WELCOME

Energy & Environmental Science

Energy and Environment
L-T-P-C: 2-0-0-2

Syllabus:

Unit – 1 [4 Hours]: Present Energy resources in India and its sustainability:

Energy Demand Scenario in India, Different type of **conventional Power Plant**, Advantage and Disadvantage of conventional Power Plants, **Conventional vs Non- conventional power generation**.

Unit – 2 [4 Hours]: Basics of Solar Energy: Solar Thermal Energy; Solar Photovoltaic: Advantages and Disadvantages, Environmental impacts and safety.

Unit – 3 [4 Hours]: Wind Energy: Power and energy from wind turbines, India's wind energy potential, **Types of wind turbines, Offshore Wind energy**, Environmental benefits and impacts.

Unit – 4 [4 Hours]: Biomass Resources: Biomass conversion Technologies, Feedstock pre-processing and treatment methods, Bioenergy program in India, Environmental benefits and impacts; **Other energy sources**: **Geothermal Energy resources, Ocean Thermal Energy Conversion, Tidal Energy.**

Unit – 5 [4 Hours]: Air pollution: Sources, effects, control, air quality standards,

air pollution act, air pollution measurement; **Water Pollution**: Sources and impacts; **Soil Pollution**: Sources and impacts, disposal of solid waste. **Noise pollution**

Unit – 6 [4 Hours]: **Greenhouse gases effect**, acid rain; Pollution aspects of various power plants; **Fossil fuels and impacts, Industrial and transport emissions impacts.**

Course Objectives

The objective of the course to teach

- ❑the **principal renewable energy systems,**
- ❑the **environmental impact of various energy sources** and
- ❑the **effects of different types of pollutants**

3

Unit – 1
Present Energy resources in India and its sustainability:

- ❑ **Global Energy Scenario and Global Environmental Issues**
- ❑ **Different types of Energy sources: Conventional vs Non-conventional Energy**

4

Faculty

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Accredited Energy Auditor
ENSAVE ACADEMY

- **Accredited Energy Auditor (*BEE*)**
- **Certified ISO 50001 –EnMS Auditor**
- **CMVP & Green Building Professionals**

➢ **35 Years of Energy Auditing experience in India & Abroad**
  - **Conducted >450 +Energy Audit in Industry & buildings**
  - **Trained >20,000+ engineers in energy efficiency, plant utilities, green buildings etc.**
  - **Developed >250+ certified energy auditor in Iran, Nepal, Fiji, APO,UNEP ,Egipt, Ghana**

✓ **Lead-author of BEE Energy Efficiency guide books**

✓ **Established Practical Energy efficiency Centre @NPC Chennai**

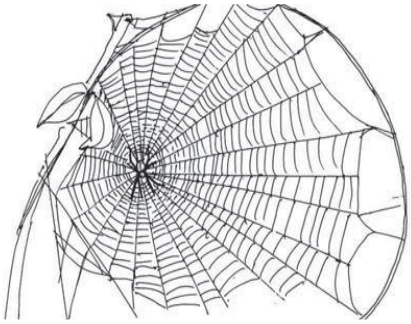
✓ **Recipient of AEE's Asia Subcontinent Region Energy Professional Development Award for 2017 ,USA.**

5

Energy and Environmental studies

Definition

- Energy and Environmental studies deals with **every issue that affects an organism**.
- It is essentially a **multidisciplinary approach** that brings about an appreciation of **our natural world and human impacts on its integrity.**
- It is an **applied science as its seeks practical answers** to making human civilization sustainable on the earth's finite resources.
- Its components include biology, geology, chemistry, physics, engineering, sociology, health, anthropology, economics, statistics, computers and philosophy.



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Renewable and non-renewable resources :Natural resources and associated problems.

a) Forest resources : Use , deforestation. Timber extraction, mining, dams and their effects on forest and tribal people.

b) Water resources : Use and over-utilization of surface and ground water, floods, drought, conflicts over water

c) Mineral resources : Use and exploitation, environmental effects of extracting and using mineral resources

d) Food resources : World food problems, changes caused by agriculture and overgrazing, effects of modern agriculture, fertilizer-pesticide problems, waterlogging, salinity

e) Energy resources : Growing energy needs, renewable and non renewable energy sources, use of alternate energy sources.

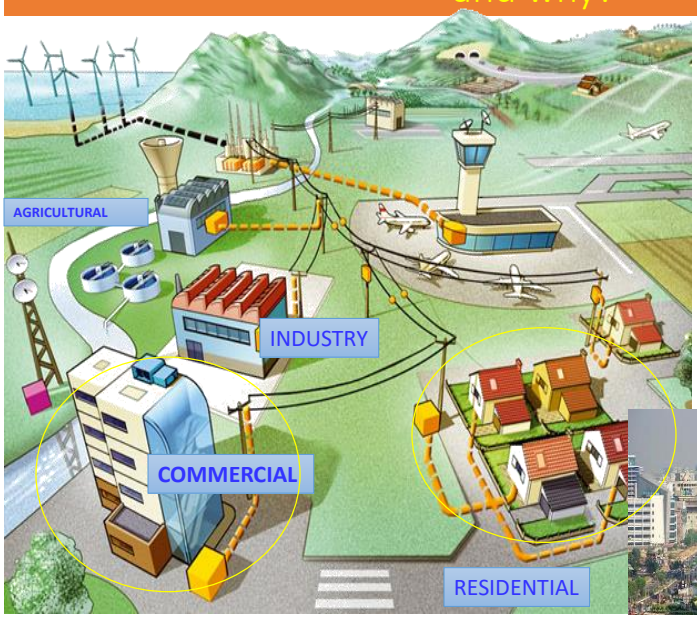
f) Land resources : Land as a resource, land degradation, man inducedlandslides, soil erosion and desertification.

What are the Role of an individual in conservation of natural resources?

Civil Society Perspective

People need energy	• For domestic use • For infrastructure requirements • For entrepreneurial needs
People need energy	• That is affordable • That is supplied un-interrupted
People need energy	• That does not pollute environment during production and transmission • Use of which does not result in environmental degradation

Which Sectors accounts for higher Resource consumption and why?



Urbanization

Global Issuse

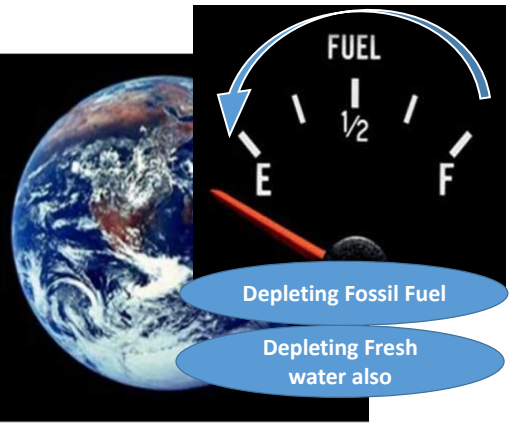
- Climate change
- Natural resource depletion
- Water pollution
- Human health
- Ecological degradation
- Water scarcity
- Energy security

By 2035, 75% of buildings will be new or renovated

What's the biggest problem facing humanity over the next 50 years?

Humanity's ten top problems for next 50 years

1. **ENERGY**
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

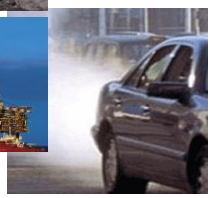


2.History of Energy Usage

I-Fire

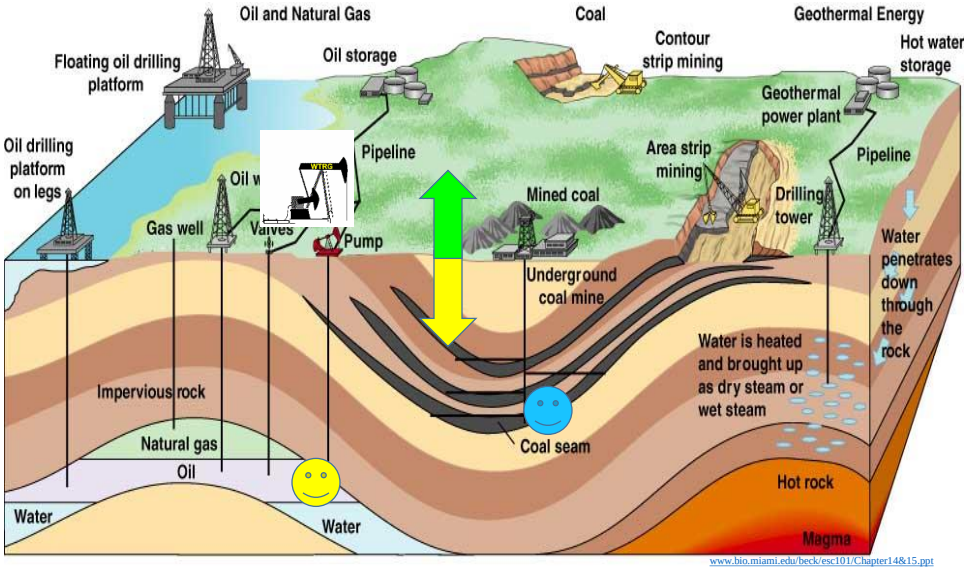
II-Animals, Wind & water usage

III -Steam engines powered by **coal.**Then use of **oil** & **Gas** more (1800 AD)



Renewable energy(1979

Energy resources removed from the earth's crust include: oil, natural gas, coal, and uranium

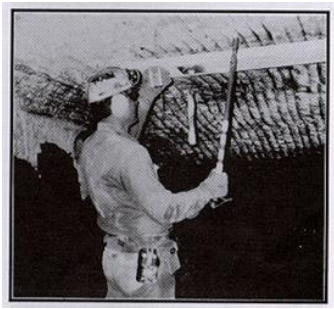


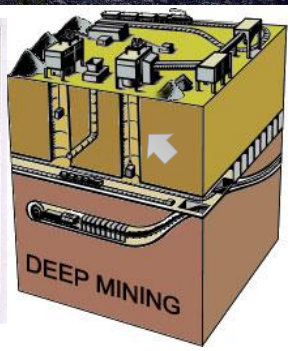
www.bio.miami.edu/beck/esc101/Chapter14&15.ppt

Environmental impact of coal mining

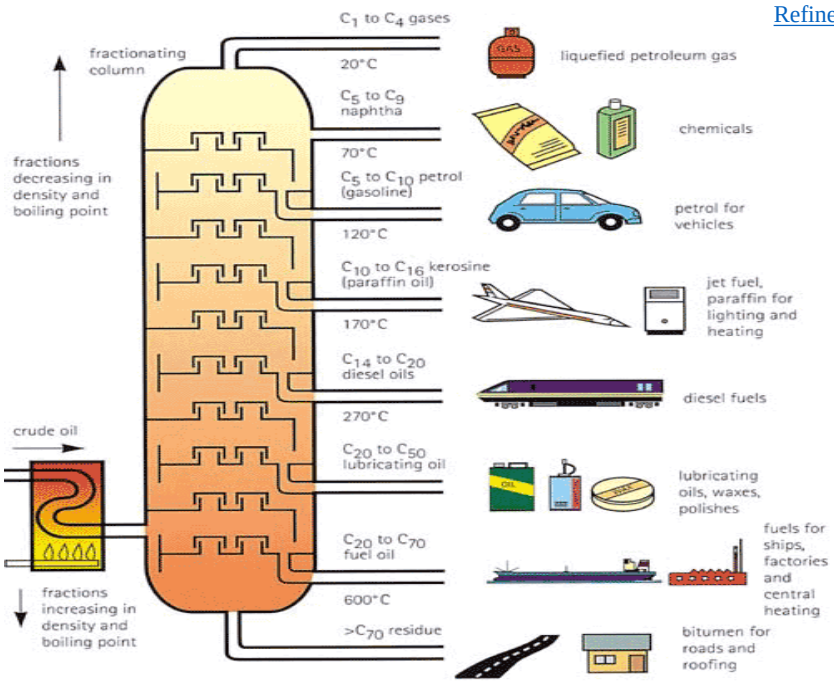
- **In surface mining**,
- removed the top-soil and layers of rock to expose large beds of coal.

- **Underground mining**, sometimes called deep mining, is used when the coal is buried several hundred feet below the surface. Some underground mines are **1,000 feet deep**.

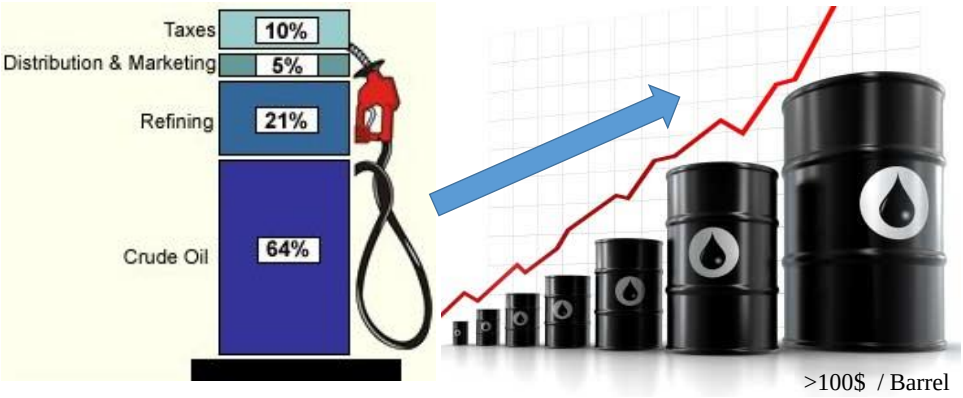




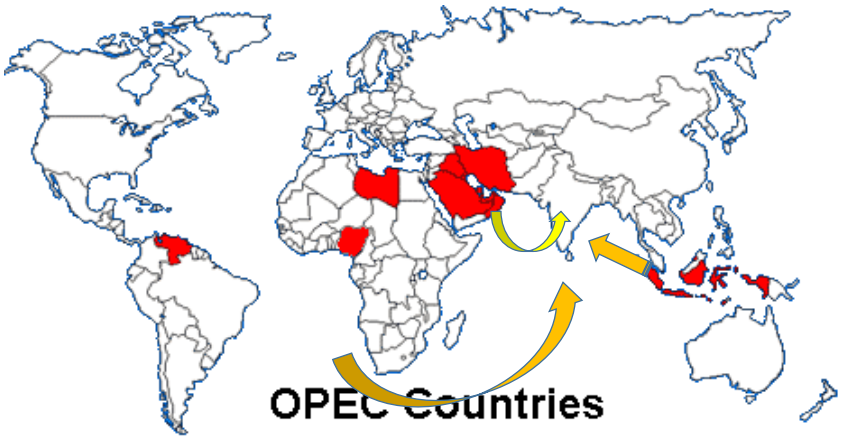
Refinery



Volatile Crude Oil Prices

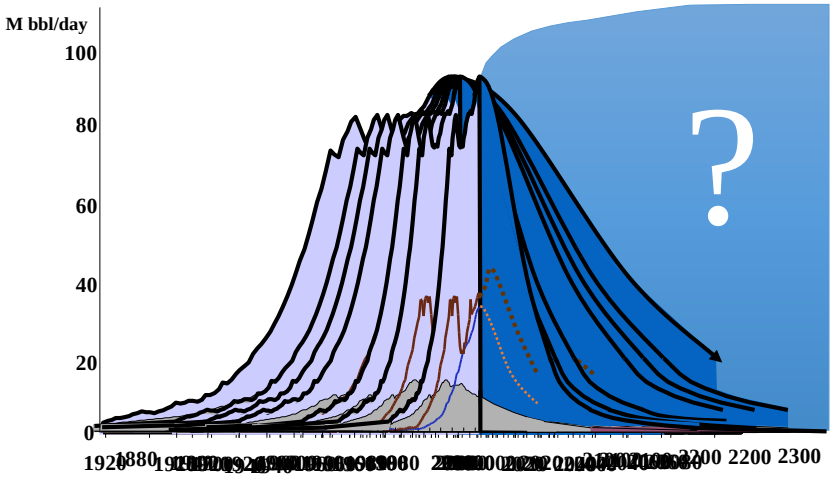


Who are Exporting Oil ?



- **Organization of Petroleum Exporting Countries-OPEC**

The Big Picture – Oil Production over History



World Energy Modeling

Life of energy Resources

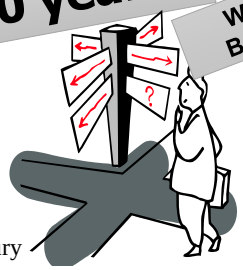
Oil – 40 years !

Gas – 60 years !

Coal –100 years !

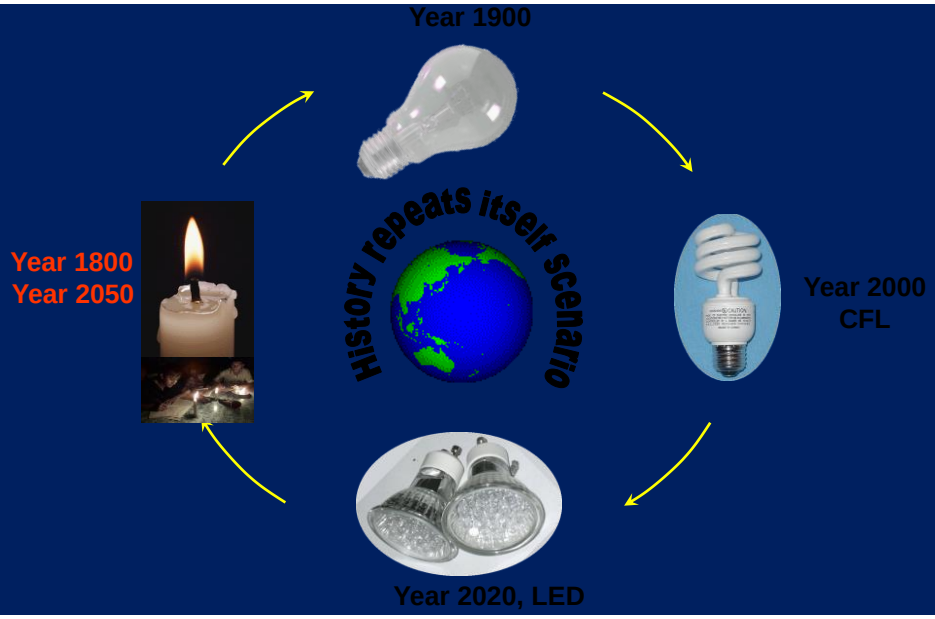
What is Beyond !

HISTORY

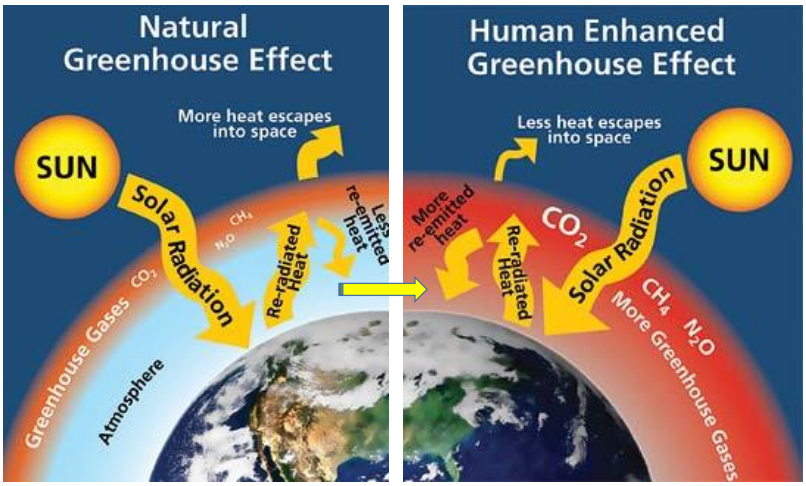


All will be depleted by the end of the 21st century

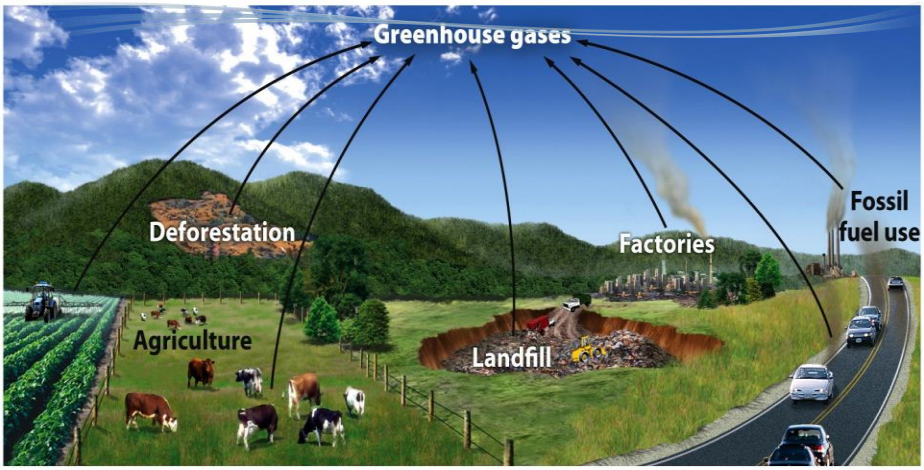
One of the scenarios with respect to an extremely "energy hungry" world



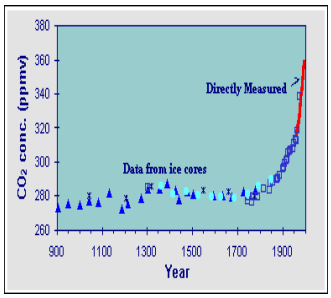
Enhanced Green house effect



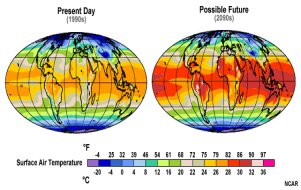
Building & Green House Gas – Major Causes



Energy sources have different impacts or effects on the environment.



- Impurities are major source of pollution
  - SO_2 travels on air currents & falls with precip. as acid rain



- Burning fossil fuels produces large amounts of CO_2, which contributes **to global warming**

Effects of Global Warming

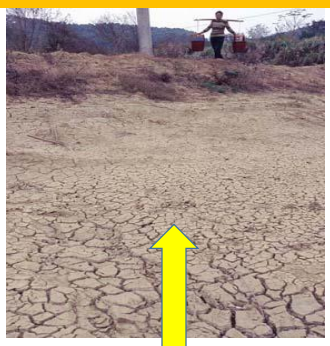
- ✓ Snow and Ice Melting
- ✓ Altered Rainfall Patterns
- ✓ Increasing ocean temperature & rising sea levels
- ✓ Extreme Weather Events
- ✓ Loss of Biodiversity
- ✓ Increased diseases
- ✓ Dwindling fresh water supply
- ✓ Food Shortages

Increased Temperature

Habitat Damage and Species Affected

Glacier retreat

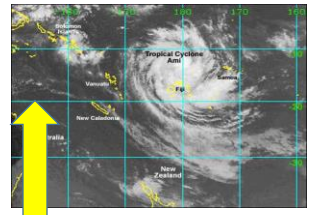
Increase in Global surface temperature leads to Extreme Weather



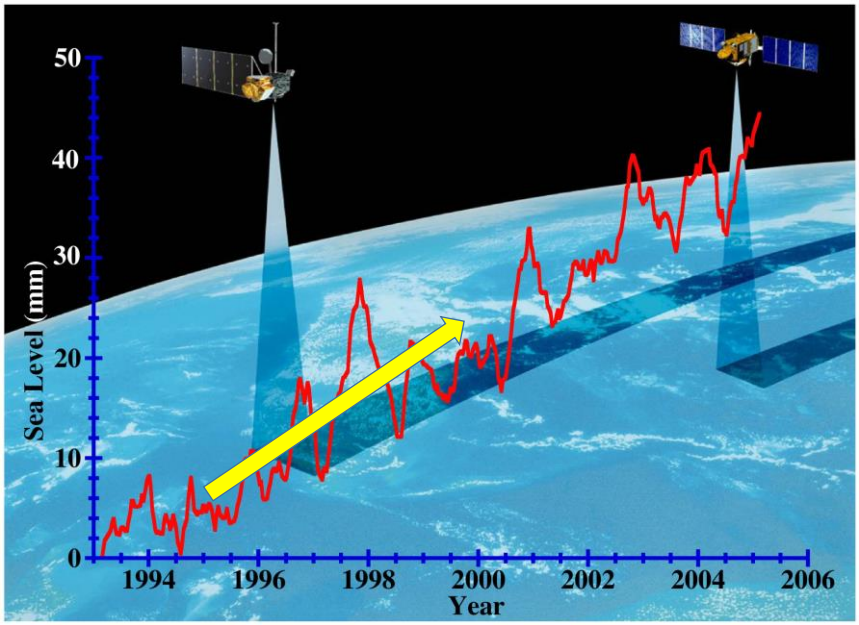
One third of the world's population is now subject to water scarcity

Population facing water scarcity will more than double over the next 30 years

✓ Altered Rainfall Patterns



Sea-level from satellites: 4 cm rise in last 10 years

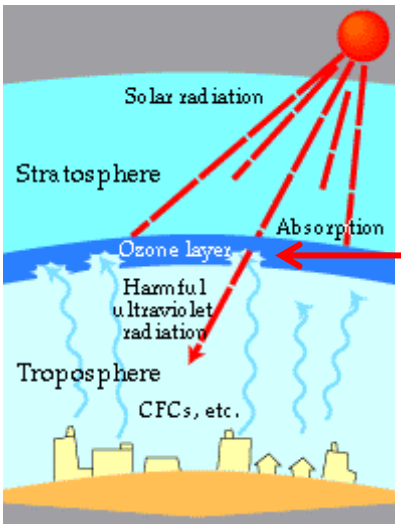


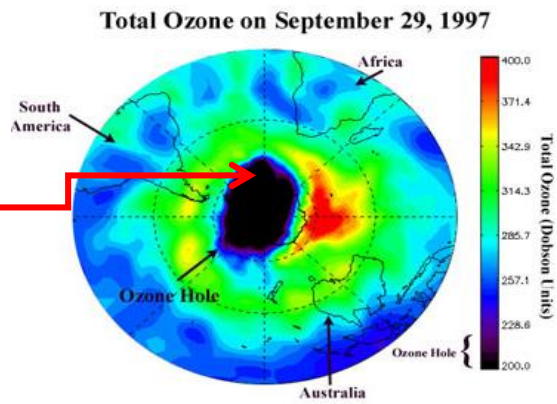
Rising Sea Levels Threaten Low-lying Islands

Areas of Florida, U.S., to Flood If Average Sea Level Rises by One Meter

Low-Lying Island Nation: Maldives in the Indian Ocean

Ozone layer Depletion





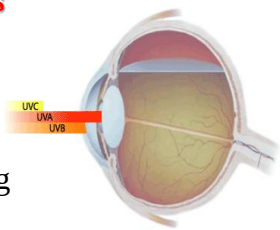
UV-B Effects on Human Effects

Over exposure may:

- Increase **risk of skin cancer**
- severe **sunburns** – especially in childhood
- Suppress immune system
- Accelerate aging of skin due high exposure

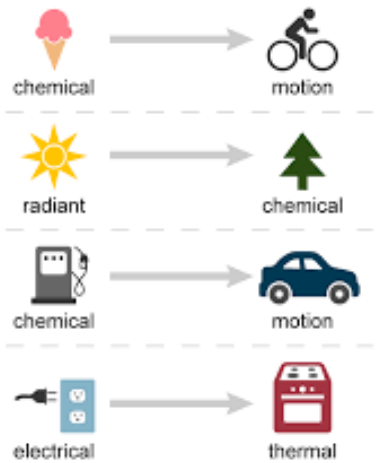
Increases the **risk of cataracts**

- Induces type of protein that provokes splitting in the lens
- Leading cause of **blindness**
- cataract after age 30 is doubling each decade



Different Energy sources and Types

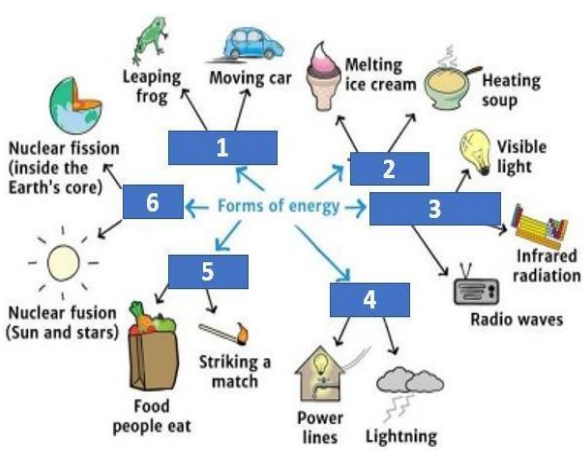
1. Application of Energy



- Lighting
- Cooking
- Transportation
- Power generation
- Melting iron
- Missile launching
- Agriculture/growing plants
- Ex: Lamp, heat engines, Automobiles, fuel cell, battery

33

1. Definition of Energy



- Energy is defined as the ability to do work or as the ability to carry a heat transfer
- Energy has many different forms (gravitational, thermal, electrical, chemical, nuclear etc.)
- The SI unit of energy is joule (equals to one newton applied through one meter)
- Energy is a conserved quantity, meaning that it cannot be created or destroyed, but only converted from one form into another.
- Energy has no direction in space, and is considered a scalar quantity.
- Thus, the total energy of the universe always remains constant.

34

Various forms of energy

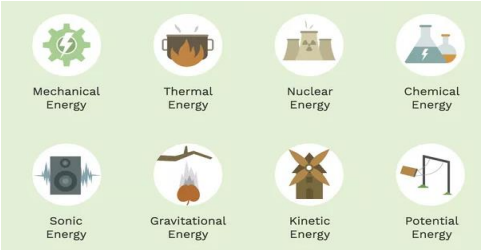
Energy is classified as potential (stored) and kinetic (velocity) energy.

❑ Potential energy

- **Chemical**
- **Nuclear**
- **Mechanical stored energy**
- **Gravitational**

❑ Kinetic energy

- **Radiant**
- **Thermal**
- **Motion**
- **Sound and Electrical**



Potential energy (E_p) = mass x gravitational acceleration x height= m g h

Chemical energy: Biomass, petroleum, N.Gas, LPG and coal are stored chemical energy.
(e.g. **kJ/kg) or number of molecules ,e.g. kJ/mol**

Kinetic energy (E_k) == half x mass x velocity squared = ½ mv^2

Nuclear energy (E_n) = mass x speed of light squared = $m\ c^2$ (where c= 3 x 10^8 m/s)

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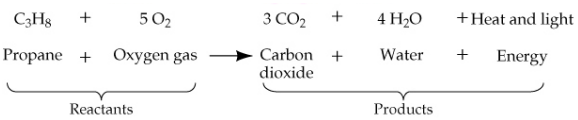
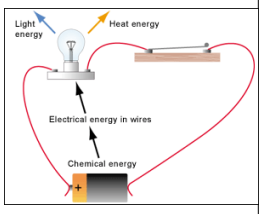
1. Importance of Energy

- All forms of life and society require Energy
- Plants use sun for energy
- Animals consume food for energy
- We also need energy for society to function and live
- Many objects around us work on electricity or heat.
- It supports quality of life and economic development
- If no energy, society would be chaotic

2 Different forms of energy: Chemical Energy

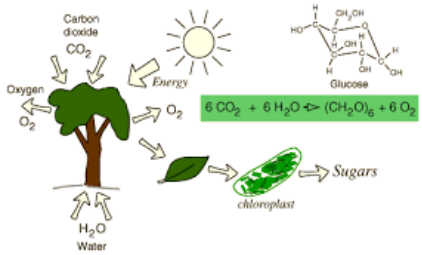


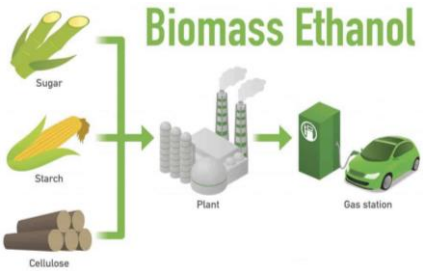


- Chemical energy is energy stored in atoms and molecules
- Energy released in chemical reactions.
  - Ex
  - Burning candle release light & heat
  - Pertrolem,Coal, N.Gas
  - Food,wood,battery

37

2.Different forms of energy: Biological energy





Biological energy is energy contained in living or recently living biological organisms

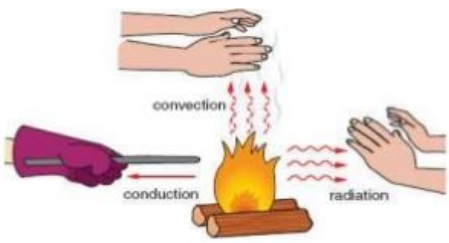
Bioenergy sources are replenished through the cultivation of fast growing trees and grasses

Ex Bio fuels

- Bioethanol
- Biodiesel
- Biogas

38

2.Different forms of energy: Thermal energy



- Thermal energy is the total kinetic & potential energy of all particle in a substance
- Thermal Energy is the heat made when molecule moves.
- Faster the molecules move higher the temperature
- Heat always flows from hotter to colder objects
- Thermal energy is measured in Jules (J)

39

Q & A

Thank You

Save energy and water for Sustainable Life

Session 2

Energy & Environmental Science

Unit – 1 : Present Energy resources in India and its sustainability

Syllabus

Session

1. Present Energy resources in India and its sustainability:
2. Energy Demand Scenario in India,
3. Different type of conventional Power Plant, Advantage and Disadvantage of conventional Power Plants,
4. Conventional vs Non- conventional power generation.

Types of Energy and Classification

1.1 Introduction

- Energy is defined as the ability to do work or as the ability to carry a heat transfer. Energy has many different forms (thermal, electrical, chemical, nuclear etc.)
- All forms of life and society require Energy
- We also need energy for society to function and live
- Energy is one of the major **inputs for the economic development** of any country. But critical requirement for developing nations for basic needs
- Energy can be classified as
  - **Primary energy and secondary energy**
  - **Commercial and non commercial energy**
  - **Renewable and non-renewable energy**

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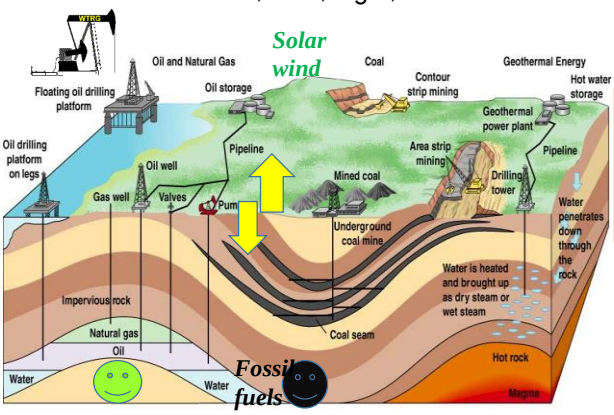
1.2 Primary Energy

Energy resources removed from the earth's crust include: Oil, Coal ,N. gas, and uranium



- **Primary energy : A**ll types of energy **extracted or captured directly from natural resources**.
- It is classified into two distinctive groups
  - Renewable (Ex. solar, wind, biomass etc.
  - Non-renewable (fossil fuels: oil , coal, N.Gas, etc.)

- **Primary energy** contributes, over 85% from fossil fuels. **Non-renewable**
- Fossil fuels, is **not sustainable** in the long term as it affects the **natural environment and clear evidence for Climate change caused by human activity**

- Primary Energy Content of all the fuel is expressed as toe (tonne of oil equivalent).

1toe = 1 x 10^7 kcal = 11630 kWh = 41868 MJ

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Major Primary and Secondary Energy Sources

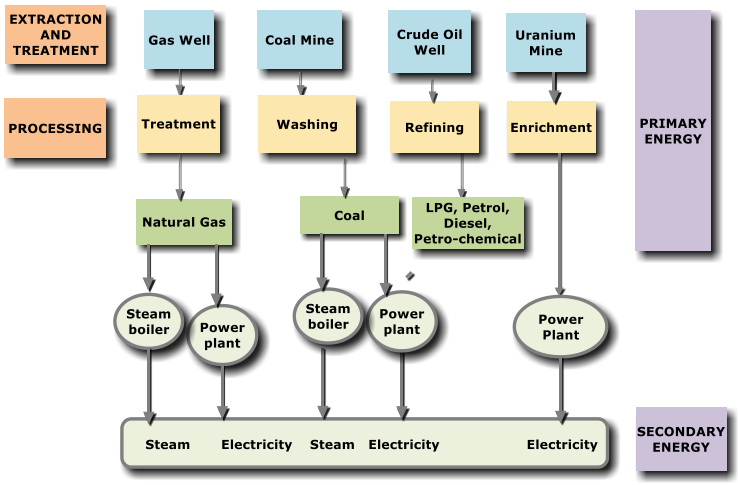

Fig 1.1

- Primary energy are mostly converted into secondary energy sources in industrial utilities
- Primary energy can **also be used directly.** Ex. coal or natural gas is used as a **feedstock in fertilizer plants**

Secondary Energy Sources are derivatives from Primary Energy Sources.
(ex: **electricity, steam etc.**)

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Commercial Energy and Non Commercial Energy

Commercial Energy

- Energy that is available in the market for a definite price

•Commercial fuels are predominant sources of energy not only for industrial use, but also for many household needs.

Example.

1.Electricity

2.Coal

3.refined petroleum products

4.natural gas

Non-Commercial Energy

- Energy which is sourced within a community and its surrounding area, and which is not normally traded in the commercial market

Example.

1.Firewood, agro waste *in rural areas,*
2.solar energy *for water heating, electricity generation, drying grain, fish*
*3. A**nimal power** for transport, threshing, lifting water*
4.wind energy *for lifting water and electricity generation.*

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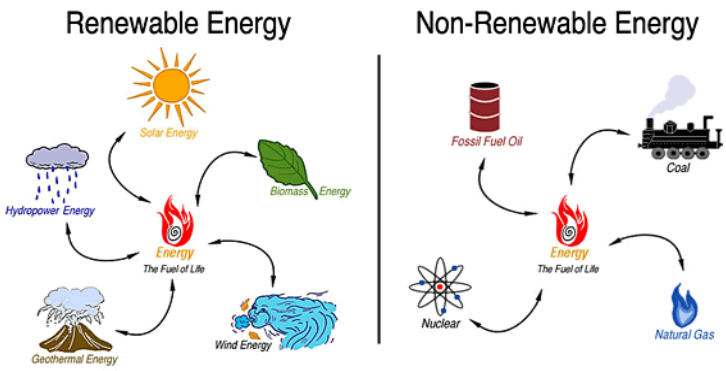
1.4 Renewable and non-renewable energy



Renewable energy is the energy **obtained from natural sources** which are essentially **inexhaustible.**

It is a natural resource **which cannot be produced, grown, replenished**.

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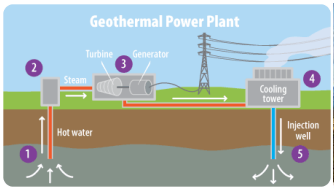
3.Major Renewable energy: Solar & Wind

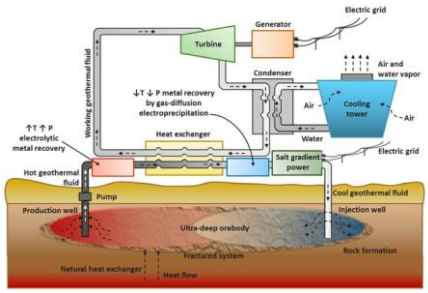
- **Solar energy** is radiant light and heat from the **Sun** that is harnessed into thermal or electrical energy
- It is the cleanest ,most abundant ,fastest growing and cheapest renewable source in the world
- Ex **solar** heating,photovoltaics, **solar** architecture , molten salt power plants

- **Wind energy** refers to capturing the **energy** from moving air, i.e., **wind**, and converting it into electricity
- Wind is caused by the uneven heating of the atmosphere by the sun, variations in the earth's surface, and rotation of the earth.
- Ex: windmill, wind pump, or wind charger.
- Wind energy is known to be used as early as 200 B.C

3.Major Renewable energy: Geothermal energy



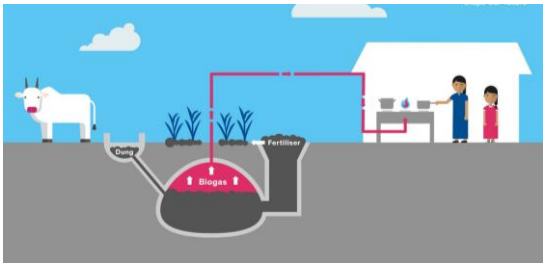
- Geothermal energy is heat derived within the sub-surface of the earth. Water or steam carry the geothermal energy to the Earth's surface. It can be used for heating and cooling or to generate clean electricity



- Hydrothermal power generation, also known as **ocean thermal energy conversion** (OTEC) is the practice of producing electric power from the potential energy of water temperature differences of at least 20°C
- Hydrothermal energy is the process of obtaining heat from a large body of water. It is a kind of geothermal energy on seabed. Organic Rankine Cycle (ORC) is a method of exploiting heat energy to become electricity

3.Major Renewable energy : Bio-fuels & Bio-gas

- Biofuels can be produced from plants ,agricultural and industrial wastes
- Biofuel is a cost-effective and environmentally benign alternative



- **Biogas** is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen (methane and carbon dioxide.
- Biogas is environment friendly and has various applications in cooking, drying, cooling, heating etc. It is used in the production of electricity, methanol and steam.

Quiz

1	**Which one of the following is not a Renewable energy ?** a) solar b) wood c) nuclear d) wind	
2	**Which one of the following is Non-Renewable energy?** a) Bio mass b) Geothermal c) Hydropower d) Natural Gas	

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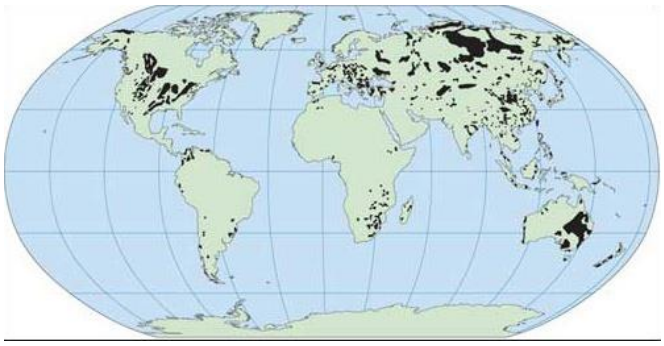
World Energy Scenario
Global Energy Reserves, production and Consumption



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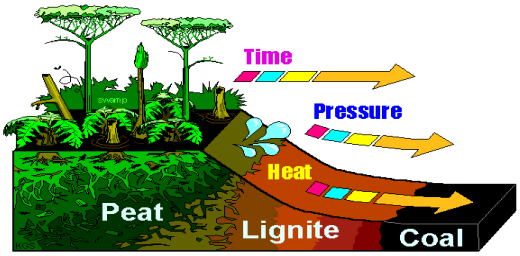
1.5 Global Primary Energy Reserves and Commercial Energy Production

How coal formed ?



Coal : Coal is the most abundant and geographically dispersed fossil fuel and exists as **peat, brown coal (lignite), sub-bituminous, bituminous and anthracite**

Estimated that there are around 892 billion tonnes of proven coal reserves worldwide. **Proved coal reserves are shown for anthracite and bituminous (including brown coal) and sub-bituminous and lignite**.

There is enough coal to last around 113 years at current rates of production

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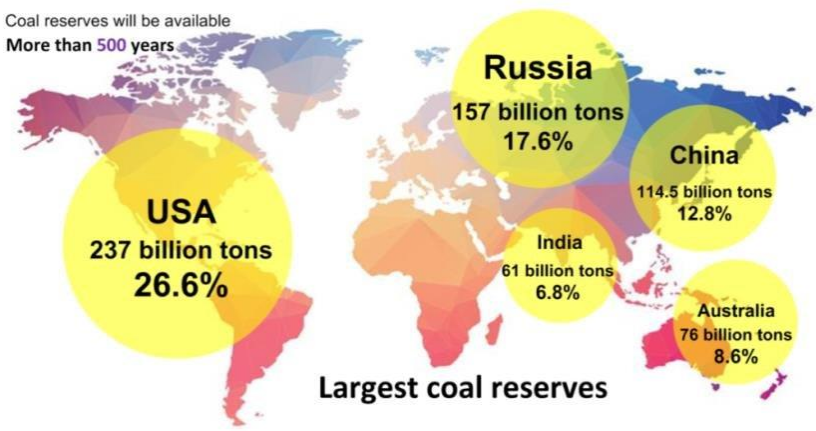
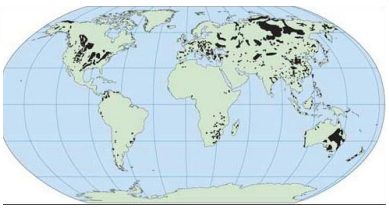
Proven Coal reserves are available in almost every country worldwide with recoverable reserves in around 75 countries. The largest coal reserves are available in the USA followed by Russia, China, Australia and India





India is fifth largest coal reserves in the world.

- India is **second largest in coal consumption** after China

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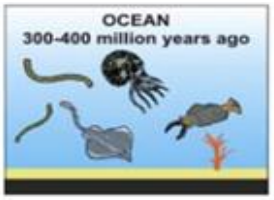
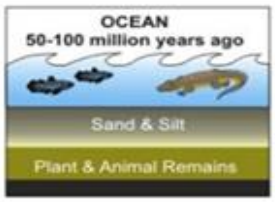
Oil
How Oil Formed ?

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



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



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

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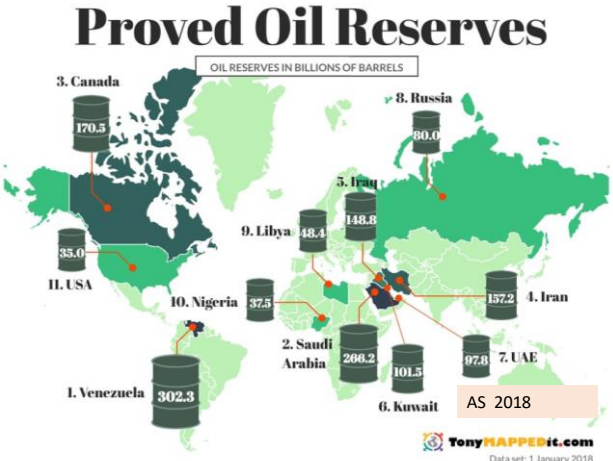
Proven World OIL Reserves

- The **global proven oil (crude) reserve** was estimated to be **1687.9 billion barrels** by 2013.
- **Middle East a**lone has about **48 % of the proven oil reserves**
- **Saudi Arabia** has the largest reserve of 15.8%.

Country	Billion tonnes	Billion barrels	Share of total, %	R/P years
Venezuela	56.6	298.3	17.7	> 100
Saudi Arabia	36.5	265.9	15.8	63.2
Canada	28.1	174.3	10.3	> 100
Iran	21.6	157	9.3	> 100
Iraq	20.2	150.0	8.9	> 100
India	0.8	5.7	0.3	17.5
Others	74.4	636.7	37.7	-
World	238.2	1687.9	100	53.3



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World OIL Production

Table: Top Oil Producing Countries by End of 2013
(Source: BP Statistical Review of World Energy June 2014)

Region	Million tonnes per year	Share of total, %
Saudi Arabia	542.3	13.1
Russia	531.3	12.9
USA	446.2	10.8
China	208.1	5.0
Canada	193	4.7
Iran	166.1	4.0
Iraq	153.2	3.7
Nigeria	111.3	2.7
Others	2351.5	43.1
World	**4130.2**	**100**

The top oil producing countries **Saudi Arabia was the largest oil** (end of 2013) followed closely by Russian Federation and USA. Although the United States ranks third in terms of oil production, it only ranks tenth in terms of proven oil reserves.
As against the top producing countries (end of 2013), **India's share is 42 million tonnes and share of total is 1%.**

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NATURAL GAS

Natural gas resources are large, but, like oil, they are highly concentrated in a few countries**.**

- Global proved gas reserve was estimated of **186 trillion cubic metres** by the end of 2013.
- **Iran has the largest share of the reserve followed by Russia and Qatar**.
- **India has only about 0.7%** of global natural gas reserves.

Top Natural Gas Consumers

USA is the world's largest **natural gas consumer** at around 22% followed by **Russia** at around 12%..

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Indian Energy Scenario
Indian Energy Reserves, production & Imports and Consumption

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1.7 Indian Energy Scenario

primary energy consumption mix in India

Energy Type	Mtoe	% share in total primary Energy Consumption
Oil	175.2	29.5%
Natural Gas	46.3	7.8%
Coal	**324.3**	**54.5%**
Nuclear energy	7.5	1.3%
Hydro Power	29.8	5.0%
Renewable energy	11.7	2.0%
Total Primary Energy consumption	**595**	**100.00**

- Coal dominates the energy production mix in India, contributing to about **55% of the** total primary energy production.
- There is a gradual **increase in the share of natural gas** in primary energy production

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Energy Supply-*Coal Sector*

- India has huge coal reserves of about 60.6 billion tonnes
- This amount to about 6.8 % of the world reserves and it may last for about 100 years
- India is one of the largest producers of coal and lignite in the world.
- Majority of the coal **(over 80%)** is mined only upto 150 - 300 m depth with open cast mining and balance 20% of coal is mined from underground mines.

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Importing 30% of coal consumption

Coal use: Coking10%,non coking 90%

76% of electricity generated from coal

Avg power plant efficiency: 28-32% Most efficient- 45%

Oil Sector

India is the fourth largest oil-consuming country in the world. India **imports over 82%** of its crude oil needs, mainly from Gulf nations. In terms of sector wise petroleum products consumption, transport sector is the largest followed by domestic and industry sector. Table below gives the crude oil import bill trend over the last few years.

India has 0.3% of world Oil reserves

India consuming 4.8% of world oil consumption.

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Natural Gas Sector

- Natural gas (mainly methane)- **environmentally friendly**, greater efficiency and cost effectiveness.
- Termed as the **fuel of the 21st century**.

Liquefied Natural Gas (LNG)

- When natural gas is cooled to **-161ºC**, it is transformed into **Liquefied Natural Gas (LNG)** for **ease of storage and transportation**.
- Liquefaction reduces the volume occupied by the natural gas **by 600 times and** LNG is transported in specially built ships with cryogenic tanks.

Compressed Natural Gas (CNG)

- Natural gas is compressed to less than 1% of the volume it occupies at std atmospheric pressure.
- CNG can be used in petrol vehicles / converted into bi-fuel vehicles (petrol/CNG).

India's **gas reserves** are estimated at 1.4 trillion cubic metres by end of 2013 which amounts to about **0.7% of the total World reserves**.

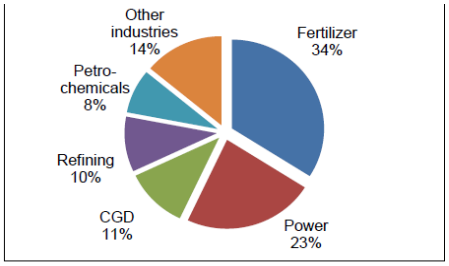

Figure 1.11: Gas Demand by Sector ***FY 2015-16***
Source: MoPNG

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Installed Power Generating Capacity of India

Thermal -64.8%

Hydro -13.2%

Renewable-20.1%

Nuclear -2.0%

Total = 3,70,106 KW

- India is the **world's third largest producer and consumer of electricity** with capacity of 344 GW as on 31 Mar 2020.
- India's electricity sector is dominated by coal-based power plant for meeting about 76.2% of all electricity.

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Nuclear Power Supply

- India currently operates 21 nuclear power units at seven locations..
- The installed capacity of nuclear power plant is 6780 MW
- Nuclear power contributes to only about **2 % of the total installed** capacity in India.
- The Uranium produced in India is **2-3 times costlier** since **Indian ores contain only about 0.1% Uranium compared to 12-13% in the Uranium ores mined abroad**.

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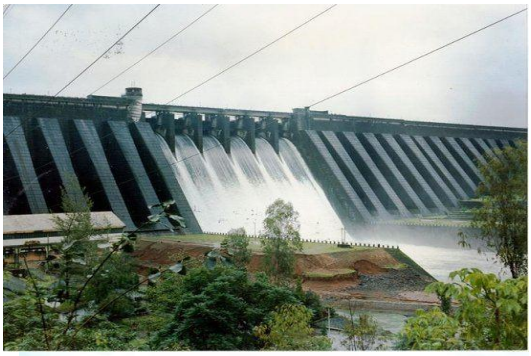
Hydro Power Supply

Indian hydro power capacity of over **84,000 MW at 60% load** factor. Around 80% of this has been identified in the Brahmaputra, Indus and Ganges basins.

The **share of hydropower in the country's** total generated units has steadily decreased over time and it stands at about 17% by 2013 Development of **small and mini hydro power** at an accelerated (for 15000MW) .

Projects up to 25 MW have been brought under the domain of the **MNRE**, while projects beyond 25 MW continue to remain under the of **Ministry of Power.**



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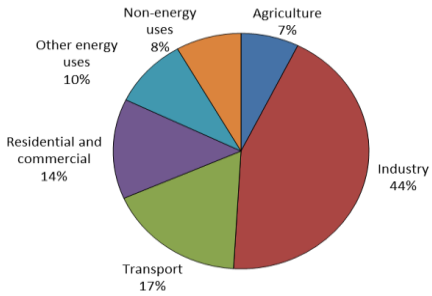
1.8 Sector wise Energy Consumption in India



The major commercial energy consuming sectors in the country are shown in the figure.

The **industrial sector consumes almost 44 % of the total commercial energy consumption followed by transport.**

commercial energy Consumption

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7. Sectors that use energy :Residential & Commercial sector

Residential sector

- The **rural households** in India uses biomass to meet 85% of their cooking needs, while the urban meet 56% of their cooking through LPG.
- Almost **70% of the population** in India is rural household, which accounts for only 42% of the demand for oil, gas and electricity.
- The use of electricity is growing rapidly in the residential sector.

Commercial sector

The energy consumption for **commercial building** and services activities is growing rapidly due to high growth rate in commercial establishments, hotels, shopping malls, IT parks and hospitality industry.

7. Sectors that use energy : Transportation and Agricultural sector

Transportation sector

- Energy consumption in transportation sector is growing at 16% per annum .
- **This sector almost consumes around 40% of the petroleum products.**
- By the end of 2030, out of the total transport energy demand, Road vehicles would account for 86% followed by aviation at 9%. Railways, marine and others are expected to consume 5%.

Agricultural sector

- Both electricity and diesel consumption increases in agriculture sector due mechanized farming.
- The electricity consumption in **agriculture sector** has increased at faster rate compared to other sectors during the last four decades

29

9 Strategies to meet energy needs –Energy Security

Reducing energy requirements

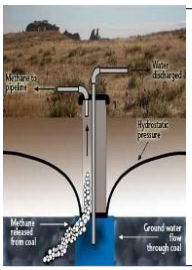
- Improving the efficiency of extraction of fossil fuels
- Installing super critical boilers
- Adopting **energy efficiency &** DSM
- Promotion of mass transport & **renewable energy sources**

Diversifying energy supply sources

- Modify the Energy Mix with no dependence on any particular fuel
- Sourcing oil / LNG from different countries
- Importing gas through pipelines from neibouring countries

Substituting imported oil/gas with domestic alternatives

- Ethanol / Biodiesel as substitute for petrol / diesel
- Biomass gasification for heat or power as alternative to gas / coal.
- Conversion of coal to oil ,Gas to Liquid (GTL)
- Biogas Plants, Energy plantation

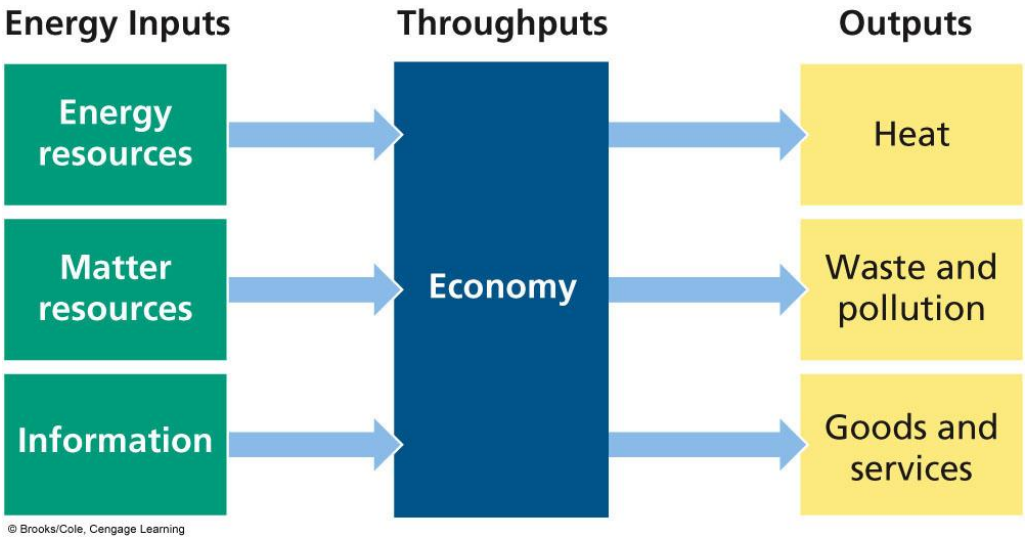


Expanding and developing alternative energy sources

- Improved Recovery of oil and gas from abandoned or marginal fields
- In-site coal gasification/Capturing Coal Bed Methane
- Stepping up exploration to find new reserves

30

Inputs, Throughput, and Outputs of an Economic System



connected thinking in core engineering

Pollution from All sectors

Knowledge Check

7.	**The major source of electrical power generation in India is** a) thermal b) hydel c) nuclear d) wind
8.	**Nuclear energy development in India is constrained by** a) low % of Uranium in the ore b) inadequate supply of Uranium c) constraints in import of Uranium d) all of the above

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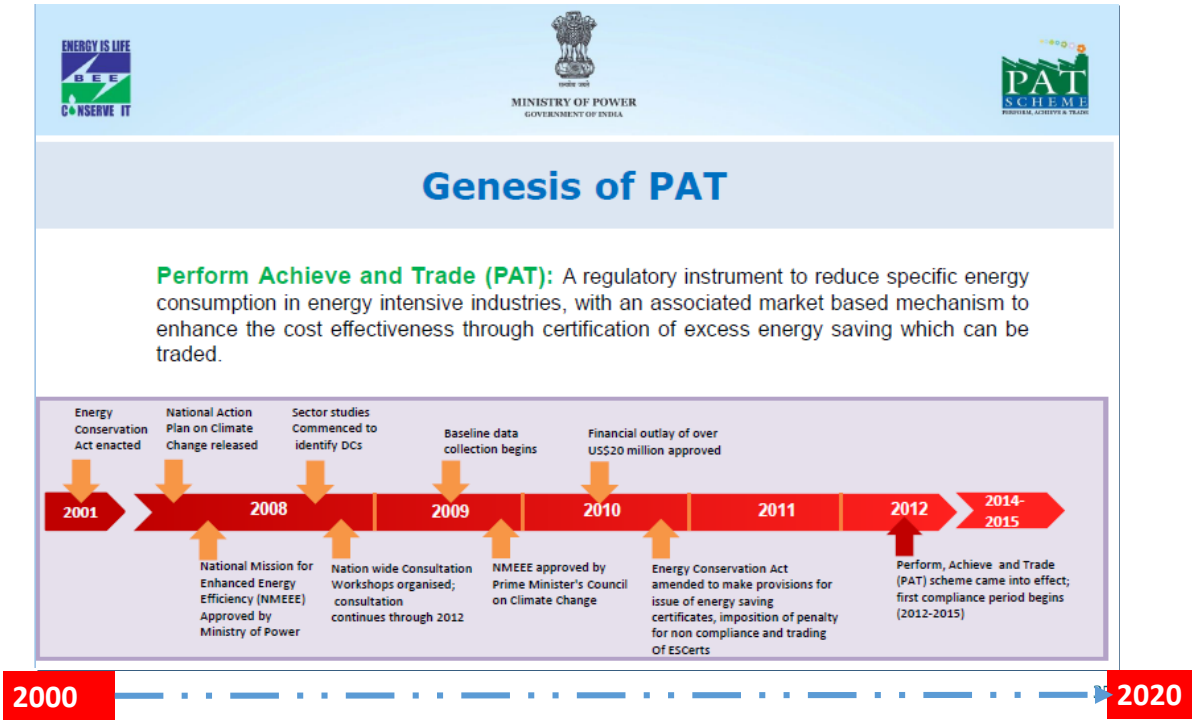

2.3 Schemes of BEE under the Energy Conservation Act-2001

1. Energy Conservation Building Codes **(ECBC)**
2. Standards and Labeling **(S & L)**
3. Designated Consumers **(DCs)**
4. Demand Side Management **(DSM)**
5. Bachat Lamp Yojana **(BLY)**
6. Promoting Energy Efficiency in Small and Medium Enterprises **(SMEs)**
7. Certification of energy auditors and energy managers,**CEM/CEA**

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Appliances/equipment notified under S&L program

Mandatory labelling & under Voluntary labelling

Products notified under **mandatory labelling** As of September 2018,

1. Frost Free (no-Frost) Refrigerators
2. Tubular Fluorescent Lamps
3. Room Air Conditioners
4. Distribution Transformers
5. Room Air Conditioners (Cassette, Floor Standing Tower, Ceiling, Corner AC)
6. Direct Cool Refrigerators
7. Electric Geysers
8. Color TV
9. Room Air Conditioners (Inverter type)
10. LED lamps

- The BEE S&L scheme is invoked for 22equipment/appliances including 10 for which it is mandatory (sep 2018)

Products under **voluntary labelling** As on September 2018,

1. **Induction Motors**
2. **Agricultural pump sets**
3. **Ceiling fans**
4. **Domestic Liquefied Petroleum Gas Stoves**
5. **Washing machine (Presently process of revising)**
6. **Computer (Notebook/Laptops)**
7. **Ballast (Electronic/Magnetic)**
8. **Office equipment's (Printer, Copier,Scanner)**
9. **Diesel Engine Driven Monoset Pumps for Agricultural**
10. **Solid State Inventor**
11. **Diesel Generator**
12. **Chiller**

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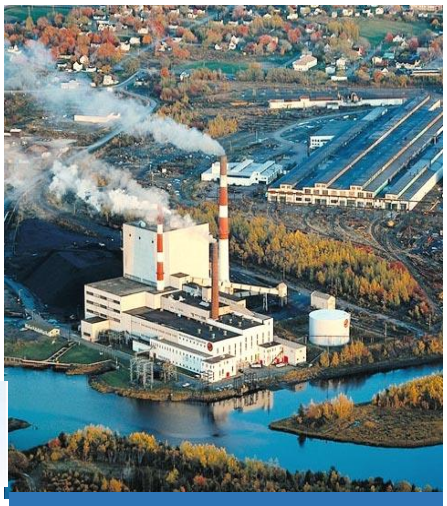
Energy Audit in Industry-Mandatory

- Electrical system,Transformers
- Lighting
- Motors
- HVAC systems
- Pumps and blowers
- Compressed air system
- Heating and cooling processes
- Boilers/Furnaces
- Refrigeration
- Drying
- Waste Treatment

Conduct Energy Audit in Industry

PAT SCHEME
PERFORM, ACHIEVE, TRADE



Fuel & Power bill in Rs…..Crores/yr

Building energy audit +Green Buildings Initiatives

Conduct Energy Audit

Electricity
Oil & Gas
Water
Embedded energy material

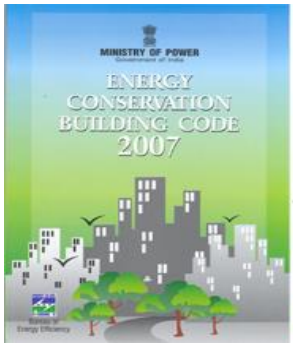
- ❑Lighting and fan
- ❑Air conditioning
- ❑Refrigeration
- ❑Water pumps
- ❑Boiler & steam
- ❑Invertors/DGSets

- ❑Washing machines
- ❑Electric heater, Iron box
- ❑Kitchen equipments
- ❑Computer
- ❑UPS
- ❑Transport

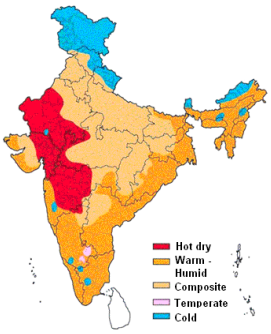
ECBC / Green buildings ?

39

ENERGY CONSERVATION BUILDING CODE [ECBC]



Energy Conservation
Building Codes (ECBC)

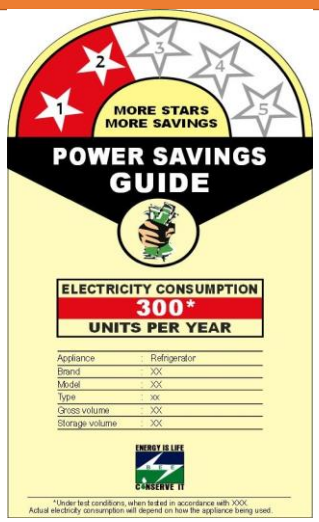


Energy Use for buildings

Building would get a 5-Star rating if its EPI falls below **90 kWh/sq m/year** and 1 Star if it is between **165-190 kWh/sq m/year**

Standards and Labeling of Appliances

- Energy labeling to enable consumers to make informed choice
  - Domestic devices
  - Agriculture pumps and motors
  - Industrial equipments



Products notified under mandatory labelling

As of September 2018, the following products have been notified under mandatory labelling:

1. Frost Free (no-Frost) Refrigerators
2. Tubular Fluorescent Lamps
3. Room Air Conditioners
4. Distribution Transformers
5. Room Air Conditioners (Cassette, Floor Standing Tower, Ceiling, Corner AC)
6. Direct Cool Refrigerators
7. Electric Geysers
8. Color TV
9. Room Air Conditioners (Inverter type)
10. LED lamps

S&L scheme is invoked for 21 equipment/appliances mandatory.

41

Energy Management

42

Energy management is the process of monitoring, controlling, and **conserving energy** in an Indistry or organization

Energy conservation

- **Behavior that results in the use of less energy**
- e.g. Turning the lights off when leaving the room
- Stop idling machine, motors

- Starting point is *Employee Awareness* and Behavioural change

Energy Efficiency

- **Using technology that requires less energy to**
- **perform the same function**
- Using LED bulb instead of CFL
- USE Energy efficient motor, pumps etc

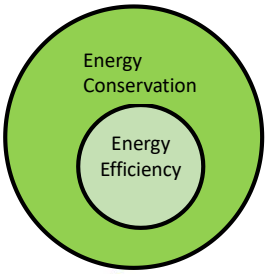
It will save energy without any human involvement

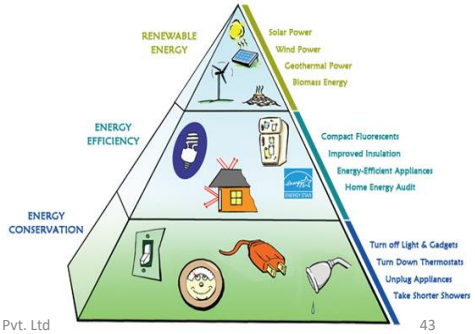
What is the Difference between Energy Conservation and Energy Efficiency?

Energy conservation is achieved when growth of energy consumption is reduced in physical terms
Energy Conservation is the result of several improvements such as productivity improvement or Technological advances.

Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels.
Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

In simple terms, energy efficiency means using less energy to perform the same function





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Energy Conservation and its Importance

Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.
LED ,BLDC fan IE4 motors

Example
Replacing Incandescent lamps with LEDs will require about 1/8th of the energy to light a room. Pollution levels also reduce by 1/8th the initial pollution amount.

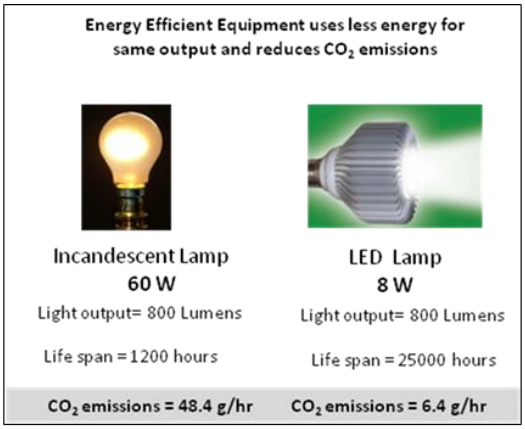

Figure 1.6 Energy Efficient Equipment

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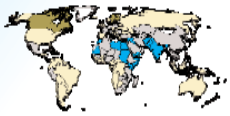
Energy Efficiency Benefits

Industry	Nation	Globe
		
• Reduced energy bills • Increased Competitiveness • Increased productivity • Improved quality • Increased profits !	• Reduced energy imports • Avoided costs can be used for poverty reduction • Conservation of limited resources • Improved energy security	• Reduced GHG and other emissions • Maintains a sustainable environment

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45

What nation can do?

EC Act 2001, ECBC, PAT ETC

What Industry/ Individual can do?

Do energy audit & take action to conserve energy

Q & A

Thank You

Save energy and water for Sustainable Life

Energy and Environment Sceince
L-T-P-C: 2-0-0-2

Syllabus:

Unit – 1 [4 Hours]: Present Energy resources in India and its sustainability:

Energy Demand Scenario in India, Different type of **conventional Power Plant**, Advantage and Disadvantage of conventional Power Plants, **Conventional vs Non- conventional power generation**.

Unit – 2 [4 Hours]: Basics of Solar Energy: Solar Thermal Energy; Solar Photovoltaic: Advantages and Disadvantages, Environmental impacts and safety.

Unit – 3 [4 Hours]: Wind Energy: Power and energy from wind turbines, India's wind energy potential, **Types of wind turbines, Offshore Wind energy**, Environmental benefits and impacts.

Unit – 4 [4 Hours]: Biomass Resources: Biomass conversion Technologies, Feedstock pre-processing and treatment methods, Bioenergy program in India, Environmental benefits and impacts; **Other energy sources**: **Geothermal Energy resources, Ocean Thermal Energy Conversion, Tidal Energy.**

Unit – 5 [4 Hours]: Air pollution: Sources, effects, control, air quality standards,

air pollution act, air pollution measurement; **Water Pollution**: Sources and impacts; **Soil Pollution**: Sources and impacts, disposal of solid waste. **Noise pollution**

Unit – 6 [4 Hours]: **Greenhouse gases effect**, acid rain; Pollution aspects of various power plants; **Fossil fuels and impacts, Industrial and transport emissions impacts.**

1

Unit – 1 [4 Hours]:
Present Energy resources in India and its sustainability:

Energy Demand Scenario in India,
Different type of conventional Power Plant,
Advantage and Disadvantage of conventional Power Plants,
Conventional vs Non- conventional power generation

CLASSIFICATION OF ENERGY SOURCES

1. Based on Usability of Energy

a) **Primary resources -** These include resources embodied in nature prior toundergoing any human-made conversions or transformations. This only involves extraction or capture. Examples of primary energy resources are coal, crude oil, sunlight, wind, running rivers, vegetation and radioactive material like uranium

b) **Secondary Resources** -energy resources supplied directly to consumer for utilization after one or more steps of transformation are known as secondary or usable energy, e.g. electrical energy, thermal energy (in the form of steam or hot water), refined fuels or synthetic fuels such as hydrogen fuels, etc.

CLASSIFICATION OF ENERGY SOURCES

2. Based on Traditional Use

a) **Conventional -** Energy resources, which are being traditionally used, for many decades and were in common use around oil crisis of 1973, are called conventional energy resources, e.g. fossil fuels, nuclear and hydro resources.

b) **Non-conventional** - Energy resources, which are considered for large-scale use after the oil crisis of 1973, are called non-conventional energy sources, e.g. solar, wind, biomass, etc.

CLASSIFICATION OF ENERGY SOURCES

3. Based on Long-Term Availability

a) Non-renewable - Resources, which are finite and do not get replenished after their consumption, are called non-renewable

e.g. fossil fuels, uranium, etc. They are likely to deplete with time.

b) Renewable - Renewable energy is energy obtained from sources that are essentially inexhaustible. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power.

CLASSIFICATION OF ENERGY SOURCES

4. Based on Commercial Application

a) **Commercial Energy Resource -** The energy sources that are available in the market for a definite price are known as commercial energy. By far the most important forms of commercial energy are electricity, coal and refined petroleum products.

b) **Non-commercial Energy -** The energy sources that are not available in the commercial market for a price are classified as non-commercial energy. Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and not bought at a price, used especially in rural households.

CLASSIFICATION OF ENERGY SOURCES

5. Based on origin

(a) Fossil fuels energy
(b) Nuclear energy
(c) Hydro energy
(d) Solar energy
(e) Wind energy
(f) Biomass energy
(g) Geothermal energy
(h) Tidal energy
(i) Ocean thermal energy
(j) Ocean wave energy

COMMON FORMS OF ENERGY

1. **Electrical Energy -** About 30–40 per cent energy distribution in the world is met through electrical supply system at present. It can be very conveniently and efficiently converted to other forms of energy.
2. **Mechanical Energy -** Mechanical energy is required for movement of objects, changing the shape of the objects, etc. It is used in transportation, agriculture, handling, processing, and other industrial processes.
3. **Chemical Energy -** Fuels and organic matter contain chemical energy. Exothermic chemical reactions release heat energy. Also chemical energy is directly converted into electrical energy in fuel cells, storage batteries, etc. and into thermal energy by combustion.

4. Thermal Energy -Thermal energy is considered to be of lower grade as compared to electrical and mechanical energy. It is used to raise the temperature of an object during industrial processes. It can also be converted to mechanical energy with the help of heat engines. There are three grades of thermal energy depending on the temperature at which it available:

1. **High grade (500–1000 °C and higher):** It can be converted efficiently into mechanical energy.
2. **Medium grade (150–500 °C):** It can be converted into mechanical energy with difficulty and with lower efficiency.
3. **Low grade (80-50 °C):** It cannot be ordinarily converted into mechanical energy and used mostly for the purpose of heating only.

Advantages and Disadvantages of Conventional & Non- Conventional sources

Advantages and Disadvantages of conventional sources

Energy Sources

- Fossil fuels, nuclear and hydro resources are considered as conventional sources. There use has following advantages and disadvantages.

- **Advantages**

1. Cost : At present these are cheaper than non-conventional sources.

2. Security : As storage is easy and convenient, by storing certain quantity, the energy availability can be ensured for certain period.

3. **Convenience:** These sources are very convenient to use as technology for their conversion and use is universally available.

Disadvantages

1. Fossil fuels generate pollutants. Main pollutants are **CO, CO2, NOx, SOx, particulate matter and heat**. These pollutants degrade the environment, pose health hazards and cause various other problems. CO2 is mainly responsible for global warming also.

2. There are **safety and technical issues with nuclear energy**. Major problems associated with nuclear energy are

(a) The waste material generated in nuclear plants **has radioactivity of dangerous le**vel. Its safe disposal, which is essential to prevent radioactive pollution, is a **challenging task**.

(b) Disposed radioactive waste is required **to be guarded for a long period** (till its radioactivity level comes down to a safe limit)

(b) Possibility of **accidental leakage of radioactive material** from reactor (as happened in Chernobyl, former USSR in April 1986)

(c) Uranium resource has **limited availability.**

(d) **Sophisticated technology is required** for using nuclear resources.

Advantages and Disadvantages of Non-conventional sources

Merits

1. Non-conventional sources are available in nature free of cost.
2. They produce no or very little pollution. Thus by and large they are environment friendly.
3. They are inexhaustible.
4. They have low gestation period.

Demerits

1. In general the energy is available in dilute form from these sources.

2. Though available freely in nature the cost of harnessing energy from nonconventionalsources is generally high.

3. Uncertainty of availability: the energy flow depends on various natural phenomena beyond human control.

4 Difficulty in transporting this form of energy.

5. Difficulty in storage.

Energy, economy and social development

Environmental Aspects of Energy

Trade-off between Energy and Environment

Environment literally means surroundings.

Air, soil and water are the main constituents of environment.

Nature has originally provided them to human beings in clean form.

However, with the passage of time, their quality is continuously being degraded due to various manmade reasons.

Chief **among them are a number of activities involving**

- **energy generation and its utilization**. During any energy conversion process some energy is expelled by the energy conversion system into surroundings in the **form of heat**. Also some **pollutant**s may be produced as a by-product of this process. Both of these cause certain degradation of environment.
- Therefore, while supplying the **increased energy demand**, efforts should be made to adopt measures to minimize the degradation of environment.
- The present trend is to have a **trade-off between the two**. Future seems to be in favour of **developing renewable and environment friendly energy resources**.

Ecology

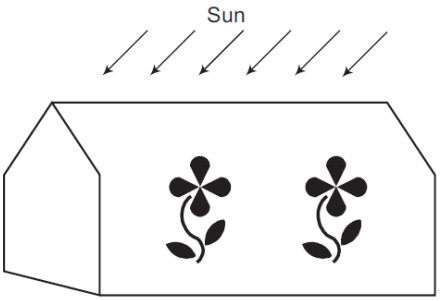
Ecology deals with the **relationship existing between living organisms** (man, animals, plants and vegetation) and the **environment.**

Normally, nature has self-cleaning capability and recycles (renews) its resources through various processes thus maintaining a state of equilibrium.

Water cycle, nitrogen cycle and carbon cycle are the well-known examples of this. However, when human interference exceeds the limits, the **ecological balance is disturbed.**

Greenhouse Effect

- A green house is an enclosure having transparent glass panes or sheets It behaves differently for incoming visible (short wave) radiation and outgoing infrared (long wave) radiation.
- It appears as transparent for incoming solar radiation, allowing entry of sunlight and becomes largely opaque for reflected infrared radiation from earth surface, preventing exit of heat. Thus it maintains a controlled warmer environment inside for growth of plants, in places where the climate is very cold.
- Carbon dioxide (CO_2) enveloppe présent around the globe in the atmosphere behaves similar to a glass pane and forms a big global green house. This tends to prevent the escape of heat from earth, which leads to global warming. This phenomenon is known as greenhouse effect.



Energy, economy and social development

- Energy is universally recognized as one of the most important input for economic growth and human development.
- Access to modern energy services is fundamental to fulfilling basic social needs, driving economic growth and fueling human development.
- Energy services have an **effect on productivity, health, education, safe and potable water and communication services.**
- **Modern services such** as electricity, natural gas, modern cooking fuel and mechanical power are necessary for improved health and education, better access to information and industrial as well as agricultural productivity.
- Thus, secure, reliable, affordable, clean and equitable energy supply is fundamental to global economic growth and human development.
- One of the major challenges facing the world at present is that approximately **1.3 billion people live without any access to modern energy services.**
- **Access to energy is a fundamental pre-requisite for modern life** and a key tool in **eradicating extreme poverty across the globe.**
- Broadly, there are four major energy end use sectors:
  1. **Industrial**
  2. **Commercial**
  3. **Residential**
  4. **Transportation**

Example: A poor rural family of five persons consumes 1 kg per person per day of firewood for cooking needs and 2 kg of kerosene oil per month for lighting. Calculate the annual primary energy consumption per person in KGOE. Assume heating value of wood as 4000 kcal per kg and that of kerosene oil as 45 MJ per kg.

Solution

- Annual firewood consumption of the family for cooking = 5 × 1 kg × 365
- = 1825 kg
- Annual primary energy required for cooking = 1824 × 4000 kcal
- = 73,00,000 kcal
  = 730 KGOE (refer Appendix A)
- Annual kerosene requirement of the family for lighting = 12 × 2 kg = 24 kg
- Annual primary energy required for lighting = 24 × 45 = 1080 MJ
  = 1080 × 23.884 × 10–3 KGOE
  = 25.795 KGOE (refer Appendix A)
- Total annual primary energy consumption of the family = 730 + 25.795
- = 755.8 KGOE
- Total annual primary energy consumption per person = 755.8 / 5
  = 151.2 KGOE

IMPORTANCE OF NON-CONVENTIONAL ENERGY SOURCES

- The concern for environment due to ever-increasing use of fossil fuels and rapid depletion of these resources has led to development of alternative sources of energy, which are renewable and environment friendly. Following points may be mentioned in this connection:

  1. Conventional sources (except hydro) are non-renewable and finite assets. With present rate of consumption their availability is rapidly declining.

  2. The demand of energy is increasing exponentially due to rapid industrialization and population growth, the conventional sources of energy alone will not be sufficient in the long run, to meet the growing demand.

  3. Conventional sources (fossil fuels, nuclear) also cause pollution leading to degradation of the environment. Ultimately, their use has to be restricted within acceptable limits.

  4. Large hydro resources affect wild life, cause deforestation and pose various social problems.

  5. In addition to supplying energy, fossil fuels are also used extensively as feedstock for the manufacture of organic chemicals. As reserves deplete, the need for using fossil fuels exclusively for such purposes may become greater

- **Due to these reasons it has become important to explore and develop nonconventional energy resources to reduce too much dependence on conventional resources**. However, the present trend of developments of non-conventional sources indicate that these will serve as supplement rather than substitute for conventional sources for some more time to come.

ENERGY-ENVIRONMENT-ECONOMY

- Thus the "**three Es**" - **environment, energy, and economic development** **are closely interrelated in a complex manner**. The strategy for mitigating "three Es" issues is a strategy for environmentally sustainable economic development. Herman Daly, a famous ecological economist laid down **three conditions for sustainability**:
  1. **The consumption rate of renewable resources is not higher than its recovery rate.**
  2. **The consumption rate of non-renewable resources is not higher than the rate of increase in renewable resource supply.**
  3. **The emission of pollutants is within the absorption capacity of the environment.**

➢ Unfortunately these conditions have been violated for years. Examples of respective violations typically include deforestation, the depletion of fossil fuels, and the increase in CO_2 concentration in the air. Such violations may be hard to reverse in the short term but, unless long-term remedial actions are taken, present global development trends will not be sustainable.

➢ In particular, a substantial reduction in resource consumption and emissions of pollutants is essential for the development of a sustainable human society on this planet.

➢ As evident from the above discussions, the Economy, Environment and Energy are closely interrelated and an overall policy is required to deal with them.

SAVING THE EARTH AND ENERGY RESOURCES

1. Earth and life in the Biosphere
2. Natural recourses
3. Carbon cycle and Energy resources
4. Energy ,Environment and Climatic change
5. Energy Audit and Conservation
6. Summery and Conclusion

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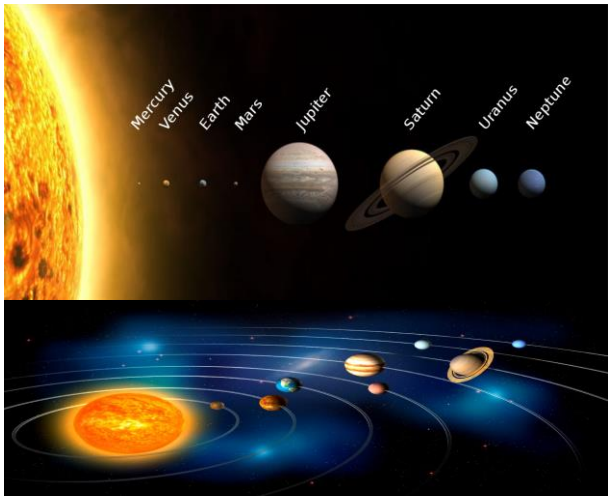
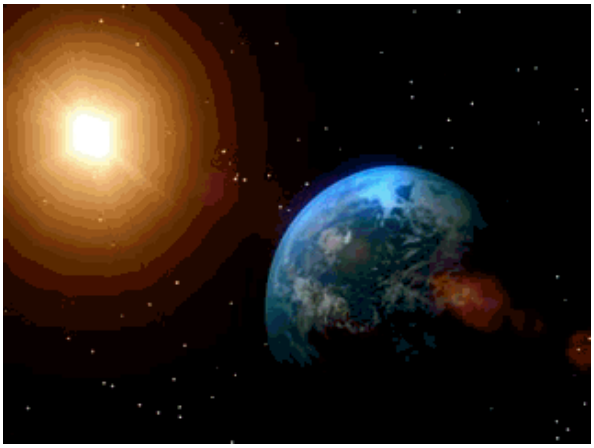
1. Earth and life in the Biosphere

Earth is the only place in the known universe confirmed to host life





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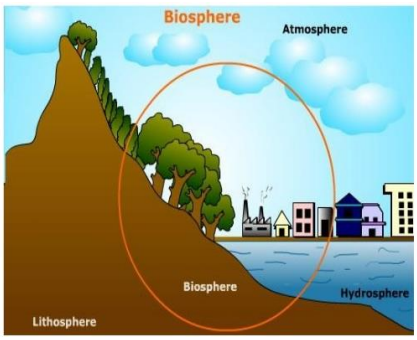
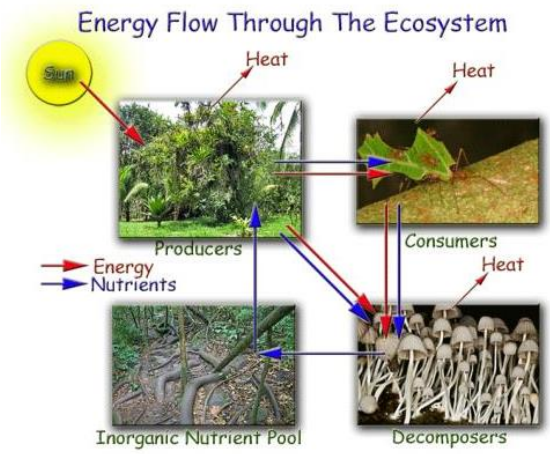
Biosphere

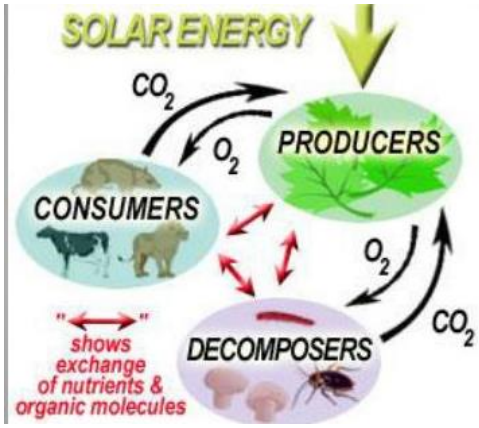


It is the entire interconnected ecosystem of earth Air,land,surface water where life occurs



The biosphere is the portion of the earth that supports living things. It includes living and non-living things.

Energy Flow from Sun



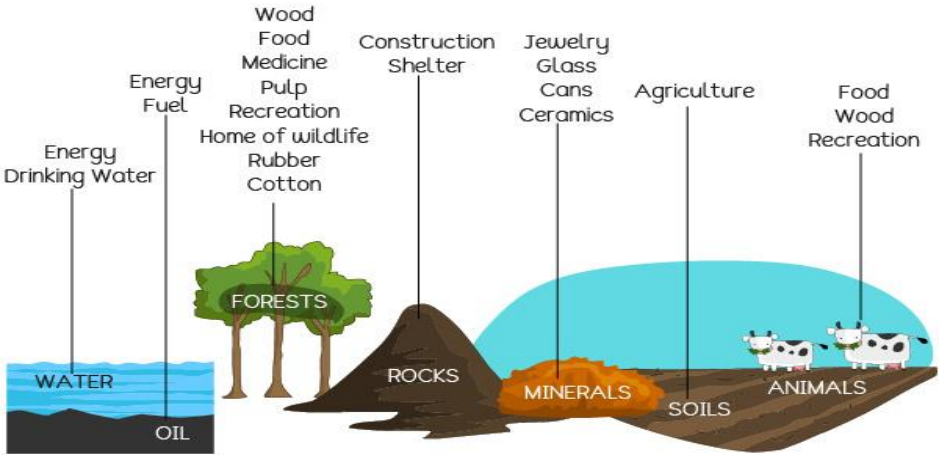
Energy Flow cont…

- Producers: Produce food other organisms use
- Consumers: Consume plants and other organisms for food
- Decomposers: Break down and use dead plants and animals for food

Energy flows from environment through producers to consumers and finally to decomposers

2. Natural Resources

What are the Natural Resources?



Resources may be **solids, liquids, or gasses**. They may also be **organic or inorganic**. They may also be metallic or non-metallic. They may be **renewable or non-renewable**

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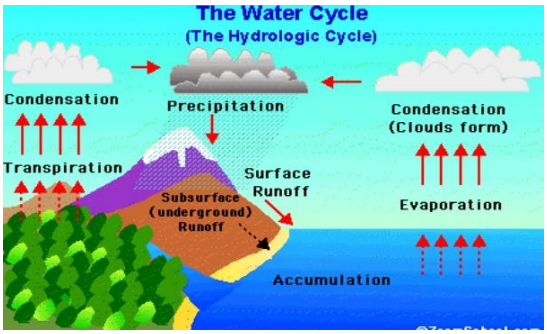
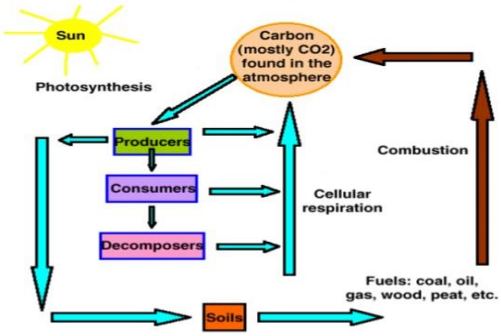
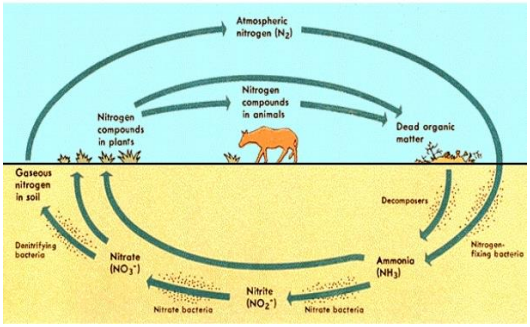


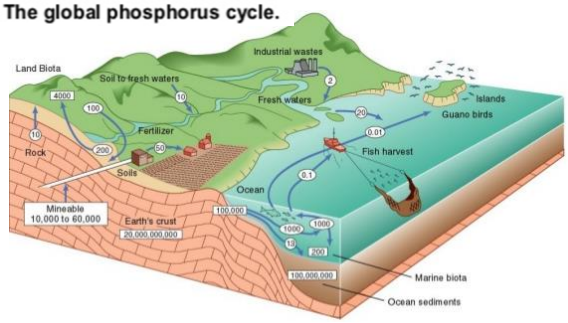
Carbon Cycle



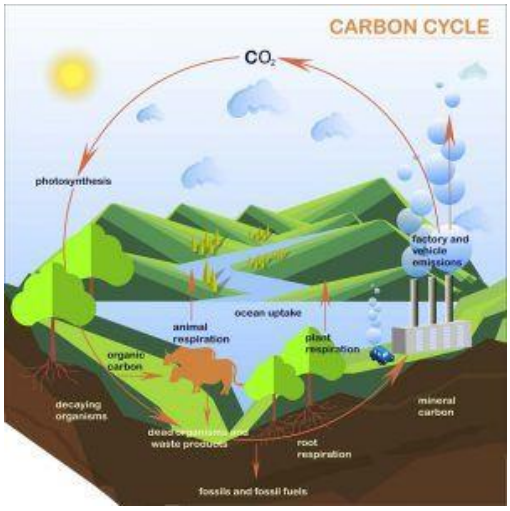
Nitrogen Cycle



The global phosphorus cycle.



Why is the Carbon Cycle Important?



- The carbon cycle, under normal circumstances, works to ensure the stability of variables such as
  - ✓ **Earth's atmosphere,**
  - ✓ **the acidity of the ocean, and**
  - ✓ **the availability of carbon for use by living things**.
- Each of its components is of crucial importance to the health of all living things – especially humans, who **rely on many food crops** and animals to feed our large population.

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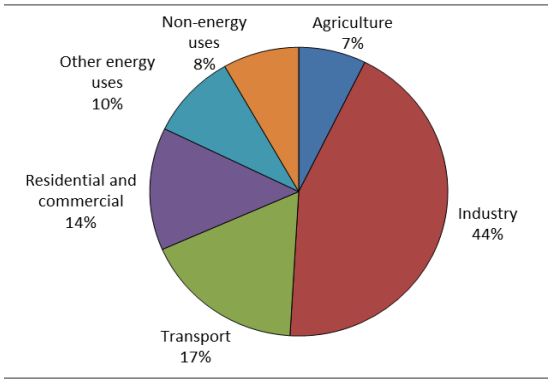
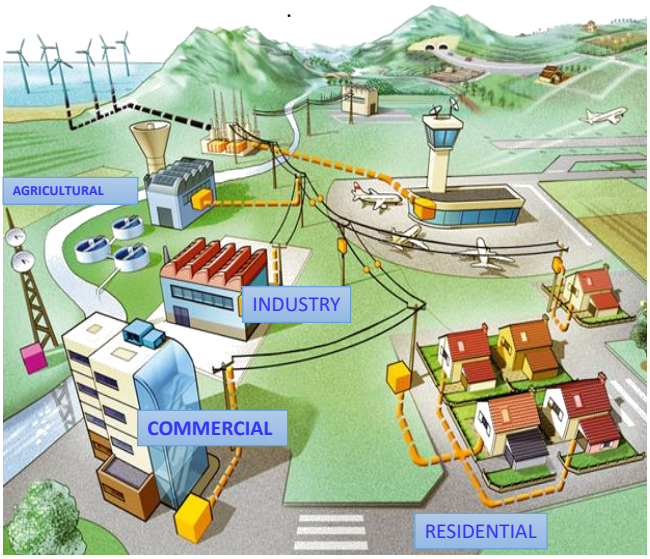
Sectors that use energy



The industrial sector consumes almost 44 % of the total commercial energy consumption followed by transport.



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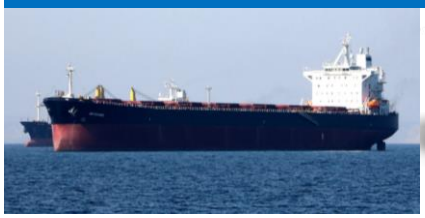
Fossil Fuel Energy Scenario in India



- India has 0.3% of world Oil
- 4.8% of world oil consumption.
- **Imported- 82% of oil**
- Huge import bill

- Coal is the major share of Energy Mix, 56 %
- **Importing 30% of coal consumption**
- 76% of electricity generated from coal
- Avg power plant efficiency: 28-32% Most efficient- 45%

- India has 0.6% of world N.Gas
- **Importing 40% of N.Gas**
- ✓ City Gas distribution-Auto taxi,Bus
- ✓ Piped Natural gas- Industry,commercial,domestic

If the exchange rate shifts by a rupee to a dollar, OR a dollar per barrel, India's oil import bill reduce by Rs 3000 crore

28

Installed Power Generating Capacity of India

	MW	% of Total
Total Thermal	2,31,456	62.2%
Coal	1,99,595	53.7%
Lignite	6,360	1.7 %
Gas	24,992	6.7%
Diesel	510	0.1%
Hydro (Renewable)	45,699	12.3%
Nuclear	6,780	1.8%
RES* (MNRE)	88,042	23.7%
Total	371,977	

* Installed capacity in respect of RES (MNRE) as on 31.07.2020.
RES (Renewable Energy Sources) include Small Hydro Project, Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power, Solar and Wind Energy.

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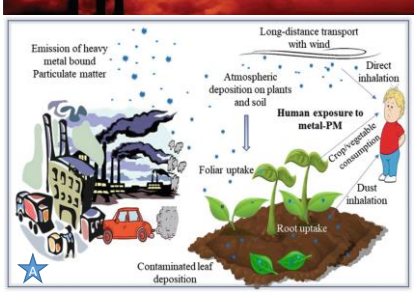
4. Energy ,Environment and Climatic change



- The principal emissions causing impact on the air environment are particulate matter (dust), Sulphur oxides, nitrogen oxides, and carbon monoxide.

1. **Particulate matter - G**enerated from the combustion of solid fuels like coal, lignite, biomass etc. (***ash content*** **)**
2. **Sulphur oxide (SOx)** emissions mainly occur from combustion of oil and coal due to ***sulphur content*** .
3. **Nitrogen oxides (NOx)** emissions are also **associated with fuel combustion and air**
4. **SOx and NOx** emissions **lead to acid rain** which is a trans-boundary environmental issue
5. **Carbon dioxide** is a **major contributor to global warming** and climatic change though **it is not consider as pollutants**.

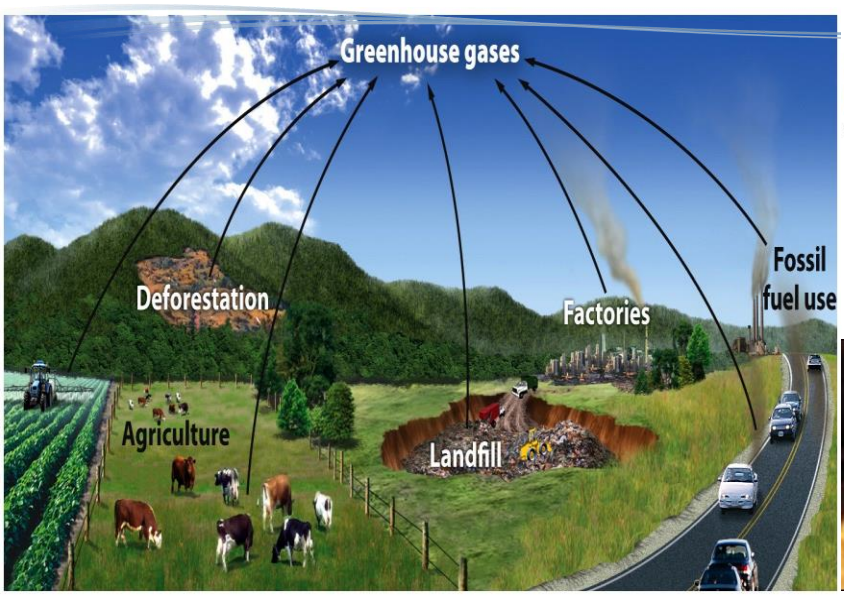
Global Greenhouse Gas Emissions

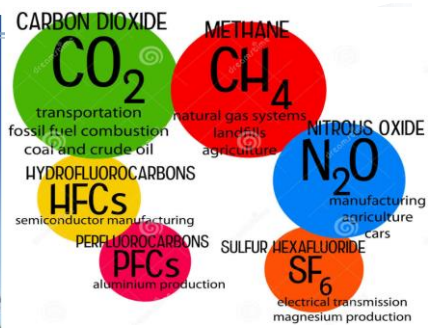
- Since the Industrial Revolution, annual CO2 emissions from fuel combustion dramatically increased
- Agriculture activity producing small shares of CH4 and N2O from domestic livestock and rice cultivation,
- CO2 from fossil fuels & cement contributes almost 70% of global GHG emissions

India's Greenhouse Gas Emissions

- India contributed to almost 7% of global emissions
- India is world's fourth largest contributor in terms of CO_2 emissions (5%) behind China (22%), USA(20%) and Russia. Major source - coal, petroleum, N.gas

Green House Gas – Major Causes

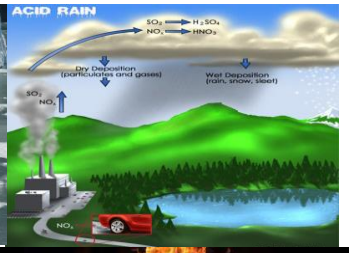


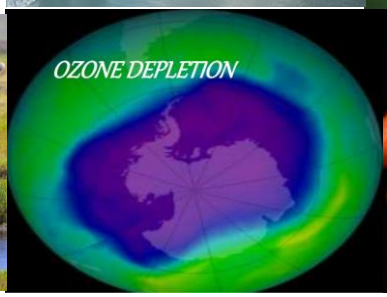


Global Environmental Issues

Some of the key environmental issues of global significance are

- ❑ Acid rain
- ❑ Ozone layer depletion
- ❑ Global warming and climatic change
- ❑ Loss of biodiversity





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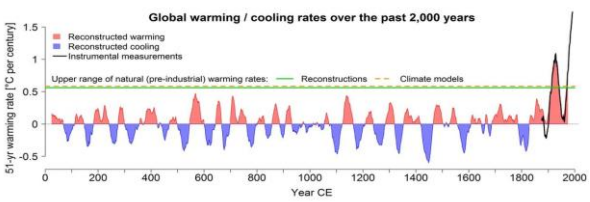
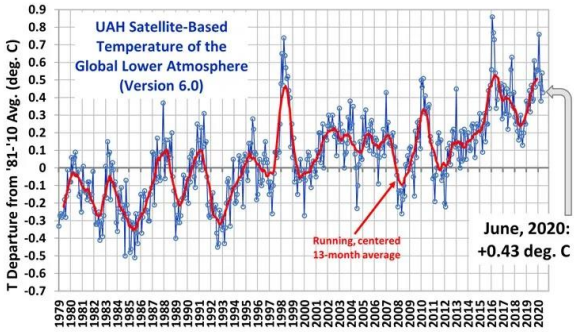
U.N. climate summit-Paris Agreement

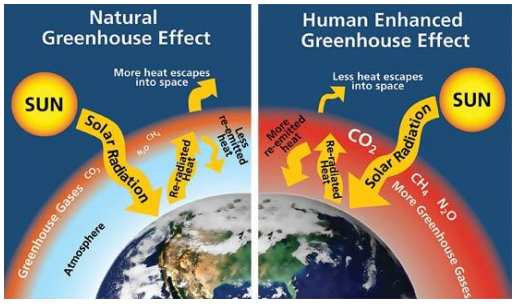




- The average global temperature in 2020 is set to be about 1.2 °C above the pre-industrial (1850-1900) level.
- Paris agreement 2015 — countries mostly stuck to a set of voluntary promises
- It would lead to global warming of 2.7 degrees
- A lot has changed over the last five years

- **There is a need for immediate GHG Emission cuts**
- EU leaders agreed on a new target of slashing net greenhouse gas emissions by 55 percent by 2030.
- China -the biggest polluter on the planet would reach net carbon neutrality in less than 40 years.

Unwelcome threshold -1.5 ^{O}C



- 1.5 degree threshold represents a milestone the world is trying not to reach:
- 2015 Paris Agreement on climate change, backed by almost every country on earth, calls for keeping the global temperature to 1.5°C above pre-industrial era levels.
- Countries must decrease production of fossil fuels by 6 per cent per year between 2020 and 2030 if the world is to avert "**catastrophic" global temperature rise,**
- UN Secretary-General said the **fight against the climate crisis** was the top priority for the 21st Century.

Energy Management ,Energy Audit and Conservation

The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems

- **Eliminate waste:** Ensure that energy is used at the highest possible efficiency.
- **Maximize efficiency:** Utilise the most appropriate technology
- **Optimize supply:** Purchase or supply energy at the lowest cost.

Energy management is the process of monitoring, controlling, and **conserving energy** in an Industry or organization.

What is an Energy Audit ?

- *As per the Energy Conservation Act, 2001, Energy Audit is defined as* "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption "

- ✓ Energy Audit is the key to a systematic approach for decision-making in the area of energy management.
- ✓ It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility.
- ✓ It quantifies energy usage according to its discrete functions

In your Organization, Industry, Office Building Commercial building , or Home

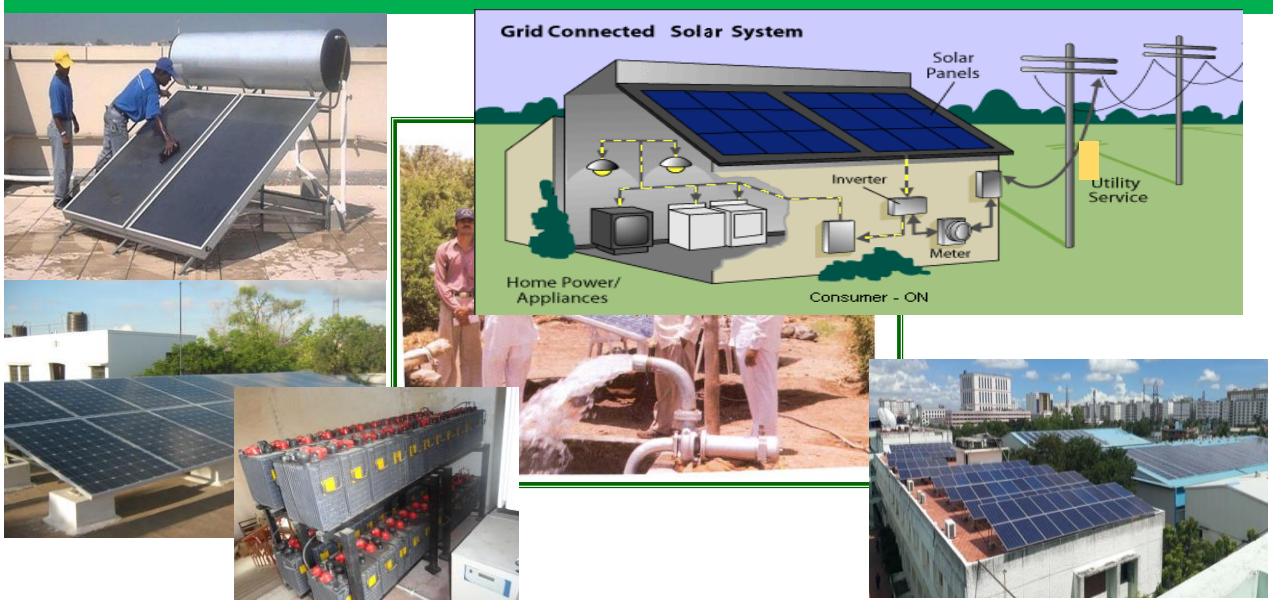
- What type of energy used?
- How much energy is used?
- How much does it cost?
- Where Electricity / fuels are used?
- How efficiently it is used?
- How can it be managed more efficiently and effectively?

Where do we start to find the answer?

This is identified through carrying out

ENERGY AUDITs

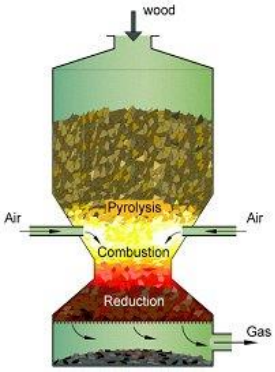
Strat your own Renewable Energy Products/Services



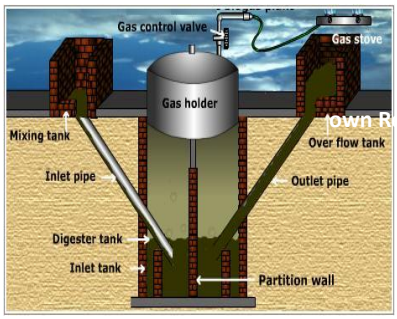
Strat your own Bio- Energy Products/Services

BRIQUETTEDBIOMASS

GREEN COAL



PRODUCER GAS



BIO GAS PLANT

Save energy, Save environment and Save the earth

There's a direct connection between your energy use and the environment.

When you consume less power, you reduce the amount of toxic fumes released by power plants, conserve the earth's natural resources and protect ecosystems from destruction.

By taking steps to reduce your energy intake, you'll contribute to a healthier and happier world.

- Everyone can do their bit to prevent this depletion.
- We must reduce our dependence on fossil fuels which are soon running out.
- Don't waste water ,don't pollute water and use efficiently and make clean water and safe.
- Don't cut down forests, but plant more trees.

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Company Services

EnSave Consultancy and Training Pvt. Ltd

- Established under Companies Act, (2015)

Areas of Services

1. Energy Audit (Electrical &Thermal)
2. PAT Mandatory Audit / M&V Audit
3. ISO 50001-2018 EnMS Implementation
4. Building Audit , Green Buildings LEED/IGBC/GRIHA
5. Energy Manager certification training
6. Interactive Project Development training & Panel Discussion
7. Entrepreneurship in solar / bio-energy projects
8. IOT/BMS/EMS/Electronics integration
9. Energy efficient products /ESCO
10. Water Audit, Electrical Safety audit

Industries

- Thermal power plants,
- Steel, foundry,
- Cement, Paper, sugar, refinery,
- Chemical, fertilizer,
- Textile, pharmaceutical
- Dairy
- Railways
- Hotels, IT sector, Hospital , retail shops, banks, Educational institute and Residential building

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https://ecourse.ensaveindia.in

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Training Services

In-house/ Corporate Training

LIST OF ENERGY MANAGEMENT COURSE MODULES

A-Electrical Utility

Module-1: ELECTRICAL DISTRIBUTION SYSTEM- TRANSFORMERS, PF, MD, CAPACITORS, LOSS REDUCTION
Module-2: ENERGY EFFICIENCY IN ELECTRIC MOTOR
Module-3: VFDs, HARMONICS & POWER QUALITY MANAGEMENT
Module-4: LIGHTING SYSTEM AND CONTROLS
Module-5: DG SET OPERATION AND MAINTENANCE

B-Mechanical Utility

Module-6: ENERGY EFFICIENCY IN PUMP AND PUMPING SYSTEM
Module-7: ENERGY EFFICIENCY IN FAN SYSTEM
Module-8: ENERGY EFFICIENCY IN COMPRESSED AIR SYSTEM
Module-9: ENERGY EFFICIENCY IN REFRIGERATION SYSTEM
Module-10:ENERGY EFFICIENCY IN AIR CONDITIONING SYSTEM
Module-11:ENERGY EFFICIENCY IN COOLING TOWER

C-Thermal Utility

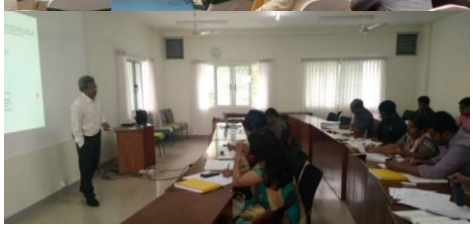
Module-12: FUELS AND COMBUSTION (Oil &Gas)
Module-13: EFFICIENT OPERATION AND MAINTENANCE OF BOILER
Module-14: EFFICIENT USE OF STEAM AND STEAM TRAP
Module-15: BOILER & COOLING WATER TREATMENT
Module-16: HEAT EXCHANGERS & TRI-GENERATION

D-Energy Audit, Management and General Aspects

Module-17: CLIMATIC CHANGE AND NEED FOR ENERGY EFFICIENCY
Module-18: ENERGY AUDITING AND MANAGEMENT
Module-19: ISO-50001 EnMS CERTIFICATION
Module-20: GREEN BUILDINGS INITIATIVES, ECBC/LEED
Module-21: WATER AUDIT AND CONSERVATION
Module-22: WATER TREATMENT/ETP

E-Renewable Energy

Module-23: SOLAR THERMAL TECHNOLOGY & APPLICATION
Module-24: SOLAR POWER GENERATION TECHNOLOGY & APPLICATION
Module-25: BIO ENERGY TECHNOLOGY & APPLICATION



ENSAVE CONSULTANCY AND TRAINING PVT LTD

Online Training & e-learning Courses

Testimonials

Concept and procedure were explained with actual onsite experiences help a lot
Dr Chandira Sekeran

Possible mistakes that one can make while solving problems was highlighted nicely with example
Omkar Avinash

Problem solving, Doubt clearance, To the point, According to exam pattern and especially pointing from where there is possibility of questions to come, Condensed ppt
Anurag Amrit

Easy understanding and stress on important topics
P Rajesh

We have inherited this planet from our fathers
… ……only to look after it for our children

Thank You

Q & A

EnSave Consultancy & Training Pvt Ltd
Dr.P.Dharmalingam
9444177914

Save energy and water for Sustainable Life

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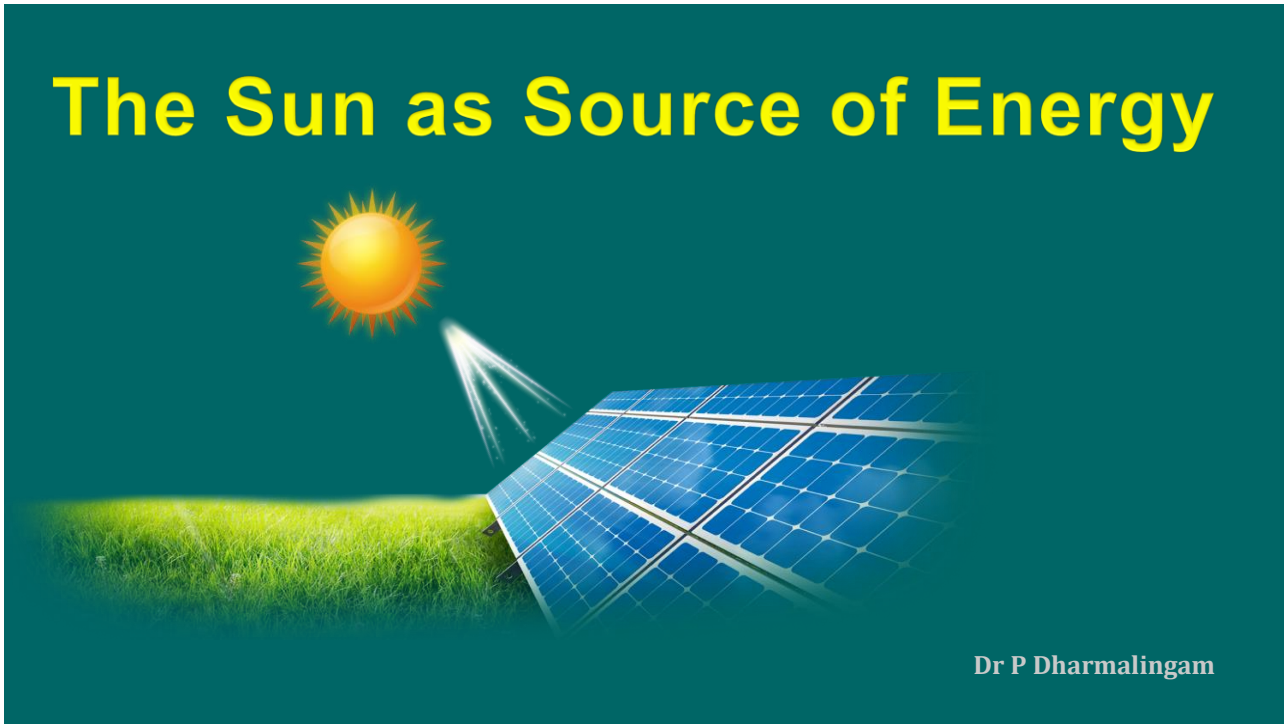
Unit – 2 [4 Hours]: Solar Energy

- ✓ Basics of Solar Energy
- ✓ Solar Thermal Energy
- ✓ Solar Photovoltaic:
- ✓ Advantages and Disadvantages,
- ✓ Environmental impacts and safety



Solar Energy—Basic Concepts
Learning Objectives

- **In this chapter you will be able to:**

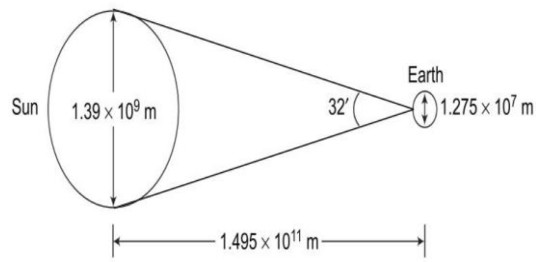
➢Know about the origin of solar energy
➢Discuss the characteristics and distribution of **solar radiation**
➢Measure various components of solar radiation
➢Analyze the collection and interpretation of **solar radiation data**
➢Explain the estimation of **availability of solar radiation at a location**
➢Observe the effect of tilting the surface of collector with respect to horizontalsurface

The Sun

- **Largest member of solar system.**
- **Intensely hot gaseous sphere.**
- **Core temperature is 15 million degree C and Surface temperature is about 5800 K.**
- **Diameter 13,90,000 km, Mass consists of 75% Hydrogen and 25% Helium.**
- **Fusion reaction generates Energy about 386 billion megawatts.**
- **Radiation strikes the earth with in 8 minutes.**
- **30 minutes of radiation is equal to the world energy demand for one year**

THE SUN AS SOURCE OF ENERGY

- The sun, which is the largest member of the solar system, is a sphere of intensely hot gaseous matter with a diameter of 1.39×10^9 m and, at an average distance of 1.495×10^{11} m from the earth.
- The earth may be considered as a sphere with a diameter of about 1.275×10^7 m.
- The earth makes one rotation about its axis every 24 hours and completes a revolution about the sun in a period of approximately 365.25 days.
- Its axis is inclined at an angle of 23.5°. As a result the length of days and nights keep changing.
- The earth reflects about 30 percent of the sunlight that fall on it. This is known as earth's albedo.



THE SUN AS SOURCE OF ENERGY

- As observed from the earth , the **sun rotates on its axis** about once in every four weeks, though it does not rotate as a solid body.
- The equator takes about 27 days and **the polar region takes about 30 days for each rotation**. At the innermost region, the core, the temperature is estimated between 8×10^6 to 40×10^6 K.
- the sun is a big natural fusion reactor with its constituent gases retained by gravitational forces.
- Several fusion reactions takes place.
- Most important of them is a reaction in which four hydrogen atoms (protons) combine to form one helium atom.

$$4({}_1H^1) \rightarrow {}_2He^4 + 26.7 \text{ Mev}$$

The surface of the sun is maintained at a temperature of approximately 5800 K.

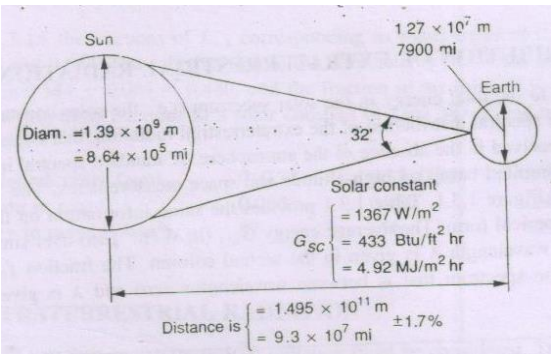
INTRODUCTION

- Solar energy is the mother of all forms of energy: conventional or non-conventional, renewable or non-renewable, the only exception being nuclear energy.
- Various sources of energy find their origin in sun, as mentioned below:

1. Wind energy
2. Biomass energy
3. Tidal energy
4. Ocean wave energy
5. Ocean thermal energy
6. Fossil fuels and other organic chemicals
7. Hydro energy

- Archimedes (212 BC), it is said, set the Roman fleet on fire by concentrating solar radiation using large number of small plane mirrors at a distance of several hundred feet.
- Antoine Lavoisier (1740–1794), achieved temperatures up to 1700 °C by concentrating sun's rays.

geometry of sun-earth relationships.



- **The eccentricity of the earths orbit is such that the distance between the sun and the earth varies by 1.7%.**
- **At a distance of one astronomical unit, 1.495 x 10^{11} m. the mean earth-sun distance, the sun subtends an angle of 32'.**

A Solar constant:-

A Photovoltaic device, outside the earth's atmosphere which maintains normal incidence to the sun's rays receives nearly constant rate of energy."
This amount is called the Solar Constant.
Solar constant approx. = 1367.7 W/m2

- **The Solar constant is the energy from the sun per unit time received on a unit area of surface perpendicular to the direction of propagation of the radiation at mean earth-sun distance outside the atmosphere.**

SUN, EARTH RADIATION SPECTRUM

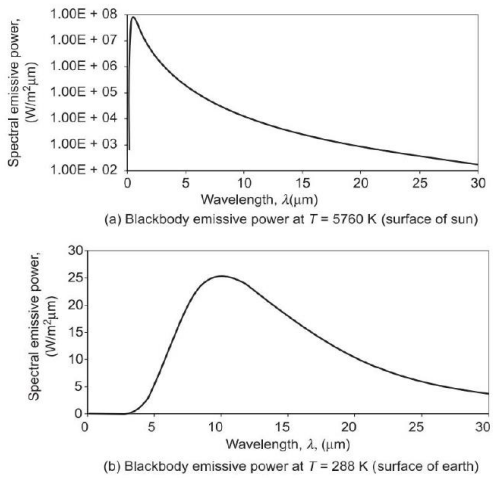


Figure 4.2 Radiant powers per unit wavelength at the surface of sun and earth

The power density distribution of solar radiation at the surface of the sun at the surface temperature 5760 K is calculated.
For the earth surface it calculated at average earth temperature to be 288 K (15 °C).

Solar Constant,
I_{sc} is defined as the energy received from the sun per unit time, on a unit area of surface perpendicular to the direction of propagation of the radiation, at the earth's mean distance from the sun.

The World Radiation Center (WRC) has adopted a value of **solar constant as 1367 W/m$_2$**

This has been accepted universally as a standard value of solar constant.

SPECTRAL POWER DISTRIBUTION OF SOLAR RADIATION

- Solar radiation covers a continuous spectrum of electromagnetic radiation in a wide frequency range.
- About 99 per cent of the extraterrestrial radiation has wavelengths in the range from 0.2 to 4 μm with maximum spectral intensity at 0.48 μm (green portion of visible range)
  - About **6.4 per cent** of extraterrestrial radiation energy is contained in ultraviolet region (l < 0.38 μm);
  - another **48 per cent** is contained in the **visible region** (0.38 μm < l < 0.78 μm) and
  - the remaining **45.6 per cent** is contained in the infrared region (l > 0.78 μm).
- The **spectral solar irradiation distribution** both for **extraterrestrial and terrestrial radiation** is shown in Fig.
- The areas under these curves indicate the total radiation intensities in W/m2 respectively for extraterrestrial and terrestrial regions

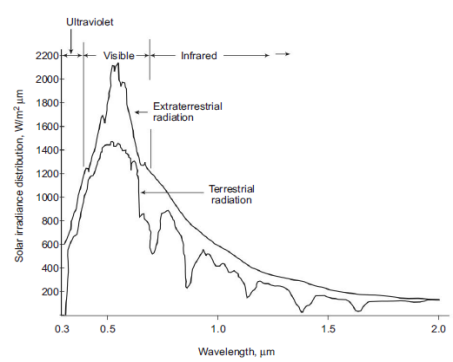
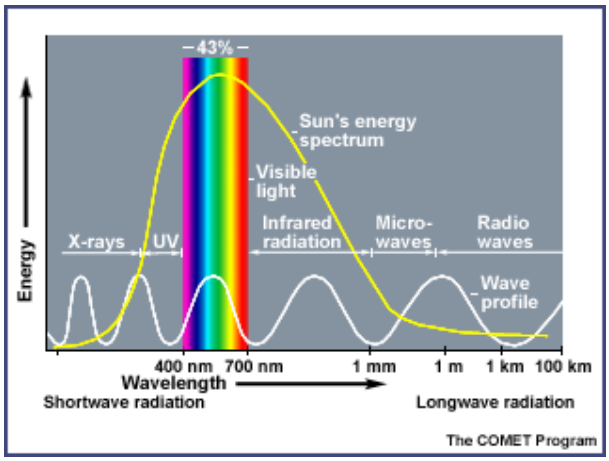


Figure 4.4 Special solar irradiation, extraterrestrial and terrestrials

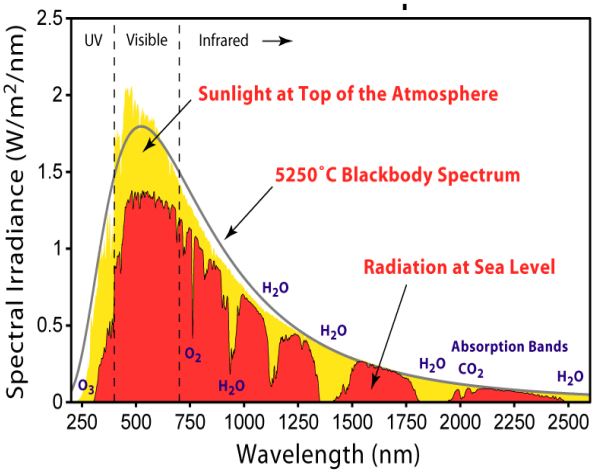
Solar Energy



- **Originates with the thermonuclear fusion reactions occurring in the sun.**
- **Represents the entire electromagnetic radiation**
- **(visible light, infrared, ultraviolet, x-rays, and radio waves).**

B) Solar Spectrum:-

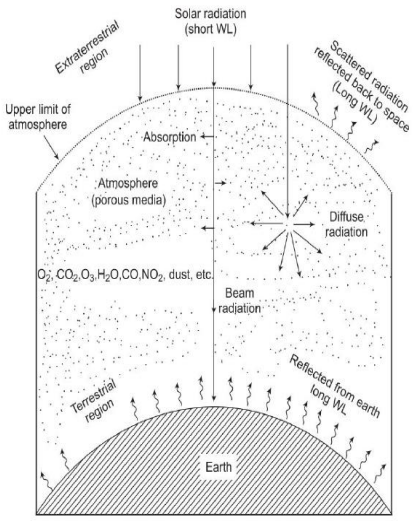
- **The solar radiation spectrum is distributed as;**
- **a good portion of the sun's radiation is in the visible range (46%) (Source – solar cell central).**
- **Radiation in the ultraviolet region (5%), which is not visible, causes the skin to tan and has more energy than that in the visible region.]**
- **Radiation in the infrared region (49%), which we feel as heat, has slightly more total energy than the radiation in the visible region.**



EXTRATERRESTRIAL AND TERRESTRIAL RADIATIONS

- Solar radiation incident on the outer atmosphere of the earth is known as Extraterrestrial Radiation, I_{ext}.
- The **extraterrestrial radiation**, being outside the atmosphere, is not affected by changes in atmospheric conditions. While passing through the atmosphere it is subjected to mechanisms of atmospheric absorption and scattering depending on atmospheric conditions, depleting its intensity.

- A fraction of scattered radiation is reflected back to space while remaining is directed downwards. Solar radiation that reaches earth surface after passing through the earth's atmosphere is known as Terrestrial Radiation.
- The **terrestrial radiation** expressed as energy per unit time per unit area (i.e. W/m2) is known as Solar Irradiation.



Propagation of solar radiation through atmosphere

C) Radiation Types:-

- **Sun emits energy in the form of electromagnetic radiation at an extremely large and constant rate.**
- **Beam Radiation (Gb) : It is the solar radiation received from the sun without having been scattered by the atmosphere (beam radiation is often referred to as direct solar radiation; to avoid confusion between subscripts for direct and diffuse, we use the term beam radiation, subscript "b").**
- **Diffuse Radiation (Gd) : it is the solar radiation received from the sun after its direction has been changed by scattering by the atmosphere (diffuse radiation is referred to, in some meteorological literature, as sky radiation or solar sky radiation; the definition used here will distinguish the diffuse solar radiation from infrared radiation emitted by the atmosphere. Diffuse radiation, subscript "d").**
- **Global Solar Radiation (G) : It is the sum of the beam and the diffuse solar radiation on a surface (the most common measurements of solar radiation are total radiation on a horizontal surface, often referred to as global radiation on the surface.**

$$G = Gb + Gd$$

D) Solar Radiation Terminology :-

- **Radiant energy:**
  - **Energy emitted in the form of electromagnetic radiation. Measured in joules (J)**

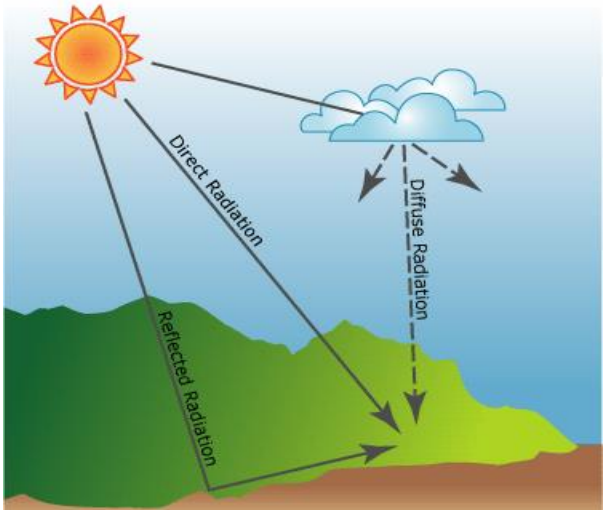
    Radiant flux: Rate of flow of radiant w. r. t. time (Watt)
- **Insolation:**
  - **The actual amount of sunlight falling on a specific geographical location (incident solar radiation). Unit of Insolation is W/m².**
- **Irradiance (E):**
  - **Radiant energy incident on a surface per unit area per unit time (Watt/m2), (J/m2/sec) more popular kWh/m2/day.**

SOLAR RADIATION

Direct Normal Irradiance

Diffused Radiation

→ **Global Radiation**



Units	kWhr / m^2 /year
	kWhr / m^2 / day

EXTRATERRESTRIAL AND TERRESTRIAL RADIATIONS

- Solar radiation incident on the outer atmosphere of the earth is known as Extraterrestrial Radiation, I_{ext}.
- The extraterrestrial radiation, being outside the atmosphere, is not affected by changes in atmospheric conditions. While passing through the atmosphere it is subjected to mechanisms of atmospheric absorption and scattering depending on atmospheric conditions, depleting its intensity.
- A fraction of scattered radiation is reflected back to space while remaining is directed downwards. Solar radiation that reaches earth surface after passing through the earth's atmosphere is known as Terrestrial Radiation.
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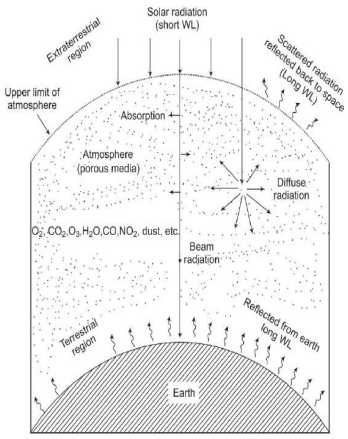


Propagation of solar radiation through atmosphere

DEPLETION OF SOLAR RADIATION

- The earth's atmosphere contains various gaseous constituents, suspended dust and other minute solid and liquid particulate matter.
- These are air molecules, ozone, oxygen, nitrogen, carbon dioxide, carbon monoxide, water vapour, dust, and water droplets.
- Therefore, solar radiation is depleted during its passage through the atmosphere. Different molecules do different things as explained below

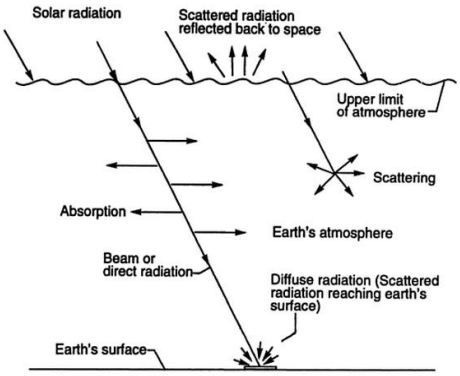
1. Absorption

- Selective absorption of various wavelengths occurs by different molecules.
- The absorbed radiation increases the energy of the absorbing molecules, thus raising their temperatures:

2. Scattering

- Scattering by dust particles, and air molecules (or gaseous particles of different sizes) involves redistribution of incident energy.
- A part of scattered radiation is lost (reflected back) to space while remaining is directed downwards to the earth's surface from different directions as diffuse radiation. It is the scattered sunlight that makes
- the sky blue. Without atmosphere and its ability to scatter sunlight, the sky would appear black, as it does on the moon.

E) Solar Radiation



Global Radiation:

- **The sum of the diffuse and direct solar radiation**
- **Measured by Pyranometer**
- **The measured global horizontal solar irradiance is,**

Direct solar radiation:

i.e., in line with sun is called beam or direct radiation

Reaches the Earths surface without being diffused, direct beam Atmospheric conditions reduce:

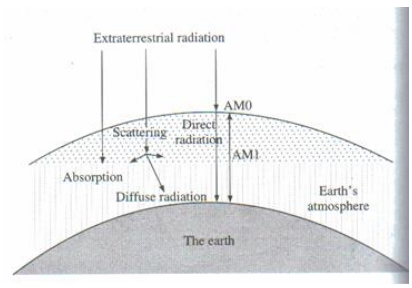
10% on clear, dry days

100% during thick, cloudy days

Diffuse solar radiation:

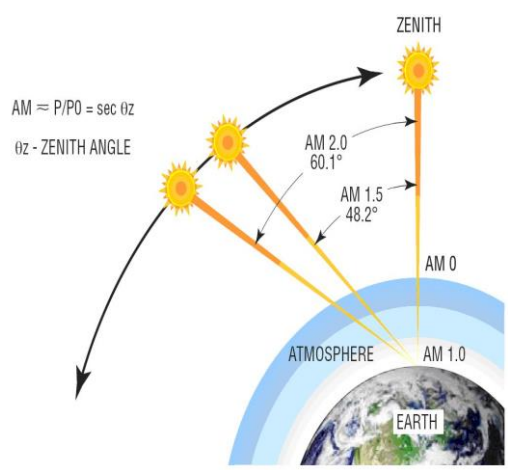
Radiation scattered and reflected by: Air molecules (Rayleigh scattering), Water vapour (Mia scattering), Clouds, dust, pollutants, Forest fires and volcanoes

It does not have a unique direction.



G) Solar Air Mass :-

- Ratio of the distance that solar radiation travels through the earth's atmosphere (path length), to the distance (path length) it would travel if the sun were directly overhead.
- The Air Mass quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust.
- The relative air mass is simply a trigonometric function of the zenith angle:



$$AM = \left(\frac{1}{cos(\theta z)}\right)$$

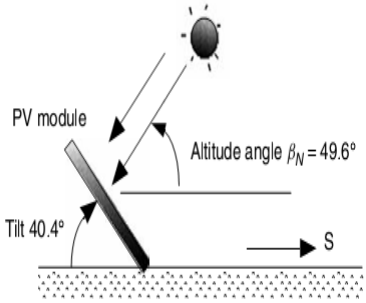
AM = sec (z), where, **θz** is the solar zenith **angle.**

airmass, m = $\frac{\text{pathlength traversed by beam radiation}}{\text{vertical path length of atmosphere}}$

The abbreviation AM0 refers to zero (no) atmosphere, AM1 refers to m = 1

F) Tilt Angle :-

- It is the angle, between array and horizontal surface, which gives maximum solar irradiation.
- Solar panels should always face true south in the northern hemisphere, or true north in the southern hemisphere. This shall give maximum incidence of sunlight on the solar modules.
- The tilt angle and orientation is generally optimised for each PV Power plant according to location.
- This helps to maximise the total annual incident irradiation and total annual energy yield.
- For Indian sites, the optimum tilt angle is generally between 10º and 35º, facing true south.



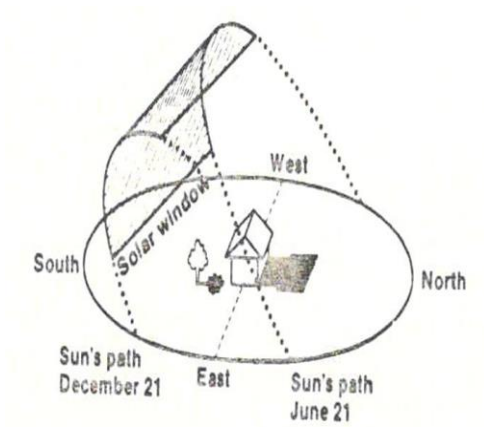
8/25/2021

Solar energy reaching earth's surface at different sun's Positions

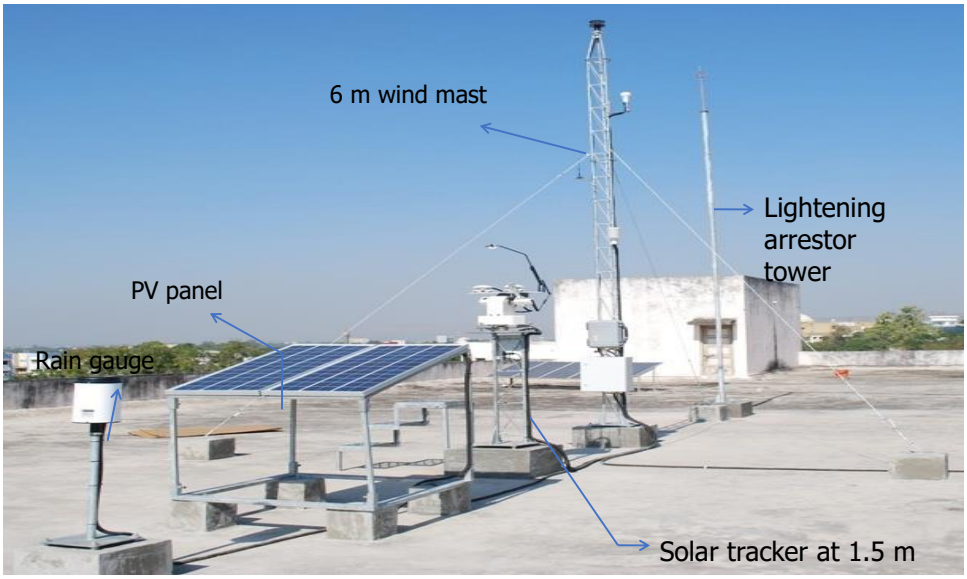
Distance travelled by sun rays to reach earth's surface, or Air Mass	Solar radiation flux reaching the surface (W / m^2)
AM 0 (extraterrestrial)	1 376
AM 1 (sun at overhead position)	1 105
AM 1.5 (sun at about 48° from overhead position)	1 000
AM 2 (sun at about 60° from overhead position)	894

H) The Solar Window :-

- Solar window represents the effective area through which useful levels of sunlight pass throughout the year in a specific location.
- Solar window is used to determine potential shading when designing a photovoltaic system.
- In India, in the winter (December 21), the Sun rises in the Southeast and sets in the Southwest and has relatively short path.
- In the summer time (June 21), the sun rises in the Northeast and sets in the Northwest and has a longer path.
- The effective area between the Sun's path of June 21 and Sun's path of December 21 is known as solar window



Typical SRRA Station



PYRHELIOMETER

- This is an instrument using a collimated detector for measuring solar radiation from the sun (i.e. beam radiation)

PYRANOMETER

Used for measuring the total radiation (beam + diffuse). It can be used to measure diffuse radiation only by using a shade ring or disc, which shades the beam radiation

MEASUREMENT OF SOLAR RADIATION

Solar radiation data are measured mainly by following instruments:

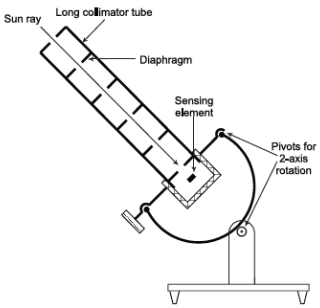
(i) Pyranometer: A pyranometer is designed to measure global radiation, usually on a horizontal surface but can also be used on an inclined surface. When shaded from beam radiation by using a shading ring, it measures diffuse radiation only.

(ii) Pyrheliometer: An instrument that measures beam radiation by using a long and narrow tube to collect only beam radiation from the sun at normal incidence.

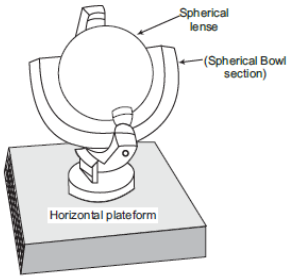
(iii) A sunshine recorder measures the sunshine hours in a day.

Pyranometer

A pyranometer with shadow and



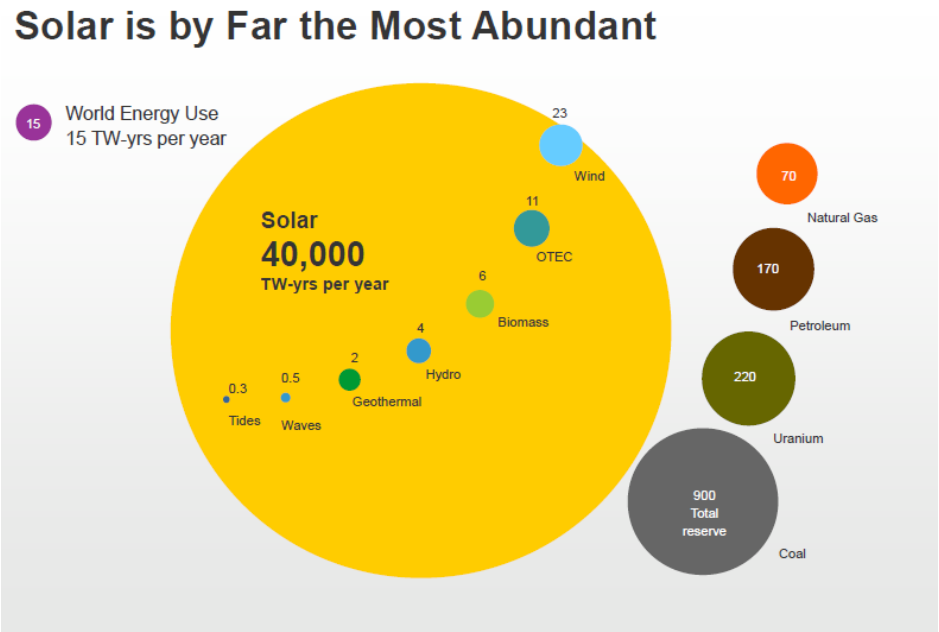
Pyrheliometer



Sunshine recorder

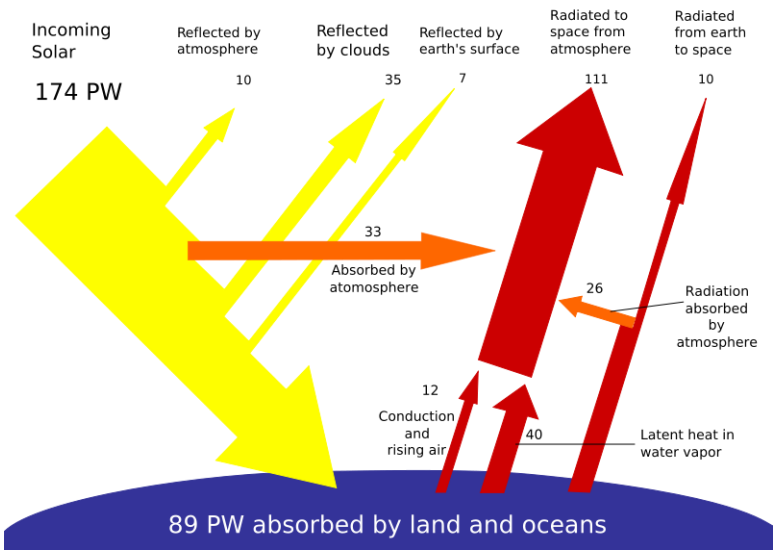
Infinite Source

Energy/Fuel Supply Available



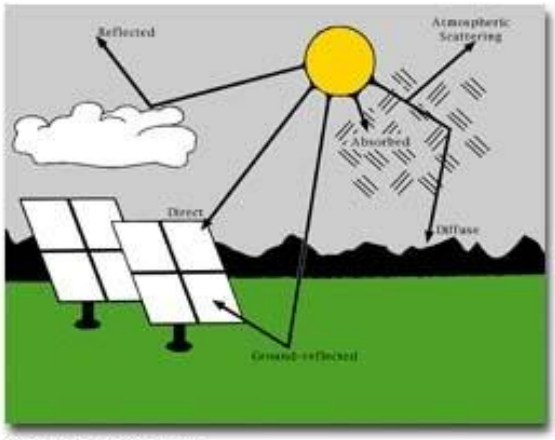
27

Breakdown of incoming solar energy



http://en.wikipedia.org/wiki/File:Breakdown_of_the_incoming_solar_energy.svg

- About half the incoming solar energy reaches the Earth's surface.
- The Earth receives 174 petawatts (PW) (10^{15} watts) of incoming solar radiation at the upper atmosphere.
- Approximately **30% is reflected** back to space while the rest is **absorbed by clouds, oceans and land masses.**
- Earth's land surface, oceans and atmosphere absorb solar radiation, and this raises their temperature. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C.
- By photosynthesis green plants convert solar energy into chemical energy, which produces food, wood and the biomass from which fossil fuels are derived.



SOLAR RADIATION

SOLAR ENERGY

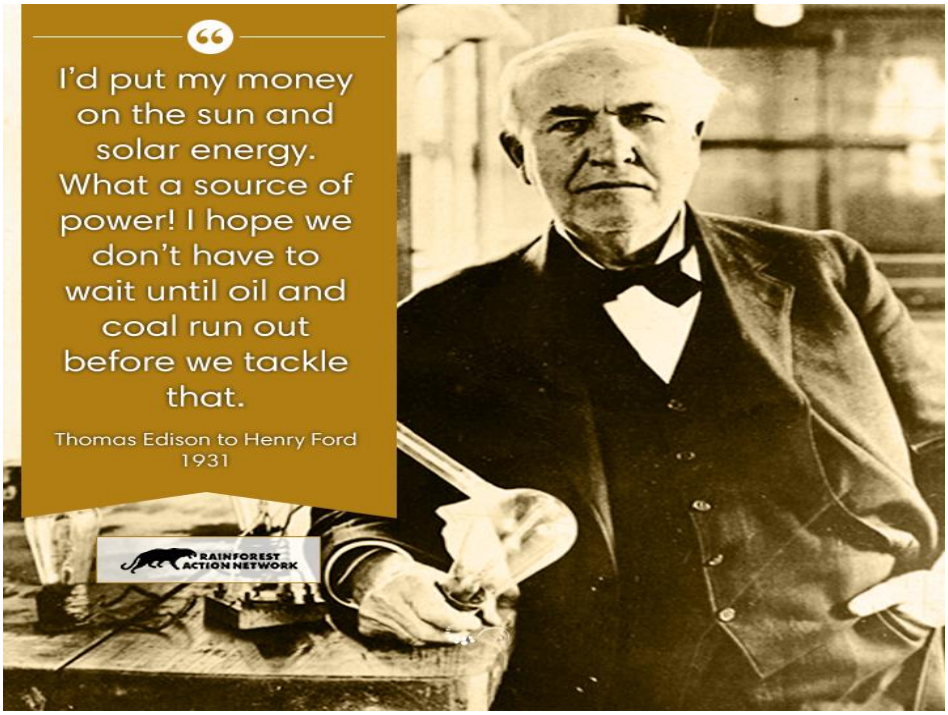
- Earth Receives 10^{18}kwh of solar energy every year
- The surface of the earth receives about 10^{14} kW from sun
- Heat to Earth Heat Flux Density – 1.3kw/Sq.M

  This varies in different places of Earth due to 23^0 Slant
- 1.3kw x 7hrs (if uniform through) = 9kwh – but due to intensity variation, this is 6 - 7kwh for India

- **Solar PV Power and India**
- India has 3.2 Million Sq. Km.Area
- India has 250 to 300 sunney days
- Solar Power Potential is 4 to 7 Kwh/Sq.M/Day
- Energy can be used both for 'Heat' and Electricity Generation.

Obstacles in harnessing solar energy

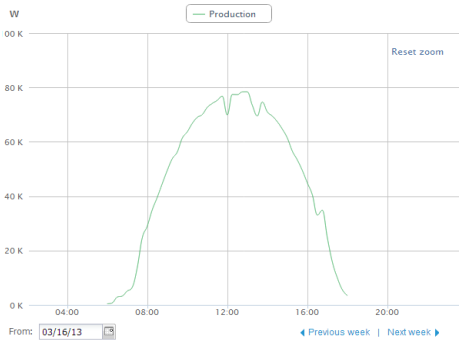
- Solar energy is diffused.
- It therefore calls for large area, land as well as the equipment to harness substantial Energy.
- This makes the 'System' costly.
- Cost Effectiveness and Efficiency of Conversion are the Important Issues.
- It is not constantly available on earth. Thus some form of storage is needed to sustain solar energy through the night and during rainy season

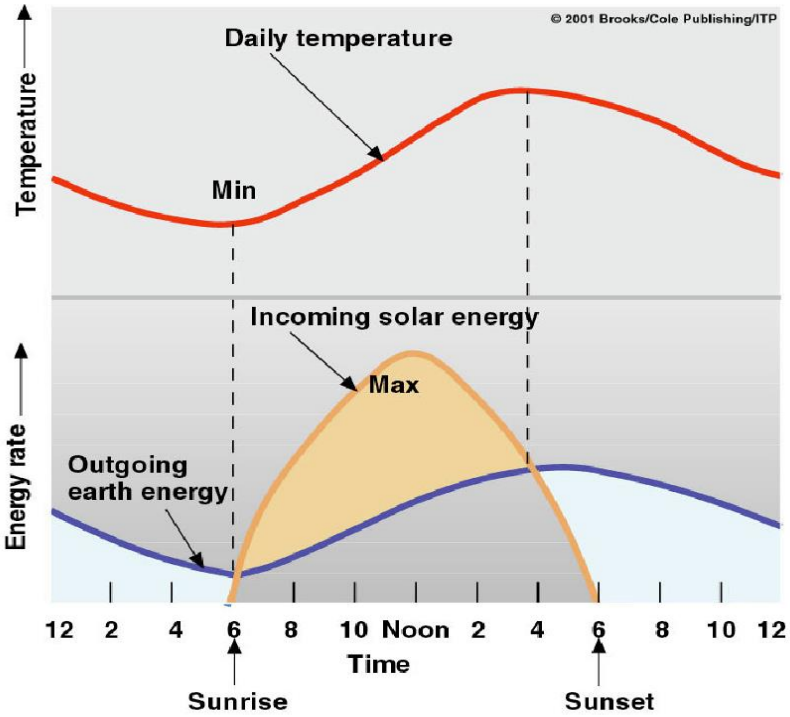


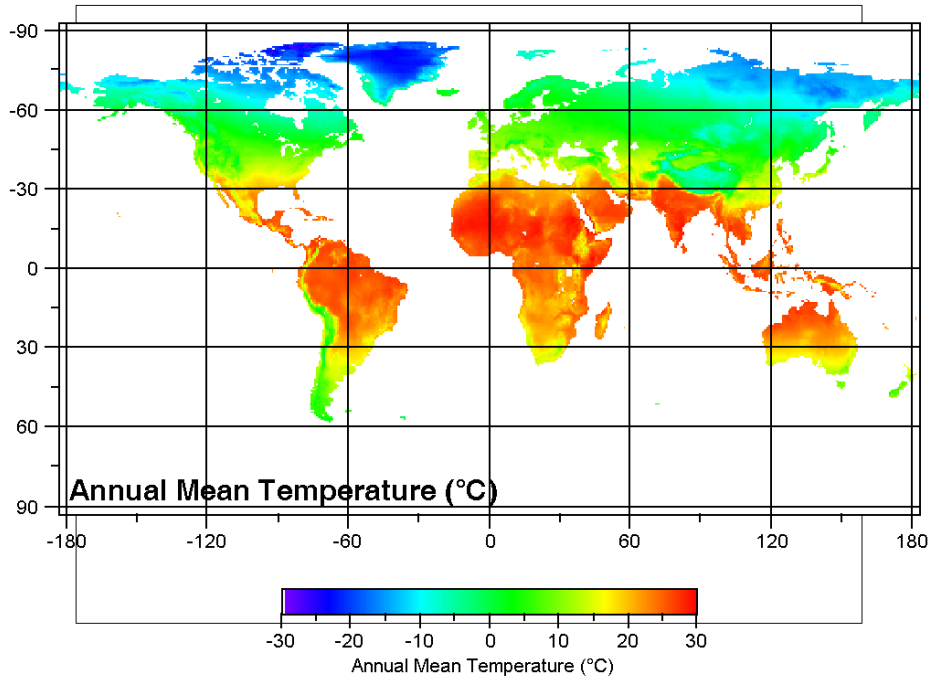
Surface Area Required to Power the World

Sun's Position in the Sky Keeps Changing

Solar is not a constant source







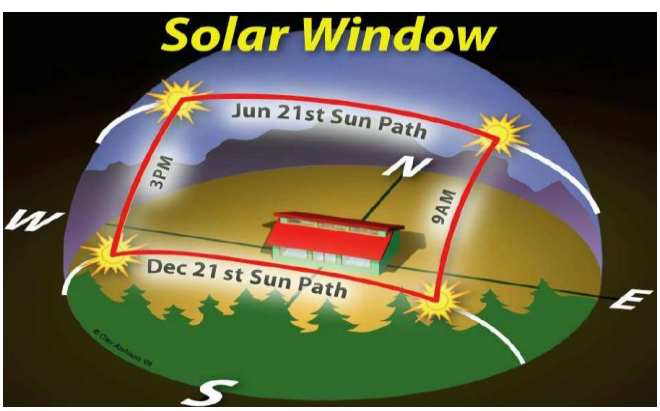
Advantages of Solar Technologies

- **Solar Energy is abundant (more than 5.5 kWh/Sq.m.).**
- **Simple modular technology, flexibility from Watts to Megawatts.**
- **Fuel (solar radiation) available for free.**
- **Long life (more than 20 years).**
- **No moving parts and therefore no noise or wear & tear.**
- **Low gestation period.**
- **Minimum maintenance if designed properly.**
- **Possible to operate in stand alone, de-centralised, grid interactive and hybrid modes.**
- **Ideally suitable for remote area applications.**

11.2 Fundamentals of Solar Energy

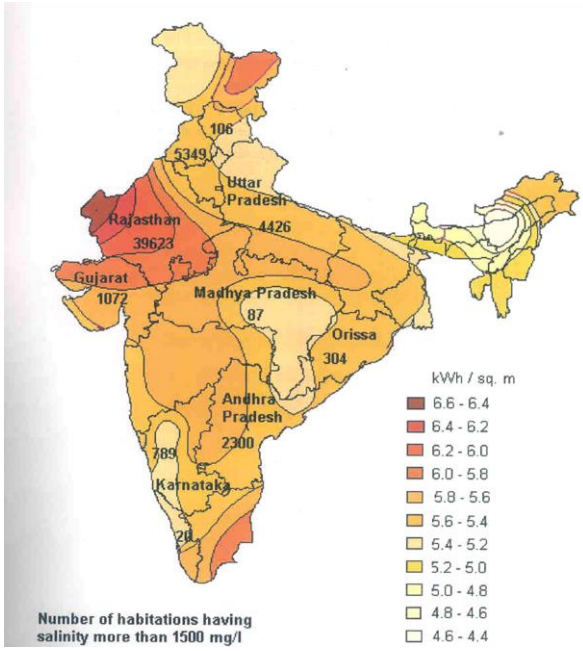
- **Solar radiation** is radiant energy emitted by the sun comprising of ultra-violet, visible and infra-red radiation.
- **Solar constant** is the rate at which solar energy, at all wavelengths, is received per unit area at the top level of Earth's atmosphere . The solar constant varies 0.3% over the 11-year solar cycle but averages about **1,368 W/m2**.
- **Solar Insolation** is the amount of solar energy that strikes a square meter of the earth's surface in a single day. The average incoming radiation is known as solar insolation , **342 W/m2**

- The insolation values is expressed in $kWh/m^2/day$.
- India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year.

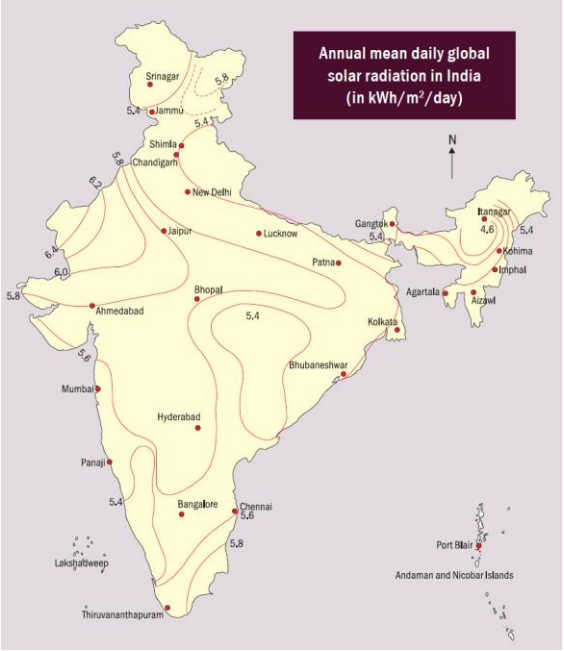


Solar Window is the period, typically 9 AM - 3 PM, when maximum sunlight is available

Solar Power Map

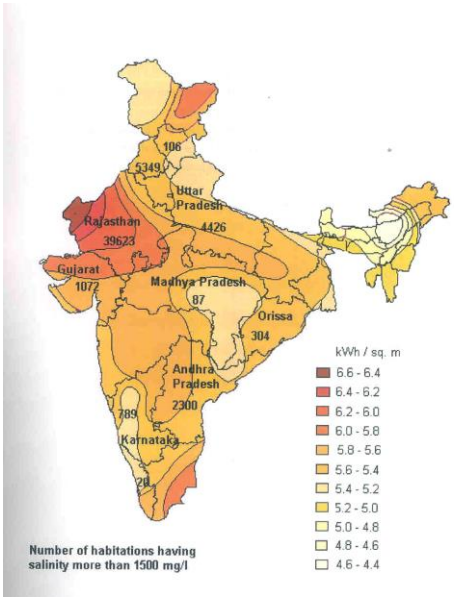


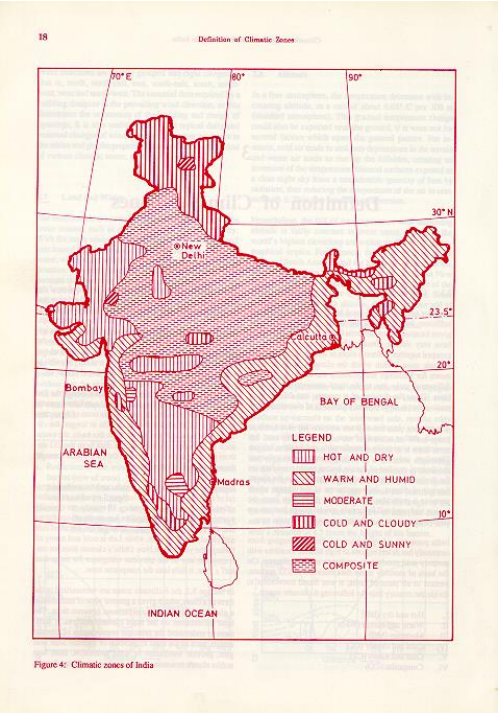
SOLAR POWER DENSITY



Solar Radiation Map of India

- Most parts of India receive good solar radiation 4- 7 kWh/sq. m/day
- Possible to meet growing energy demands and cover deficit areas
- Can substantially reduce consumption of kerosene and diesel for lighting and power generation
- Provide access and empowerment at grass root level





Climatic Zones of India

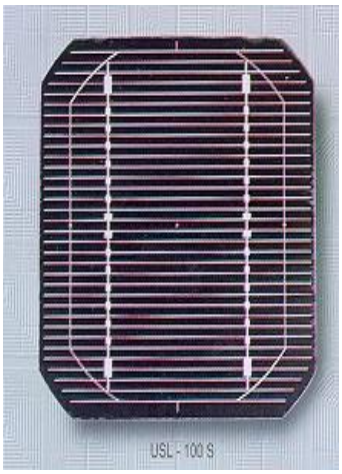
- After analyzing the climatic data of the country, six climatic zones identified
- Design guidelines for each climatic zone developed
- Buildings in different climatic zones designed and constructed

India: Land of a Billion Energy Needs

- 2.4% of land area with 16% of the world's population
- Life Expectancy 64.71 years
- Household sector: largest consumer of energy accounting for 40-50 % of total energy consumption
- About 2/3 of India's more than 1 billion people live in rural areas
- In rural areas, the domestic sector accounts for nearly 80 percent of total energy consumption

SOLAR NERGY

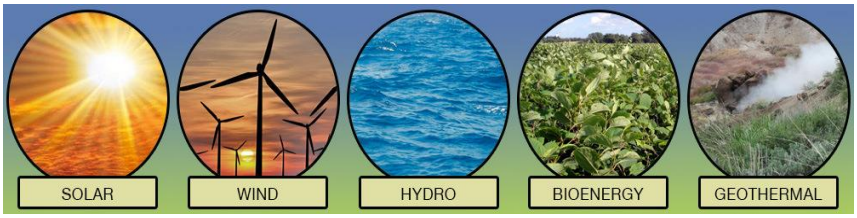
HEAT



ELECTRICITY

Solar Thermal energy

Solar energy devices & saving potential



Dr.P.Dharmalingam
Accredited Energy Auditor
Director, EnSave Academy

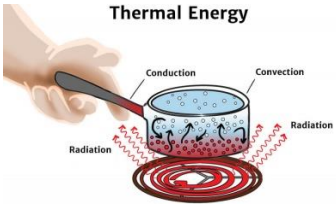
Unit – 2 [4 Hours]: Solar Energy

- ✓ Basics of Solar Energy
- ✓ Solar Thermal Energy
- ✓ Solar Photovoltaic:
- Advantages and Disadvantages,
- Environmental impacts and safety

In this chapter you will be able to

1. Describe the **process of harnessing solar energy** in the form of heat
2. Explain the **construction and operation of various types of solar Collectors**
3. Discuss **various useful thermal applications** of solar energy and its advantages.

Thermal Energy Basics



Temperature

1. **Temperature** is the degree of hotness or coldness measured on a definite scale and is denoted in Fahrenheit (^{o}F) or Celsius (^{o}C) .
2. In **Fahrenheit scale** (British system), the freezing point of water is 32 ^{o}F and the boiling point of water is 212°F at atmospheric pressure.
3. **The Kelvin scale** is the temperature standard and fixes its origin, or **null point, at absolute zero (^{0}K = –273.15°C)**

Conversion of the degree Celsius into Fahrenheit = (^{o}C x 1.8) + 32

Conversion of the Fahrenheit into degree Celsius , ^{o}C = (^{o}F - 32) / 1.8

Degrees Celsius (C) to degrees Kelvin (K) = (^{o}C) + 273 = (K)

$$^{o}C = (^{o}F - 32) \times 5/9$$

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Thermal Energy Basics

- **Calorie** is unit of heat: 1 kilocalorie can raise 1 kg of water by 1°C
- **Specific heat** is amount of heat required to raise 1 kg of water by 1°C
- **Heat quantity** =mass x specific heat x rise in temperature **M cp Delta T**

Specific Heat of Some Common Substances	
Substance	Specific heat (J/kg°C)
Copper	390
Aluminium	910
Water	4200
Alcohol	2400
Iron	470

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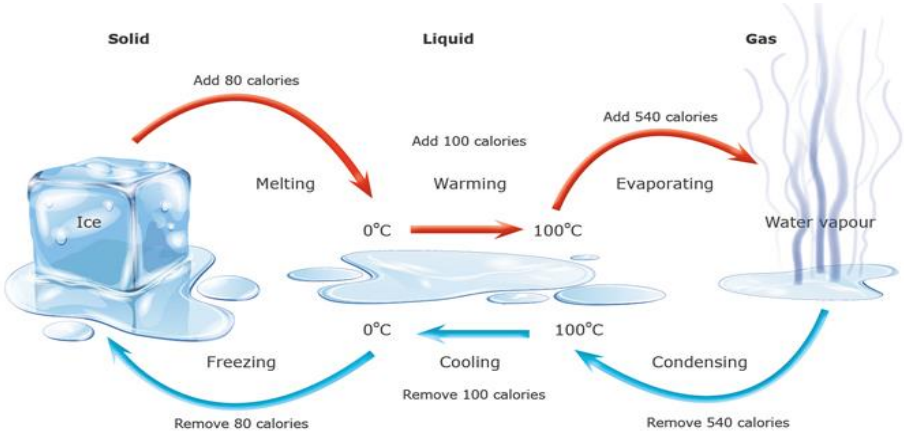
Properties of Steam: Sensible and Latent Heat



Latent heat of fusion – 80 calories

Latent heat of vaporisation – 540 calories

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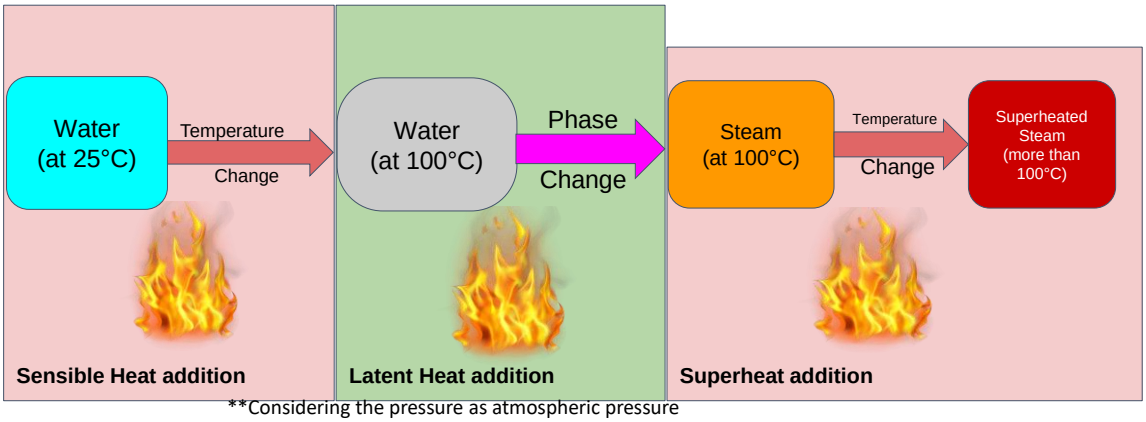
Properties of Steam:
Sensible and Latent Heat



**Considering the pressure as atmospheric pressure

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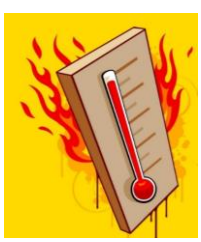

Heat is transferred from one body to another body at a lower temperature by virtue of temperature difference It is the quantity of heat, which can raise the temperature of 1 g of water by 1°C.
1 kilocalorie can raise the temperature of 1000g (i.e. 1kg) of water by 1°C.
Calorie = 4.187 J

Sensible Heat The amount of heat which when added to any substance causes a change in temperature. Sensible heat = mass x specific heat x change in temperature

Latent heat It is the change in heat content of a substance, when its physical state is changed without a change in temperature. The latent heat of fusion of a substance is the quantity of heat required to convert 1 kg solid into liquid state without change of temperature. **Q_L (ice) = 335 KJ/kg.** $Q_L = m \times h_{if}$

Super Heat
Super heating is the heating of vapour, particularly saturated steam to a temperature **much higher than the boiling point** (saturation temperature) at the existing pressure.

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1. Concept of New and Renewable Energy

- ❑ Renewable energy is energy obtained from sources that are essentially inexhaustible .
  - ➢ **Examples: solar, wind ,geothermal , tidal ,bio-energy & hydropower**.
- ❑ Important feature of renewable energy is that it can be used without the release of harmful pollutants

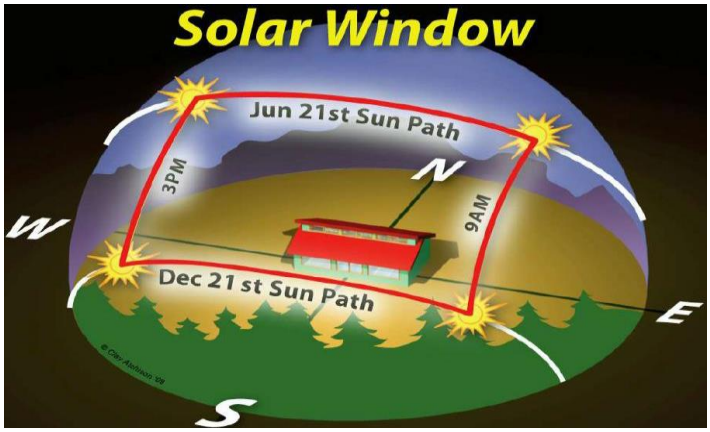
Solar Window is the period, typically 9 AM - 3 PM, when maximum sunlight is available

2. Fundamentals of Solar Energy

- ❑ **Solar radiation** is radiant energy emitted by the sun comprising of ultra-violet, visible and infra-red radiation.
- ❑ **Solar constant** is the rate at which solar energy, at all wavelengths, is received per unit area at the top level of Earth's atmosphere . The solar constant varies 0.3% over the 11-year solar cycle but averages about **1,368 W/m2**.
- ❑ **Solar Insolation** is the amount of solar energy that strikes a square meter of the earth's surface in a single day.
- ❑ The average incoming radiation is known as solar insolation and is one-fourth the solar constant, or **342 W/m2.**

- The insolation values is expressed in kWh/m^2/day.
- India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year.
-
- This energy is sufficient to set up 20 MW solar power plant per square kilometre land area.

❑ **Solar Window** is the period, typically 9 AM - 3 PM, when maximum sunlight is available



Solar Thermal Systems

Solar Energy In Rural India

Rural Needs are Simple
- **Light for studying**
- **Water for drinking**
- **Fuel for cooking**
- **Television and telephone**

- Current sources available for cooking are firewood, crop residues and animal dung in rural
- Promoted by the Government of India
  - **Parabolic Dish Solar Cookers**
  - **Solar Box Cooker**
  - Community Solar Cooker
  - Solar Steam Cooking System

700 Million Rural People

80% of total energy for these needs

Making India's rural population and India more energy independent

Solar Thermal Energy Systems

- Solar thermal systems uses the sun's heat and convert it into heat energy while solar photovoltaic systems uses sun's heat to produce electricity.
- **Solar collectors are the main component of most of solar energy** systems. The collector absorbs the sun's energy and converts it into **heat energy.**

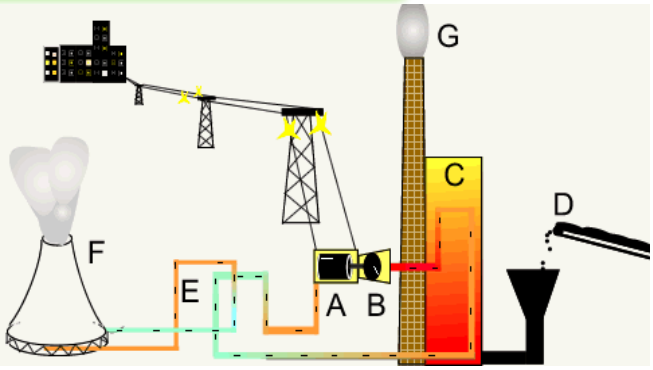
This energy is then transferred to a fluid or air which is used

- ✓ **heat water,**
- ✓ **generate electricity,**
- ✓ **dry materials,**
- ✓ **distill water or**
- ✓ **cook food.**

When used for heating purpose, solar thermal system can partially or fully **replace the conventional fuels such as coal, oil and electricity**

When used for heating purpose, solar thermal system can partially or fully replace the conventional fuels such as coal, oil and electricity

Thermal Power Plant



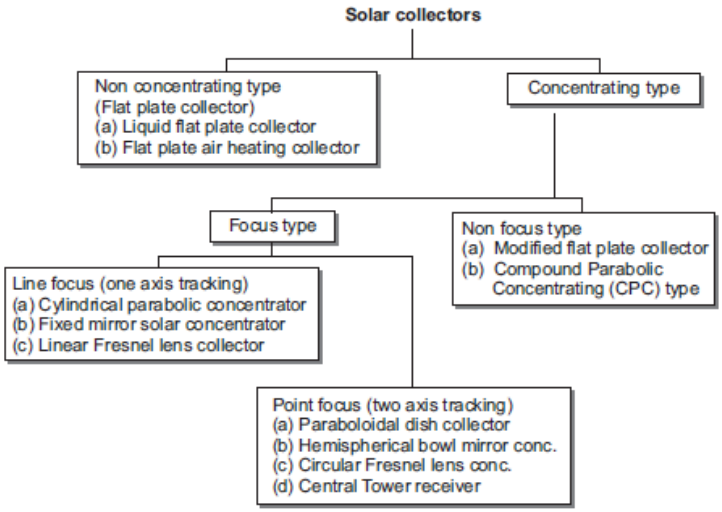
SOLAR THERMAL TECHNOLOGIES

Technologies can be used for both, supplying thermal energy as well as for generating electricity.

1. **Solar water and space heating**
2. **Solar process heating for industrial applications**
3. **Solar drying**
4. **Solar refrigeration and air conditioning**
5. **Solar cooking**
6. **Solar passive architecture**
7. **Solar water desalination and water purification,**
8. **Solar thermal power generation**

SOLAR COLLECTORS

- Solar power has low density per unit area . Hence it is to be collected by covering **large ground area** by solar thermal collectors.
- It **absorbs solar energy as heat** and then transfers it to heat transport fluid efficiently.
- The heat transport fluid **delivers this heat to thermal storage tank** / boiler / heat exchanger, etc., to be utilized in the subsequent stages of the system.



Types of solar collectors

SOLAR COLLECTORS

Performance Indices

Collector efficiency is defined as the **ratio of** the energy actually absorbed and transferred to heat transporting fluid by the collector (useful energy) to the energy incident on the collector.

Concentration ratio (CR) is defined as the **ratio of** the area of aperture of the system to the area of the receiver. The aperture of the system is the projected area of the collector facing (normal) the beam.

Temperature range is the range of temperature to which the heat transport fluid is heated up by the collector.

Solar Thermal Energy Devices

Applications of solar thermal energy are

1. **Solar Water Heating System**
2. **Solar Thermal Power Systems**

Solar Water Heating System

i. **Solar Flat Plate Collector**

ii. **Evacuated Tube Collector**

Solar Electrical Energy system

i. **Power Towers**

ii. **Parabolic Trough Collector**

iii. **Solar Photovoltaic Technology**

Solar Thermal Technologies
(based on output temperature)

Low
(<100^{0}C)

1. Flat Plate
2. Solar Chimney
3. Solar Pond

Medium
(100^{0}C - 400^{0}C)

1. Parabolic Trough
2. Linear Fresnel

High
(> 400^{0}C)

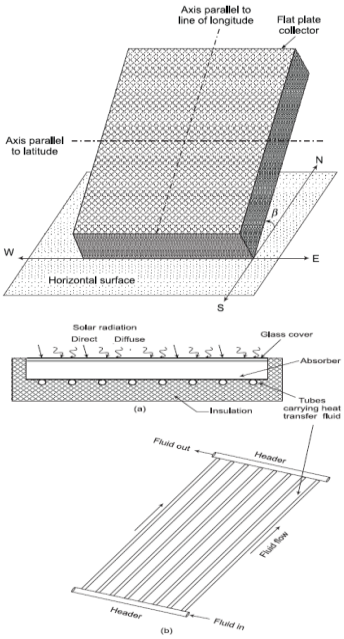
1. Dish with
a. Power Cycle
b. Sterling Engine

2. Solar Tower Heliostat

SOLAR COLLECTORS

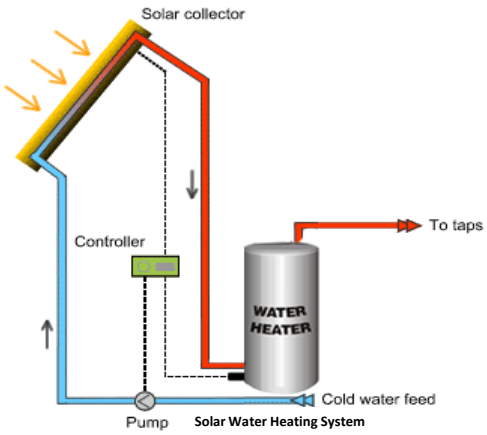
Liquid Flat Plate Collector

- A flat plate collector is placed at a location in a position such that **its length aligns with** line of **longitude and suitably tilted towards south** to have maximum collection.
- **water is used as heat transport medium** from collector to next stage of the system.
- As **solar radiation strikes on specially treated metallic absorber plate**, it is absorbed and raises its temperature.
- The heat is transferred to heat transfer liquid circulating in the tube (or channels), beneath the absorber plate and in intimate contact with it.
- The **glass-cover permits the entry of solar radiation** as it is transparent for incoming **short wavelengths** but is largely opaque to the longer infrared radiation reflected from the absorber. **As a result, heat remains trapped in the airspace between the absorber plate and glass cover** in a manner **similar to green house**.
- **The glass cover** also **prevents heat loss due to convectio**n by keeping the air stagnant.



Solar Water Heating System

- A solar water heating system (Figure 11.1) consists of a flat plate or evacuated tube solar collector, a storage tank and connecting pipes.
- The system is generally installed on the roof or on open ground, with the collector facing the sun and connected to a continuous water supply.
- The collectors are generally mounted on a north-facing roof (in southern hemisphere).
- Water stored in the tank remains hot overnight as the storage tank is insulated and heat losses are small



Solar Water Heating System

Solar Flat Plate Collector

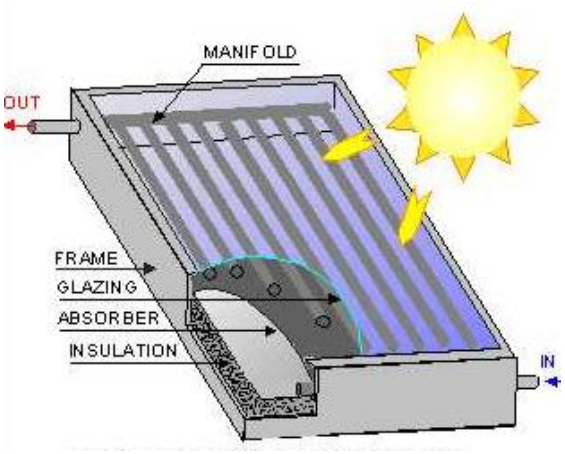


Figure 11.2 Solar Flat Plate Collector

- ✓ The most common collector is called a flat-plate collector.
- ✓ Heat the circulating fluid to a temperature of about **40-60°C.**
- ✓ Usually comprises of **copper tubes** welded to copper sheets (both coated with a highly absorbing **black coatings**) with toughened **glass sheet** on top for cover and insulating material at the bottom. The entire assembly is placed in a flat box.

Case Study

- **SOLAR THERANL**
- This training is imparted in a real life scenario using the 3x 300 LPD system installed on the rooftop .
- practical training trials carried out are:
- Solar Water heating Technologies available
- Solar irradiance variation
- Hourly Variation of temperature
- Performance assessment
- Case studies for industrial & commercial application

100% hot water generation
for Gust house is from solar energy

Evacuated Tube Collector

Evacuated Tube Collector

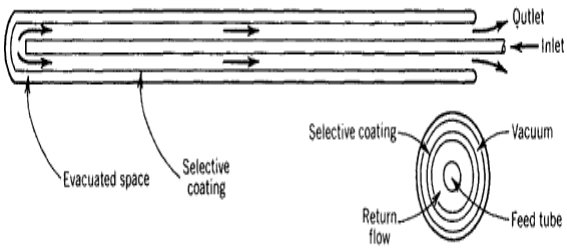
- Used for higher temperatures.
- Evacuated tube collector is less dependent upon ambient temperature unlike flat plate collector and its efficiency **does not drop with ambient temperature**.
- **Evacuated glass tubes** are used instead of copper in which case a separate cover sheet and insulating box are not required.
- Can reach high temperatures upto **150°C.**

Evacuated Tube Collector

Evacuated tube collector comprises of two concentric glass tubes fused in the ends as shown in Figure.

The air is evacuated from the gap between the tubes. The evacuated double-walled glass tube provides thermal insulation similar to that of thermally insulated "Thermos" bottle.

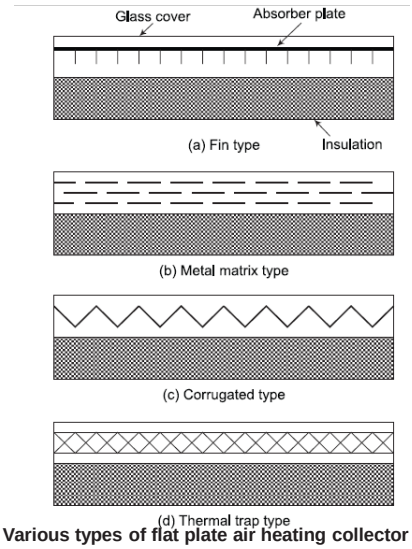
The outer glass tube is clear, and the surface of the inner glass tube is coated with a special heat material that absorbs the sun's energy.



SOLAR COLLECTORS

Flat Plate Air Heating Collector (Solar Air Heater,Solar Air Collector)

- A **solar air-heating collector** is **similar to a liquid** flat plate collector with change in configuration of absorber and tube (riser).
- The value of heat transfer coefficient between the absorber plate and the air is low. For this reason the surfaces are sometimes roughened or longitudinal fins are provided in the airflow passage. **Corrugated, V-shape, matrix, etc., are some of the other variations of absorber plate.**
- The principal applications of theses collectors are **drying for agricultural and industrial purposes, and space heating**.

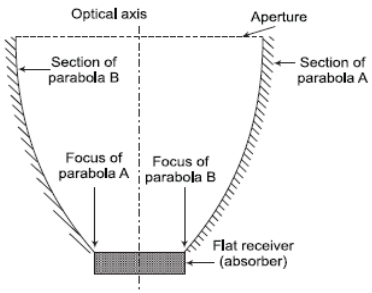


Various types of flat plate air heating collector

SOLAR COLLECTORS

Compound Parabolic Concentrator (CPC)

- Compound parabolic concentrator consists of **two parabolic mirror segments**, attached to a flat receiver.
- The segments are oriented such that focus of one is located at the bottom end point of the other in contact with receiver.
- It has a large acceptance angle and need to be adjusted intermittently.
- Rays in the central region of the aperture reach the absorber directly whereas those near the edges undergo one or more reflections before reaching the absorber.
- The concentration ratio achieved from this collector is in the range of **3-7**.

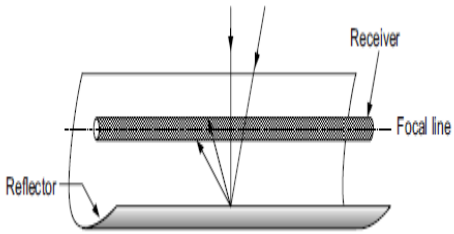


Compound parabolic concentrator

SOLAR COLLECTORS

Cylindrical Parabolic Concentrator

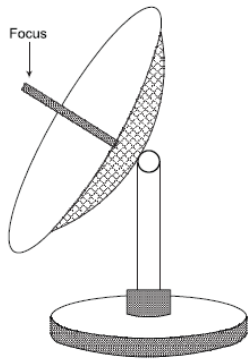
- It consists of a cylindrical parabolic trough reflector and a metal tube receiver at its focal line. The receiver tube is blackened at the outside surface to increase absorption.
- It is rotated about one axis to track the sun. The heat transfer fluid flows through the receiver tube, carrying the thermal energy to the next stage of the system.
- This type of collector may be oriented in any one of the three directions: East-West, North-South or polar.
- The concentration ratio in the range of 5–30 may be achieved from these collectors.



Cylindrical parabolic concentrator

SOLAR COLLECTORS

Paraboloidal Dish Collector (Scheffler Solar Concentrator)



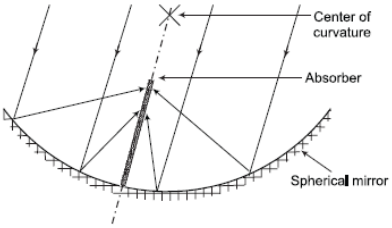
Paraboloidal dish collector (Scheffler solar concentrator)

- When a parabola is rotated about its optical axis a paraboloidal shape is produced.
- **Beam radiation** is focused at a point in the paraboloid. This requires two-axis tracking.
- It can have concentration ratio ranging from 10**°C** to few thousands and can yield temperature up to **3000 °C.**
- Paraboloidal dish collectors of **6-7m** in diameter are commercially manufactured.

SOLAR COLLECTORS

Hemispherical Bowl Mirror Concentrator

- It consists of hemispherical fixed mirror, a tracking absorber and supporting structure.
- All rays entering the hemisphere **after reflection cross the paraxial line at some point** between the focus and the mirror surface.
- Therefore, a linear absorber pivoted about the center of curvature of the hemisphere intercepts all reflected rays. **The absorber is to be moved so that its axis is always aligned with solar rays passing through the center of the sphere.**
- This requires **two-axis tracking**. The absorber is either driven around a polar axis at a constant angular speed of 15 degrees hour or adjusted periodically during the day. This type of concentrator gives lesser concentration, owing to spherical aberration, than that obtained in paraboloidal concentrator.

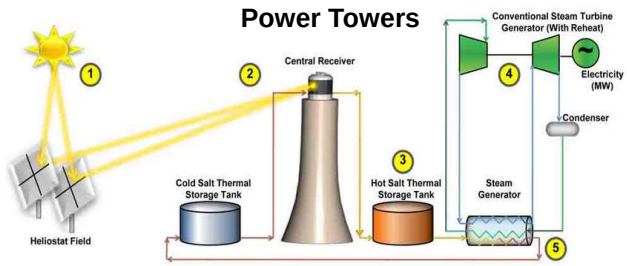


Hemispherical bowl mirror concentrator

1.4 Solar Electrical Energy Generation Technology

Solar Electrical Energy

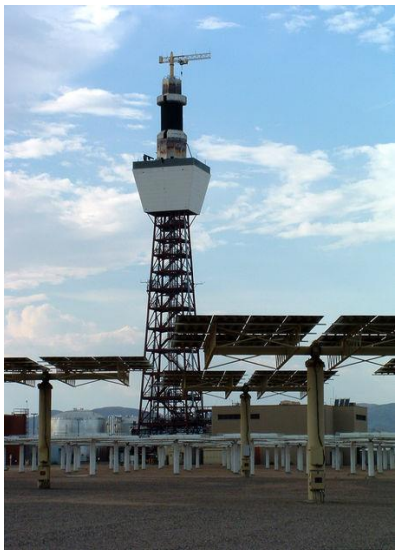
- ❑ Power Towers
- ❑ Parabolic Trough Collector
- ❑ Solar Photovoltaic Technology



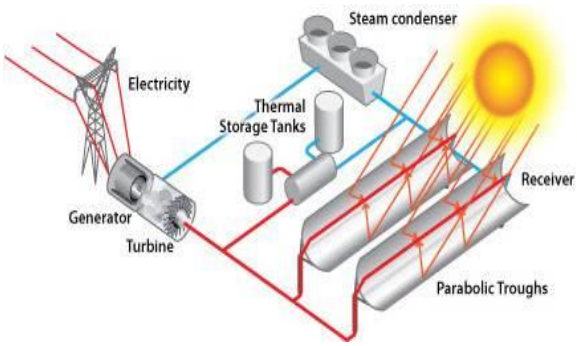
1. **Sunlight is concentrated** and directed from a large field of heliostats (mirrors) to a receiver on a tall tower.
2. Molten salt from the cold salt tank is pumped through the central receiver where it is **heated to 566°C).**
3. The heated salt from the receiver is stored in the **hot salt thermal storage tank**.
4. **Molten salt is pumped** from the hot salt tank through a steam generator that creates steam, which **drives a steam turbine, generating electricity**.
5. Cold salt at **288°C** flows back to the cold salt thermal storage tank and is re-used.

Solar Tower Technology

- **Power Tower (also known as 'central tower') use an array of flat, moveable mirrors (called Heliostats) to focus the sun's rays upon a collector tower (the receiver).**
- **A heat transfer medium (molten salt or saturated steam) is heated up to about 600 deg C.**
- **Molten salt is composed of a mixture of 60% sodium nitrate and 40% potassium nitrate for the desired temperature range.**
- **Operating Temperature – 565 Deg C**
- **Peak Efficiency - 23%**



Parabolic Trough Collector

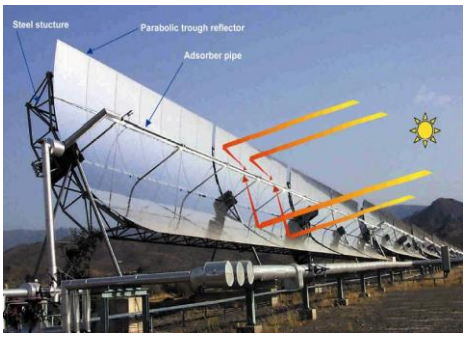


- Uses a series of specially designed parabolic curved, trough shaped reflectors that focus the sun's energy onto a receiver tube running at the focus of the reflector
- Because of parabolic shape, troughs can focus the sun at 30-60 times its normal intensity on the receiver pipe
- Heat transfer fluid (water) in the receiver is heated to a temperature of about 400°C.

- Large arrays of these collectors are coupled to provide high temperature water for driving a steam turbine. power stations can produce many MW of electricity, but are confined to areas where there is sufficient solar insolation.

Parabolic Trough Technology

- **Most established of CSP technologies**
- **Consists of rows of parabolic mirrors, aligned on a north-south horizontal axis**
- **As the liquid runs through a tube in the trough, it heats up.**
- **Common fluids are synthetic oil, molten salt and water-steam.**
- **Hot liquid is passed through a series of heat exchangers to generate steam**
- **Conventional turbine is used to generate power.**
- **Operating Temperature- around 380 deg C**
- **Peak Efficiency-20%**



Paraboloid Dish Technology

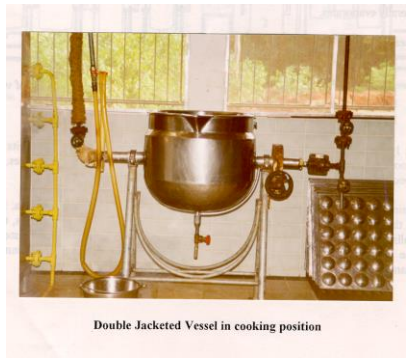
Key Technology Indices	
Max Temperature	**300 C (d)** **800 C (p)**
Overall Efficiency	**15% (d)** **21% (p)**
Maximum Thermal Storage [Hrs]	**3 Hrs (d)**
Status of Technology	•**High Temp-High Efficiency** •**Demo Plant**
d: Demonstrated p: Predicted	

HiTek's 14 m^2 dish prototype

Australian National Univ 400 m^2 dish

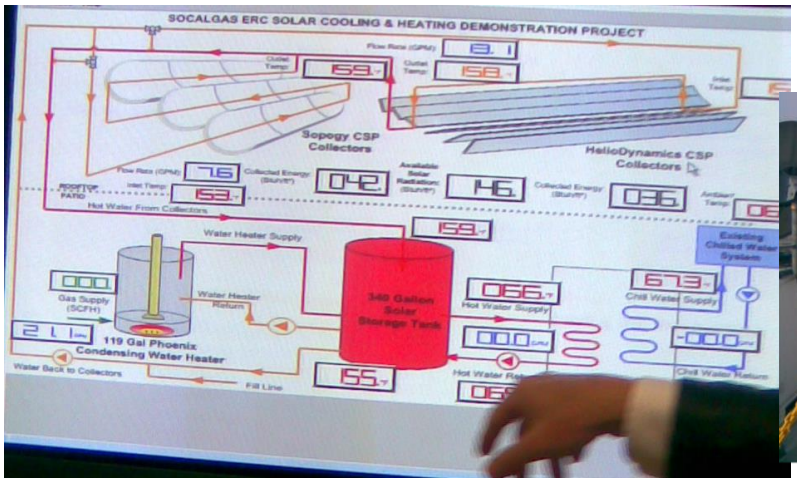
Bergermann Solar dish

Solar Bowl Concentrator for Steam Cooking at CSR, Auroville



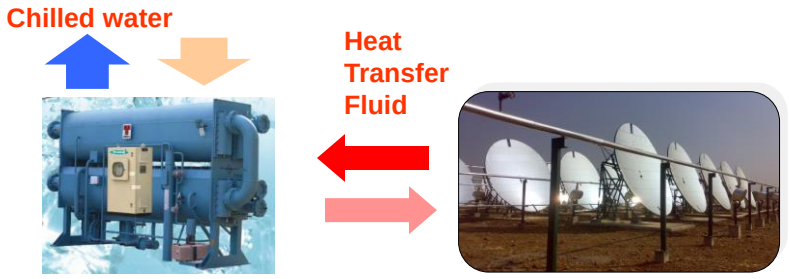
Double Jacketed Vessel in cooking position

Parabolic Dishes and Troughs



Solar Air condioning

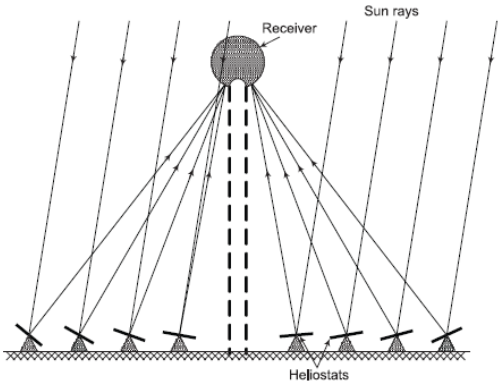
- Produce chilled water directly from solar THERMAL energy
- Solar cooling technologies use solar thermal energy collected through solar collectors to power thermally driven cooling machines.



SOLAR COLLECTORS

Central Tower Receiver

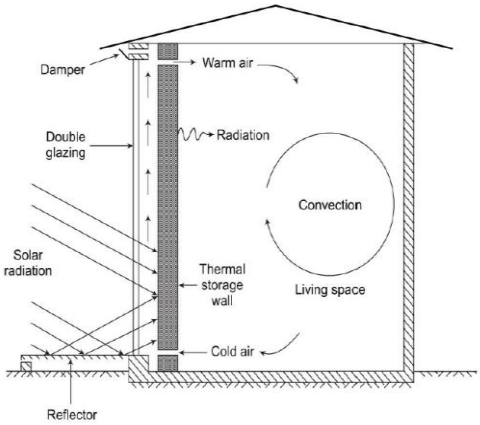
- In **central tower receiver collector**, the receiver is located **at the top of a tower**.
- **Beam radiation** is reflected on it from a large number of independently controlled; almost flat mirrors, known as **heliostats**, spread over a large area on the ground, **surrounding the tower**.
- Thousands of such heliostats track the sun to direct the beam radiation on the receiver from all sides.
- Concentration ratio of as high value as 3000 can be obtained.
- The absorbed energy can be extracted from the receiver and delivered at a temperature and pressure suitable for **driving turbines for power generation.**



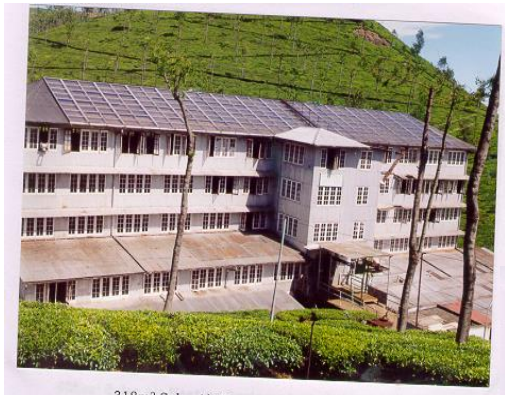
Central tower receiver

SOLAR PASSIVE SPACE HEATING AND COOLING SYSTEMS

- The **south facing thick wall,** called 'Trombe Wall'. In order to increase the absorption, the outer surface is painted black.
- The entire south wall is covered by one or two sheets of glass or plastic sheet with some **air gap** (usually 10–15 cm) between the wall and inner glazing.
- Solar radiation after penetration through the glazing is absorbed by the thermal storage wall. The air in the air gap between the glazing and the wall thus gets heated, rises up and enters the room through the upper vent while cool air from the room replaces it from the bottom vent.
- The circulation of air continues till the wall goes on heating the air.
- **Thus the thermal wall collects stores and transfers the heat to the room**.
- **Heating can be adjusted by controlling the airflow** through the inlet and outlet vents by shutters.
- Opening the damper at the top of the glazing allows the excess heat to escape outside, when heating is not required.



Solar space heating

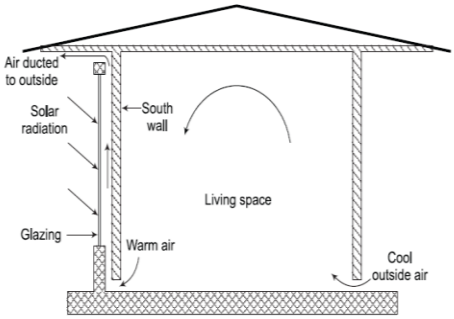


318m² Solar Air Heating Systems installed at Parkside Tea Factory– Coonoor, Tamilnadu

380 m² Solar Air Heating System Installed for tea drying at Glendale Tea Factory – Coonoor, Tamlnadu.

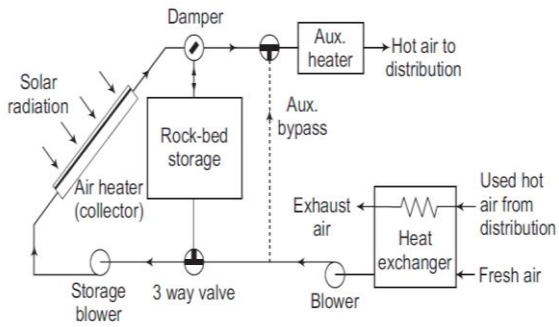
SOLAR PASSIVE SPACE HEATING AND COOLING SYSTEMS

- This **scheme utilizes solar 'chimney effect' a**nd is effective where outside temperatures are moderate.
- Solar radiation is allowed to heat up the air between the glazing and interior south wall.
- The heated air rises up and ducted outside and the warm air from the room is drawn into this space due to natural draught thus produced.
- As a result, cool outside air enters the room from the bottom air vent on the other side of the room.



Solar passive cooling through ventilation

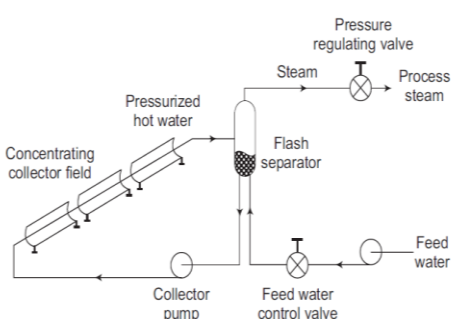
SOLAR INDUSTRIAL HEATING SYSTEMS



Hot air industrial process heat system

- Solar active heating systems are used for several industrial process **heat requirements**
- **Thermal energy is transported from collector through hot air and utilized for process heat**. The **excess heat is stored in rock bed thermal storage** to be used later when solar radiation is not available.
- Auxiliary heating augments the supply when the heat supplied by collector or storage is not sufficient.
- The used air is passed through a heat exchanger to recover the heat from the exhaust air to raise the initial temperature of fresh air entering the collector.

SOLAR INDUSTRIAL HEATING SYSTEMS

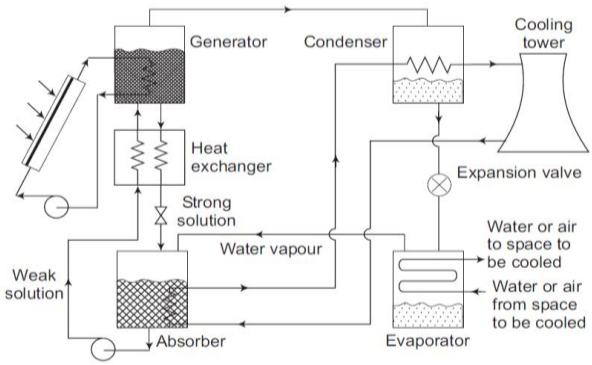


Solar process steam system

- Pressurized water is circulated through concentrating collector to prevent boiling. The high-pressure heated water is throttled and flash separated in a flash separator. To maintain the necessary liquid level in the flash tank, boiler feed water is injected into the pump suction.
- The **saturated steam obtained from the flash separator** is recirculated through the collector field and distributed for use. A pressure regulator valve regulates the pressure

SOLAR REFRIGERATION AND AIR CONDITIONING SYSTEMS

A solar energy operated Lithium Bromide-Water Absorption Cooling System



- A flat plate collector is used to supply heat to the generator and water vapours are raised at a temperature lower than 100 °C at low pressure.
- These vapours are condensed in condenser by cooling water supplied from cooling tower.
- The condensed water is evaporated by passing it through the expansion valve and maintaining lower pressure in the evaporator.
- Cooling effect is produced here and heat is absorbed from the space to be cooled through heat transport fluid.
- The water vapours from evaporator go to the absorber where they are absorbed in lithium bromide solution.

1.Solar Water Heaters

Collector : converts solar radiation into thermal energy

- **Hot water at 60-80C for hotels**
- **hospitals,**
- **dairies,**
- **swimming pools, industry**
- **domestic use etc.**

SOLAR COOKERS

- Thermal energy requirements for cooking purpose forms a major share of total energy consumed, especially in rural areas.
- Variety of fuels like **coal, kerosene, cooking gas, firewood, dung cakes and agricultural wastes are being used to meet the requirement.**
- Fossil fuel is a fast depleting resource and need to be conserved, firewood for cooking causes deforestation and cow dung, agricultural waste, etc., may be better used as a good fertilizer.

Harnessing solar energy for cooking purpose is an attractive and relevant option.

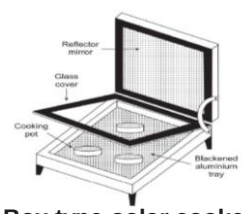
A variety of solar cookers have been developed, which can be clubbed in four types of basic designs:

(i) box type solar cooker,
(ii) dish type solar cooker,
(iii) community solar cooker, and
(iv) advance solar cooker.

SOLAR COOKERS

Box Type Solar Cooker

- This cooker is simple in construction and operation.
- An insulated box of blackened aluminum contains the utensils with food material.
- The box receives direct radiation and also reflected radiation from a reflector mirror fixed on inner side of the box cover hinged to one side of the box.
- The angle of reflector can be adjusted as required. A glass cover consisting of two layers of clear window glass



Box type solar cooker

Paraboloidal Dish Type (Direct Type) Solar Cooker

- The vessel directly receives the concentrated solar radiation. The reflector is periodically adjusted to track the sun.
- A fairly high temperature of about 450 °C can be obtained and a variety of food requiring boiling, baking and frying can be cooked for 10–15 persons.
- It can save on fuel up to 10 LPG cylinders annually on full use. Cooking time is approximately 20–30 minutes.

Paraboloidal dish type solar cooker

- **Community Solar Cooker-** Community solar cooker has been developed for indoor cooking. It has a large automatically tracked paraboloidal reflector standing outside the kitchen. The reflector reflects the sunrays into the kitchen through an opening in its north wall.
- It can cook all types of food for about **40–50 people and can save up to 30 LPG cylinders** in a year with optimum use.

BENEFITS:

- Approximate cost of 100 LPD solar water heating system is Rs.30,000/-.
- 100 LPD solar water heating system cater to 5 to 6 persons for bathing.
- Saves about 1,500 units of electricity per annum.
- Pay back period is 4 to 5 years.
- Life period is 15 years and above.

100 LPD SWHS prevents **1.5 tons of C O2 emission / annum**

Solar Water Heaters

Soft Loan Scheme

Participating Financial Institutions

IREDA
Canara Bank
Union Bank of India
Punjab & Sind Bank
Andhra Bank
Bank of Maharashtra
Syndicate Bank
Punjab National Bank

Himurja
Office Building, Shimla

A retrofitted building

- Air heating panels
- Double glazed windows
- Solar chimney
- Solarium on South for heat gain
- Integration of windows and light shelves for day lighting
- Solar water heating system
- Solar photovoltaic system

OBJECTIVE TYPE QUESTIONS

1. A solar thermal collector:
(a) collects the solar energy and reflects it back
(b) absorbs the solar radiation and dissipate it to the ambient
(c) collects and coverts the solar energy into electrical energy
(d) collects and coverts the solar energy into thermal energy and delivers it to heat transfer fluid,

2. The concentration type solar collectors:
(a) first absorb the radiation and then increase its concentration,
(b) increase the density of solar radiation before absorbing it
(c) dilute the density of solar radiation before absorbing it
(d) increase the intensity of solar radiation and then reflect it back

3. In evacuated tube collectors:
(a) both conductions as well as convection losses are suppressed,
(b) only conductions losses are suppressed
(c) only convections losses are suppressed
(d) only radiation losses are suppressed

4. Solar thermal water pump:
(a) uses solar thermal energy to evaporate water
(b) uses solar thermal energy to circulate hot water,
(c) uses electric powered pump to circulate water heated by solar energy
(d) uses solar thermal energy for production of power to drive the pump

5. A solar green house:
(a) uses solar energy to provide conducive conditions for growth of vegetation,
(b) provides enhanced radiation for photosynthesis process
(c) prevents fresh air to come into contact with plants
(d) uses solar thermal pump for irrigation

6. Solar constant is _____.
(a) 342 W/m2
(b) 1368 W/m2,
(c) 1342 W/m2
(d) 1380 W/m2

7. What is the Solar window period? _____.
(a) typically 6 AM - 6 PM
(b) typically 7 AM - 5 PM,
(c) typically 9 AM - 3 PM,
(d) typically 9 AM - 5 PM

REVIEW QUESTIONS

1. Define concentration ratio of a solar collector.
2. What are the main advantages of flat plate solar collector?
3. Discuss the principle of a solar collector. How collector coating can be used to improve the performance of a collector?
4. explain the working of solar water heating.
5. What is a greenhouse
6. Why evacuated tube collector is more efficient than flat plate collector?

Q & A

Thank You

Save energy and water for Sustainable Life

Dr.P.Dharmalingam
Accredited Energy Auditor
Director, EnSave Academy
Former Director,NPC

https:// ensaveindia.in
https://training.ensaveindia.in
https://ecourse.ensaveindia.in

Energy and Environment Science

Unit – 2 : Solar Energy

- ✓ Basics of Solar Energy
- ✓ Solar Thermal Energy
- ✓ Solar Photovoltaic Power:
- ✓ Advantages and Disadvantages,
- ✓ Environmental impacts and safety

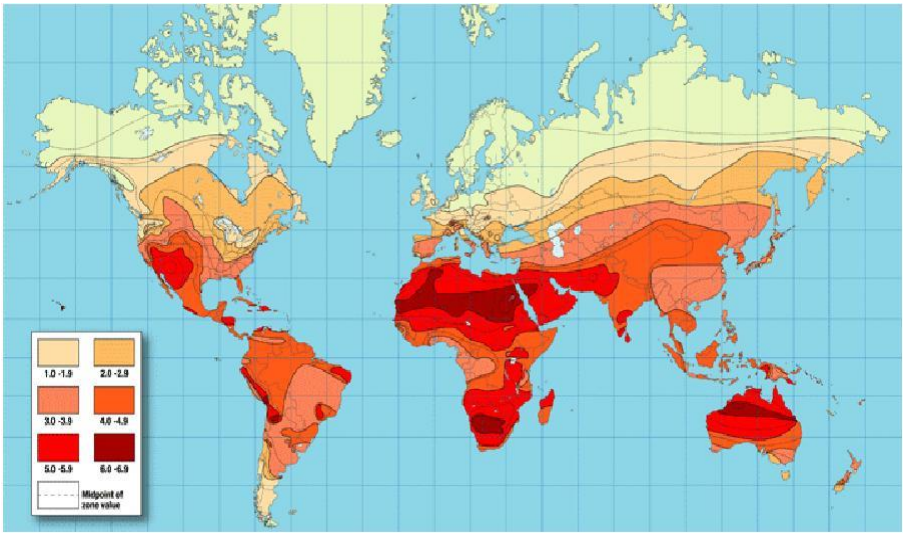
Learning Objectives

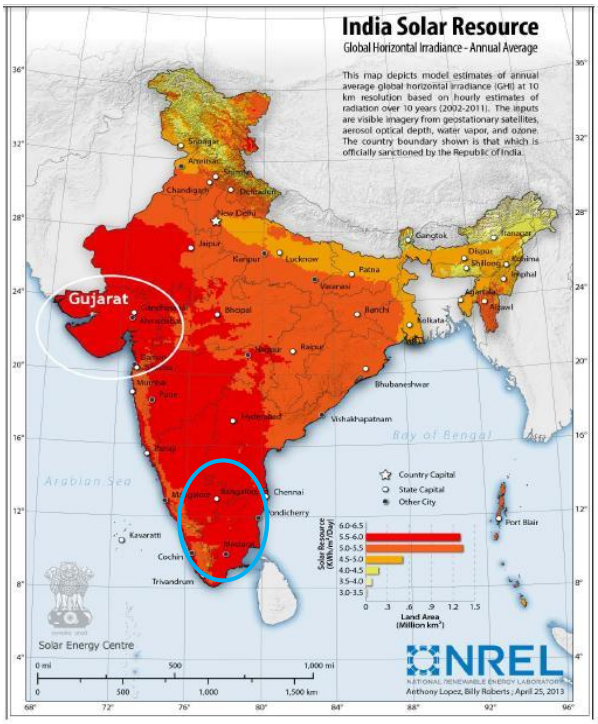
- **Basic principle involved in the operation of solar cell**
- **Environmental effects on electrical characteristics of solar cell**
- **Components of solar PV systems**
- **Design of typical solar PV systems**
- **Various applications of solar PV energy**

Major Advantages

1. It converts solar energy directly into electrical energy without going through thermal-mechanical link.
2. It has no moving parts.
3. Solar PV systems are reliable, modular, durable and generally maintenance free.
4. These systems are quiet, compatible with almost all environments, respond instantaneously to solar radiation and have an expected life span of 20 years or more.
5. It can be located at the place of use and hence no or minimum distribution network is required, as it is universally available.

Global Solar Insolation

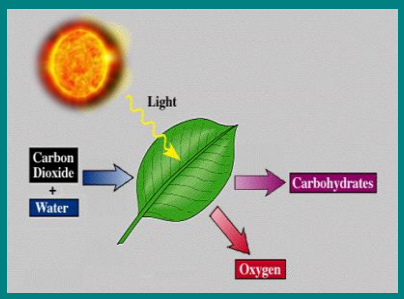




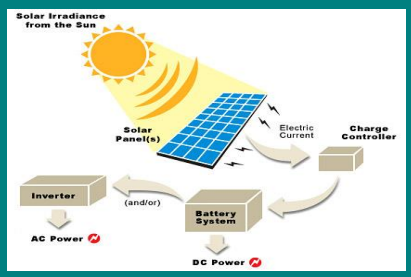
India is endowed with huge solar energy potential with most states having about 300 sunny days per year with annual solar radiation in the range of 4.5-6.5 kWhr/sq.m/day

SOLAR PV SYSTEM: FUNDAMENTAL

When photon falls on plants their energy is combination with O_2 is converted to chemical energy of plants (Photosynthesis process).



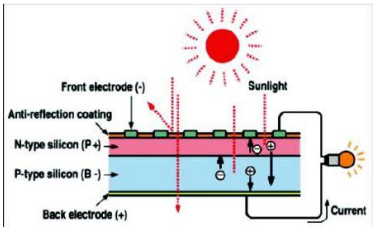
When photon falls on solar cells, their energy is converted into electrical energy.



Solar PV Power

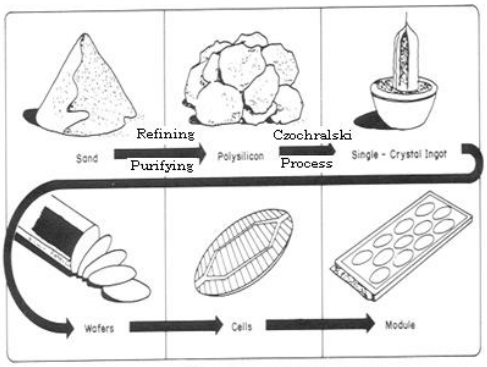
Solar Cells Background

- 1839 - French physicist A. E. Becquerel first invented the photovoltaic effect.
- **Photo+voltaic = convert light to electricity**
- 1883 - first solar cell built, by Charles Fritts, coated semiconductor selenium with an extremely thin layer of gold to form the junctions.
- **1954** - Bell Laboratories, experimenting with semiconductors, accidentally found that silicon doped with certain impurities was very sensitive to light.
- Resulted in the production of the first practical solar cells with a **sunlight energy conversion efficiency of around 6%.**
- 1958 - First spacecraft to use solar panels was US satellite



Solar Photovoltaic Effect

Solar Cell Manufacturing



Solar-cell-manufacturing process.

Semiconductors – Silicon Cells

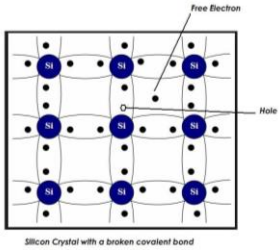
Process of Manufacture:
Sand – Poly Silicon – Single Crystal – Wafers – Cells – Modules

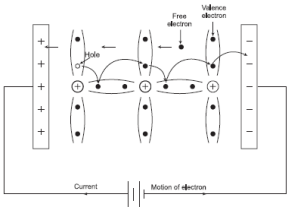
Wafer Based – Mono Crystalline, Poly Crystalline Cells
Thin Film Technology – Poly Silicon Sheets, Compound Semiconductors

SOLAR CELL FUNDAMENTALS

Electric Current Conduction in Semiconductors

- A silicon crystal is intrinsic if every atom in the crystal is a silicon atom. There are equal number of free electrons and holes in an intrinsic semiconductor.
- When a **potential is applied across such a crystal, free electron moves away from negatively charged plate until it reaches positively charged plate** and completes the path through external circuit.
- A hole near positively charged plate attracts a valence electron on the other side.
- This causes the valence electron to move into the hole creating new hole at this new location.
- The process continues and the **valence electron moves across the crystal from negative to positive plate** or the hole moves in a direction opposite to this.
- Thus free electrons and holes continuously move in opposite directions inside a semiconductor and **constitute electrical current.**



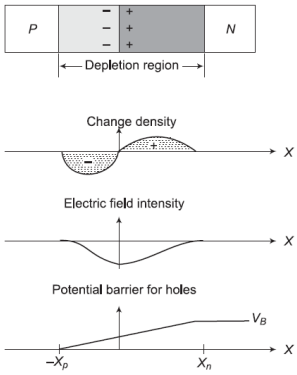


Free electron, hole flow through a semiconductor

SOLAR CELL FUNDAMENTALS

A PN Junction

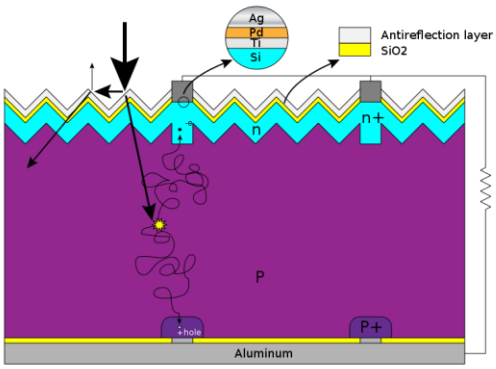
- A PN junction, where the **material changes suddenly from P to N is known as abrupt PN junction**.
- When a junction between a P-and N-type materials is formed, the carriers (free electrons and holes) diffuse from higher concentration side to lower concentration side.
- Soon after crossing the junction, these carriers recombine with the other types of carriers found in majority on the other side.
- We see that the holes, which neutralized the acceptor ions near the junction in the P-type side, disappeared as a result of recombination with free electrons, which have diffused from across the junction.
- Similarly, free electrons near the junction in the N-type side have recombined with holes, which have crossed the junction from P side.



Charge density, electric field intensity and potential barrier in a PN junction

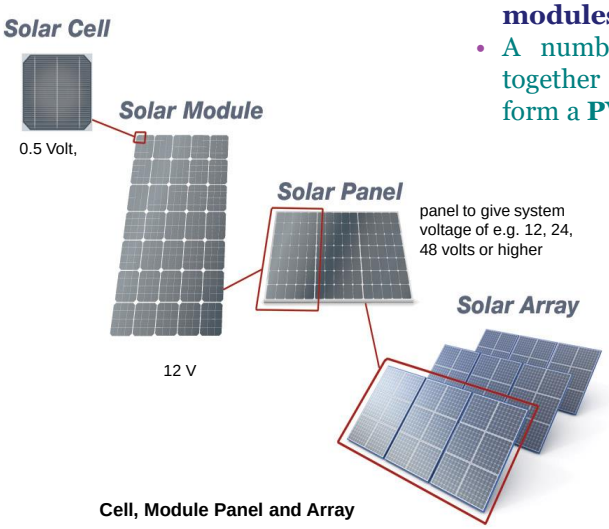
How Solar Cells Work

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
2. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity.
3. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

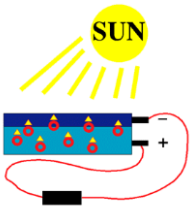


COMPONENTS OF SOLAR PV SYSTEM

- The individual units that you place in the sun to produce electricity from the sun are called **PV modules.**
- A number of modules connected together in different configurations form a **PV array.**



Cell, Module Panel and Array



Crystalline Silicon – 1.12 eV
Amorphous Silicon – 1.72eV

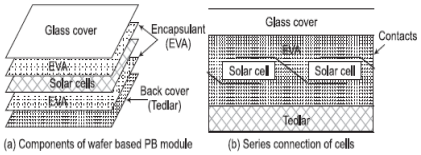
SOLAR CELL, MODULE, AND ARRAY CONSTRUCTION

Solar PV Module

- A bare single cell cannot be used for outdoor energy generation by itself.
- It is because
  (i) the output of a single cell is very small and
  (ii) it requires protection (encapsulation) against dust, moisture, mechanical shocks and outdoor harsh conditions.

- **Workable voltage and reasonable power is obtained by interconnecting an appropriate number of cells**.

- The electrically connected cells are encapsulated, typically by using two sheets of **ethylene vinyl acetate (EVA) at either side. EVA is a good electrical insulator**, transparent material and has very low water absorption.

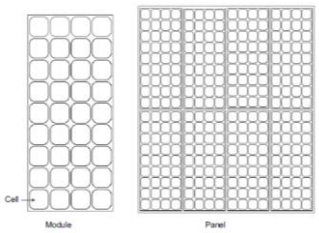


(a) Components of wafer based PB module (b) Series connection of cells

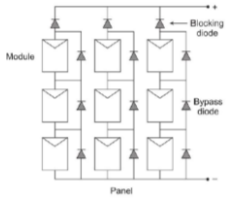
PV module details

Solar PV Panel

- Several solar modules are **connected in series/parallel to increase the voltage/current ratings.**
- When modules are connected in **series**, it is desirable to have each module's maximum power production occur **at the same current**.
- When modules are connected in **parallel**, it is desirable to have each module's maximum power production occur **at the same voltage**.
- Solar panel is a group of several modules connected in series-parallel combination in a frame that can be mounted on a structure. Fig.shows the construction of module and panel.



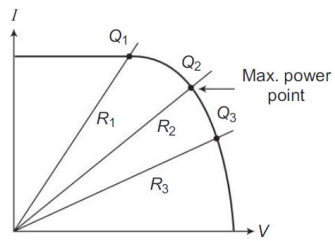
Cell, module and panel



A typical panel: Series-parallel connection of modules

MAXIMISING THE SOLAR PV OUTPUT AND LOAD MATCHING

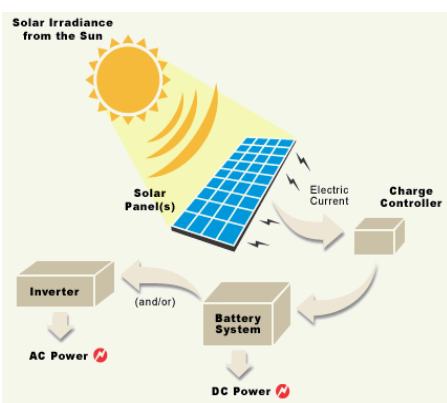
- To make best use of solar PV system, the output is maximized in two ways.
- The first is **mechanically tracking the sun and always orienting the panel in such a direction as to receive maximum solar radiation under changing positions of the sun**. That means adjusting the panel such that the sun rays always fall normal to its surface.
- The second is electrically tracking the operating point by manipulating the load to maximize the power output under changing conditions of insolation and temperature.



Load matching with resistive load

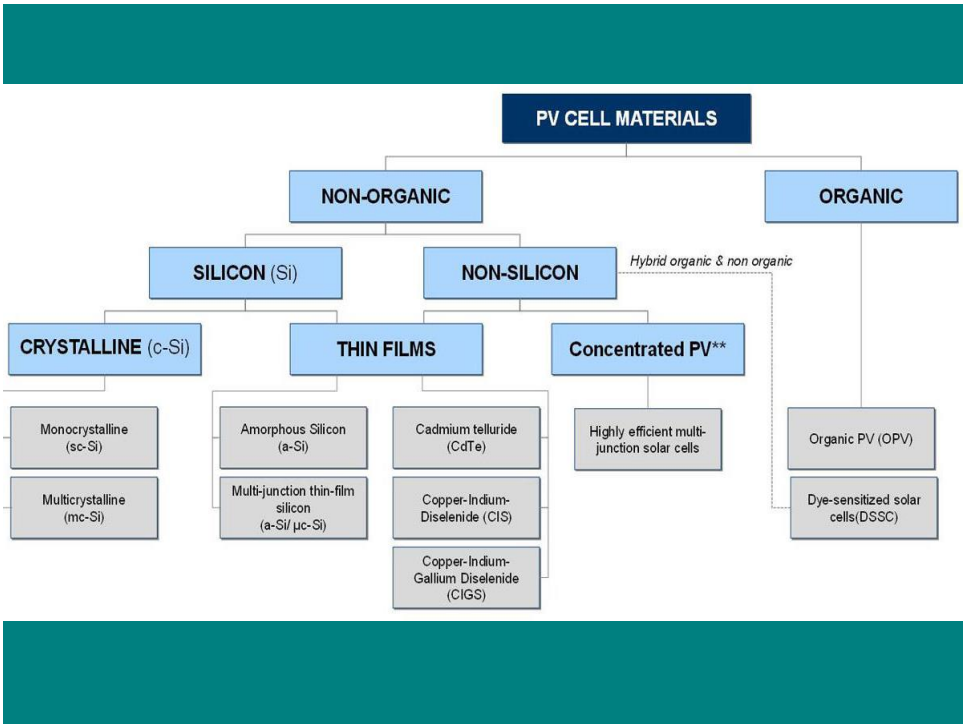
Solar Photovoltaic Technology

PV System



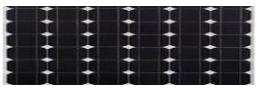
- A Photovoltaic (PV) module comprise of PV panels (known as **solar panels**), battery system, charge controller, inverter.
- PV panels comprise of PV cells

- PV module can be maOne silicon **cell** produces 0.5 Volts. 36 such cells connected together are called a **PV module** and it has enough voltage to charge 12 V battery and run pump and motor.
- Manufactured with capacity ranging from **5 Wp to 120 Wp. (250/300Wp)**



Difference Between Monocrystalline, Polycrystalline and Thin film Module

Mono-Si Panels	Poly-Si Panels	Thin Film Panels
1. Most efficient with max. efficiency of 21%.	1. Less efficient with efficiency of 16% (max.)	1. Least efficient with max. efficiency of 12%.
2. Manufactured from single Si crystal.	2. Manufactured by fusing different crystals of Si.	2. Manufactured by depositing 1 or more layers of PV material on substrate.
3. Performance best at standard temperature.	3. Performance best at moderately high temperature.	3. Performance best at high temperatures.
4. Requires least area for a given power.	4. Requires less area for a given power.	4. Requires large area for a given power.
5. Large amount of Si hence, high embodied energy.	5. Large amount of Si hence, high Embodied energy.	4. Low amount of Si used hence, low embodied energy.
6. Performance degrades in low-sunlight conditions.	6. Performance degrades in low-sunlight conditions.	5. Performance less affected by low-sunlight conditions.



20

Classification

Solar Photovoltaic Technology

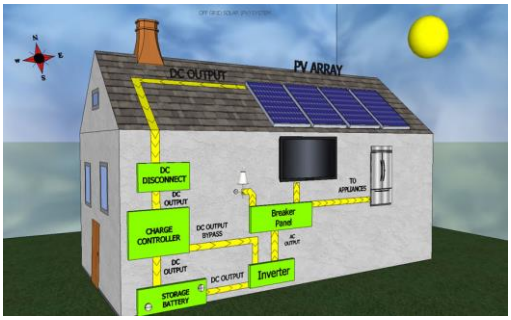
Solar Photovoltaic Technology

Classification

There are two types of PV system, namely:

a) Off-grid (Stand-alone) system

b) Grid-tied system



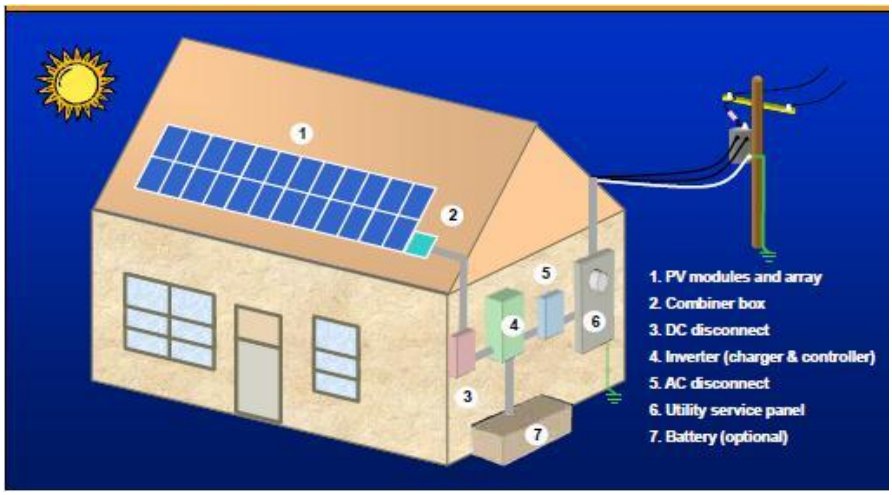
Stand-alone System (AC-Off Grid)

Stand-alone SPV Power Plant*:* In an SPV power plant, electricity is generated and made available to users through a local grid in a 'stand-alone mode.

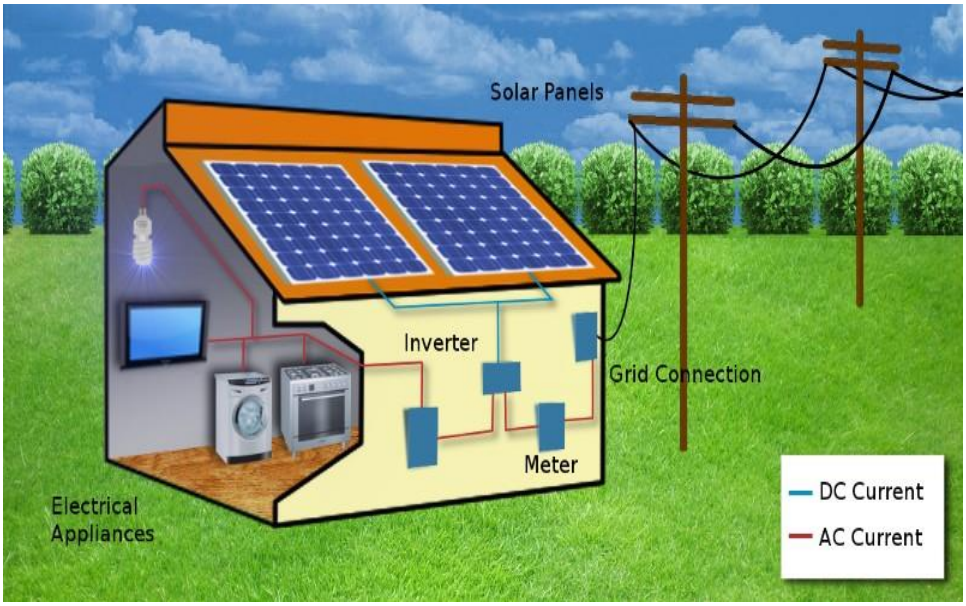
- Used for electrification of remote villages, power for **hospitals, hotels, communication equipment, railway stations, border outposts** etc

Solar Photovoltaic Power Systems

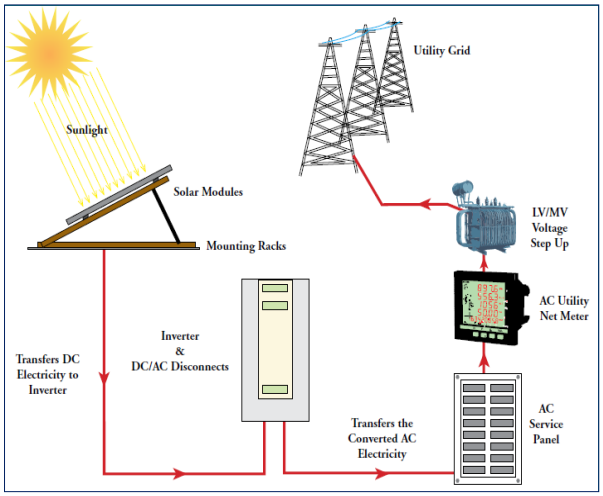
PV System Components



Type of Solar PV Systems – Grid Connected

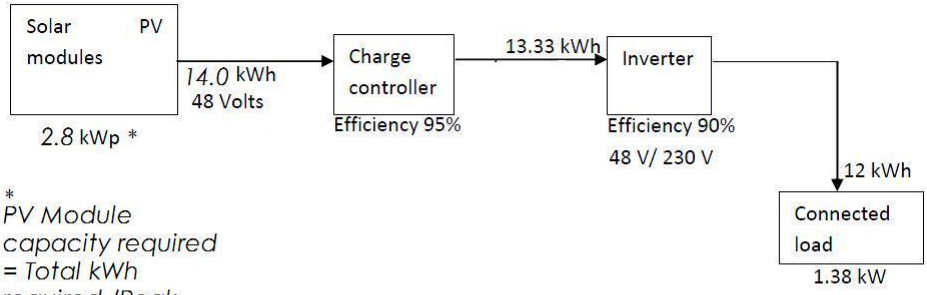


SOLAR PV TECHNOLOGY

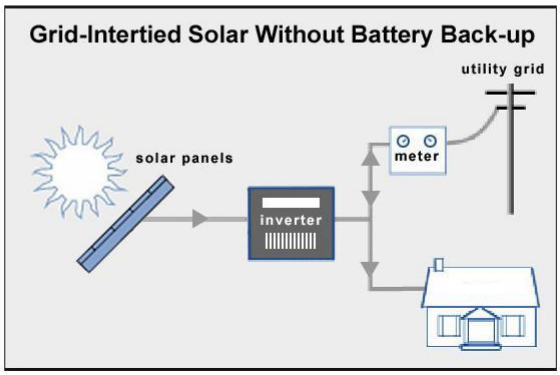


Grid connected Solar System: used as an inverter that synchronizes with the utility power. These systems **do not generally require batteries,** although batteries can be used to provide backup power if the utility power goes out.

Overall System Design



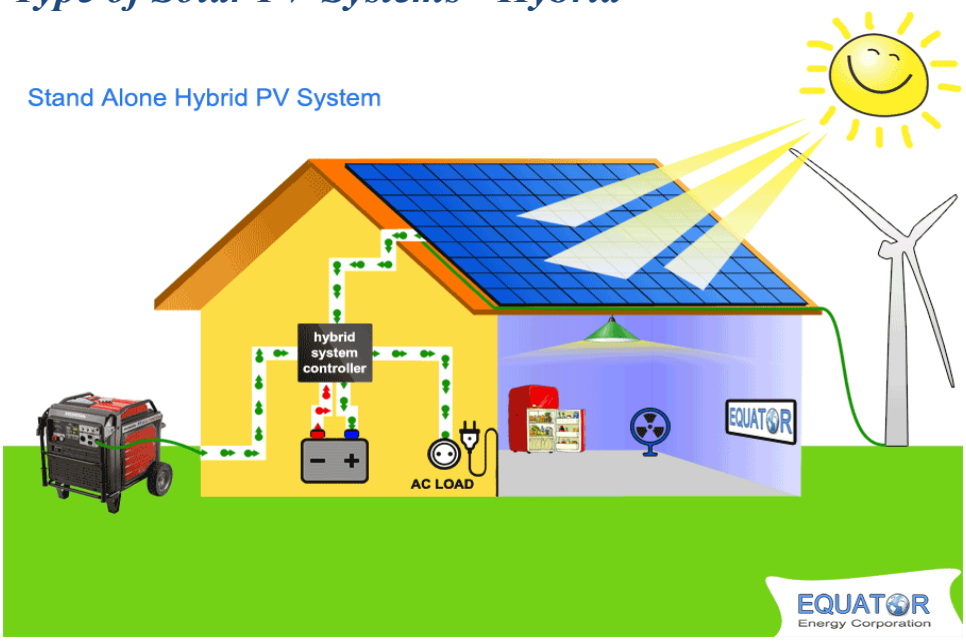
*
PV Module capacity required = Total kWh required /Peak sunshine hrs
= 14/5 = 2.8 kWp



➢Advantages of grid connected system

- Reduce the power bill as it is possible to sell surplus electricity produced to the local electricity supplier.
- Easier to install as they do not require a battery system.
- Effective utilization of generated power because there are no storage losses involved.
- A photovoltaic power system is carbon negative over its lifespan, as any energy produced over and above that to build the panel initially offsets the need for burning fossil fuels.
- Even though the sun doesn't always shine, any installation gives a reasonably predictable average reduction in carbon consumption.

Type of Solar PV Systems - Hybrid



Off-grid or grid-tied PV?

Parameters	Off-grid	Grid-tied
Grid connection	Operates independent of the utility power grid	Connected to the utility power grid
Suitability	Suitable when utility power is not easily accessible or cannot be installed	Used when selling power to utility or the system smaller than the minimum power load.
Storage required	Yes	No
Cost	Costlier– due to battery bank	Less expensive
Installation	Easy to commission	Complex – restricted by the utility grid
Monitoring	Important, but not critical	Requires grid related monitoring, feedback and safety features

How much of Solar Energy is converted into Electrical Energy in Photovoltaic Cells?

Numerical problem

The energy conversion efficiency is a measure of how much of the solar energy is converted into electrical energy. The calculation for the energy conversion factor is,

$\eta = (Pm / (E * A)) * 100$

Where,

η = Energy conversion factor, percent.

Pm = Maximum power output, watts.

E = Solar energy, insolation, watts per square meter.

A = Area of the solar cell, square meters.

Example:

For example, what is the energy conversion efficiency of a 175-watt solar panel that measures 0.75 x 1.50 meters, if the solar insolation is 1,000 W/m^2?

Ans

Since the area of the solar cell is 0.75 * 1.50 = 1.125 m^2, the efficiency is,

$\eta = (175 / (1.125 * 1{,}000)) * 100$

$\eta = 15.6\%$.

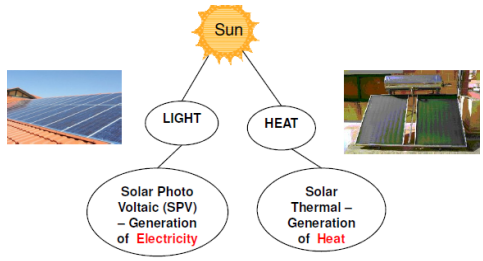
This particular unit converts **15.6% of** the available solar energy into electrical energy.

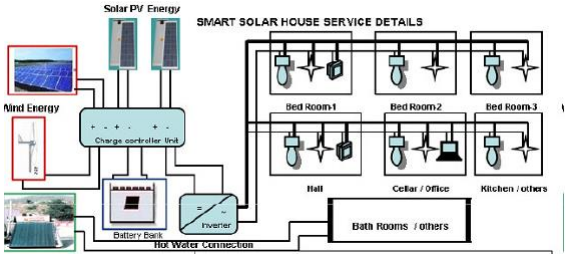
Solar PV System Design considerations

- Energy required = **Load x No. of Hrs** (say Load 2.5 Kw and 4 Hrs) = 2.5 x 4 = 10Kwh
- Battery Energy = Kwh/Inv.Eff = 10/0.9 = 11Kwh
- Battery Voltage Assumed 48V
- Battery Storage (say for 2 days) = 11000 x 2/48v
- With DoD factor of 80%, AH = 460/0.8= 515AH
- Battery Spc. 48V, 600AH (Battery 24 x 2V)
- Inverter Rating = Max. Load = 2.5Kw

PV APPLICATION

Solar and Smart Homes





SM - RE Solar Energy

33

Electrical Power (PV)

- Solar Lamp
- Home Lighting System
- Garden Lighting System
- Street/Yard/Forest Lighting
- Solar Signalling (Rail / Roadways)
- Remote Village Electrification
- Solar Pumps
- Solar Mini Refrigerator

Solar Signalling

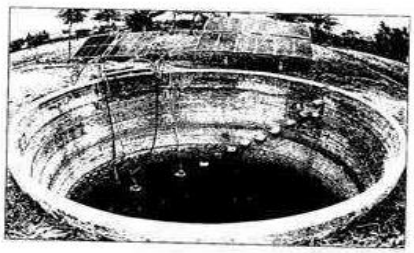
Street Light

Home Lighting System

Solar Pumps

Garden Lighting System

Innovative Solar Cooler

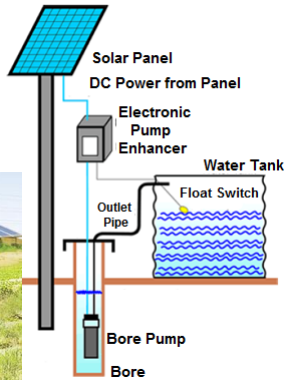


Solar PV Power and Irrigation

Solar Panel and Sub. Pump

SPV water pumping system

Capacity of motor pump set is from 0.5 HP to 2 HP
Deliver a 65,000 liters per day with a 900 watts panel
watts panel from a depth of 7 meters on a clear sunny day
deep well submersible pumps, the water output will be 45000 liters from a 1200 watts panel.



Solar Photovoltaic Power Systems

- Charge Controllers
- Limits the voltage and or current delivered to a battery from a charging source to regulate state-of-charge (prevent damage to batteries or hazardous conditions resulting from overcharging)
- Overdischarge protection for the battery by disconnecting dc loads at low state-of-charge.
- Controls load
- Provides monitoring and indicators of battery voltage and other system parameters

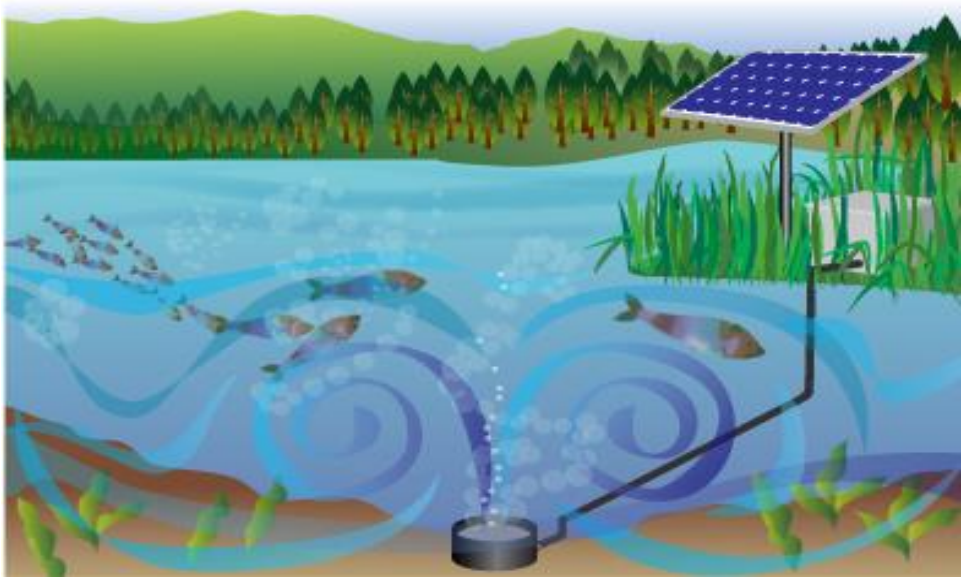
Building-integrated PV Systems: PV panels are integrated into the roof or façade of a building as shown in Figure 11.10. BIPV provides photovoltaic power as well as weather proofing and glazing of buildings

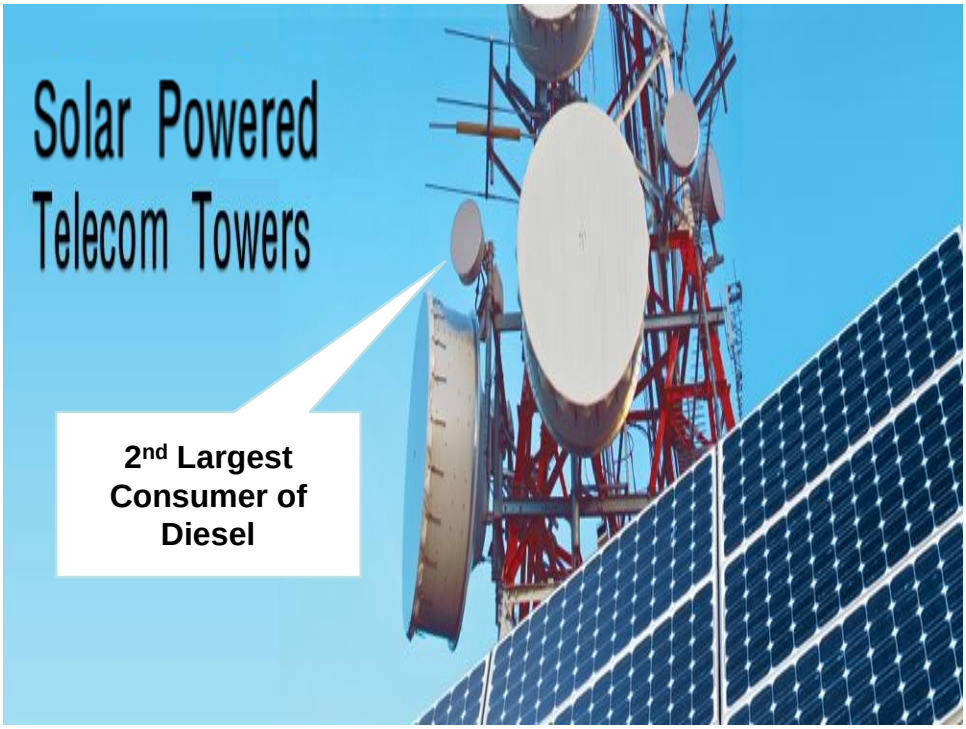
.Since PV cells are integrated into the buildings, no separate costly mountings are required

BIPV

Solar Street Lights

Solar Aerator





Solar Micro / Mini Grid

Solar Desalination Plant

Solar Car Charging Station

Solar Boats

Solar Fountain

Solar Greenhouse

Case Study

SOLAR PHOTO VOLTAIC STAND ALONE

ENERGY EFFICIENT STREET LIGHTING

Institute street lighting is 100% powered by solar power

SOLAR PHOTO VOLTAIC GRID connected

NPC CASE STUDY

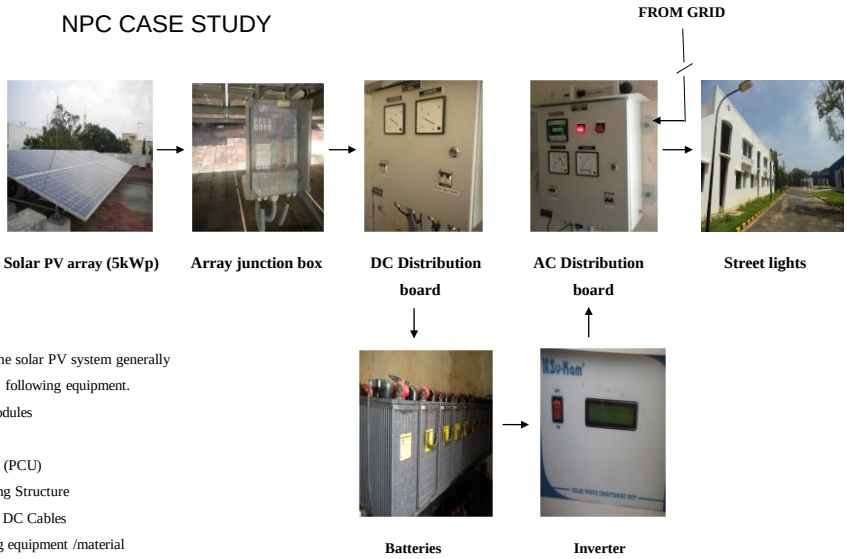


Plate 2.3. Components of the Standalone Photovoltaic System installed at NPC

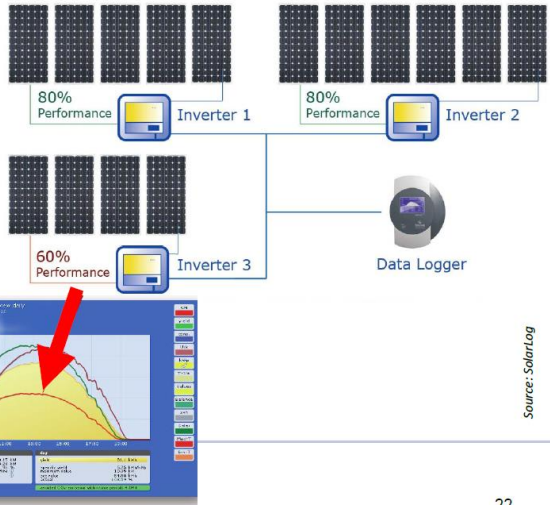
The stand alone solar PV system generally comprises the following equipment.

- SPV modules
- Battery
- Inverter (PCU)
- Mounting Structure
- AC and DC Cables
- Earthing equipment /material
- Junction Boxes or combiners
- Instruments and protection equipments

PV Performance Monitoring

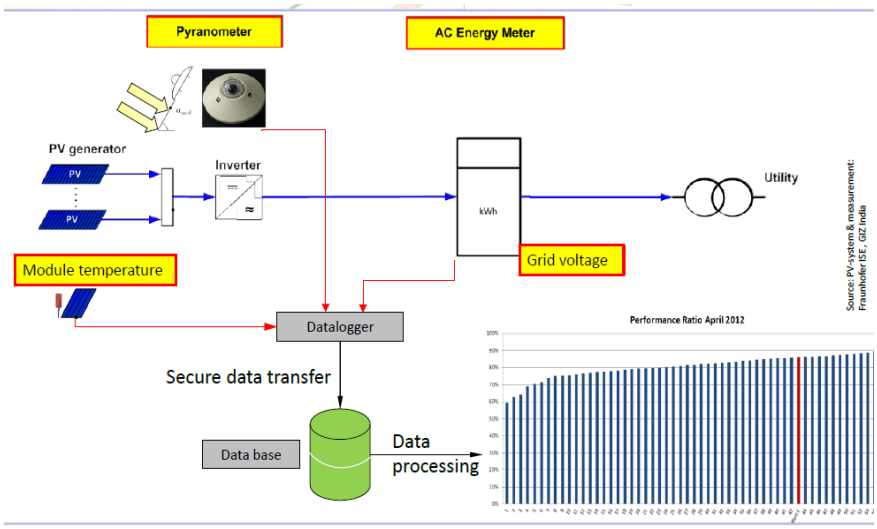
PV Performance Monitoring

Many malfunctions can be detected with detailed plant monitoring units used by skilled operators .



Source: SolarLog

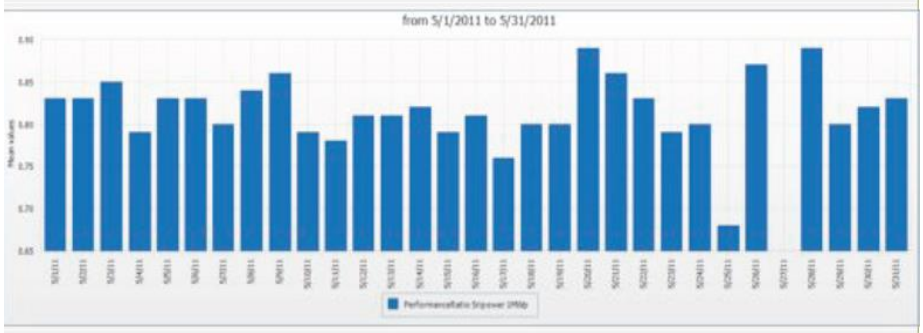
PV Performance Monitoring



Source: PV-system & measurement: Fraunhofer ISE, GIZ India

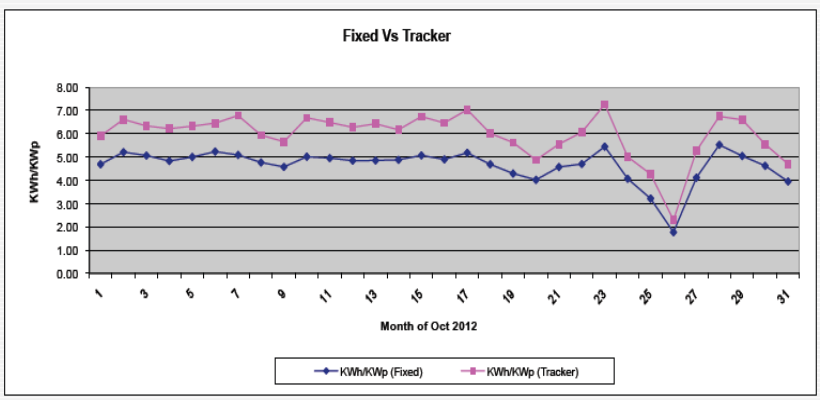
Performance Evaluation

$$\text{Performance Ratio} = \frac{\text{Actual Reading of Plant Output in KWh}}{\text{Calculated, Nominal Plant Output in KWh}}$$



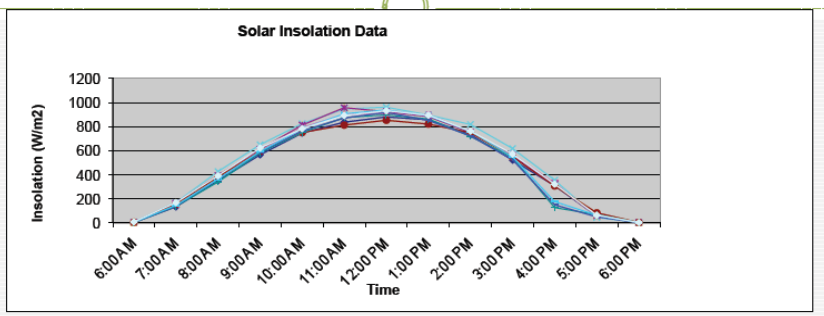
Average Performance Ratio = 82.6%

Tracking Vs Fixed Performance



Single Axis Tracking: On Average is 23% better than Fixed Tracking

PV Central Inverters



- Loads on the Inverters are not the same through-out the day, as the solar insolation is not constant.
- Inverter Efficiency is not flat for all loads from 0-100%
- At lesser input loads, the efficiency is less than the peak efficiency.

MCQ

1. Plants convert solar energy into _____ energy

(a) Chemical energy,
(b) Light energy
(c) Heat energy
(d) None of the above

2. Which of the following statement is not true about solar cell?

(a) It has no moving part
(b) It is reliable and almost maintenance free
(c) It is modular in design
(d) It is cheap and efficient,

3. The charge carrier available in a semiconductor material:

(a) free electrons and holes,
(b) only electrons
(c) only holes
(d) Positively charged ions

4. If no load is connected to solar PV system:

(a) it will stop absorbing light,
(b) it will dissipate energy in the panel and increase its temperature
(c) its voltage will go on increasing till its breakdown
(d) it will start reflecting the light

5. At a temperature of 0 K, silicon behaves as a (an):

(a) superconductor,
(b) normal conductor
(c) insulator
(d) semiconductor

6. The energy associated with a photon is:
(a) directly proportional to wavelength
(b) inversely proportional to frequency
(c) directly proportional to intensity of radiation
(d) inversely proportional to wavelength,

7. The single solar cell voltage is about _____
(a) 0.2 V
(b) 0.5 V ,
(c) 1.0 V
(d) 2.0 V

8. The solar energy directly used for _____
(a) Drying
(b) Water heating
(c) Distillation
(d) **All of the above,**

9. The efficiency of a solar cell may be in the range_____
(a) 2 to 7%
(b) 10 to 20%,
(c) 30 to 40%
(d) 50 to 60%

10. A module in a solar panel refers to_____.
(a) series arrangement of solar cells
(b) parallel arrangement of solar cells
(c) **series and parallel arrangement of solar cells,**
(d) None of the above

Thank You

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