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.**

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.

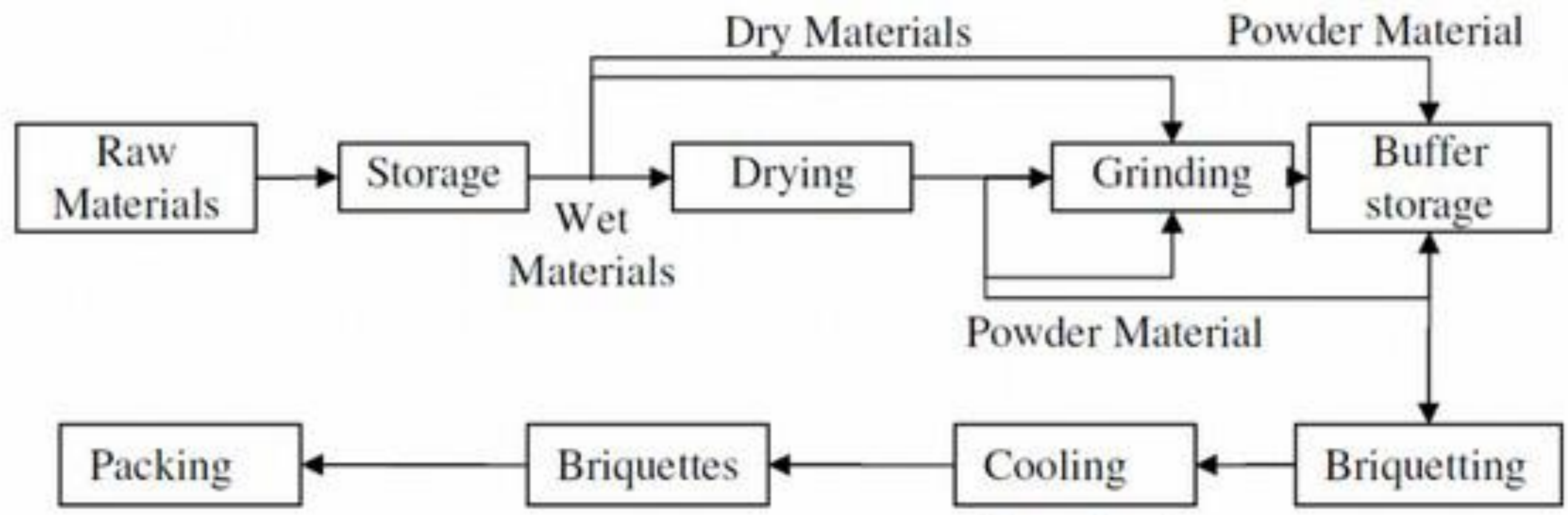
Pelletization reduces the moisture to about 7 to 10 percent and increases the heat value of the biomass

(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.

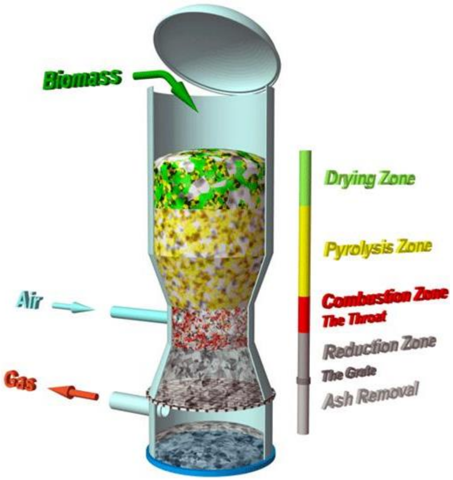
Source: Gokhale, Gupta, Kishwan et al. (2007)

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^{o}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.

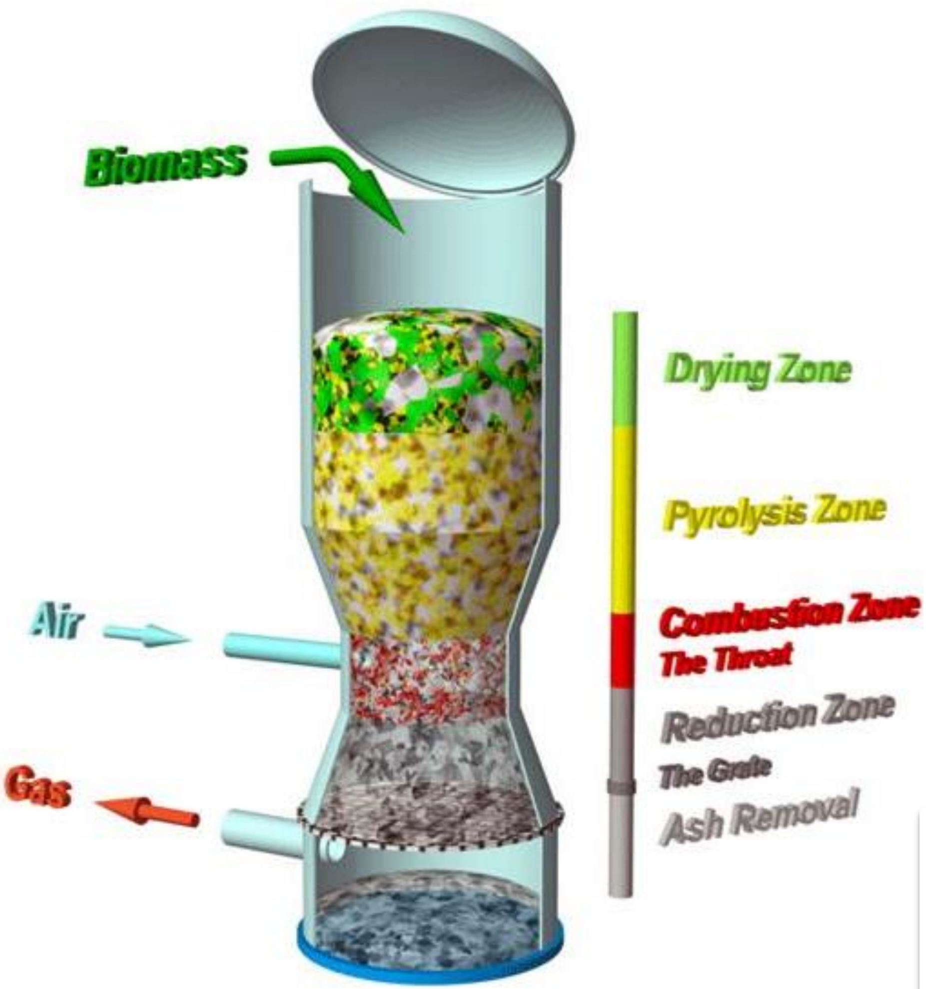
$CO_2 + C = 2CO -172.6$ kJ/g.mol

$C+H_2O = CO + H_2 -131.4$ 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

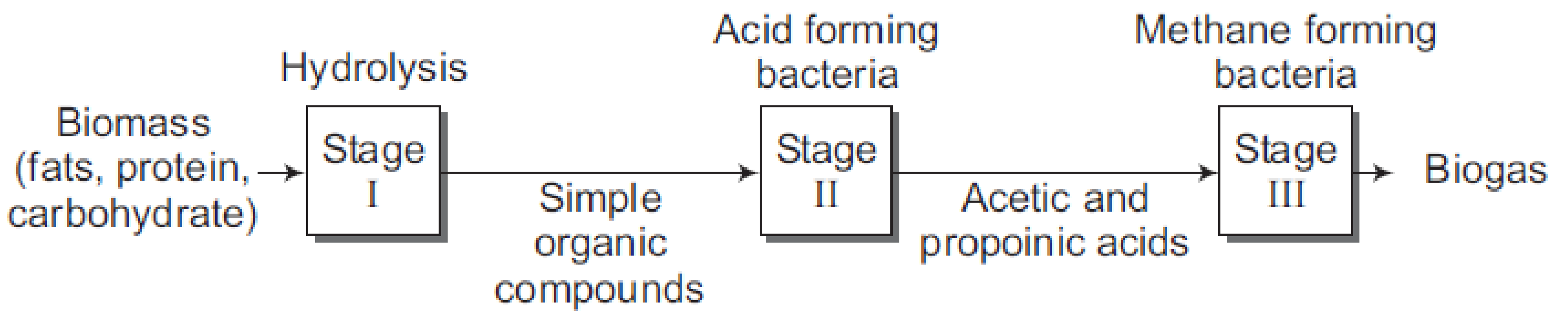


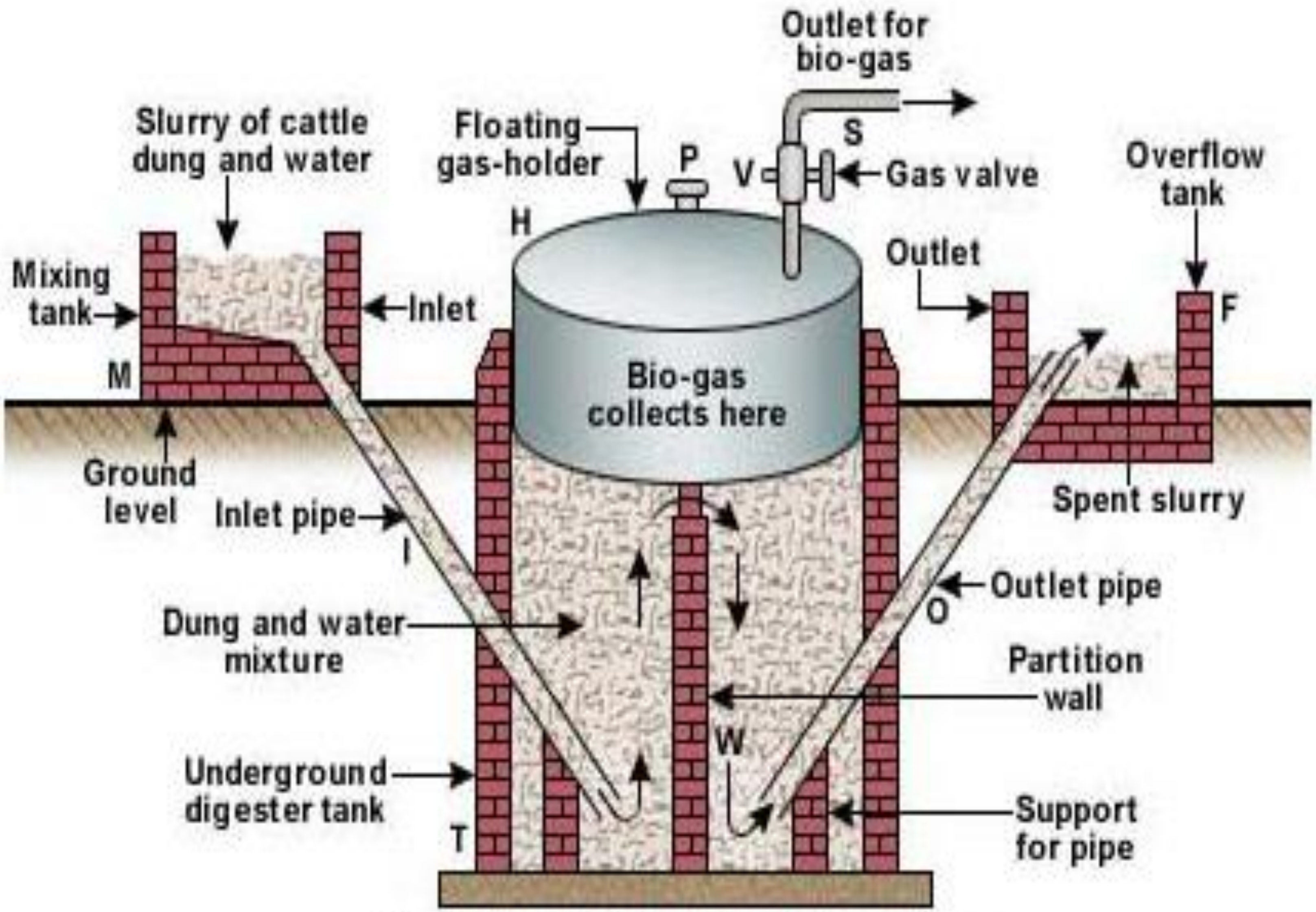
Figure 8.9 Various stages of anaerobic digestion process

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 m^3 biogas plant

Horizontal biogas plant for treating kitchen and dining wastes

Household biogas plant at rooftop


Dr.P. Venkatachalam TNAU

Basic information of biogas

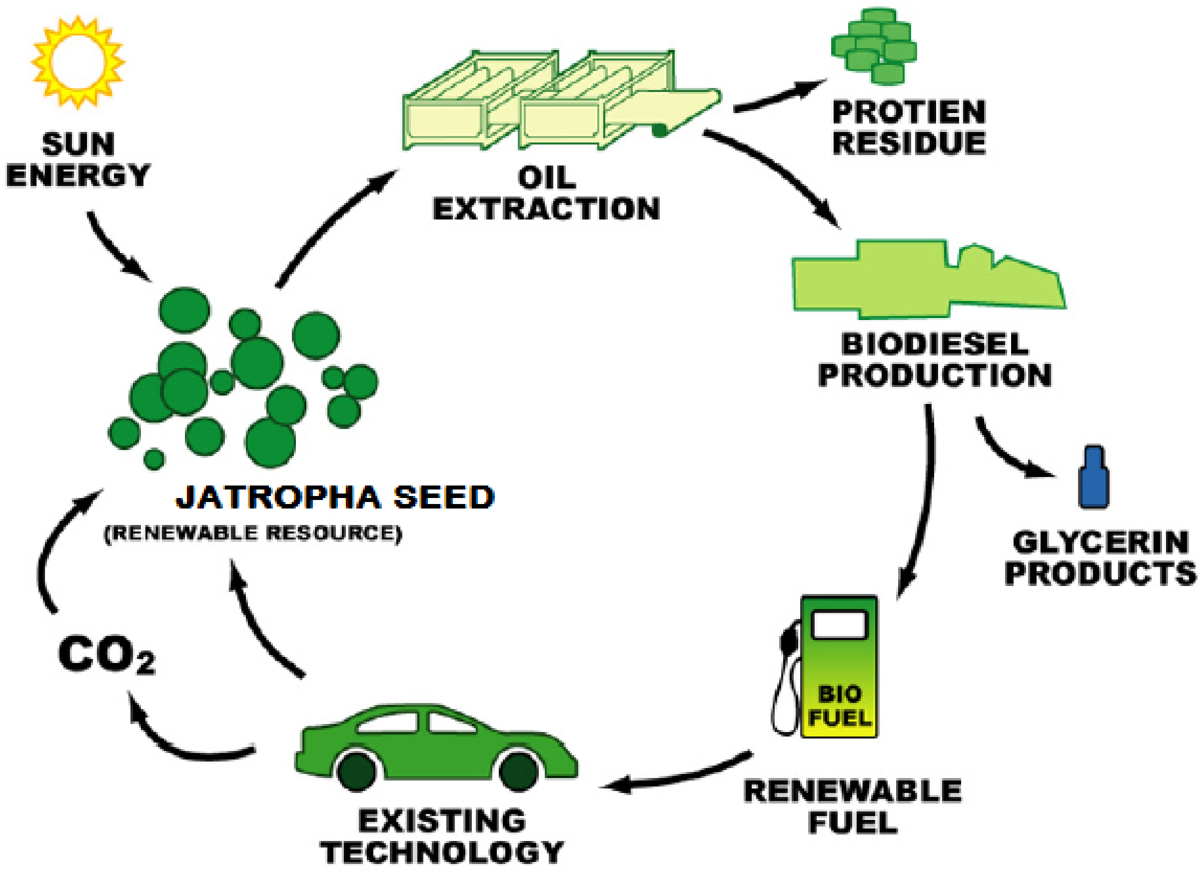
Particulars	Equivalent
$1m^3$ of biogas	1000 liters
Gas requirement for cooking	0.3 to $0.4m^3$/day/person
Gas requirement for lighting	0.10 to 0.12 m^3/hr/100cantle power light
Gas requirement running the engine	0.4 to 0.5 m^3/HP/hr
Calorific value of biogas	3500 to 4800 KCal/m^3
Optimum gas to air 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.

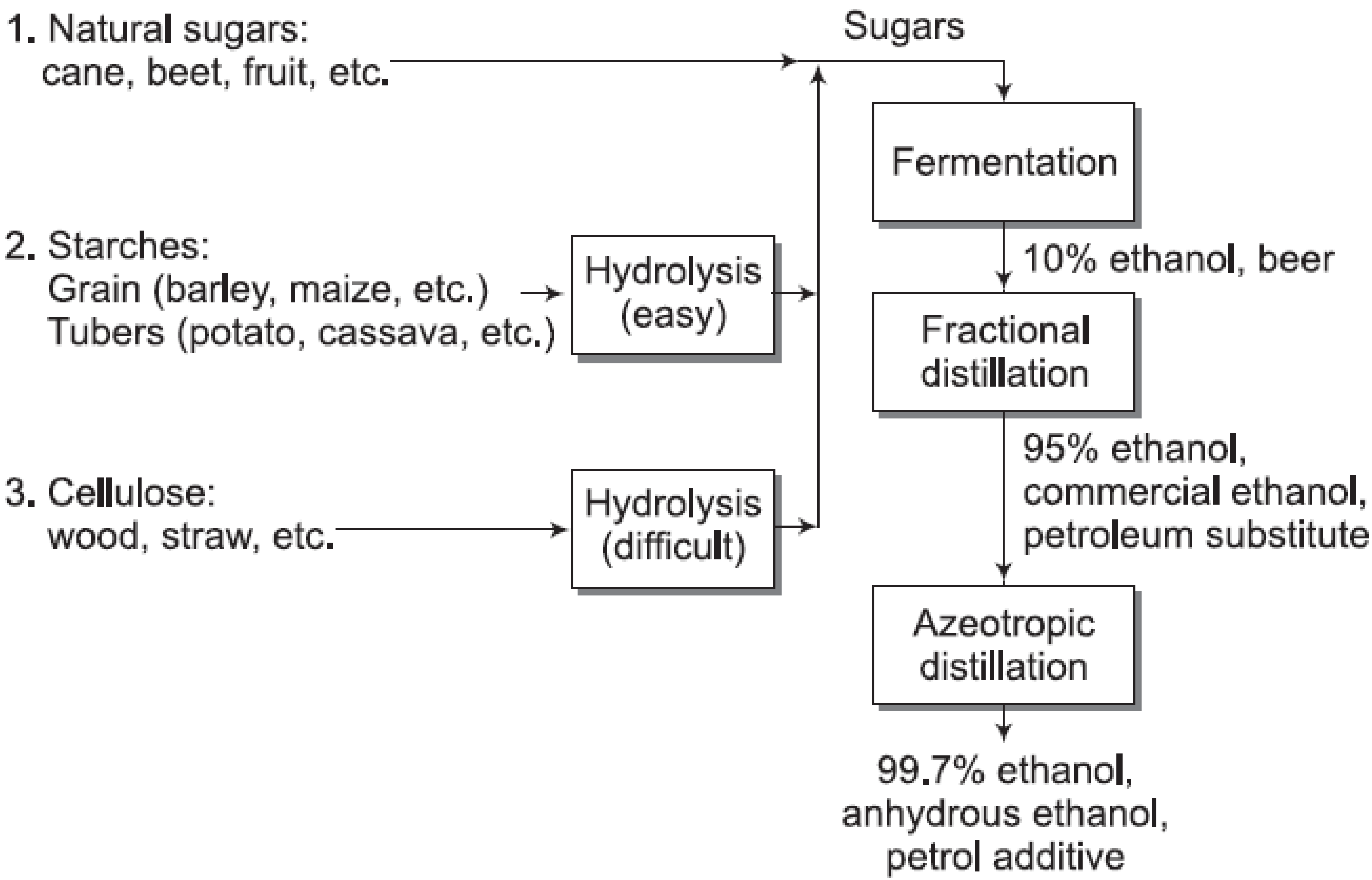


Figure 8.8 Ethanol production from various types of biomass

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

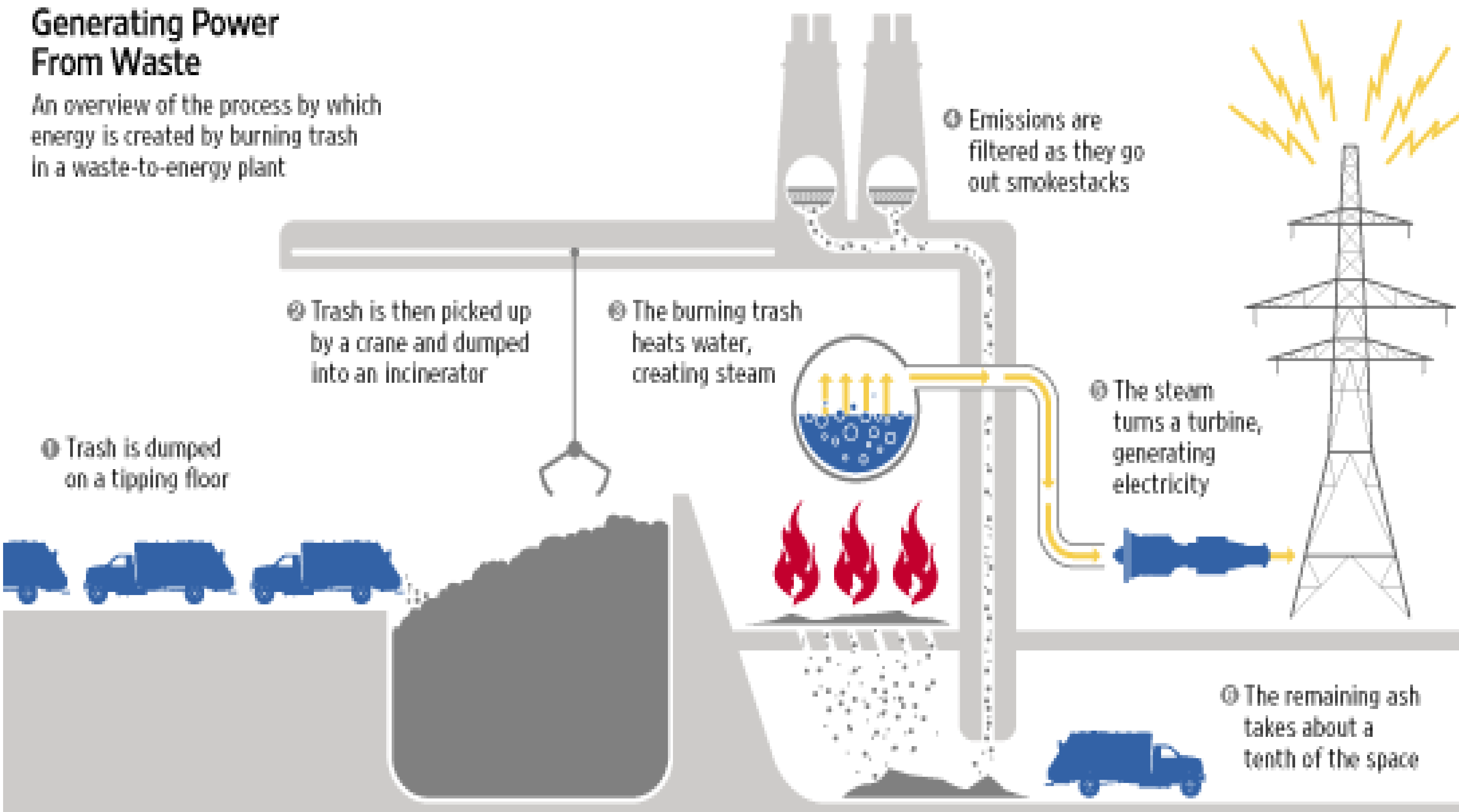
MSW Incineration Plant

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.

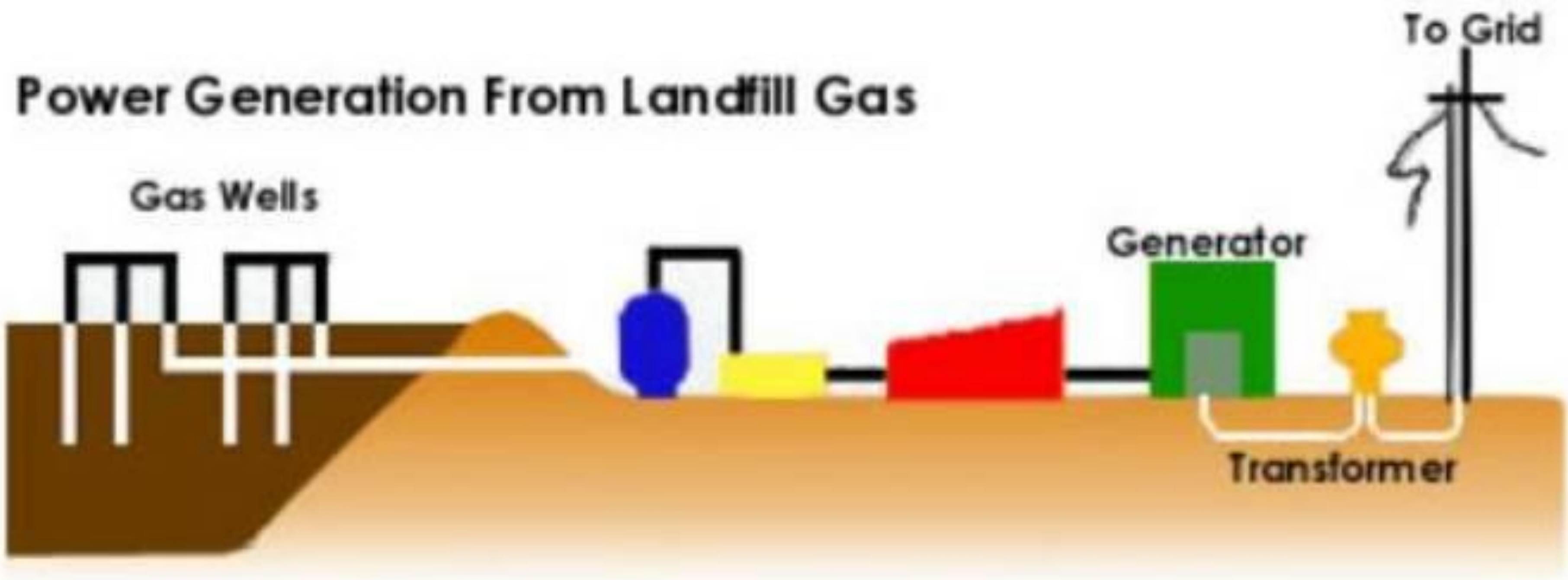
S.N.	Waste material	Percentage
1.	Paper and paper board	39.2
2.	Food and yard waste	21
3.	Glass	6.2
4.	Metals	7.6
5.	Plastics, rubber	9.1
6.	Wood	7.1
7.	Others (including hazardous wastes, e.g. chemicals, lead, insecticides, household cleaning chemicals, etc.)	9.8

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