Bio-mass:

Bio-mass is a key rese, meaning it is an alternative to traditional fossil fuels like coal, oil, and natural gas.

What is Biomass?

Biomass refers to organic material derived from living or recently living organisms- mainly plant materials and animal waste, that can be used as a renewable source of energy.

Sources of Biomass:

* Wood, wood chips, sawdust.
* Crop residues like straw and husks.
* Animal manure
* Municipal solid waste
* Agricultural waste
* Algae.

How Biomass Produces Energy:

Biomass can be converted into energy through several methods:

1. Combustion: Burning biomass directly to produce heat or electricity.
2. Anaerobic digestion: Microbes break down organic waste in the absence of oxygen to produce biogas.
3. Gasification: Biomass is converted into a gas (called syngas) which can be used as fuel.

4) Fermentation: Biomass like sugarcane or corn is fermented to produce ethanol, a biofuel.

Advantages of Biomass:

-> Renewable and available in large quantities.

-> Helps manage organic waste.

-> Produces lower greenhouse gas emissions that fossil fuels.

-> can be used for rural electrification.

Disadvantages:

-> can lead to deforestation if wood is overused.

-> Emits CO_2 (although considered carbon-neural over time)

-> Requires land & water, which could be used for food crops.

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2) Principles of Bio-conversion

Bio-conversion plays a crucial role in producing energy from non-convential sources, particularly biomass energy. It involves using biological processes to convert organic waste or biomass into renewable energy like biogas, bioethanol or biodiesel.

Key principles of Bio-conversion:

1. Utilization of Biomass:

-> Bio-conversion uses natural organic matter such as crop residues, animal waste, municipal waste as raw materials.

-> These materials are renewable & available in large quantities, especially in rural areas.

2) Microbial Action:

-> specific microorganisms (like bacteria or fungi) break down complex organic compounds into simpler substances.

-> This biological process releases chemical energy, which is captured as biofuels (like biogas or ethanol)

3) Anaerobic and Aerobic processes:

-> Anaerobic digestion (no oxygen) -> produces biogas (mainly methane).

-> Aerobic digestion (with oxygen) -> produces compost and heat, used indirectly for energy

4) conversion of complex compounds:

-> Complex carbohydrates, fats, and proteins in biomass are broken down into simpler molecules like sugars, acids and gases.

-> Enzymes or microbial activity aid in this biochemical transformation.

5) Energy Recovery:

-> The bio-conversion process transforms stored chemica[l] energy in biomass into:

-> Biogas -> used for cooking, lighting & power generatio[n]

-> Bioethanol & biodiesel - used as renewable fuels in transportation.

-> Heat or electricity - generated in biomass power plants.

6) Eco-Friendly & sustainable:

-> It reduces reliance on fossil fuels and lowers greenhouse gas emissions.

-> It also helps manage organic waste & improve rural energy access.

Common Bio-conversion Techniques in Energy production.

Method	process Type	Energy output
Anaerobic digestion	Biological (No O_2)	Biogas (CH_4)
Alcoholic fermentation	Biological (yeast)	Ethanol (Biofuel)
composting	Biological (with O_2)	Heat, organic fertilizer
Biodiesel production	Transesterification (biological (chemical)	Biodiesel.

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2) Anaerobic & Aerobic processes:

Anerobic:

- Breakdown of organic matter without oxygen.
- used in Anaerobic digestion
- Energy output -> produces biogas (mainly methane & carbon dioxide)

Eg:

- cow dung in biogas plants
- sewage treatment
- organic waste in land fills.

Equation (simplified):

$$\text{Organic matter} \xrightarrow{\text{Anaerobic bacteria}} CH_4 + CO_2 + \text{slurry}.$$

Applications

- Cooking gas (Biogas)
- Rural electricity
- Organic fertilizer (from slurry)

Aerobic process

- Breakdown of organic matter in the presence of oxygen.
- used in composting
- Energy output Produces heat (low-grade energy), CO_2, & compost

Egs:

- compost pits in gardens / farms
- Municipal solid waste composting.

Equation (simplified):

$$\text{Organic matter} + O_2 \xrightarrow{\text{Aerobic bacteria}} CO_2 + H_2O + \text{Heat}$$

Applications:

* soil enrichment (compost)
* Waste management.

Comparison Table:

Feature	Anaerobic	Aerobic
oxygen requirement	NO	Yes
Main products	Biogas ($CH_4 + CO_2$), slurry	CO_2, H_2O, compost, heat
Energy output	High (methane)	Low (mainly heat)
speed	slower	Faster
Environment	closed tanks	open air.

4) Types of bio-gas digesters:

A biogas digester is a tank or system where organic waste is broken down anaerobically to produce biogas (mainly methane) and slurry (used as fertilizer)

1) Floating Drum Type Digester:

Design

-> Underground digestion tank

-> steel drum floats over the slurry & stores biogas.

working

-> Gas is collected in the drum, which rises & falls with gas production.

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Advantages

-> Simple to monitor gas level.

Disadvantages

-> steel drum can rust, needs maintenance.

-> Used in Rural households, small-scale farming.

2) Fixed Dome Type Digester:

Design

-> Dome-shaped underground tank made of concrete or brick

-> No moving parts (no drum).

Working

-> Gas accumulates in the fixed dome & pushes slurry into the overflow tank.

Advantages

-> Long-lasting, low maintenance.

-> No corrosion

Disadvantages

-> Harder to measur gas production visually.

popular in: India (like the Deenbandhu model), China, Nepal.

3> Bag (Balloon) Type Digester

Design:

-> Flexible plastic or rubber bag for both digenstion & gas storage.

-> Working.

-> Portable & easy to install

Advantages:

-> cheap, lightweight, good for temporary or emergency setups.

Disadvantages:

-> Less durable, prone to damage.

Used in: Remote areas, experimental projects.

4> Horizontal & Vertical Digesters:

-> Horizontal Digesters: Long & cylindrical, used where height is limited.

-> Vertical Digesters: Deeper tanks, better mixing, need more depth for contruction.

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~~Comparsion~~ Table:

Fig1

5) Gas yield

Gas yield refers to the amount of biogas produced per kilogram of biomass input in non-conventional (renewable) energy systems like biogas plants.

Units used

* Gas yield is usually expressed in:
  - → m^3/kg of dry biomass
  - → m^3/kg of volatile solids (VS)
  - → Litres/kg of feedstock.

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Typical Gas Yields from Different Feedstocks

Feedstock	Gas Yield (m^3/kg)	Methane content(%)
Cow dung	0.03 - 0.04	55-60%
Food waste	0.4 - 0.6	60-70%
Poultry manure	0.35 - 0.5	60-65%
Agricultural waste	0.2 - 0.4	50-60%
Sewage sludge	0.2 - 0.3	55-65%
Distillery waste	0.6 - 0.7	65-70%

Factory Affecting Gas Yield:

1. Type of biomass:
   Sugary, oily, or protein-rich waste gives more gas.
2. Temperature:
   Optimum: 35-37°c (mesophilic range)
3. Reatention time:
   30 to 50 days of cow dung.

4) pH level :
Ideal : 6.8 to 7.5

5) Carbon Nitrogen Ratio (C/N ratio) :
Ideal : 25 - 30 : 1

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6) Combustion characteristics of biogas

Biogas is a renewable, non-conventional energy source produced through anaerobic digestion of organic matter such as agricultural waste, manure, municipal waste, plant material, sewage, green waste, or food waste.

→ It mainly contains methane (CH_4) & carbondioxide (CO_2), with small amounts of hydrogen sulfide (H_2S), nitrogen (N_2), & water vapor.

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Key combustion characteristics of Biogas.

1) Flammability:
- Methane content (50 - 70%) makes biogas combustible.
- It ignites at air-fuel ratios of 5% to 15% methane by volume.
- Lower heating value (LHV) is about 20-25 MJ/m³, less than natural gas (~35 MJ/m3).

2) Ignition Temperature:
- The auto-ignition temperature of methane is around 650 - 750°C
- Biogas requires proper preheating or spark ignition to ~~igni~~ initiate combustion.

3) Combustion Efficiency:

- Efficient combustion depends on clean gas (free from H_2S & vapor) and good mixing with air.
- Incomplete combustion results in CO emissions & soot formation.

4) Flame Temperature:

- The adiabatic flame temperature of biogas is around 1,000 - 1,100°c, lower than that of pure methane (around 1,950°c)

5) Combustion control:

- For efficient use, combustion must be controlled using proper air-fuel ratios, pressures and burner geom.

- Applications

- Domestic use: cooking, lighting
- Industrial use: boilers, kilns
- Power generation: in IC engines & gas turbines
- co-generation (CHP): heat & electricity generatio

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7) Utilization for cooking.

Non-conventional (or renewable) energy sources are increasingly being used for cooking to reduce reliance on fossil fuels & promote sustainability.

1) Biogas:

- Source: organic waste like animal dung, food waste and agricultural residue.

- usage: Biogas stoves burn the gas (mainly methane) to produce a clean flame.

Advantages
- Eco-friendly & renewable
- Reduces indoor air pollution
- Low operating cost

2) Solar Energy:
- Technology used: solar cookers (box-type, parabolic, panel-type)
- Working: Uses solar radiation to heat & cook food directly.

Advantages
- No fuel cost
- Simple to operate & maintain
- Ideal for sunny regions.

- Limitations: Dependent on weather & sunlight availability.

3) Electricity from Renewable sources:
- source: solar panels, wind turbines, hydroelectric power.
- usage: Electric cooktops, induction stoves powered by renewable electricity.

Advantages
- clean & efficient
- can be used anytime with battery | storage backup

limitation: Initial cost for setup can be high.

4) Ethanol & Bioethanol stoves

• Source : Ethanol from sugarcan, corn, or other biom

• Usage : Burns alcohol to produce a clean flame.

Advantages

- Portable & clean
- Reduces dependence on LPG or kerosene

Limitation : Requires supply of bioethanol.

5) Wood Pellets and Biomass Briquettes

• Source : Compressed sawdust, ~~org~~ agricultural waste

• Usage : used in specially designed biomass stoves.

Advantages :

- cleaner than traditional wood
- Efficient combustion

Limitation : smoke still present if not properly ventilated.

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I.C (Internal combustion) Engine operation

An I.C (Internal combustion) engine is a heat engine where fuel combustion occurs inside the engine cylinder. Traditionally, it uses fossil fuels like petrol & diesel.

However, ncse are now being adapted to power I.C. engines for environmental & economic benfits.

Working Principle of I.c Engiene :

1. Intake stroke : Air - fuel mixture enters the cylinder
2. Compression stroke : The piston compresses the mixture.
3. Power stroke : Mixture ignites, producing pressure that pushes the piston.
4. Exhaust stroke : Burnt gases are expelled.

Non- conventional fuels used in I.c Engines

Fuel Type	Source	Engine Type	Remarks.
Biogas	Animal waste, sewage	spark Ignition (SI)	Need gas carburetor or conversion kit
Biodiesel	vegetable oil, used cooking oil	compression Ignition (CI)	used directly or blended with diesel (e.g. B20)
Ethanol	sugarcane, corn, biomass	Flex-fuel / SI engine	used as E10-E85 blends or pure ethanol.
Hydrogen	water electrolysis, biomass	Modified SI engine	zero CO_2 emissions, needs high-pressure storage.

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Modifications Required for I.C. Engines.

- Fuel injectors / carburetor tuning.
- Material compatibility (ethanol & biodiesel are corrosive)
- Ignition system adjustment
- compression ratio optimization,

Benefits

- Reduces greenhouse gas emissions
- Promotes rural energy generation (biogas)
- Utilizes waste materials (biodiesel, ethanol)
- Reduces dependency on fossil fuels.

challenges

- High initial modification cost.
- Fuel storage & distribution infrastructure (especially for hydrogen).
- Inconsistent fuel quality in rural areas.

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Economic Aspects:

The shift from conventional fossil fuels to non-conventional (renewable/alternative) energy sources in I.C (Internal combustion) engines has both economic advantages & challenges.

Positive Economic Aspects

1. Reduced Fuel costs:

- Fuels like biogas, biodiesel & ethanol are cheaper or can be produced locally.
- Lowers the operational cost of vehicles, generators & irrigation pumps.

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2. ~~Decr~~ Decreased Import Dependency:
- Reduces reliance on expensive imported petroleum products
- Helps in strengthing national energy security & foreign exchange savings.

3. Local Economic Development.
- Prometes rural industrie like:
  - Biogas plants
  - Ethanol distilleries
  - Biodiesel productionunits.
- creates jobs in agriculture, waste management & fuel production,

Negative Economic Aspects / challenges

1. High Initial cost.
- Engine modifications or new equipment needed:
  - Duel-fuel systems
  - Gas storage tanks
  - corrosion-resistant parts.
- Initial investment can be a barrier for small farmers or low-income users.

2. Fuel supply Inconsistency:
- Ethanol, biodiesel, or biogas availability may vary by region or season, affecting reliability & pricing.

3. Maintenance cost:
- some fuels (like biodiesel or ethanol) may increase engine wear or require more frequent servicing.
eg: engine

Advantages:

-> Lower fuel cost
-> Reduced Fuel import dependency
-> Job creation
-> Long-Term cost savings
-> Government subsidies & Incentives

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