MODULE IV

Resources and its utilisation:

Basic concepts of Conventional and non-conventional energy,

General idea about solar energy, Fuel cells, Wind energy, Small hydro plants, bio-fuels, Energy derived from oceans and Geothermal energy.

Energy Sources

Energy is involved in all life cycles

Consider an elementary food chain:

- ✓crops need energy from solar radiation to grow
- ✓harvesting needs energy from the human body in work
- ✓ cooking needs energy from biomass in a fire.
- ✓food, in its turn, provides the human body with energy.

Energy can exist in various forms.

Radiation Energy

Chemical Energy

Potential Energy

Kinetic Energy

Thermal Energy

Mechanical Energy

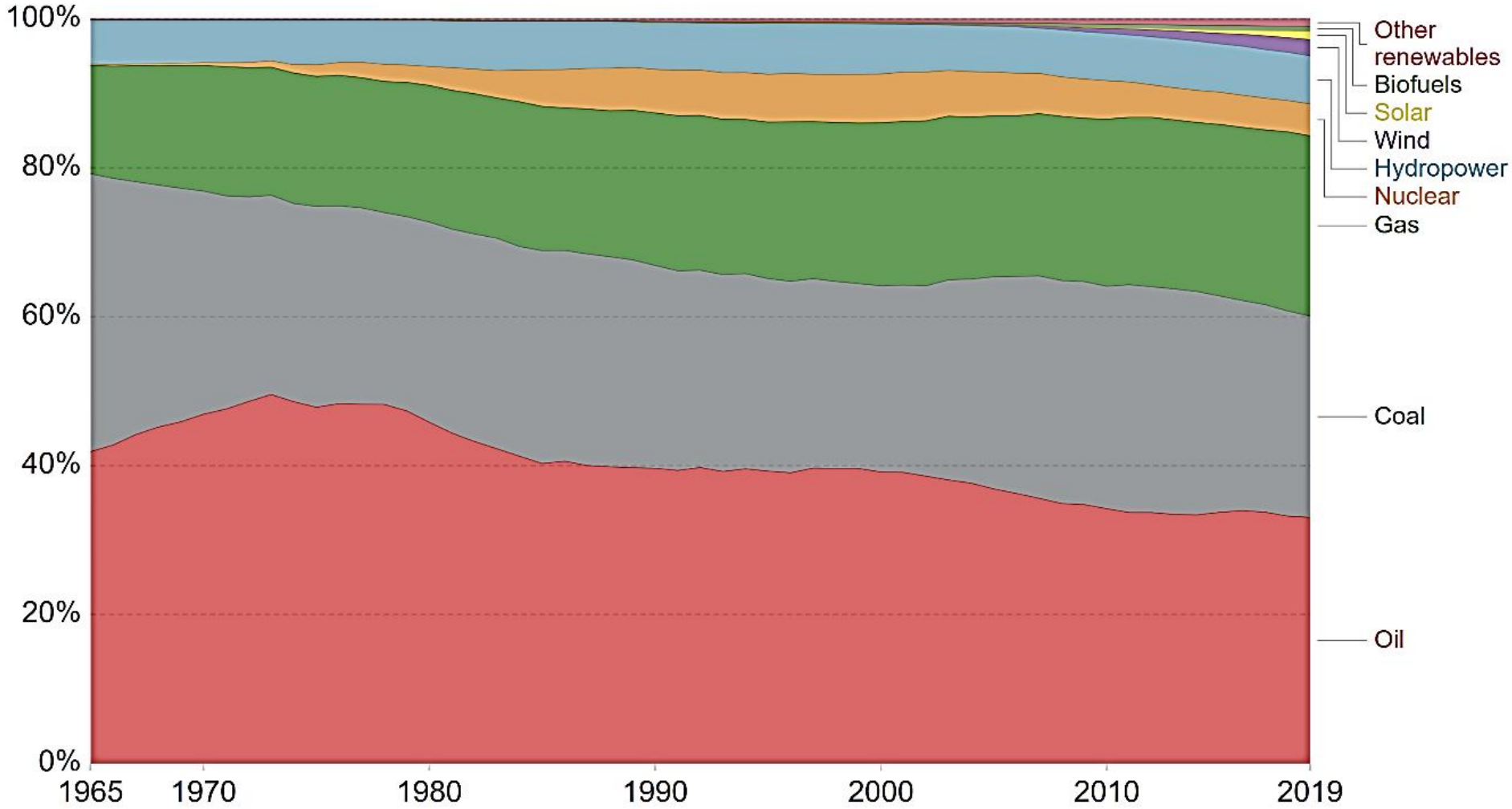
Electrical Energy

The potential for energy :

- improve living standards, whether through the freeing of time from household chores (for example, washing clothes or cooking)
- increased productivity
- improved healthcare and education services
- digital connections to local, regional and global networks.

Energy consumption by source, World

Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption.



Source: BP Statistical Review of World Energy
Note: 'Other renewables' includes geothermal, biomass and waste energy.

OurWorldInData.org/energy • CC BY

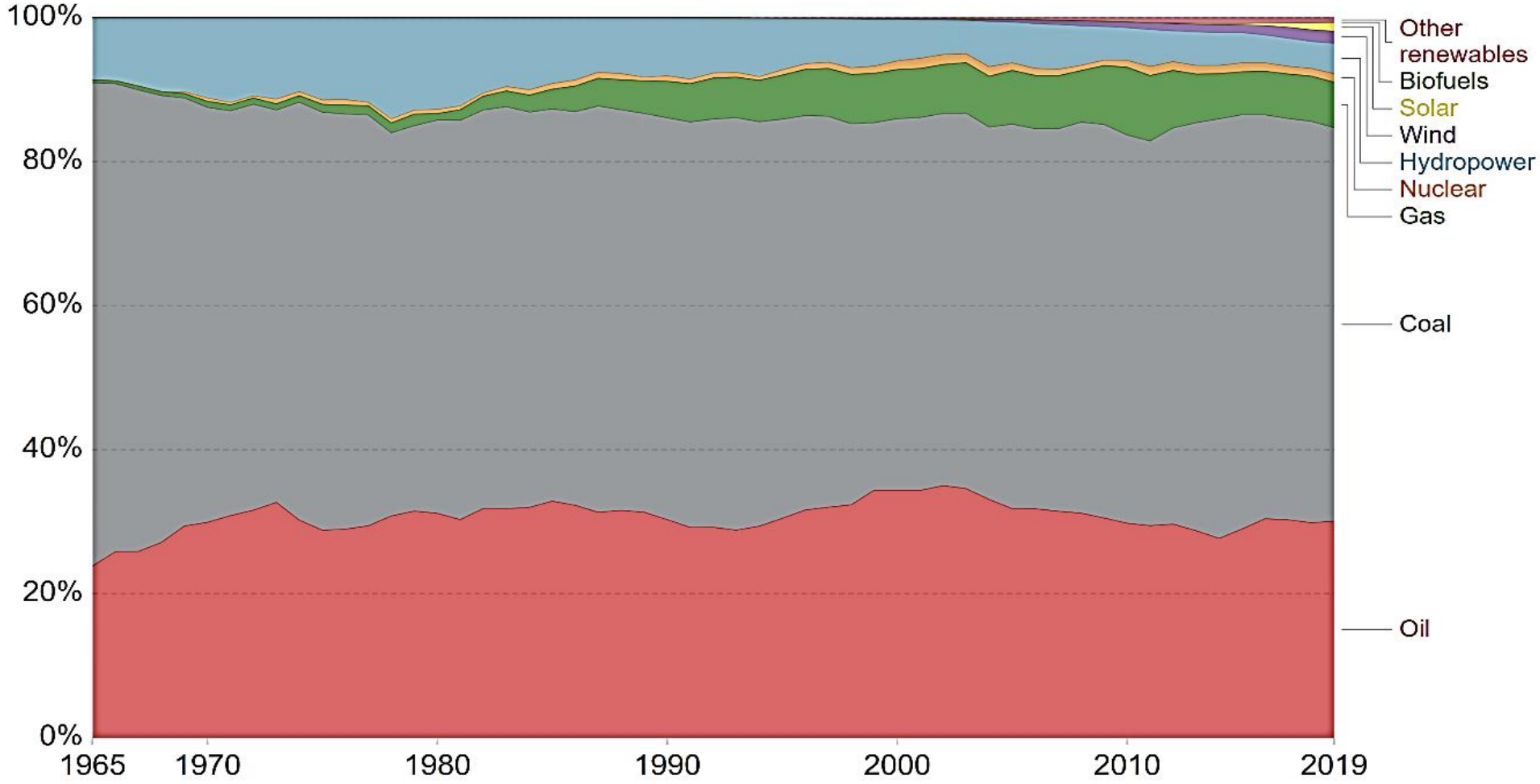
1965	
Other renewables	0.12%
Biofuels	0%
Solar	0%
Wind	0%
Hydropower	5.93%
Nuclear	0.16%
Gas	14.58%
Coal	37.33%
Oil	41.88%
Total	**100%**

2019	
Other renewables	1%
Biofuels	0.68%
Solar	1.11%
Wind	2.18%
Hydropower	6.45%
Nuclear	4.27%
Gas	24.23%
Coal	27.04%
Oil	33.06%
Total	**100%**

https://ourworldindata.org/energy

Energy consumption by source, India

Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the 'substitution' method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption.



2019	
Other renewables	0.66%
Biofuels	0.01%
Solar	1.21%
Wind	1.66%
Hydropower	4.24%
Nuclear	1.18%
Gas	6.31%
Coal	54.67%
Oil	30.06%
Total	**100%**

Source: BP Statistical Review of World Energy
Note: 'Other renewables' includes geothermal, biomass and waste energy.

OurWorldInData.org/energy • CC BY

Terawatt-hour (**TWh**), a measure of electrical energy, 10^{12} watt-hours.

- If we want to reduce our *global greenhouse gas emissions*, the world has to transition from an energy system dominated by fossil fuels to a low-carbon one

(set long-term targets to achieve within the Paris climate agreement.)

- With the exception of carbon capture and storage (CCS) technology two options to achieve this are renewable technologies (including bioenergy, hydropower, solar, wind, geothermal, and marine energy) and nuclear energy.

- Both of these options produce very low CO_2 emissions per unit of energy compared with fossil fuels. We call this process of transitioning from fossil fuels to low-carbon energy sources ‘decarbonisation’.

Sources of Energy

- Conventional
- Non - conventional

Non – Conventional (renewable energy)

Renewable energy is defined as energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat.

Renewable energy replaces conventional fuels in four distinct areas:

- Electricity generation
- Hot water/space heating
- Motor fuels
- Rural (off-grid) energy services.

Non – Conventional energy sources

Solar Energy

Wind Energy

Biomass Energy

Ocean Energy (Tidal Energy, Wave Energy, Ocean Thermal Energy)

Geothermal Energy

Conventional Sources of Energy

The sources of energy which have been in use for a long time, e.g., coal, petroleum, natural gas and water power.

They are exhaustable except water.

They cause pollution when used, as they emit smoke and ash.

They are very expensive to be maintained, stored and transmitted as they are carried over long distance through transmission grid and lines.

Solar energy

Solar energy is radiant light and heat from the Sun harnessed using a range of ever-evolving technologies such as *solar heating, photovoltaics, solar thermal energy, solar architecture and artificial photosynthesis*

https://en.wikipedia.org/wiki/Solar_energy

The United Nations Development Programme in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,387 exajoules (EJ).

This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012

The exajoule (EJ) is equal to one quintillion (10^{18}) joules

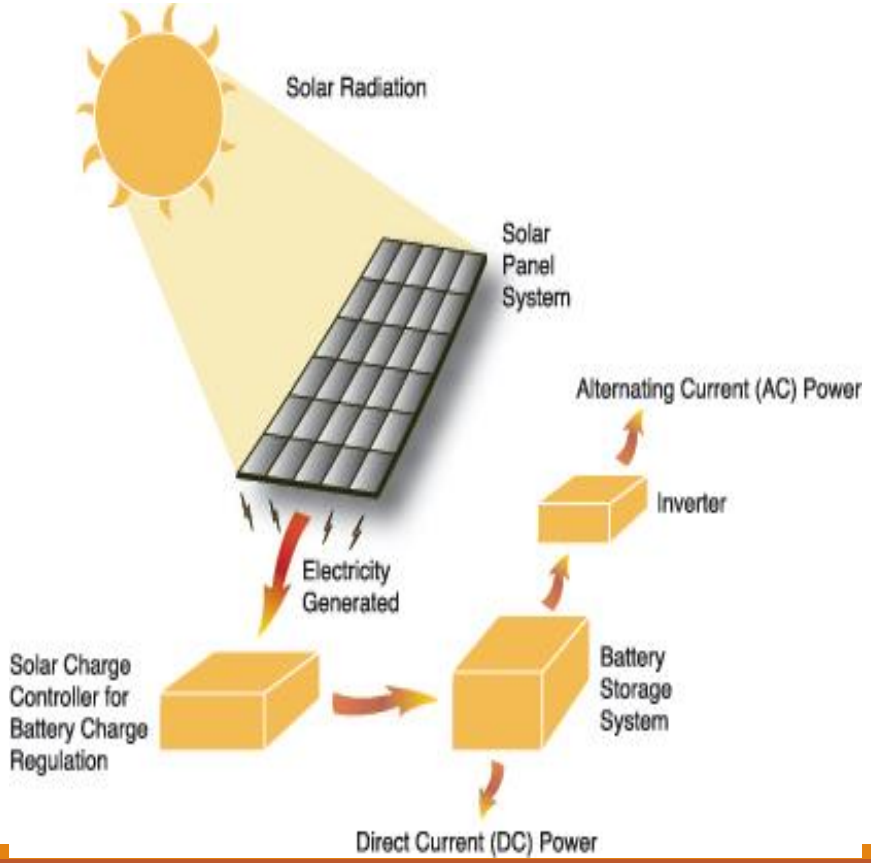
Solar energy

- It is an important source of renewable energy and its technologies are broadly characterized as either

passive solar or active solar depending

on the way they capture and distribute

solar energy or convert it into solar power.



Active solar techniques include the use of *photovoltaic systems*, concentrated *solar power*, and *solar water heating* to *harness the energy*.

Passive solar techniques include *orienting a building to the Sun*, selecting *materials with favorable thermal mass* or *light-dispersing properties*, and *designing spaces* that naturally circulate air.

The development of affordable, inexhaustible and clean solar energy technologies

- will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource,
- enhance sustainability,
- reduce pollution,
- lower the costs of mitigating global warming,
- keep fossil fuel prices lower than otherwise.

Solar Energy Technologies

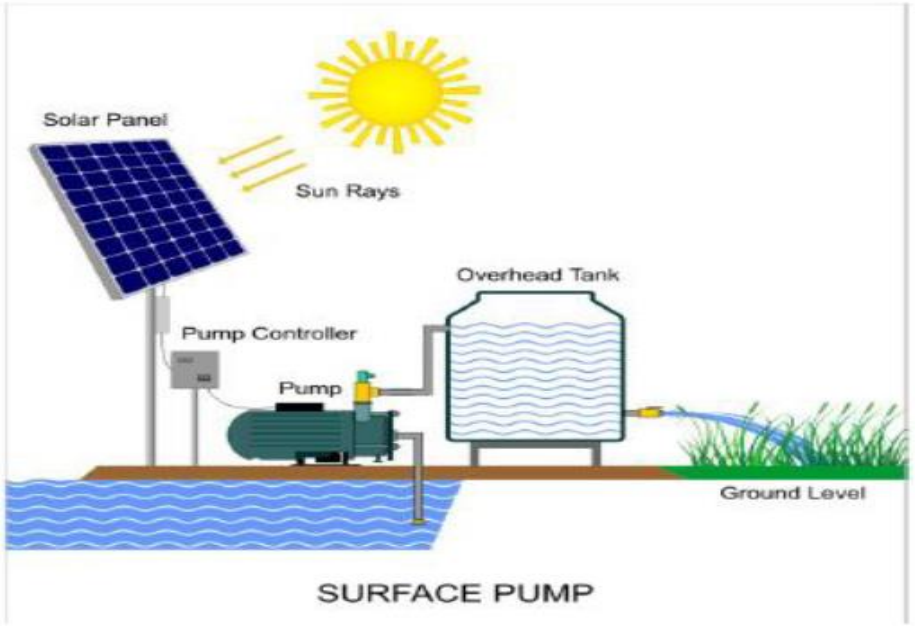
- Solar water heater
- Solar Air conditioning
- Solar drying
- Solar green houses
- Solar desalination
- Solar Electricity – thermal
- Solar cooking
- Solar furnaces
- Salt production

Solar water heaters facing the Sun to maximize gain.

Heating, cooling and ventilation

Parabolic dish produces steam for cooking, in Auroville, India

Electricity production



Solar pump and solar cooker

Photovoltaic (PV) cell

A **photovoltaic** (**PV**) **cell** is an energy harvesting technology, that converts solar energy into useful electricity through a process called the photovoltaic effect.

There are several different types of PV cells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.

Advantages

- After initial investment , electricity production is free of cost
- Solar energy is abundant, everlasting, available almost everywhere, free from political barriers.
- Incentives and rebates from governments and companies offset the initial costs.
- Reduce or eliminate electricity bill
- Cost of solar panels are decreasing but efficiency is increasing

Disadvantages

- Solar energy can be harnessed when it is daytime and sunny

- Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly
- Solar power stations can be built but they do not match the power output of similar sized conventional power stations. They are also very expensive
- Large area is required to capture suns energy
- Solar power can be used to charge batteries. These batteries are heavy and large and need storage space. They also need replacement from time to time.

Wind Energy

The origin of wind energy is from sun.

When suns rays fall on our planet, it's surface get heated up and as a consequence unevenly winds are formed.

Boats were sailing on wind power from historic times

Babylonians and Chinese used wind power to irrigate crops 4000 years ago

Wind power was used to grind cone,

from where "windmill" comes from

Muppandal wind farm in Tamil Nadu

Offshore wind turbines near Copenhagen, Denmark

Burbo Bank Offshore Wind Farm
North West England

https://www.youtube.com/watch?v=8PE69jcleKg

In modern days, kinetic energy in the wind can be used to run wind turbines but the output power depends on the wind speed.

Turbines require a wind in the range of 20km/hr.

Most of wind turbines are erected at high altitudes as the speed of wind is more than at low altitudes which helps to generate large amount of electricity.

The best places for wind farms are in coastal areas ,at top of rounded hills, open plain and gaps in mountains.

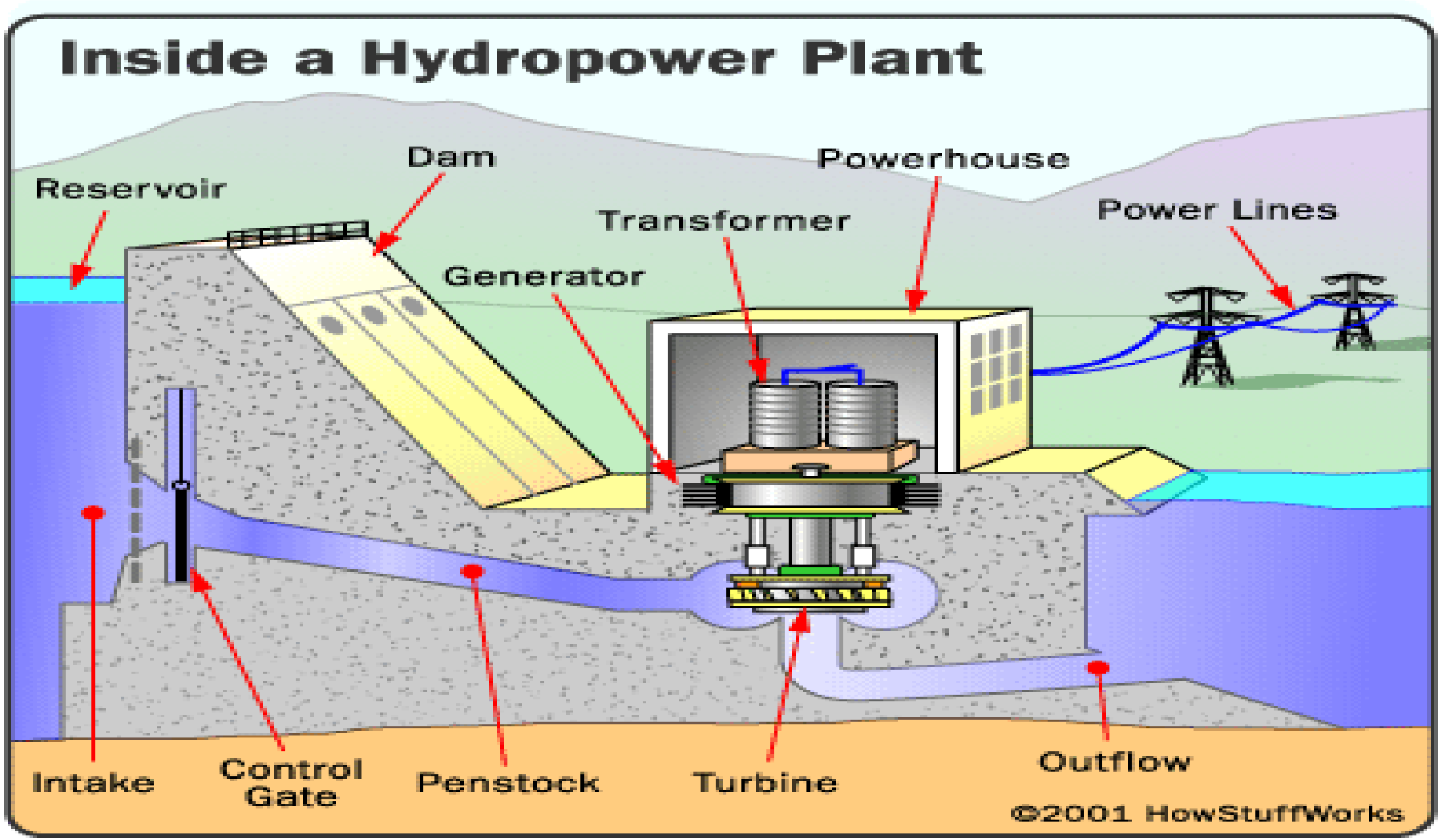
Advantages	Disadvantages
Wind is free, windfarm need no fuel	Wind is not always predictable
Produces no waste or green house gases	Can affect television reception
Land beneath wind farm can be used for farming	Can kill Birds
A good method of supplying energy to remote areas	

Hydro Electric Power

Refers to production of electrical power through use of gravitational force of falling or flowing water.

A dam is a hydraulic structure constructed across a flowing river to store water on its upstream side and the artificial water body created as a result of construction of dam on the upstream side is called storage reservoir.

Gravitational potential energy is stored in the water above the dam. Water has kinetic energy when it flows from higher elevation to lower elevation. Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators producing electrical energy.


Inside a Hydropower Plant
Reservoir
Dam
Powerhouse
Transformer
Power Lines
Generator
Intake
Control Gate
Penstock
Turbine
Outflow
©2001 HowStuffWorks

https://www.youtube.com/watch?v=-hooifWJ1jY

Types of Hydro-electric power plants

Classified based on station capacity

- Micro hydro power : < 100 kW
- Mini hydro power:101 – 2000 kW
- Small hydro power: 2001 – 25000 kW

Small Hydro power

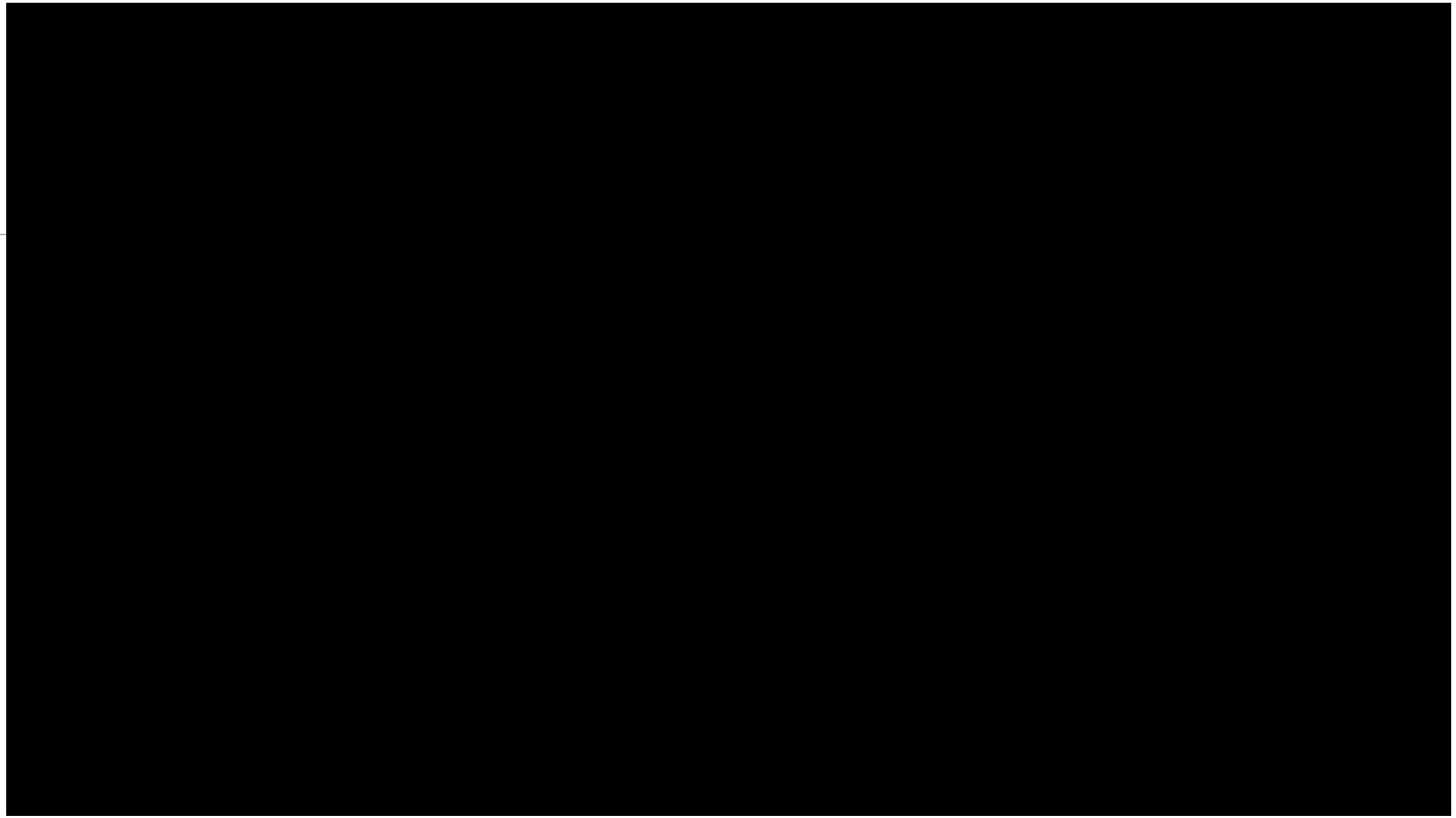
In India, hydro projects up to 25 MW station capacities have been categorized as Small Hydro Power (SHP) projects

Small hydro power can provide clean, renewable and relatively inexpensive energy.

Small hydro power schemes does not necessitate a reservoir.

They can be constructed in any location where there is enough water flow and head to make generation of energy viable.

Since no reservoir is created on the upstream, there is minimal impact on nearby communities with respect to displacement.



Advantages:

- Clean energy source
- Minimal impact on environment
- Long useful life
- Low running cost

Disadvantages:

- To be economical, energy consumers need to be located near the hydropower scheme, thus limiting hydropower to stream side communities.
- The stream flow limits the power generation
- Seasonal variation in stream flow causes variation and disturbances in energy supply

Geothermal Energy

The term geothermal comes from the Greek

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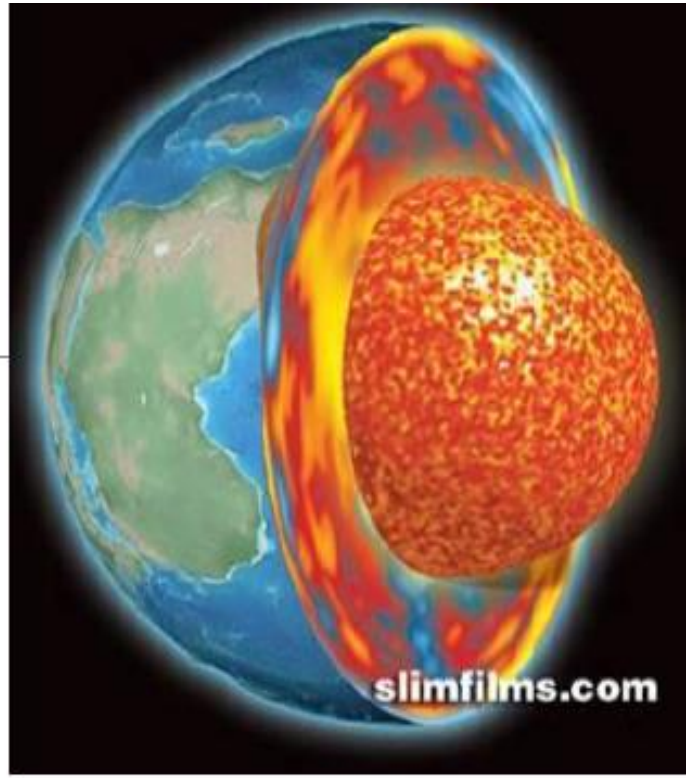
geo meaning ***earth***

Thermal meaning ***heat***

Thus geothermal energy

is energy derived from the natural heat of the earth



As we travel down earth's surface radially, there exists a temperature gradient of 0.03°C per meter.

Thus a 30°C increase in temperature can be obtained per kilometre depth from the earth crust.

There are many local hot spots below the surface where the temperature are much higher than expected.

Ground water, when comes into with hot spots, either dry or wet steam is formed.

By drilling holes to these locations,

hot water and steam can be tapped and

these can be used for power generation or space heating

http://science.howstuffworks.com/environmental/energy/geothermal-energy.htm

The heat inside the Earth core is continually generated by the decay of the long lived radioactive isotopes of uranium, thorium and potassium, which are present in the Earth.

Sometimes the hot magma reaches all the way to the surface, where we know it as lava.

But most often the magma remains below earth's crust, heating nearby rock and water (rainwater that has seeped deep into the earth) - sometimes as hot as 700 degrees F.

Some of this hot geothermal water travels back up through faults and cracks and reaches the earth's surface as *hot springs* or *geysers*, but most of it stays deep underground, trapped in cracks and porous rock.

This natural collection of hot water is called a *geothermal reservoir*.

The ancient Romans used hot springs to heat their homes, bathe and cook.

In 1892, the first modern district heating system was developed in Boise, Idaho.

The first geothermal energy plant was built in Larderello, Italy, in 1904.

Iceland is one of the biggest users of geothermal energy - virtually the entire city of Reykjavik is heated with water pumped in from hot springs and geothermal wells.

Some cities - like Klamath Falls, Ore. even pump hot water underneath their roads and sidewalks in the winter to melt snow and ice.

Generating electricity : Geothermal power plants

In geothermal power plants, we use the natural hot water and steam from the earth to turn turbine generators to produce electricity.

Unlike fossil fuel power plants, no fuel is burned. Geothermal power plants give off water vapour, but have no smoky emissions.

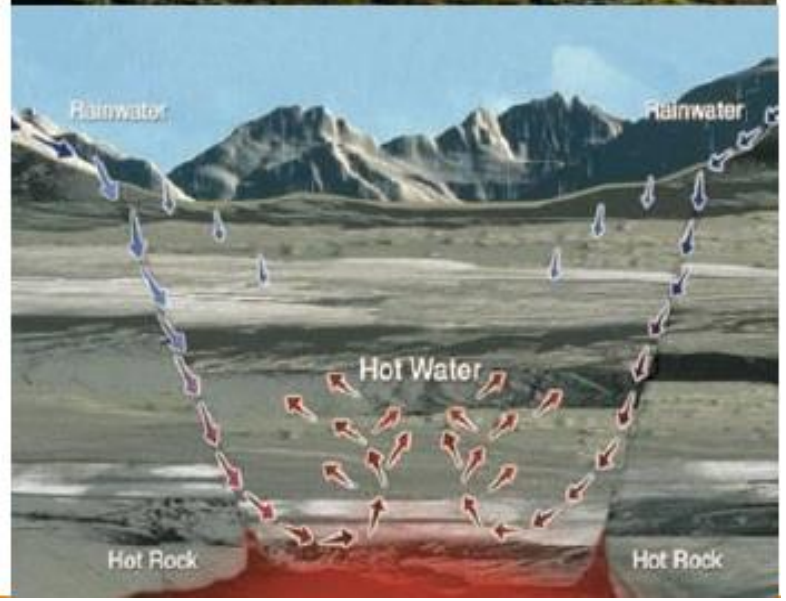
There are several different types of plants:

flashed steam plants

dry steam plants

binary power plants

https://www.youtube.com/watch?v=rfUQy86ZMpQ

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Agriculture and aquaculture

Geothermal energy is used directly in agriculture and aquaculture: to help grow flowers, vegetables, and other crops in greenhouses

Industry

drying fish, fruits, vegetables and timber products,

washing wool, dying cloth,

manufacturing paper and

pasteurizing milk.

Hot Spring Bathing and Spas (Balneology)

For centuries, peoples of China, Iceland, Japan, New Zealand, North America and other areas have used hot springs for cooking and bathing. The Romans used geothermal water to treat eye and skin disease and, at Pompeii, to heat buildings. Medieval wars were even fought over lands with hot springs.

Geothermal well testing, Guatemala

52kW electrical generating capacity

Advantages of geothermal energy

1. Renewability and sustainability

2. Conservation of resources

when we use renewable geothermal energy for direct use or for producing electricity, we conserve exhaustible and more polluting resources like fossil fuels and uranium. Installed geothermal electricity generation capacity around the world is equivalent to the output of about 10 nuclear plants.

3. Protection of the environment:

Energy from Ocean

ocean energy is replenished by the sun and through tidal influences of the moon's and sun's gravitational forces

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near-surface winds induce wave action and cause wind-blown currents at about 3% of the wind speed

tides cause strong currents into and out of coastal basins and rivers

ocean surface heating by some 70% of the incoming sunlight adds to the surface water thermal energy, causing expansion and flow

wind energy is stronger over the ocean due to less drag, although technically, only seabreezes are from ocean energy

Ocean energy can be captured in three ways

(a) Tidal energy

(b) Wave energy

(c) OTEC (Ocean Thermal Energy Conversion)

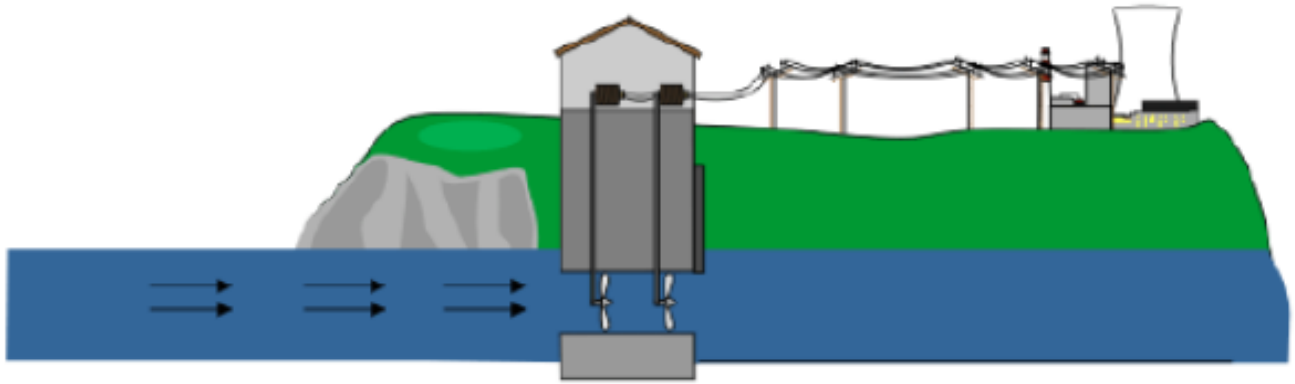
Tidal Energy

Tidal energy is the energy due to the water waves created in the ocean.

Tidal energy is also called hydropower, mainly due to rising and falling of waves

The raising and falling waves are used to rotate the turbines

Rising and falling is due to gravitational forces of sun and moon, and also due to rotation of earth



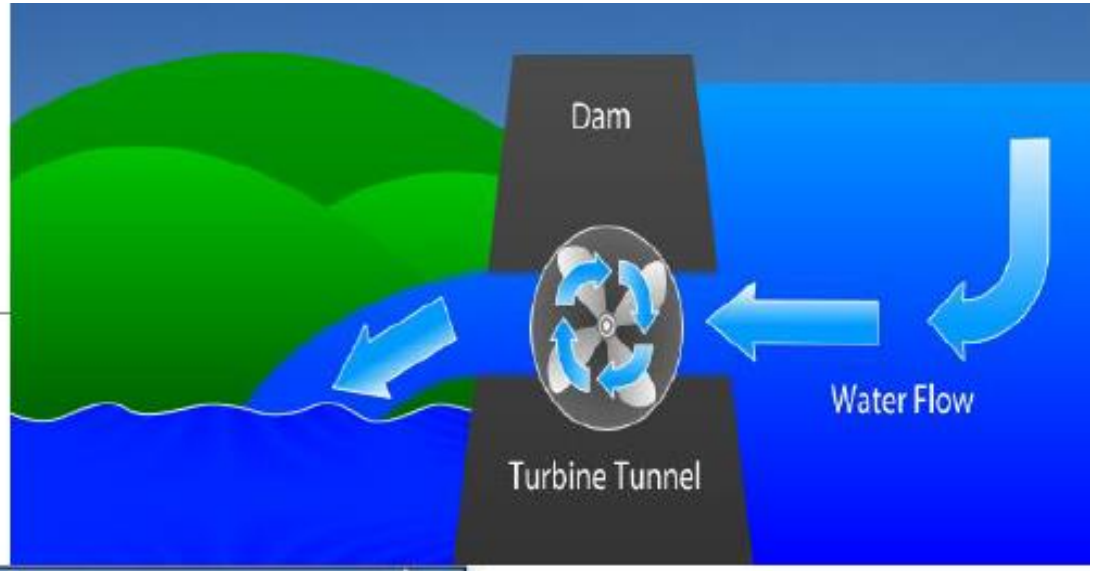
TIDE COMING IN

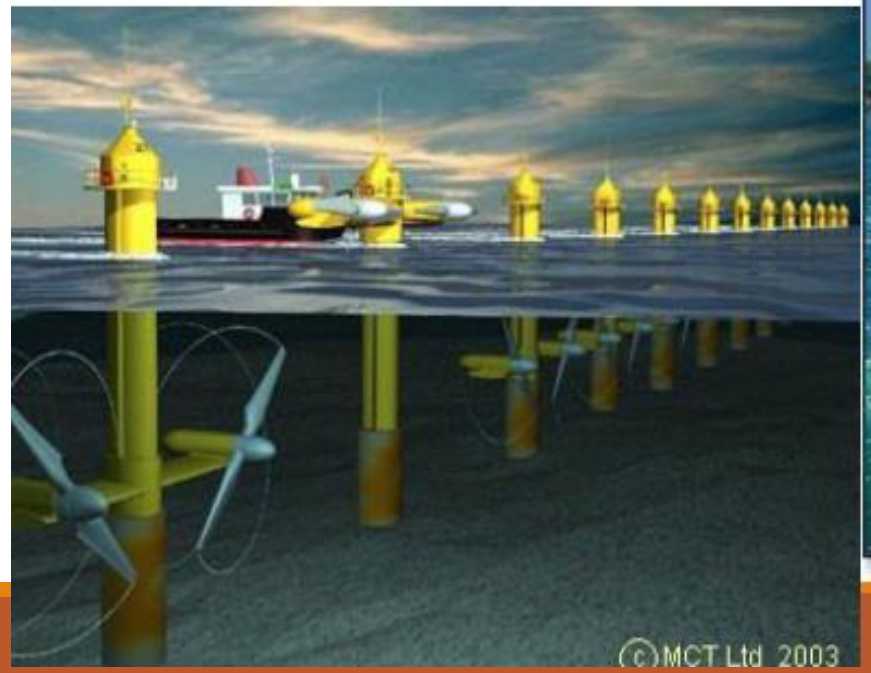

SWANSEA BAY, WALES
Crazy World

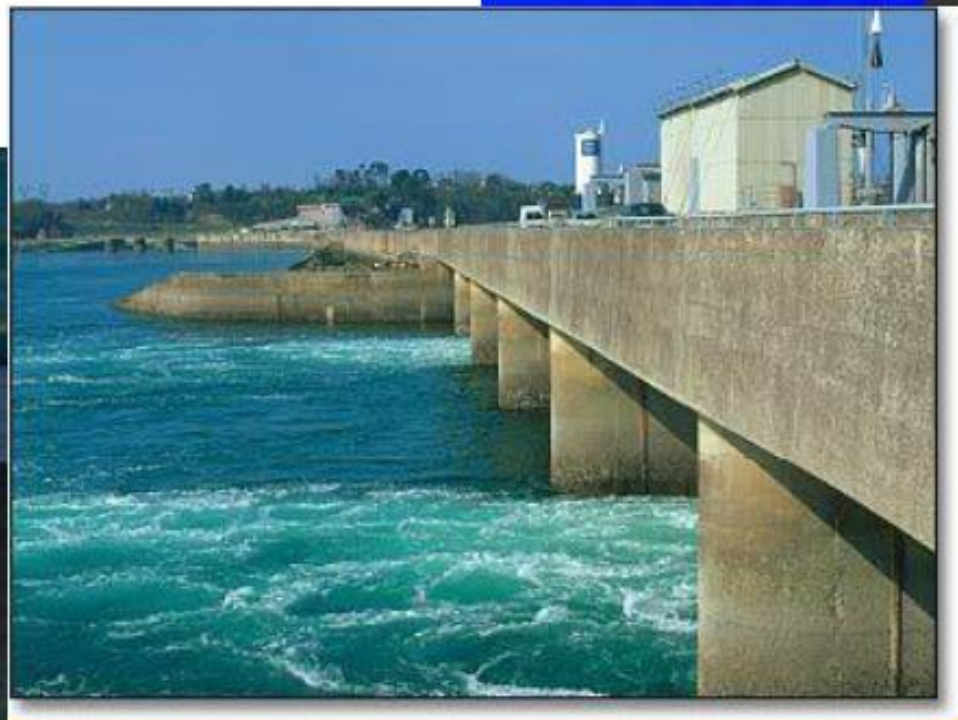
Tidal Stream system

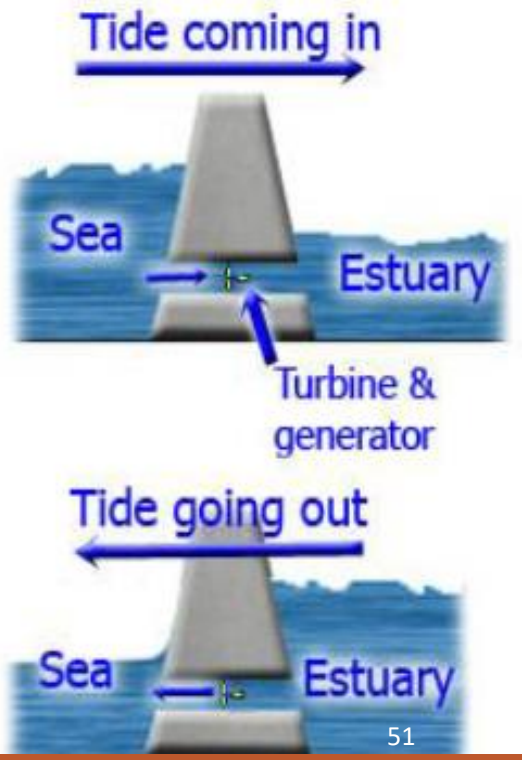
Barrages

Tidal Lagoons



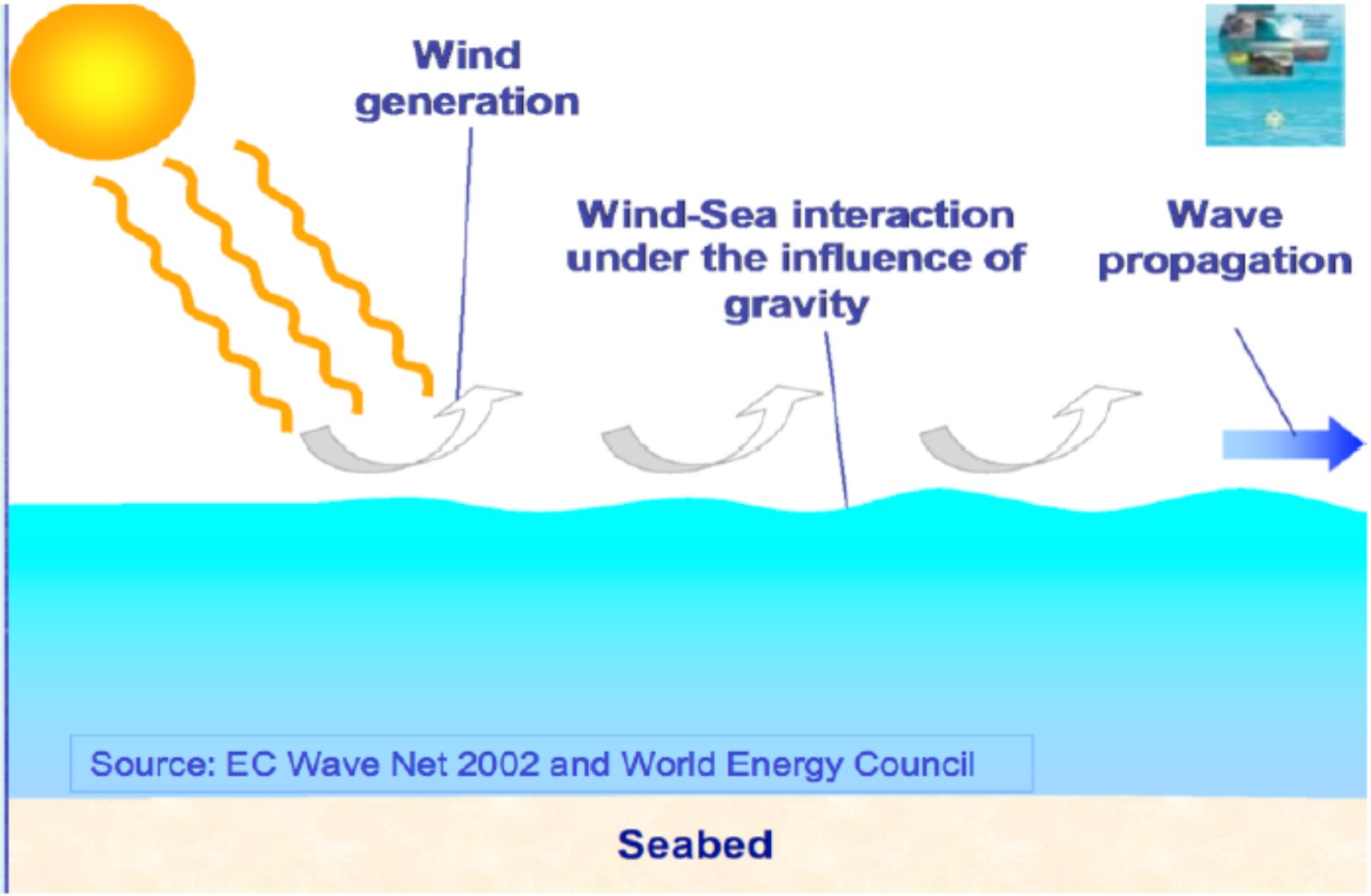




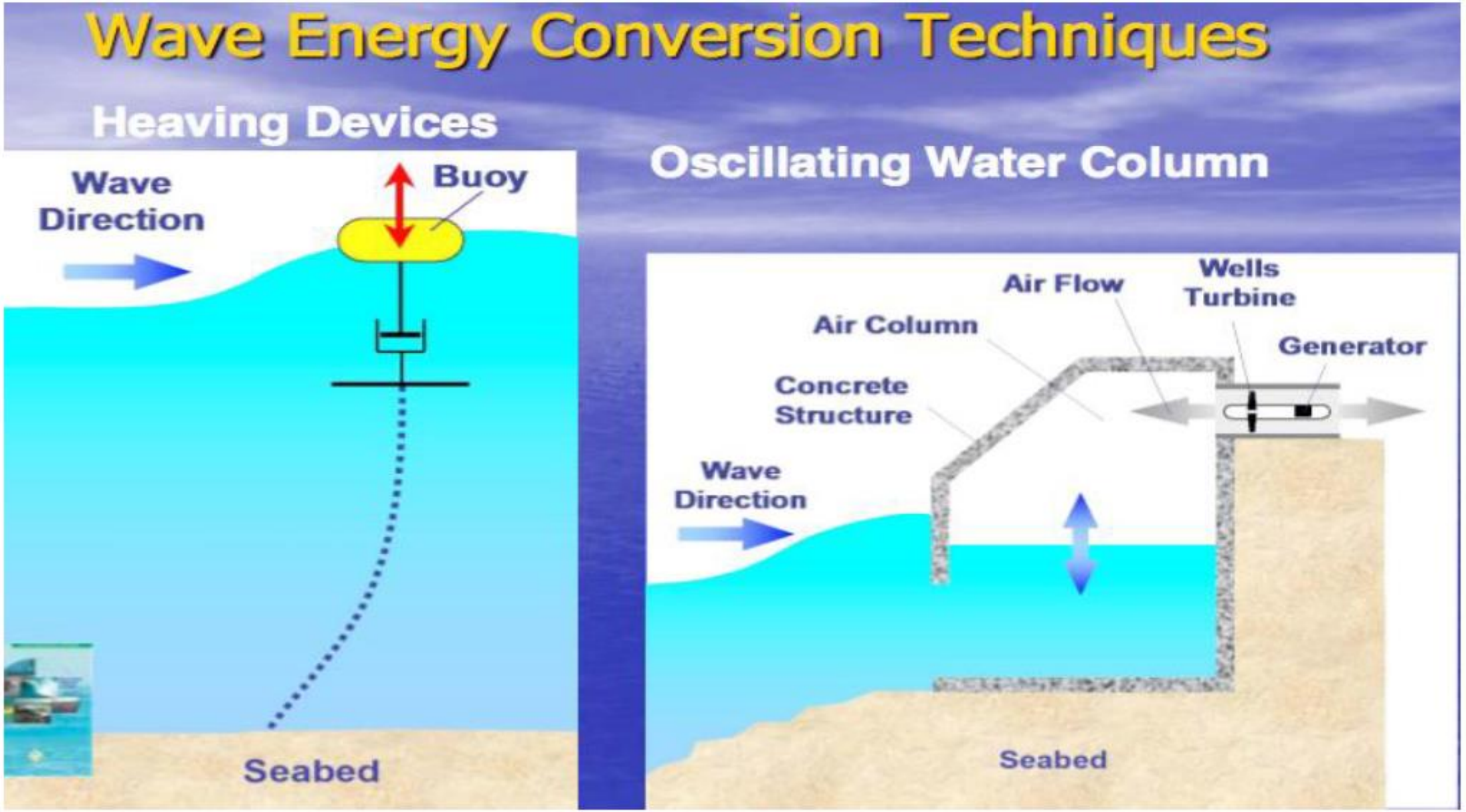


Source of Ocean Wave Energy

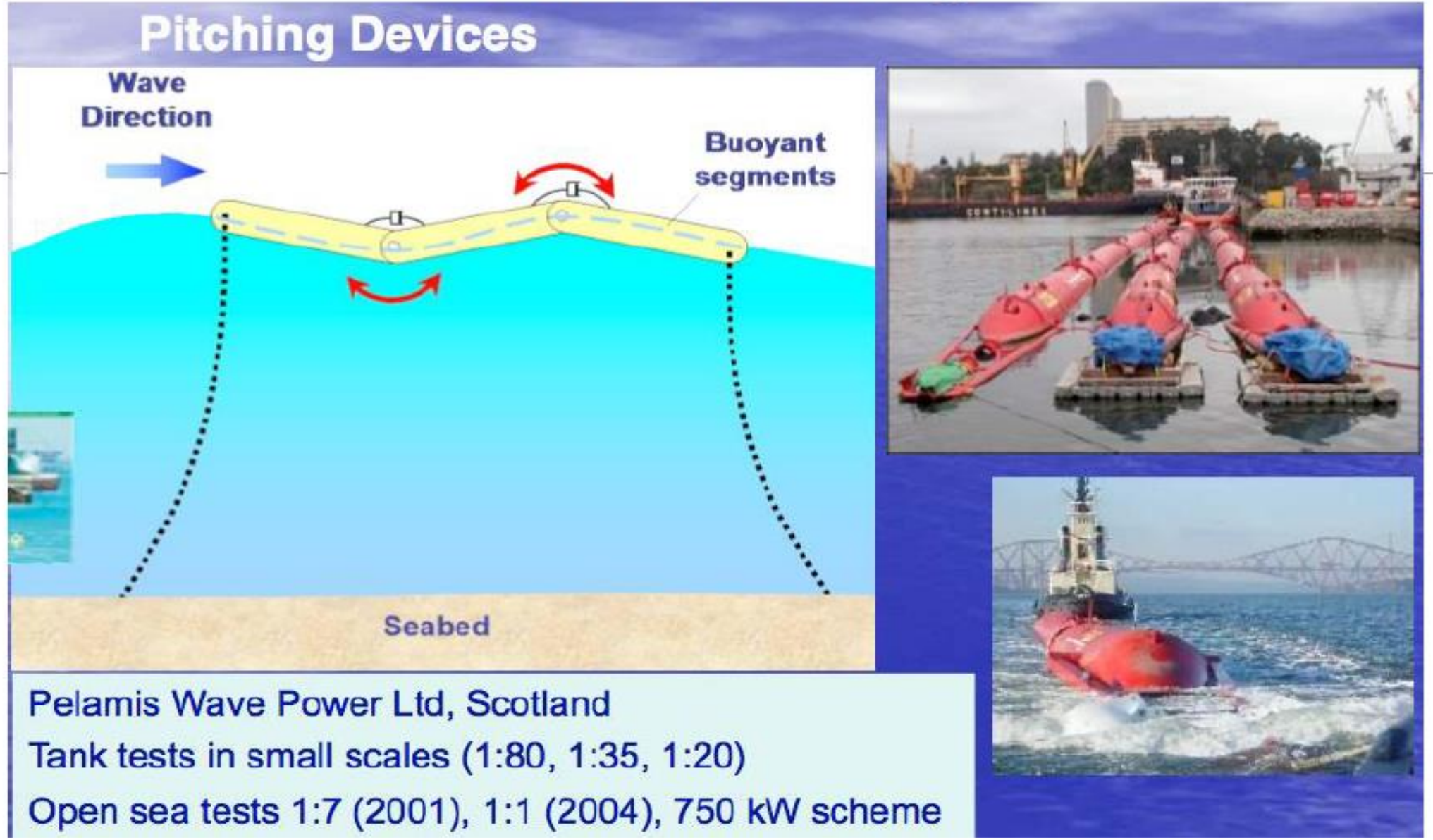
- Oceans cover 3/4 of earth's surface
- 0.1% ocean renewable energy is equivalent to 5 times world demand
- 50% of the worlds electricity consumption can be covered by wave energy

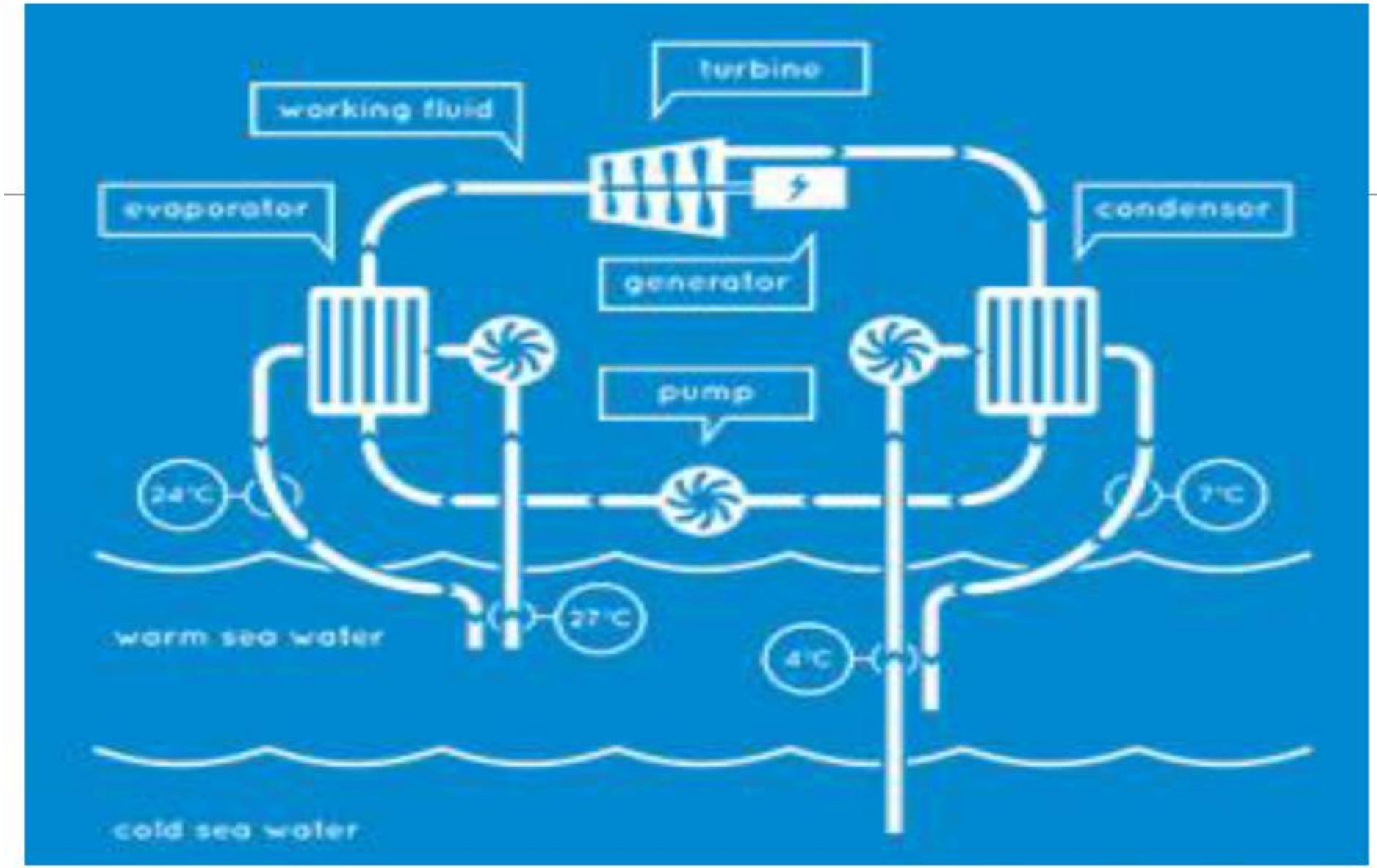


Wave Energy Conversion Techniques



"Sea Snake" Wave Energy




turbine
working fluid
evaporator
condenser
generator
pump
24°C
7°C
27°C
4°C
warm sea water
cold sea water

Biomass

Is any organic material which has stored sunlight in the form of chemical energy

Energy stored in different non-fossil organic materials

- Wood
- Straw
- Vegetable oils
- Wastes from forest, agriculture & industry
- Organic fraction of municipal solid waste
- Sewage sludge

These are burnt to produce energy.

Photosynthesis

In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose—or sugar.

(water) (carbon dioxide) (sunlight) (glucose) (oxygen)

$6H_2O + 6CO_2 + \text{radiant energy} \rightarrow C_6H_{12}O_6 + 6O_2$

Biomass

Biomass falls under three categories

Biomass in its traditional form : Wood and agricultural residue is burnt to produce energy

Biomass in its non traditional form : Biomass is converted to ethyl alcohol and methyl alcohols to be used as liquid fuels in engines

Biomass for domestic use: Organic waste is decomposed anaerobically to produce mixture of gases namely methane, H_2S

Methods for converting Biomass to Energy

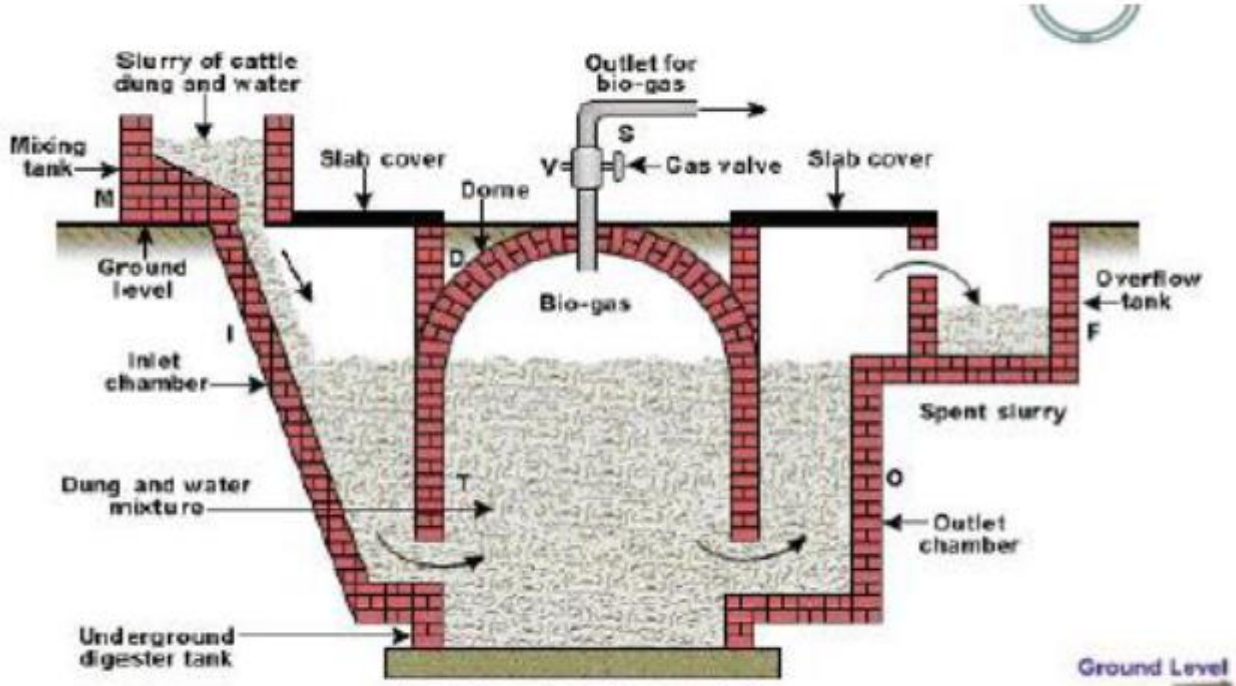
Thermal Conversion

- Burning
- Gasification
- Pyrolysis

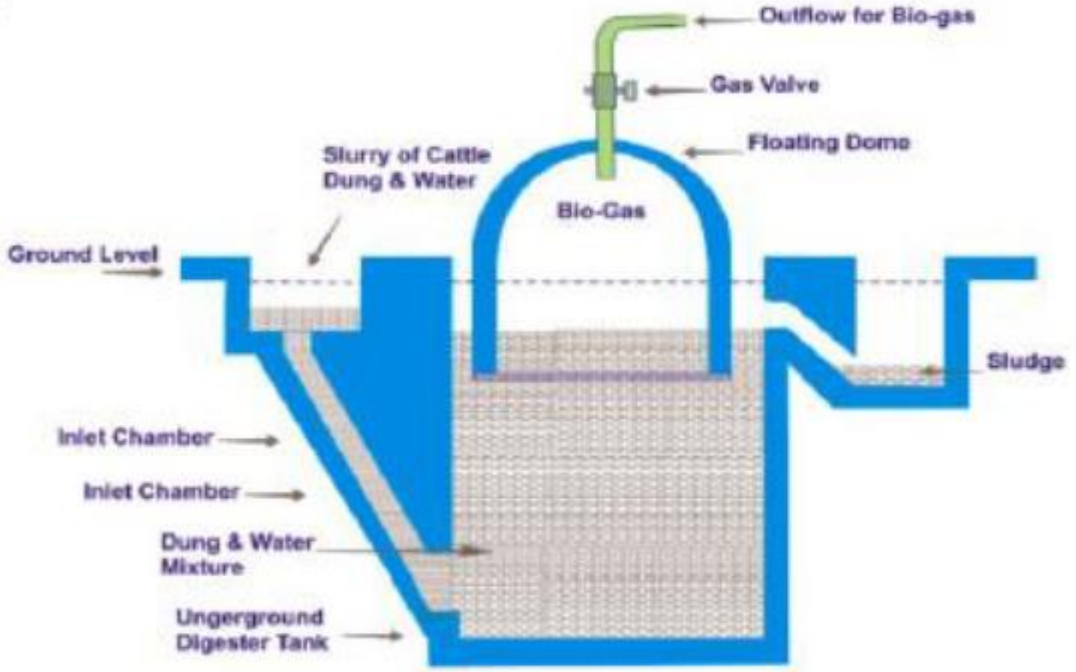
Biochemical conversion

- Fermentation
- Anaerobic digestion

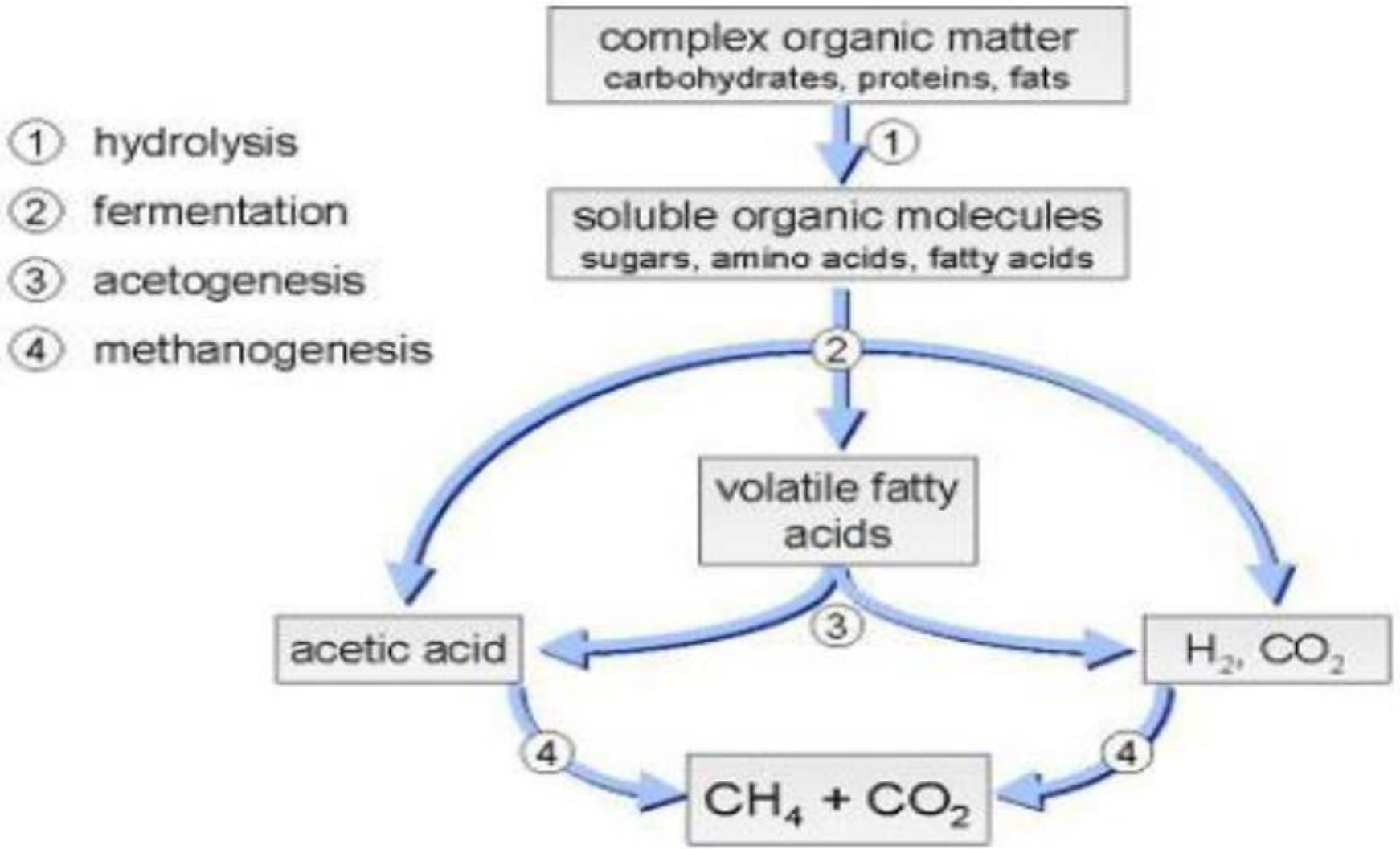
Chemical Conversion



Fixed-dome type bio-gas plant.

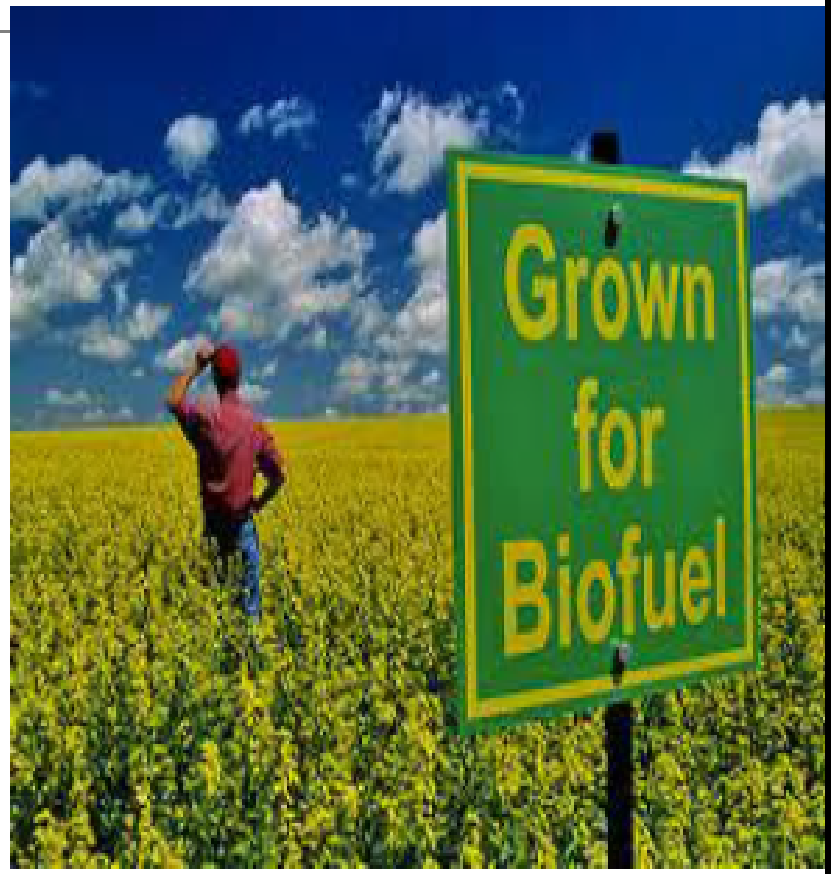


Floating Dome type Bio-gas Plant


1 hydrolysis
2 fermentation
3 acetogenesis
4 methanogenesis
complex organic matter
carbohydrates, proteins, fats
1
soluble organic molecules
sugars, amino acids, fatty acids
2
volatile fatty acids
3
acetic acid
H2, CO2
4
4
CH4 + CO2

Biofuel

A biofuel *is a fuel produced through biological processes like agriculture and anaerobic digestion*.



Biofuels can be derived directly from plants,
or indirectly from agricultural, commercial, domestic,
and/or industrial wastes.

Biomass can be converted directly into liquid fuels,
called "biofuels," to help meet transportation fuel needs.

The two most common types of biofuels in use today are ethanol and biodiesel.

Biofuel

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter.

Two methods currently used to convert biomass energy to liquid fuel

i. In first method, sugar crop or starch are grown and through fermentation, ethanol is produced

ii. Plants are grown that naturally produce oil like jatropha and algae

Evolution of Biofuel

First Generation

Second Generation

Third Generation

Biofuels

Bioethanol

~~Biodiesel~~

Bioethers

Biogas

Aviation Biofuel

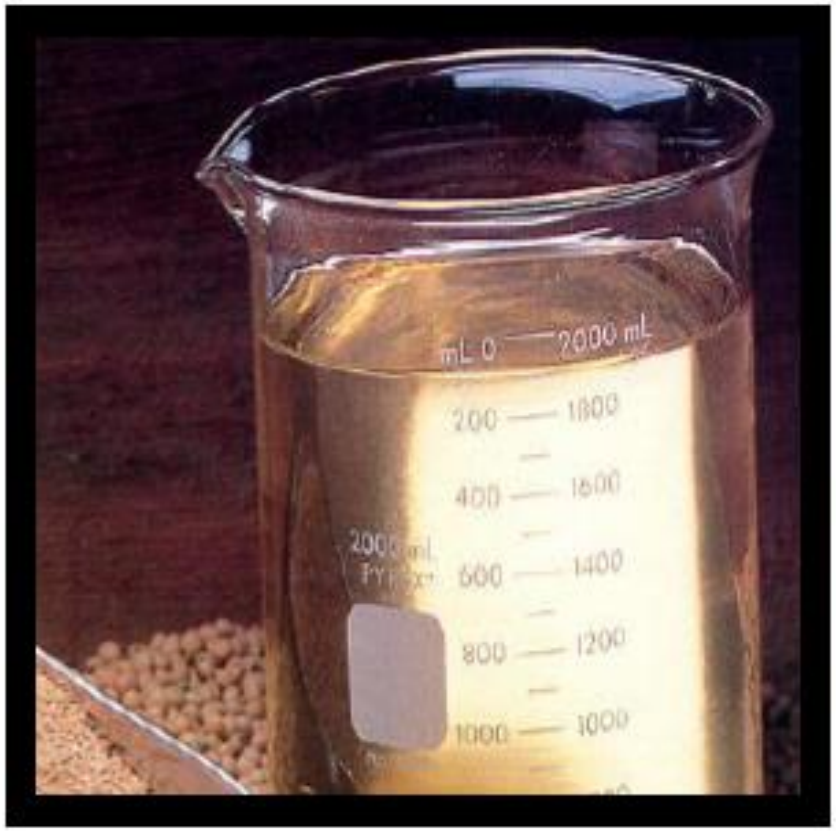
Solid Biofuel

Advanced Biofuel

a. Lignocellulose b. Jatropha c. Camelina d. Algae

Biodiesel

A diesel fuel replacement produced from vegetable oils or animal fats through the chemical process of *transesterification*



Biodiesel can be used in any diesel motor in any percent from 0-100% with little or no modifications to the engine

Biodiesel produced by reacting triglycerides with alcohol to produce fatty acid esters as well as glycerol

Advantages of Biodiesel

- Biodegradable
- Non-toxic
- Favorable Emissions Profile
- Renewable
- Carbon Neutrality

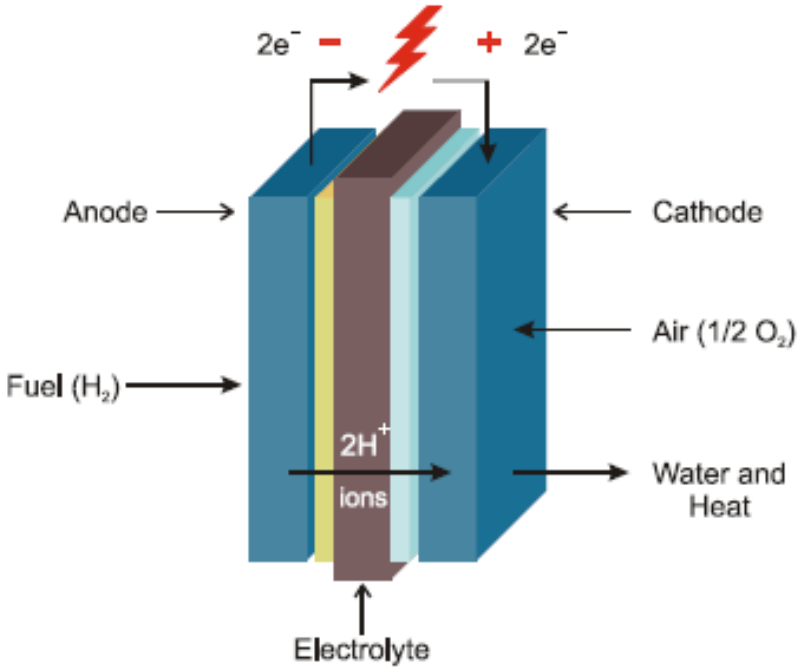
Advantages of Biodiesel

- Requires no engine modifications (except replacing some fuel lines on older engines).

- Can be blended in any proportion with petroleum diesel fuel.
- High cetane number and excellent lubricity.
- Very high flashpoint (>300°F)
- Can be made from waste restaurant oils and animal fats

Fuel Cell

A fuel cell is a device that converts chemical energy into electrical energy, water, and heat through electrochemical reactions.



- Fuel and air react when they come into contact through a porous membrane (electrolyte) which separates them.
- This reaction results in a transfer of electrons and ions across the electrolyte from the anode to the cathode.
- If an external load is attached to this arrangement, a complete circuit is formed and a voltage is generated from the flow of electrical current.

The voltage generated by a single cell is typically rather small (< 1 volt), so many cells are connected in series to create a useful voltage.

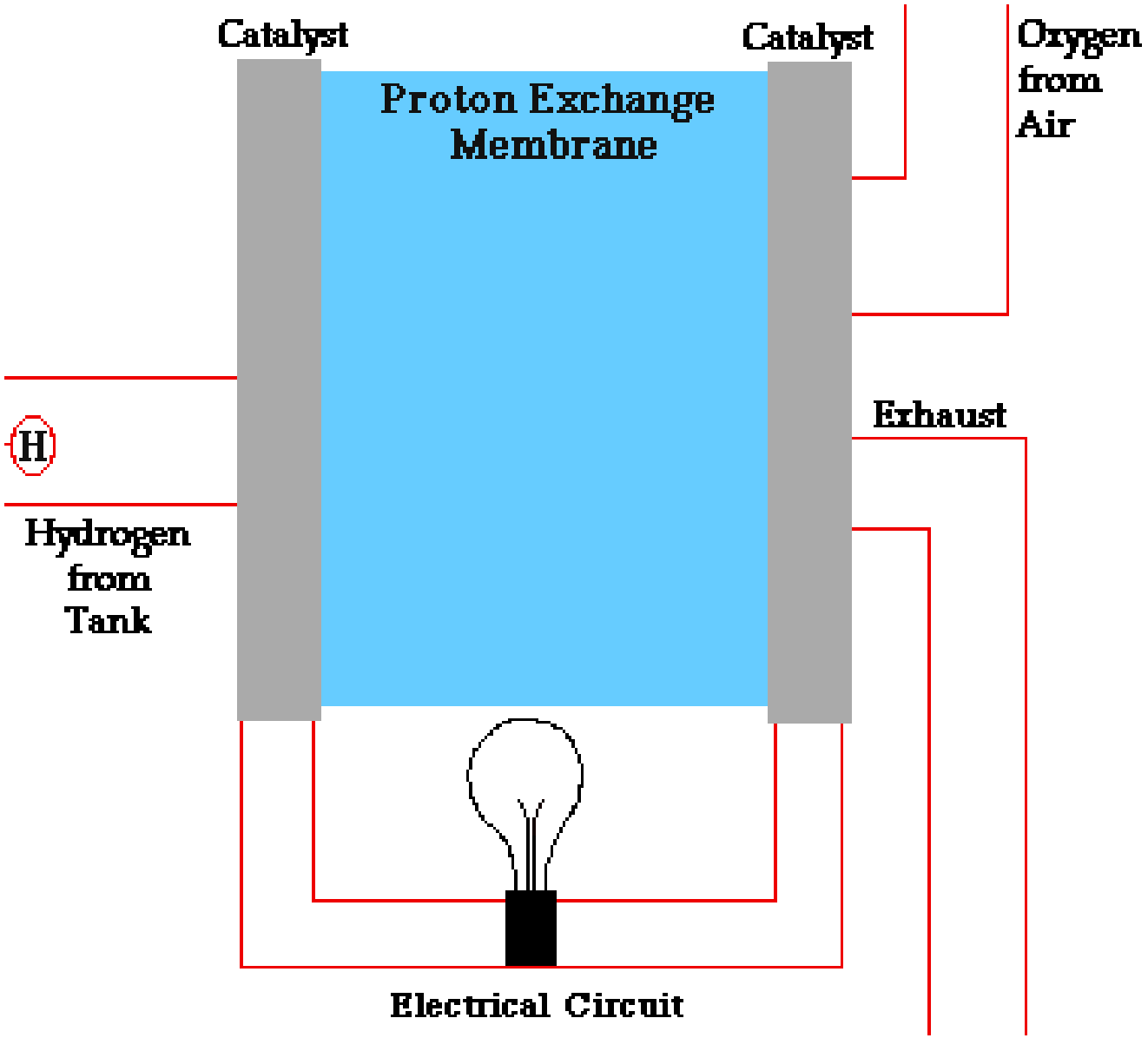
Components

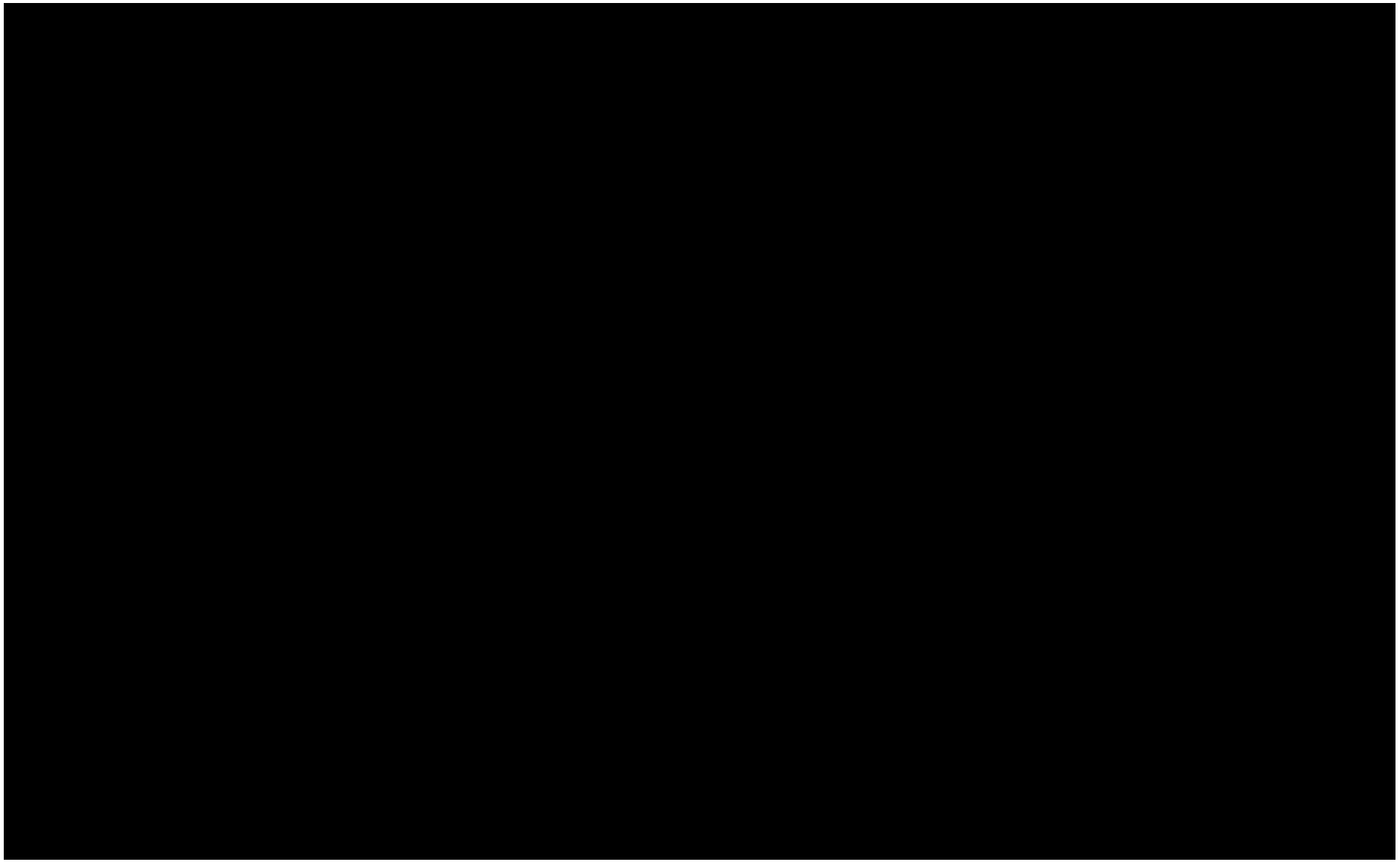
Anode

Cathode

Electrolyte

Catalyst


Catalyst
Catalyst
Proton Exchange Membrane
Oxygen from Air
Exhaust
H
Hydrogen from Tank
Electrical Circuit



Types of fuel cell

Alkali Fuel cell

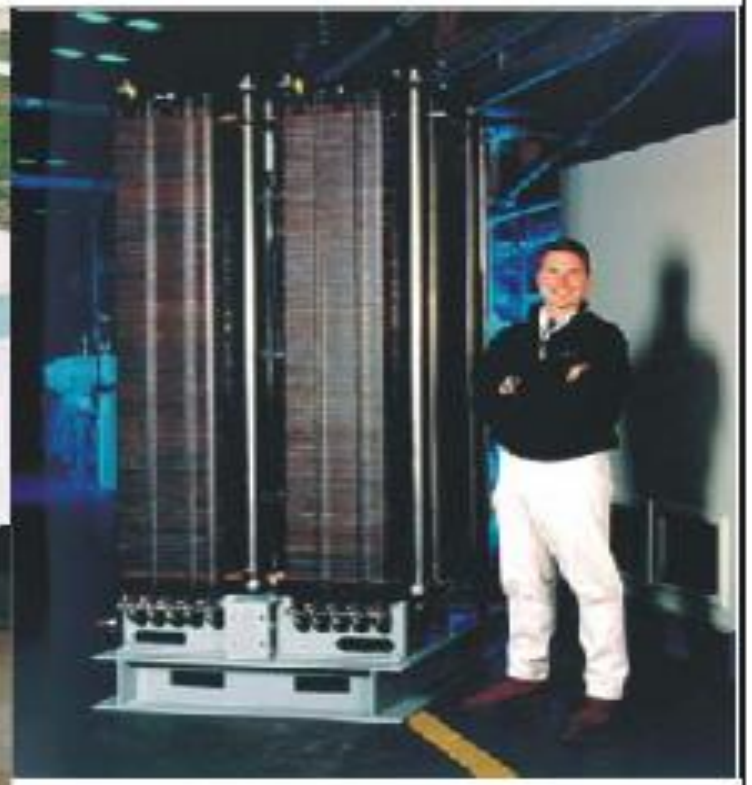
Molten carbonate fuel cell

Phosphoric Acid fuel cell

Solid oxide fuel cell

Fuel Cells in Use: Stationary Systems

Ballard Generation Systems' 250 kW Natural-Gas Fueled Fuel Cell Powerplant



These massive proton exchange membrane fuel cell stacks are the most powerful in the world

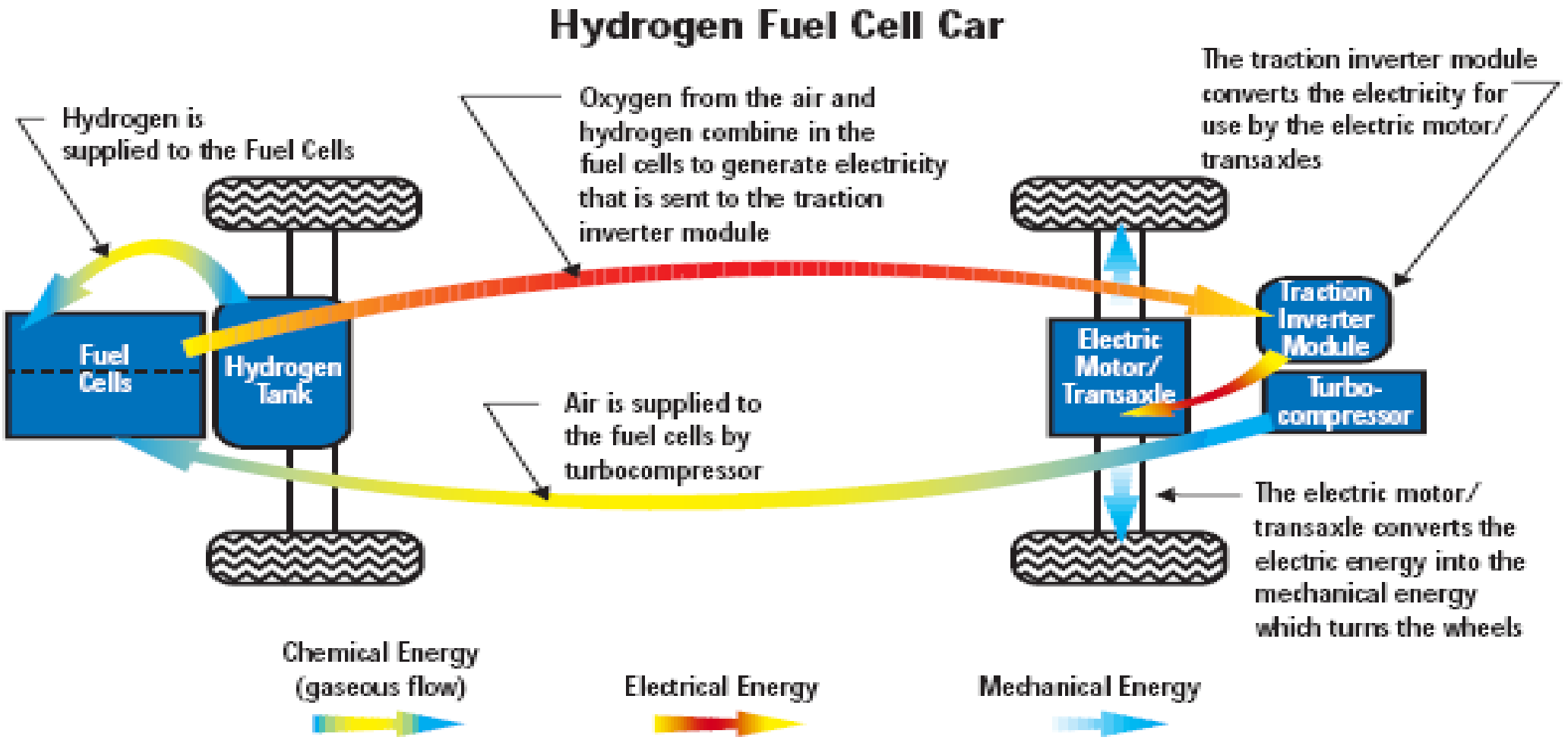
Courtesy of Ballard Power Systems, Inc.

Fuel Cells in Use: Stationary Systems

This 80 kW powerplant was built by Ballard Power Systems for German submarine manufacturer Howaldtswerke-Deutsche Werft AD and operates using pure hydrogen and oxygen.

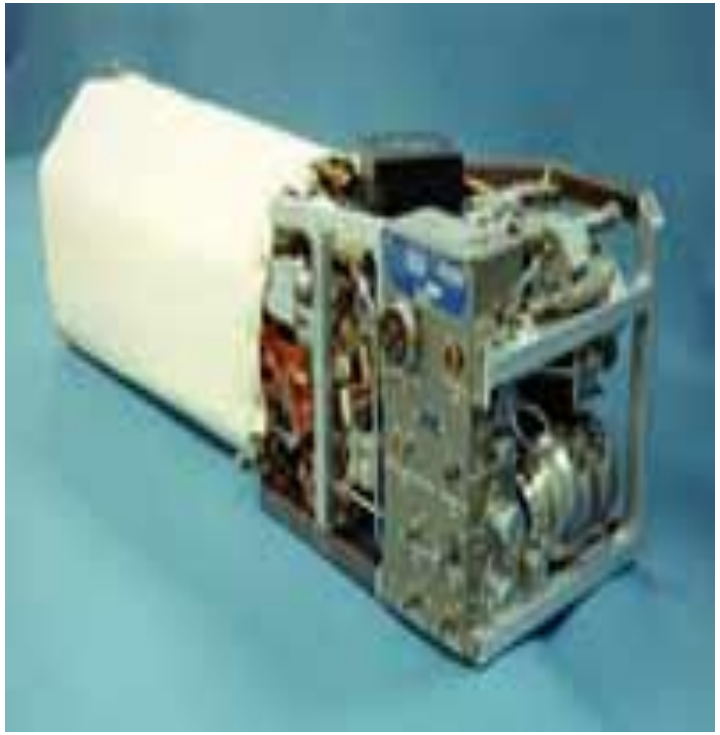
Fuel cell system for submarine

Fuel Cells in Use: Hydrogen Fuel Cell System



The P2000, from Ford Motor Company, is a zero-emission vehicle that utilizes a direct hydrogen polymer electrolyte fuel cell. (Courtesy of Ford Motor Co.)

Fuel Cells in Use: Space Systems

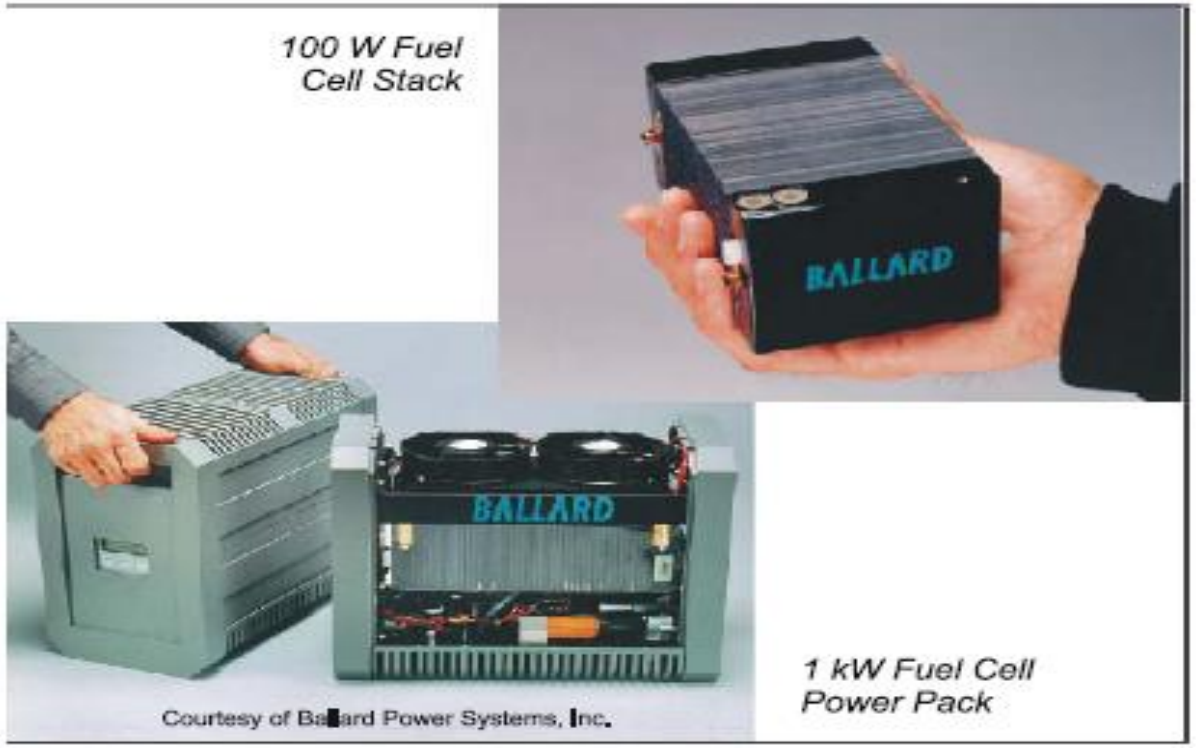


12 kW Space shuttle fuel cell
Weight: 120 kg
Size: 36x38x114 cm
Contains 32 cells in series

1.5 kW Apollo fuel cell
Apollo used two of these units.

Fuel Cells in Use: Portable Systems

A laptop using a fuel cell power source can operate for up to 20 hours on a single charge of fuel (Courtesy: Ballard Power Systems)



Advantage

Compact, lightweight and have no moving parts

Pollution is less

High efficiency (about 65%)

Disadvantage

Production cost is higher

Fuel cells in cars, doesn’t operate as well in higher temperature