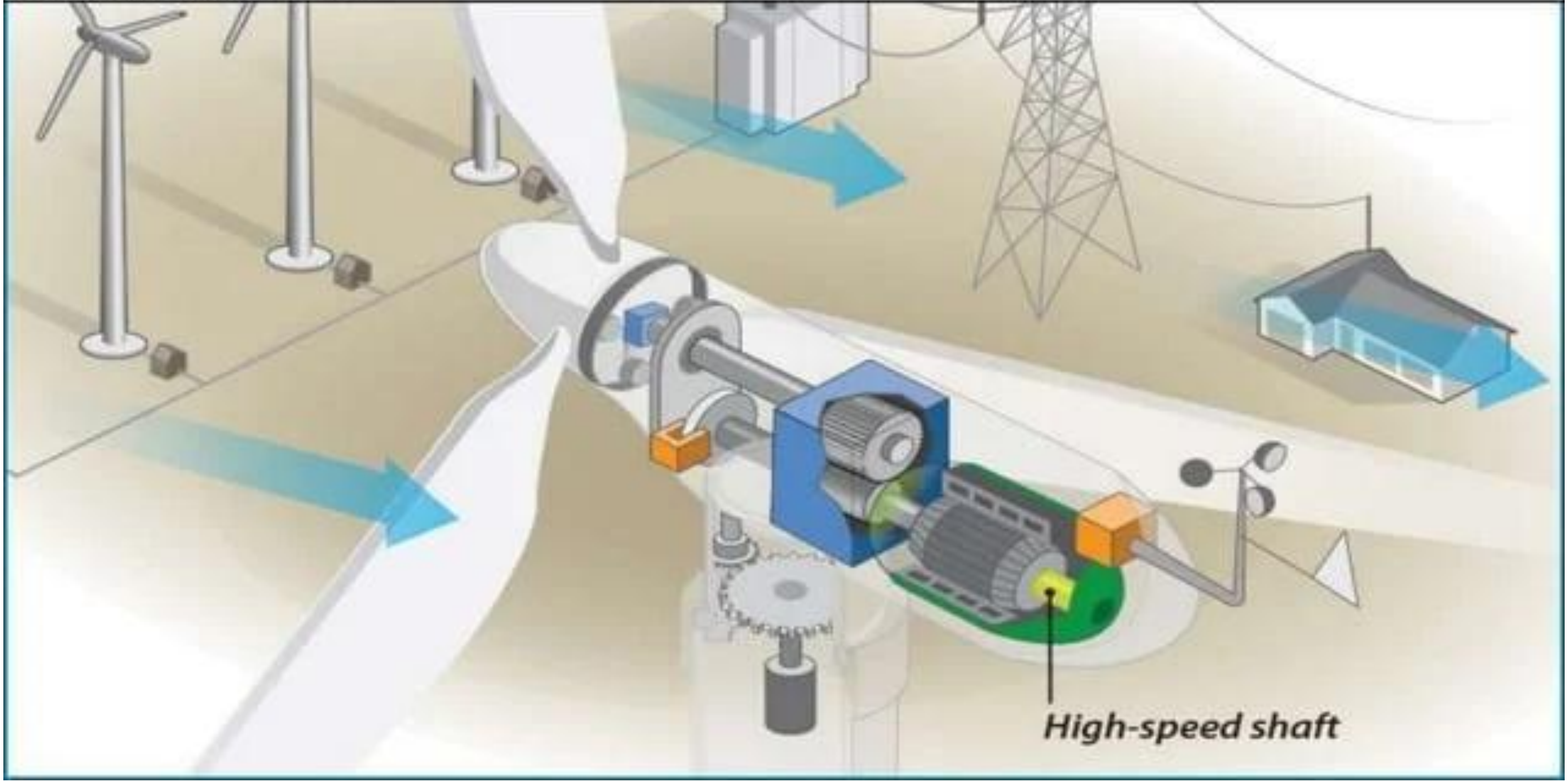


Low-speed shaft:
Turns the low-speed shaft at about 30-60 rpm.

Gear box:
Connects the low-speed shaft to the high-speed shaft and increases the rotational speeds from about 30-60 rotations per minute (rpm), to about 1,000-1,800 rpm; this is the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and don't need gear boxes.



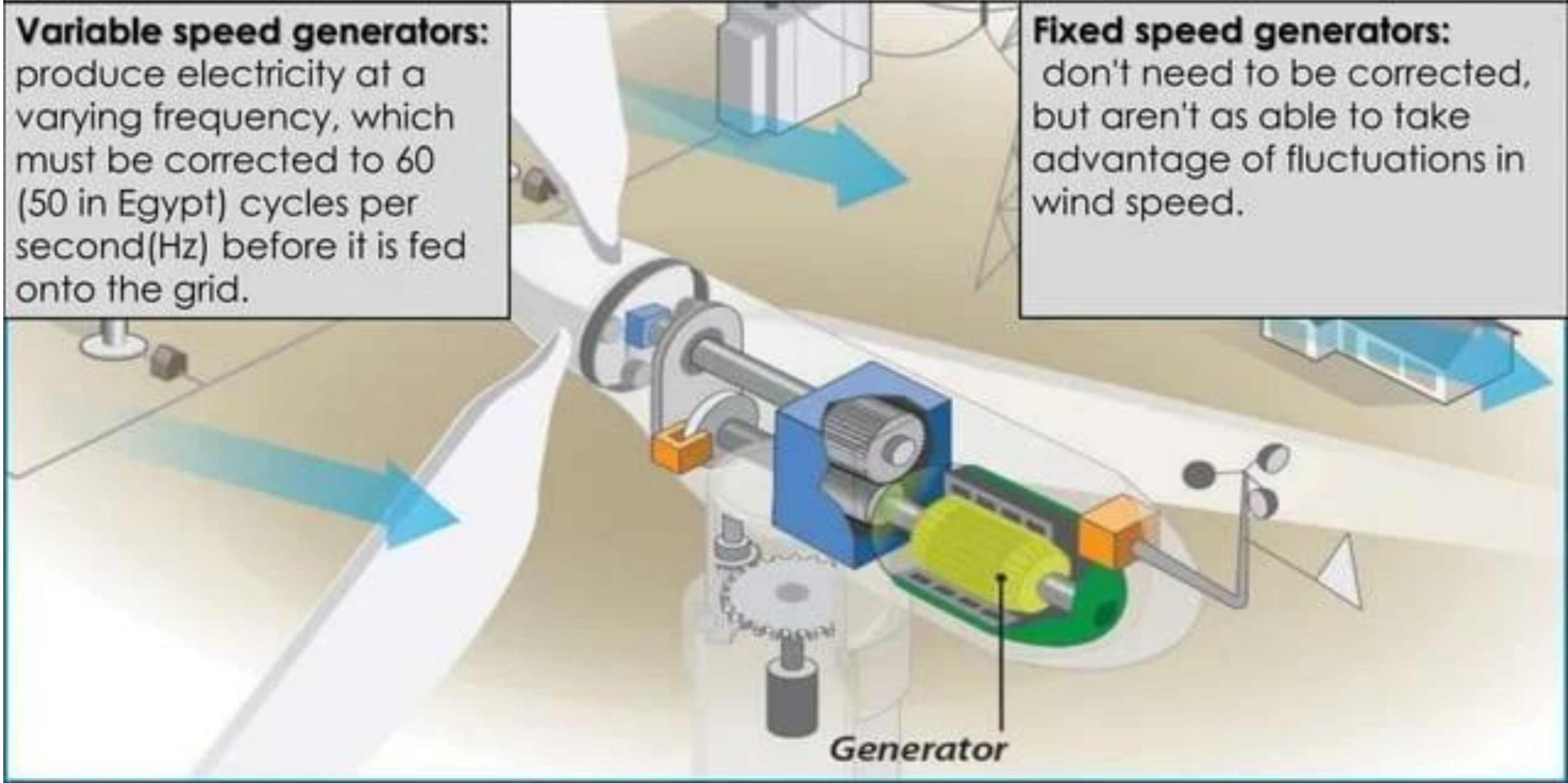
High-speed shaft:
Drives the generator.



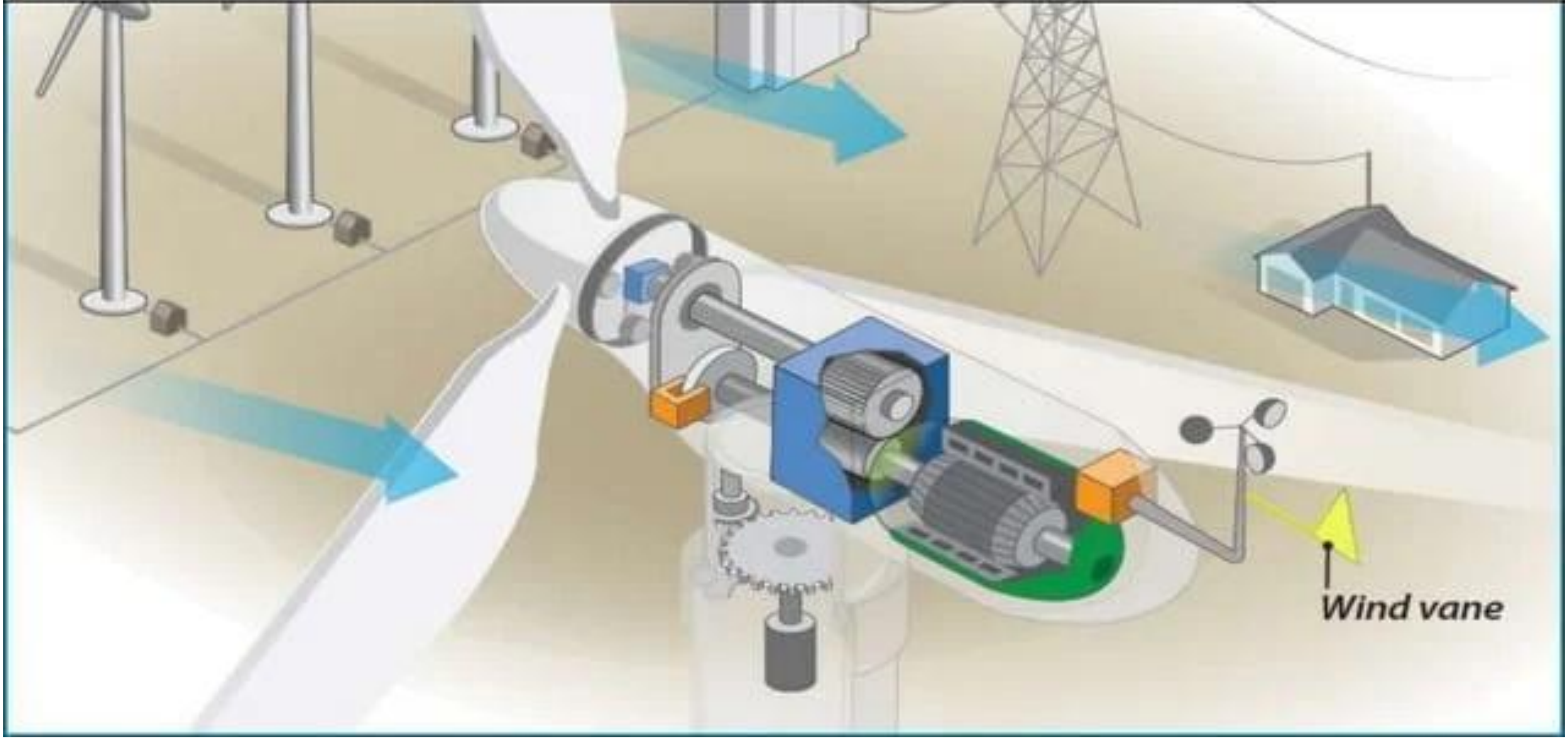
Generator:
Produces 50-cycle AC electricity.

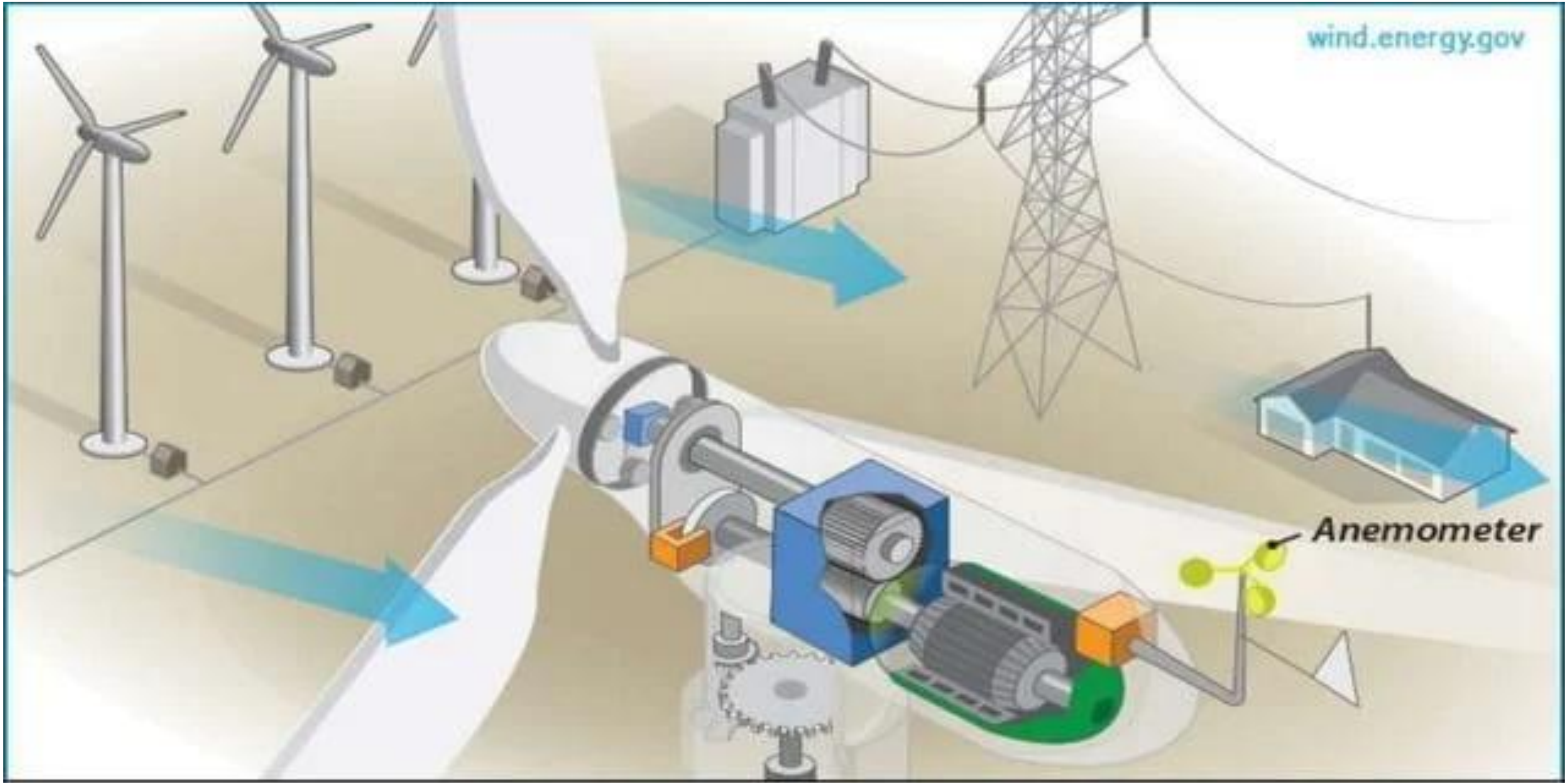
Variable speed generators: produce electricity at a varying frequency, which must be corrected to 60 (50 in Egypt) cycles per second(Hz) before it is fed onto the grid.

Fixed speed generators: don't need to be corrected, but aren't as able to take advantage of fluctuations in wind speed.

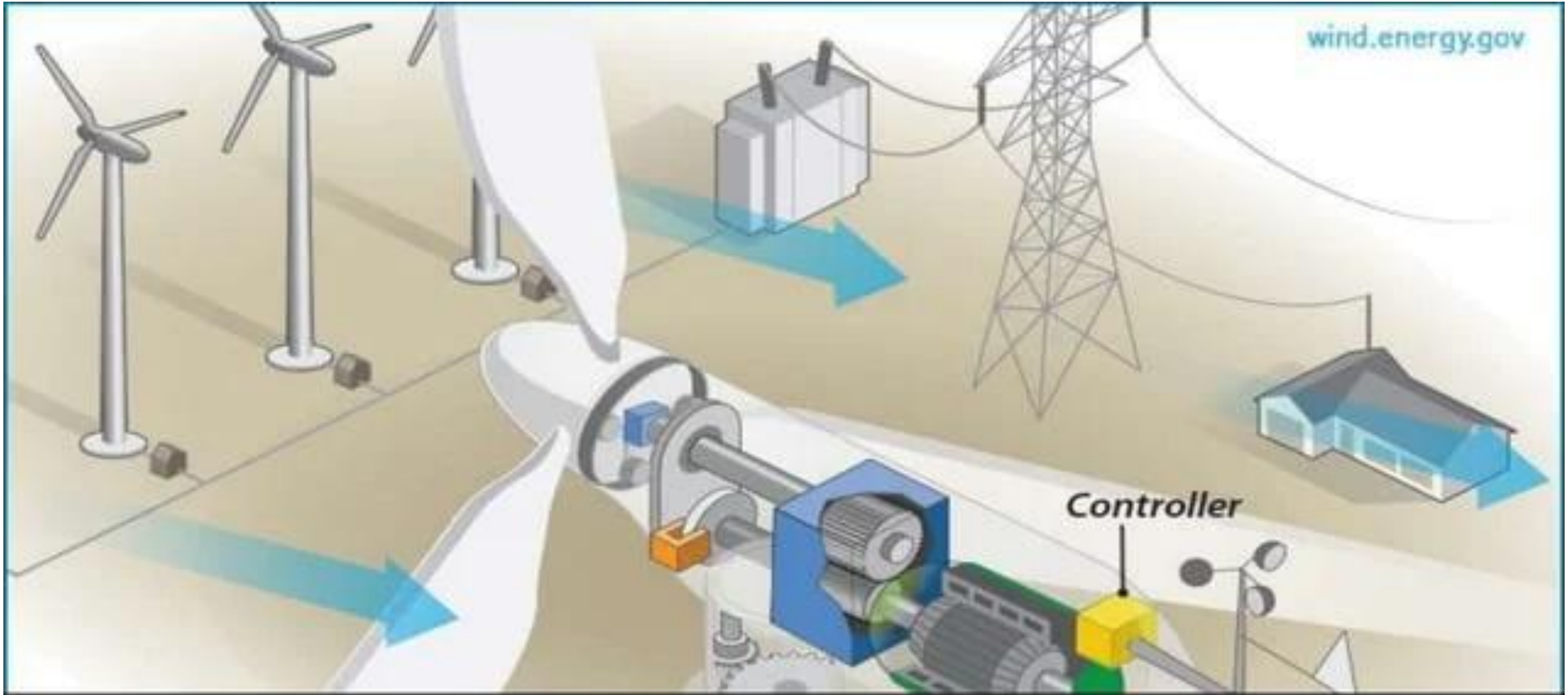


Wind vane:
Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.





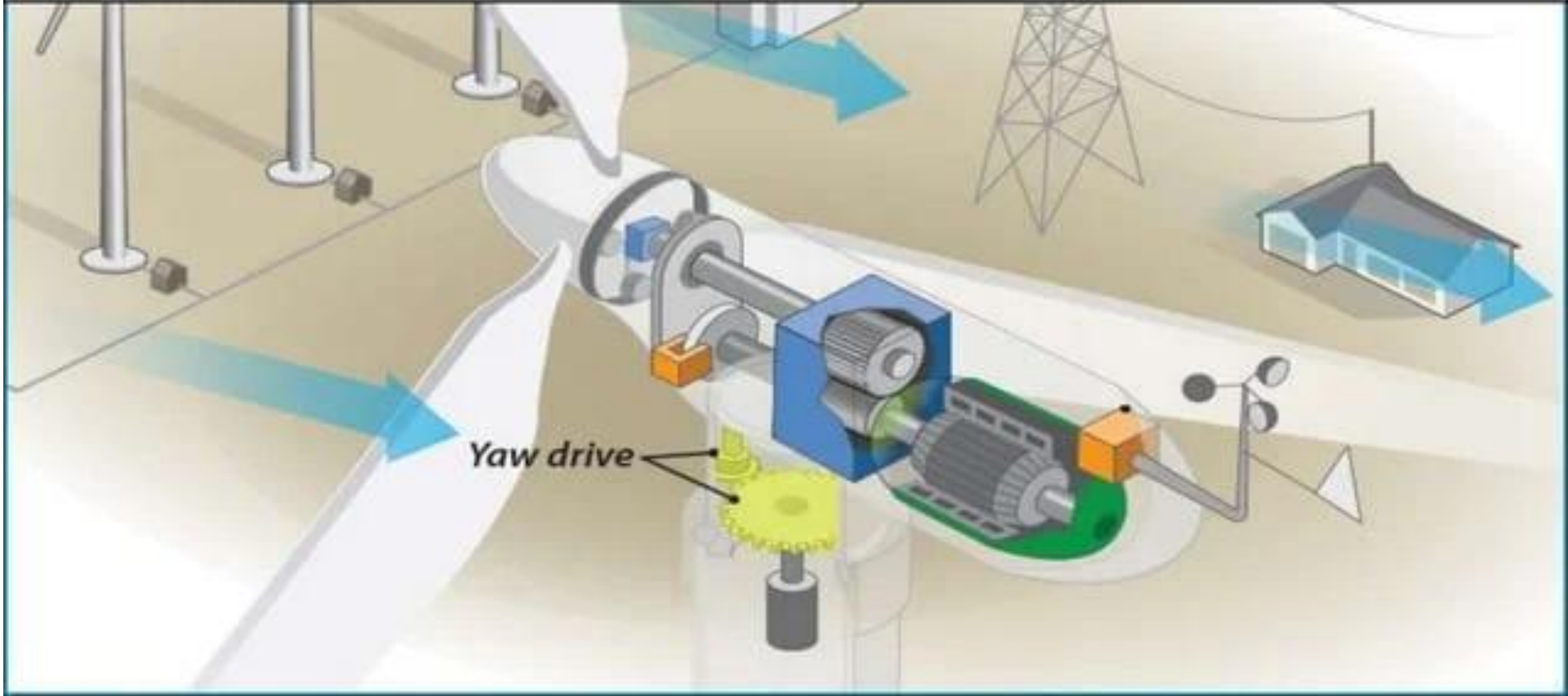
Anemometer:
Measures the wind speed and transmits wind speed data to the controller.



Controller:
Starts up the machine at wind speeds of about 8 to 16 miles per hour (mph)(5-10)km/h and shuts off the machine at about 55 mph(34 km/h). Turbines do not operate at wind speeds above about 34 km/h because they may be damaged by the high winds.

Yaw drive:

Orients upwind turbines to keep them facing the wind when the direction changes. Downwind turbines don't require a yaw drive because the wind manually blows the rotor away from it.



Basics of Wind Energy System At A Glance

$$P_{mech} = \frac{1}{2}\rho A v^3$$

$$P_{net} = \frac{1}{2}\rho A C_P(\lambda, \beta) v^3$$

$$Tturbine = \frac{1}{2}\rho A Cp \frac{V}{\lambda}$$

No wind turbine could convert more than **59.2%** of the kinetic energy of the wind into mechanical energy turning a rotor.

- P_{mech} = Power developed by Wind turbine
- P_{net} = Net power developed by Wind turbine
- T=Torque produced by Wind turbine
- C_P=The power-coefficient
- ρ=Air density=1.225 kg/m^3
- A=Area of wind turbine blades in m^2
- V=Velocity of Wind
- T=Output torque N.m
- λ = Tip Speed Ratio (TSR)

Terms related to Wind Energy

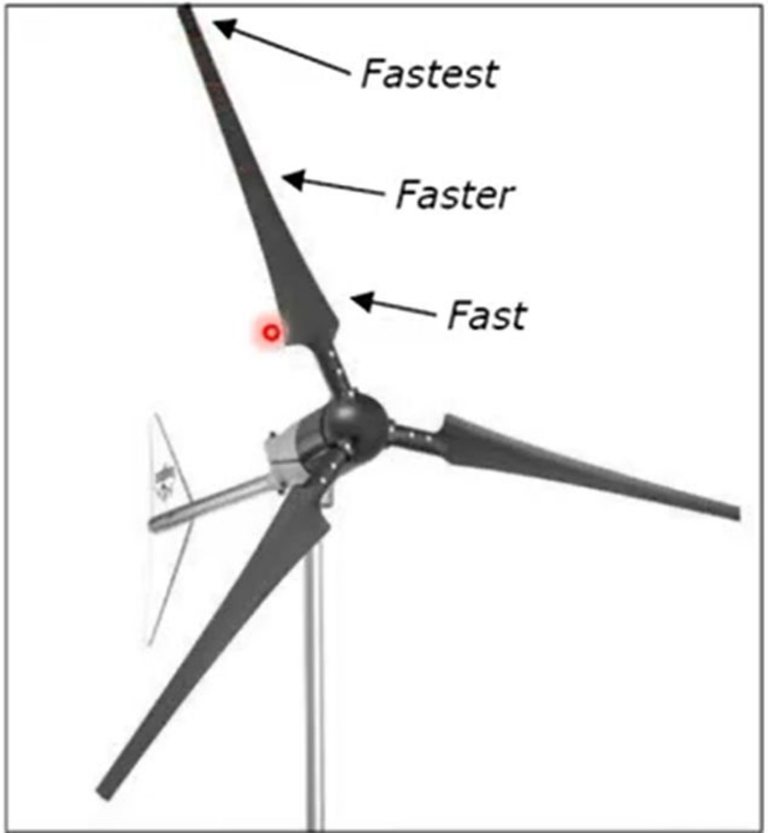
- **Cut-in wind speed**: the speed at which the wind turbine starts to operate.
- **Cut-out wind speed**: is the wind speed where the wind turbine stops production and turns out of the main wind direction.
- **Tip Speed Ratio**: TSR is the speed of the blade at its tip divided by the speed of the wind.
- **The design wind speed**: when the windmill reaches its maximum efficiency.
- **The rated wind speed**: when the machine reaches its maximum output power.

Tip Speed Ratio (TSR)

- By definition, TSR is the speed of the blade at its tip divided by the speed of the wind.
- For example, if the tip of a blade is traveling at 100 mph (161 kph) and the wind speed is 20 mph (32 kph or 9 m/s), then the TSR is 5 (100 mph/20 mph). Simply put, the tip of the blade is traveling five times faster than the speed of the wind.
- Wind Turbines Tip Speed Ratio - SixtySec.mp4

Importance of TSR

- If the rotor of the wind turbine spins too slowly, most of the wind will pass straight through the gap between the blades, therefore giving it no power! But if the rotor spins too fast, the blades will blur (make or become less distinct) and act like a solid wall to the wind.

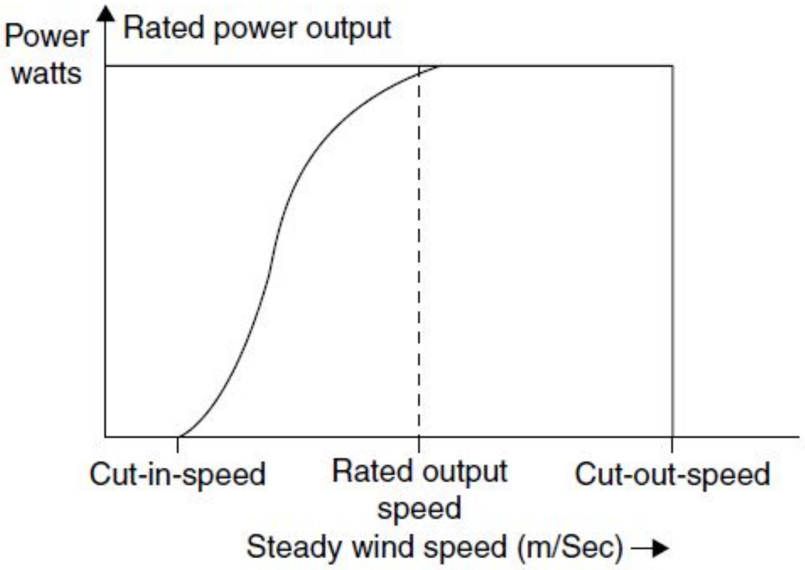


The further away from the center, the faster the blades spin.

There are five important characteristic wind speeds and they are as follows:

1. Start-up speed is the speed at which the rotor and blade assembly begin to rotate.
2. The cut-in wind speed is the speed when the machine begins to produce power.
3. The design wind speed is the speed when the windmill reaches its maximum efficiency.
4. The rated wind speed is the speed when the machine reaches its maximum output power.
5. The furling wind speed is the speed when the machine furls to prevent damage at high wind speeds.

Wind turbine power output with steady wind speed



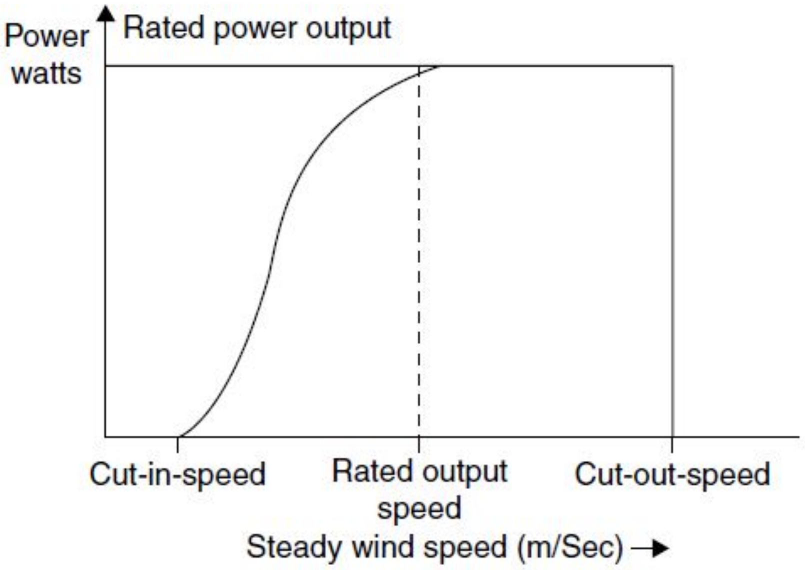
Cut-in speed is the minimum wind speed at which the wind turbine will generate usable power.

This wind speed is typically between 7 and 10 mph for most turbines. At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate.

However, as the speed increases, the wind turbine will begin to rotate and generate electrical power.

The speed at which the turbine first starts to rotate and generate power is called the cut-in speed and is typically between 3 and 4 m/s.

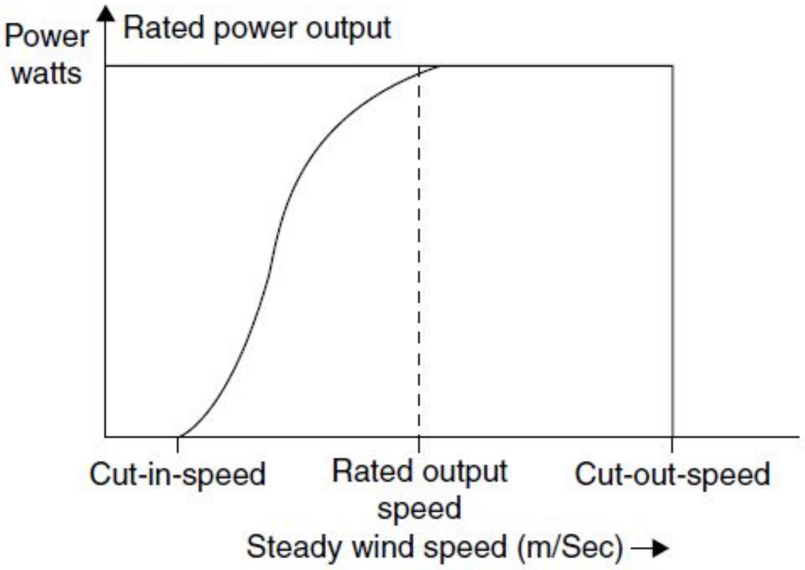
Wind turbine power output with steady wind speed



Rated speed At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs, called 'power curves,' showing how their wind turbine output varies with wind speed.

Typically somewhere between 12 m/s and 17 m/s, the power output reaches the limit that the electrical generator is capable of. This limit to the generator output is called the rated power output and the wind speed at which it is reached is called the rated output wind speed.

Wind turbine power output with steady wind speed



Cut-out speed At very high wind speeds, usually around 25 m/s, most wind turbines cease power generation and shutdown. The wind speed at which the shutdown occurs is called the cut-out speed, or sometimes the furling speed.

Having a cut-out speed is a safety feature that protects the wind turbine from damage. Shutdown may occur in one of the several ways.

In some machines, an automatic brake is activated by a wind speed sensor. Some machines twist or ‘pitch’ the blades to spill the wind.

Blade Materials

- ✔ Wood and canvas sails were used on early windmills due to their low price, availability, and
- ✔ ease of manufacture.
- ✔ Wood and canvas construction limits the airfoil shape to a flat plate, which has a relatively high ratio of drag to force captured (low aerodynamic efficiency) when compared to solid airfoils.
- ✔ The constructions of solid airfoil designs require inflexible materials such as metals or composites.
- ✔ Small blades can be made from light metals such as aluminium.
- ✔ New wind turbine designs push power generation from the single megawatt range to upwards of 10 MW using very large blades

Blade Design :

Computer-aided engineering software such as **HyperSizer** (originally developed for spacecraft design) can be used to improve blade design.

The current production of wind turbine blades is as large as 100 m in diameter with prototypes in the range of 110−120 m.

In 2001, an estimated 50,000,000 kg of fiberglass laminate were used in wind turbine blades.

Proven fiberglass composite fabrication techniques are used in manufacturing blades in the 40−50 m range.
Each technique use a glass fibre reinforced polymer composite materials constructed with different complexities

Blade Materials:

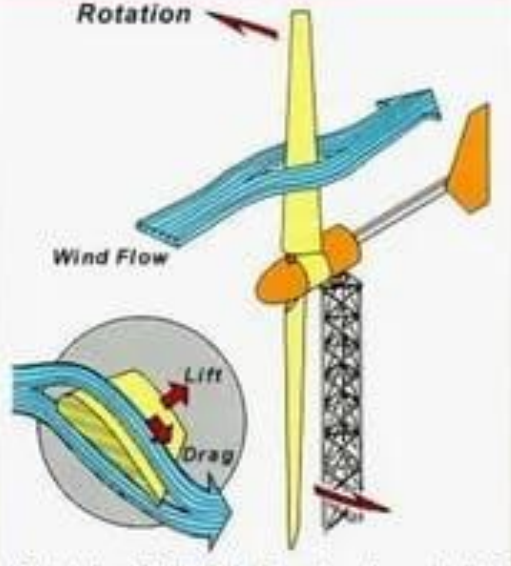
- ✔ Pre-impregnated materials and resin infusion techniques avoid the release of volatiles by containing all reaction gases.

- ✔ Epoxy-based composites have environmental, production, and cost advantages over other
- ✔ resin systems.
- ✔ Carbon fibre-reinforced spars for load bearing can reduce weight and increase
- ✔ stiffness.
- ✔ Using carbon fibres in 60 m turbine blades is estimated to reduce total blade mass by
- ✔ 38% and decrease the cost by 14% when compared to 100% fiberglass.

- ✔ Carbon fibres have the added benefit of reducing the thickness of fiberglass laminate sections and also solves the problems associated with resin wetting of thick lay-up sections.

- ✔ Wind turbines may also benefit from the general trend of increasing use and decreasing cost of carbon fibre materials.

LIFT AND DRAG : THE BASIS FOR WIND ENERGY CONVERSION

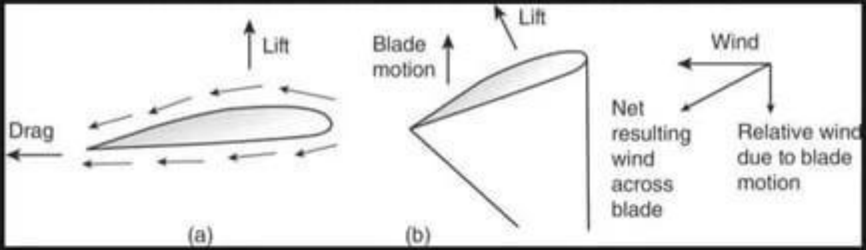


Principles of Wind Turbine Aerodynamic Lift

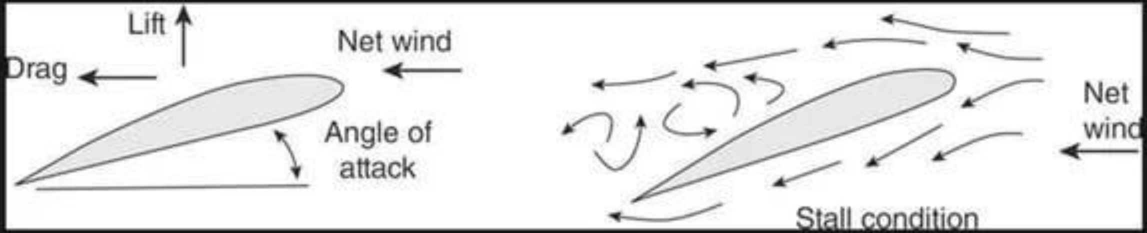
- Two primary mechanisms for producing forces : lift and drag
- Lift - perpendicular to the air flow
- Drag – parallel to the flow
- Airfoil – pressure difference produces a force that begins to act on high P side and moves towards low P side of the lifting surface
- Stalling- lift decrease, drag increases

➢Forces on the blade power in the wind

Turbine Blade – an Air Foil



(a) Lift in wing (b) wind turbine blade forces



Increasing the angle of attack can cause a wing to stall

Types of wind turbine

1. Horizontal axis type

A horizontal axis machine has its blades rotating on an axis parallel to the ground.

Single blade Horizontal wind turbine	Two blades Horizontal wind turbine	Three blades Horizontal wind turbine
Lower blade weight and less cost.	Similar to single blade HAWT.	Balance of gyroscopic forces
More vibration & unconventional look.	Have stability problem	increases gearbox costs
		

Types of wind turbine

2. Vertical axis type

Vertical axis wind turbines(VAWTs) have the main rotor shaft arranged vertically.
VAWTs runs in any wind direction.

Darrieus wind turbine	Savonius wind turbine
Good efficiency Produce large torque and cyclic stress on the tower Require some external power source to start turning 	drag type turbine used in cases of high reliability in many things such as ventilation and anemometers. self starting less efficient 

Horizontal axis wind turbine

- More popular
- The axis of the rotor's **rotation is parallel** to the wind stream and the ground.
- Most HAWTs today are **two- or three-bladed, though some may have fewer or more blades.**

Horizontal axis wind turbine

There are two kinds of Horizontal Axis Wind Turbines:

1. Upwind wind turbine
2. Downwind wind turbine.

Advantages of Horizontal axis wind turbine

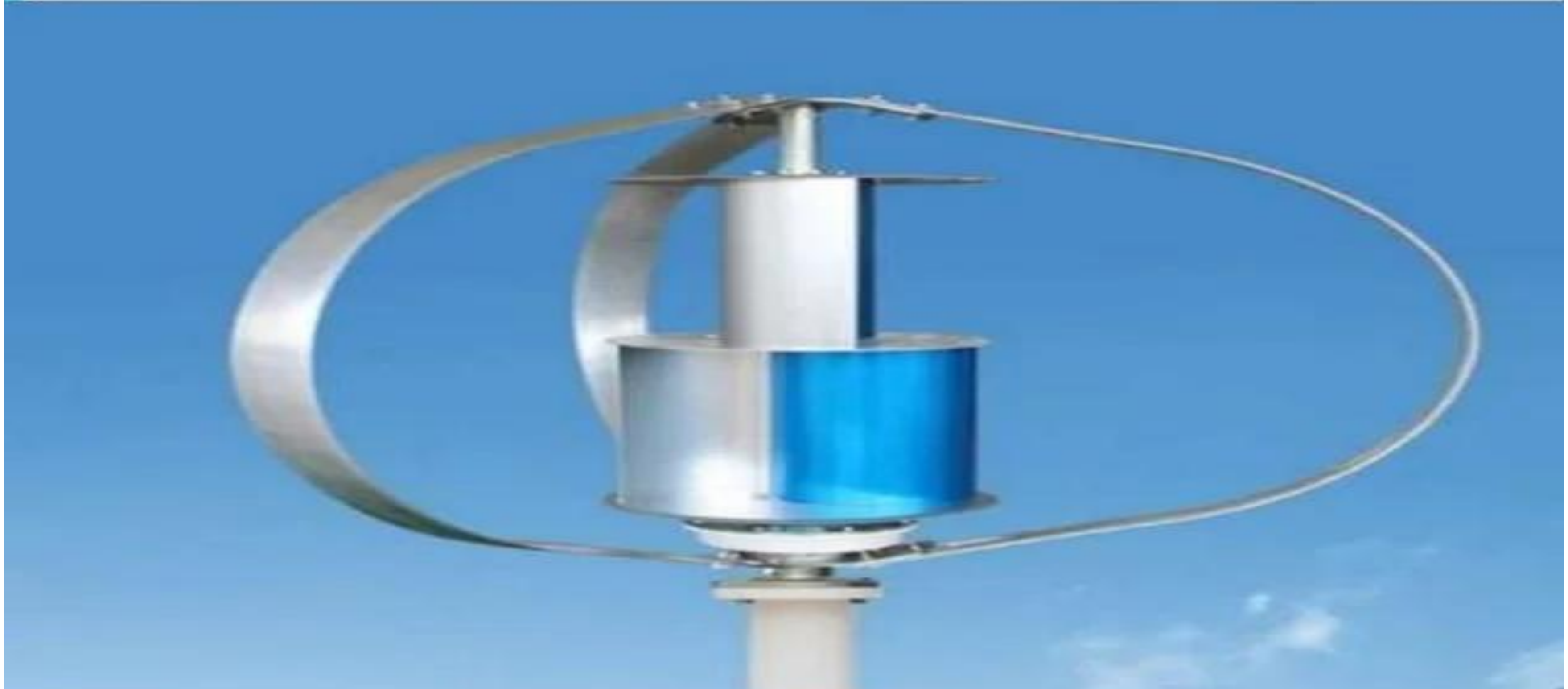
- Higher stability
- The turbine collects the maximum amount of wind energy
- The ability to pitch the rotor blades in a storm so that damage is minimized
- The tall tower allows the access to stronger wind
- Self-starting
- Cheaper because of higher production volume

Disadvantages of Horizontal axis wind turbine

- It has difficulties operating near the ground
- The tall towers and long blades
- Hard to transport from one place to another
- They need a special installation procedure
- They can cause a navigation problem when placed offshore

Vertical axis wind turbine

Vertical axis wind turbine



Vertical axis wind turbine

- The vertical axis wind turbine is an old technology, dating back to almost 4,000 years ago.
- The rotor of the VAWT rotates vertically around its axis
- This is not as efficient as a HAWT,

Vertical axis wind turbine

- This does offer benefits in low wind situations wherein HAWTs have a hard time operating.
- It tends to be easier and safer to build,
- This can be mounted close to the ground and handle turbulence better than the HAWT.
- its maximum efficiency is only 30%,

Differentiate between Horizontal and Vertical Axis Wind Turbine	07 04	JUNE-2015,DEC-2015 JUNE-2017, NOV-2017

Horizontal Axis	Vertical Axis
1. Major components at height	1. Major components at ground level
2. Rotating Speed -High	2. Rotating Speed -Low
3. Maintenance- High	3. Maintenance- Low
4. Cable standing Problem	4. No Cable standing Problem
5. Less life span	5. Long Life Span
6. Installation cost is High	6. Installation cost is Low
7. It run on high wind speed	7. It can run on lower wind speed
8. High tip to wind speed ration so high power output	8. Low tip to wind speed ration so low power output
9. Starting torque is less	9. Starting torque is high
10.Rotation is parallel to the wind direction.	10. Rotation is perpendicular to the wind direction

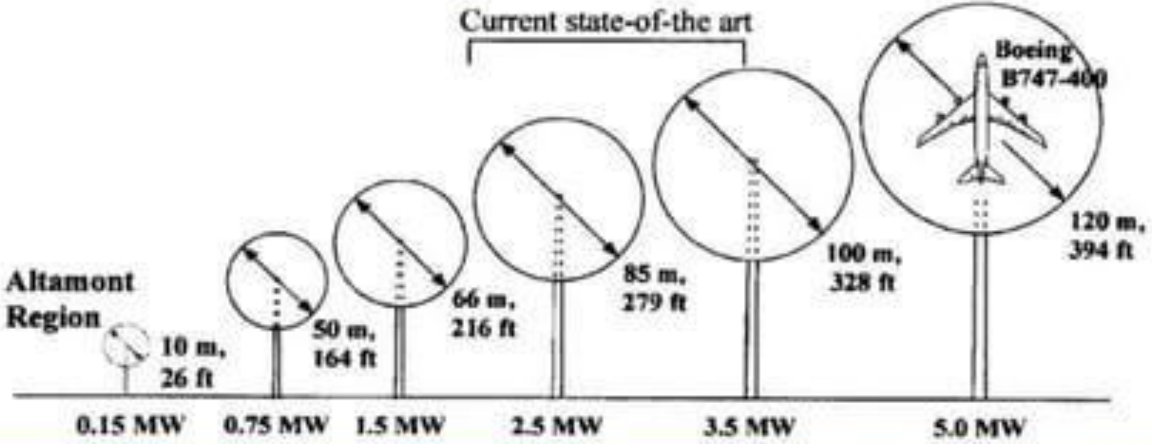
Size of wind turbine

Small (≤10 kW)
- Homes
- Farms
- Remote Applications

(e.g. water pumping, telecom sites,)

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

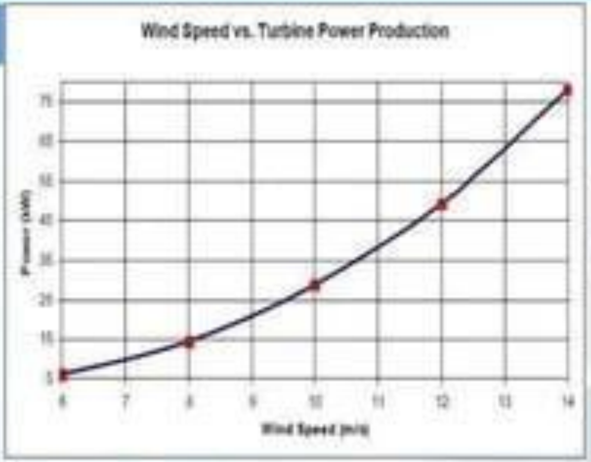
Large (250 kW - 2+MW)
- Central Station Wind Farms
- Distributed Power



Site Selection

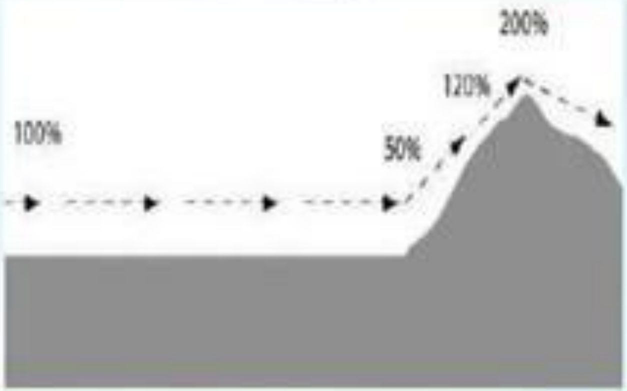
Consideration during site selection

- High annual average wind speed
- Altitude of proposed site
- Terrain and aerodynamic
- Ease of transportation
- Nearness to users/centers
- Local ecology & Nature of ground



Best sites for wind turbine

- Off shore and sea coast (2400 kWh/m^2 per year)
- Mountains (1600 kWh/m^2 per year)
- Planes (750 kWh/m^2 per year)



Considerations and Guidelines for Site Selection

Hill effect:

Roughness or the amount of friction that earth's surface exerts on wind:

Tunnel effect:

Turbulence:

Variations in wind speed:

Wake:

Wind obstacles:

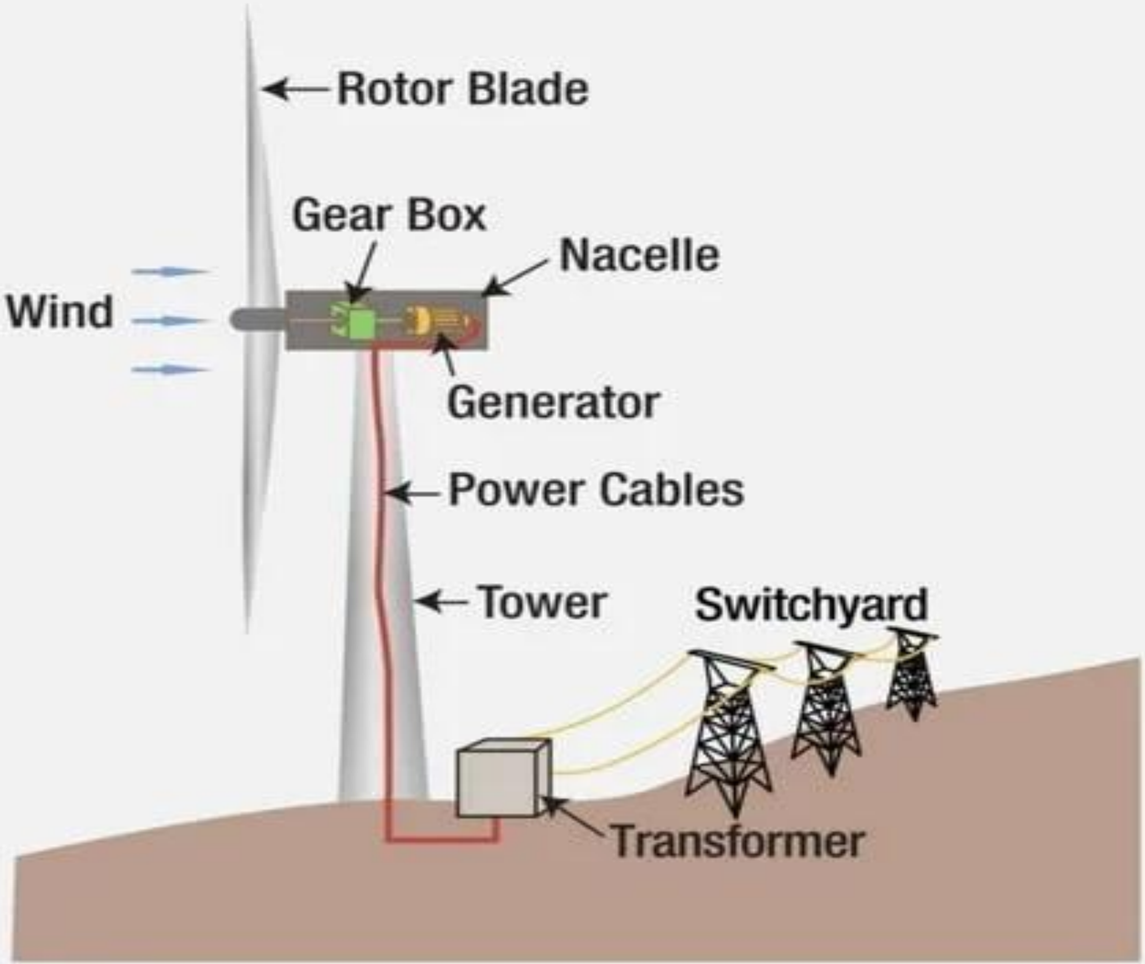
Wind shear:

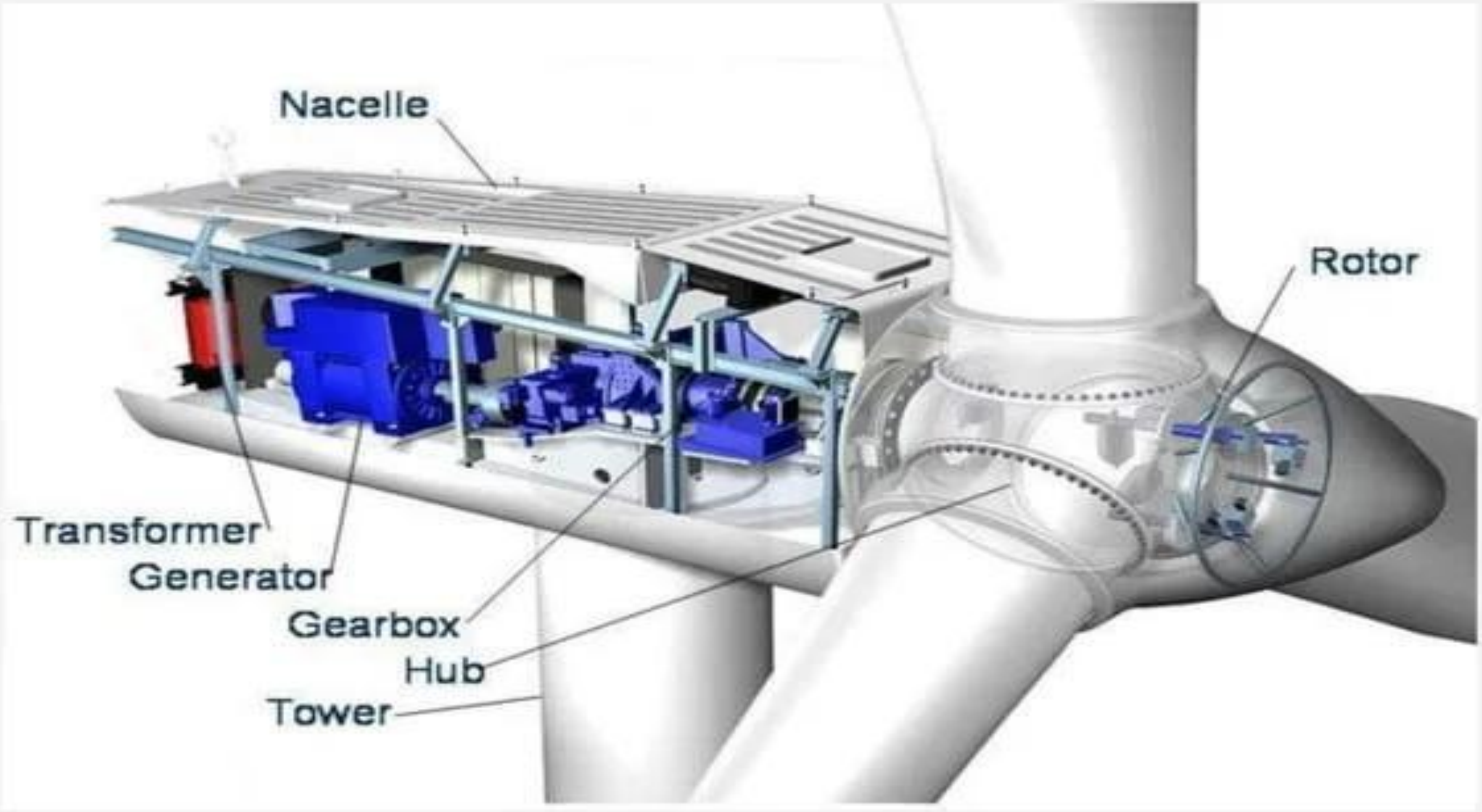
The following guidelines can be followed to evaluate site for the installation of wind turbines:

1. Turbines work best when on high and exposed sites. Coastal sites are especially good.
2. Town centres and highly populated residential areas are usually not suitable sites for wind turbines.
3. Avoid roof-mounted turbines as there is no guarantee that these devices will not damage property through vibration.
4. The farther the distance between the turbine and the power requirement, the more power will be lost in the cable. The distance of the cabling will also impact the overall cost of the installation.
5. Turbulence disrupts the air flow that can wear down the blades and reduces the lifecycle of the turbine. It is recommended that installing a turbine may be considered only when the distance between the turbine and the nearest obstacle is more than twice the height of the turbine, or when the height of the turbine is more than twice the height of the nearest obstacle.
6. Small turbines require an average wind speed of over 4.5 m/s to produce an efficient level of electricity.
7. If site is in a remote location, connecting wind turbine to the national grid will be very expensive and it may be worth considering an off-grid connection instead using battery storage.

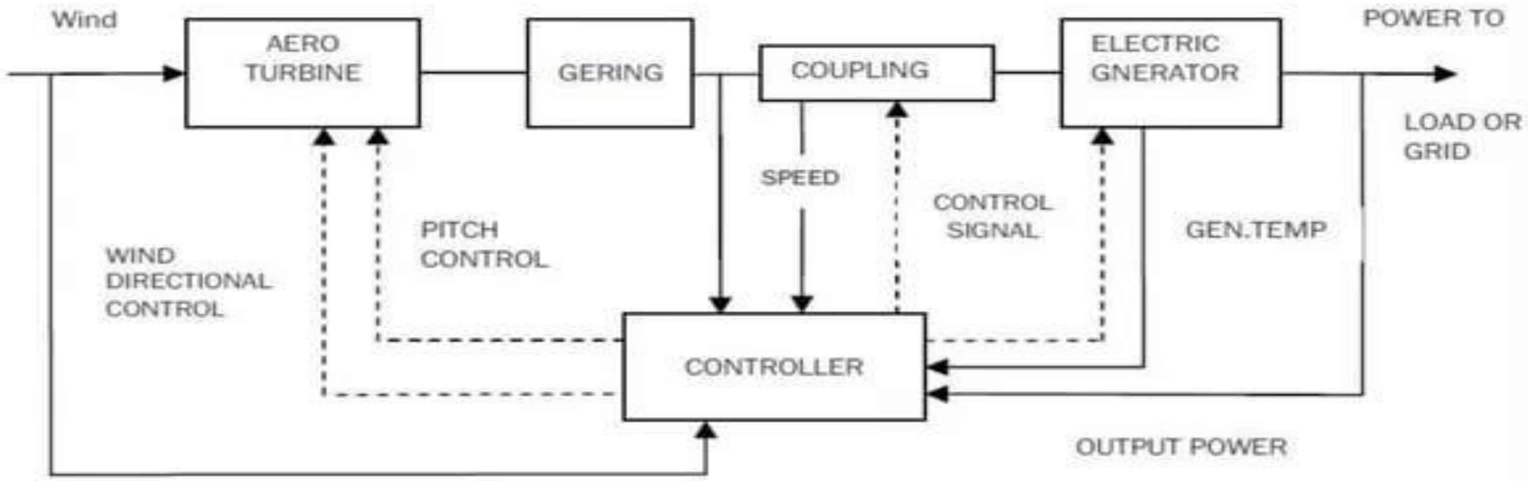
SITE SELECTION CONSIDERATIONS

1. High annual average wind speed
2. Availability of anemometry data
3. Availability of wind Vt curve at the proposed site
4. Wind structure at the proposed site
5. Altitude of the proposed site
6. Terrain and its aerodynamics
7. Local ecology
8. Distance to road and railways
9. Nearness of site to local Centre/users
10. Nature of ground
11. Favourable Land Cost
12. Other Conditions like icing problem, salt spray or blowing dust


Rotor Blade
Gear Box
Nacelle
Wind
Generator
Power Cables
Tower
Switchyard
Transformer


Nacelle
Rotor
Transformer
Generator
Gearbox
Hub
Tower

BLOCK DIAGRAM



BASIC COMPONENTS OF WIND ENERGY CONVERSION SYSTEMS (WECS)

- Aero turbine – convert energy in moving air to rotary mechanical energy.
- They require pitch control and yaw control
- Gearing and Coupling – transmits the rotary mechanical energy into electrical generator
- Controller – sense the wind speed, wind direction shafts speeds and torque at one or more points
- The physical embodiment for such an aero generator is shown in generalized form in fig.

BASIC COMPONENTS OF WIND ENERGY CONVERSION SYSTEMS (WECS)

1) **Rotors** are mainly of two types:
    - Horizontal axis rotor
    - Vertical axis rotor

- One advantage of vertical axis machines is that they operate in all wind directions
- The portion of the wind turbine that collects energy from the wind is called the rotor.

BASIC COMPONENTS OF WIND ENERGY CONVERSION SYSTEMS (WECS)

2) Windmill head

- Supports the rotor, housing the rotor bearings
- Also incorporated like changing the pitch of the blades for safety devices and tail vane to orient the rotor to face the wind

BASIC COMPONENTS OF WIND ENERGY CONVERSION SYSTEMS (WECS)

3) **Transmissions:**

- The number of revolutions per minute (rpm) of a wind turbine rotor can range between 40 rpm and 400 rpm, depending on the model and the wind speed.
- Generators typically require rpm's of 1,200 to 1,800.
- As a result, most wind turbines require a gear-box transmission to increase the rotation of the generator to the speeds necessary for efficient electricity production.

CONTINUE….

- Some DC-type wind turbines do not use transmissions.
- Instead, they have a direct link between the rotor and generator.
- These are known as direct drive systems.
- Without a transmission, wind turbine complexity and maintenance requirements are reduced.
- But a much larger generator is required to deliver the same power output as the AC-type wind turbines.

BASIC COMPONENTS OF WIND ENERGY CONVERSION SYSTEMS (WECS)

4) **Control:**

- The modern large wind turbine generator requires a versatile and reliable control system to perform the following functions:
  - Orientation of the wind in the rotor
  - Generator output monitoring – status, data computation and storage

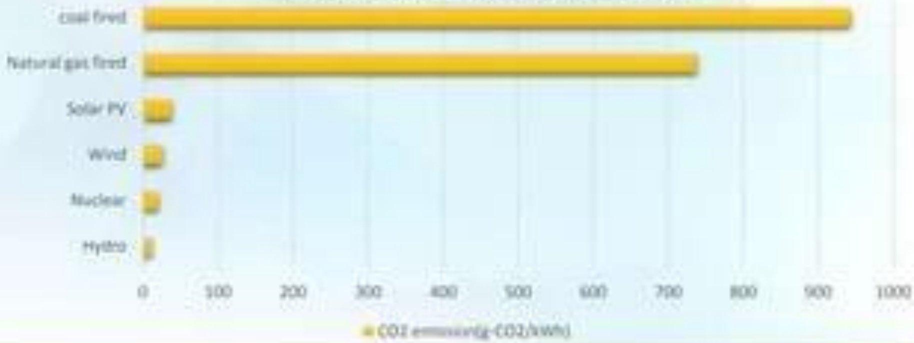
ADVANTAGE

- Good for environment as it uses renewable source of energy as wind.
- Wind is freely available in nature.
- Can be setup in remote areas where electricity through transmission wire cannot be reached.
- Clean source of energy as it does not produce any green house gases or any other pollutants.
- Once setup is completed the cost of generation electricity become less.
- Can be combined with solar electricity to give reliable supply of electricity.

Cost comparison of different sources

Power plant type	Cost ($/kW-hr)	Renewable sources
Natural gas	0.07-0.13	No
Hydro	0.08	Yes
Coal	0.08-0.14	No
Wind	***0.08-0.15***	***Yes***
Nuclear	0.10	No
Biomass	0.10	Yes
Solar PV	0.13	Yes

CO_2 Emissions of diff. Power Sources per Electric-generating Capacity



DISADVANTAGE

- Site Specific i.e suited to particular region.
- Create a lot of Noise Disturbances
- Prediction of wind is difficult i.e wind speed varies.
- Threat to wild life as it kills birds.
- Cause visual impact.
- High Initial cost.
- Large requirement of land for wind farm.
- Turbines Interfere With the Reception of Televisions and communication signals.

problems faces the use of wind power

Problems faced by the use of wind power

- **Noise problems**

Turbines can, under some circumstances be heard at distances at least as great as 2.5km. While the sound is not loud, some people find it annoying, and at smaller distances (perhaps 1km or less) it may stop some people from sleeping and lead on to anxiety and stress in some people; this, in turn, can lead to health problems.

- **Power availability and transmission problems**

The wind does not blow all the time. When the wind is not blowing wind turbines do not generate power. At times of peak electricity demand on very hot days winds tend to be lighter than average.

Problems faced by the use of wind power

- **Social disruption**

Sometimes, when a wind farm is proposed , communities are split into supporters and opponents. Occasionally bad feeling arises. In my experience this is more often due to people spreading misinformation about wind farms than being due to the wind farms themselves.

- **The turbine fire problem**

The fire problem in wind turbines arises as a result of large amounts of highly flammable material (hydraulic oil and lubricants, composite materials, insulation, and polymers) contained within the nacelle of the wind turbine and packed in close proximity to potential ignition sources such as overheated mechanical components (hot surfaces) and electrical connections that could fail.

MCQ

The amount of energy available in the wind at any instant is proportional to ___ of the wind speed.

(A) Square root power of two

(B) Square root power of three

(C) Square power

(D) Cube power

MCQ

Wind energy is harnessed as _______ energy with the help of windmill or turbine.

(A) Mechanical

(B) Solar

(C) Electrical

(D) Heat

MCQ

Winds having following speed are suitable to operate wind turbines.

(A) $5 - 25 m/s$

(B) $10 - 35 m/s$

(C) $20 - 45 m/s$

(D) $30 - 55 m/s$

MCQ

3. Which type of wind mills are termed as "cross-wind axis" machines:

a) Horizontal axis wind mills

b) Vertical axis wind mills

c) Both (a) and (b)

d) None of the above

MCQ

The drawbacks of wind energy is:

a) Unreliability an non-steadiness

b) Output voltage and frequency fluctuations

c) Can affect the bird life

d) All the above

MCQ

Which type of Generator is employed in wind power plant:

a) Synchronous generator

b) Induction generator

c) Permanent magnet motor

d) Brushless motor

MCQ

The kinetic energy per unit volume is given by where ρ is the density of the air and v is the velocity of wind in m/sec

a) $0.5 \times \rho \times V^2$
b) $\rho \times V^2$
c) $2 \times \rho \times V^2$
d) $4 \times \rho \times V^2$

MCQ

The Magnitude of power constant in wind mill depends on

(a) Shape of rotor blades

(b) Wind velocity

(c) Orientation of rotor blades

(d) Both (a) and (b)