Xinming Li
College of Chemistry, Chemical Engineering and Material Science
Email: xinmingli@suda.edu.cn
Office:912-0607

Renewable Resources and Green Products

- Non-renewable resources
- Earth minerals and metal ores, fossil fuels (coal, petroleum, natural gas) and groundwater
- Renewable resources
- Solar energy, geothermal sources, tide power, wave power, hydropower, wind power
- Chemicals from feedstock
- Bioethanol, biodiesel, fatty acids, erucic acids, and varied biopolymers

Non-renewable resources

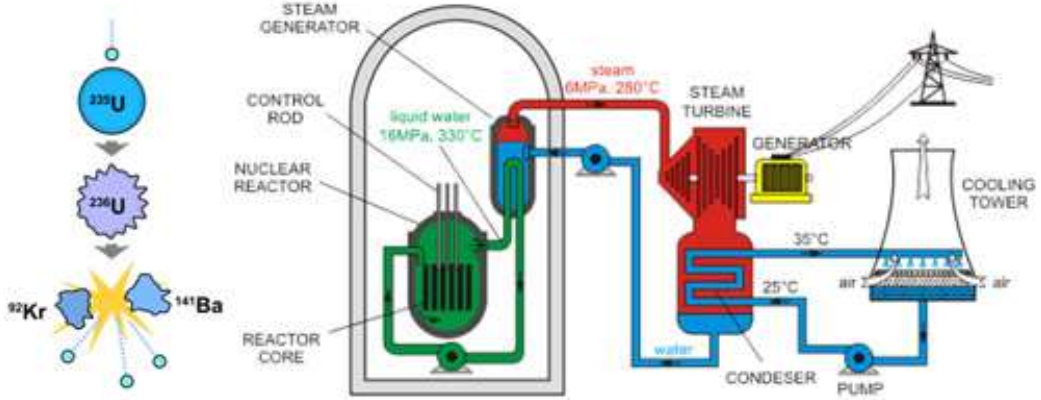
A nonrenewable resource is a natural resource that cannot be re-made or re-grown at a time-scale comparable to its consumption.

coal

petroleum

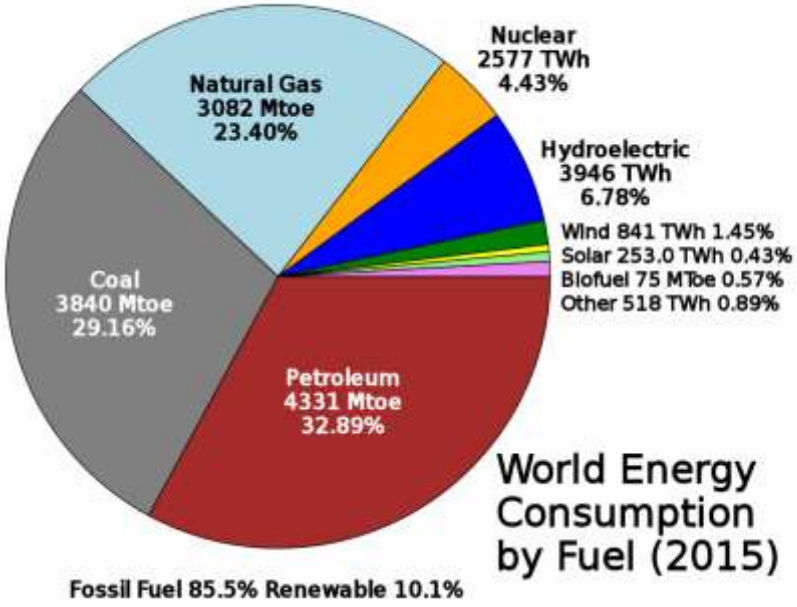
Natural gas

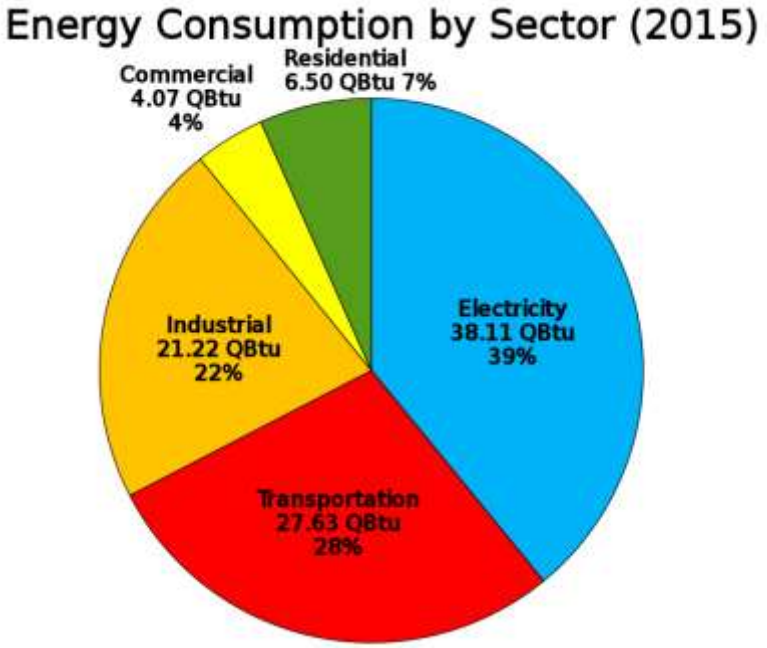
Nuclear energy



Nonrenewable Energy

- Nonrenewable energy, including petroleum, coal, natural gas and nuclear power, make up the vast majority of the energy portfolio of the world, although the portion of other resources (hydroelectric, wind, solar, biofuel., etc) was increased in recent years.





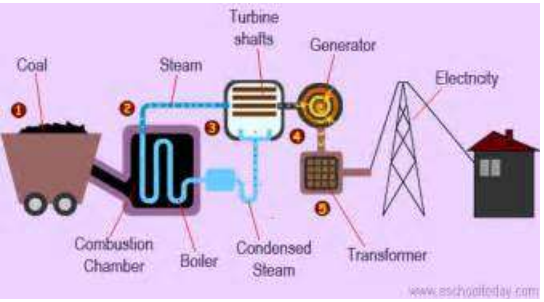
In the long-term, there are two major issues with this reliance on nonrenewable energy:

Dwindling supplies.

Environmental pollution.

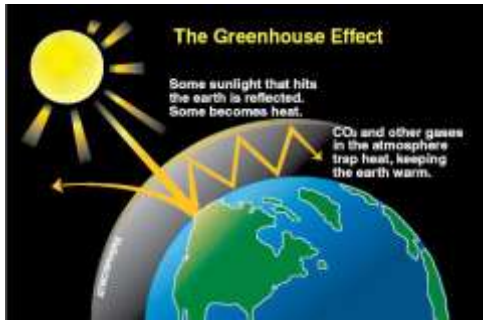
Coal

Coal – nonrenewable fossil fuel, a combustible black or brownish-black sedimentary rock usually occurring in layers or veins called coal beds or coal seams.



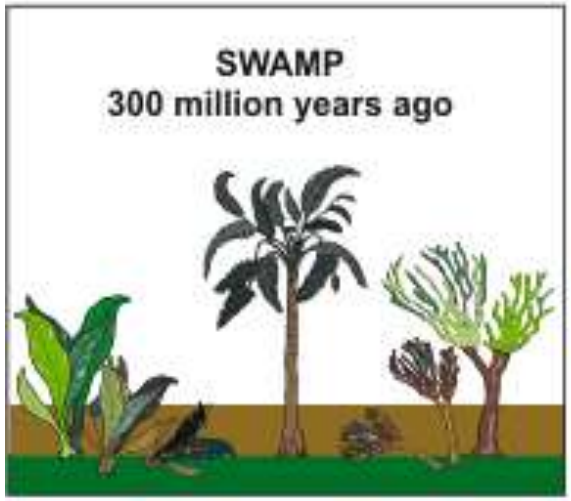
Coal has been used as an energy resource, primarily burned for the production of electricity and heat, and is also used for industrial purposes, such as refining metals.

Coal is the largest source of energy for the generation of electricity worldwide, as well as one of the largest worldwide sources of carbon dioxide releases.

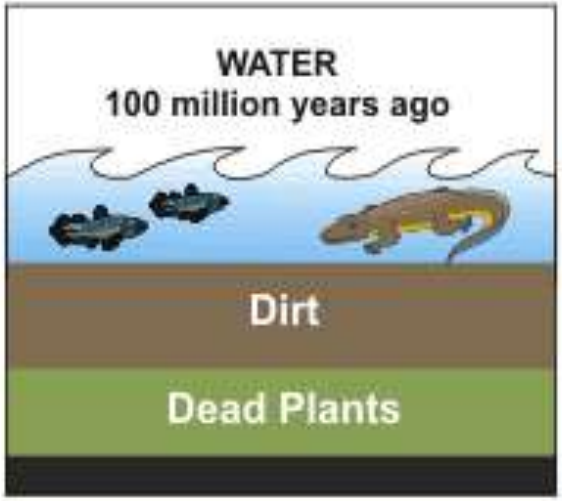


The extraction of coal, its use in energy production and its byproducts are all associated with environmental and health effects including climate change.

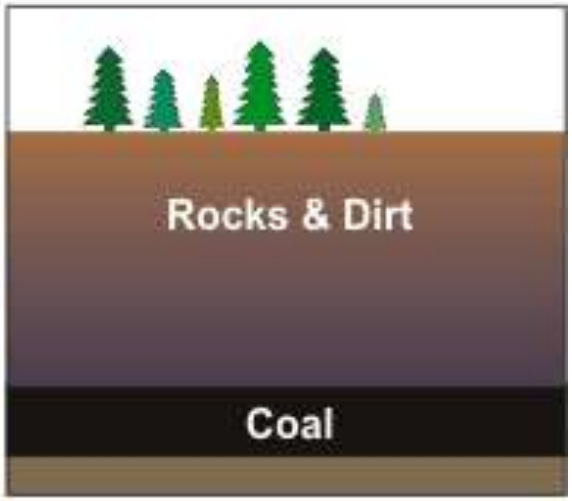
HOW IS COAL MADE ???



Before the dinosaurs, many giant plants died in swamps.



Over millions of years, the plants were buried under water and dirt.



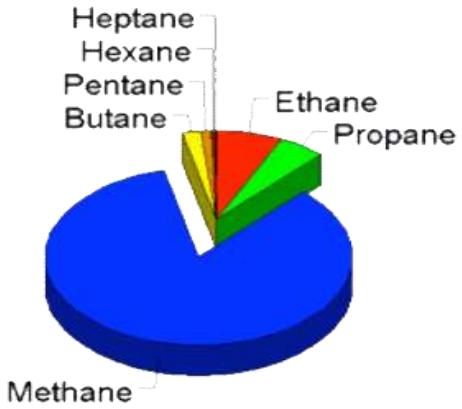
Heat and pressure turned the dead plants into coal.

- Coal is made from trees or plants that decayed on the ground free from oxidation and biodegradation.
- Over millions of years, the plant were buried under water and mixed with dirt, eventually forming into a solid material which is mainly composed of carbon.
- But aside from carbon, there are also other elements present in coal. These elements include some **sulfur, nitrogen, oxygen, and hydrogen.**

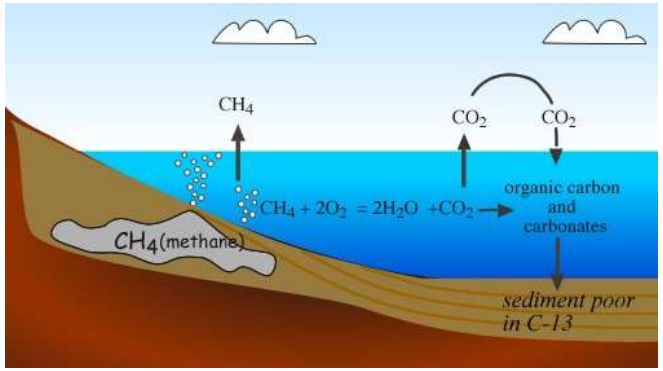
Advantages and disadvantages with coal as resources of energy

Advantages & Disadvantages of Coal-Fired Power Stations	
Advantages	Disadvantages
Coal-fired processes are **reliable** during peak and off-peak times and blackouts are extremely rare.	The burning of coal releases **green house gas emissions** and **harmful substances** such as mercury, sulfur dioxide, selenium, and arsenic.
The energy produced is affordable compared to other energy sources because coal is **cheap** and **abundant** compared to other fuels.	Mining coal **destroys environments** for both wildlife and humans by causing pitting of the earth.
The production and use of coal as fuel is widespread, so the **technology** is constantly advancing to become more efficient.	Coal-fired processes produce millions of tons of waste that cannot be reused, contributing to **waste disposal problems**.

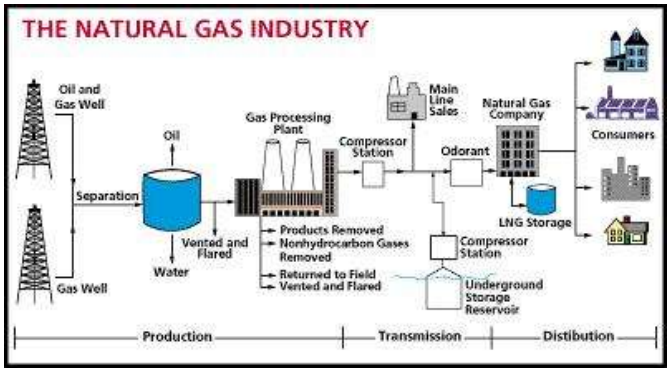
Natural gas



Natural gas –a naturally occurring hydrocarbon gas mixture consisting primarily of methane, but commonly including varying amounts of other higher alkanes, and sometimes a small percentage of carbon dioxide, nitrogen, hydrogen sulfide, or helium. nonrenewable fossil fuel.

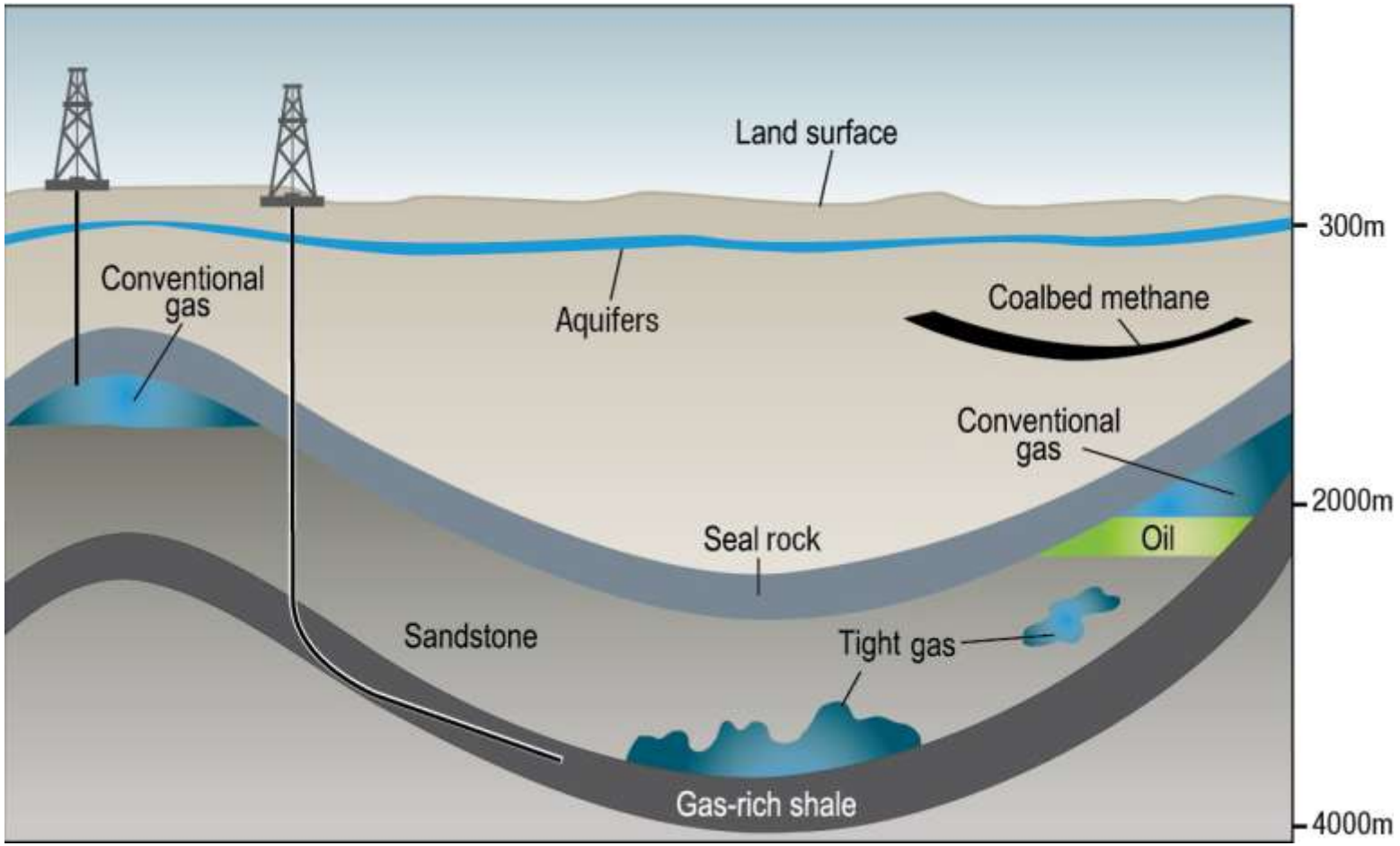


Natural gas is found in deep underground rock formations or associated with other hydrocarbon reservoirs in coal beds and as methane clathrates (甲烷冰）.



Natural gas is a fossil fuel used as a source of energy for heating, cooking, and electricity generation. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals.

- Natural gas is formed when layers of decomposing plant and animal matter are exposed to intense heat and pressure under the surface of the Earth over millions of years.
- Methane and some other gases trapped between seams of rock under the earth's surface.
- Pipes are sunk into the ground to release the gas.



Advantages and Disadvantages of Natural Gas

Advantages

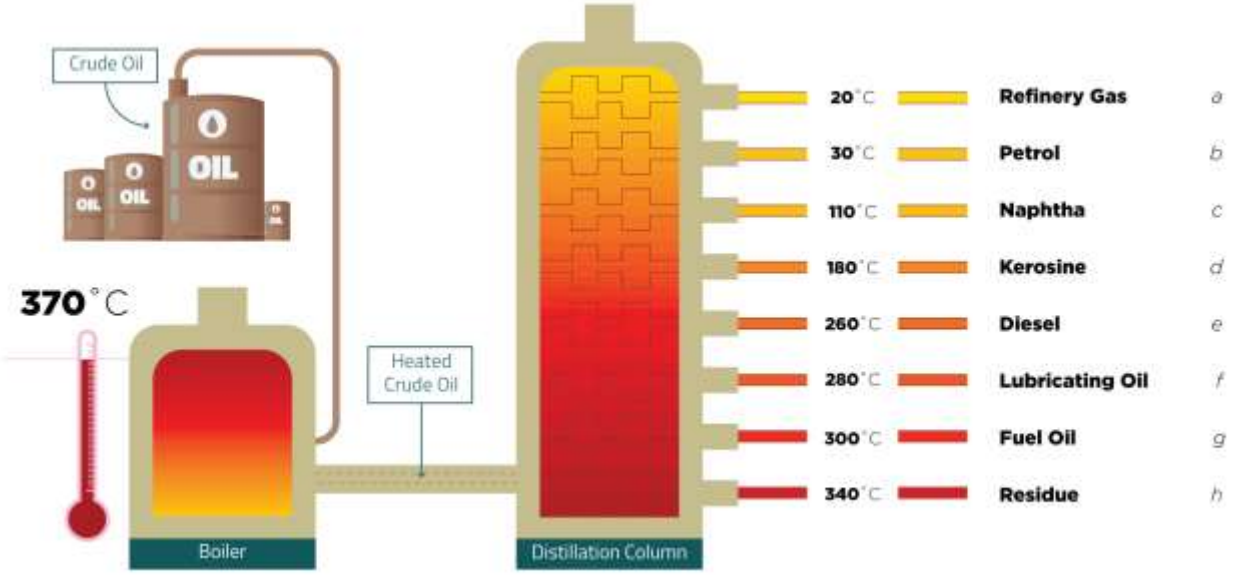
- Found in lots of places
- Transports in pipes, ships, or tanker
- Doesn't pollute water or ground when it's burned.
- Natural gas can come in small tanks for those without pipes

Disadvantages

- Non-renewable
- Adds to global warming
- Prices increase as supplies run out
- Workers are in danger of explosions
- Miles per gallon is lower in cars and trucks with natural gas.
- Can cause fires
- If your home isn't properly insulated it can be expensive to use natural gas.

Petroleum

- Petroleum – nonrenewable fossil fuel, a naturally occurring, yellow-to-black liquid found in geological formations beneath the earth's surface
- Because each fraction has its own boiling point, when the crude oil is heated, each fraction will boil at different temperatures and leave the crude oil mixture as a gas. This allows them to be separated and collected.
- The most common form of petroleum used to make electricity is fuel oil, a type of oil that is refined from crude oil.

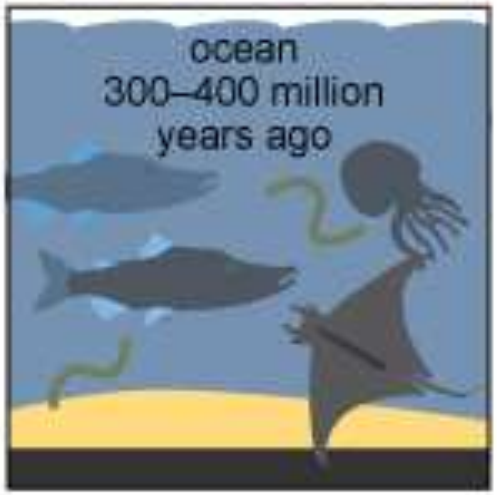


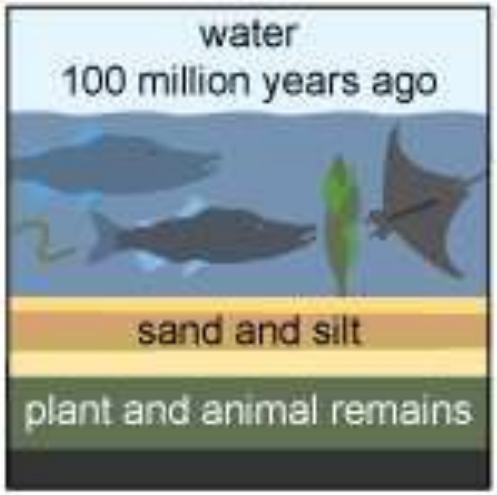
Petroleum and natural gas formation

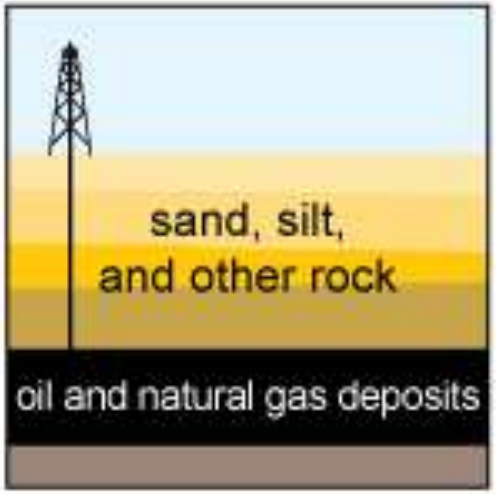
Tiny marine plants and animals died and were buried on the ocean floor. Over time, the marine plants and animals were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned the remains into oil and natural gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and natural gas deposits.







Source: Adapted from National Energy Education Development Project (public domain)

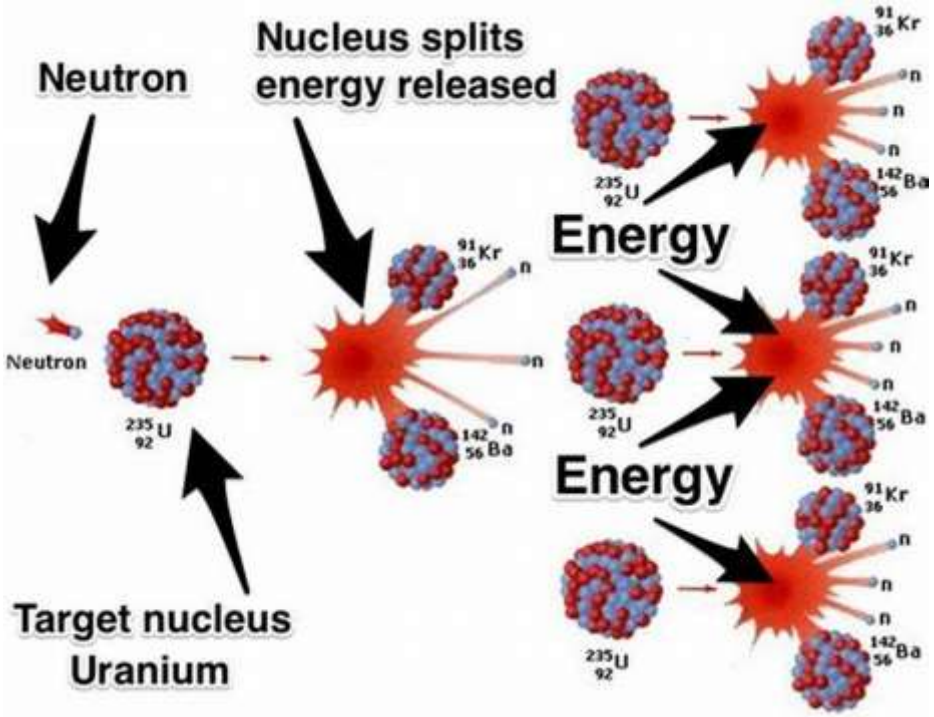
- Carbon-based liquid formed from fossilized animals.
- Lakes of oil are sandwiched between seams of rock in the earth.
- Pipes are sunk down to the reservoirs to pump the oil out.

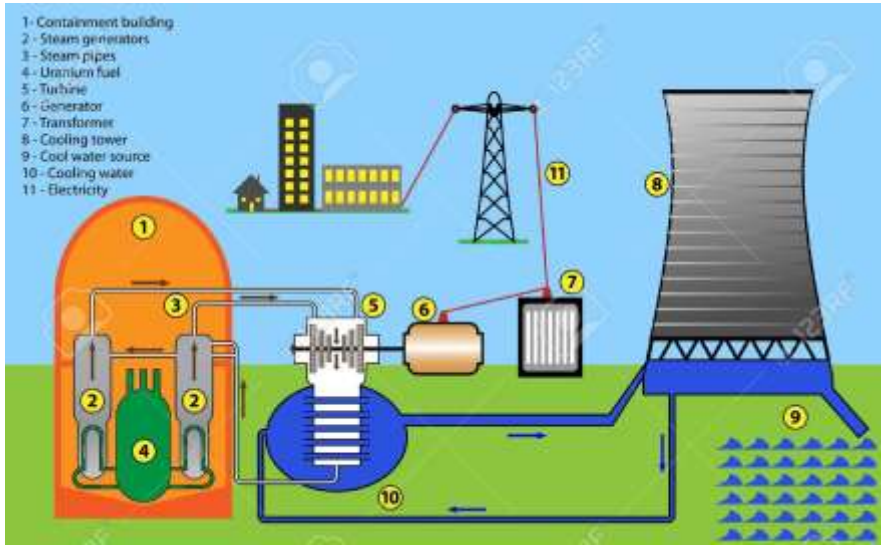
Advantages and Disadvantages of Petroleum

Advantages	Disadvantages
Convenient to transport and use	Releases carbon dioxide into atmosphere
Relatively energy-dense	Possibility of leaks when extracted and transported
Cleaner-burning than coal	
	Releases sulfur, mercury, lead, and arsenic into the atmosphere when burned

A NUCLEAR CHAIN REACTION

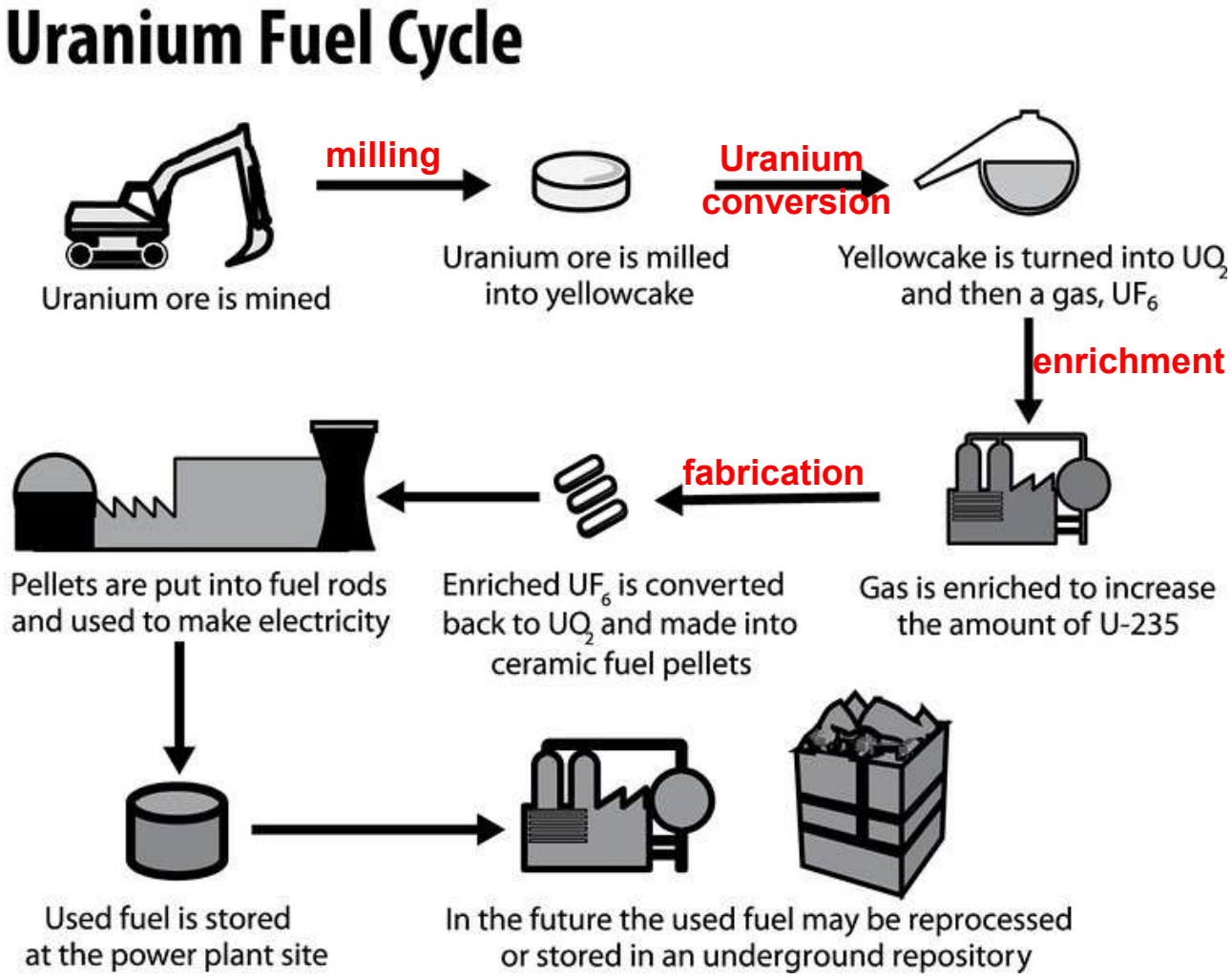
- Nuclear power involves a process called fission triggered by neutrons, in which the atoms of the element uranium split
- The splitting of atoms releases heat to turn water into steam and rotate the turbine blades.
- Nuclear power is nonrenewable and is used to generate about 10 percent of electricity in US.





NUCLEAR ENERGY

- Nuclear energy is a nonrenewable resource because once the uranium is used, it is gone!
- Radioactive minerals such as uranium are mined.



Advantages and Disadvantages of Nuclear Energy

Advantages

- No greenhouse gases
- A little makes ***A LOT*** of energy
  - The energy obtained from nuclear power is 10 million times more powerful than the energy that would be made in the same amount of coal.
- Reliable
  - Is unaffected by strikes and worldwide shortages.

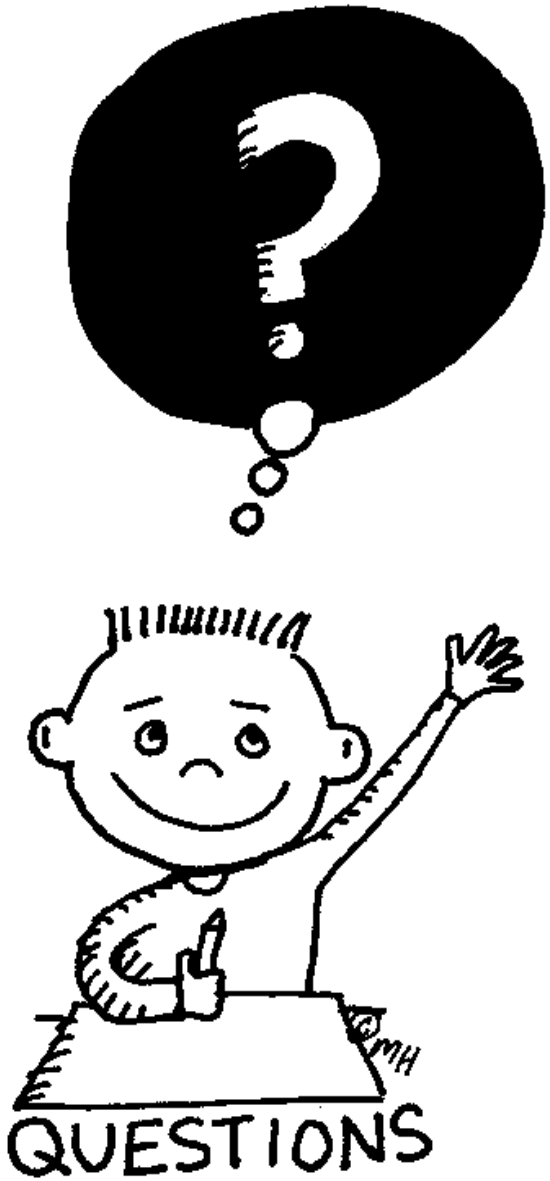
Disadvantages

- The waste is radioactive and harmful, thus having to be disposed of carefully.
- Supplies will run out in 50 years
- Power stations are at risk of being attacked
- If it is needed, it takes days to shut down a power plant.
- In a nuclear meltdown high dosages of radioactivity is exposed.

Dwindling Supplies

- Non-renewable resources are finite and will eventually be used up.
  - Most of the easily recoverable sources of coal, oil, and natural gas have already been tapped.
- As supplies of these resources tighten, or they become more expensive to extract, price will increase.
- The extraction, transport, and burning of fossil fuels is also a highly polluting process

HMMMM....



If nonrenewable resources are resources that cannot be re-made at a scale comparable to its consumption, what are renewable resources?

Renewable resource

A renewable resource is a natural resource which has the ability to revitalise itself naturally over an extended period of time. These resources are used to convert into energy and aid in helping provide alternatives to the current usage of oil, gas and coal which are finite.

Solar energy

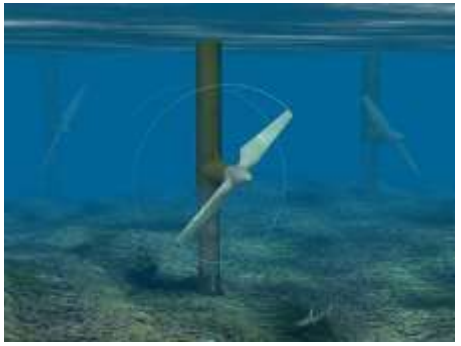
Biomass

Geothermal power

Hydroelectricity

Wind power

Wave power

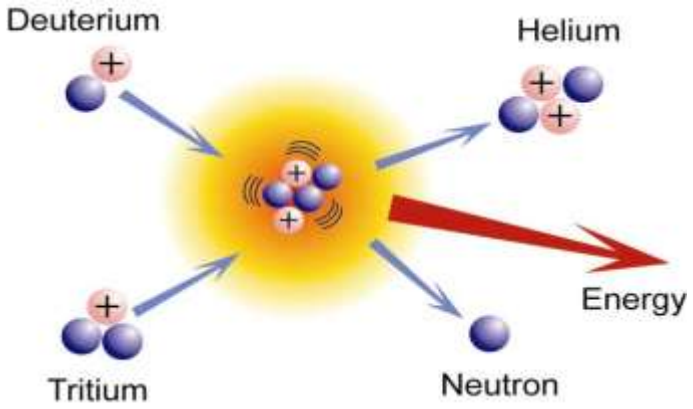


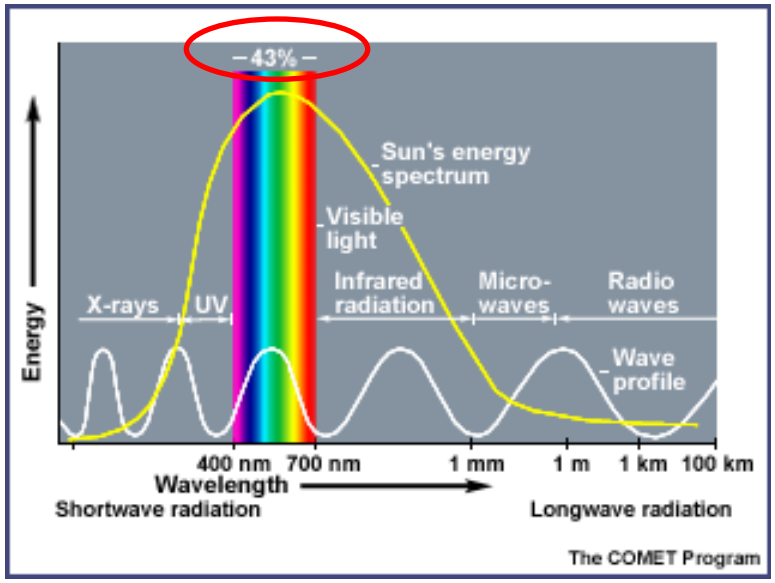
Tidal power

Solar energy

- **Solar energy** is radiant light and heat from the Sun, **originating with the thermonuclear fusion reactions occurring in the sun.**
- **Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).**

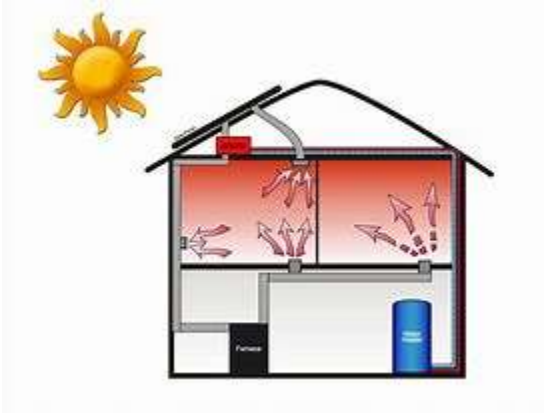
Nuclear Fusion

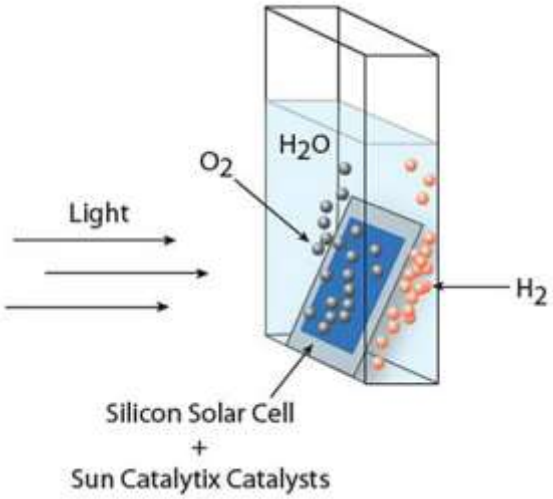




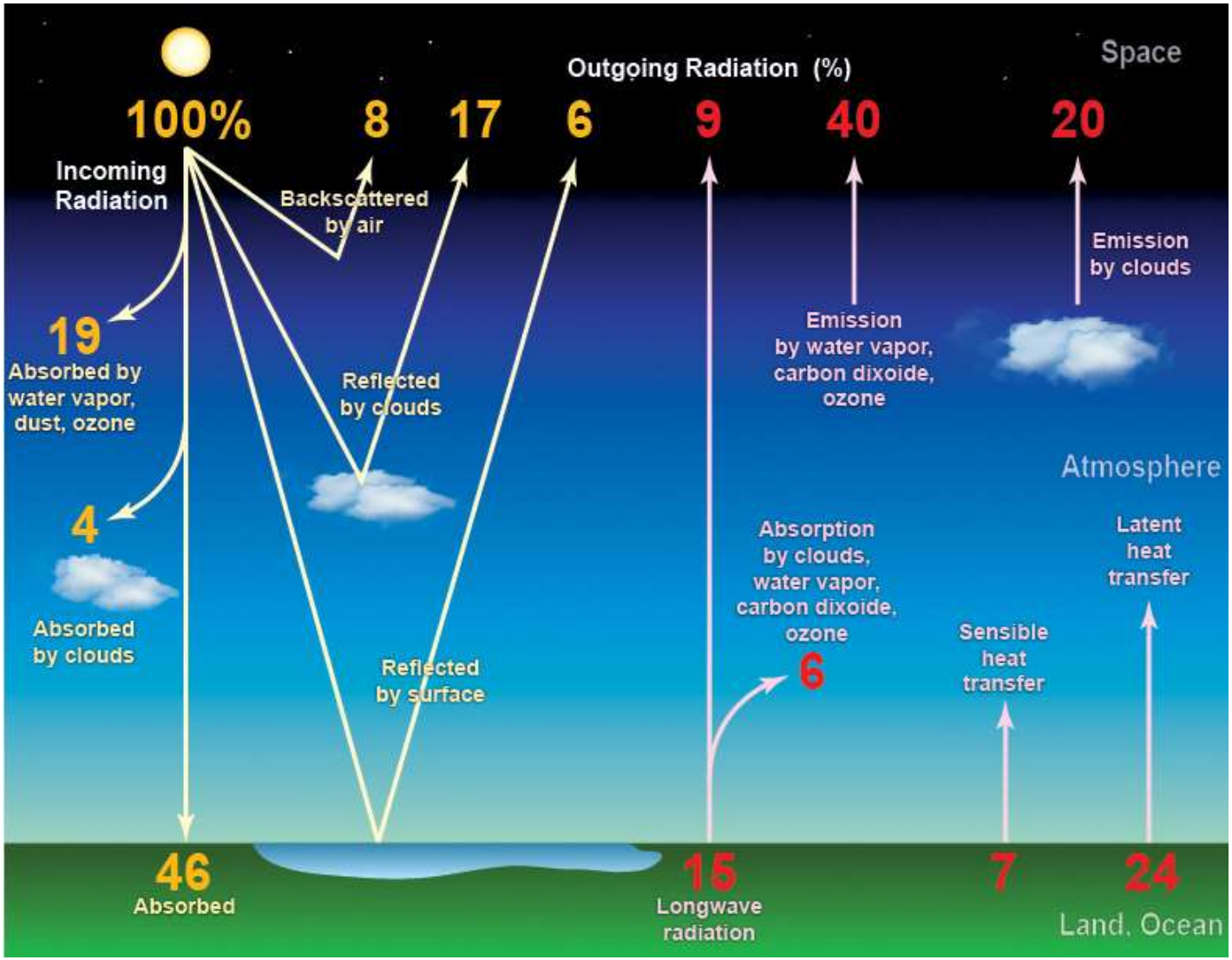
Major Uses of Solar Energy

- Solar heating
- Photovoltaics
- Solar thermal energy,
- Solar architecture
- Artificial photosynthesis





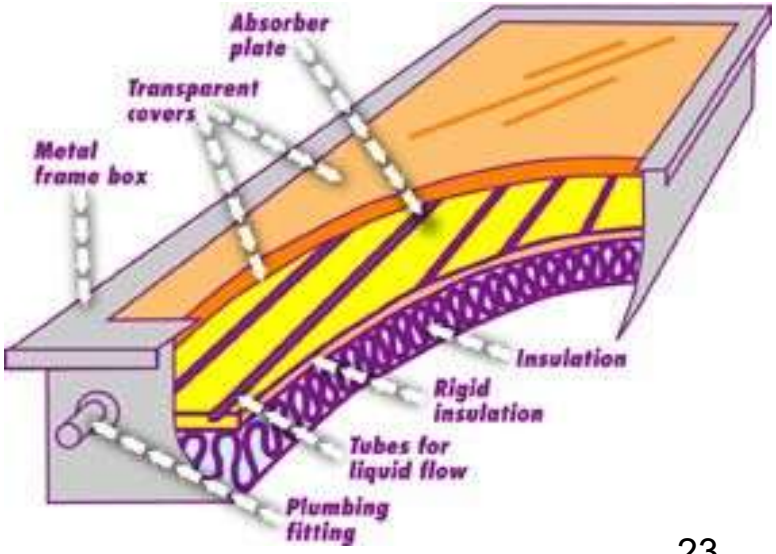
How much solar energy?



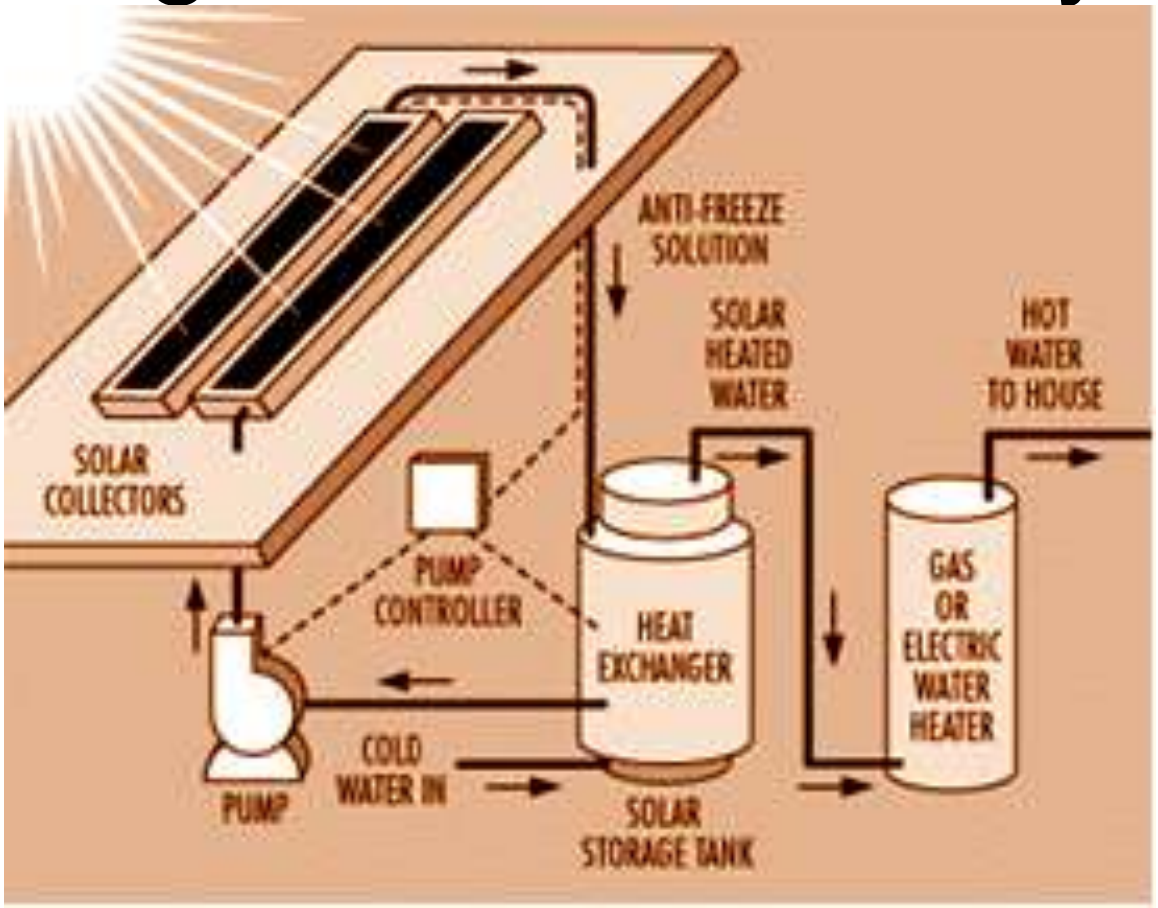
The surface receives about 47% of the total solar energy that reaches the Earth. Only this amount is usable.

Putting Solar Energy to Use: Heating Water

- Efficient solar heating relies on the ability of **glass** and **certain plastics** such as the polyester to be **transparent to light and short-wave infrared** but **opaque to the reflected longer-wave infrared**.
- A flat-plate collector is used to absorb the sun's energy to heat the water.
- The water circulates throughout the closed system due to convection currents.
- Tanks of hot water are used as storage.
- Currently, there are well over 20 million square meters of panels like this in use globally.



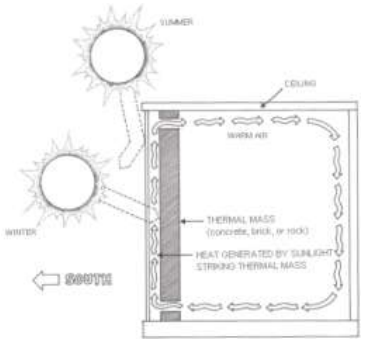
Heating Water: Active System



Active system uses pumps and antifreeze so that the liquid circulates throughout the closed system and does not freeze if outside temperature drops below freezing.

Heating Water—Last Thoughts

- Efficiency of solar heating system is always less than 100% because:



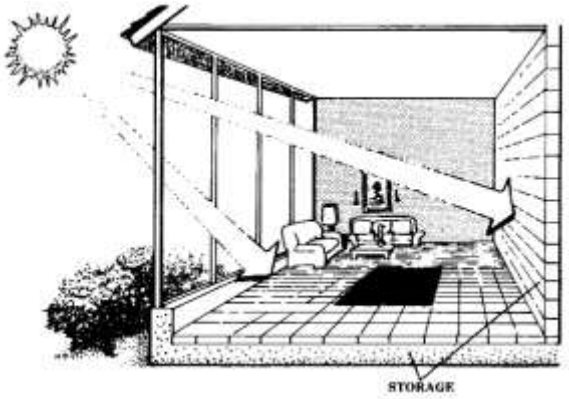
  - » % transmitted depends on angle of incidence,
  - » Number of glass sheets (single glass sheet transmits 90-95%), and
  - » Composition of the glass (high borosilicate glass)

- Solar water heating saves approx. 1000 megawatts of energy a year, equivalent to eliminating the emissions from two medium sized coal burning power plants.

- By using solar water heating over gas water heater, a family will save 1200 pounds of pollution each year.

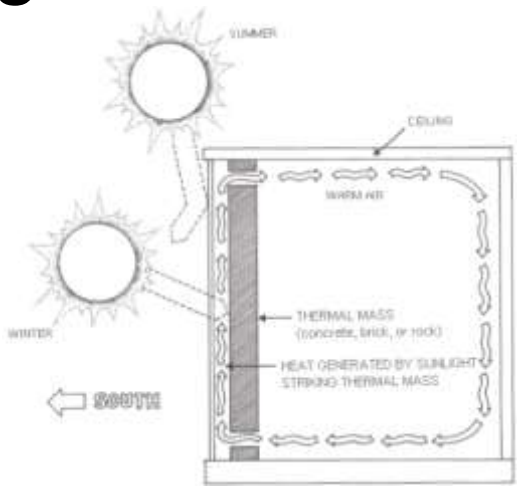
- While solar water heating is relatively low in the US, in other parts of the world such as Cyprus (90%) and Israel (65%), it proves to be the predominate form of water heating.

Heating Living Spaces



Passive Solar

Passively heated home in Colorado



Trombe Wall

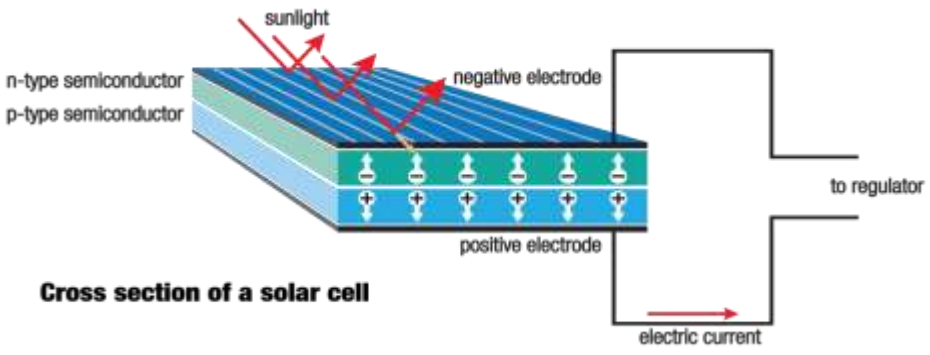
- Best design of a building is for it to act as a solar collector and storage unit. This is achieved through three elements: insulation, collection, and storage.
- Efficient heating starts with proper insulation on external walls, roof, and the floors. The doors, windows, and vents must be designed to minimize heat loss.
- Collection: south-facing windows and appropriate landscaping.

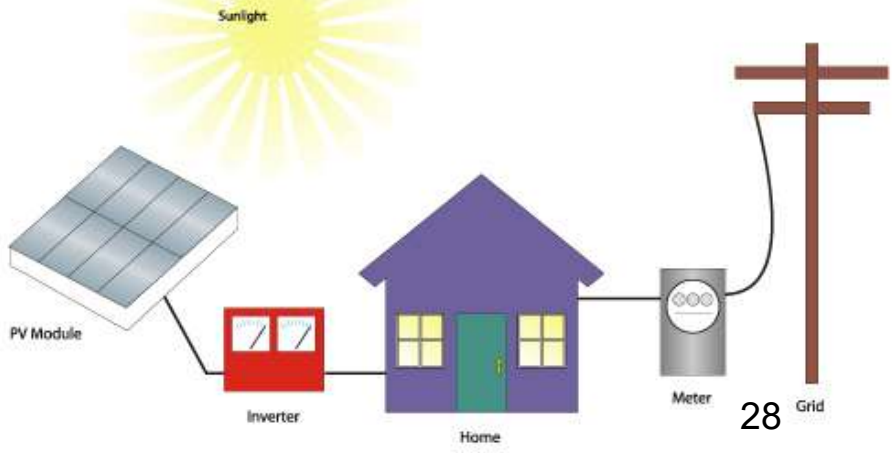
Heating Living Spaces

- A passively heated home uses about 60-75% of the solar energy that hits its walls and windows.
- The Center for Renewable Resources estimates that in almost any climate, a well-designed passive solar home can reduce energy bills by 75% with an added construction cost of only 5-10%.
- About 25% of energy is used for water and space heating.
- Major factor discouraging solar heating is low energy prices.

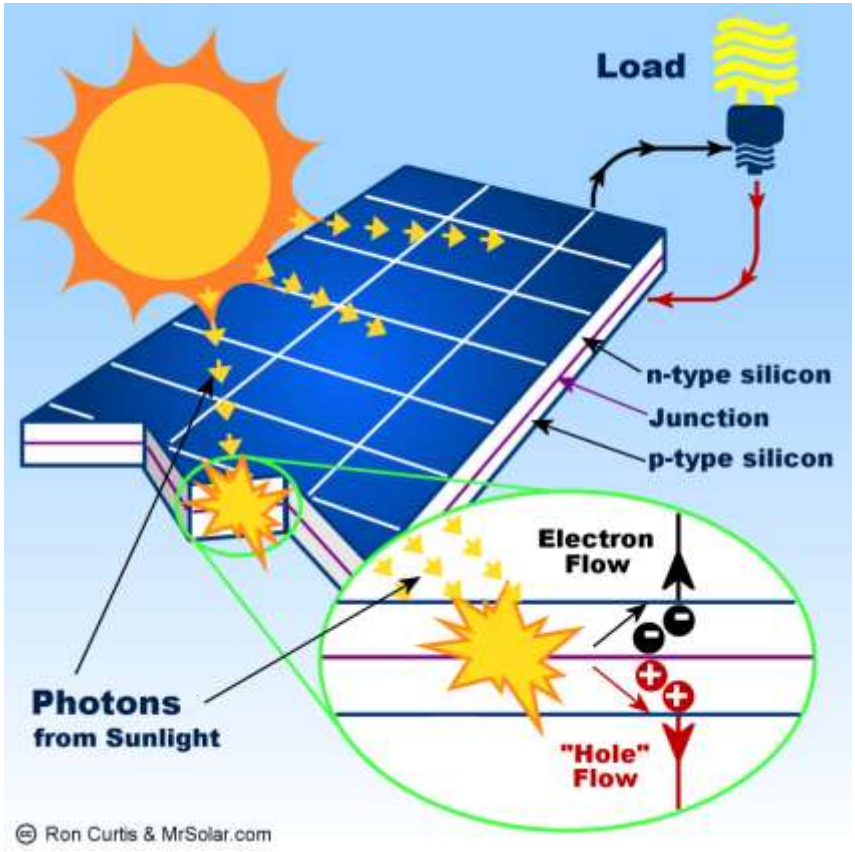
Solar cell

- The second more complex method involves converting the sun's energy into electricity and is known as photovoltaics, by using semi-conducting materials, such as silicon.
- By doping the silicon crystal with a small amount of phosphorus, which has five valence electrons, an n-type semiconductor is produced.
- Conversely, positive or p-type semiconductors can be made by doping the silicon with boron, which only has three valence electrons leaving holes in the structure.
- By joining n- and p-type semiconductors together, a junction is set which in simple terms enables electrons to move to fill the holes. When light above a certain wavelength hits the p-n junction, it gives electrons enough energy to escape the valence band and leaves them free to move around the material conducting electricity.





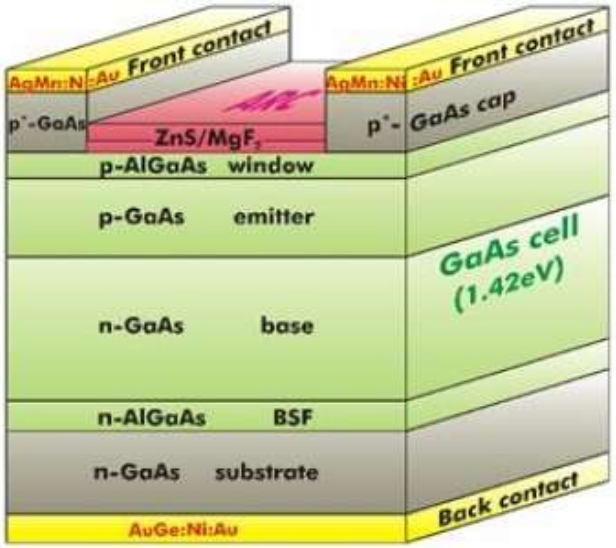
Direct Conversion into Electricity

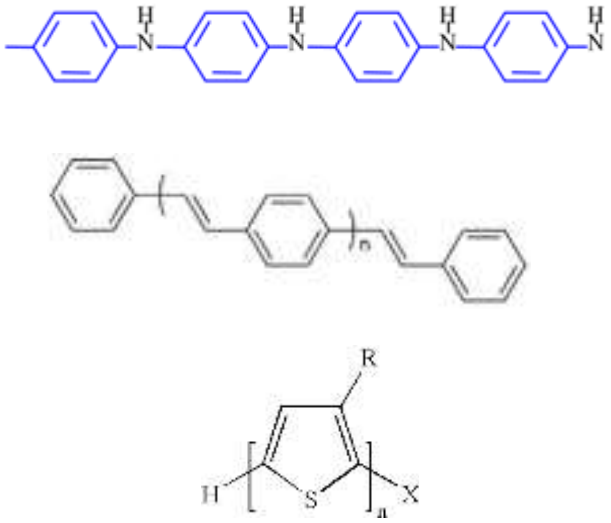


- Photovoltaic cells are capable of directly converting sunlight into electricity.
- A simple wafer of silicon with wires attached to the layers. Current is produced based on types of silicon (n- and p-types) used for the layers. Each cell=0.5 volts.
- Battery needed as storage
- No moving parts→do no wear out, but because they are exposed to the weather, their lifespan is about 20 years.

Solar cell

- Although the costs of silicon solar cells are falling because of improved manufacturing techniques, several other cell types are either commercially available or are being studied.
- Cells based on gallium arsenide (GaAs) are highly efficient, but very expensive and are generally only used in applications such as space, where cost is not a major concern.
- Although not yet commercialized, a whole range of conducting polymers is being assessed in photovoltaic (PV) cells, including polyanilines, poly-(p-phenylenevinylenes) and polythiophenes.
- The whole area of PV cells is the subject of intense research; this coupled with current market growth rates of over 20% per year, and the high profile given to the subject by companies such as BP and Shell, will surely mean that PV cells will soon be contributing significantly to energy supplies.



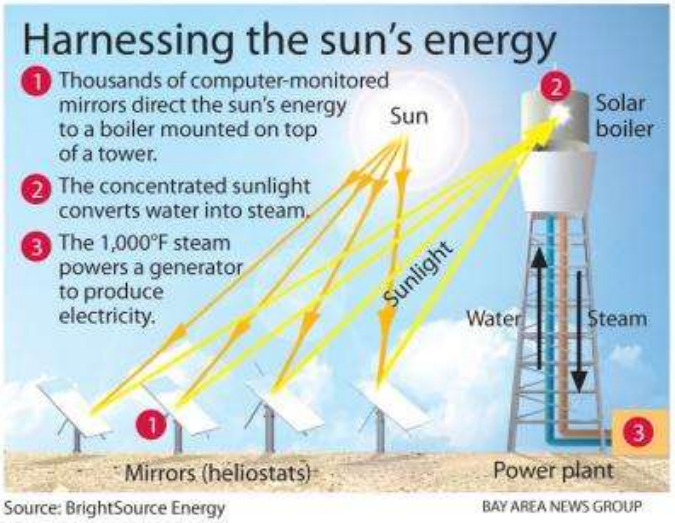


Solar Panels in Use

- Because of their current costs, only rural and other customers far away from power lines use solar panels because it is more cost effective than extending power lines.
- Utility companies are already purchasing, installing, and maintaining PV-home systems (Idaho Power Co.).
- Largest solar plant in US, sponsored by the DOE, served the Sacramento area, producing 2195 MWh of electric energy, making it cost competitive with fossil fuel plants.

Solar-Thermal Electricity: Power Towers

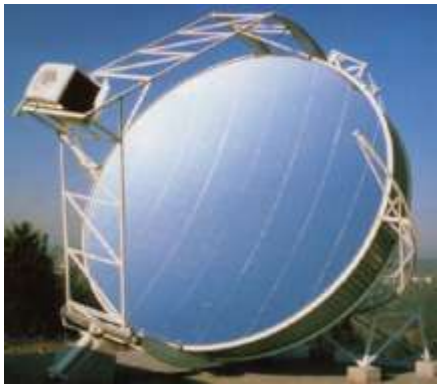
- General idea is to collect the light from many reflectors spread over a large area at one central point to achieve high temperature.
- Example is the 10-MW solar power plant in Barstow, CA.
    - 1900 heliostats, each 20 ft by 20 ft
    - a central 295 ft tower



•Capital cost is greater than coal fired power plant, despite the no cost for fuel, ash disposal, and stack emissions.
•Capital costs are expected to decline as more and more power towers are built with greater technological advances.
•One way to reduce cost is to use the waste steam from the turbine for space heating or other industrial processes.

Solar-Thermal Electricity: Parabolic Dishes and Troughs

Because they work best under direct sunlight, parabolic dishes and troughs must be steered throughout the day in the direction of the sun.



parabolic heliostat

Trough heliostat

Collectors in southern CA

- Focus sunlight on a smaller receiver for each device; the heated liquid drives a steam engine to generate electricity.
- The first of these Solar Electric Generating Stations (SEGS) was installed in CA by an Israeli company, Luz International.
- Output was 13.8 MW; cost was $6,000/peak kW and overall efficiency was 25%.
- The more recent facilities converted a remarkable 22% of sunlight into electricity.

Advantages and Disadvantages

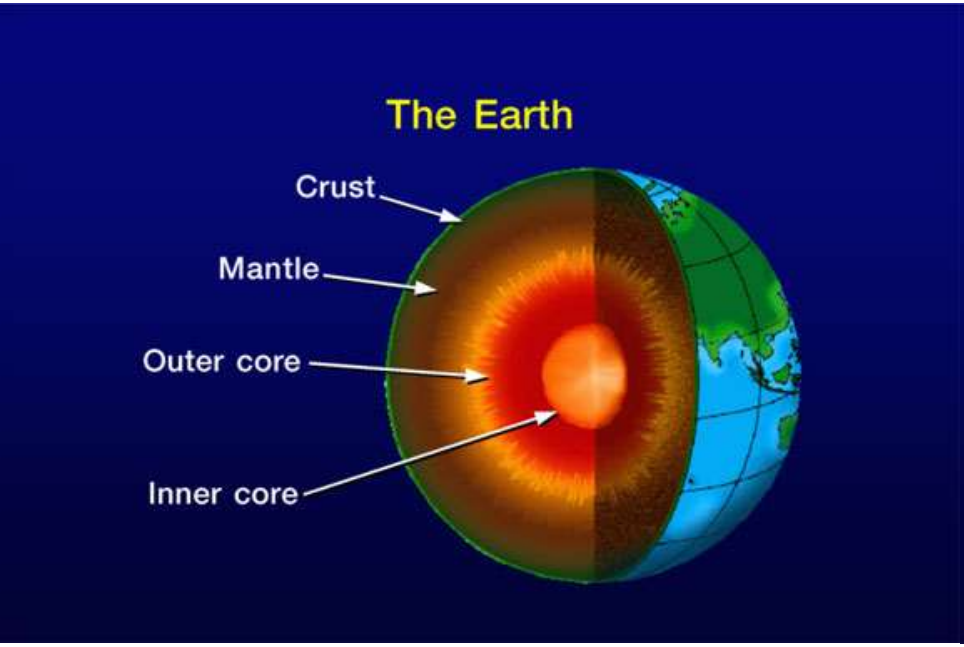
- Advantages
  - All chemical and radioactive polluting byproducts of the thermonuclear reactions remain behind on the sun, while only pure radiant energy reaches the Earth.
  - Energy reaching the earth is incredible. By one calculation, 30 days of sunshine striking the Earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused!
- Disadvantages
  - Sun does not shine consistently.
  - Solar energy is a diffuse source. To harness it, we must concentrate it into an amount and form that we can use, such as heat and electricity.
  - Addressed by approaching the problem through:
    1) collection, 2) conversion, 3) storage.

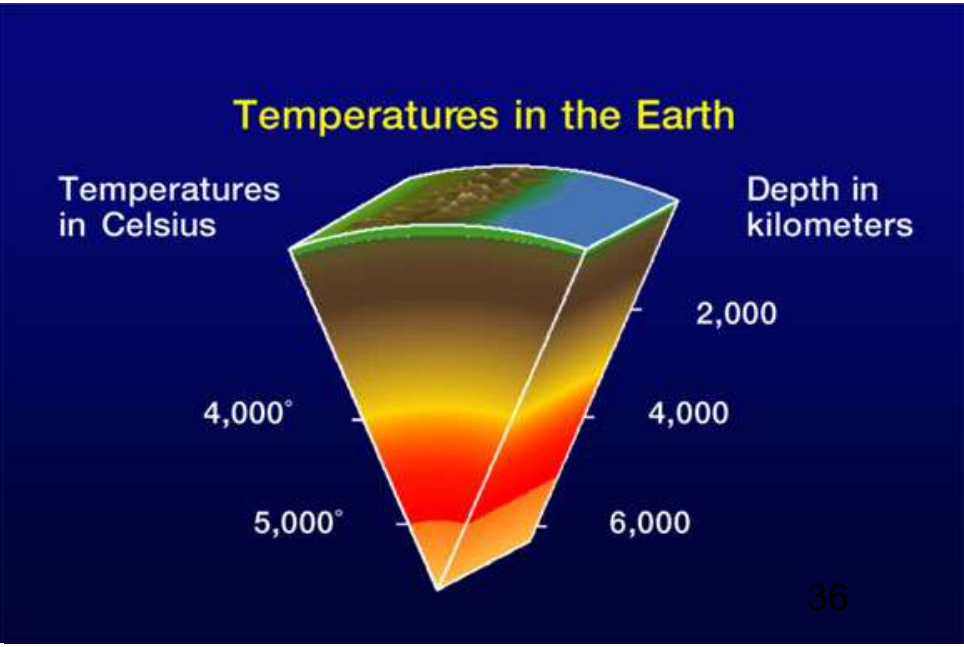
Final Thought

- Argument that sun provides power only during the day is countered by the fact that 70% of energy demand is during daytime hours. At night, traditional methods can be used to generate the electricity.
- Goal is to decrease our dependence on fossil fuels.
- Currently, 75% of our electrical power is generated by coal-burning and nuclear power plants.
- Mitigates the effects of acid rain, carbon dioxide, and other impacts of burning coal and counters risks associated with nuclear energy.
- pollution free, indefinitely sustainable.

Geothermal energy

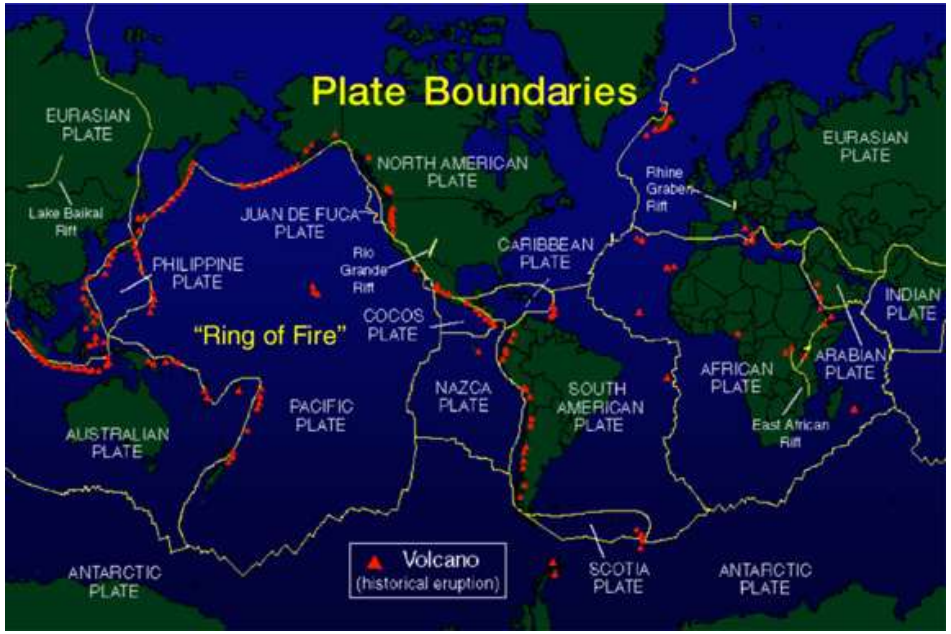
- Geothermal energy is heat energy generated and stored in the Earth.
- 70% comes from the decay of radioactive nuclei with long half lives that are embedded within the Earth
- Some energy is from residual heat left over from Earths formation.
- The rest of the energy comes from meteorite impacts.
- Normal thermal gradient is 30°C/km of depth.
- In general, the deeper we go into the earth, the hotter it gets.

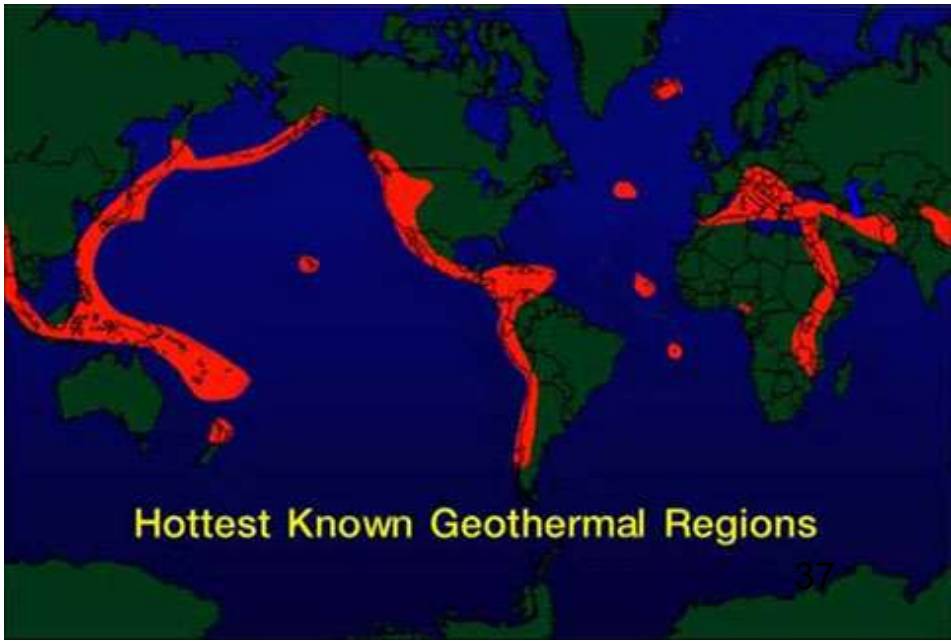


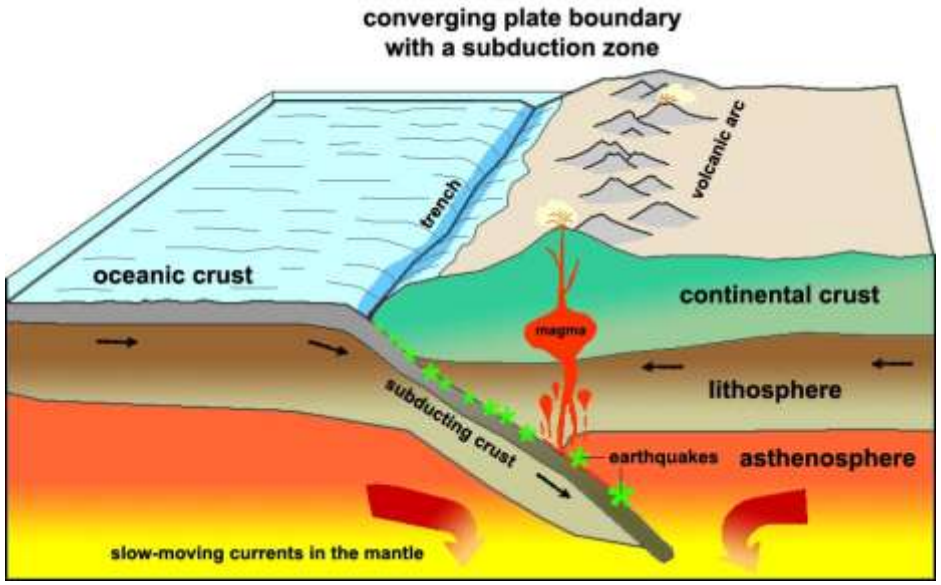


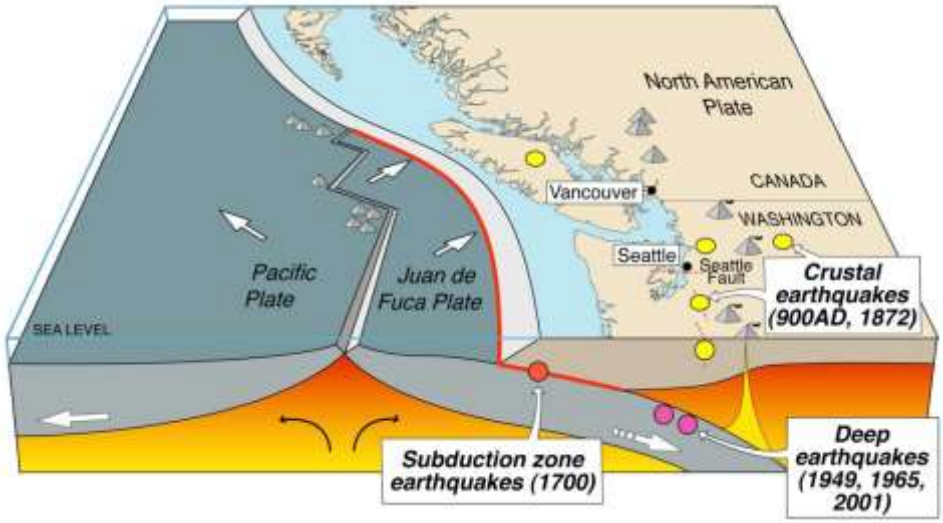
Good Geothermal Regions Associated with Plate Boundaries

- One of the most active geothermal areas in the world is called the Ring of Fire. This area encircles the Pacific Ocean.
- The most active geothermal resources are usually found along major tectonic plate boundaries where earthquakes and volcanoes are located.









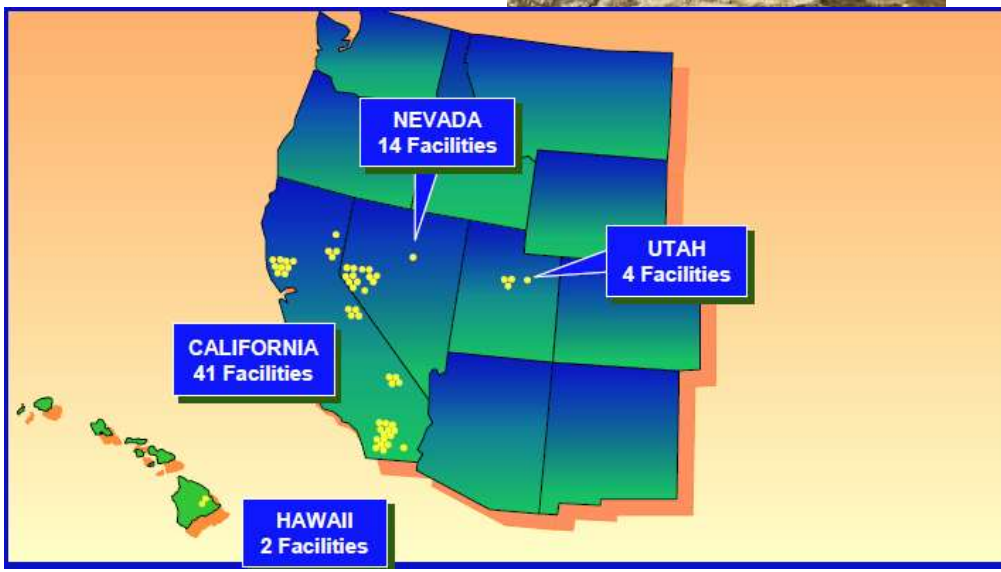
•Tectonic plate collisions generate tremendous force.
•Since oceanic plates are typically heavier than continental plates, when they collide the oceanic plate is forced down under the edge of the continental plate creating a subduction zone.
•Once a subduction zone is created, the oceanic plate slips further underneath under high pressure, creating violent earthquakes.
•When the edge of the oceanic plate is pushed down far enough, it melts from the heat of the earth's core and rises through the broken plates to form volcanoes.

Geothermal

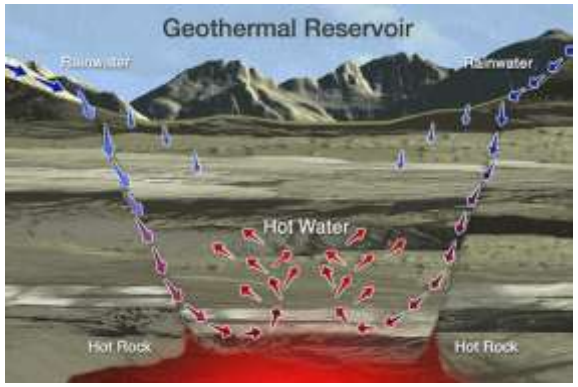
- Not a new idea
- Used the heat from inside the Earth for thousands of years for bathing (hot springs) and space heating.
- First electric power use was by Prince Piero Ginori Conti tested the first geothermal power generator on 4 July 1904 in Larderello, Italy.
- In 1958 New Zealand built a plant of its own.
- First geothermal power plant in the United States was made in 1922 by John D. Grant at The Geysers Resort Hotel.
- In the early-1970s, small experimental power units were established along the east coast of China at Fengshun in Guangdong Province in 1970 (0.3 MW flash steam).
- In 1977, a geothermal power plant was put online at Yangbaijing in Tibet supplying power to Lhasa. The installed capacity was 3 MW.

The Geysers

- A geyser is a spring characterized by intermittent discharge of water ejected turbulently and accompanied by steam.
- The Geysers is a geothermal power field located 72 miles (116 km) north of San Francisco, California.
- It is the largest geothermal development in the world.
- It is currently outputting over 750 MW. It consists of 22 separate power plants that utilize steam from more than 350 producing wells.



Different Geothermal Energy Sources



•**Hot Water Reservoirs**: are reservoirs of hot underground water. They are more suited for space heating than for electricity production.

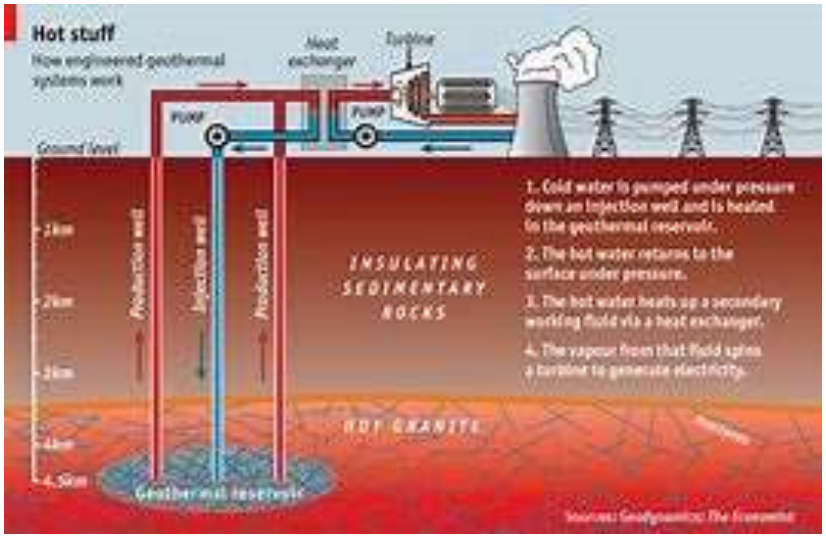
•**Natural Steam Reservoirs**: In this case a hole dug into the ground can cause steam to come to the surface.

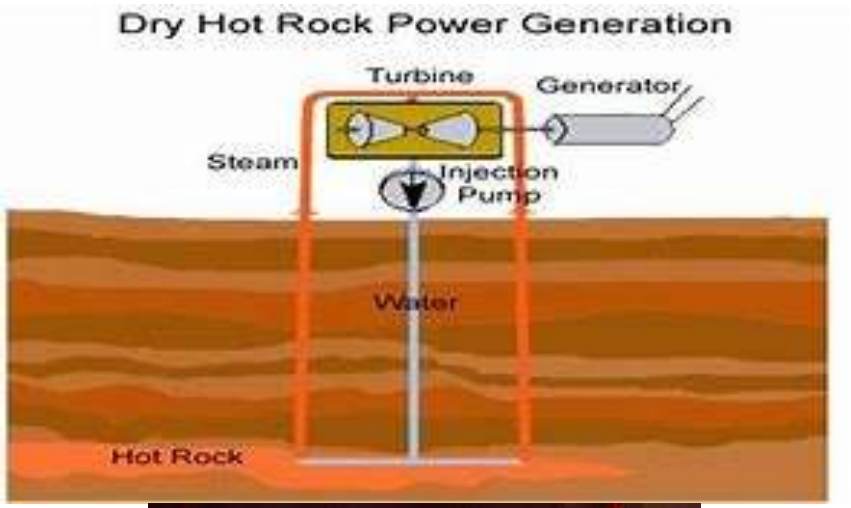
•**Geopressured Reservoirs**: In this type of reserve, brine completely saturated with natural gas in stored under pressure from the weight of overlying rock. This type of resource can be used for both heat and for natural gas.

- **Normal Geothermal Gradient**: At any place on earth, there is a normal temperature gradient of $+30^0$C per km dug into the earth. Therefore, if one digs 20,000 feet the temperature will be about 190^0C above the surface temperature. This difference will be enough to produce electricity.

- **Hot Dry Rock**: It is similar to normal geothermal gradient, but the gradient is 40^0C/km dug underground.

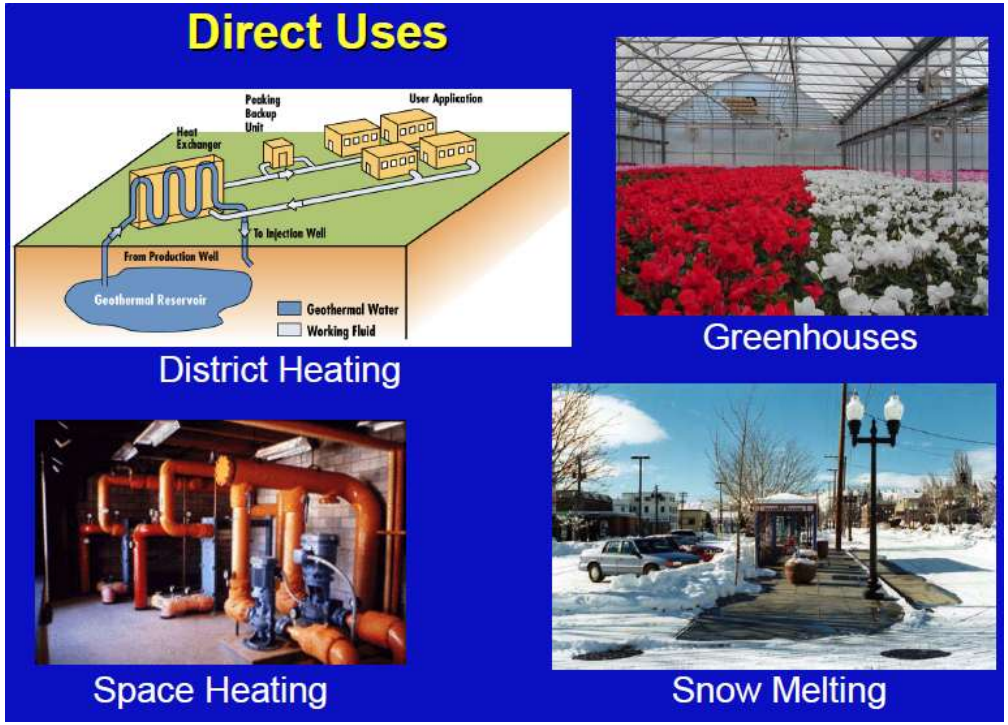
- **Molten Magma**: No technology exists to tap into the heat reserves stored in magma.





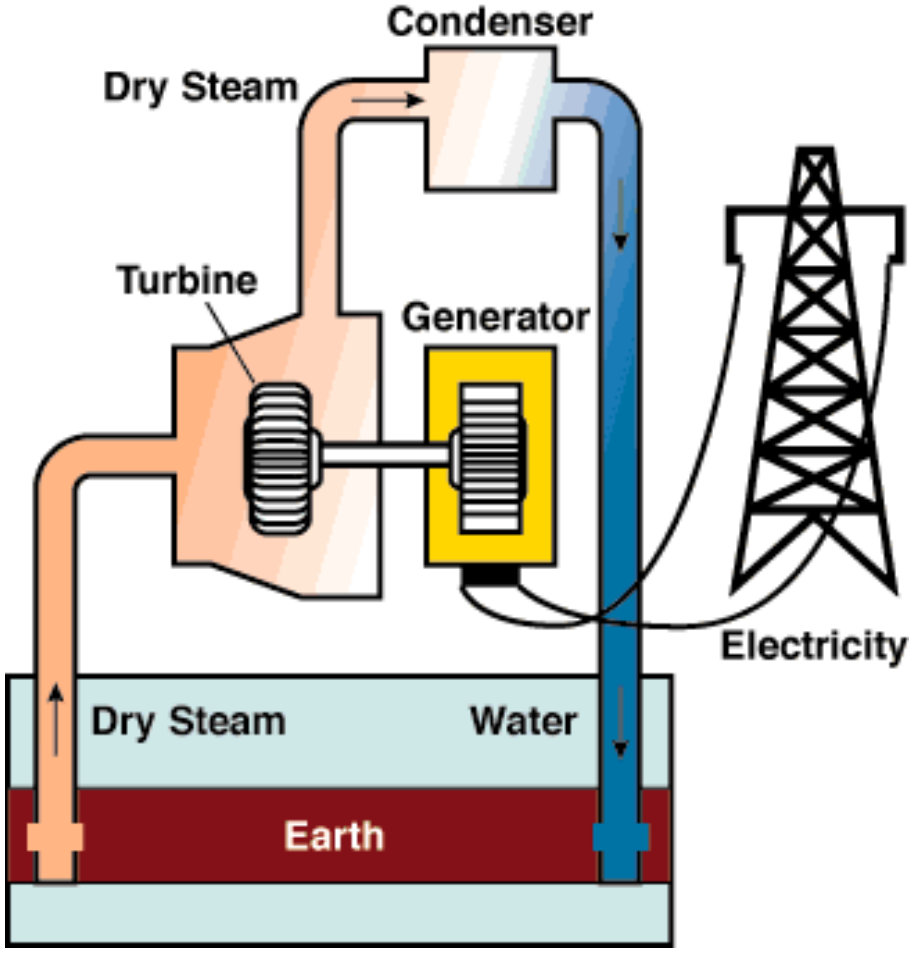
Hot Water reservoirs

- Example of a direct use system
  - a well is drilled into a geothermal reservoir to provide a steady stream of hot water.
  - The water is brought up through the well, piping, a heat exchanger, and controls and delivers the heat directly for its intended use.
  - A disposal system then either injects the cooled water underground or disposes of it in a surface storage pond.
- Used for heating buildings, raising plants in greenhouses, drying crops, heating water for fish farms, or for industrial processes



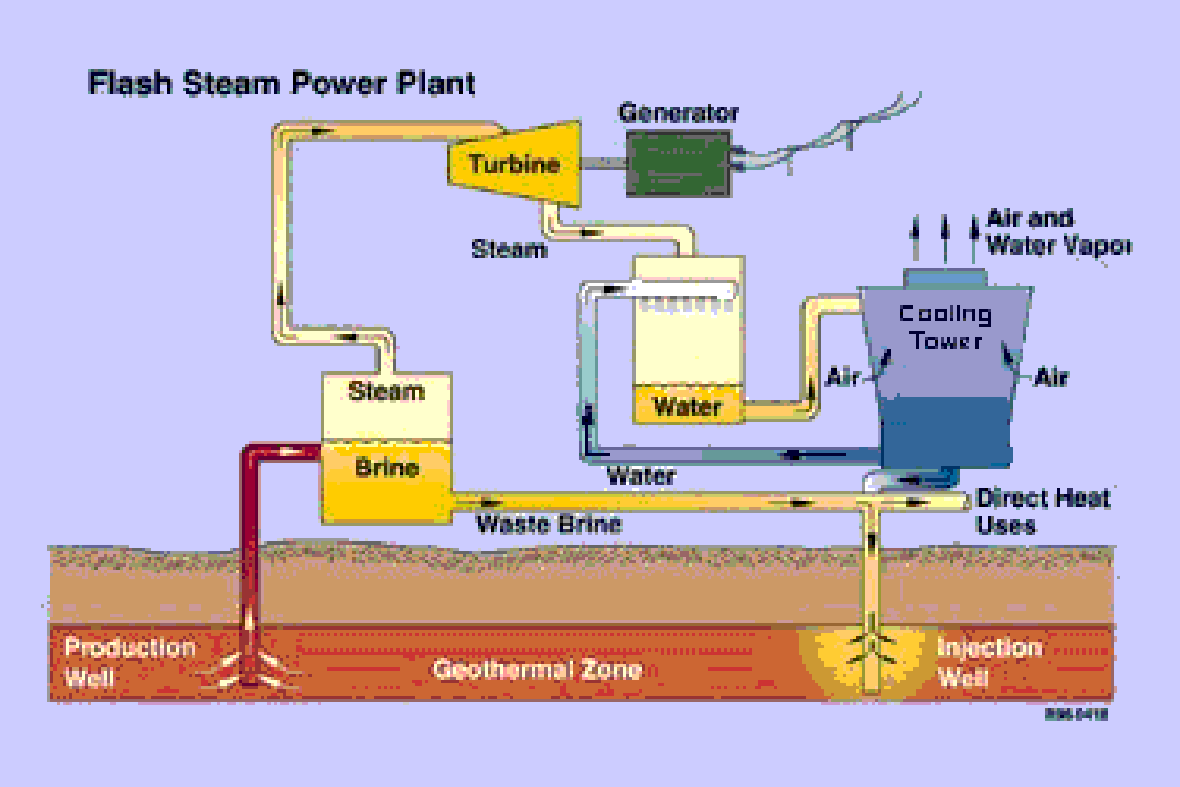
Natural Steam Reservoirs

- Steam is produced when hot water boils underground and some of the steam escapes to the surface under pressure.
- Once at the surface, impurities and tiny rock particles are removed, and the steam is piped directly to the electrical generating station
- Sources of natural steam can be used to drive a turbine.
- Hydrothermal reservoirs consist of a heat source covered by a permeable formation through which water circulates.



Geopressurized reservoirs

- Geopressurized reservoirs are sedimentary formations containing hot water (brine-water saturated with salt) and methane gas.
- Could be a source of both power and natural gas



Normal geothermal gradient/Hot Dry Rock

- Natural geothermal gradient of about 30°C/km exists.
- A geothermal heat pump system consists of pipes buried in the shallow ground near a building, a heat exchanger, and ductwork into the building.
- In winter, heat from the relatively warmer ground goes through the heat exchanger into the house.
- In summer, hot air from the house is pulled through the heat exchanger into the relatively cooler ground.
- Heat removed can be used as no-cost energy to heat water.

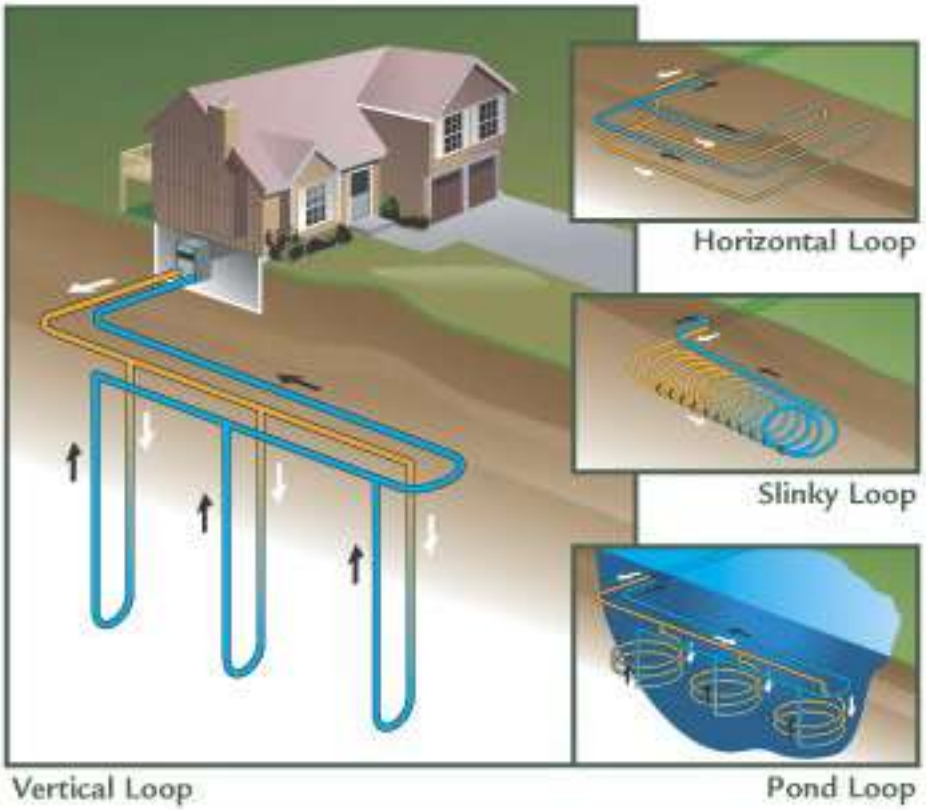


Table 1. Installed (gross) Geothermal Power Worldwide (2004).

Country	Installed MW	Est. Energy Produced (GWh/a)
Argentina	(1)	not operating
Australia	<1	3
Austria	<1	5
China	32	100
Costa Rica	162	1,170
El Salvador	105	550
Ethiopia	7	30
France (Guadalupe)	4	21
Germany	<1	2
Greece	(2)	not operating
Guatemala	29	180
Iceland	200	1,433
Indonesia	807	6,085
Italy	790	5,300
Japan	535	3,470
Kenya	127	1,100
Mexico	953	6,282
New Zealand	453	3,600
Nicaragua	78	308
Papua New Guinea	30	100
Philippines	1,931	8,630
Portugal (Azores)	8	42
Russia	100	275
Taiwan	3	15
Thailand	<1	2
Turkey	21	90
United States	2,395	16,000
TOTAL	**8,771**	**54,793**

Advantages

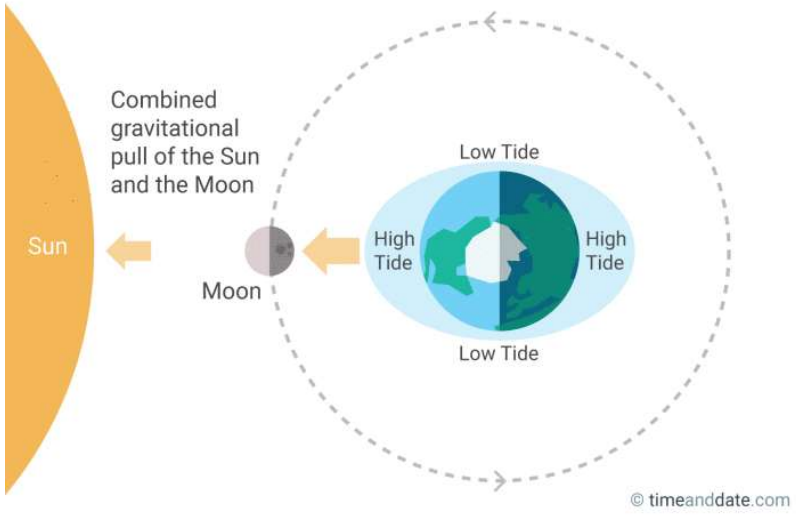
- Geothermal power requires no fuel and is emissions free and is not susceptible to fluctuations in fuel cost.
- Geothermal power station don't rely on transient sources of energy (wind, sun)
- It is considered to be sustainable because the heat extraction is small compared to the size of the heat reservoir.
  - individual wells may need to recover, geothermal heat is inexhaustible and is replenished from greater depths. The long-term sustainability of geothermal energy production has been demonstrated at the Lardarello field in Italy since 1913, at the Wairakei field in New Zealand since 1958, and at The Geysers field in California since 1960.
  - However, there has been a decrease in output noted at The Geysers
- Geothermal has minimal land use requirements

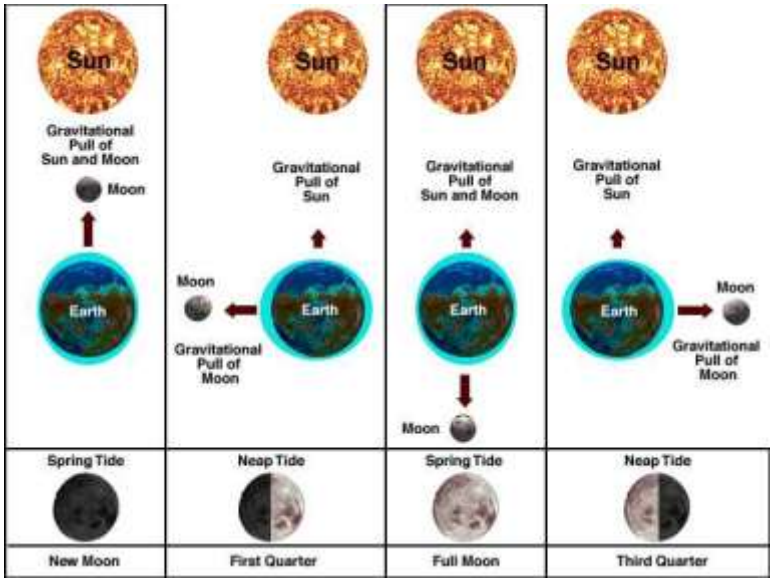
Disadvantages

- The geothermal fluid is corrosive and, worse, is at a low temperature compared to steam from boilers, this limits the efficiency of heat engines in extracting useful energy during the generation of electricity. Much of the heat energy is lost.
- Construction of the power plants can adversely affect land stability in the surrounding region. This is mainly a concern with Enhanced Geothermal Systems, where water is injected into hot dry rock where no water was before.
- Dry steam and flash steam power plants also emit low levels of carbon dioxide, nitric oxide, and sulphur, although at roughly 5% of the levels emitted by fossil fuel power plants..
- Hot water from geothermal sources will contain trace amounts of dangerous elements such as mercury, arsenic, and antimony which, if disposed of into rivers, can render their water unsafe to drink.
- Locations may eventually cool down.

Tidal power

Tide energy comes from the gravitational attraction of the moon and sun on the earth's oceans.



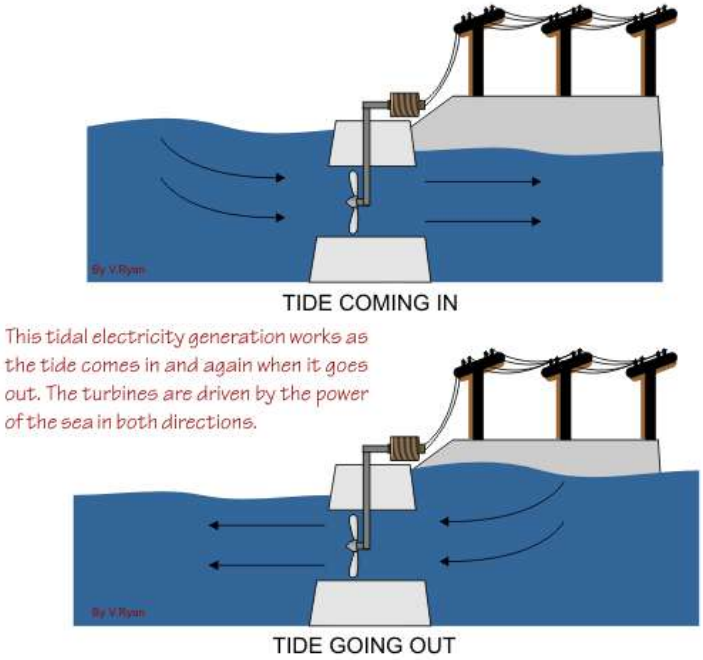


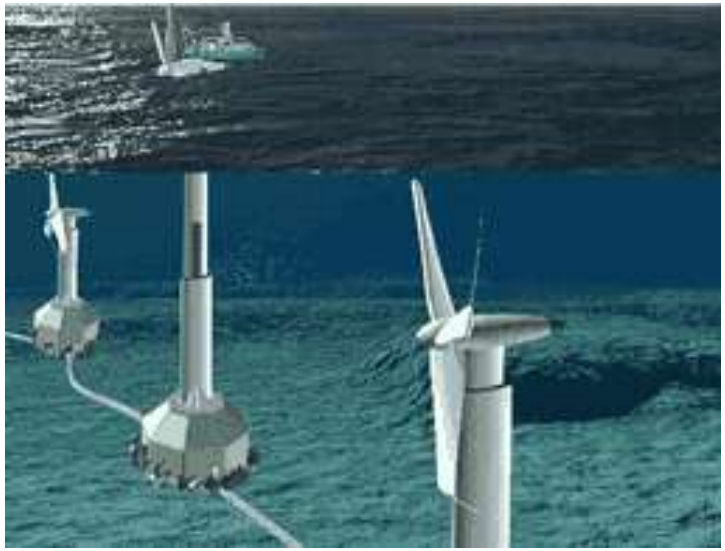
- The gravitational force of the Moon and the Sun pulls the water in the oceans upwards making the oceans bulge, which creates high tide in the areas of Earth facing the Moon and on the opposite side.
- At the same time, in other parts of the planet, the ocean water drains away to fill these bulges, creating low tides.
- When the sun and moon are at right angles to each other, the bulge of the ocean caused by the sun partially cancels out the bulge of the ocean caused by the moon. This produces moderate tides known as **neap tides**.."

Tidal power

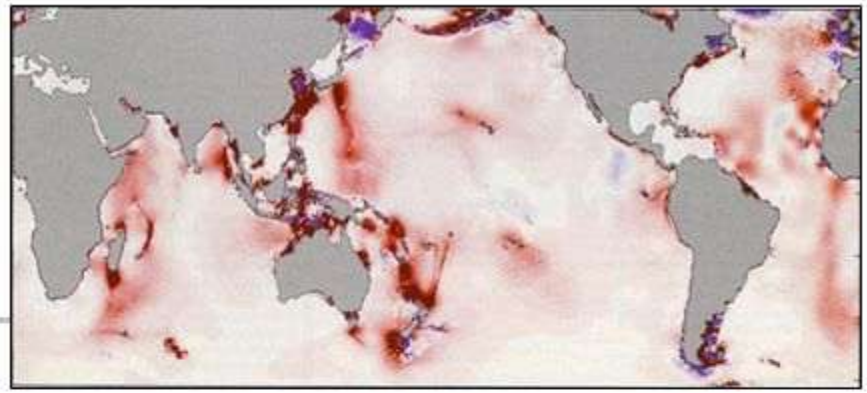
Tidal power, also called **tidal energy**, is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

- A huge dam (barrage") is built across a river estuary. When the tide goes in and out, the water flows through tunnels in the dam. The ebb and flow of the tides can be used to turn a turbine.
- Tidal stream generators (or TSGs) make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use wind to power turbines.





The worldwide distribution of Tidal Energy



These countries can receive significant benefits from Tidal Energy:

Indian Ocean: Comoros, Madagascar, Maldives, Seychelles.

Asia: China, India, Indonesia, Korea, Philippines, Vietnam.

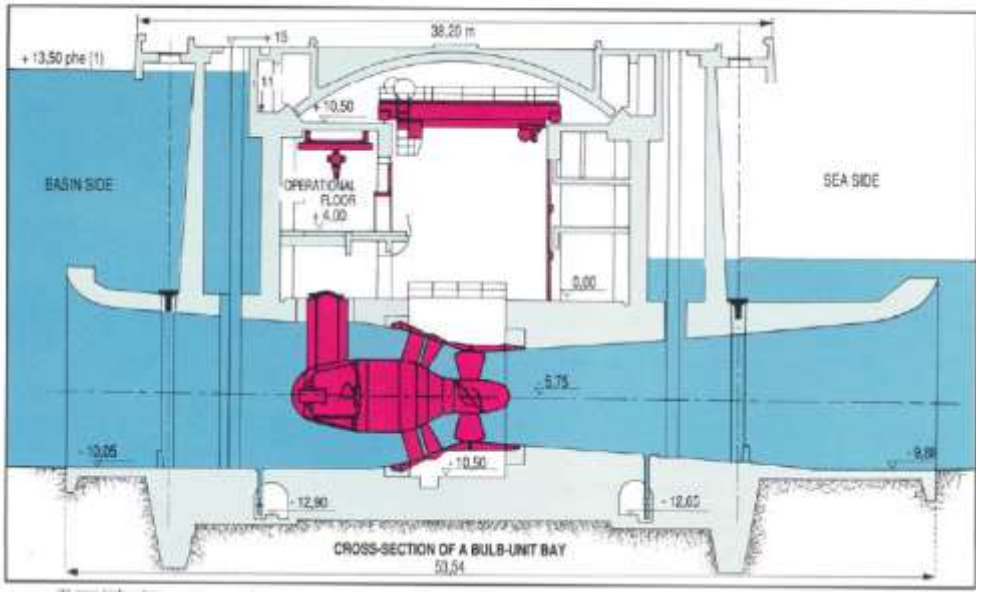
Pacific Ocean: Fiji, Kiribati, Micronesia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor, Tuvalu, Vanuatu.

Central and South America: Argentina, Brazil, Ecuador, Guyana, Panama, Surinam.

Atlantic Ocean: Cape Verde.

All coastal nations with tidal passes between coral reefs or offshore islands.

The first tidal power station in the world is in the Rance estuary in northern France. It was built in 1966. It has an output capacity of 240 MW.



The largest tidal power station in the world is located on Lake Sihwa. It was built in 1994. The annual output capacity of the facility is 254MW.

Swansea Bay Tidal Lagoon, United Kingdom – 240MW

Annapolis Royal Generating Station, Canada – 20MW

The **Jiangxia Tidal Power Station** (江厦潮汐电站) is the fourth largest tidal power station in the world, located in Wuyantou, Wenling City, Zhejiang Province, China. The facility was 3,000 kW

- A major drawback of tidal power stations is that they can only generate when the tide is flowing in or out - in other words, only for 10 hours each day.
- However, tides are totally predictable, so we can plan to have other power stations generating at those times when the tidal station is out of action.

Wave Energy

- **Wave power** is caused by a number of forces, i.e. wind, gravitational pull from the sun and moon, changes in atmospheric pressure, earthquakes etc.
- The capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a **wave energy converter**.

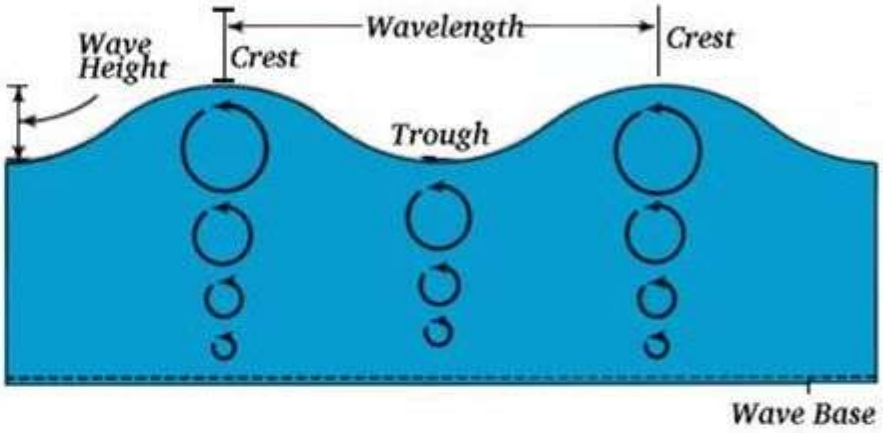
- The global wave power resource is 2.11TW.

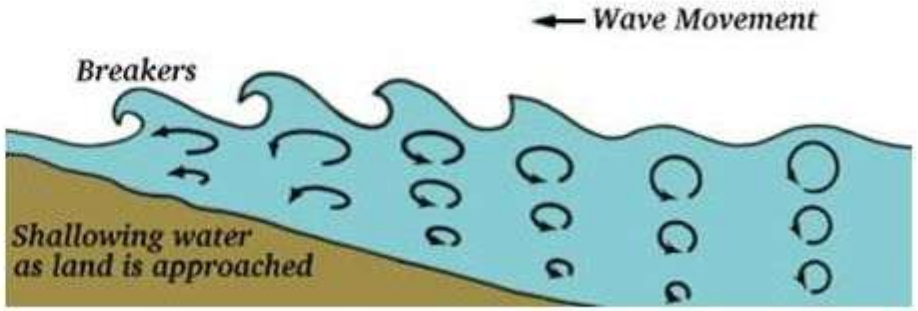
Renewable Energy 44 (2012) 296e304

Wave formation

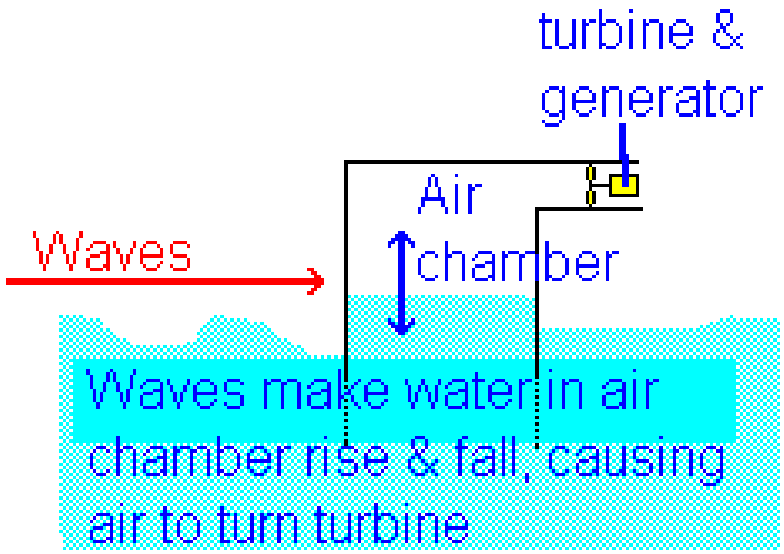
Is due to the wind blowing across the top of the water, causing friction, making the water move and forming waves.

When a wave approaches shore the friction at its base will slow it down, but as the top is still travelling at the same speed, it will topple over.



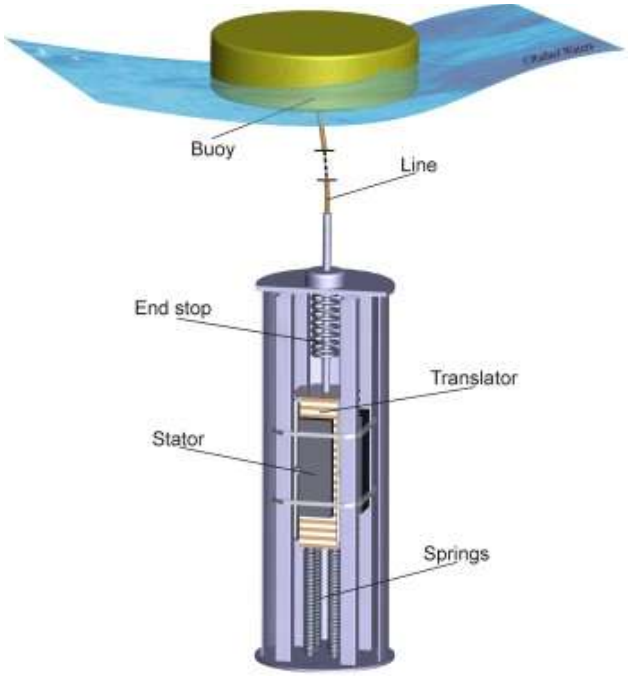


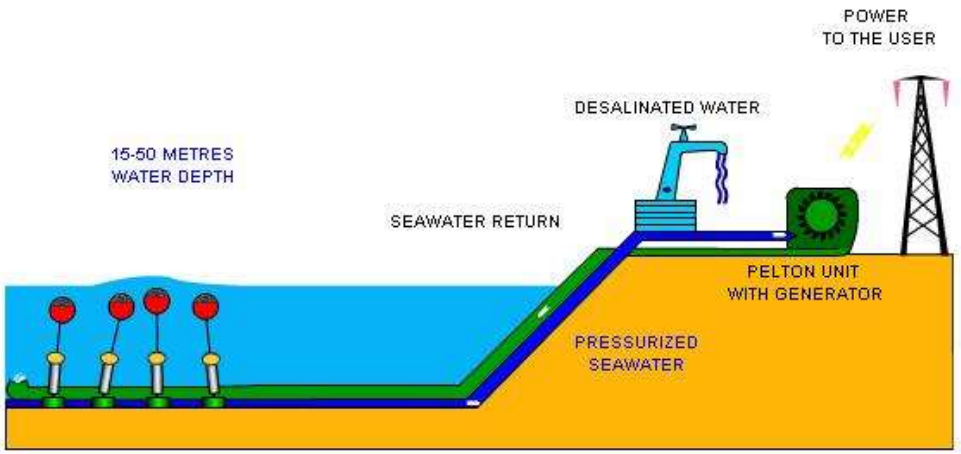
Wave power



At a wave power station, the waves arriving cause the water in the chamber to rise and fall, which means that air is forced in and out of the hole in the top of the chamber. We place a turbine in this hole, which is turned by the air rushing in and out. The turbine turns a generator.

A company called Pelamis Wave Power are developing a method of offshore wave energy collection, using a floating tube called "**Pelamis**". This long, hinged tube (about the size of 5 railway carriages) bobs up and down in the waves, as the hinges bend they pump hydraulic fluid which drives generators.





A buoy at the sea surface is moving due to the motion of the waves, and connects to a direct-driven, linear generator where the motion is converted to electricity.

Hydropower

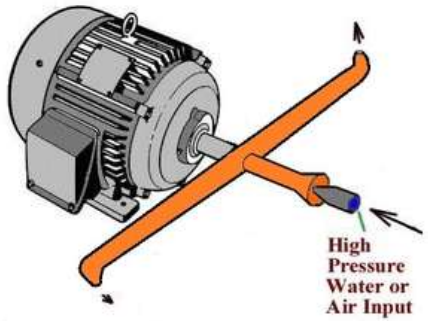
Hydropower is power derived from the energy of falling water or fast running water, which may be harnessed for useful purposes.

a) Potential energy

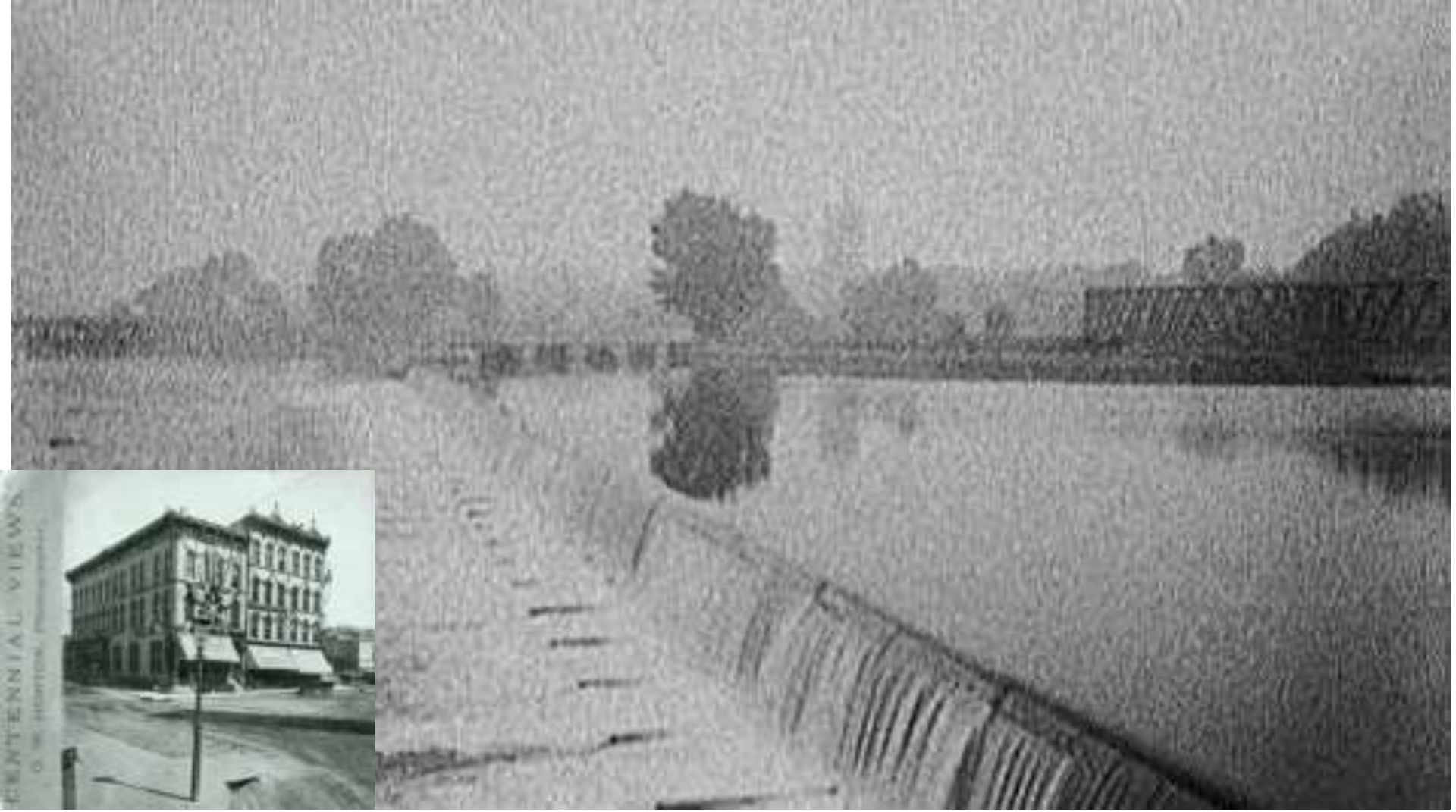
(b) Kinetic energy

Hydropower

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 gristmills, sawmills, textile mills, trip hammers, dockcranes, domestic lifts, and ore mills.

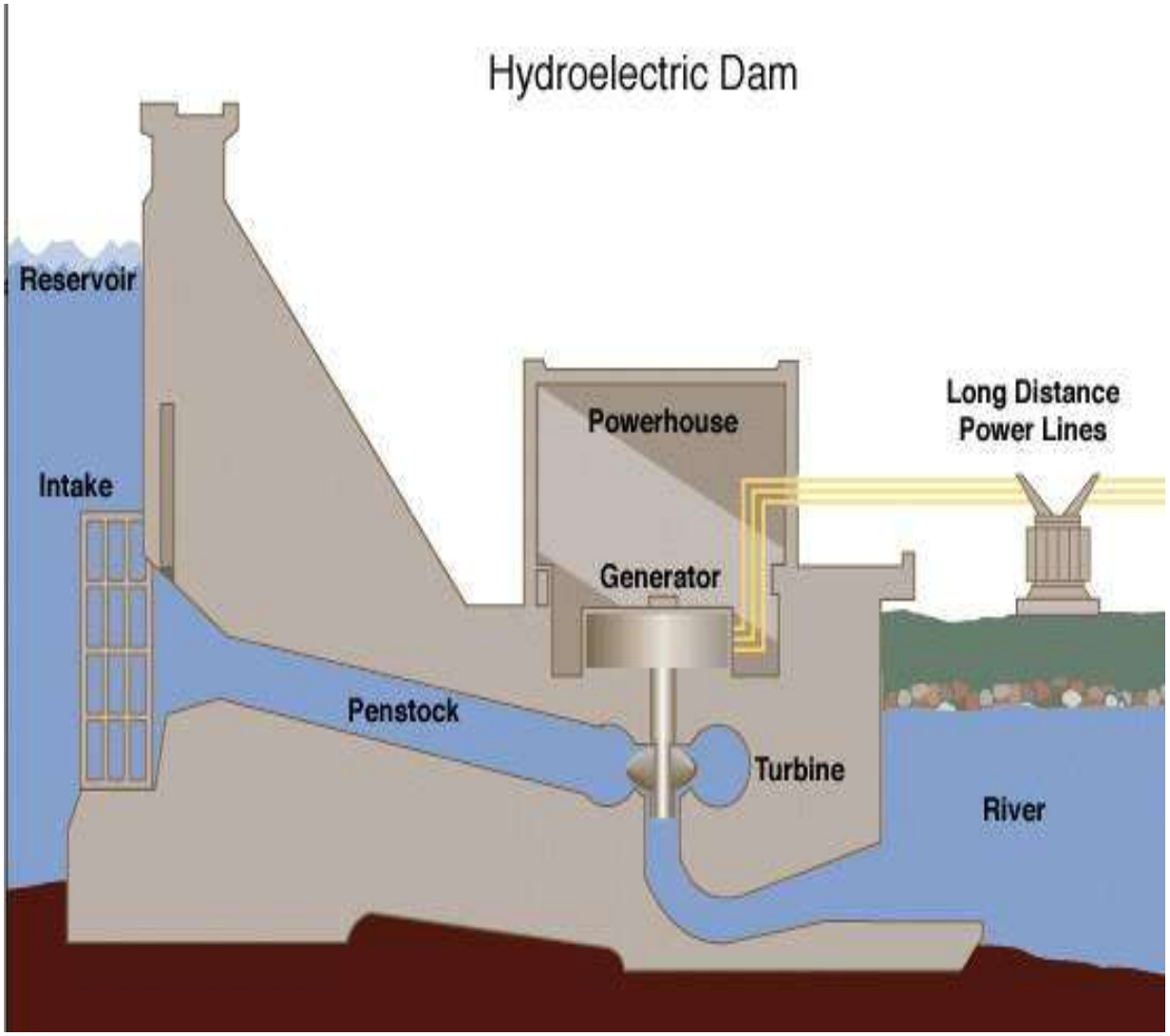


Jet Turbine



In 1880, the Grand Rapids Electric Light and Power Company used a water turbine to generate enough electricity to power 16 lights.

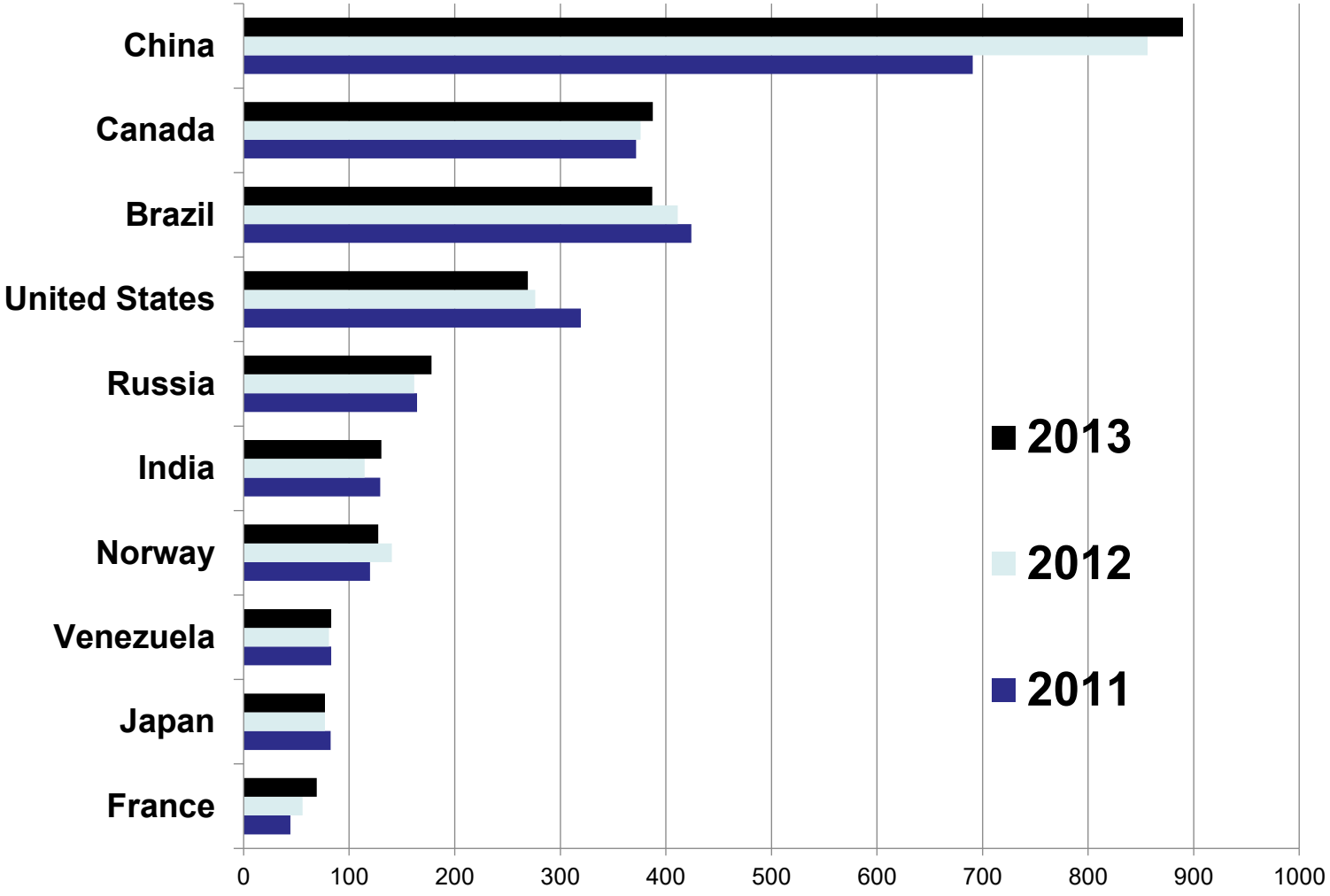
Soon after, in 1882, the world's first hydroelectric power plant began operation on the Fox River in Appleton, WI.



The energy of falling water or fast running water was exploited to drive the turbine for electricity.

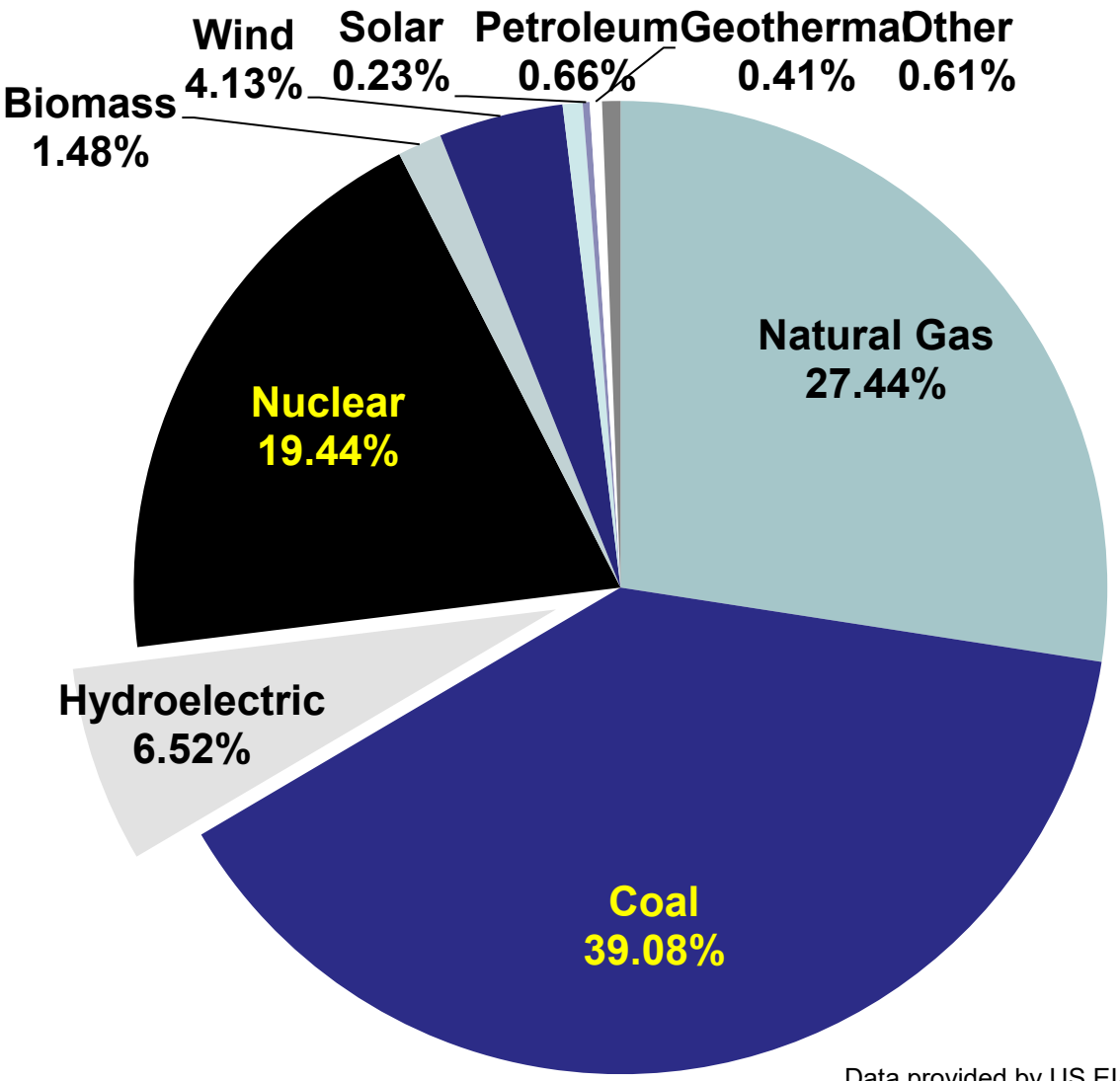
Hydroelectric Generation by Country

- Billion kilowatt-hours



Data: EIA

U.S. Electricity Production 2013



Data provided by US EIA Net Generation by Energy Source

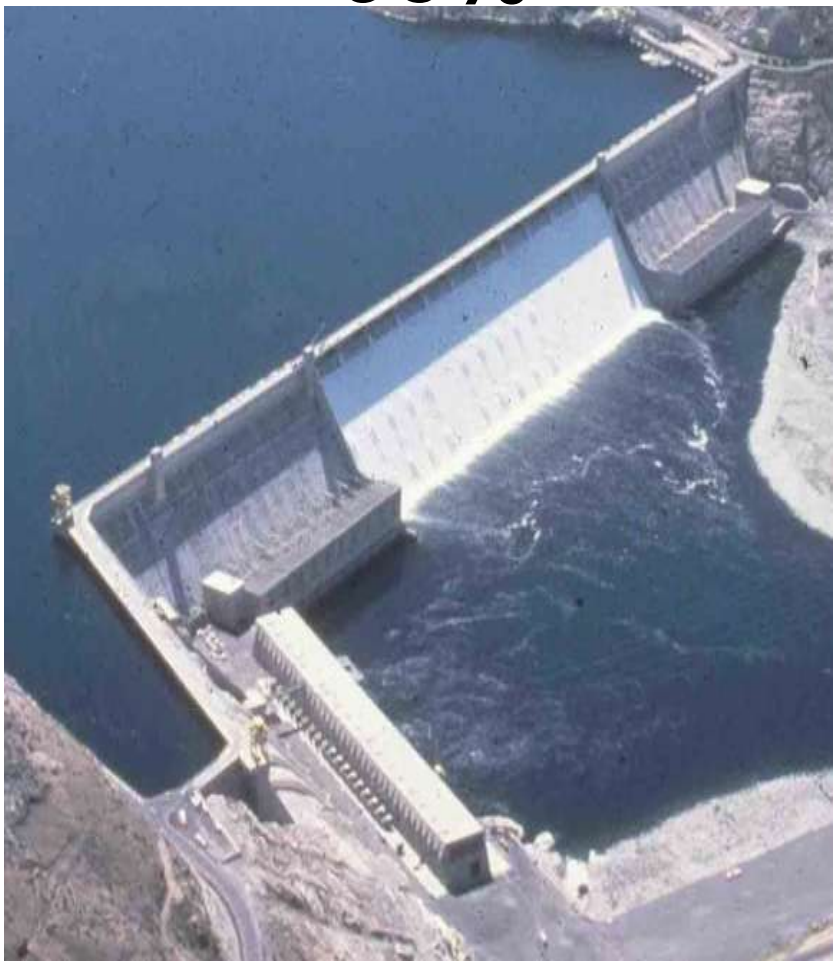
Advantages

- Renewable Energy
- Clean Energy Source
- Domestic Energy Source
- Generally Available As Needed
- Provides Recreational Opportunities
- Water Supply and Flood Control

Coal vs. Hydro Kinetic Energy Conversion

- **35%**

- **95%**



Possible Environmental Impacts

- Fish Population
- Quality and Flow of Water
- Ecosystems of Rivers and Streams

Other Disadvantages

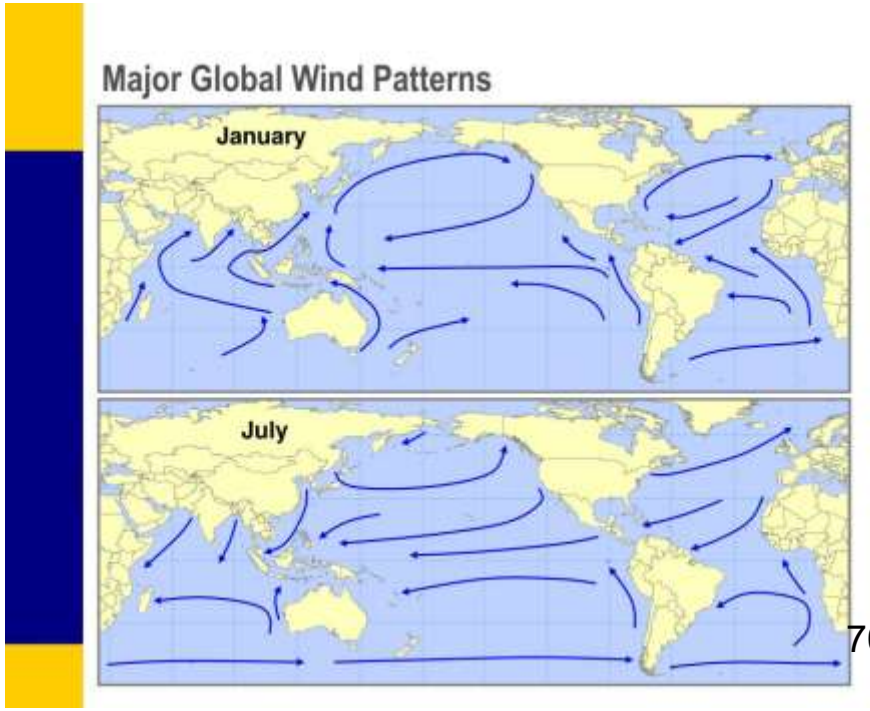
- Drought
- Impact on Local Environment and Land Use
- Preservation Concerns

Wind power

Wind power is the use of air flow through wind turbines to mechanically power generators for electric power.

What Makes Wind

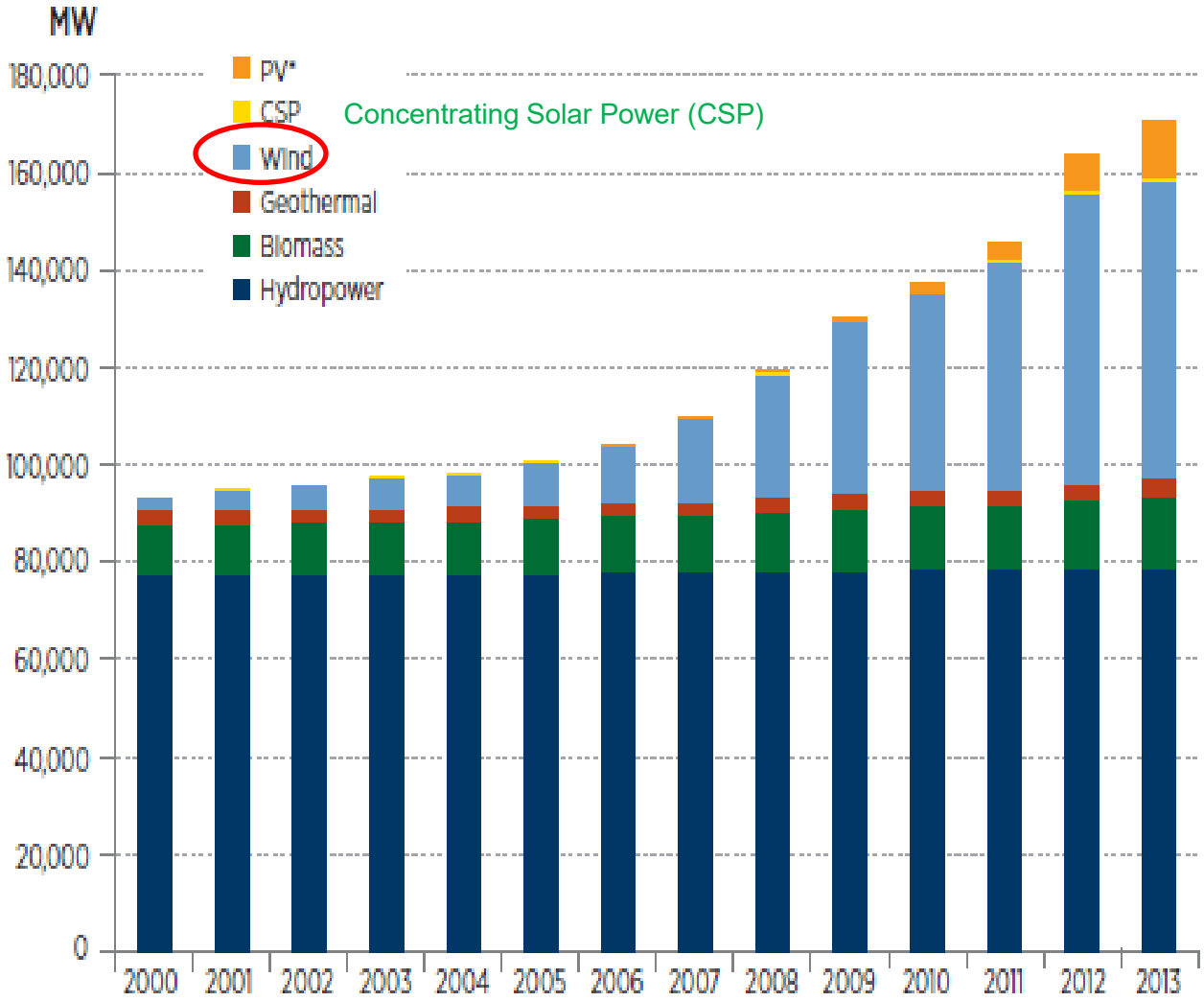
Global Wind Patterns



Why Wind Energy?

- Clean, zero emissions
  - NO_x, SO_2, CO, CO_2
  - Air quality, water quality
  - Climate change
- Reduce fossil fuel dependence
  - Energy independence
  - Domestic energy—national security
- Renewable
  - No fuel-price volatility

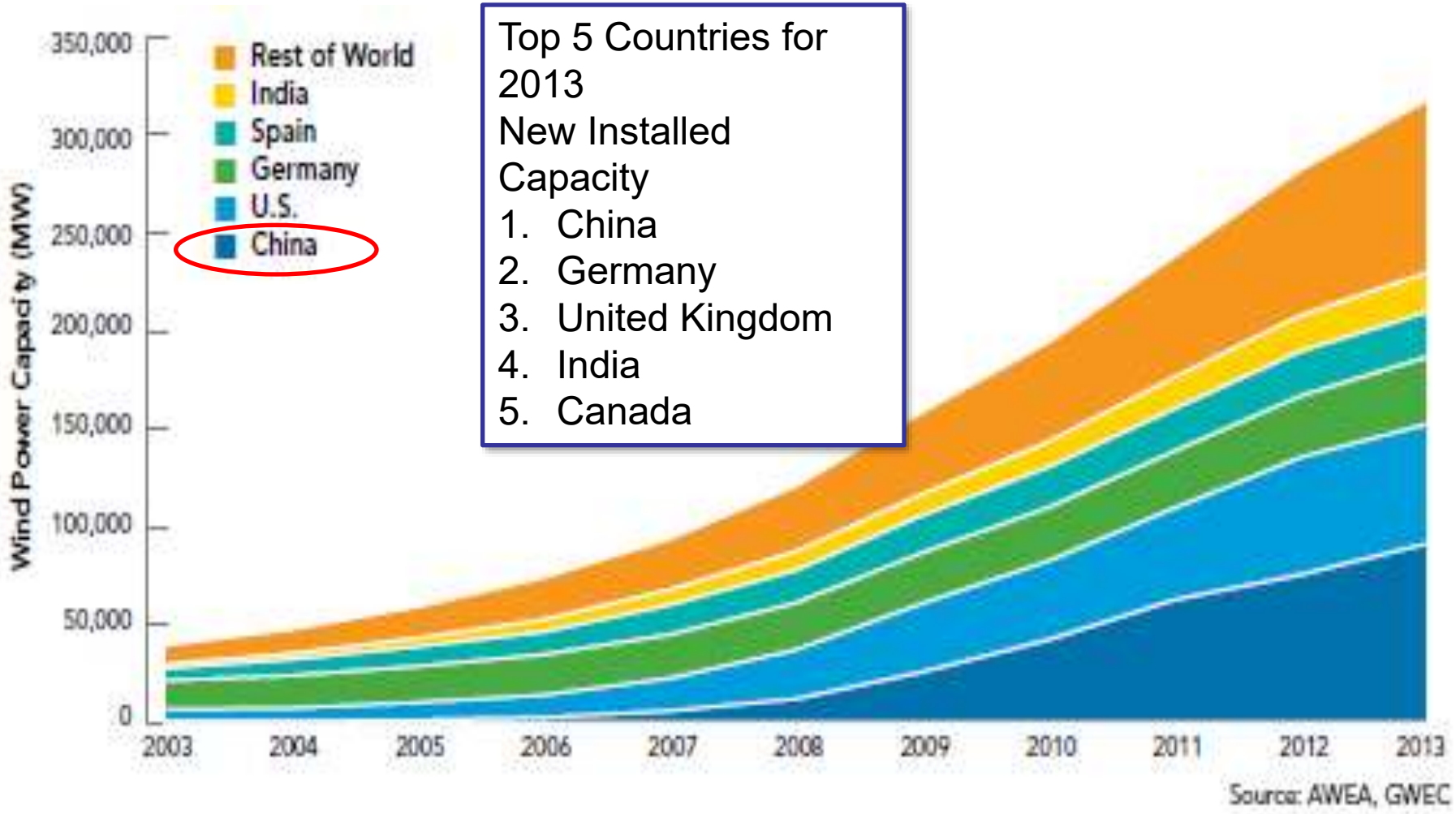
Renewable Electric Capacity Worldwide



US DOE, EERE 2013 Renewable Energy Data Book

China Leads the World in Wind Capacity

Total Installed Generating Capacity (MW)



Top 5 Countries for 2013
New Installed Capacity

1. China
2. Germany
3. United Kingdom
4. India
5. Canada

Why Such Growth? …costs are low!

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

1979
40
cents/kWh

2000
4-6
cents/kWh

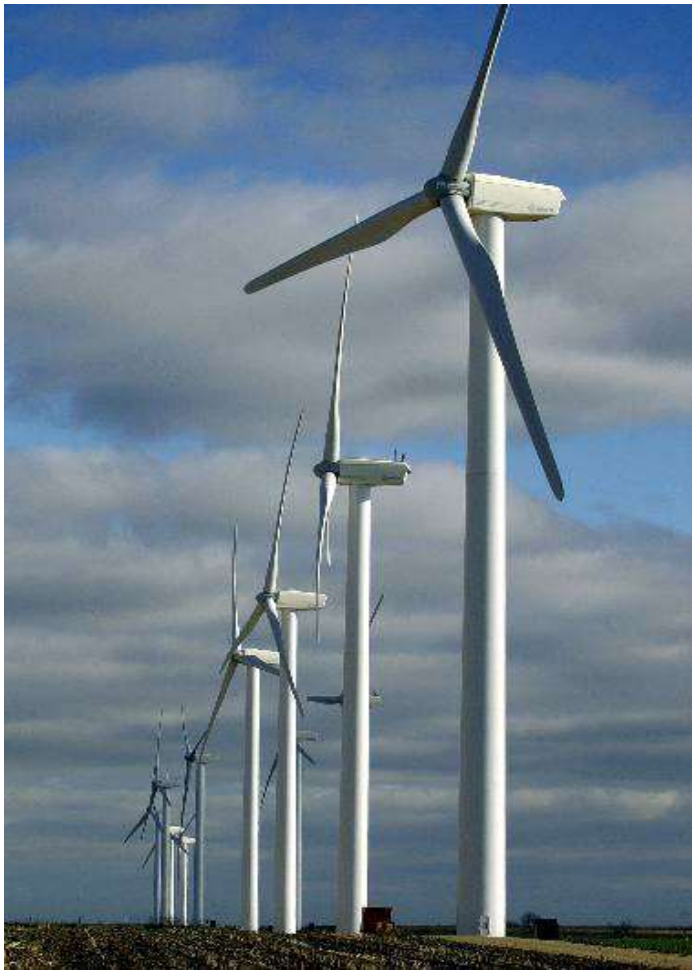
2004
3-4.5
cents/kWh

2011
Less than 5
cents/kWh

Modern Wind Turbines

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

Vertical axis



Horizontal axis

Vertical Axis Wind Turbines

- Vertical axis wind turbines have the main rotor shaft arranged vertically.
- The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind.
- This is an advantage on sites where the wind direction is highly variable or has turbulent winds.

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**

Horizontal axis turbines

ADVANTAGES

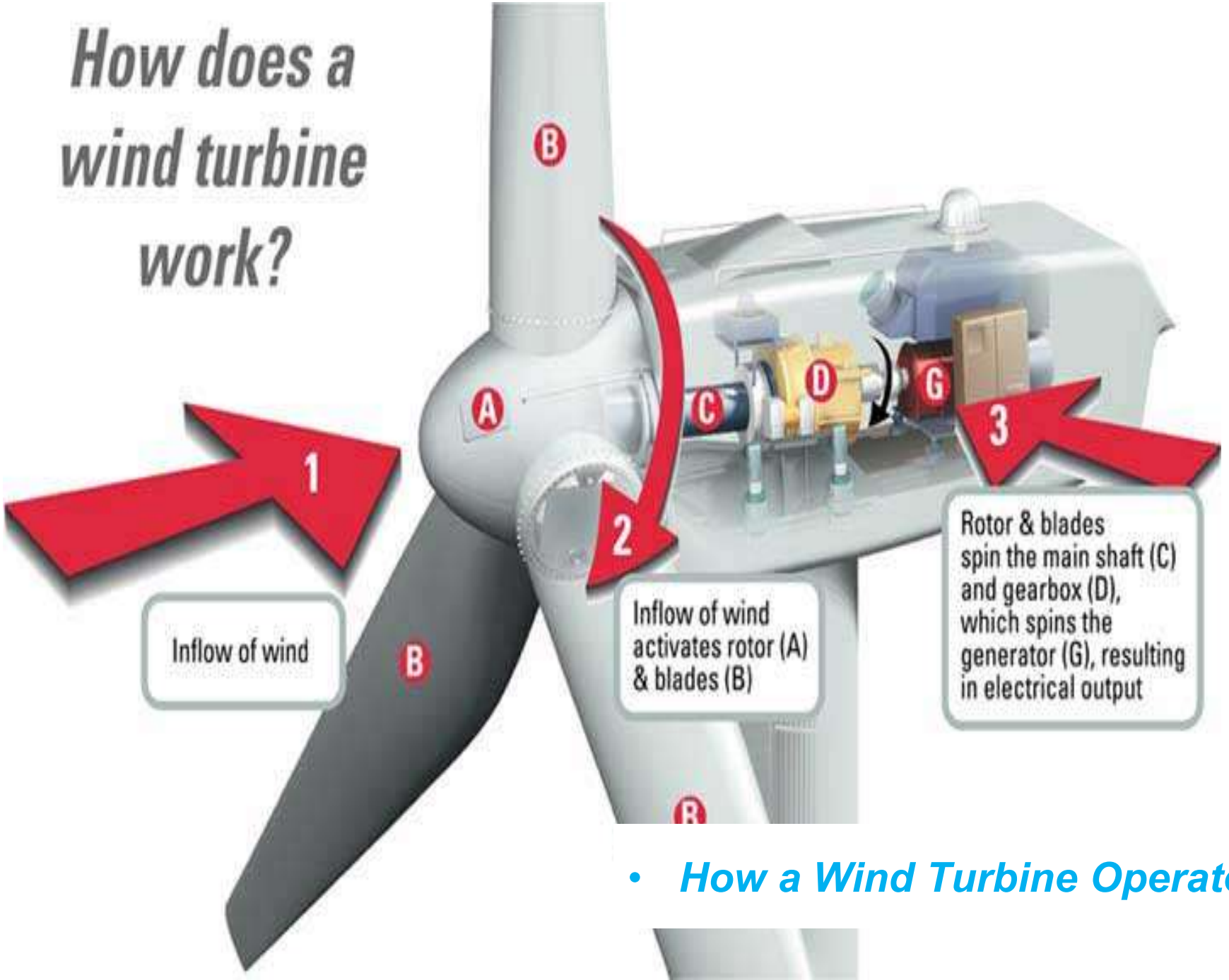
- Variable blade pitch, which gives the turbine blades the optimum angle of attack
- The tall tower base allows access to stronger wind in sites with wind shear.
- High efficiency, since the blades always move perpendicularly to the wind, receiving power through the whole rotation.

DISADVANTAGES

- Tall towers and blades up to 90 meters long are difficult to transport. Transportation can now cost 20% of equipment costs.
- Tall HAWTs are difficult to install, needing very tall and expensive cranes and skilled operators
- Massive tower construction is required to support the heavy blades, gearbox, and generator

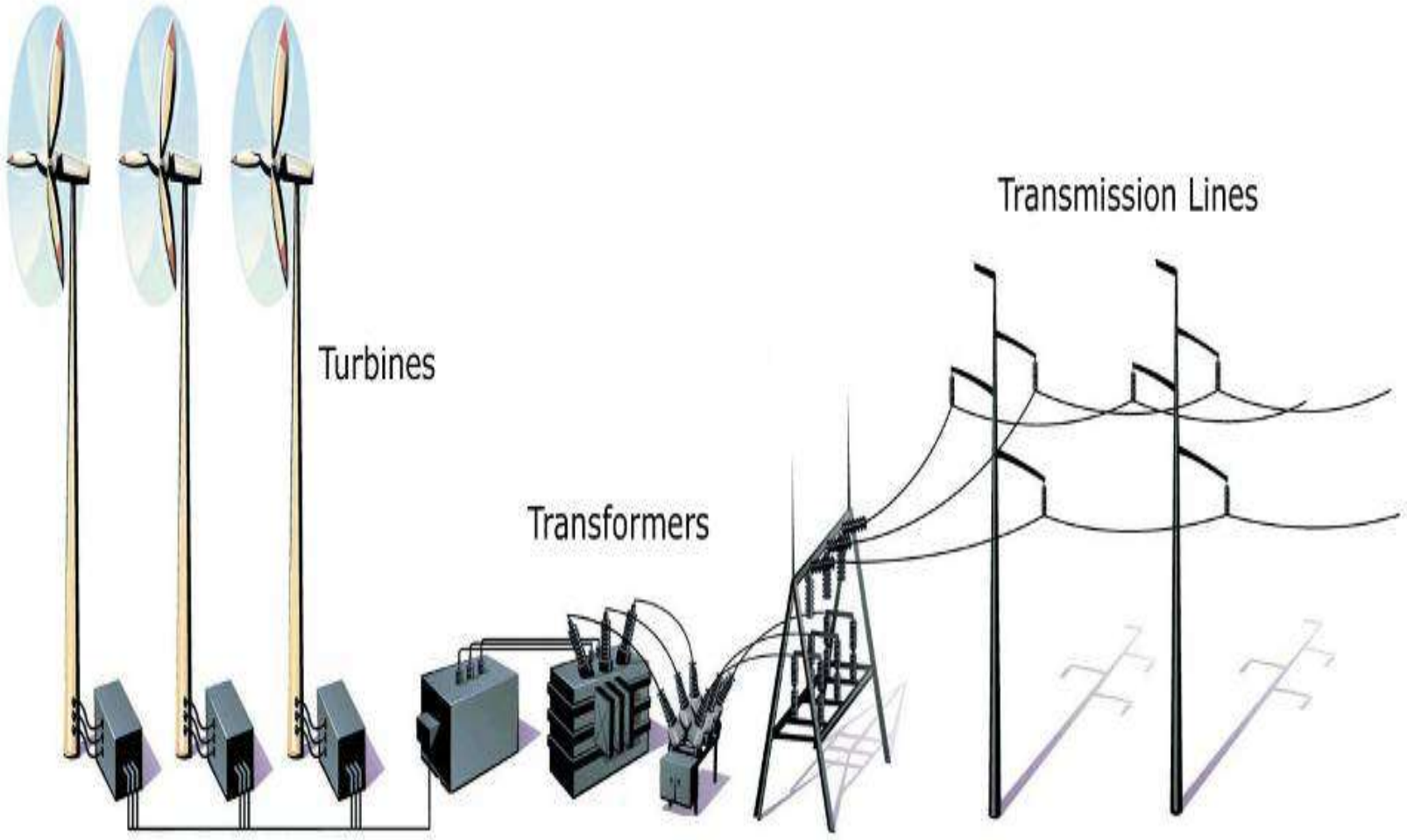
Large Wind Turbines

- 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 about 500 homes



- ***How a Wind Turbine Operates***

Wind Farms



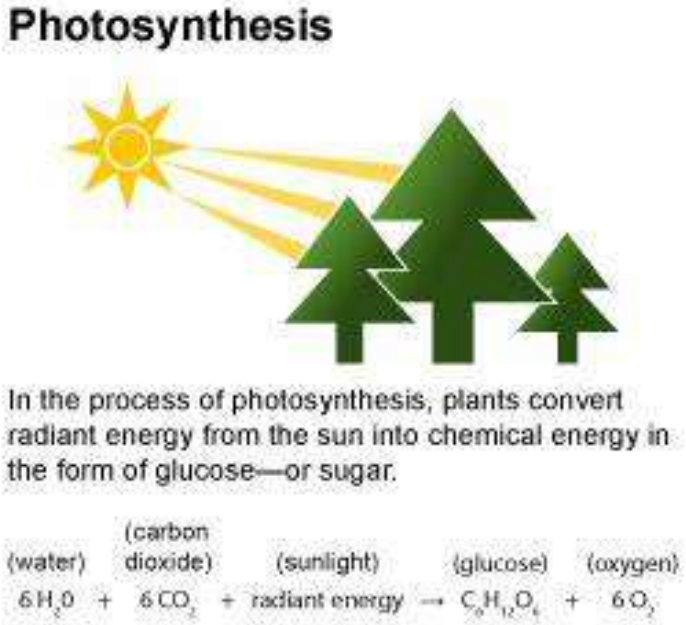
Limitations of Wind Power

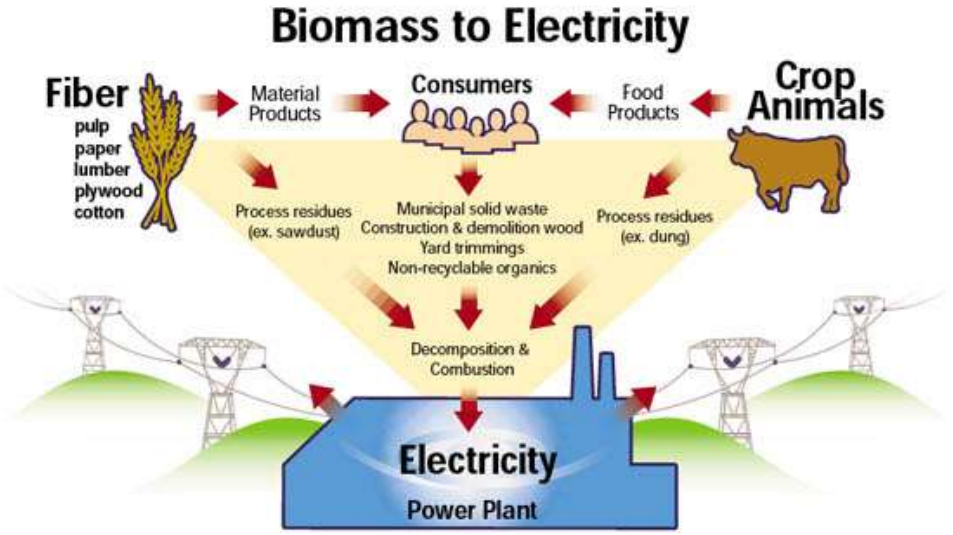
- Power density is very low.
  - Needs a very large number of wind mills to produce modest amounts of power.
- Cost.
- Environmental costs.
  - material and maintenance costs.
  - Noise, birds and appearance.
- Cannot meet large scale and transportation energy needs.

The Future of Wind Energy

- Future of wind energy can be bright if government policies subsidize and encourage its use.
- Technology improvements unlikely to have a major impact.
- Can become cost competitive for electricity generation if fossil energy costs skyrocket.

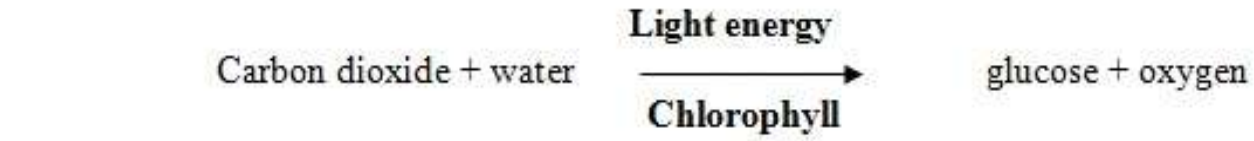
Biomass



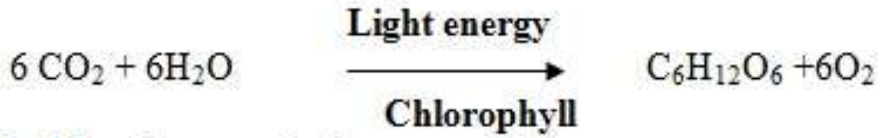


- Biomass refers to organic matter derived from living organisms that has stored energy through the process of photosynthesis (plants and woods).
- Organic matter may be transferred through the food chain to animals' bodies and their wastes.
- These stuff can be converted for everyday human use through processes such as combustion, or indirectly after converting it to various forms of biofuel.

Review of Photosynthesis



Balanced equation



- Plant takes in water and carbon dioxide. The energy in visible light excites atoms in the water and carbon dioxide which allows bonding to take place. As a result, compounds with hydrogen, carbon and oxygen are formed (called carbohydrates).
- The simplest carbohydrate formed is sugar, and these compounds are the plant's fuel.

Biomass as a renewable resource

- Many of the biomass fuels used today come in the form of wood products, dried vegetation, crop residues, and aquatic plants.
- Biomass has become one of the most commonly used renewable sources of energy in the last two decades, second only to hydropower in the generation of electricity.[86]

Energy from biomass: Direct Combustion

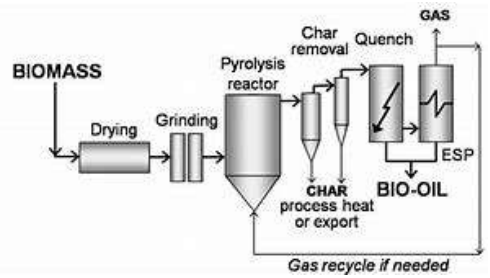
$$[CH_2O] + O_2 \rightarrow CO_2 + H_2O$$

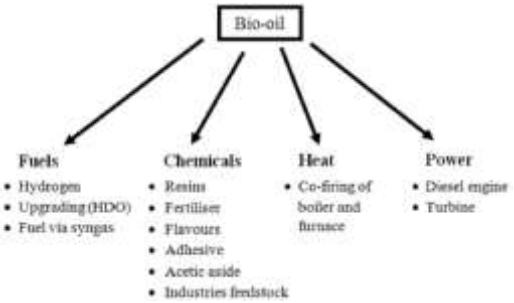
- Most of the biomass used for energy is burned either directly to provide heat, or in a power station to provide electricity.
- Although biomass is a complex mixture of starch, cellulose, *etc.,* the burning process can be viewed as being represented by a simple equation of oxidation of organic compounds.
- The actual energy content of even dried biomass is typically in the range 14-17 GJ tonne^{-1}, this being roughly one-third that of oil.

Gasification

- Gasification is a process that converts organic or fossil based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide by reacting the material at high temperatures (>700 ^oC) without combustion, with a controlled amount of oxygen and/or steam.
- The resulting gas mixture is called syngas (CO and H_2). The power derived from gasification and combustion of the resultant gas is considered to be a source of renewable energy.
- The main products are CO (around 17%) and H_2 with varying amounts of methane and CO_2 being formed. The product can be used for electricity generation or to generate synthesis gas as a chemical feedstock.
- This process differs from the purely thermal ones in that air, and steam are used to give a product richer in oxygen.

Thermolysis and Pyrolysis



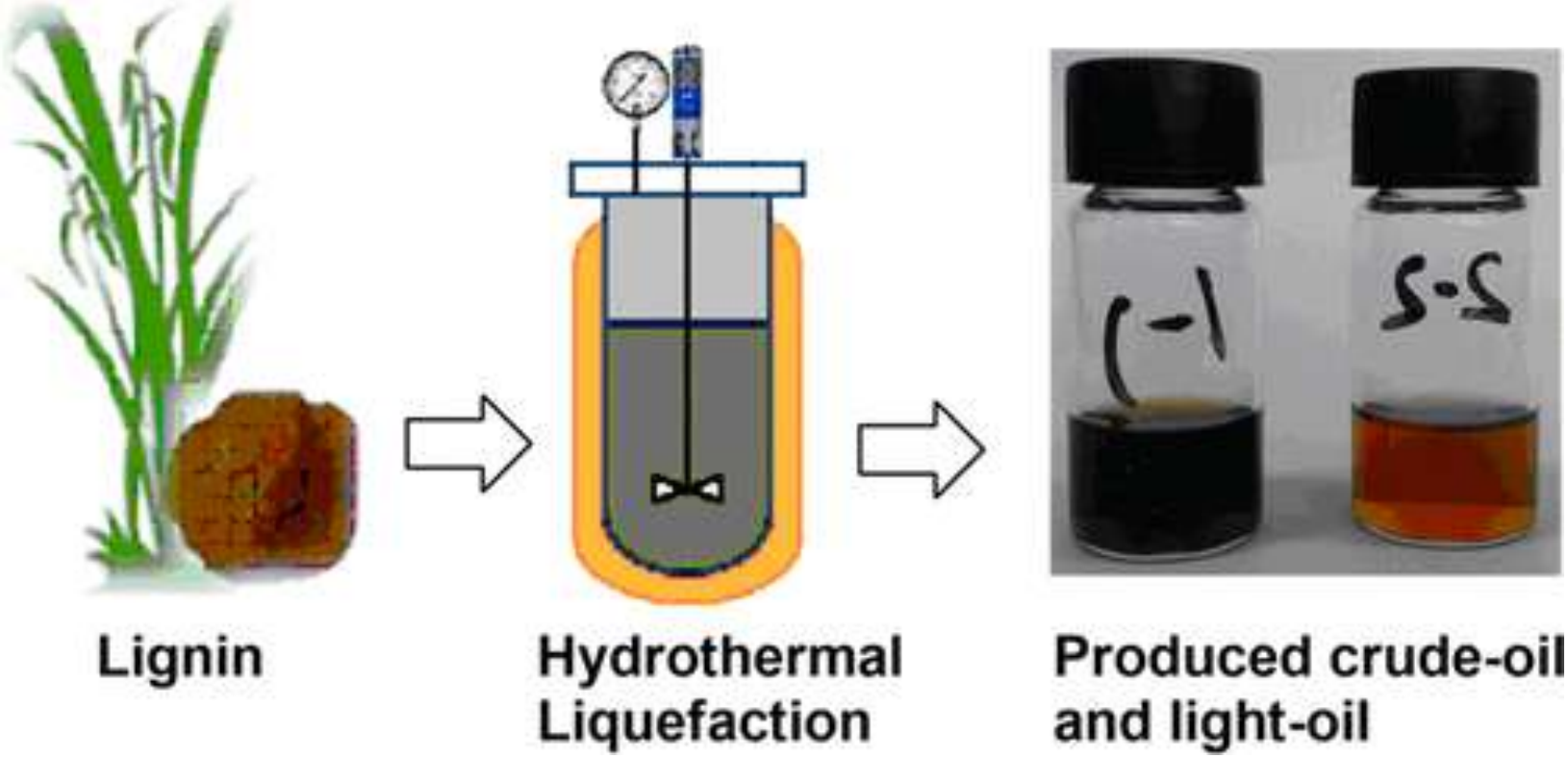


Fast Pyrolysis Bio-Oil (Pine)		wet	dry	C	H	N	O
Whole oil		**23,9**	**0**	**53,3**	**6,5**	**0,08**	**40**
Water	wt-%	23,9	0				
Acids	**wt-%**	**4,3**	**5,6**	40,0	6,7	0	53,3
Formic acid	wt-%		1,5				
Acetic acid	wt-%		3,4				
Propionic acid	wt-%		0,2				
Glycolic acid	wt-%		0,6				
Alcohols	wt-%	**2,2**	**2,9**	37,5	12,5	0	50,0
Ethylene glycol	wt-%		0,3				
Methanol	wt-%		2,6				
Aldehydes, ketones, furans, pyrans	wt-%	**15,4**	**20,3**				
Nonaromatic Aldehydes	wt-%		9,72	40,0	6,7	0,0	53,3
Aromatic Aldehydes	wt-%		0,009				
Nonaromatic Ketones	wt-%		5,36	48,6	8,11	0,0	43,2
Furans	wt-%		3,37				
Pyrans	wt-%		1,10				
Sugars	wt-%	**34,4**	**45,3**	44,1	6,6	0,1	49,2
Anhydro-ß-D-arabino-furanose, 1,5-	wt-%		0,27				
Anhydro-ß-D-glucopyranose(Levoglucosan)	wt-%		4,01				
Dianhydro-α-D-glucopyranose, 1,4:3,6-	wt-%		0,17				
Hydroxy, sugar acids	wt-%						
LMM lignin	wt-%	**13,4**	**17,7**	68	6,7	0,1	25,2
Catechols	wt-%		0,06				
Lignin derived Phenols	wt-%		0,09				
Guaiacols (Methoxy phenols)	wt-%		3,82				
HMM lignin	wt-%	**1,95**	**2,6**	63,5	5,9	0,3	30,3
Extractives	wt-%	**4,35**	**5,7**	75,4	9,0	0,2	15,4
Fatty acids	wt-%						
Triglyserides	wt-%						
Resin acids	wt-%						

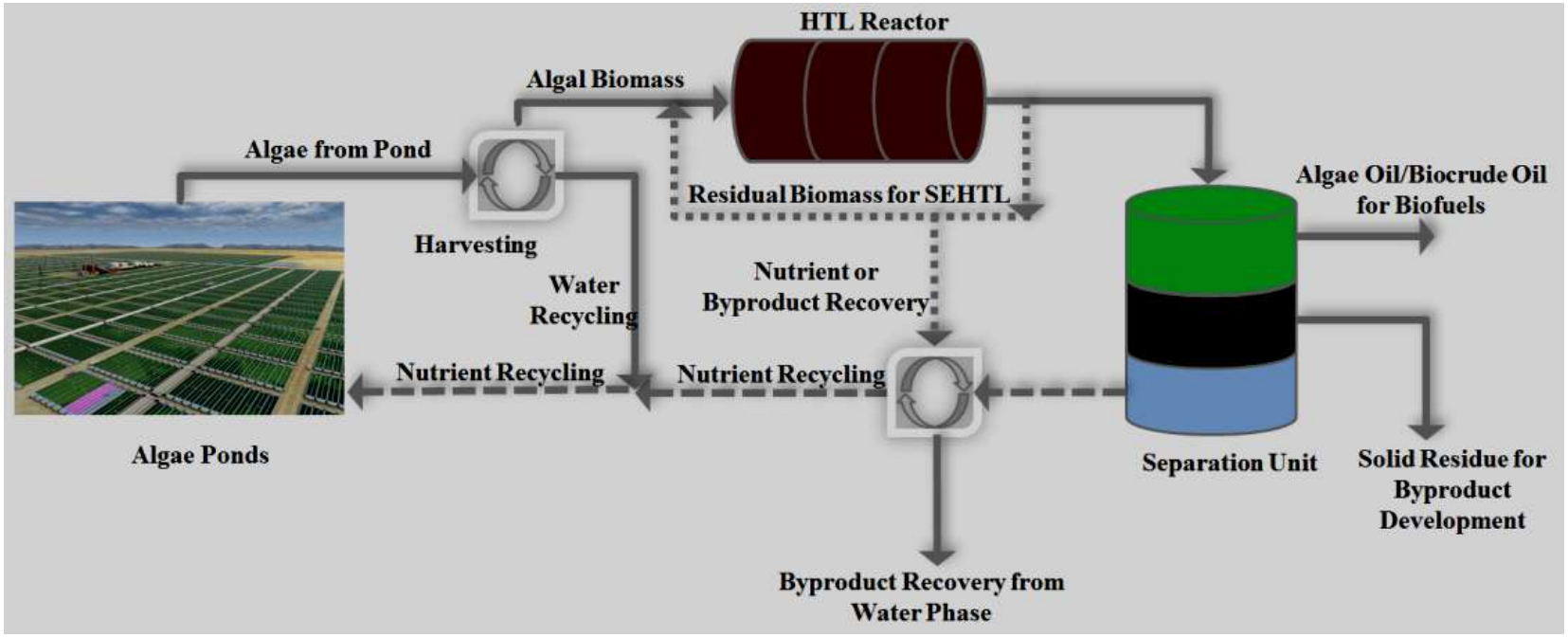
- Thermolysis and pyrolysis both involve heating biomass (mainly wood), largely in the absence of oxygen, at temperatures from a few hundred degrees centigrade (thermolysis) up to 1500 ^{0}C (pyrolysis).
- Overall thermolysis is relatively inefficient, with well over 50% of the energy content of the original biomass being lost.
- At the lower temperature char or charcoal is a major product. The other main product is a fuel oil.
- At higher temperatures the char content is considerably reduced, the main product being a gas mixture rich in H_2, CO and acetylene.

Hydrothermolysis

- Hydrothermolysis: is a specific process developed by Shell for producing an oil-like material, called bio-crude, with a low oxygen content.
- The process is so called because it involves treatment of the biomass with water at temperatures of 200-330 ^{0}C and pressures over 30 bar.

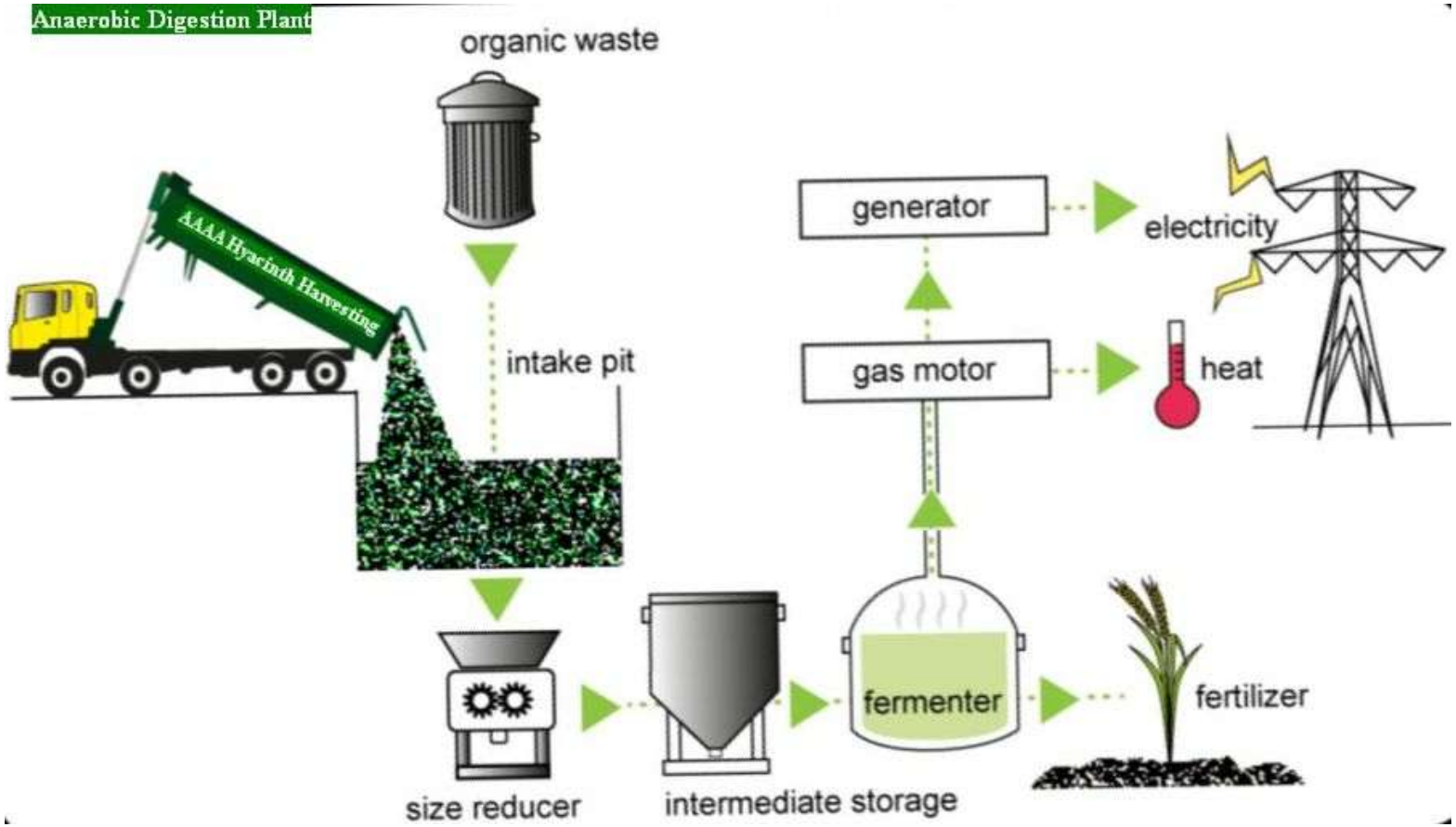


Hydrothermolysis



- Algae can have faster growth rates than terrestrial crops, as they do not have to produce structural compounds such as cellulose for leaves, stems, or roots.
- Because the cells grow in aqueous suspension, with more efficient access to water, CO_2 and dissolved nutrients, algae are capable of producing large amounts of biomass and usable oil.
- Algae can convert a much higher fraction of their biomass to oil than conventional crops, e.g. 60% versus 2-3% for soybeans

Anaerobic Digestion



- Anaerobic digestion is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen.
- By treatment of biomass with bacteria in the absence of air, a gas rich in methane can be produced; a typical digester may produce over 300 m^3 of gas containing over 50% methane per tonne of dry biomass.

Primary conversion processes for biomass

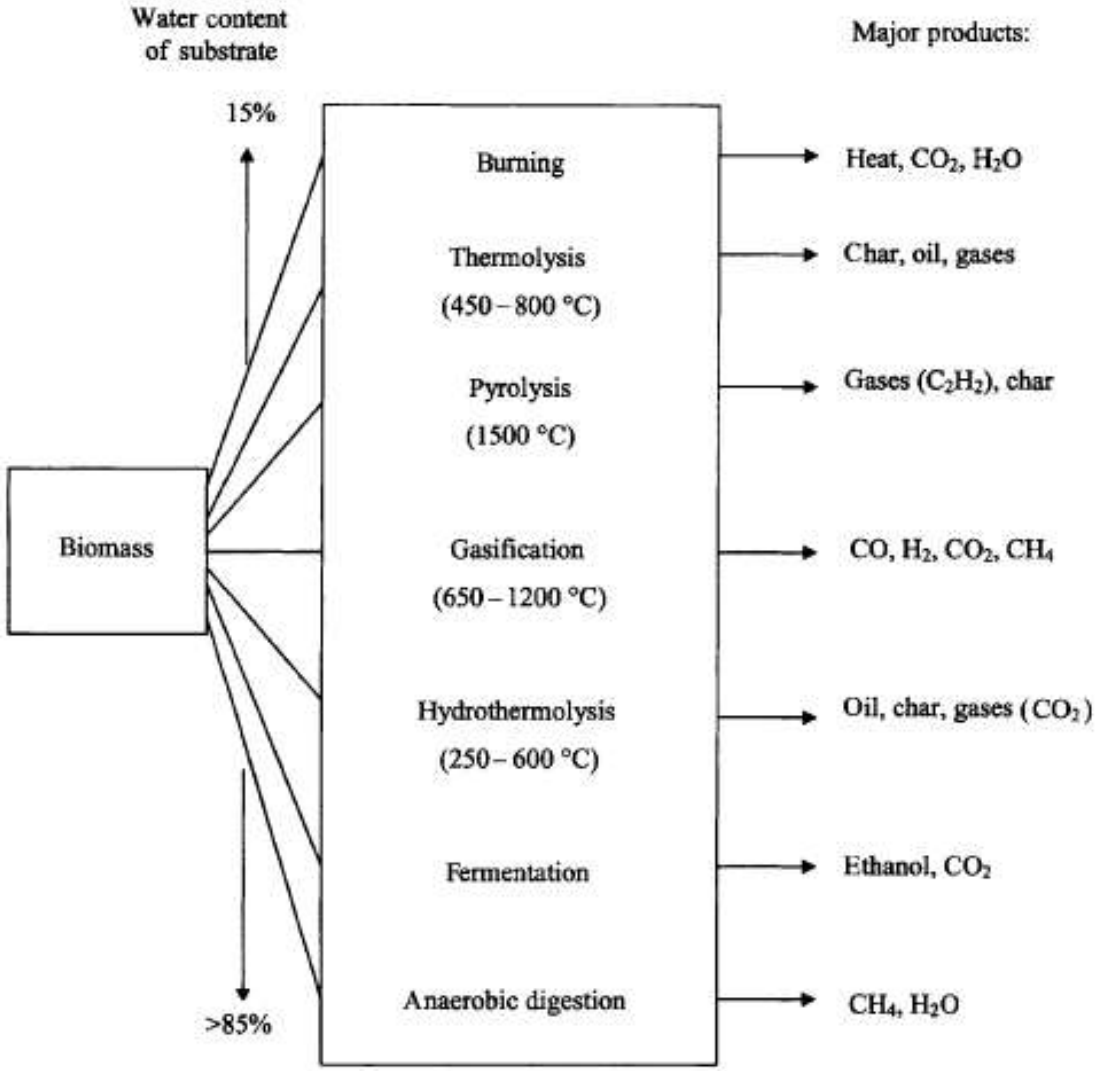
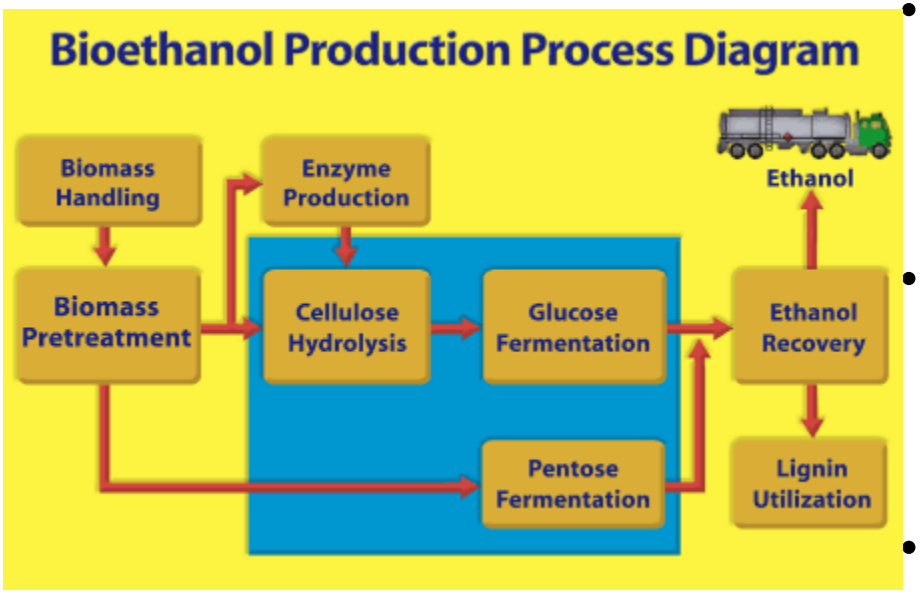


Figure 6.3 *Biomass conversion processes*
Reproduced with permission of the RSC from C. Okkerse and H. van Bekkum, *Green Chemistry*, 1999, **1**, 107-114.

Creating Fuel from Biomass

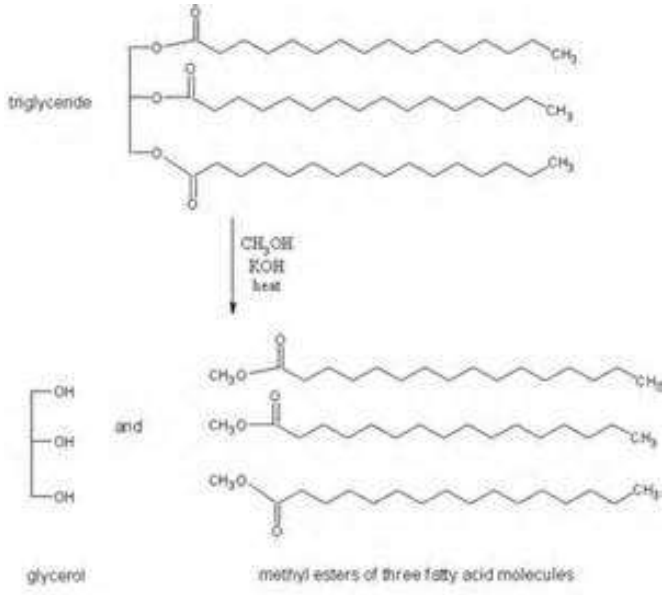
- Ethanol – common form of alcohol, it is an oxygenated hydrocarbon (a hydrocarbon with oxygen added).
- Also known as ethyl alcohol, pure alcohol, grain alcohol, or drinking alcohol,
- volatile, flammable, colorless liquid.
- Type of alcohol found in alcoholic beverages and in modern thermometers.
- Fermentation of sugar to ethanol is one of the earliest organic reactions employed by humanity

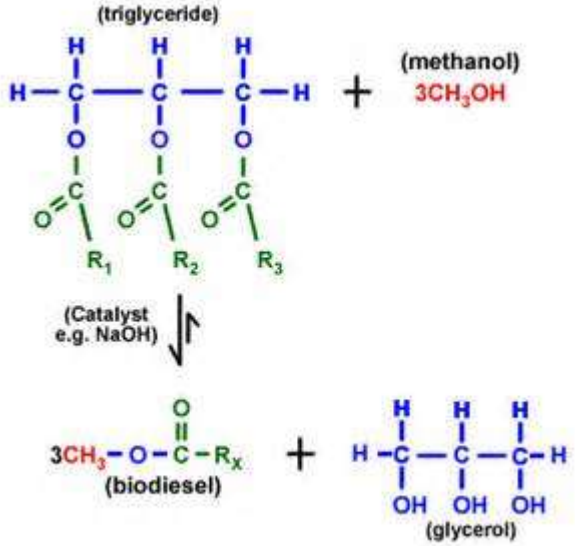
Bioethanol

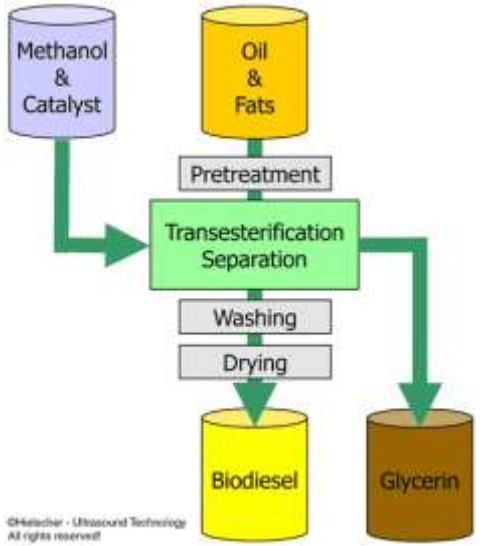


- Bioethanol is ethanol, the same type of alcohol found in alcoholic beverages. It is most often used as a motor fuel, mainly as a biofuel additive for gasoline.
- Production of ethanol by fermentation of glucose-based crops such as sugar cane and corn starch using *Saccharomyces* yeasts.
- As a result of the oil crisis in the mid-1970s, some countries, such as Brazil, began commercial production of bioethanol to use as a fuel in place of gasoline.
- Bioethanol may be used either alone or as a blend with gasoline.
- Production volumes in Brazil have reached some 16 billion litres per annum.

Biodiesel







- Biodiesel refers to a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl, or propyl) esters. Biodiesel is typically made by chemically reacting lipids (e.g., vegetable oil, animal fat) with an alcohol producing fatty acid esters.
- The main constituents of vegetable oils are triglycerides, which are esters of glycerol with long-chain saturated and unsaturated fatty acids.
- In order to convert the raw oils into useful material, transesterification technology is used. The oil is reacted with a low molecular weight alcohol, commonly methanol, in the presence of a catalyst to form the mixture of fatty acid ester (biodiesel)and glycerol.

Chemicals from Feedstocks

crops

woods

grass

corns

Wood dust

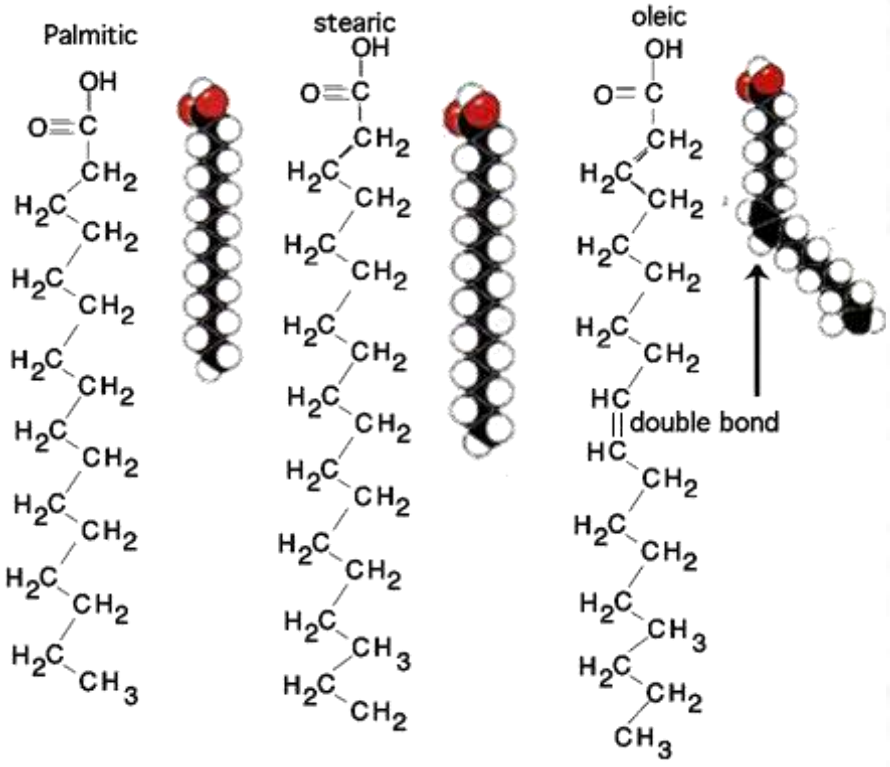
waterweeds

Municipal wastes

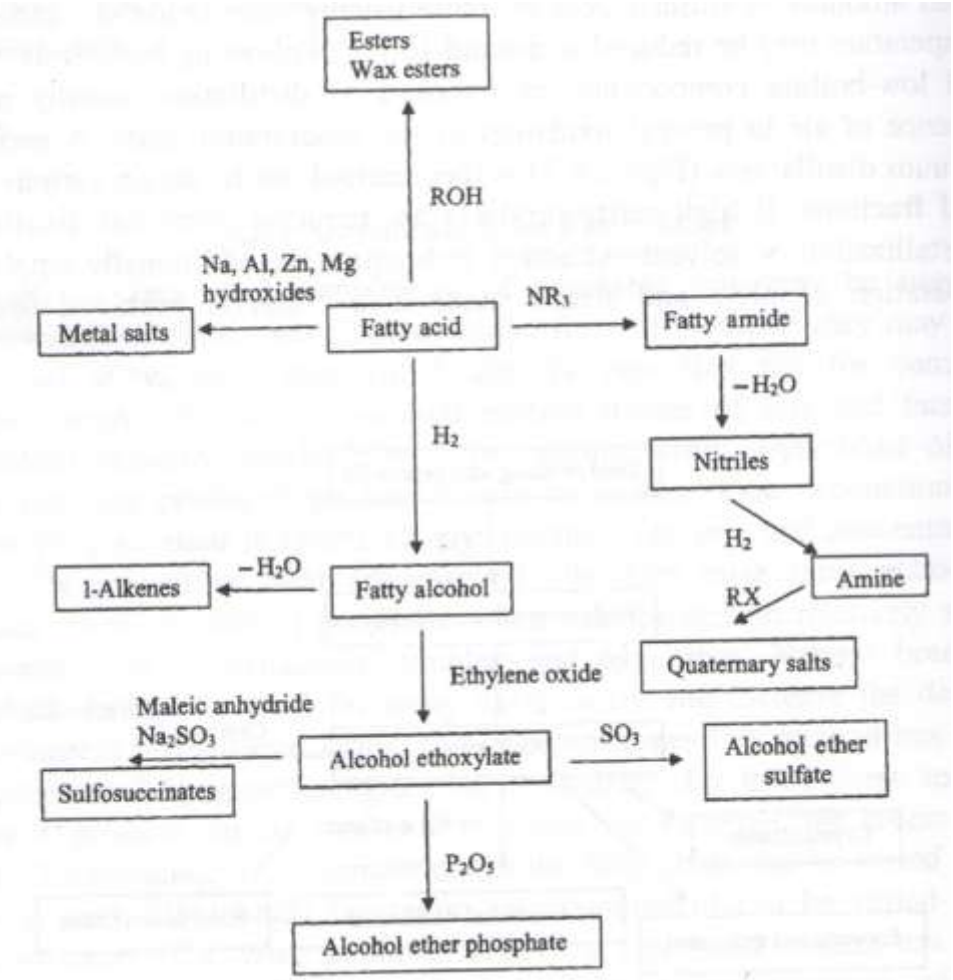
- Feedstock is a general term for the plant matter used to make fuel. Agricultural wastes, trees, grasses, corn, wood wastes and residues, aquatic plants, animal wastes and municipal wastes are examples of biomass feedstocks.
- Lubricants
- Fibers and composites
- Polymers
- Solvents
- Surfactants, dyes and paints
- pharmaceuticals

Chemicals from Fatty Acids

棕榈酸 硬脂酸 油酸

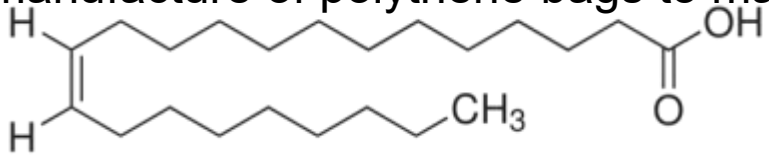


16:0 18:0 18:1



Chemicals from Erucic Acids顺芥子酸

- The main commercial source of erucic acid is a specially bred form of rape seed (油菜籽). The high level of erucic acid found in this type of rape seed oil make it unsuitable for human consumption, owing to the indigestibility of such large amounts of this acid.
- The current major use is in the production of erucamide, a 'slip agent' used in the manufacture of polythene bags to make them open more easily

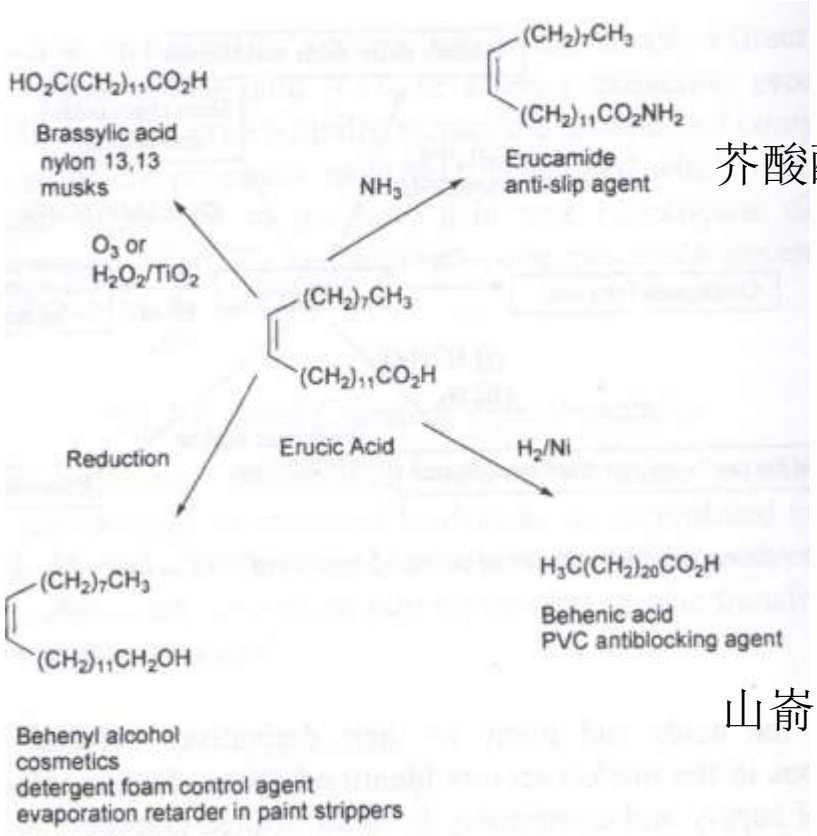


巴西基酸

Erucic acid

Rape seed

山嵛醇

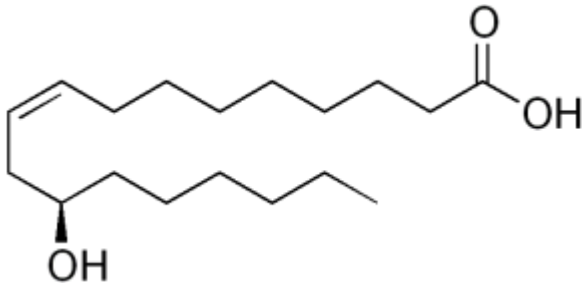


芥酸酰胺

山嵛酸

Chemicals from Ricinoleic Acids蓖麻酸

- Ricinoleic acid, or 12-hydroxyoleic acid, is a major component of castor oil (蓖麻油) (>87%) and is also found in useful quantities in ergot (麦角).
- The metal salts of the acid find use in dry cleaning soaps.
- The majority is converted to aminoundecanoic acid which is used to make nylon 11. Nylon 11 has very good chemical and shock-resistance properties, which have led to it being used in the automotive industry.



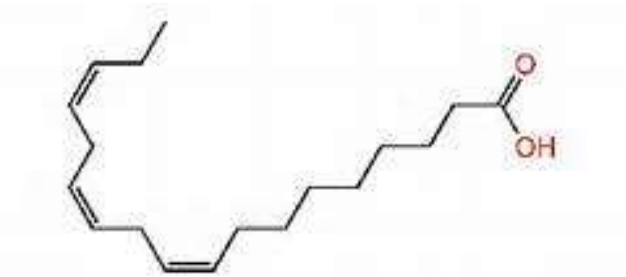
$$CH_3(CH_2)_5CH(OH)CH_2CHCH(CH_2)_7CO_2CH_3 \xrightarrow{>300^\circ C} CH_3(CH_2)_5CHO + H_2CCH(CH_2)_8CO_2CH_3$$

$$H_2CCH(CH_2)_8CO_2CH_3 \xrightarrow[H_2O_2]{HBr} Br(CH_2)_{10}CO_2H \xrightarrow{NH_3} H_2N(CH_2)_{10}CO_2H$$

Aminoundecanoic acid

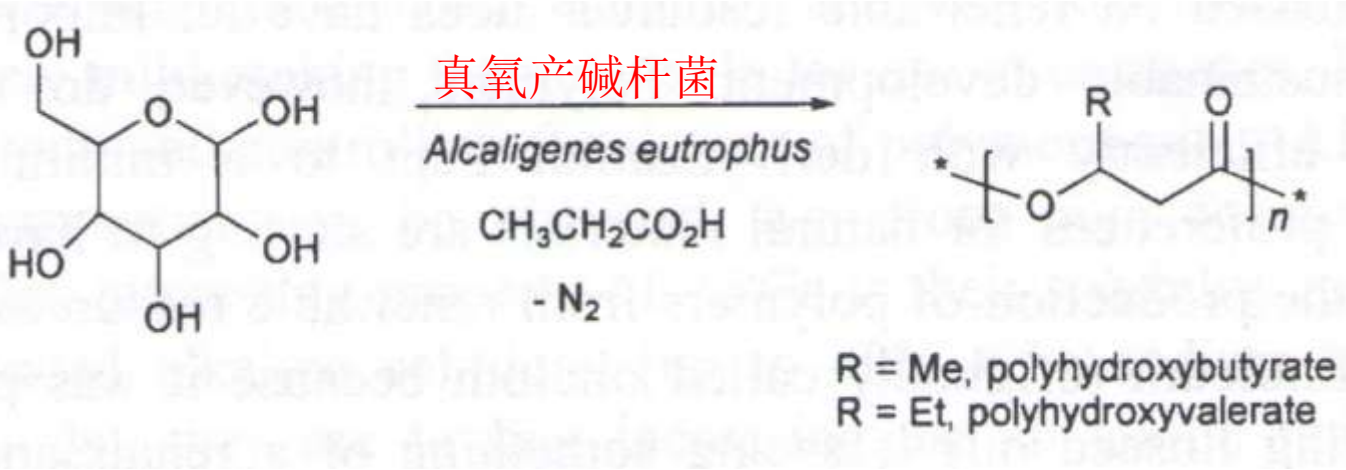
Linolenic acid亚麻酸

- Linolenic acid is the major constituent of linseed oil (approximately 47%) which is obtained from flax. The high degree of unsaturation present in this acid makes the oil an excellent drying agent for use in paints, varnishes and inks.
- High intake of gamma-linolenic acid can reduce inflammation and provide relief to allergy, ADHD, diabetes, eye disease, and high blood pressure.

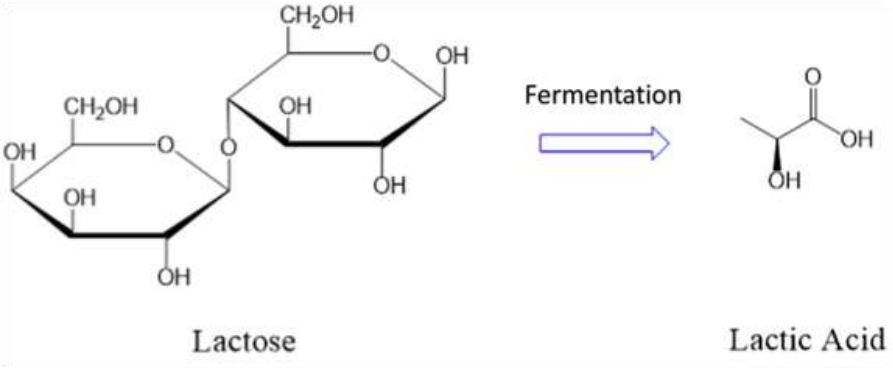


Polymers from renewable resources

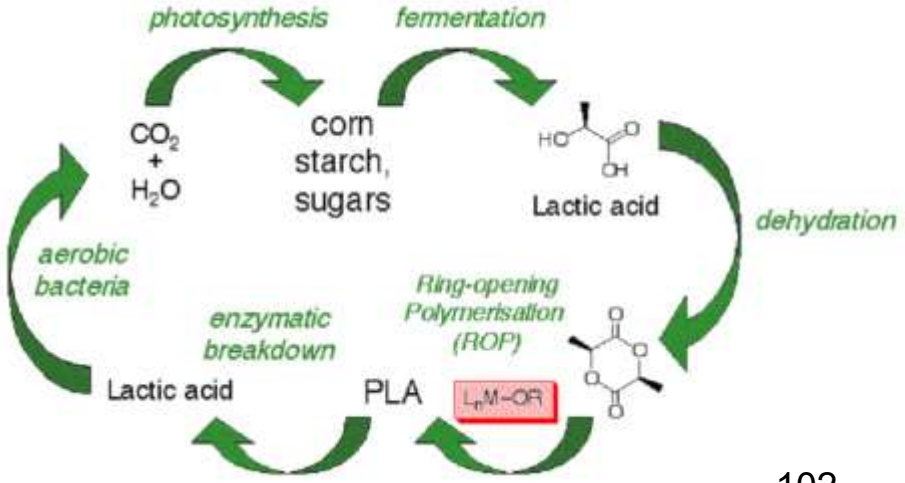
(1) Polyhydroxyalkanoates 聚羟基脂肪酸酯



(2) Polylactic acid



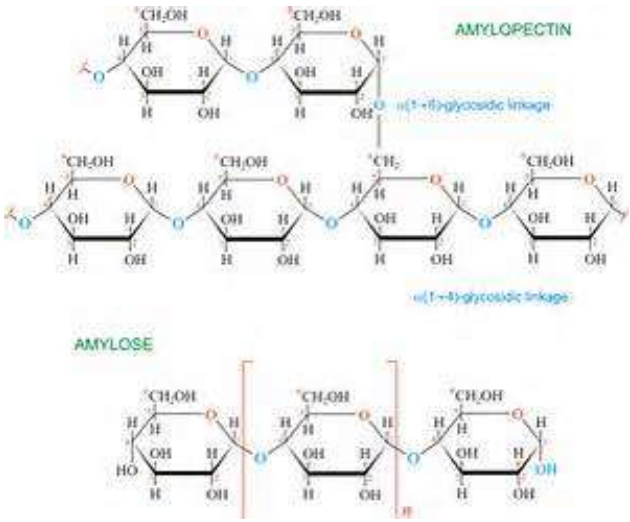
Lactobacillus acidophilus



嗜乳酸杆菌

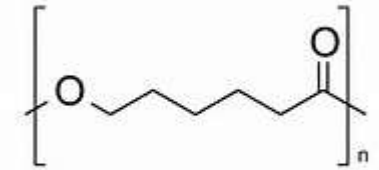
Biopolymer from starch

Starch is a polymeric carbohydrate consisting of a large number of glucose units joined by glycosidic bonds, which contains two components, amylose(直链淀粉)and amylopectin(支链性淀粉). It is the most common carbohydrate in human diets and is contained in large amounts in staple foods such as potatoes, wheat, maize (corn), rice, and cassava (木薯).

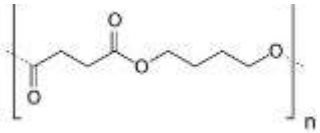


Biodegradable Plastics Market

Polylactic acid,
starch blends,
Polycaprolactone,聚己内酯
regenerated cellulose,
Polybutylene succinate,聚丁二酸丁二醇酯
Polyhydroxyalkanoates.



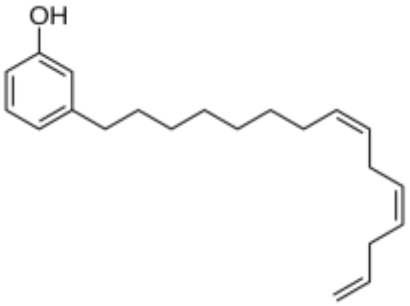
Polycaprolactone

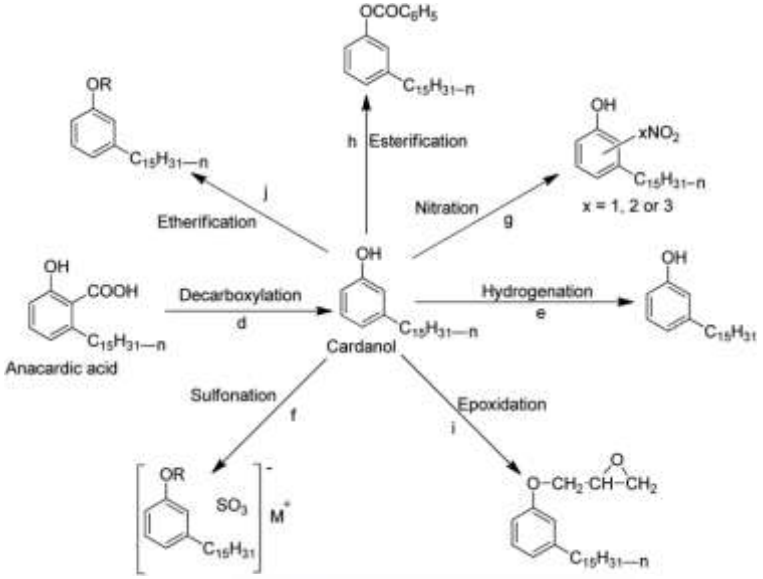


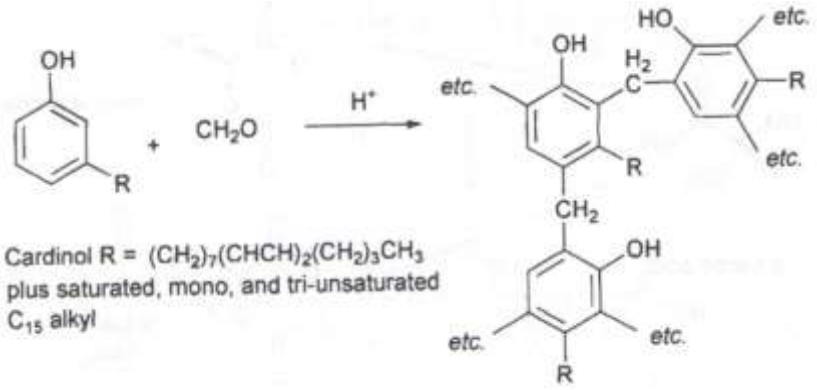
Polybutylene succinate

Cardanol

Cardanol (腰果酚) is a phenolic lipid obtained from anacardic acid (腰果酸), the main component of cashew nutshell liquid, a byproduct of cashew nut processing, which consists of a mixture of saturated and (mainly) unsaturated alkylphenols. Cardanol finds use in the chemical industry in resins, coatings, frictional materials, and surfactants used as pigment dispersants for water-based inks.







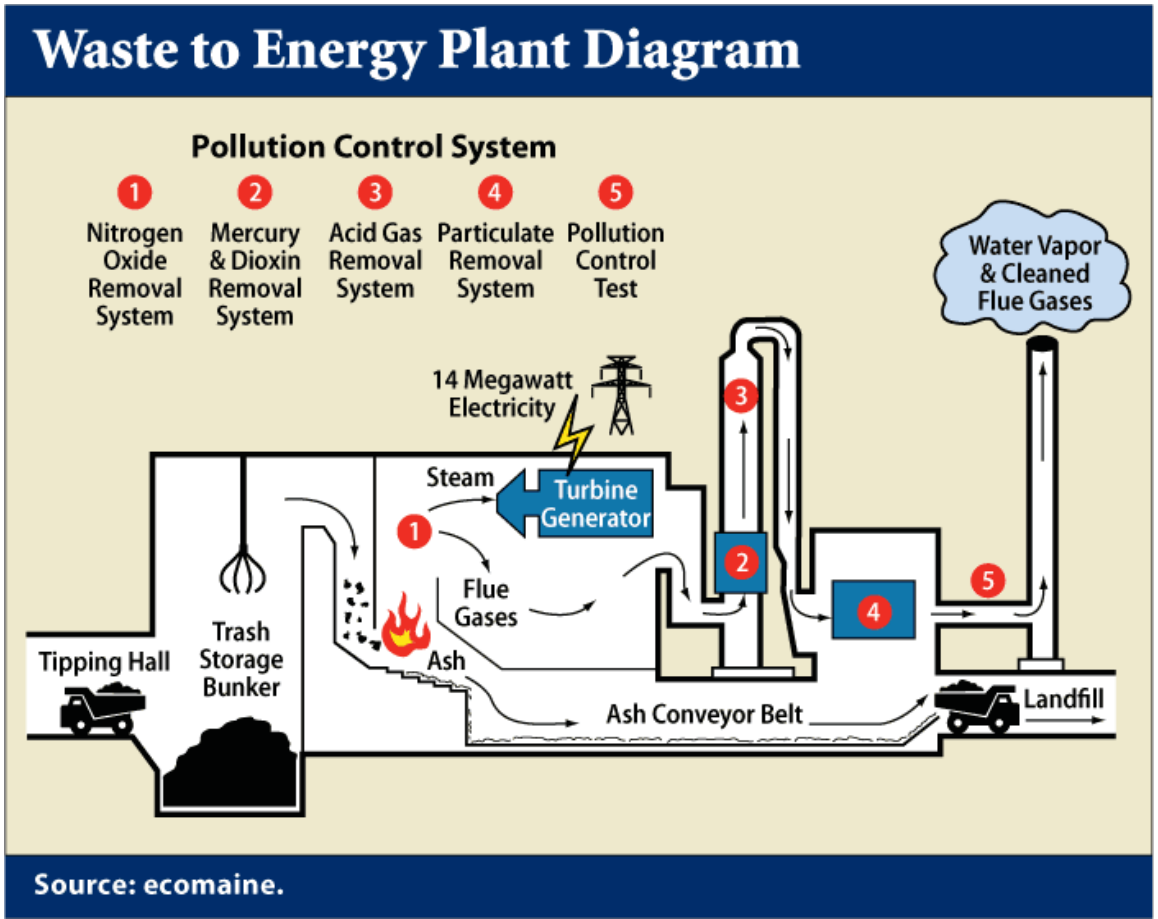
Cardanol-formaldehyde resins

Municipal Waste

- Our solid waste (garbage) needs a home-we normally put it in a landfill (polite name for a dump!)
- Landfill sites are diminishing for a variety of reasons, but our waste production is increasing.
- Unfriendly to the environment:
  - Can contaminate groundwater
  - Nasty smell
  - Harbor diseases and disease carrying rodents
  - Can contain toxic chemicals
  - Emit methane (produced in the decay of organic materials and is not only toxic, but a greenhouse gas)

Municipal waste

- This waste has energy stored in it, which can be released if the waste is burned.
- Energy produced is modest, but this solves another environmental problem.
- Plants are expensive to construct and maintain, most cities do not have the money to get one started. Rely on private investors or companies



Conclusion

- The first priority in this area is undoubtedly to reduce the amount of fossil fuels used for energy.
- The use of renewable resources for manufacturing specific performance and special chemicals, and for fibres to replace synthetic ones, is growing.
- In order to have a major impact on the amount of oil and gas used there is a need to convert biomass into new, large-scale basic feedstocks such as synthesis gas or methanol.

Thank you!