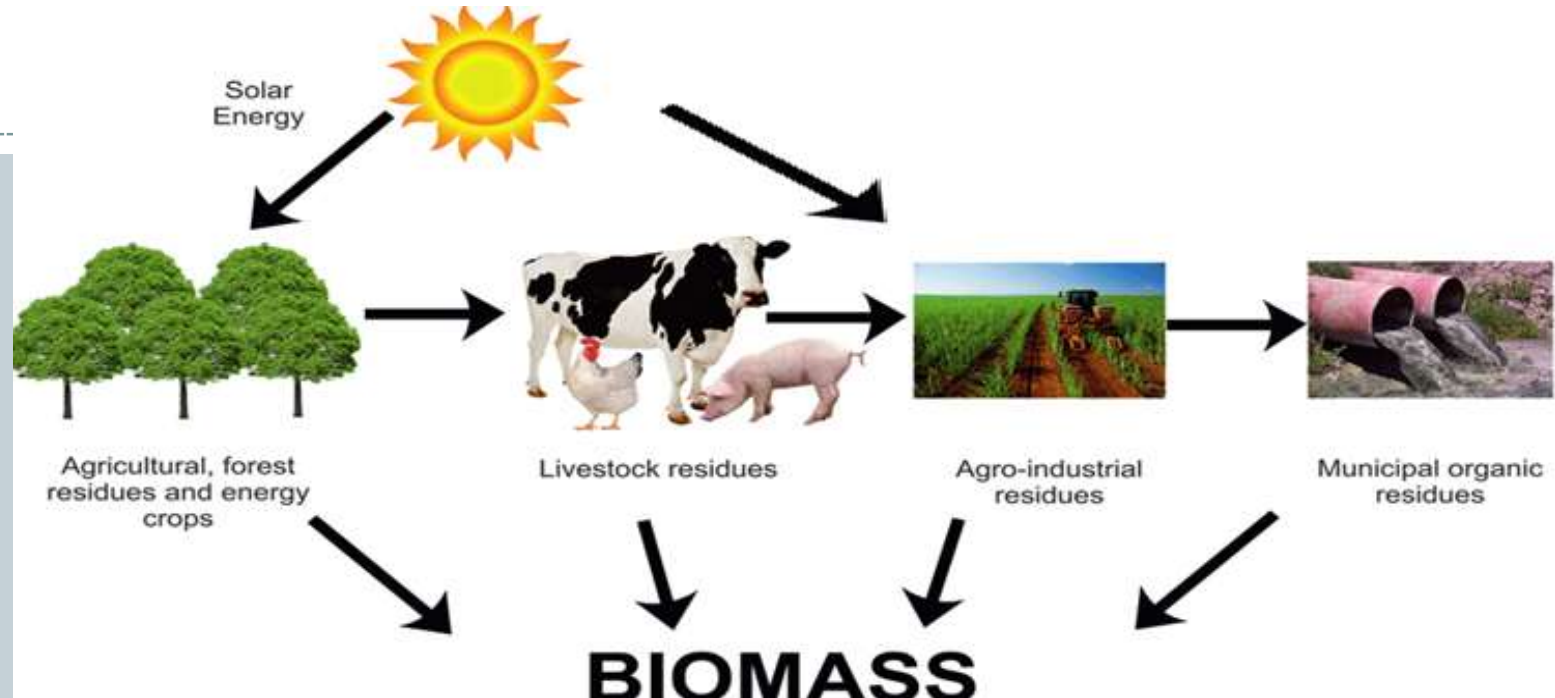


## GENERATION AND UTILIZATION OF BIOMASS



## Unit-II - Syllabus

- **Biomass:** Generation and utilization, Properties of biomass, Agriculture Crop & Forestry residues used as fuels. Biochemical and Thermo-chemical Conversion, Combustion, Gasification, Biomass gasifiers and types etc. Applications of **Gasifiers** to thermal power and Engines, Biomass as a decentralized power generation source for villages
- **Concept of Bio-energy:** Photosynthesis process, Bio-fuels, Biomass resources Bio based chemicals and materials Thermo-chemical Conversion: Pyrolysis, Combustion, Gasification, Liquification. Bio-Chemical Conversion: Aerobic and Anaerobic conversion, Fermentation etc.

## **Unit-II**

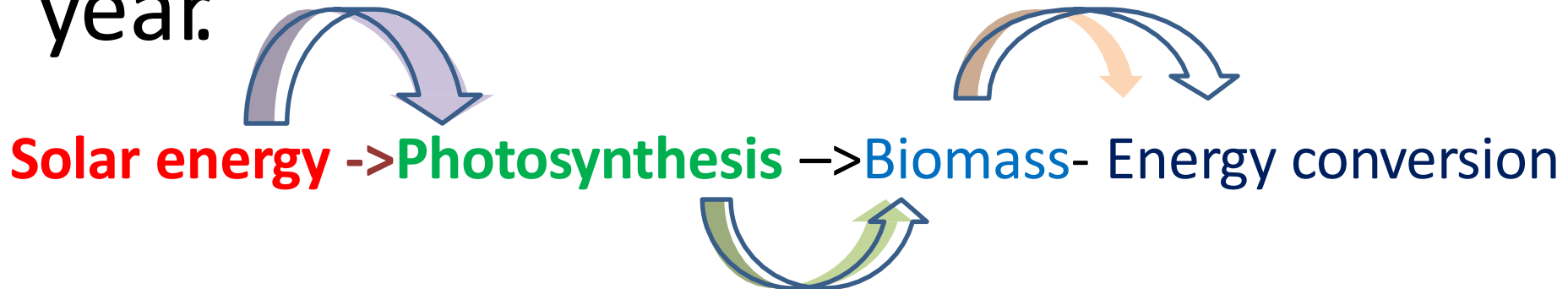
**Bio-fuels:** Importance, Production and applications.

Bio-fuels: Types of Bio-fuels, Production processes and technologies, Bio fuel applications, Ethanol as a fuel for I.C. engines, Relevance with Indian Economy.

11 Bio-based Chemicals and Materials: Commercial and Industrial Products, Biomass, Feed stocks, Chemicals, Plastics, Fibres etc. Government Policy and Status of Bio fuel technologies in

**Biomass** is organic matter produced by plants, both **terrestrial**, **aquatic** and their derivatives.

Biomass can be considered a renewable energy source because plant life renews & adds to itself every year.



# UNDERSTANDING BIOMASS

## What Is It?

A renewable low carbon fuel available throughout the UK

A sustainable fuel that can deliver a significant reduction in net carbon emissions when compared with fossil fuels

Biomass includes organic matter like grass, leaves, wood, wood chips, rice husk, peanut shells, sugarcane fiber, sewage etc

Fuels are sourced from wood, including pellets, chips and logs

## What Can It Do?

20% Average rate of return provided

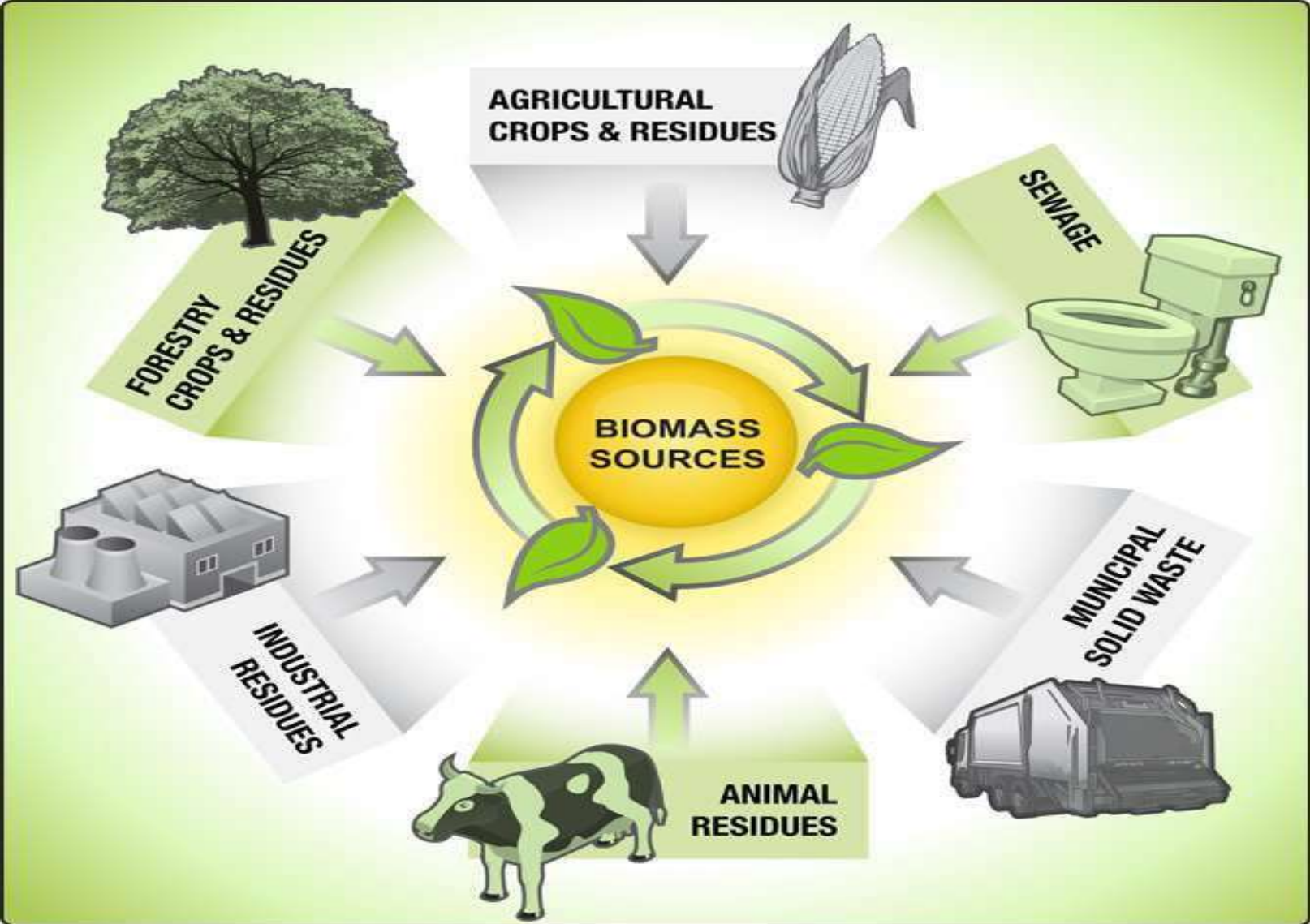
30%-50% The amount you can save on fuel bills

Beat oil, gas and electricity prices

Provide all your home or business' heating needs

5-7 years Average payback time

# BIOMASS SOURCES



# 1. Field and plantation biomass

- ▶ Agricultural crop residues– Cobs, stalks, Straw, Cane thrashes and etc
- ▶ Edible matters from crops–Environmentally spoiled grains, pulses, fruits, nuts, spices, seeds and lint etc
- ▶ Dedicated energy crops– Bamboo
- ▶ Plantation debris–Leaves, barks and trunks
- ▶ Livestock wastes from fields

# 2. Urban waste biomass

- ▶ Municipal solid wastes
- ▶ Sewage sludges
- ▶ Kitchen and canteen wastes

### 3. Industrial biomass

- ▶ Agro-industrial processed biomass and their wastes - Husk
- ▶ Oil cake
- ▶ Sugar molasses
- ▶ Hides and skin wastes
- ▶ Fruit and pulp debris Saw dust
- ▶ Wood pulp and paper shavings
- ▶ Fermented microbial mass etc


## 4. Forest biomass

- ▶ Log residues
- ▶ Timber
- ▶ Forest floor debris
- ▶ Animal carcass

## 5. Aquatic biomass

- ▶ Sea weeds (E.g. Kelp)
- ▶ Fresh water weeds (E.g. Water Hyacinth)
- ▶ Dead fishes
- ▶ Microalgae blooms

# Utilization of Biomass

Technology	Energy services provided	
Biogas	<ul style="list-style-type: none"> <li>• Cooking</li> <li>• Heating</li> <li>• Electricity (local pumping, milling, lighting, and possible distribution via utility grid)</li> </ul>	
Producer gas	<ul style="list-style-type: none"> <li>• Electricity (local pumping, milling, lighting, and possible distribution via utility grid)</li> <li>• Heating</li> </ul>	
Ethanol / Bio-diesel	<ul style="list-style-type: none"> <li>• Vehicle transportation</li> <li>• Cooking</li> </ul>	
Boiler + Steam turbine	<ul style="list-style-type: none"> <li>• Electricity (for industrial processing)</li> <li>• Heating process heat</li> </ul>	
Biofuel + Gas turbine	<ul style="list-style-type: none"> <li>• Electricity (for industrial processing)</li> <li>• Heating process heat</li> </ul>	

# Properties of Biomass

## Physical Properties

Following are important for solid fuels for combustion / thermal processing:

- **Moisture Content**
- **Particle Size and Size distribution**
- **Bulk Density & Specific gravity**
- **Higher Heating/Calorific Value**

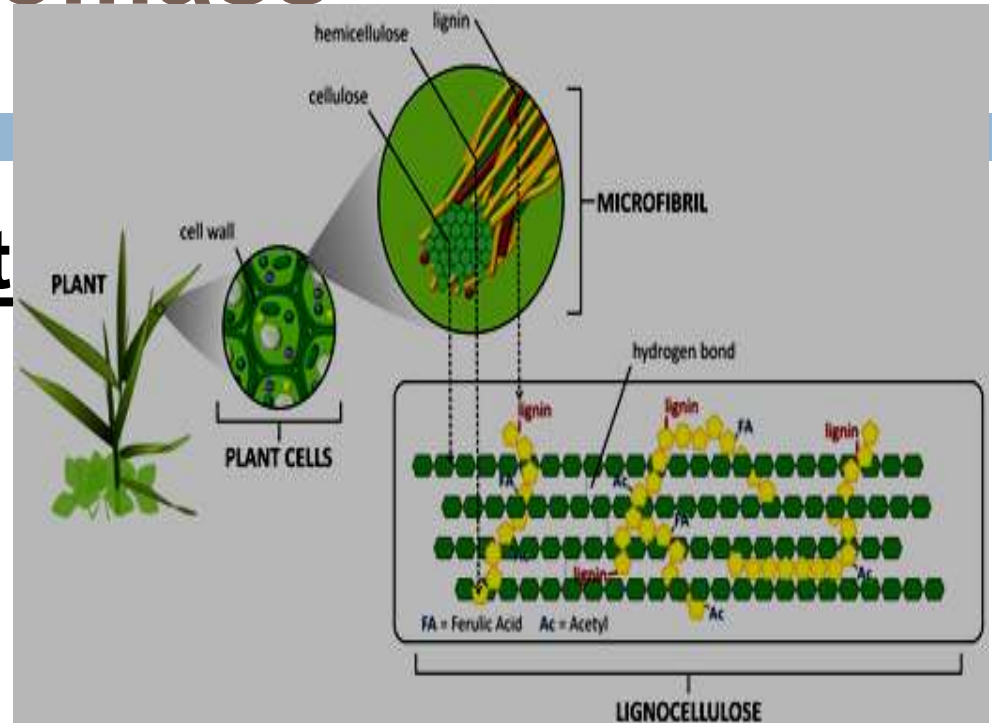
**TABLE** Typical proximate analysis of sugar-cane bagasse at 20% moisture

Component	Mass % w.b.
Moisture	20.00
Volatile	65.24
Fixed carbon	12.11
Ash	2.65
High heat value (MJ/kg) (dry basis)	19.04

# Properties of Biomass

## Chemical Composition

- Total Ash %,
- Solvent soluble %,
- Water Soluble %,
- Lignin %,
- Cellulose %,
- Hemi-cellulose %



- Wood is grouped as either hardwood or softwood.
- Softwoods have 40–45% cellulose, 24–37% hemicellulose and 25–30% lignin.
- Hardwoods contain approximately 40–50% cellulose and 22–40% hemicellulose.

# Properties of Biomass

## Elemental Composition

- • Carbon
- • Hydrogen
- • Oxygen
- • Nitrogen
- • Sulphur

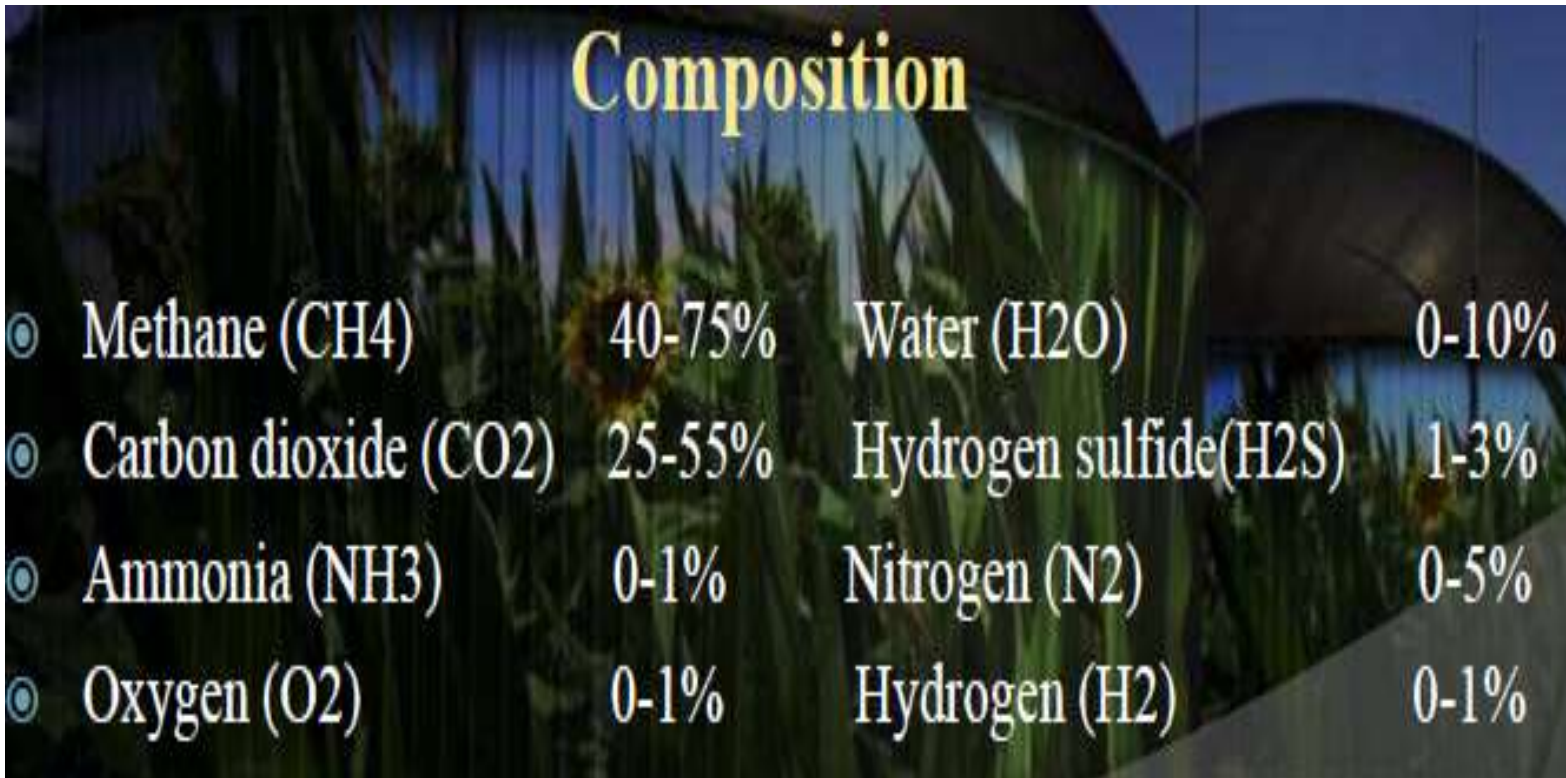
**TABLE** Typical ultimate analysis of sugar-cane bagasse

Component	Mass %, d.b.
C	49.66
H	5.71
O	41.08
N	0.21
S	0.03
Ash	3.31

# FYI: Composition of Biogas

Methane in atmosphere, from biogenic sources: 90 %

Methane in atmosphere, from petro-sources: 10%



**Composition**

● Methane (CH <sub>4</sub> )	40-75%	Water (H <sub>2</sub> O)	0-10%
● Carbon dioxide (CO <sub>2</sub> )	25-55%	Hydrogen sulfide(H <sub>2</sub> S)	1-3%
● Ammonia (NH <sub>3</sub> )	0-1%	Nitrogen (N <sub>2</sub> )	0-5%
● Oxygen (O <sub>2</sub> )	0-1%	Hydrogen (H <sub>2</sub> )	0-1%

# BIOMASS ENERGY CONVERSION

# How is Biomass Converted to Energy?

- ▶ Biomass power is simply carbon neutral electricity produced from renewable organic waste products, which could have been openly burned, dumped in landfills or just left in the forest to cause fires.
1. Energy from the sun is transferred and stored in plants in the form of chemical energy. When the plants are cut or die, wood chips, straw and other plant matter is delivered to biogas plant. When biomass is burnt, it releases energy in the form of heat.
  2. The biomass plants burn wood or other forms of waste to generate steam. The energy from the steam is directed via pipes to run turbines.

3. The steam rises up to run turbines that produce electricity or generate heat for homes and industries.
4. In most countries, biomass plants have been built in the countryside to provide electricity to the local population. There are waste-to-energy plants that burn trash to produce electricity and power millions of homes. Energy can also be used by burning the scrap wood or wood chips that are left over after trees have been trimmed.

1. Carbon Dioxide, rain and solar energy



2. Converted into plant material through photosynthesis



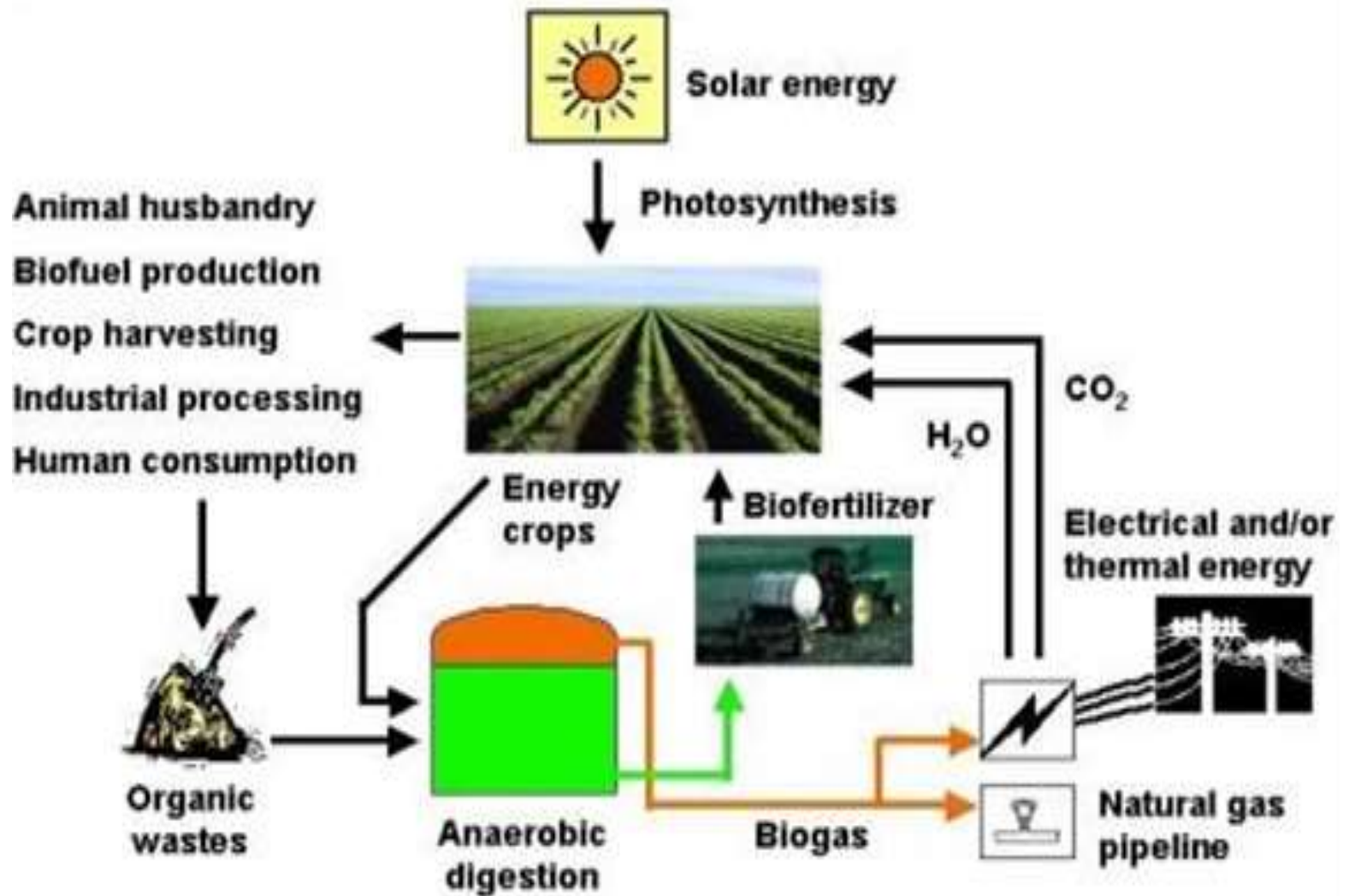
**BIOMASS  
CARBON  
CYCLE**



3. Plant material is turned into Biomass wood pellets

4. Wood pellets are burnt, releasing CO<sup>2</sup> back into the atmosphere and releasing heat as a by-product





A wide variety of conversion technologies is available for manufacturing premium fuels from biomass.

Each biomass resources-wood, dung, vegetable waste can be treated in many different ways to provide a wide spectrum of useful products.

The choice of the process is determined by a number of facts- the location of the resources & its physical conditions, the economics of competing process & availability of a suitable market for the

# Biomass Conversion

```
graph TD; A[Biomass Conversion] --> B[Direct Combustion]; A --> C[Thermo chemical Conversion]; A --> D[Biochemical conversion]; C --> E[Gasification]; C --> F[Pyrolysis]; D --> G[Anaerobic Digestion]; D --> H[Fermentation];
```

The diagram is a hierarchical flowchart. At the top is a purple box labeled 'Biomass Conversion'. A blue line descends from this box and branches into three arrows pointing to three orange boxes: 'Direct Combustion' on the left, 'Thermo chemical Conversion' in the center, and 'Biochemical conversion' on the right. From the 'Thermo chemical Conversion' box, a blue line descends and branches into two arrows pointing to two green boxes: 'Gasification' on the left and 'Pyrolysis' on the right. From the 'Biochemical conversion' box, a blue line descends and branches into two arrows pointing to two red boxes: 'Anaerobic Digestion' on the left and 'Fermentation' on the right.

**Direct  
Combustion**

**Thermo chemical  
Conversion**

**Biochemical  
conversion**

**Gasification**

**Pyrolysis**

**Anaerobic  
Digestion**

**Fermentation**

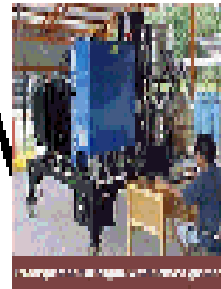
# ThermoChemical Process

Bum

Remove air & Add heat 800-1000°F



Add air & heat 1300-2000°F



Direct  
Combustion  
(Wood waste)

Pyrolysis  
(Liquid BioFuel)  
Synthetic  
Fuel Oil

Gasification  
(BioGas)  
Producer  
Gas

# BioChemical Process

Add yeast



Remove air & add heat 70-150°F

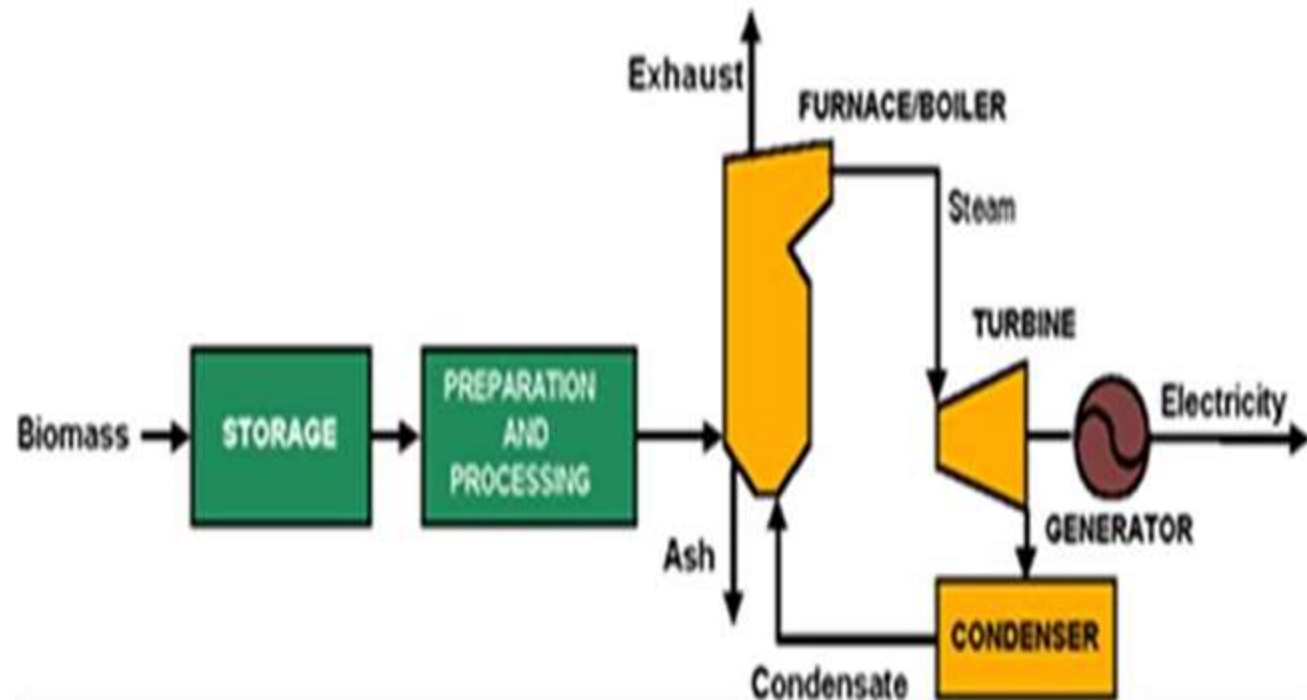


Alcoholic  
Fermentation  
(Liquid BioFuel)  
Ethanol

Anaerobic  
Digester  
(BioGas)  
Digester Gas

# Direct Combustion

In a direct combustion system, biomass is burned in a **combustor** or **furnace** to generate hot gas, which is fed into a boiler to generate **steam**, which is expanded through a steam **turbine** or steam engine to produce **mechanical** or **electrical energy**.



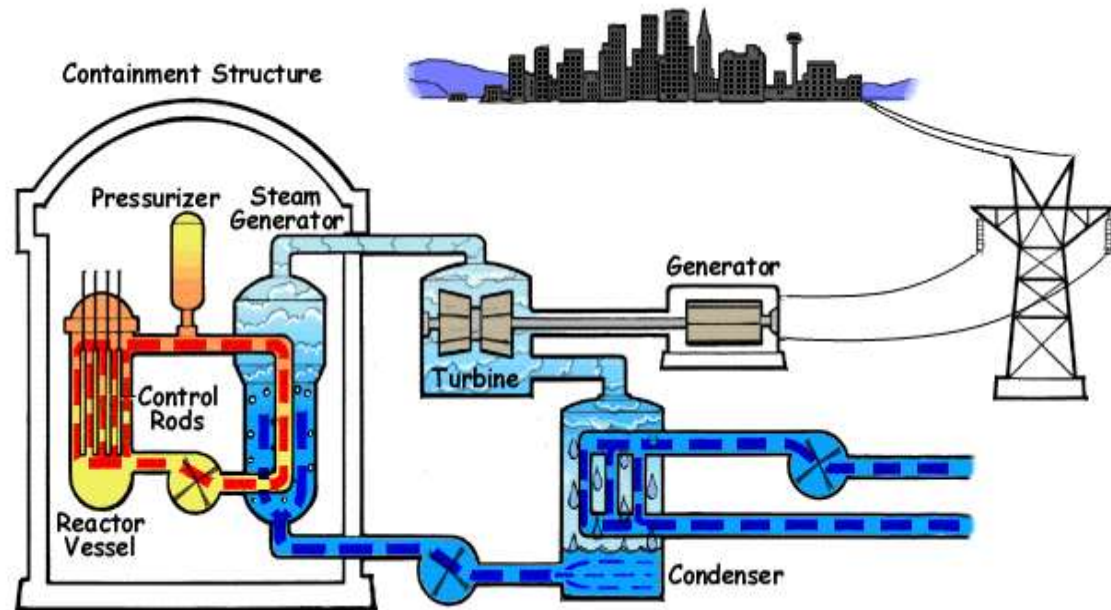
# Direct Combustion

- The direct combustion of biomass in **presence of oxygen/air** to produce heat and by products is called direct combustion.
- The complete combustion of biomass into ash is called incineration.
- This heat energy in the product gases or in the form of steam can be used for various applications like space heating or cooling, power generation process heating in industries or any other application.
- However, if biomass energy by combustion is used as co generation with conventional fuels, the utilization of biomass energy makes it an attractive proposition.

# Direct Combustion

A simple biomass electric generation system is made up of several key components. For a steam cycle, this includes some combination of the following items:

- Fuel storage and handling equipment
- Combustor / furnace
- Boiler
- Pumps
- Fans
- Steam turbine
- Generator
- Condenser
- Cooling tower
- Exhaust / emissions controls
- System controls (automated).



# Direct Combustion

Direct combustion systems **feed** a biomass **feedstock** into a **combustor** or **furnace**, where the biomass is burned with excess air to heat water in a boiler to create **steam**.

Steam from the boiler is then **expanded** through a **steam turbine**, which runs a generator and produces electricity.

In general, all biomass systems require fuel storage space and some type of fuel handling equipment and controls. A system using wood chips, sawdust, or pellets typically use a bunker or silo for short-term storage and an outside fuel yard for larger storage. An automated control system conveys the fuel from the outside storage area using some combination of cranes, stackers, reclaimers, front-end loaders, belts, augers, and pneumatic transport.

# Thermo-Chemical Conversion

The thermo chemical reaction can convert the organic biomass into more valuable and convenient form of products as gaseous and liquid fuels, residue and by-products etc.

These processes can be carried out in following ways:

- 1) Gasification
- 2) Pyrolysis

**Gasification**- takes place by heating the biomass with **limited oxygen / Air** (deficient O<sub>2</sub> and Air) to produce low heating value gas or by reacting it with **steam & oxygen at high pressure & temperature** to produce medium heating value gas like H<sub>2</sub>,CO,CH<sub>4</sub>,N<sub>2</sub>



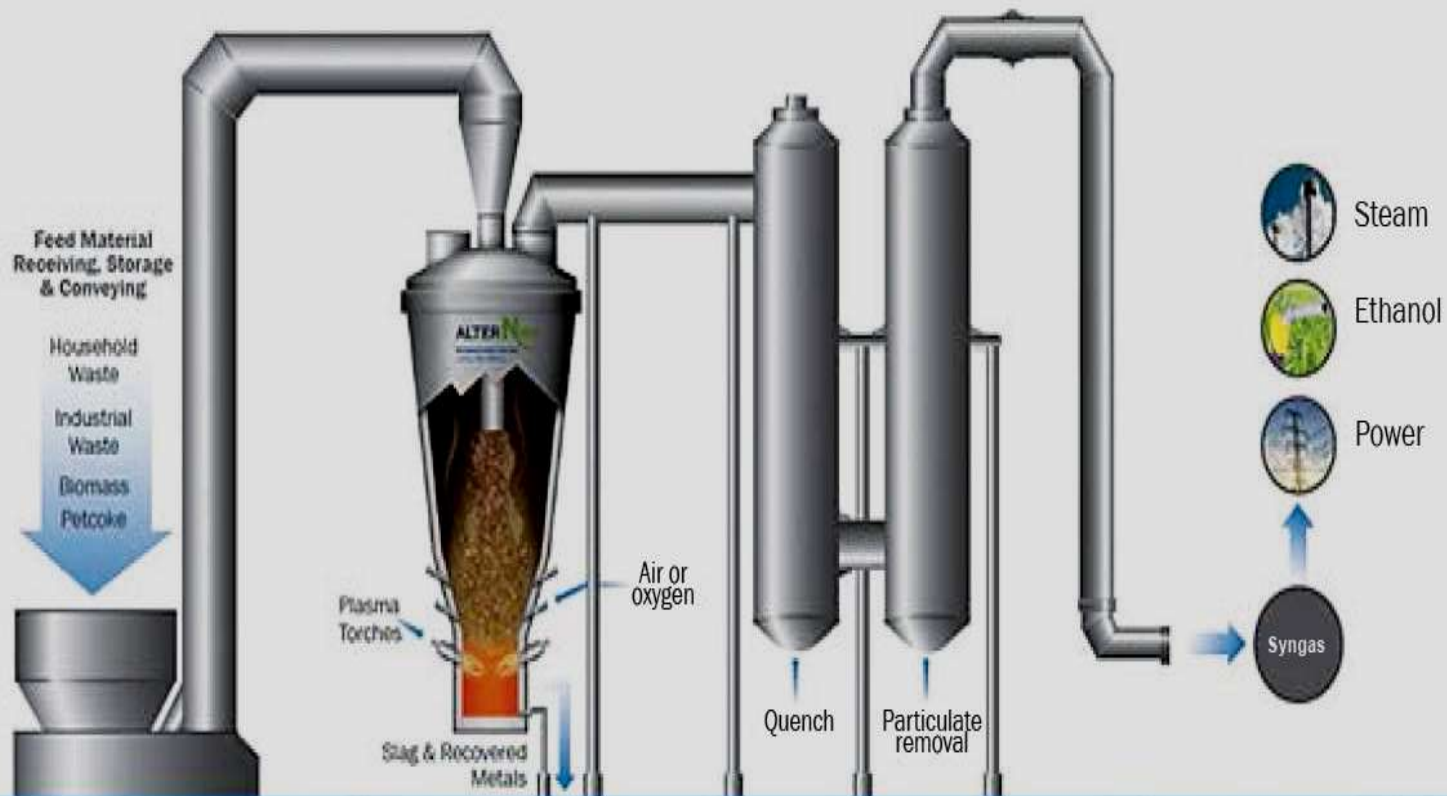
Feed handling

Plasma  
gasification

Gas cooling

Syngas clean-up

Product options



Wide variety of feedstocks  
low \$ cost

Flexibile process  
gasifier

Wide variety of products  
high \$ value

- The facility exports 80% of the energy input to Syngas
- Plasma torches use 2% to 5% of the energy input

- Gasification is not incineration
- Gasification creates hydrogen and carbon monoxide: an energy rich gas steam

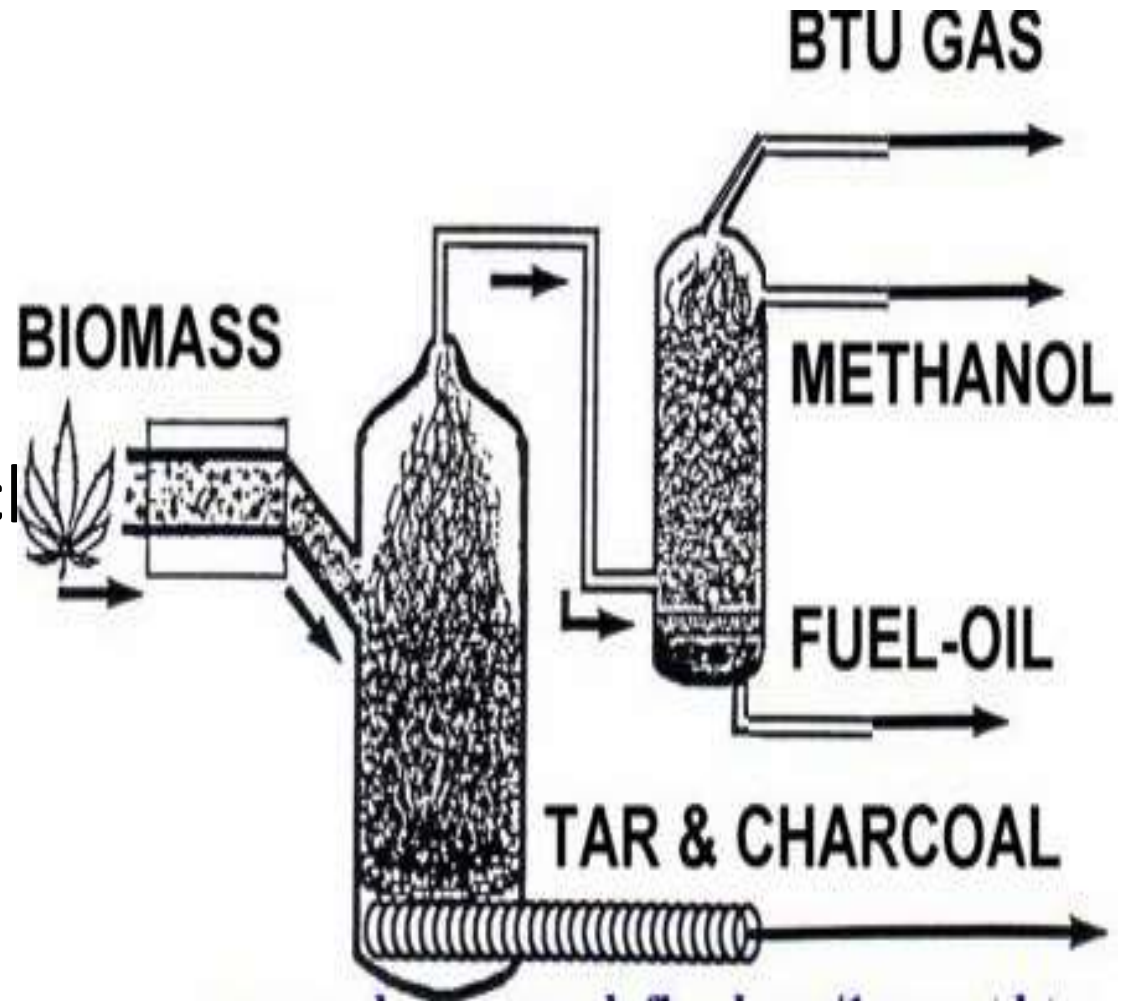
# Pyrolysis

---

It is the heating of biomass in a closed vessel at temperatures in the range 500°C-900°C in **absence** of **O<sub>2</sub>/air** or with steam. It produces solid, liquid and gases.

The pyrolysis process can use all type of organic materials including plastic and rubeers.

Pyrolysis is the decomposing of biomass (fresh or fossil) by the heat of **anaerobic** (reduced air) combustion which converts organic material into gases and/or fuel oils.



# Biochemical Conversion

---

In biochemical processes the **bacteria and micro organisms** are used to transform the raw biomass into useful energy like methane and ethane gas. Following organic treatments are given to the biomass:

- 1) Fermentation of biomass (Aerobic digestion)
- 2) Anaerobic digestion of biomass

# Fermentation

---

Fermentation is a process of decomposition of complex molecules of organic compound under the influence of micro-organism(**ferment**) such as **yeast**, bacteria, enzymes etc.

The example of fermentation process is the conversion of grains and sugar crops into ethanol and  $\text{CO}_2$  in presence of yeast.

# Fermentation

---

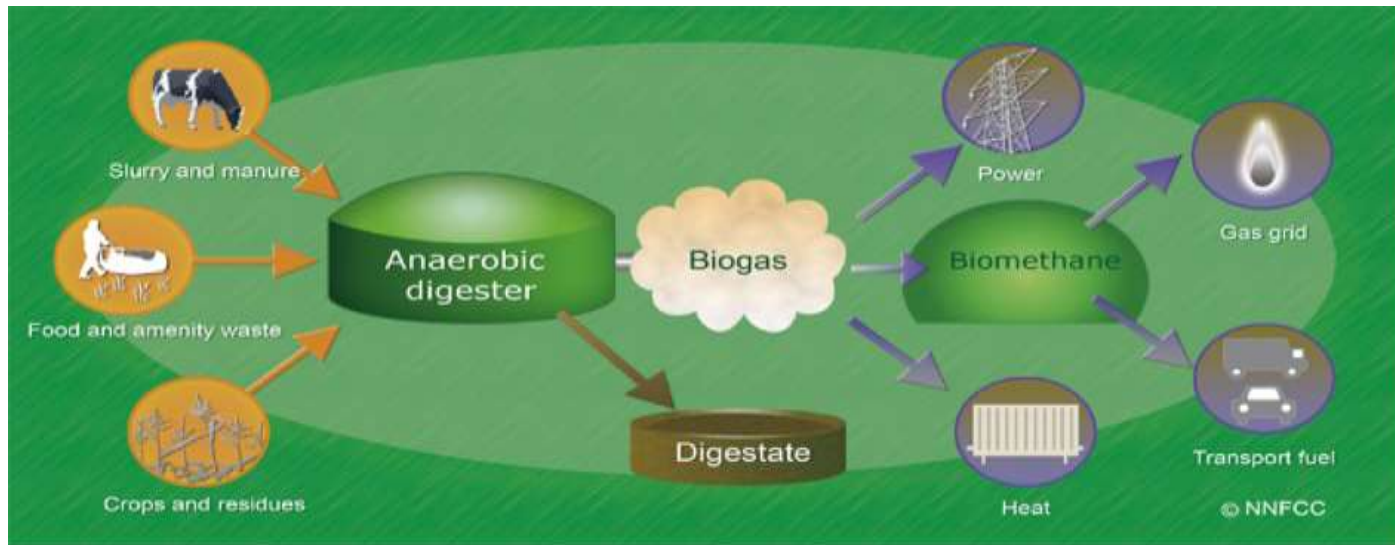
Fermentation is a process of decomposition of complex molecules of organic compound under the influence of micro-organism(**ferment**) such as **yeast**, bacteria, enzymes etc.

The example of fermentation process is the conversion of grains and sugar crops into ethanol and  $\text{CO}_2$  in presence of yeast.

# Fermentation



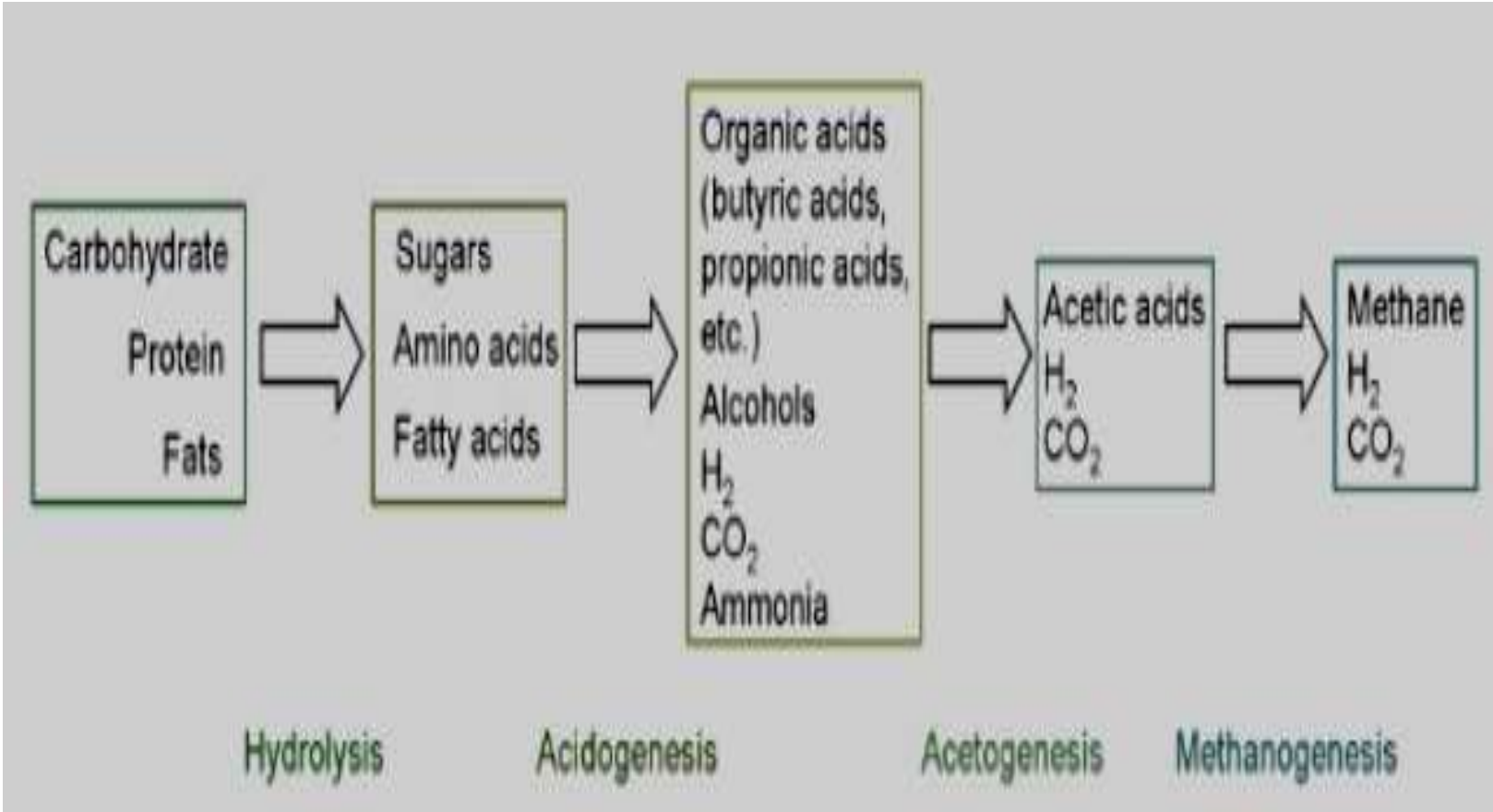
# Anaerobic Digestion



The anaerobic digestion or anaerobic fermentation process involves the conversion of decaying wet biomass and animal waste into biogas through decomposition process by the action of anaerobic bacteria.

The most useful biomass for production of biogas are animal and human waste, plant residue and other organic waste material with high moisture content.

# Anaerobic Digestion



In other Words.....

- 1. Anaerobic* digestion involves the microbial digestion of biomass. The process takes place at **low** temperature up to **60°C** & requires a moisture content of at least **80%**, and generates a gas consisting of CO<sub>2</sub> & methane (CH<sub>4</sub>)
- 2. Fermentation* is the breakdown of complex molecules in organic compound under influence of a ferment such as *Yeast, bacteria, enzymes* etc.