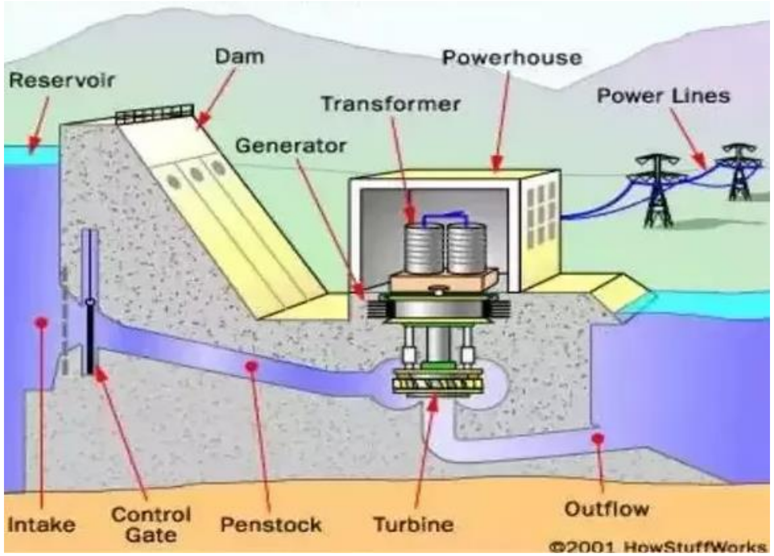
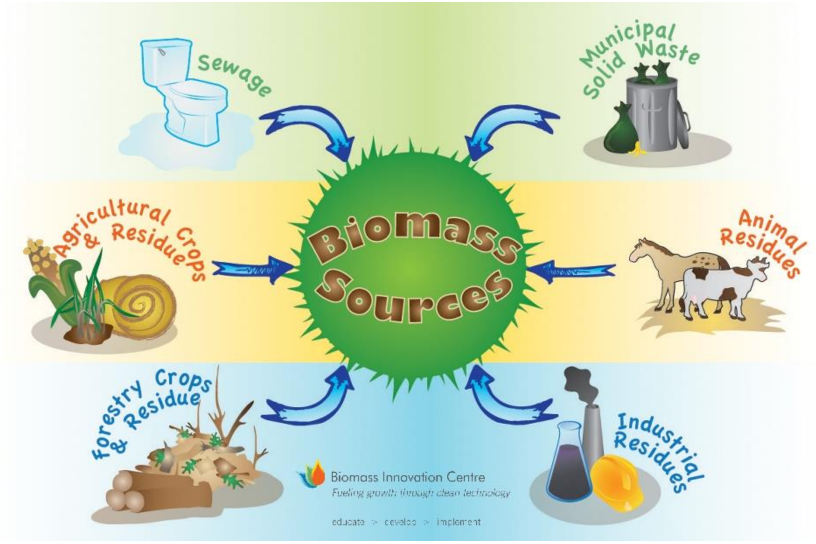
Clean Energy Sources

Wind Energy



Hydro-Energy

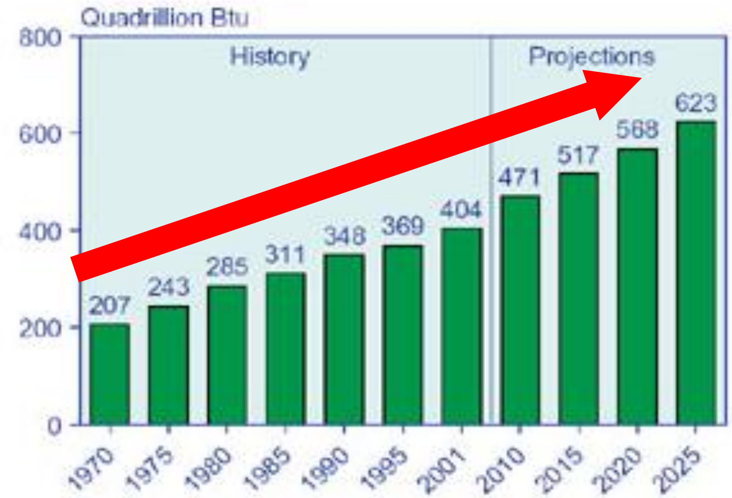


Bio-Energy

Solar-Energy

Why Clean Energy Sources ?

Fuel Depletion-A Global Threat



World energy consumption

- Fossil fuel energy will soon meet its end, while World energy consumption is expected to rise by more than 50 % over the next two decades.
- It cannot be reproduced (Finite & Non renewable).
- It releases waste products to the environment.

- Alternative renewable energy sources are in increasing demand.

Wind and Hydro Energy and their Applications

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March 2018

Collaborators

University of Jaffna Sri Lanka

Western Norway University of Applied Sciences

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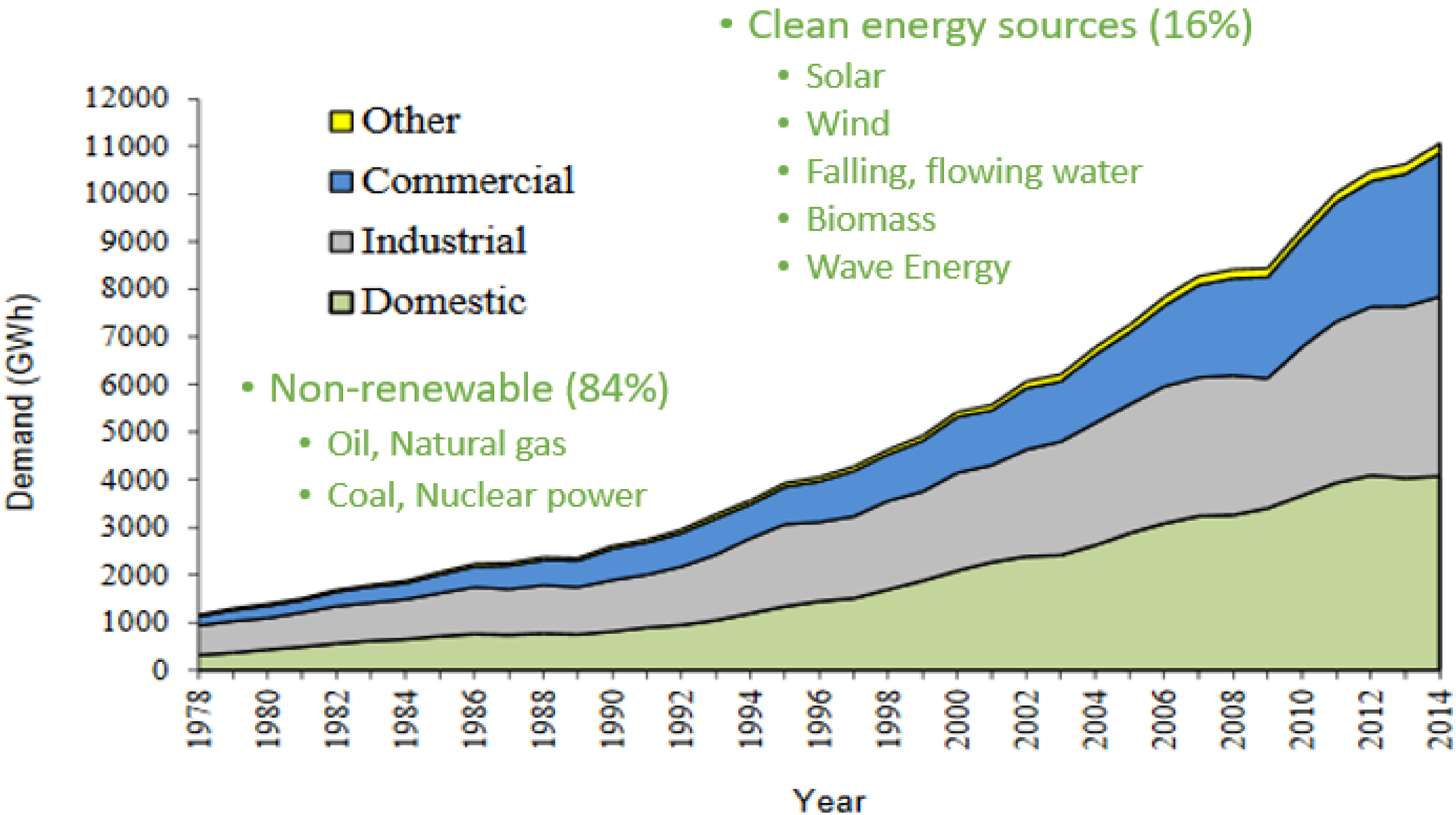
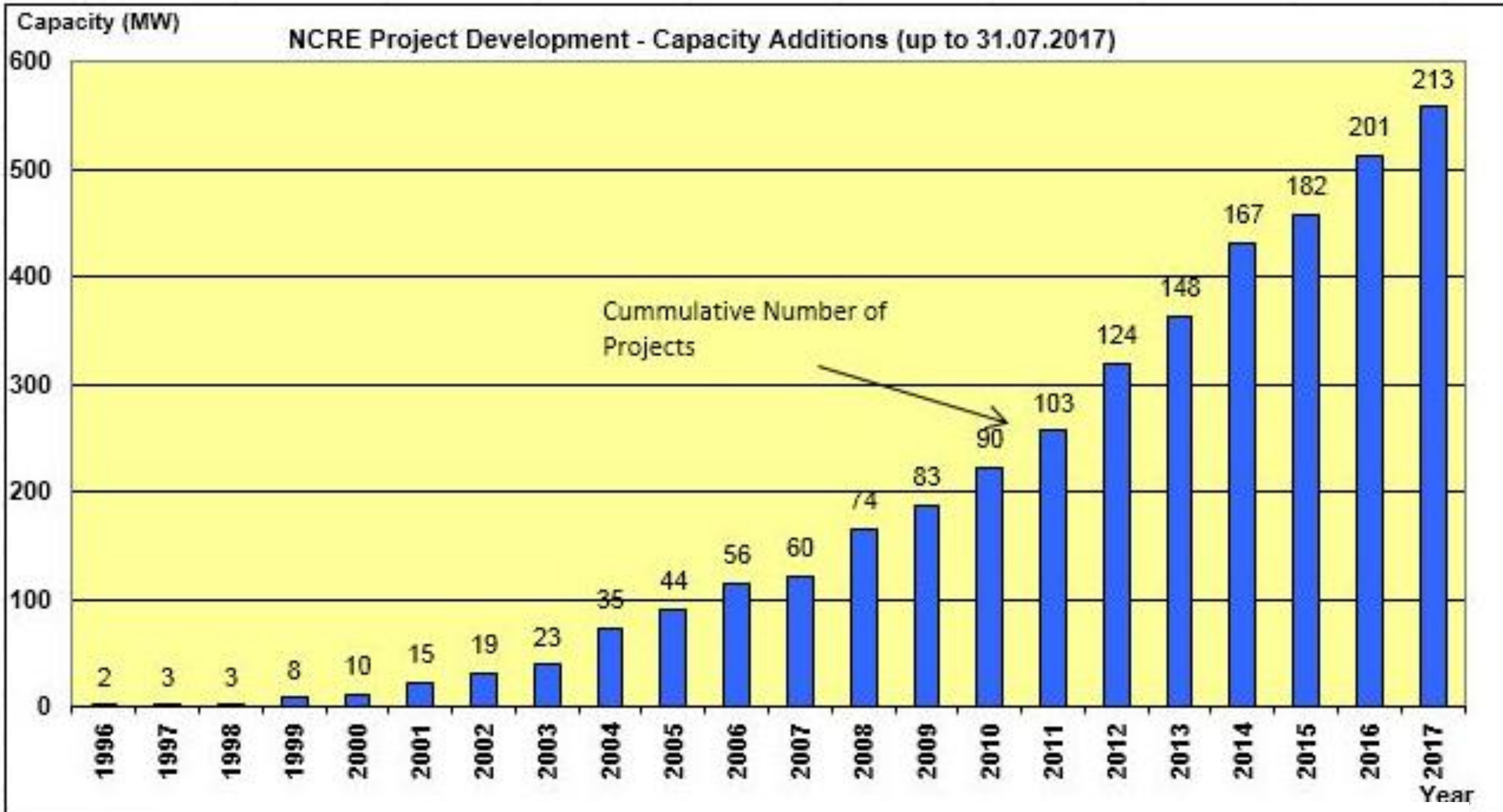
Increasing load in Sri Lanka



Consumption Share among Different Consumer Categories

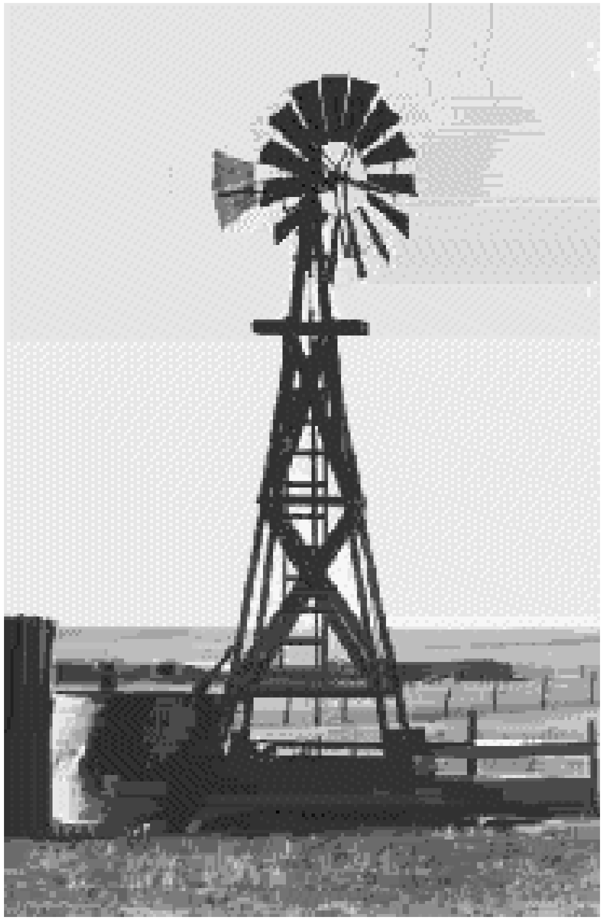
Present Status of Clean Energy Development (as at 31/07/2017)

http://www.ceb.lk/do-business-with-us/#tab-1439815407733-3-3



Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cap. (MW)	115	121	165	188	222	257	320	363	431	457	512	558

History of Wind Power

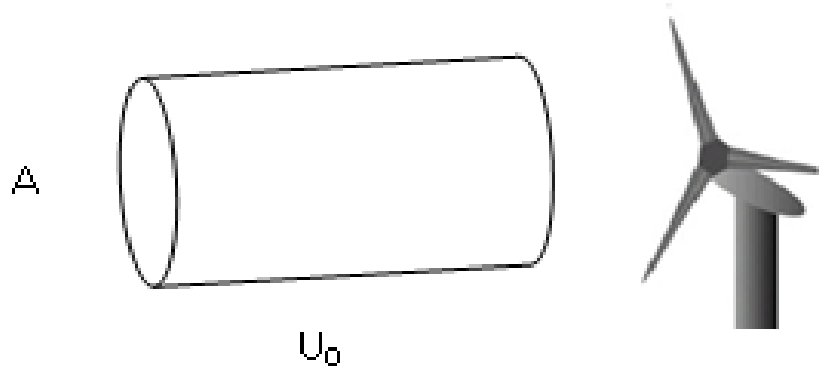


- We've used the wind as an energy source for a long time.
- The Babylonians and Chinese were using wind power to pump water for irrigating crops 4,000 years ago, and sailing boats were around long before that.
- Wind power was used in the Middle Ages, in Europe, to grind corn, which is where the term "windmill" comes from.
- Electricity generation by using wind turbine invented by Scottish Eng James Blyth.

How the Wind Generates?

- The Sun heats our atmosphere unevenly, so some patches become warmer than others.
- These warm patches of air rise, other air blows in to replace them - and we feel a wind blowing.
- Wind energy is an indirect form of Solar energy
- Wind turbines are used to convert kinetic energy of the wind in to usable form of Mechanical energy

Available Energy in the wind



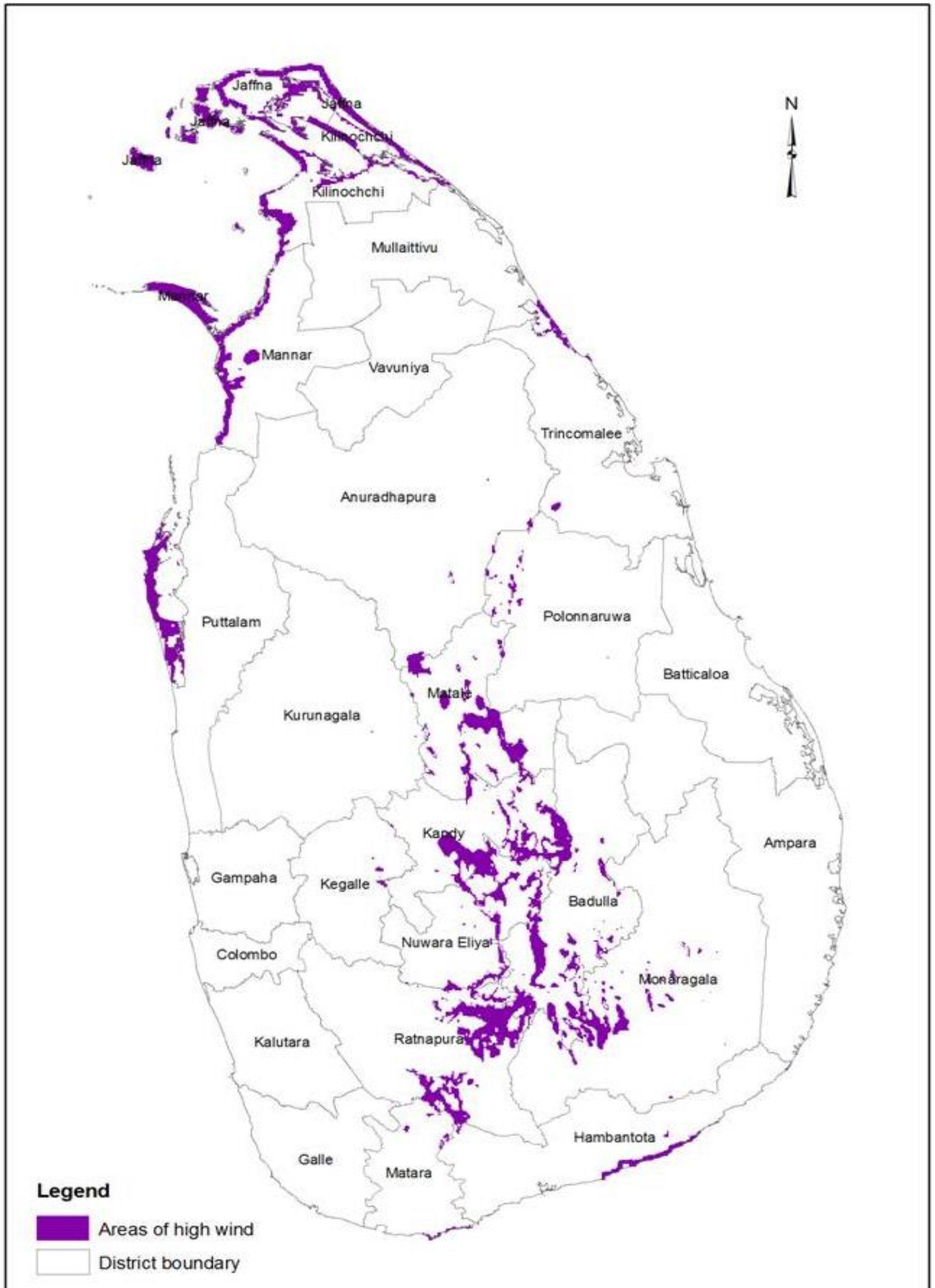
$$P_0 = \frac{1}{2}(\rho A U_o)U_0^2 = \frac{1}{2}\rho A U_0^3$$

Wind can reach much higher *power densities* :

- 10 kW/m^2 during a violent storm.
- over 25 kW/m^2 during a hurricane.
- gentle breeze of 5 m/s has a power density of only 0.075 kW/m^2.

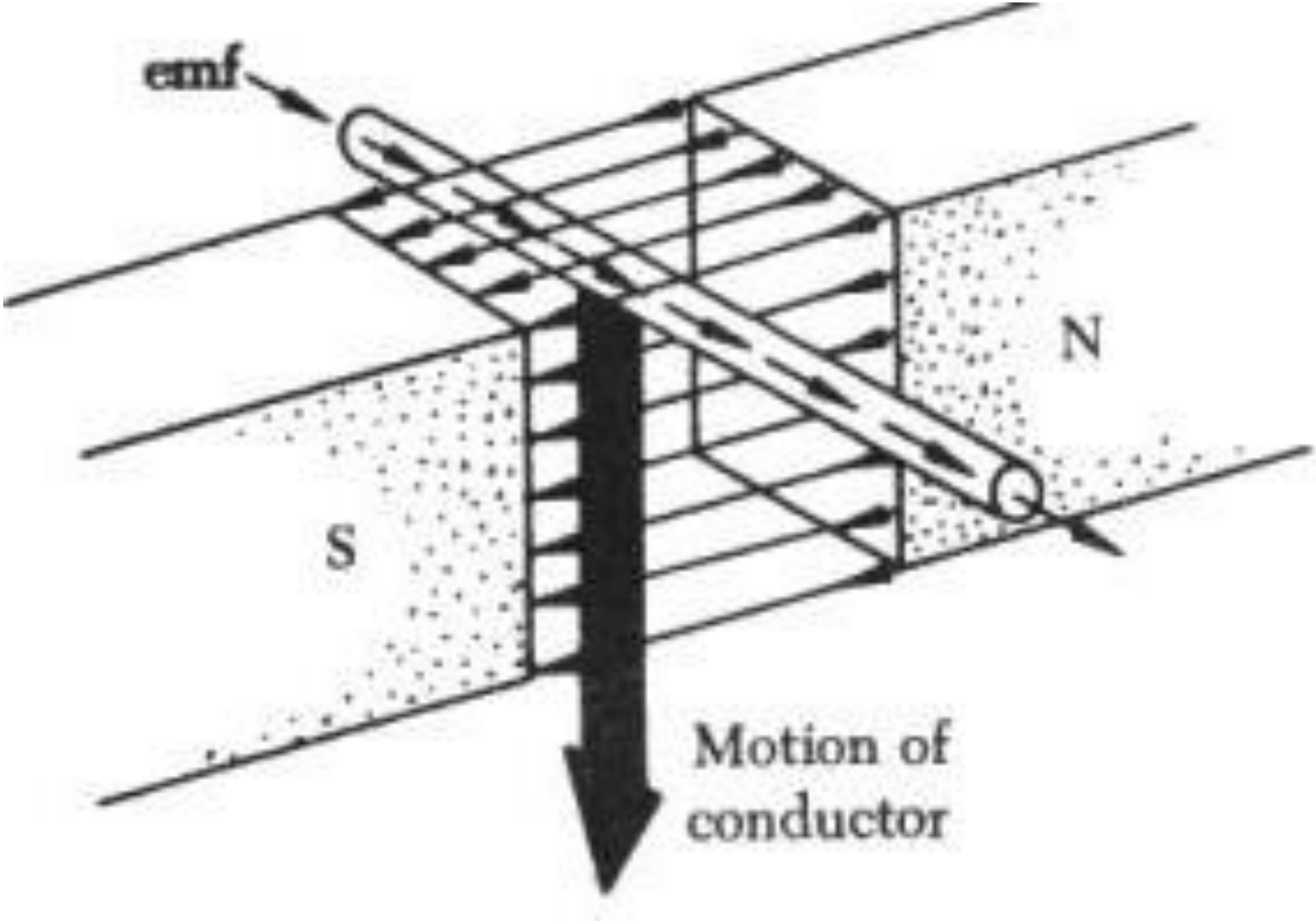
maximum terrestrial solar irradiance of about 1 kW/m^2.

Available wind resources in Sri Lanka:



Regions with Mean Annual Wind Speed > 7.0 m/s at 50m above Ground Level are marked in colour

Simple technique used for electricity generation



Inducing an *e.m.f* in a conductor

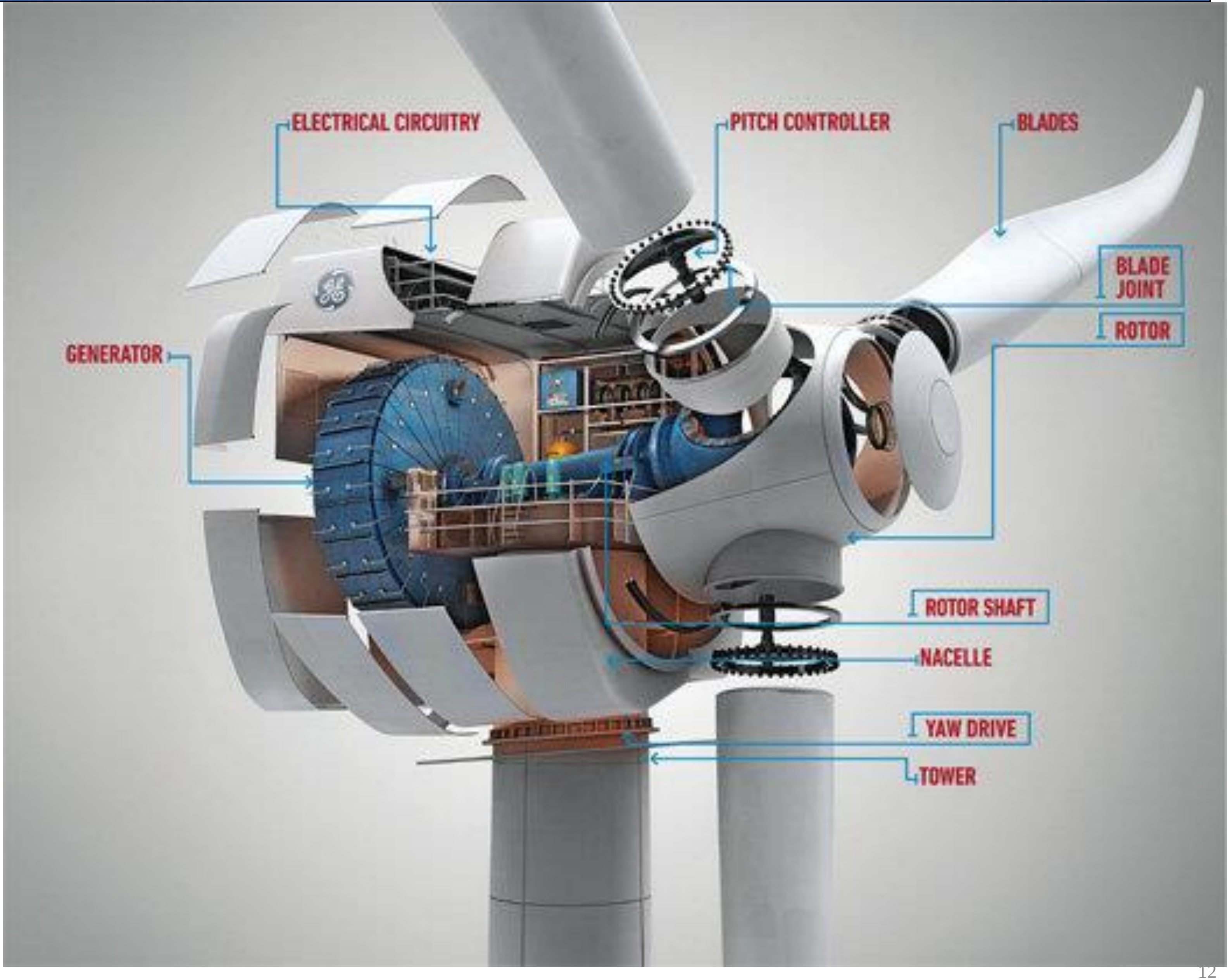
Possible wind turbine types

Horizontal-axis Wind Turbines (HAWT)

Vertical-axis Wind Turbines (VAWT)

Source: SEA Presentation by Mr. Harsha Wickramasinghe

Details components inside Wind Turbine



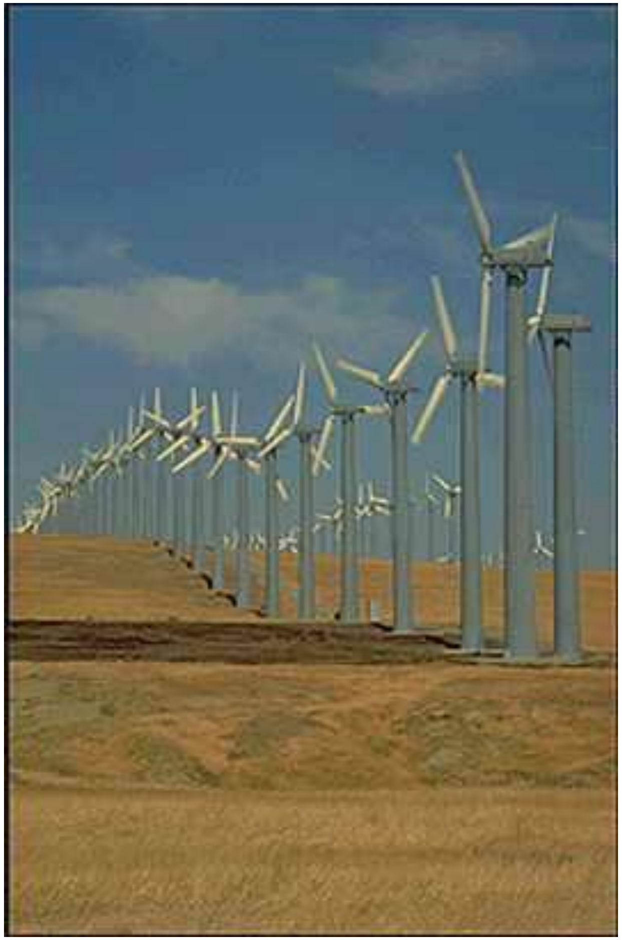
Source: SEA Presentation by Mr. Harsha Wickramasinghe

Advantages to Wind power

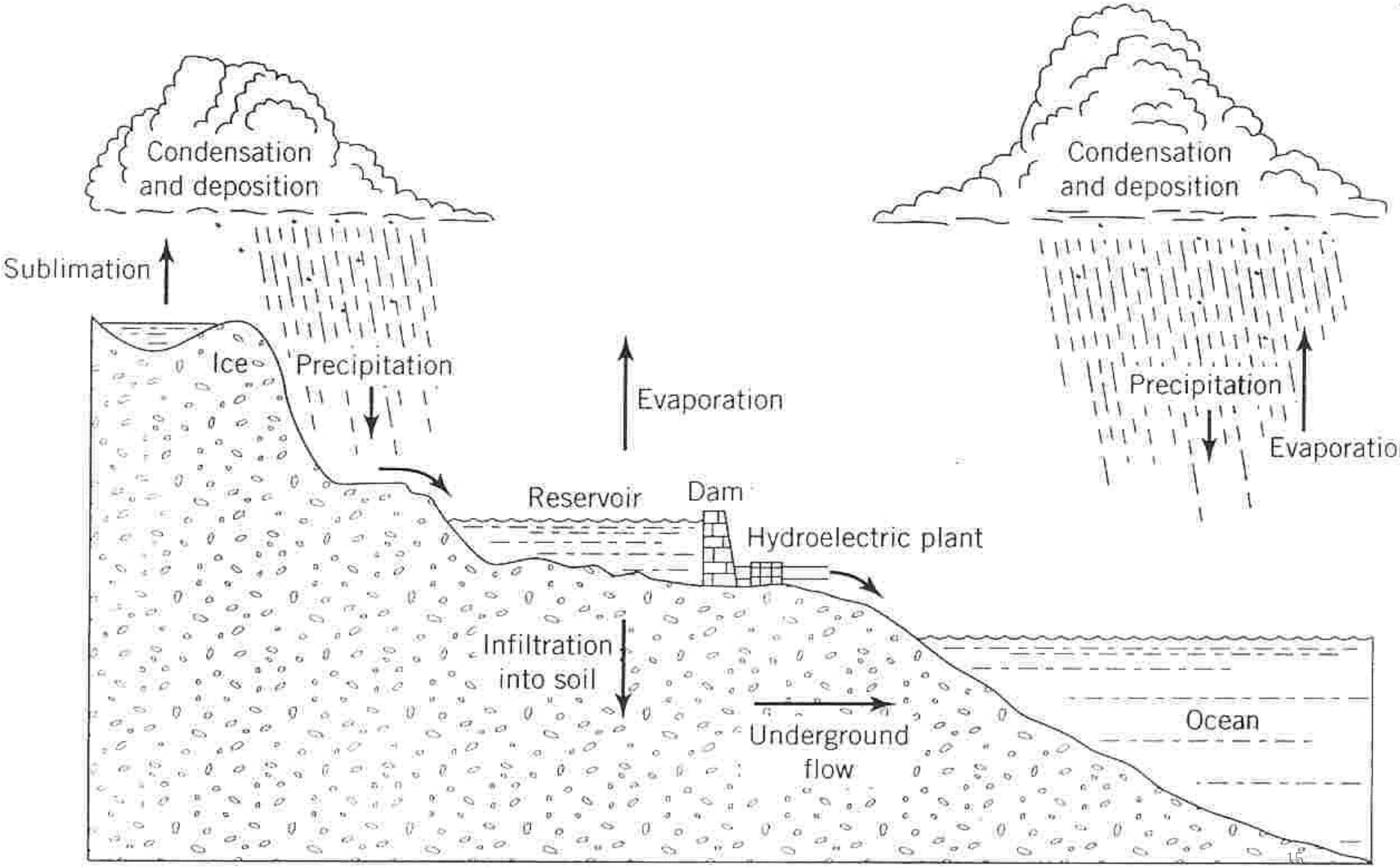
- Wind is free, wind farms need no fuel.
- Produces no waste or greenhouse gases.
- The land beneath can usually still be used for farming.
- Wind farms can be tourist attractions.
- A good method of supplying energy to remote areas.

Disadvantages of Wind Power

- The wind is not always predictable some days have no wind.
- Suitable areas for wind farms are often near the coast, where land is expensive.
- Some people feel that covering the landscape with these towers is unsightly.
- Can kill birds - migrating flocks tend to like strong winds. Splat!
- Can affect television reception if you live nearby.
- Noisy. A wind generator makes a constant, low, "swooshing" noise day and night.



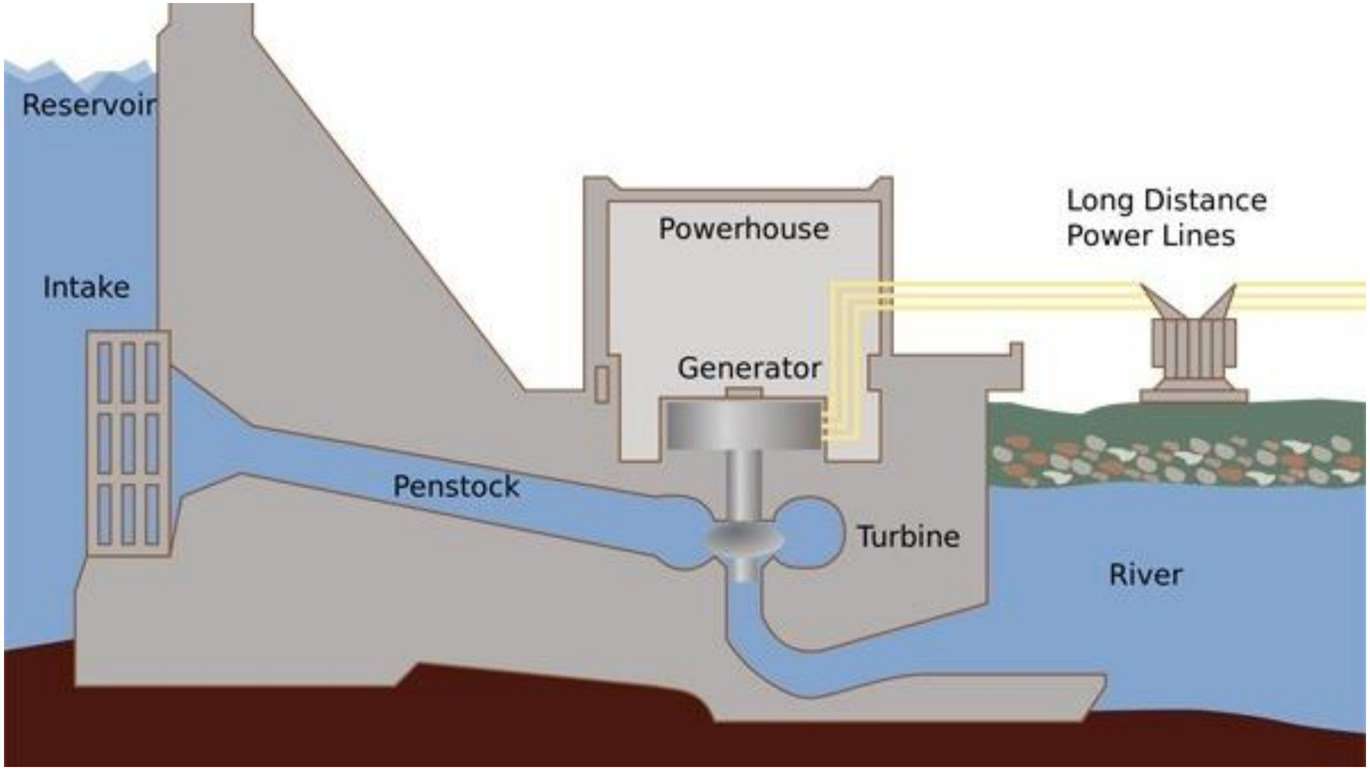
Water cycle as a great big heat engine



Hydroelectricity

- A dam is built to trap water, usually in a valley where there is an existing lake.
- Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators.
- Hydro-electricity provides 20% of the world's power

How does ‘Hydroelectric dams’ produce electricity?



Convert Potential Energy of Water Into Kinetic Energy to Run a Generator

- Potential Energy ➔ Kinetic Energy
- $mgh = \frac{1}{2}mv^2$
- *h* is called the “head” of the dam
- Modern hydroelectric plants convert ~90% of PE into electricity

Bioenergy and its application

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March 2018

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What is Biomass?

Organic material which has stored sunlight in the form of chemical energy

Bioenergy

- Alternative to fossil fuel to meet the increasing energy demand
- Refers to renewable energy produced from biomass
- Includes solid, liquid, or gaseous fuels
- Helps to reduce greenhouse gas emissions and minimize the carbon footprint

- Sugar
- Starch
- Cellulose
- Hemi-cellulose
- Lipids

→

Energy crops

Agricultural and forestry residues

Processing wastes

Energy Crops

Sunflower

Corn

Soybeans

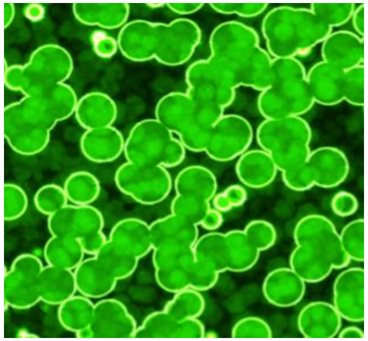
Rapeseed

Sweet sorghum

Sugarcane

Switch grass

Cattail



Microalgae

Agricultural and Forestry Residue

Corn Stover

Rice/wheat Straw

Wood chip

Husk/shell/peel from seeds

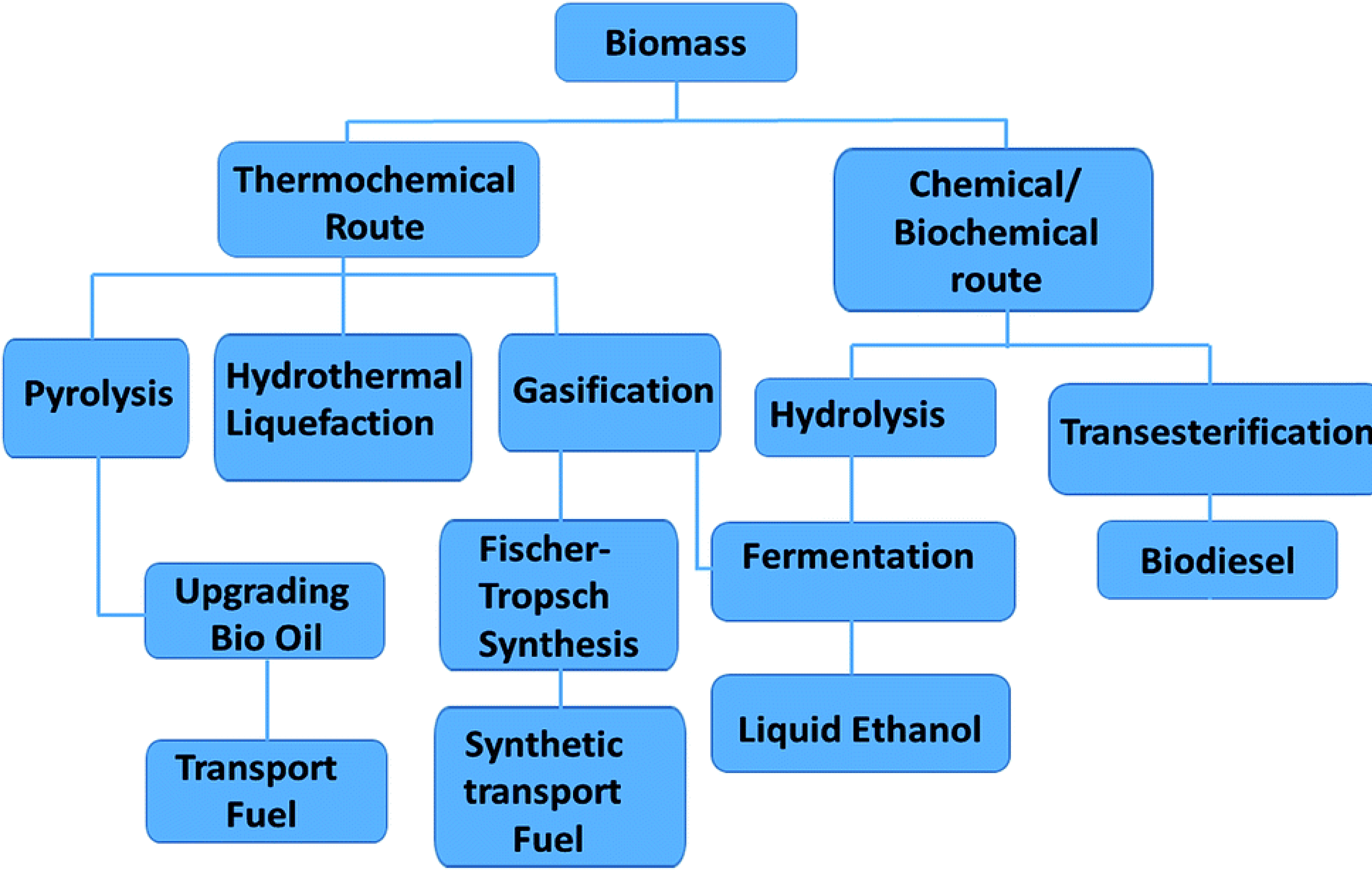
Processing Wastes

Municipal solid waste

Animal waste

Food waste

Biomass to Bioenergy Conversion Technologies

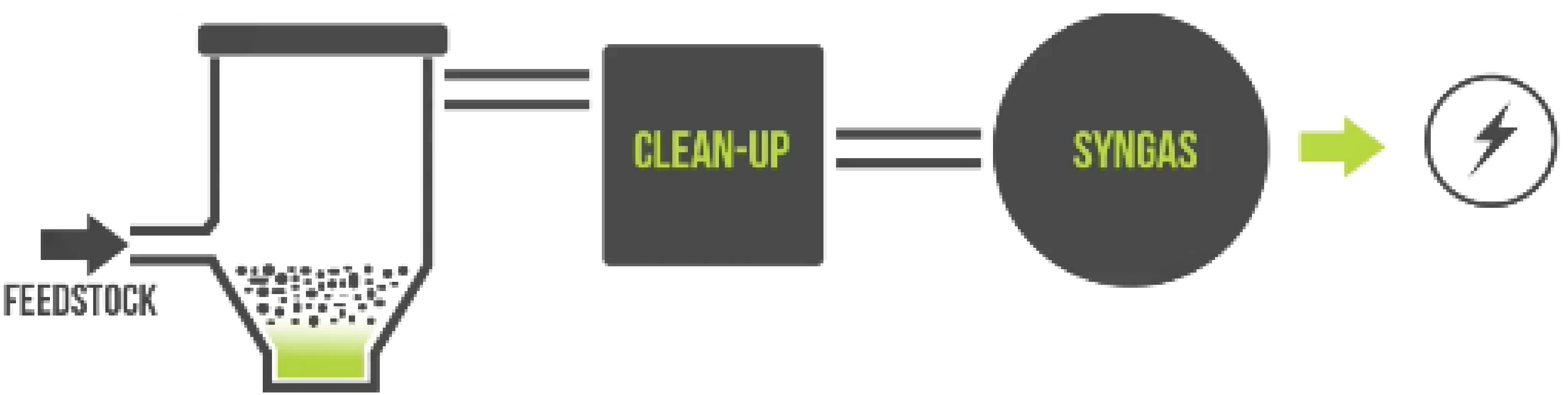


Thermochemical Route

- Combustion
- Gasification
- Pyrolysis
- Hydrothermal Liquefaction
- Fischer-Tropsch process

Gasification

- Solid biomass breaks down at high temperature (750-1100 °C) to form gaseous mixture
- Reaction takes place with limited amount of oxygen
- Gaseous mixture includes H_2, CH_4, CO, and CO_2
- Gaseous mixture can be
  - burned directly for heating or cooking
  - converted to electricity via an internal combustion engine
  - used as a **syngas** (CO and H_2 mixture) for producing higher quality fuels or chemical products such as hydrogen or methanol



Pyrolysis

Rapid thermal decomposition of biomass in the absence of oxygen. The end products are

- Bio-oil (dark-brown oil that can be upgraded to transportation fuel)

- Biochar (fine-grained charcoal high in organic carbon and can be used as a soil amendment)

- Gases including methane, hydrogen, carbon monoxide, and carbon dioxide

Biochemical Route

- Microbial Fermentation
  - Bioethanol/Butanol/Propanol production
- Transesterification
  - Biodiesel production
- Anaerobic digestion
  - Biomethane production
  - Biohydrogen production

Bioethanol

- The most common type of biofuel
- Bioethanol
  - Produced by fermenting any biomass high in carbohydrates
  - Produced from sugar (feedstock: sugar cane, sugar beet and, sweet sorghum)
  - Produced from starch (feedstock: maize, wheat and cassava)

Biochemical production of Ethanol

Sugar

- Catalysed by enzymes
- Sucrose/starch + H_2O

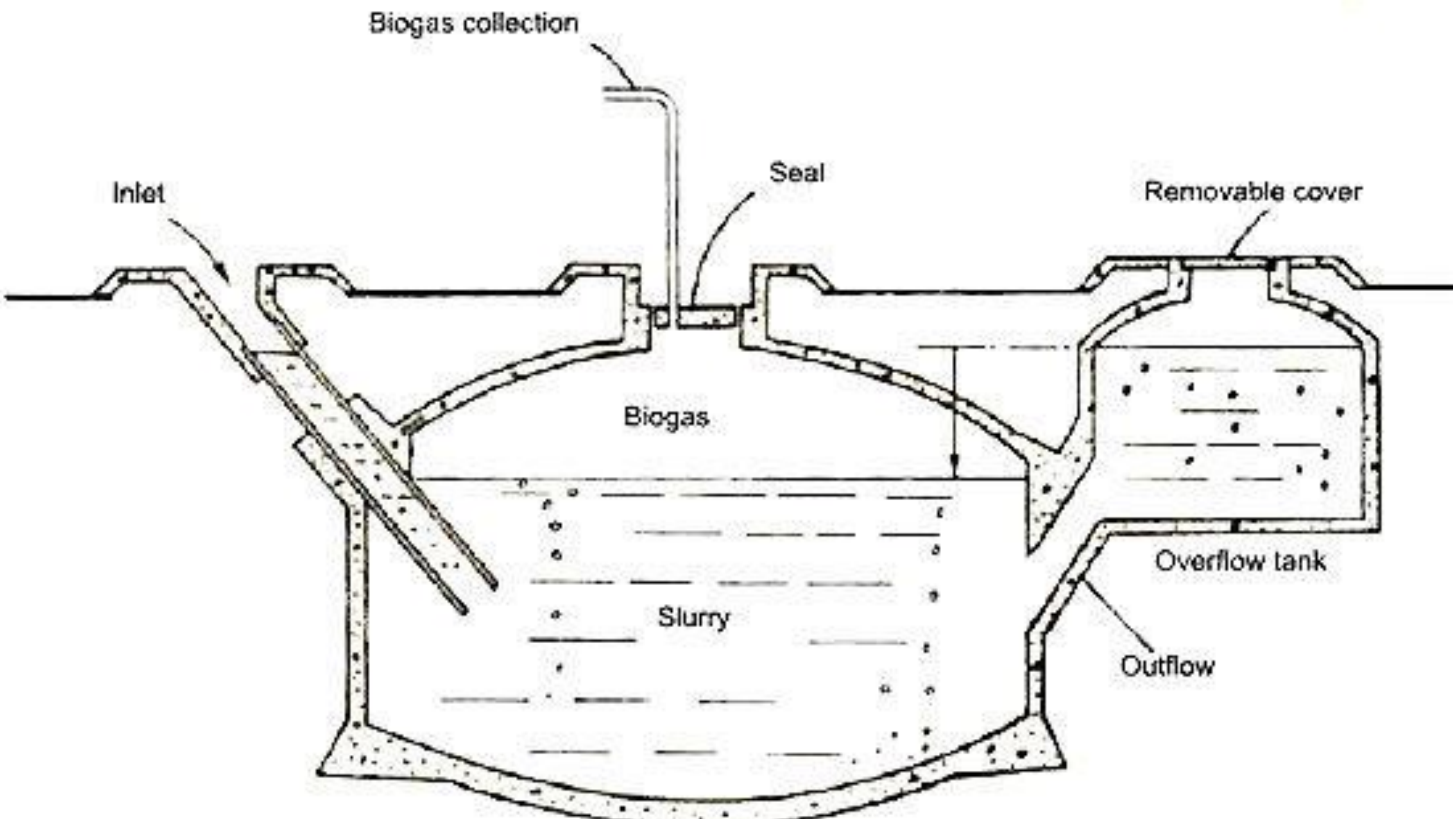
Glucose

Yeast addition

Ethanol + CO_2

Anaerobic Digestion

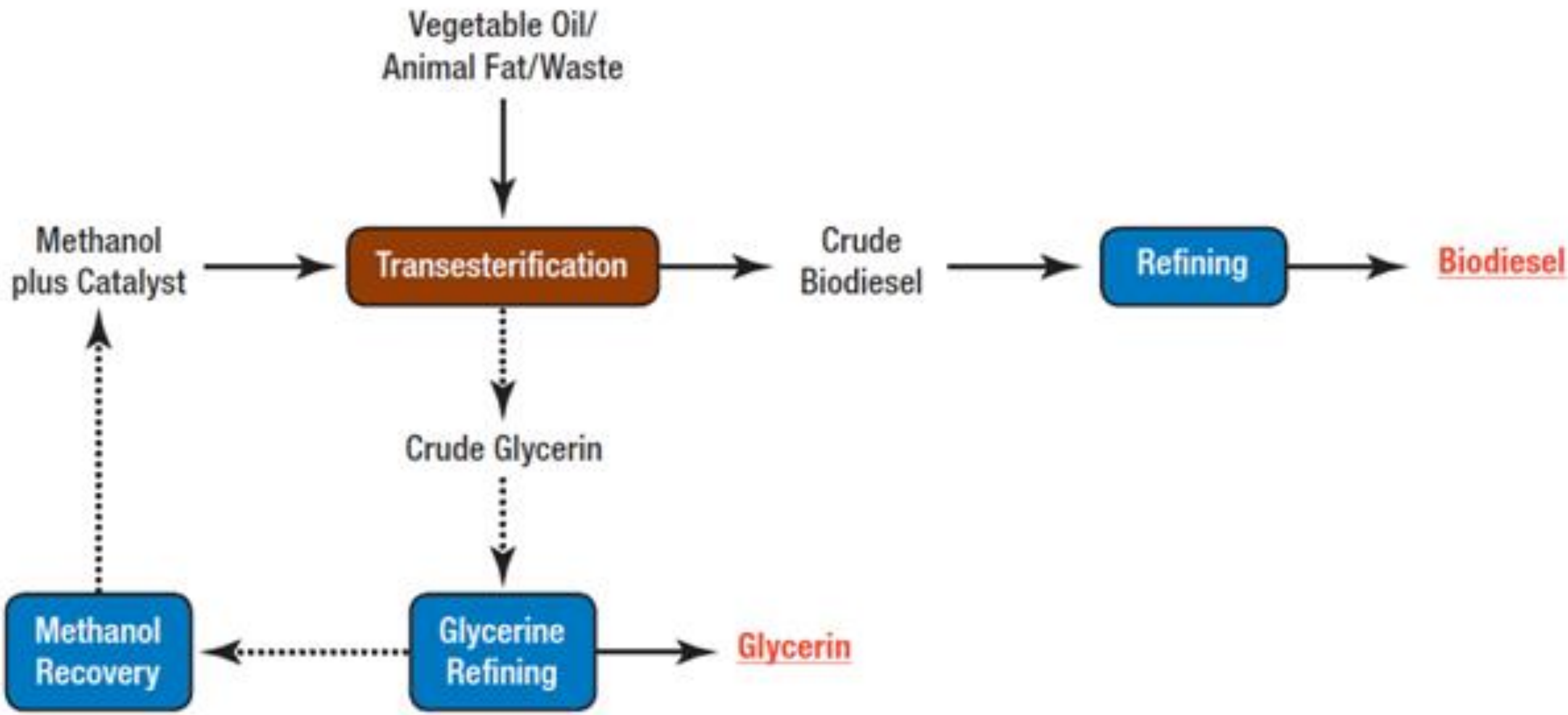
- Conversion of biomass to biomethane
- Methane can be used in internal combustion engine for producing electricity



A simple Household Anaerobic Digester

Bio-diesel

- Fuel derived from vegetable oils and animal fats through transesterification
- A biodegradable transportation fuel for use in diesel engines



Bio-fuels

1st Generation

- Derived from sugar, starch, vegetable oil originating from food source
- Fuel *vs* food controversy

2nd Generation

- Derived from biomass comprised of the residual non-food parts of current crops
- Crops that are not used for food purposes and industry wastes e.g. switch grass, wood chips, skins and pulp from fruit pressing *etc.*

3rd Generation: Algal biofuel

- Carbon neutrality
- Renewability
- Does not compete with food crops
- Minimum modification to diesel engine

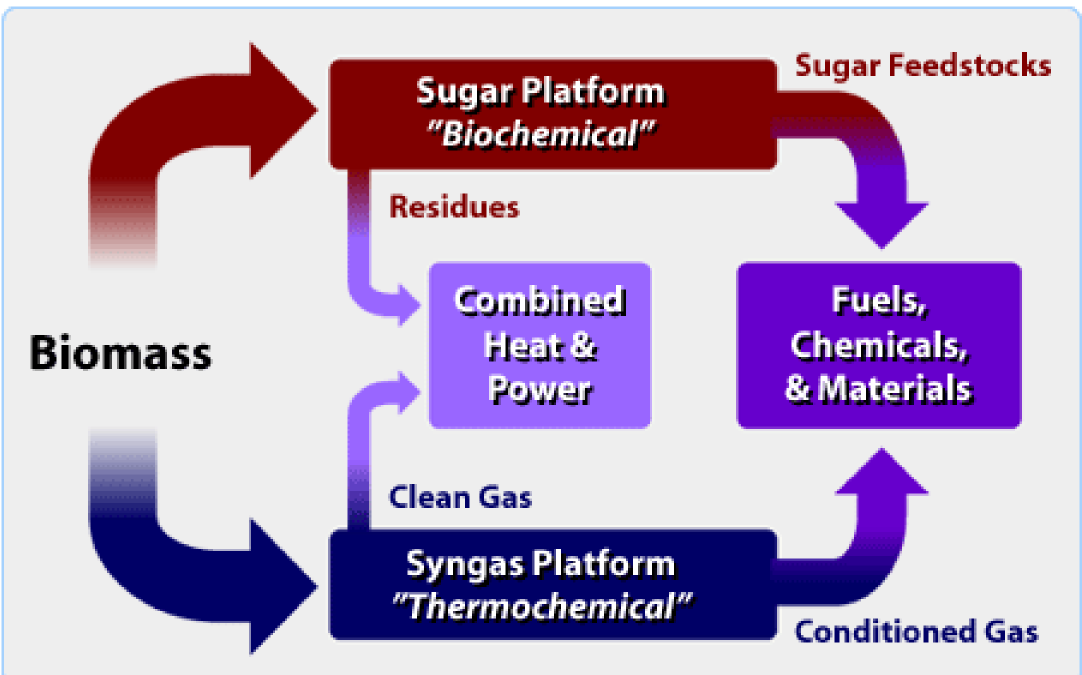
Bio-refinery Concept

- A bio-refinery involves the co-production of a spectrum of bio-based products (food, feed, materials, chemicals) and energy (fuels, power, heat) from biomass

- A bio-refinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and value-added chemicals from biomass.

- The bio-refinery concept is analogous to today's petroleum refinery, which produces multiple fuels and products from petroleum

Biorefinery Concept



Solar Energy and its application

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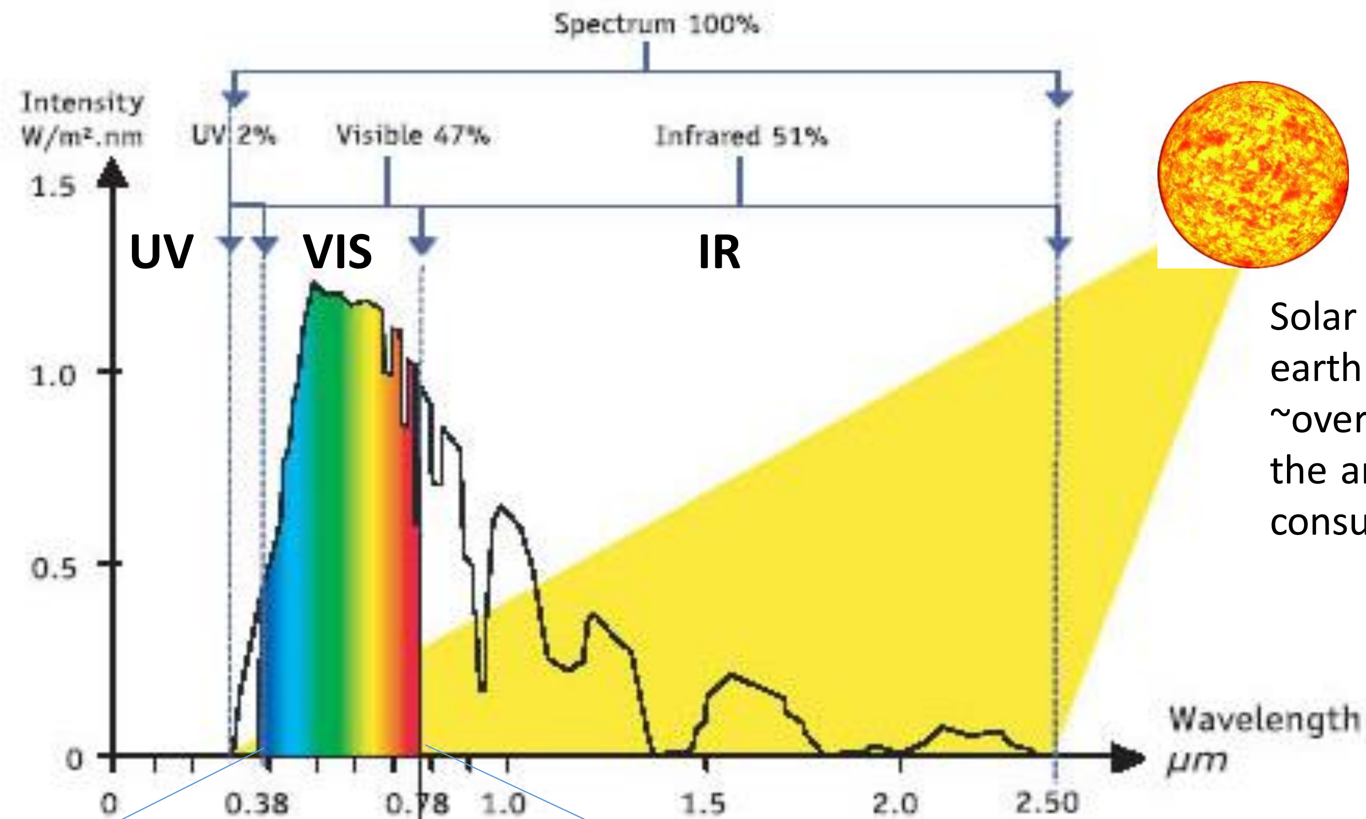
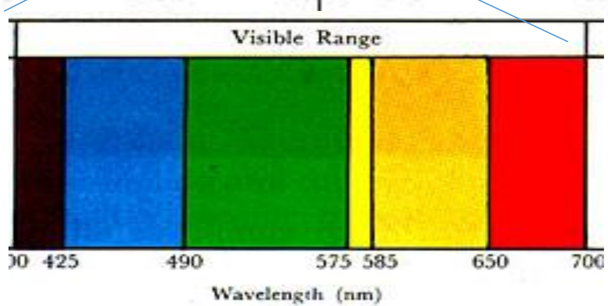
Solar energy

Solar energy originates with the thermonuclear fusion reactions occurring in the Sun which continuously radiates enormous amounts of solar energy at wavelengths that cover the UV, VIS and IR bands.



Solar energy received by the earth ~100 000 TW

~over 66,000 times greater than the annual world wide electricity consumption (1.5 TW)



Applications of Solar energy:

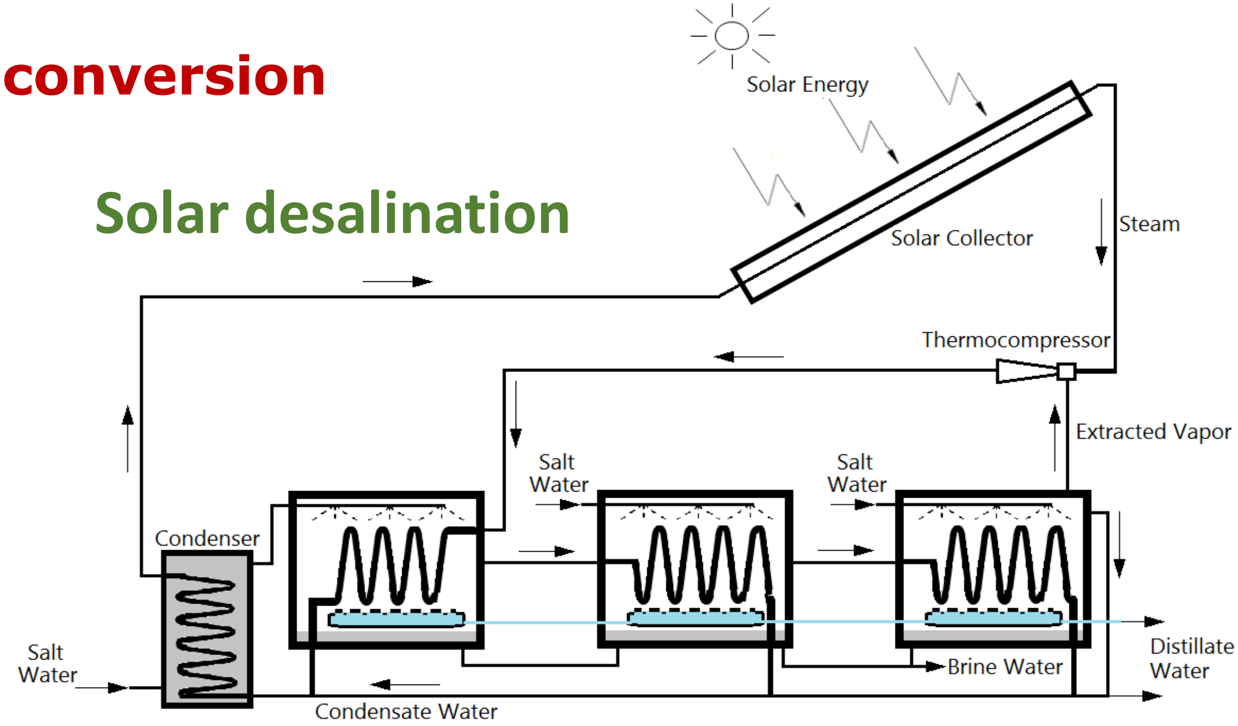
- **Thermal energy conversion (Solar Thermal)**, Eg. Solar cooker, water heater, dryer, desalination etc
- **Photo-energy conversion (Solar PV)**: Eg. Solar cells

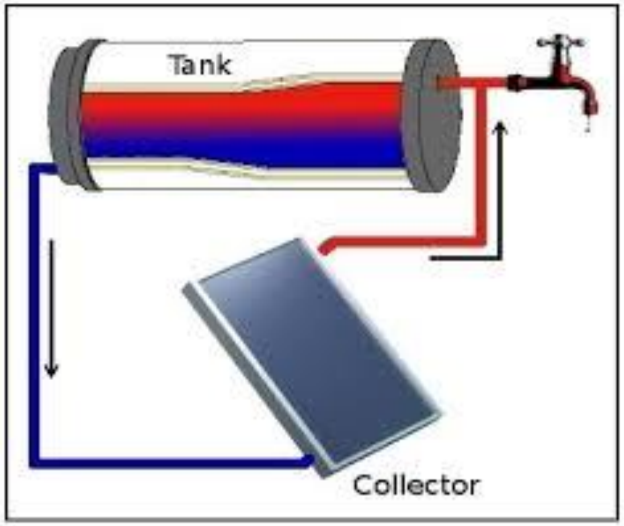
Application of Solar Energy

Solar Thermal energy conversion

Solar Cooker

Solar desalination





Solar water Heater

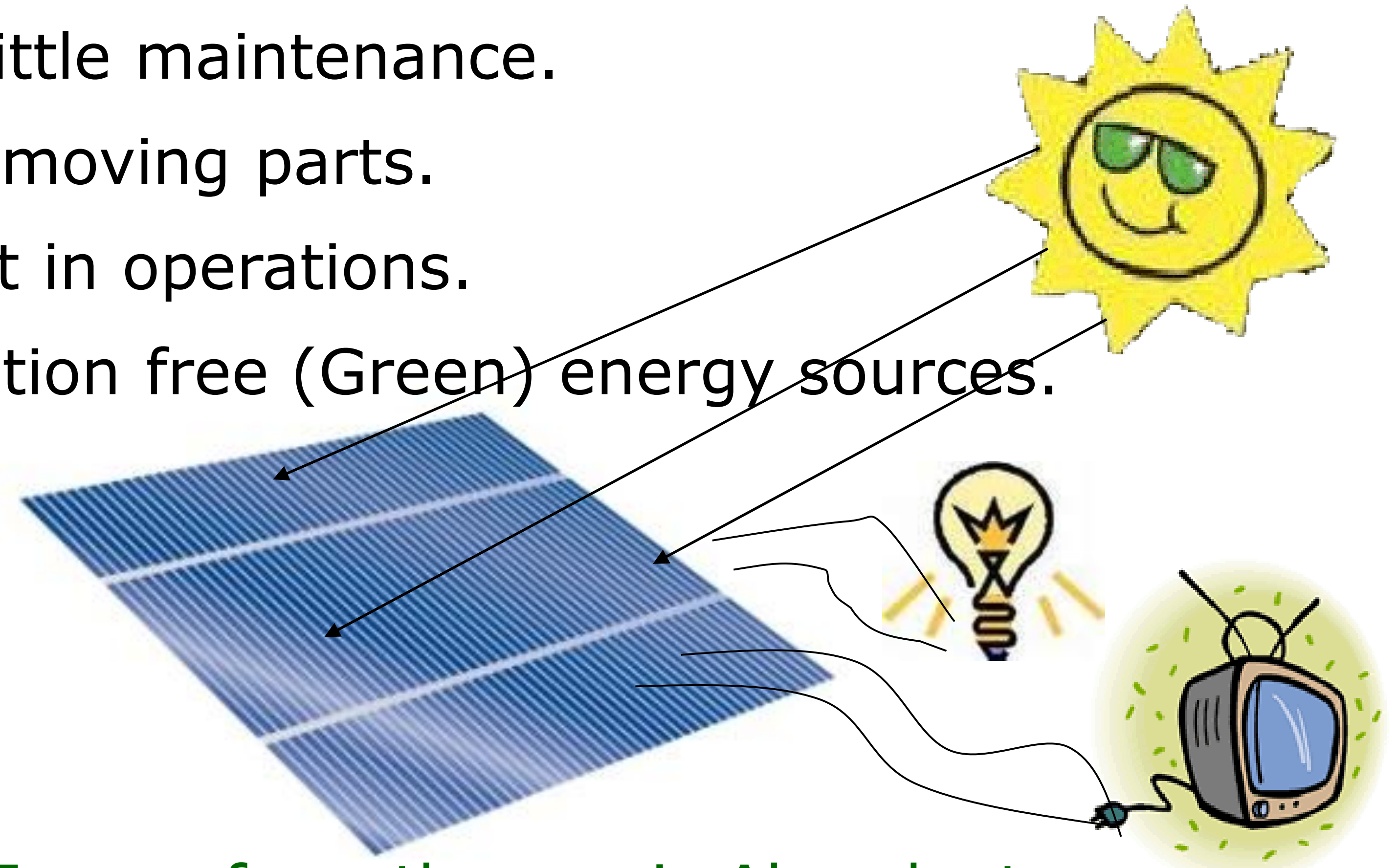
Solar dryer

Application of Solar Energy

Solar Photovoltaic (PV) energy conversion

Advantages

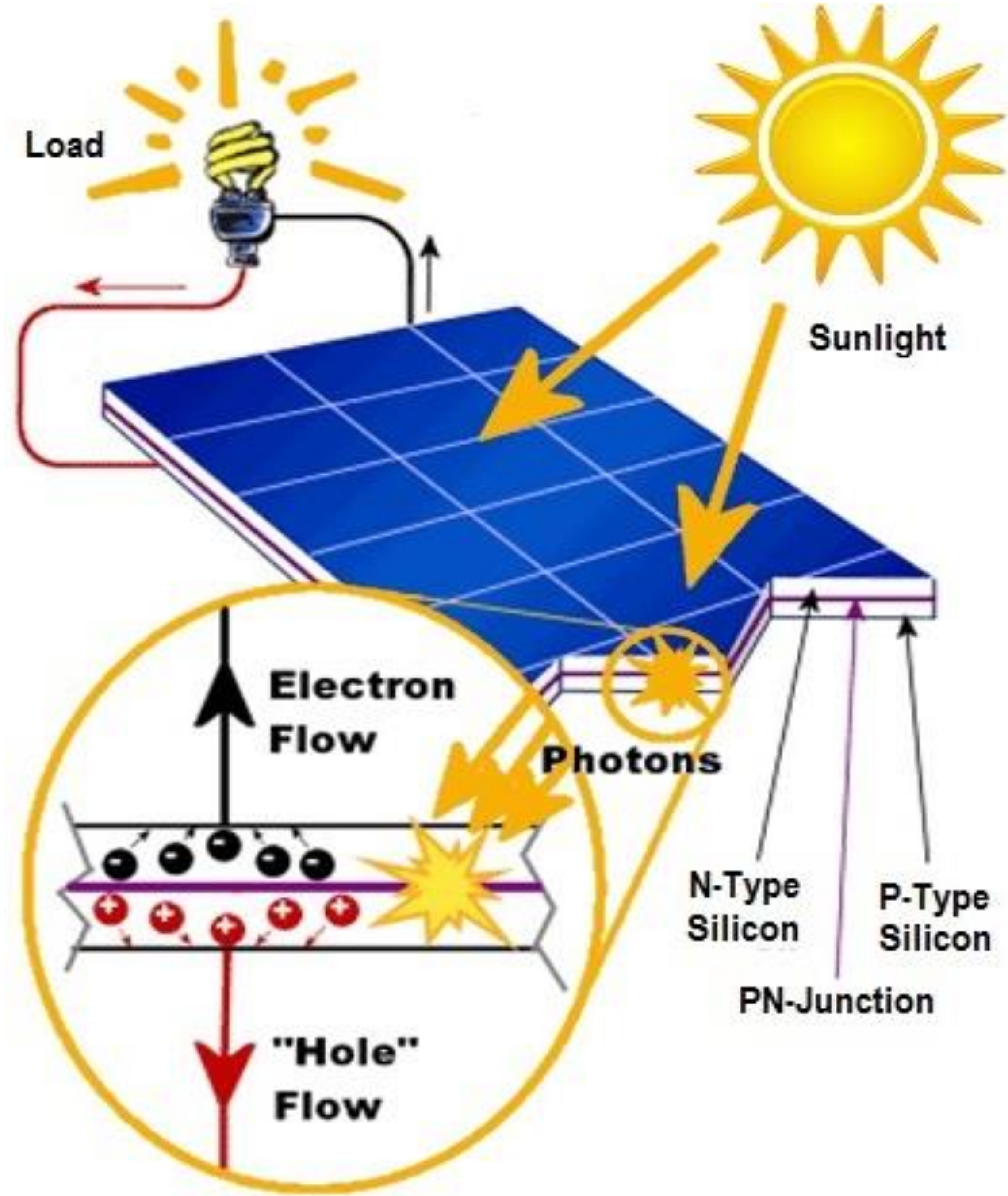
- ✓ convert light energy directly into electricity.
- ✓ do not require any cooling water system.
- ✓ require little maintenance.
- ✓ have no moving parts.
- ✓ are silent in operations.
- ✓ are pollution free (Green) energy sources.



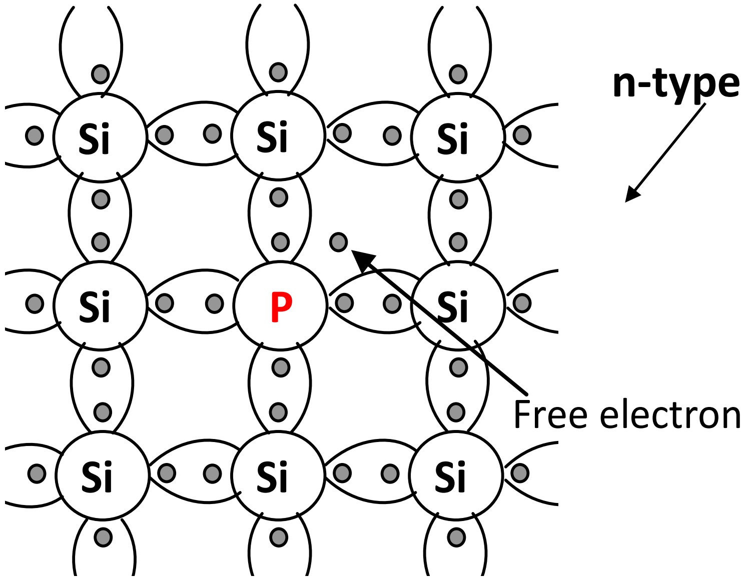
Moreover, Energy from the sun is Abundant.

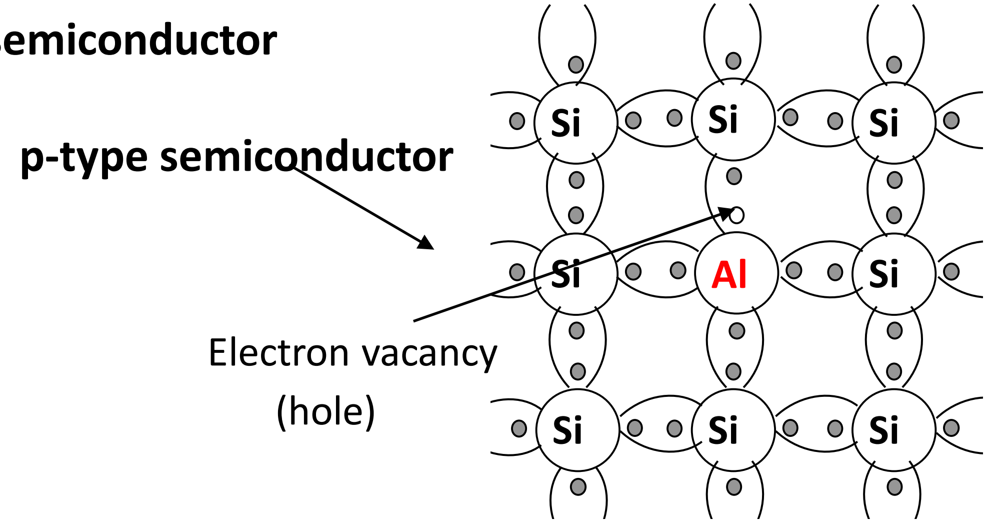
What is Solar cells?

Solar cells are photovoltaic cells that convert the **photons of sunlight** into **electrical power**.

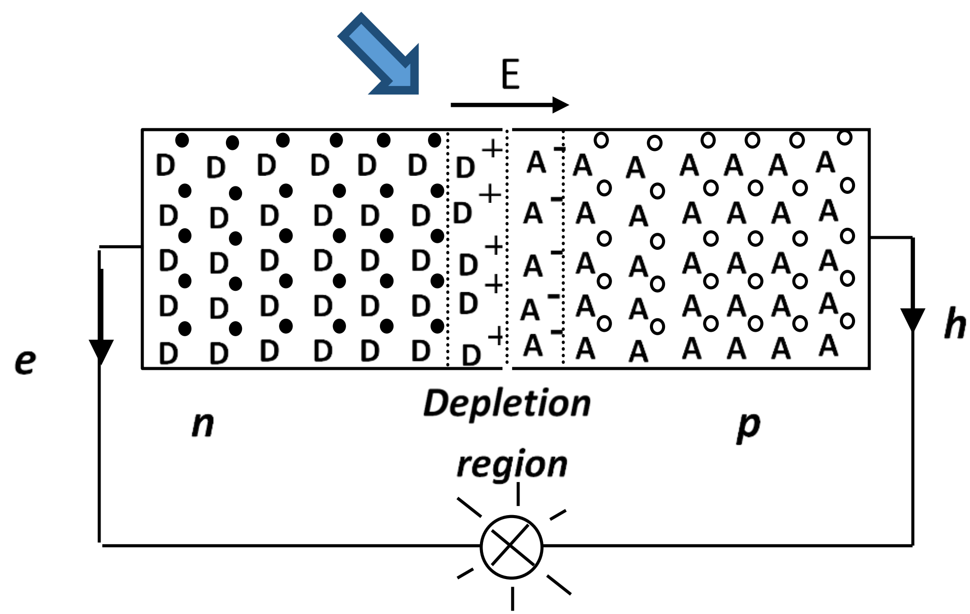


Operating principle of Solar cells

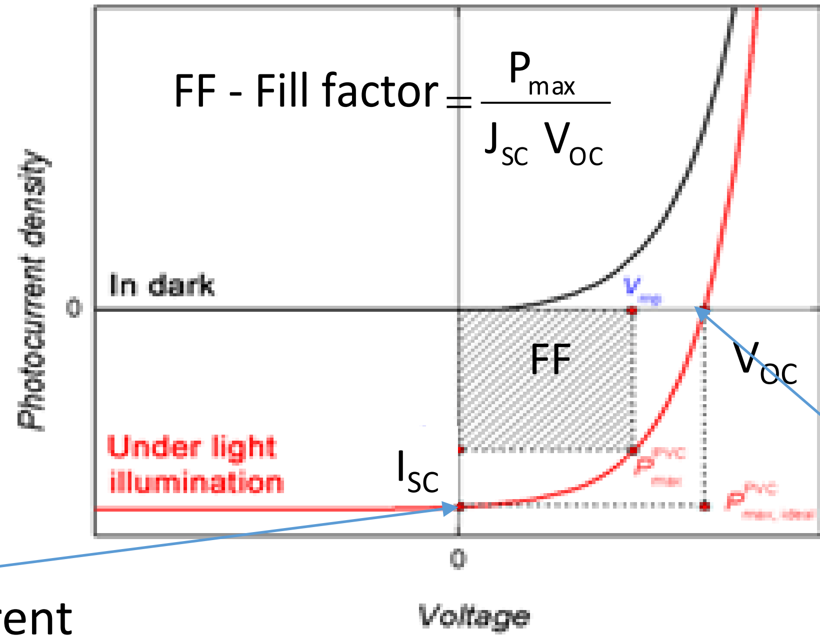




- The **absorption of light**, generating electron-hole (*e*-*h*) pairs
- The **separation of charge carriers** of opposite types
- The separate extraction of those **carriers** (*e, h*) **to an external circuit**



Evaluating Solar cells



I_{SC} - short-circuit current

V_{OC} - Open circuit voltage

$$\text{Efficiency of a solar cell } \eta = \frac{P_{max}}{P_{in}} \times 100\,\% = \frac{J_{sc}\ V_{oc}\ FF}{P_{in}} \times 100\ \%$$

- V_{OC} - Open circuit voltage which is the maximum voltage available from a solar cell, and this occurs at zero current (i.e., when the solar cell is open circuited).

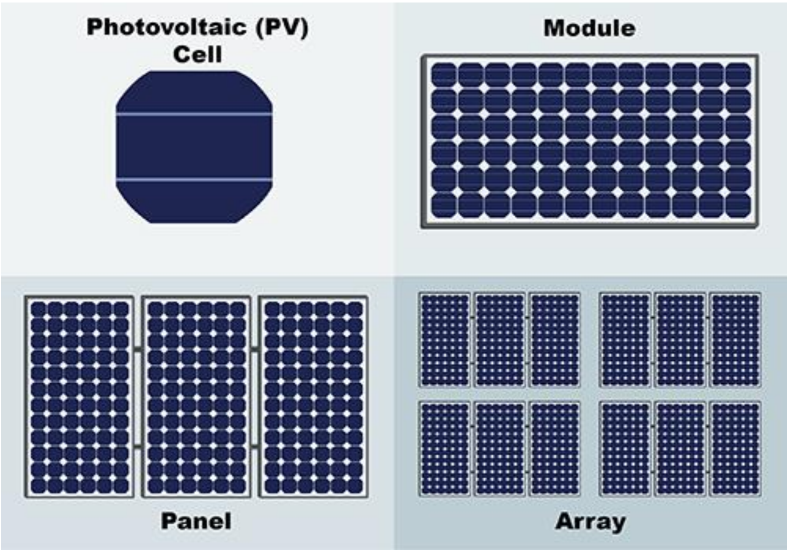
- $J_{SC} = \frac{I_{SC}}{A}$, where A is the area of the solar cell and I_{SC} is the short-circuit current which is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited).

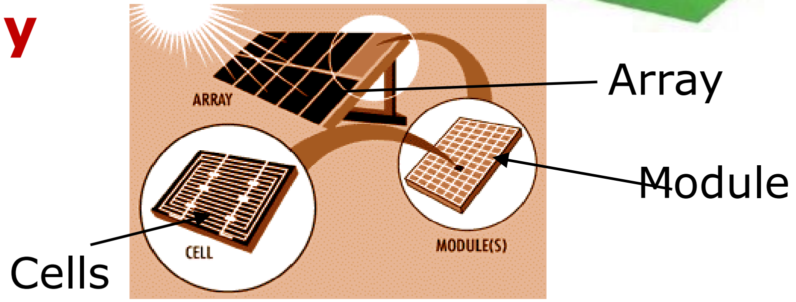
Application of Solar cells

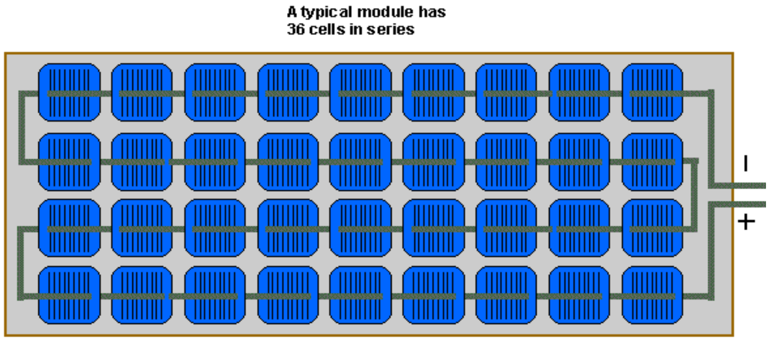
Required components for installation of a solar array

- **Solar Array**
- Batteries
- Charging controller
- Inverter
- Bulbs
- Wires

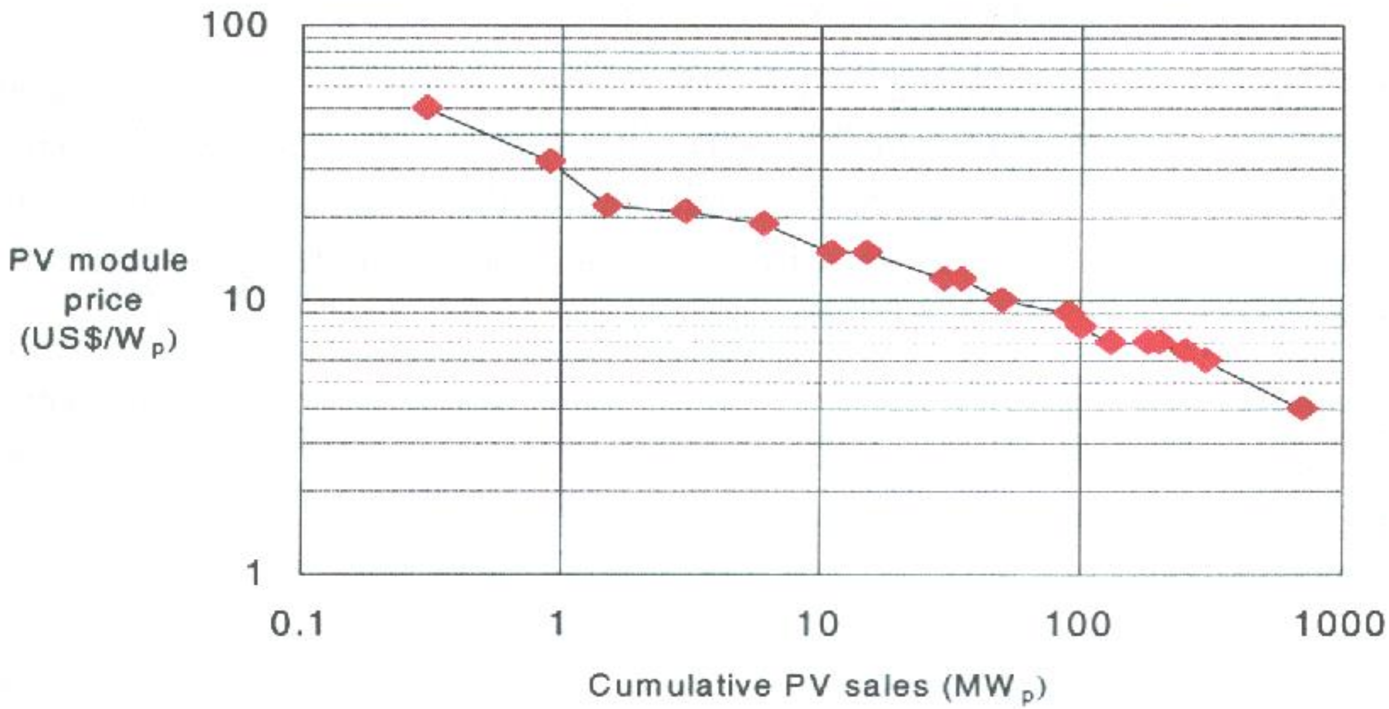
Components in a solar array

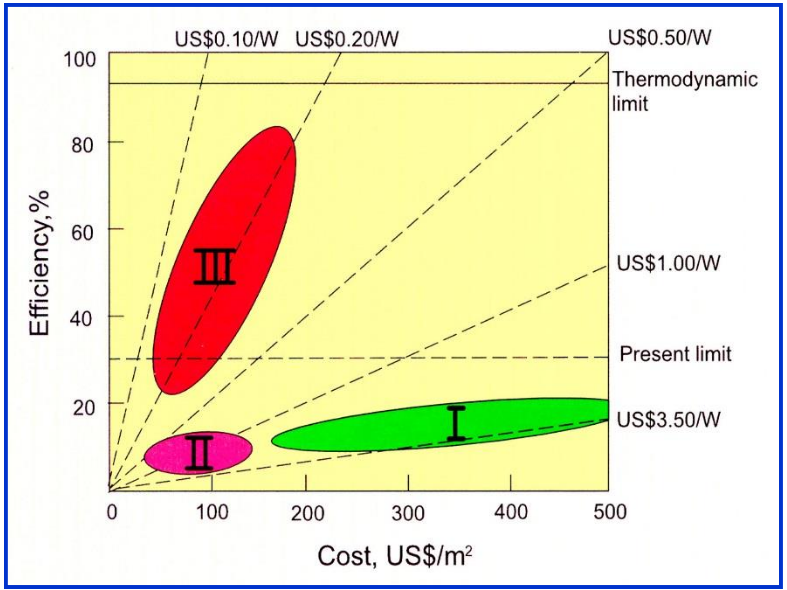






PV "learning curve"





Need new technology for making cheap solar cells

Nanotechnology may bring the cost down!

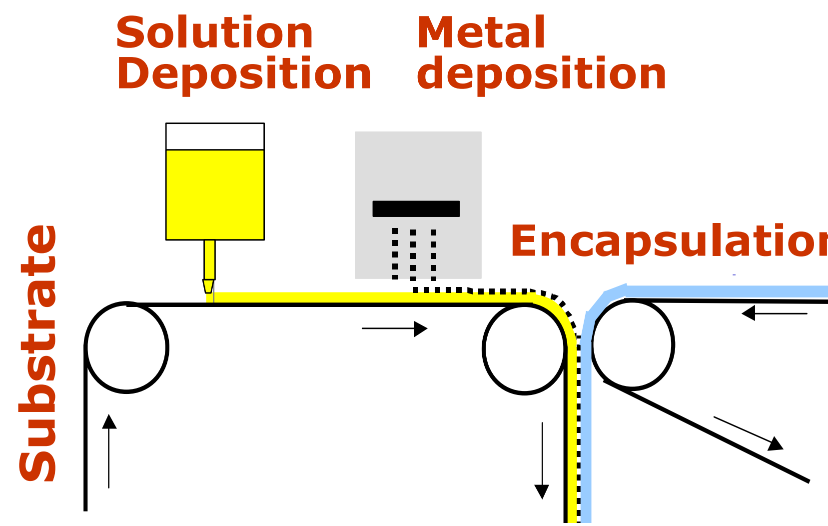
Why Nanostructured Solar Cell ?

Hard

Soft

Advantages

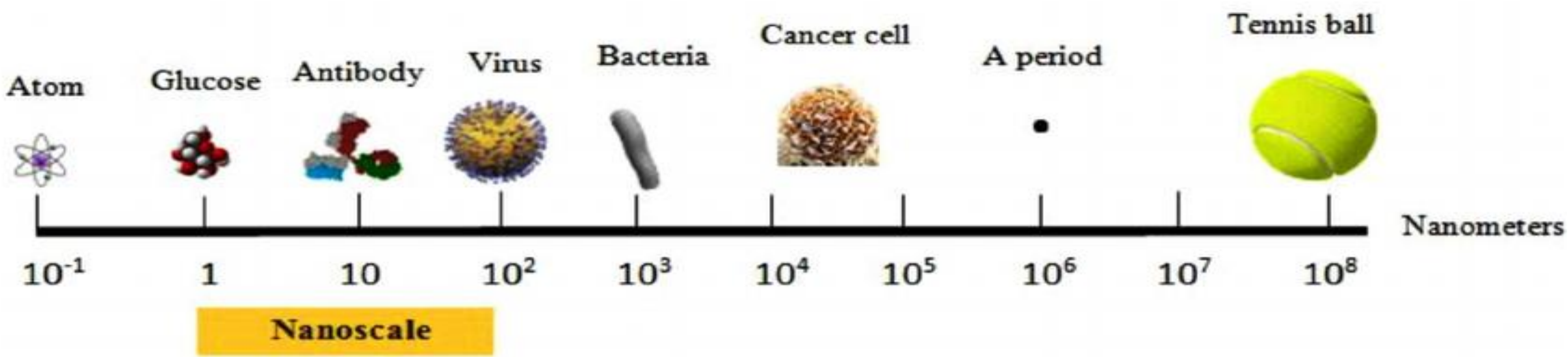
- ✓ Low cost (<1 US$(LKR 155)/W)
- ✓ Low weight
- ✓ Low material requirements
- ✓ Ease of manufacture
- ✓ Mechanical flexibility
- ✓ Large field of application

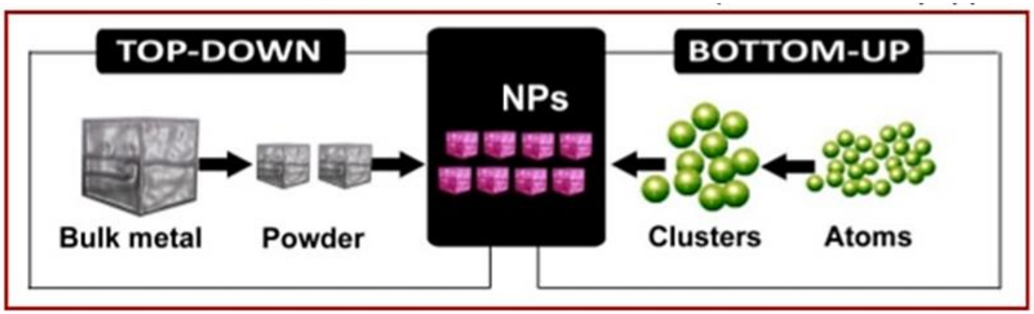


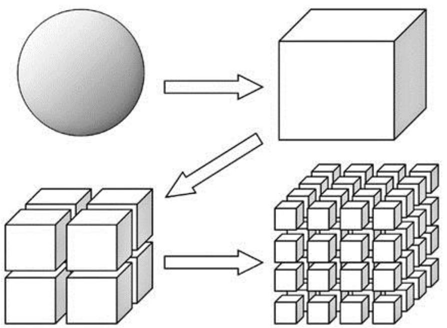
➢ However, there are constrains such as poor stability and low efficiency for commercialisation.

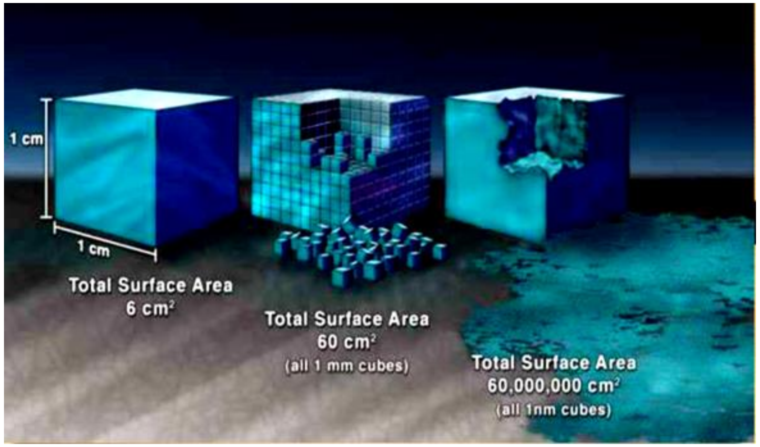
What is nanotechnology ?

Technology deals with materials in nanoscale.









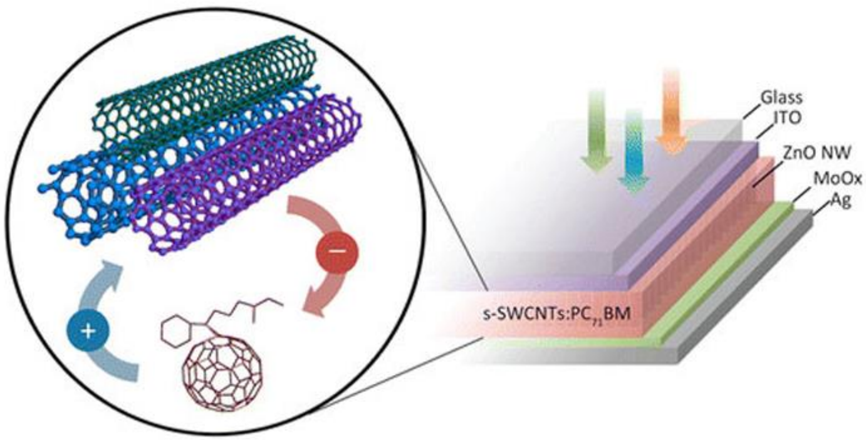
Surface area of the particles tremendously increases when the size of particles decreases

Efficiency increases with decreasing size of the particles!

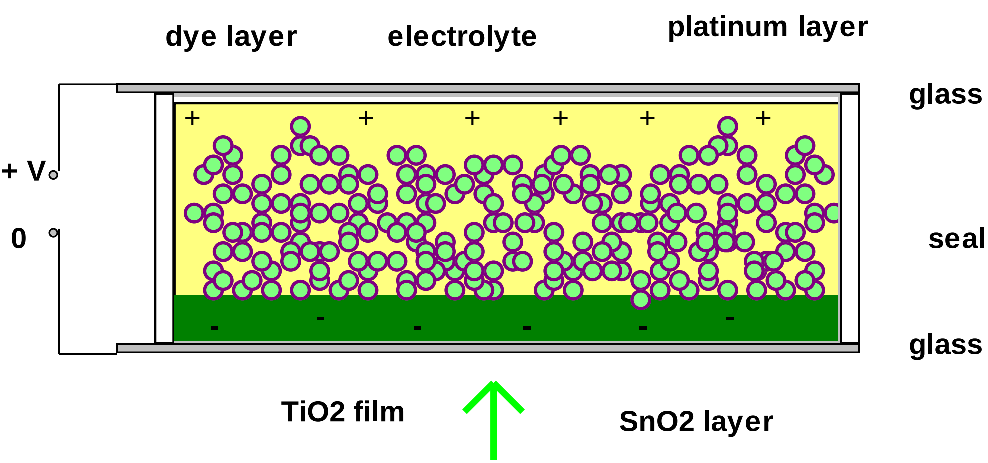
Nanomaterials in Clean Energy Application

Solar Cells

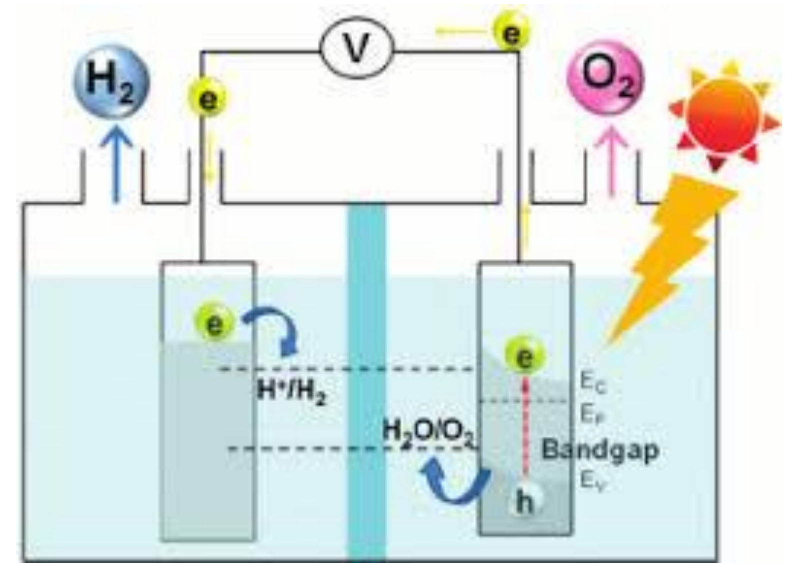
(a) Polymer blend solar cells

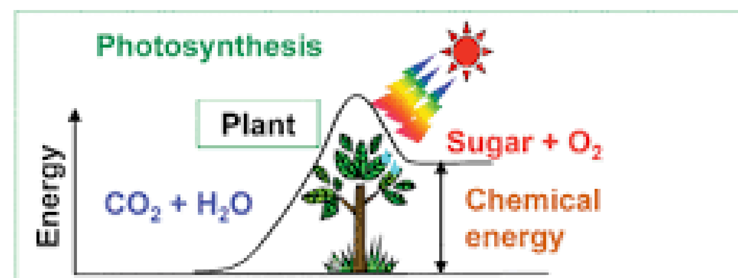


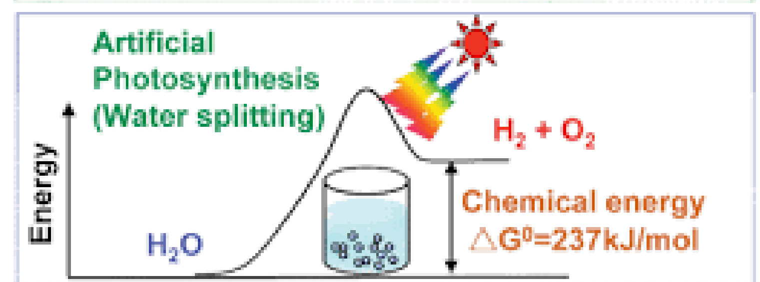
(b) Dye Sensitized Solar Cells



Water splitting

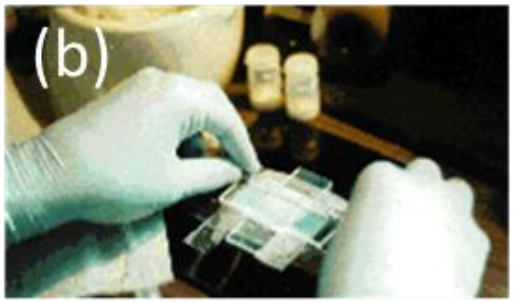






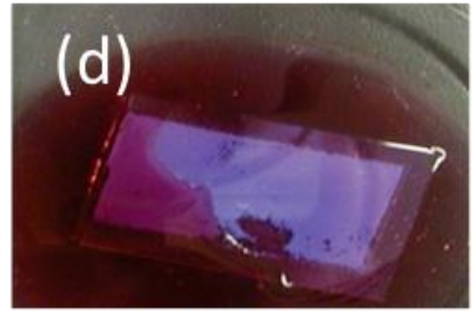
How to make Nanostructured Solar Cells?

TiO_2 nanoparticles

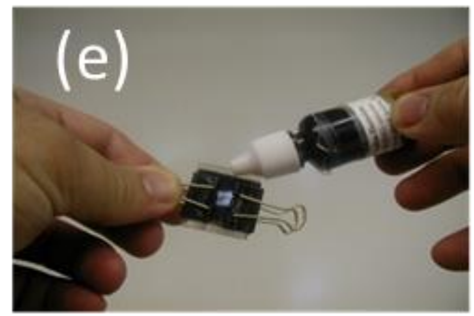


Depositing TiO_2 paste

Burning the organics

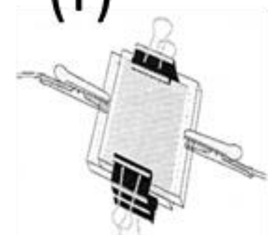


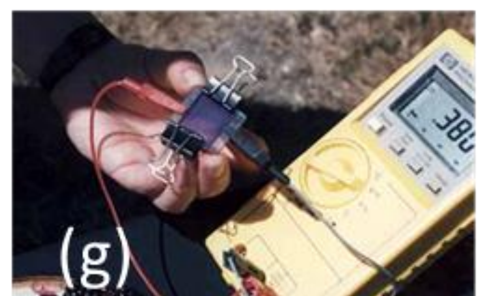
Socking TiO_2 film in dye solution



Inserting electrolyte

(f)



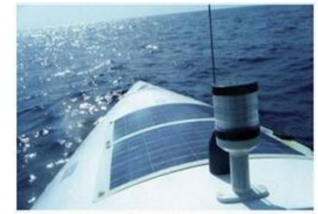


Testing a solar cell

Airplane

Bus station

Car charging



Yacht / Boat

Car Navigator

Houses

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