Energy and Environment Science

Unit – 3 : Wind Energy Syllabus:

i. Power and energy from wind turbines
ii. Wind energy theory and Fundamentals
iii. Types of wind turbines
iv. Offshore Wind energy
v. India’s wind energy potential
vi. Environmental benefits and impacts.

Class 3

- ✓Wind power Potential in India
- ✓Applications,
- ✓Advantages, disadvantages,
- ✓Cost Economics
- ✓ENVIRONMENTAL ASPECTS

Wind power Potential in India

- The country's wind power potential at 100 m above ground level is 302 GW.
- The Indian wind industry is on track to achieve the government's 60 GW wind capacity target ahead of the 2022 deadline as it has already crossed 34 GW.

Wind energy sector **contributes to the country** by

- generating employment,
- reducing the adverse effects of greenhouse gases
- and increasing the size of gross domestic product.

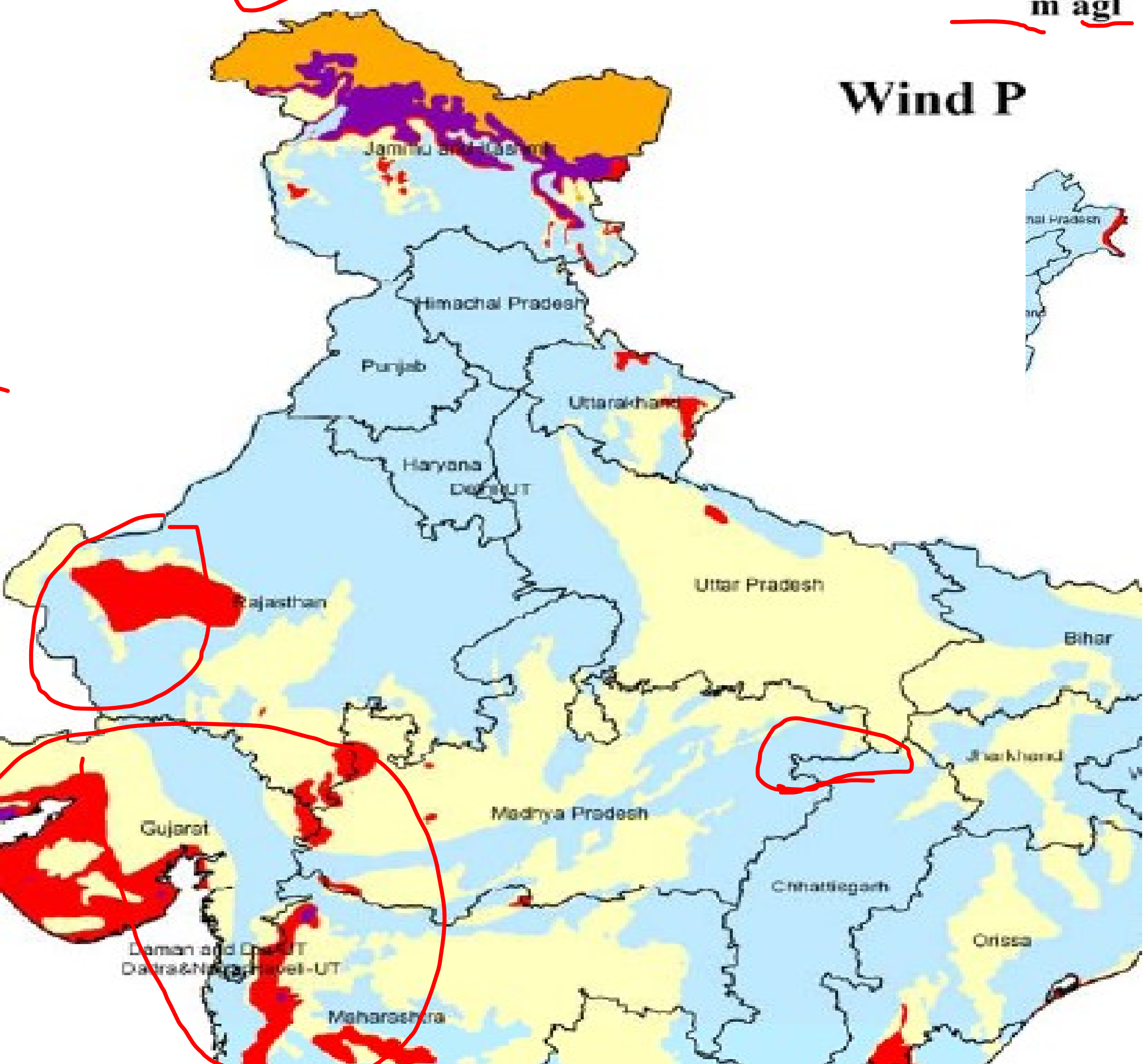
- Wind power generation capacity in India has **significantly increased in recent years**.
- As of 28 February 2021, the total installed wind pow capacity was 38.789 GW, the **fourth largest installed wind power capacity in the world**
- Wind power costs in India are decreasing rapidly.
- The levelised tariff of wind power reached a record lo of ₹2.40 per kWh (without any direct or indirect subsidies)

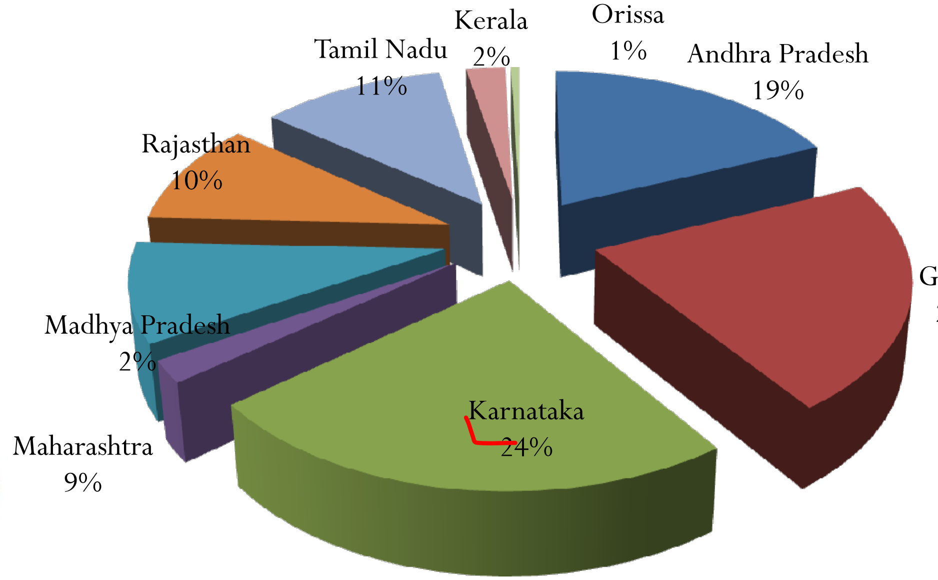
Power Potential

100

m agl

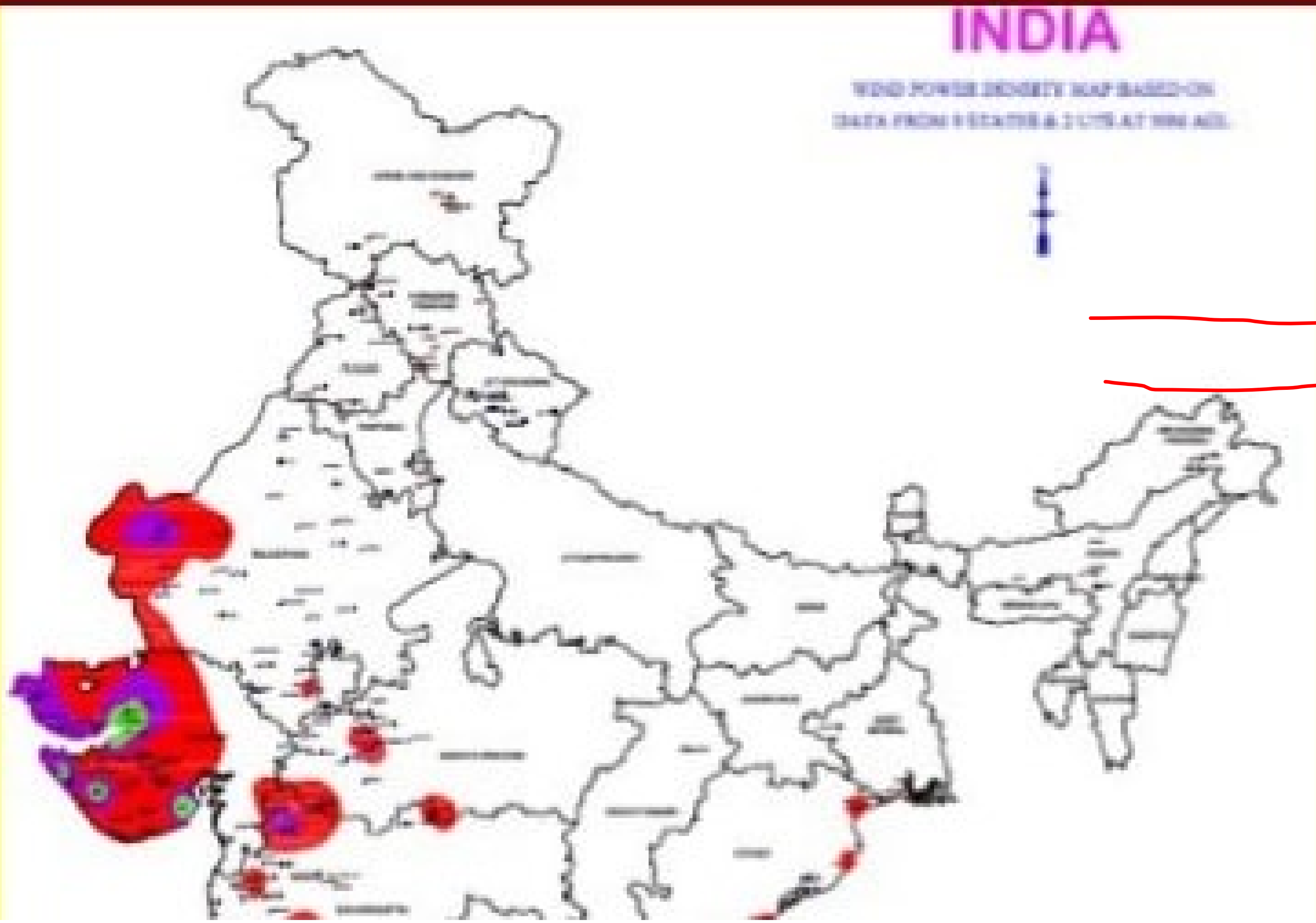
Wind P





State Wise -Wind potential in India		
Sl.No.	Sources	Potential i
1	Andhra Pradesh	8968
2	Gujarat	10645
3	Karnataka	11531
4	Madhya Pradesh	1019
5	Maharashtra	4584
6	Rajasthan	4858
7	Tamil Nadu	5530
8	Kerala	1171
9	Orissa	255
Total		48561

Wind Power Poter



The
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5 M

nstalled wind capacity by state as of 31 October 2019]

State	Total Capacity (MW)
Tamil Nadu	9231.77
Gujarat	7203.77
Maharashtra	4794.13
Karnataka	4753.40
Rajasthan	4299.73
Andhra Pradesh	4077.37[28]
Madhya Pradesh	2519.89
Telangana	128.10
Kerala	62.50
Others	4.30
Total	**37090.03**

Installed Wind Power Capacity	
Fiscal	Year End Cumulative Capacity (in MW)
2005	6,270
2006	7,850
2007	9,587
2008	10,925
2009	13,064
2010	16,084
2011	18,421
2012	20,149
2013	21,264
2014	23,354
2015	26,769
2016	32,280
2017	34,046
2018	35,626
2019	37,669
2020	38,785

nil Nadu

nil Nadu's wind power capacity is around **29% of India's total**

Government of Tamil Nadu realized the importance and need

renewable energy, and set up a separate Agency, as registered

ety, called the Tamil Nadu Energy Development Agency (TEDA

early as 1985. Tamil Nadu is a leader in Wind Power in India.

Muppandal **windfarm the total capacity is 1500 MW**, the large

d power plant in India.

total wind installed capacity in Tamil Nadu is 7633 MW

harashtra is one of the prominent states that installed wind po
ects second to Tamil Nadu in India.

he major manufacturers of wind turbines including ReNew
ver, Suzlon, Vestas, Gamesa, Regen, Leitner Shriram have prese
laharashtra.

arat

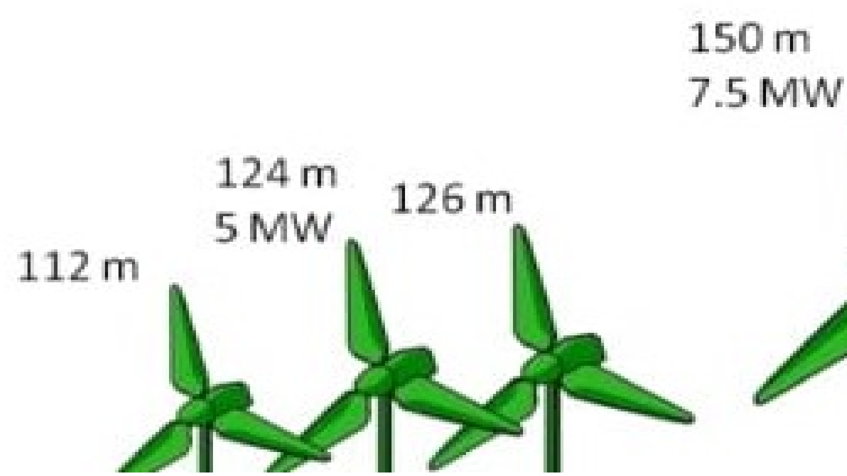
arat government's focus on tapping renewable energy has led
rp rise in the wind power capacity in the last few years. Accord
fficial data, wind power generation capacity in the state has
eased a staggering ten times in the last six years.

arat has 16% of total capacity of country.

TIMELINE OF SIZE AND CA
OF WIND TURBINES

The power transferred to generator (P) is directly proportional to the rotor surface area (A)!

$$P \propto A$$



Future of Wind Power in In

Year	Wind Energy Installed Capacity in MW (Aggressive Scenario- Theoretical Possibility)	Wind in
2020	54602	
2025	108835	
2030	221080	

WIND ENERGY POTENTIALS OF I

- The National Institute of Wind Energy, fo
Energy Technology, recently announced th
energy potential in the country is 302 GW (
of 100 meters).
- The fresh estimates are six-times the wind e
at a 50 meter hub height, and three-times t
hub height of 80 metres.
- Of the total estimated 302 GW potential
wasteland, 146 GW in cultivable land, and 3
2015)
- “The new Berkeley Lab study has found the

The Future of Wind - C

Wind Energy Applications

1. Electricity Production

2. Wind Energy for Water Applications

- ✓ Water Pumping

3. Industrial Applications

- ✓ Telecommunications
- ✓ weather stations

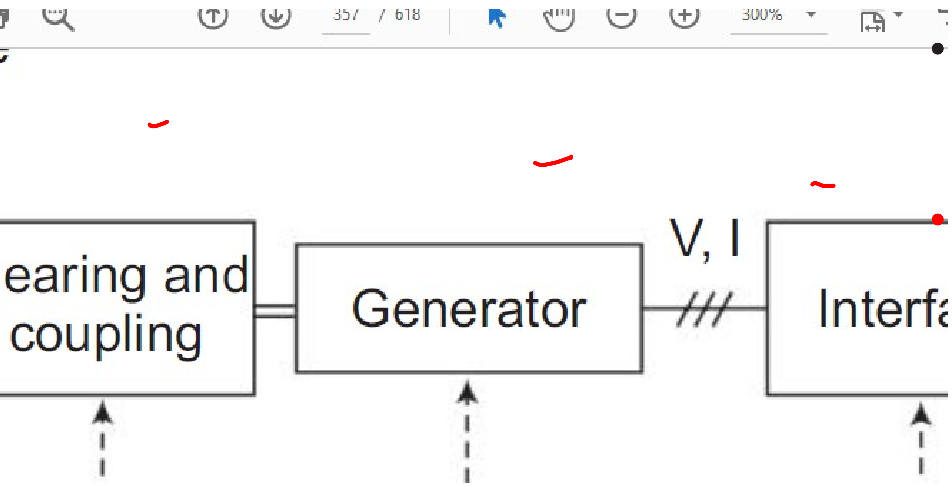
4. windmill

Wind Energy Applicati

- Wind Energy For Water applications
- For hydropower Applications
- Wind energy for generation of electricity

WIND SYSTEMS

WIND ENERGY CONVERSION SYSTEMS (WECS)



wind energy conversion tem converts wind energy o some form of electrical ergy.

synchronous or induction erators are used for mechanical electrical power conversion ending on the design of the em.

- Main features of various types of generators and thei in wind power generation are discussed below:
- (a) DC Generator Conventional dc generators are no more due to their high cost, weight and maintenance problems commutator. However, permanent magnet (brush less and commutator less) dc machines are considered in small rat hundred kW) isolated systems.
- (b) Synchronous Generator Synchronous generators produ quality output and are universally used for power generat conventional plants. However, they have very rigid require maintaining constant shaft speed and any deviation from synchronous value immediately reflects in the generated f
- (c) Induction Generator Primary advantages of induction r the rugged, brush less construction, no need of separate c power and tolerance of slight variation of shaft speed (±10 as these variations are absorbed in the slip. Compared to synchronous machines they have low capital cost, low ma and better transient performance.

WIND ENERGY CONVERSION SYSTEMS (WECS)

Based on the generator drive, two schemes have been developed for the operation of WECS:

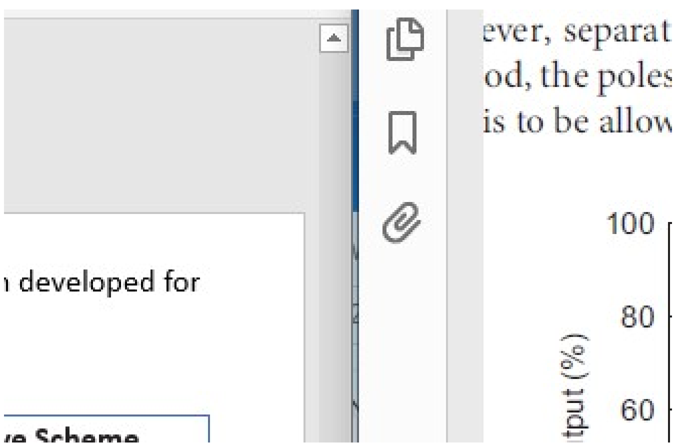
- (i) fixed speed drive scheme and
- (ii) variable speed drive scheme.

Fixed Speed Drive Scheme

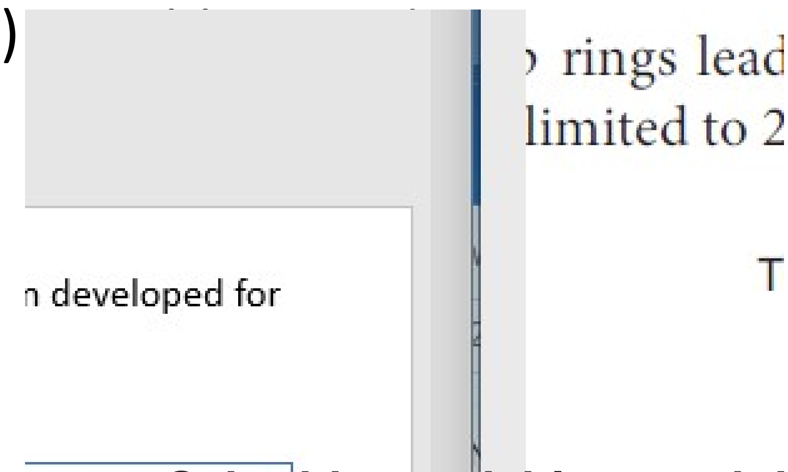
(a) One Fixed Speed Drive

(b) Two Fixed Speed Drive

- **Variable Speed Drive Scheme**
  - (a) Variable Speed Drive Using Power Electronics
  - (b) Scherbius Variable Speed Drive
  - (c)



Power output vs wind speed for two fixed speed drives

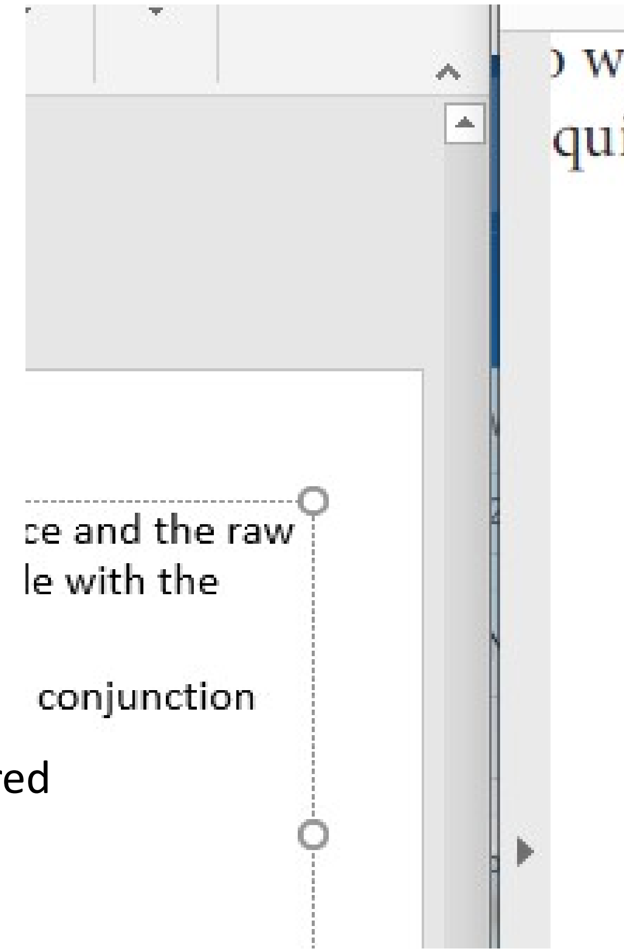


Scherbius variable speed drive

WIND–DIESEL HYBRID SYSTEM

ortunately, wind is a highly fluctuating power rce and the raw output at the terminals of a d turbine is incompatible with the demand of rmal domestic or commercial user.

uch places isolated wind turbines can be alled in conjunction with diesel generating s for backup.



es of operational schedule is possible for diesel unit:

nuous Diesel Unit Operation

simplest way to incorporate the wind turbine into the standard diesel powered em, without increasing the risk of loss of load, is to operate wind turbine in allel with a continuously running diesel generator.

ittent Diesel Unit Operation

his mode diesel unit is switched off during periods when the output of wind bine is sufficiently high to meet the demand without any backup. The saving in is more in this case.

EFFECTS OF WIND SPEED AND GRID CONDITION (SYSTEM INTEGRATION)

A utility has to serve the varying load of its customers by the power available fror various power plants.

As wind power is a varying power source, which cannot really b dispatched, conventional power plants or storage facilities have to deal with thes variations.

If the penetration of wind power into the grid is continuously increased, it might reach t a level where economics of the total power production is affected in a negative way. Thi will limit the penetration of wind power into the grid.

The optimum penetration depends on specific circumstances and characteristics of th utility system.

In most cases wind power penetration level less than 10 per cent of the total electricit production will cause no severe problem and will not cause any economic disadvantage.

For higher penetration, total electricity production system is to be re-optimized. This ma require integration of some more peak load units or storage capacity plants.

Also the distance of the wind resource from the grid poses another limiting factor as i influences the economics of wind power.

A distance of less than 50 km is generally considered as economically feasible.

WIND ENERGY STORAGE

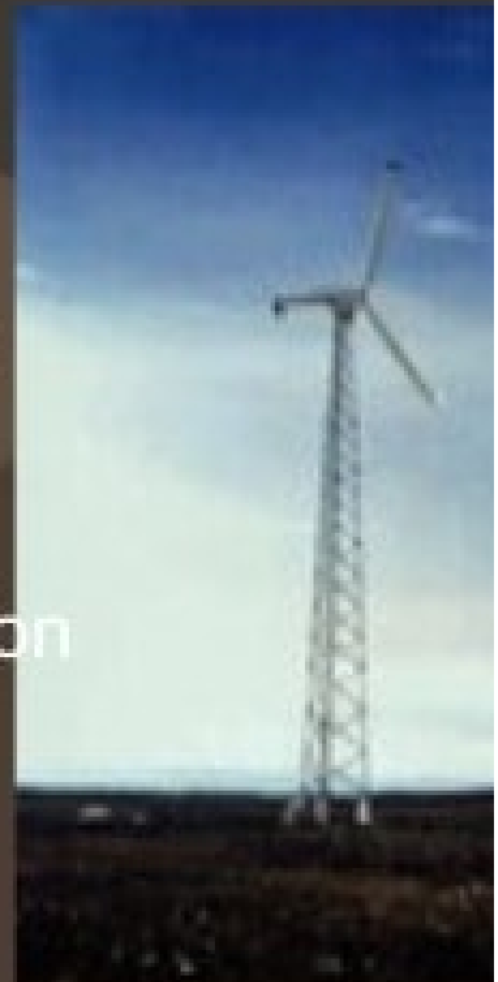
- **place of a generator,** **a compressor** is used in the nacelle.
- he highly compressed air is sent down the tower into underground storage such as caves o
epleted gas wells through pipelines.
- he **pressurized air can be released when needed to power an electricity generator**, ev
wind is not spinning the turbine.
- lechanology", a compressor research and development firm, has designed a compressor a
as tested a prototype wind energy storage system. The company plans to build its largesca
ersion now.

- **wind power plant can also be integrated with pumped storage plant**. The excess power generated
n be utilized to store water at a higher reservoir.
- he stored energy can be later recovered by running the pumped storage plant as a normal hydro
ant.
- e **excess wind energy can also be stored as thermal energy** (e.g. hot water) and may be utilized la
r space heating, heating of green house or crop drying.

Sizes and Applica

Small (≤10 kW)

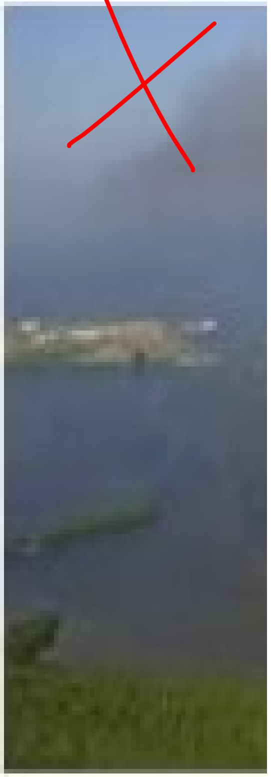
- Homes
- Farms
- Remote Application



ADVANTAGES & DISADVANTAGES

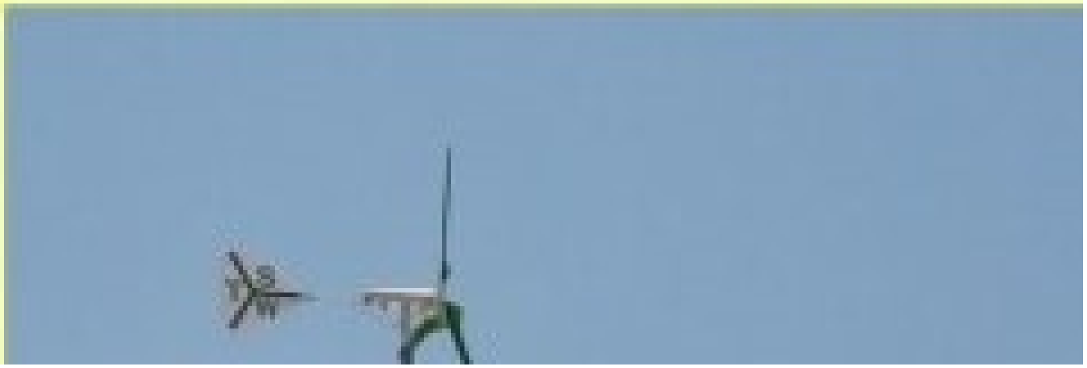
Advantages of Wind Pow

- Environmental Benefits
- Economic Development Benefits
- Fuel Diversity & Conservation Benefits
- Cost Stability Benefits



Why Wind Energ

- Wind, for now, is the renewable energy resource/
- "Free" resource
- A "clean" resource due to:
  - Replacement of a "dirty" energy source (coal) and,
  - No emissions associated with its use
- Can be utilized on underutilized land or on lands
crop production ("harvest" on the surface and "ha
surface)



Wind Ene

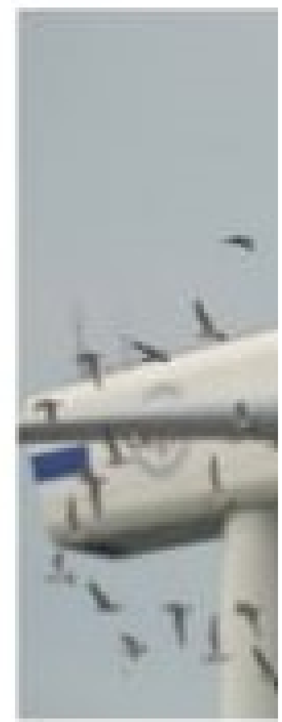
- No air em
- No fuel t
  store
- No coolin
- No water
- No waste

Advantages

- Safe, clean, renewable form of energ
- No air pollution or waste materials pr
  not contribute to global warming or c
- Minimal effect on local ecosystems. L
  farmed at the same time.
- Winds are stronger in winter when d
  electricity rises

Disadvantages

- Birds - A Serious Obstacle
- Noise Disturbances
- Cost of Wind Turbine
- Threat to Wildlife
- Wind Can Never Be Predicted



DISADVANTAGES OF WIND E

- Wind energ
in nature ar
storm force
- Wind energ
operation; a
many kilom
- Birds and b
flying into t

Disadvantage

- 30m tall – visual concerns e
grouped together on 'wind f
- Expensive to build and main
- Wind does not blot all the t
- Hum noise and can interrup

Cost Economics

Energy Cost Tre

1979: 20 INR/kWh

2000: 3 INR/kWh

- Increased

Scale of Wind Turbines

Scale	Rotor diameter
Micro	Less than 3 m
Small	3 m to 12 m

CRITERION

- Criterion for identification of a potential site
- Sites having wind power density greater than 200 W/m^2 at 50 m height

ECONOMICS

- Annual Energy Production
- Capital Cost
- Annual capital charge rate
- Pay back period
- Operation & maintenance cost, insurance, land leasing, e
- Life Cycle Cost Analysis

ANNUAL ENERGY PRODUCTION DEPENDS

- Speed power curve of wind turbine
- Wind speed frequency distribution of site
- Availability of wind turbine

Average Wind Speed i

- Most important variabl

  Power ~ V^3

- Double speed and pow
  increases 8 times
- 73% more power in a 1
  wind than a 10 mph wi
- This is why it is so impor

Factors Affecting

- *Elevation*
- **Obstructions**
- **Surface Roughness**
- **Perpendicular Ridg**
- **Time of day**

ENVIRONMENTAL ASPECTS

ENVIRONMENTAL ASPECTS
Main environmental concerns are discussed below

direct Energy Use and Emissions

Energy is required to produce materials used to construct the wind turbine and in its installation.

rd Life

Large wind turbines pose a threat to bird life as a result of collision with tower or blades. Their resting and breeding patterns are also affected.

oise

The disturbance caused by the noise produced by wind turbine s one of the important factors that prevent its siting close to nhabited areas.

4. **Visual Impact**
   - Wind turbines are massive structures quite v over a wide area in most locations. Visual impa wind turbine is qualitative in nature.
5. **Telecommunication Interference**
   - Wind turbines present an obstacle for inc electromagnetic waves (i.e. TV or microwave sign
6. **Safety**
   - Accidents with wind turbines are rare but the happen, as in other industrial activities
7. **Effects on Ecosystem**
   - Large-scale use of wind generation can reduce speed and cause stress to ecosystem. Lakes tha downhill from the wind turbines might be warmer because of reduced evaporation from surface.

Environmental Impact

Noise

- **Mechanical Noise - gear box, generator**
- **Aerodynamic Noise - Swishing sound**
- **Wind farm at 350 m away**
- ***noise level - dB(A) 35-45***
- **Electromagnetic interference**
- **Visual impact**
- **Shadow flicker**
- **Ecology, Loss of Bird Life**

Thank You

Save energy and water for Sustainable Life

ENSAVE ACADEMY

Dr.P.Dharmalingam
Accredited Energy Auditor
Director, EnSave Academy
https:// ensaveindia.in
https://training.ensaveindia.in
https://ecourse.ensaveindia.in

Energy and Environment Science

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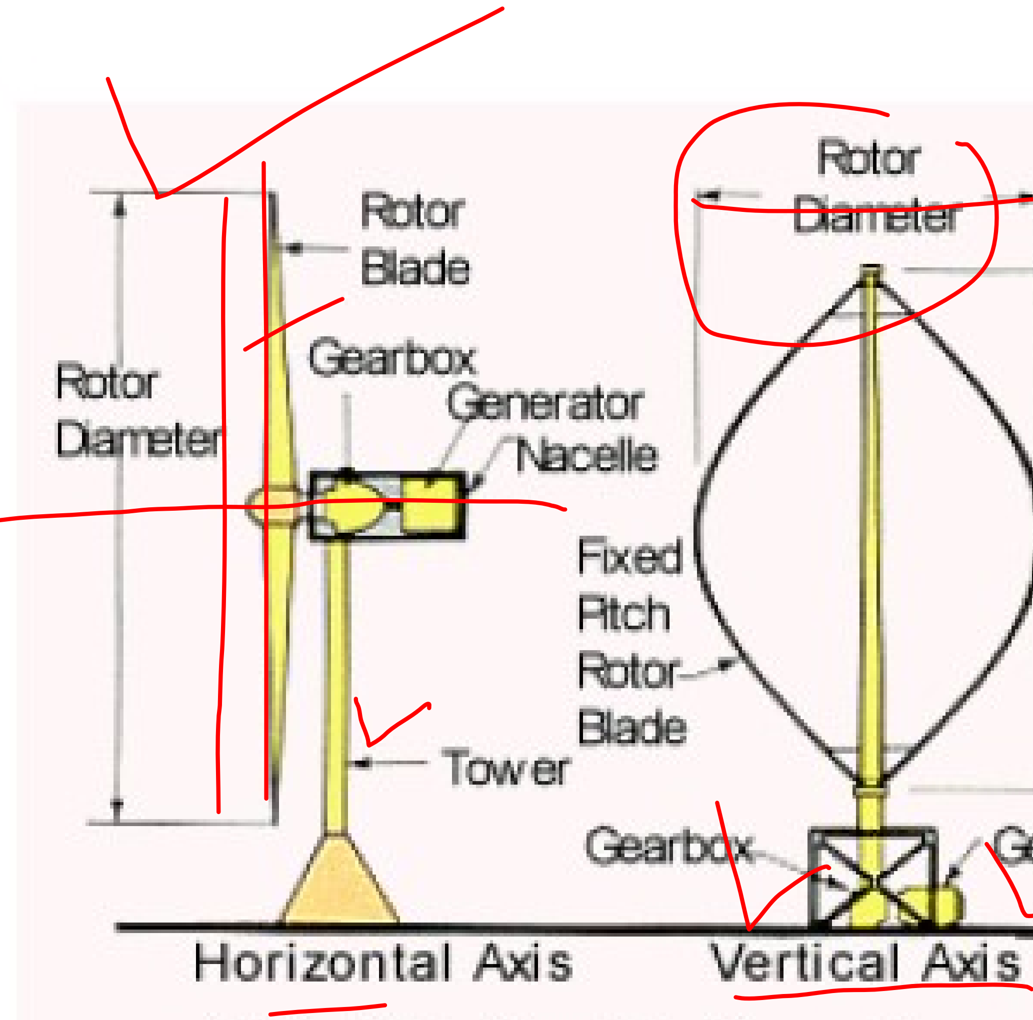
Types of Wind Mill and Classification

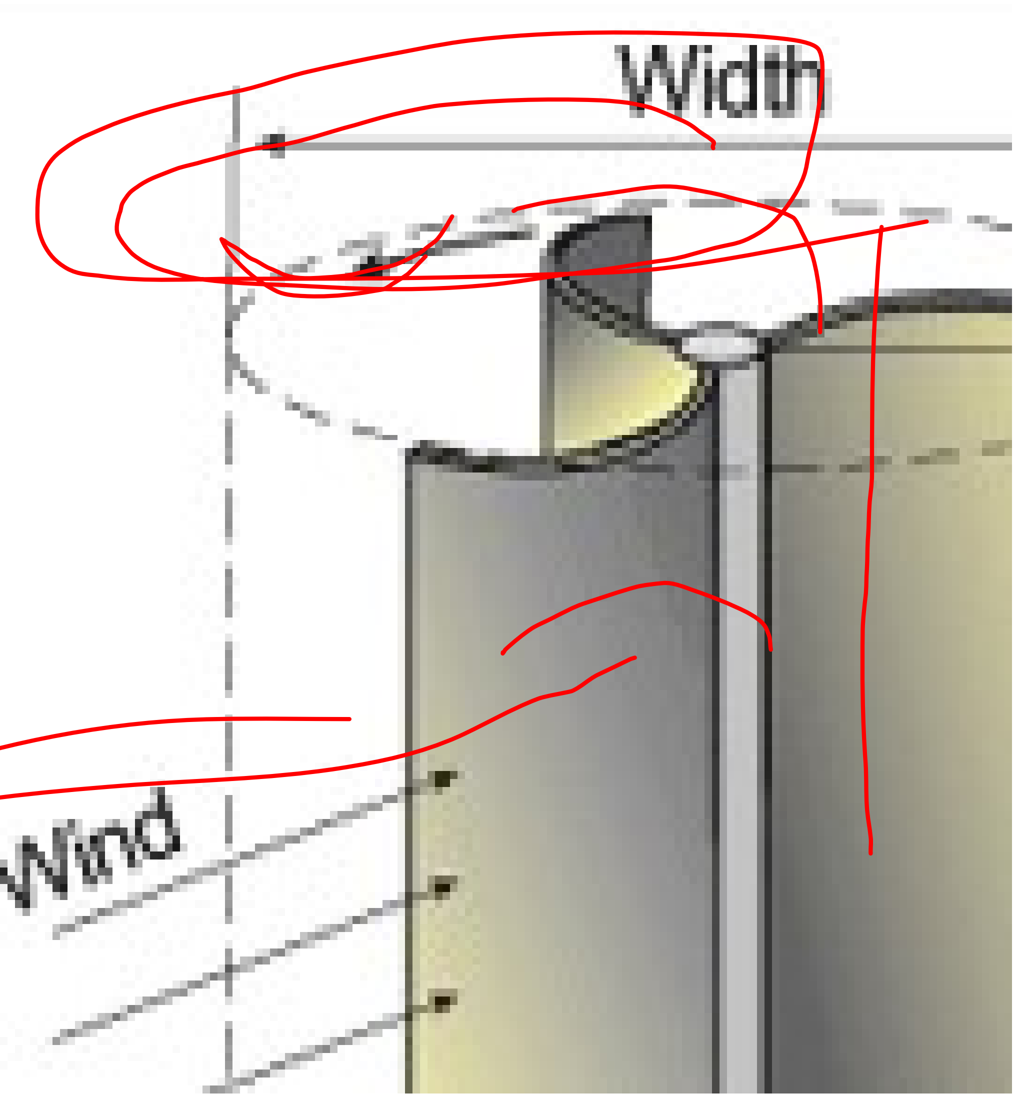
Wind Energy Design

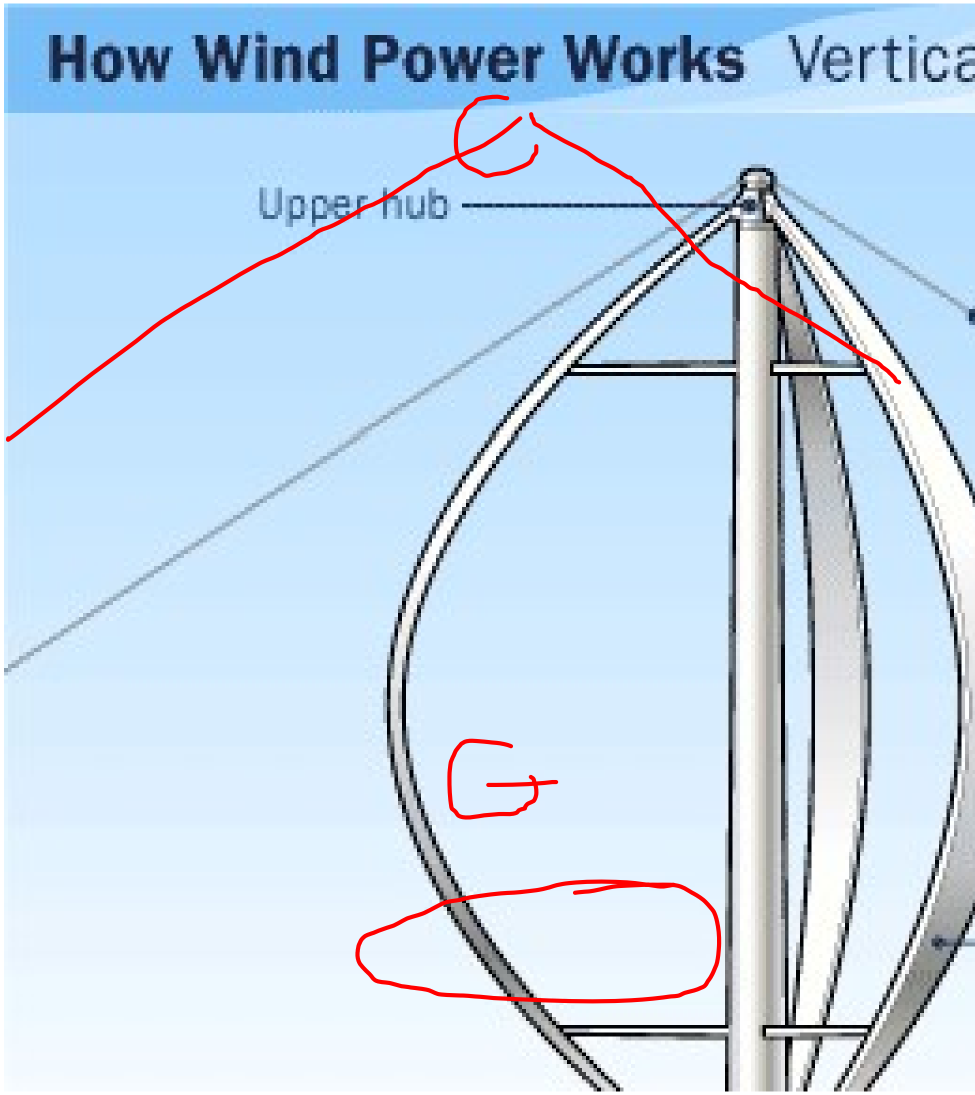
re are two basic designs wind electric turbines: **ical-axis, or "egg-beater" e, and horizontal-axis chines**. Horizontal-axis d turbines are most mon today.



Wind Turbine Configurations

2.3.2.Wind energy- Classification





Vertical wind mill (Darrieus rotar)

WIND TURBINE TYPES AND THEIR CONSTRUCTION

Wind turbines are broadly classified into two categories.

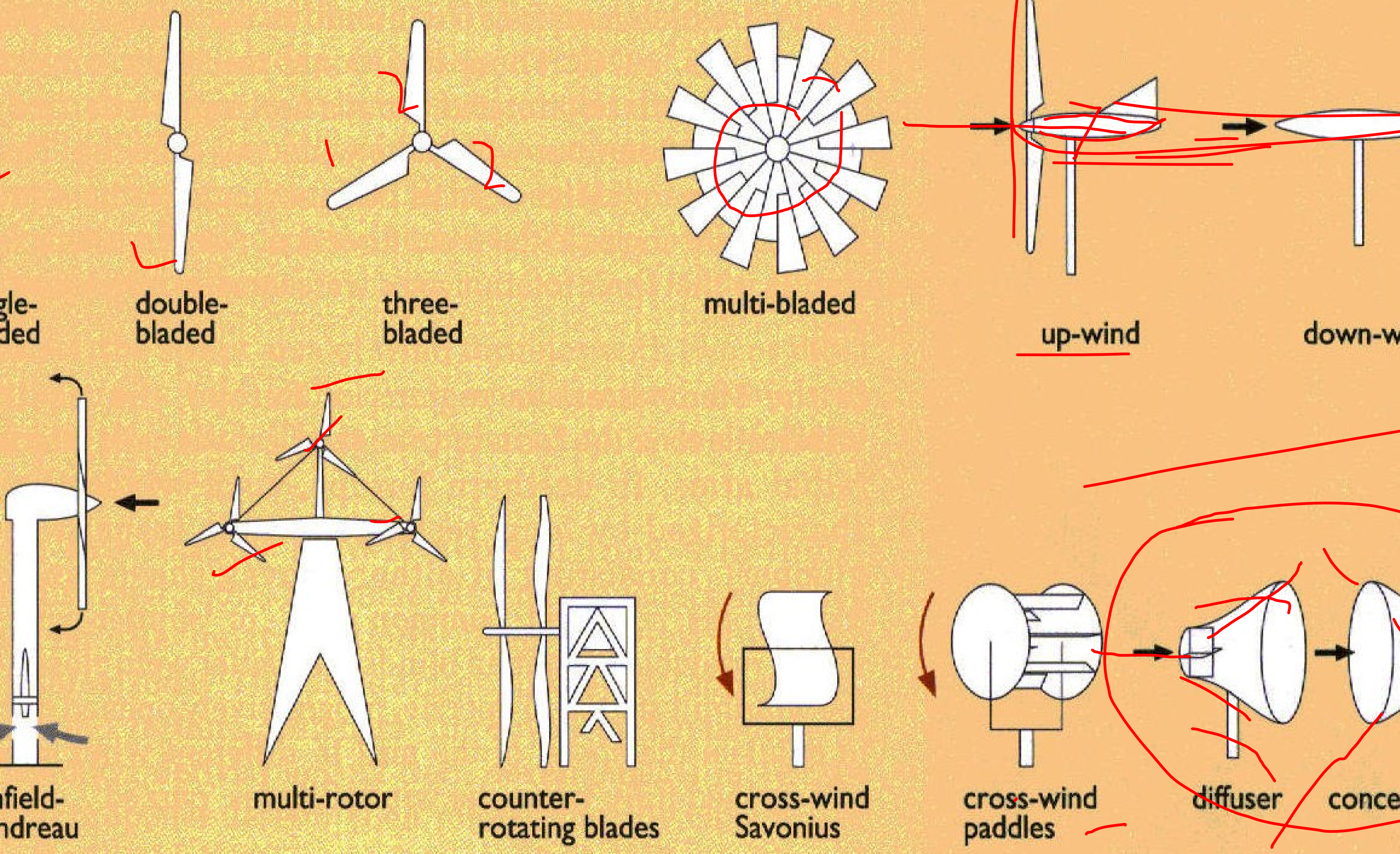
1. **Horizontal Axis Wind Turbine (HAWT),**
2. **Vertical Axis Wind Turbine (VAWT).**

When the axis of rotation is **parallel** to the air stream (i.e. horizontal), the turbine is said to be a **Horizontal Axis Wind Turbine (HAWT), A horizontal axis machine has its blades rotating on an axis parallel to the ground**

When it is **perpendicular** to the air stream (i.e. vertical), it is said to be a **Vertical Axis Wind Turbine (VAWT).**

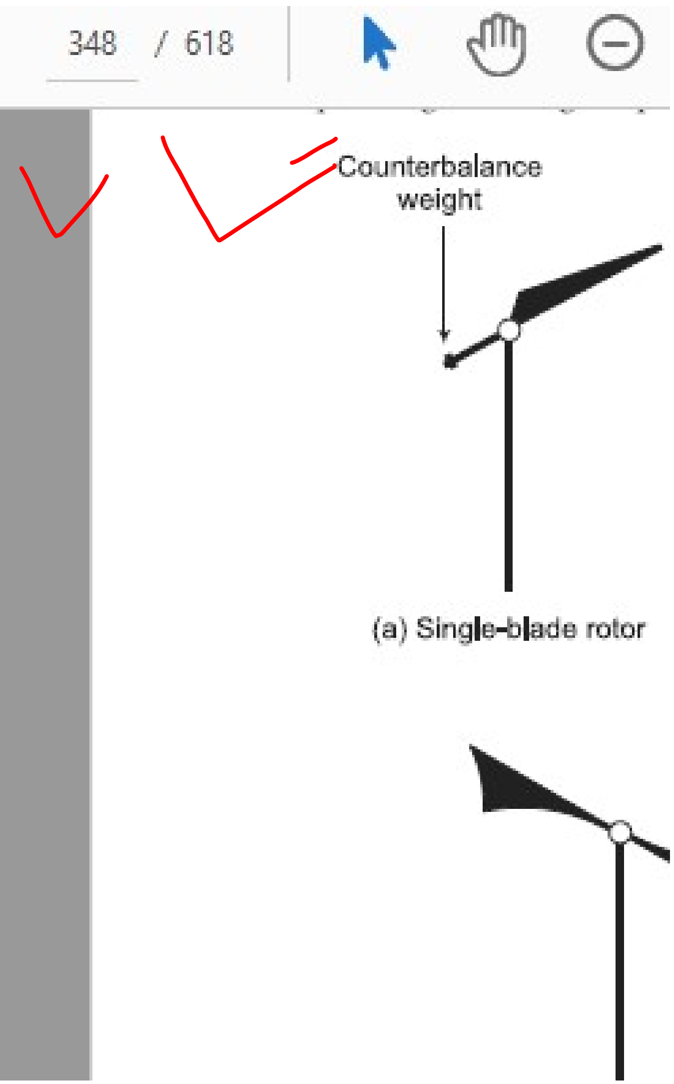
A vertical axis machine has its blades rotating on an axis perpendicular to the ground.

rizontal axis



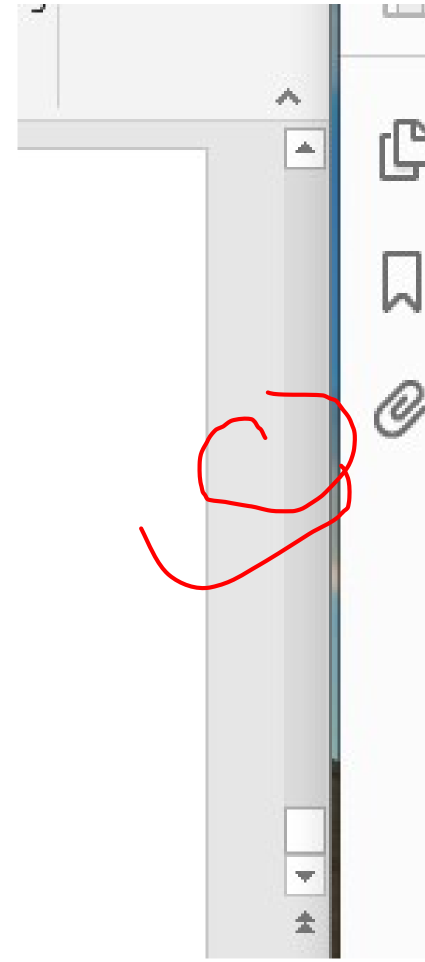
Horizontal Axis Wind Turbine (HAWT)

Types of Rotors



3. Teetering of Rotor

- As wind speed rises with height, the axial force on blade when it attains the upper position is significantly higher as compared to that when it is at lower position.
- For one and two blade rotors this causes cyclic (sinusoidal) load on a rigid hub leading to fatigue. This is greatly relieved by providing a teeter hinge (a pivot within the hub) that allows a see-saw motion to take place out of the plane of rotation



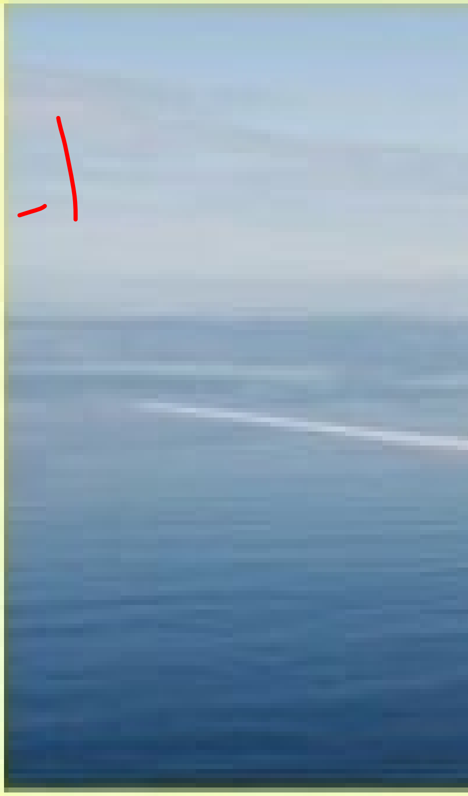
A teetered hub

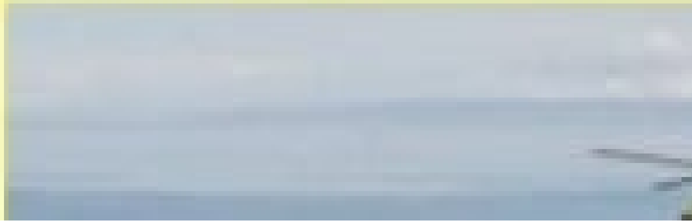
Number of Blades –

- Rotor must move more rapidly to capture same amount of wind
  - Gearbox ratio reduced
  - Added weight of counterbalance negates some benefits of lighter design
  - ~~Higher speed~~ means more noise, visual, and wildlife impacts
- Blades easier to install because entire rotor can be

Number of Blades -

- Advantages & disadvantages similar to one blade
- Need teetering hub and or shock absorbers because of gyroscopic imbalances
- Capture 5% less



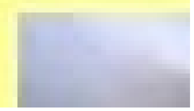


Number of Blades - T

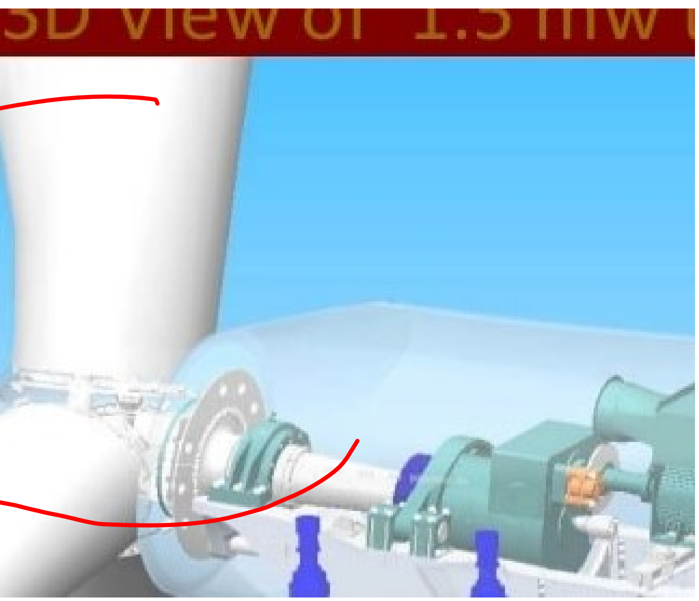
- Balance of gyroscopic forces
- Slower rotation
  - increases gearbox & transmission costs

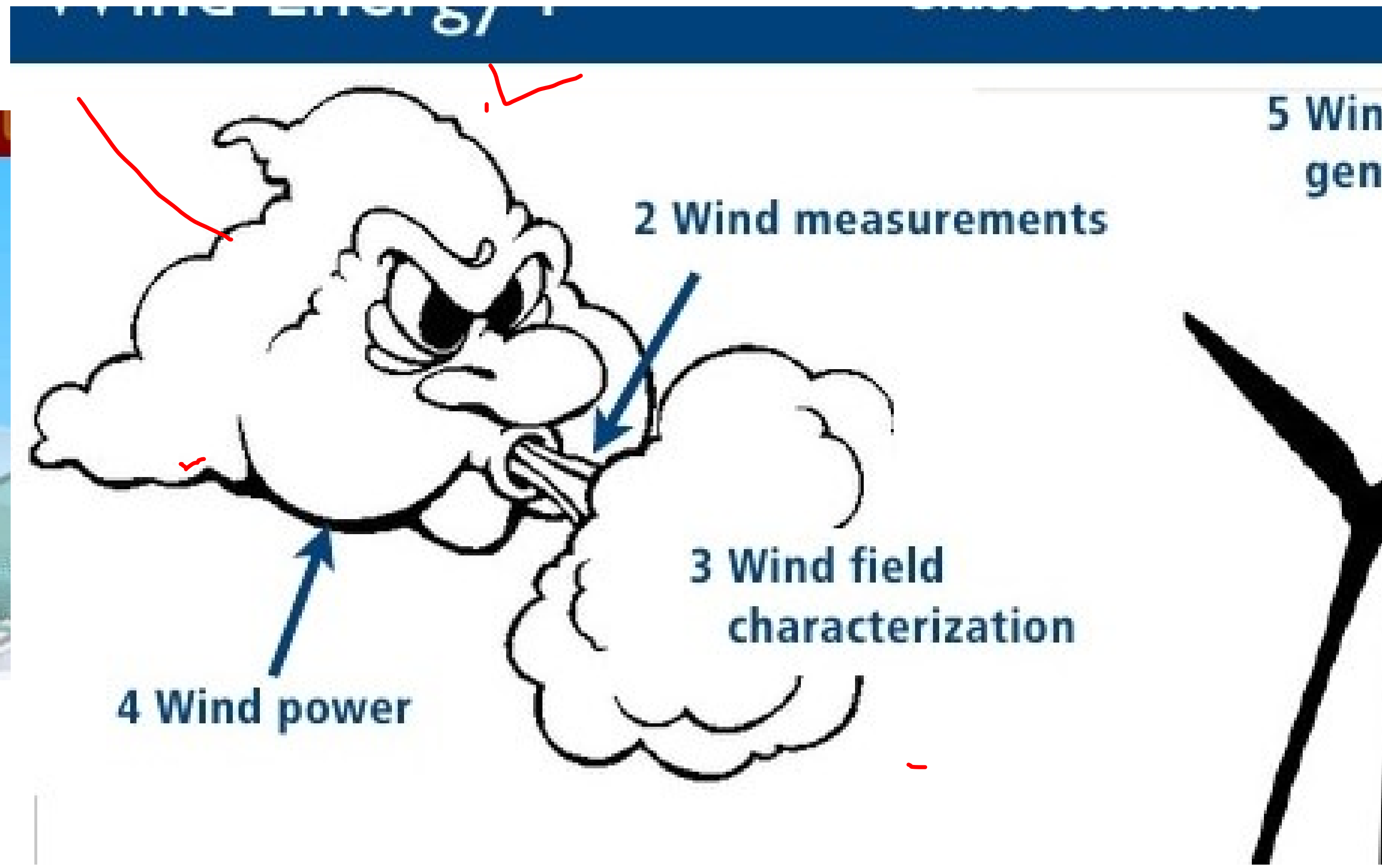
Blade Composition Metal

- Steel
  - Heavy & expensive
- Aluminum
  - Lighter-weight and easy

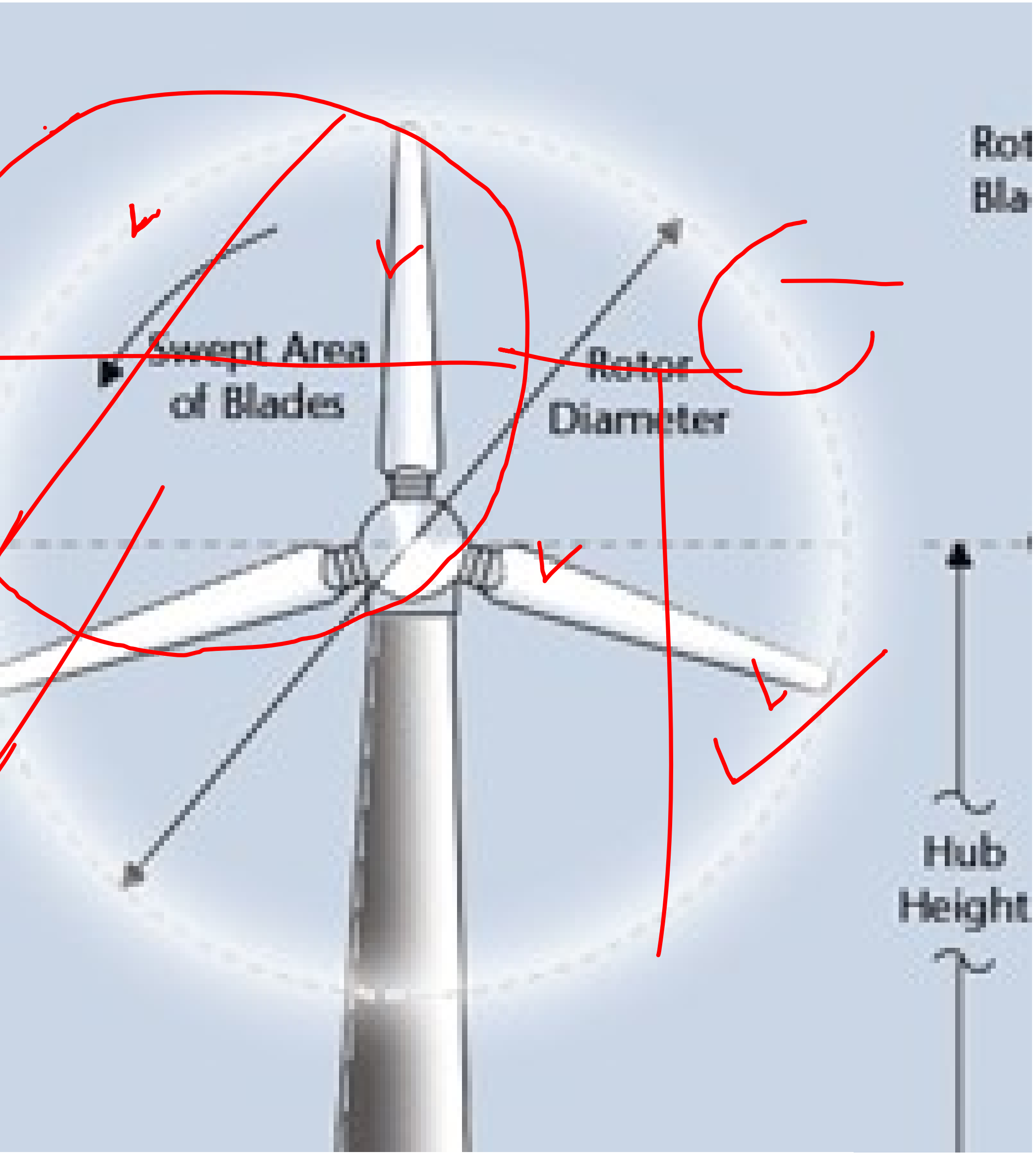


WIND MILL SYSTEMS & ITS COMPONENTS





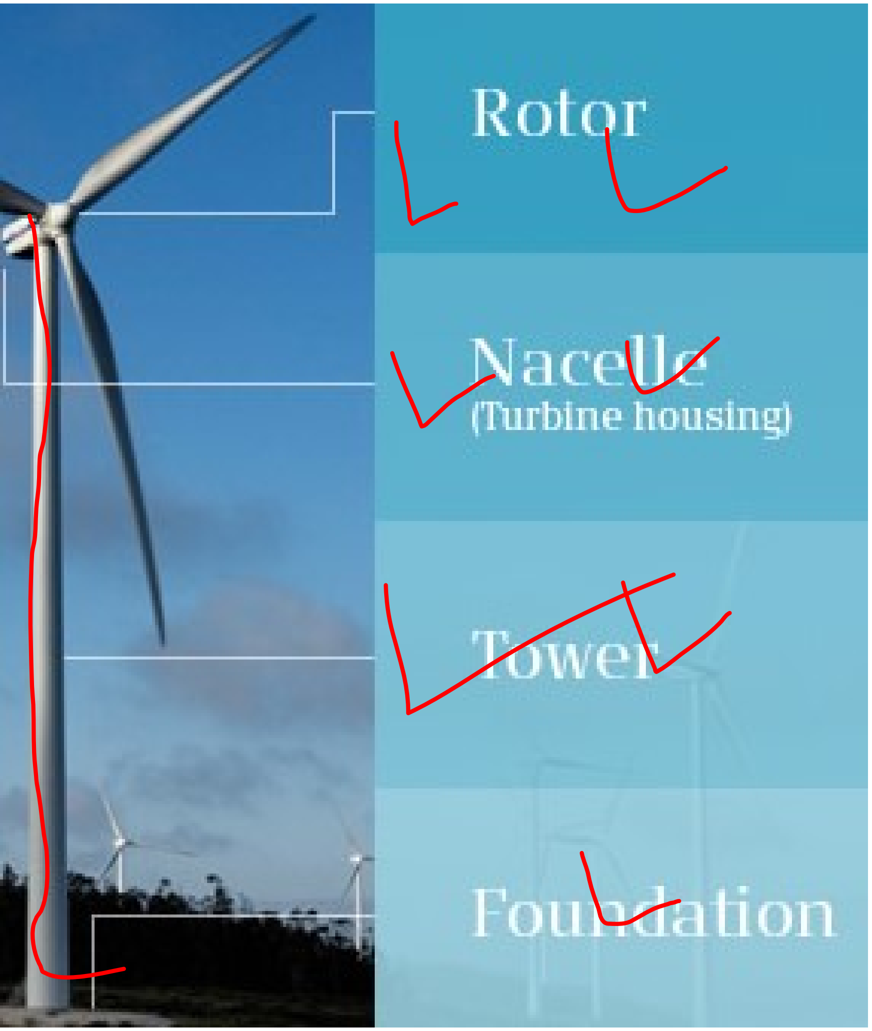
Horizontal-axis wind Mill



Rotor and Blades

Horizontal-axis wind turbi
which are the **most comm**
have the main rotor shaft
and electrical generator at t
top of a tower, and must be
pointed into the wind.

Major components of System



- **Rotor, or blades,** which **convert the wind's energy into rotational shaft energy.**
- **Nacelle (enclosure)** containing a dr train, usually including a **gearbox (S turbines operate without a gearbo and a generator.**
- **Tower,** to support the rotor and dri train; and
- **Electronic equipment** such as contr electrical cables, ground support equipment, and interconnection equipment.

Horizontal Axis Wind Turbine (HAWT)

in Components

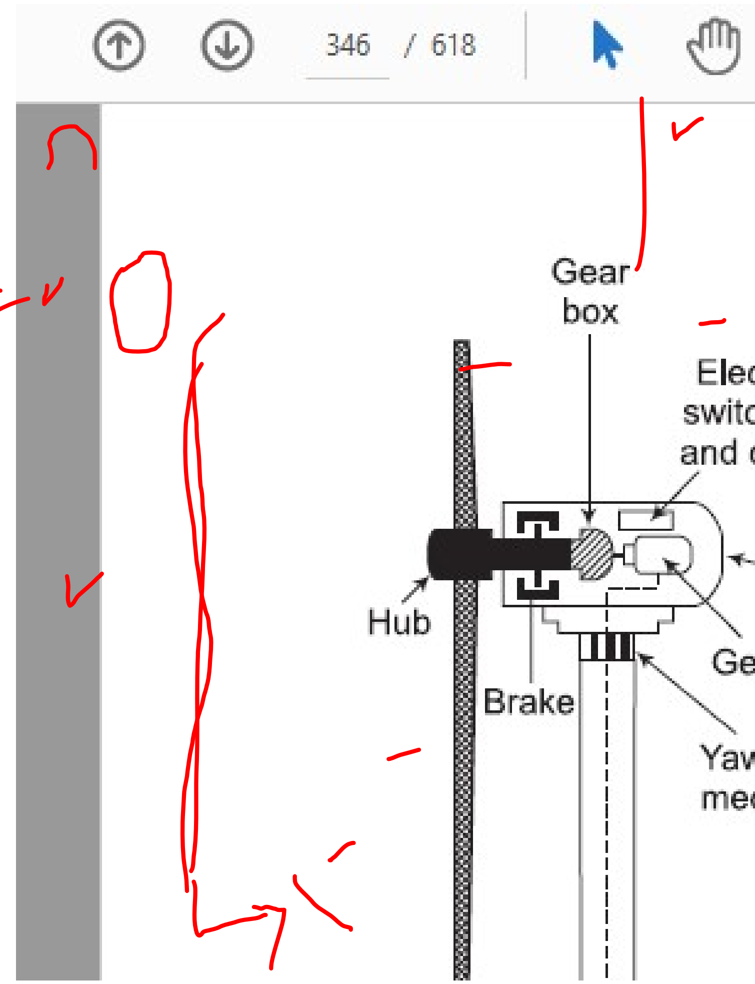
rbine Blades - Turbine blades are made of high-
ensity wood or glass fiber and epoxy
mposites. They have airfoil type cross-section.

ub - The central solid portion of the rotor wheel
known as hub.

acelle - The term nacelle is derived from the
me for housing containing the engines of an
rcraft. The rotor is attached to nacelle, mounted
the top of a tower.

w Control Mechanism - The mechanism to
ljust the nacelle around vertical axis to keep it
cing the wind is provided at the base of nacelle.

wer - Tower supports nacelle and rotor. For
edium and large sized turbines, the tower is
ghtly taller than the rotor diameter.



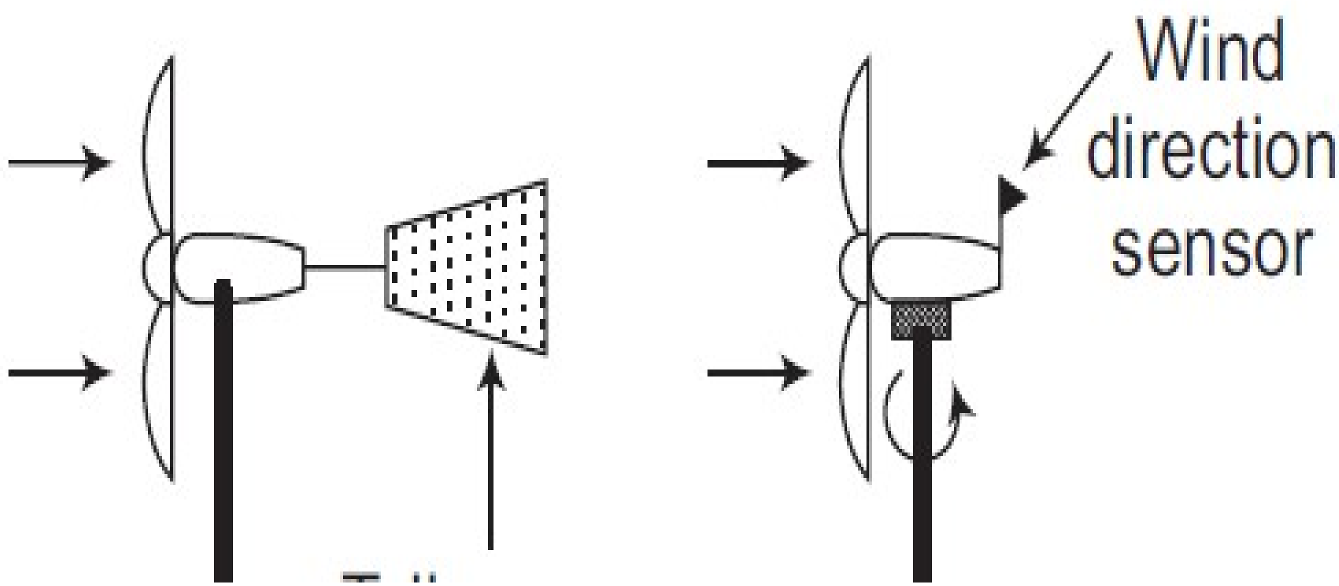
Horizontal Axis Wind Turbine (HAWT)

wind and Downwind Machines

In upwind machine, rotor is located upwind (in front) of the tower whereas in downwind machine, the rotor is located downwind of (behind the tower

dangerous as it may excite any natural mode of t

harmonics.

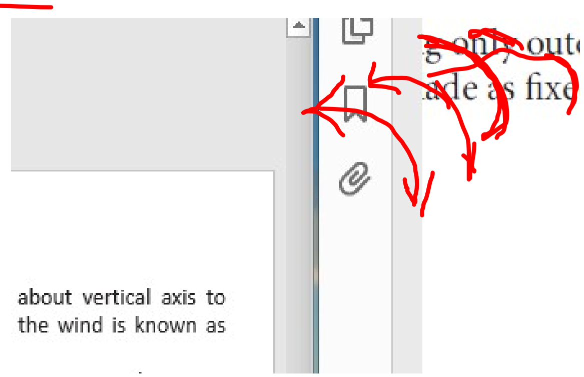


Horizontal Axis Wind Turbine (HAWT)

'aw Control System

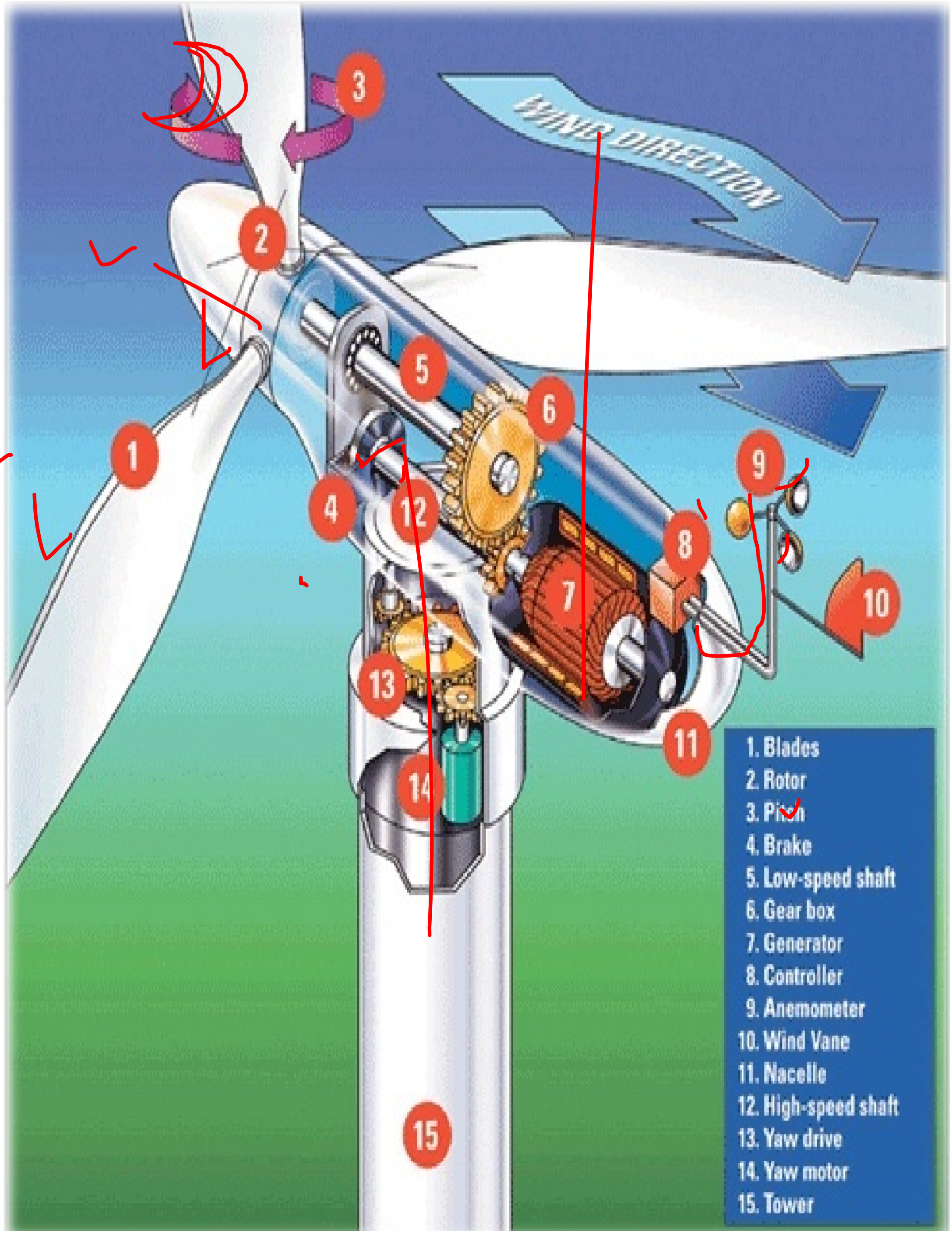
usting the nacelle
out vertical axis to
ng the rotor facing
wind is known as
v control.

e yaw control
stem continuously
ents the rotor in the
ection of wind.



6. Pitch Control System

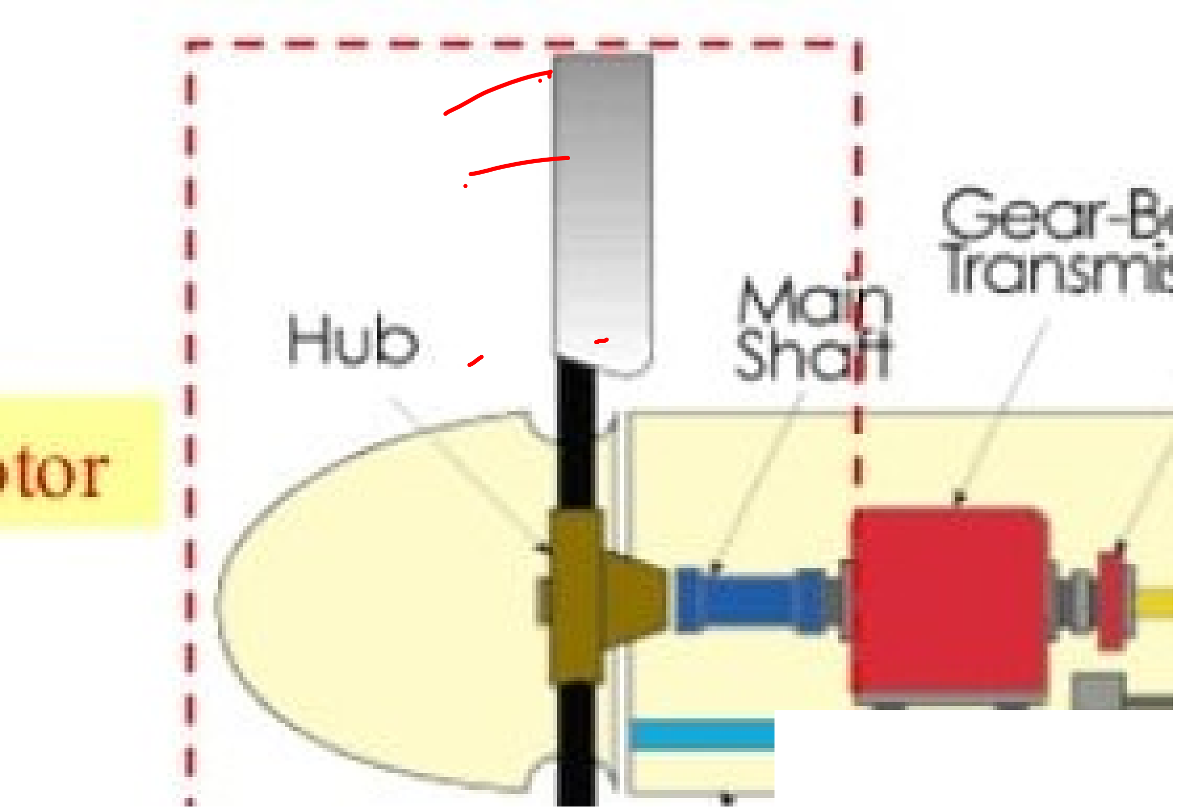
- Pitch contr
mechanism is provide
through the hub usin
hydraulic jack in th
nacelle.
- The control syste
continuously adjus
the pitch to obta
optimal performance.



Components of Wind Turbine

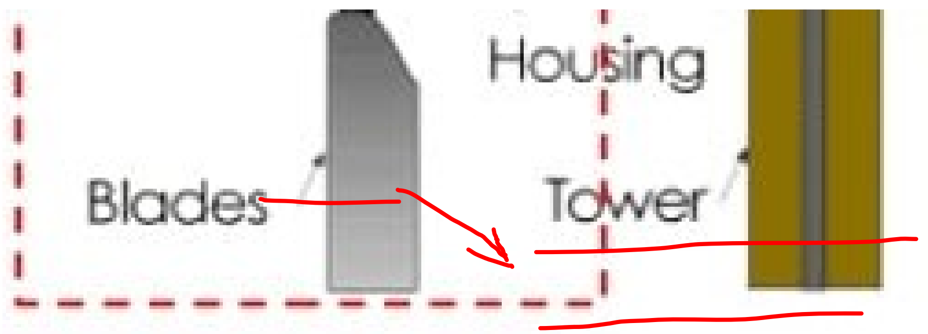
1. ROTOR
2. DRIVE TRAIN
3. TOWER
4. CONTROL SYSTEM
5. YAW SYSTEM
6. MAIN FRAME
7. NACELLE

Rotor



- **Two- and three-bladed rotors a commonly used for power generation.**

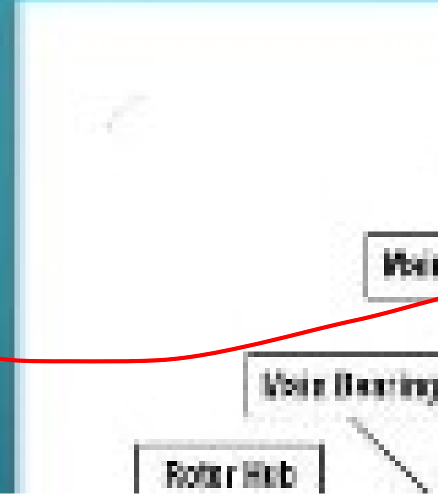
Multi-bladed rotors have large starting torque in light winds and used for water pumping and low frequency mechanical power.

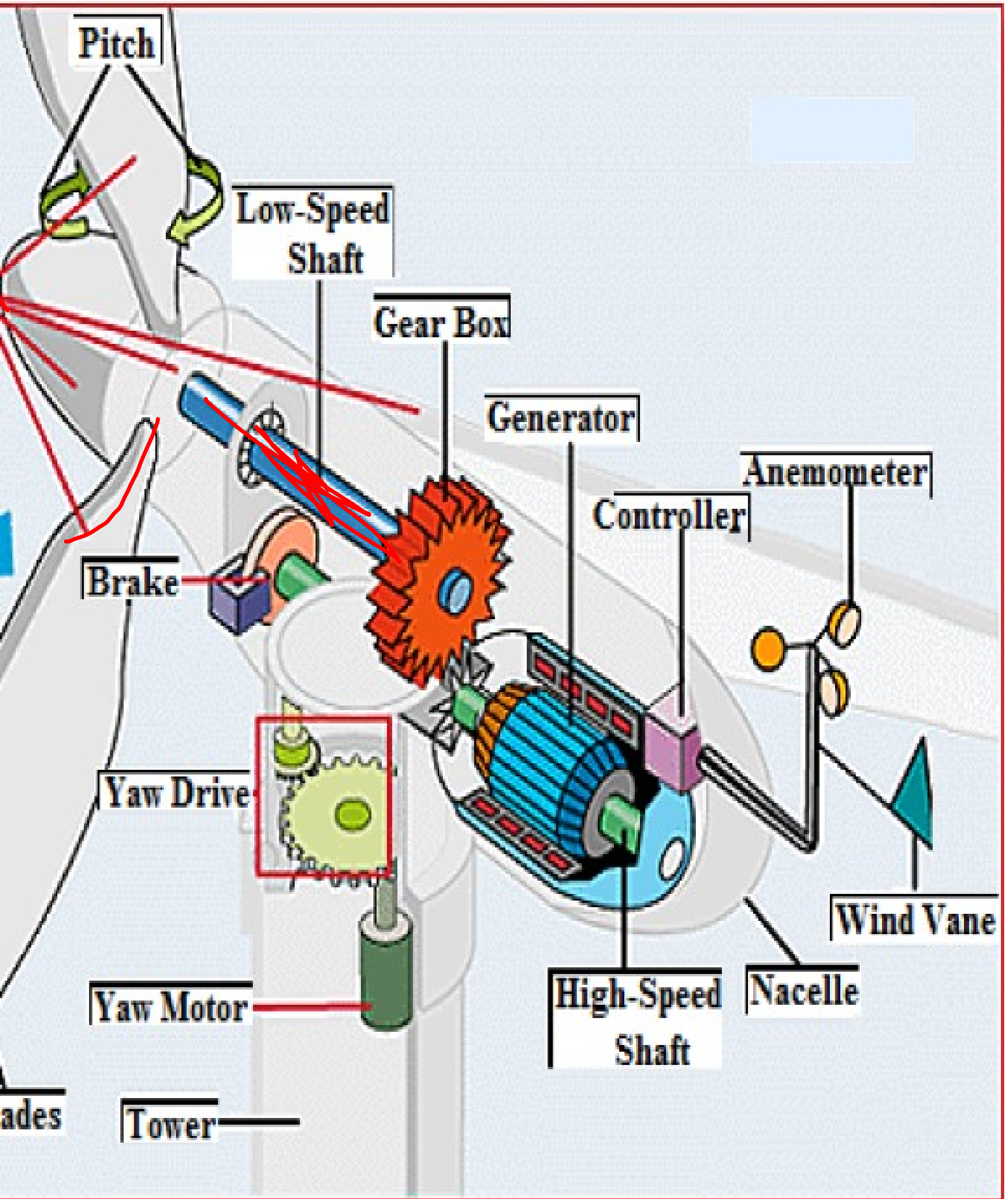


- **Blades are connected to a hub, whic**

NACELLE

- The term nacelle is derived from the name for housing (casing) containing the engines of an wind turbine (Aerogenerator).
- The rotor is attached to the nacelle, and mounted at top of a





Nacelle Assembly: Nacelle is t

part of wind turbine at top of tower

housing containing gear box, gene

assemblies and any control

component.

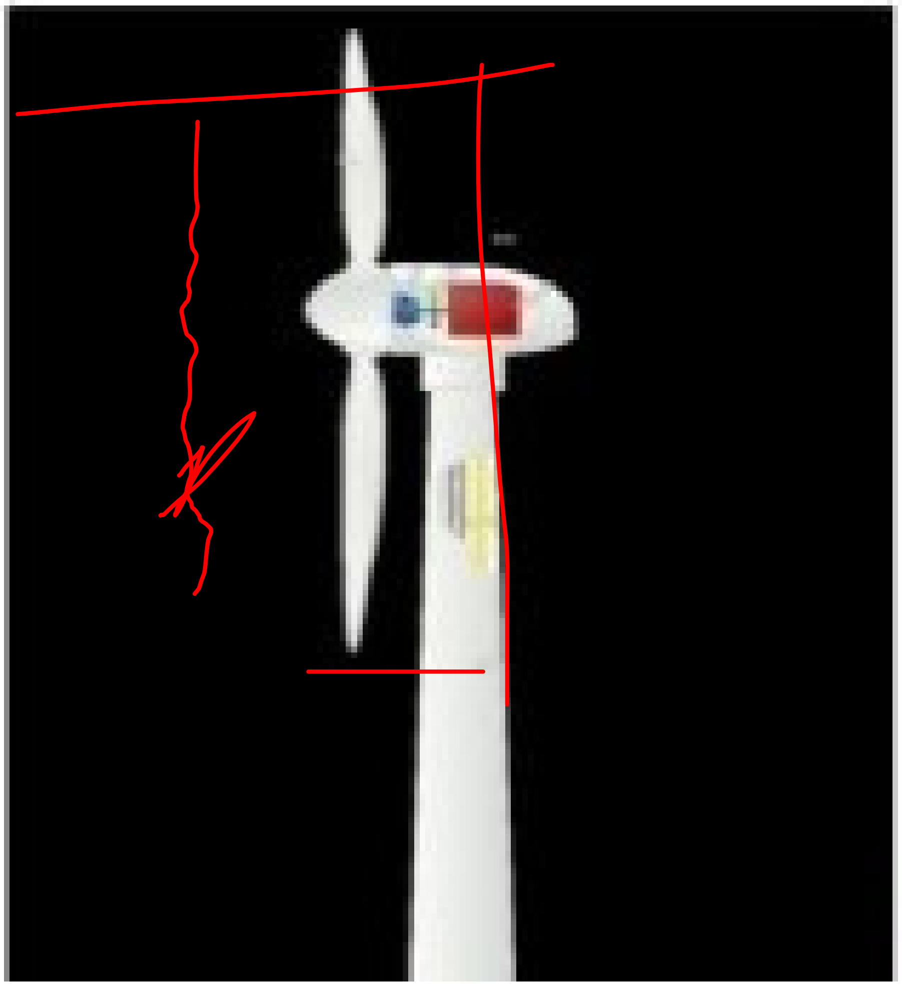
Low-speed shaft: The low-speed

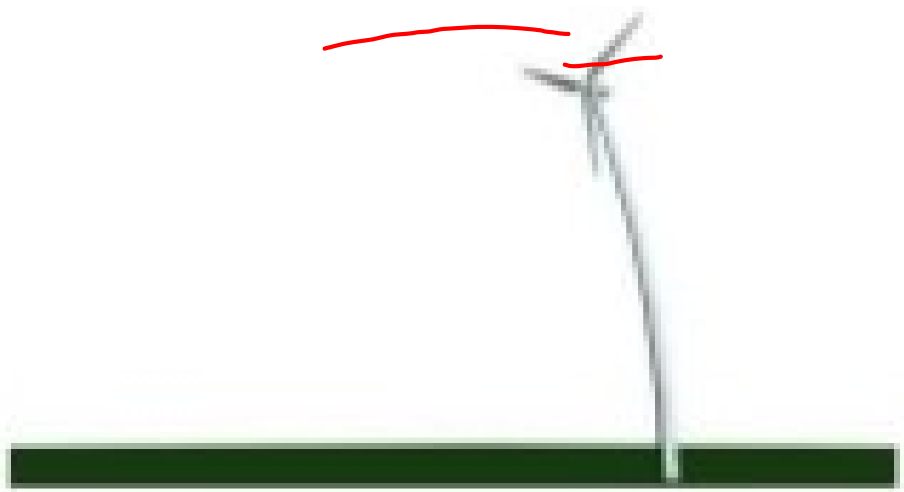
shaft, which is the main shaft, is

connected directly to the rotor hub.

rotor turns the low-speed shaft at a

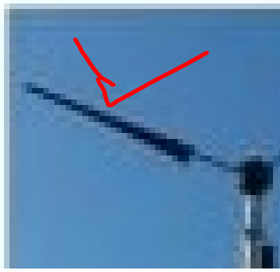
30 to 60 rotations per minute.





TYPES OF TOWERS

1. The reinforced concrete tower,
2. The pole tower,
3. The built up shell-tube tower, and



Features of major Compone

Tower

- Tubular Tower for be
- Designed stiffness to
- frequencies
- Designed to reduce th
- minimum
- Load Separation plate
- foundation for better
- distribution.
- Ergonomically design
- necessary safety equi
- Superior cable manag

Wind turbines: Components

lades	Most turbines have three blades. The turning of
ub	Centre of the rotor to which the rotor blades are
otor	Blades and hub referred together
ow-speed shaft	Turned by the rotor at about 30 to 60 rotations p
ears	Connects low-speed shaft to high-speed shaft a from about 30 to 60 rpm to about 1000 to 1800 r required by most generators to produce electrici
enerator	Produces electricity
igh-speed shaft	Drives generator
ontroller	Starts up and shuts off the machine
nemometer	Measures wind speed and transmits wind speec
Vind vane	Measures wind direction and communicates witl

Technical specifica

- Tower

Nominal Power -1500 k

Rotor dia

Hub height

Rotor cone an

Swept area -5

Rotor speed (at rated p

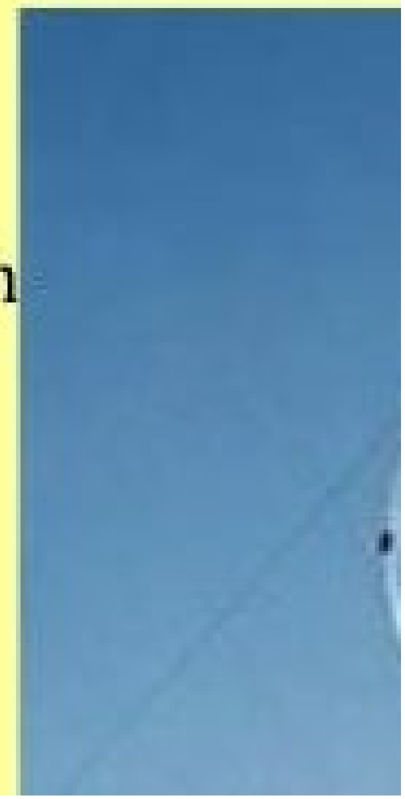
Rotational speed 1

Tip speed (at rated

Blade lengt

Vertical Axis Wind Turbin

- 1920 :Invented by G. M. Darrieus (French Engineer): Darrieus Rotor
- 500 kW, 34m long was undertaken in 1980 by Sandia national Lab, USA but leaving the business in 1997



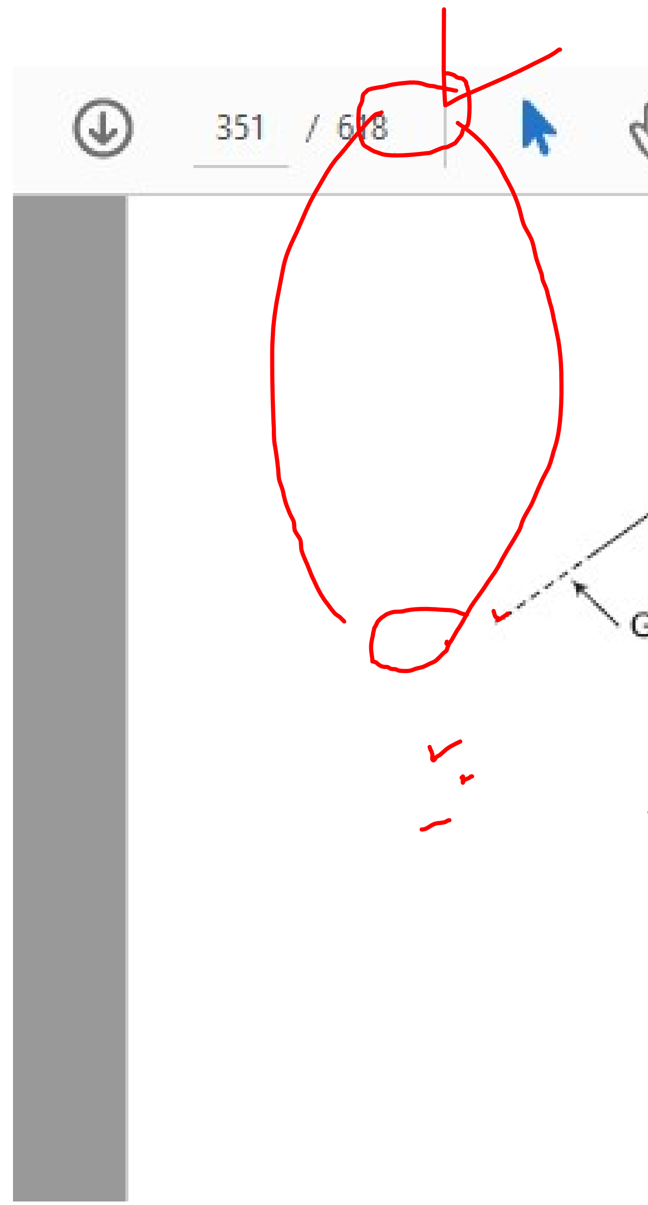
Vertical Axis Wind Turbine (VAWT)

. Main Components

Tower (or Rotor Shaft) - The tower is a hollow vertical rotor shaft, which rotates freely about vertical axis between top and bottom bearings. It is installed above a support structure.

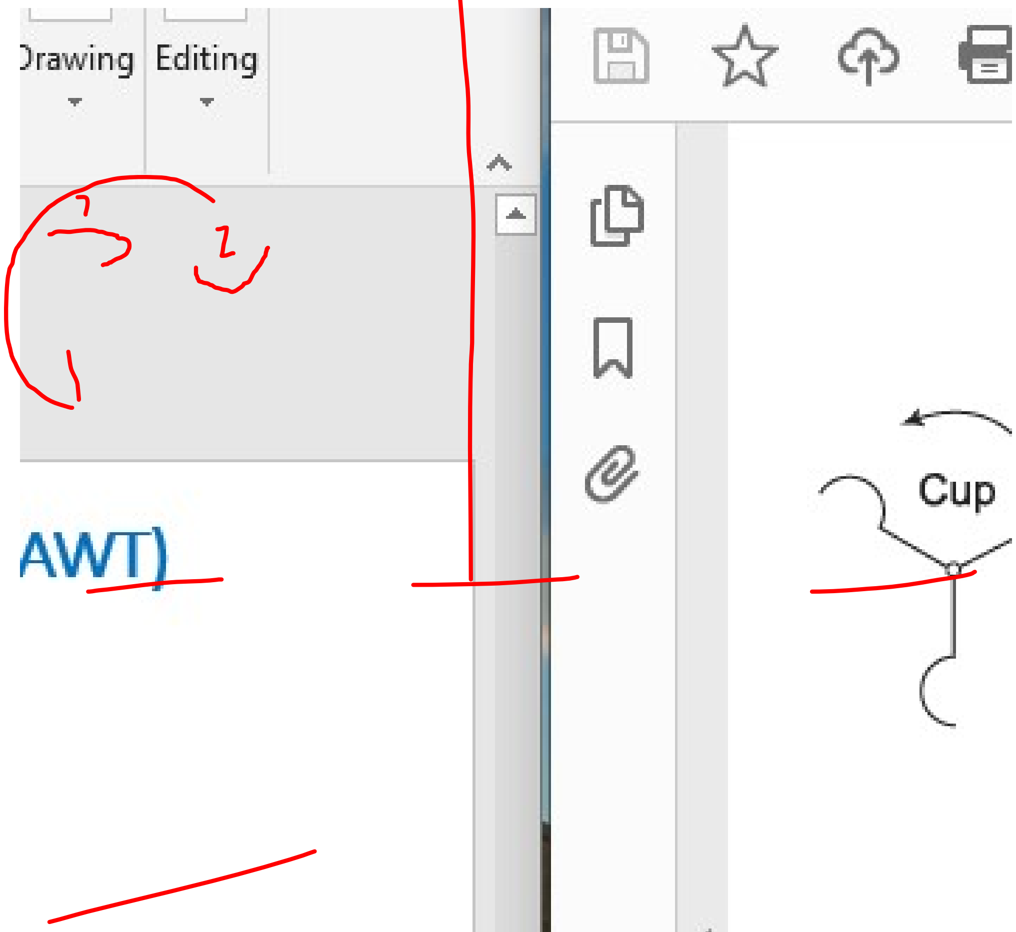
Blades - It has two or three thin, curved blades shaped like an eggbeater in profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces-the so-called 'Troposkien' profile. The blades have airfoil crosssection with constant chord length.

Support Structure - Support structure is provided at the ground to support the weight of the rotor. Gearbox, generator, brakes, electrical switchgear and controls are housed within this structure.



Vertical Axis Wind Turbine (VAWT)

2. Types of Rotors



(a) Cup type

Types of WT contd..

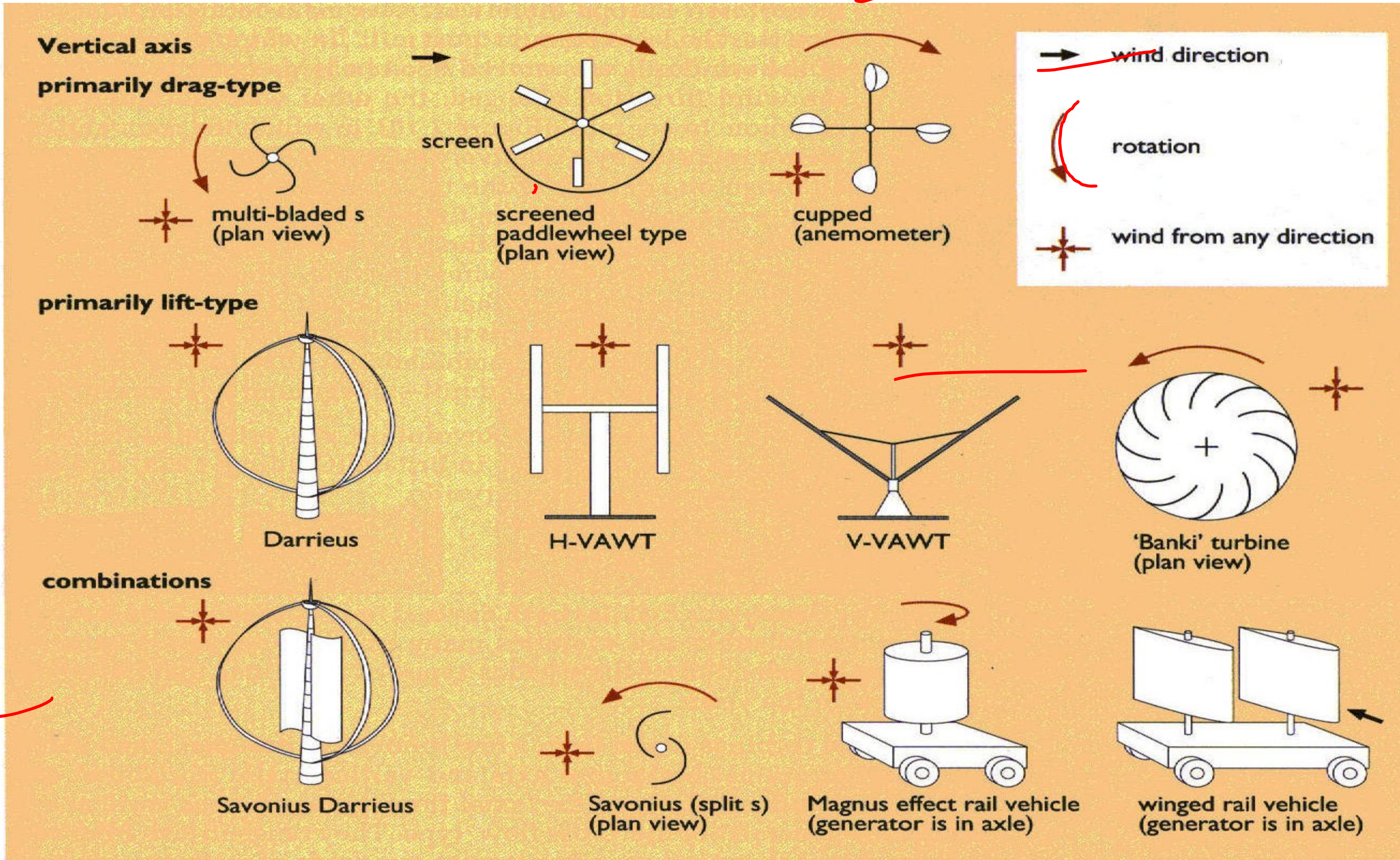
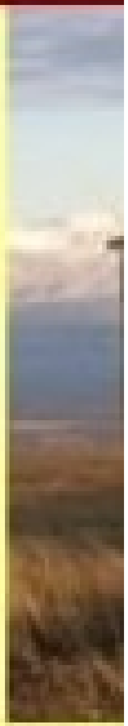


Figure 7.9 Some examples of the machines that have been proposed for wind energy conversion (source: adapted from Eldridge, 1975. For further information on these machines see Eldridge, 1975 and Golding, 1955)

TYPES OF WIND TU

- **1. Onshore:**
- Onshore wind turbines are placed in hilly and mountainous places and are at least three kilometers away from the nearest shore.



Near-shore win
within thr
nearest sh

Lift and Drag Type Machines

ind turbines make use of either lift force or drag force predominantly
use motion and accordingly known as **lift or drag type machines.**

lift devices the ratio of lift to drag forces may be as high as 30:1.

r the drag design, the wind literally pushes the blades out of the way.

ag devices are less efficient and turn slower than wind.

ey produce high torque and thus are suitable for pumping applicatio
high wind speeds they spill wind instead of producing more energy.

us they do not benefit from high energy density available in wind.

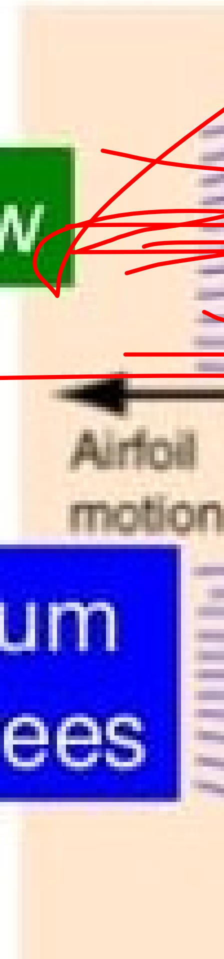
e lift blade design employs the same principle that enables aeroplanes
es and birds to fly.

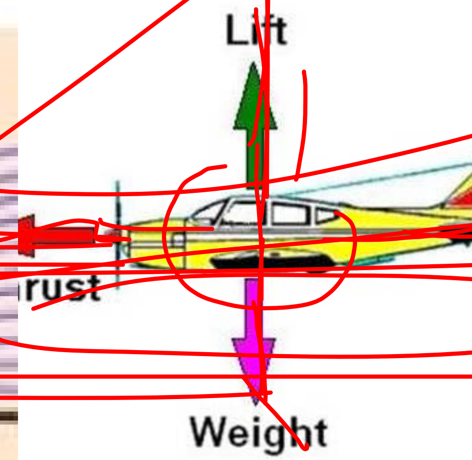
e blade is essentially an airfoil, or wing. When air flows past the blade,
nd speed and pressure differential is created between the upper and
wer blade surfaces.

Lift & Drag Forc

The *Lift Force* is perpendicular to the direction of motion. We want to make this force BIG.

α = low





α = medium
<10 degrees

Effect of Solidity

High solidity rotors use drag force and turn slower.
Solidity of Savonious rotor is unity and that of American multi-blade rotor it is typically 0.7.
Low solidity rotors, on the other hand, use lift force.
Lift devices usually have solidity in the range of 0.01 to 0.1.
They have slender airfoil blades. When solidity is less than 0.1, the device will usually not start up without first being rotated to generate lift.

Horizontal Axis vs Vertical Axis Turbin

lost wind turbines, used at present are of horizontal axis type.
hey have been well researched and have gone through extensive field trial.
s a result, well-established technology is available for HAWTs.
ome advantages of VAWT have recently generated considerable interest in
ype of turbine.
hese are:
(i) it can accept wind from any direction without adjustment, which avoids th
cost and complexity of yaw orientation system,
(ii) gearing and generators, etc., are located at ground level, which simplifie
design of tower, the installation and subsequent inspection and maintenanc
and (iii) also they are less costly as compared to HAWTs.

Wind turbines: Types

- Depending on Capacity
  - Utility scale (900kW to 2MW per turbine): us
generate bulk energy sold in power markets.
  - Industrial scale (50kW to 250kW per
commercial/community power applications, typi
  - Residential Scale (400 watts to 50kW): used in
- Depending on operations at different wind spe

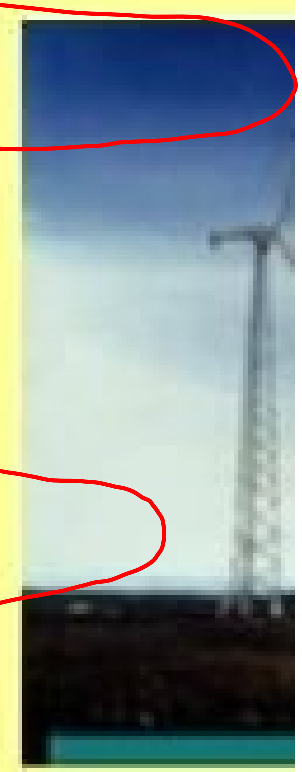
Variable speed	
Operates at a wider range of wind speeds	Attains peak

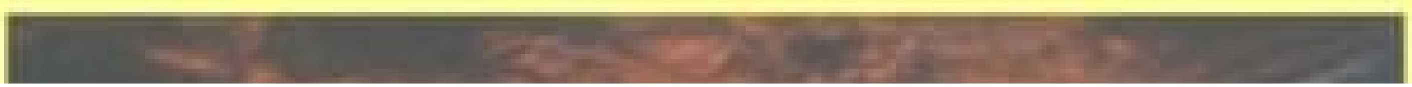
Turbines: Different Sizes an

Small (≤10 kW)

- Homes (Grid-connected)
- Farms
- Remote Applications

(e.g. battery changing, water pumping, telecom sites)



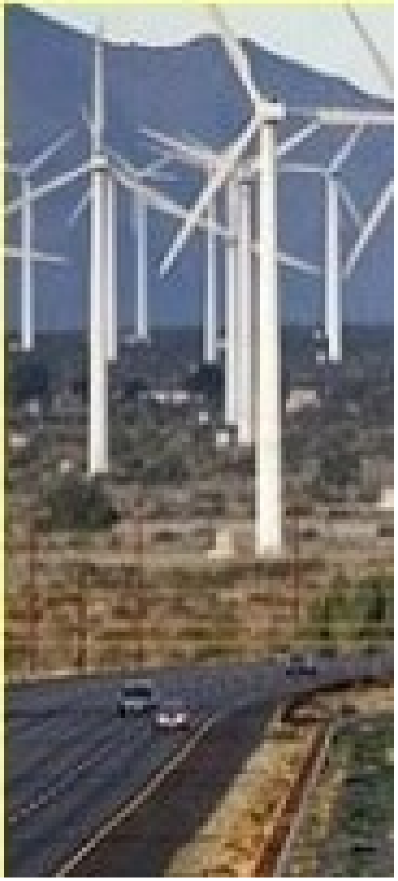


Wind Turbine Techn

Part 4

WIND FIRMS

Wind farms



Wind farms

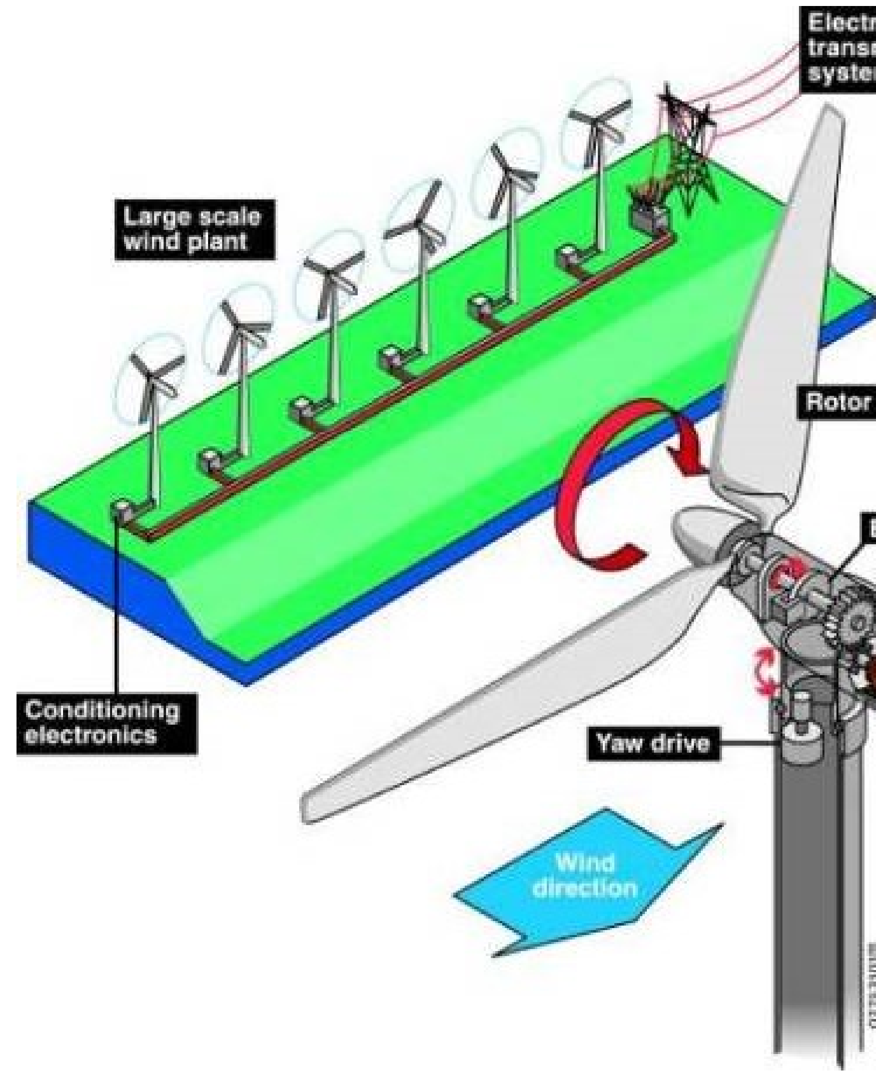
- Group of wind turbines operating in the same a
- Sizes range between 20 and 300MW
- Can be typically set up in a year
  - quicker than conventional energy plants

Inter-turbine and inter-row spacing varies as a function of rotor diameter and wind resource characteristics

Wide spacing
can maximize
increase infras
off exists.

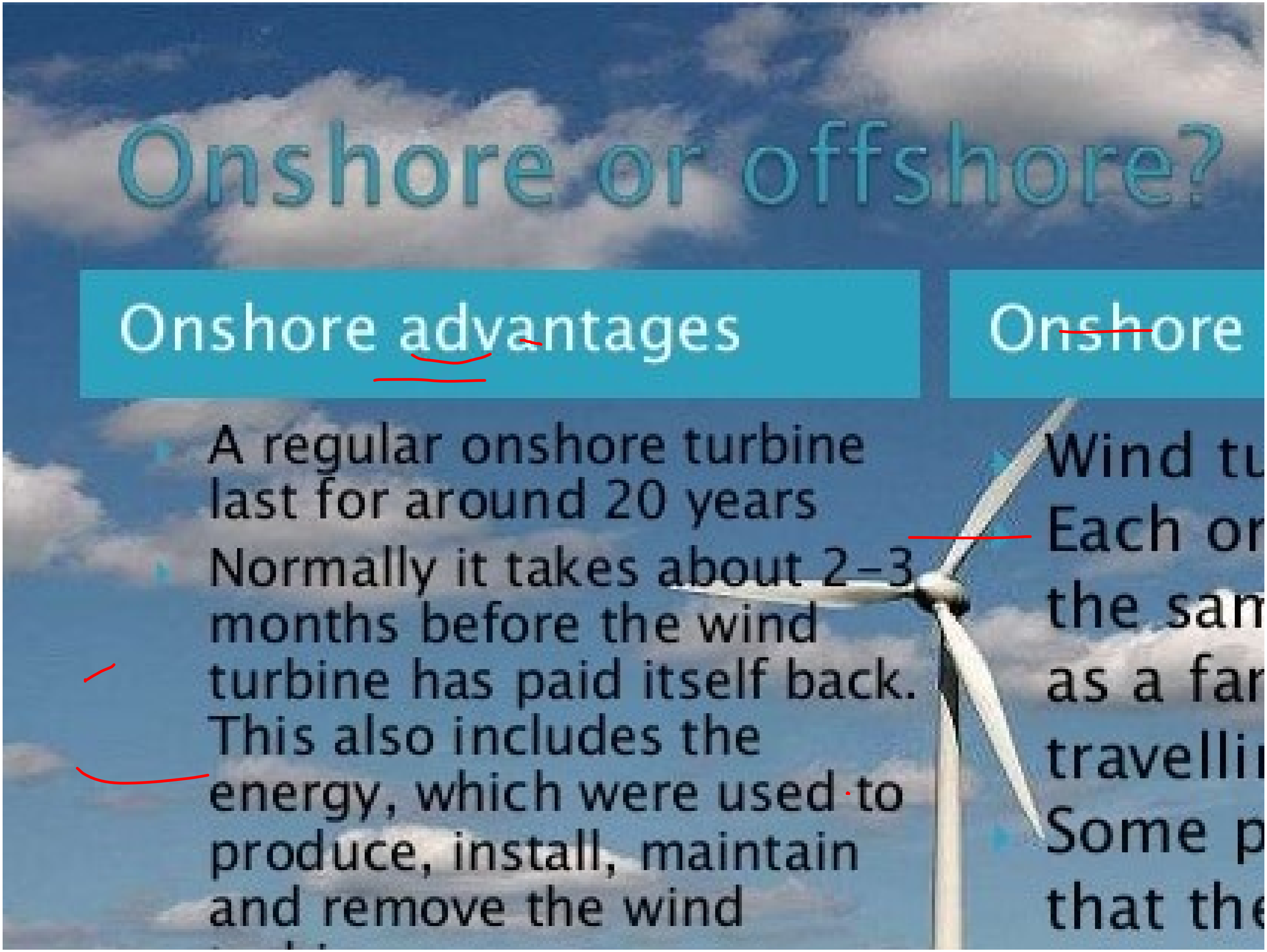
Sub-station

Large Wind Turbines / Wind Farms



Part 4

On shore off shore


Onshore or offshore?
Onshore advantages
A regular onshore turbine last for around 20 years
Normally it takes about 2-3 months before the wind turbine has paid itself back. This also includes the energy, which were used to produce, install, maintain and remove the wind
Onshore
Wind tu
Each or
the sam
as a far
travelli
Some p
that the

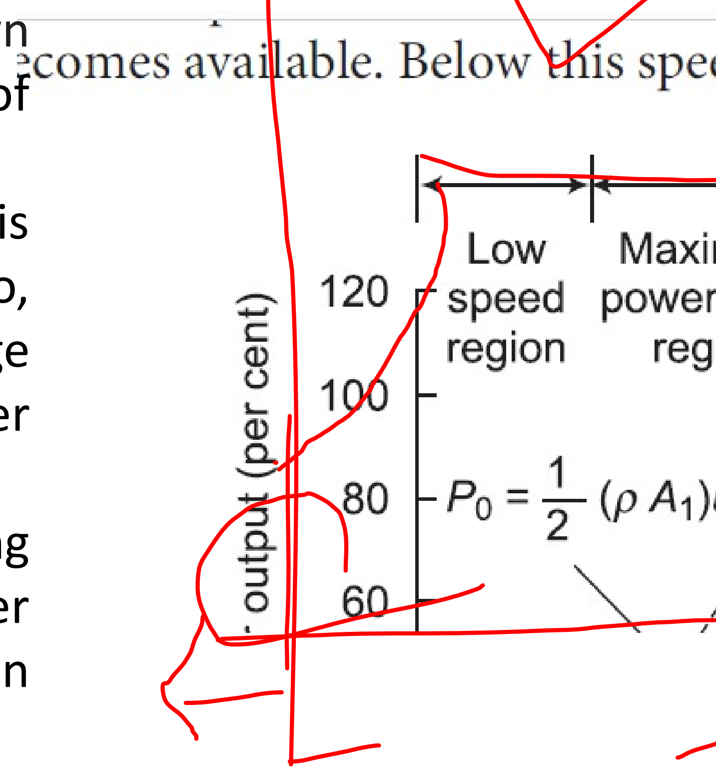

Onshore or offsh
Offshore advantages
A offshore wind turbine is stronger than a onshore turbine. It lasts around 25-30 years, and produces about 50 % more energy than a onshore turbine.
When a strong wind blows, it produces around 3-5
Offshore
More ex
More di
maintai

Speed Control Strategies for Wind Turbine

- Various options are available for speed control of a turbine. The particular control strategy depends on the size of the turbine.
- These methods may be grouped in the following categories:
  i. **No speed control at all**. Various components of the entire system are designed to **withstand extreme speed under gusty wind.**
  ii. **Yaw and tilt control**, in which the **rotor axis is shifted out of wind direction,** either by yaw control or by tilting the rotor plane with respect to normal vertical plane **when the wind exceeds the design limit.**
  iii. **Pitch control**, in which the pitch of the rotor blades is controlled **to regulate the speed**.
  iv. **Stall control**, in which the blades are shifted to a position such that they stall **when wind speed exceeds the safe limit**.

Wind Turbine Operation and Power versus Wind Speed Characteristics

Speed **Region (**Zero to Cut-in Speed**)** In this region, the turbine is
in braked position till minimum wind speed (about 5 m/s), known
t-in speed becomes available. Below this speed the operation of
urbine is not efficient.
mum Power **Coefficient Region** In this region, rotor speed is
d with wind speed so as to operate it at constant tip-speed ratio,
esponding to maximum power coefficient, CP max. In this range
nature of characteristics is close to that of maximum power
able in the wind
tant Power **Region (Constant Turbine Speed Region)** During
speed winds (above 12 m/s), the rotor speed is limited to upper
nissible value based on the design limits of system components. In
egion the power coefficient is lower than CP max.
ng Speed **Region (**Cut-out Speed **and Above)** Beyond certain
mum value of wind speed (around 25 m/s) rotor is shut down and
er generation is stopped to protect the blades, generator and
r components of the system.



Thank You

Save energy and water for Sustainable Life

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Dr.P.Dharmalingam
Accredited Energy Auditor
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Energy and Environment Sceine
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.**

Unit – 4 : Bio Energy

Bio Energy

- Introduction
- Biomass Types and Sources
- Biomass conversion Technologies p
- 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.

Dr.P Dharmalinam

BIO ENERGY

Session 1

Learning Objectives

In this Session you will be able to:

- ✓ **Know about the origin of biomass energy**
- ✓ **Recognize the importance of biomass as a useful source of renewable energy**

The Ex-President's Message: Independence

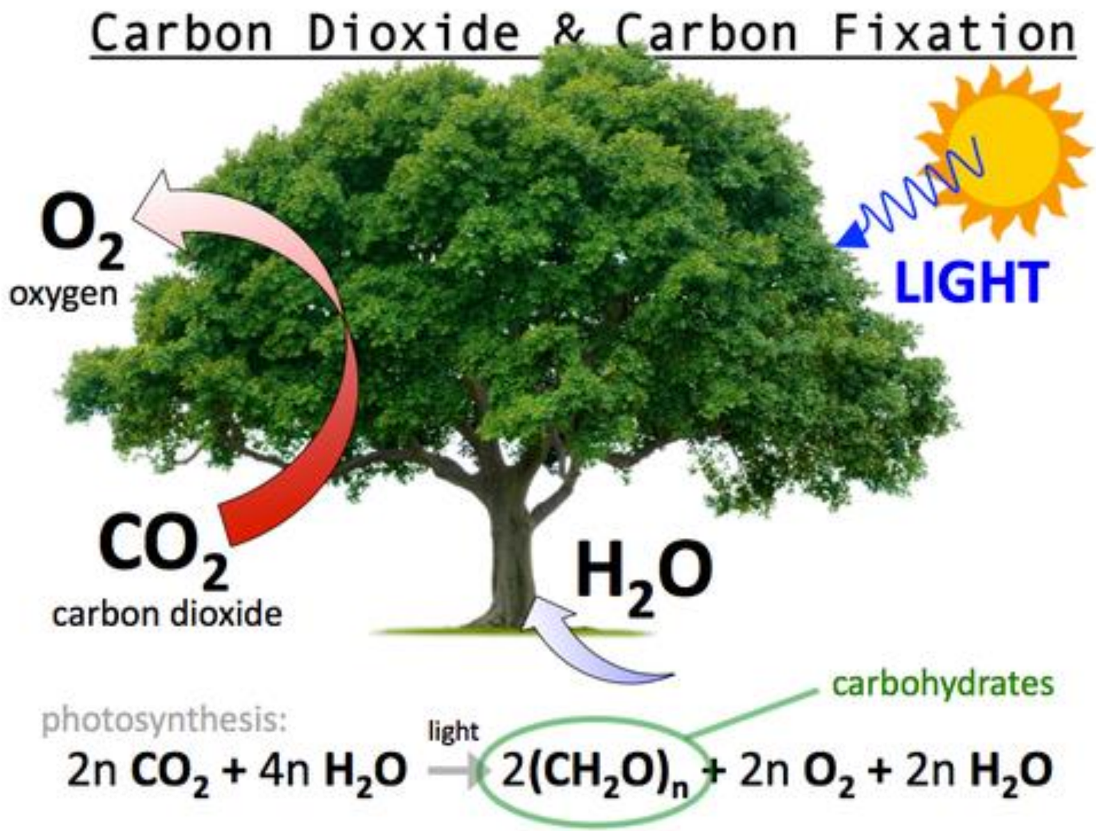
- Cut down energy losses
- Utilize technologies to provide a diverse supply of environmentally friendly energy
- "We must achieve Energy Independence by 2030", including a cut down in ALL sectors
- Increase the power generated **through renewable energy** sources from 5% to 25%
- *This is the **nation's "first and highest priority"***

Ex-**President A.P.J. Abdul Kalam**

(Rocket Scientist)

What is a Biomass?
How it is Generated?

A Lesson Learned from Nature

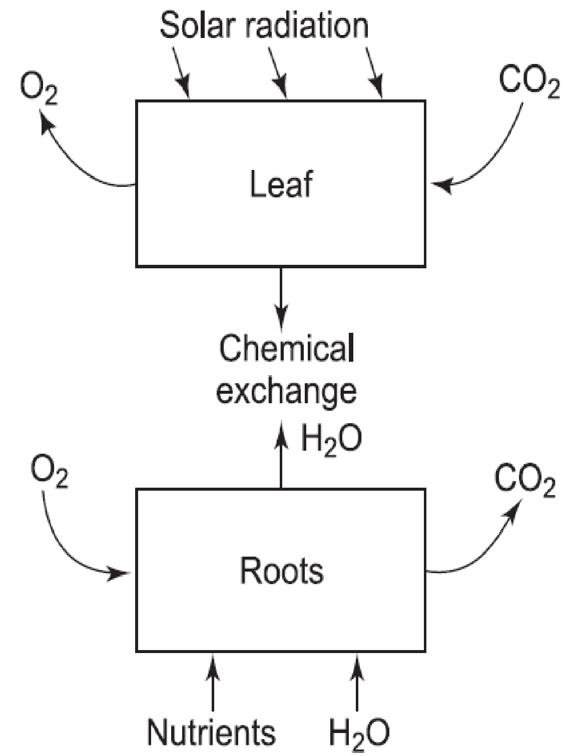


In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose - or sugar.

water	+	carbon dioxide +		sunlight	$\longrightarrow$	glucose + oxygen
$6\ H_2O$	+	$6\ CO_2$	+	radiant energy	$\longrightarrow$	$C_6H_{12}O_6 + 6\ O_2$

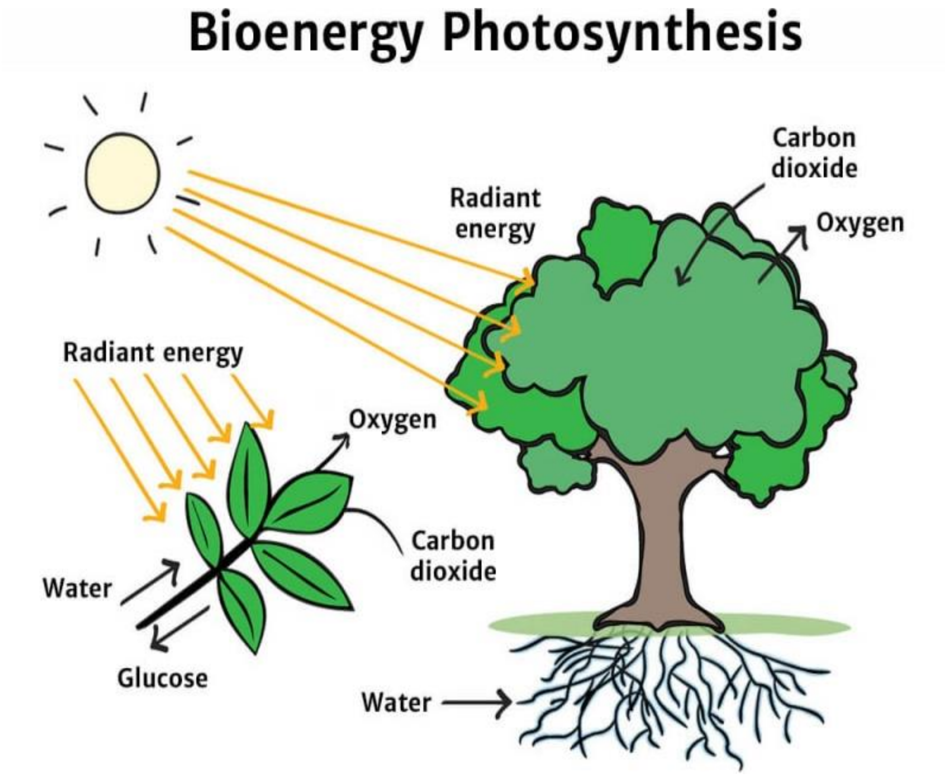
PHOTOSYNTHESIS PROCESS

- Solar radiation incident on green plants and other photosynthetic organisms performs **two basic functions:**
  i) **temperature control** for chemical reactions to proceed and
  ii) **photosynthesis process**.
- The fundamental conversion process in green plants is photosynthesis, which is the process of **combining CO_2 from the atmosphere with water plus light energy to produce oxygen and carbohydrates** (sugars, starches, celluloses and hemicelluloses).



$$6CO_2 + 6H_2O + \text{light energy} \xrightarrow{\text{Photosynthesis}} C_6H_{12}O_6 + 6O_2$$

Introduction to Biomass Energy



Biomass is a collective term used for all materials that are biogenic in origin, that is, derived from the product of photosynthesis

Biomass is **organic matter – anything that is alive or was a short time ago** - that can be used as an energy source.

1. Biomass is a form of **stored solar energy**.
2. Biomass is considered as **a carbon neutral**.

Introduction to Biomass Energy

- Biomass is a general term **for living material plants, animals, fungi, bacteria**.
- Biomass is basically organic matter such **as wood, straw, crops, algae, sewage sludge, animal waste and/or other biological waste**
- The energy obtained from biomass is known as biomass energy.

1. since biomass can be re-grown, it is potentially a **renewable resource.**
2. Animals feed on plants and plants grow through photosynthesis process using solar energy.
3. **photosynthesis process** is primarily responsible for generation of biomass energy.

Pelleted Fuel

Who are (*the persons*) spending most of their life to gather fuel(energy) in rural areas.?





BIOMASS ENERGY IN INDIA:

STATUS

- Biomass contributes **over a third of primary energy in India.**
- Biomass fuels are predominantly used in **rural households for cooking and water heating, as well as by traditional and artisan industries.**
- Biomass delivers most energy for the domestic use (rural - 90% and urban - 40%) in India (NCAER, 1992).
- Wood fuels contribute 56 percent of total biomass energy (Sinha et. al, 1994).
- Consumption of wood has grown annually at 2 percent rate over past two decades
- the biomass sources contribute **14% of global energy** and **38% of energy in developing countries (**Woods and Hall, 1994)

What are the different types of Biomass?

What are usable forms of BIOMASS and its composition properties

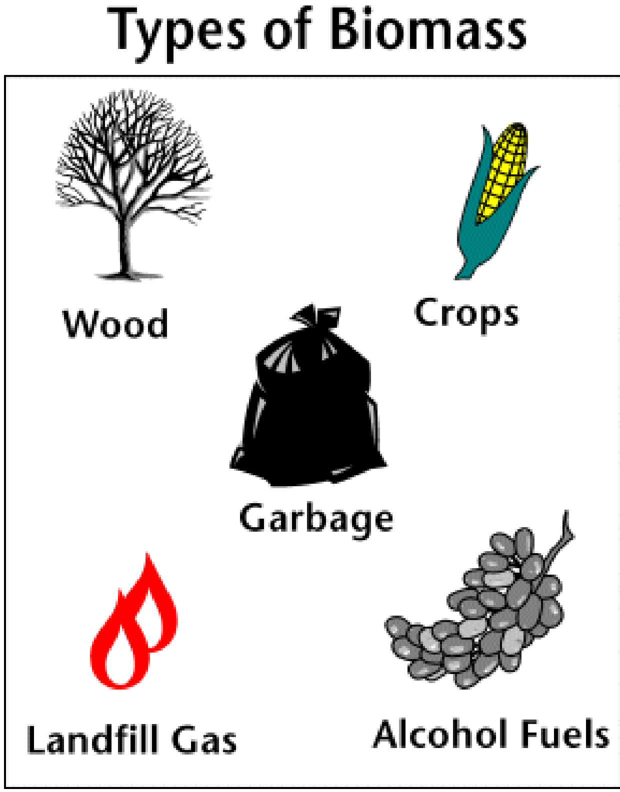
What is Biomass?

Biomass is dead organic matter

- Examples: corn, algae, sugar cane

Types of biomass

- **Woody**
  - Examples: coconut, oil palm, poplar, pine
  - Generally burned to heat space or heat water to produce steam to generate electricity via a turbine generator
    - When utilized directly: **direct biomass**
- **Non-Woody**
  - Examples: corn, sugar cane, soybeans, algae
  - Generally processed to produce different liquid biofuels
    - **Indirect biomass**



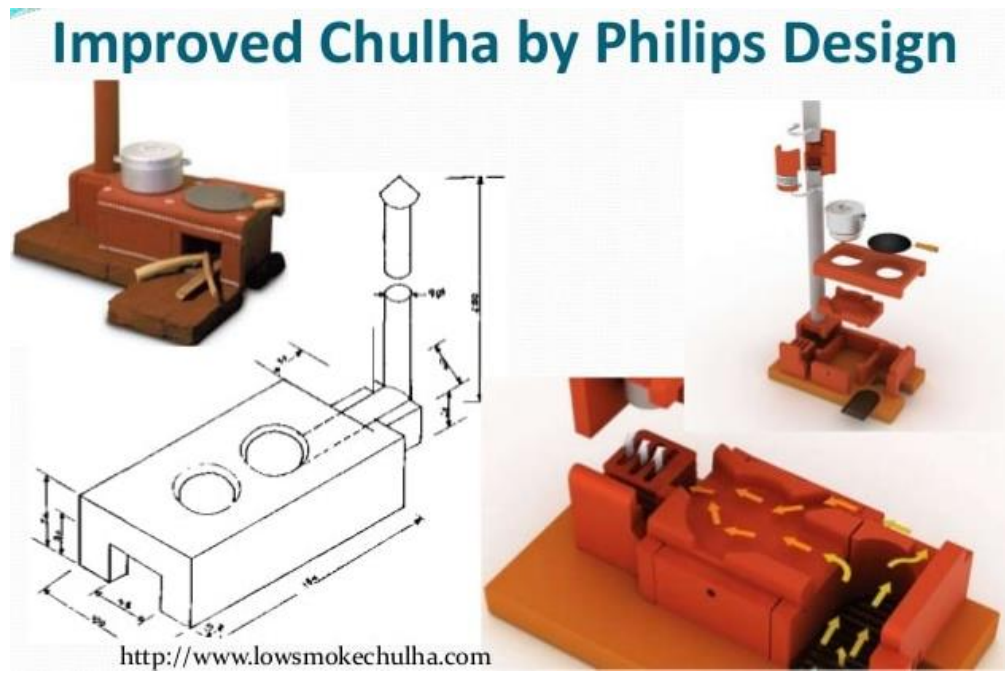
USABLE FORMS OF BIOMASS, THEIR COMPOSITION & FUEL PROPERTIES

1 Fuel Wood (Virgin Wood)

- Wood is the oldest source of biomass energy and main source of energy used by mankind for centuries.

- **Direct combustion** is the simplest way to obtain heat energy. Its energy density is 16–20 MJ/kg. It can also be converted to more useful forms such **as charcoal or producer gas**.

- Conventional household stove (Chulhas), only 5 % efficiency.
- Improved stoves (Chulhas) and use of pressure cooker is being encouraged for better fuel utilization.



USABLE FORMS OF BIOMASS, THEIR COMPOSITION AND FUEL PROPERTIES

2 Charcoal :

- Charcoal is a clean (smokeless), dry, solid fuel of black color.
- It has 75–80 per cent carbon content and has energy density of about 30 MJ/kg.
- Obtained by carbonization process of woody biomass to get higher energy density .
- Chemical grade charcoal has many uses in laboratory and industrial chemical processes. It is also used for making high quality **steel**

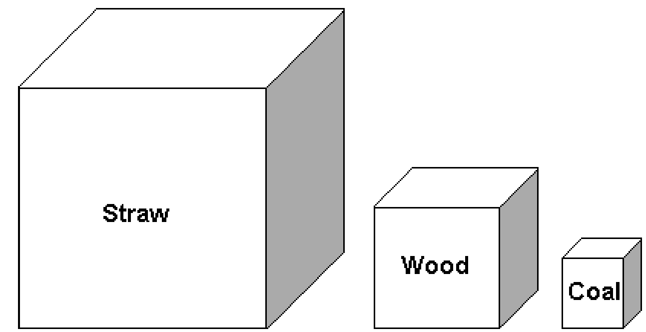
USABLE FORMS OF BIOMASS, THEIR COMPOSITION AND FUEL PROPERTIES

3. Fuel Pellets and Briquettes

- Crop residues such as **straw, rice husk etc. and waste wood** are **pressed to form lumps**, known as fuel **pellets or briquettes** and used as solid fuel.
- The purpose is to reduce moisture content and increase the energy density of biomass making it more feasible for long distance transportation.

Pelleted Fuel

Huge volume of Bio mass transportation Transport cost is high



Equivalent energy content by volume of unprocessed materials.

Why Densify?

The low density of biomass materials poses a challenge for the handling, transportation, storage and combustion processes. These problems may be addressed through densification, a process that produces either liquid or solid fuel with denser and more uniform properties than the raw biomass.

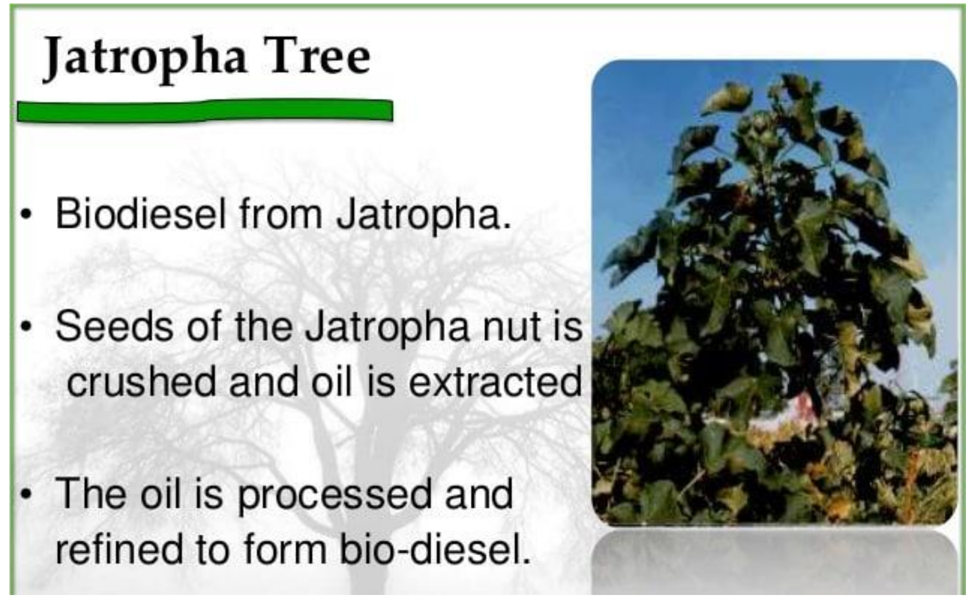
BRIQUETTED BIOMASS

Bulk Density : **600 – 800 kg / m^3**

USABLE FORMS OF BIOMASS, THEIR COMPOSITION AND FUEL PROPERTIES

4. Bio-diesel –

- Vegetable oils, edible as well as non-edible can be used *(after some chemical processing)* in pure form or its blend with petroleum diesel as fuel in a compression–ignition (diesel) engine.
- Bio-diesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics



5. Bio-ethanol

1. Ethanol (C_2H_5OH) is a colorless liquid biofuel.
2. Its boiling point is 78 °C and energy density is 26.9 MJ/kg.
3. It can be derived from wet biomass containing **sugars** (e.g. sugarcane, sugarbeet, sweet sorghum, etc.), **starches** (grains, tubers such as potato, cassava, etc.) **or cellulose** (woody matter).

Replace Conventional Oil

corn/suar cane

ethanol plant

cellulosic breakdown to sugar or fuel

cellulosic biofuel

lasts a long time

does no harm

Methanol and ethanol blending in petrol

Advances

✓ Euro 6/VI- 20km/lit

✓ Electric Car/Hybrid

✓ Ethanol Blending 20%

- India has adopted Euro 6/VI equivalent standards that will go into effect in 2020.
- The government is promoting use of electric and hybrid vehicles.
- Government of India has also proposed **methanol and ethanol** blending in petrol.

USABLE FORMS OF BIOMASS, THEIR COMPOSITION AND FUEL PROPERTIES

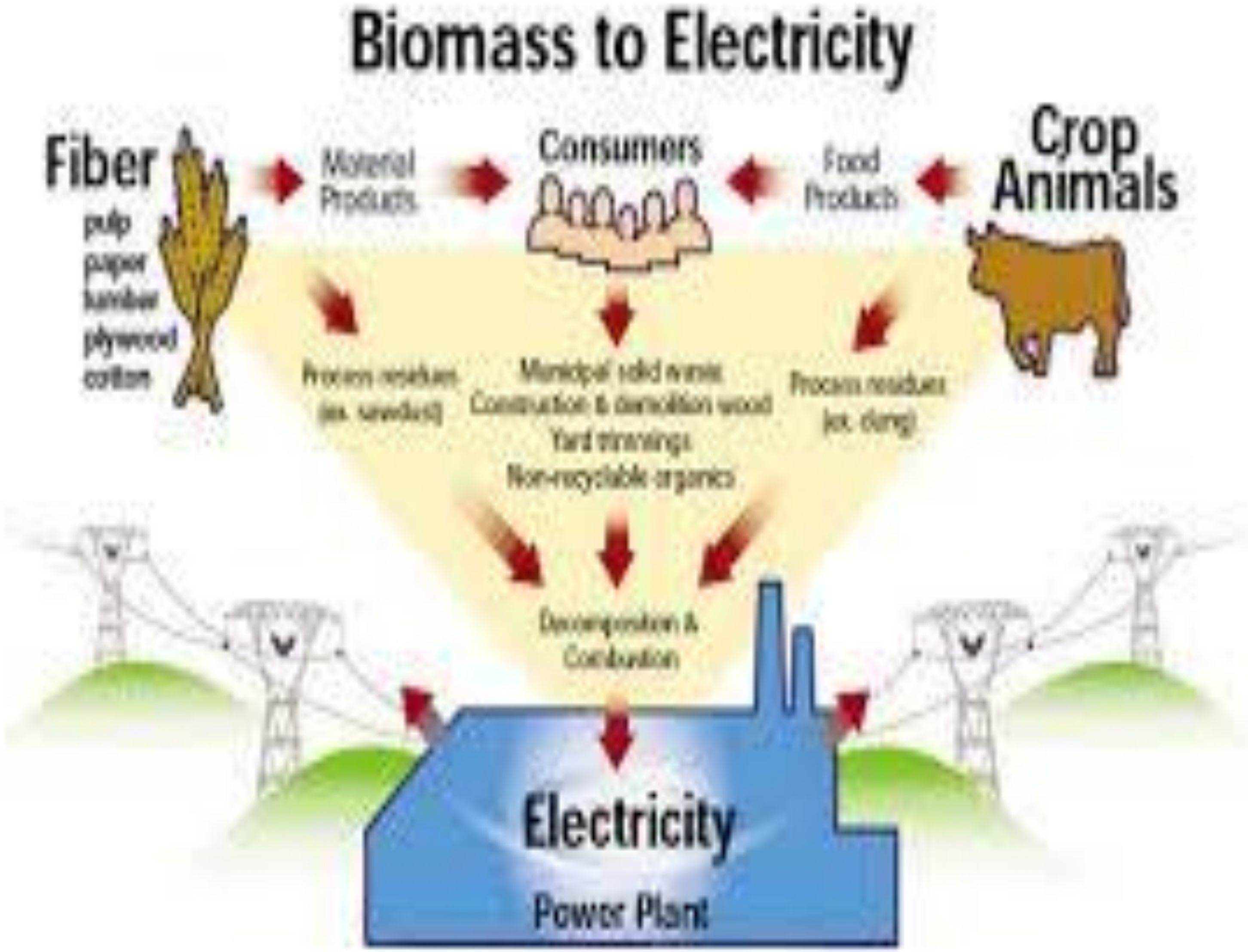
6. Biogas - Organic wastes from plants, animals and humans contain enough energy to contribute significantly to energy supply in many areas, particularly the rural regions of developing countries. Aquatic biomass can also be used. Biogas is produced in a biogas fermenter or digester. Nitrogen rich sludge (fertilizer) is also produced as a byproduct with improved sanitation as an added bonus

7. Producer Gas - Woody matter such as crop residue, wood chips, bagasse (fibrous residue of sugarcane after juice extraction), rice husk, coconut shell, etc., can be transformed to producer gas (also known as synthesis gas, syn gas, wood gas, and water gas or blue gas) by a method known as thermal gasification of solid fuel. The composition of gas produced depends upon the type of biomass and the design of gasifier.

Bio mass Energy

Community Biogas plant at Methan, Distt. Mehsana, Gujarat

Biomass gasifier based village electrification project commissioned at Gosaba village in sunderbans, West Bengal.


Biomass to Electricity
Fiber
pulp
paper
lumber
plywood
cotton
Material Products
Consumers
Food Products
Crop
Animals
Process residues
(ex. dung)
Construction & demolition wood
Non-recyclable organics
Decomposition &
Combustion
Electricity
Power Plant

Direct Combustion of Biomass
and Electricity Generation

Direct combustion is the combustion of biomass in a grate, stoker or fluidized bed with excess air followed by capturing the release of energy, which can then be used to provide steam or hot water for process heating and/or for providing **electricity**

Agro Residues

Table 1.15 Ultimate Analysis of Typical Agro Residues

	Deoiled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Mineral Matter	19.77	16.73	1.63	3.52
Carbon	36.59	33.95	48.55	44.95
Hydrogen	4.15	5.01	6.99	4.99
Nitrogen	0.82	0.91	0.80	0.56
Sulphur	0.54	0.09	0.10	0.08
Oxygen	31.02	32.52	41.93	31.94
GCV (Kcal/kg)	3151	3568	4801	4565

Rice Husk

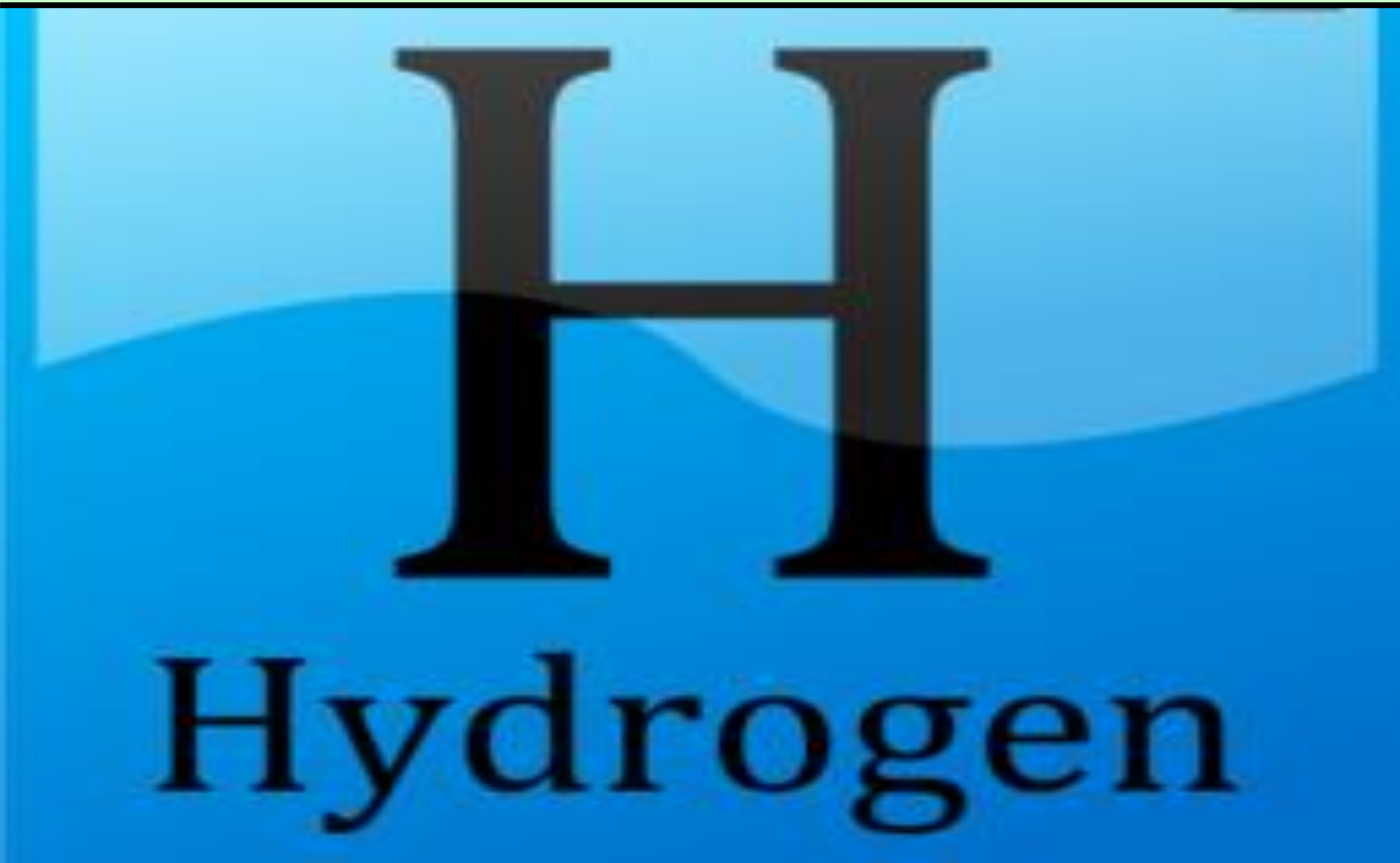
Rice Straw

Saw dust

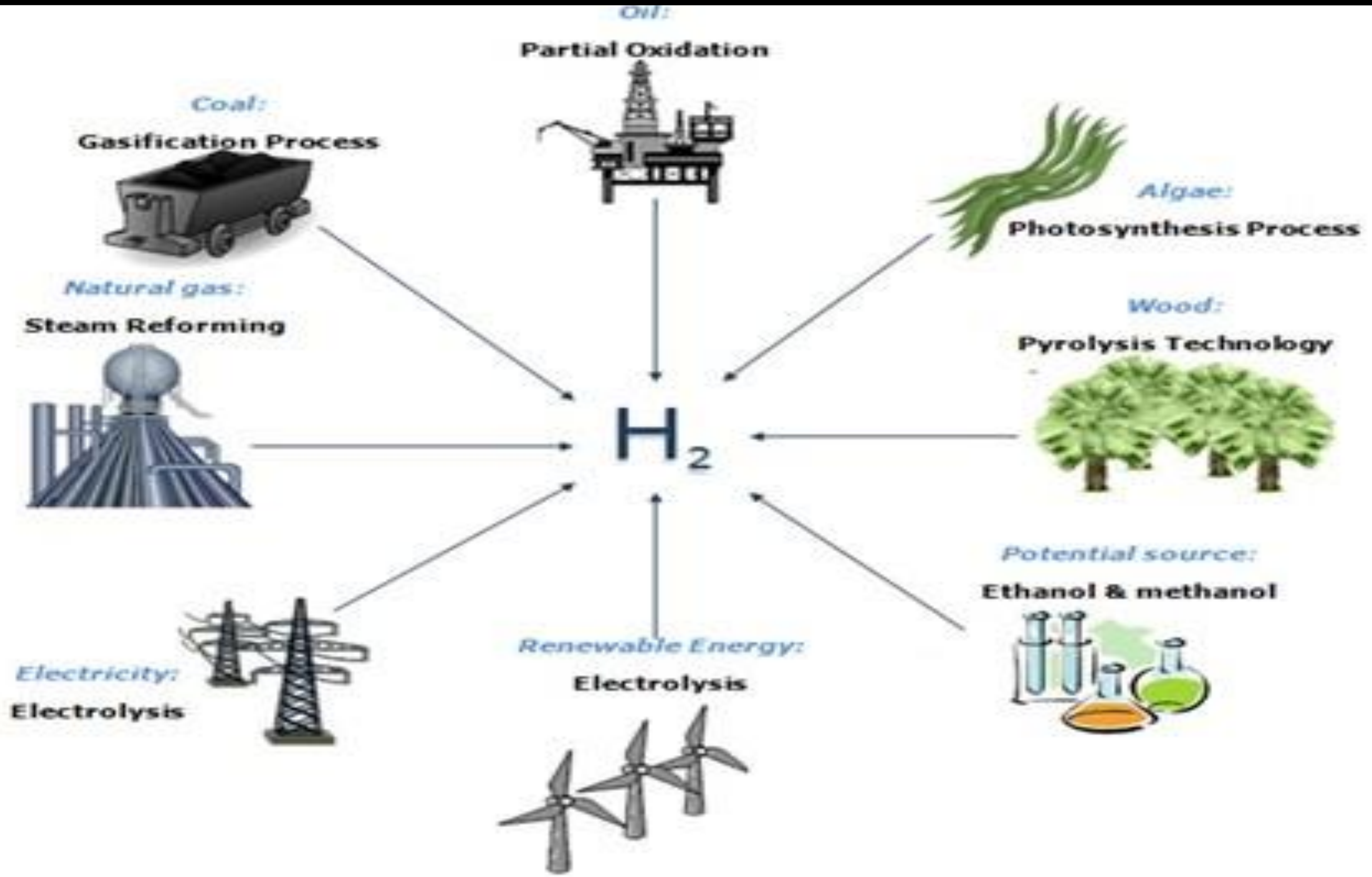
Coconut shell

Palm Shells

NEW ENERGY SOURCES



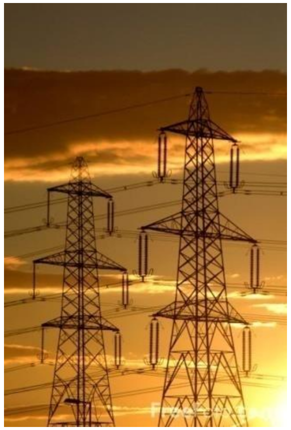
HYDROGEN SOURCES & PRODUCTION PROCESSES



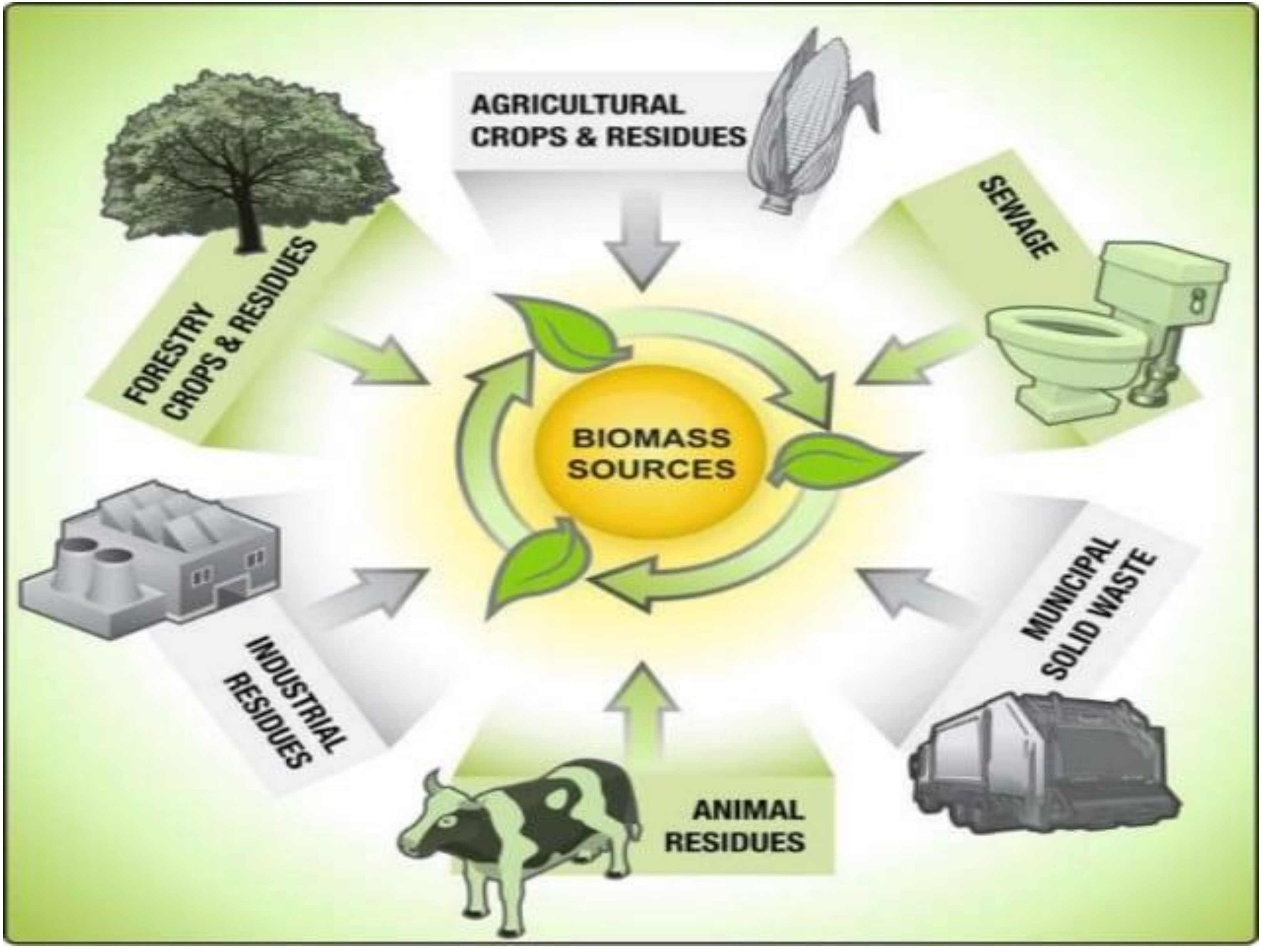

Shell
Hydrogen
HYDROGEN
WARNING
Shell
Hydrogen

Bioenergy Types

- **Biofuels**
  - Liquids
    - Methanol, Ethanol, Butanol, Biodiesel
  - Gases
    - Methane, Hydrogen
- **Bioheat**
  - Wood burning
- **Bioelectricity**
  - Combustion in Boiler to Turbine
  - Microbial Fuel Cells (MFCs)



What are the different Sources of Biomass?



Different Sources of Biomass

Biomass resources for energy production encompass a wide spectrum of materials ranging from

1. **silviculture (forest),**
2. **agriculture (field),**
3. **aquaculture (fresh and sea water)**
4. **industrial and social activities that produce organic wastes residues (food processing, urban refuse, etc.).**

Agricultural and Forestry Wastes

1. Crop and forestry residues
2. Animal manures
3. Food / feed processing residues
4. Logging residues (harvesting and clearing)
5. Wood processing mill residues
6. Paper & pulping waste slurries
7. municipal solid wastes, sewage, industrial waste

BIOMASS RESOURCES

1. Forests

- Forests; natural as well as cultivated, serve as a source of fuel wood, charcoal and producer gas.
- Forest waste and residues from forest processing industries can be utilized at the mill itself.
- Forest resource is consumed, not just for firewood but also for sawn timber, papermaking and other industrial purposes.
- Some fast growing energy intensive trees such as eucalyptus, poplar, pine are specially cultivated for the purpose of energy.

BIOMASS RESOURCES

Forests - Some fast growing energy intensive trees such as eucalyptus, poplar, pine are specially cultivated for the purpose of energy.

BIOMASS RESOURCES

2. Energy Crops

Certain cultivated plants produce raw material for bio-fuels. The greatest potential for energy farming occurs in tropical countries, especially those with adequate rainfall and soil condition.

.

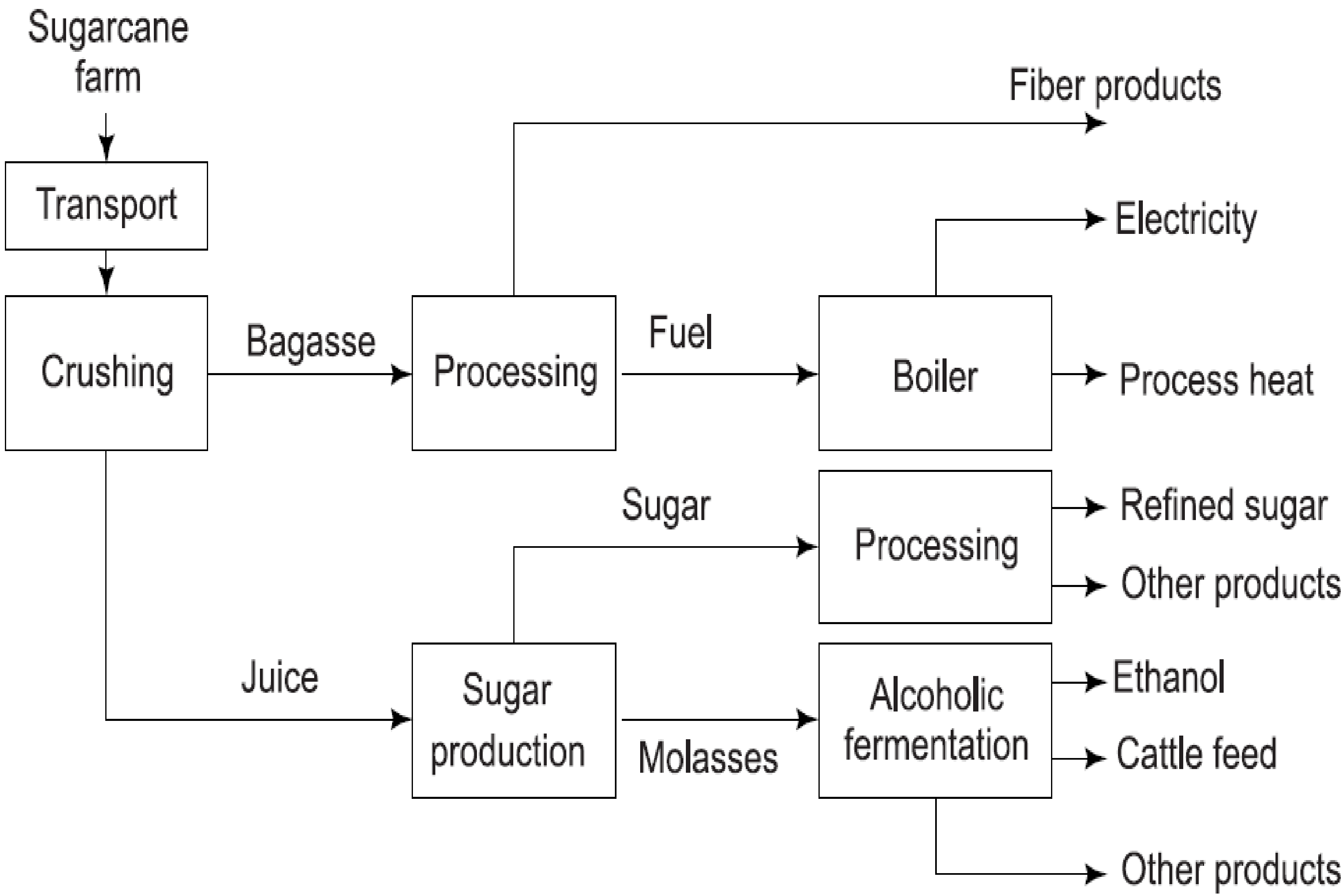
(a) Sugar Plants - Sugarcane is a major raw material source for bio-ethanol

(b) Starch Plants - Jerusalem artichoke provides raw material for bio-ethanol**.**

Grains, such as maize, barley, rice and wheat provide starch, which can be converted to ethanol.

(c) Oil Producing Plants In a short-term diesel engine test, over 40 different plant derived oils have been evaluated including sunflower, rapeseed, palm oil, castor oil, soybean, groundnut and cottonseed.

BIOMASS RESOURCES



Sugarcane industry products

BIOMASS RESOURCES

3. Agricultural Residues

Crop residues such as straw, rice husk, coconut shell, groundnut shell, sugarcane bagasse etc., are gasified to obtain producer gas. Alternatively, these are converted to fuel pellets or briquettes and used as solid fuel.

4. Aquatic Plants

Some water plants grow faster than land based plants and provide raw materials for producing biogas or ethanol. These are water hyacinth, kelp, seaweed and algae, etc.

5. Urban Waste

Urban waste is of two types: (a) Municipal Solid Waste (MSW or garbage) and (b) sewage (liquid waste). Energy from MSW can be obtained from direct combustion (incineration) or as landfill gas. Sewage can be used to produce biogas after some processing.

Benefits of biomass energy

Energy security: **Decentralized biomass energy could help nation to substantially** reduce dependence on fossil fuels.

Rural economic growth: **Biomass energy could stimulate growth in farming,**
forestry and rural industry leading to overall rural development. Biomass energy could also provide a productive avenue for using agricultural and forestry wastes, besides plantations.

Environmental protection: **By offsetting fossil fuel use and related emissions of** nitrogen oxides, sulfur dioxides, and other pollutants, biomass energy will
contribute to cleaner air and water. Furthermore, increased cultivation of carbonfixing plants will help mitigate greenhouse gas emissions that contribute to global

Main advantages of biomass energy are:

1. it is a **renewable source**; the **energy storage** is its in-built feature;
2. it is **indigenous source** requiring little or no foreign exchange;
3. forestry and agricultural industries that supply feed stocks also provide **substantial economic development** opportunities in rural areas;
4. **pollutant emissions from combustion of biomass are usually lo**wer than those from fossil fuels;
5. commercial use of biomass may avoid the problems of waste disposal in other industries
6. use of biogas plants supply clean gas, leads to improved sanitation, better hygienic conditions in rural areas
7. the nitrogen-rich bio-digested slurry and sludge from biogas plant serves as a very good soil conditioner and improves the fertility of the soil

Its main disadvantages are:

it is a **dispersed and lan**d intensive source,

it is often of **low energy density** and

it is also **labor inte**nsive and the cost of collecting large quantities for commercial application is significant.

- Most current commercial applications of biomass energy use material that has been collected for other reasons, such as timber and food processing residues and urban waste.

  capacity is determined by availability of biomass and not suitable for varying loads not feasible to set up at all locations

Quiz Session

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.**

BIO ENERGY

Session 2

Biomass conversion **Technologies part ii**
Bioenergy program in India,
Environmental benefits and impacts;

.

Renewable Energy Park

BIOMASS CONVERSION TECHNOLOGIES

Energy conversion technologies may be grouped into four basic types:

i) Physical method
   - (a) Pelletizaton
   - (b) Briquettng
   - (c) Expelling Agro Products
   - (d) Fuel Extraction

ii) Incineration (direct combustion)

iii) Thermo-chemical method

iv) Biochemical method.
   - (a) Ethanol Fermentation
   - (b) Anaerobic Fermentation

(i) Physical method

(a) Pelletizaton

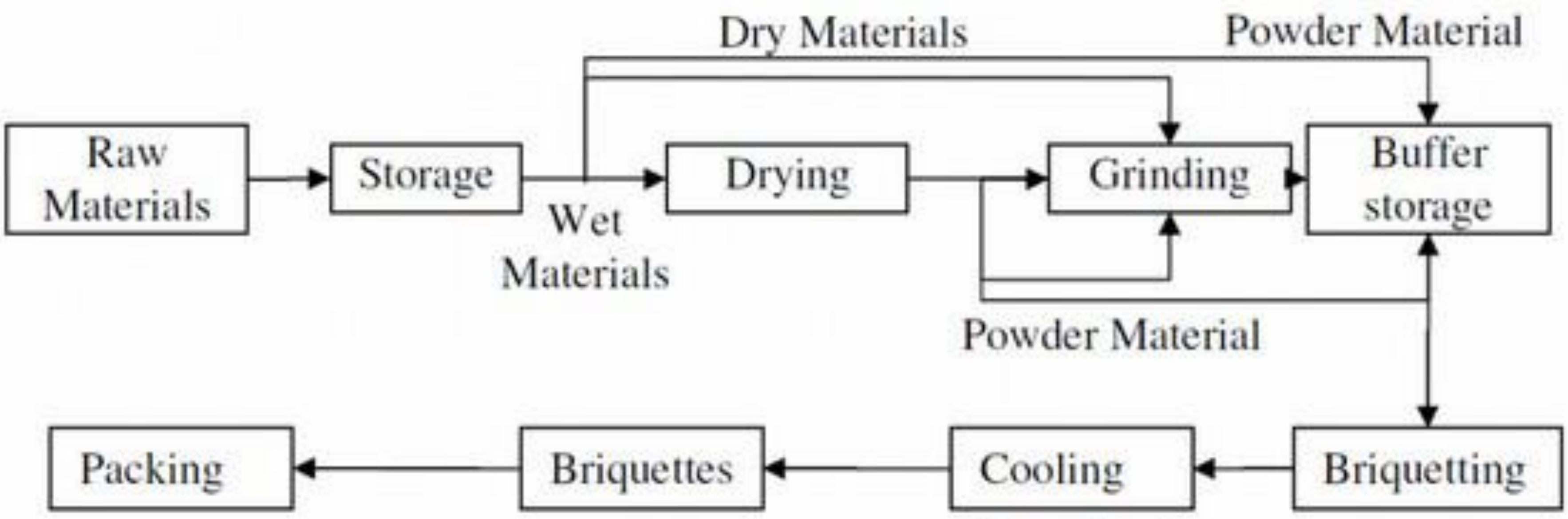
- Pelletization is a process in which waste wood is **pulverized, dried and forced under pressure through an extrusion device.**
- The extracted mass is in the form of pellets (rod; 5 to 10-mm dia and 12-mm long), facilitating its use in steam power plants and gasification system.

Pelletization reduces the moisture to about 7 to 10 percent and increases the heat value of the biomass

(i) Physical method

(b) Briquettng

- Biomass briquettes are **made from woody matter** (e.g. agricultura waste, sawdust, etc.).
- **It is a process similar to forming a wood pellet but on a larger scale.**
- The **screw press briquettes** are more homogeneous, have better crushing strengthThe natural lignin in the wood binds the particles of wood together to form a solid piece. no binders used
- Briquetting is brought about by **compression and squeezing out moisture**
- Burning a wood briquette is far **more efficient than burning firewood**.
- Moisture content of a briquette can be **as low as 4 %**, whereas in **green firewood it may be as high as 65%.**
- Used for replacement for oil or coal, and can be used to heat boilers /furnaces



Dry Materials
Powder Material
Raw Materials
Storage
Wet Materials
Drying
Grinding
Buffer storage
Powder Material
Packing
Briquettes
Cooling
Briquetting

(c) Expelling

- Agro Products Concentrated vegetable oils may be obtained from certain agro products and may be used as fuel in diesel engines.
- But ,direct use of plant oil is difficult due to high viscosity and combustion deposits.
- Therefore, these oils are upgraded by a chemical method known as **trans-esterification to overcome these difficulties.**
- Categories of certain materials with examples are
  - ✓ Seeds: Sunflower, rapeseed, soya beans, etc.
  - ✓ Nuts: oil palm, coconut copra, jojoba nuts
  - ✓ Fruits: olive, etc.
  - ✓ Leaves: eucalyptus, etc.

(d) Fuel Extraction

A milky **latex** is obtained from freshly cut plants,occasionally, .

- The material is called exudates and is obtained by cutting (tapping) the stems trunks of the living plants (a technique **similar to that, used in rubber production).**
- Some plants are not amenable to tapping and in such cases the whole plant (usuallya shrub) is crushed to obtain the product.

For example,

- **Euphorbia lathyris** plant is crushed to extract hydrocarbons of less molecular weight than rubber.
- The extract may be used as petroleum substitute.

(ii) incineration (direct combustion),

- **Incineration means direct combustion** of biomass for immediate useful heat.
- The heat (usually in the form of steam) produced are either **used to generate electricity or provide the heat for industrial process**

Furnaces and boilers have been developed for large scale burning of various types of biomass such as wood, waste wood, black liquid from pulp industry, food industry waste, and MSW. The economic advantage of **cogeneration** makes it attractive for adoption

(iii) Thermo-chemical method

Thermo-Chemical

- Biomass is **heated either in** **absence of oxygen or by partial combustion** of some of the biomass in restricted air or oxygen supply.
- Pyrolysis can process all forms of organic materials including rubber and plastics, which cannot be handled by other methods. The products are **three types of** fuels, usually

1. **a gas mixture** (H_2, CO, CO_2, CH_4 and N_2),
2. **oil like liquid** (water soluble phase including acetic acid, acetone, methanol and non-aqueous phase including oil,tar)
3. and a nearly pure **carbon char.**

Thermo-Chemical

The **distribution of these products** depends upon the type of feedstock, the temperature and pressure during the process and its duration and the heating rate.

A. **High temperature pyrolysis (~1000 °C)** maximizes the gaseous product. The process is known as **gasification.**

B. **Low temperature pyrolysis (up to 600 °C)** maximizes the char output. The process has been used for centuries for production of charcoal.The process is known as **carbonization.**

C. Liquid product is obtained through catalytic **liquefaction** process. **Liquefaction is** **a relatively low temperature (250–450** °C), highpressure (270 atm) thermo-chemical conversion of wet biomass,.

(iv) Biochemical method.

Biochemical: The process makes use of metabolic action of microbial organism on biomass to produce liquid and gaseous fuel. **Two major biochemical** processes are explained below:

(a) Ethanol **Fermentation**

- Alcoholic Fermentation is the decomposition in absence of air of simple hexose sugars (sugars containing six carbon atoms per molecule, i.e. $C6H12O6$) in aqueous solution by action of enzyme (a natural catalyst) present in yeast, in acidic conditions (pH value 4 to 5).
- The products are **ethanol and carbon dioxide ,**
- **$2C2H5OH + 2CO2$**

b) Anaerobic Fermentation (Anaerobic Digestion)

This process converts decaying wet biomass and **animal wastes into biogas** through decomposition process by the action of anaerobic bacteria (bacteria that live and grow in absence of oxygen).

- Carbon present in biomass may be ultimately divided between fully oxidized CO_2 and fully reduced CH_4.
- **Biogas = (largely CH_4 & CO_2)**
- The biomass material in the form of water slurry is digested by the bacteria anaerobically for several days in an airtight container.
- The reactions are slightly exothermic and small amount of heat (equivalent to 1.5 MJ per kg dry digestible material) is also generated that helps in maintaining favorable temperature.
- The most useful biomass materials appear to be animal manure, algae, kelp, hyacinth, plant residues with high moisture content.

Energy available from various biomass

The energy available from various biomass resources using various conversion technologies is listed in Table

S.N.	Biomass source	Biofuel produced	Conversion technology	Available energy (MJ/kg)
1.	Wood chips, saw mill dust, forest residues etc.	(Direct heat)	Incineration	16-20
2.	„	Gas Oil Char	Pyrolysis	40 (Nitrogen removed) 40 20
3.	Grain crops	Straw	Incineration	14–16
4.	Sugarcane residue	Bagasse	„	5–8 (fresh cane)
5.	Urban refuse	(Direct heat)	„	5–16 (dry input)
6.	Sugarcane juice	Ethanol	Fermentation	3–6 (fresh cane)
7.	Animal waste	Biogas	Anaerobic digestion	4–8 (dry input)
8.	Municipal sewage	„	„	2–4 (dry input)

Modern biomass energy technologies

Technology	Type of biomass	Conversion process	End use applications	Technology Status
Biomass gasification	Wood, woody biomass, agro and agro industrial residues	Thermo-chemical process which converts biomass into producer gas	Power generation: 10kW -1000 kWe. Thermal applications in small industries up to 3 MW_{th}.	Dual fuel and 100% gas engine based gasifiers available commercially
Biogas	Animal dung	Bio-methanation process which converts biomass into biogas	Cooking in households, Motive Power and Electricity generation	Dung-based plants commonly being built.
Biofuels	Non-edible vegetable oil seeds	Extraction of bio-oil from the oilseeds. Bio-diesel production through trans-esterification	Motive power and Electricity generation	Bio-diesel and Straight Vegetable Oil (SVO) demonstrated as fuels for transportation and power generation.

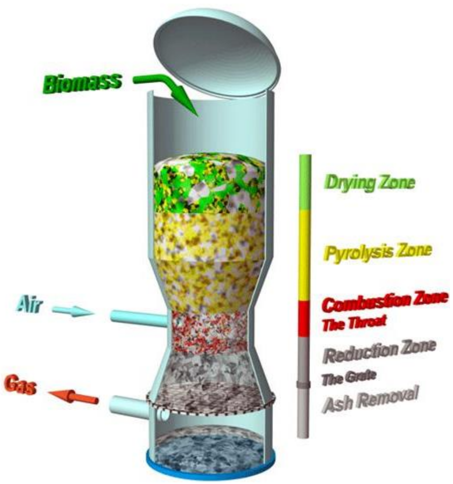
Source: Gokhale, Gupta, Kishwan et al. (2007)

A-Gasification of Biomass

Producer gas

A-Gasification of Biomass

- **Partial combustion** of biomass **produces carbon monoxide (CO) and hydrogen (H_2),** which are combustible gases and the gas produced this way is **called producer gas**
- Reaction takes place at temperature of about 1000°C. **Partial combustion is facilitated** by **<u>supplying air less than stoichiometric requirements</u>**.
- The products of combustion are combustible gases like Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4) and non useful products like tar and dust.



- The following reactions take place in the biomass gasification.

$C + O_2 = CO_2$

$H_2 + 1/2\ O2 = H_2O$ **Exothermic Reaction**

When these gases passes through bed of biomass converted charcoal in the reduction zone, the following reactions takes place

$C + CO_2 = 2CO$

$C + H_2O = CO + H_2$ **Reduction Reaction**

$CO_2 + H2 = CO + H_2O$ **Water GasReaction**

$C + 2H_2 = CH_4$ **Methanation Reaction**

Gasification Reactions **in a gasifier are:**

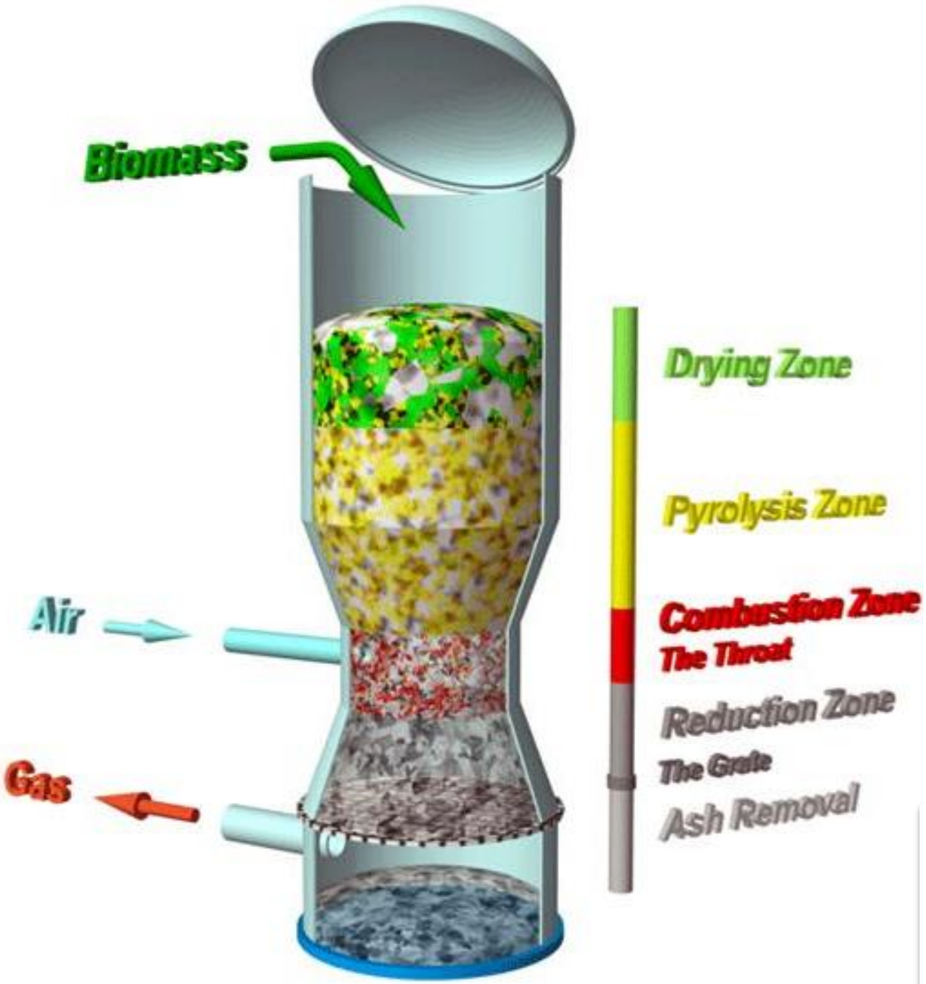
Drying*: Biomass fuels usually contain upto 35% moisture. When the biomass is heated to* around 100oC, the moisture gets converted into steam.

Pyrolysis*: After drying as the biomass is heated it undergoes pyrolysis. Pyrolysis is the* thermal decomposition of biomass fuels in the absence of oxygen. Biomass decomposes into solid charcoal, liquid tars and gases.

Oxidation: *Air is introduced in a gasifier in the oxidation zone. The oxidation takes place at* about 700-1400 oC, in which the solid carbonized fuel reacts with oxygen in the air producing carbon dioxide and releasing heat.
$C+O_2 = CO_2 + 406$ kJ/g.mol

Reduction*: At higher temperatures and under reducing conditions several reactions take place* which results in formation of CO, H_2 and CH_4.
$CO_2 + C = 2CO - 172.6$ kJ/g.mol
$C+H_2O = CO + H_2 - 131.4$ kJ/g.mol
$CO_2+H_2 = CO + H_2O - 41.2$ kJ/g.mol
$C+2H_2 = CH_4 + 75$ kJ/g.mol

A-Gasification of Biomass



A gasification system consists of four main stages:

- Feeding of feedstock
- Gasifier reactions where gasification takes place
- Cleaning of resultant gas
- Utilization of cleaned gas.

Producer gas

Typical Producer Gas Composition

$CO = 19 \pm 3\ \%$	$CH_4 = 03 \pm 1\%$
$H_2 = 18 \pm 2\%$	$CO_2 = 10 \pm 3\%$
$N_2 = 50 \pm 2\%$	

Average conversion efficiency of a gasifier is

$$\eta_{Gas} = \frac{\text{Calorific value of gas/kg of fuel}}{\text{Avg. calorific val ue of 1 kg of fuel}}$$

Find out the conversion efficiency of a gasifier, if 20 kg of wood (having a calorific value of 3200 kcal /kg) produces 46 m^3 of producer gas having an average calorific value of 1000 kcal / Nm^3.

Heat Input in the Gasifier= 20 x 3200= 64000 kcal

Heat Output as Producer gas= 46 x 1000= 46000 kcal

Conversion efficiency of Gasifier= Heat Output / Heat Input
= 46000 x 100 / 64000= 71.88 %

Replacement for Diesel

- The producer gas has relatively low calorific value, ranging from **1000 to 1200 kCal / Nm^3**.
- The conversion efficiency of the gasification process is the range of 60-70%.
- Spark ignition engines running on producer gas on an average produces 0.55-0.75 kWh of energy from 1 kg of biomass.
- Compression ignition (diesel) engines cannot run completely on producer gas.
- Thus to produce 1 kWh of energy they consume 1 kg of biomass and 0.07 litres of diesel.
- When gas is used in dual fuel DG set, it can result in **65-85% diesel savings.**

B-Biomethanation of Biomassass

Bio gas

BIOGAS PRODUCTION FROM WASTE BIOMASS

- Biomass, if left to **decompose in open air**, is acted upon by **aerobic bacteria** (bacteria that require oxygen for their survival and growth) to produce mainly CO_2, NH_3, etc.
- Thus **total carbon component completely get oxidized** to produce CO_2 and **no fuel is produced**.
- Biogas is produced from wet biomass with about 90–95 % water content by the action of **anaerobic bacteria** (bacteria that live and grow **in absence of oxygen**).Part of carbon is oxidized and another part reduced to produce CO_2 and CH_4.
- *These bacteria live and grow without oxygen*. They derive the needed oxygen by decomposing the biomass. The process is favored by wet, warm and dark conditions. The airtight equipment used for conversion is known as **biogas plant or digester**

B-Biomethanation of Biomass(Anaerobic Process)

Anaerobic digestion is a four-stage process.

- First stage, acidic bacteria dismantle the complex organic molecules into smaller molecules.
- second stage, these molecules further breakdown into organic acids, carbon dioxide and ammonia.
- A second type of bacteria (methanogenic bacteria) starts to convert these molecules into acetates and hydrogen in the **third stage**. which then converts to methane in the fourth stage

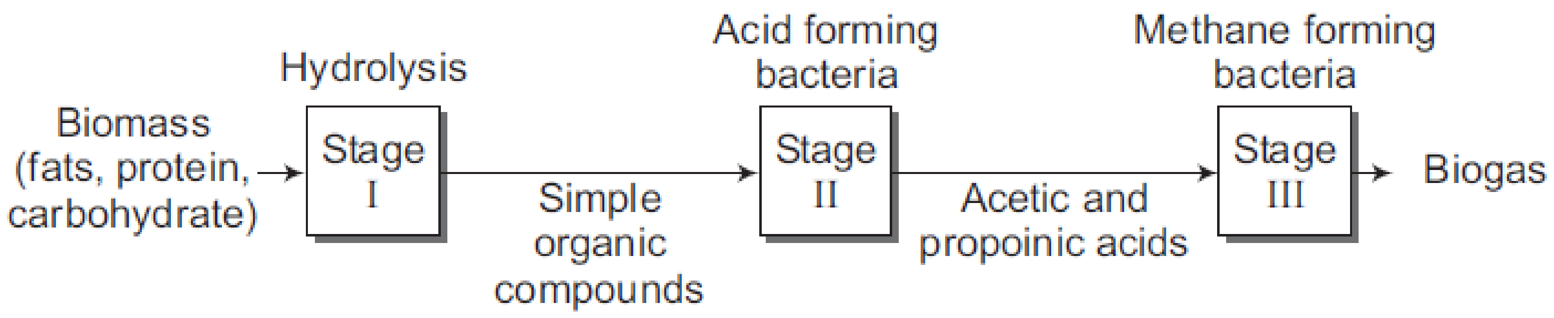


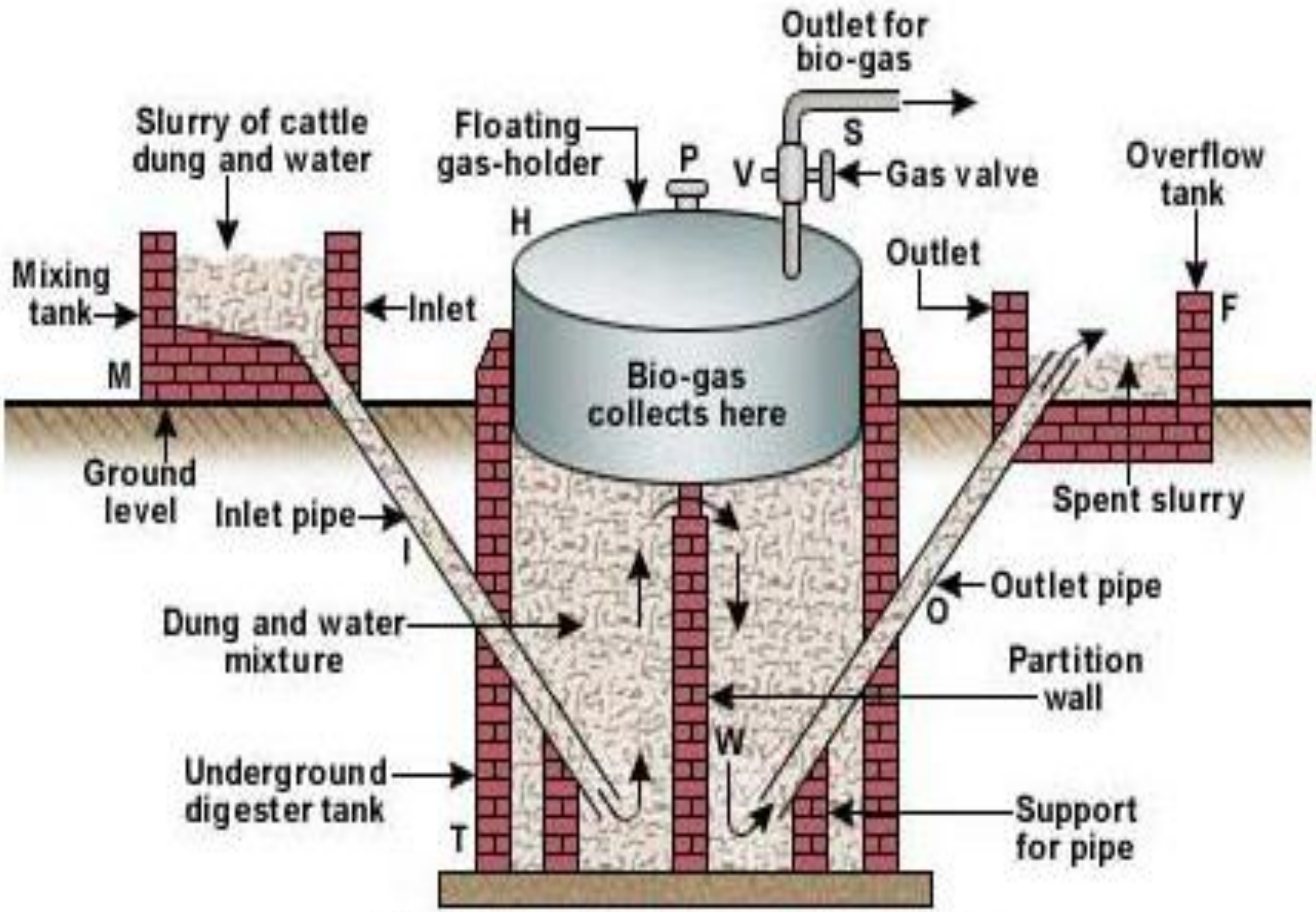
Figure 8.9 Various stages of anaerobic digestion process

B-Biomethanation of Biomass(Anaerobic Process)

- Biomass can also be converted into **bio-methane gas** which is composed mainly of **methane and carbon dioxide.**
- **Raw materials** for bio-methanation process include manure, sewage sludge, municipal solid waste, fruit and vegetable waste, food waste, distillery wastes and other biodegradable wastes.

- Biogas produced through anaerobic process using cow dung as input material is generally called as **Gobar gas** and typically comprising of around **60% methane and 40% carbon dioxide**
- **completely replace natural gas for applications** using natural gas such as **boilers, furnaces, IC engines** etc.

Anaerobic digestion is a four-stage process.



Floating gas-holder type bio-gas plant.

Applications of Biogas

3 million m³ biogas plant

Horizontal biogas plant for treating kitchen and dining wastes

Household biogas plant at rooftop

Dr.P. Venkatachalam TNAU

Basic information of biogas

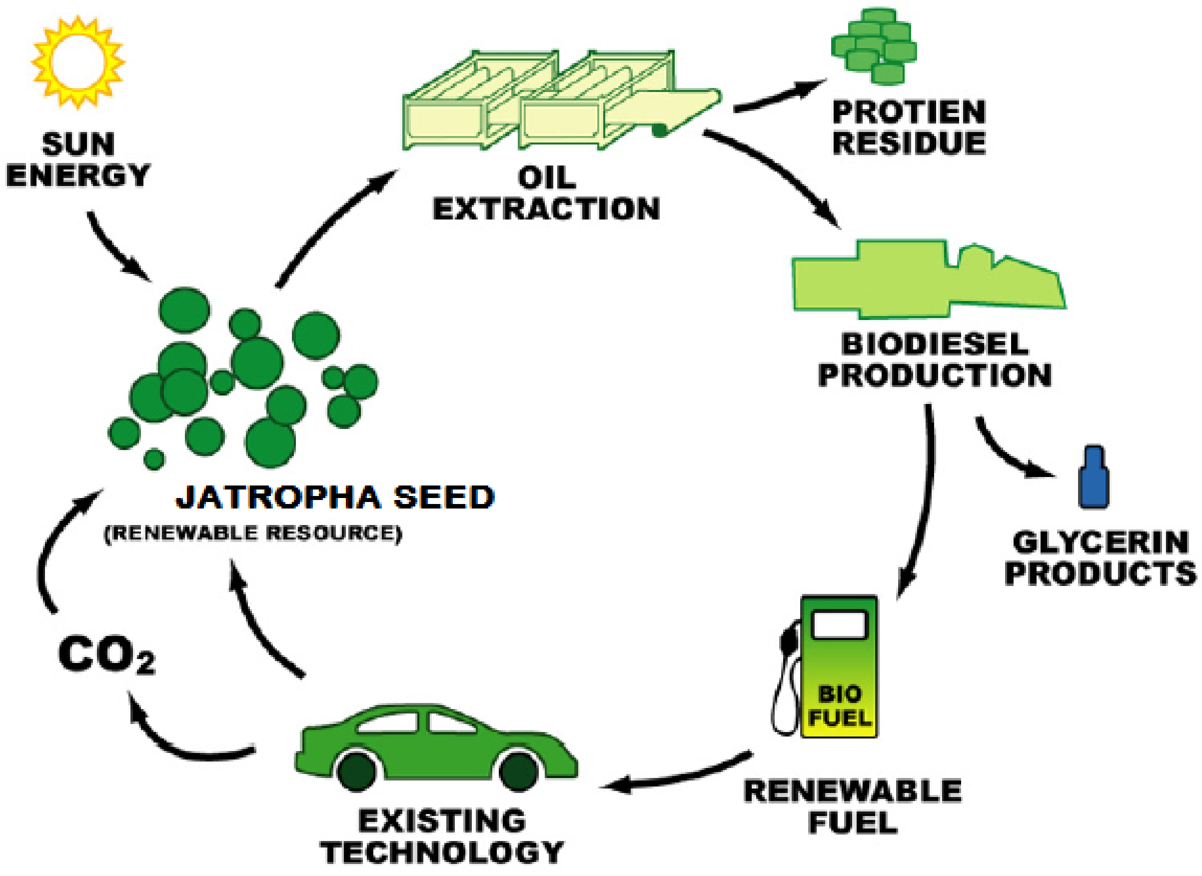
Particulars	Equivalent
$1m^3$ of biogas	1000 liters
Gas requirement for cooking	0.3 to $0.4m^3$/day/person
Gas requirement for lighting	0.10 to 0.12 m^3/hr/100cantle power light
Gas requirement running the engine	0.4 to 0.5 m^3/HP/hr
Calorific value of biogas	3500 to 4800 KCal/m^3
Optimum gas to air ratio for complete combustion	1.6 to 7
Gas production per kg of wet dung	0.04 to $0.05m^3$
Optimum temperature for maximum gas production	30 to 35°C

25 kg Fresh Dung

Direct Burning		Biogas
5 kg dry dung	← Product →	1 cu m biogas
10460 kCal	← Gross energy →	4713 kCal
10%	← Device efficiency →	55%
1046 kCal	← Useful energgy →	2592 kCal
None	← Manure →	10kg air dried manure

C- Biofuels from Biomass

❖ Biomass can be converted into liquid fuels such as **Ethanol and Biodiesel** to partially **replace the conventional petroleum fuels**.



Ethanol

- Ethanol is **commonly produced by the** fermentation of molasses, a **by-product in sugar** manufacture.
- It is also p**roduced by fermenting any biomass feedstock** rich in carbohydrates (starch, sugar or cellulose). e.g.: Sugar beet, Sweet corn and Ligno-cellulosic materials (straw and wood waste), which are much cheaper than molasses, are now being considered for manufacturing ethanol.
- **Ethanol is used as a fuel additive** to cut down vehicle's carbon monoxide and other smog causing emissions.
- Flexible fuel vehicles, which **run on mixture of gasoline, use up to 85% ethanol**.

Biodiesel

- Biodiesel is a good alternative for diesel.
- The most economical way of producing biodiesel is by transesterification of extracted oil (e.g. Jatropha seeds oil) with alcohol such as methanol.
- Jatropha is a non edible tree-borne oilseed which grows in dry and arid land. **Biodiesel can be used as an additive** to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines.
- All oils extracted from plant origin, waste cooking oil and animal fat can be used as raw materials for biodiesel production.

BIOMASS TO ETHANOL PRODUCTION

- Ethanol is manufactured by action of microorganisms on carbohydrates.
- The process is known as **alcoholic fermentation**. Carbohydrates can be divided into three major classes in order of increasing complexity.
- (a) Monosaccharides .Most common monosaccharides are glucose ($C_6H_{12}O_6$) and fructose ($C_6H_{12}O_6$). More precisely glucose and fructose can be represented by formulae $HCO - (HCOH)_4 - CH_2OH$ and $CH_2OH - CO - (HCOH)_3 - CH_2OH$ respectively. Glucose occurs naturally in sweet fruits (e.g. ripe grapes), honey, etc.

BIOMASS TO ETHANOL PRODUCTION

(b) Oligosaccharides Oligosaccharides yield few but definite numbers (2–10) of monosaccharide molecules on hydrolysis. For example, disaccharide (such as sucrose, maltose, etc., both having formula $C_{12}H_{22}O_{11}$) produces two monosaccharide molecules on hydrolysis. Sucrose (common sugar) occurs naturally in sugar cane and beetroot. Maltose (malt sugar) is derived from starch.

(c) Polysaccharides These are high molecular mass carbohydrates, which yield large number of monosaccharides molecules on hydrolysis. Examples are starch and cellulose, both having general formula $(C_6H_{10}O_5)_n$. Large numbers (few hundreds to few thousands) of glucose units are joined together in a complex chain. Starch occurs naturally in all plants, particularly in seeds. The main sources are maize, barley, rice, wheat, potato, cassava and sorghum, etc. Wood contains 45–50 per cent while cotton contains 90–95 per cent cellulose.

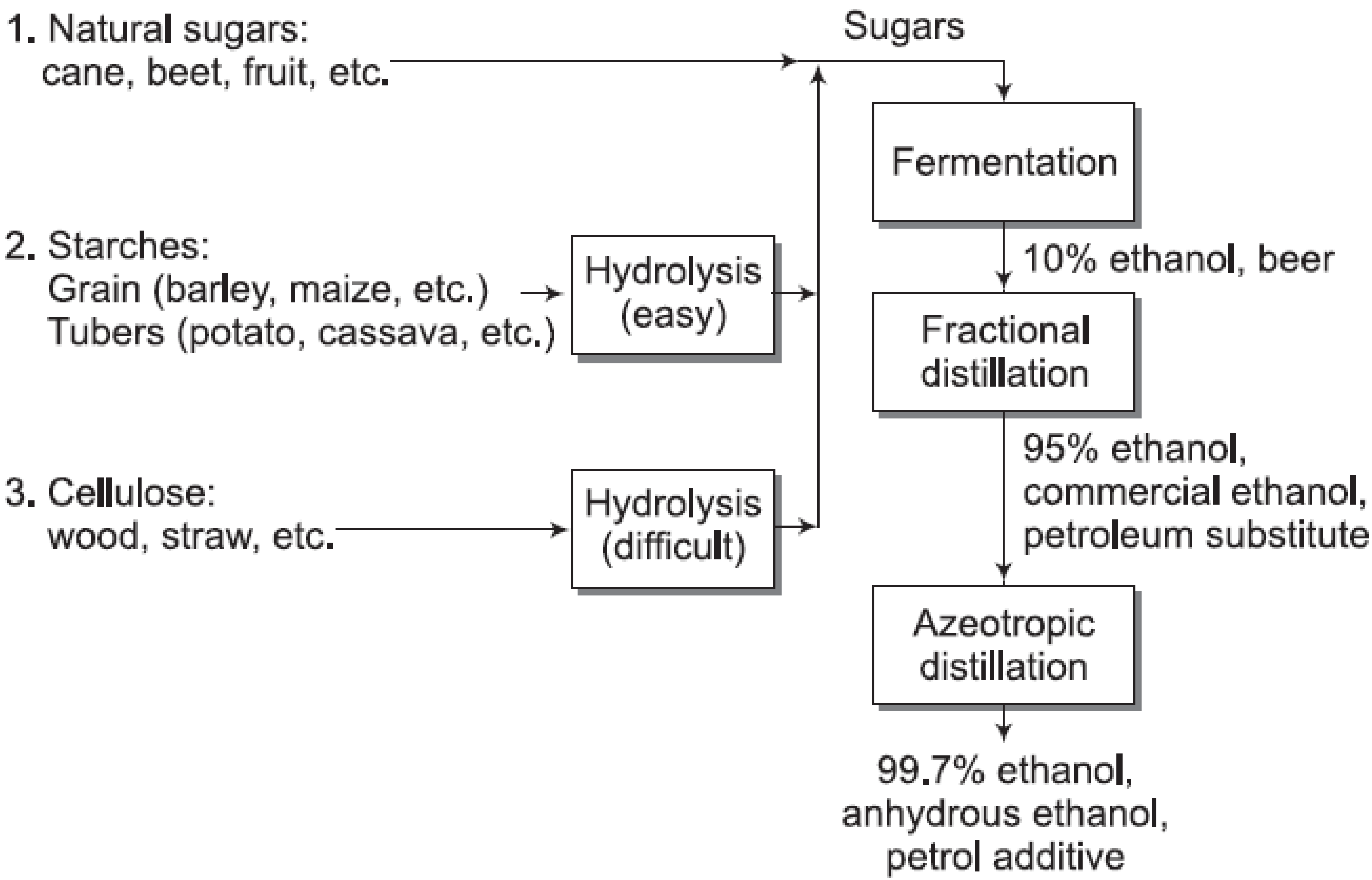


Figure 8.8 Ethanol production from various types of biomass

Use of Ethanol as Fuel

- Hydrous ethanol (95 per cent by volume) or commercial ethanol is used as fuel in specially designed IC engines with 25 per cent mileage penalty compared to conventional vehicles.
- **Up to 22 per cent blend** of anhydrous ethanol (99.7 per cent, by volume) with petrol requiring **no engine modification** and incurring no mileage penalty is being used by a large number of automobiles in the world.
- The blended petrol is known as gasohol (in USA), proalcol (in Brazil) and carburol (in France).

Pilot plant for ethanol production

Development of mini pilot plant for ethanol production from paddy straw

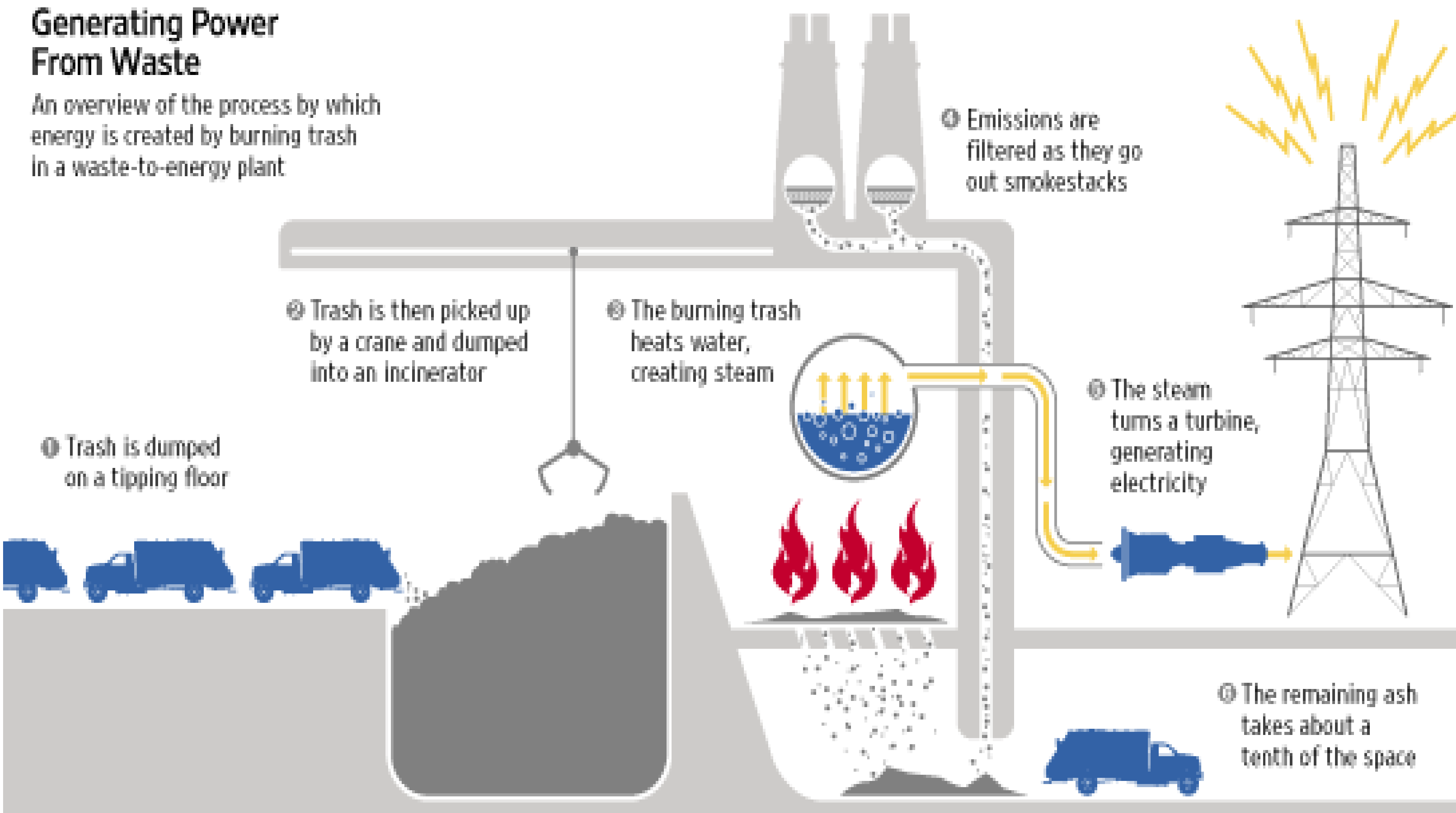
MSW Incineration Plant

Municipal solid waste MSW is the solid waste generated by households, commercial and institutional operations and some industries.
Disposal of MSW is a major problem in big cities where large quantities of waste is to be disposed of, far away from the city centers. The emerging solution is to use this waste biomass as an energy resource in a waste-to-energy conversion plant near city center. The energy thus generated is used within city itself and only a relatively small residue of used biomass (ash etc.) is disposed away in landfills. Through incineration or gasification, electrical energy may be generated along with thermal energy for process heat.

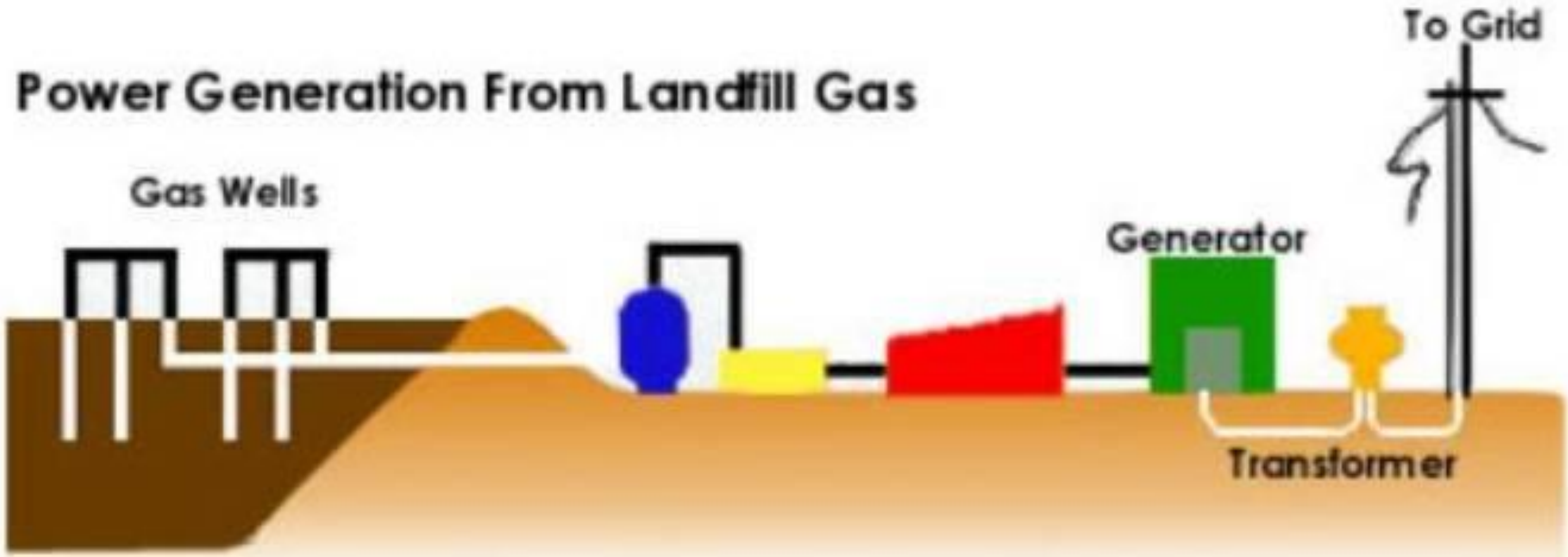
S.N.	Waste material	Percentage
1.	Paper and paper board	39.2
2.	Food and yard waste	21
3.	Glass	6.2
4.	Metals	7.6
5.	Plastics, rubber	9.1
6.	Wood	7.1
7.	Others (including hazardous wastes, e.g. chemicals, lead, insecticides, household cleaning chemicals, etc.)	9.8

Waste-to-Energy power plant

Energy can be recovered from wastes (trash) via combustion of waste in incinerators and generating power. Waste-to-Energy power plant



Power generation from landfill gas- Biogas produced from landfill is known as Landfill gas This process is also an anaerobic digestion process as bacteria decompose organic matter naturally in absence of oxygen over time. Landfill gas is composed mainly of methane and carbon dioxide. The methane gas produced in landfill sites normally escapes into the atmosphere and contributes to greenhouse gas emissions. However, if perforated pipes are inserted into the landfill, the landfill gas will travel through the pipes under natural pressure to be used as energy source



Direct Combustion of Biomass

- **Biomass energy used to generate heat and electricit**y through direct combustion in modern devices, ranging from very small scale **domestic boiler t**o multi megawatt size **power plant** electricity.
- Direct combustion is the combustion of biomass in a **grate, stoker or fluidized bed with excess air** followed by capturing the release of energy, which can then be **used to provide steam or hot water for pr**ocess heating and/or for **providing electricity.**
- Solid biomasses include coconut shells, rice husks, bagasse, wood waste, oil seed cakes such as de-oiled bran (DOB) etc. Biomasses of low bulk density are processed into pellets or briquettes.

Q & A

Thank You

Save energy and water for Sustainable Life

Energy and Environment Sceine
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.**

Energy and Environment Science

Unit – 5 : Pollution

Unit – 5

1. **Air pollution:** Sources, effects, control, air quality standards, air pollution act, air pollution measurement
2. **Water Pollution**: Sources and impacts;
3. **Soil Pollution**: Sources and impacts, disposal of solid waste.
4. **Noise pollution**

Unit-5, Class-1

"AIR POLLUTION"

Coverage

1. Introduction
2. Energy ,Environment and Climatic change
3. Air pollution and Types
4. Air pollution Sources
5. Effects
6. Controls
7. Air quality standards,
8. Air pollution act,
9. Air pollution measurement

Faculty & Accredited Energy Auditor (AEA 091)
Dr. P.Dharmalingam , B.Tech (Hons),PGEM, MS, Ph.D

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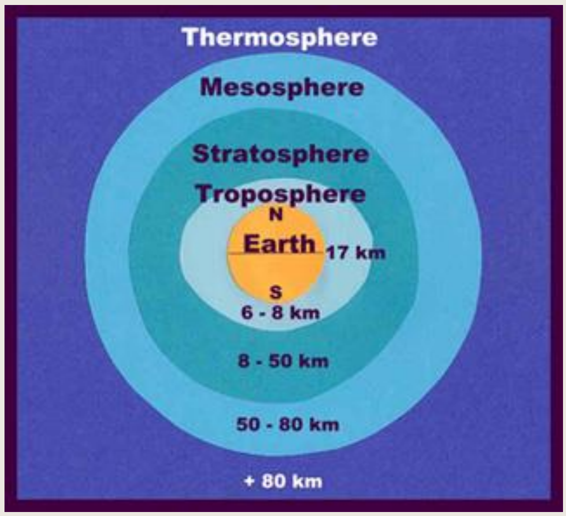
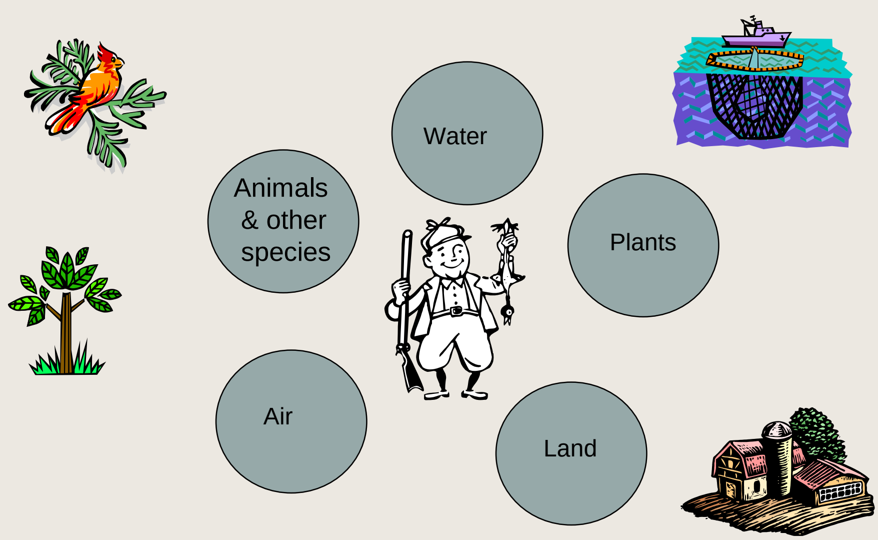
- 35 Years of Energy Auditing experience in India & Abroad
  - Conducted 450+ Energy Audit in Industry & buildings
  - Trained 15,000+ engineers in energy efficiency –India
  - 16 years experiences in conducting preparatory training for EA/EM BEE exam
  - Developed 300+ certified energy auditor in Iran, Nepal, Fiji, APO,UNEP ,Egipt, Ghana
- Co-author of BEE Energy Efficiency Exam Guide book
- 16 years experiences in conducting preparatory training for EA/EM BEE exam
- Established Practical Energy efficiency Centre @NPC Chennai
- Recipient of AEE's Asia Subcontinent Energy Professional Development Award,USA.

What is Atmosphere?

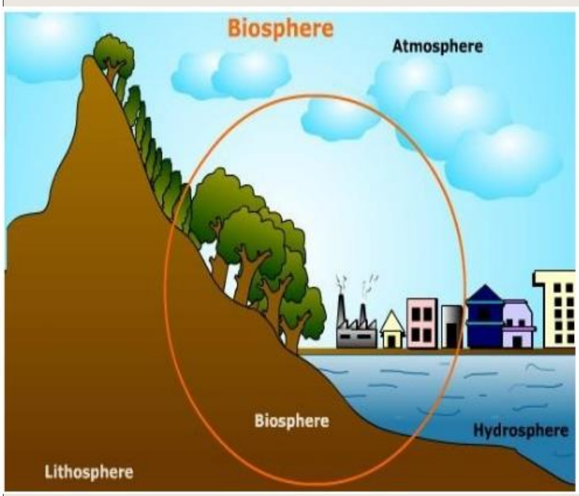
- Atmosphere is the life blanket of Earth.



What is Environment?



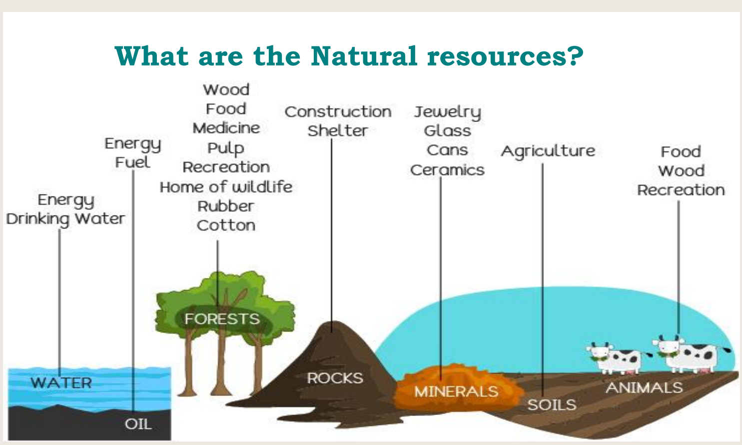
Biosphere



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.

2. Natural recourses

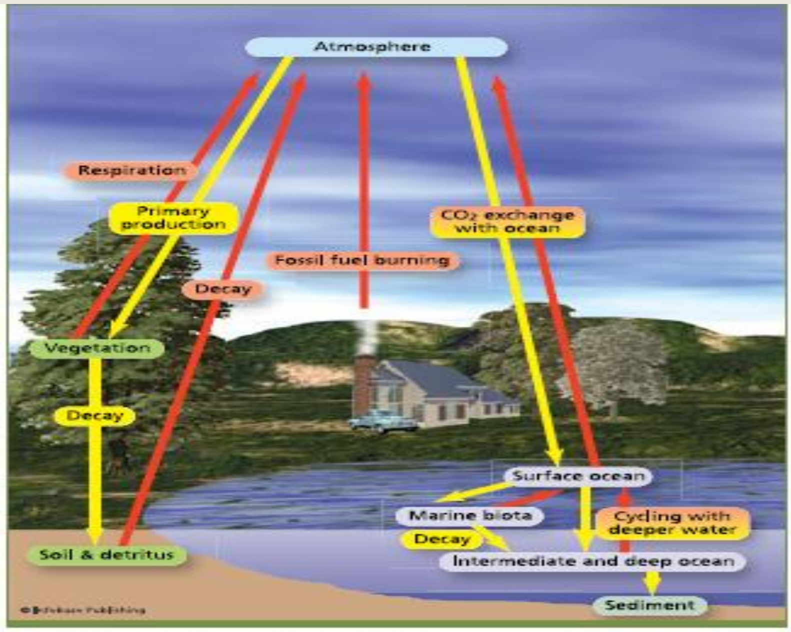


Resourses may be **solids, liquids, or gasses**.

They may also be **organic or inorganic**.

They may also be metallic or non-metallic.

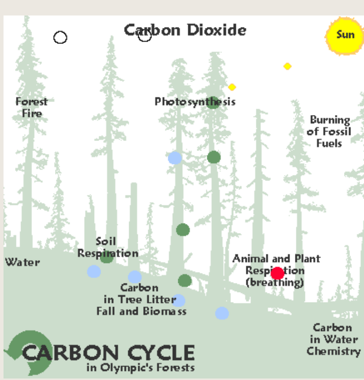
They may be **renewable or non-renewable**

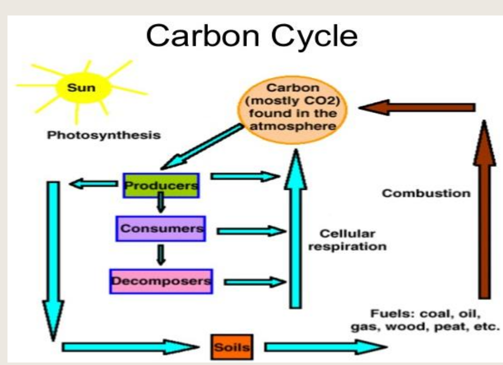


The carbon cycle, showing inputs of carbon into the atmosphere (red) and outputs of carbon from the atmosphere (yellow).

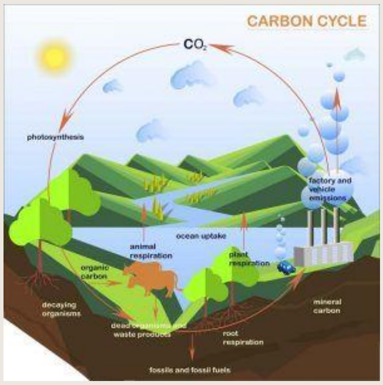
3. Carbon cycle and Energy resources

The carbon cycle or CO2 cycle is an **important part of everyday life**. Due to the abundance of carbon found in all elements of life, including animals, rocks, air, water, and more, the cycle of carbon is one that is constantly moving and changing due to the ever-changing nature of the things.





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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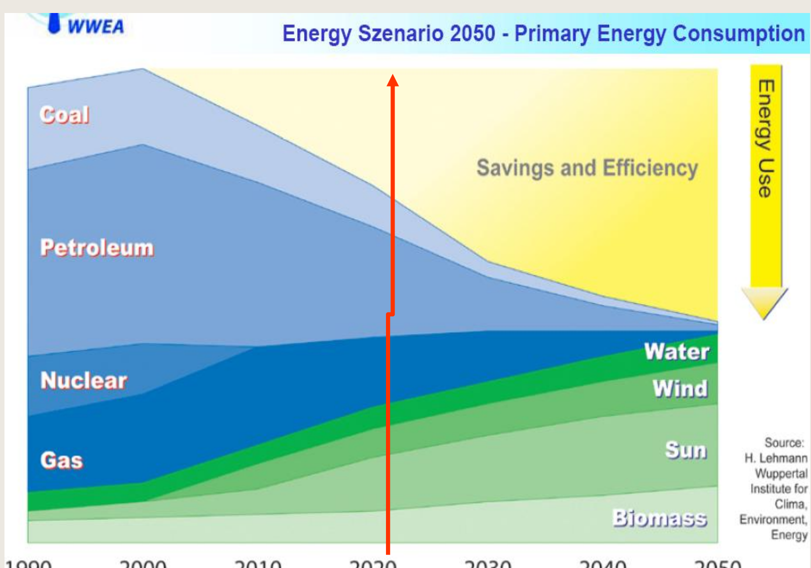
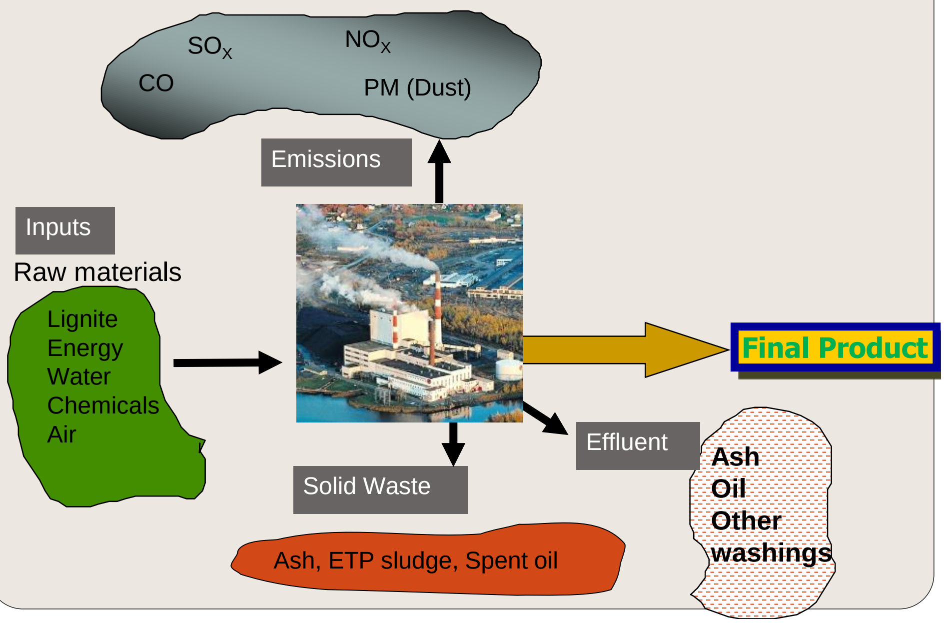
Energy USE

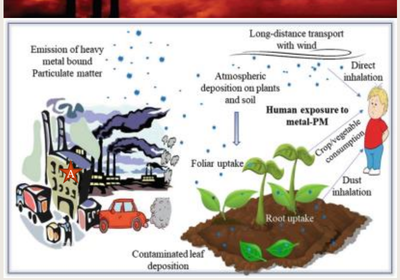


12

How Pollution is caused



4. Energy ,Environment and Climatic change

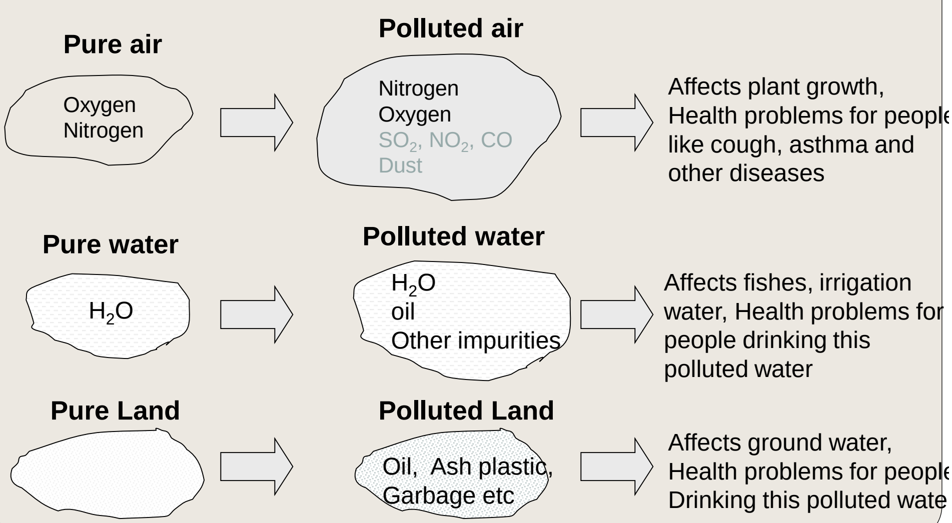


- The principal emissions causing impact on the air environment are <u>particulate matter (dust), Sulphur oxides, nitrogen oxides, and carbon monoxide</u>.

1. **Particulate matter -** Generated 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**.

What is pollution?

Undesirable elements in the Environment

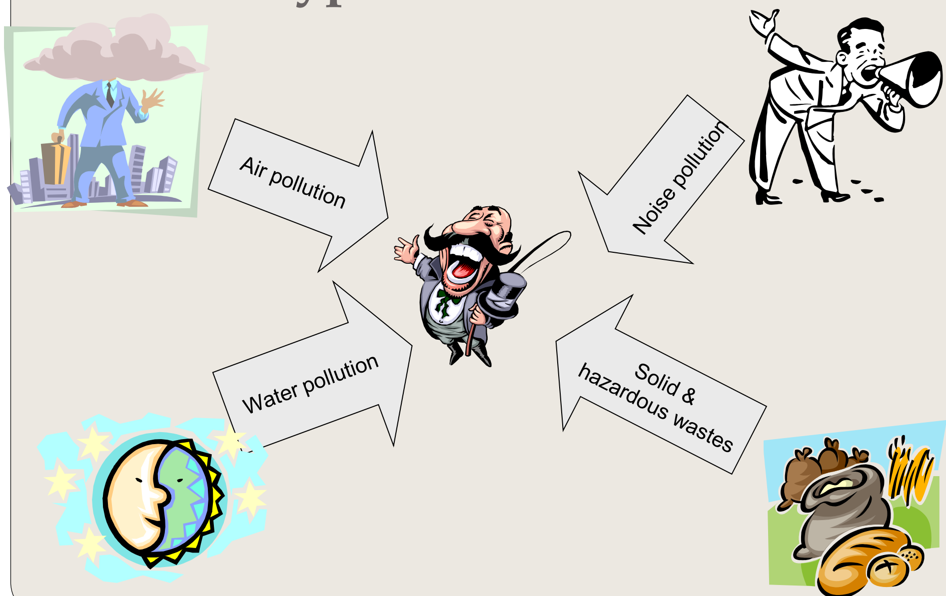


Definition of Pollution

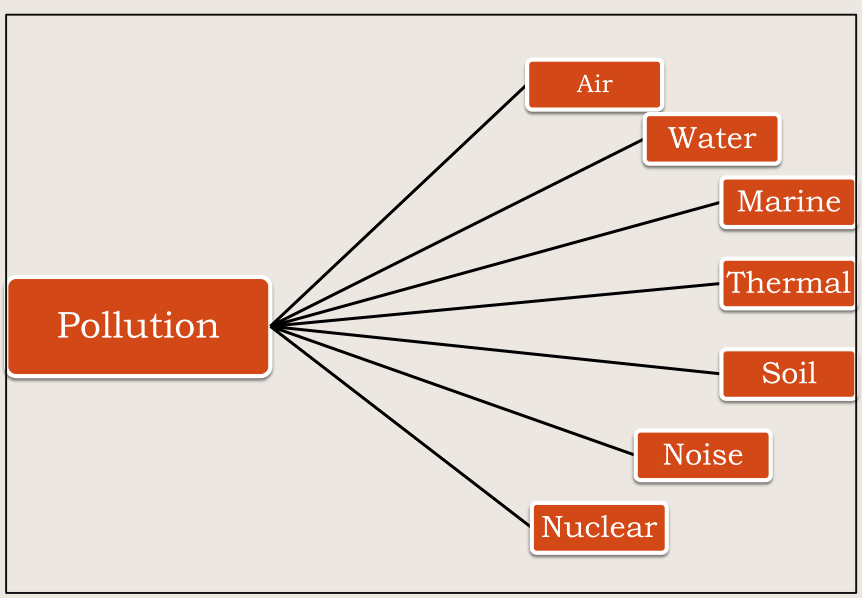
- When **Harmful Substances Contaminate the environment** it is Called Pollution.

- It can be defined as any undesirable change in the physical, chemical, biological characteristics of any component of the environment which can **cause harm to life and property.**

Types of Pollution



Types of Pollution



Air pollution

Pollution from All sectors

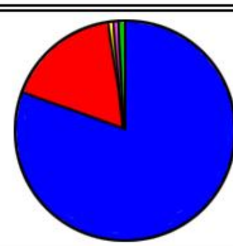
Air....

- Air supplies us with ***oxygen*** **which is essential for our bodies to live.**
- **Air is a mixture of** nitrogen, oxygen, water vapor, carbon dioxide and inert gases.
- **Human activities can release** substances into the air, some of which can cause problems to humans, plants, and animals.

Natural Composition of Gases

Dry Air Expressed in Volumes	
Nitrogen (N_2)	78.1%
Oxygen (O_2)	20.9%
Argon (A)	0.9%
Carbon dioxide (CO_2)	0.035%
Others	0.065%

Others : Neon (Ne)
Helium (He)
Krypton (Kr)
Hydrogen (H_2)
Xenon (Xe)
Ozone (O_3)
Radon (Rn)



Definition

- **Air pollution** : An atmospheric condition in which certain substances (including normal constituents in excess) are present in concentrations which can cause undesirable effects on man and his environment.

They are in the form of

1. **Gases** (Nox, Sox, CO,VOC);
2. **Particulate matter(dust**, smoke, fumes, etc)
3. &**Radioactive** (rado-222, Iodine-131, etc)

Classification of Air Pollutants

- Air pollutants may be **particulate or gaseous**.

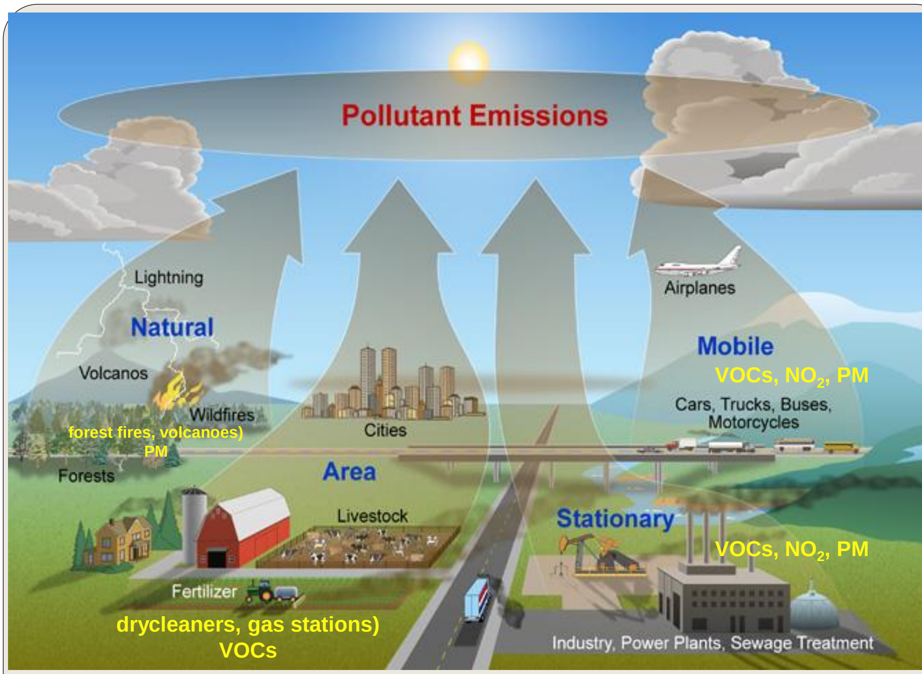
  On the basis of origin they are divided as
- **Primary pollutants** ---- Are emitted directly from the point source. e.g. : **CO, NO_2, SO_2**
- **Secondary pollutants** ---- formed by interaction of primary pollutants

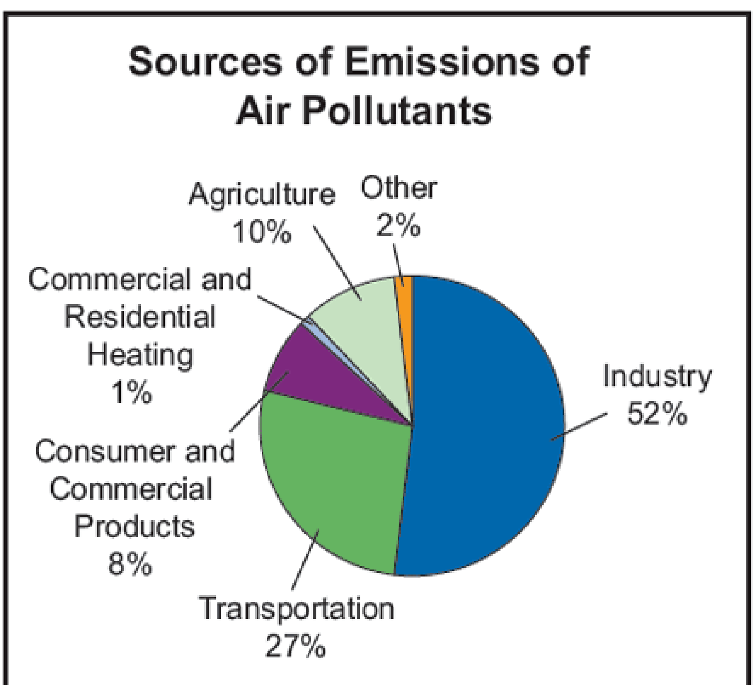
  e.g. : **Smog, Ozone** etc

Sources of Air Pollution

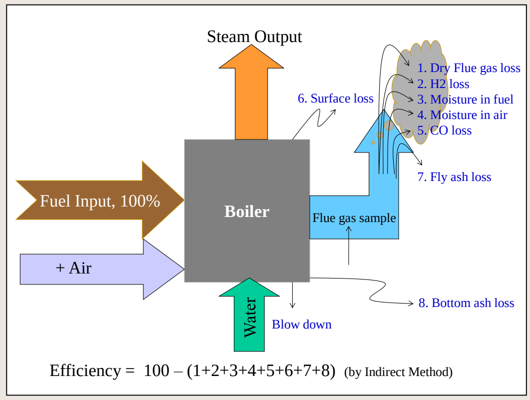
Sources

- **Natural**
  - Volcanic Eruptions, Forest Fires, Sea Salt Sprays, Biological Decay, Pollen Grains, Marshes, Photochemical Oxidation of Terpenes
- **Anthropogenic**
  - Thermal Power Plants,
  - Vehicular Emissions,
  - Industrial Units


Pollutant Emissions
Lightning
Natural
Volcanos
Wildfires
forest fires, volcanoes)
PM
Forests
Cities
Area
Livestock
Fertilizer
drycleaners, gas stations)
VOCs
Airplanes
Mobile
VOCs, NO_2, PM
Cars, Trucks, Buses, Motorcycles
Stationary
VOCs, NO_2, PM
Industry, Power Plants, Sewage Treatment


Sources of Emissions of Air Pollutants
Agriculture 10%
Other 2%
Commercial and Residential Heating 1%
Industry 52%
Consumer and Commercial Products 8%
Transportation 27%

Air pollution from our plant-Boilers

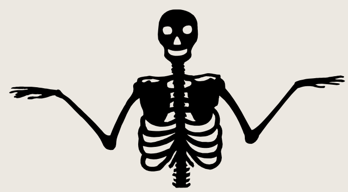


- Carbon monoixide, Carbon di-oxide from boilers
- Nitrogen oxides from boilers
- Sulphur oxides from boilers
- Dust generation/Ash dust from boilers
- **Can you think of any other ?**

Pollution problems

- Air you breathe = **10 Cigarettes** every day
- More than ***40,000 people die*** every year due to air pollution
- No. of patients with **respiratory diseases** and **allergies** has **doubled** in the last five years
- Child death has increased

Dust in air affects lungs..



Sulphur and Nitrogen oxides cause Acid Rain

- Caused by release of SO_X and NO_X , which mixes with water vapour to form acids
- Effects
  - Acidification of lakes, streams and soils
  - Release of metals, washing away of nutrients
  - Killing wild life
  - Corrosion
  - Asthma and chronic bronchitis

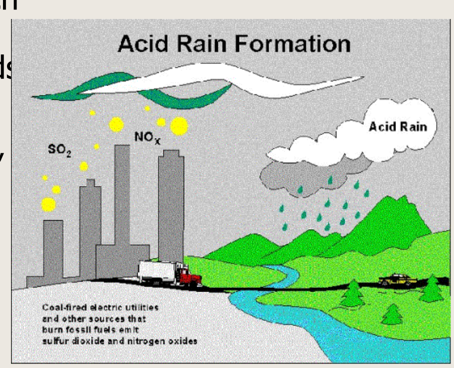
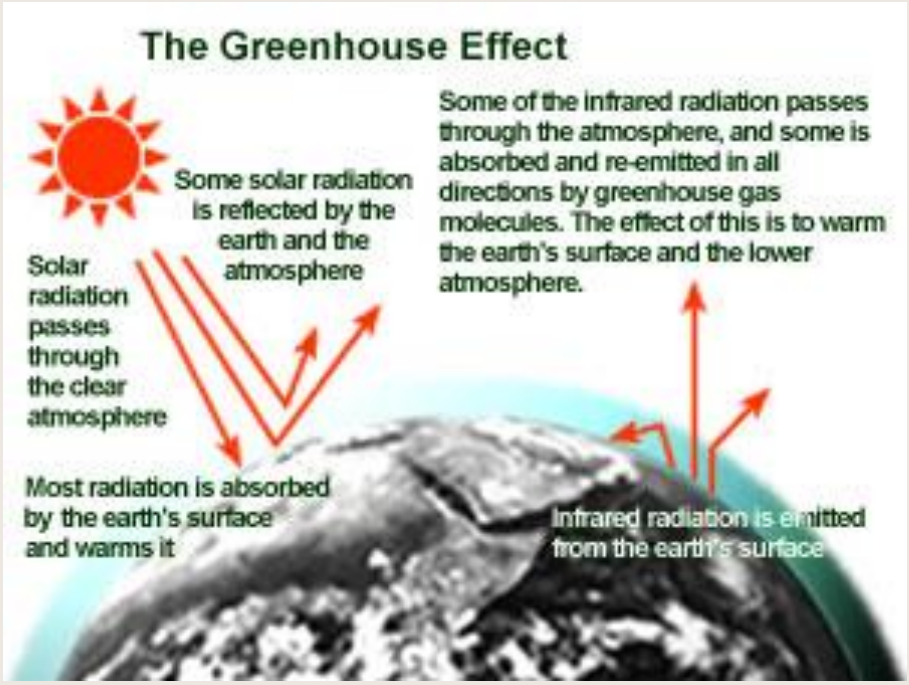


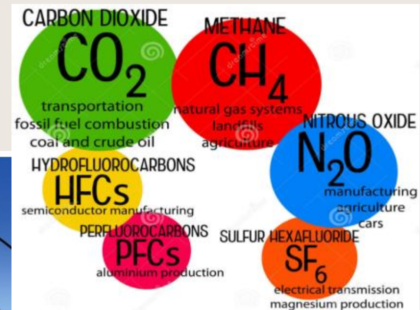
Figure 1.16

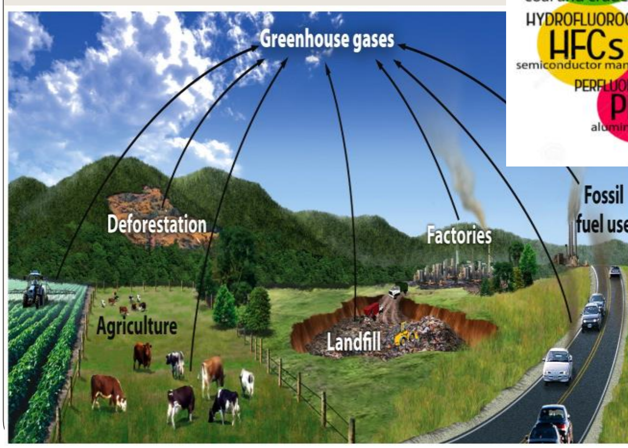


CO_2 causes Global Warming

- Global temperatures increased by 0.6°C in 20th century and expected to rise by about 5.8°C by 2100
- CO_2 from fossil fuel combustion, methane and nitrous oxide emissions through agricultural activities are responsible
- Sea level is expected to rise up to 88 cm by 2100 - flooding in coastal areas
- Displacement of people, changes in cropping pattern , changes in rainfall, reduction in agricultural yield and threat of food shortage looms large

Green House Gas – Major Causes





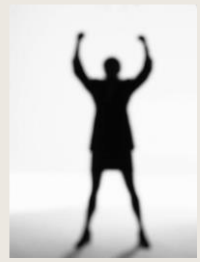
Criteria of Pollutants

Name of the gas	Characteristics	Source
Nitrogen dioxide (N_2 in air is oxidized); No_x sum of NO, NO_2, other oxides of N	Brownish gas irritates the respiratory system originates from combustion	Burning fuels including petrol, diesel, and coal
Ground level O3 (primary constituent of smog)	Reaction of VOC + nox in presence of heat +sun light	Vehicles and industries are the major source
Carbon monoxide	Reduces bloods ability to carry O_2	Produced by the incomplete burning of carbon-based fuels & natural and synthetic products such as cigarettes
Carbon dioxide	Principle greenhouse gas.	Emitted as a result of human activities such as the burning of coal, oil, and natural gases
Sulphur dioxide	Precursor to acid rain along with Nox	Formed when fuel (coal, oil) containing S is burned and metal smelting
Chorofluoro carbon (CFC)	Ozone depletion	Released from air-conditioning systems and refrigeration.
Lead	Cause learning disabilities in children , toxic to liver, kidney, blood forming organs	Present in petrol, diesel, lead batteries, paints, hair dye products, etc
Particulate matter **(PM 10 & 2.5)**		

Effects of Air Pollution

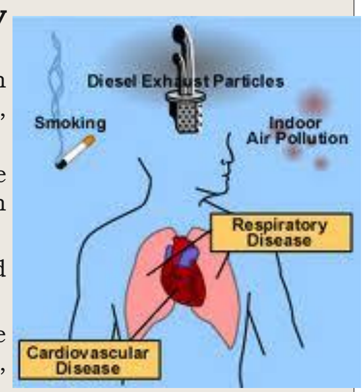
Air Pollution affects???

1. Human health
2. Animals
3. Plants
4. Materials
5. Environment



Effect on Human health

- Main problems are related to **Respiratory Track** - Asthma, hay fever,allergic diseases.
- **Irritation of the eye, nose and throat**. In severe cases there may be **headaches, nausea**, and loss of coordination.
- Prolonged exposure can cause damage to the **nervous system, digestive problems**, and in some cases cause **Lung cancer**.
- It **lowers our resistance** to colds and pneumonia.
- **CO** has affinity towards Hb which cause disturbance in transportation of Oxygen, impairing our concentration, slow our reflexes, and make us confused and sleepy.
- **SO_2** in the air leads to diseases of the lung and other lung disorders such as wheezing and shortness of breath.



- Chronic respiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver, or kidneys. **Effects of Arsenic, Asbestos, Mercury , Benzene**

Effect on Plants

- Pollutants enter through stomata
- Destroy chlorophyll and Affect photosynthesis
- Cuticle(Wax Layer on Leaves) is lost
- Necrosis – Damage to Leaf Structure
- Chlorosis - Loss/ reduction of Chlorophyll
- Abscission - Dropping of leaf
- Epinasty – Downward curling of Leaf
- DEATH

Effect on Animals and materials

- Corrosion of metal surfaces, fading
- SO_2 & water form H_2S – corrosion as well as disfigurement of statues made up of limestone or Marble
- Air pollutants mix with rain water and increase acidity (Acid Rain) of water body and kill fish.
- Ozone causes crackling of rubber

Effect on Environment

1. **Visibility**
2. **Pollutants in the presence of sunlight produce photochemical Smog**
3. **Emission of Green House Gases tend to Global Warming**
4. **CFC's cause Ozone Depletion**

Air Pollution is not a new problem

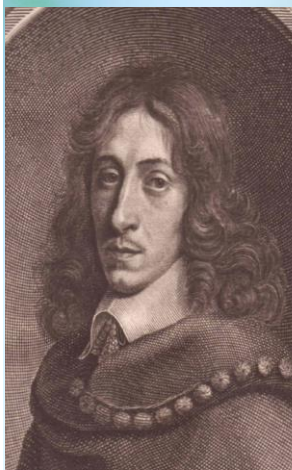
- **In ancient Babylon** (circa 1754 BCE), one of Hammurabi's codes (no. 232) specified **compensation for another's property damaged by your smoke.**
- **Many ancient Egyptian mummies** have evidence of **smoke induced lung disease** as do more recent mummified remains of Vikings.
- Edward I "Longshanks" (1239-1307 CE), **King of England from 1272-1307 C**E **banned burning "sea coal" while parliament** was in session under penalty of death.

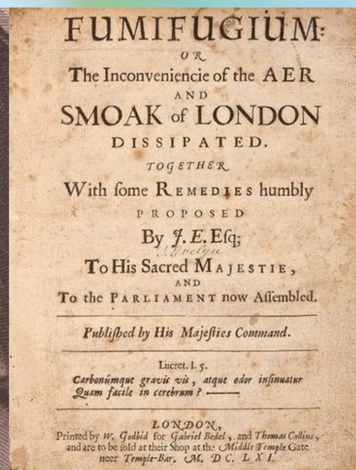
CARTEEH

42

Fumifugium (1661)

John Evelyn (1620-1706 CE)


Alamy.com


FUMIFUGIUM:
OR
The Inconveniencie of the AER
AND
SMOAK of LONDON
DISSIPATED.
TOGETHER
With ſome REMEDIES humbly
PROPOSED
By J. E. Eſq;
To His Sacred MAJESTIE,
AND
To the PARLIAMENT now Aſſembled.

Publiſhed by His Majeſties Command.

Lucret. l. 5.
Carbonúmque gravis vis, atque odor inſinuatur Quam facile in cerebrum?

LONDON,
Printed by W. Godbid for Gabriel Bedel, and Thomas Collins, and are to be ſold at their Shop at the Middle Temple Gate neer Temple-Bar. M. DC. LXI.

Theehp.com

Written by John Evelyn an English aristocrat and father of the "English Garden" to King Charles II of England.

Blamed the poor air quality of London on the burning of sea coal

Proposed substitution of wood for coal for domestic heating in the environs of London

Major 20th Century Air Pollution Events


Meuse Valley 1930 (listserve.com)


London Killer Fog 1952 (wjla.com)

- Meuse Valley, Belgium (1930)
  - 65 deaths due to **thermal inversion (flouride)**
- Donora, Pennsylvania (1948)
  - 20 deaths due to **thermal inversion**
- London, England (1952)
  - "Killer Fog" resulting in ~4000 deaths
  - **Sulfur Dioxide and other compounds**
- **Bhopal, India** (1984)
  - ~4000-22,000 deaths and ~575,000 injuries
  - Industrial accident **(methyl isocyanate)**

WHY IS AIR QUALITY IMPORTANT?

- Millions of people are exposed to unhealthy air every year.
- Ozone and particle pollution are the two most widespread air pollutants of concern.
- Everyone can be harmed by unhealthy levels of ozone and particle pollution - especially people with asthma, heart or lung disease, older adults, children and teens, and people who are active outside.

Particulate Matter: Size Matters

Size is important to the behavior of PM in the atmosphere and human body and determines the entry and absorption potential for particles in the lungs.

Particles **larger than 10 µm** are trapped in the nose and throat and never reach the lungs. Therefore, particles 10 µm in diameter or less are of most concern for their effects on human health.

Particles between **5 and 10 µm** are removed by physical processes in the throat.

Particles **smaller than 5 µm** reach the bronchial tubes, while **particles 2.5 µm in diameter or smaller are breathed into the deepest portions of the lungs.**

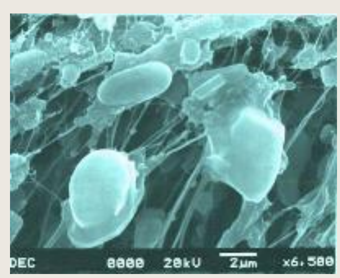
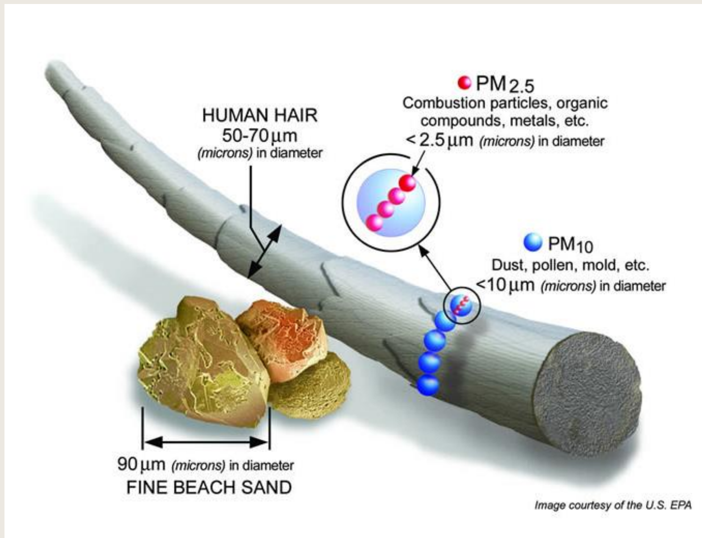


Image: PM2.5. By D. Hershey. From New York State Department of Environmental Conservation. http://www.dec.state.ny.us/website/dar/baqs/micro/two.html

PARTICULATE MATTER: WHAT IS IT?

A complex mixture of extremely small particles and liquid droplets.



Where Does **PM Originate**?

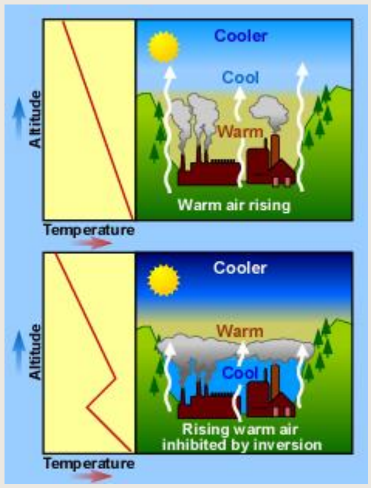
Sources may emit PM directly into the environment or emit **precursors** such as **sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and volatile organic compounds (VOCs),** which are transformed through atmospheric chemistry to form PM.

VOCs $\longrightarrow$

NO_2 $\xrightarrow{\text{Ammonia } (NH_3)}$ **PM**

SO_2 $\xrightarrow{\text{Ammonia } (NH_3)}$

The **Role of Inversions**



Source: http://www.epa.gov/apti/course422/ ce1.html

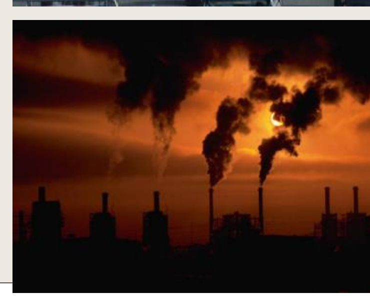
An inversion is an extremely stable layer of the atmosphere that forms over areas.

Temperature inversions trap pollutants close to the ground.

These inversions involve layers of hot air sitting above cooler air near ground level. When particles accumulate in the air layer, they are **unable to rise into the atmosphere** where winds will disperse them.

GROUND-LEVEL OZONE (O_3)

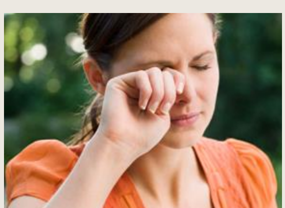
- Ozone is a primary component of smog.
- Ozone is <u>not</u> emitted into the air.
- Ozone forms when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react in the presence of sunlight.
- Ozone levels can be high in urban <u>and</u> rural areas.



WHAT CONTRIBUTES TO OZONE POLLUTION?

- Motor vehicles
- Power plants
- Factories
- Consumer & commercial products
- Fuel combustion processes

Ozone and particle pollution

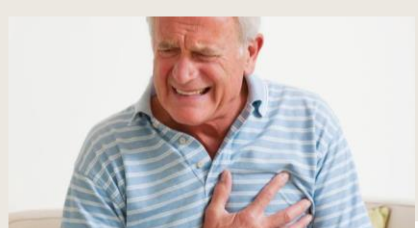


Can cause eye, nose & throat irritation

Can cause coughing & difficulty breathing

Can trigger asthma attacks

Can affect the development of children's lungs



Can cause heart disease, abnormal heart rhythms, congestive heart failure, stroke, & premature death

What Adverse Health Effects Have Been Linked to PM?

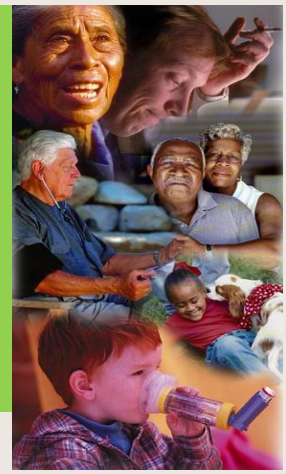
- Premature death
- Lung cancer
- Exacerbation of COPD
- Development of chronic lung disease
- Heart attacks
- Hospital admissions and ER visits for heart and lung disease
- Respiratory symptoms and medication use in people with chronic lung disease and asthma
- Decreased lung function
- Pre-term birth
- Low birth weight

The doctor says particle pollution…

- Aggravates lung disease including asthma
- Aggravates heart disease including congestive heart failure
- Resulting in:
  - More premature deaths
  - More admissions to hospitals
  - More trips to emergency rooms
  - More visits to doctors' offices
  - More school and work absences
  - More symptom days

So Who's at Risk?

- People with heart or lung disease (including asthma)
  - Conditions make them vulnerable
- Older adults
  - Greater prevalence of heart and lung disease
- Children
  - More likely to be active
  - Breathe more air per pound



How do I know if I am breathing unhealthy air?

- **Check the Air Quality Index (AQI),** a color-coded system for reporting air quality conditions.
- The colors in the AQI indicate how clean or dirty the air is. When the air quality is unhealthy, you can take actions to protect your health.

Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy

What Color is Your Air Today?

What do you say?

AQI color code	Who is affected?	What is the significance?	What action should people take?
Green	–	Air quality is good	Enjoy activities
Yellow	People who are unusually sensitive to air pollution	Air quality is a concern for people who are unusually sensitive to air pollution	People unusually sensitive to air pollution: Plan strenuous activities when air quality is
Orange	People with heart or lung disease (including asthma), older adults, and children	Air quality is unhealthy for people in sensitive groups	Sensitive groups: Cut back or reschedule strenuous activities
Red	Everyone, especially people with heart or lung disease (including asthma), older adults, and children	Air quality is unhealthy for everyone	Everyone: Cut back or reschedule strenuous activities Sensitive groups: Avoid strenuous
Purple	Everyone, especially people with heart or lung disease (including asthma), older adults, and children	Air quality is very unhealthy for everyone	Everyone: Significantly cut back on physical activities Sensitive groups: Avoid all physical activities

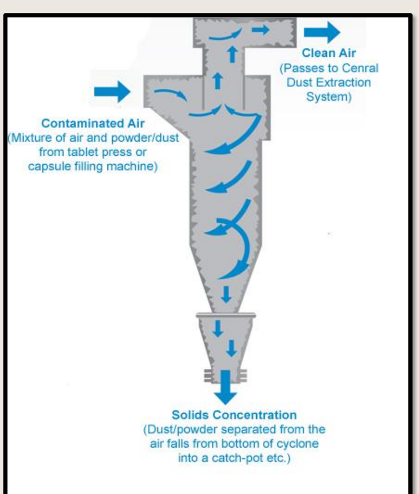
How can we minimise air pollution in our plant?

- Reducing energy wastages
  - We burn less fuel
  - So less SO_2, NO_2, CO_2, dust etc
- Wetting lignite to make fines stick with larger lumps
  - Dust generation will be reduced
- Working with face masks in fuel preparatory and boiler section
  - We can protect us from dust
- Any other suggestions ?

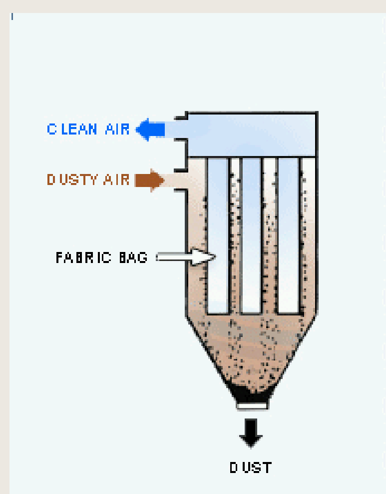
Control of Air Pollution

1. Proper air pollution control devices in industries
2. Using low sulphur coal
3. Regular engine tune up, replacement of old more polluting vehicles
4. Using mass transport system, bicycles etc
5. Shifting to less polluting fuels
6. Planting more trees
7. No to FIRE CRACKERS in Diwali and other occasions

Pollution Control Devices



Cyclone Separator



Bag House Filter

NATIONAL AIR QUALITY MONITORING PROGRAMME (NAMP)

- **Central Pollution Control Board** is executing a nation-wide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP).
- The network consists of three hundred and forty two (342) operating stations covering one hundred and twenty seven (127) cities/towns in twenty six (26) states and four (4) Union Territories of the country.
- Under N.A.M.P., four air pollutants *viz* ., Sulphur Dioxide (SO2), Oxides of Nitrogen as NO2, Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM / PM10) have been identified for regular monitoring at all the locations.
- The monitoring of meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality.

The **Air (Prevention and Control of Pollution) Act,** 1981

Responsibilities

☹ Obtain **"Consent to Establish"** prior to taking any steps to establish any industry, operation or process or any treatment and disposal system which is likely to discharge effluent/emission

☹ Obtain **"Consent to Operate"** prior to commencing operations of any industry, operation or process or any treatment and disposal system which is likely to discharge effluent/emission

☹ Apply for **renewal** of **"Consent to Operate"** before the expiry of validity period, as specified in the consent granted earlier

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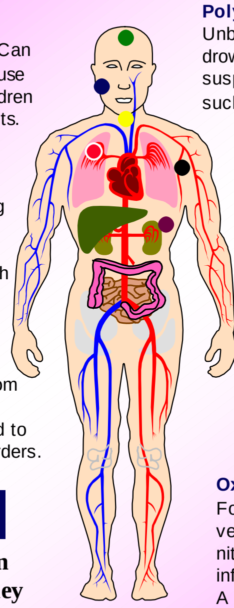
How the Poisons in the Air Affect You

Lead:
A toxic metal that's present in normal petrol and in the air as fine particles. Can affect the central nervous system, cause renal damage and hypertension. Children are three times more at risk than adults.

Suspended Particulate Matter
Particles of dust and carbon, coated with toxic gases, all emanating from factory emissions and vehicle exhaust. They coat the lungs. Cause respiratory infections, persistent cough and throat irritation. Aggravate asthma.

Carbon Monoxide:
Colourless and odourless, it comes from petrol vehicles, mostly two and three wheelers. Reduces the ability of blood to carry oxygen. Exacerbates heart disorders.



Polycyclic Aromatic Hydrocarbons (PAHS) :
Unburnt from diesel engines. Cause drowsiness, eye irritation, cough and are suspected to be cancer causing. There is no such thing as a safety level for PAHs.

Sulphur dioxide:
Colourless gas that is a part of diesel exhaust and factory emissions. Affects upper respiratory tract. Causes bronchial problems, nose blockage and a hacking cough.

Benzene:
Cannot be seen, It's part of unleaded petrol and is emitted from catalytic converters. A known carcinogen, it has been linked to lung cancer and leukemia and is said to damage the central nervous system. No safe limit: there just shouldn't be any benzene around.

Oxides of Nitrogen:
Formed during fuel combustion in motor vehicles and power stations. Convert to nitrogen dioxide, which leads to bronchial infections, clods, headaches and eye irritation. A recent spurt in fibrosis cases in Mumbai has been traced to these pollutants.

Areas Affected

- Lungs
- Respiratory Tract
- Nose/Eyes
- Brain
- Kidney
- Entire body

Thank You

Save energy and water for Sustainable Life

ENSAVE

Dr.P.Dharmalingam
Accredited Energy Auditor
https://ensaveindia.in

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**

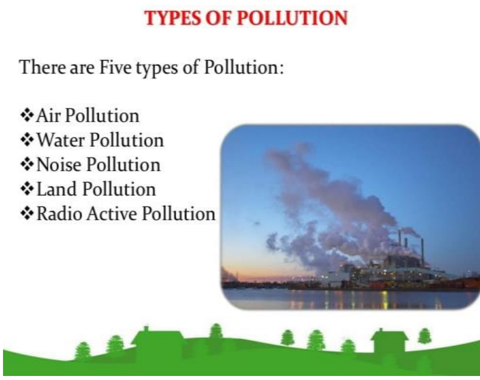
Unit – 6 [4 Hours]: **Greenhouse gases effect**, acid rain; Pollution aspects of various power plants; **Fossil fuels and impacts, Industrial and transport emissions impacts.**

1

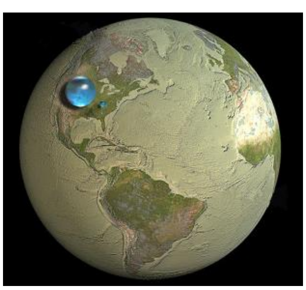
Introduction to Water Pollution

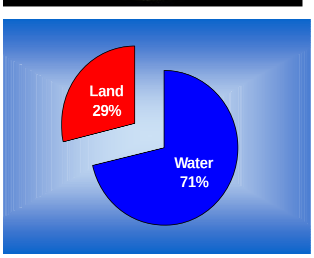
Unit-5, Water Pollution, Class 2

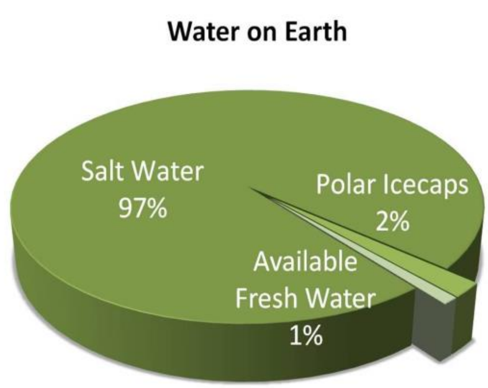
Introduction



HOW MUCH FRESH WATER DO WE HAVE ON EARTH?

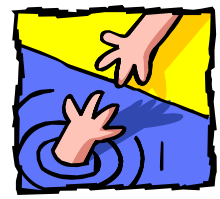






How much water do we use ?

- Each person requires 100 litres/day !
- Pollution control Board requires only 400 litres/tonne of cane crushed
- If you use more water,
  - more will be your effluent
  - Bigger will be your ETP and so more costs
  - more treatment costs
  - More money to be paid as water tax



What is a Water foot print

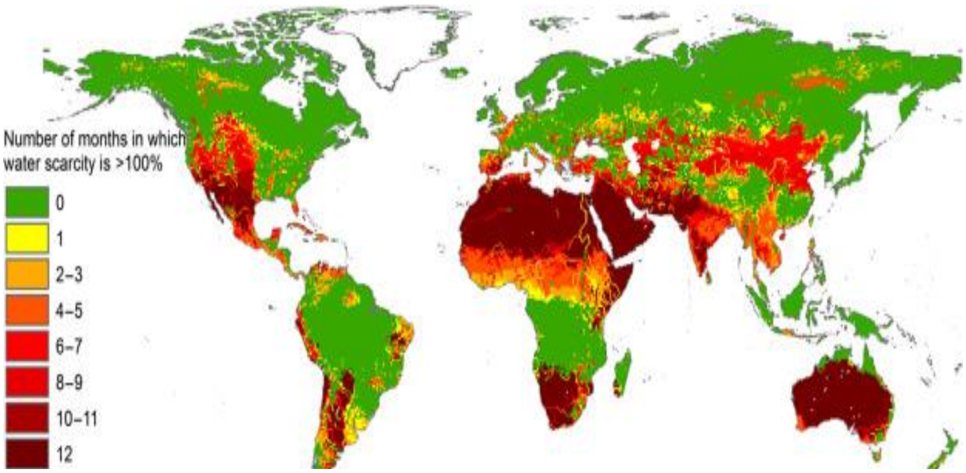
[Hoekstra & Chapagain, 2008]

individual water footprint averages 1.385 million liters per year

[Hoekstra & Chapagain, 2008]

Water Scarcity

Is a major GLOABLE PROBLEM?



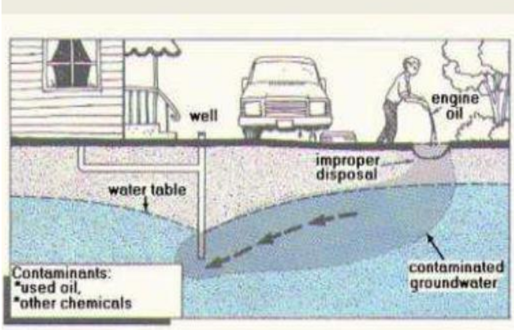
CAPE TOWN, SOUTH AFRICA

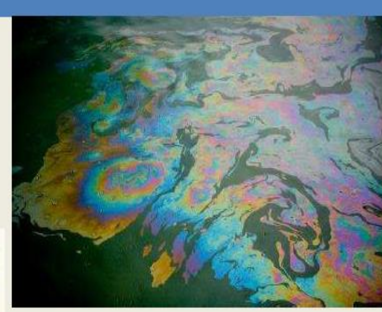
India

Many countries (BRAZIL)
WAS AFFECTED BY
A SEVERE DROUGHT
&WATER POLLUTION

WATER STRESS DUE TO CONSTRUCTION SECTOR

- *Pollute ground water table at times*
- *Buildings use a huge amount water during construction and operation, which adds to stress on water resources*



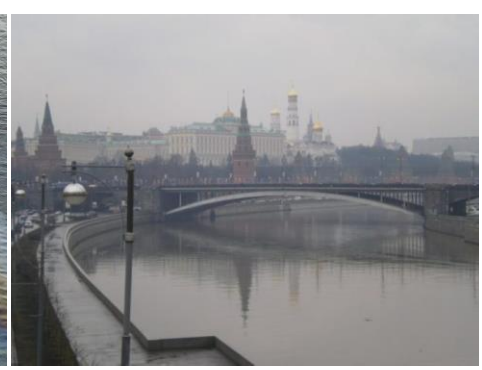


Water Pollution

Is a major GLOABLE PROBLEM?

CARIO, EGYPT
WATER POLLUTION OF THE NILE
THEIR MAIN WATER SOURCE

MOSCOW, RUSSIA
THEIR WATER SUPPLY IS VERY
POLLUTED



BANGALORE, INDIA

WATER WASTAGE AND POLLUTTION

BEIJING, CHINIA
THE MOST POPULATED CITY IN THE WORLD WITH SEVERE WATER POLLUTION

REASONS BEHIND WATER STRESS

- No sense of Ownership
- Over exploitation of ground water
- Contamination of surface/ground water sources
- Mismanagement of water
- Variations in rainfall

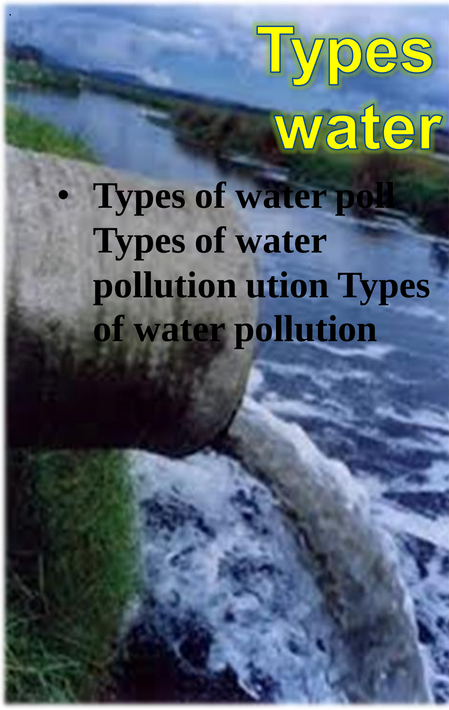
Water Pollution: Types, Sources and Effects

- ❑ **What is water pollution?**
- ❑ **Major types of pollutants, sources**
- ❑ **Point and nonpoint sources**
- ❑ **water pollution effects**
- ❑ **Is the water safe to drink?**

Water Pollution

- Is contamination by foreign matter like
  - Microorganisms
  - Chemicals
  - Industrial or other wastes, or sewage.
- **Water pollution**
  - Change in water quality that can harm organisms or make water unfit for human uses
  - Contamination with chemicals
  - Excessive heat
- Deteriorates the quality of the water and renders it **unfit for its intended uses**.

Types of water pollution



1. **Surface water pollution**
2. **Oxygen Depletion**
3. **Ground water pollution**
4. **Nutrients**
5. **Microbiological**
6. **Suspended matter**
7. **Chemical pollution**

Pollution Sources

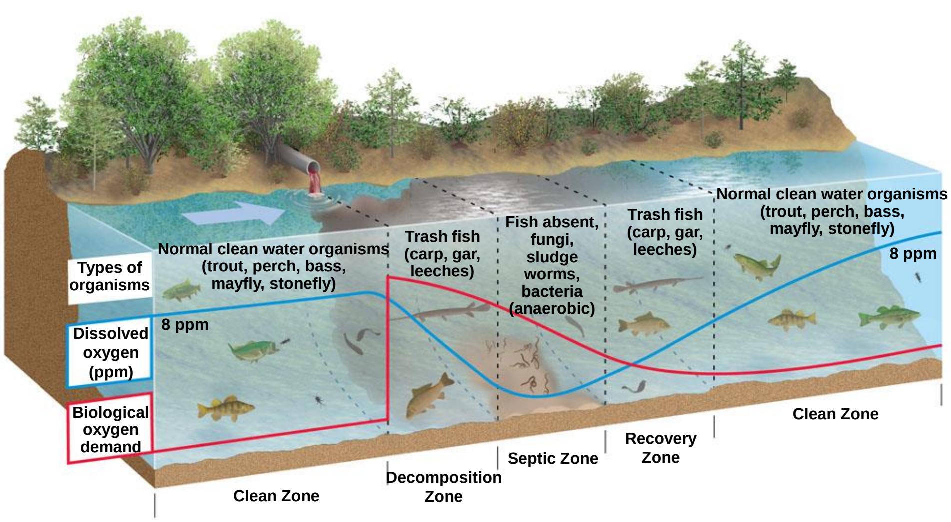
- ***Point sources*** are direct discharges to a single point;
  - examples include discharges from **sewage treatment plants, injection wells** and some **industrial sources**.
- ***Non-point sources*** are **diffused across a broad area** and their contamination cannot be traced to a single discharge point.
  - Examples include runoff of excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; and sediment from improperly managed construction sites, crop and forest lands and eroding stream banks.

Water Pollution Comes from Point and Nonpoint Sources

Point sources
- Located at specific places
- Easy to identify, monitor, and regulate
- Examples : Point Source of Polluted Water in Gargas, France

Nonpoint Sediment from Unprotected Farmland Flows into Streams

Pollution in Streams



Sources of Water Pollution

SOURCES OF WATER POLLUTION

- **Most of Water Pollution is man made It may also occur naturally by addition of soil particles through erosion animal wastes and leaching of minerals from rocks**

- **The sources of water pollution can be classified as**
  - **Municipal Waste Water**
  - **Industrial Waste**
  - **Inorganic Pollutants**
  - **Organic Pollutants**
  - **Agricultural Wastes**
  - **Marine Pollution**
  - **Thermal pollution**

Surface Water Pollution

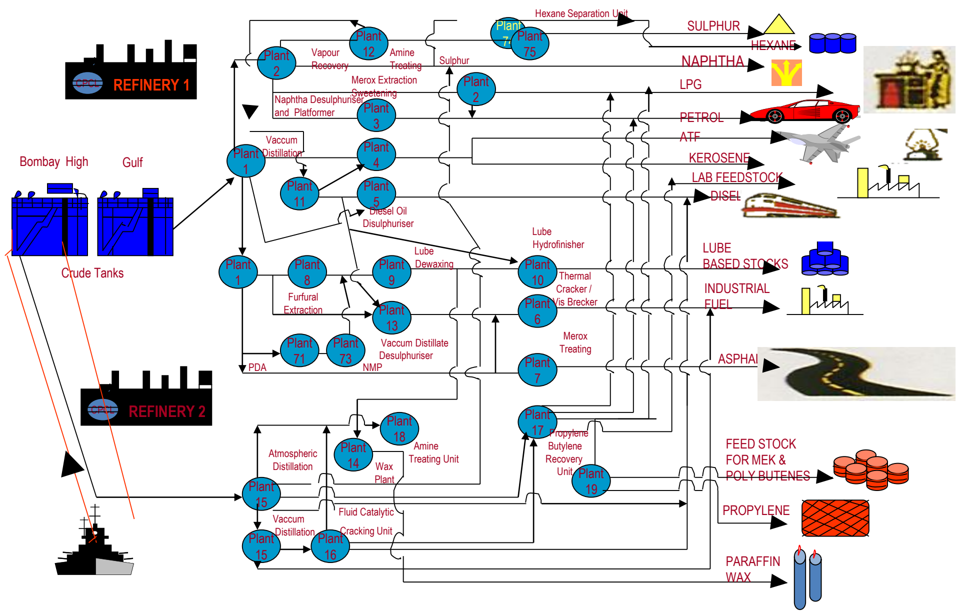
- Sewage
- Industrial effluents
- Synthetic detergents
- Agrochemicals
- Oil
- Waste heat

MUNICIPAL WASTE WATER


Industrial waste/ Effluents

- The major source of water pollution is the waste water discharged from industries and commercial bodies.
- These industries are chemical, metallurgical, food processing industries, textile, paper industries.
- Industrial waste water usually contains specific and readily identifiable chemical compounds .They discharge several organic and inorganic pollutants. That prove highly toxic to living beings. (toxic wastes Chromium, mercury, lead, copper, cadmium etc)


CRUDE-OIL PROCESSING



ORGANIC POLLUTANTS

- **They Include oils, fats, phenols, organic acids grease and several other organic compounds**

INORGANIC POLLUTANTS

- **They include fine particles of different metals, chlorides, sulphates, oxides of iron, cadmium, acids and alkalies.**

AGRICULTURAL WASTES

- **Chemical fertilizers and pesticides have become essential for present day high yielding crops.**
- **Consequently, they have become , potential source a of water pollution**
- These fertilizers containmajor plants nutrients mainly nitrogen, phosphorous, and potassium.
- Excess fertilizers may reach the ground water by leaching or may be mixed with surface water of rivers, lakes and ponds by runoff and drainage.

- Adds Nitrogen and Phosphorus to water Causes Eutrophication and algal blooms

MARINE POLLUTION

- **Ocean are the final sink of all natural and manmade pollutants. Rivers discharge their pollutants into the sea. The sewage and garbage of costal cities are also dumped into the sea. The other sources include, discharge of oils, grease, detergents, and radioactive wastes from ships.**

THERMAL POLLUTION

- **Thermal Pollution of water is caused by the rise in temperature of water. The main source of thermal pollution are the thermal and nuclear power plants. The power generating plants use water as coolants and release hot water into the original source. Sudden rise in temperature kills fish and other aquatic animals.**

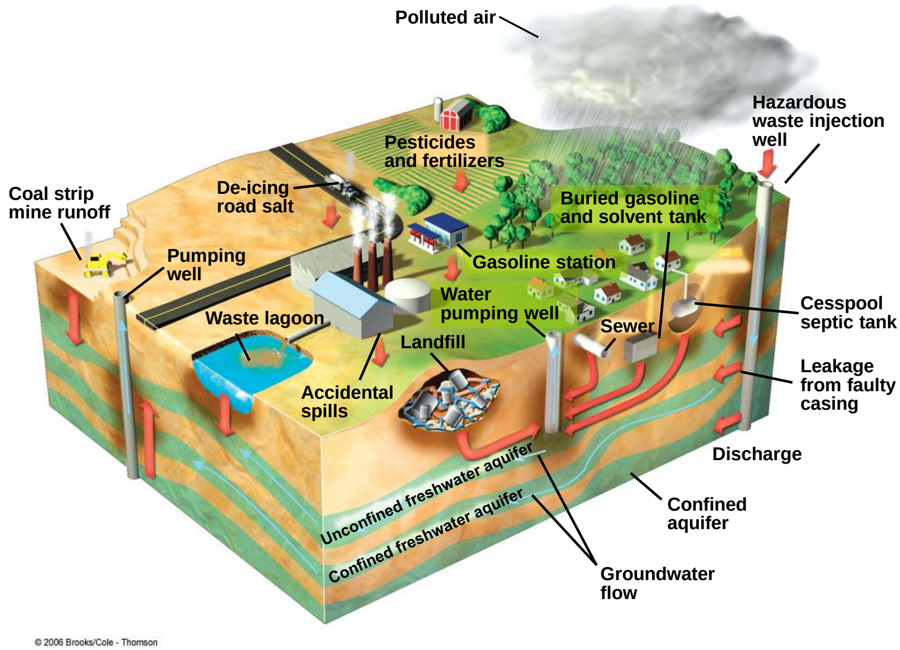
Domestic Sewage

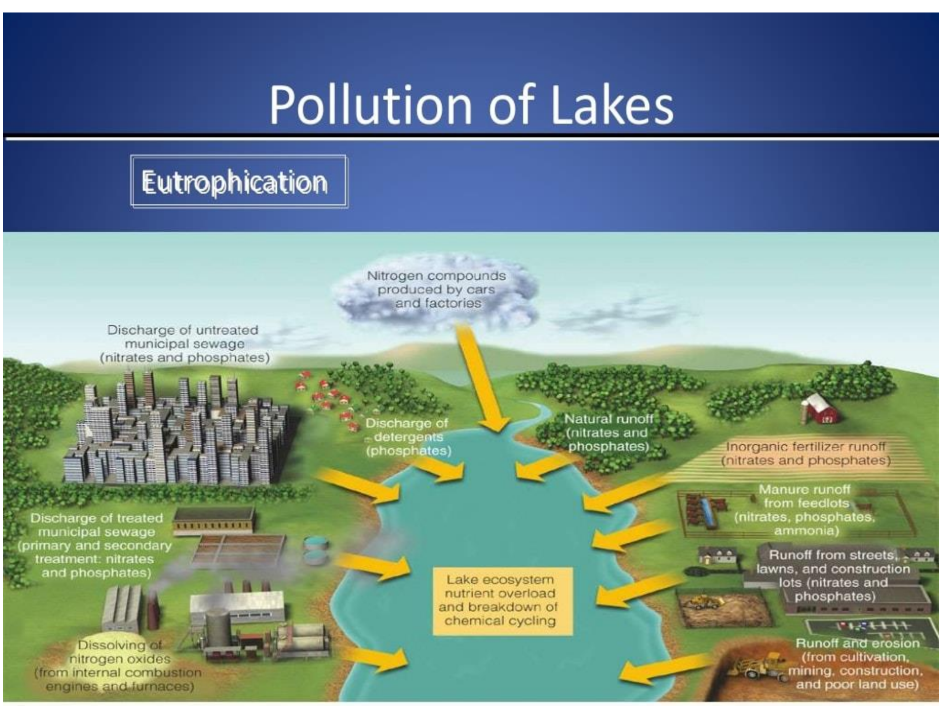
- Refers to waste water that is discarded from households. Also referred to as sanitary sewage, such water contains a wide variety of dissolved and suspended impurities.
- The main organic materials are food and vegetable waste, plant nutrient come from chemical soaps, washing powders, etc.
- Domestic sewage is also very likely to contain disease-causing microbes.

Synthetic Detergents And Oils

- Added because of washing clothes, cleaning utensils.
- In industries for washing
- Add surfactants and soaps to water
- Toxic to fish, aquatic life.
- Oceans are polluted by oil on a daily basis from oil spills, routine shipping, run-offs and dumping.

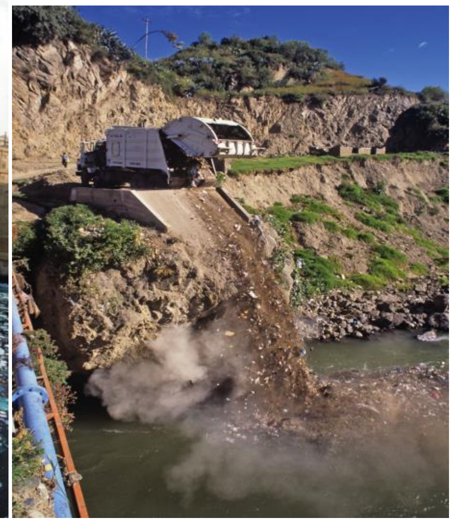
Groundwater Pollution





Highly Polluted River in China

Trash Truck Disposing of Garbage into a River in Peru



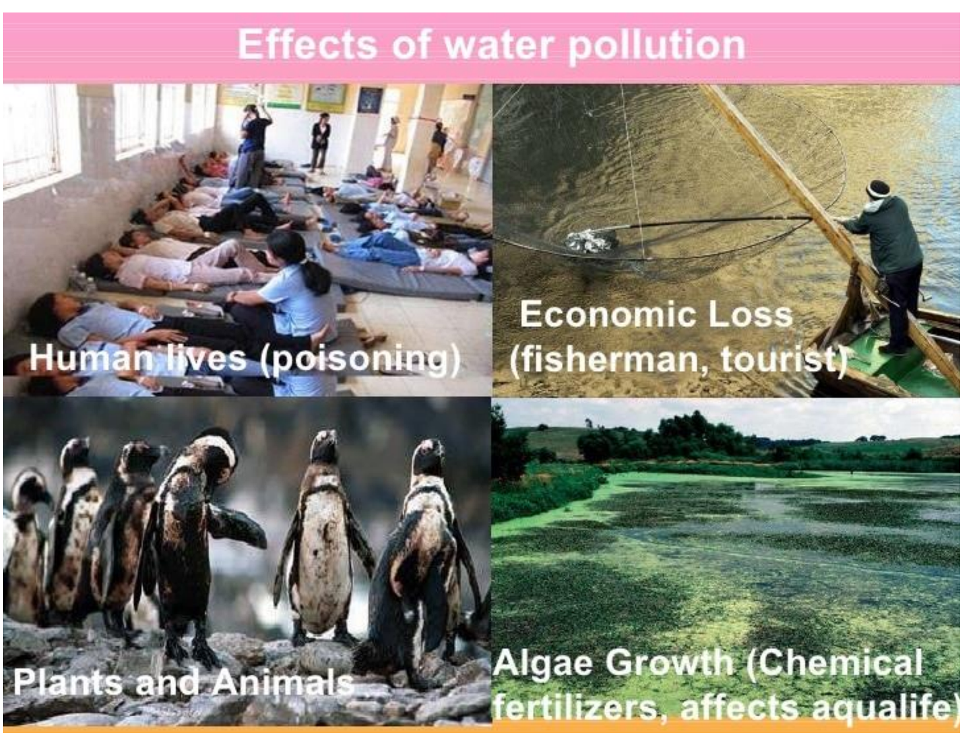
Effects of Water Pollution

Effects of Water Pollution

- Depletion of dissolved oxygen
- Eutrophication
- Pathogen….spreading diseases
- Bio-magnification
- Genetic deformities

- Blue baby Syndrome
- Minamata disease

According to the World Health Organisation, about **5 million people die every year from drinking polluted water.**

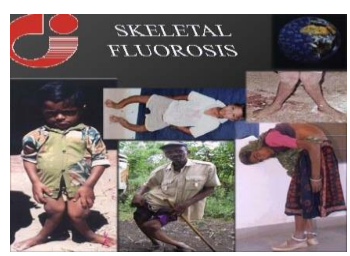


Lake Fish Killed by Water Pollution

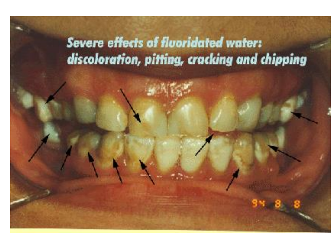
Fig. 20-10, p. 536

Fluoride Poisoning

- The incidence of fluoride above permissible levels of 1.5ppm occur in 14 Indian states, namely: Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra,
- Some Estimates find that 65 per cent of India's villages are exposed to fluoride risk.



- Fluoride had been reported to cause depressions in DNA and RNA synthesis in cultured cells.
- Another study on the effects of fluorides in mice showed significant reductions in DNA and RNA levels.
- Conditions including ageing, cancer, and arteriosclerosis are associated with DNA damage and its disrepair.



Arsenic Poisoning

- High levels of arsenic above the permissible levels of 50 parts per billion (ppb) are found in the alluvial plains of Ganges covering six districts of West Bengal.
- Arsenic contamination of drinking water causes a disease called arsenicosis, for which there is no effective treatment.
- Arsenic contamination is by far the biggest mass poisoning case in the world putting 20 million people from West Bengal and Bangladesh at risk though some other estimates put the figure at 36 million people.

Pathogen Spread

- **Stagnant water and other untreated water** provide a habitat for the mosquito and a host of other parasites and insects that cause a large number of diseases especially in the tropical regions.
- Among these, **malaria is undoubtedly** the most widely distributed and causes most damage to human health.

- *Pesticides*. The organophosphates and the carbonates present in pesticides affect and damage the nervous system and can cause cancer.
- Some of the pesticides contain carcinogens that exceed recommended levels. They contain chlorides that cause reproductive and endocrinal damage.
- *Lead*. Lead is hazardous to health as it accumulates in the body and affects the central nervous system. Children and pregnant women are most at risk.
- *Petrochemicals.* Benzene and other petrochemicals can cause cancer even at low exposure levels.
- *Chlorinated solvents.* These are linked to reproduction disorders and to some cancers.
- *Other heavy metals*. –Heavy metals cause damage to the nervous system and the kidney, and other metabolic disruptions.

Control of Water Pollution

Control of Water Pollution

- Treatment of water before leaving in water bodies.
- Restoration of polluted water bodies.
- Ganga Action Plan
- River Water Monitoring

Global Environmental Monitoring Stations/ Monitoring of Indian National Aquatic Resource

- CPCB in collaboration with concerned SPCBs/PCCs established a nationwide network of water quality monitoring comprising 2500 stations in 28 States and 6 Union Territories.
- The monitoring is done on monthly or quarterly basis in surface waters and on half yearly basis in case of ground water.
- The monitoring network covers 445 Rivers, 154 Lakes, 12 Tanks, 78 Ponds, 41 Creeks/Seawater, 25 Canals, 45 Drains, 10 Water Treatment Plant (Raw Water) and 807 Wells.
- Among the 2500 stations, 1275 are on rivers, 190 on lakes,
- Water samples are being analysed for 28 parameters consisting of 9 core parameters, 19 other physico-chemical and bacteriological parameters apart from the field observations.

Major Water Pollutants and Their Sources

Table 20-1 Major Water Pollutants and Their Sources

Type/*Effects*	Examples	Major Sources
Infectious agents (pathogens) *Cause diseases*	Bacteria, viruses, protozoa, parasites	Human and animal wastes
Oxygen-demanding wastes *Deplete dissolved oxygen needed by aquatic species*	Biodegradable animal wastes and plant debris	Sewage, animal feedlots, food-processing facilities, paper mills
Plant nutrients *Cause excessive growth of algae and other species*	Nitrates (NO_3^-) and phosphates (PO_4^{3-})	Sewage, animal wastes, inorganic fertilizers
Organic chemicals *Add toxins to aquatic systems*	Oil, gasoline, plastics, pesticides, fertilizers, cleaning solvents	Industry, farms, households, mining sites, runoff from streets and parking lots
Inorganic chemicals *Add toxins to aquatic systems*	Acids, bases, salts, metal compounds	Industry, households, mining sites, runoff from streets and parking lots
Sediments *Disrupt photosynthesis, food webs, other processes*	Soil, silt	Land erosion from farms and construction and mining sites
Heavy metals *Cause cancer, disrupt immune and endocrine systems*	Lead, mercury, arsenic	Unlined landfills, household chemicals, mining refuse, industrial discharges
Thermal *Make some species vulnerable to disease*	Heat	Electric power and industrial plants

Table 20-1, p. 532

Water Quality as Measured by Dissolved Oxygen Content in Parts per Million

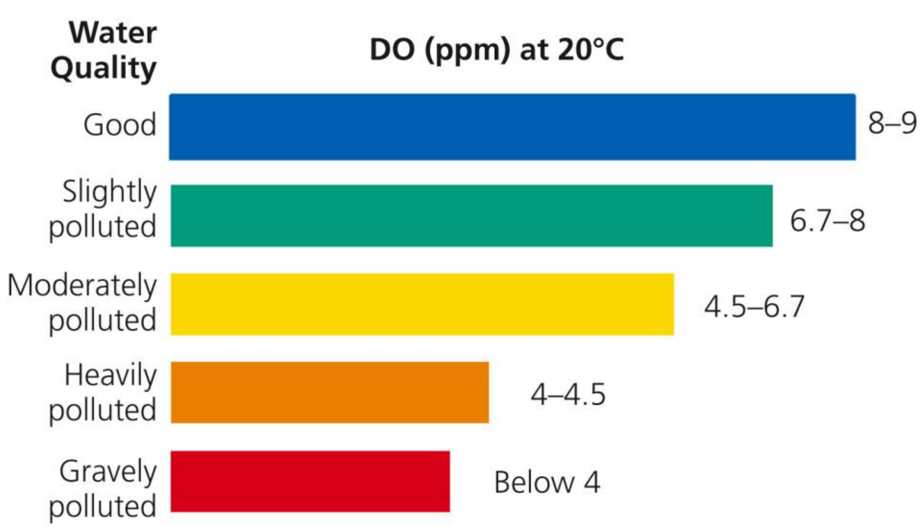


Fig. 20-A, p. 533

Solutions: Septic Tank System

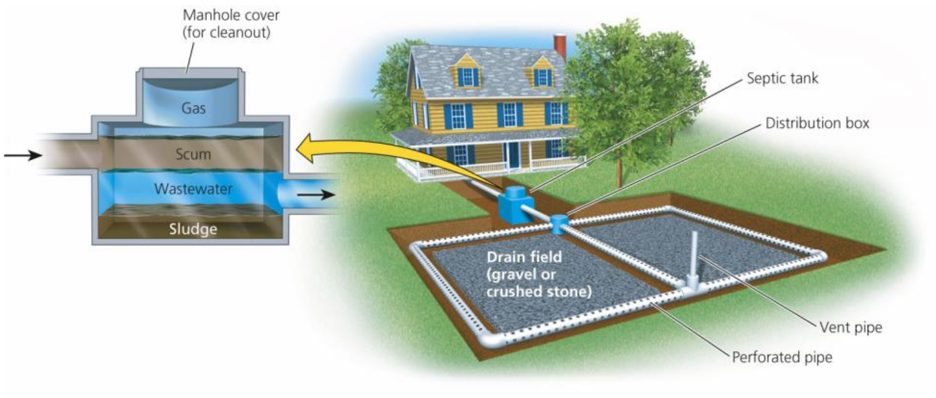


Fig. 20-19, p. 550

Solutions: Primary and Secondary Sewage Treatment

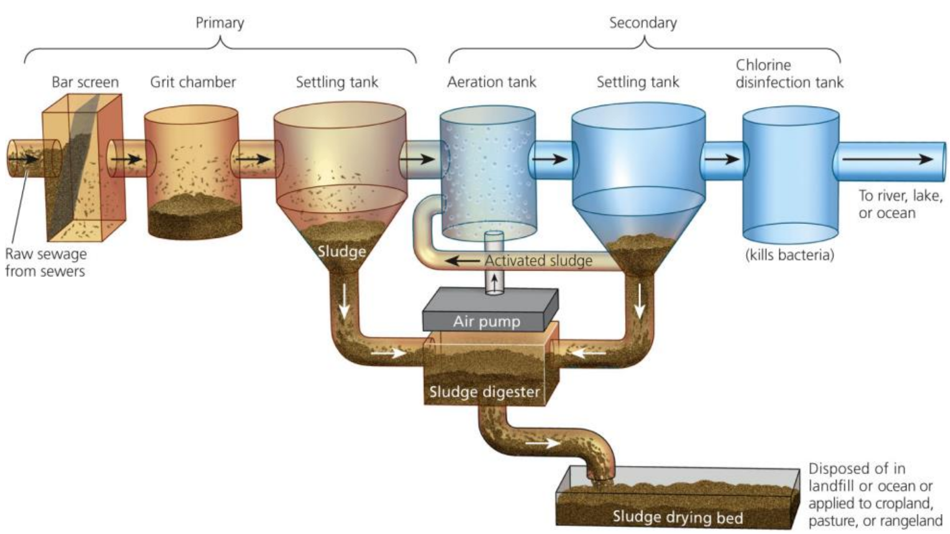


Fig. 20-20, p. 551

We need to be continually aware of saving water and keeping it clean

WHAT HAVE WE LEARNT?

1. **KEEP WATER CLEAN FROM ALL KINDS OF POLLUTION.**
2. **MAKE SURE ALL LEAKING TAPS AND OLD PLUMBING FITTINGS ARE FIXED REGULARLY.**
3. **COLLECT RAINWATER IN TANKS FROM THE ROOF.**
4. **USE GREY WATER TO FLUSH TOILETS AND WATER TREES**
5. **LOOK AFTER OUR WETLANDS TO PROTECT THE WATER TABLE AND AQUIFERS.**
6. **REGULATE THE DRILLING OF WELLS.**

Solutions

Water Pollution

- Prevent groundwater contamination
- Greatly reduce nonpoint runoff
- Reuse treated wastewater for irrigation
- Find substitutes for toxic pollutants
- Work with nature to treat sewage
- Practice four R's of resource use (refuse, reduce, recycle, reuse)
- Reduce resource waste
- Reduce air pollution
- Reduce poverty
- Reduce birth rates

What Can You Do?

Water Pollution

- Fertilize your garden and yard plants with manure or compost instead of commercial inorganic fertilizer.
- Minimize your use of pesticides.
- Never apply fertilizer or pesticides near a body of water.
- Grow or buy organic foods.
- Compost your food wastes.
- Do not use water fresheners in toilets.
- Do not flush unwanted medicines down the toilet.
- Do not pour pesticides, paints, solvents, oil, antifreeze, or other products containing harmful chemicals down the drain or onto the ground.

Water Conservation Options

Operational and Housekeeping Measures

- Monitor water consumption and establish baseline.
- Optimise blowdown from evaporative cooling towers.
- Adopt reuse practices such as final rinses from tank cleaning, refrigeration equipment defrost, equipment cleaning, soak water (electroplating plant), filter backwash etc.
- Segregate waste process streams (low- and high-strength) at their potential reuse.
- Inspect nozzles regularly for clogging and clean them.

Low-cost Measures

- Adopt pressure reduction valves where applicable: Potential savings: up to 25%.
- Increase COC through chemical treatment of circulating water. This will reduce blowdown.
- Adopt low-flush and ultra-low-flush toilets (commercial buildings).
- Install efficient drift eliminators to improve cooling tower efficiency.
- Adopt rainwater harvesting.
- Uses drift irrigation for landscaping or garden.

Retrofit Measures

- Adopt electronic hand wash(saves 70% water), water less urinals (100% water) for buildings.
- Adopt ozonation (use of ozone) to treat cooling water which can reduce blowdown by 80% when compared to traditional treatment.
- Install meters on individual water consuming equipment.
- Replace old equipment with water saving models.

Sustainable Development Goals

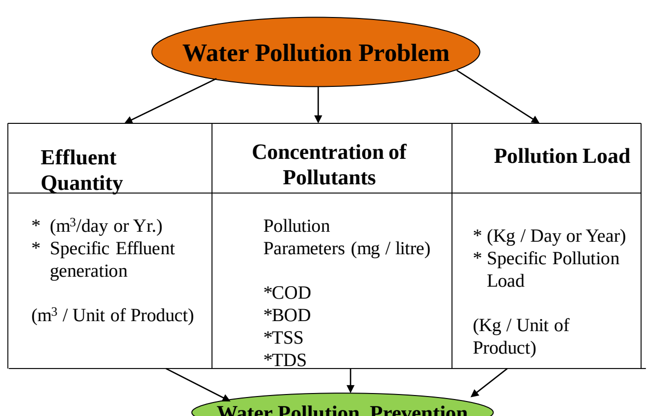
ENSURE AVAILABILITY AND SUSTAINBLE MANGEMENT OF WATER AND SANITAITON FOR ALL

By 2030, **improve water quality** *by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally*

By 2030, substantially **increase water-use efficiency** *across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity*

By 2020, **protect and restore water-related ecosystems,** *including mountains, forests, wetlands, rivers,aquifers and lakes*

WATER POLLUTION PROBLEM AND ITS PREVENTION



MINIMISATION OF ONE OR TWO OR ALL OF THE ABOVE

WATER POLLUTION PREVENTION HIERARCHY

BEFORE PRODUCTION PROCESS & UTILITIES
- Water Sourcing
- Water Treatment

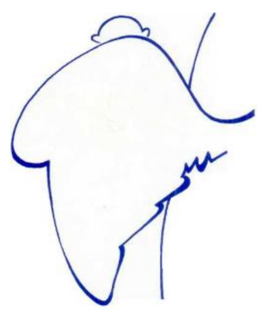
AT PRODUCTION PROCESS
- Water use Minimisation
- Pollution Load Reduction
  - # House Keeping
  - # Process Modifications

AT UTILITIES
Optimisation of Water use & Chemical use

WASTEWATER MANAGEMENT
Characterisation
Segregation
Recycling
Treatment
Reuse

ENVIRONMENTAL MANAGEMENT SYSTEM ISO 14001

- ISO 14001 is a certificate given for keeping a good environment and Continuous environment
- ISO – International organisation for standardisation
- By saying we are ISO 14001 company, we will have a good public image



SAVE *the Nature to --* YOU !!!

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.

Pollution aspects of various power plants; Fossil fuels and impacts, Industrial and transport emissions impacts

Thermal Power Plant
Combustion and Pollution

Introduction to Fuels

What are the Types of fuel used in all combustion equipment?

Solid, Liquid, and gaseous fuels are being used in Industrial boilers/furnaces for combustion

Type of Fuels	**Categories**
Solid	**Coal & Lignite**
Liquid	**HSD, LDO, F.Oil, LSHS**
Gaseous	**N.Gas, Bio- gas**
Agro- Waste	**Bagasse, Pith, Rice Husk, coconut shell**

A good knowledge of fuel properties will be helpful for selecting right type of fuel for right application and also efficient of fuel

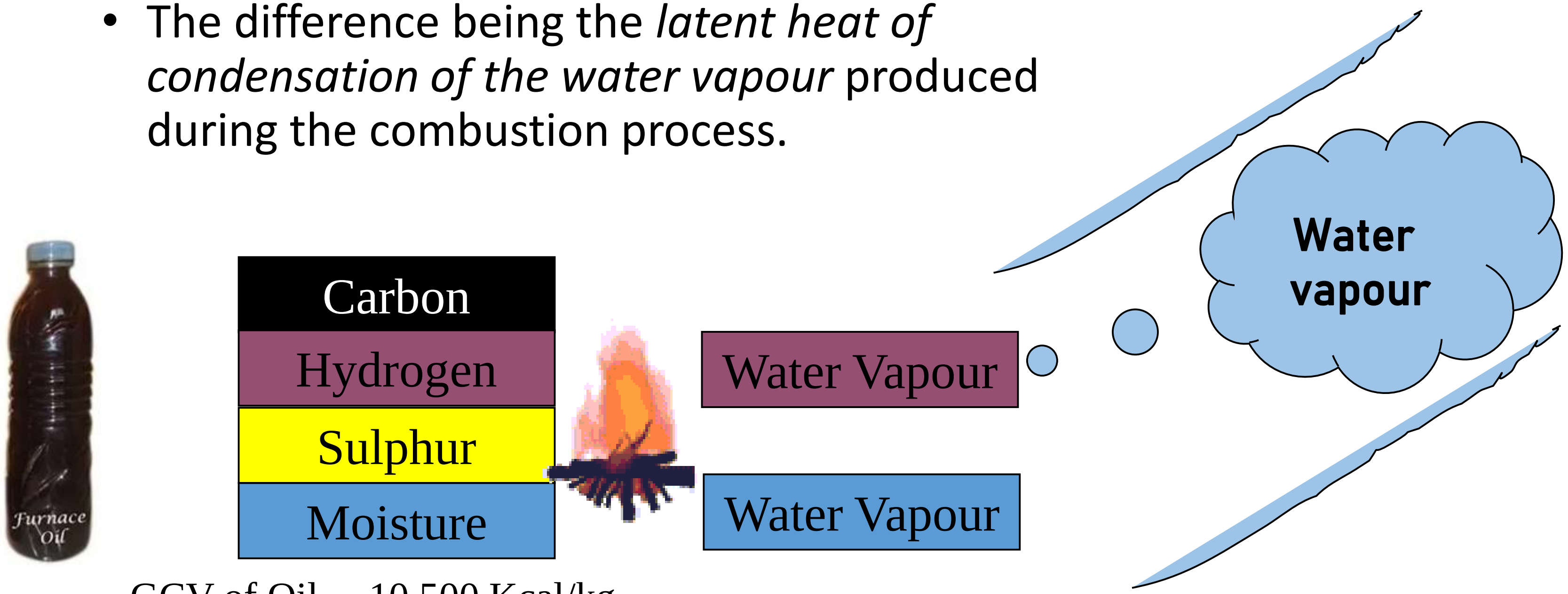
Calorific Value

- The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value.

$$C + O_2 \rightarrow CO_2 + \underline{8084} \text{ Kcals/kg of Carbon}$$

$$2C + O_2 \rightarrow 2\,CO + 2430 \text{ Kcals/kg of Carbon}$$

- The difference being the *latent heat of condensation of the water vapour* produced during the combustion process.



GCV of Oil – 10,500 Kcal/kg

NCV – 9800 Kcal/kg

Properties of Coal

Coal Classification

ANTHRACITE

Oldest & hard coal
High carbon with little volatile content & practically no moisture

BITUMINOUS COAL
Sum-bituminous

Commonly used in India

LIGNITE

Youngest & soft coal
Mainly high volatile matter and moisture with Low fixed carbon

Table 1.4 GCV for Various Coals				
Parameter	**Lignite** (Dry Basis)	**Indian Coal**	**Indonesian Coal**	**South African Coal**
GCV, (kcal/kg)	4,500*	4,000	5,500	6,000

Properties of Gaseous Fuels

LPG, N.gas, producer gas, blast furnace gas, coke
oven gas etc . The GCV is expressed kcal/Nm3 i.e. at

Typical Physical and Chemical Properties of Various Gaseous Fuels				
Fuel Gas	Relative	Higher Heating	Air/Fuel ratio,	Flame

- **Methane** is the main constituent (> 95%)
- No Sulphur content.
- **Lighter than air** (0.668 KG/M3)

Sulphur	3	0.41	-
Oxygen	1	9.89	Trace
Nitrogen	Trace	1.22	0.75
Ash	Trace	38.63	-
Water	Trace	5.98	-

Combustion of Gas

Natural gas is pure methane, CH_4. Its combustion equation is

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

for every 16 kgs of methane consumed, 64 kg O2 = 44 kgs of carbon dioxide & 36 Kg of water vapour produced. <u>Stoichiometric air fuel ratio by volume 10:1</u>

Liquefied Petroleum Gases (LPG) C3H8

Low-And High-Pressure Gas Burners.

Low-pressure burners using gas at a pressure less than 0.15 kg/cm^2 (2 psi)

Excess air levels in natural gas burner are in the order of 5%.

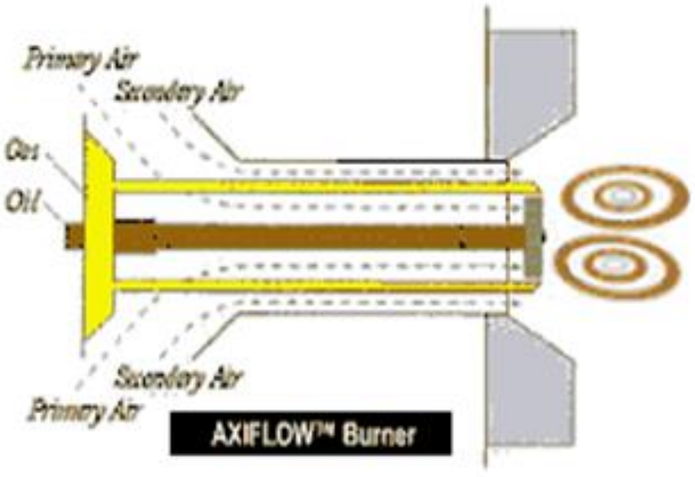


Figure 1.8 High Pressure Gas Mixer

Properties of Agro Residues

Table 1.15 Ultimate Analysis of Typical Agro Residues				
	Deoiled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Mineral Matter	19.77	16.73	1.63	3.52
Carbon	36.59	33.95	48.55	44.95
Hydrogen	4.15	5.01	6.99	4.99
Nitrogen	0.82	0.91	0.80	0.56
Sulphur	0.54	0.09	0.10	0.08
Oxygen	31.02	32.52	41.93	31.94
GCV (Kcal/kg)	3151	3568	4801	4565

What is bulk density?
Transport cost is high




Which among the above Agro residue has higher and lowest GCV?

Combustion of Biomass

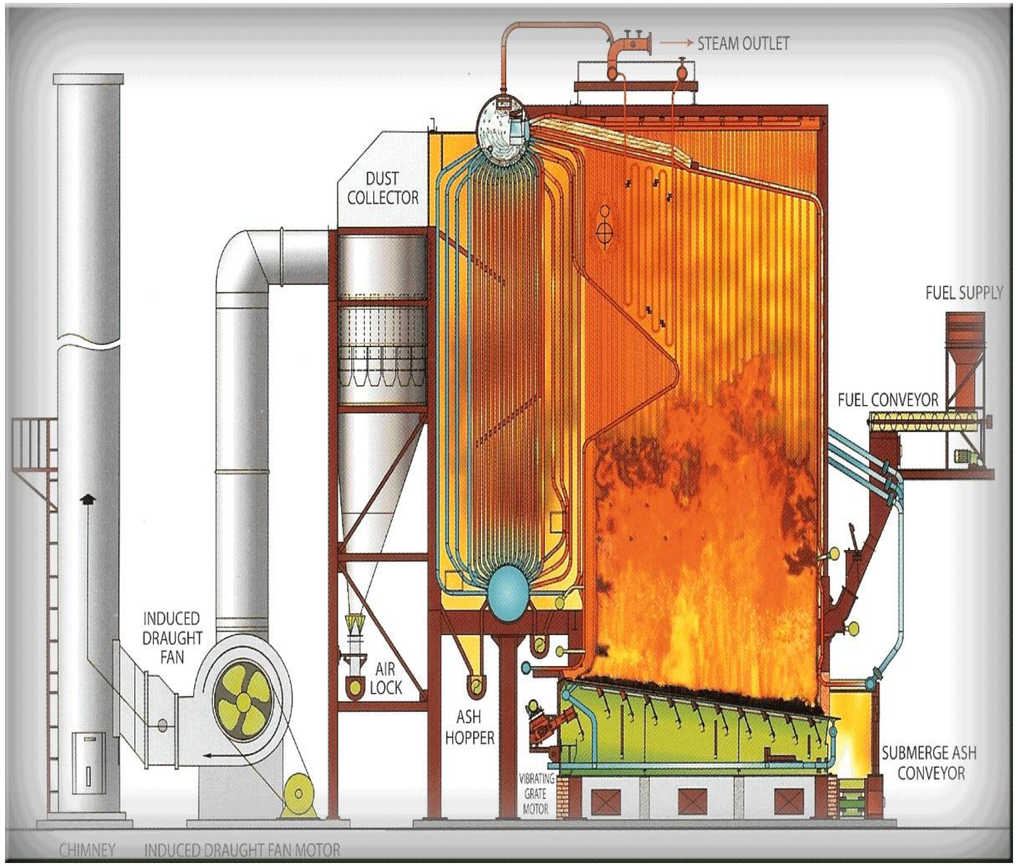
Biomass can be converted into energy (heat/Power)

During combustion,

1. First looses moisture at up to 100°C on heating
2. Then dried particle heats up, volatile gases (HCs, CO, CH_4) are released & contributing >70% of the heating value
3. Finally, char oxidises and ash remains.

Moisture in feed may vary from 25 - 55%
Temperatures of biofuels -800 to 1200°C

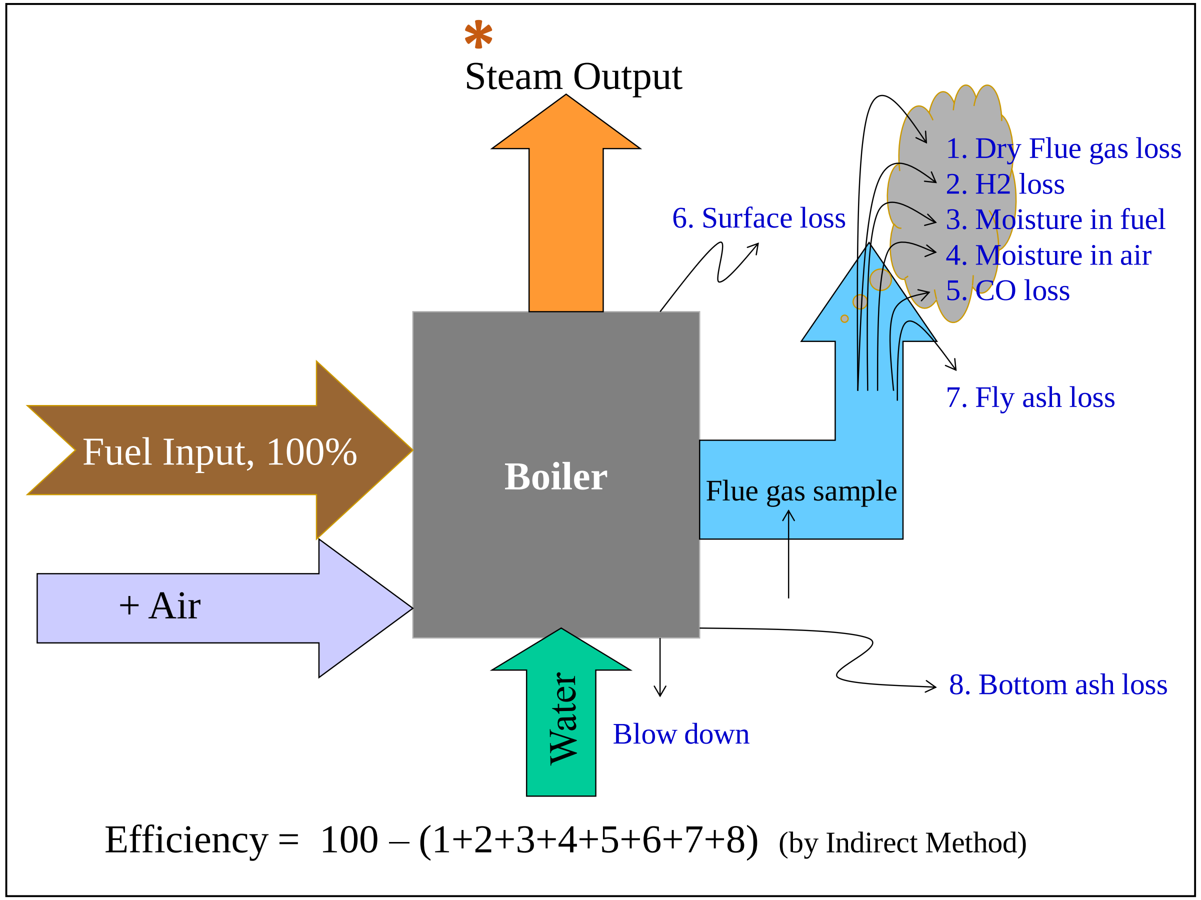
Fixed bed combustion: Grate furnaces are appropriate for high moisture, different particle sizes, and high ash content fuels. *For smaller plants, fixed bed systems are usually more cost-effective.*
Fluid bed combustion plants are used for largescale applications (30 MWth).



Biomass Combustion in a Boiler Biomass Cogen Video

1.7 Indirect Method Testing- Concept Diagram

***Measure**
All Input & all Output **except** steam output



1. which method is most accurate one?

In direct method, If boiler efficiency is 90%, an error of 1% will result in significant change in efficiency.

i.e.90 $\pm$ 0.9 = 89.1 to 90.9.

In indirect method, 1% error in measurement of losses will result in

Efficiency = 100 – (10 $\pm$ 0.1)

= 90 $\pm$ 0.1 = 89.9 to 90.1 ***most accurate***

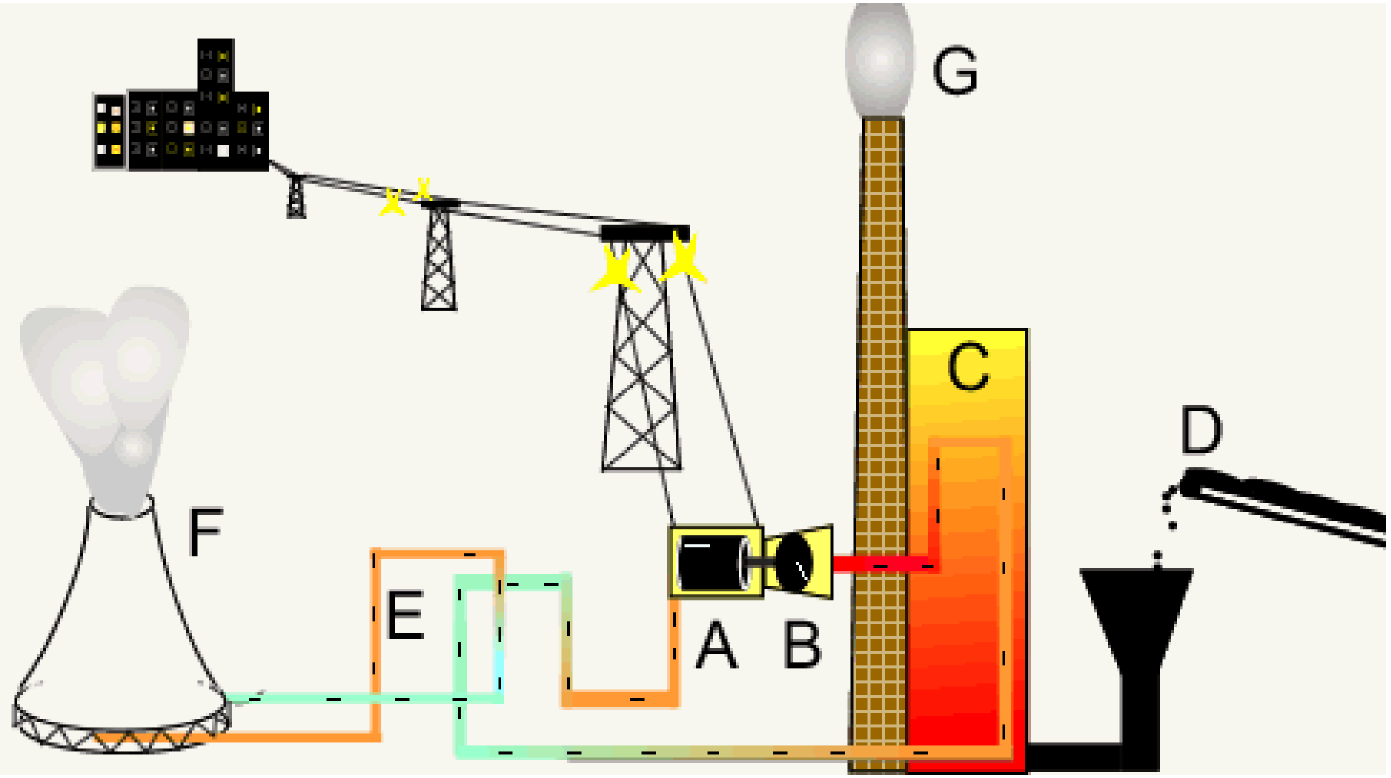
2. State two causes for rise in exit flue gas temperature in a boiler

3. Why boiler efficiency by indirect method is more useful than direct method?

Thermal Power Station

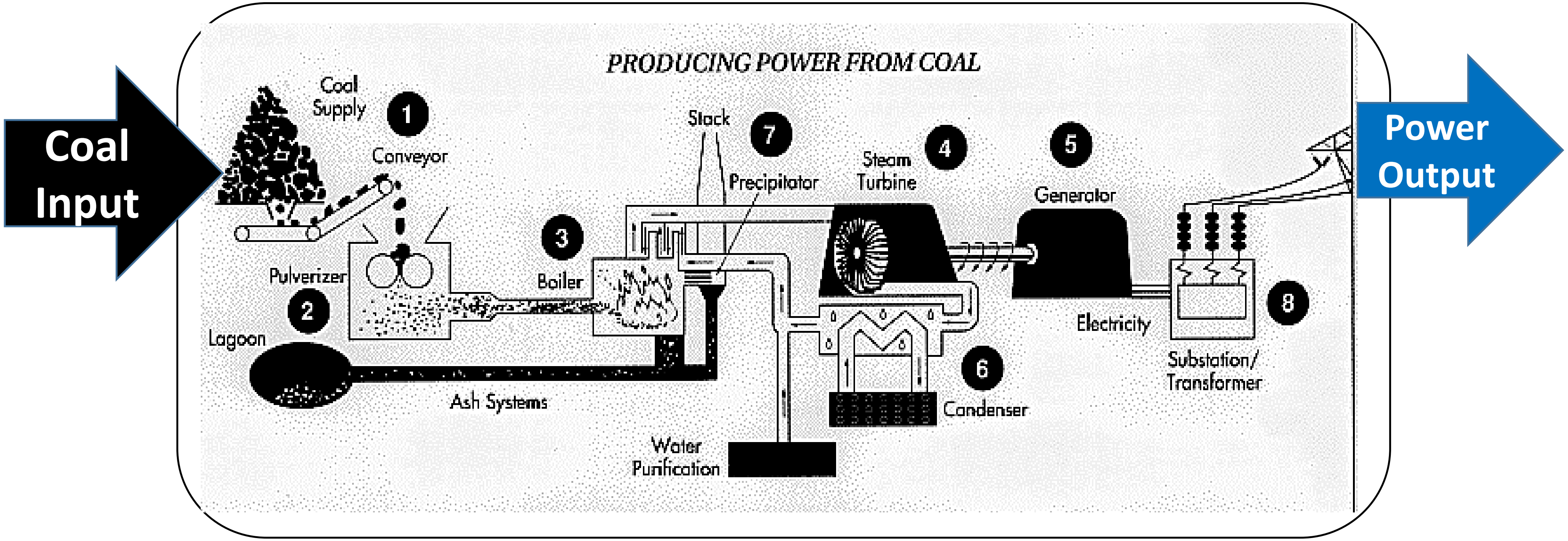
Contents

Fundamental Concepts



https://youtu.be/IdPTuwKEfmA

Thermal Power Generation Plant



What is the power plant efficiency ?

$$\frac{\text{Output power in kcals} \times 100}{\text{Input coal in kcals}}$$

What is the power plant heat rate?

$$\frac{\text{Input coal in K.Cal}}{\text{Output power in KWH}}$$

11.1 Introduction

Purpose of the Performance Test

The purpose of the performance test is to find the efficiency parameters for **the power plant as a whole** and also the **various components of the power plant.**

Performance Terms and Definitions

1 Gross Heat Rate **or 'GHR'** means the heat energy input in kCal required to generate one kWh of electrical energy at generator terminals;

$$\text{Gross heat rate } (Q_e), \text{kcal/kWh} = \frac{\text{Fuel consumption, kg} \times \text{GCV of fuel, kcal/kg}}{\text{Generator output, kWh}}$$

Net heat rate refers to the heat rate after deducting the auxiliary power consumption

2 Net Heat Rate **or NHR** – The heat energy in kCal, input to a Generating Station to deliver one kWh **at the switchyard**.

$$\text{Net heat rate } (Q_e), \text{kcal/kWh} = \frac{\textit{Gross heat rate, kcal / kWh}}{1-(\%\ \textit{auxiliary power consumption} / 100)}$$

3 Plant Load Factor or 'PLF' =

$$\frac{\text{Energy generated during the period (MWh)}}{\text{Total capacity (MW) x total hours in the period}} 100$$

4 Overall efficiency

The term "overall efficiency" as defined **solely for power generation only**

$$\text{Overall efficiency}, \eta\ \% = \frac{\text{Generator output, kW}}{\text{Mass flow rate of fuel, kg/s} \times \text{Gross calorific value, kJ/kg}} \times 100$$

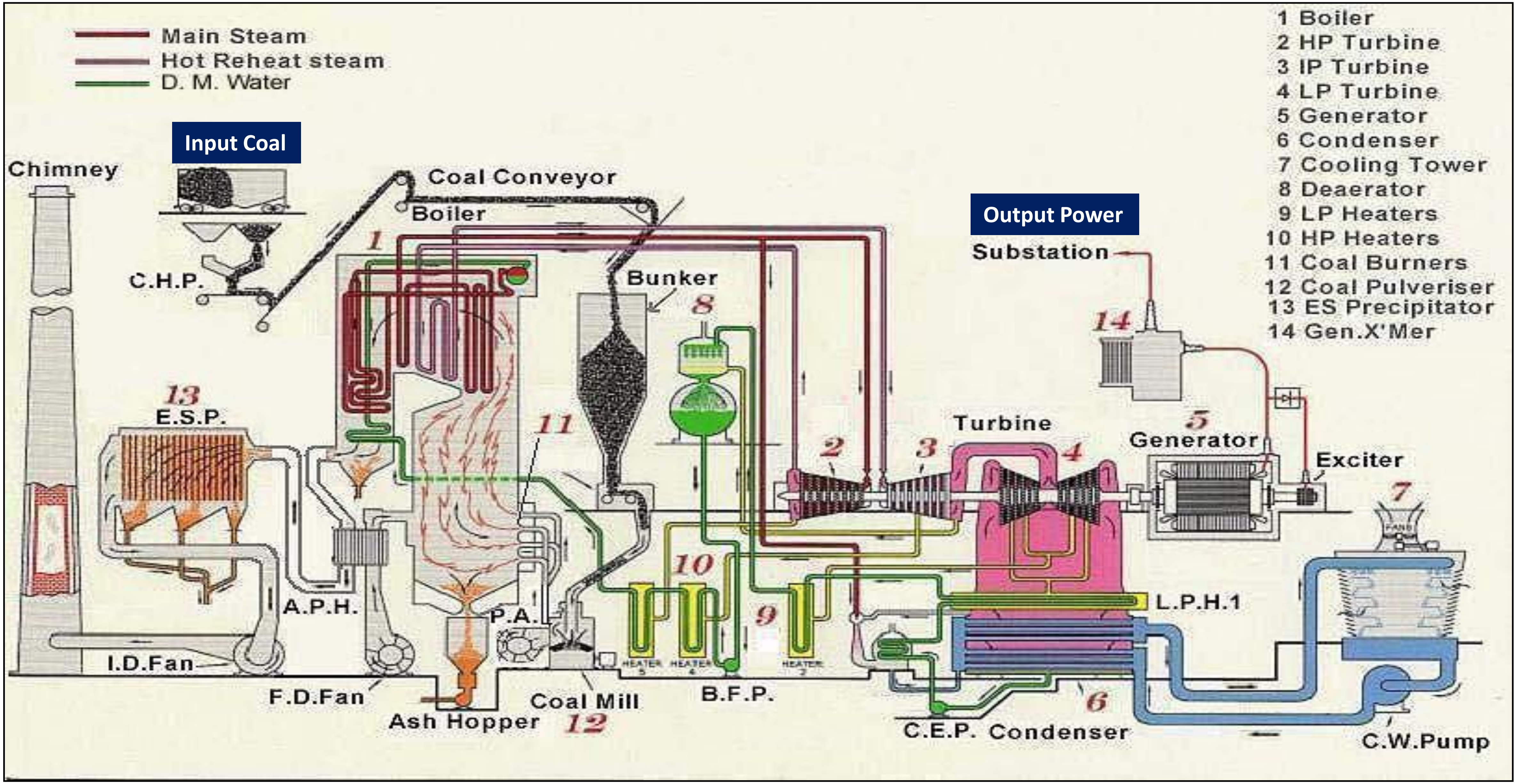
$$\text{Overall efficiency, \%} = \frac{860}{\text{Gross heat rate, kcal/kWh}} \times 100$$

5 Specific fuel consumption

$$\text{Specific fuel consumption, kg/kWh} = \frac{\text{Total fuel consumption, kg}}{\text{Gross generation, kWh}}$$

Auxiliary Energy Consumption energy consumed by auxiliary equipment of the generating station and transformer losses within the generating station, and shall be expressed as a % of the sum of gross energy generated **at the generator terminals;**

Components of a Typical Power Plant



Major Area/Equipments in Thermal Power Plant are

1. **Fuel handling system and preparation** *(Coal handling system and coal mills)*
2. **Boilers and its associated parts**
3. **Steam Turbines and its associated parts**
4. **Condensers**
5. **Draft system and Fans** *(ID fans, FD fans, PA fans)*
6. **Water pumping systems** *(Boiler feed water , Condensate extraction pump, DM water pump, Make up water pump, Raw water pump, etc).*

Typical auxiliary power consumption in power plant

Equipment Ref.	500 MW		210 MW		110 MW	
	% Gen	% APC	% Gen	% APC	% Gen	% APC
BFP	0.00*	0.00*	2.70	33.60	2.94	24.50
CEP	0.40	5.70	0.27	3.34	0.36	3.00
CWP	1.00	14.20	0.66	8.31	1.26	10.50
IDF	1.30	18.70	1.26	15.80	1.71	14.23
PAF	0.60	8.50	0.68	6.50	1.78	14.46
FDF	0.30	4.10	0.40	5.00	0.26	2.13
Mills	0.60	8.20	0.58	7.23	0.83	6.92
CT fans	0.23	3.20	0.32	3.54	0.48	4.00
Air Comp.	0.08	1.20	0.12	1.56	0.24	2.00
A/C Plant	0.04	0.50	0.08	0.94	0.11	0.92
CHP	0.12	1.70	0.14	1.70	0.29	2.41
AHP	0.09	1.20	0.13	1.66	0.31	2.54
Lighting	0.06	0.80	0.08	1.00	0.08	0.68
others	2.23	31.90	0.60	7.44	1.36	11.32
APC	**7.00**	**100.00**	**8.00**	**100.00**	**12.00**	**100.00**

1- Coal Handling Plant

Coal handling plant is one of the important energy consumers in thermal power plants and contains the following energy consuming equipments. Crushers, Conveyors, Feeders Tipplers

The major objectives of coal handling plant energy audit are

- To evaluate specific energy consumption of the CHP equipments (kWh/ton of coal)
- To evaluate percentage power consumption of CHP with respect to total auxiliary power consumption
- To analyse the crushed coal size and rejects

Coal Mills

The major objectives of coal mill energy audit are

- To evaluate specific energy consumption of the mills. **(kWh/ton of coal)**
- To establish air to coal ratio of the mills **(ton of air per ton of coal)**
- To perform heat balance of the mills
- To analyse the coal fineness and mill rejects

Example 11.1. Determine the air fuel ratio and specific energy consumption of mill from the following data

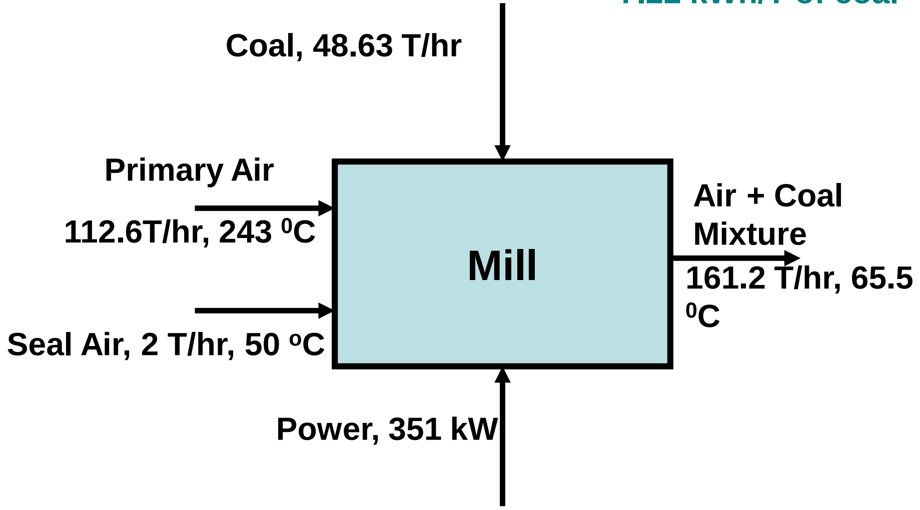
Coal flow rate	= 48.64 TPH
Air flow rate	= 112.6 TPH
Energy consumption	= 351 kW

$$\text{Air to coal ratio of the mill} = \frac{\text{Air flowrate, kg/hr}}{\text{Coal flowrate, kg/hr}}$$

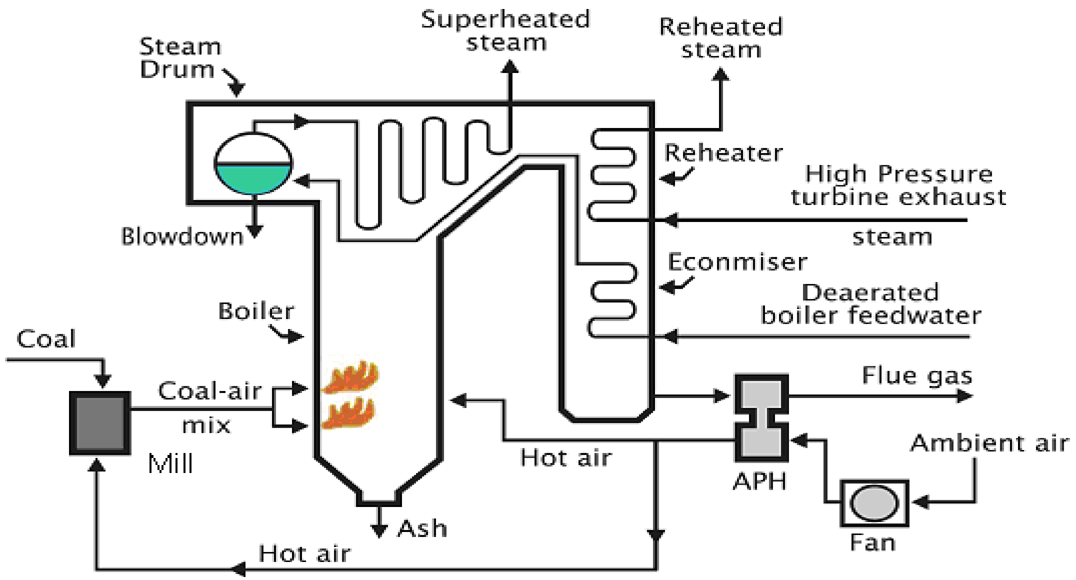
= 112.6 / 48.64
= 2.31 kg of air/kg of coal

$$\text{Specific energy consumption the mill, kWh/T} = \frac{\text{Electricity consumption, kW}}{\text{Coal flowrate, TPH}}$$

= 351 / 48.64
= 7.22 kWh/T of coal



2. Boiler



Schematic diagram of a utility boiler

For performance evaluation of boiler, refer to Chapter – 1 of this book.

Air leakage estimation:

$$APH\ leakage\% = \frac{(O_2\%\ in\ the\ gas\ leaving\ the\ APH\ -\ O_2\%\ in\ the\ gas\ entering\ APH)}{(21 - O_2\%\ in\ the\ gas\ leaving\ APH)} \times 100$$

APH Effectiveness

= (Air temp APH out – Air Temp APH in)/(Flue Gas temp. APH in – Air temp. APH in)
= (354 – 35) / (379 – 35)
= 92.7 %

Economiser Effectiveness

= (F. W temp out – FW temp in) / (F. Gas temp ECO in – F. Water temp in)
= (274 – 244) / (473 – 244)
= 13.1 %

Typical boiler specifications for a 210 MW unit

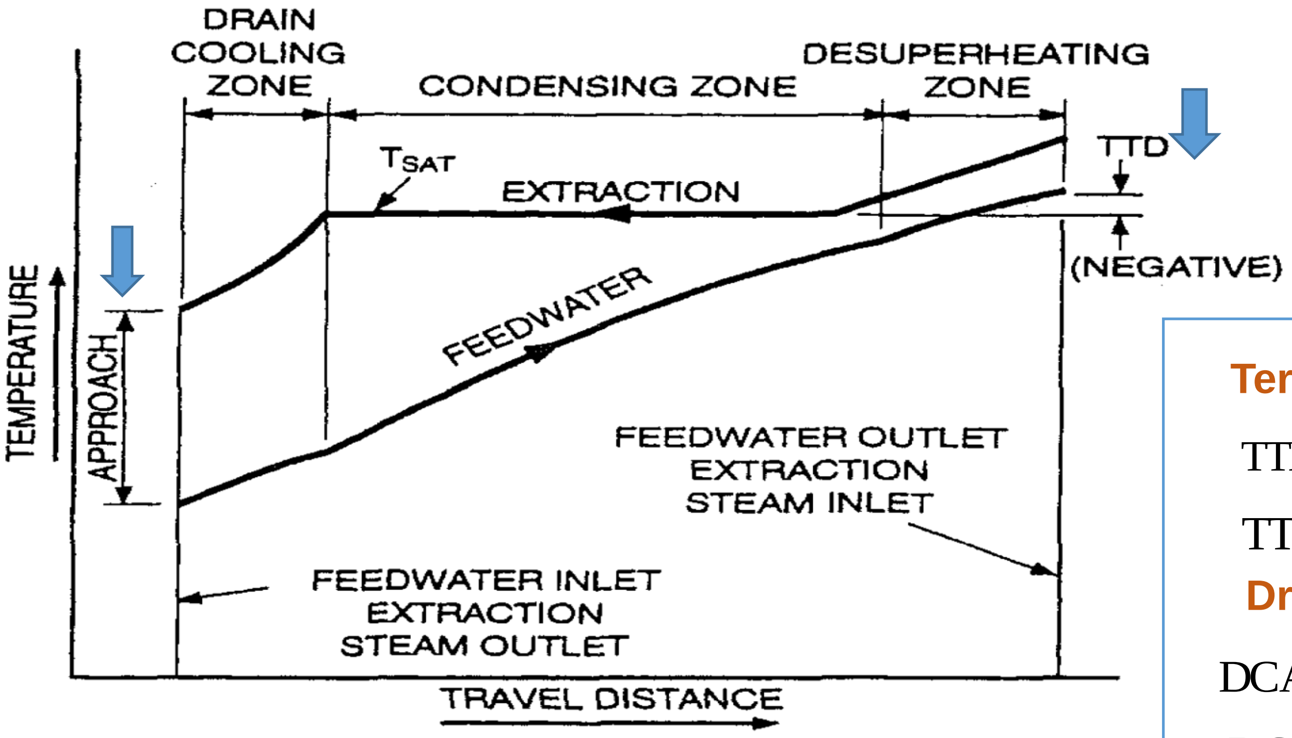
Particulars	Unit	Details at Continuous Rating (NCR)
Type		Water tube single drum
Capacity	TPH	627.32
Main Steam pressure	kg/cm^2	155
Main Steam temperature	^{0}C	540
Boiler efficiency	**%**	**87.16**
Super heater outlet flow	TPH	627.32
Reheater outlet flow	TPH	565.6
GCV of coal	kCal/kg	4350
Coal consumption	TPH	106.2
Total combustion air	TPH	822
Re-heater outlet temperature	^{0}C	540
Water-economizer inlet temperature	^{0}C	241
Water-economizer outlet temperature	^{0}C	280
Oxygen content at economizer outlet	%	4.23

LP and HP Heaters Performance

❑ Performance of the feed water heaters

Terminal Temperature Difference (TTD)

Drain Cooler Approach (DCA)



Temperature profile for a feed water heater

Parameter Reference	UNIT	LP Heater
Extraction steam pressure	kg/cm^2 (a)	0.614
Extraction steam temperature	^oC	86.5
Shell steam pressure	kg/cm^2 (a)	0.488
Shell steam temperature	^oC	86.5
Saturated temperature of steam @ shell pressure	^oC	86.5
Inlet feedwater temperature	^oC	47
Outlet feedwater temperature	^oC	77.5
Drain outlet temperature	^oC	61.8

Terminal Temperature Difference (TTD)

$$TTD = \text{Saturation temp. of extraction steam, } ^oC - \text{Feed water outlet temp., } ^oC$$

$$TTD = 86.5\ ^oC - 77.5\ ^oC \quad TTD = 9\ ^oC$$

Drain Cooler Approach (DCA)

$$DCA = \text{Drain outlet temp., } ^oC - \text{Inlet feed water temp., } ^oC$$

$$DCA = 61.8\ ^oC - 47\ ^oC \quad DCA = 14.8\ ^oC$$

Increased values of TTD and DCA with respect to the design values indicate extent of drop in heat transfer mainly due to fouling.

6. Condenser

Purpose of the Condenser Performance Test

Condenser is designed for certain **cooling water inlet temperature, thermal load and condenser back pressure.**

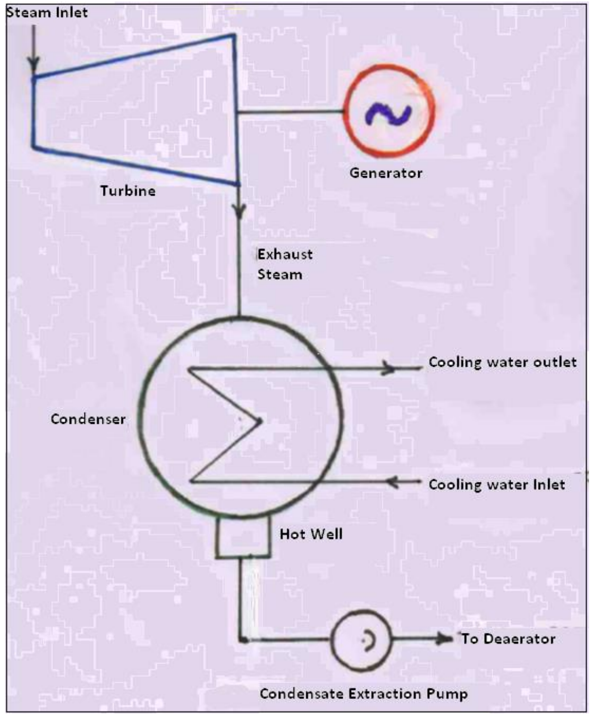
1. The performance of the condenser is expected to deteriorate over a period of time due to bad chemistry of cooling water maintained in it resulting in **scale formation and tube fouling affecting the heat tran**sfer badly.
2. **Low cooling water flow** through the condenser tubes raises the exhaust steam **temperature and thus the condenser back pressure**.
3. **Air ingress** into the condenser through leaky valves, pipe fittings and instrument tapings and improper functioning of Steam Jet Air Ejector will also contribute to **increased condenser back pressure.**

As the condenser back pressure increases, the Turbine output decreases because each unit mass of steam does less work on the turbine.

Hence performance assessment of the condenser is periodically required to determine:

- **i. Condenser effectiveness**
- **ii. Condenser heat load**
- **iii. The terminal temperature difference (TTD)**

The values achieved during performance assessment are compared with the design values or performance guaranteed values or the values recorded during first time commissioning of the plant and the reasons for deviations are analysed and actions are taken to improve the performance of the condenser to its rated value and there by maintaining the efficiency of the Turbine cycle.



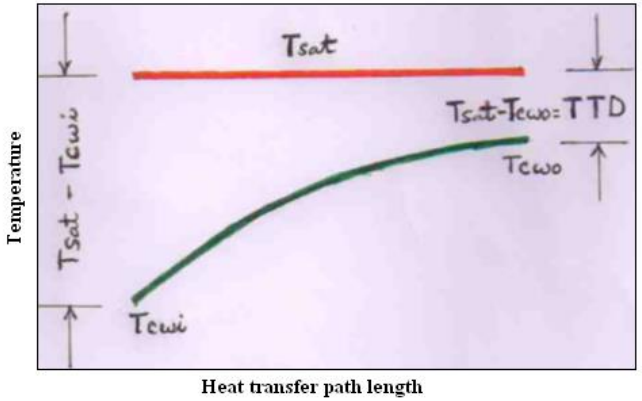
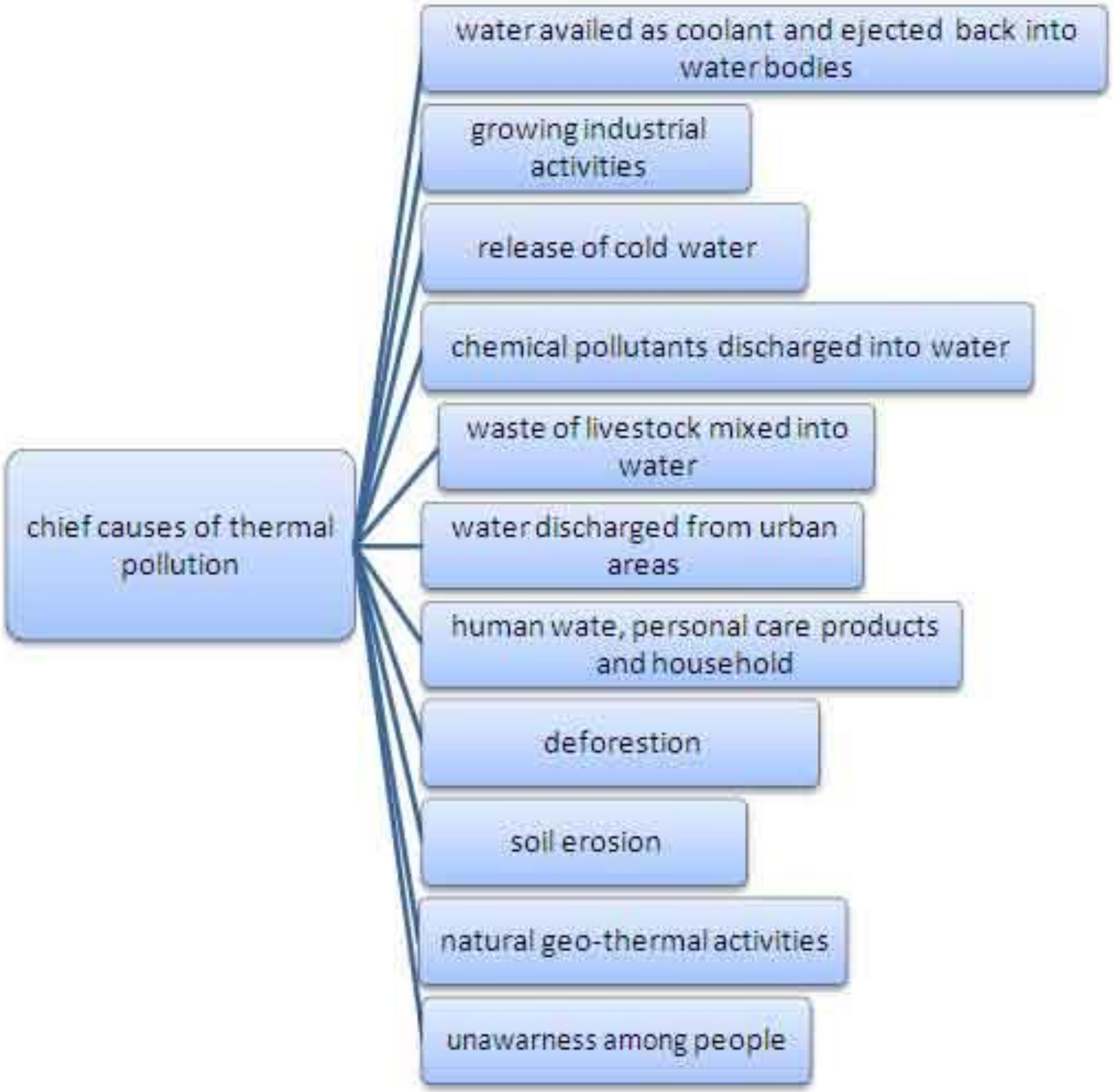
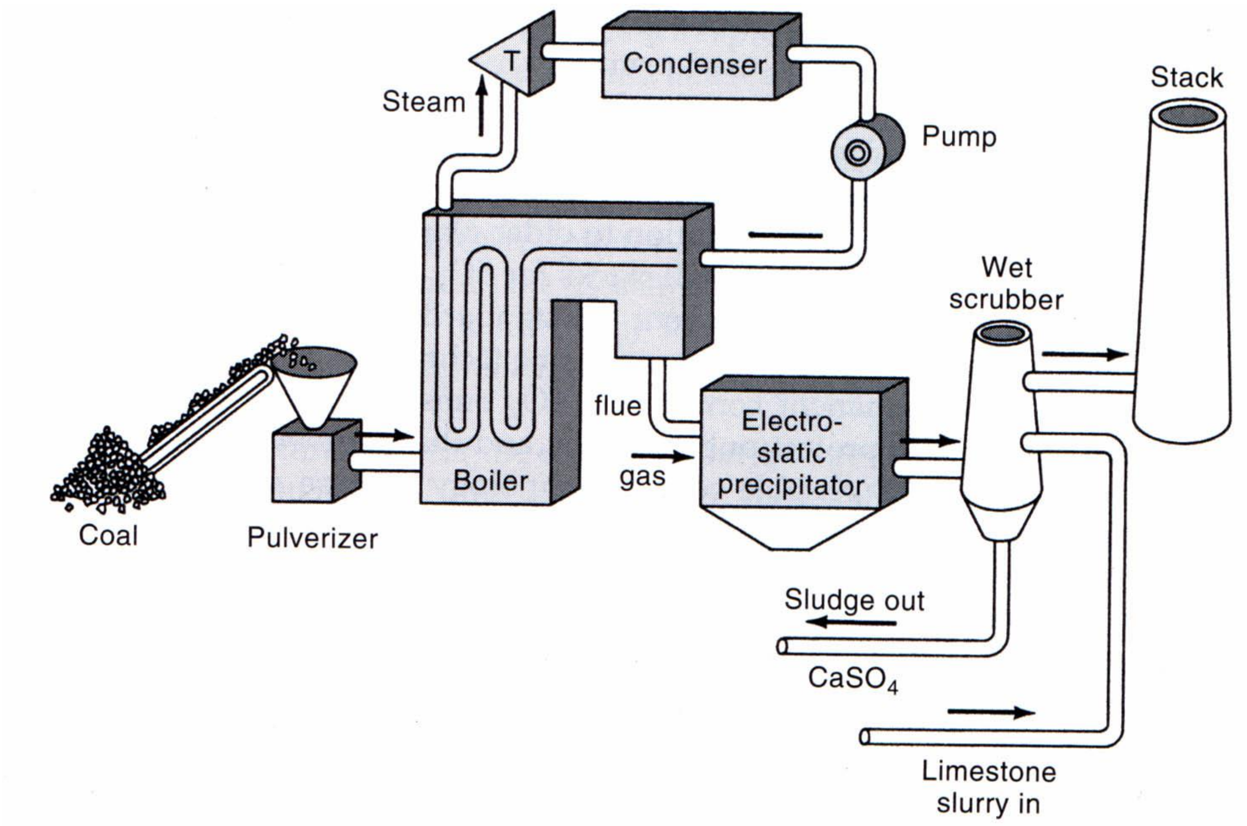


Figure 11.8 Temperature profile across condenser


chief causes of thermal pollution
water availed as coolant and ejected back into water bodies
growing industrial activities
release of cold water
chemical pollutants discharged into water
waste of livestock mixed into water
water discharged from urban areas
human wate, personal care products and household
deforestion
soil erosion
natural geo-thermal activities
unawarness among people

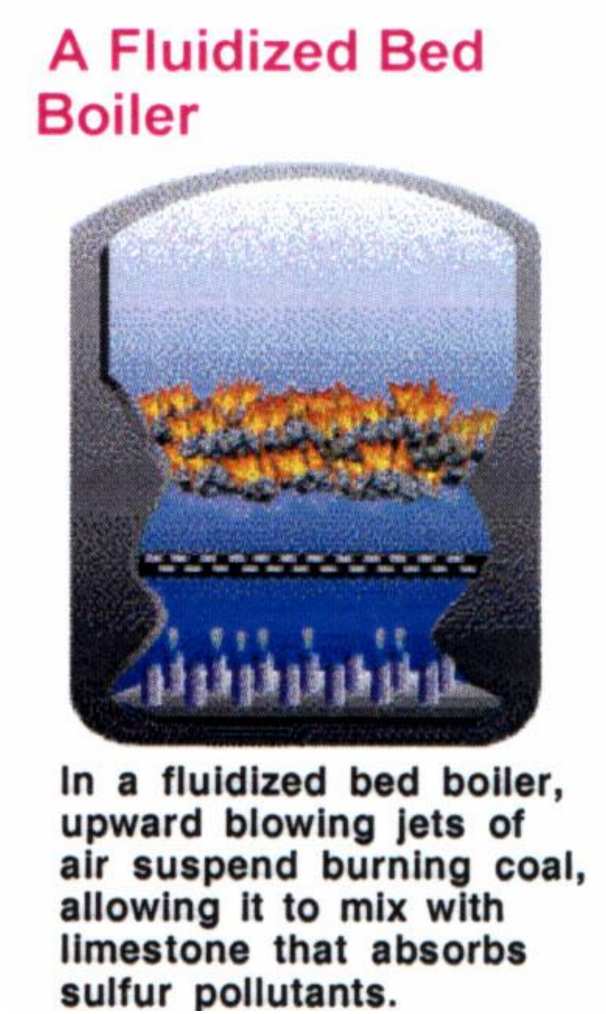
Power Plant Pollution Control



What is being
Removed by
The electrostatic
Precipitator?

By the wet
Scrubber?

Fluidized Bed Combustion



Key Reaction:

CaO (lime) + $1/2 O_2$ + SO_2
= $CaSO_4$ (calcium sulfate)

Limestone = $CaCO_3$

What else besides calcium sulfate
Is emitted by Fluidized Bed
Combustion (FBC)?

FBC reduces NOx by lowering
Temperature of burning

Fossil fuel, biomass, and waste burning power plants

- In the United States, about 65% of total electricity generation in 2018 was produced from fossil fuels (coal, natural gas, and petroleum), materials that come from plants (biomass), and municipal and industrial wastes.
- In India , 75 % electricity is generated from thermal plant
- The substances that occur in combustion gases when these fuels are burned include
- Carbon dioxide (CO2)
- Carbon monoxide (CO)
- Sulfur dioxide (SO2)
- Nitrogen oxides (NOx)
- Particulate matter (PM)
- Heavy metals such as mercury

Negative effects

- Nearly all combustion byproducts have negative effects on the environment and human health:
- CO_2 is a greenhouse gas, which contributes to the greenhouse effect.
- SO_2 causes acid rain, which is harmful to plants and to animals that live in water. SO_2 also worsens respiratory illnesses and heart diseases, particularly in children and the elderly.
- NO_x contribute to ground-level ozone, which irritates and damages the lungs.
- PM results in hazy conditions in cites and scenic areas and coupled with ozone, contributes to asthma and chronic bronchitis, especially in children and the elderly. Very small, or *fine PM*, is also believed to cause emphysema and lung cancer.
- Heavy metals such as mercury are hazardous to human and animal health.

Coal power plants release particulate matter

Soot contains particles anywhere from 2.5 to 10 micrometers in diameter.

These have irregular surfaces that allow sulfur dioxide and nitrogen oxides to bind to them.

If it doesn't have a control system, a typical plant can emit as much as **500 tons of particles into the air each year**.

The particles can cause health problems such as asthma, chronic bronchitis, and even premature death.

Mercury is released during coal combustion:

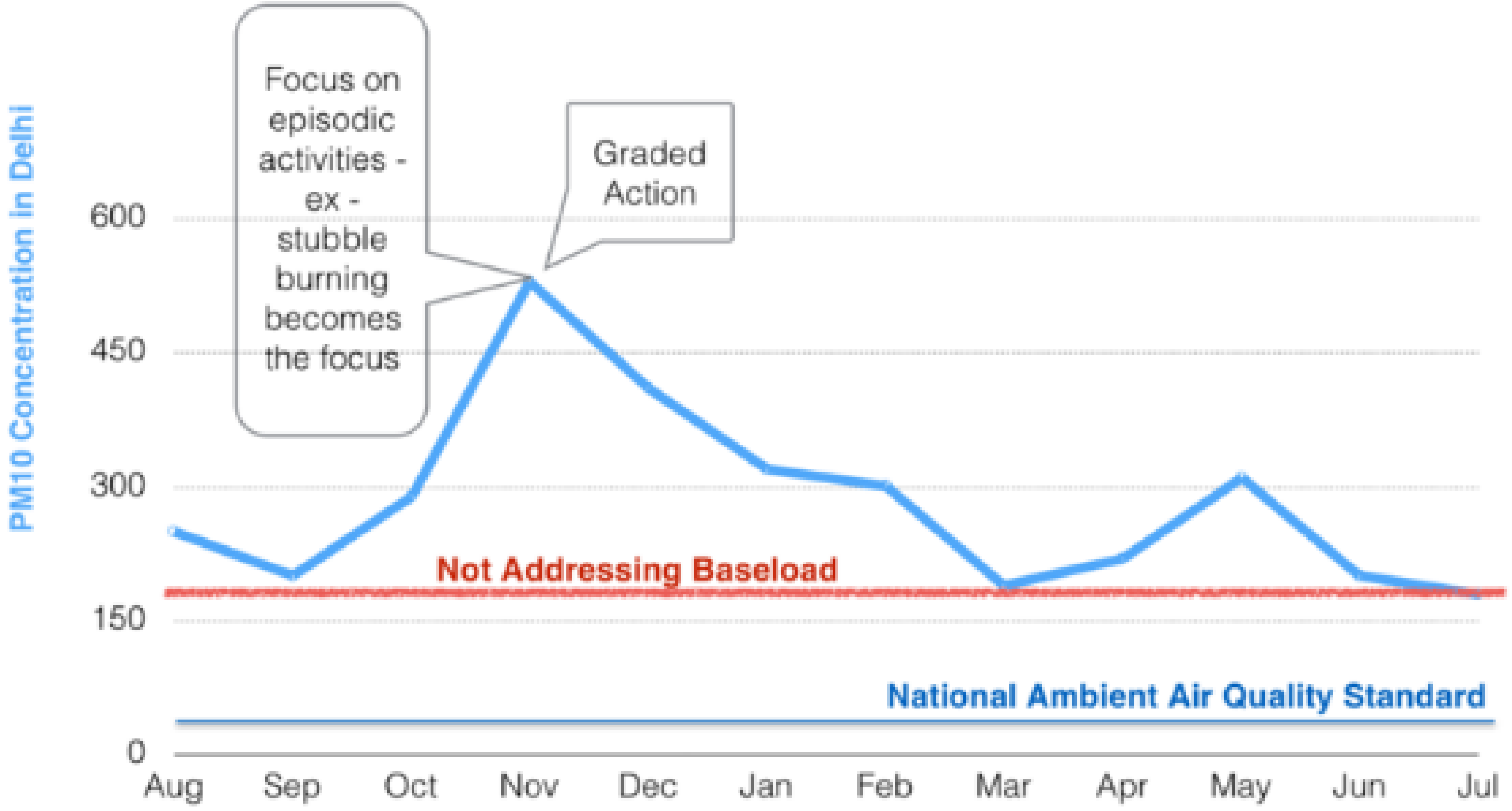
- In general, power plants emit 50 percent of the mercury released into the air, and 75 percent of the acid gases released.

- Mercury vapor is highly toxic, and can easily enter water and be converted by bacteria into a neurotoxin known as methyl mercury, which can cause seizures, cerebral palsy, and even death.

Power plants reduce air pollution emissions in various ways

- Burning low-sulfur-content coal to reduce SO_2 emissions.
- Some coal-fired power plants *cofire* wood chips with coal to reduce SO_2 emissions. Pretreating and processing coal can also reduce the level of undesirable compounds in combustion gases.
- Different kinds of particulate emission control devices treat combustion gases before they exit the power plant:
  - *Bag-houses* are large filters that trap particulates.
  - Electrostatic precipitators use electrically charged plates that attract and pull particulates out of the combustion gas.
  - Wet scrubbers use a liquid solution to remove PM from combustion gas.
- Wet and dry scrubbers mix lime in the fuel (coal) or spray a lime solution into combustion gases to reduce SO_2 emissions. Fluidized bed combustion also results in lower SO_2 emissions.
- NOx emissions controls include low NOx burners during the combustion phase or selective catalytic and non-catalytic converters during the post combustion phase.

Changing the focus from ‘Peak’ to ‘Baseload’

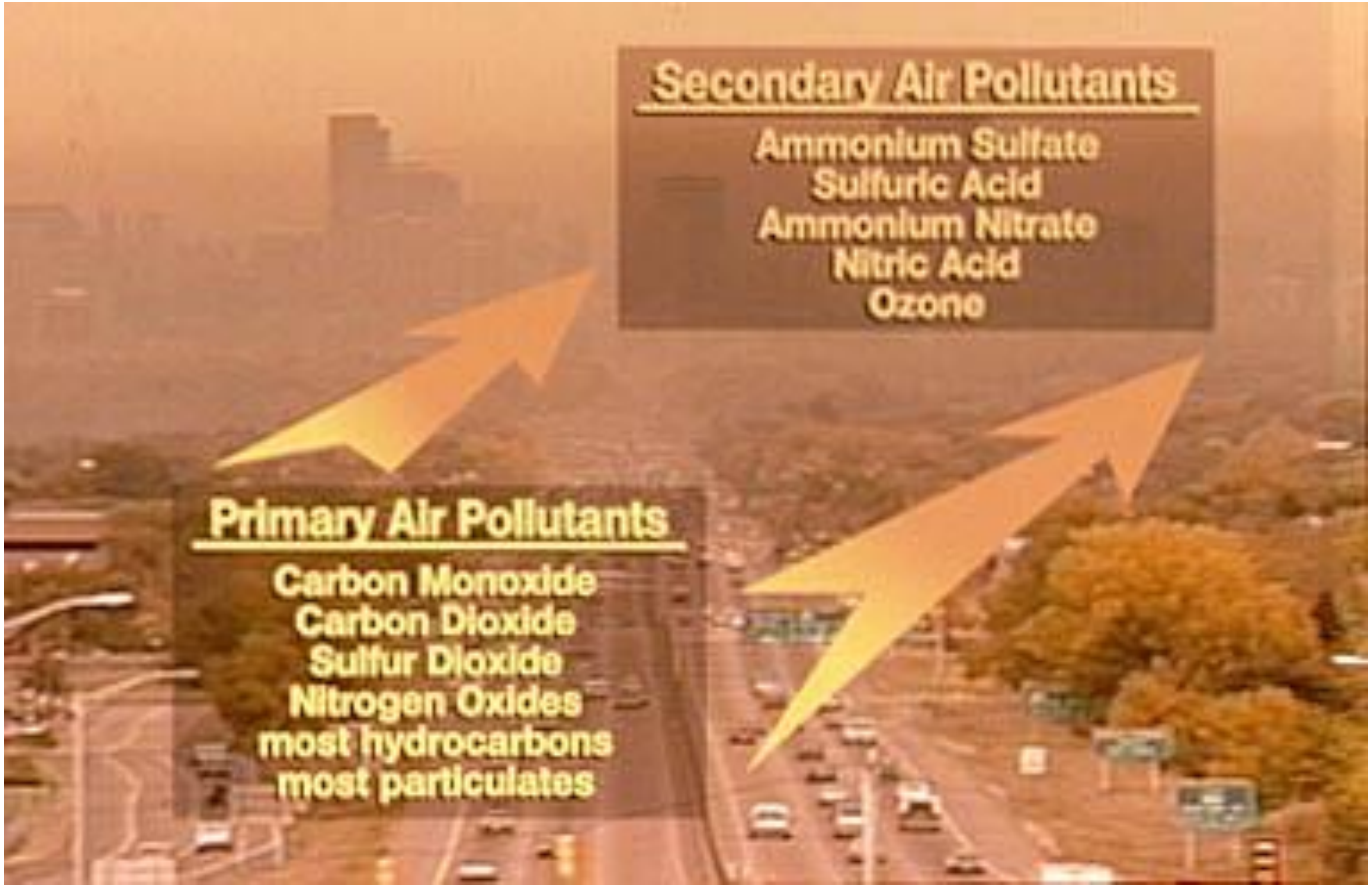


Air Pollution From Fossil Fuels

Stationary Point Source

Mobile Point Source

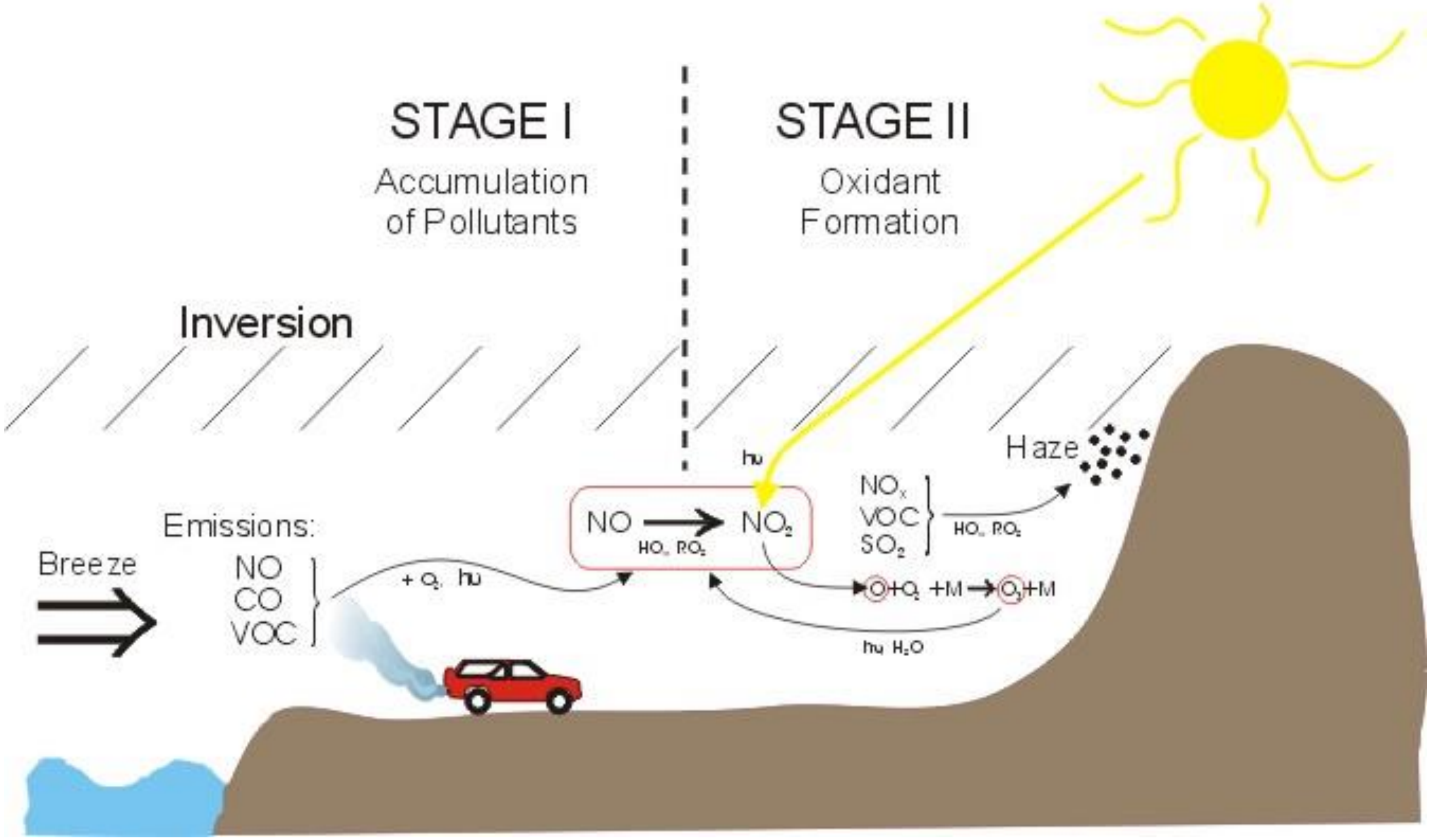
Primary & Secondary Pollutants



Photochemical Smog (Brown Smog)

- Photochemical smog is a mixture of primary and secondary pollutants formed under the influence of sunlight.
- Primary Pollutants involved are mostly NOx and volatile hydrocarbons + sunlight to produce ozone (O_3), aldehydes (CH2O), PANS (peroxyacyl nitrates), and nitric acid (HNO_3).

PHOTOCHEMICAL SMOG



Industrial Smog (gray smog)

- Industrial smog consists mostly of sulfur dioxide, suspended droplets of sulfuric acid, and a variety of suspended solid particles and droplets that emanate from coal and heavy oil burning power plants and factories.

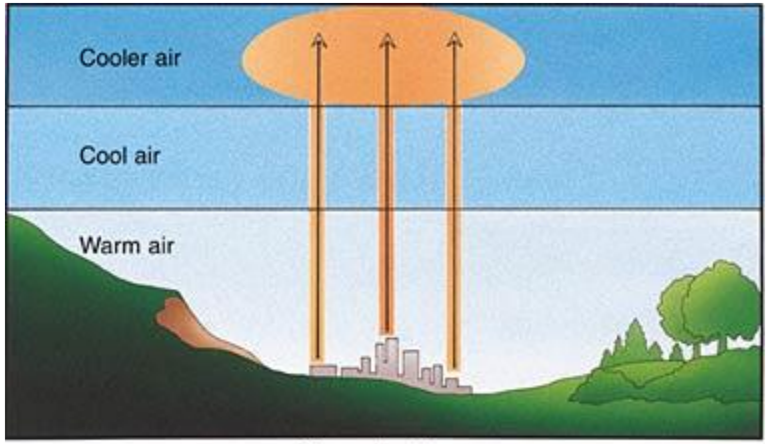
Factors That Influence The Formation of Smog

- Local climate
- Topography
- Amount of industry
- Fuels used in industry, heating & transportation
- Amount of precipitation (rain and snow cleanse atmosphere of pollutants)
- Wind patterns (winds sweep pollutants away)
- Hills and mountains reduce flow of air in valleys and allow pollutants to accumulate at ground level.
- Diurnal temperature fluctuations allow pollutants to move upward and downward in atmosphere (density differences) to prevent pollutants from accumulating at ground level.

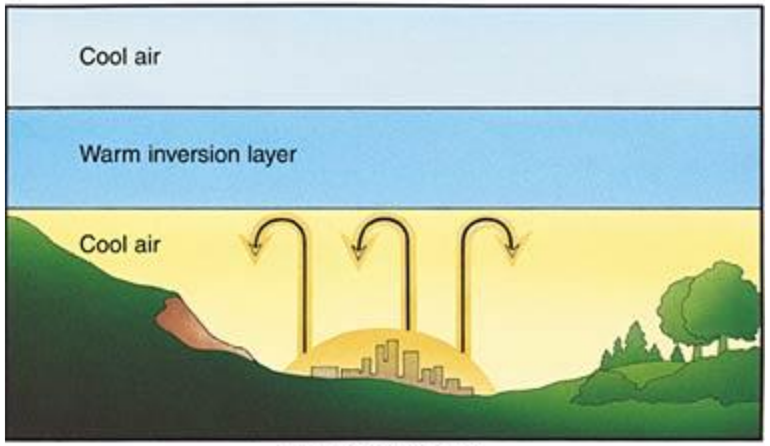
Thermal Inversions

- Warm air normally rises in the atmosphere. In a valley, a layer of dense, cool air, can become trapped below a layer of warm air capped by a denser cool air layer. This prevents air from ascending keeping air pollutants trapped in the lowest cool air layer. These events typically only occur for a few hours. When high pressure air masses stall over valley areas, thermal inversions can last for several days.

- Las Angeles California is surrounded by mountains on three sides with over 15 million people, over 24 million motor vehicles and is subject to thermal inversions 50% of the year!
- LA = has the worst air pollution in the USA



Normal pattern



Thermal inversion

Other Highly Polluted Cities in the World

- Denver, Colorado
- Mexico City, Mexico
- Rio de Janeiro and Sao Paulo, Brazil
- Beijing and Shenyang, China
- Bangkok, Thailand

Human Respiratory System

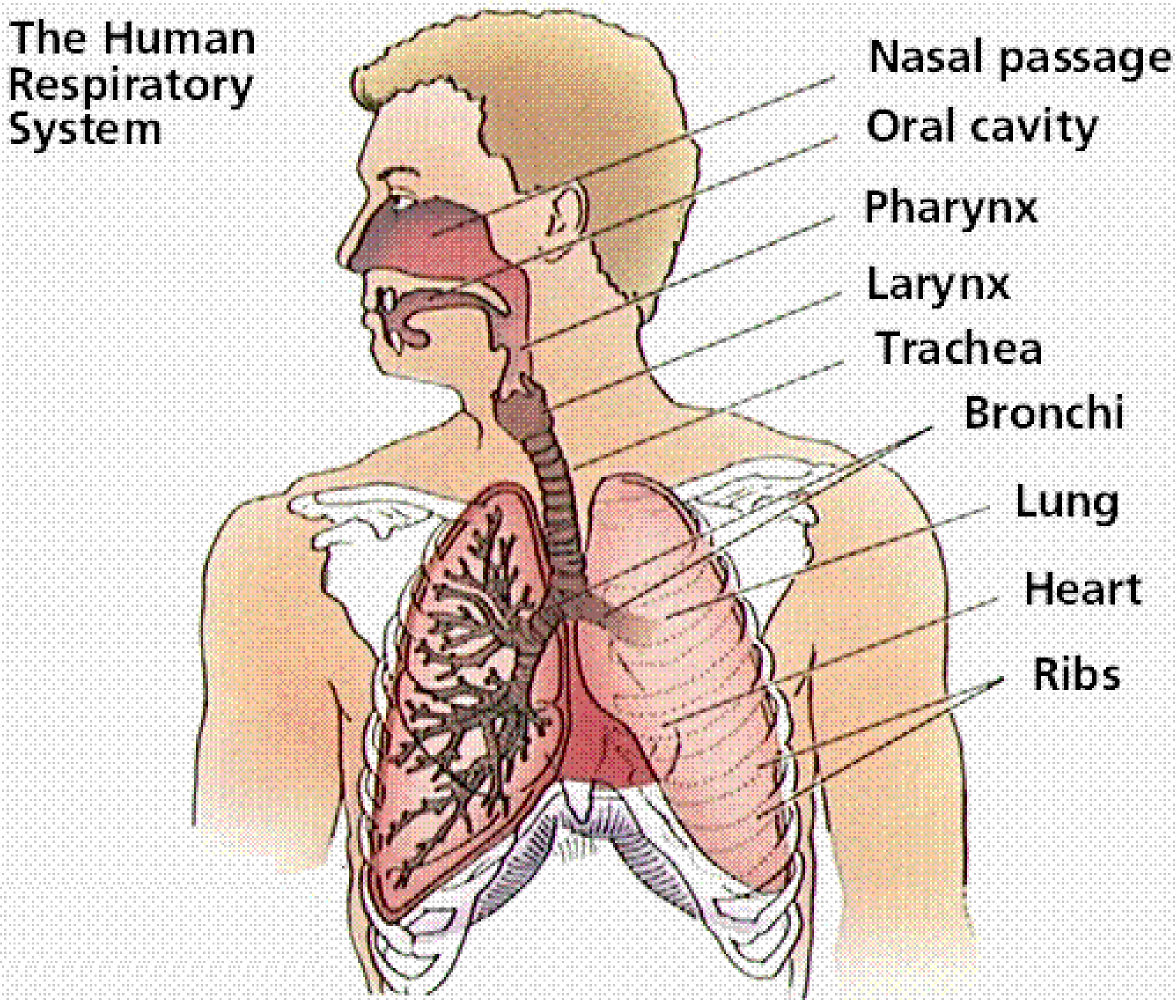
Nasal Passage – hairs to filter out pollutants

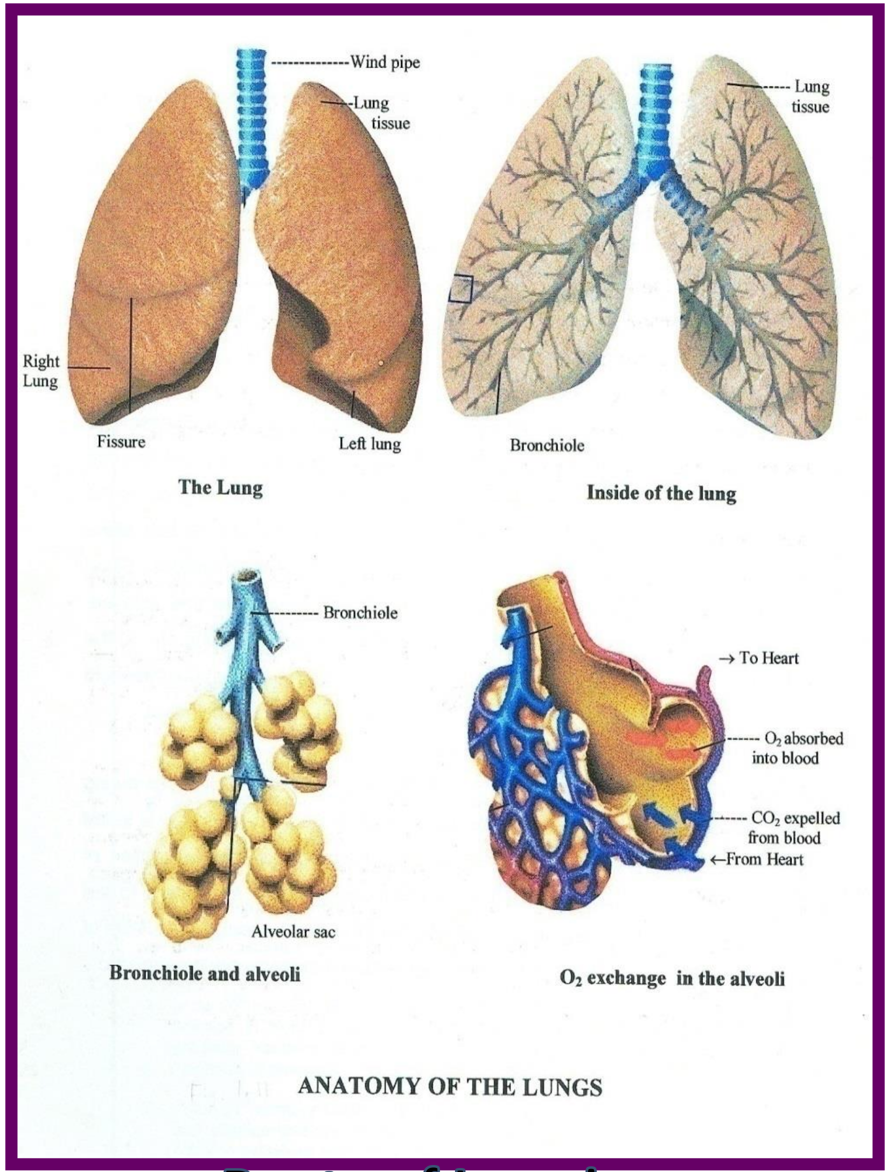
Sneezing and coughing expel contaminated air.

Sticky mucus in upper respiratory track capture small particles and filter some gaseous pollutants.

Cells of upper respiratory tract are lines with cilia that move back and forth, transporting mucous and the pollutants they trap to your throat where they can be expelled.

Alveoli in bronchioles allow for proper gas exchange.

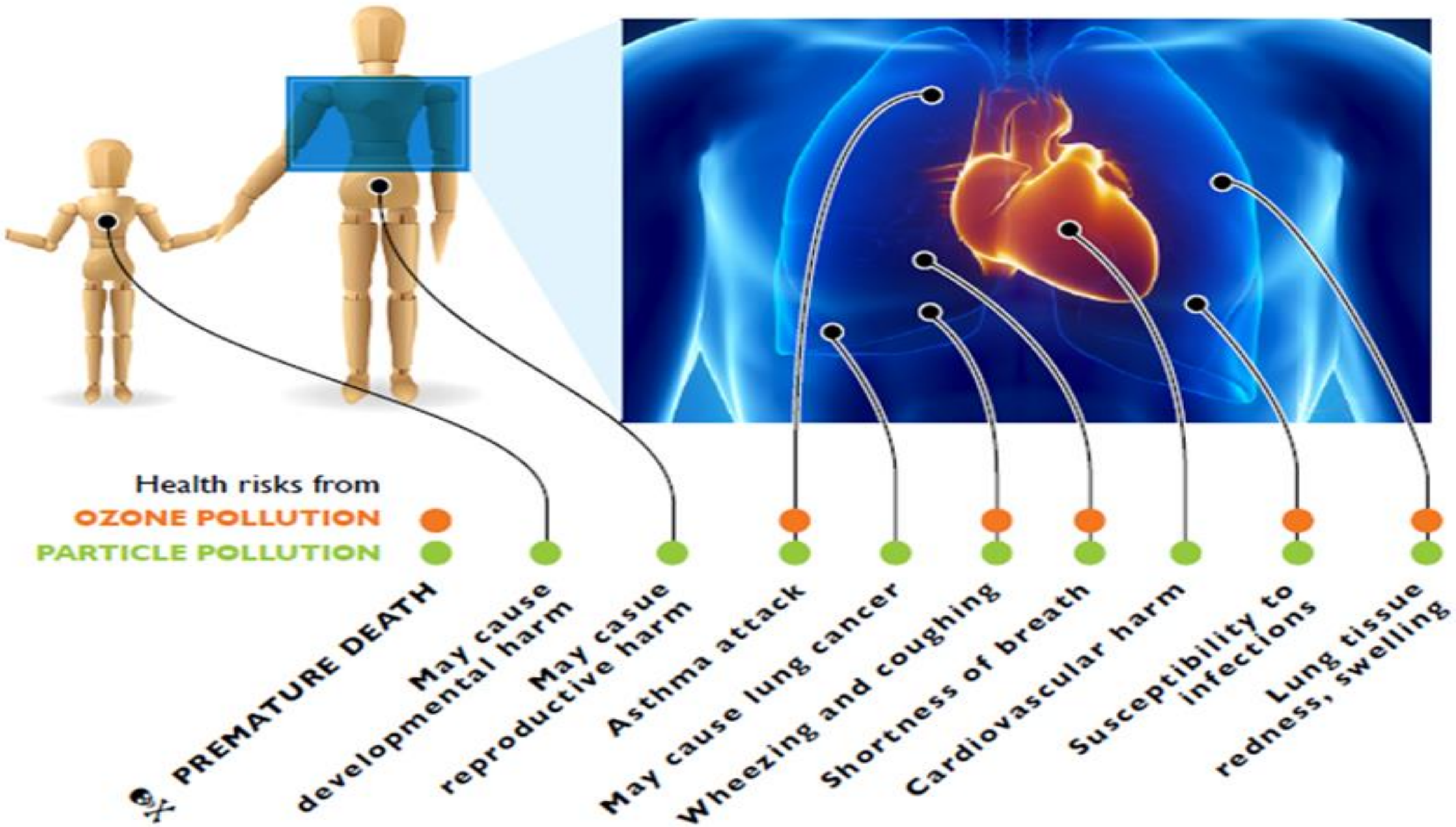




- Route of Invasion

- Lung - the main entry point of air pollutants, and the target organ is the alveolus. (There are 300 million alveoli in human lungs)
- 10,000 – 15,000 litres air enters every day in an adult lung.
- Increase in the concentration of pollutants cause parallel increase in the toxic insult to the lungs
- From the alveolus, pollutants travel via lymph or blood to different organs.

Air pollution remains a major danger to the health of children and adults.



Effects of Air Pollution on Human Health

- Elderly, infants, pregnant woman, and people with heart disease, asthma, or other respiratory diseases are most vulnerable to air pollution (indoor and outdoor).
- lung cancer [+]
    - asthma: acute inflammation of alveoli and/or bronchi/ bronchioles (typically an allergic reaction caused by muscle spasms in the bronchiole walls).
    - chronic bronchitis - persistent inflammation and damage to the cells lining the bronchi and bronchioles causing mucus buildup, painful coughing, and shortness of breath.
    - emphysema: irreversible damage to alveoli leading to abnormal dilation of air spaces, loss of lung elasticity, and shortness of breath.
    - Carbon monoxide (CO) - reacts with hemoglobin in red blood cells to reduce ability of blood to carry oxygen. This occurs mostly as an indoor air pollutant from smoking, kerosene heaters, woodstoves, fireplaces, and faulty heating systems.
    - Suspended Particulate Matter – Small enough to penetrate the lungs and lodge in cellular tissue, mostly carcinogenic. They can cause cancer, trigger asthma attacks, aggravate other lung diseases such as bronchitis, and interfere with the blood's ability to take in oxygen and release carbon dioxide.

Effects of Air Pollutants on Health

- Sulfur dioxide – causes constriction of the airways and causes severe constriction for people with asthma. (WHO estimates 625 million people exposed from burning fossil fuels).
- Nitrogen Oxides – especially NO_2 can irritate the lungs, aggravate asthma and chronic bronchitis, cause emphysema-like conditions, and increase susceptibility to respiratory infections. NO_2 has recently been attributed to the cause of malignant melanoma.
- VOC's – (benzenes and formaldehyde) and toxic particulates such as lead, cadmium, PCB's and dioxins (agent orange) can cause mutations, reproductive problems, and cancer.
- Ozone – causes coughing, chest pain, shortness of breath, and eye, nose, and throat irritation. "Ozone alert days" - Has nothing to do with UV index!

How Many People Die Prematurely?

- No one really knows.
- Estimated annual deaths in USA related to outdoor air pollution = 65,000 – 200,000 mostly due to exposure to fine or ultra-fine particulate matter (after 9-11 will now start to see tremendous increases in those numbers in from NYC metropolitan region)
- According to the American Lung Association air pollution in the USA costs a minimum of 150 billion dollars/year in health care costs and losses in work productivity.
- WHO and World Bank estimated in 1997 that in China 2.7 million people die prematurely each year from the effects of outdoor air pollution.

Harmful Effects of Air Pollutants on Materials

- Fallout of soot and grit on buildings, cars, and clothing.
- Air pollutants break down exterior paint on cars, buildings and deteriorate roofing materials.
- Irreplaceable marble statues, historic buildings, and stained glass windows have been pitted, gauged, and discolored by air pollutants.

Solutions: Preventing and Reducing Air Pollutants

- Clean Air Acts of 1970, 1977, and 1990 – These laws require the EPA to establish national ambient air quality standards (NAAQS) for seven outdoor pollutants:

1. Suspended particulate matter
2. Sulfur oxides (SOx)
3. Carbon monoxide (CO)
4. Nitrogen oxides (NOx)
5. Ozone (O_3)
6. Volatile Organic Compounds (VOC's)
7. Lead (Pb)

Prevention of Significant Deterioration

- EPA under the Clean Air Act for regions in which air is cleaner than NAAQS, should not be allowed to deteriorate!
- National Emission Standards for Toxic Air Pollutants – includes 302 compounds and 20 categories of chemical compounds that are harmful to human health.
- Due to lack of money provided to EPA, standards have only been set for a few of these compounds.
- Car emissions tests – catalytic converters
- Automotive gasoline must have 10% additive of ethanol or MTB's in nine cities (Baltimore, Chicago, Hartford, Houston, LA, Milwaukee, NY, Philadelphia, and San Diego)
- Clean Air Act calls for overall reduction in these seven pollutants by motor vehicles and fossil fuel power plants and industry.

- Presently there have been decreases in atmospheric pollutants since the 1970's for ground ozone, CO, Sox, suspended particulate matter, NO_2 and lead levels have decreased.

How Can US Air Pollution Laws Be Improved?

- 1. Pollution prevention is best! Leaded gasoline outlawed, lead in air was reduced by 98%.
- 2. Increase fuel efficiency standards for cars and trucks, this will reduce oil imports.
- 3. Require stricter emission standards.
- 4. Fund research and development of alternative energy resources.
- Subsidize businesses and homeowners, vehicle owners for using energy conservation approaches such as hybrid vehicles, solar and wind energy for space heating, green buildings, etc..

Power plants discharge polluted water:

- Many power plants are placed along bodies of water, where they can draw it in for cooling.
- Billions of gallons may be used daily. The water is then delivered back to the river or sea, creating warm plumes, which can starve aquatic life of oxygen in summer and trap species in ice-free areas during the winter.
- Discharge waters may also contain chlorine and heavy metals.

AMBIENT AIR QUALITY STANDARDS 2009

S.No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement	Remarks
			Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Government)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Sulphur Dioxide (SO_2), µg/m^3	Annual* 24 hours**	50 80	20 80	a) Improved West and Gaeke b) Ultraviolet fluorescence	Facilities available
2.	Nitrogen Dioxide (NO_2), µg/m^3	Annual* 24 hours**	40 80	30 80	a) Modified Jacob & Hocheiser (Na-Arsenite) b) Chemiluminiscence	Facilities available

Contd..

3.	Particulate Matter (size less than 10 μm) or PM_{10} μg/m^3	Annual* 24 hours**	60 100	60 100	a) Gravimetric b) TOEM c) Beta attenuation	• Most of the NAMP Stations have Gravimetric measurement facility including CPCB • CAQMS is having BAM • TEOM has to be introduced gradually
4.	Particulate Matter (size less than 2.5 μm) or $PM_{2.5}$ μg/m^3	Annual* 24 hours**	40 60	40 60	a) Gravimetric b) TOEM c) Beta attenuation	• Gravimetric measurement facility may be developed countrywide • CAQMS is having BAM • TEOM is yet to be introduced gradually
5.	Ozone (O_3) μg/m^3	8 hours* 1 hour**	100 180	100 180	a) UV photometric b) Chemiluminiscence c) Chemical Method	• CAQMS equipped with UV based or Chemiluminescence Online Analysers and may be used for 1 hrly data • Chemical method may be adopted nationwide but monitoring hours is not specified, however 09 hrs to 17 hrs may be introduced

6.	Lead (Pb) $\mu g/m^3$	Annual* 24hours**	0.5 1.0	0.5 1.0	a) AAS/ICP method after sampling on EPM 2000 or equivalent filter paper b) ED-XRF using Teflon filter	• It appears that Pb is to be monitored in PM_{10}, this standard already exists but monitored in SPM only at few locations. • Once the sampling is done in Teflon the same may also be analyzed by other method ED-XRF
7.	Carbon Monoxide (CO) $\mu g/m^3$	8 hours* 1 hour**	02 04	02 04	Non Dispersiv Infra Red (NDIR) spectroscopy	• Only option is to go with online analyzer
8.	Ammonia (NH_3) $\mu g/m^3$	Annual* 24hours**	100 400	100 400	a)Chemiluminiscence b) Indophenol blue method	• Recently introduced at few locations in CAQMS • Chemical method may be adopted nationwide
9.	Benzene (C_6H_6) $\mu g/m^3$	Annual*	05	05	a)Gas chromatography based continuous analyzer b) Adsorption and Desorption followed by GC analysis	• BTX analysers are being used at CAQMS • Active 24 hourly sampling in diffusion tubes followed by desorption in CS_2 and finally GC Analysis may be adopted nationwide in NAMP

10.	**Benzo(a) Pyrene (BaP) – particulate phase only, ng/m^3**	**Annual***	**01**	**01**	**Solvent extraction followed by HPLC/GC analysis**	• **Facilities available with CPCB but BIS method using GC-FID may not attain the desired lowest concentration level below $1 ng/m^3$ alternatively GC-MS or HPLC-UV Fluorescence may be provided**
11.	**Arsenic (As), ng/m^3**	**Annual***	**06**	**06**	**AAS/ICP method after sampling on EPM 2000 or equivalent filter paper**	• **It appears that 'As' is to be monitored in PM_{10}.** • **Micro-wave digester is required for digestion alternatively acid digestion at 70^0 C for 12 hours is required.**
12.	**Nickel (Ni), ng/m^3**	**Annual***	**20**	**20**	**AAS/ICP method after sampling on EPM 2000 or equivalent filter paper**	• **It appears that 'Ni' is to be monitored in PM_{10}.** • **Micro-wave digester is required for digestion alternatively acid digestion at 70^0 C for 12 hours is required.**

National Ambient Air Quality Monitoring

- four air pollutants *viz* ., Sulphur Dioxide (SO_2), Oxides of Nitrogen as NO_2, and Respirable Suspended Particulate Matter (RSPM / PM10) are regularly monitored at all the locations along with meteorological parameters such as wind speed and wind direction, relative humidity (RH) and temperature were also integrated with the monitoring of air quality.

- monitoring is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week, to have one hundred and four (104) observations in a year.

Air Quality Index

- The AQI system is based on maximum operator of a function (i.e. selecting the maximum of subindices of individual pollutants as an overall AQI)

- Eight parameters (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb)

- quickly disseminate information and associated health risks to public

- For continuous air quality stations, AQI is reported in near real-time for as many parameters as possible. For manual stations,

Good (0-50)	Satisfactory (51-100)	Moderately polluted (101-200)	Poor (201-300)	Very poor (301-400)	Severe (> 401)


Think.
Act.
Save.

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.**

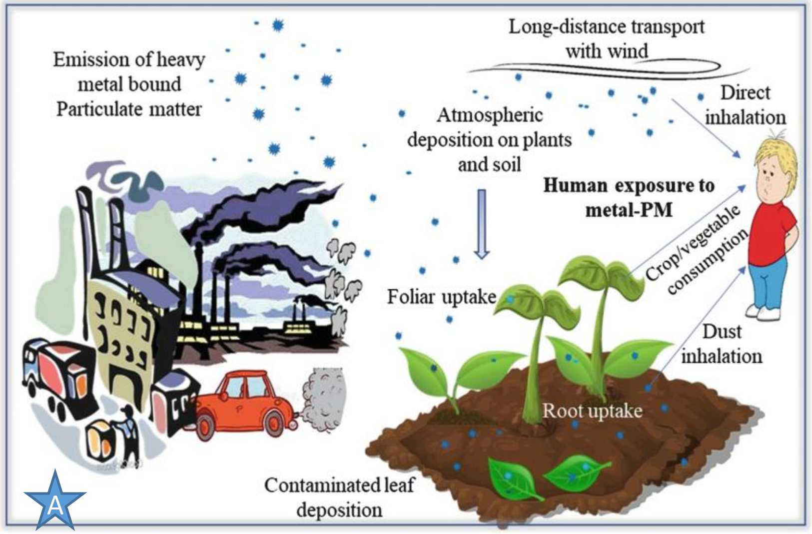
Climate Change issues and environmental impacts

Contents

- Energy and Environment
- Greenhouse gases effect
- Global Warming and Climatic Change Impacts
- Acid Rain

Energy and Environment

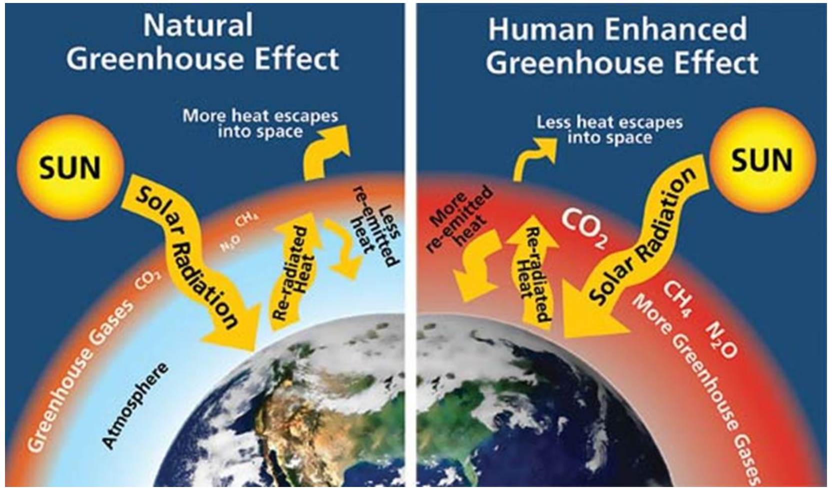
Emissions Due to Energy Use



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

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 Warming and Climatic Change



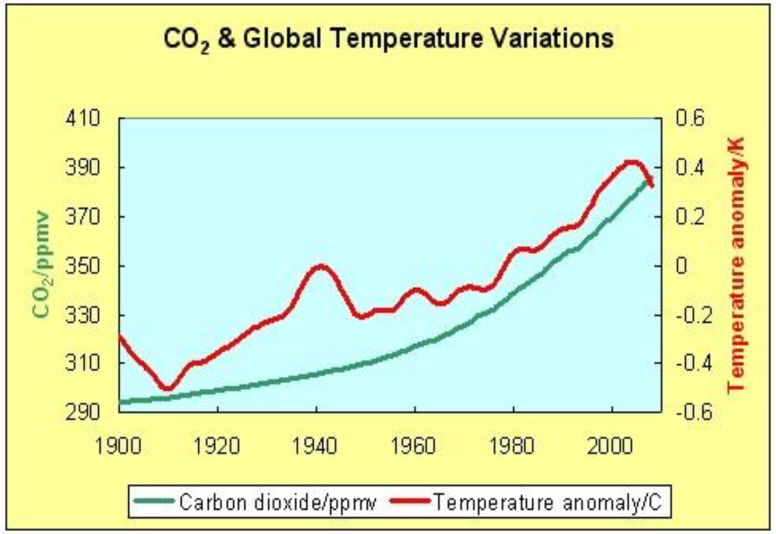
- Atmosphere is composed mainly of 21% Oxygen, 78% Nitrogen, 0.04% carbon dioxide, and Argon 0.04% by volume
- The two most important layers in the atmosphere are known as the troposphere and the stratosphere. 90% of all the molecules in the atmosphere are in the troposphere.

What is the Greenhouse Effect

- Greenhouse gases are those gases in the atmosphere which by absorbing thermal radiation emitted by the earth's surface have a **blanketing effect** over the surface keeping it warmer .
- Without naturally occurring greenhouse gases such as water vapor, carbon dioxide, methane and nitrous oxide, the earth's average **surface temperature would be a cold -18°C rather than the tolerable 15°C.** This warming of the earth called the greenhouse effect

What is the Enhanced Greenhouse Effect

Natural greenhouse effect is **enhanced by** the increase of greenhouse gases in the atmosphere **especially carbon dioxide** from burning of fossil fuels, coal, oil and gas, together with wide deforestation over the past 200 years and more substantially over the past 50 years

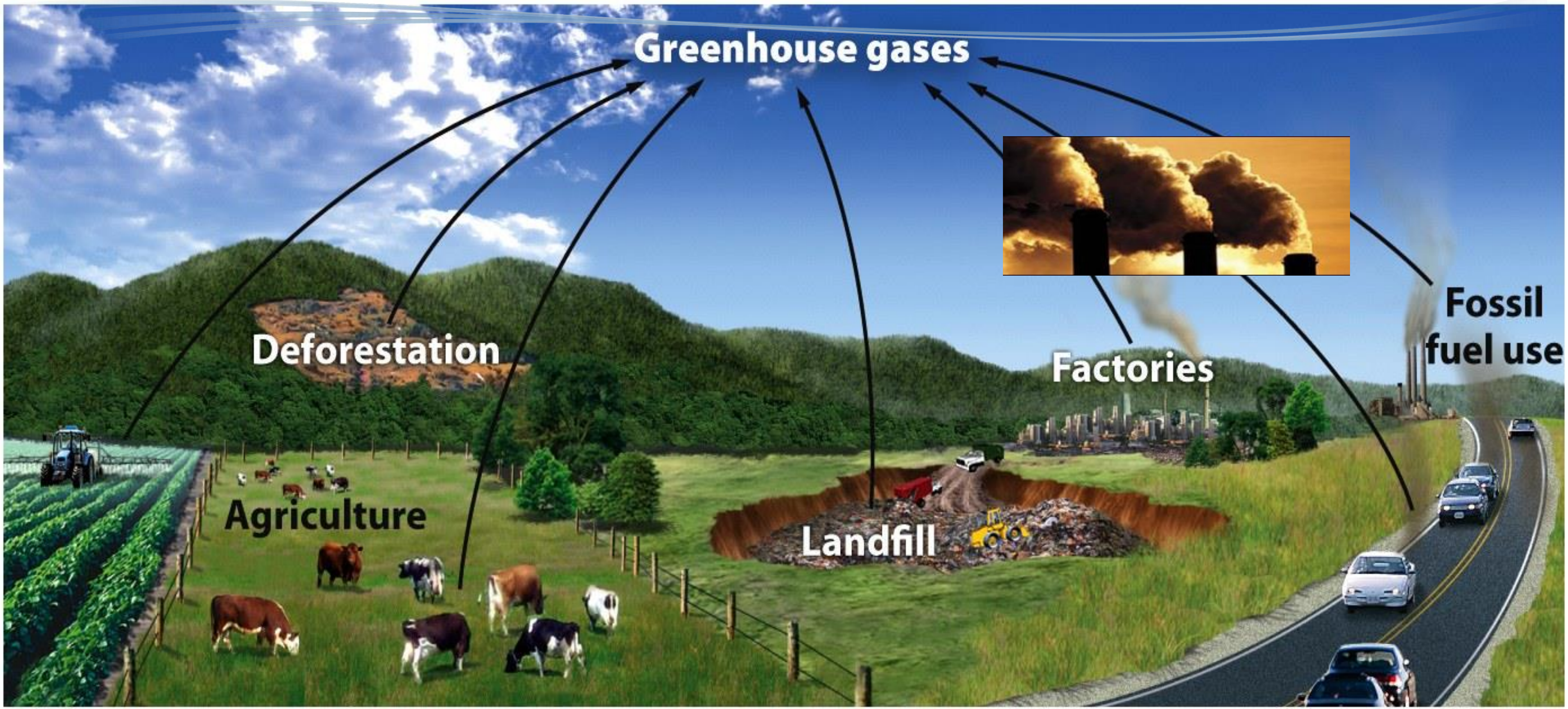


Rising Global Temperatures

Water vapor is also considered as greenhouse gas & it is not changing directly because of human activities.
carbon dioxide, methane, nitrous oxide, the chlorofluorocarbons (CFCs) and ozone. are directly influenced by human activities

Estimated : earth's average temperature has risen by 0.75°C since 1880 because of emissions of greenhouse gases from human activity. The relation between CO2 and global temperature variations is shown

Green House Gas – Major Causes



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

What are the Greenhouse Gases?

1.Carbon Dioxide

- Carbon dioxide is the largest greenhouse gases with atmospheric lifetime of over 100 years.

Carbon Sequestration

- **It is the term** given to the **process of removing CO_2 from large point sources** such as power plant, oil refineries, industrial process.
- The CO_2 is then stored in depleted oil and gas reservoirs or saline reservoirs. Oceans are a major CO_2 sink. Trees and grasses store about three times more CO_2 than the atmosphere.

2.Methane

- from wetlands and anaerobic decomposition.

3.Nitrous Oxide

- from use of nitrogen fertilizer, *fossil fuel combustion*

4.Chlorofluorocarbons (CFCs)

The CFCs are man-made chemicals which vaporise just below room temperature and are non-toxic and non-flammable.

5.Perflurocarbons

Primary aluminum production and semiconductor manufacture are the largest known man-made sources of perfluorocarbons.

6.Sulphur Hexafluoride (SF_6)

Sulfur hexafluoride is the most potent greenhouse gas. It is used in insulation, electric power transmission equipment.

7.Ozone

Ground-level ozone forms from Volatile Organic Compounds (VOCs) and nitrogen oxides in the presence of heat and UV radiation.

Global Warming Potential (GWP)

Increasing Concentration of Atmospheric Greenhouse Gases

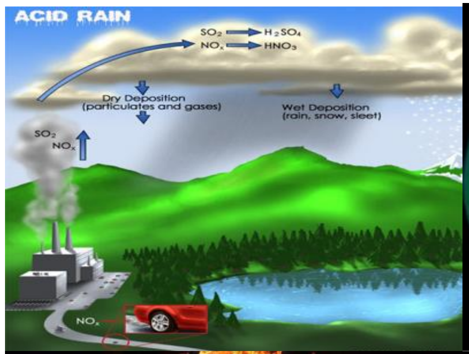
Greenhouse gas	Baseline	Current level	GWP	Lifetime in atmosphere (years)
Carbon dioxide (CO_2)	280 ppm	395 ppm	1	5-200
Methane (CH_4)	700 ppb	1893 ppb	23	12
Nitrous oxide (N_2O)	275 ppb	326 ppb	300	114
Ozone	-	-	-	Days/weeks
Chloroflurocarbons (CFC) and related chemicals	0	ppt levels	4000-8000	5-100
Perfluromethane, one of the Perfluorcarbons(PFC)	40 ppt	80 ppt	5700	50000
Sulphur hexafluoride (SF_6)	0.01 ppt	7.79 ppt	22000	3200

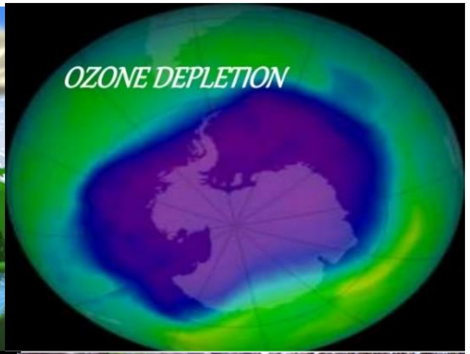
- Atmospheric lifetime of CO2 is over 100 years.
- Some greenhouse gases are 140 to 23,900 times more potent than CO2 in terms of their ability to trap and hold heat in the atmosphere over a 100-year period.
- GWP a measure of the "potential for global warming per unit mass relative to carbon dioxide

- If methane has a GWP of 23 and carbon has a GWP of 1 (the standard), this means that methane is 23 times more powerful than CO_2 as a greenhouse gas
- The higher the GWP value, the larger the infrared absorption and the longer the atmospheric lifetime.
- The increasing concentration of greenhouse gases, GWP and lifetime is given in Table below

1 ppm = 1g in 1000 kg,
1 ppb = 1 g in 1000 tonnes,
1 ppt = 1 g in 1000 000 tonnes

10.2 Global Environmental Issues






The key environmental issues of global significance are

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

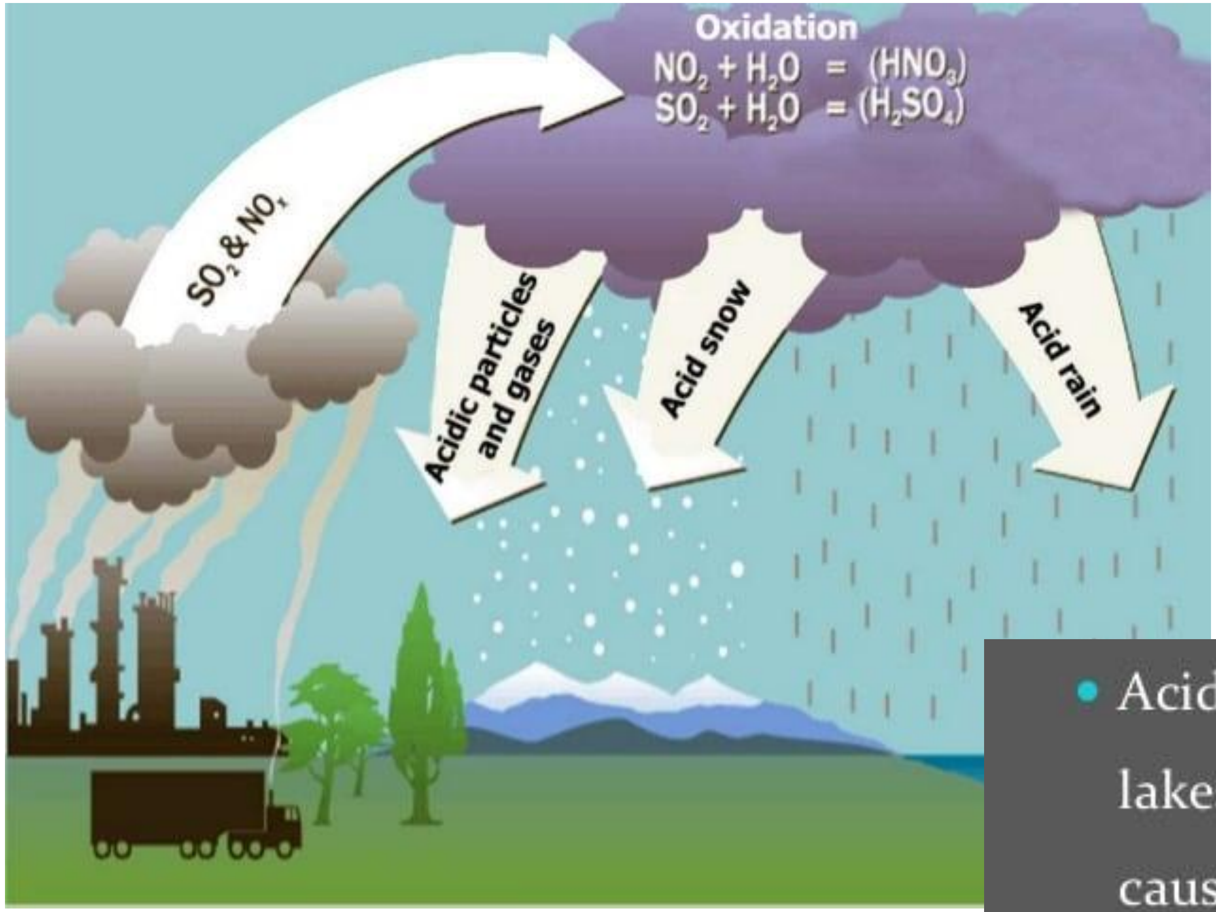
10.3 Acid Rain **caused by** release of Sulphur oxides and Nitrogen oxides which then mix with water vapor in atmosphere to form sulphuric and nitric acids

Effects of acid rain are : Acidification of lakes, streams, and soils ,Direct effects (release of metals) , Killing of wildlife (trees, aquatic plants, animals) , Decay of building materials paint, and Health problems

10.6 Global Warming and Climatic Change Impacts

- ❑ Increasing Ocean Temperature and Rising Sea Levels
- ❑ Snow and Ice Melting
- ❑ Altered Rainfall Patterns
- ❑ Extreme Weather Events
- ❑ More Severe Heat Waves
- ❑ Loss of Biodiversity
- ❑ Increased Diseases
- ❑ Dwindling Freshwater Supply
- ❑ Food Shortages


pH SCALE
Acidic
Neutral
Basic
©2007 HowStuffWorks
pHO
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Battery acid
ACID RAIN
Normal Rain (5.6)
Pure Water (7.0)
Ocean Water
Liquid drain cleaner
Concentration of Hydrogen ions compared to distilled water
Examples
10,000,000 pH 0 Battery acid
1,000,000 pH 1 Hydrochloric acid
100,000 pH 2 Lemon juice, vinegar
10,000 pH 3 Grapefruit, soft drink
1,000 pH 4 Tomato juice, acid rain
100 pH 5 Black coffee
10 pH 6 Urine, saliva
1 pH 7 "Pure" water
1/10 pH 8 Sea water
1/100 pH 9 Baking soda,
1/1,000 pH 10 Great Salt Lake
1/10,000 pH 11 Ammonia solution
1/100,000 pH 12 Soapy water
1/1,000,000 pH 13 Bleach
1/10,000,000 pH 14 Liquid drain cleaner



- Acid rain is a big problem. It causes the death of our lakes, our rivers, wildlife and also harms people. It also causes other problems which are also very serious such as the release of aluminum and lead in our water supplies. Unfortunately, we suffer because of this. Hopefully acid rain in the future will be reduced as a result of the measures taken.

- Because the various gases of fossil fuels like oil and coal, often contains (acidic) oxides of sulfur and nitrogen, among others, this produces acid rain containing dissolved corresponding acids.

Consequences

Acid rain has a strong impact on natural ecosystems (forests, wetlands, soil), directly or indirectly killing life forms, but also in residential ecosystems, eroding historical monuments, causing damage to buildings and vehicles, but also directly harming human health.

EFFECTS OF ACID RAIN

People, forest, soil, lakes and rivers and the animals are affected by **acid rain**. When the acid rain falls on the forests, the trees die including the different animal species living there.

The soil is ruined of its nutrients and therefore, the plants will not grow for animals to eat and live. In addition, the bodies of water become acidic, killing the fish and the plants grown in that place.

Remedies

- Reduced emissions
- Create awareness
- Plantation of Trees
- Renewable and clean source of energy
- More efforts by government
- Protecting coral reefs

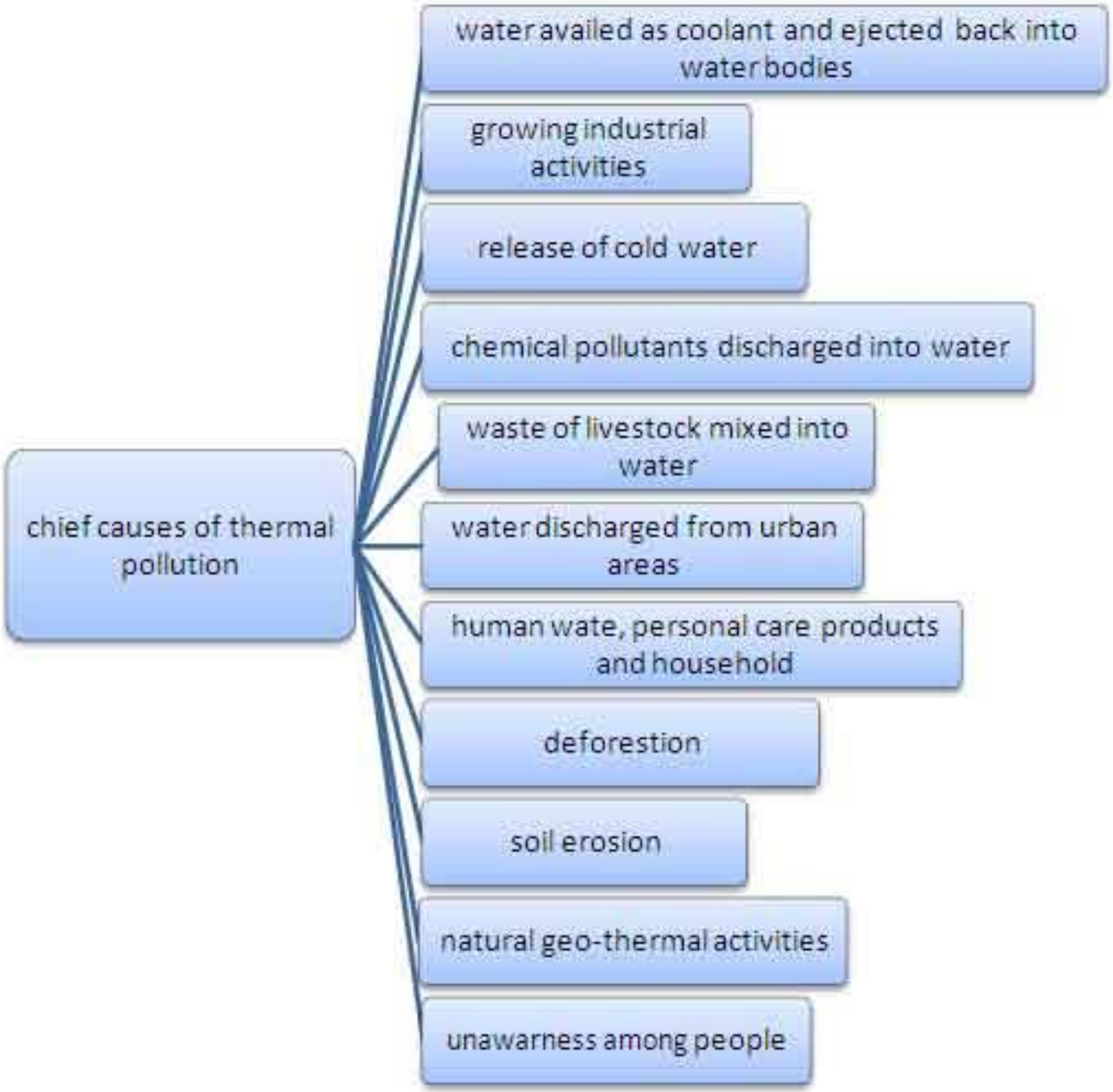
Conclusion

Global warming is affecting plants, animals, humans and the earth. We need to learn how to conserve our use of fossil fuels to minimize carbon dioxide production. This will slow down the effects of global warming.

Thank You

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

Save energy and water for Sustainable Life


chief causes of thermal pollution
water availed as coolant and ejected back into water bodies
growing industrial activities
release of cold water
chemical pollutants discharged into water
waste of livestock mixed into water
water discharged from urban areas
human wate, personal care products and household
deforestion
soil erosion
natural geo-thermal activities
unawarness among people

Fossil fuel, biomass, and waste burning power plants

- In the United States, about 65% of total electricity generation in 2018 was produced from fossil fuels (coal, natural gas, and petroleum), materials that come from plants (biomass), and municipal and industrial wastes.
- In India , 75 % electricity is generated from thermal plant
- The substances that occur in combustion gases when these fuels are burned include
- Carbon dioxide (CO2)
- Carbon monoxide (CO)
- Sulfur dioxide (SO2)
- Nitrogen oxides (NOx)
- Particulate matter (PM)
- Heavy metals such as mercury

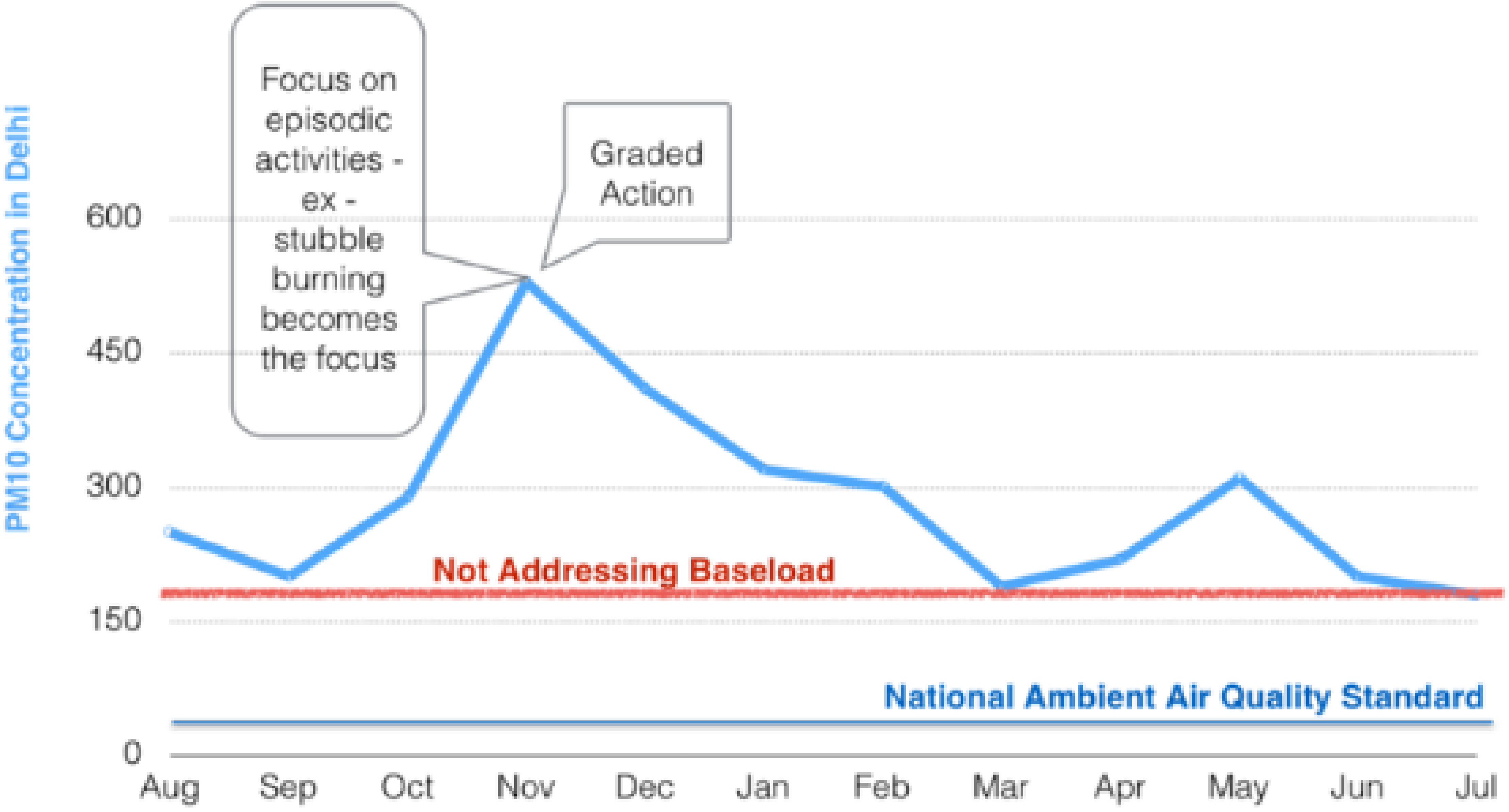
Negative effects

- Nearly all combustion byproducts have negative effects on the environment and human health:
- CO2 is a greenhouse gas, which contributes to the greenhouse effect.
- SO2 causes acid rain, which is harmful to plants and to animals that live in water. SO2 also worsens respiratory illnesses and heart diseases, particularly in children and the elderly.
- NOx contribute to ground-level ozone, which irritates and damages the lungs.
- PM results in hazy conditions in cites and scenic areas and coupled with ozone, contributes to asthma and chronic bronchitis, especially in children and the elderly. Very small, or *fine PM*, is also believed to cause emphysema and lung cancer.
- Heavy metals such as mercury are hazardous to human and animal health.

Power plants reduce air pollution emissions in various ways

- Burning low-sulfur-content coal to reduce SO_2 emissions.
- Some coal-fired power plants *cofire* wood chips with coal to reduce SO_2 emissions. Pretreating and processing coal can also reduce the level of undesirable compounds in combustion gases.
- Different kinds of particulate emission control devices treat combustion gases before they exit the power plant:
  - *Bag-houses* are large filters that trap particulates.
  - Electrostatic precipitators use electrically charged plates that attract and pull particulates out of the combustion gas.
  - Wet scrubbers use a liquid solution to remove PM from combustion gas.
- Wet and dry scrubbers mix lime in the fuel (coal) or spray a lime solution into combustion gases to reduce SO_2 emissions. Fluidized bed combustion also results in lower SO_2 emissions.
- NOx emissions controls include low NOx burners during the combustion phase or selective catalytic and non-catalytic converters during the post combustion phase.

Changing the focus from 'Peak' to 'Baseload'



Coal power plants release particulate matter

Soot contains particles anywhere from 2.5 to 10 micrometers in diameter.

These have irregular surfaces that allow sulfur dioxide and nitrogen oxides to bind to them.

If it doesn’t have a control system, a typical plant can emit as much as **500 tons of particles into the air each year**.

The particles can cause health problems such as asthma, chronic bronchitis, and even premature death.

Mercury is released during coal combustion:

- In general, power plants emit 50 percent of the mercury released into the air, and 75 percent of the acid gases released.

- Mercury vapor is highly toxic, and can easily enter water and be converted by bacteria into a neurotoxin known as methyl mercury, which can cause seizures, cerebral palsy, and even death.

Power plants discharge polluted water:

- Many power plants are placed along bodies of water, where they can draw it in for cooling.
- Billions of gallons may be used daily. The water is then delivered back to the river or sea, creating warm plumes, which can starve aquatic life of oxygen in summer and trap species in ice-free areas during the winter.
- Discharge waters may also contain chlorine and heavy metals.