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UNIVERSITI MALAYSIA PAHANG

Sustainable Engineering Design:
Renewable Energy Technology

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Part 1: Renewable Energy Technology

Content of Lecture

- Non-renewable Energy
- Renewable Energy
- World Energy Outlook

Non-Renewable Energy

What is Non- Renewable Energy?

Non-renewable energy is energy derived from finite resources that are not replaced quickly enough to keep up with the speed of consumption.

What are the Non - Renewable Resources?

Non - renewable energy resources include coal, natural gas, oil, and nuclear energy. Once these resources are used up, they cannot be replaced, which is a major problem for humanity as we are currently dependent on them to supply most of our energy needs.

Types of Non-Renewable Energy

Coal

Natural Gas

Nuclear

Oil

Non-Renewable Energy:
The Good, the Bad and the Ugly!

- Widely Available
- Easily Locatable
- Very efficient
- Simple Configuration

- Environmental Pollutions
- Public Health Issues
- Rapid Depletion
- Rise in cost
- Oil Spills
- Health risk to workers


The FUTURE is shifting to
RENEWABLES!

Renewable Energy: Energy Trends Shaping the Future

What are renewable resources?

Renewable resources include solar energy, wind, falling water, the heat of the earth (geothermal), plant materials (biomass), waves, ocean currents, temperature differences in the oceans and the energy of the tides.

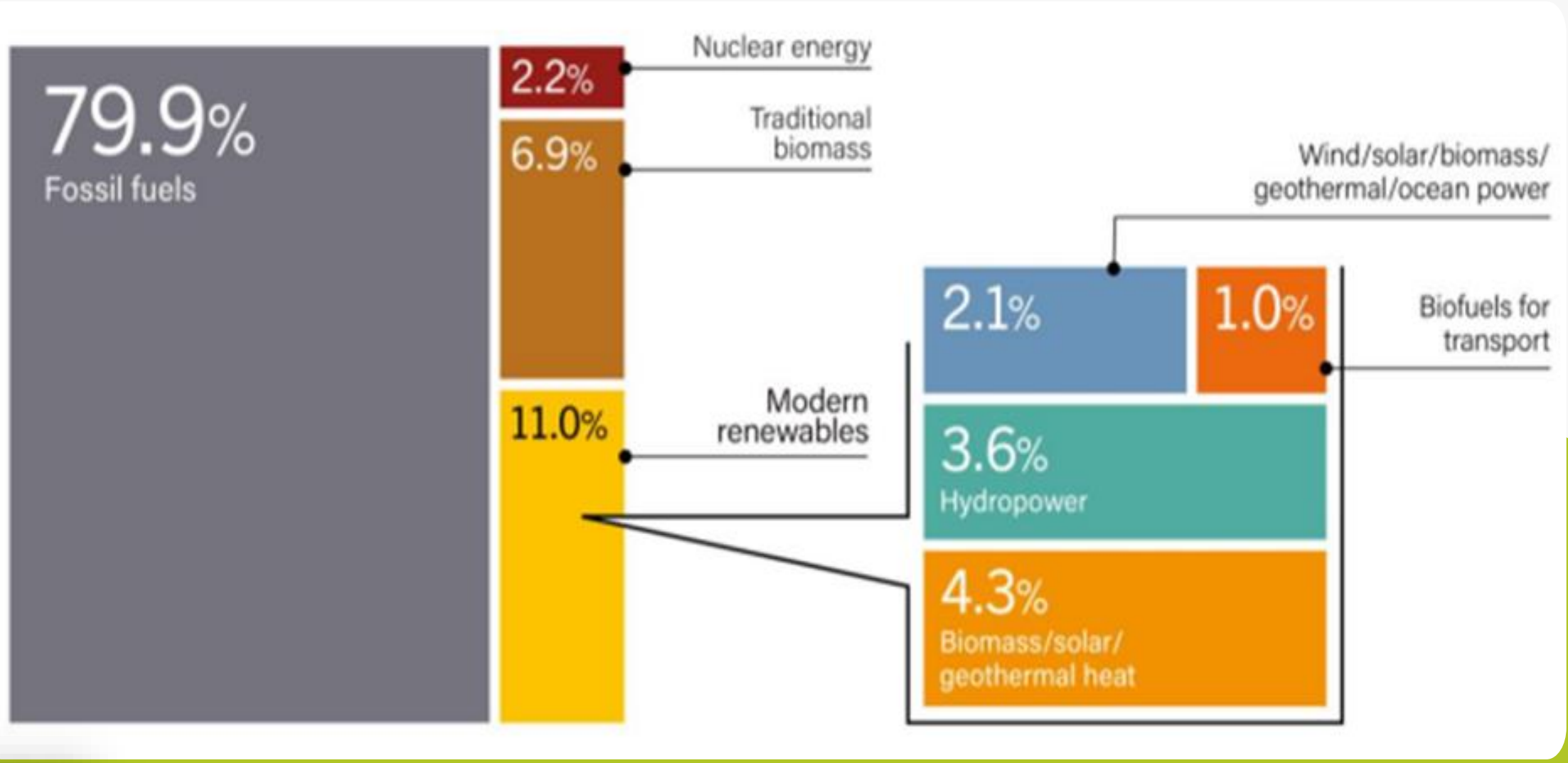
Therefore, what constitutes renewable energy technology?

Renewable energy technologies produce power, heat or mechanical energy by converting the previously mentioned resources either to electricity or to motive power

What Are the Benefits of Using Renewable Energy?

- Conservation of fossil fuels
- Slow and reverse climate change
- Minimize risk and environmental impact
- Minimize fuel dependency
- Reduce severe whether
- Economic and job development

Utilization of Energy



6 Types of Renewable Energy: The Future of Energy

- Solar Energy
- Hydroelectric Energy
- Wind energy
- Geothermal Energy
- Ocean Energy (Wave, Tidal)
- Biomass Energy

Part 2:

Application of Renewable Energy Technology

Content of Lecture

- Solar Energy
- Wind Energy
- Hydrothermal Energy
- Ocean – Wave Energy

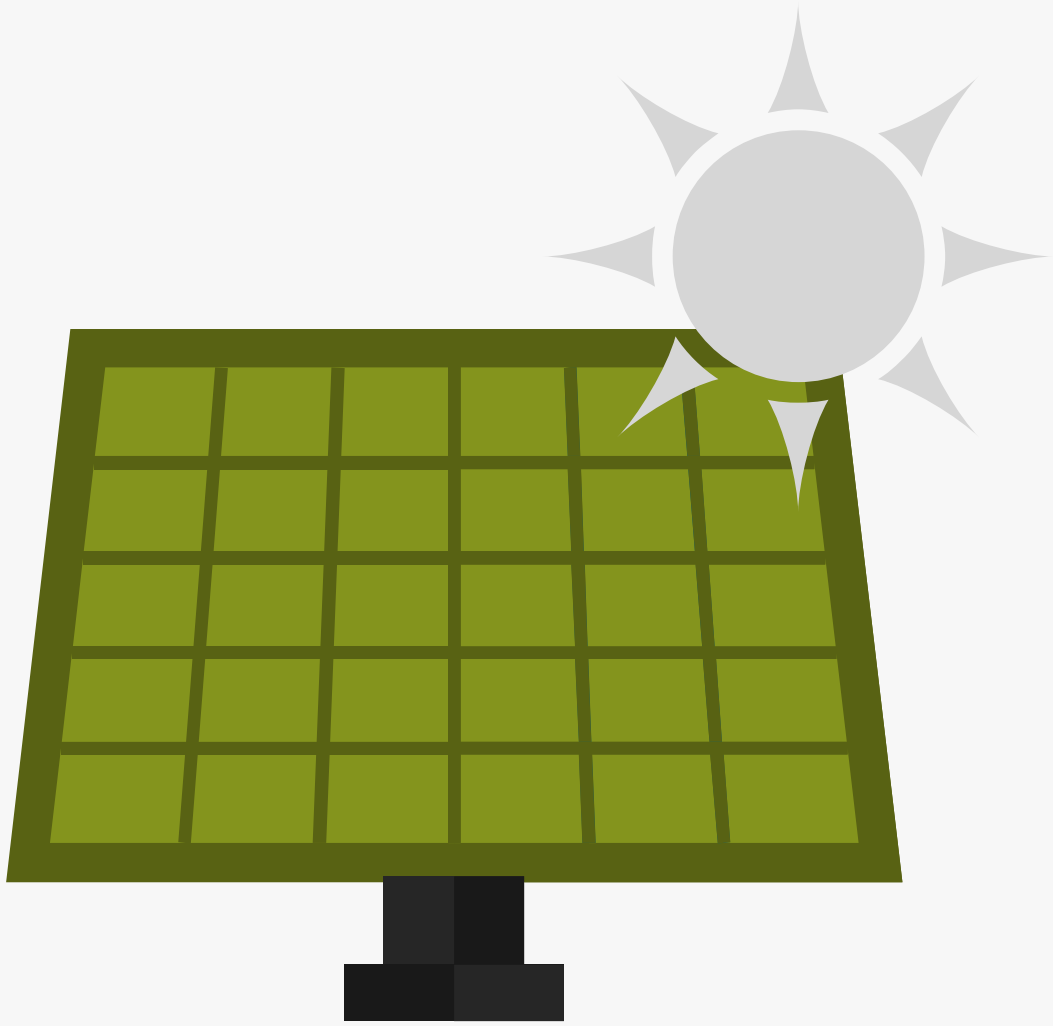
Solar Energy

Solar Energy

“I’d put my money on the sun and solar energy. What a source of power! I hope we don’t have to wait ‘til oil and coal run out before we tackle that.”
–Thomas Edison

According to the energy explorers, humans have been harnessing solar energy for a very long time!

Introduction to Solar Energy



What is Solar Energy?

Solar energy is power or heat that comes from the sun

What are the uniqueness of this energy source?

Solar energy is inexhaustible and renewable, since it comes from the Sun, solar energy is harnessed using panels and mirrors.

Why solar energy is the future?

In the coming years, technology improvements will ensure that solar becomes even cheaper. It could well be that by 2030, solar will have become the most important source of energy for electricity production in a large part of the world.

Categories of Solar Energy

Solar Thermal

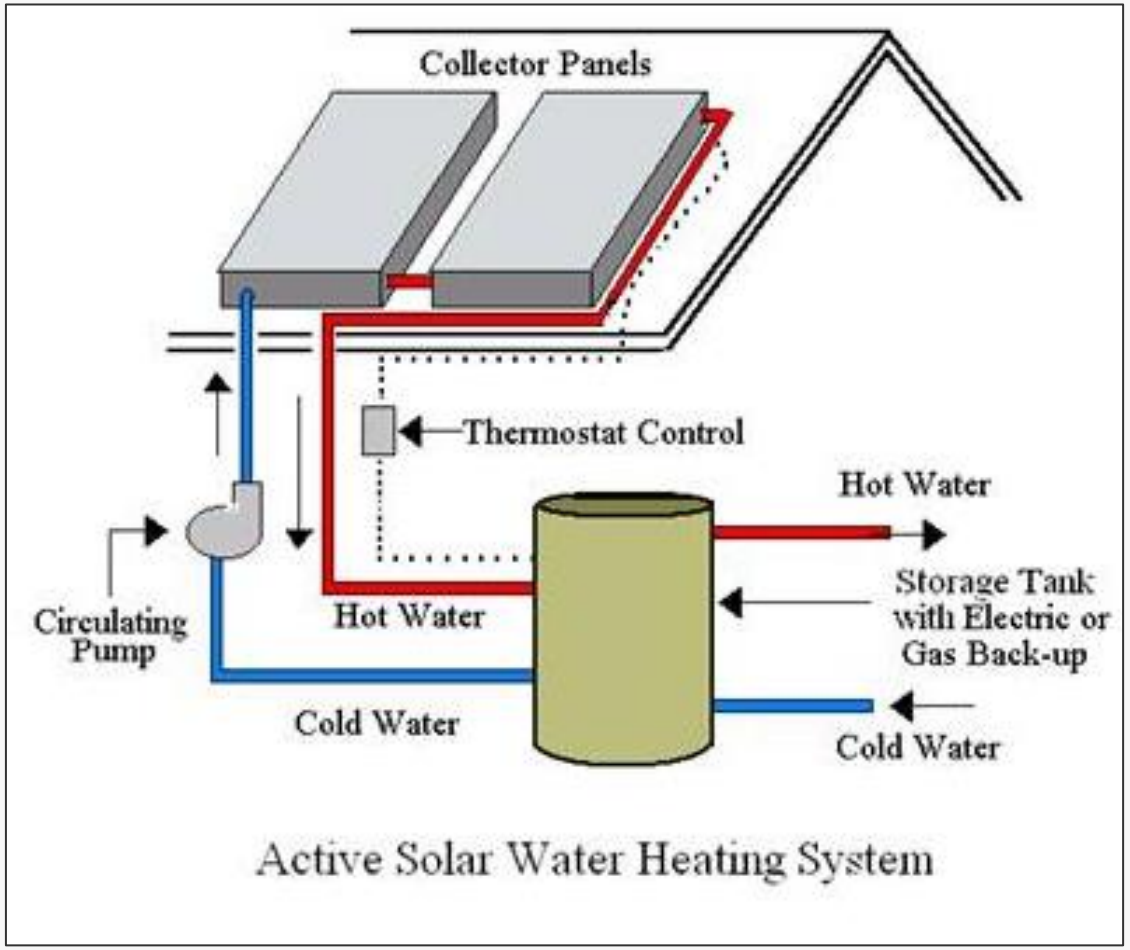
Solar Thermal - Using the sun’s energy to heat things like your house, water, food, etc.

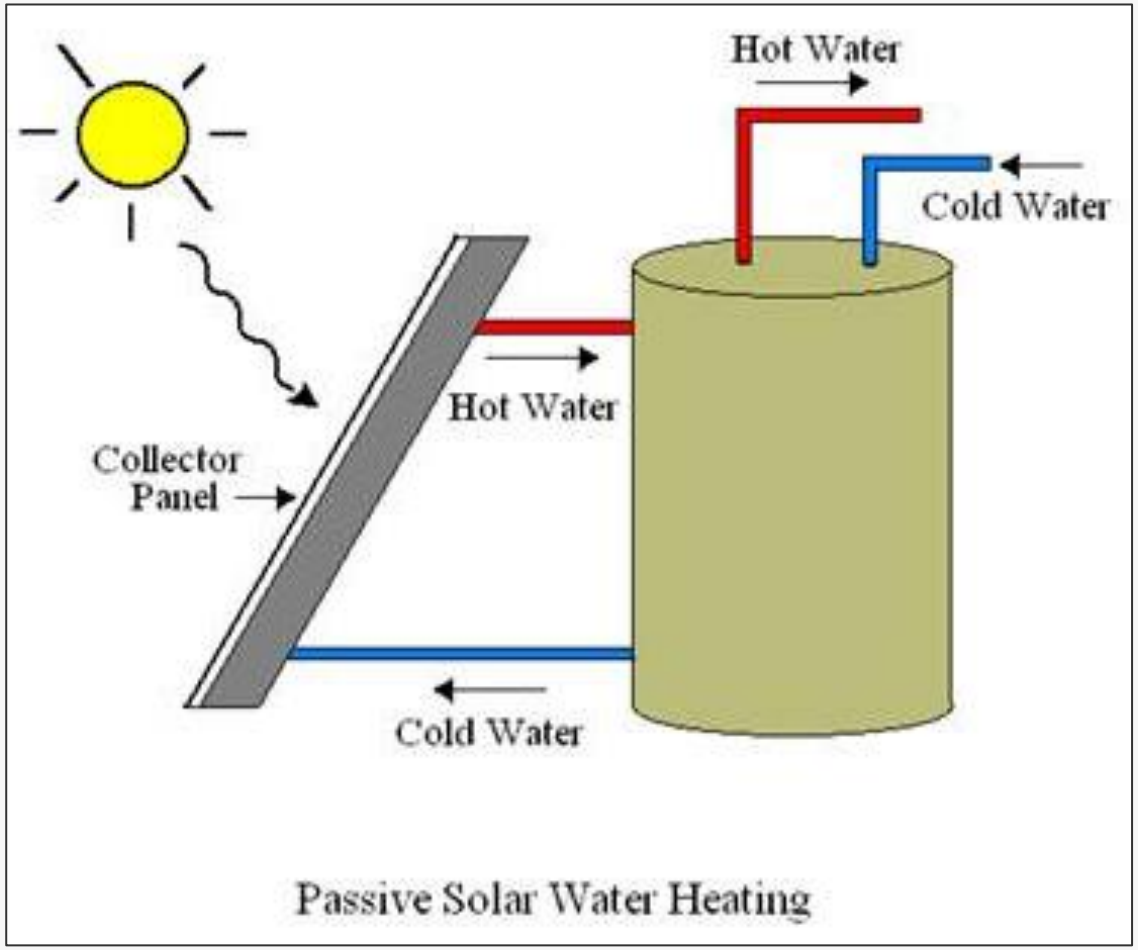
Solar Photovoltaic

Solar Photovoltaic - Turning light from the sun directly into electricity, using solar panels.

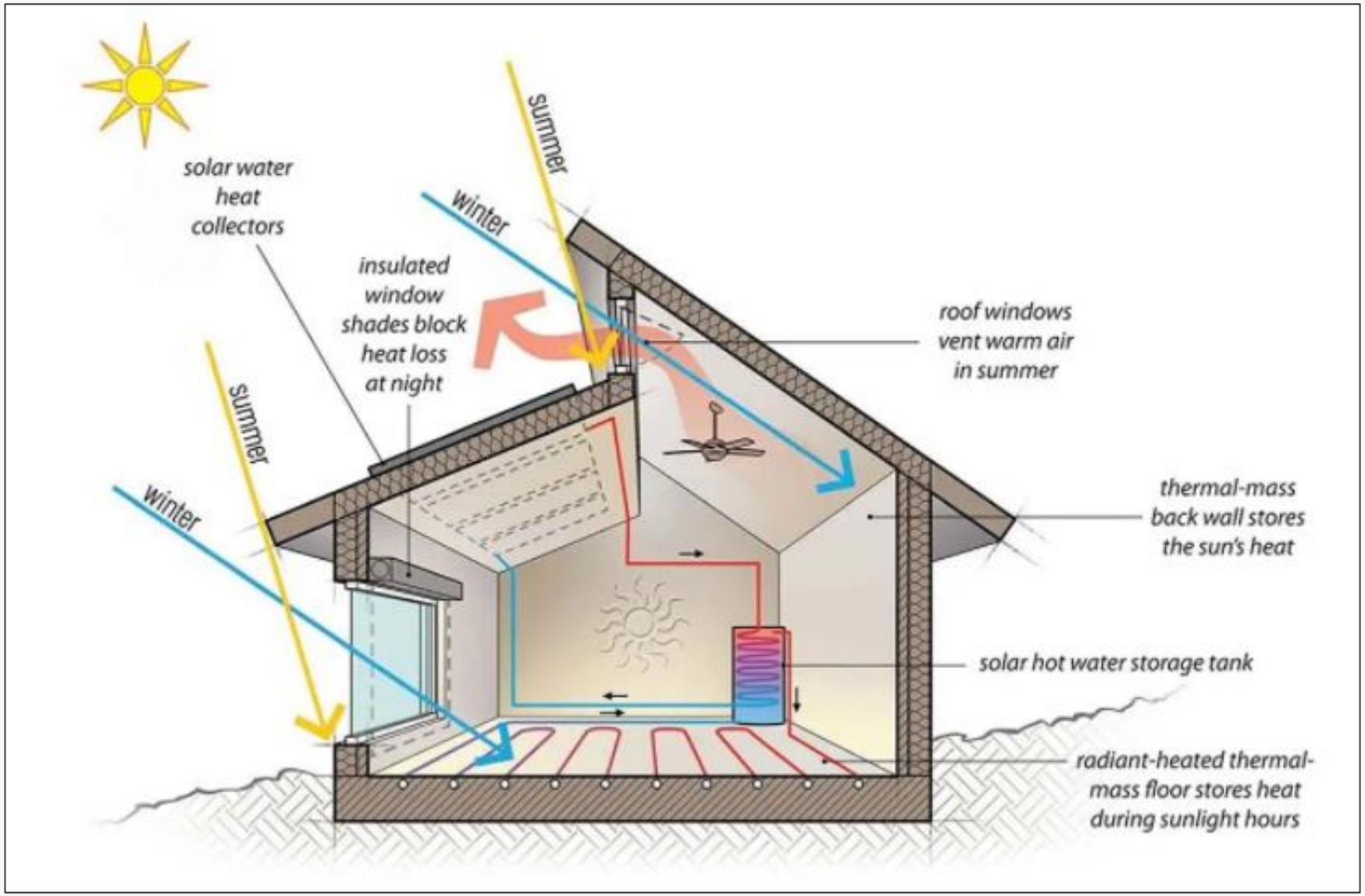
Technology of Solar Heating System for Houses

How does solar thermal system works?

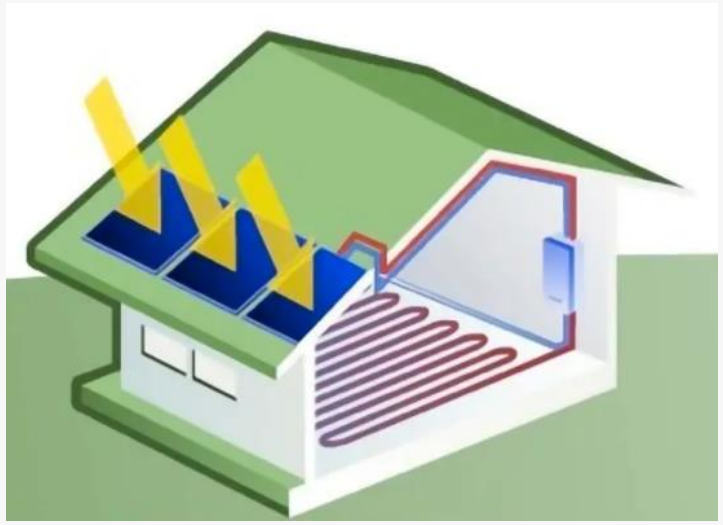




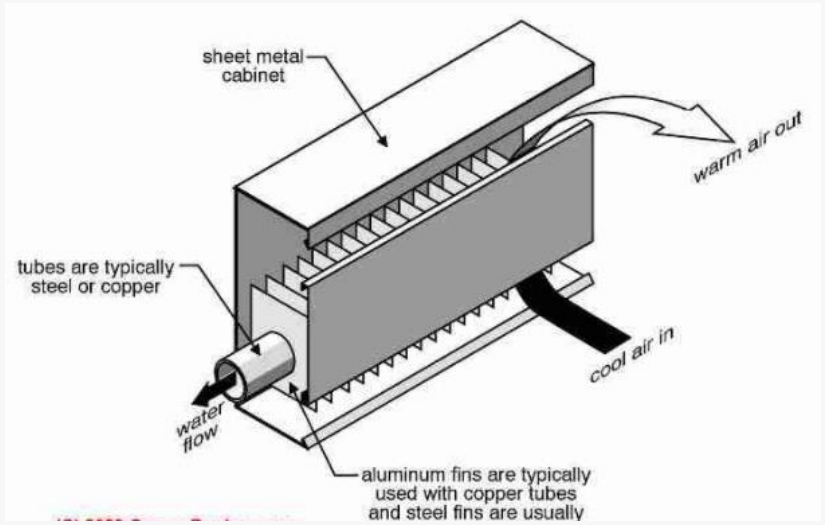
Solar heating systems - art of minimizing electricity bills



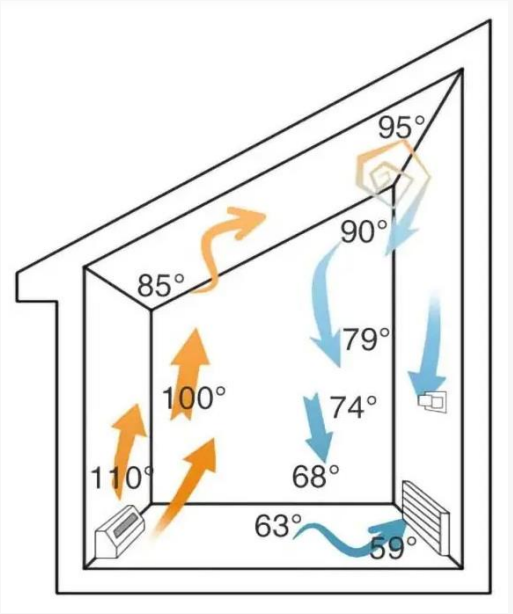
What are the different ways to use active solar heating in homes?



Radiant floor system



Hot water baseboard heaters



Forced air heating system

Benefits of solar heating system

Maintain comfortable temperature inside home

Reduce CO2 emission by avoiding energy generated by fossil fuel/natural gas

Harness limitless solar power, free of charge

Cut monthly bills on electricity

Solar photovoltaic system (PV)

DEFINITION

Solar PV (Solar Photovoltaics) is the generation of electricity using energy from the sun.

WHAT ARE THEY MADE OF?

semiconducting materials similar to those used in computer chips.

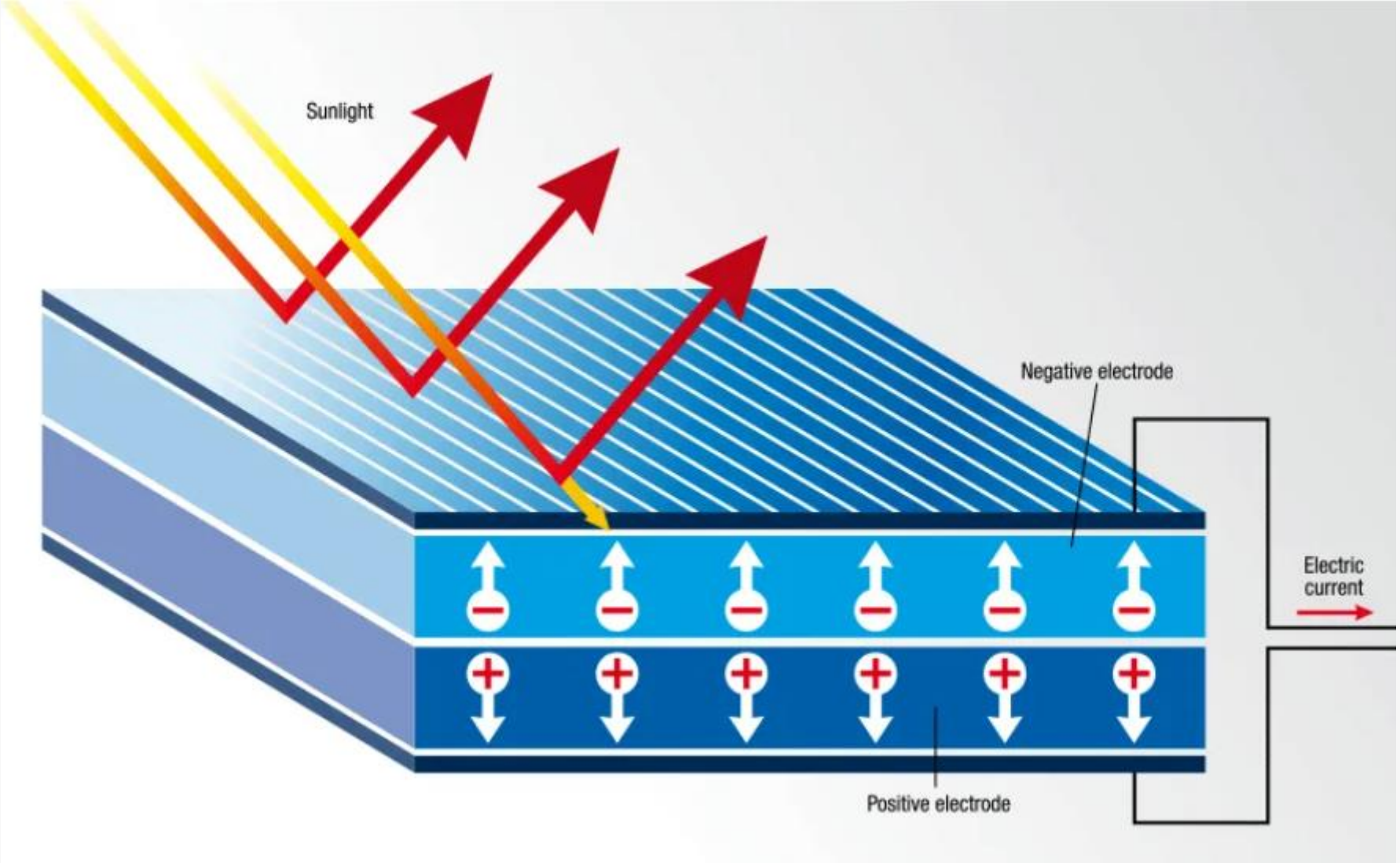
WHY IS IT ATTRACTIVE?

The simplest systems power the small calculators we use every day.

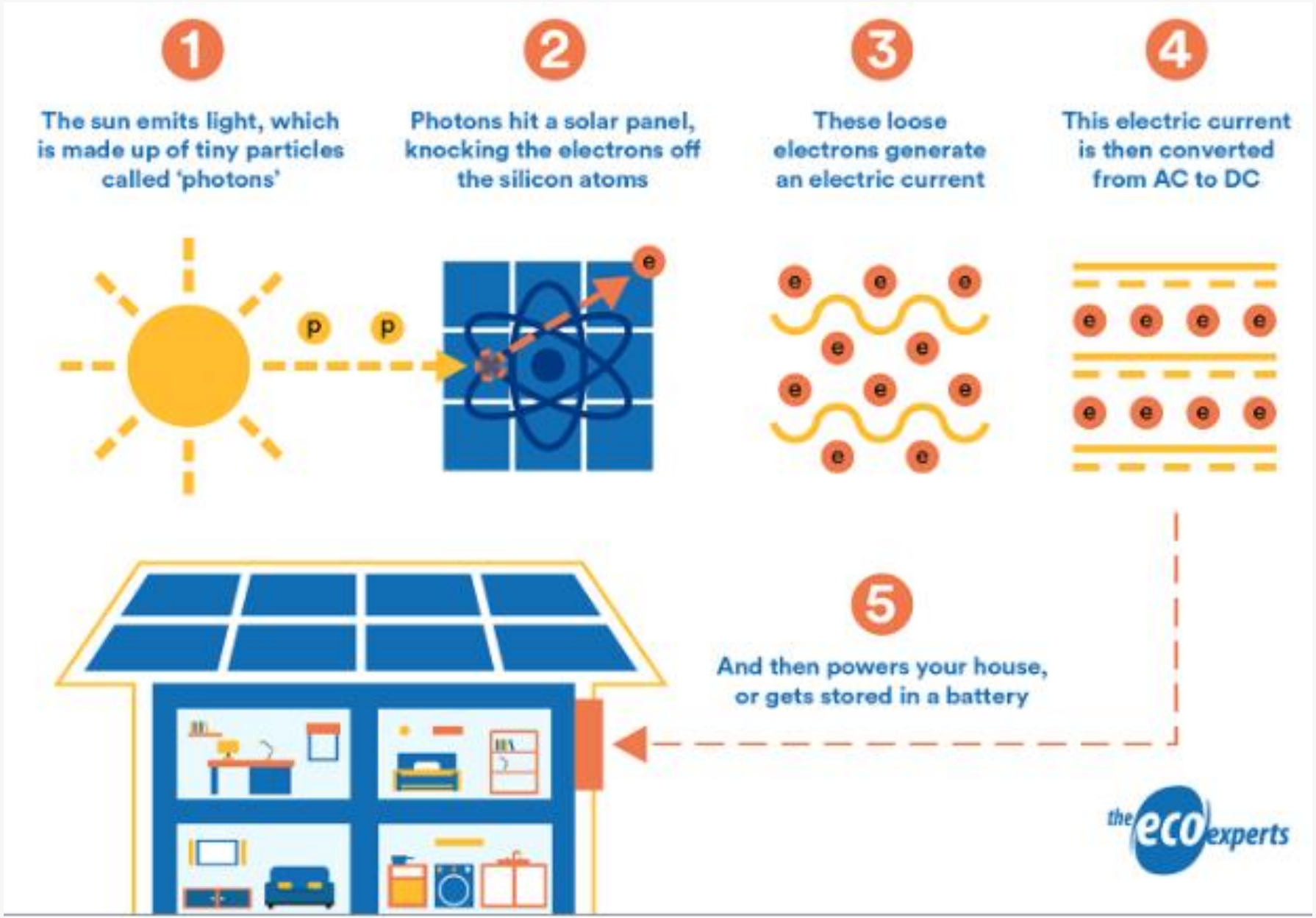
HOW BIG IT CAN BE?

PV systems range from small, rooftop-mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts.

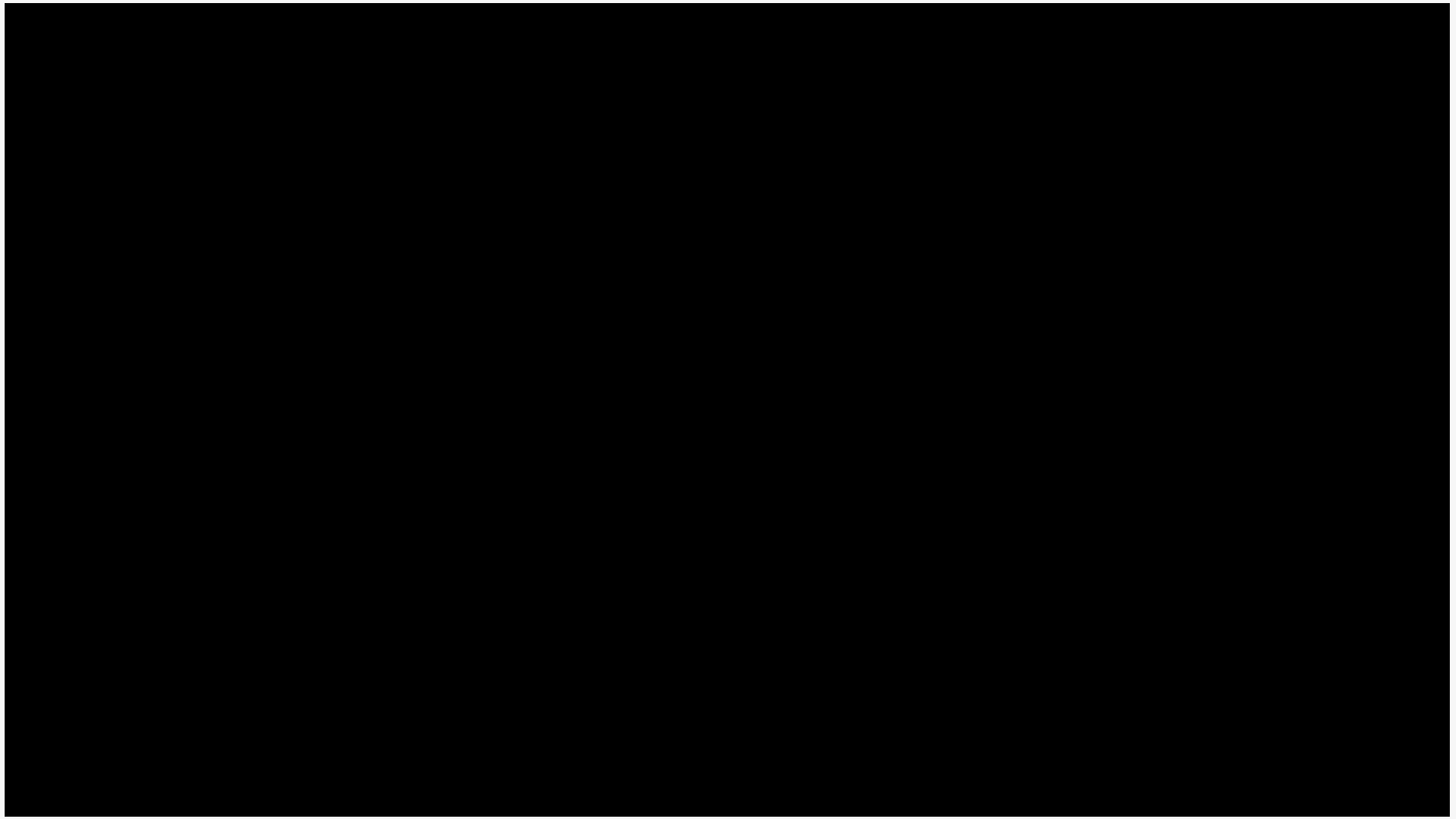
What are solar cells made of?



How does solar panels works?



Solar Photovoltaic Technology Basics



Types of Solar Panel

Monocrystalline Solar Panel

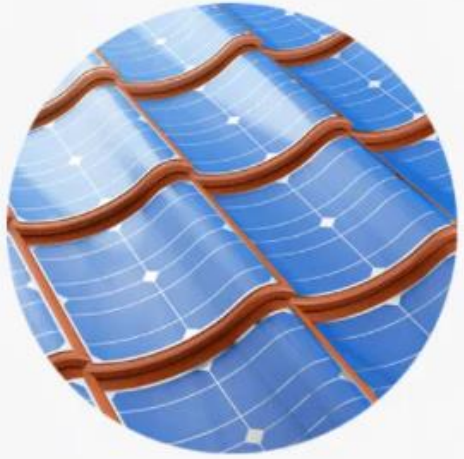
Polycrystalline Solar Panel

Thin-Film Solar Panel

Innovation in Solar Panel Technologies

Bifacial Solar

Concentrated PV (Photovoltaic) Cell



Solar Tiles

Transparent Solar Panels

Advantages & Disadvantages Solar Energy


Wind Energy

Introduction to Wind Energy

DEFINITION

process of harnessing energy from the movement of the wind and converting it to useful forms of mechanical power and electricity.

WHY IS IT ATTRACTIVE?

is a free, renewable, clean energy source. It produces no greenhouse gases or pollution, and uses no water in the generating process, unlike other power sources.

UNIQUE FACTS ON WIND ENERGY

Fact 1: one of the fastest-growing energy sources in the world

Fact 2: Windmills have been in use since 200 B.C. – first developed in Persia and China.

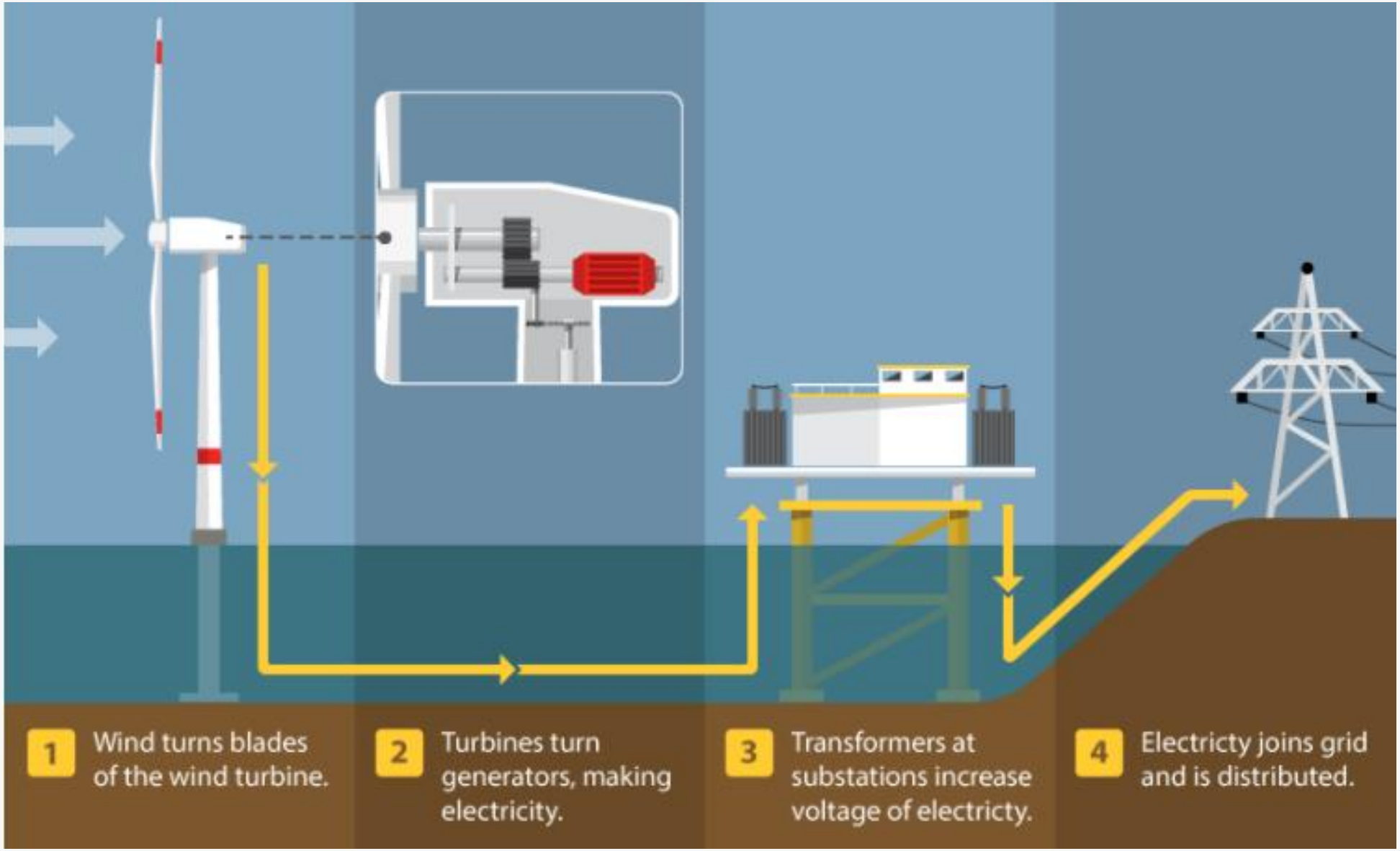
Types of Wind Energy

Land-Based Wind Energy

Distributed Wind Energy

Offshore Wind Energy

How Does Wind Energy Works?



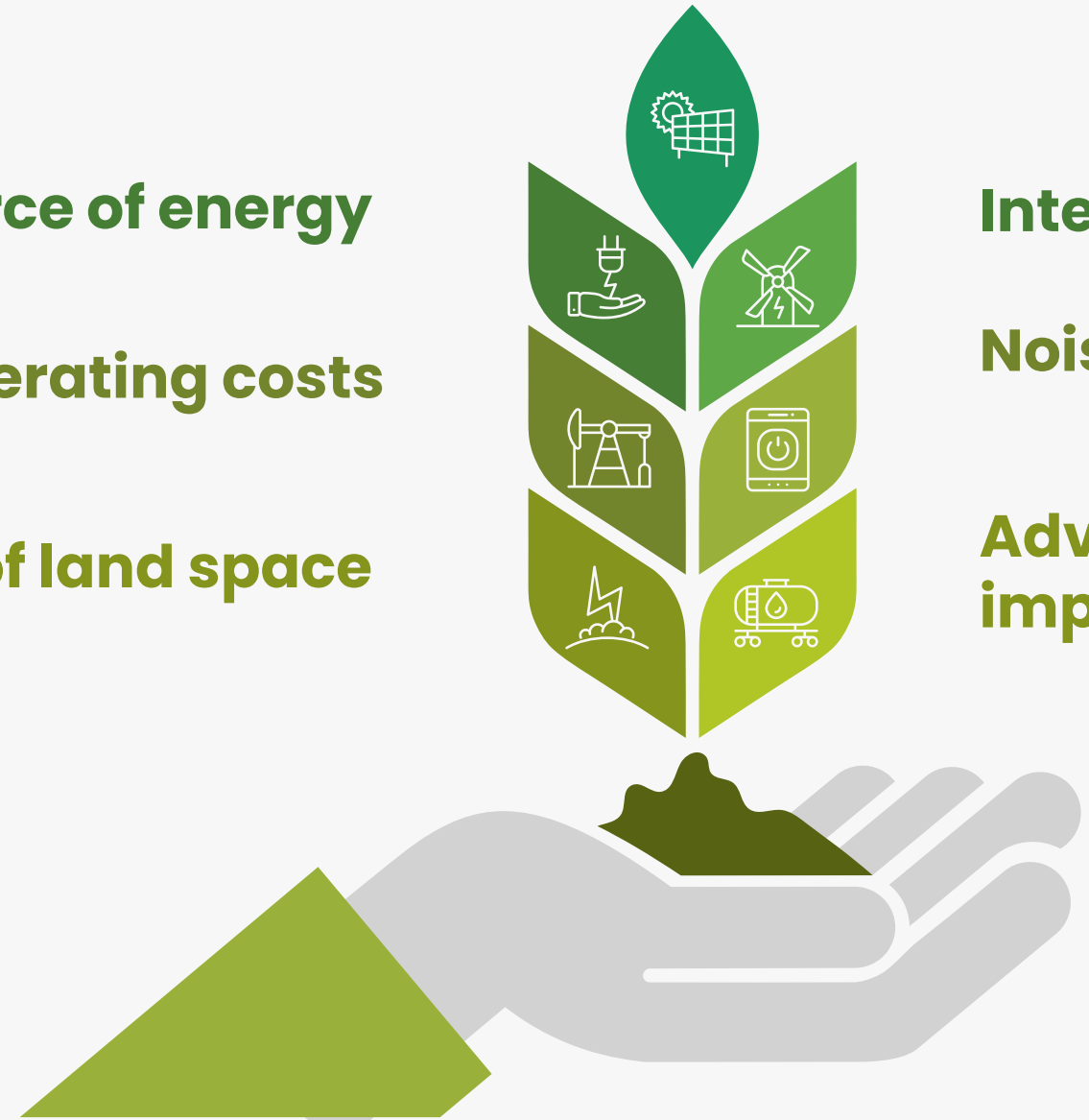
Energy –Wind Power

Advantages & Disadvantages of Wind Energy

Clean source of energy

Low operating costs

Efficient use of land space

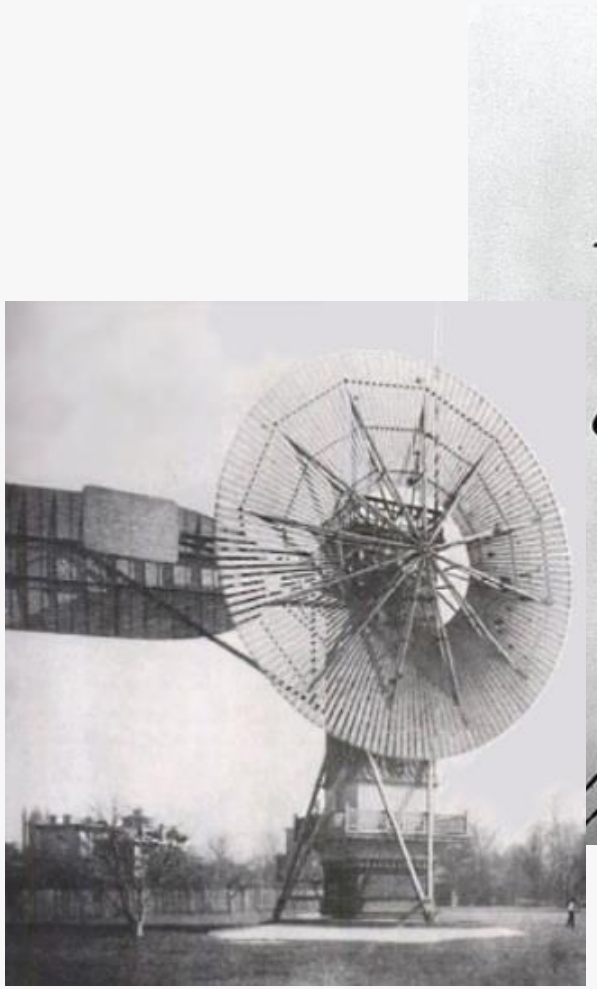


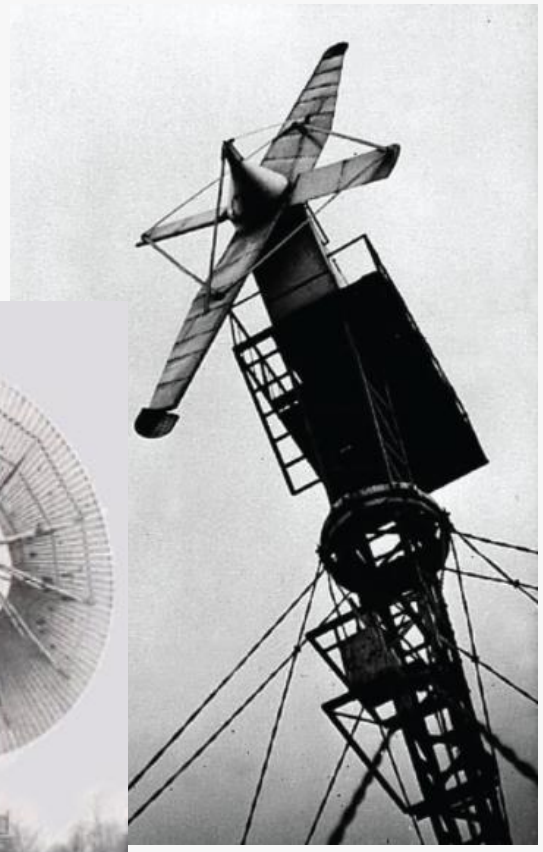
Intermittent

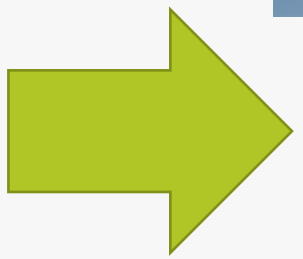
Noise and visual pollution

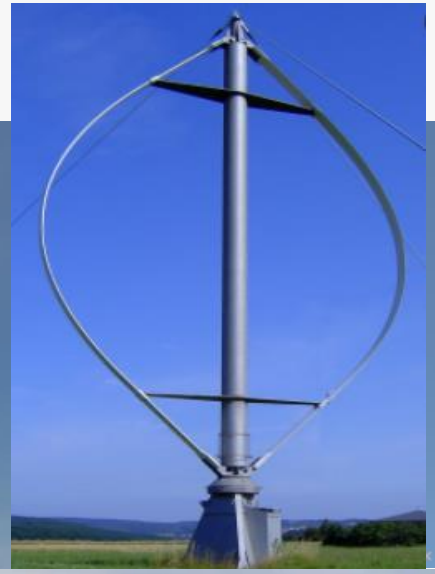
Adverse environmental impact

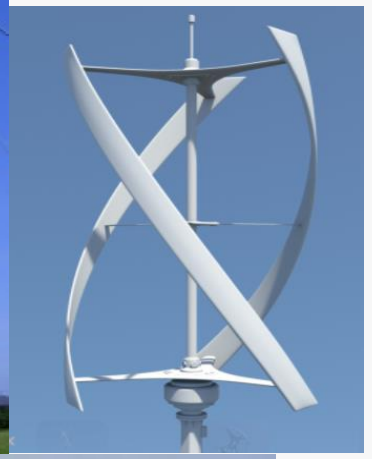
Evolution of Windmill









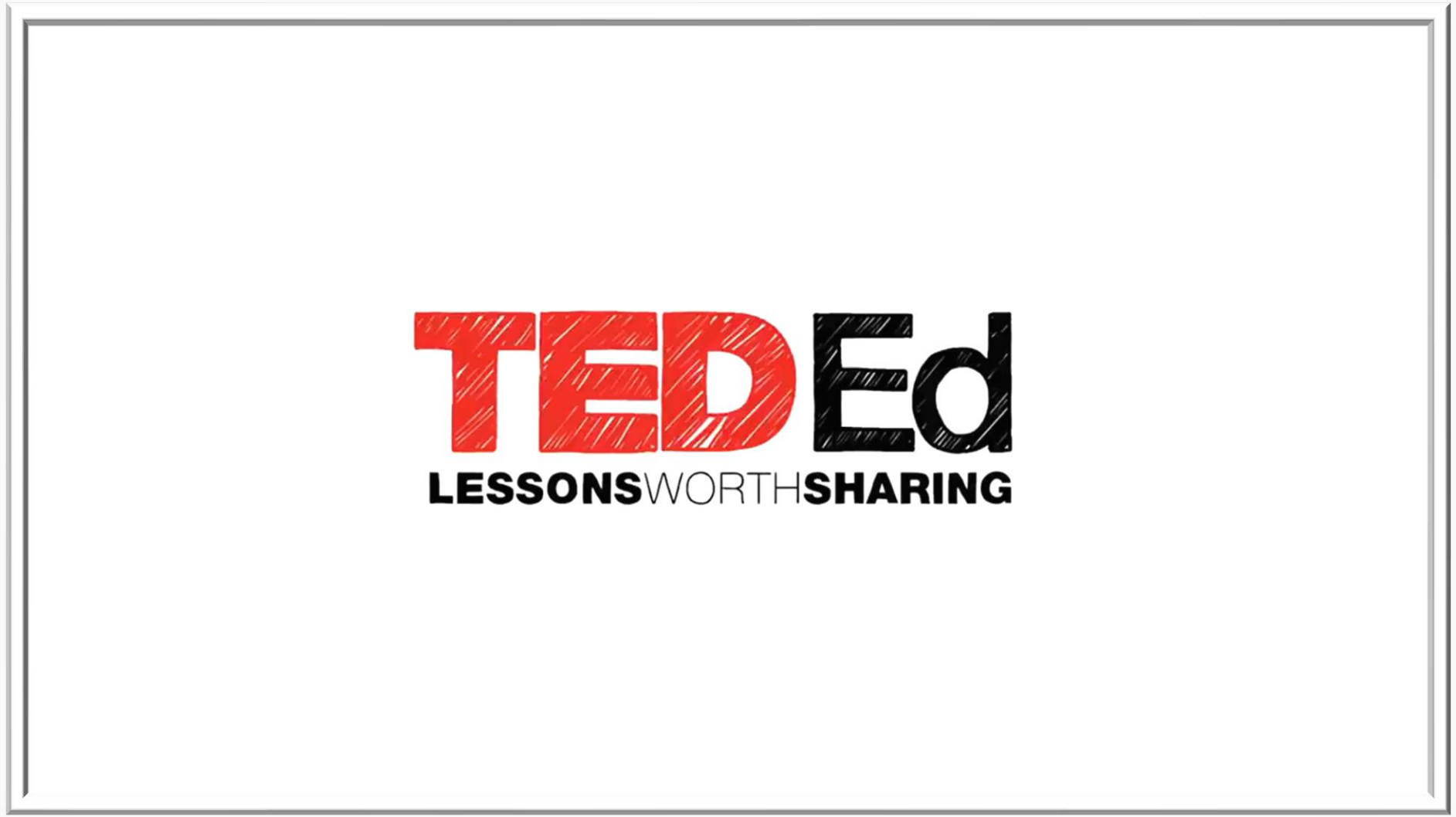


Types of Wind Energy Turbines

Vertical – Axis Wind Turbine (VAWT)

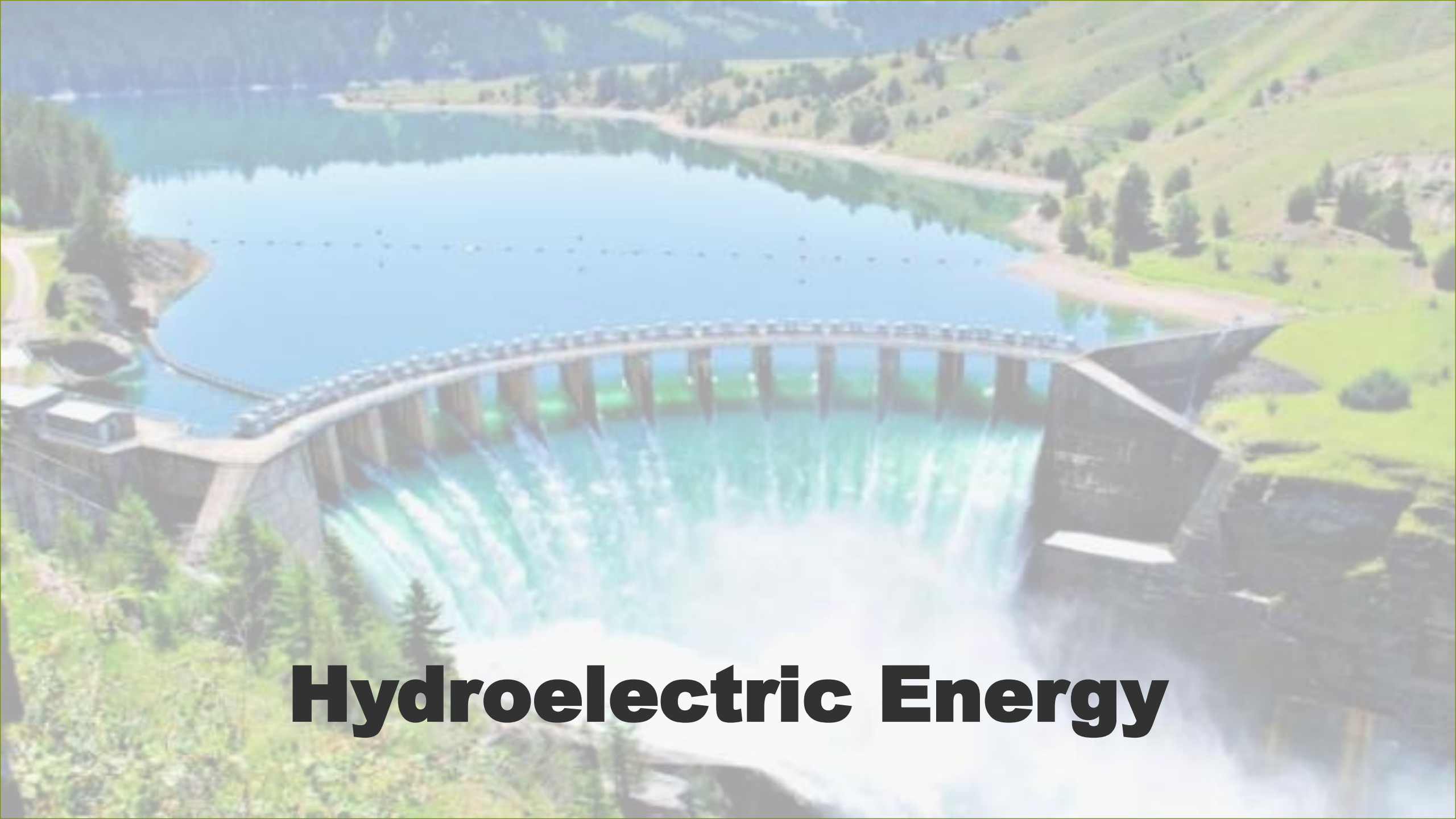
Horizontal – Axis Wind Turbine (HWWT)

How Does Wind Turbines Works ?



Challenges of Wind Power

- **Wind power must still compete with conventional generation sources**
- **Good land-based wind sites are often located in remote locations, far from cities where the electricity is needed.**
- **Wind resource development might not be the most profitable use of the land**
- **Turbines might cause noise and aesthetic pollution**
- **Wind plants can impact local wildlife**



Hydroelectric Energy

Introduction to Hydro Energy

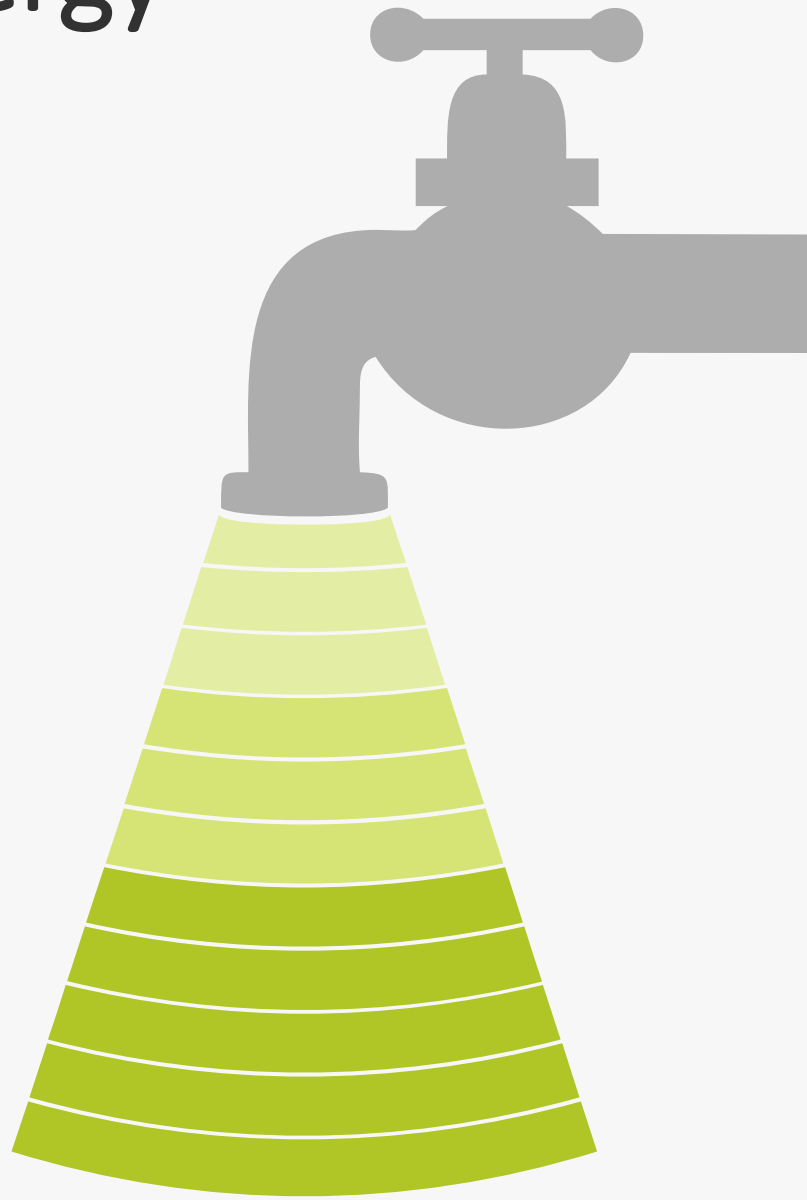
Hydroelectric energy, also called hydroelectric power or hydroelectricity, is a form of energy that harnesses the power of water in motion

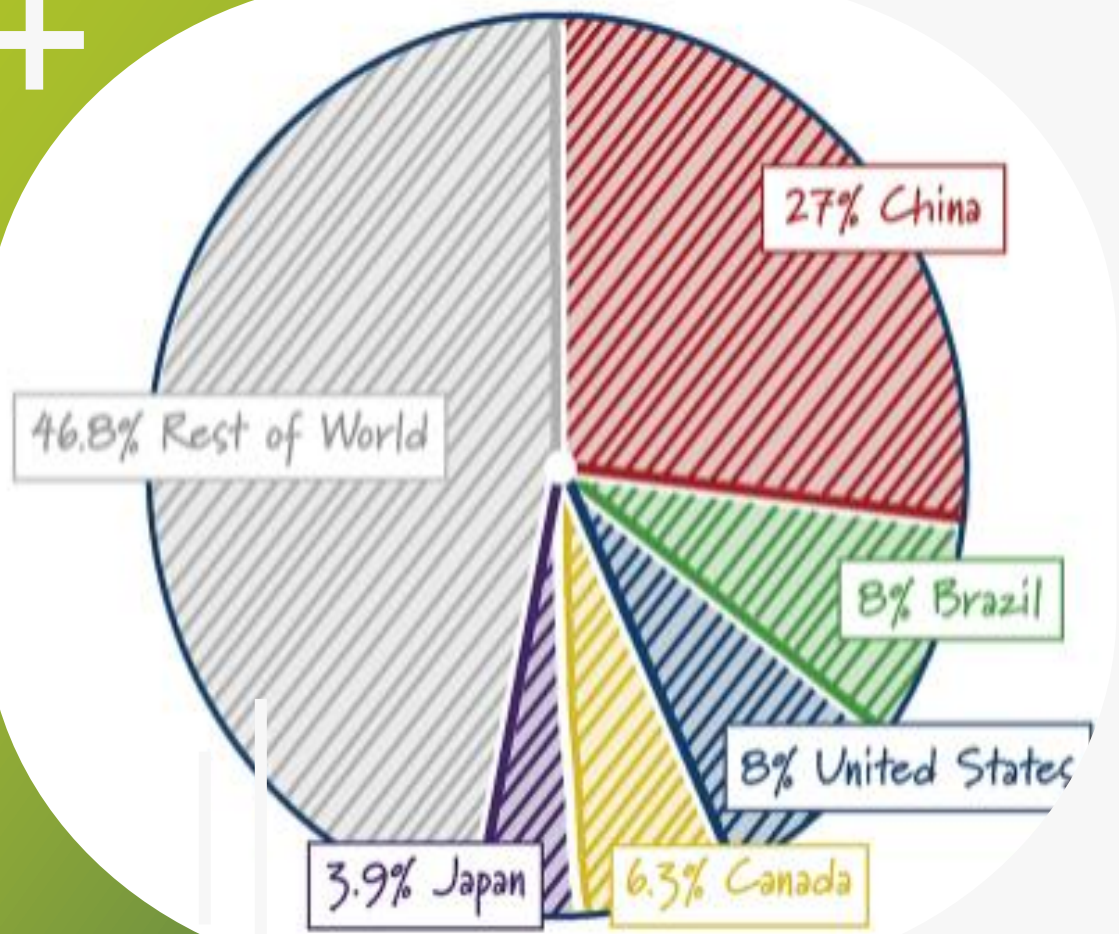
It is considered the most mature and environment-friendly renewable energy resource.

Hydropower is the energy obtained by water falling from high to low potential, where the potential energy is harnessed from falling water by running a hydro turbine.

Electrical current is generated from the kinetic energy of flowing water, we call it hydroelectricity

Hydropower is used to control flood, help in irrigation, and water supply. Hydropower plays a major role in reducing greenhouse gas emissions.





"Hydropower represents approximately 16% of the total electricity production in the world with China possessing the most capacity, three times more than the second largest, Brazil. China installed the most new capacity in 2019, 8,540 MW compared to Brazil with 3,866 MW."

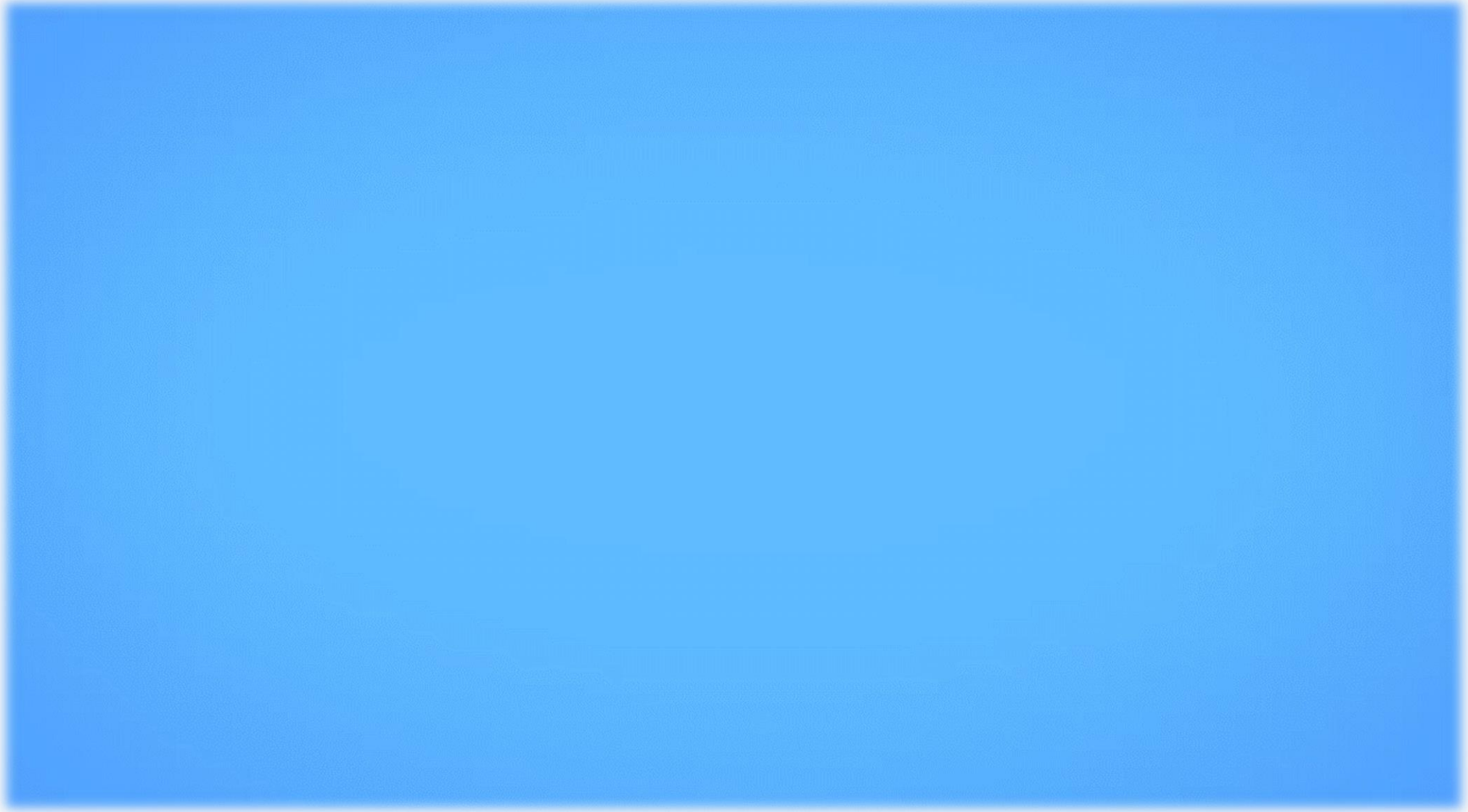
Three Most Impressive Hydroelectric Power Plant

The Three Gorges Dam on China's Yangtze River

Jinsha River's Xiluodu Dam, China

The Itaipu Dam on the Paraná River, Brazil and Paraguay

How Does Hydropower Pant Works ?

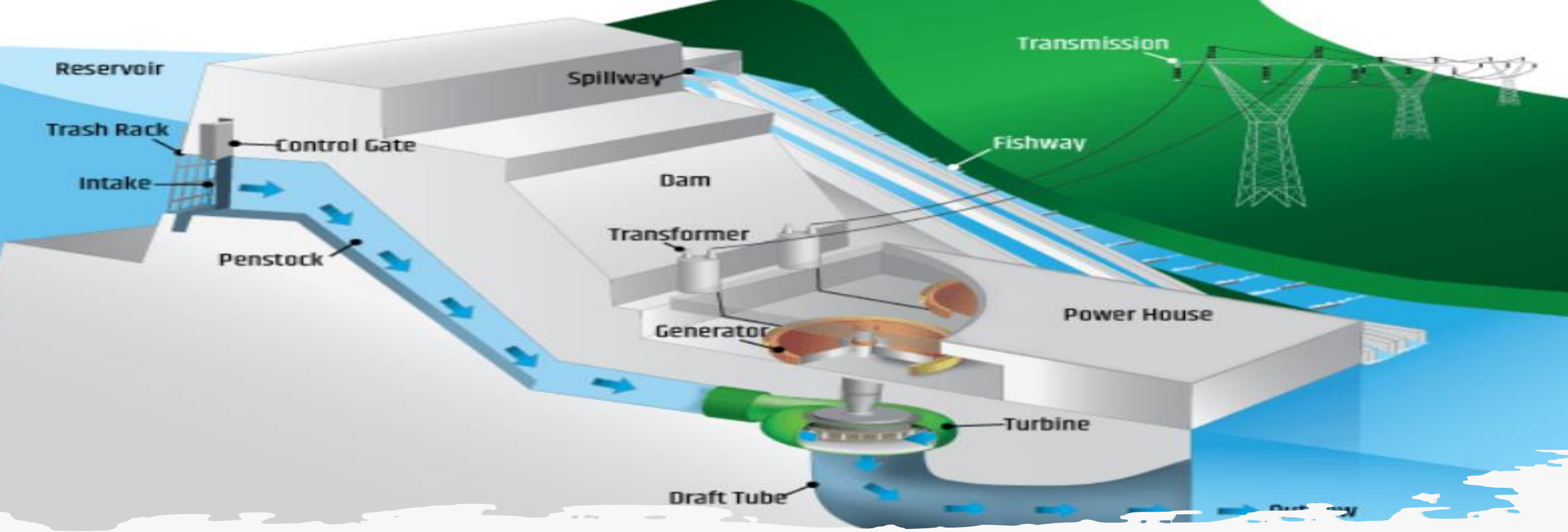


Types of Hydropower Plants

Impoundment

Diversion

Pumped Storage

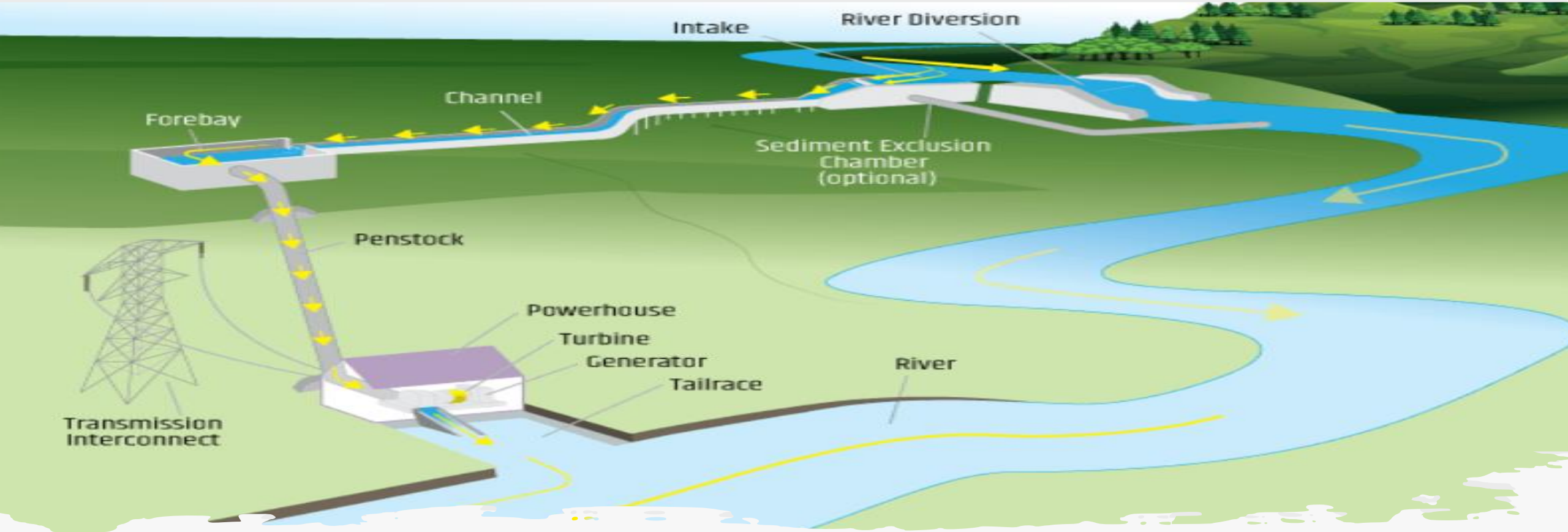


Impoundment Facility

most common type of hydroelectric power plant - uses a dam to store river water in a reservoir

Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity.

The water may be released to meet changing electricity i.e. flood control, recreation, fish passage etc



Diversion Facility

sometimes called a “run-of-river” facility

channels a portion of a river through a canal and/or a penstock to utilize the natural decline of the river bed elevation to produce energy

penstock is a closed conduit that channels the flow of water to turbines with water flow regulated by gates, valves, and turbines

Pump Storage Facility

works like a giant battery- store energy by pumping water from a reservoir at different elevation

demand for electricity is low – the facility stores energy by pumping water from the lower reservoir to an upper reservoir.

high electrical demand - the water is released back to the lower reservoir and turns a turbine, generating electricity.

Advantages of Hydropower

clean source of energy - won't pollute the air

domestic source of energy - allowing each state to produce its own energy

offer **recreational opportunities** - fishing, swimming, and boating

Flexible - can generate power to the grid immediately - provide essential backup power during electricity outages

benefits beyond electricity generation - **flood control, irrigation support, and clean drinking water**.

Hydropower is affordable.- provides low-cost electricity and durability over time

Disadvantages of Hydropower

- Hydropower plants can adversely affect surrounding environments
- Building hydropower facilities is expensive up-front
- Hydropower facilities rely on local hydrology

Introduction to Hydropower Turbines

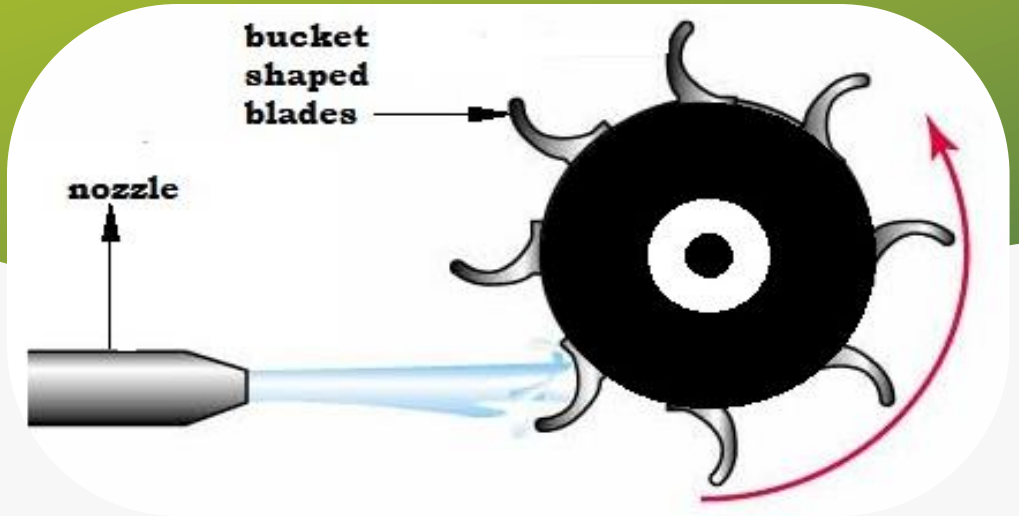
devices used in hydroelectric generation plants

can be classified based on water flow – axial, radial and mixed flow

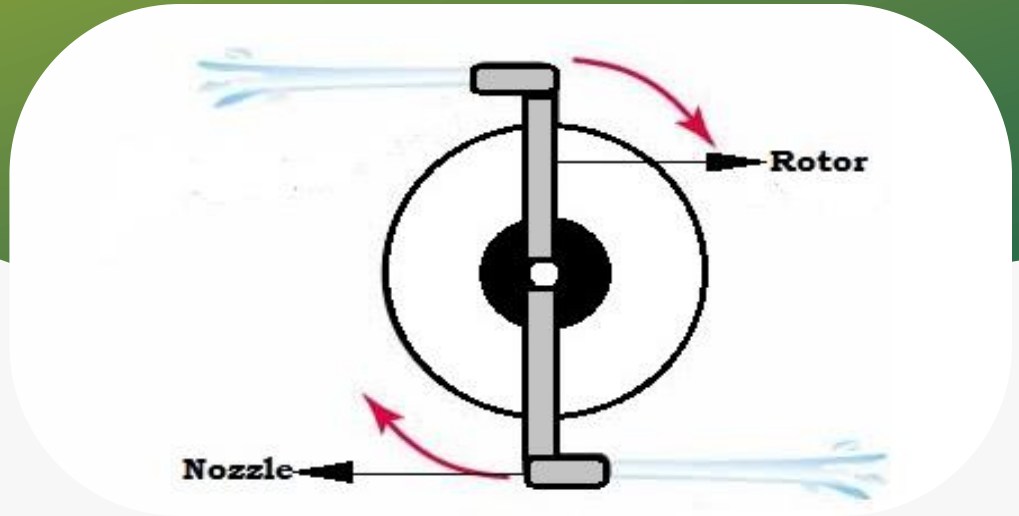
Mechanism of operation – same as wind turbine

The type of turbine selected is based on the height and speed of the incoming water

Types of Turbines: Impulse Turbine vs. Reaction Turbine



Impulse Turbine

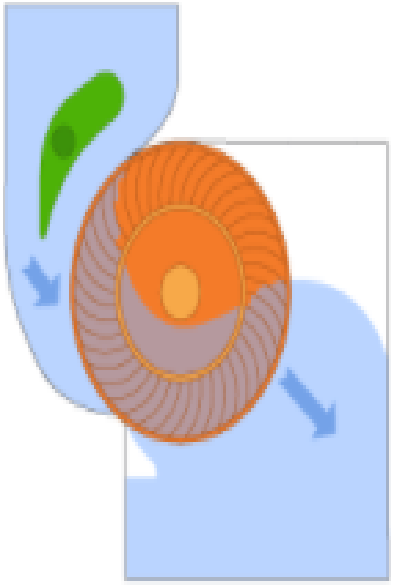


Reaction Turbine

Types of Turbines: Impulse Turbine

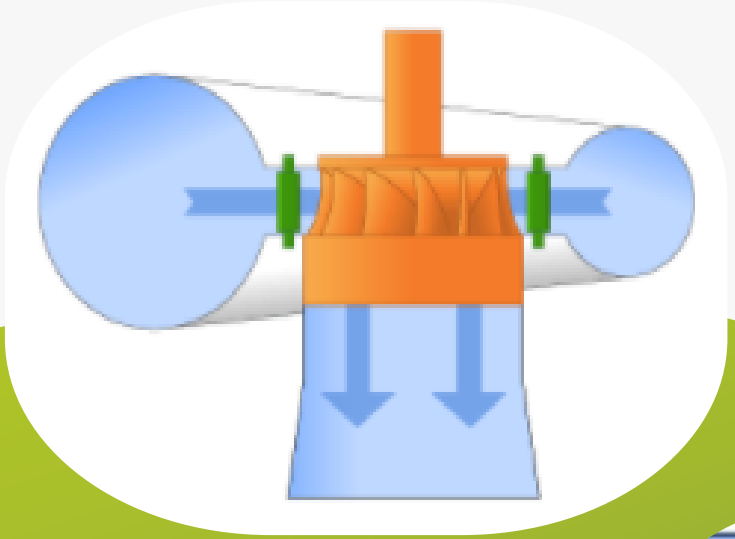
Pelton Turbine

Cross Flow Turbine

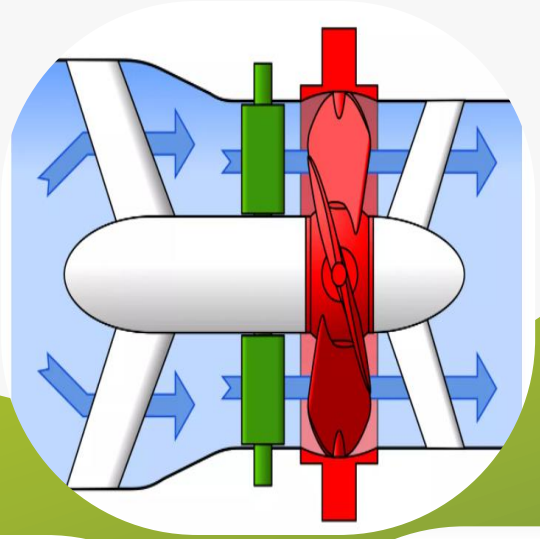


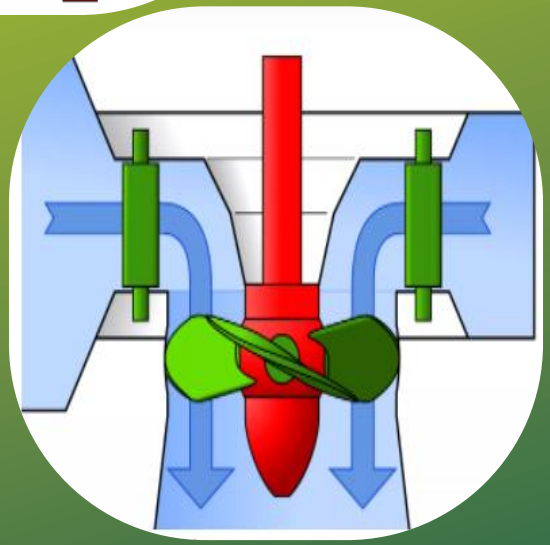
Types of Turbines: Reaction Turbine

Francis Turbine

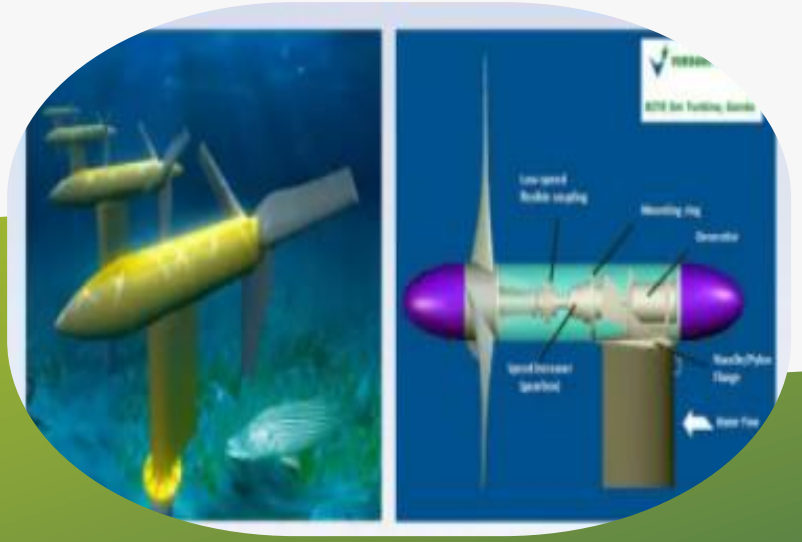


Propeller Turbine





Kinetic Turbine



Challenges in Establishment of Hydroelectric Power Plant

- **Increase of hydropower flexibility**
- **Hydro generators with current-controlled rotors**
- **Digitalization of hydropower operation**
- **Hydroelectric energy storage and variable speed turbines:**
- **Novel technologies in small-scale hydropower**
- **Fish-friendly hydropower technologies**

Ocean Energy

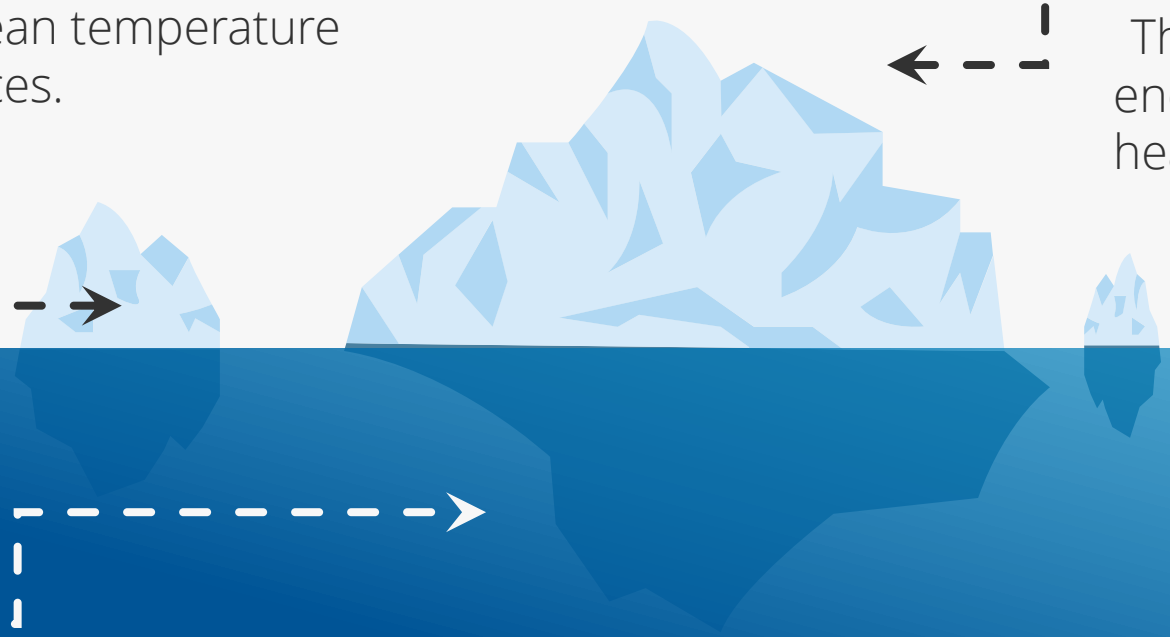
Ocean Energy: An Introduction

Definition

refers to the energy carried by ocean waves, tides, salinity, and ocean temperature differences.

Source of Energy

The ocean can produce two types of energy: thermal energy from the sun's heat, and mechanical energy from the tides and waves.



Mechanism

The movement of water in the world's oceans creates a vast store of kinetic energy, or energy in motion. Some of this energy can be harnessed to generate electricity to power homes, transport and industries.

Commercialization

All forms of energy from the ocean are still at an early stage of commercialization. Wave energy remains more costly than the other ocean technologies.

Types of Ocean Energy

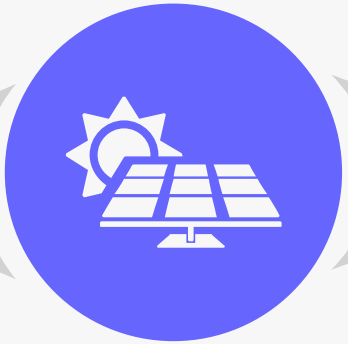
WAVE

using wave energy converters (WEC) to generate electricity

TIDAL

using tidal barrages, fences and turbines to generate electricity.

THERMAL



generates power from the temperature difference between warm surface seawater and cold seawater

SALINITY GRADIENT

Pressure generated from differences in salt concentrations, occurs where a river empties into an ocean

Wave Energy

FACT 1

the largest estimated global resource form of ocean energy

FACT 2

The kinetic motion of surface ocean waves is captured by wave energy technologies

FACT 3

application: electricity generation, water desalination, and pumping of water

Wave Energy: How It Works?

Wave Energy Converter (WEC)

What is WEC?

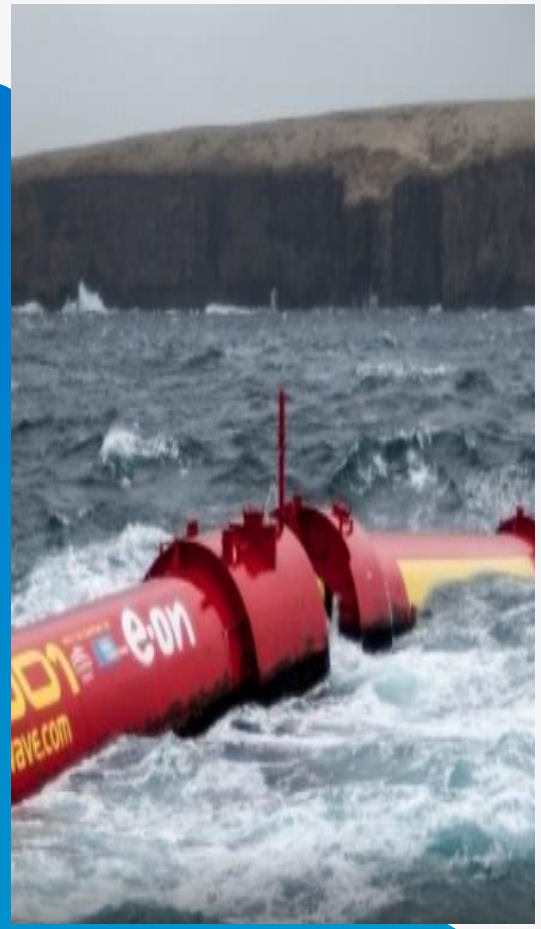
devices that convert the kinetic and potential energy associated with a moving ocean wave into useful mechanical or electrical energy

Classification of WEC

Wave energy converters can generally be classified into one of six different categories, or design archetypes: point absorbers, terminators, attenuators, oscillating wave surge, submerged pressure differential, and rotating mass devices.

Wave Energy Converter

Wave Energy Converter: Attenuators



Fact 1

oriented parallel to the direction of wave travel - usually modular in design and rely on the flexing of joints to generate power

Fact 2

dominant wave length is an important consideration for these designs so that maximum power can be extracted from a given wave climate

Fact 3

The wave-induced motion of the joints is resisted by hydraulic rams that pump high-pressure fluid to drive hydraulic motors, which in turn power electrical generators to produce electricity

Wave Energy Converter: Overtopping/Terminator Devices

Fact 1

Utilize a difference in potential energy by raising a volume of water to a height above the ocean's surface - recreate a similar wave produced naturally on a beach

Fact 2

As the waves hit the artificial beach they run-up a ramp and into a storage reservoir which is at an elevation higher than the surrounding sea level. From here the fluid is allowed to drain back down, courtesy of gravity, and the flow is used to power a turbine

Fact 3

Types of wave energy converters must adjust, or tune, themselves to the height of the oncoming waves for best efficiency

Wave Energy Converter: Point Absorbers

Fact 1

Floating structures that have a small horizontal dimension compared with their vertical dimension and utilize the wave action at a single point.

Fact 2

In a the typical point absorber design one end of the absorber is fixed (or at least fixed relative to the water’s surface) while the other end moves in a vertical motion as the wave crests and troughs lift and lower the device

Fact 3

Point absorbers are one of the most prevalent design archetypes in the marine energy sector today.

Wave Energy: The Pros and Cons

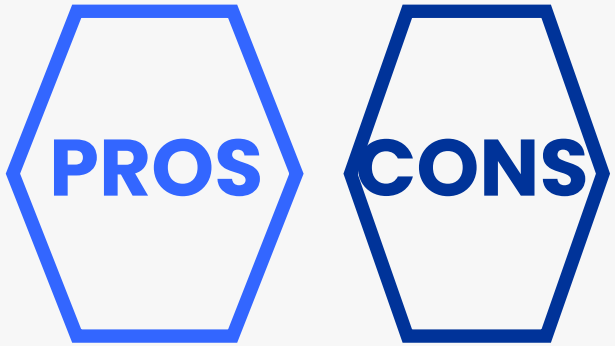
Wave energy is eco-friendly -does not emit dangerous greenhouse gasses to the atmosphere

Less dependency on fossil fuels – renewable form of energy.

No damage to land - It is a safe, clean, and consistent method to produce energy from the ocean

Reliable energy source- Waves are hardly interrupted and almost always in motion.

Enormous energy potential - ocean provides a lot of potential for energy production because it is constantly moving and generating energy.



Environmental effect - can cause damage to marine life and the surrounding ecosystems

Highly expensive - Wave power is an energy technology in the early stages of development, making speculating on prices difficult

Scalability issues - Not yet large enough to produce a considerable amount of electricity

High maintenance costs - estimated to be very expensive because they will be submerged in constantly moving saltwater

Low performance in unfavorable weather & noise/visual pollution

“An increased push for energy efficiency, renewable energy technology, electric mobility - along with the growing digitalization movement and a universal carbon pricing structure - would speed up the carbon-free future and the rise of a global middle class we desperately need. We can and must all do our part.”

Joe Kaeser

Content Credits:

I'd like to acknowledge the following sources, as the information contained in this slide were taken from the open-source media.

- Journals
- Books
- book chapters
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Thank You

The End

Any Question?

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Sustainable Engineering Design:
Renewable Energy Technology

By,
Assoc. Prof. Dr Sumaiya Zainal Abidin
Universiti Malaysia Pahang

Part 3:

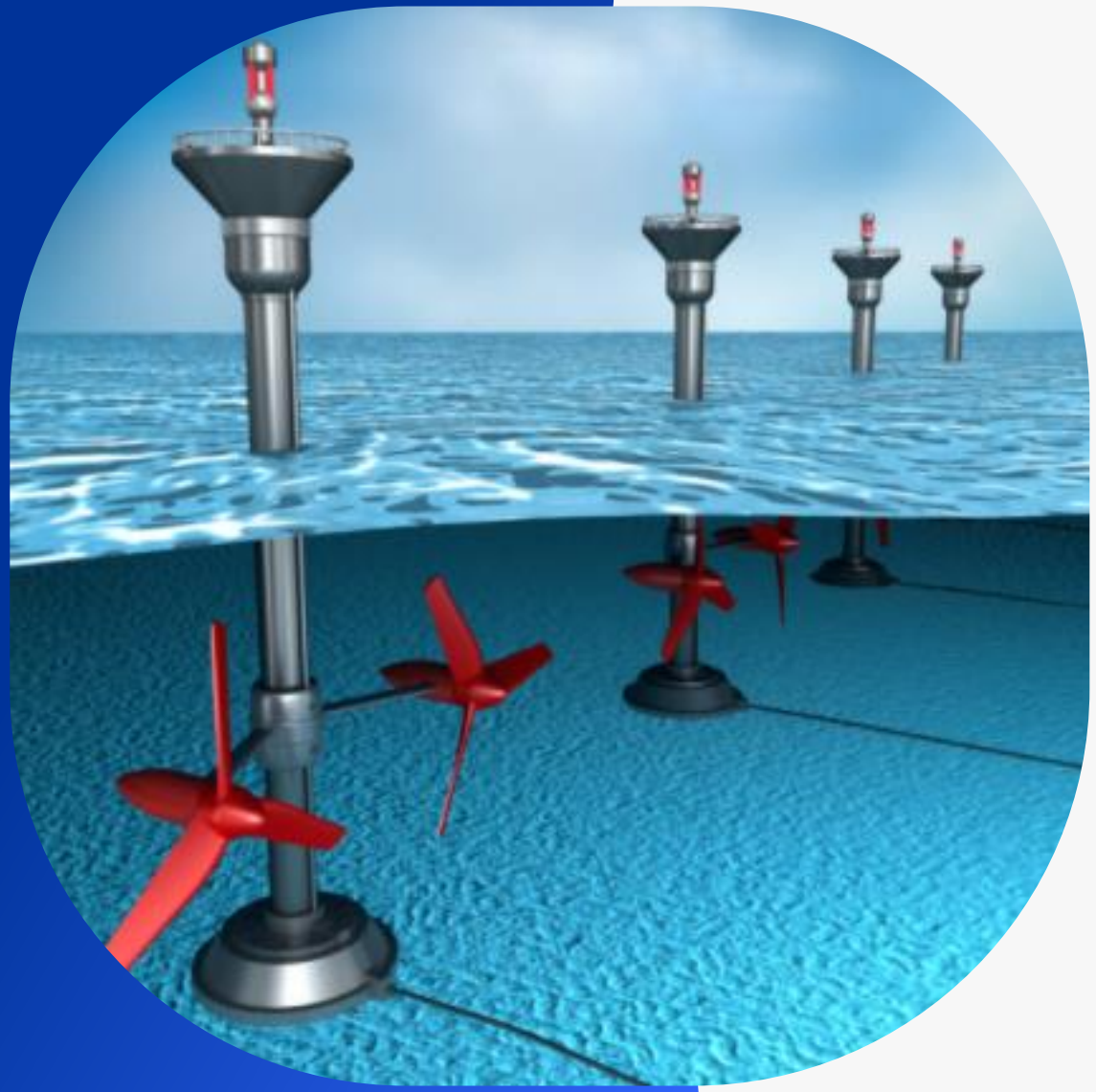
Application of Renewable Energy Technology

Content of Lecture

- Ocean – Tidal Energy
- Geothermal Energy
- Biomass Energy

Ocean Energy

Tidal Energy



FACT 1

Tidal energy is power produced by the surge of ocean waters during the rise and fall of tides.

FACT 2

Tidal energy converts the energy obtained from tidal movement into electric power using tidal generators

FACT 3

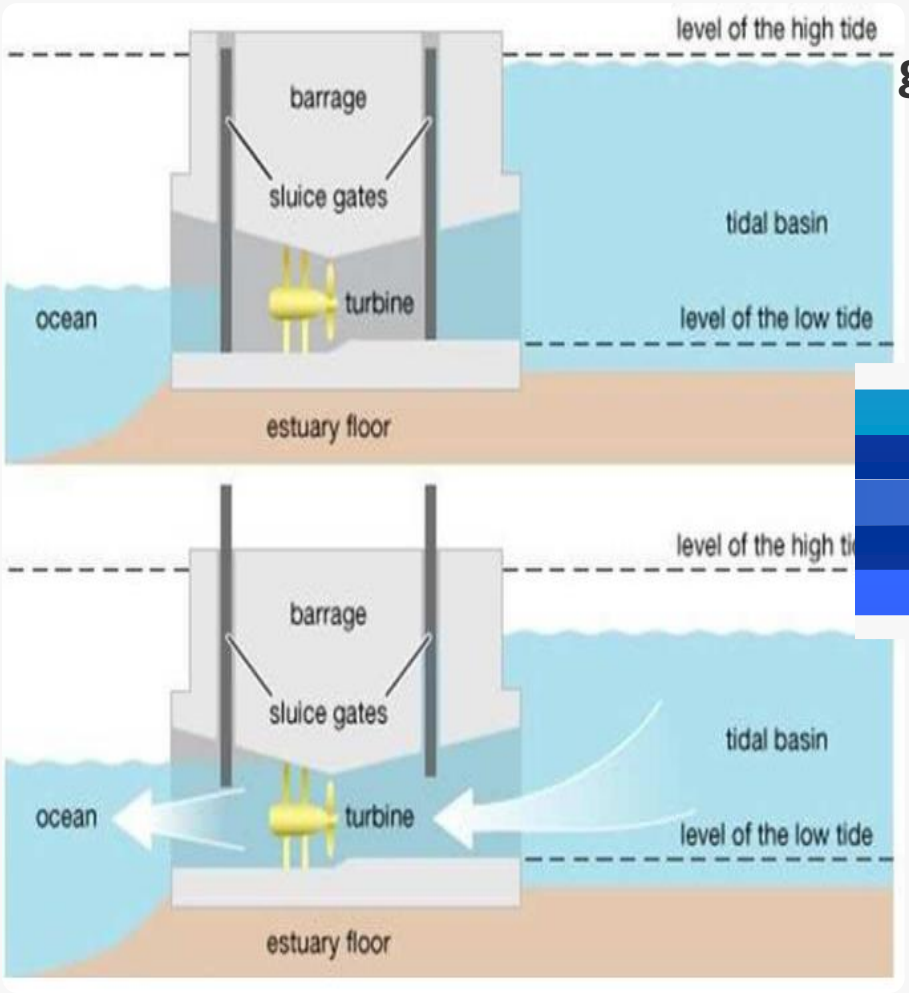
Tidal can be harnessed in three different ways; tidal streams, barrages, and lagoons.

Tidal Energy

Types of Tidal Plant Facilities

- Tidal Barrage
- Tidal Current Turbine
- Tidal Lagoon

Types of Tidal Plant Facilities: Tidal Barrage



the simplest generation system for tidal plants

dam-like structure with turbines placed at the bottom of the reservoir

Gates are used, opening and closing regularly to control the flow of water

pumping may be performed, using electricity from the grid, to further raise the water levels in the basin

difference between the sea and the basin water levels (head of water) resulting in power

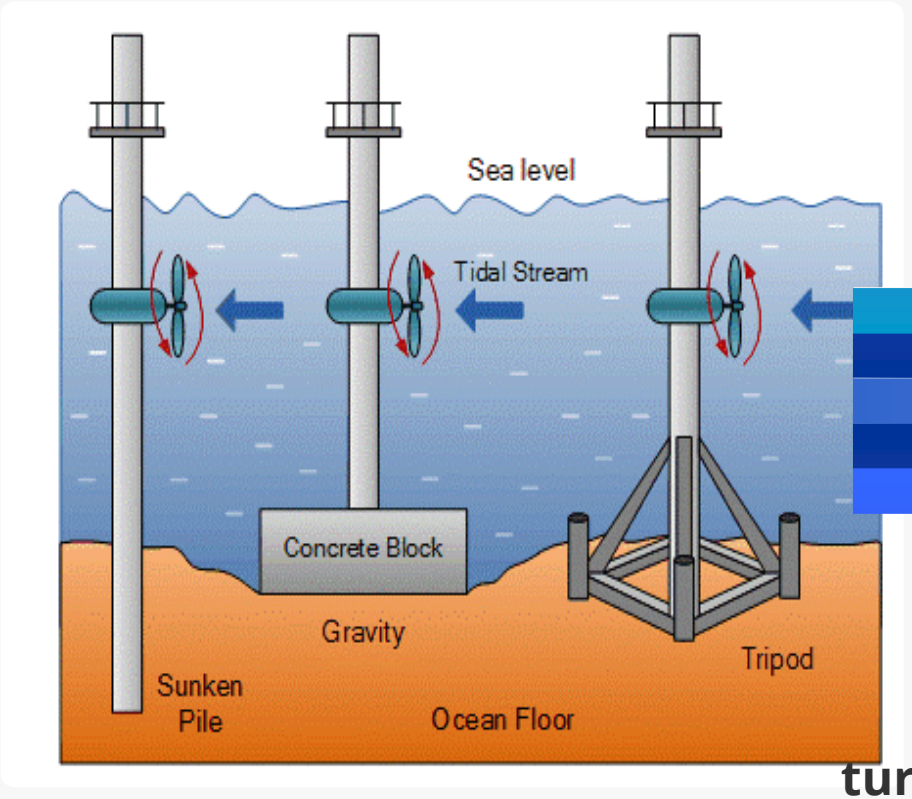
Current Sites of Tidal Barrages

La Rance, Brittany, France

- The first and largest tidal barrage power plant
- Constructed between 1961 and 1967.
- Situated on the Rance River.
- Contains 24 reversible 10 MW bulb turbines generating a capacity of 240 MW and a net power output of 480 GWh per year.

Types of Tidal Plant Facilities: Tidal Current Turbine

Tidal turbines are similar to wind turbines in that they have blades that turn a rotor to power a generator.



can be placed on the sea floor where there is strong tidal flow

tidal turbines have to be much sturdier and heavier than wind turbines because water is about 800 times denser than air

The spinning turbine is connected to another device that produces electricity.

initial cost of setting up this tidal stream system is quite high

Current Sites of Tidal Current Turbine

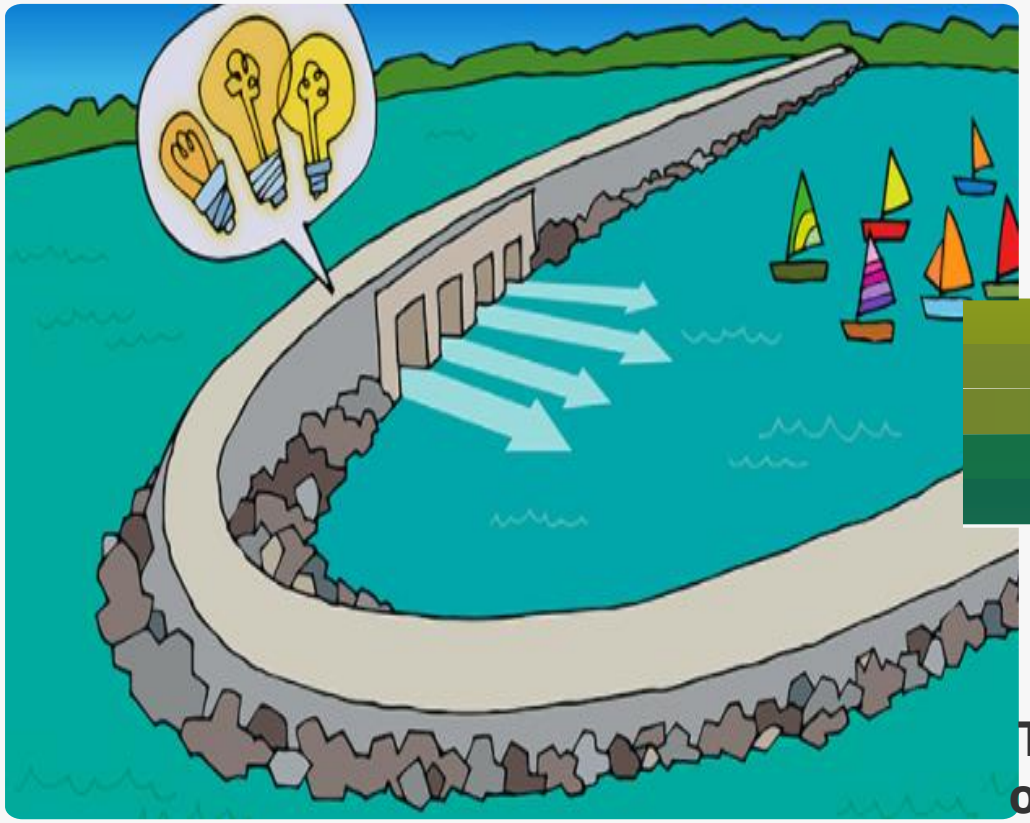
MeyGen Tidal Energy Project, Scotland

- Located in the Inner Sound of the Pentland Firth off the north coast of Caithness, Scotland
- Total installed capacity is 398MW by 2020

- Constructed between 1981 and 1984.
- Generating capacity of 20 MW and a net output of 30 GWh per year

Annapolis Tidal Generation Facility, Bay of Fundy, Canada

Types of Tidal Plant Facilities: Tidal Lagoon



has a lot in common with tidal barrages

doesn't involve a lot of initial capital outlay, and it's friendly to the environment

functionality is similar to tidal barrage since when the tide goes up, the lagoon completely fills up

When the tide subsides, the water is allowed to drain out through an opening consisting of turbines

The outward flow of water turns the turbine, which generates energy.

Current Site of Tidal Lagoon

- to be built at Swansea Bay in the UK,
- comprise 16 hydro turbines, a 9.5km breakwater wall, generating electricity for 155,000 homes for the next 120 years
- Swansea Bay Tidal Lagoon is already world-famous – the project has been presented to audiences across the globe

Technology Case Study: Sihwa Lake Tidal Power Station

Fact 1

The 552.7 GWh of electricity generated from Sihwa tidal power plant is equivalent to 862,000 barrels of oil, or 315,000 tons of CO2 – the amount produced by 100,000 cars produce annually.

Fact 2

remarkable impact on water quality and ecosystems - continuous circulation of water between the lake and the outer sea during the power generation process has improved the water quality

Fact 3

Sihwa embankment, 12.7 km in length, is also a popular spot for leisure activities and sports.

Tidal Energy: The Pros and Cons

- Predictable energy output
- Getting more cheaper and efficient
- Protects coastal flooding
- Equipment and facilities can last longer and more cost-competitive

- currently expensive to construct tidal power plants - high capital investments
- Environmental issues - habitat change, particularly with tidal barrages.
- Limited energy demand.
- the energy produced by the tides is often a long distance from where the electricity will be used inland

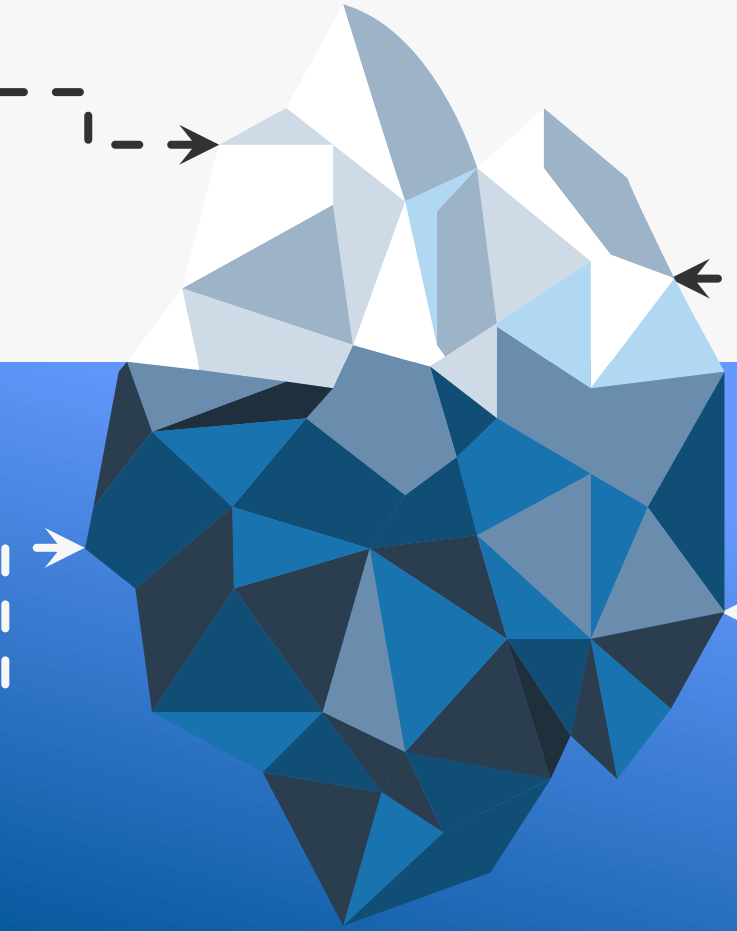
Challenges Faced by Tidal Energy

Lack of research

Effects of tidal barrages and turbines on the marine environment have not been fully explored

High construction costs

Tidal power holds one of the heaviest up-front price tags.



The impact of EMF emissions

Electro-magnetic emissions might also disrupt the sensitive marine life.

Technology challenging

Manufacturers are competing against the moving ocean, and the equipment and technical knowledge needed to successfully construct the system

Geothermal Energy

Where does geothermal energy comes from?

- Geothermal energy is the heat that comes from the sub-surface of the earth.
- contained in the rocks and fluids beneath the earth’s crust and can be found as far down to the earth’s hot molten rock, magma.
- wells are dug a mile deep into underground reservoirs to access the steam and hot water there - used to drive turbines connected to electricity generators.

How and Where to Install a Geothermal System?

GEOLOGY

Composition and properties of soil and rock can affect heat transfer rates and therefore need to be taken into consideration for designing geothermal systems.

HYDROLOGY

Ground and surface water influence the type of ground loop, as well as groundwater can be used as a source for open-loop system, if the water quality is sufficient.

LAND AVAILABILITY

The size and layout of the land, landscaping, location of sprinkler systems, etc., determine the design of the geothermal system as well.

Ways to Capture Geothermal Energy

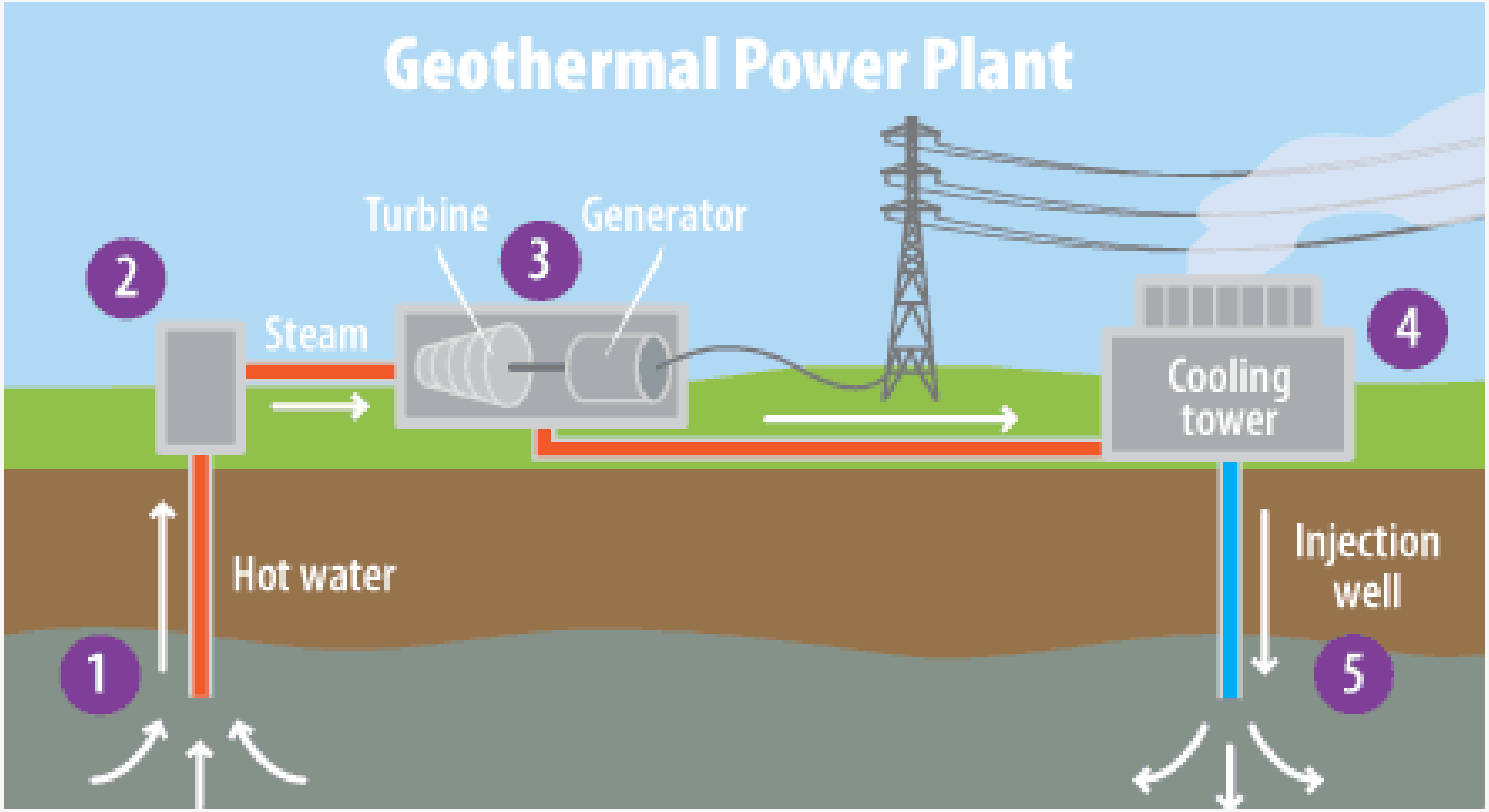
Geothermal power plants

Geothermal heat pumps

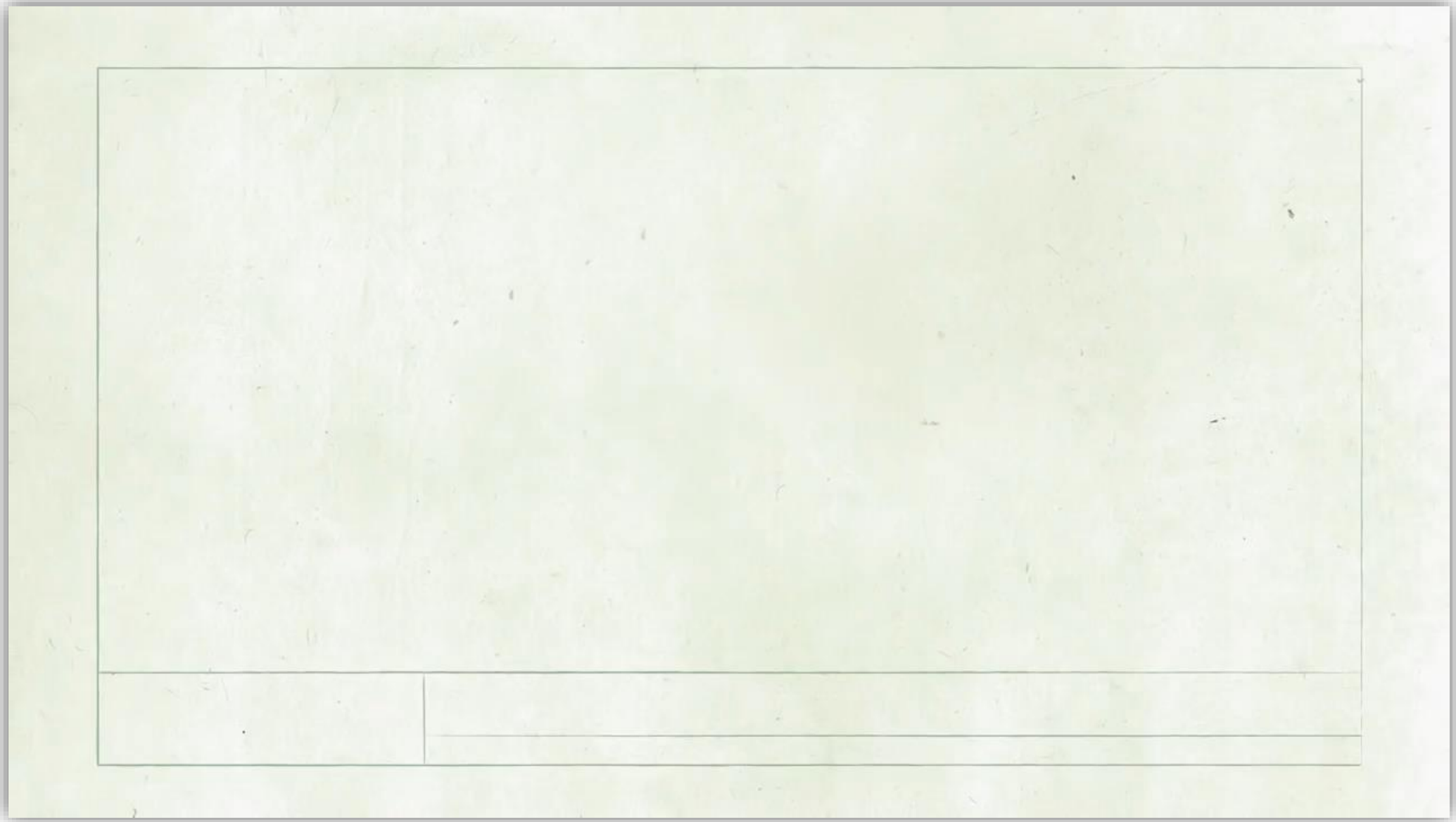
Geothermal power plant - which use heat from deep inside the Earth to generate steam to make electricity.

Geothermal heat pumps - which tap into heat close to the Earth's surface to heat water or provide heat for buildings

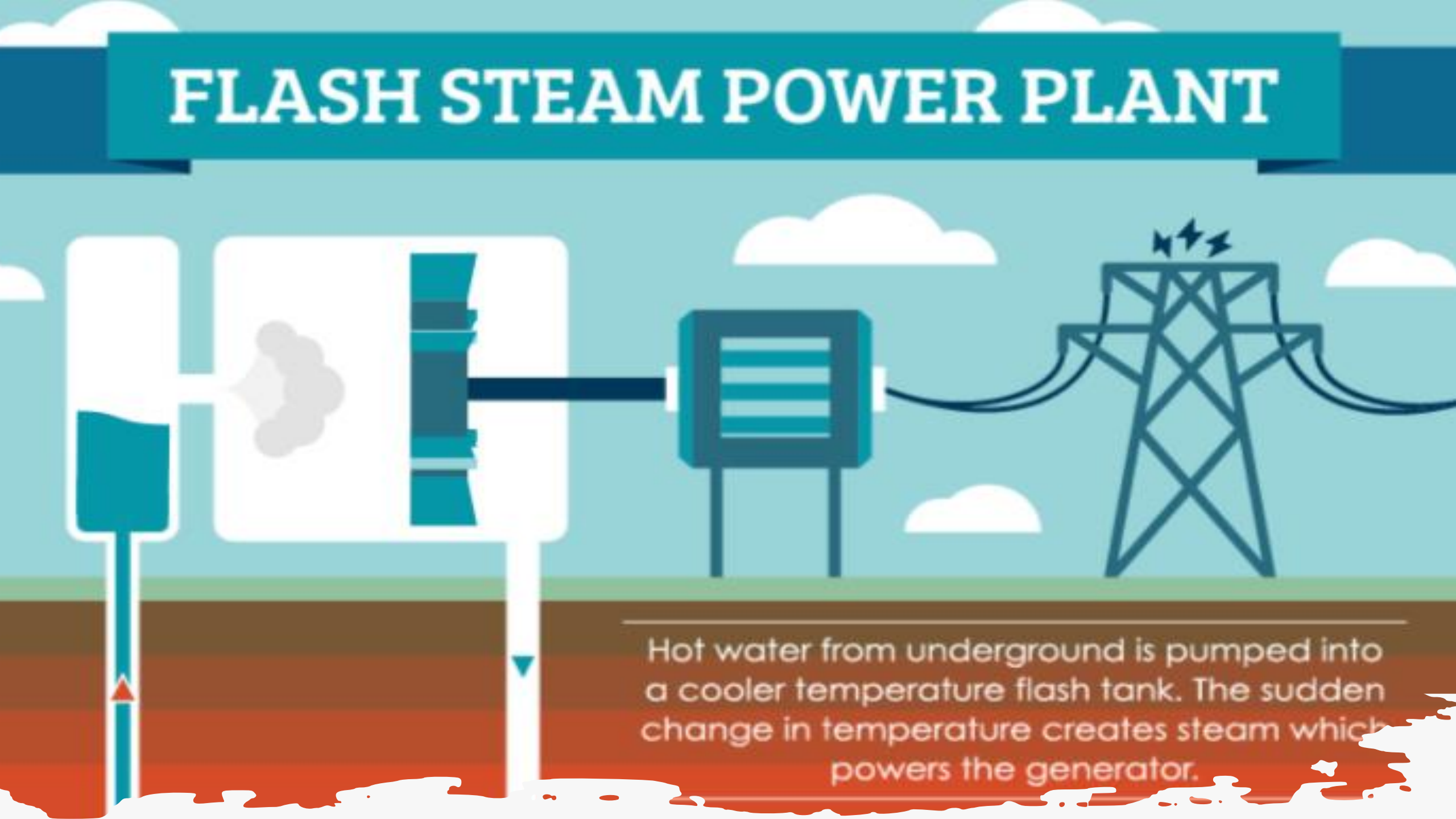
Geothermal Power Plant



Geothermal Power Plant

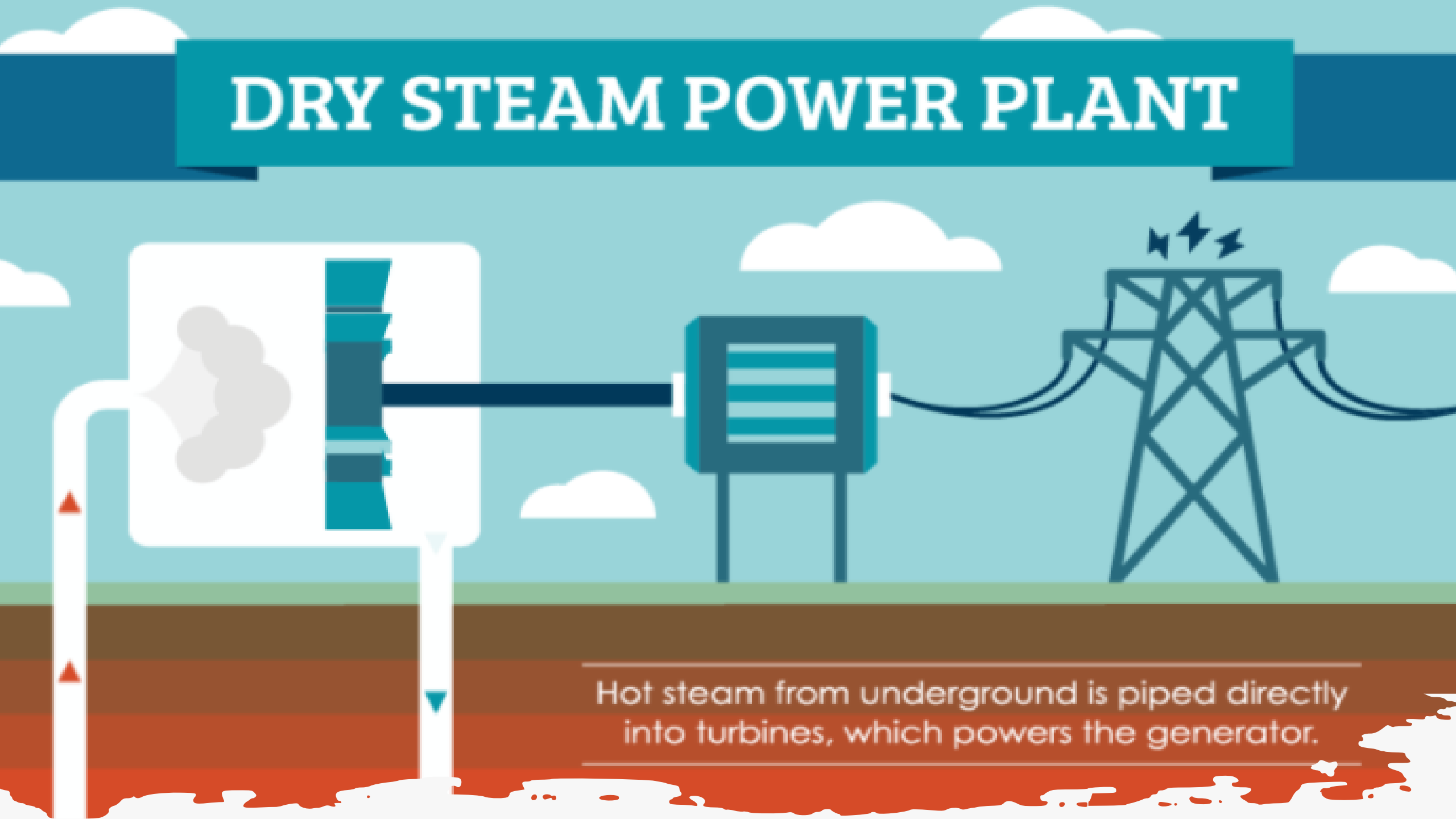


FLASH STEAM POWER PLANT



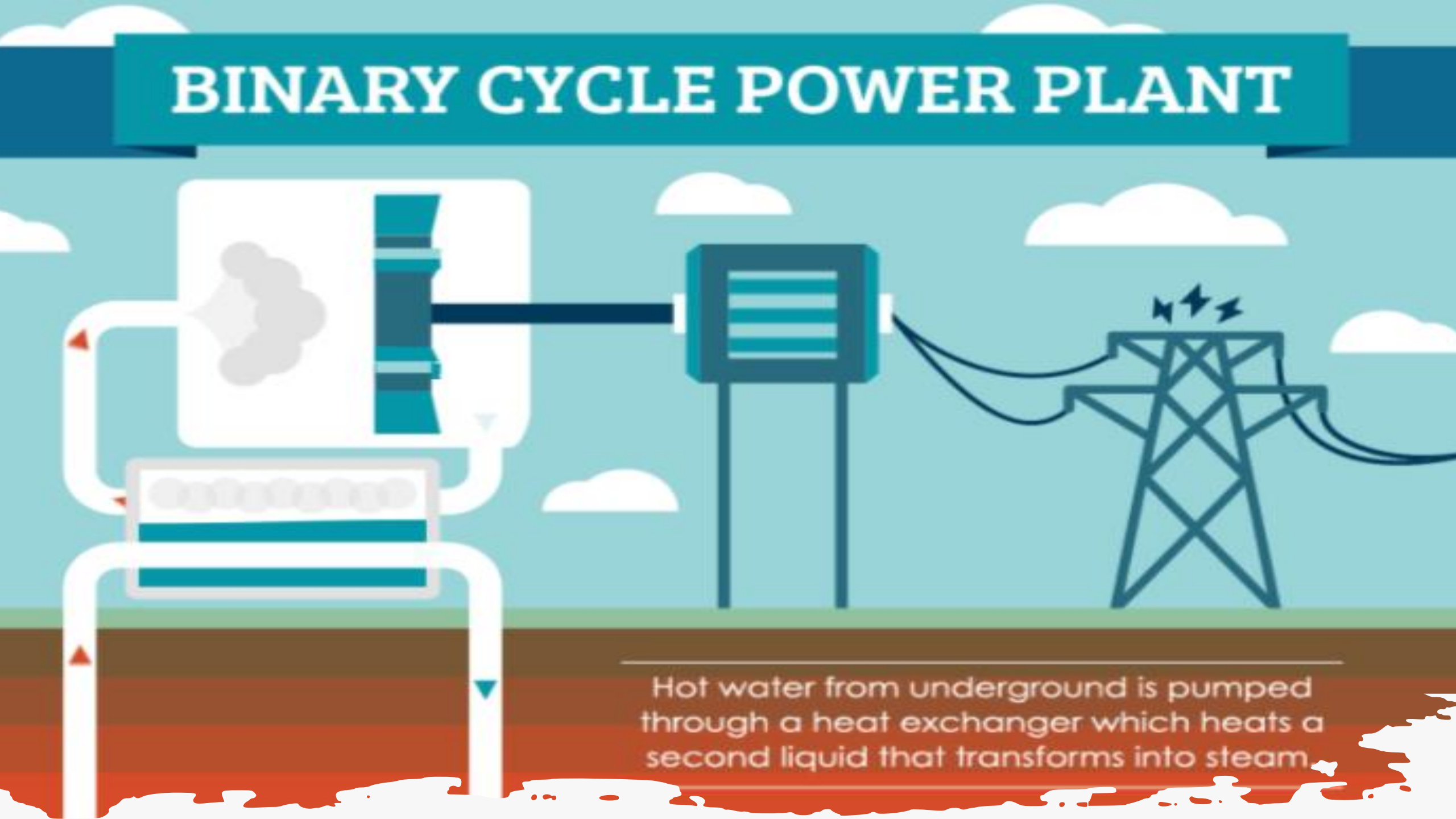
Hot water from underground is pumped into a cooler temperature flash tank. The sudden change in temperature creates steam which powers the generator.

DRY STEAM POWER PLANT



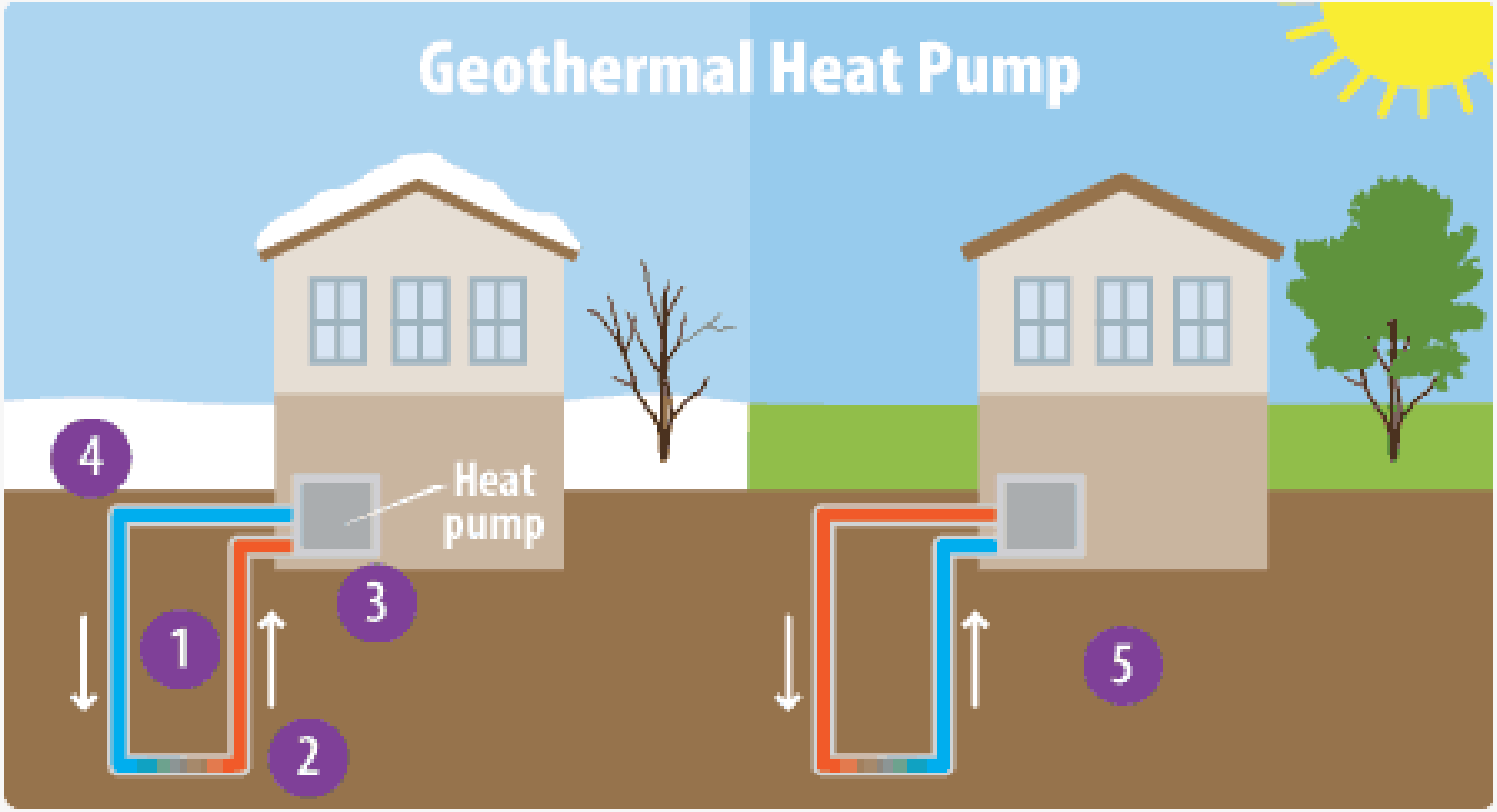
Hot steam from underground is piped directly into turbines, which powers the generator.

BINARY CYCLE POWER PLANT

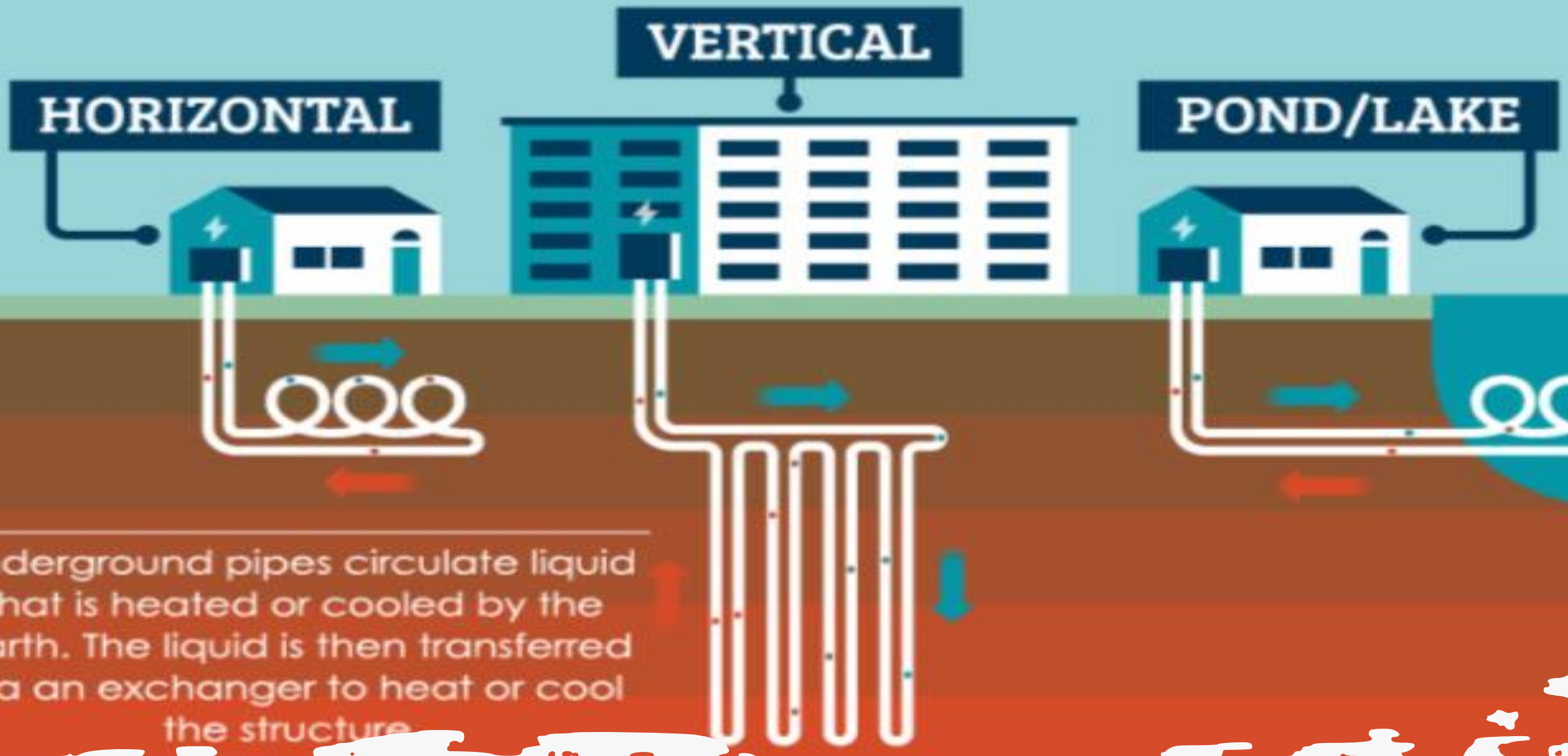


Hot water from underground is pumped through a heat exchanger which heats a second liquid that transforms into steam

Geothermal Heat Pump



CLOSED LOOP SYSTEMS



Closed Loop System—The Leading Geothermal Heating Solution

The system doesn't require a direct connection to a groundwater source but takes advantage of energy released from the sun, and exchanges heat with the ground itself.

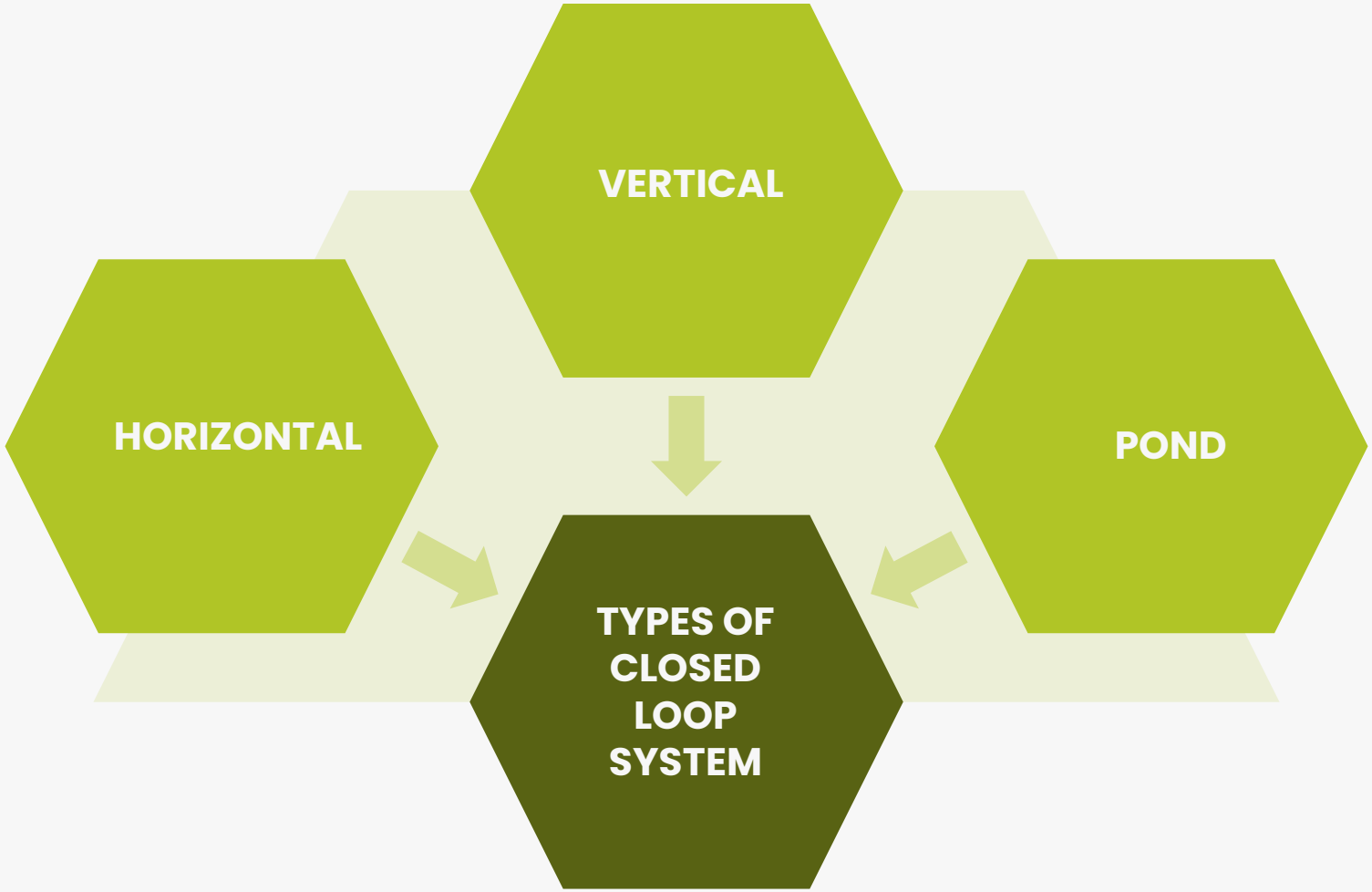
Underground temperatures remain stable all year around, the closed loop system is highly energy-efficient.

Ground source heat pumps (GSHP) can effectively help you to save on heating bills, provide your house with equal distribution of heat, reduce your reliance on fossil fuels

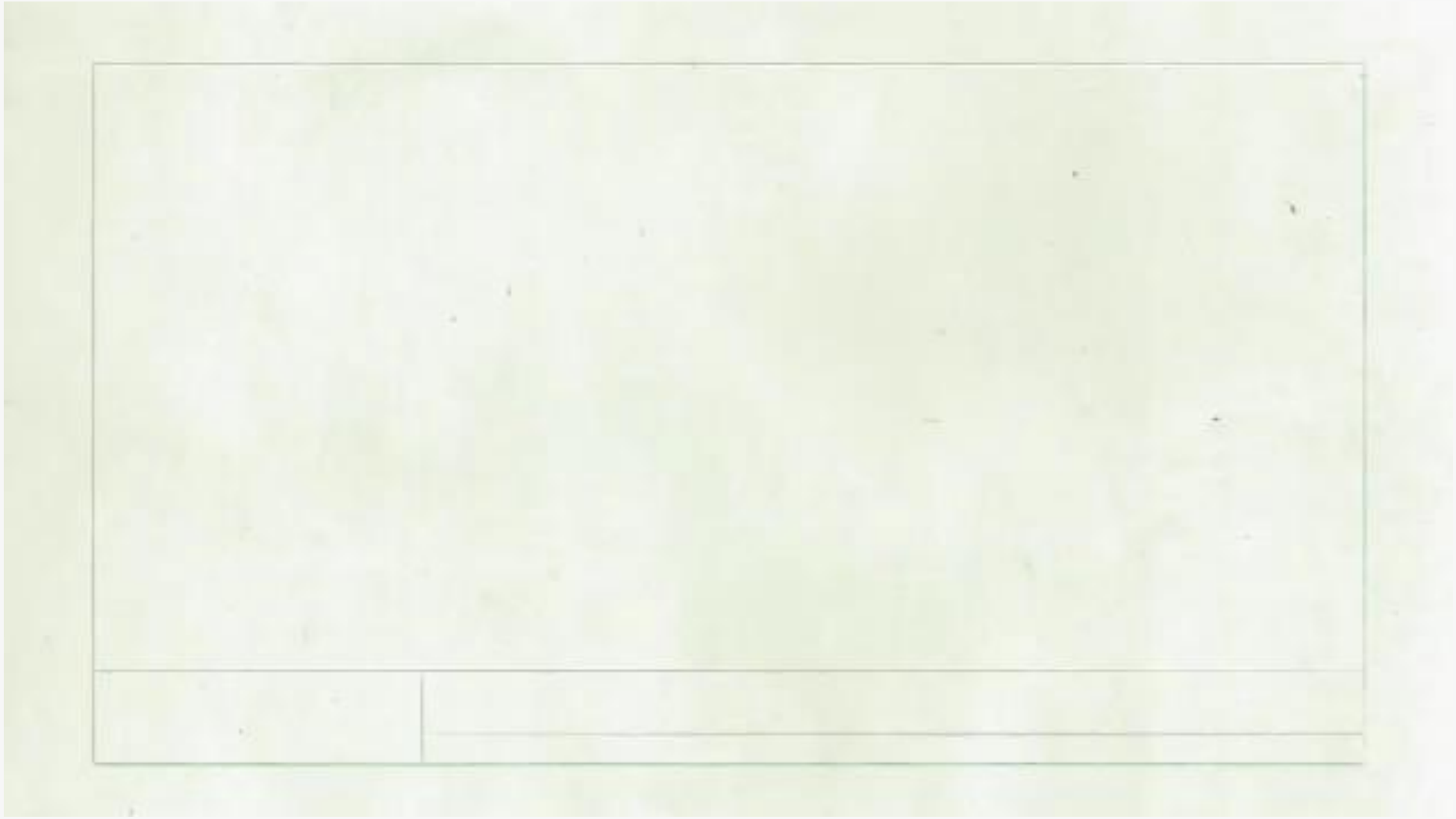
Indoor components last up to 25 years and ground loops life is estimated at 50-100 years, requiring little maintenance.

The performance of a ground source heat pump depends on a number of factors like land availability, location, budget, as well as your own preference

Types of Closed Loop System

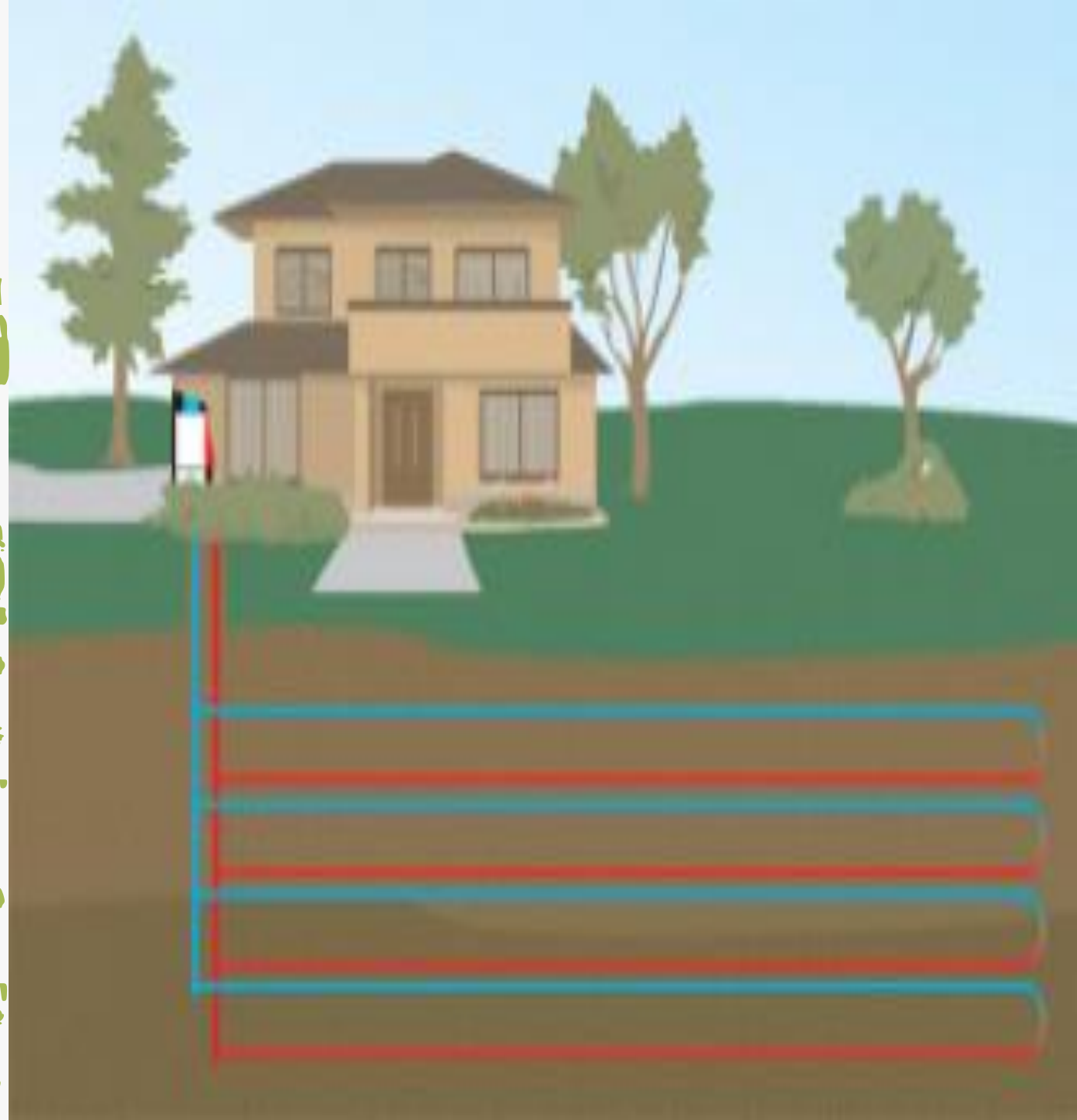


Geothermal Heat Pump



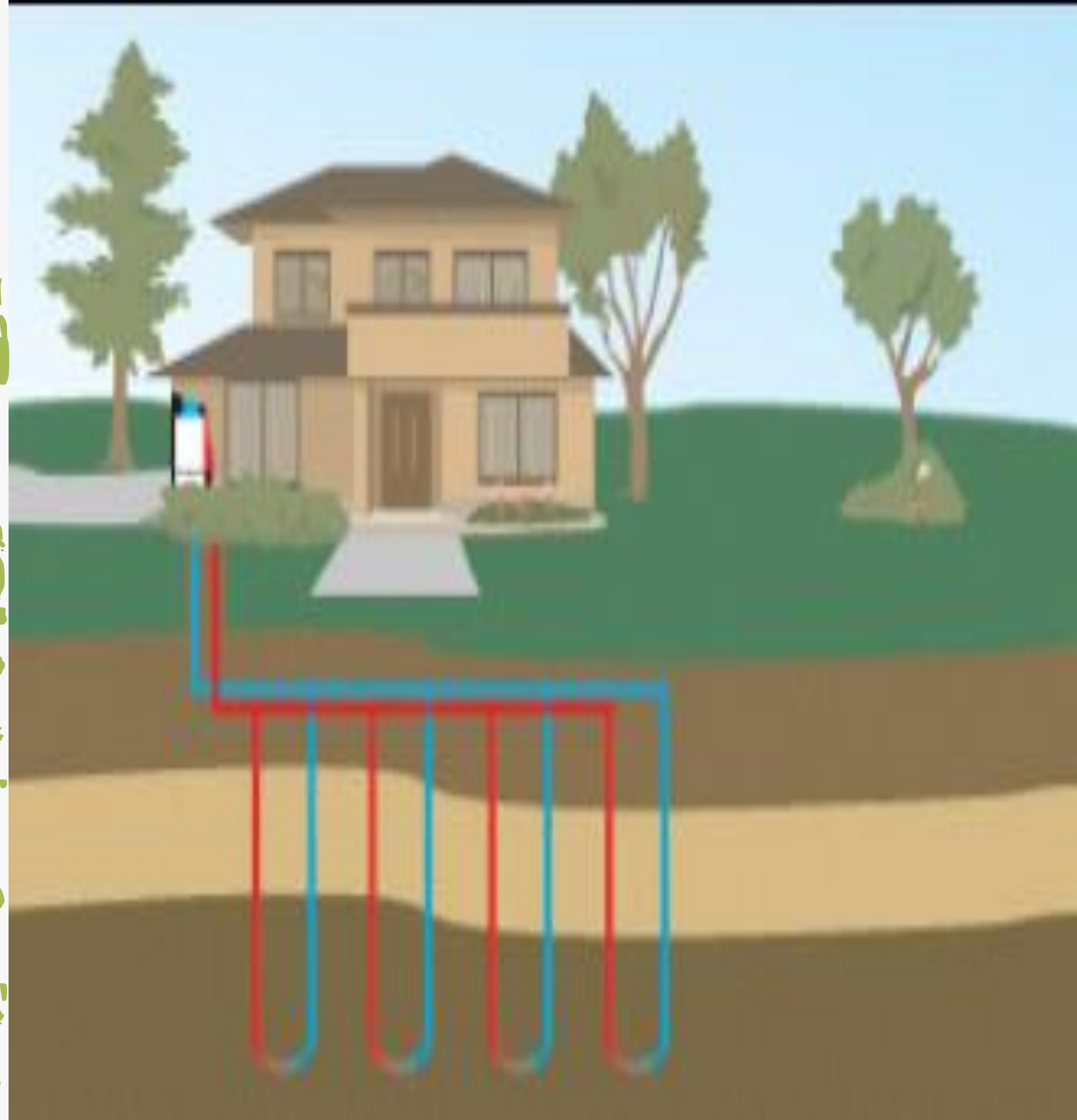
Closed Loop System Horizontal

- This type of installation is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available.
- An excavator will dig several trenches about six feet deep in the ground, each one up to 300 feet long.
- The geothermal pipe is placed in the trenches which are then backfilled with soil.



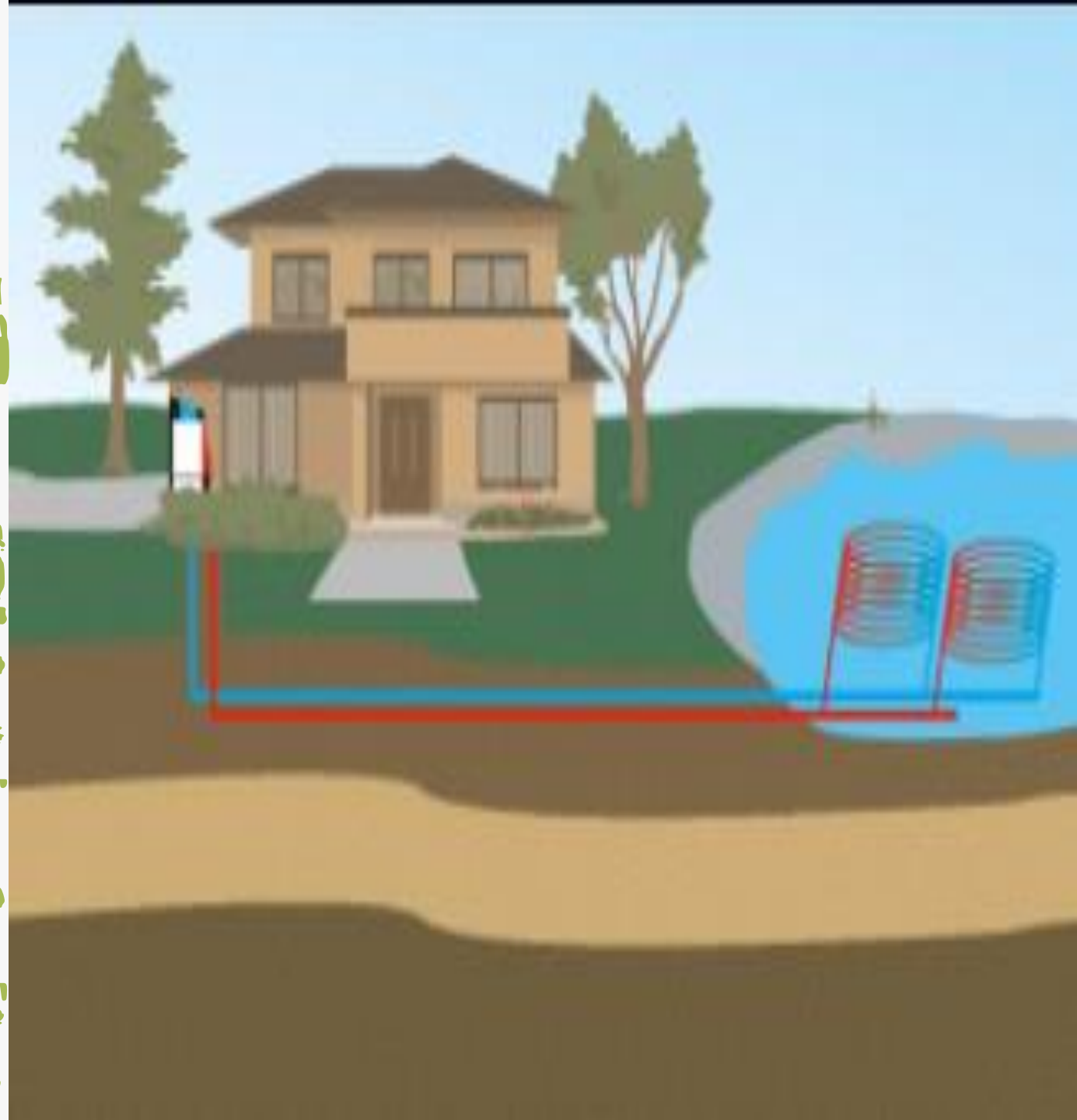
Closed Loop System Vertical

- Vertical loops are primarily used in areas with a limited land surface area (urban areas)
- A specially designed geothermal drilling rig bores vertical holes into the ground each ranging from 180 to 540 feet deep.
- Our green geothermal pipe is inserted into each vertical bore and then the holes are filled with bentonite grout.

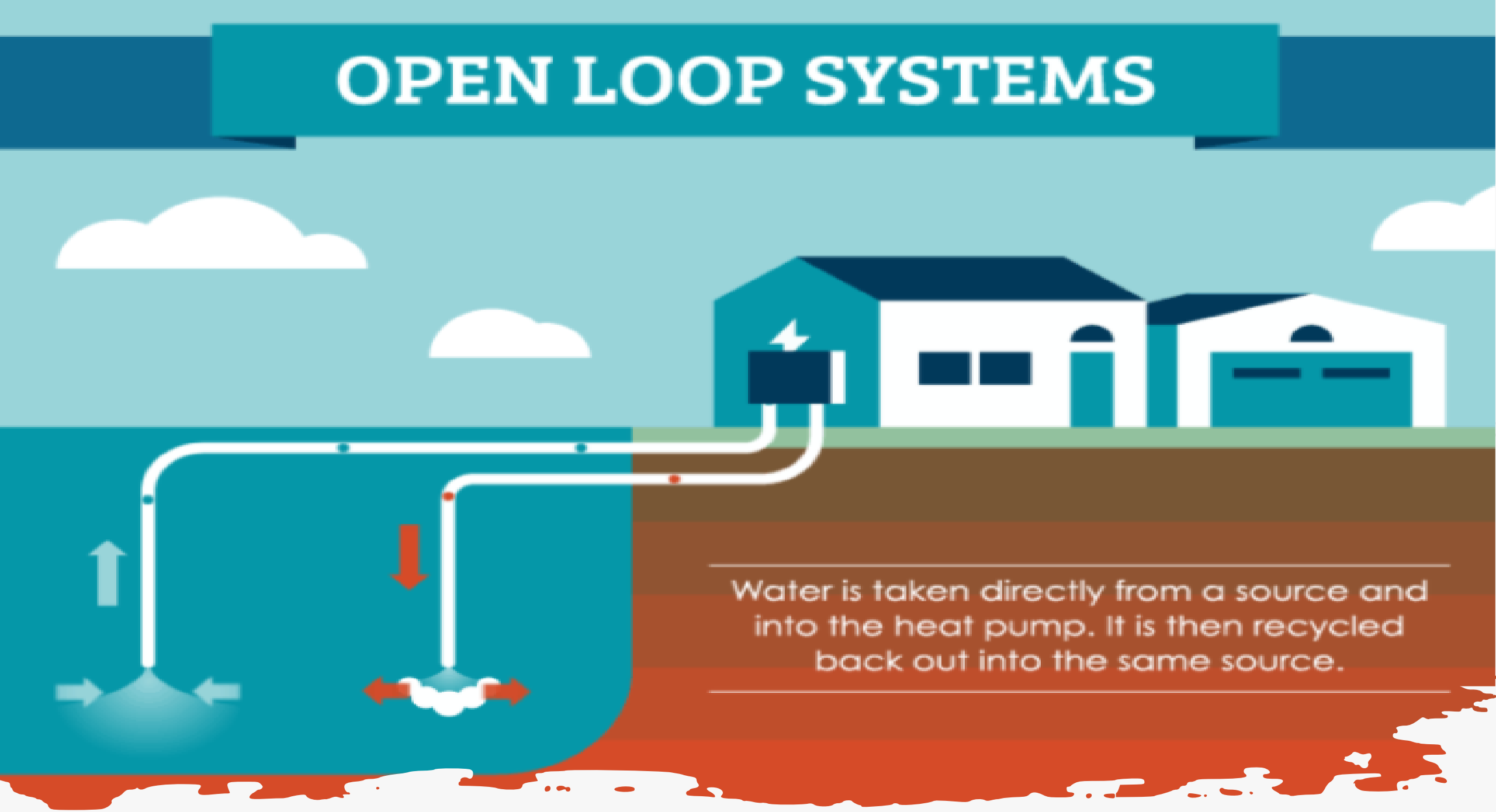


Closed Loop System Pond

- If the site has an adequate body of water, this may be the lowest cost option
- A supply line pipe is run underground from the building to the water and coiled into circles at least eight feet under the surface to prevent freezing
- The coils should only be placed in a water source that meets minimum volume, depth, and quality requirements.



OPEN LOOP SYSTEMS



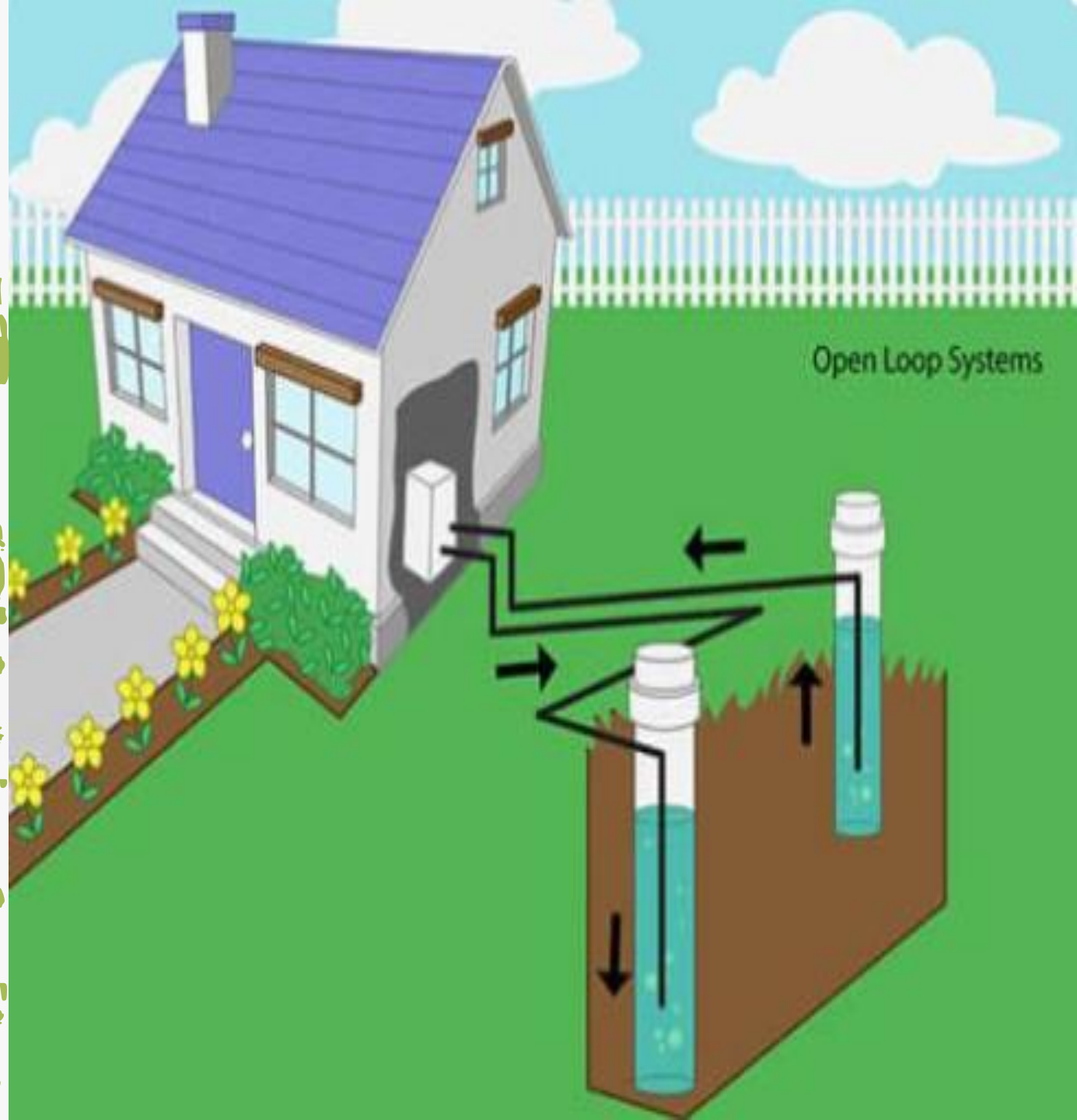
Water is taken directly from a source and into the heat pump. It is then recycled back out into the same source.

Open Loop System

Open loop geothermal systems use groundwater, which acts as a refrigerant to transfer thermodynamic energy

Open loop geothermal systems can be designed to use water from a well as a source and sink, a pond or lake as a source and sink, or a well as the source and a pond or lake as the sink.

Every installation is different and various factors of each system determine cost, space needed, and efficiency of the system.



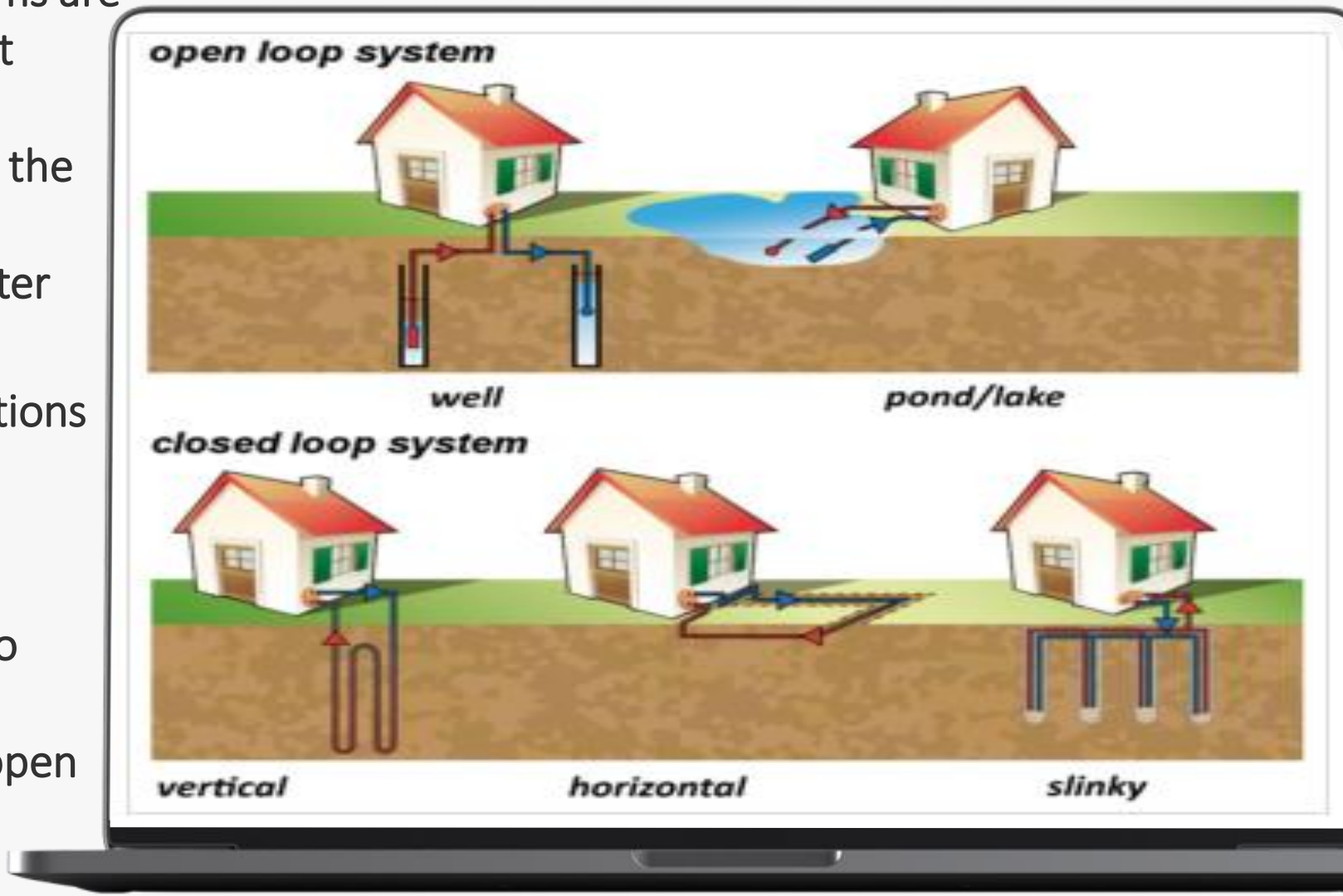
Closed Loop VS Open Loop - Which to Choose?

open loop geothermal systems are less costly and more efficient because

- constant temperature of the ground water
- Good conductivity of water

However, open loop applications are not feasible because

- no groundwater source available
- groundwater contains too much iron
- local code may prohibit open loop systems.



Advantages of Geothermal Energy

- Geothermal Energy Sourcing Is Good for the Environment
- Geothermal Is a Reliable Source of Renewable Energy
- High Efficiency of Geothermal Systems
- Little to No Geothermal System Maintenance

Disadvantages of Geothermal Energy

- Environmental Concerns about Greenhouse Emissions
- Possibility of Depletion of Geothermal Sources
- High Investment Costs for Geothermal System
- Land Requirements for Geothermal System to Be Installed

Challenges in Geothermal Energy

The Resource and Location

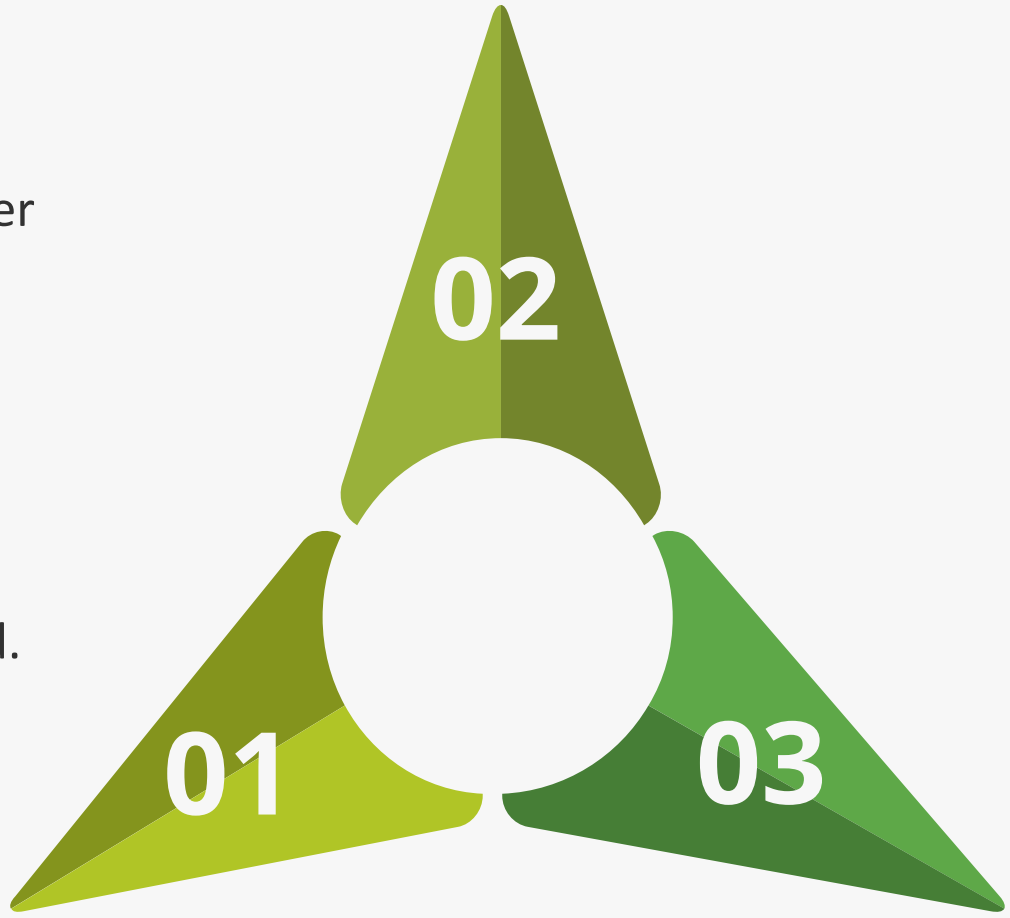
only a small percentage of land that lies above suitable pockets of water and steam that can heat homes or power electrical plants, limiting the possibility of installation of geothermal power plants

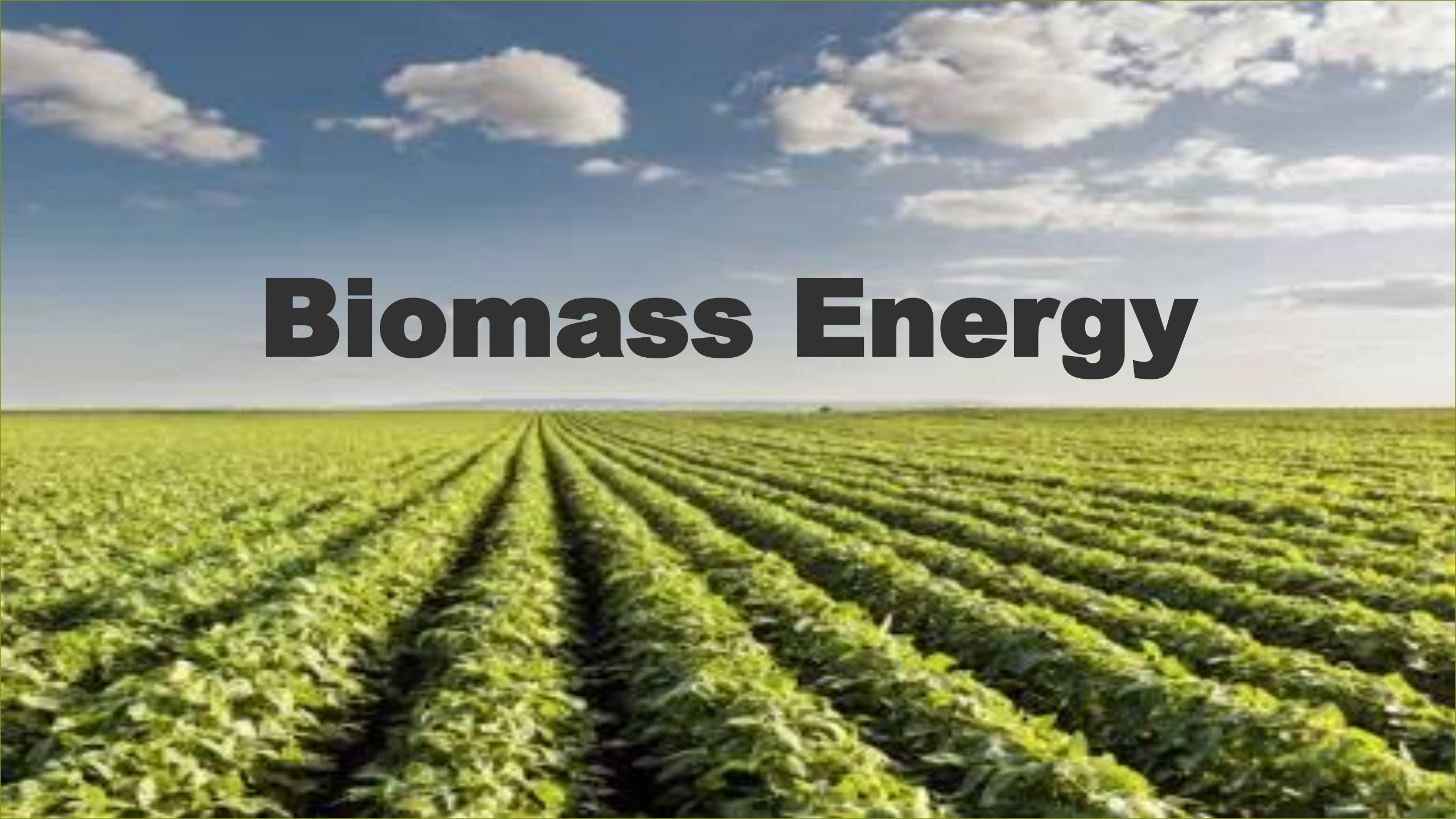
Infrastructure

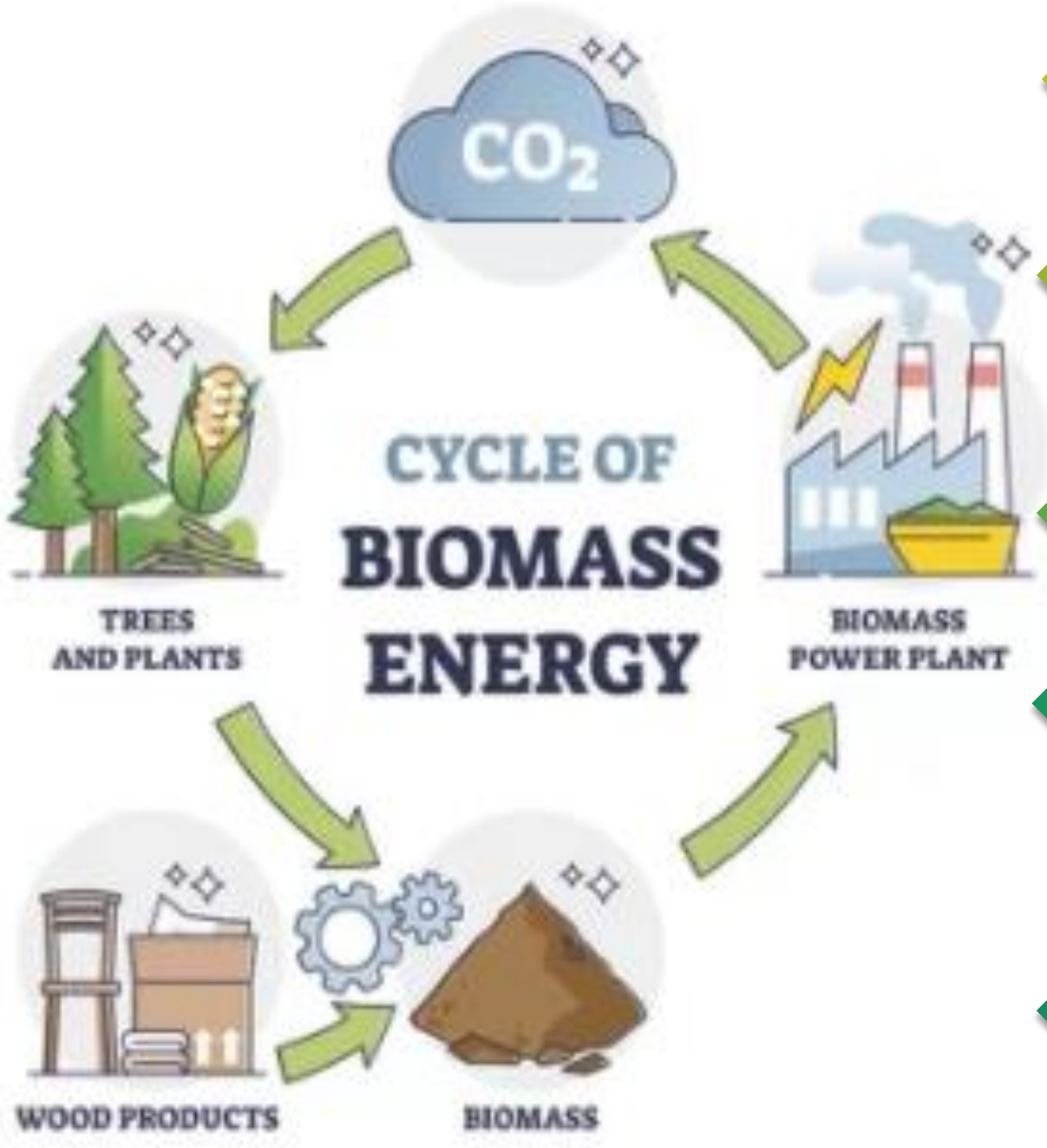
Equipment for drilling wells and setting up power plants is extraordinarily expensive and training people to staff a geothermal power plant is time consuming and costly. There is also the restriction of where the geothermal energy can be used.

Renewable Does Not Mean Unlimited

If the pressure gradient is not adequately reestablished, not only the energy source to decline, but there is also the possibility of greater geological impacts like the creation of sink holes.




Biomass Energy



1

Biomass
material derived from plants and animal material

2

Biomass Energy
type of renewable energy generated from biological (such as, anaerobic digestion) or thermal conversion (for example, combustion) of biomass resources.

3

Biomass feedstock
common biomass materials used for energy are plants, wood, and waste

4

Biomass conversion
four types of conversion technologies currently available that may result in specific energy and potential renewable products – thermal, thermochemical, biological and chemical conversion

5

Forms of biomass

Raw: forestry products, grasses, crops, animal manure, and aquatic products (seaweed)

Secondary: materials that undergone significant changes from raw biomass. Paper, cardboard, cotton, natural rubber products, and used cooking oils.

Biomass Resources

FORESTRY CROPS AND RESIDUES

MUNICIPAL SOLID WASTE

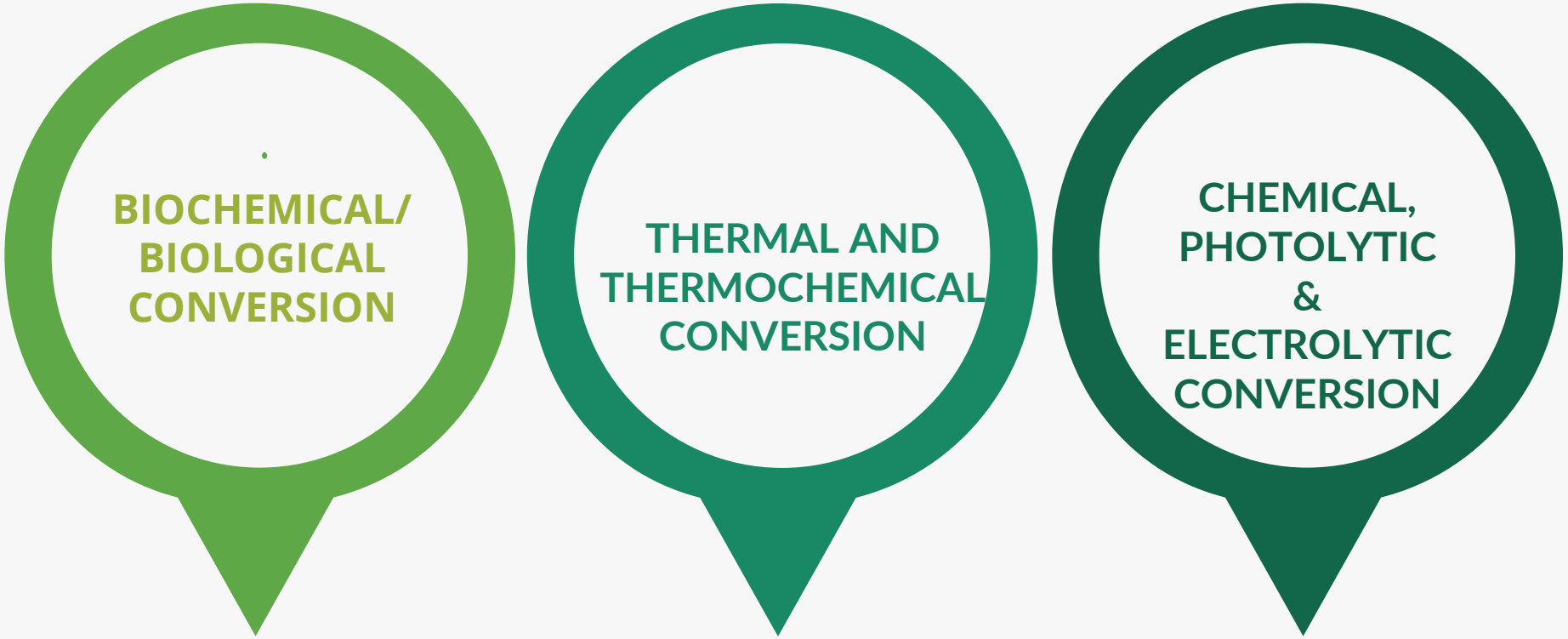
AGRICULTURAL CROPS AND RESIDUES

ANIMAL RESIDUES

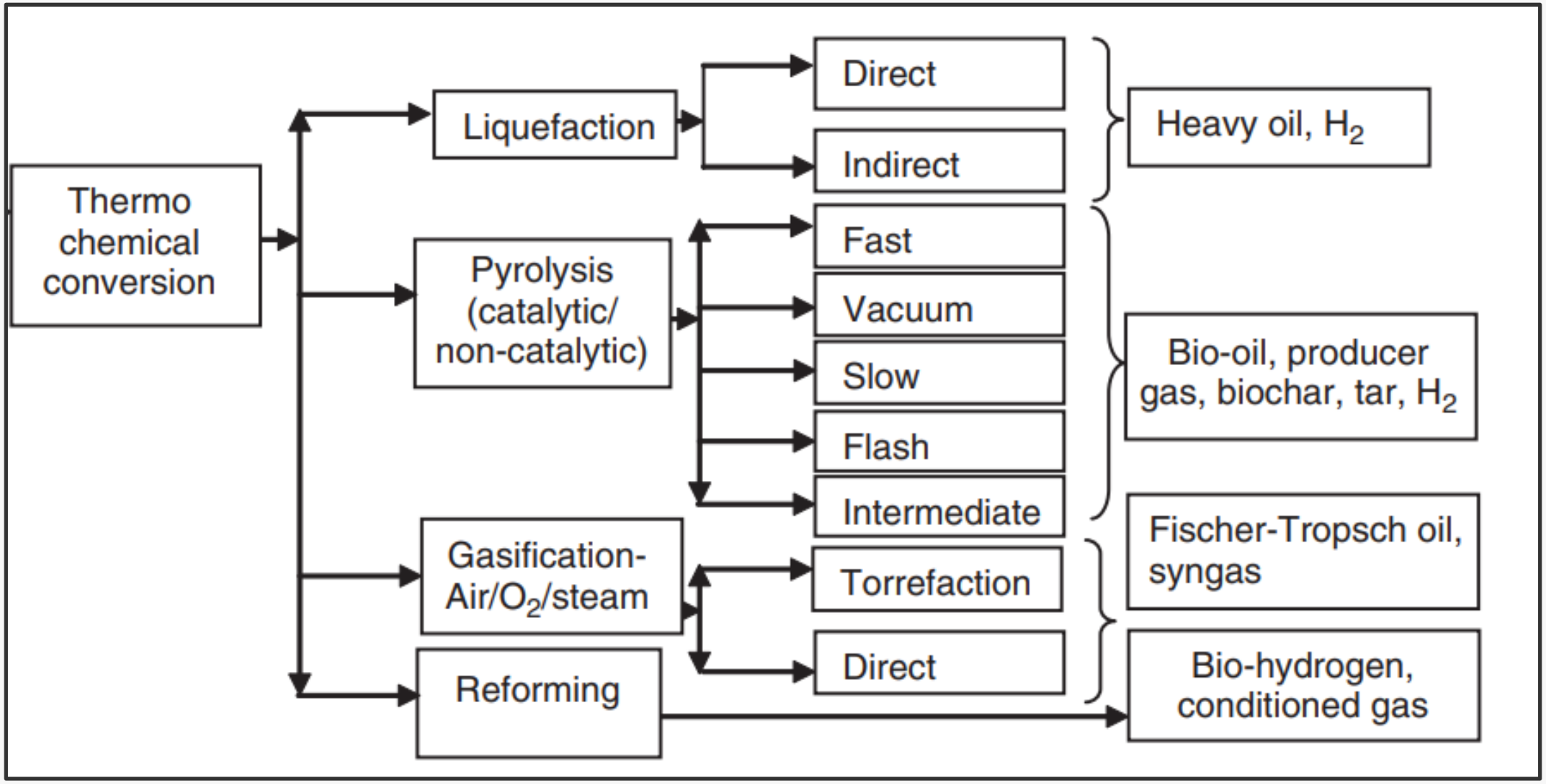
SEWAGE

INDUSTRIAL RESIDUES

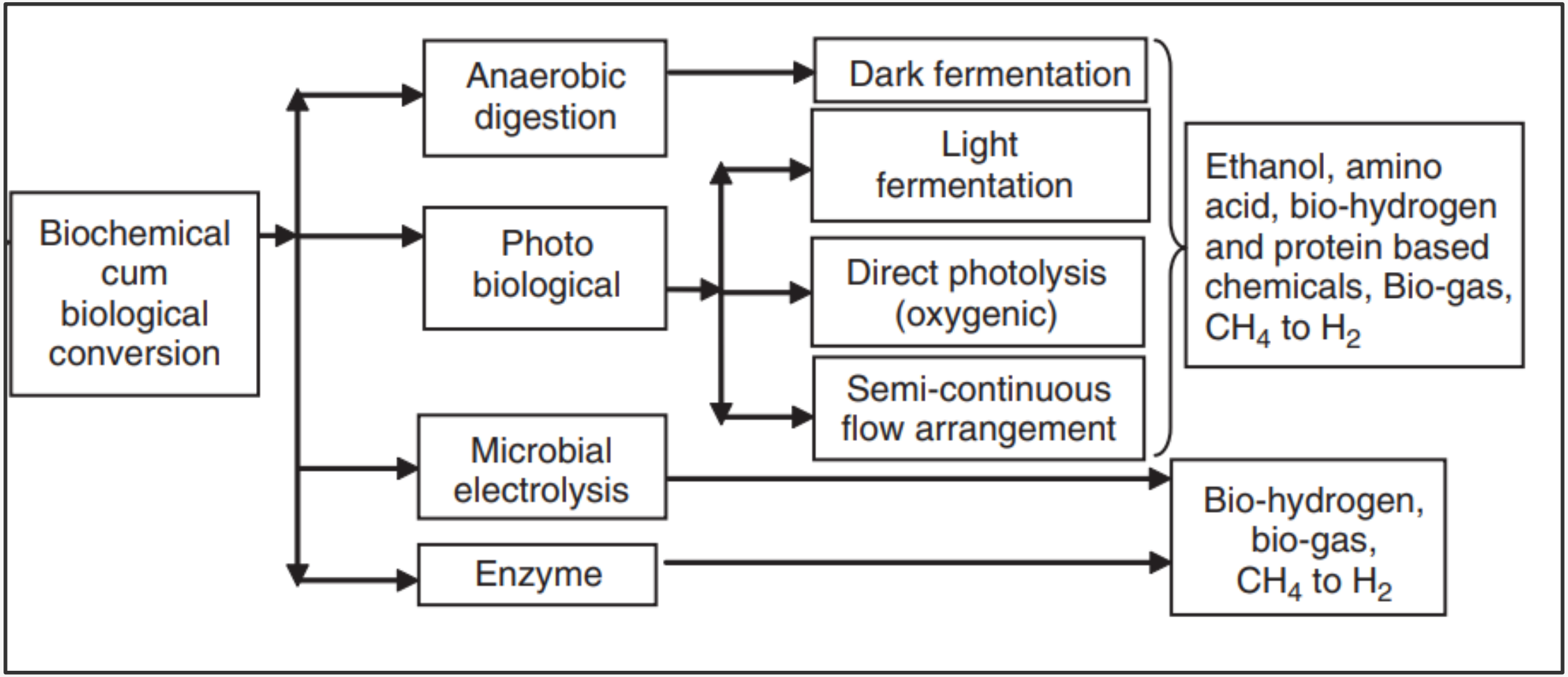
Biomass to Energy Conversion



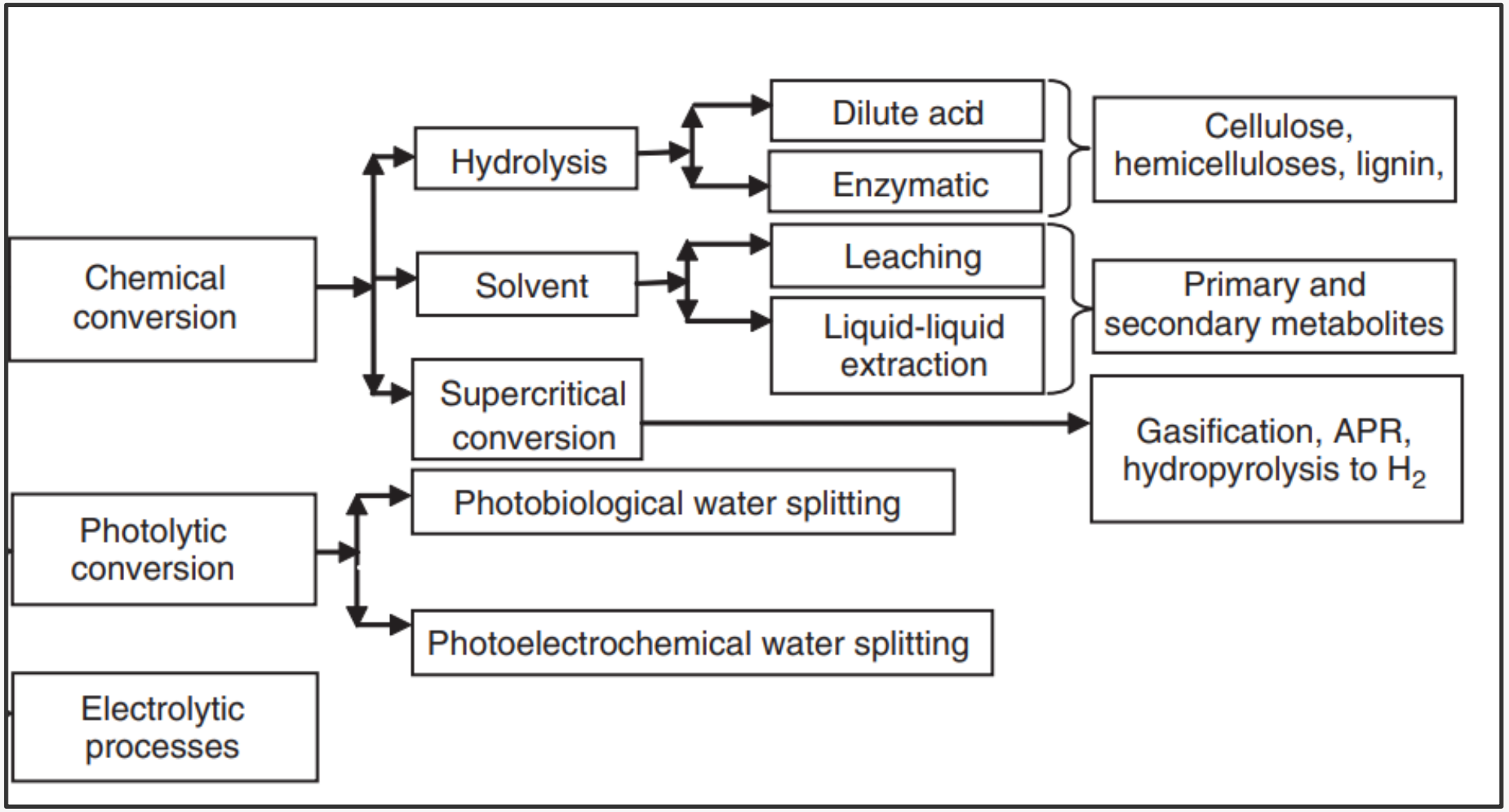
Thermochemical Conversion



Biochemical/Biological Conversion



Chemical, Photolytic & Electrolytic Conversions



Biomass Energy – Pro and Cons

Pro

- **Renewable Source of Energy**
  Renewable sources of energy are those who can get replenished even after usage
- **Cheap Raw Materials**
  No fancy machinery required, no special workforce needed for biomass manufacturing
- **Part of the Carbon Cycle**
  Carbon present in biomass is a part of the natural carbon cycle which means no excess carbon pollution
- **Wide Availability**
  widely available in every place in massive amounts
- **Helps reduce waste**
  waste to biomass energy helps reduce the size of landfills

Cons

- **Space requirements**
  Space may also be necessary to grow the organic matter and to develop the process plant.
- **Not as efficient as fossil fuels**
  Has to be fortified with fossil fuels to increase its efficiency.
- **Can lead to deforestation**
  vast amounts of wood and other waste products have to be burned to produce the desired amount of power
- **Not entirely clean**
  the use of animal and human waste escalates the amount of methane gases, which are also damaging to the environment
- **Production cost is expensive**
  Construction and operating costs of a biomass energy plant can be expensive

Thermochemical Conversion

Definition

the decomposition of organic matter of the biomass for the production of biofuels including liquid, gaseous, and solid fuels

Classification

Thermochemical conversion technologies are classified by their associated oxidation environment, particle size and heating rate.

Thermochemical Processes

Thermochemical process includes pyrolysis, gasification, combustion, reforming, torrefaction and liquefaction

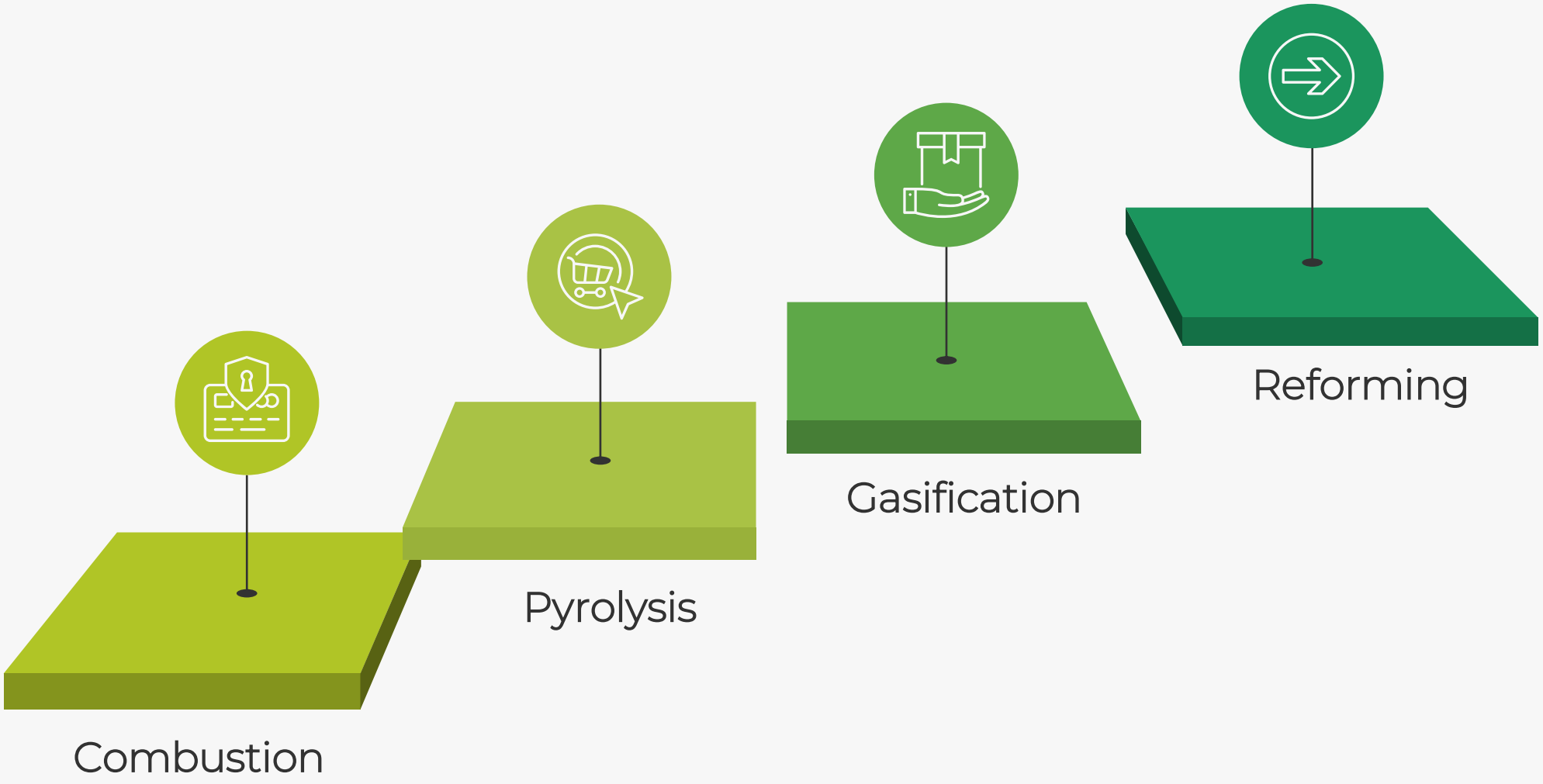
Syngas Properties

The makeup of syngas will vary due to the different types of feedstocks and its moisture content, the type of process and equipment used, the gasification agent, and the operating temperature and pressure.

Product Utilization

The syngas can be used to produce a wider variety of outputs: electricity, heat and power, liquid fuels, and synthetic chemicals.

Biomass Conversion via Thermochemical Route

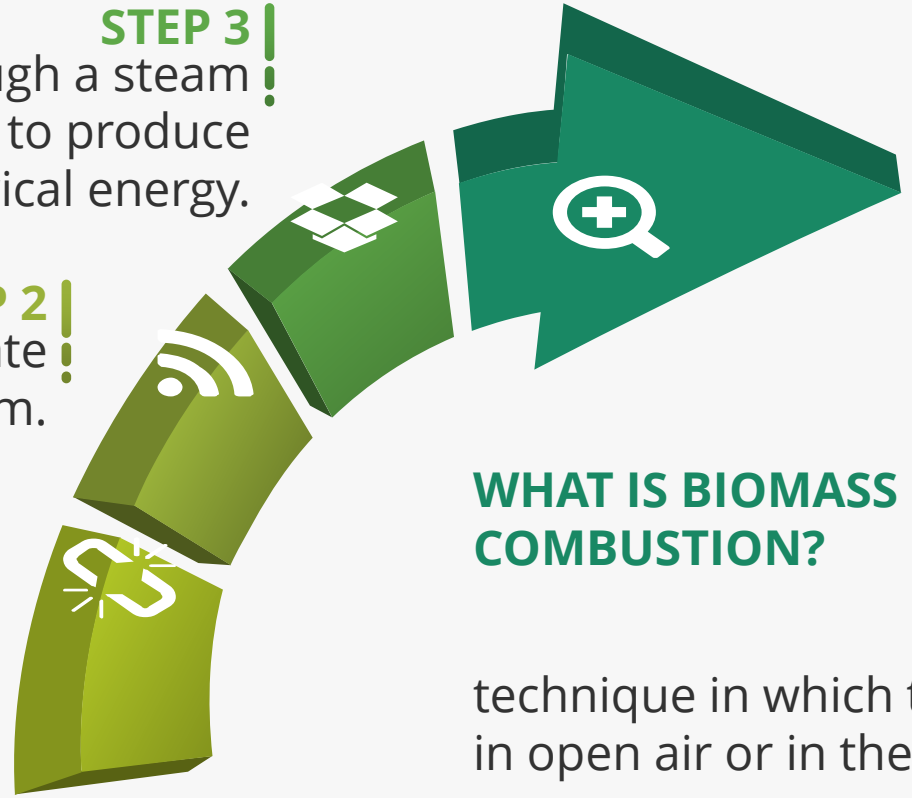


Thermochemical Conversion – Direct Combustion

STEP 3
Steam was expanded through a steam turbine or steam engine to produce mechanical or electrical energy.

STEP 2
Biomass is fed into a boiler to generate steam.

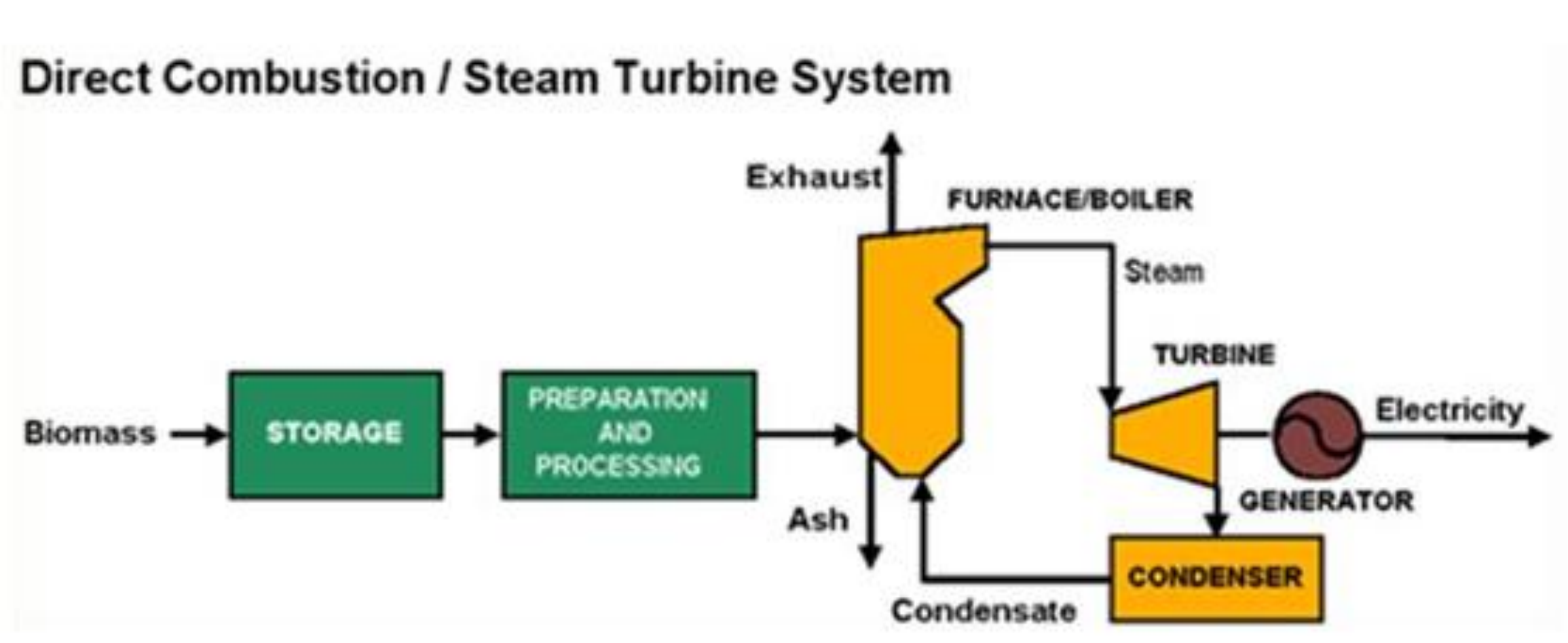
STEP 1
Biomass is burned in a combustor or furnace to generate hot gas.



WHAT IS BIOMASS DIRECT COMBUSTION?

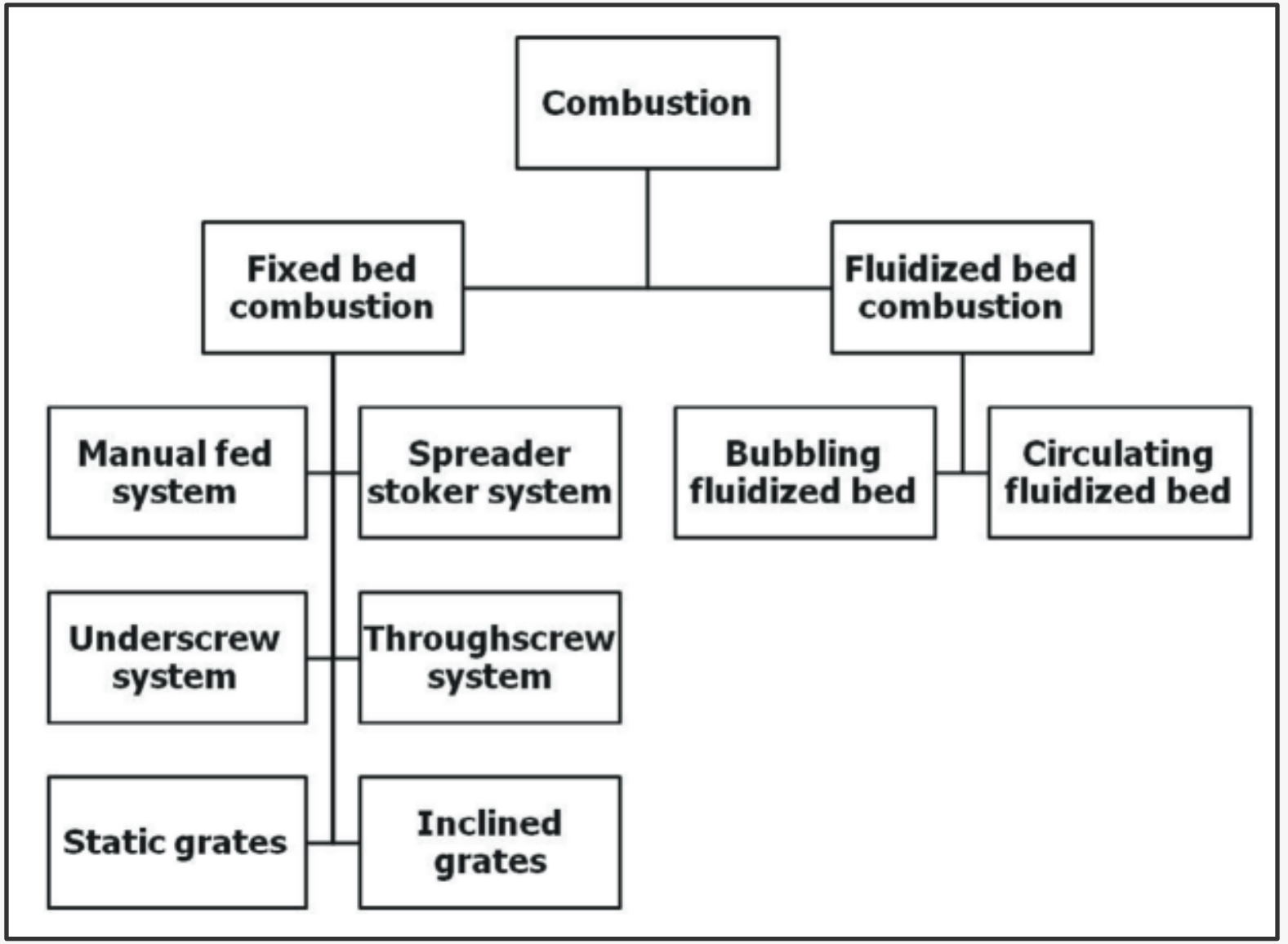
technique in which the biomass is burned in open air or in the presence of excess air

Direct Combustion – Working Principles

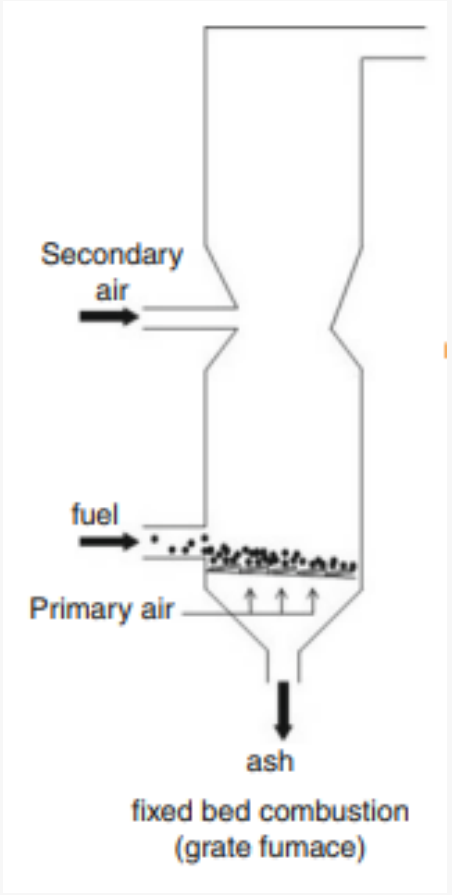


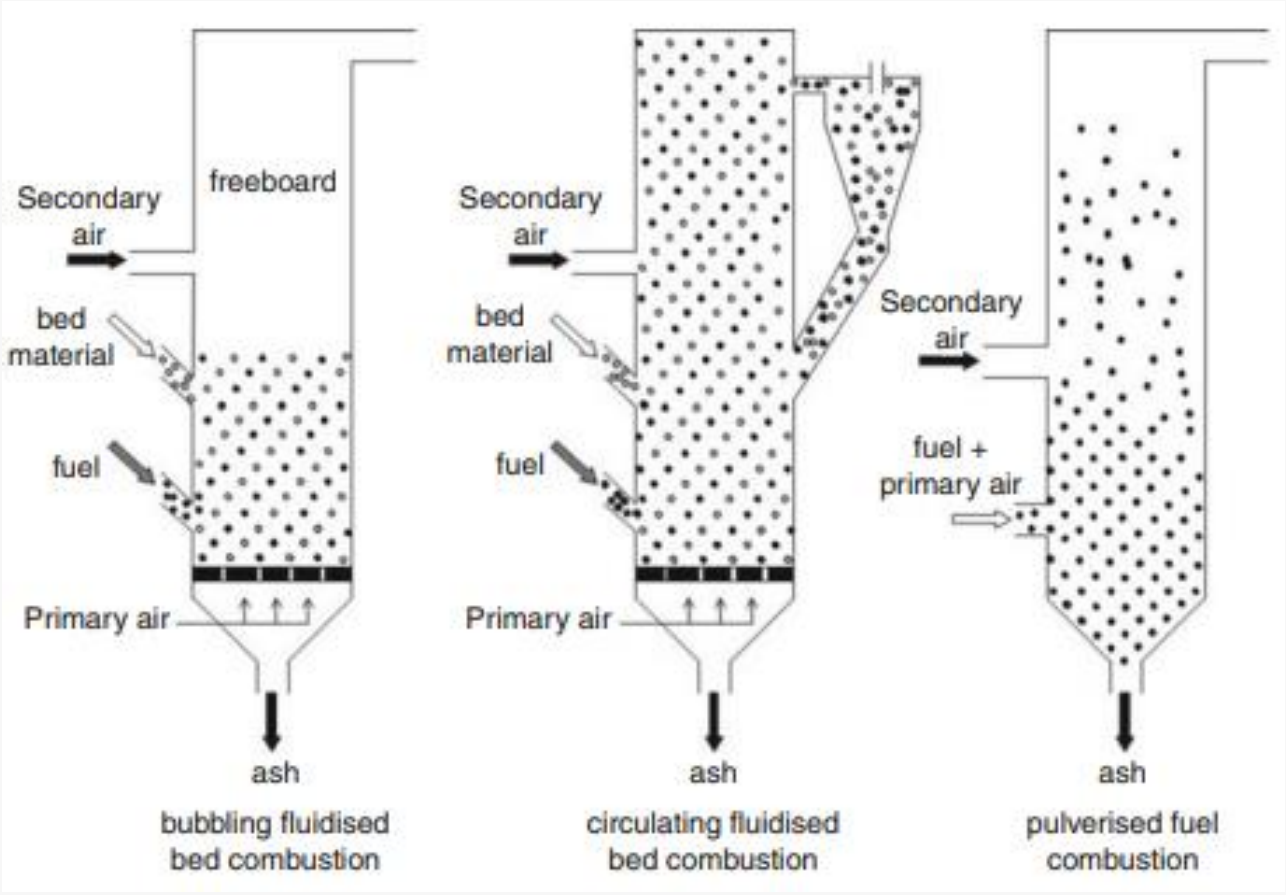
Direct Combustion – Types of Combustor

Creative Title Here



Direct Combustion – Types of Combustor





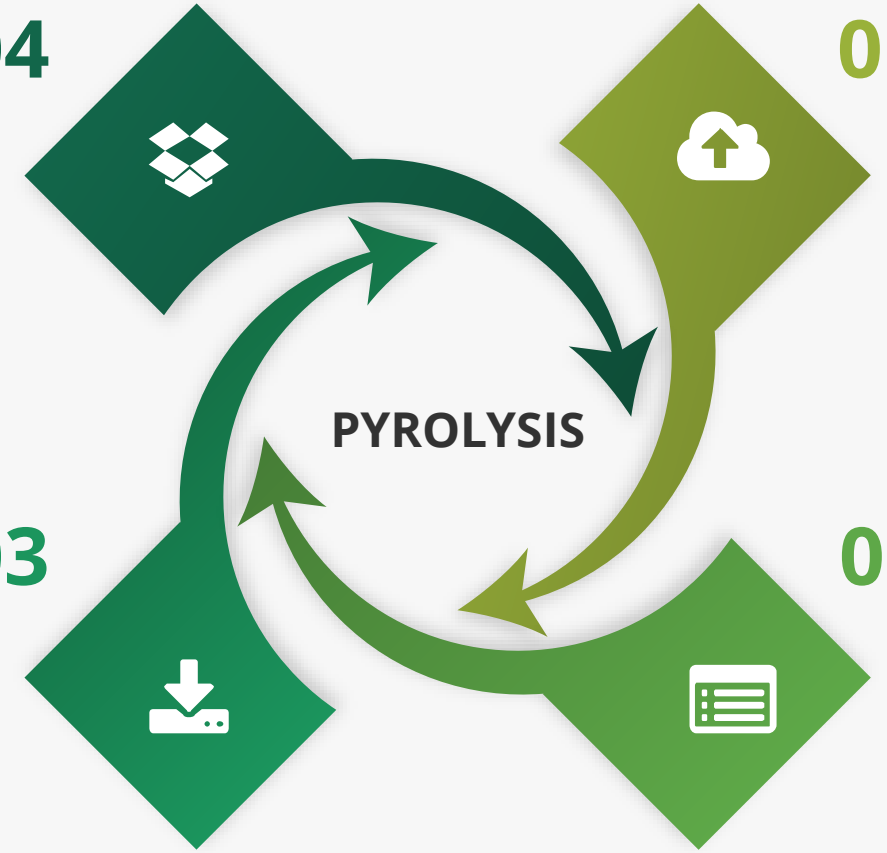
- fuel is delivered in some manner onto a grate where it reacts with oxygen in the air.
- exothermic reaction that produces very hot gases and generates steam in the heat exchanger section of the boiler.

- biomass is burned in a hot bed of suspended, incombustible particles, such as sand
- produce more complete carbon conversion, resulting in reduced emissions and improved system efficiency

Thermochemical Conversion - Pyrolysis

FACT 4 | **04**

Word pyrolysis is coined from the Greek words "pyro" which means fire and "lysis" which means separating.



01 | **FACT 1**

pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen

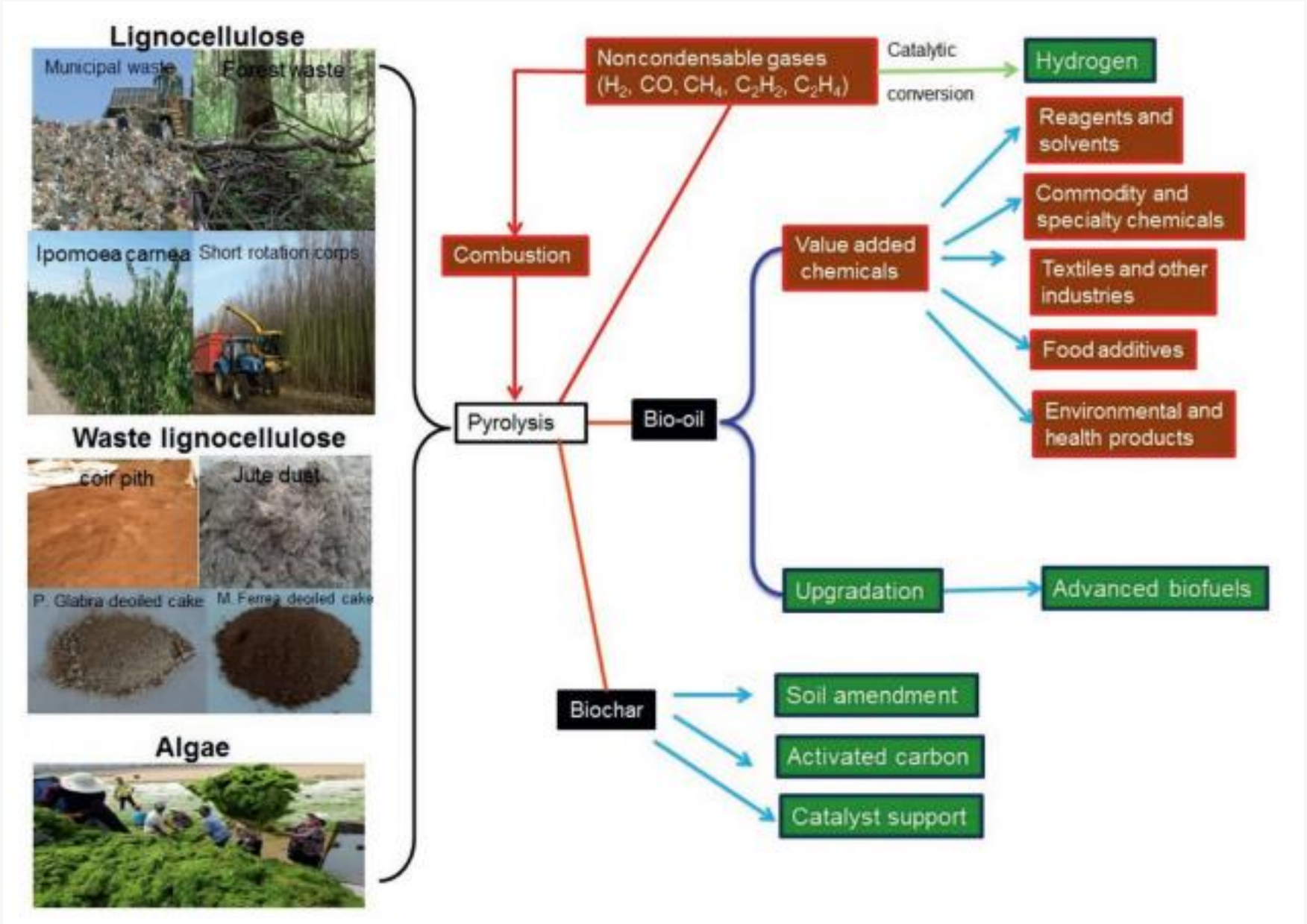
FACT 3 | **03**

Products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide.

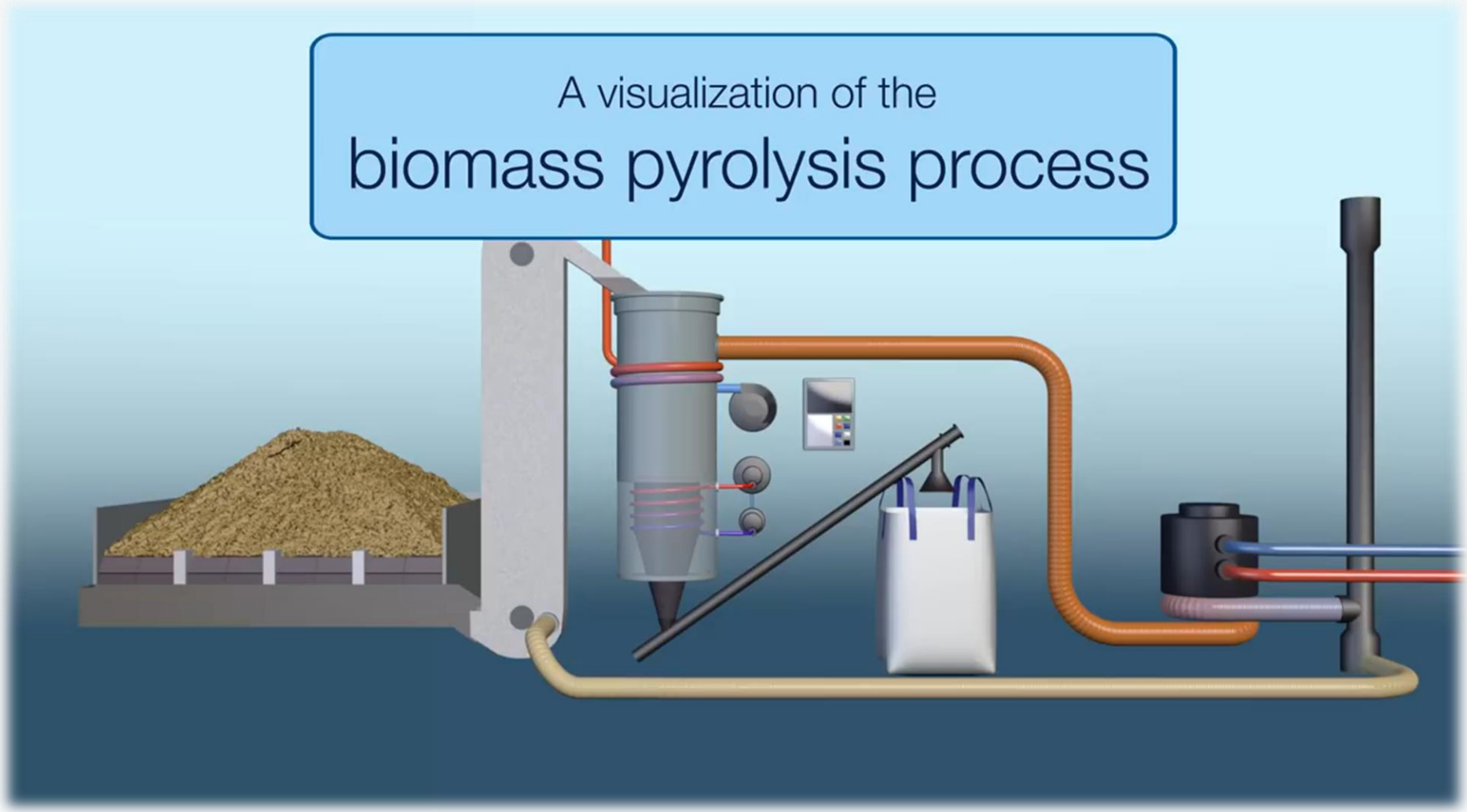
02 | **FACT 2**

process typically occurs at temperatures above 500 °C (800 °F) and under pressure.

Pyrolysis – Product Distribution



Pyrolysis – An Introduction



Types of Pyrolysis

Fast Pyrolysis

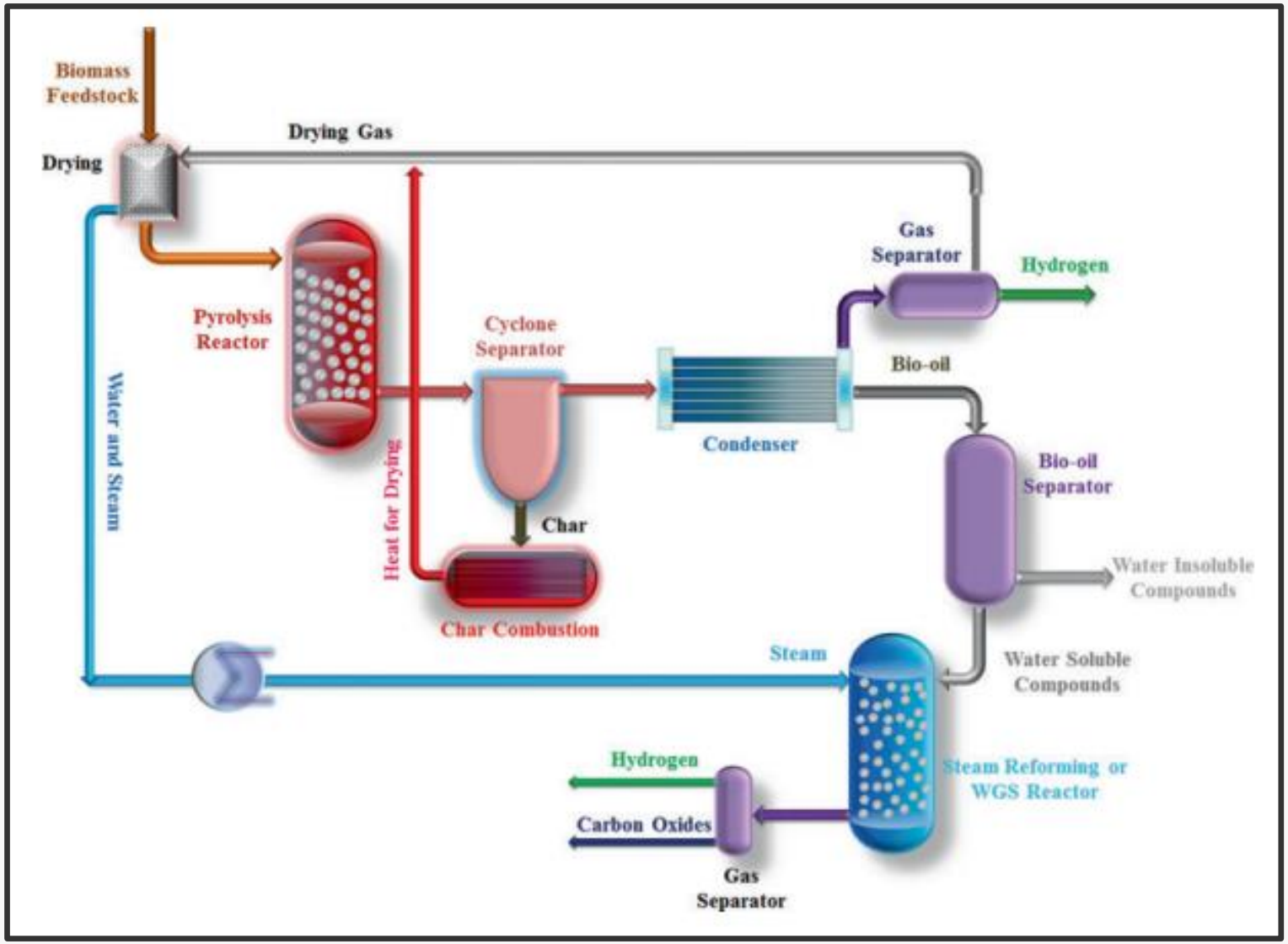
- Temperature: 400-800 deg C
- Heating Rate: 10-200 deg C/s
- Residence time: 0.5-10s

Flash Pyrolysis

- Temperature: 800 -1100 deg C
- Heating Rate: >1000 deg C/s
- Residence time: <0.5s

Slow Pyrolysis

- Temperature: 300-700 deg C
- Heating Rate: <1 deg C/s
- Residence time: >600s



Main Influencing Factors of Pyrolysis Process

PROCESS CONDITION

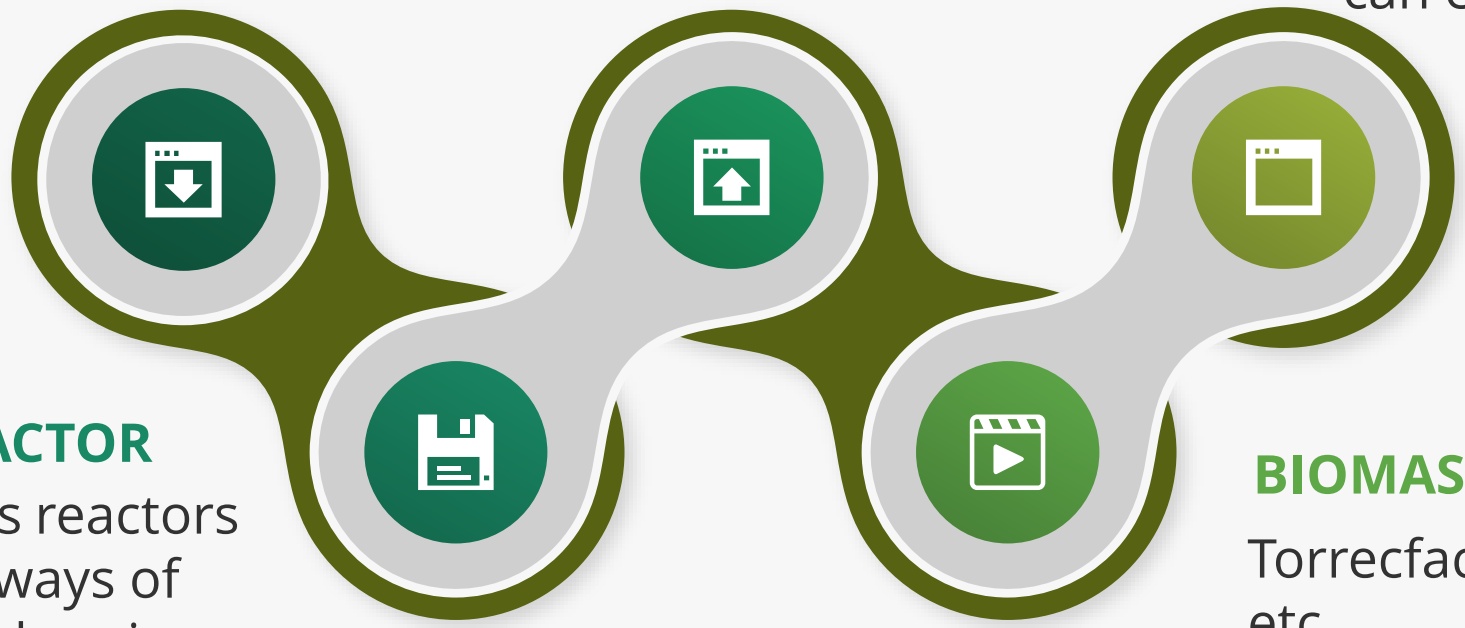
the composition of the end-products differs greatly due to the different pyrolysis temperatures.

HEATING

Types of heating (electric, microwave), heating rate and heating temperature influence the process

FEEDSTOCK MOISTURE

The moisture content of the biomass influence the rate of the energy recovered and the temperature that can eventually reach



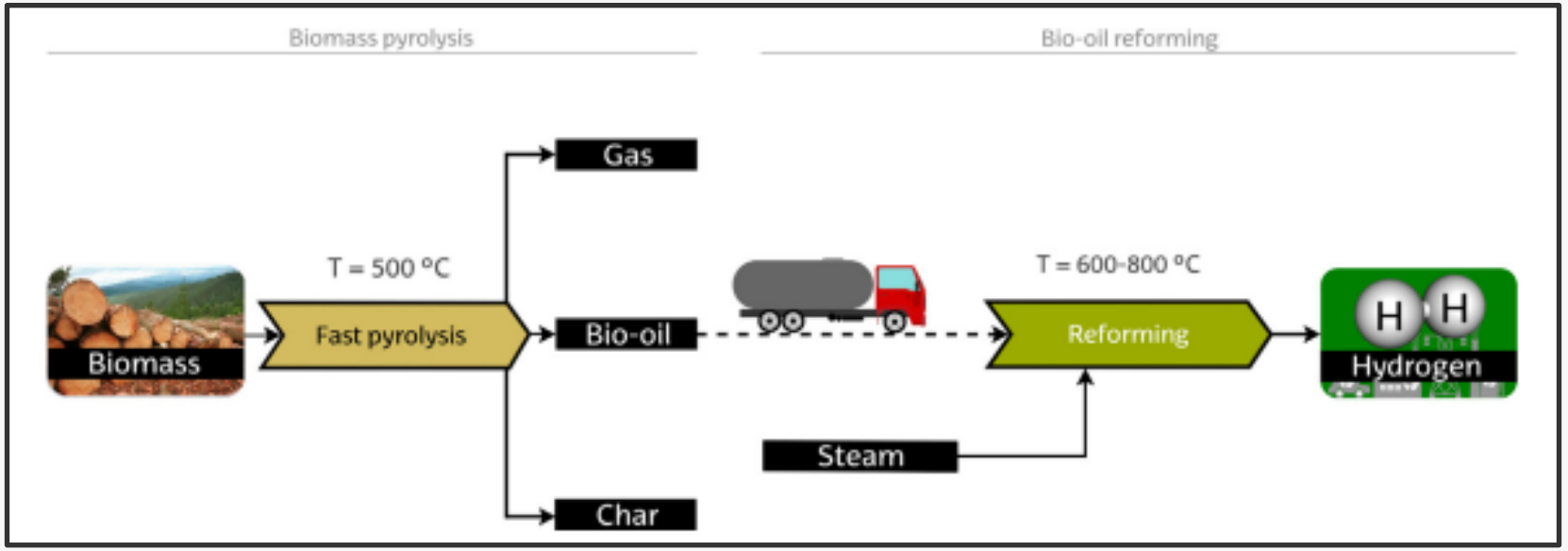
TYPE OF REACTOR

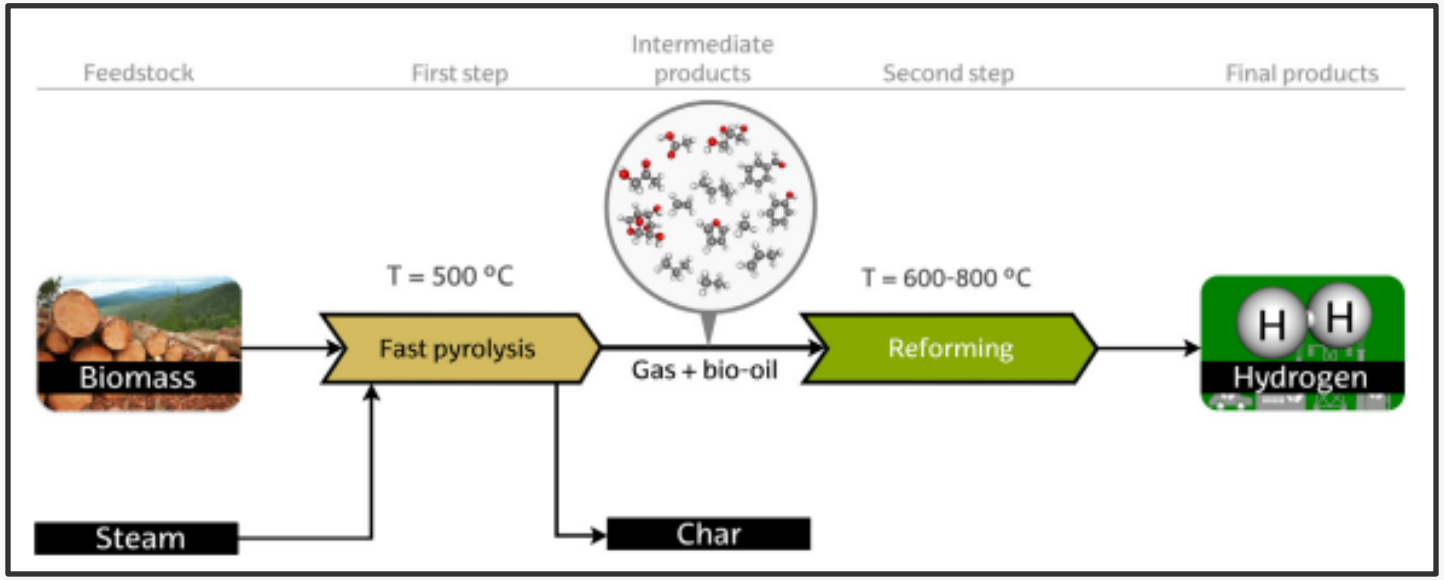
Different pyrolysis reactors have different ways of feeding and discharging i.e. fixed bed, fluidized bed

BIOMASS PRE-TREATMENT

Torrecfaction, Acid washing etc

Pyrolysis – Reforming of Biomass





Thermochemical Conversion - Gasification

DEFINITION

technology that uses a controlled process involving heat, steam, and oxygen to convert biomass to hydrogen and other products

APPLICATION

Product i.e. gaseous fuel are used in conventional equipment (e.g., boilers, engines, and turbines) or advanced equipment (e.g., fuel cells) for the generation of heat and electricity.

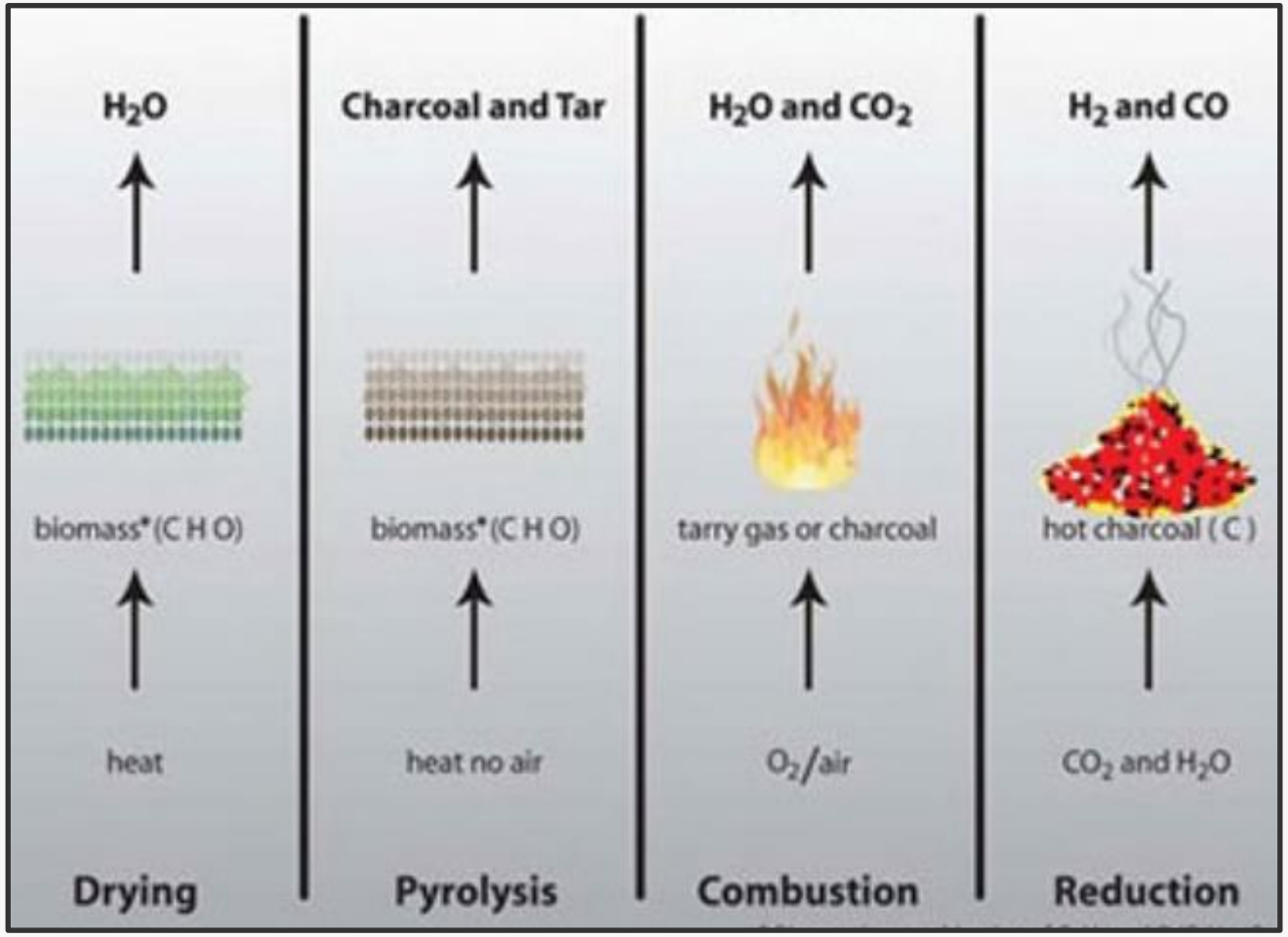
STEPS IN GASIFICATION

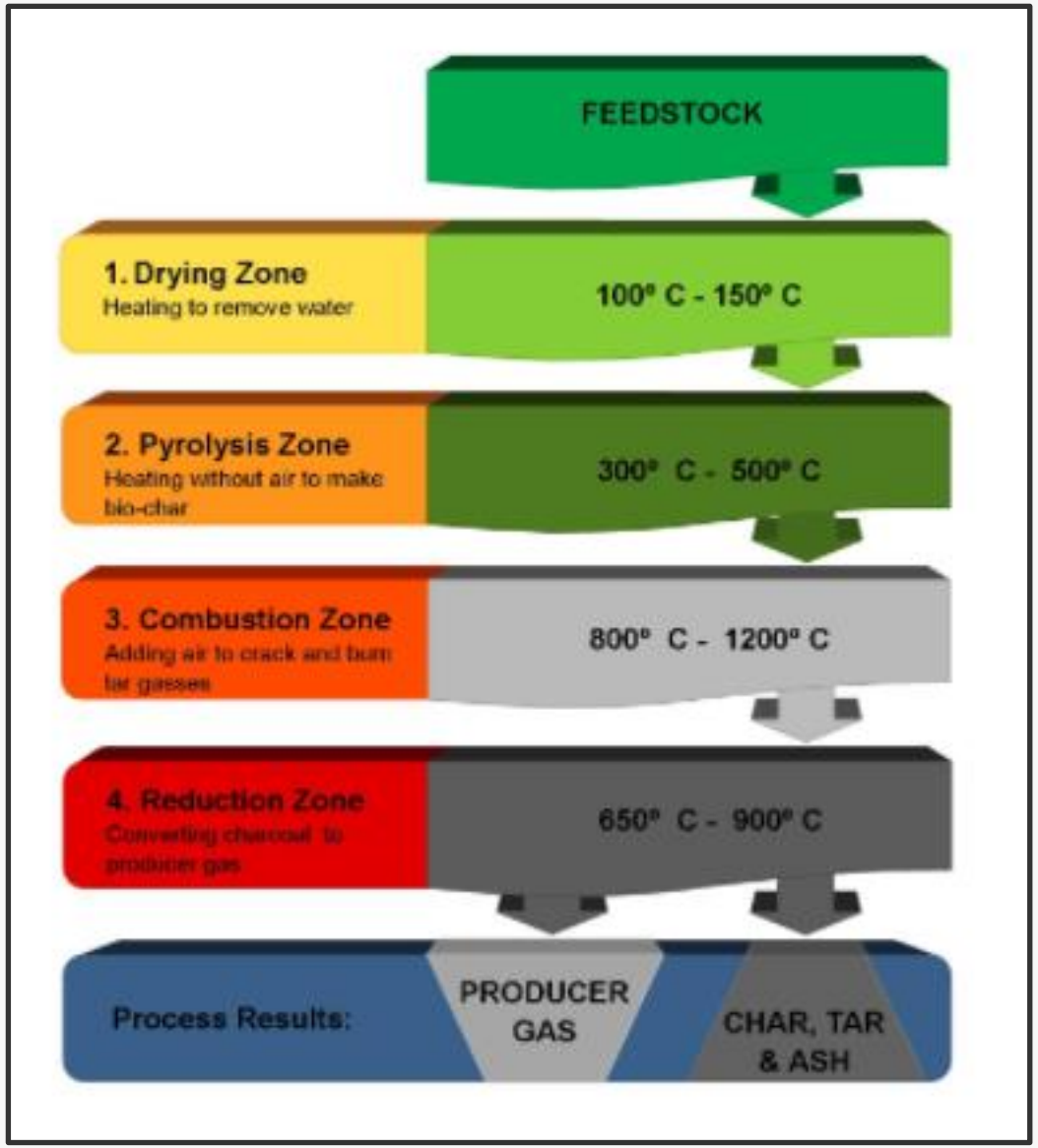
Gasification occurs in a set of four steps: drying, pyrolysis, oxidation and reduction.

TYPES OF GASIFIERS

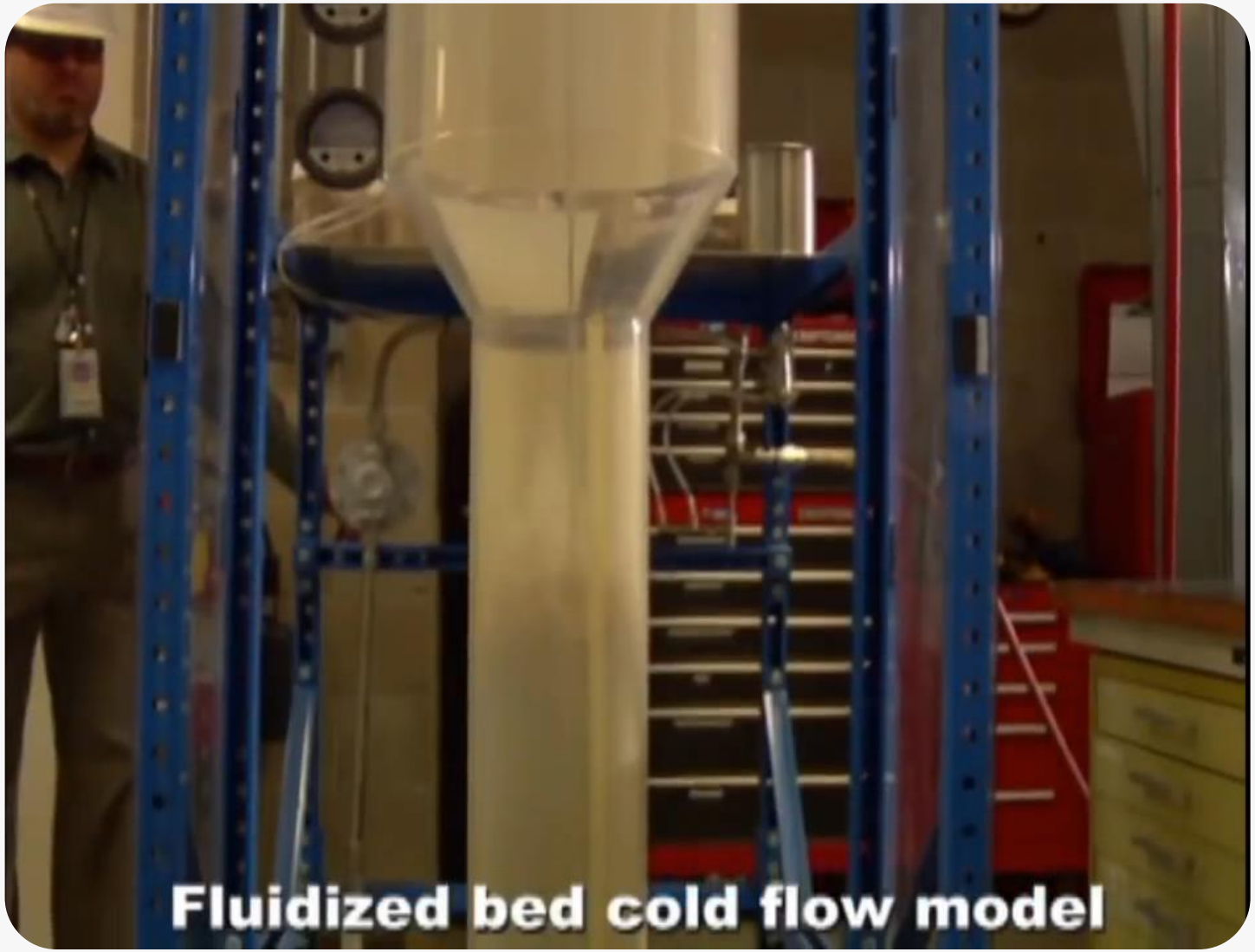
Based on the gas–solid contacting mode, gasifiers are broadly divided into three principal types (Table 6.1): (1) fixed or moving bed, (2) fluidized bed, and (3) entrained flow..

4 Processes in Biomass Gasification

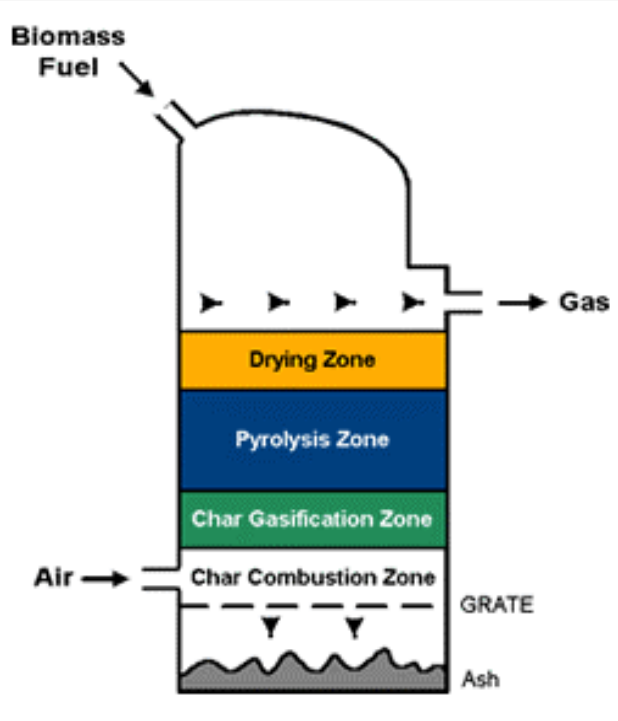




Gasification Process

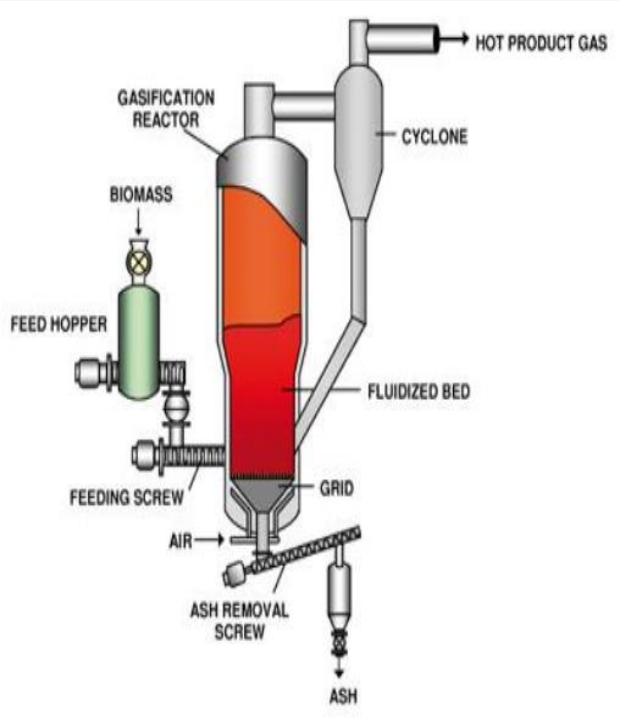


Types of Gasifiers



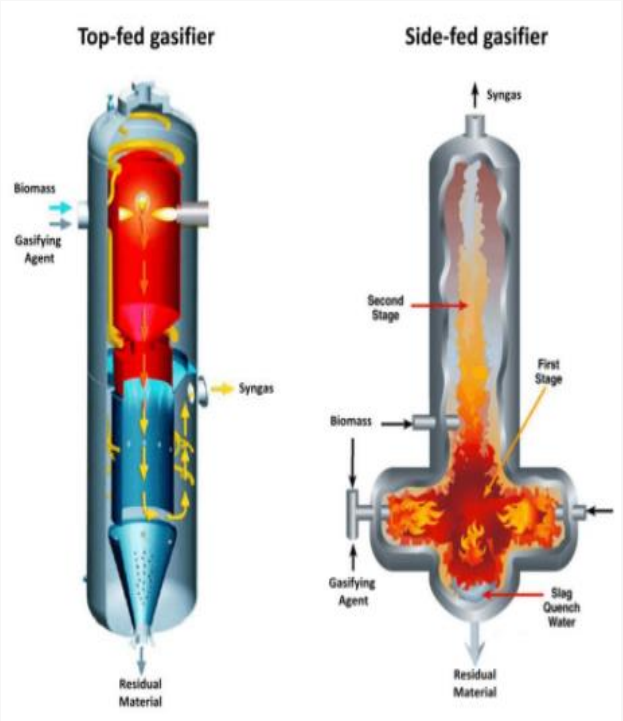
Fixed or Moving Bed

coarse solid biomass is gasified by the gasifying agent, while slowly moving downwards.



Fluidized Bed

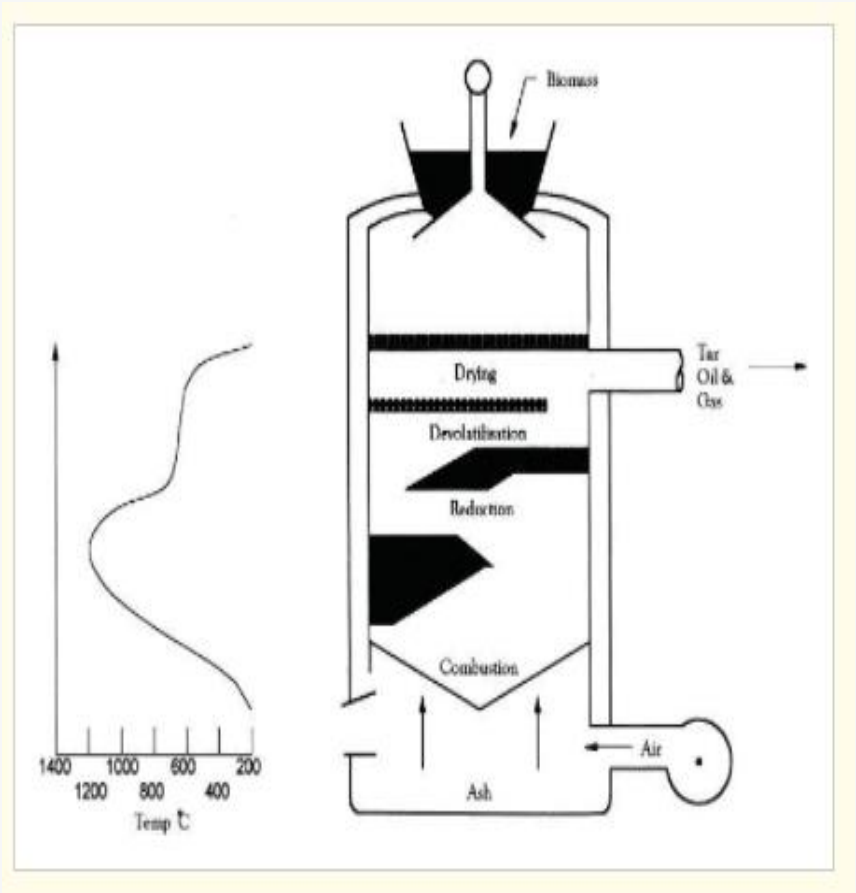
biomass and other solid materials are vigorously mixed by the gasifying agent



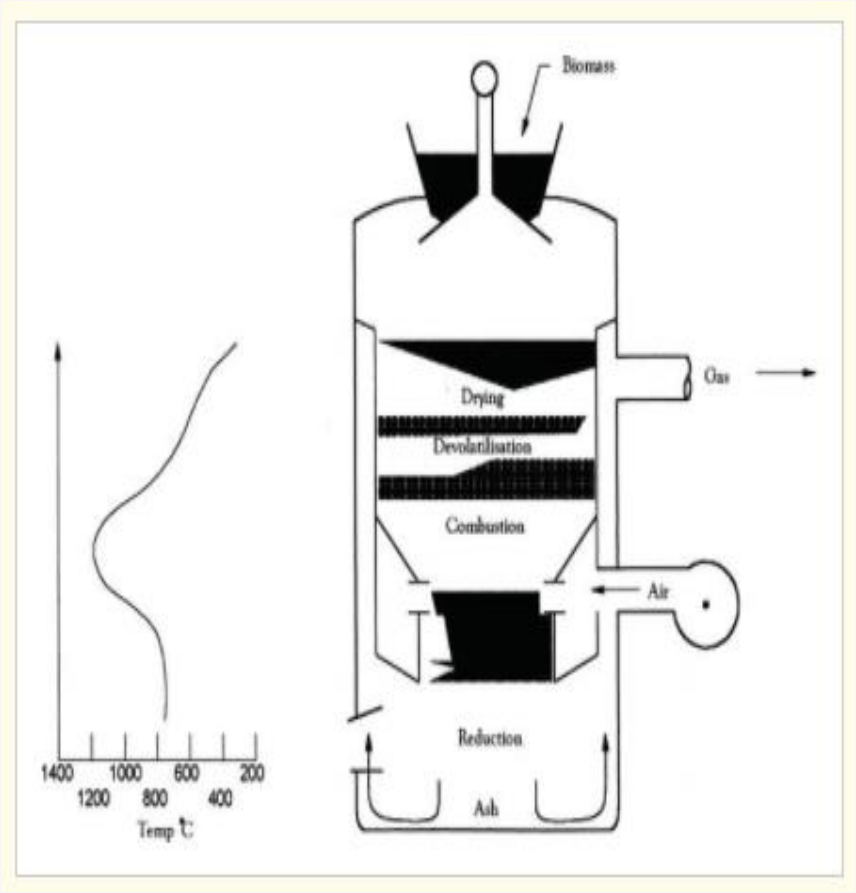
Entrained Flow

grinded solid biomass is entrained and quickly converted by the gasifying agent.

Biomass Gasifier – Fixed Bed Gasifier

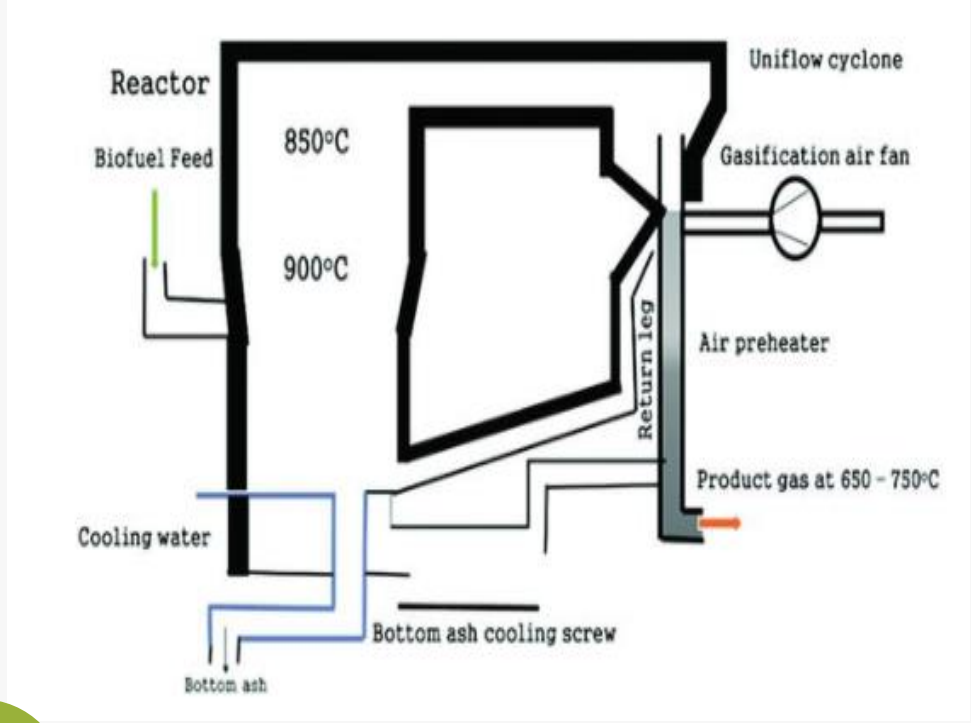


Updraft Gasifier

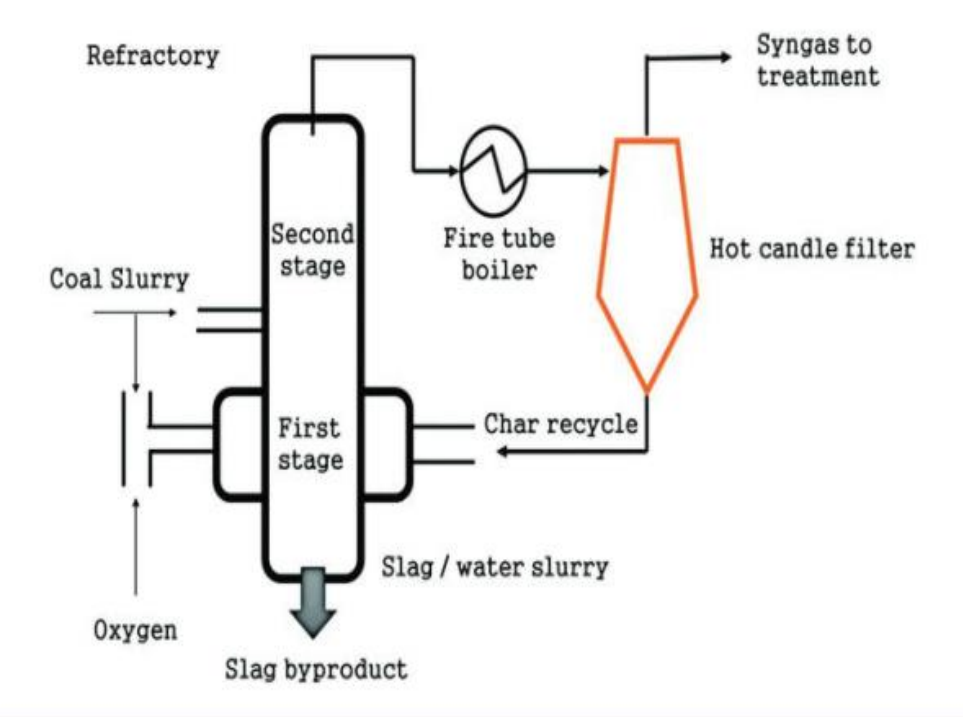


Downdraft Gasifier

Biomass Gasifier – Fluidized Bed and Entrained Flow Gasifier



Fluidized Bed Gasifier
(circulating)



Entrained Flow Gasifier
(side feed)

Hydrogen Production: Biomass-Derived Liquid Reforming

DESCRIPTION

Liquid-form of biomass such as glycerol, ethanol, methanol, and bio-oil used as feedstock the production of hydrogen-rich syngas

PROCESS

involve the reaction of the biomass-derived liquid with steam, CO_2, or O_2 at high temperature usually in the presence of a catalyst.

PRODUCT

The reforming reaction often produces hydrogen-rich syngas and some hydrocarbons

CHALLENGES

catalyst deactivation by carbon deposition and sintering, high energy requirement, and lack of understanding of the deactivation mechanisms

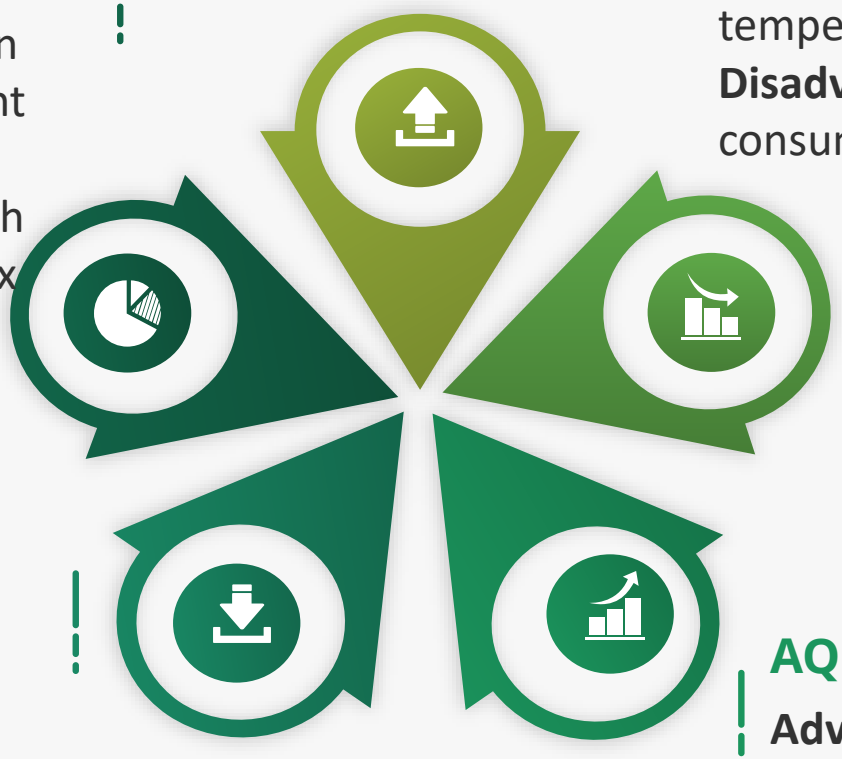
Types of Biomass-Derived Liquid Reforming

PARTIAL OXIDATION REFORMING

Advantages: Reduced desulfurization requirement, no catalyst requirement and low methane slip
Disadvantages: Low H_2/CO ratio, high operating temperatures and complex handling process

STEAM REFORMING

Advantages: Most developed industrial process, no oxygen requirement, lowest operating temperature, best H_2/CO ratio
Disadvantages: High water and energy consumptions and CO_2 emission



DRY REFORMING

Advantages: Environmental potentials for CO2 emission
Disadvantages: Low H_2/CO ratio, high operating temperature, and limited commercial experience

AUTHERMAL REFORMING

Advantages: Lower process temperature than partial oxidation and low methane slip
Disadvantages: Limited commercial experience

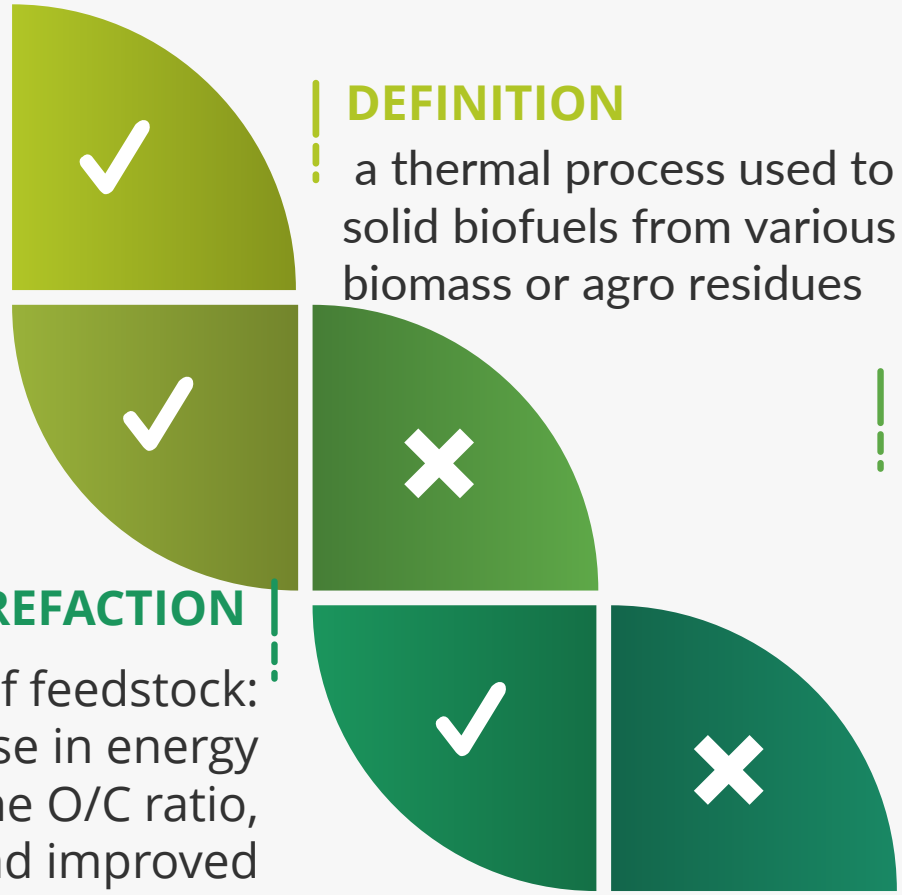
AQUEOUS PHASE REFORMING

Advantages: doesn't need to vaporize the feedstocks and requires less energy
Disadvantages: biomass oxygenates or hydrocarbons that can be completely miscible with water

Biomass Torrefaction

TORREFACTION VERSUS PYROLYSIS

torrefaction employs milder temperatures of 200–300 °C in comparison to slow pyrolysis 350–700 °C.



DEFINITION

a thermal process used to produce high-grade solid biofuels from various streams of woody biomass or agro residues

APPLICATION OF TORREFIED BIOMASS

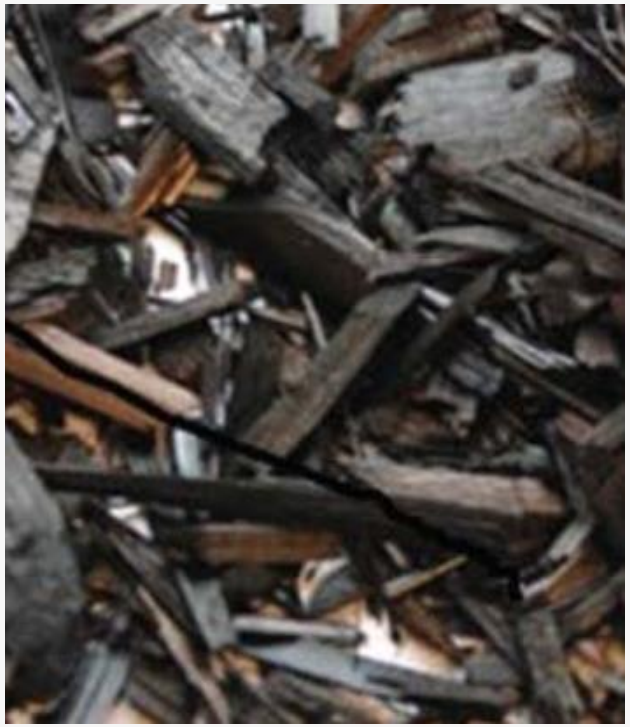
gasification, co-firing of torrefied biomass with coal, combined heat and power generation, standalone combustion, production of bio-based fuels and chemicals, heating blast furnaces and industrial applications

ADVANTAGES OF TORREFACTION

Enhances the properties of feedstock: reduction in moisture, increase in energy density, reduction in the O/C ratio, increase in heating value, and improved ignitability and reactivity of the processed fuel.

Torrified Biomass

Raw Biomass



Torrified Biomass

Torrified Pallets

Hydrothermal Biomass Processing

DEFINITION

thermal depolymerization process used to convert wet biomass, and other macromolecules, into crude-like oil under moderate temperature and high pressure.

PROCESS CONDITION

This process is usually carried out in temperature ranges between 280°C and 370°C and pressures that are in the range from 10 to 25 MPa

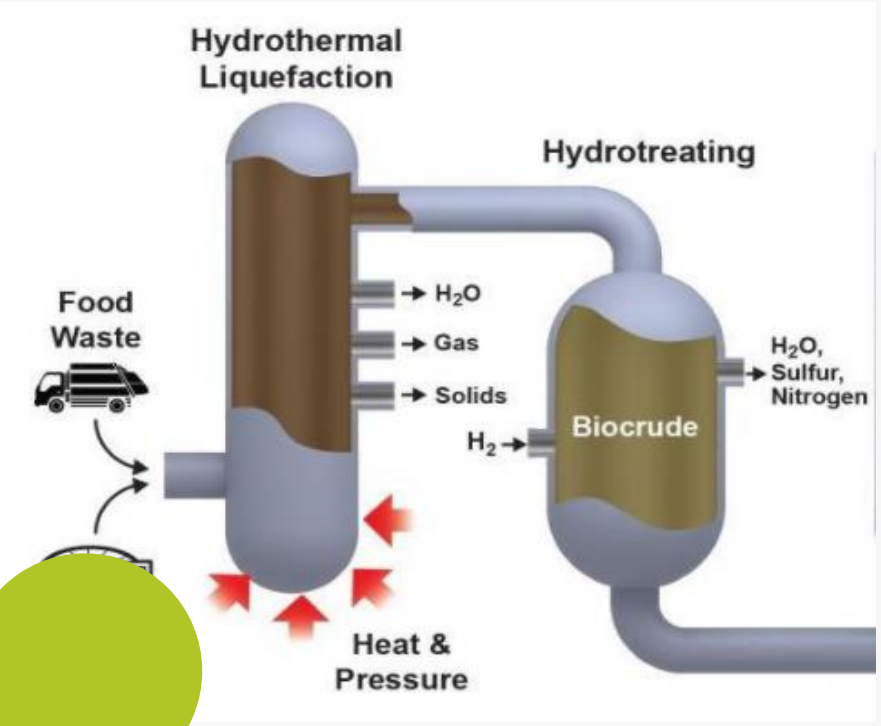
CONDITION OF FEEDSTOCK

Feedstocks with high moisture content like sewage sludge are suitable for hydrothermal processing.

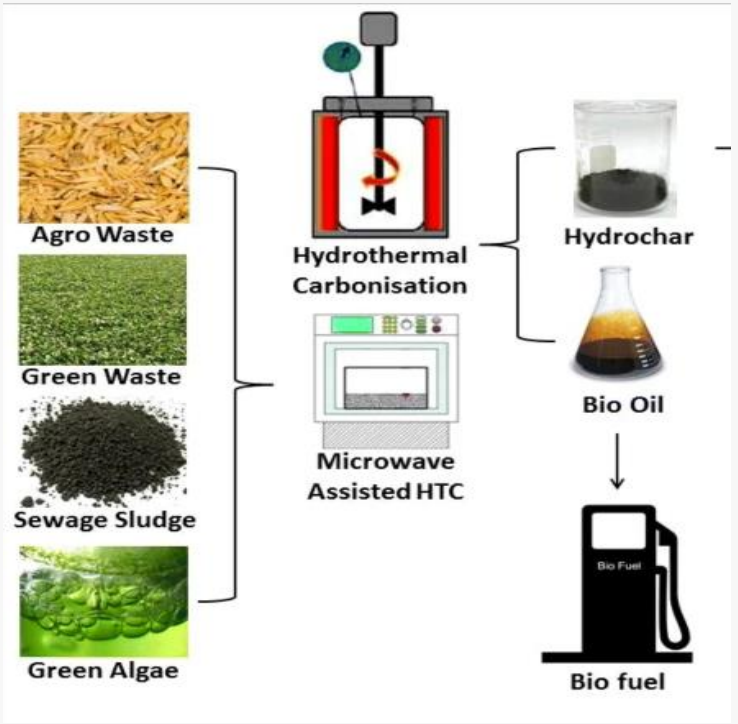
TYPES OF HYDROTHERMAL PROCESSING

- Hydrothermal liquefaction
- hydrothermal gasification
- hydrothermal carbonization

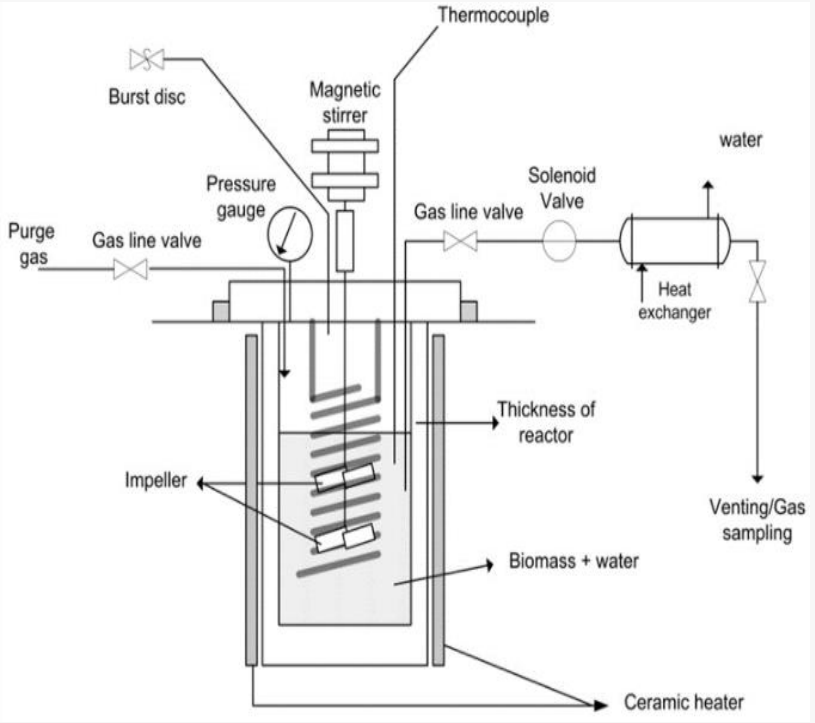
Types of Hydrothermal Biomass Processing



Hydrothermal liquefaction

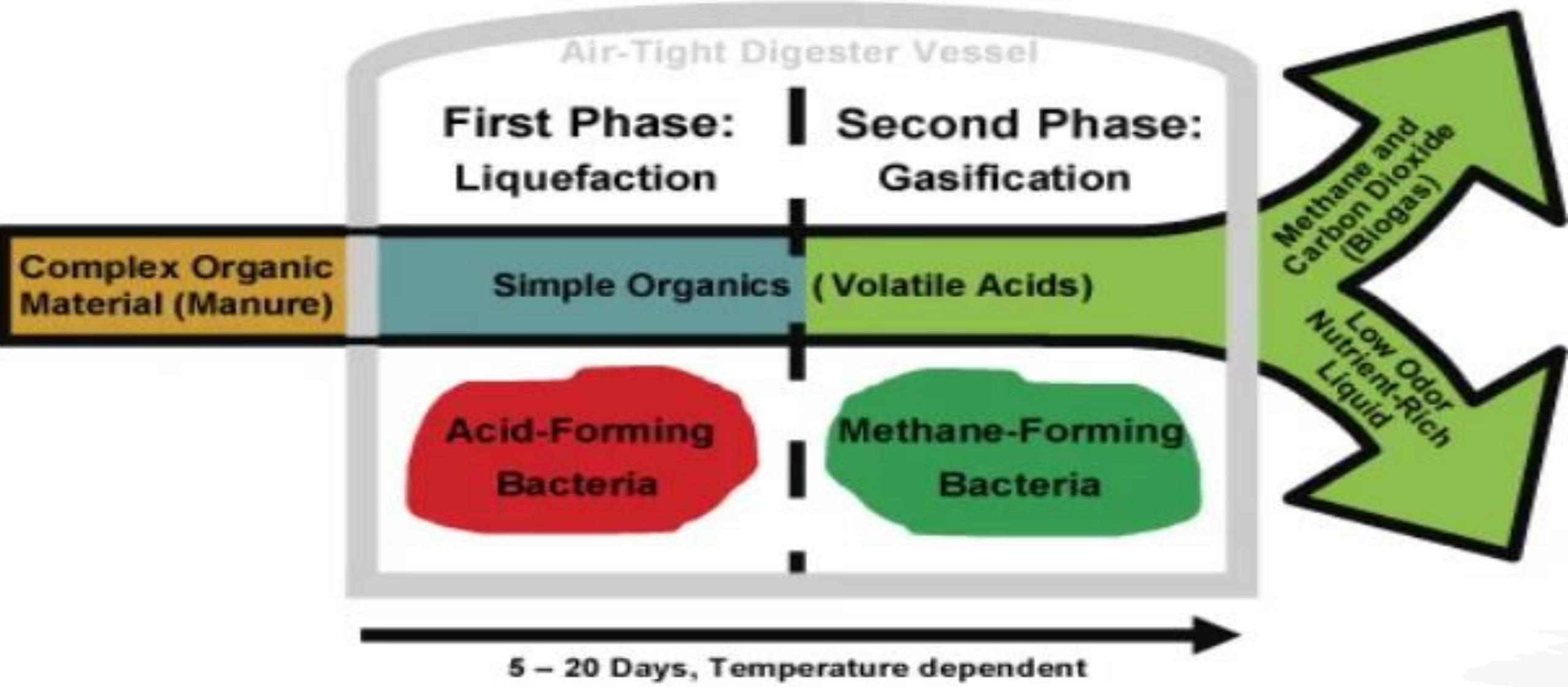


Hydrothermal Carbonization

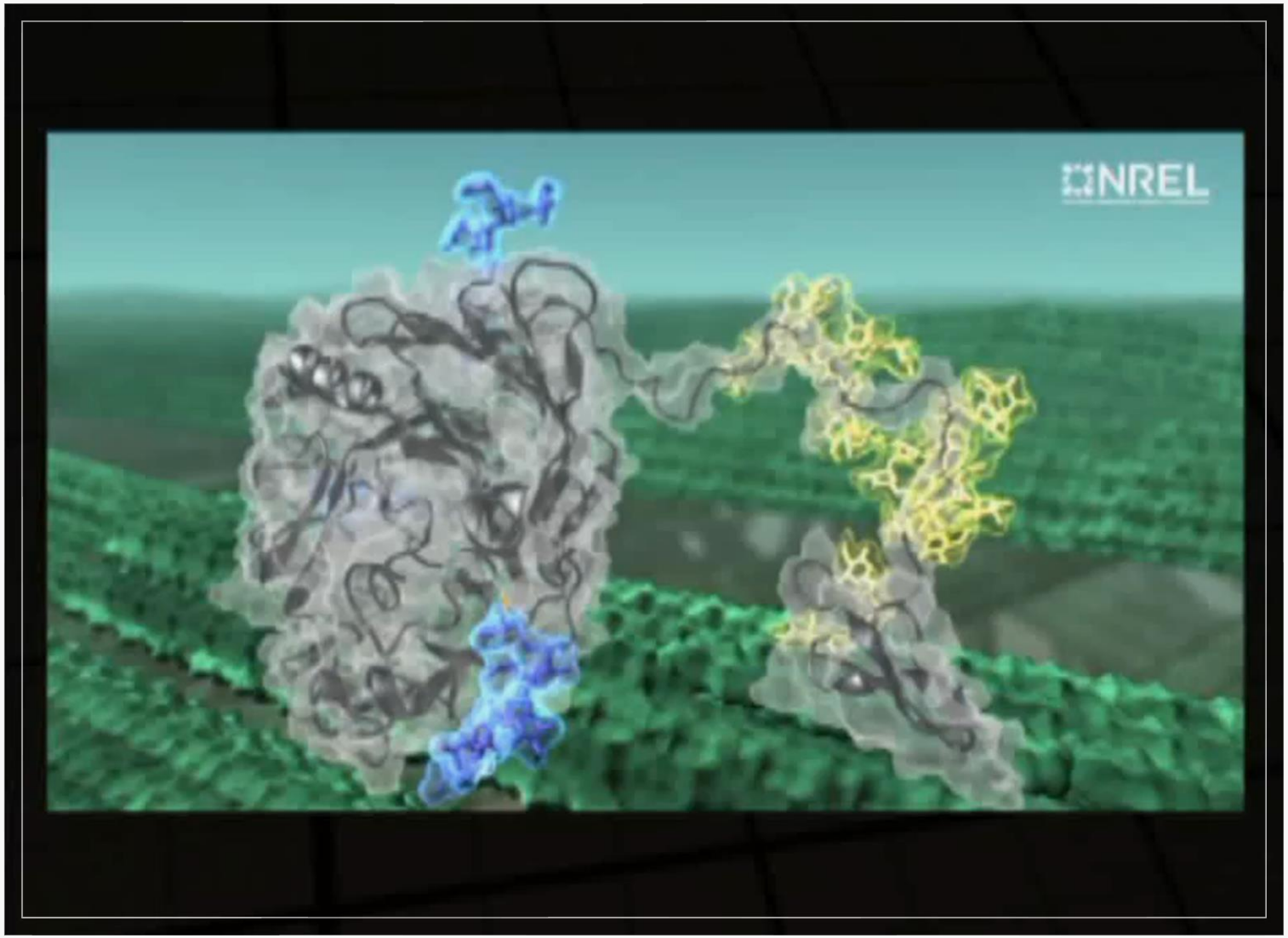


Hydrothermal Gasification

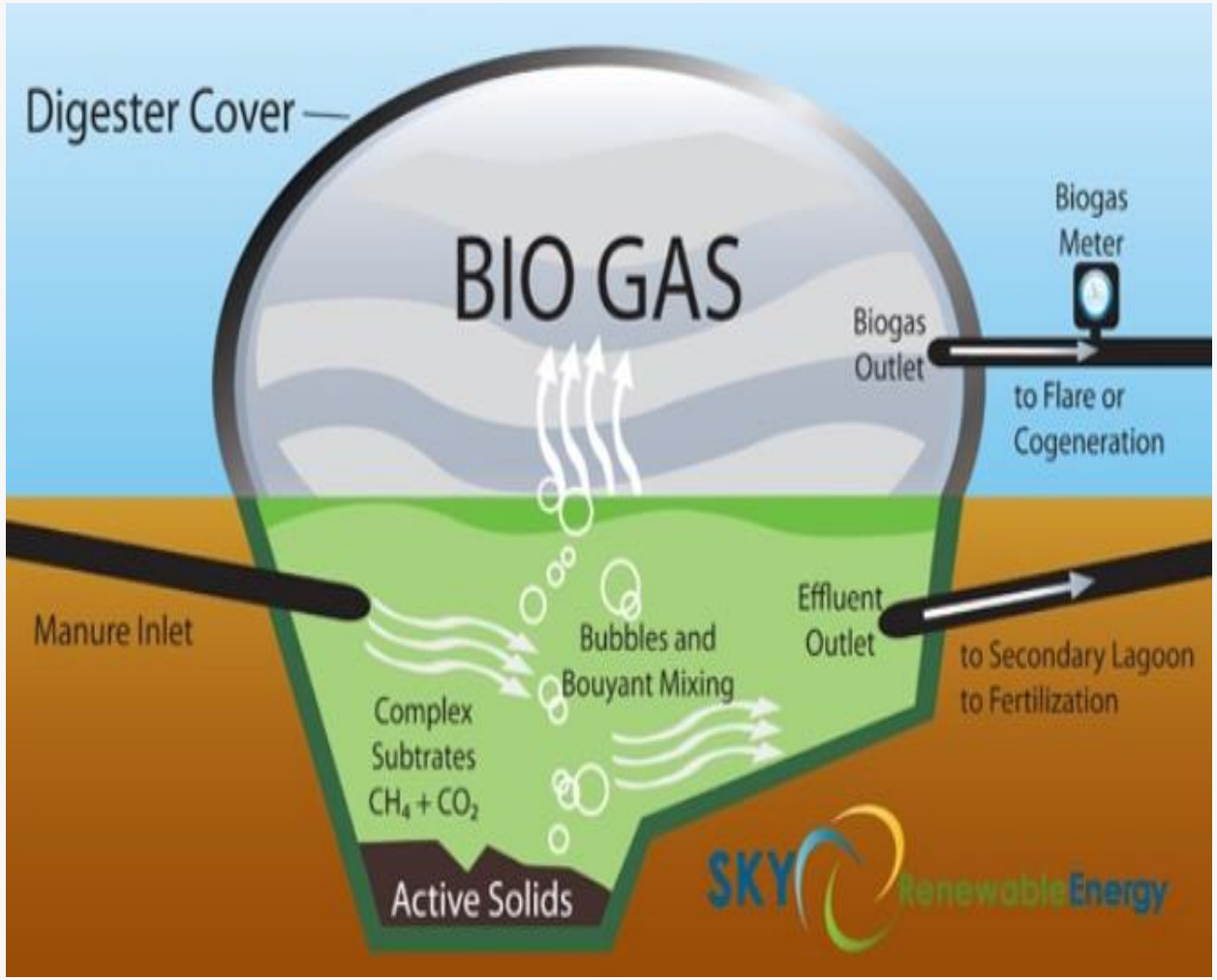
Biochemical Conversion of Biomass



Biochemical Conversion of Biomass

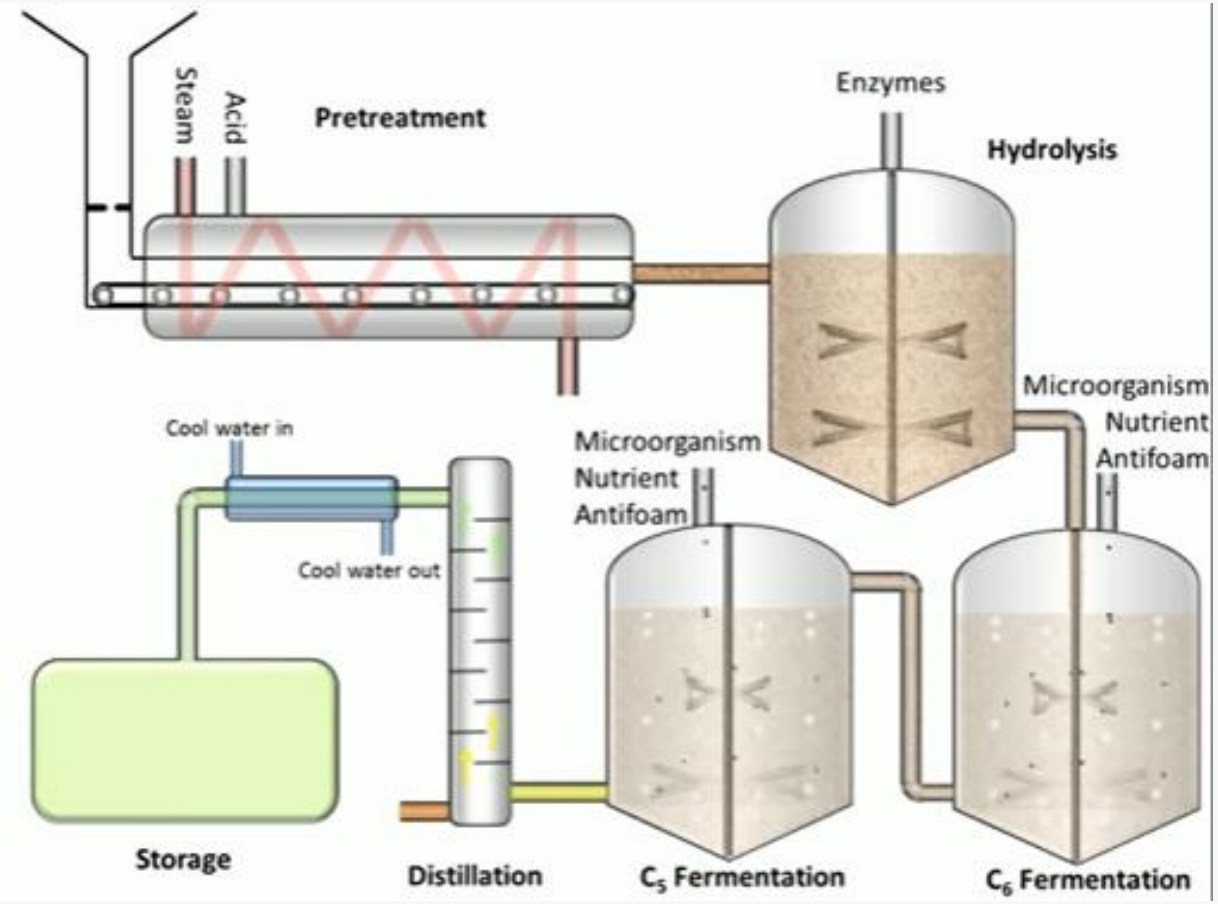


Anaerobic Digestion



- organic waste from various sources is biochemically degraded in highly controlled, oxygen-free conditions circumstances resulting in the production of biogas
- anaerobic digestion plant produces two outputs, biogas and digestate - both further processed or utilized to produce secondary outputs.
- Biogas can be used for producing electricity and heat, as a natural gas substitute and also a transportation fuel.
- Digestate can be further processed to produce liquor and a fibrous material

Biomass Fermentation



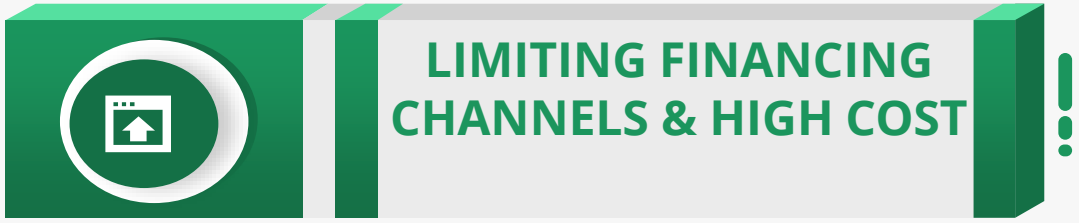
- an anaerobic process that breaks down the glucose within organic materials. It is a series of chemical reactions that convert sugars to alcohol or acid.
- yeast or bacteria are added to the biomass material, which feed on the sugars to produce ethanol and carbon dioxide.
- anaerobic digestion plant produces two outputs, biogas and digestate - both further processed or utilized to produce secondary outputs.
- Biogas can be used for producing electricity and heat, as a natural gas substitute and also a transportation fuel.
- Digestate can be further processed to produce liquor and a fibrous material

Challenges associated with Biomass Energy

Biomass Energy – Operational Challenges

Biomass Energy – Economic Challenges

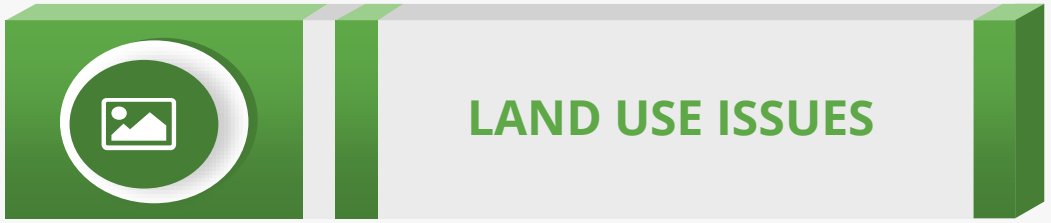
- Biomass resources are scattered and in order to reduce the cost of transportation,
- biomass projects are eager to occupy land close to the source, leading to centralization of biomass projects.



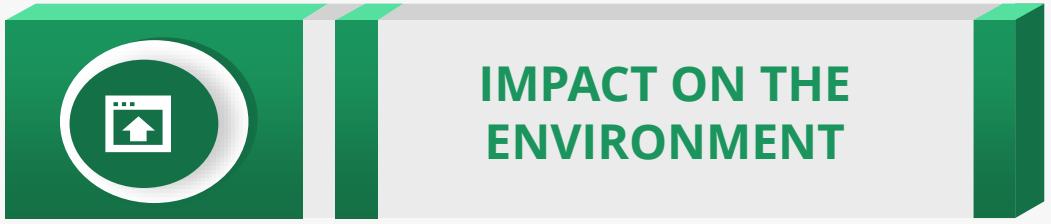
- Difficult to attract investors - decentralized capital, poor profitability, frequent fluctuations of international crude oil prices and high market risk
- excessive investment and high operating costs, pre-treatment technologies have extra costs

Biomass Energy – Social Challenges

Decision making on selection of supplier, location, routes & technologies is crucial and needs proper communication



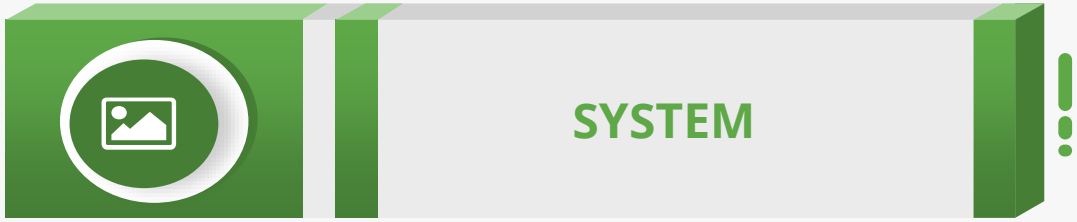
Land use issues leads to the loss of ecosystems preservation and the homes of indigenous people.



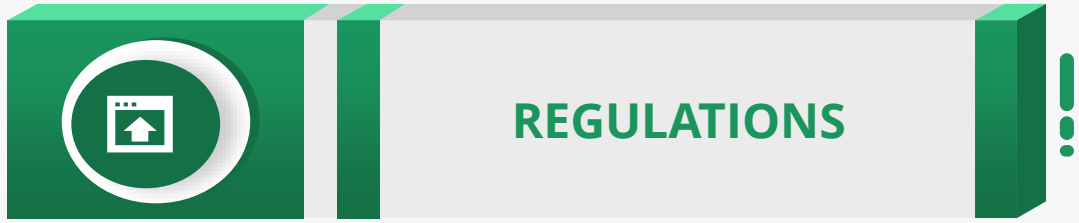
Biomass plantation depletes nutrients from soil, promote aesthetic degradation and increase the loss of biodiversity. Installation of energy farms within rural areas like increased need of services, increased traffic

Biomass Energy – Policy & Regulatory Challenges

Government is subsidizing the domestic fuel price which in turn makes the electricity generating cost from conventional sources lower than the power production cost from renewable fuels.



No specific rules to regulate the work of utilization of biomass resource



No special mechanism to manage the development of biomass resources industry and no specialized department to manage the implementation of relevant national standards and policies.

Biomass Energy – Biomass Large-Scale Supply Problems & Solution

High quality biomass is considerable but expensive and not always sustainable	Utilization of agro forestry residues. High availability and fully environmentally sustainable
Agro-forestry residues have lower quality and higher micro-elements (K, Ca, Mg, ashes) content	Blending of different biomass feedstocks to arrange suitable average composition
Low energy density and bulk volume affect storage costs and transportation	First step chipping activities, enhance biomass energy density increasing transportation efficiency
Biomass degradability affect large distances transport activities, long time storage	Agropellets production, with low moisture and high energy density. Avoiding degradation and transportation issues.

“Replacing traditional sources of energy completely with renewable energy is going to be a challenging task. However, by adding renewable energy to the grid and gradually increasing its contribution, we can realistically expect a future that is powered completely by green energy”

Tulsi Tanti

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The End

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