# Renewable energy sources:

Different sources in their forms, but shared as non depleting sources, where it is continually renewed.

The most important of these types of renewable sources are:

- Hydro – power energy
- Wind energy
- Tidal energy
- Thermal energy of oceans and seas water
- Geothermal energy
- Solar energy
- Waste energy
- Wood energy
- Biomass energy

Hydropower الطاقة الكهرومائية

Hydropower is a largest source of renewable power.

Hydropower also known as water power, is the use of falling or fast-runningwater السريان السريع to produce electricity

or to power machines تشغيل الالات. This is achieved by

**converting the gravitational potential or kinetic energy of a water source to produce power**

, Hydropower is a method of sustainable energy Production

انتاج البطاقة المستدامة. Hydropower is now used principally for

hydroelectric power generation and is Hydropower is an attractive alternative to

fossil fuels بديل جذاب للوقود الاحفوري as it does not directly produce carbon dioxide or other atmospheric

Pollutants ملوثات للغلاف الجوي and provides a relatively consistent power source مصدر طاقة ثابت نسبيا

**Advantages:**

Cheap to operate
Renewable
High yield
Lower energy cost than any other method

***Disadvantages:***

Dam failures

Human population displacement

Barriers to migrating fish

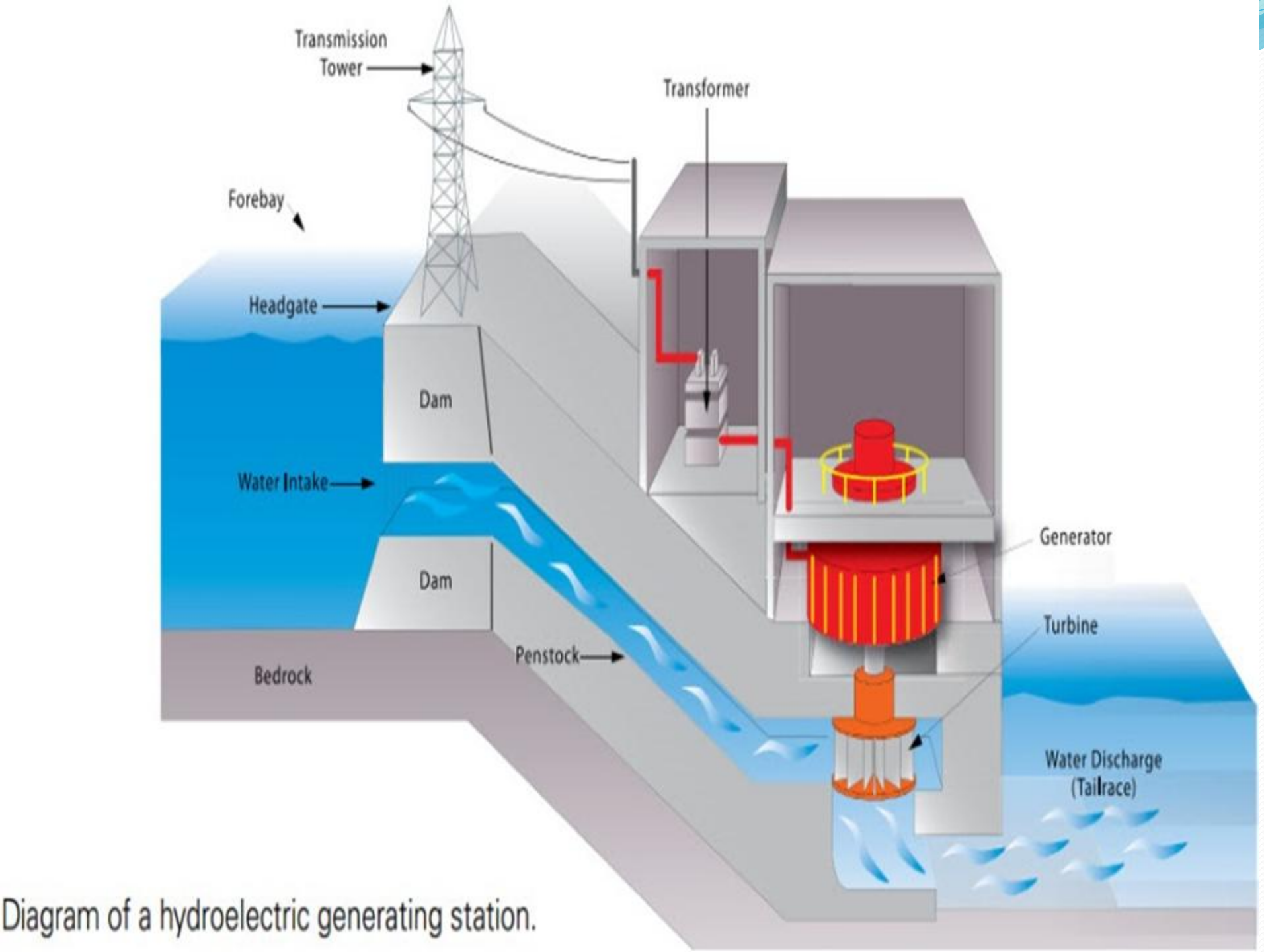



Diagram of a hydroelectric generating station.

# Wind energy

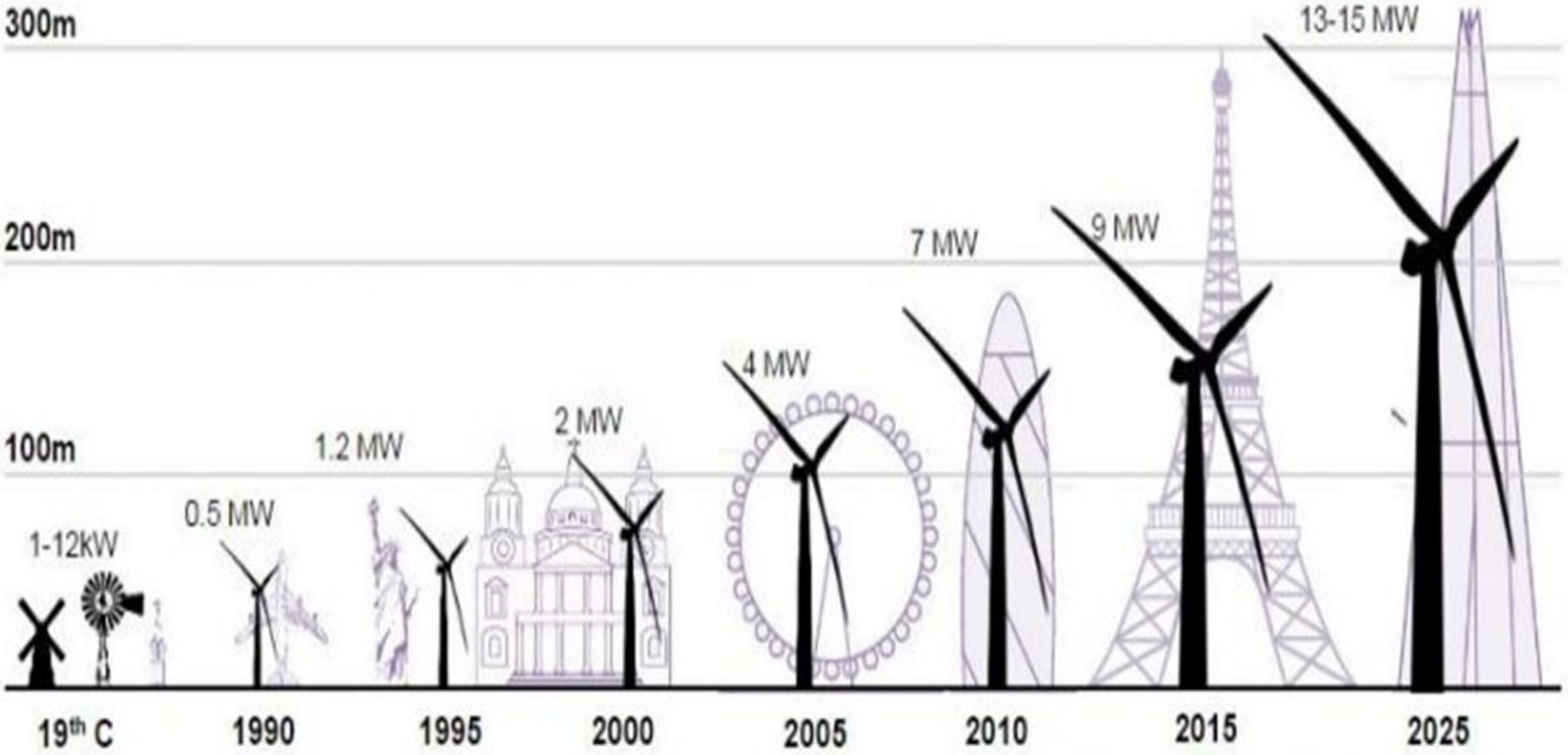
Wind energy has been used since 4000 BC to power sailboatsالمراكب الشراعية, grind grainطحن الحبوب, pump water for farms, and, more recently, generate electricity. In the United States alone, more than 6 million small windmills, have been used since the 1850s to pump water. Small windmills have been used to generate electricity since 1900, but the development of modern wind turbines occurred only recently

**Wind power is one of the fastest growing energy sources in the world** اسرع مصادر الطاقة نموا في العالم

the world's total wind energy capacity has increased to
539 GW as of the end of 2017.

**Wind is used to produce electricity by converting the kinetic energy of air in motion into electricity. In modern wind turbines, wind rotates the rotor blades الشفرات الدوارة,**
**which convert kinetic energy into rotational energy. This rotational energy is transferred by a shaft which to the generator, thereby producing electrical energy.**

# Evolution of wind turbine heights and output




*Sources: Various; Bloomberg New Energy Finance*



Bloomberg
New Energy Finance

A wind turbine converts the kinetic energy of the fluid into power.

Average wind power density

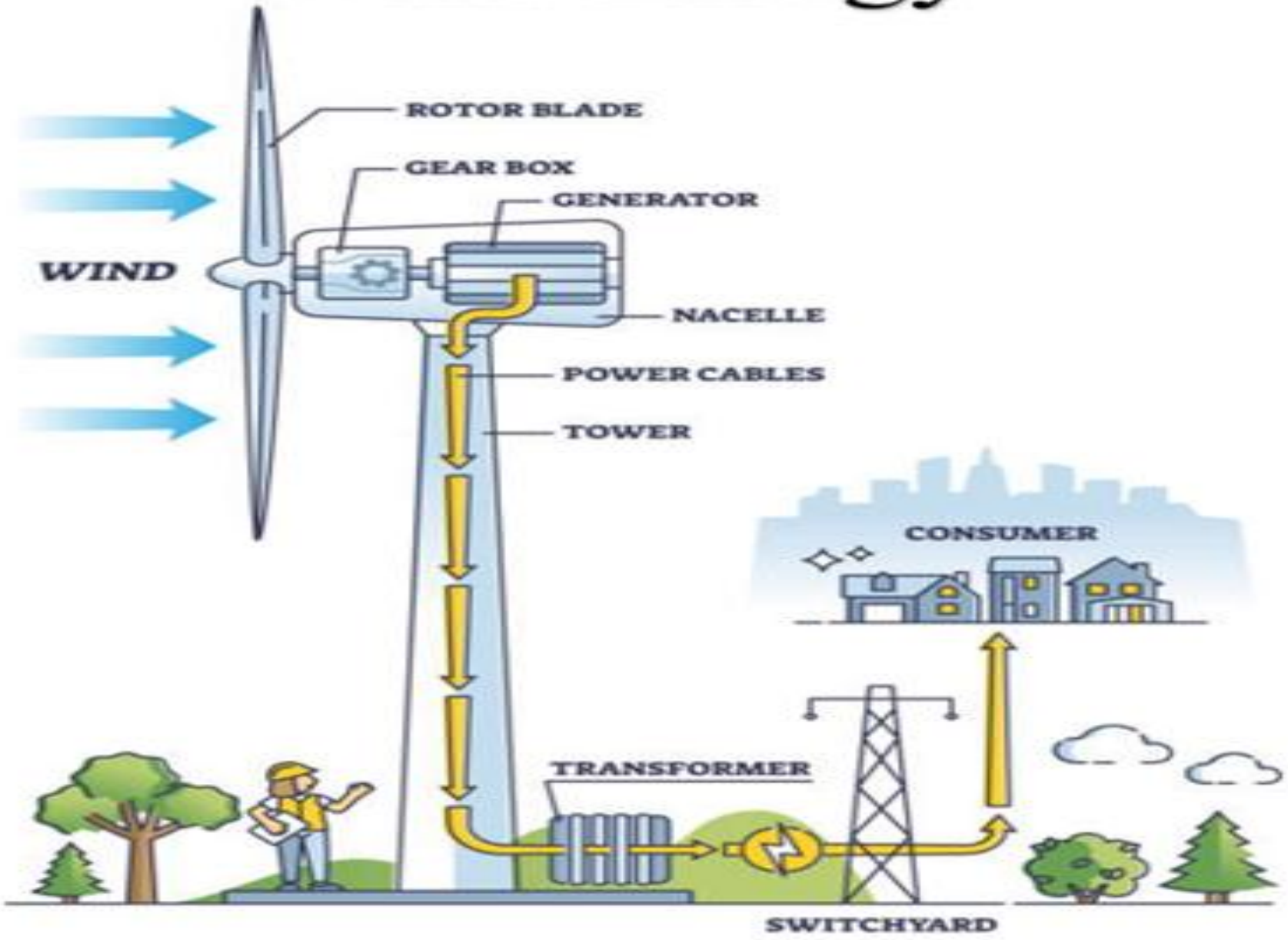
< 100 W/m2 ⇒ Poor site

≈ 400 W/m2 ⇒ Good site

- 700 W/m2 ⇒ Great site موقع رائع

- When a wind turbine project is underway on a windy siteموقع عاصف, many turbines are installed, and
- such sites are properly called as a wind farmمزارع الرياح or a wind parkحدائق الرياح

# Wind Energy


ROTOR BLADE
GEAR BOX
GENERATOR
WIND
NACELLE
POWER CABLES
TOWER
CONSUMER
TRANSFORMER
SWITCHYARD

**Advantages**

- High net energy yield
- Renewable and free
- Very clean source of energy
- No pollution (air or water) during operation
- Long operating life

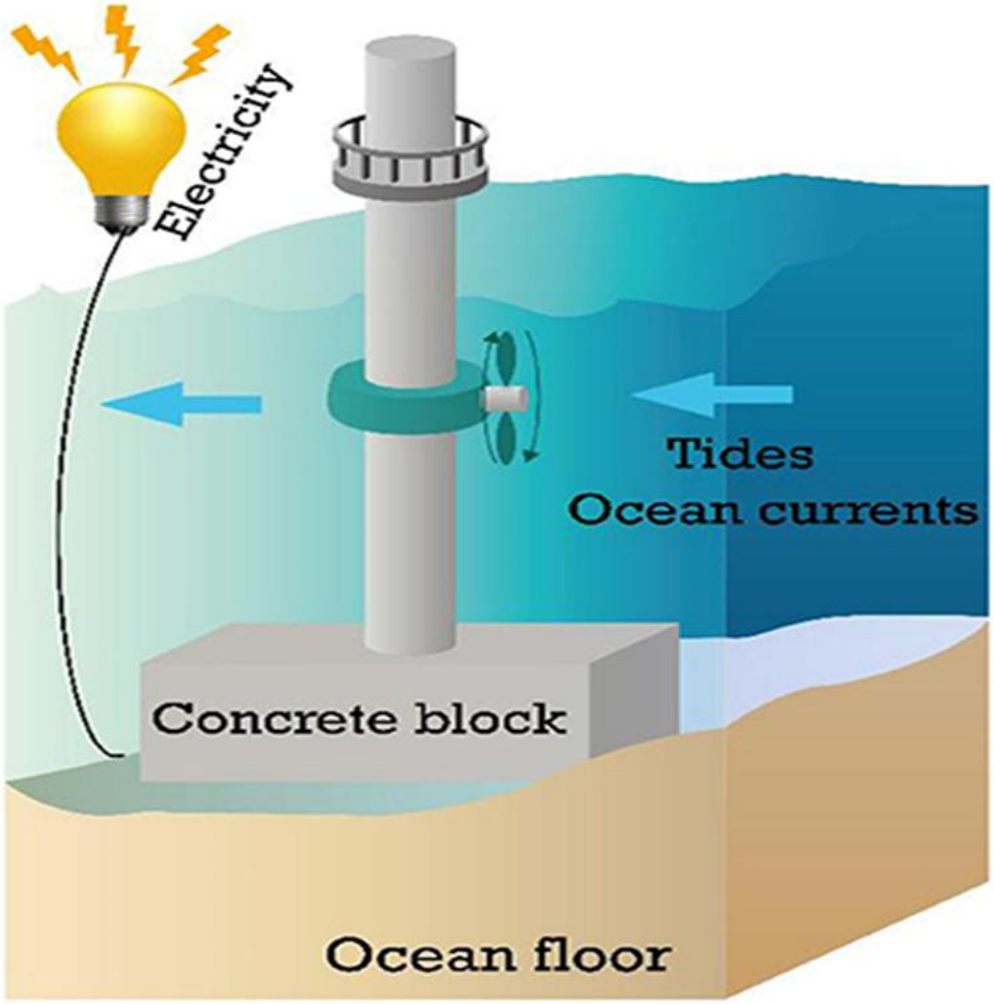
**Disadvantages**

- Energy storage issues
- An intermittent source of energy;
- Danger to birds
- Low energy density of wind

# TIDAL ENERGY طاقة المد والجزر

- Power can be produced using the energy in tides. A reservoir الخزانcan be chargedشحن by the high tide المد العاليand dischargedتفريغه by the low tide. As the water flows in and out of the reservoir it runs through a hydraulic turbine to produce power. This is similar to a hydroelectric power plantمشابه لمحطة الطاقة الكهرومائية since both systems use the potential energy of water

The tidal motionحركة of ocean and seawater is due to gravitational force قوة جاذبية of the moon القمر and that of the sun.



**Advantages:**

- It is more save than using fossil fuel
- Free Energy

**Disadvantages:**

- One of the problems with tidal energy is cost (tidal power plant is just too expensive), to build compared to other receiving power from other types of fuel like coal, gas…..etc.
- Turbines may harmمؤذي fish and animals, as well as making it difficult for fish to migrate صعوبة هجرة الاسماك.

# OCEAN THERMAL ENERGY CONVERSION (OTEC)

As a result of solar energy absorption, the water at the sea or ocean surface is warmer, and the water at a deeper locationالمواقع الاعمق is cooler. In tropical climatesالمناخات الاستوائية, surface temperatures can reach 28°C while the temperatures are as low as 4°C about 1 km below water. The ocean can be considered to be a large heat engine محرك حراري كبير with a source temperature of 28°C and a sink temperature of 4°C. Then, a heat engine can be operated that utilizes the surface warm water as heat source and deep cold water as the heat sink مشتت حراري for the conversion of heat to power.

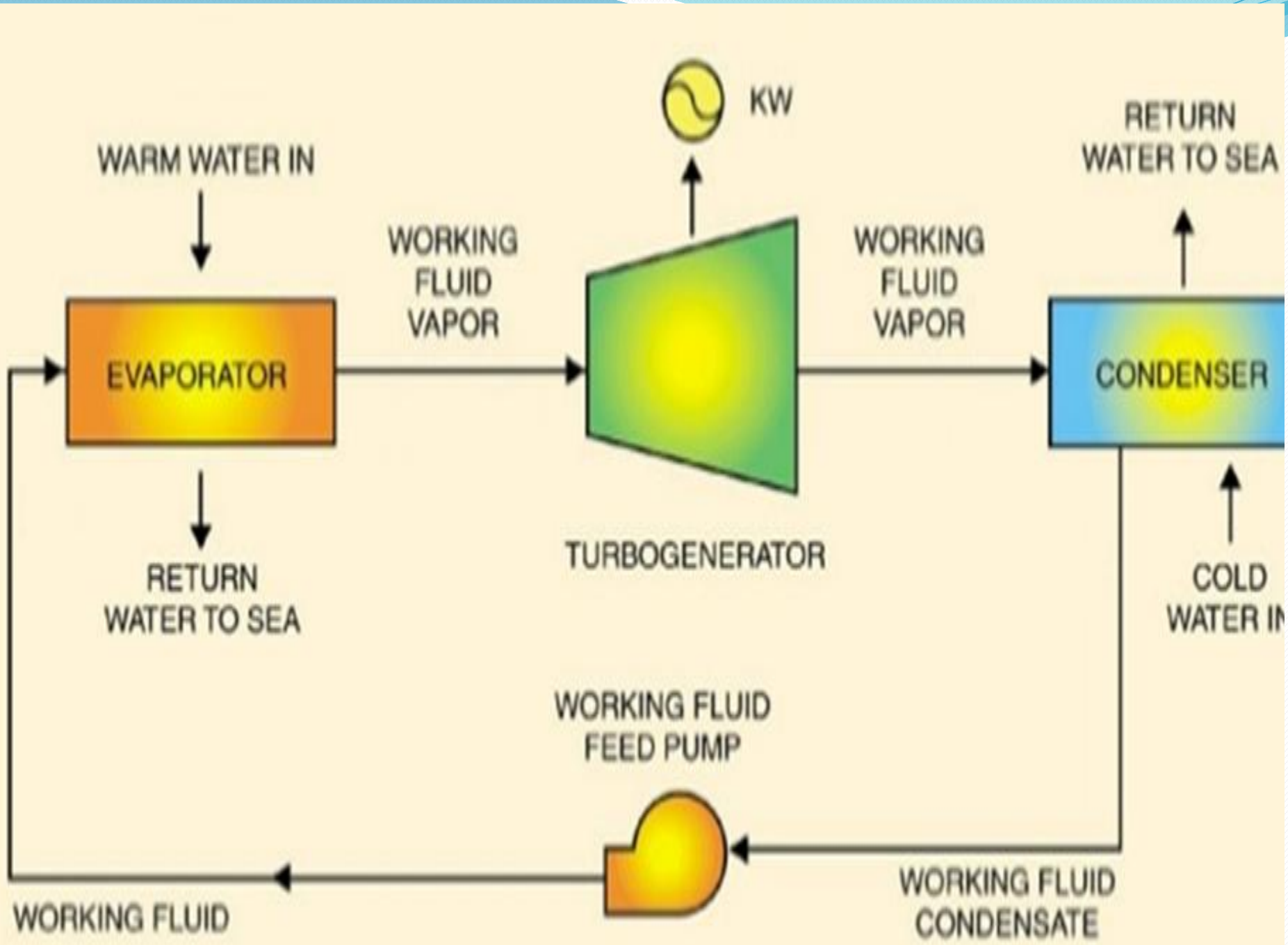
This principle of power production is called ocean thermal energy conversion (OTEC).

The energy of these processes is free مجانية, inexpensive مكلفة غيرand economically viable مجدية اقتصاديا.

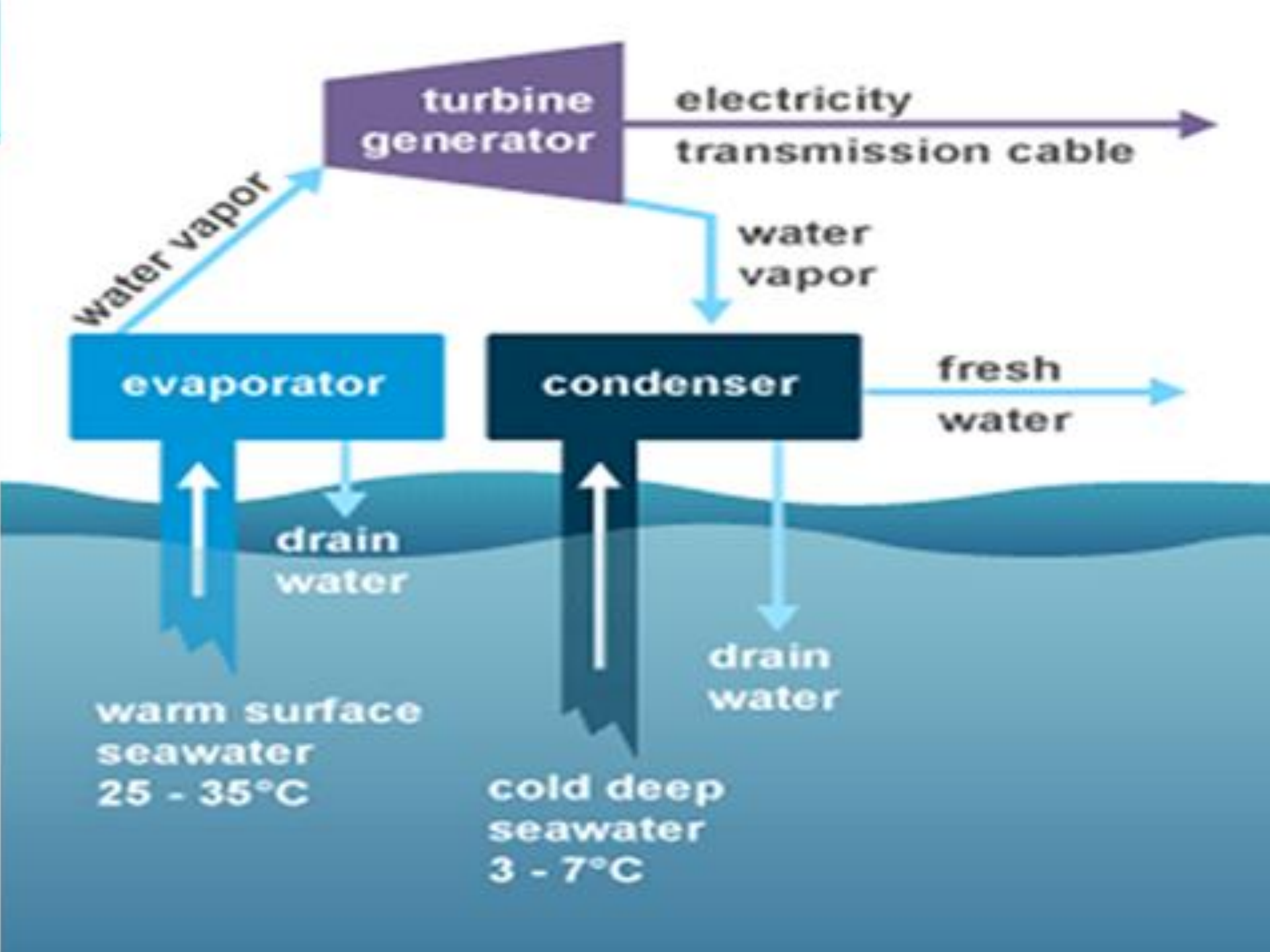
The main **disadvantage** of an OTEC plant is the low thermal efficiency.
The maximum thermal efficiency can be determined from Carnot:

$$\eta_{th,max} = 1 - \frac{T_L}{T_H} = 1 - \frac{(4 + 273)\ \text{K}}{(28 + 273)\ \text{K}} = 0.080 \text{ or } 8.0\%$$

***<u>There are two methods of application</u>:***
***The first is <u>closed-cycle system</u>****, it depends on the* use of hot water to evaporate a volatile liquid (Low boiling point) such as propane or ammonia to power a turbine to generate electricity. This liquid is then condensed.

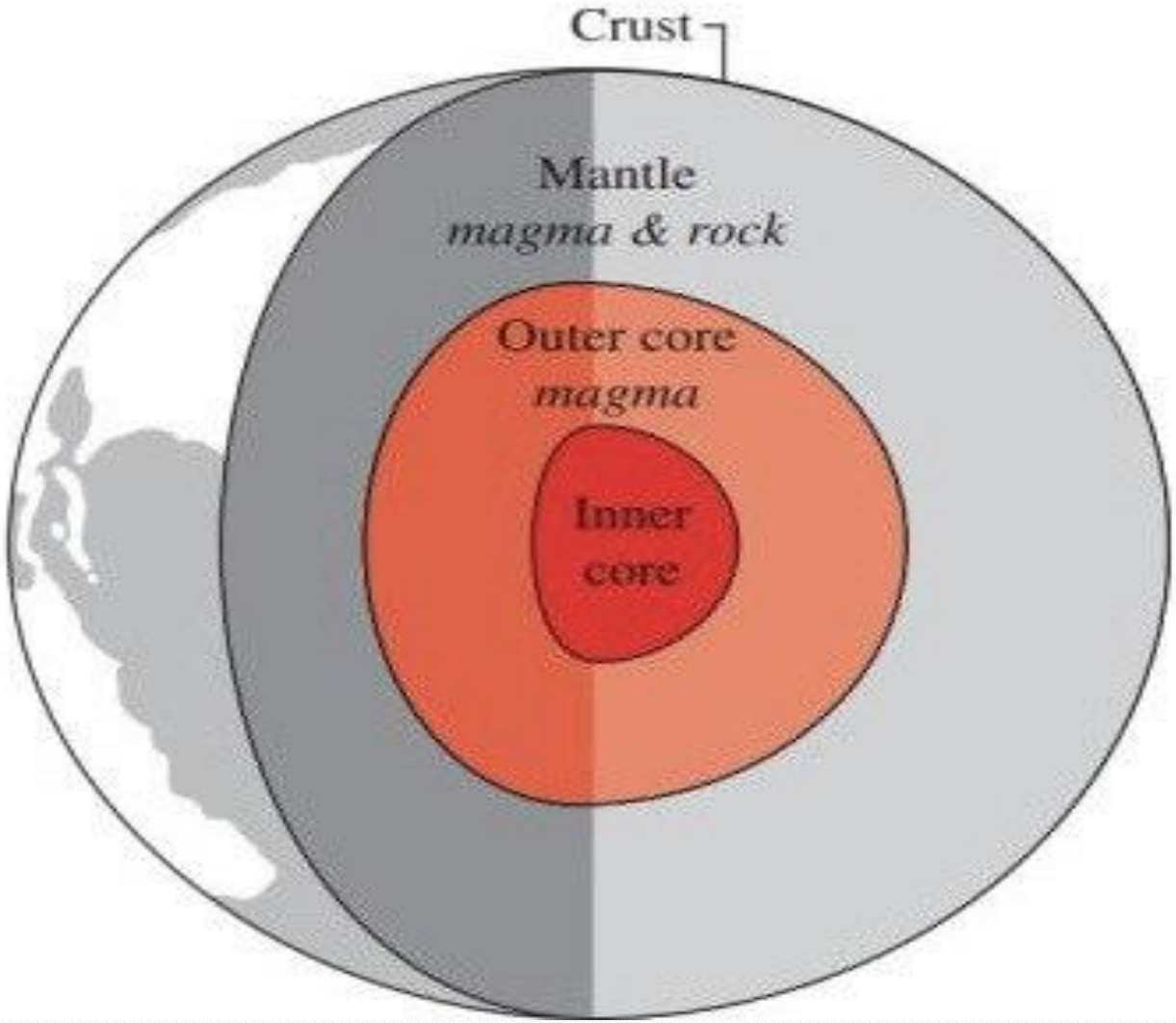

KW
WARM WATER IN
RETURN
WATER TO SEA
WORKING
FLUID
VAPOR
WORKING
FLUID
VAPOR
EVAPORATOR
CONDENSER
RETURN
WATER TO SEA
TURBOGENERATOR
COLD
WATER IN
WORKING FLUID
FEED PUMP
WORKING FLUID
WORKING FLUID
CONDENSATE

- The second method is the **open–cycle system** OTEC , depends on evaporation of the water under low pressure from the use of the hot water layer and push the steam to move the generator, and then condenses the steam again.


turbine
generator
electricity
transmission cable
water vapor
water
vapor
evaporator
condenser
fresh
water
drain
water
drain
water
warm surface
seawater
25 - 35°C
cold deep
seawater
3 - 7°C

# Geothermal

Geothermal energy is the thermal energy within the earth's interior الطاقة الموجودة في باطن الارض. It is a renewable energy source because heat is continuously transferred from within the earth to the water recycled by rainfall لان الحرارة تنتقل بشكل مستمر من داخل الارض الى المياه المعاد تدويرها عن طريق هطول الامطار. The origin of geothermal energy is earth's core and it is about 6500 km deep. The core is made up of an inner core (iron center) and an outer core made up of very hot magma الصهارة. The temperature in the magma remains very high due to **decay of radioactive** انحلال العناصر المشعة **particles**. By digging wells حفر الابار and pumping the hot water to the surface, we make use of geothermal energy الاستفادة من الطاقة الارضية.



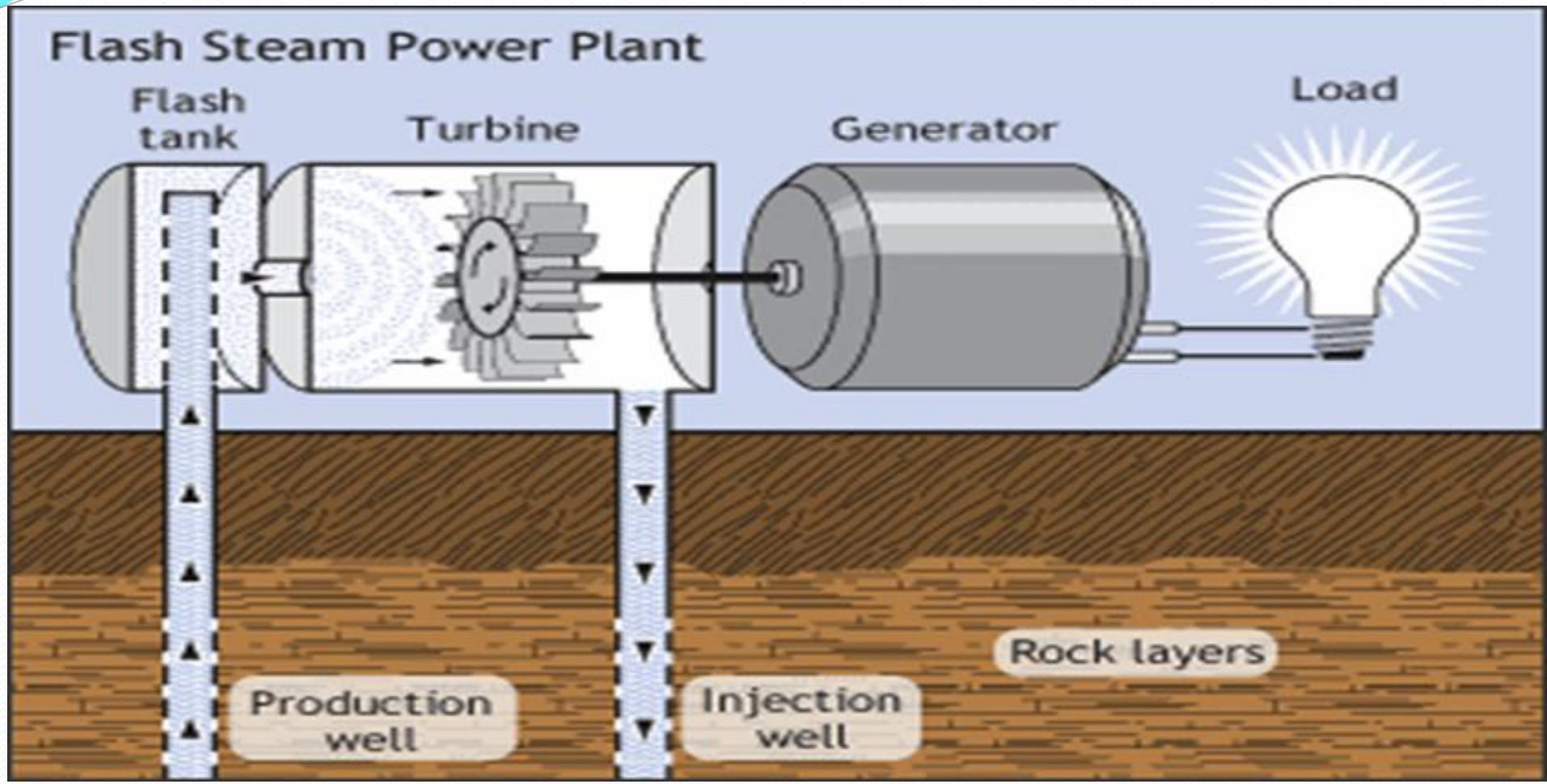

**The interior of the earth**

Geothermal energy is most commonly used for base-load الحمل الاساسيelectric power generation.

A number of residential and commercial districts مناطق are effectively heated in winter by low cost geothermal heat in many parts of the world. Some of the largest district heating installationsالمنشات are in China, Sweden, Iceland, Turkey, and the United States.

- The rate of generating electricity from geo-thermal energy about 30% in Iceland. It is a high percent.

# Generation electricity from Geo-Therm. Energy



- **Advantages of this energy:**
  No waste
- high performance
- Easy to exploit in some cases
- High net energy yield

- **Disadvantages:**
- These are the scarcity of locations (Not available everywhere)
- Air pollution, smells, some releasing of $H_2S$ gas .
- This energy can also be drained on

- The reserve of geo-thermal energy is equivalent $250\times10^9$ ton of coal which can cover the world's energy reserves for 100,000 year.

# Solar energy:

- The sun is the origin (mother) of all types of energy found on the globs. It is a renewable source and gives billion kilowatts of electricity if it is exploited correctlyصحصح بشكل استغلاله تم اذا.

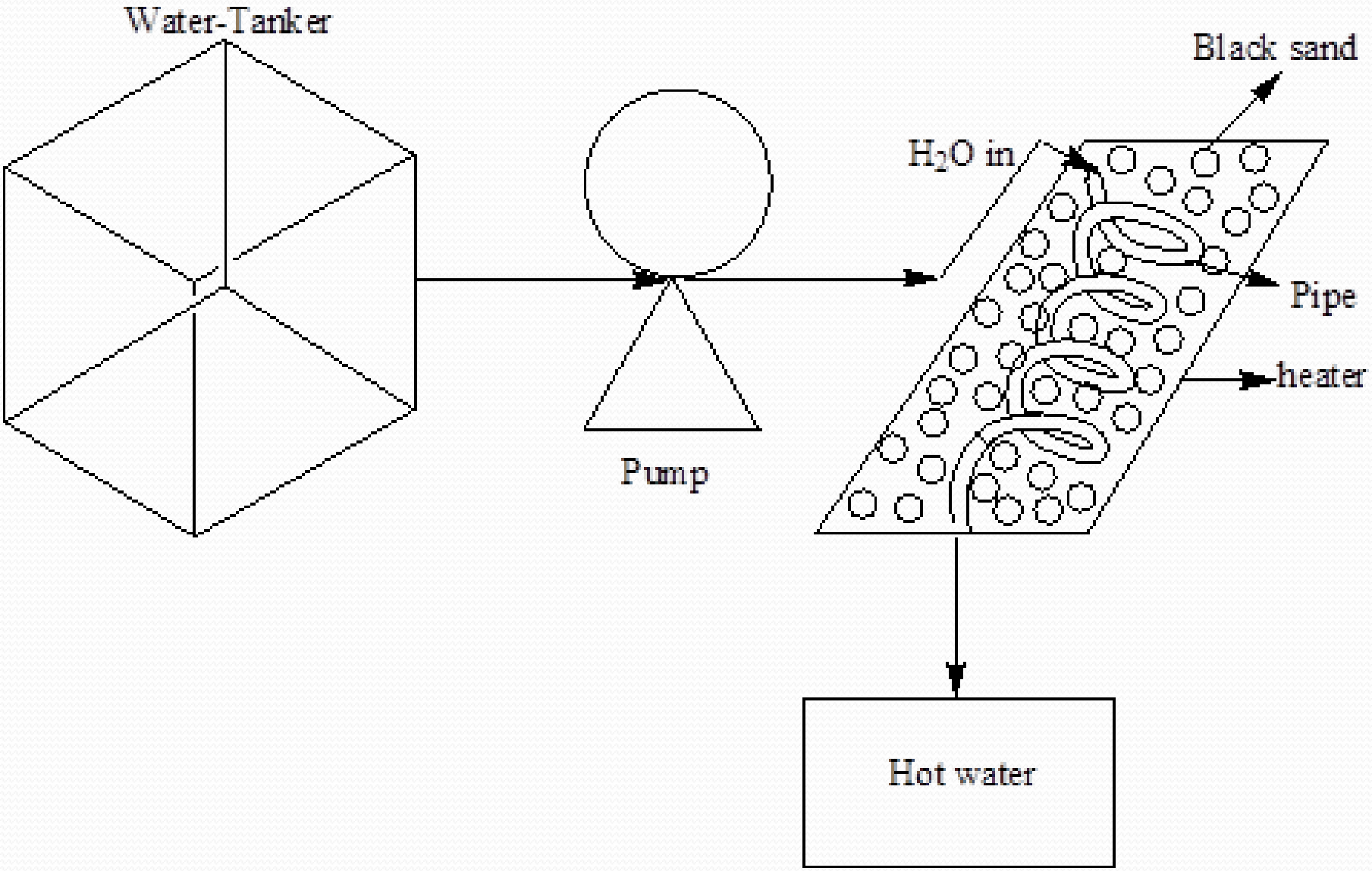
- The energy stored in oil, coal, gas and N.G is solar energy stored in the chemical bonds of these materials.
- Wind, hydro, and others are just different images of solar energy.
- The estimated amount of solar energy falling on the surface of the earth annually is about $3\times10^{15}$ G.J, which is equivalent to $10^4$ times the annual global consumption of energy الاستهلاك العالمي السنوي للطاقة($3\times10^{11}$ G.J). The bulk of this energy is reflected into space ينعكس الجزء الاكبر من هذه الطاقة الى الفضاءand a **fraction of 0.1% is stored يخزن كطاقة as a chemical energy in the process of photosynthesis عمليات التركيب الضوئي في النبات كيميائية in the plant called "biomass الكتلة الحيوية".**

- Solar energy exploited in the following directions:

# *Direct heating*: التسخين المباشر

- Collect solar radiation تجميع الاشعاع الشمسي using reflective mirrors باستخدام مرايا عاكسة of flat assemblies للتجمعات المسطحة and utilize the absorbed energy in heating water and heating homes تدفئة المنازل.

A. **Solar heater السخان الشمسي**: is an example of this application, it represented a direct means to convert sunlight to thermal energy. As in the following figure:


Water-Tanker
Pump
$H_2O$ in
Black sand
Pipe
heater
Hot water

- **Black sand** is to increase temperature.
- **Heater** is a box of glass to increase absorption of sunlight, due to glass a one direction filter.
- **The pipe is helical**حلزوني_to increase time that water spends inside the pipe so as to hotter.

B. **Solar furnaces:**

- Solar furnace is a device that uses an array of mirrorsمجموعة مرايا to redirect لاعادة توجيه and concentrate وتركيز the sun's rays اشعة الشمسon to a small surface area مساحة سطحية صغيرة thus producing extremely high tempانتاج درجة حرارة عالية جدا. The temp. Can go as high as 3500ºC.

- **General use of solar furnace:**

- Running steam turbines for solar power plant.
- Cook food and boil water in a solar oven.
- Produce hydrogen fuel
- Perform scientific experiments which require extreme temp. without pollution.

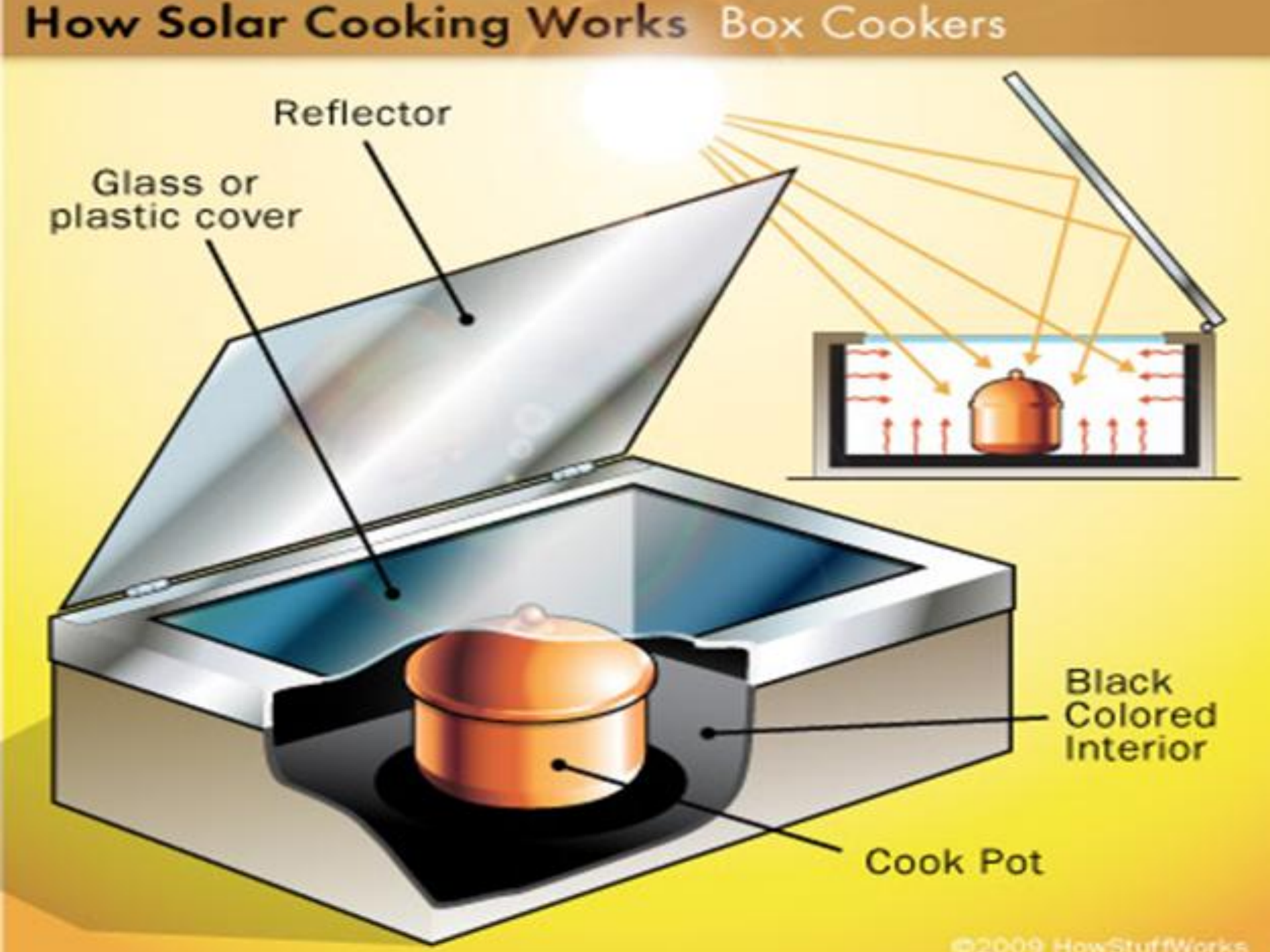
- **Advantages of solar furnace:**

- Heat produced is very clean,
- Low cost.
- Reduce to need the cut down forests for fire wood.

- **Disadvantages:**

- The radiation from it is harmful to the face and eyes.

# How Solar Cooking Works Box Cookers



1. **Solar cell**

- It is an electrical device that converts the energy of light directly into electricity.
-

1. **Photosynthesis عملية البناء الضوئي:**

- **Indirect path to energy exploitation مسار غير مباشر لاستغلال الطاقة الشمسية.**
- It's the most effective natural way الطريقة الاكثر فعالية to capture and store solar energy لاستغلال وتخزين الطاقة الشمسية despite its low efficiency بالرغم من كفاءتها الواطئة.
- The process of photosynthesis involve the reduction اختزال of $CO_2$ (obtained by the plant from the atmosphere) in the green part of the plant cell في الجزء الاخضر من الخلية النباتية, by the light of the sun, glucose is formed. in the following equation:
-

- $$6CO_2 + 6H_2O \xrightarrow{hv} C_6H_{12}O_6 + 6O_2$$

- Plants vary in their susceptibility to sunlight, so they will vary in growth and cellulose formation.
- The cellulose extracted from the plant can be converted into liquid substances similar to crude oil by a similar process to the coal liquefaction process.
- The idea of establishing plantation (energy crops) emerged ظهرت.

- **Plantation (energy crops) محاصيل او مزارع الطاقة:**
- They are used to convert the solar energy into raw materials مواد اولية for the production of energy.
- **The advantages of this technique can be summarized as follows:**

- A renewable and inexhaustible انبعاثات بدونsource.
- Source with a slight environmental impact تأثير بيئي خفيف.
- Grows in a short period of time (6-12) months and gives a bulk amounts.

- **Disadvantages of plantation or(energy crops):**

- Low land efficiency for agriculture خفض كفاءة الاراضي للزراعة.
- Mineral consumption of soil استهلاك معادن التربة.
- Competition on land and irrigation water التنافس
- على الاراضي ومياه الري بين محاصيل الطاقة وزراعة غذاء الانسان between energy crops and cultivation human food.

# Biomass Energy

- Biomass is an organic renewable energy. It is mostly produced from agriculture and forest products and residues, energy crops, and algae الطحالب. Organic component of municipal and industrial wastes النفايات السكنية والصناعيةand the fuel produced from food processing waste such as used cooking oil زيت الطهيare also considered biomass. Despite relatively long period of times involved in growing crops and trees, they can be re-grown by planting, and therefore biomass is considered to be a renewable energy source. It is estimated that about half of all renewable energy consumed in the United States is biomass تشير التقديرات الى ان نصف الطاقة المتجددة المستهلكة في اميركا هي من الكتلة الحيوية.

# CONVERSION OF BIOMASS TO BIOFUEL

- Biomass can be converted into liquid or gaseous fuels through biochemical- and thermochemical-based conversion processes.
- **In biochemical conversion processes**, enzymes and microorganisms are used as biocatalysts to convert biomass or biomass-derived compounds into desirable productsنواتج مرغوبة. Cellulose and hemicelluloses enzymes انزيمات break down the carbohydrate fractions of biomass to five- and six-carbon sugars in a process known as hydrolysis. Yeast الخميرة and bacteria then fermentتخمير the sugars into products such as ethanol.

In thermochemical conversion processes في عمليات التحويل الكيميائي الحراري, **heat energy and chemical catalysts** are used to break down biomass into intermediate compounds or products.
***In gasification***, biomass is heated in an oxygen-starved environment بيئة متعطشة للاوكسجين to produce a gas composed primarily of hydrogen ($H_2$ ) and carbon monoxide (CO).
***In pyrolysis***, biomass is exposed to high temperatures without the presence of air, causing it to decompose.

Solvents, acids, and bases can be used to fractionate biomass into an array مجموعة of products including sugars, cellulosic fibers, and lignin.

# BIOMASS PRODUCTS

- A major product of biomass is biofuels المنتج الرئيسي للكتلة الحيوية هو الوقود الحيوي, which are a replacement البديل for petroleum-based fuels الوقود النفطي.
- Biofuels can be liquid or gas. They are mostly في الغالب used for transportation as the engine fuel but also used for heating and electricity generation
- . **The two most common biofuels are ethanol and biodiesel**. Other products include methanol, pyrolysis oil, biogas and synthesis gas.
- Biomass is primarily used to produce biofuels such as ethanol and biodiesel but other products made from fossil fuels can also be made by biomass. Some of these products include antifreezeمانع الانجماد, plastics, glues المواد اللاصقة, artificial sweetenersالمحليات الصناعية, and gel for toothpaste هلام معجون الاسنان.

# Ethanol

- Ethanol or ethyl alcohol (C2 H5 OH) has a higher heating value (HHV) of 29,670 kJ/kg. and a lower heating value (LHV) of 26,810 kJ/kg. This is significantly lower than those of gasoline (HHV = 47,300 kJ/kg, LHV = 44,000 kJ/kg)
- Ethanol has less hydrocarbon (HC) emissions than gasoline اقل انبعاثات هيدروكربونية, and is commonly added to gasoline for improved emission from the engines لتحسين انبعاثات المحرك. Its use also represents a renewable replacement for gasoline يمكن استخدامه كبديل متجدد للكازولين. Adding ethanol to gasoline increases the octane number of gasoline allowing higher compression ratios نسبة الانضغاط and corresponding higher efficiencies for the engine يقابل ذلك كفاءة اعلى للمحرك.
- Two common uses of ethanol for automobiles السيارات in the United States include gasohol and E85. Gasohol is a gasoline-ethanol mixture with 10 percent ethanol while E85 contains 85 percent ethanol.

Ethanol is made primarily from the starch in corn grain. Corn, sugar beets, sugar cane, and even cellulose (wood and paper) are some of the sources of ethanol. Corn is the major source in the United States while sugar beets are primarily used in Brazil. The feedstock used for ethanol should be high in sugar content. First, **the feedstock is converted to sugar, and the sugar (glucose) is fermented into ethanol through the following reaction**:

$C_6H_{12}O_6 \rightarrow 2\,C_2H_5OH + 2\,CO_2$

The cost of producing ethanol is relatively high due to growing of corn and manufacturing and processing involved. Some studies suggest that the energy consumed during the production of ethanol (plowingالحرث, planting, harvestingالحصاد, fermentingالتخمير, and delivery) can be quite high per unit mass of the ethanol produced .

# Biodiesel

Biodiesel is ethyl or methyl ester that is produced through a process that combines organically derived oils with ethanol or methanol in the presence of a catalyst.

Common sources المصادر الشائعة of biodiesel include new and used vegetable oils, animal fats, and recycled restaurant greases شحوم المطاعم المعاد تدويرها.

The HHV of biodiesel is about 40,700 kJ/kg (17,500 Btu/lbm), which is about 12 percent less than that of petroleum diesel (HHV = 46,100 kJ/kg).

Biodiesel can be used in compression ignition engines as a single fuel or can be added to conventional diesel fuel. The most common biodiesel mixture used in the United States is B20, which is 20 percent biodiesel and 80 percent conventional diesel. Biodiesel is also used as a single fuel in compression ignition engines, called B100. Whereas B20 can be used in a diesel engine without any modification,

# Methanol

Methanol or methyl alcohol ($CH_3OH$) has a HHV of 22,660 kJ/kg and a LHV of 19,920 kJ/kg. This is less than half of the values for gasoline.
Pure methanol and its blend with gasoline have been extensively tested as an alternative fuel to gasoline.
Two common mixtures are M85 (85 percent methanol, 15 percent gasoline) and M10 (10 percent methanol, 90 percent gasoline).
M85 reduces HC and carbon monoxide (CO) emissions significantly while also replacing more of gasoline consumption يقلل من استهلاك الكازولين

## Pyrolysis Oil

Pyrolysis oil is produced when biomass is exposed to high temperatures without the presence of air, causing it to decompose. A possible reaction involves heating of cellulosic feedstock in grain form for a short period (less than half a second) to a temperature of 400°C to 600°C and quenching it.

The product is highly oxygenated and has considerable amounts of water. This makes these liquids corrosive and unstable with a low heating value.

Pyrolysis oil is not suitable as a replacement to conventional fuels such as gasoline or diesel. Further processes are needed to make this fuel compatible with conventional HC fuels. A chemical called phenol can be extracted from pyrolysis oil, and it is used to make wood adhesives, molded plastic, and foam insulation

# Biogas

Biogas, also called swamp gas, landfill gas, or digester gas, usually consists of 50 to 80 percent methane ($CH_4$ ) and 20 to 50 percent carbon dioxide ($CO_2$ ) by volume. It also contains small amounts of hydrogen, carbon monoxide, and nitrogen.

the HHV of methane is 55,530 kJ/kg,

Biogas can be produced from biological waste such as animal manure, food waste, and agricultural waste. The process is called anaerobic digestion which is the decomposition of organic waste into a gaseous fuel by bacteria action without the presence of oxygen. It is possible to produce 200 to 400 m3 of biogas from 1000 kg of organic waste with 50 to 75 percent methane by volume

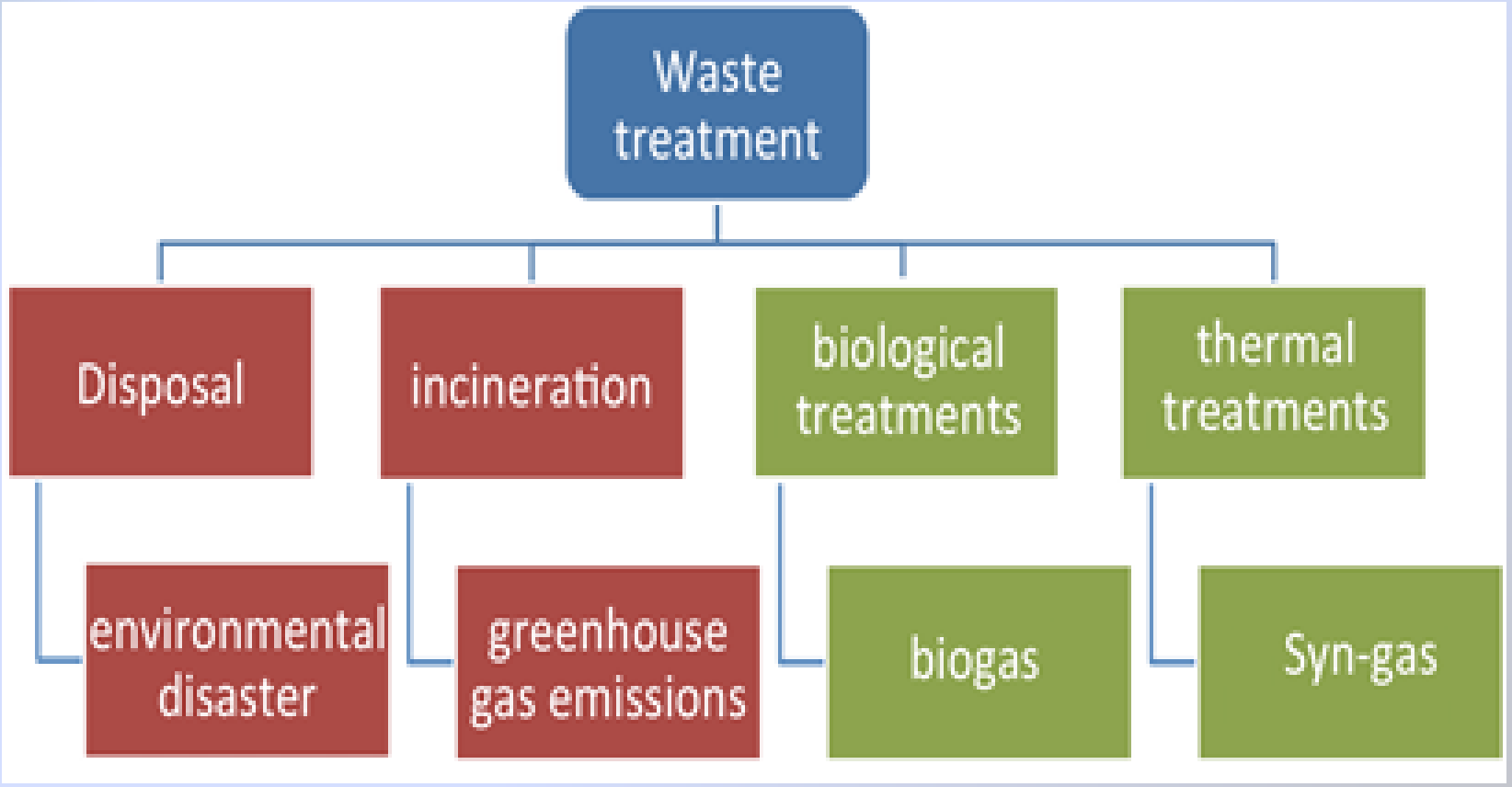
## Synthesis Gas

Synthesis gas is also called biosynthesis gas or syngas, and is produced by thermal gasification using oxygen. It consists of CO and H2 . If a synthesis gas has 50 percent CO and 50 percent H2 fraction by volume, its LHVs and HHVs will be 17,430 kJ/kg and 18,880 kJ/kg, respectively. Synthesis gas is commonly produced from natural gas, coal, and heavy diesel. However, its production from wood and other solid biomass can be used to produce syngas. In addition to being used as the fuel for conversion to heat and electricity, synthesis gas can be used to make plastics and acids, which can then be used to make photographic films, textiles, and synthetic fabrics

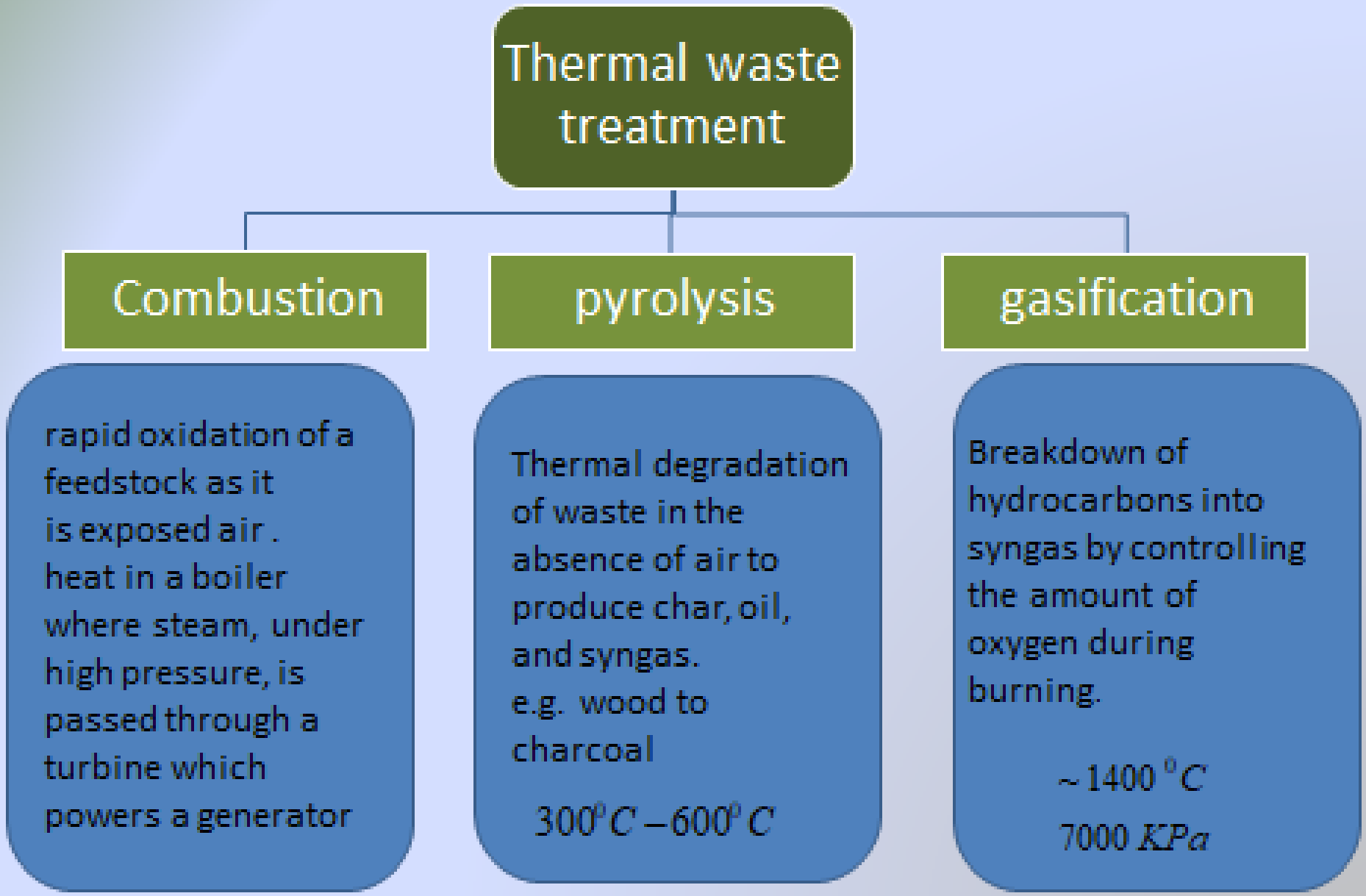
# ELECTRICITY AND HEAT PRODUCTION BY BIOMASS

The production of electricity and heat from biomass is called biopower الطاقة الحيوية. The installed capacity of bio power in the United States is about 10 gigawatts. There are three technologies used to convert biomass energy to heat and electricity: direct combustion, co-firing, and anaerobic digestion الهضم اللاهوائي

# Waste treatment: OLD *vs.* reNEWable

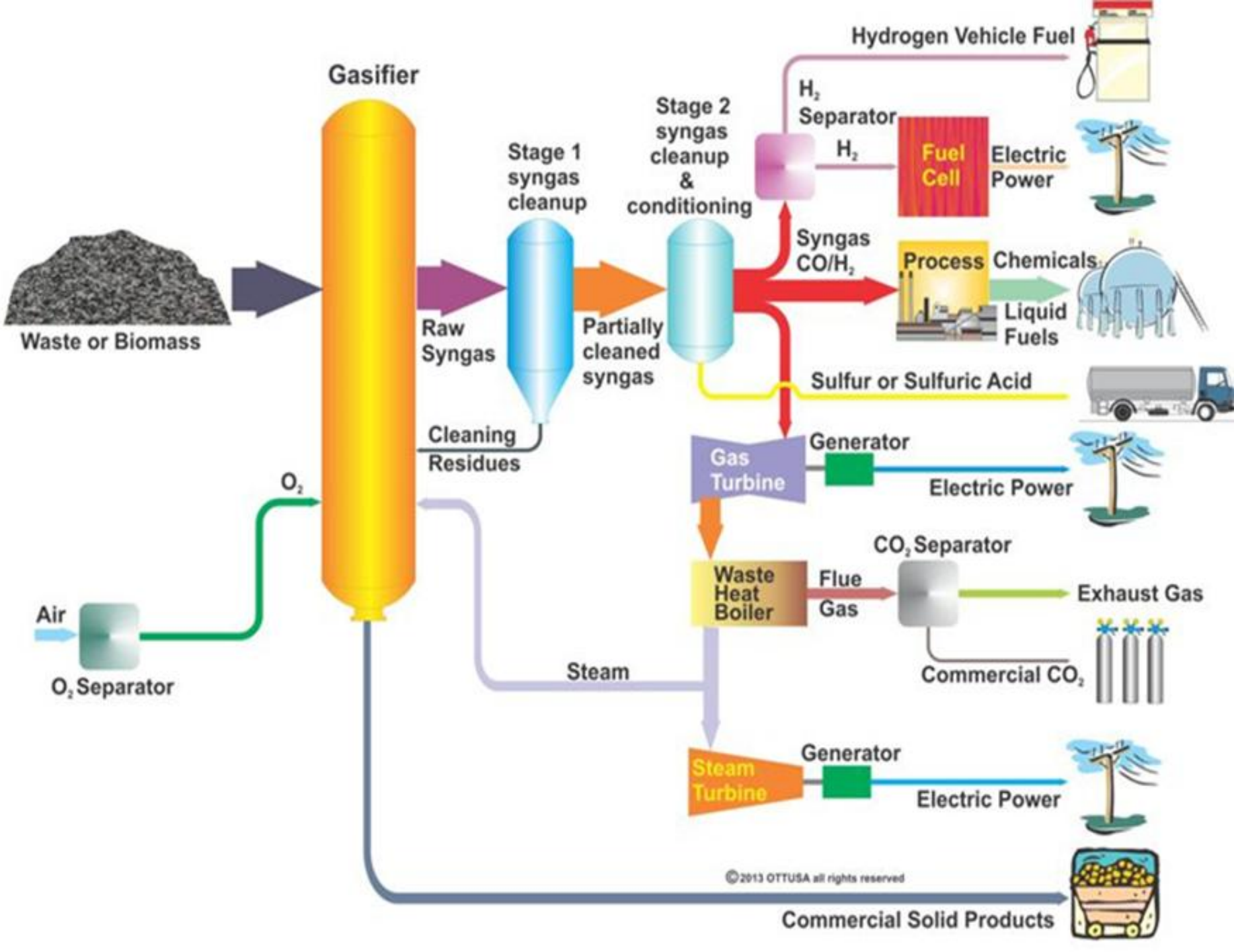


# Thermal waste treatment



# Advantages ( *if goals are achieved*)

- Reduction of municipal and industrial waste disposal.
- Reduction of $CO_2$ emissions from incineration.
- Use of renewable **low cost** feedstocks
- Converting waste into ultra clean-diesel.
- Use of sustainable methods to convert waste into useful products


Hydrogen Vehicle Fuel
Gasifier
$H_2$ Separator
Stage 2 syngas cleanup & conditioning
Stage 1 syngas cleanup
$H_2$
Fuel Cell
Electric Power
Waste or Biomass
Raw Syngas
Partially cleaned syngas
Syngas $CO/H_2$
Process Chemicals
Liquid Fuels
Sulfur or Sulfuric Acid
Cleaning Residues
Gas Turbine
Generator
Electric Power
$O_2$
$CO_2$ Separator
Waste Heat Boiler
Flue Gas
Exhaust Gas
Air
$O_2$ Separator
Steam
Commercial $CO_2$
Steam Turbine
Generator
Electric Power
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Commercial Solid Products

- **Primary and secondary sources of energy:**
- All types and forms of energy sources mentioned previously are primary sources of energy.

- **Secondary energy sources:**

The energy that can be obtained from an initial source of energy.

- Example:
- Electrical energy is a secondary sources of energy can be obtained by exploitation hydraulic sources, wind power or organic fuel burning or solar (all are primary sources of energy).

- **Hydrogen:**

- One of the secondary sources that is important position with in future energy sources.
- It's a clean fuel due to its combustion produces water as a final product.

- Many methods were used to produce hydrogen such as:

1. Gasification of coal and biomass
2. Electro analysis of water
3. Thermal chemical methods

- **Uses of hydrogen gas:**

- Operation of internal combustion engines.
- Fuel for spaceships.
- Production of current in fuel cells.

- **Advantages of $H_2$ as a fuel:**

- Renewable energy source.
- Clean and safe.
- When burned, it does not produce harmful gases.
- Has a very high energy density

- **Disadvantages:**

- Not available as independent gas.
- Extracting from water is very expensive.

# HYDROGEN: AN ENERGY CARRIER

- One major problem with renewable energy sources is inability to store the produced energy in a viable manner(قابلة للتطبيق). This is not a problem with biomass since the fuels produced from biomass such as ethanol and biodiesel can be stored and used anytime. However, the electricity produced from solar systems, hydroelectric dams, geothermal power plants, and wind turbines cannot be stored for later use. Batteries are not a viable option in today's technology due to their limited capacity. One possible solution to this problem is **production of hydrogen from renewable electricity by the electrolysis of water. Once produced, hydrogen can be stored and used anytime**.

# Hydrogen and Fuel Cells
# HYDROGEN: AN ENERGY CARRIER

- Hydrogen is a colorless, odorless, nonmetallic, tasteless, highly flammable (قابل للاشتعال بشدة)diatomic gas with the molecular formula H2 . It is also the lightest element with a molecular mass of 2.016 kg/kmol. Hydrogen is a fuel with a higher heating value of 141,800 kJ/kg and a lower heating value of 120,000 kJ/kg. Note however that hydrogen is not an energy source like coal, oil, and natural gas since there are no hydrogen reserves in the earth. Although hydrogen is the most plentiful element (اكثر العناصر وفرة)in the universe(الكون), making up about three quarters of all matter, free hydrogen is scarce. Hydrogen must be produced from other fuels such as natural gas or from water through electrolysis by consuming electricity. Therefore, hydrogen should be called an energy carrier rather than an energy source.

- Currently, most hydrogen is produced from natural gas through steam reforming process.
- This reaction can be written as
- $CH_4 + H_2O \rightarrow CO + 3H_2$
- The steam reforming reaction can be followed by a water-gas shift reaction to obtain more hydrogen:
- $CO + H_2O \rightarrow CO_2 + H_2$
- The combination of the two reactions gives
- $CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$
- Hydrogen is also produced from oil, coal, and biomass.

Once produced, hydrogen can be used as a fuel for an internal combustion engine. It can be burned just like gasoline or a fuel cell can be used to convert energy of hydrogen into electricity. **One of the greatest advantages of hydrogen** is that the exhaust of a hydrogen engine does not contain carbon monoxide, sulfur, hydrocarbon, or carbon dioxide emissions. The exhaust of a fuel cell using hydrogen is water.

Hydrogen is the primary fuel to power fuel cells. Fuel cell–powered cars, bikes, stationary and portable generators, electronic devices such as computers and cell phones can all use hydrogen as the fuel. A mobile phone powered by a fuel cell using hydrogen as the fuel can have several months of battery life compared to just several days with the current batteries. Hydrogen can be used in variety of applications including electricity generation plants, and various industrial, commercial, and residential uses .

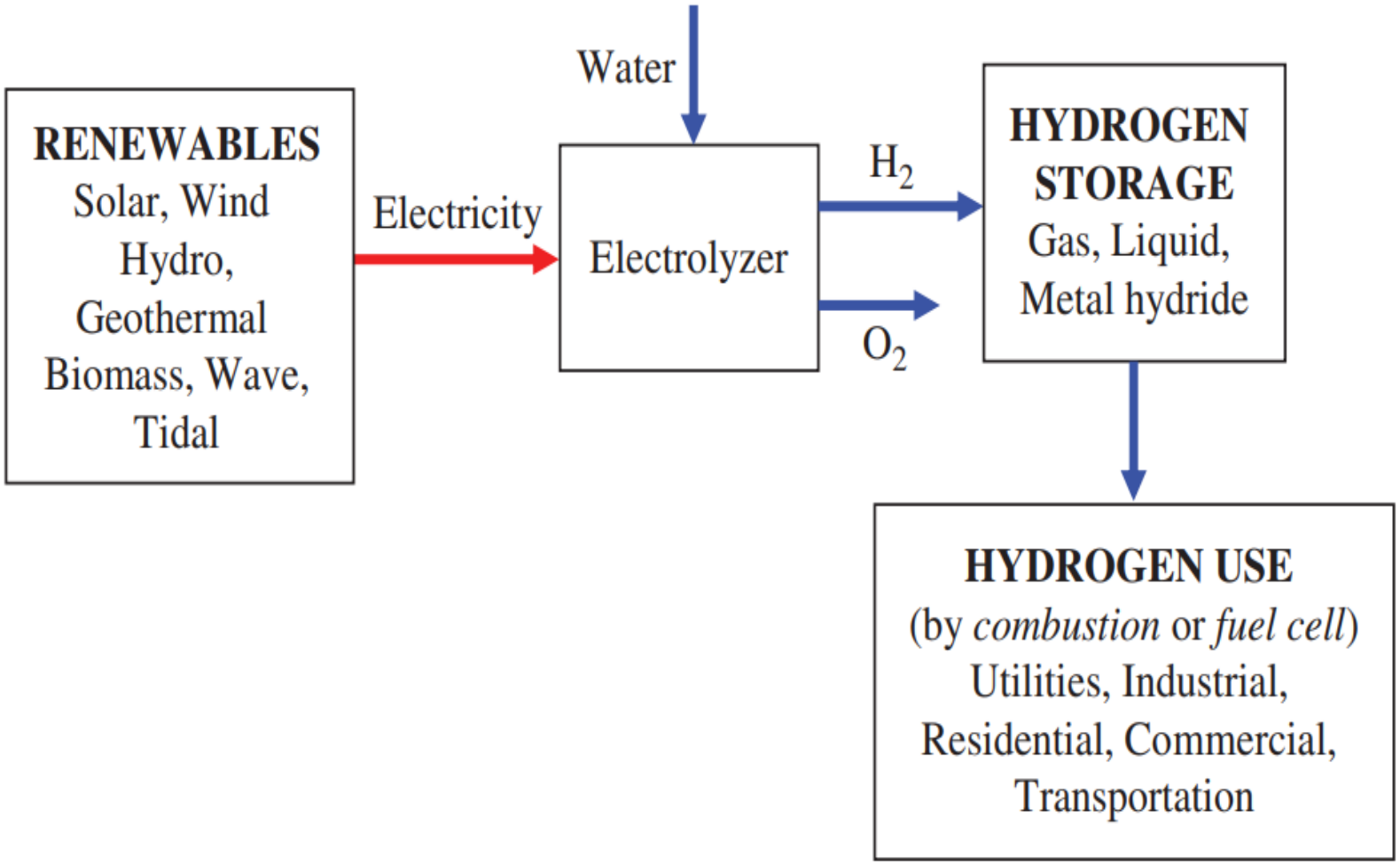
# Quiz 4 28/1/2025

- Advantages of $H_2$ as a fuel

Draw a diagram showing : Production, storage and Utilization of Hydrogen

- **Advantages of $H_2$ as a fuel:**

- Renewable energy source.
- Clean and safe.
- When burned, it does not produce harmful gases.
- Has a very high energy density




Production, storage, and utilization of hydrogen.