MODULE 5

RENEWABLE SOURCES OF ENERGY

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RENEWABLE ENERGY

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human timescale, such as

- ✓ sunlight
- ✓ wind
- ✓ rain
- ✓ tides
- ✓ waves
- ✓ geothermal heat

Renewable energy replaces conventional fuels in four distinct areas:

- ✓ electricity generation
- ✓ air and water heating/cooling,
- ✓ motor fuels
- ✓ rural (off-grid) energy services

LIMITATIONS OF CONVENTIONAL SOURCES OF ENERGY

We use the conventional sources of energy because they are cheap and easy to use.

There is no better way *yet* to store, transfer and use energy than gasoline for powering motor vehicles.

- It's quick to pump fossil fuel into a car.
- It's stable in the tank.
- A gas tank holds quite a bit.
- Gasoline powered cars are easy to manufacture.

LIMITATIONS OF CONVENTIONAL SOURCES OF ENERGY

The limitations of conventional sources of energy are as follows:

- They are non-renewable and fast depleting. They will eventually run out.

- They leave behind harmful by-products upon combustion, thereby causing a lot of pollution.

- Mining of such fuels lead to irreversible damage to the adjoining environment.

- Prices of fossil fuels are rising.

- Burning fossil fuel produces carbon dioxide, a major cause for global warming.

Various Sources of Renewable Energy

Solar Energy

Wind Energy

Hydel Energy

Geothermal Energy

SOLAR ENERGY

Solar energy is the harnessing of radiant light and heat from the Sun using a range of technologies such as solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis.

The Solar Settlement at Freiburg, Germany

A mobile station that replenishes energy for electric vehicles using solar energy.

SOLAR ENERGY

The technologies used to capture and distribute solar energy are broadly characterized as:

i. **Active solar technologies** (the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy.)
ii. **Passive solar technologies** (orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air)

Darmstadt University of Technology, Germany, won the 2007 Solar Decathlon in Washington, D.C. with this passive house designed for humid and hot subtropical climate.

SOLAR ENERGY: PHOTOVOLTAIC CELL

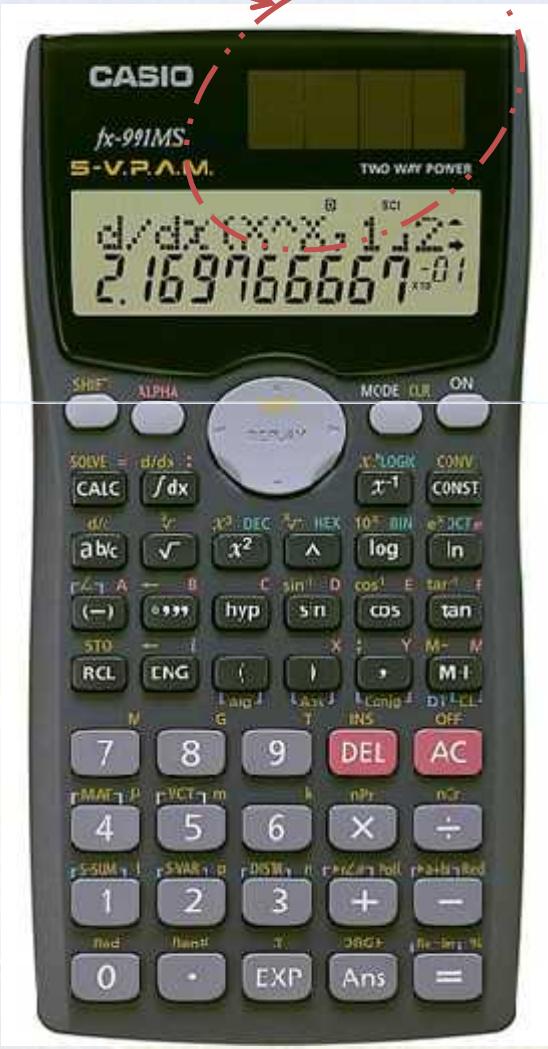
A **photovoltaic cell** or solar cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect.

The photovoltaic effect is a physical and chemical phenomenon in which voltage or current is created in a material when exposed to light.

Photovoltaic cell is a form of photoelectric cell whose electrical characteristics, such as current, voltage or resistance vary when exposed to light.

Solar cells are the building blocks of solar panels.

Solar Energy: Photovoltaic Cell



SOLAR ENERGY: PHOTOVOLTAIC CELL

Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light.

They are used as a photo detectors; detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

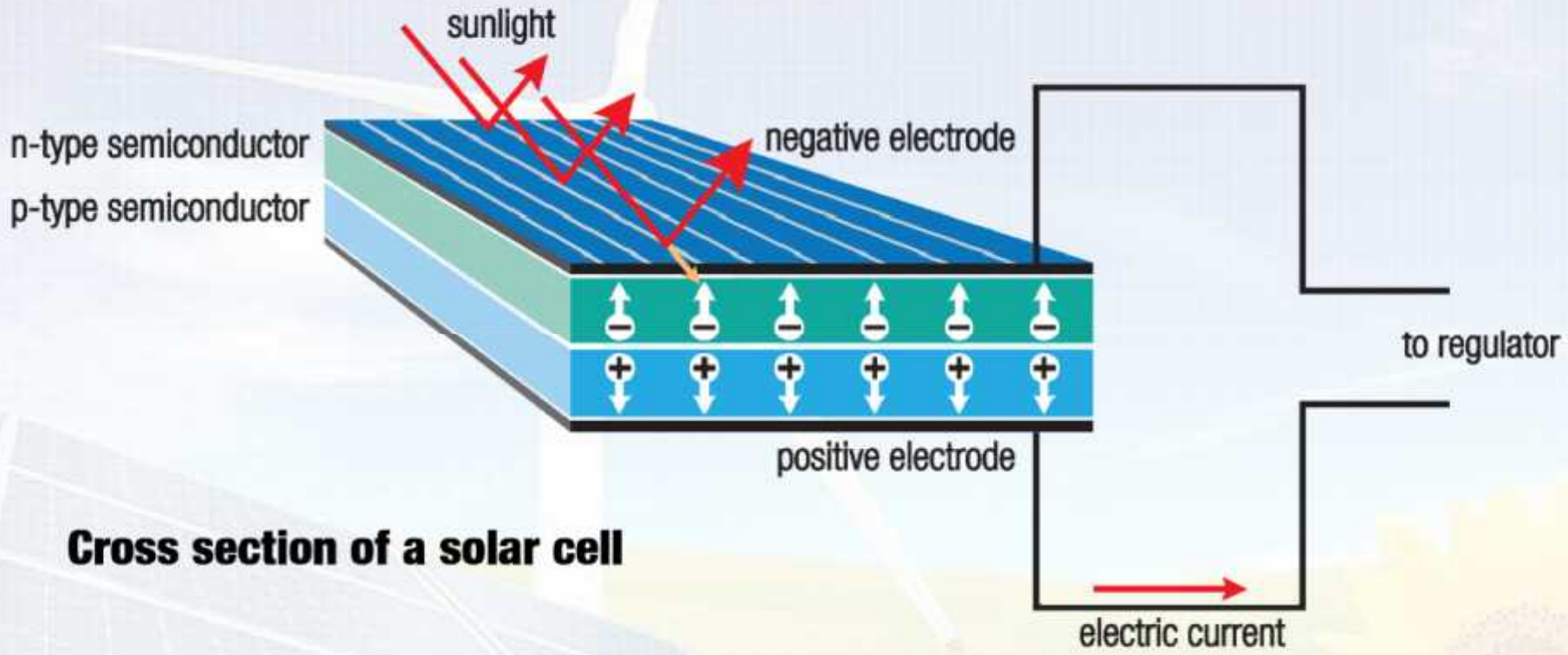
The operation of a photovoltaic (PV) cell requires 3 basic attributes:

i) The absorption of light, generating either electron-hole pairs or excitons.

ii) The separation of charge carriers of opposite types.

iii) The separate extraction of those carriers to an external circuit.

Solar Energy: Photovoltaic Cell



Cross section of a solar cell

SOLAR ENERGY: PHOTOVOLTAIC CELL

The solar cell works in several steps:

- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
- Electrons are excited from their current molecular/atomic orbital. Once excited an electron can either dissipate the energy as heat and return to its orbital or travel through the cell until it reaches an electrode. Current flows through the material to cancel the potential and this electricity is captured. The chemical bonds of the material are vital for this process to work, and usually silicon is used in two layers, one layer being bonded with boron, the other phosphorus. These layers have different chemical electric charges and subsequently both drive and direct the current of electrons.
- An array of solar cells converts solar energy into a usable amount of direct current(DC) electricity.
- An inverter can convert the power to alternating current (AC).

SOLAR ENERGY: FLAT PLATE COLLECTOR

- **Flat plate collectors**, developed by Hottel and Whillier in the 1950s, are the most common type of **solar thermal collector.**

- They collect heat by absorbing sunlight.

- It is a device for capturing solar radiation.

- Solar radiation is energy in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths.

SOLAR ENERGY: FLAT PLATE COLLECTOR

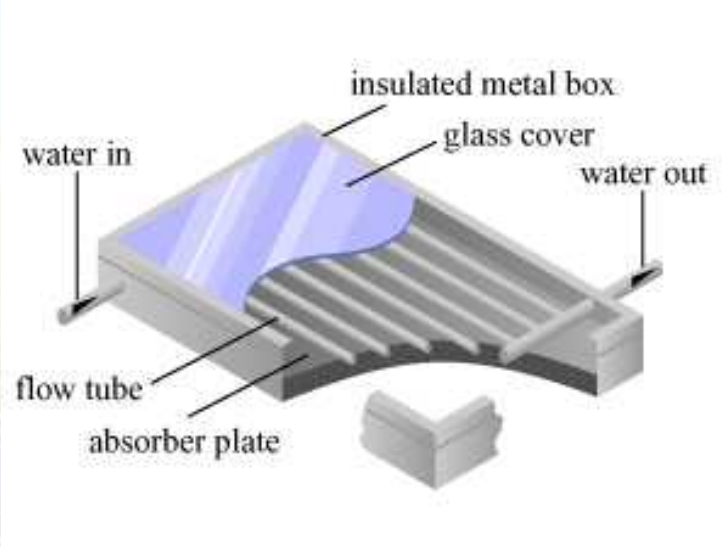
They consist of:

(1) a dark flat-plate absorber,

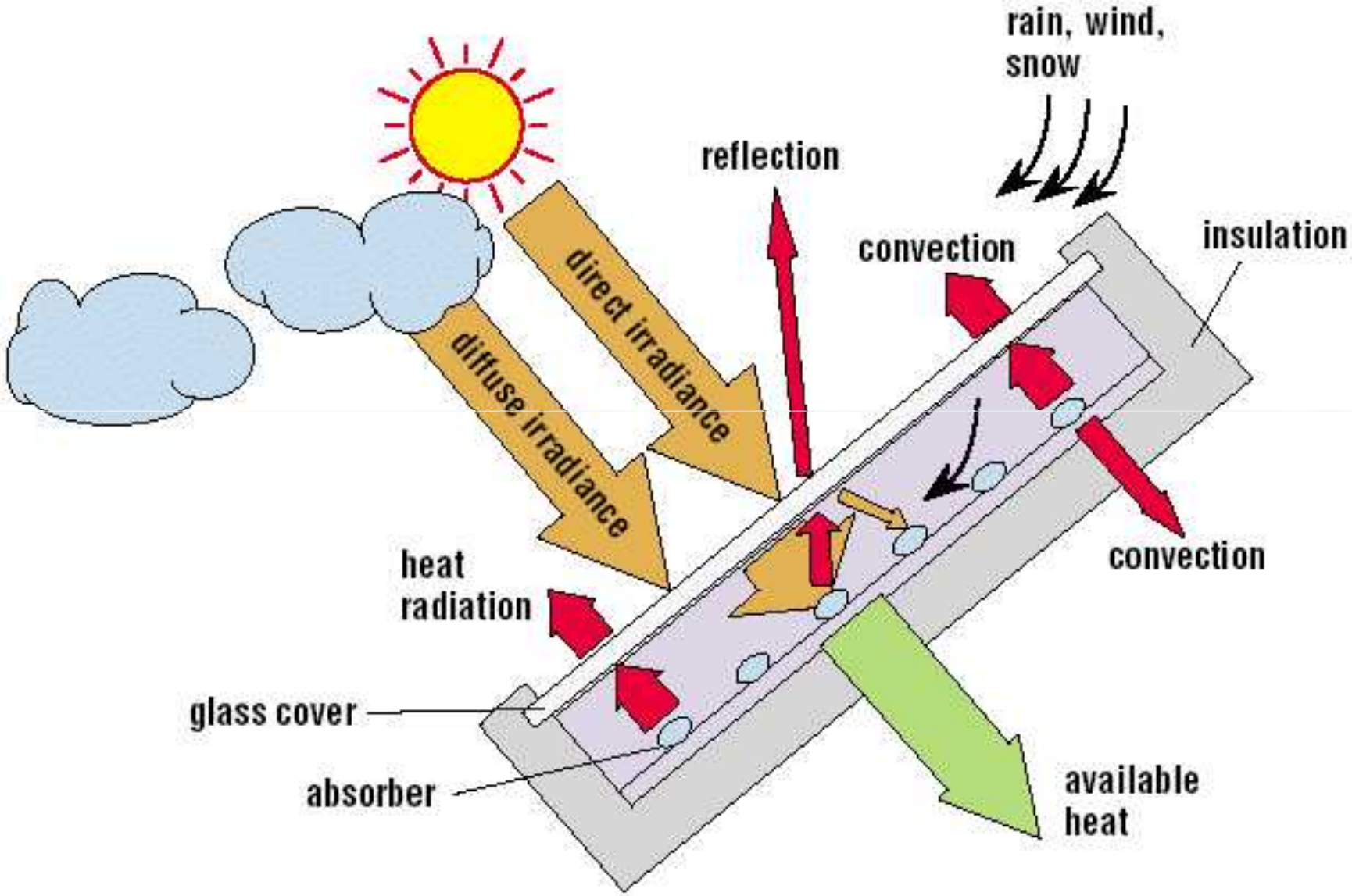
(2) a transparent cover that reduces heat losses,

(3) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber and

(4) a heat insulating backing.



SOLAR ENERGY: FLAT PLATE COLLECTOR



SOLAR ENERGY: FLAT PLATE COLLECTOR

The absorber, inside the flatplate collector housing, converts sunlight to heat and transfers it to water in the absorber tubes. As the collector can reach stagnation temperatures up to 200°C (i.e. when no water flows through), all the materials used must be able to resist such heat. Therefore, the absorber is usually made of metal materials such as copper, steel or aluminium. The collector housing can be made of plastic, metal or wood, and the glass front cover must be sealed so that heat does not escape, and dirt, insects or humidity do not get into the collector itself. Many collectors also have controlled ventilation, so as to avoid condensation inside the glass front cover. The collector housing is highly insulated at the back and sides, keeping heat losses low. However, there are still some collector heat losses, mainly due to the temperature difference between the absorber and ambient air, and these are subdivided into convection and radiation losses. The former are caused by air movements, while the latter are caused by exchange of heat by radiation between the absorber and the environment. A sheet of glass covers the collector as it faces the sun, and this helps to prevent most of the convection losses. Furthermore, it reduces heat radiation from the absorber into the environment in a similar way as a greenhouse does. However, the glass also reflects a small part of the sunlight, which does not then reach the absorber at all.

WIND ENERGY

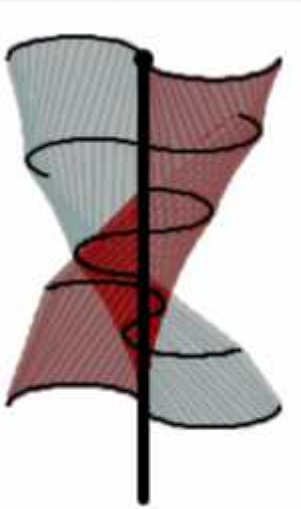
Wind energy is the extraction of **wind power** air flow using wind turbines or sails to produce mechanical or electrical power.

- Windmills are used for their mechanical power, wind pumps for water pumping and sails to propel ships.
- Wind power as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land.
- The net effects on the environment are far less problematic than those of non-renewable power sources.

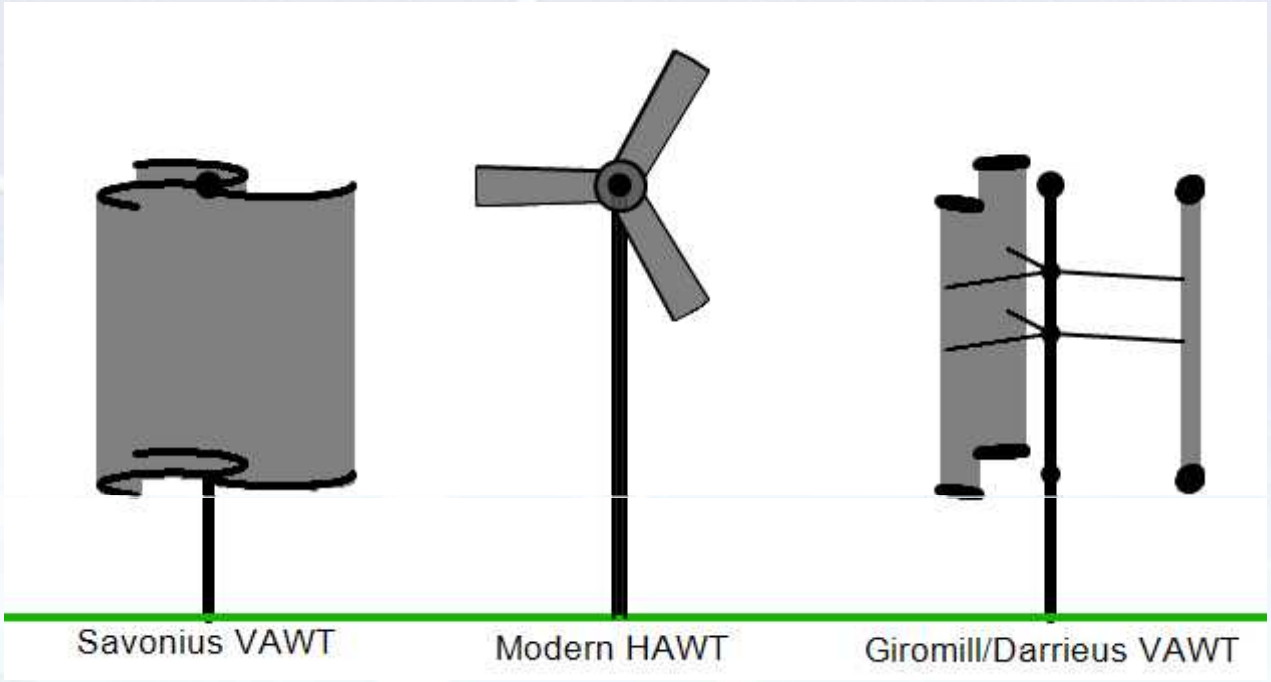
WIND ENERGY: WIND TURBINE

A **wind turbine** is a device that converts kinetic energy from the wind into electrical power.

The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.



WIND ENERGY: WIND TURBINE



Types: Wind turbines can rotate about either a horizontal or a vertical axis, the former being both older and more common. They can also include blades (transparent or not) or be bladeless.

WIND ENERGY: WIND TURBINE

Working:

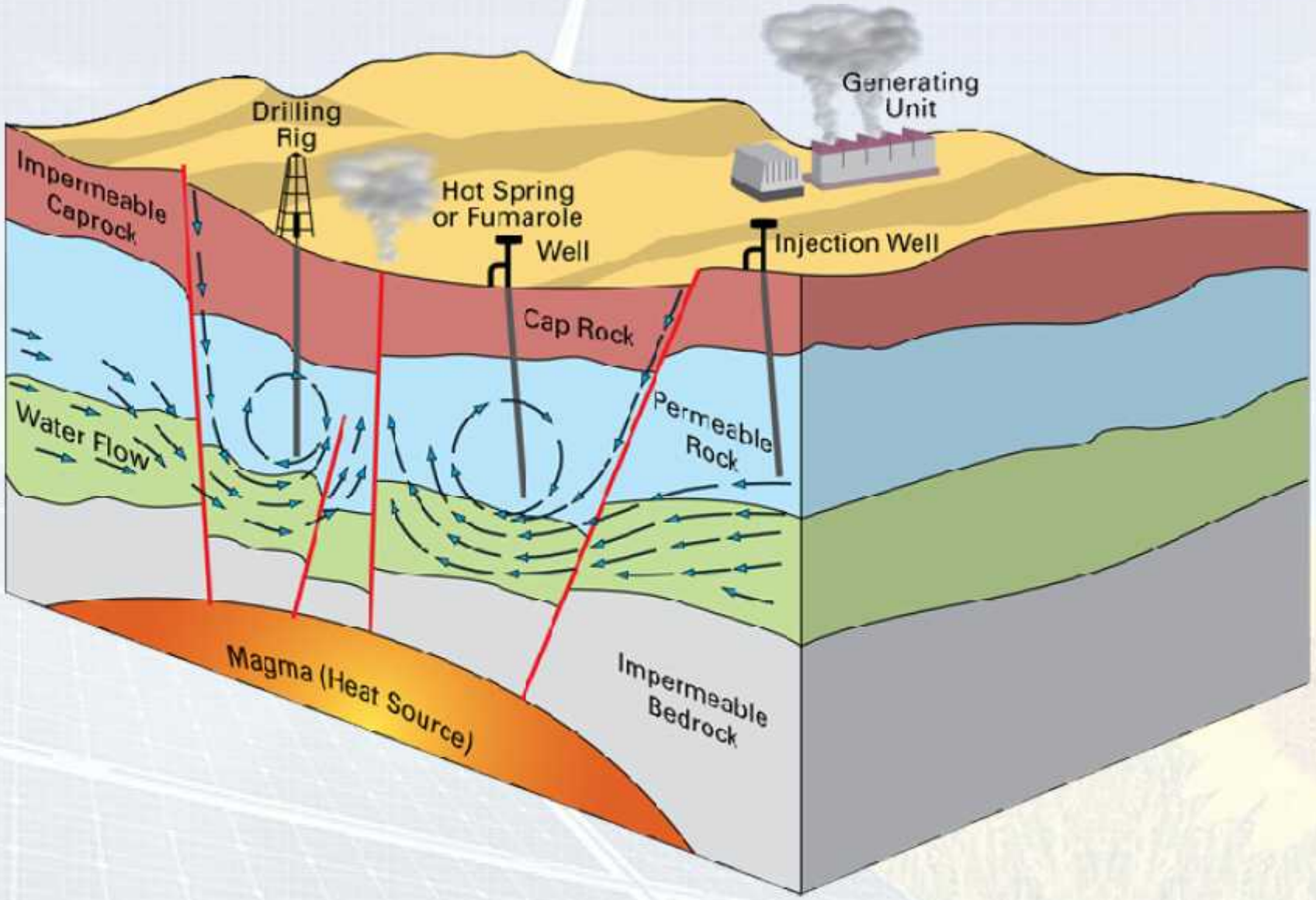
Wind turbines operate on a simple principle.
The energy in the wind turns two or three propeller-like blades around a rotor.
The rotor is connected to the main shaft, which spins a generator to create electricity.
Wind turbines are mounted on a tower to capture the most energy.
At 100 feet (30 meters) or more above ground, they can take advantage of faster and less turbulent wind.
Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid for more widespread electricity distribution.

GEOTHERMAL ENERGY

Geothermal energy is thermal energy generated and stored in the Earth. It originates from the formation of the planet and from radioactive decay of materials.

The *geothermal gradient*, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface.

GEOTHERMAL ENERGY



GEOTHERMAL ENERGY

Temperatures at the core–mantle boundary may reach over 4000 °C (7,200 °F).

The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in portions of mantle convecting upward since it is lighter than the surrounding rock.

Rock and water is heated in the crust, sometimes up to 370 °C (700 °F).

GEOTHERMAL ENERGY

- From hot springs, geothermal energy has been used for bathing since Paleolithic times and for space heating since ancient Roman times, but it is now better known for electricity generation.
- Worldwide, 11,700 megawatts (MW) of geothermal power is online in 2013.
- An additional 28 gigawatts of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications in 2010.
- Geothermal power is cost effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries.
- Recent technological advances have dramatically expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation.
- Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels.
- As a result, geothermal power has the potential to help mitigate global warming if widely deployed in place of fossil fuels.

GEOTHERMAL ENERGY: GEOTHERMAL POWER PLANT

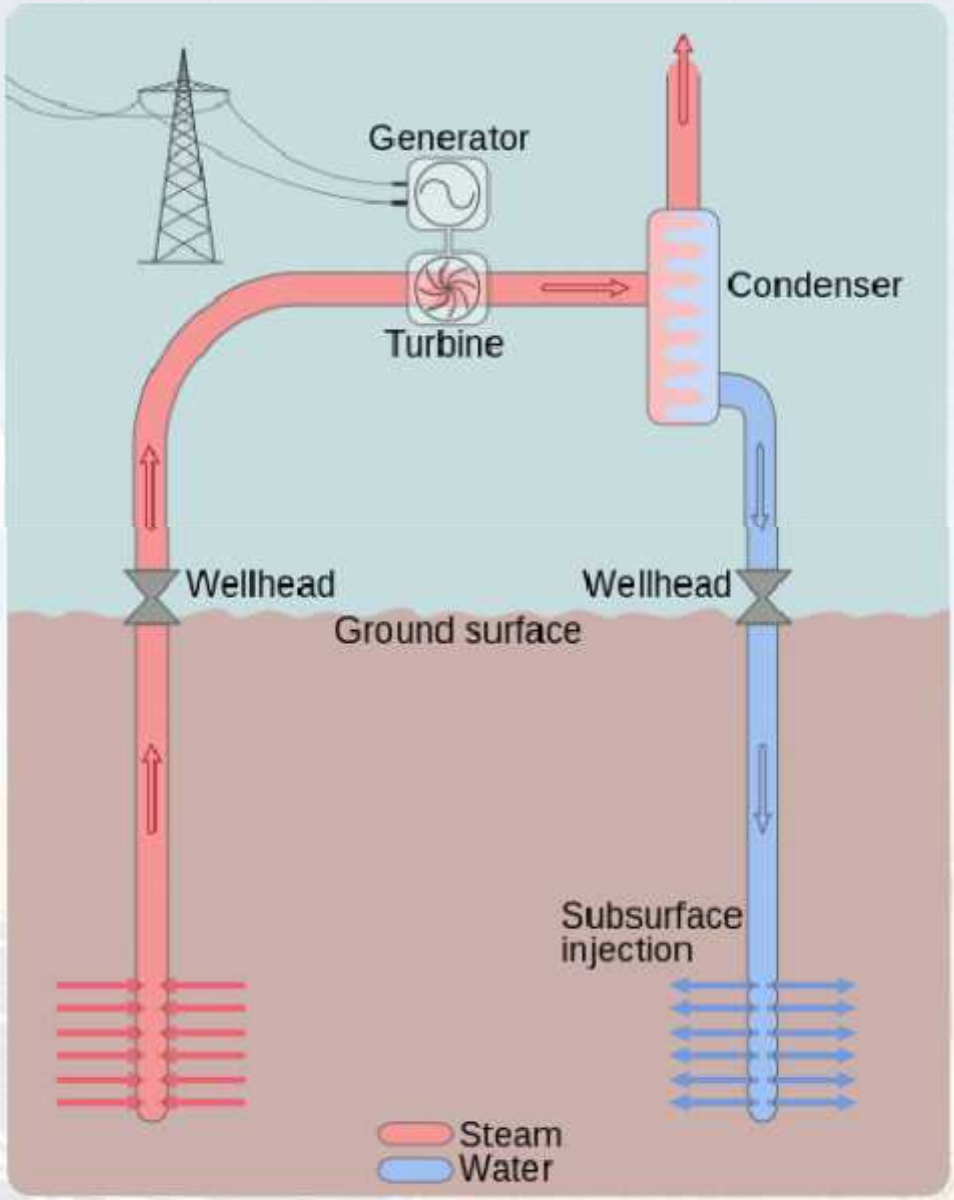
Geothermal power plants, heat from a fuel source (in geothermal's case, the earth's core) is used to heat water or another working fluid. The working fluid is then used to turn a turbine of a generator, thereby producing electricity. The fluid is then cooled and returned to the heat source.

GEOTHERMAL ENERGY: GEOTHERMAL POWER PLANT - TYPES

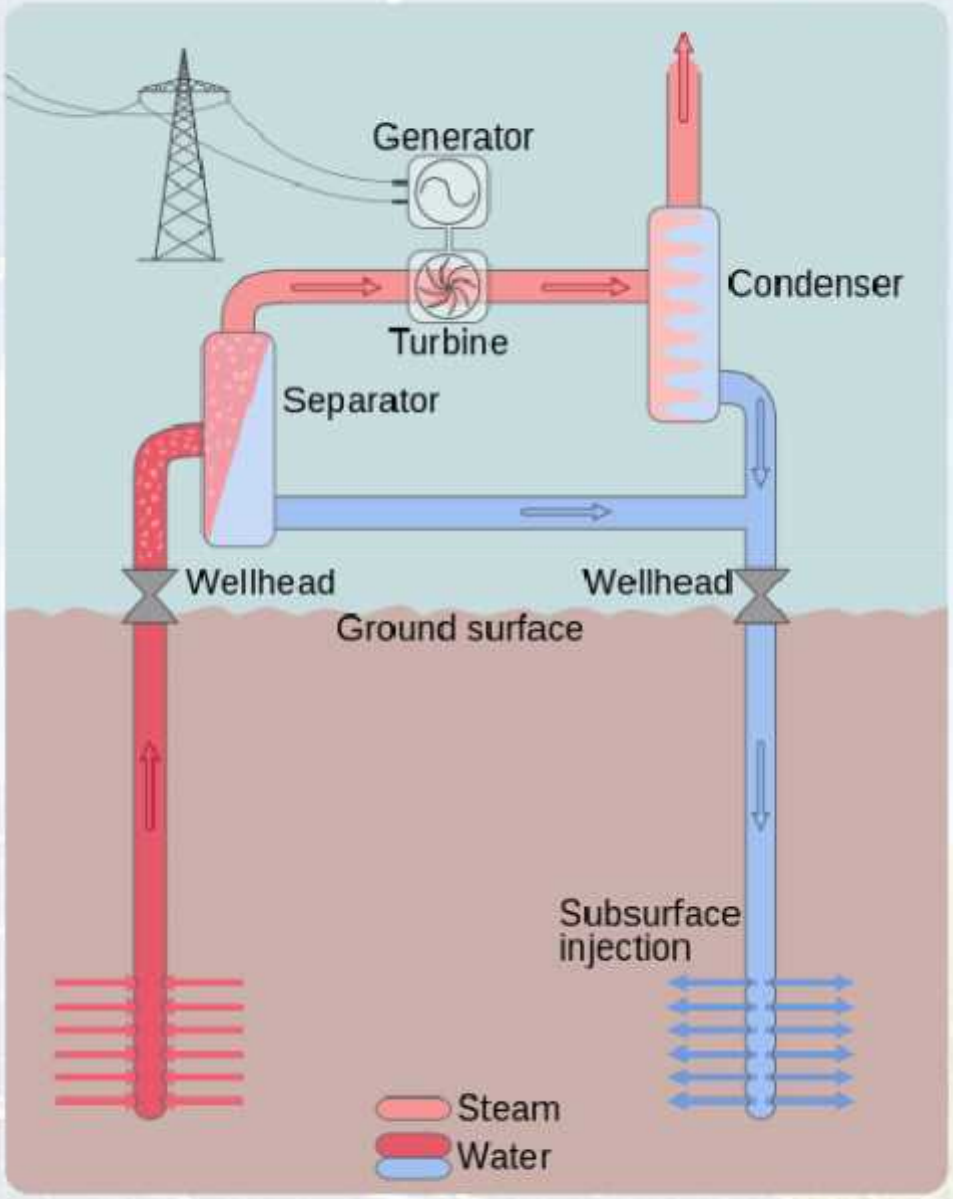
Dry steam power stations:

Dry steam stations are the simplest and oldest design.

They directly use geothermal steam of 150°C or greater to turn turbines



GEOTHERMAL ENERGY: GEOTHERMAL POWER PLANT - TYPES



Flash steam power stations

GEOTHERMAL ENERGY: GEOTHERMAL POWER PLANT - TYPES

Flash steam power stations:

Flash steam stations pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines. They require fluid temperatures of at least 180°C, usually more. This is the most common type of station in operation today. Flash Steam plants use geothermal reservoirs of water with temperatures greater than 360°F. The hot water flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Any leftover water and condensed steam may be injected back into the reservoir, making this a potentially sustainable resource. At The Geysers in California, twenty years of power production had depleted the groundwater and operations were substantially reduced. To restore some of the former capacity, water injection was developed.

GEOTHERMAL ENERGY: GEOTHERMAL POWER PLANT - TYPES

Binary cycle power stations:

Binary cycle power stations are the most recent development, and can accept fluid temperatures as low as 57°C.
The moderately hot geothermal water is passed by a secondary fluid with a much lower boiling point than water.
This causes the secondary fluid to flash vaporize, which then drives the turbines.
This is the most common type of geothermal electricity station being constructed today.
Both Organic Rankine and Kalina cycles are used.
The thermal efficiency of this type station is typically about 10–13%.

HYDEL ENERGY

Hydel Energy or Hydro-electric energy is the electric power derived from the energy of falling water, which may be harnessed for useful purposes.

Since ancient times, hydropower from many kinds of watermills has been used as a renewable energy source for irrigation and the operation of various mechanical devices, such as sawmills, textile mills, domestic lifts, ore mills etc.

HYDEL ENERGY

In the late 19th century, hydropower became a source for generating electricity.

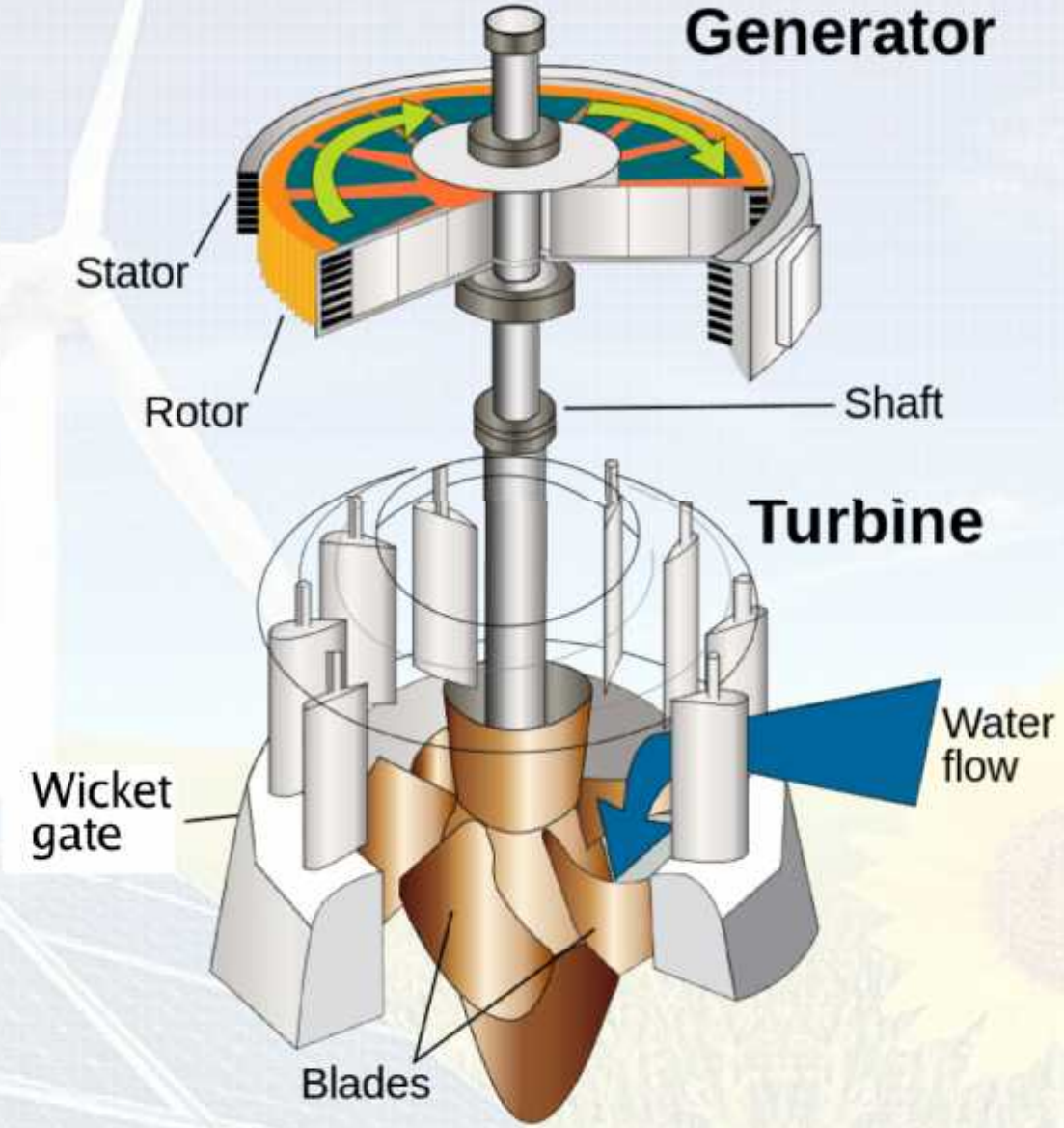
Cragside in Northumberland was the first house powered by hydroelectricity in 1878.

The first commercial hydroelectric power plant was built at Niagara Falls in 1879. In 1881, street lamps in the city of Niagara Falls were powered by hydropower.

HYDEL ENERGY

- Since the early 20th century, the term has been used almost exclusively in conjunction with the modern development of hydroelectric power.
- International institutions such as the World Bank view hydropower as a means for economic development without adding substantial amounts of carbon to the atmosphere.
- But in some cases dams cause significant social or environmental issues.

HYDEL ENERGY: PRINCIPLE



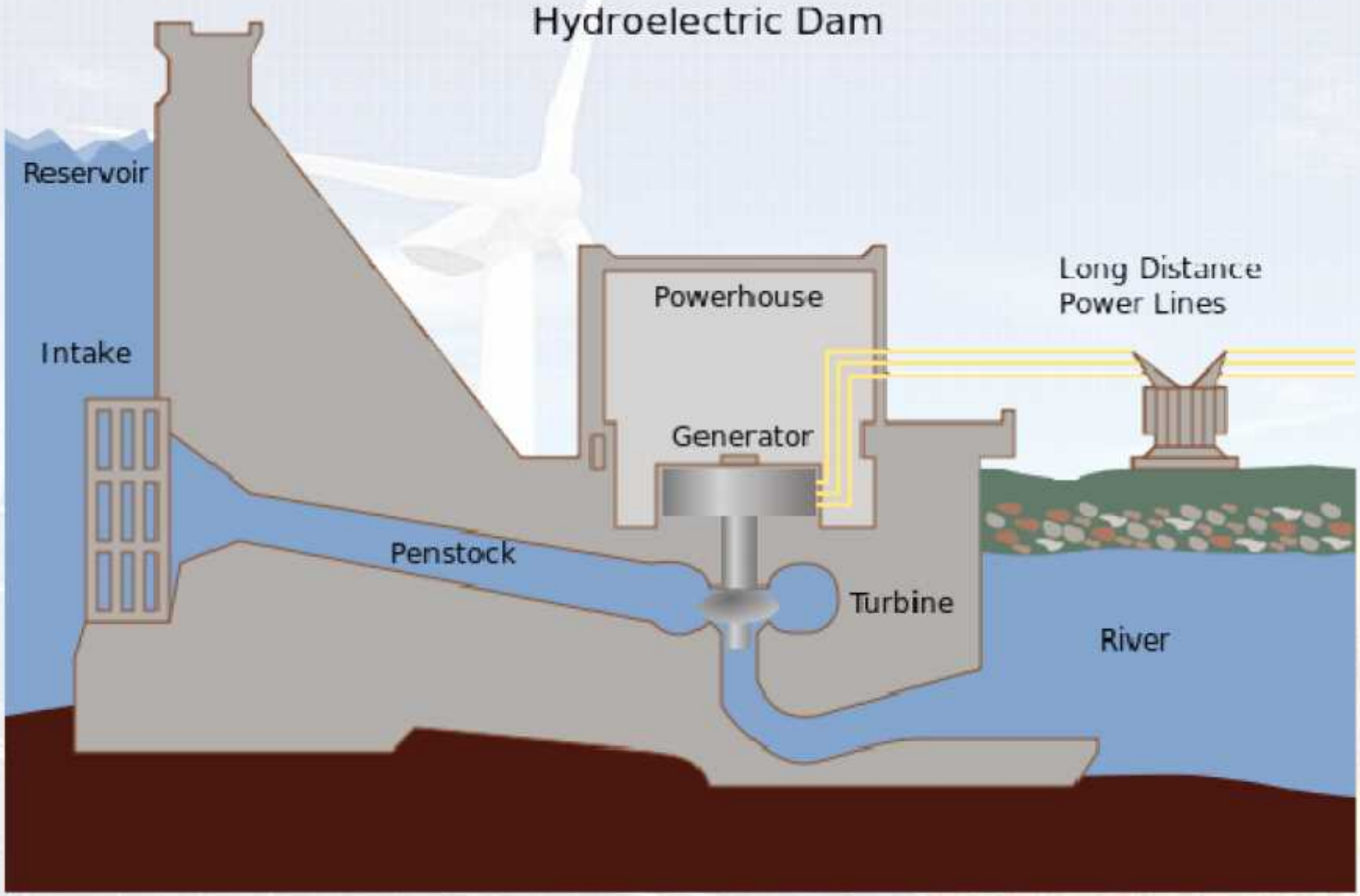
HYDEL ENERGY: PRINCIPLE

- The basic principle of hydropower is that if water can be piped from a certain upper level to a lower level, then the resulting water pressure can be used to do work.
- If this water pressure is allowed to move a mechanical device, then this movement converts the potential energy of the water into mechanical energy.
- Turbines convert water pressure into mechanical shaft power , which can be used to drive an electricity generator, a grinding mill or other useful devices.
- The theoretical power (P in watts) available from a given head of water (H in meters) is given by

$$P = Q \times H \times c$$

where Q is the flow of the river measured in meter cubed per second and c is a constant.

HYDEL ENERGY: HYDROPOWER GENERATION



HYDEL ENERGY: HYDROPOWER GENERATION – GENERATING METHODS

- **Conventional Method (dams) –**

Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator.

The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow.

This height difference is called the head.

A large pipe (the "penstock") delivers water from the reservoir to the turbine.

HYDEL ENERGY: HYDROPOWER GENERATION – GENERATING METHODS

- **Pumped Storage Method (dams) –**

This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations.
At times of low electrical demand, the excess generation capacity is used to pump water into the higher reservoir.
When the demand becomes greater, water is released back into the lower reservoir through a turbine.
Pumped-storage schemes currently provide the most commercially important means of large-scale grid energy storage and improve the daily capacity factor of the generation system.
Pumped storage is not an energy source, and appears as a negative number in listings.

HYDEL ENERGY: HYDROPOWER GENERATION – GENERATING METHODS

- **Run-of-the-River Method –**

Run-of-the-river hydroelectric stations are those with small or no reservoir capacity, so that only the water coming from upstream is available for generation at that moment, and any oversupply must pass unused.

A constant supply of water from a lake or existing reservoir upstream is a significant advantage in choosing sites for run-of-the-river.

In the United States, run of the river hydropower could potentially provide 60,000 megawatts (80,000,000 hp) (about 13.7% of total use in 2011 if continuously available)

HYDEL ENERGY: HYDROPOWER GENERATION – GENERATING METHODS

- **Tidal Method –**

A tidal power station makes use of the daily rise and fall of ocean water due to tides; such sources are highly predictable, and if conditions permit construction of reservoirs, can also be dispatchable to generate power during high demand periods.

Less common types of hydro schemes use water's kinetic energy or undammed sources such as undershot waterwheels.

Tidal power is viable in a relatively small number of locations around the world.

In Great Britain, there are eight sites that could be developed, which have the potential to generate 20% of the electricity used in 2012

Just as fossil fuels from conventional sources are finite and are becoming depleted, those from difficult sources will also run out. If we put all our energy and resources into continued fossil fuel extraction, we will have lost an opportunity to have invested in renewable energy.

— David Suzuki —


Thank you!