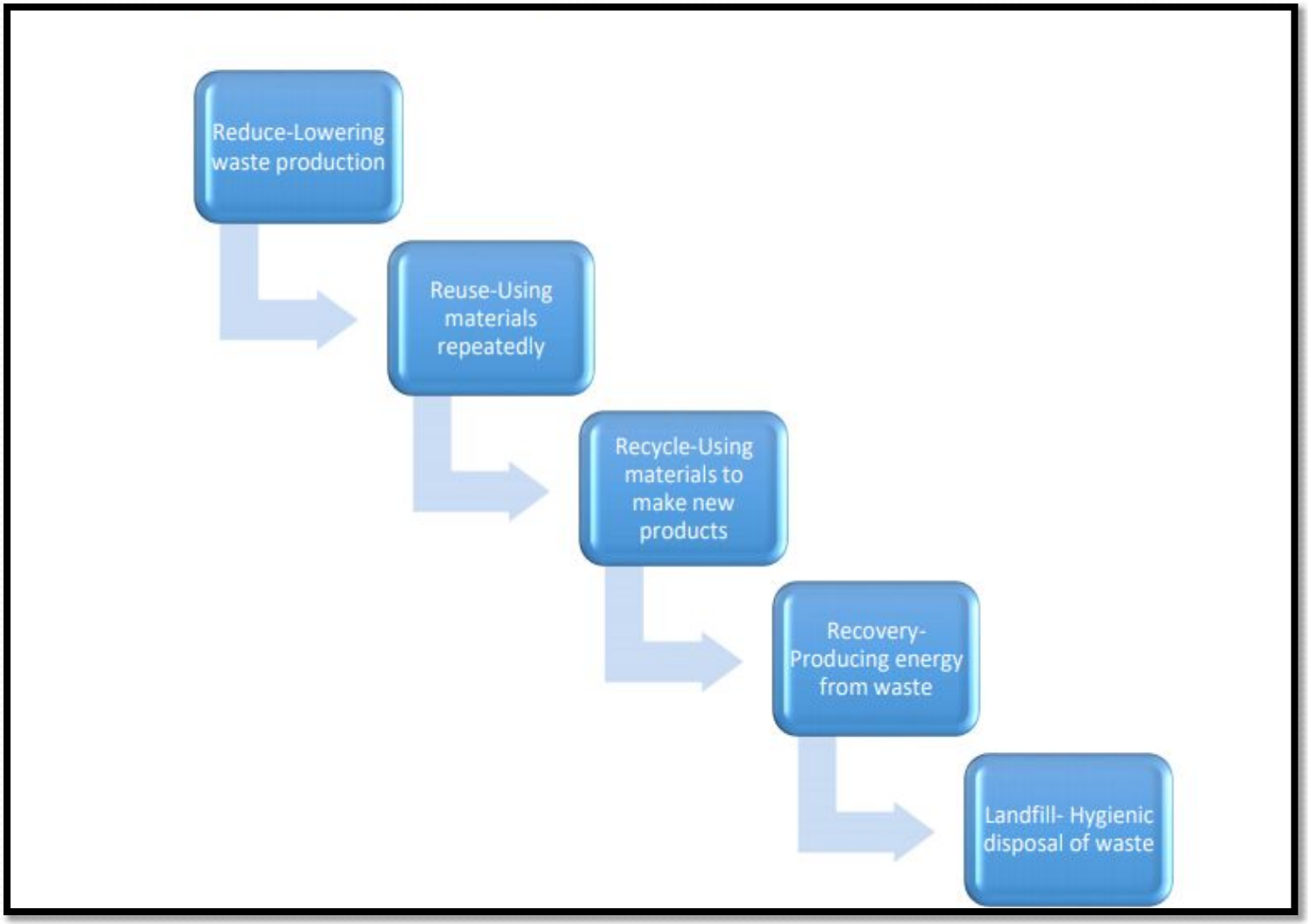
Treatment of Solid Waste Management

Waste Management Hierarchy

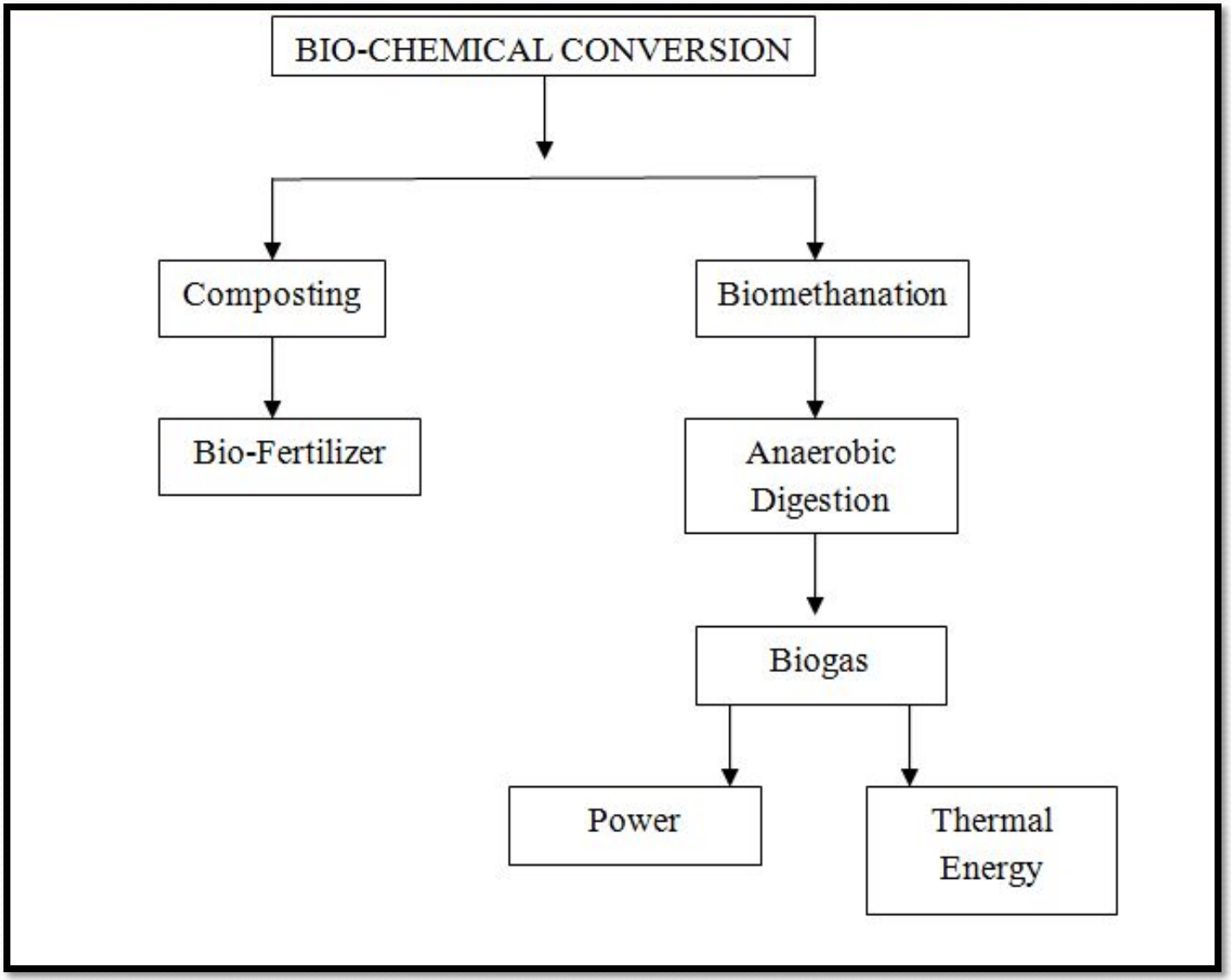


Types of Waste to Energy Technologies

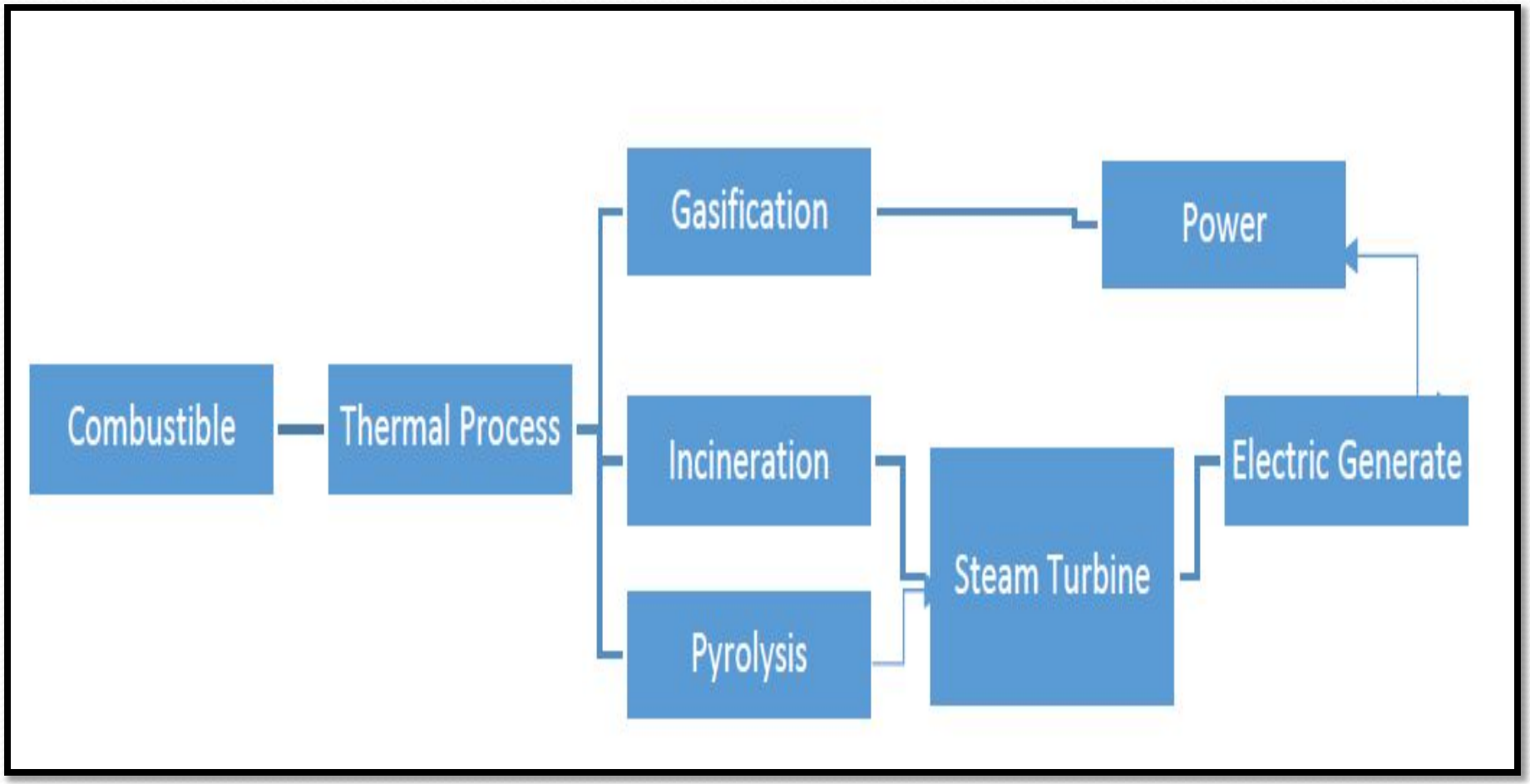
- **Bio-chemical method** of WTE technologies: Most suitable for wet wastes consisting of organic matter.

- **Thermo-chemical method** of WTE technologies: Controlled combustion of waste which gives heat to produce steam which in turn produces power using steam turbines. Most suited for low moisture feedstock which has high conversion rates.

Types of Bio-Chemical Conversion of Bio-Degradable Wastes



Types of Thermal Processing of Combustible Wastes



COMPOSTING

- Composting is a biochemical conversion of biodegradable MSW in aerobic condition, during which biological conversion of organic or biodegradable matter occurs in the presence of air and heat.
- The resulting end product called compost or humus has high nutrient value.
- It is dry, dark, brown, crumbly and earth smelling.
- The volume of compost is much less nearly 40-50% when compared to the volume of the raw materials that were used; this is mainly due to the water respiration and biochemical breakdown.
- Composting method is advanced recently, such that consortium of microbes and odour masking agents are used to reduce the processing time.

Stages of composting

- High rate composting stage
- Thermophilic or stabilisation stage
- Maturation stage

Advantages

- Benefits to our garden soil: improves quality of soil, structure of soil so that it can retain nutrients, moisture and air.

- Reduces the landfill pile
- Reduces the need of artificial fertilizers
- Provides nutrients to soil
- Reduces the pests

Factors that can affect aerobic composting

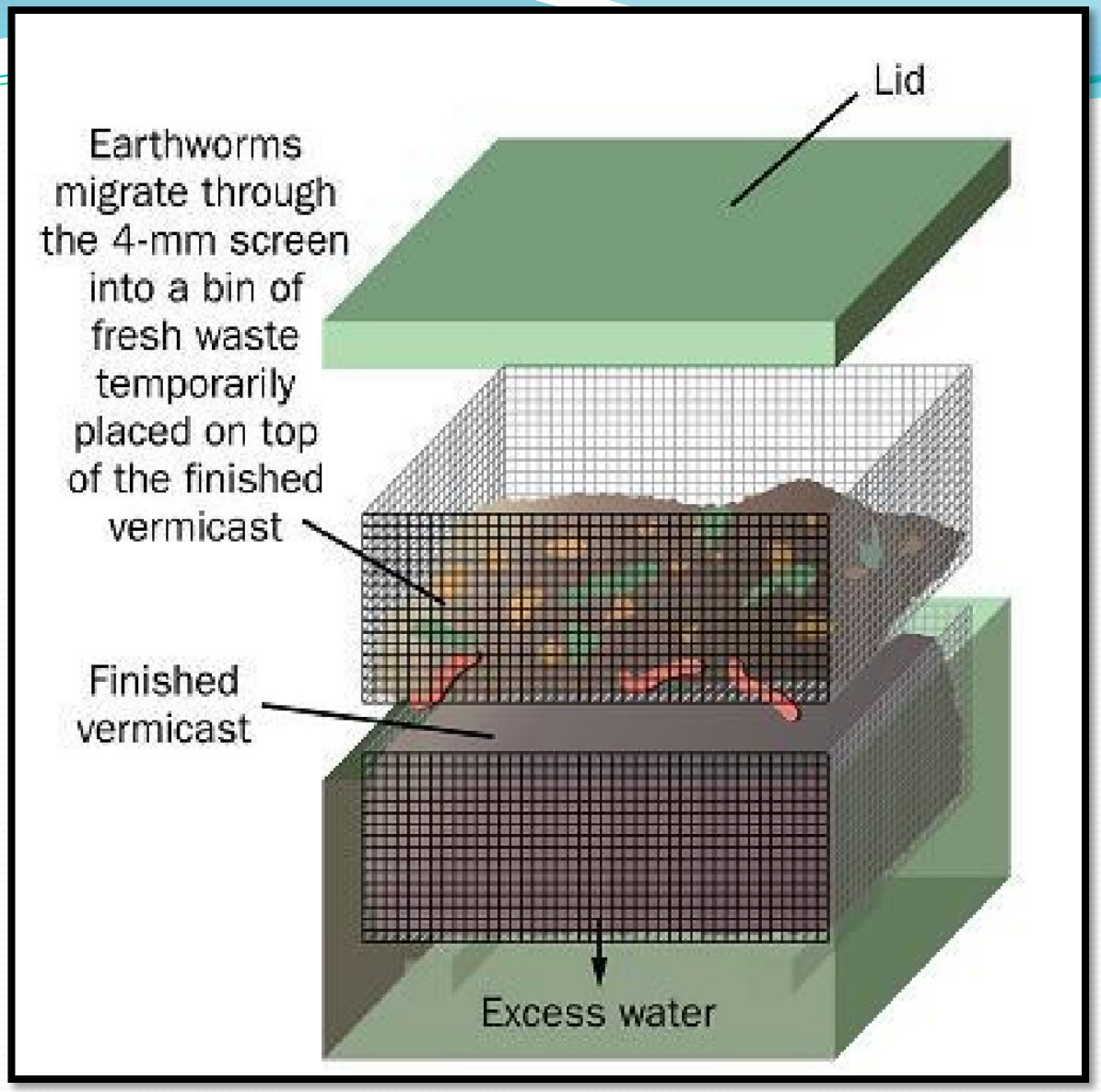
- Carbon to Green Ratio(C:N)
- Air
- Moisture
- Temperature
- Particle Size

Methods of aeration

- Windrow system
- Forced aeration system
- In-vessel system

VERMI-COMPOSTING

- Vermi-composting is where earthworms are added to semi-decomposed organic waste.
- As it is well known that earthworms can consume at least five times of organic matter each day than their actual body weight.
- **Firstly,** biodegradable waste is decomposed via microbial activity.
- **Later,** Earthworms consume the organic fraction of wastes and excrete (Vermi casting), which is then sieved and used as bio-organic fertilizer.
- The vermi-compost can be composed to improve soil health and moisture retaining capacity and thus it is known as bio-organic fertilizer.



Overview of Vermi-composting process

Phases of vermicomposting

- Collection and separation
- Digestion of organic wastes
- Preparation of earthworm bed
- Collection of the vermicompost
- Storage of the compost

Essential conditions for survival of the compost worms

- **Bedding**
  - High absorbency (moisture)
  - Good bulking potential (aeration)
  - Low protein and /or nitrogen content (food source)

Methodology for the production of vermi-compost

- Selection of suitable earthworm
- Selection of suitable location
- Selection of containers
- Vermiculture bed
- Bedding materials
- Worm food

Vermi-compost production Process

- Biodegradable wastes such as cattle dung, farm wastes, crop residues, vegetable market waste, flower market waste, agro industrial waste, fruit market waste etc are suitable for vermicompost production. Before vermicomposting, cattle dung should be dried in open sunlight and all other wastes should be pre-digested with cow dung for twenty days.

- The predigested waste material is mixed with 30% cattle dung and then placed into the container. Moisture level is maintained at 60%.

- Selected earthworms are placed uniformly over the material that has to be composted. There is no need to put the earthworms inside the waste as they move inside on their own. Roughly for one-meter length, one-meter breadth and 0.5-meter height of the vermibed, 1 kg of worm (1000 Nos.) is needed.

- Moisture should be maintained to 60% throughout the composting process. Hence, daily watering of the vermibed is not required but water should be sprinkled over the bed if necessary.

- Harvesting of the castings formed on the top layer are done periodically i.e., may be once in a week. Watering should be stopped before the harvest of vermicompost. The casting are scooped out with hand and placed as heap in a shady place. The harvesting of casting should be limited up to earthworm presence on top layer. Periodical harvesting is necessary for free flow and to retain the quality of compost or else the finished compost get compacted when watering is done.

- After the vermicompost production, the earthworm present in the bed may be harvested by trapping method wherein small, fresh cow dung balls are made and inserted inside the bed in five or six places. After 24 hours, the cow dung balls are removed. All the worms will be adhered into the ball. Putting the cow dung ball in a bucket of water will separate this adhered worm. The collected worms will be used for next batch of composting.

Worm harvesting methods

- Manual methods
- Self harvesting (migration) methods
- Storing and packing
- Nutritive value of vermi-compost

Benefits of vermi-composting

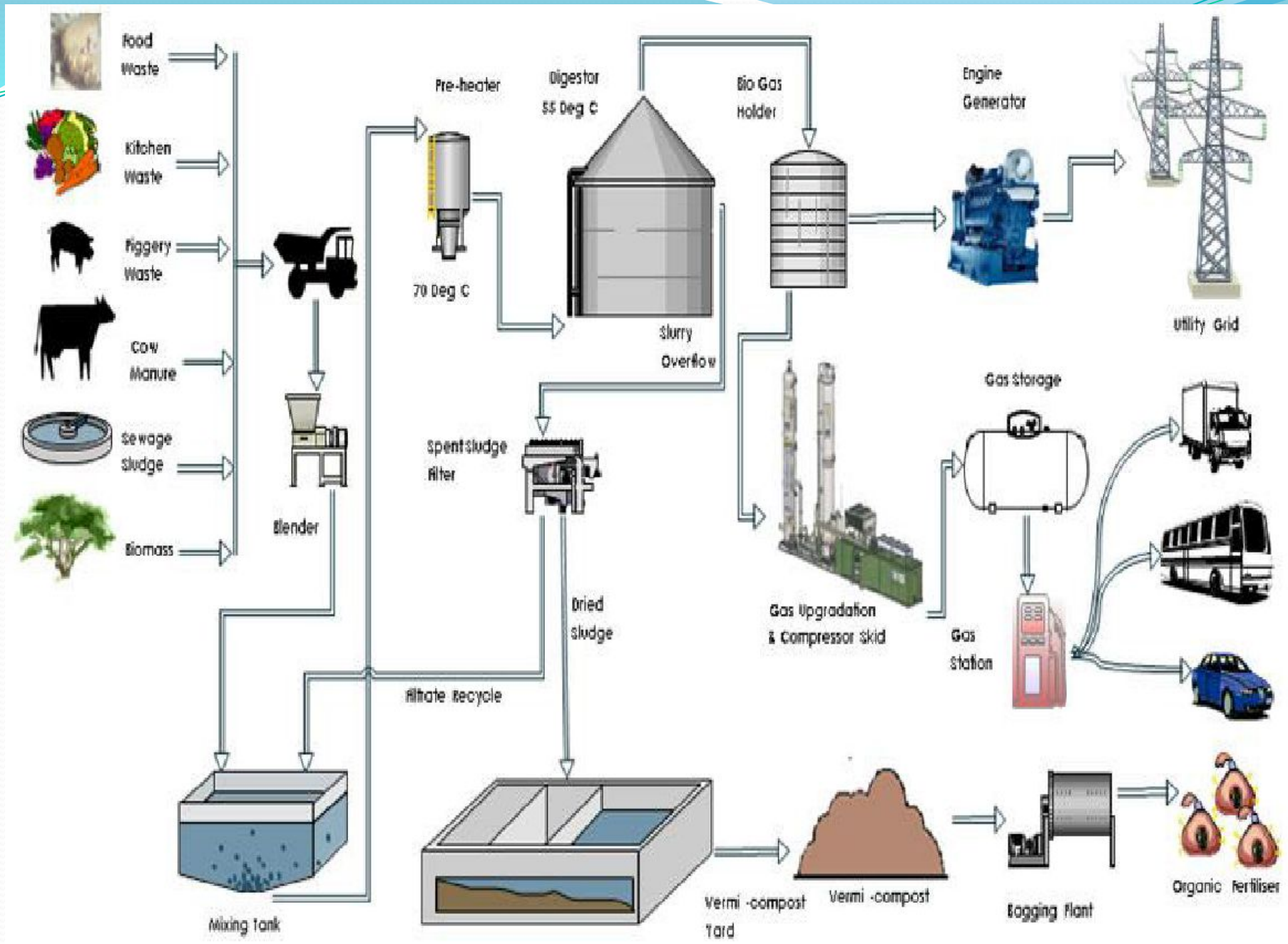
- Soil
- Plant growth
- Economic
- Environmental

Biomethanation/Biogasification

- Biomethanation is anaerobic digestion which converts organic materials into biogas, a gaseous combustible mixture, of methane (CH_4). Using this method, biodegradable municipal waste is biologically treated to recover nutrients and energy.
- Biomethanation consists of a chain of biochemical transformations as follows:

- First Stage: This consists of hydrolysis, acidification and liquefaction.
- Second Stage: In this stage Acetate, Hydrogen and Carbon di oxide are transformed into Methane.

- Thus the process results in biogas with high methane content (55-75%) which can be used as fuel.
- This process also gives manure as end product along with Biogas which is of better quality than that of composting technology.
- Biomethanation also produces organic slurry, which can be used as organic fertilizer.
- Biogas consists of Methane, Carbon di oxide (30-45%) and traces of Nitrogen, Oxygen, Hydrogen sulphide, Hydrocarbon, Ammonia, Water vapour and Siloxanes.
- The end product Biogas can also be converted into Bio methane by removing carbon di oxide from Biogas and used as transportation fuel or it can substitute natural gas even in industrial applications.
- About 1 cubic meter of Methane can produce 9,000 kilo calories of heat.
- In a cogeneration engine both heat and electricity can be produced from Methane gas.
- Biomethanation can be used to manage segregated organic wet waste from kitchen, hotels and markets.

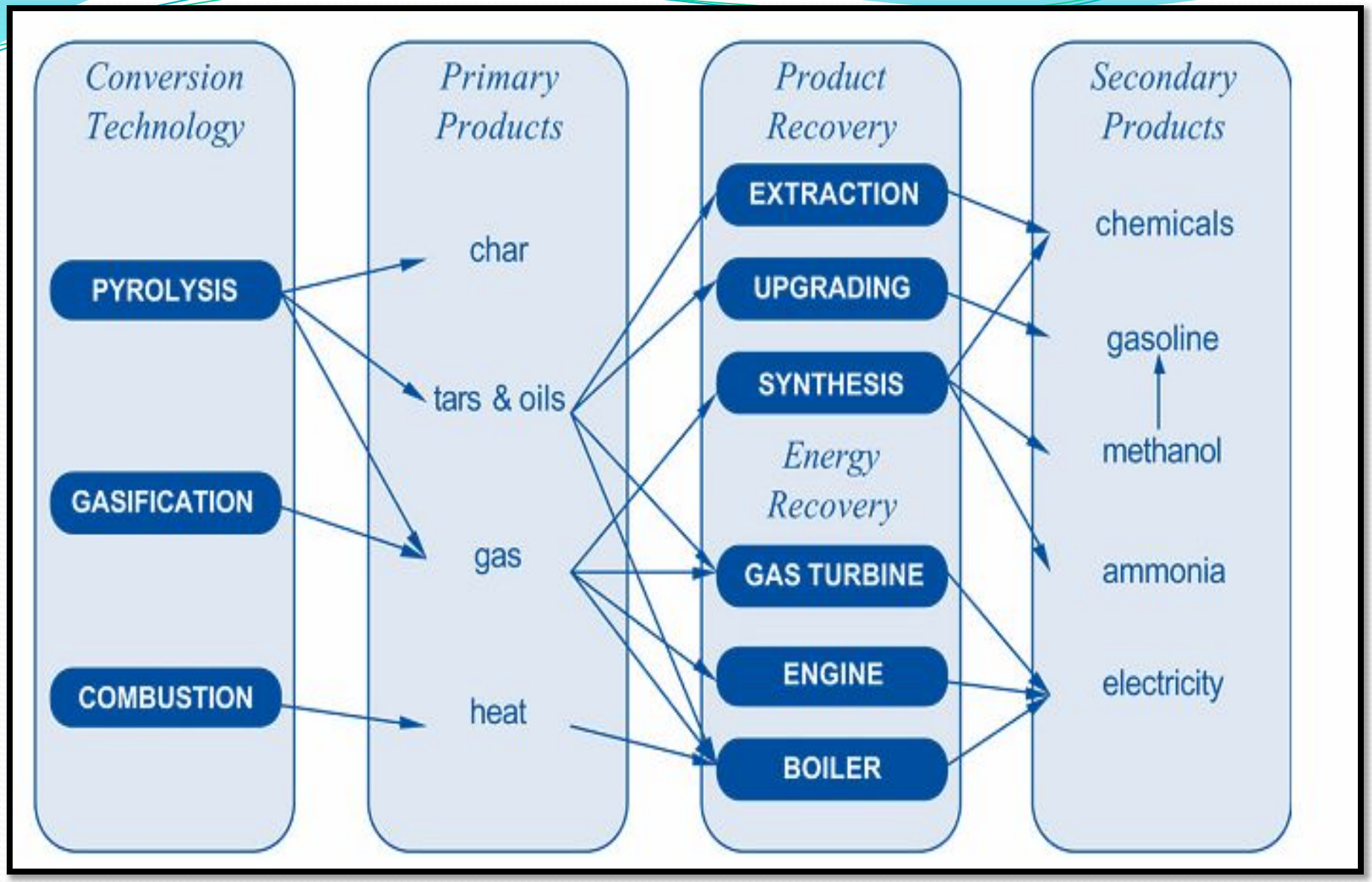

Food Waste
Kitchen Waste
Piggery Waste
Cow Manure
Sewage Sludge
Biomass
Blender
Pre-heater
70 Deg C
Digestor
55 Deg C
Slurry Overflow
Bio Gas Holder
Engine Generator
Utility Grid
Spent Sludge Filter
Dried Sludge
Filtrate Recycle
Gas Upgradation & Compressor Skid
Gas Storage
Gas Station
Mixing Tank
Vermi -compost Yard
Vermi -compost
Bagging Plant
Organic Fertiliser

Types of Thermal Processing

- **Gasification** is the partial combustion of materials, thus materials convert to combustible gases (such as carbon monoxide, hydrogen, and gaseous hydrocarbons).

- **Pyrolysis** can be defined as destructive distillation; materials are combusted with absence of oxygen.

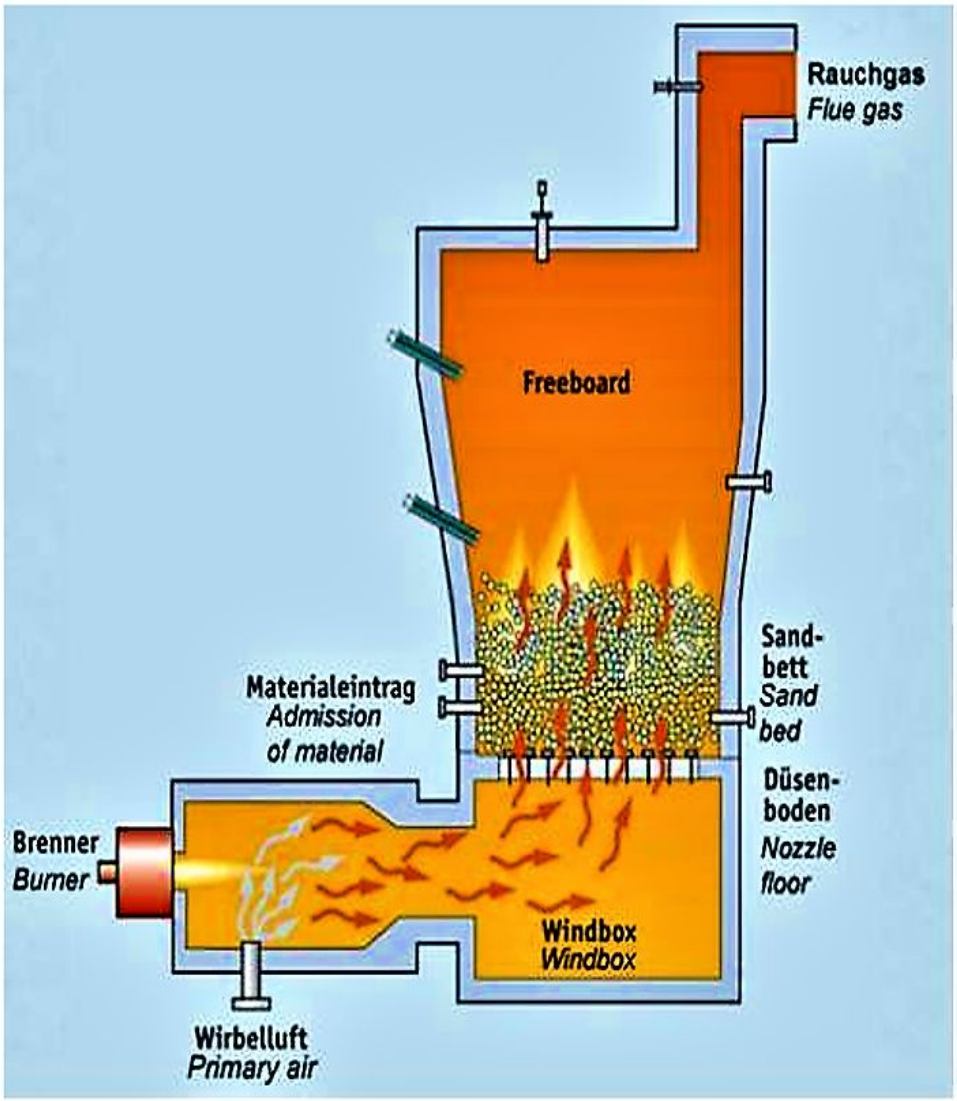
- **Incineration/Combustion** is a thermal processing in which complete combustion of waste occurs to recover heat which is used to produce steam, that is then used to produce power through the steam turbines.

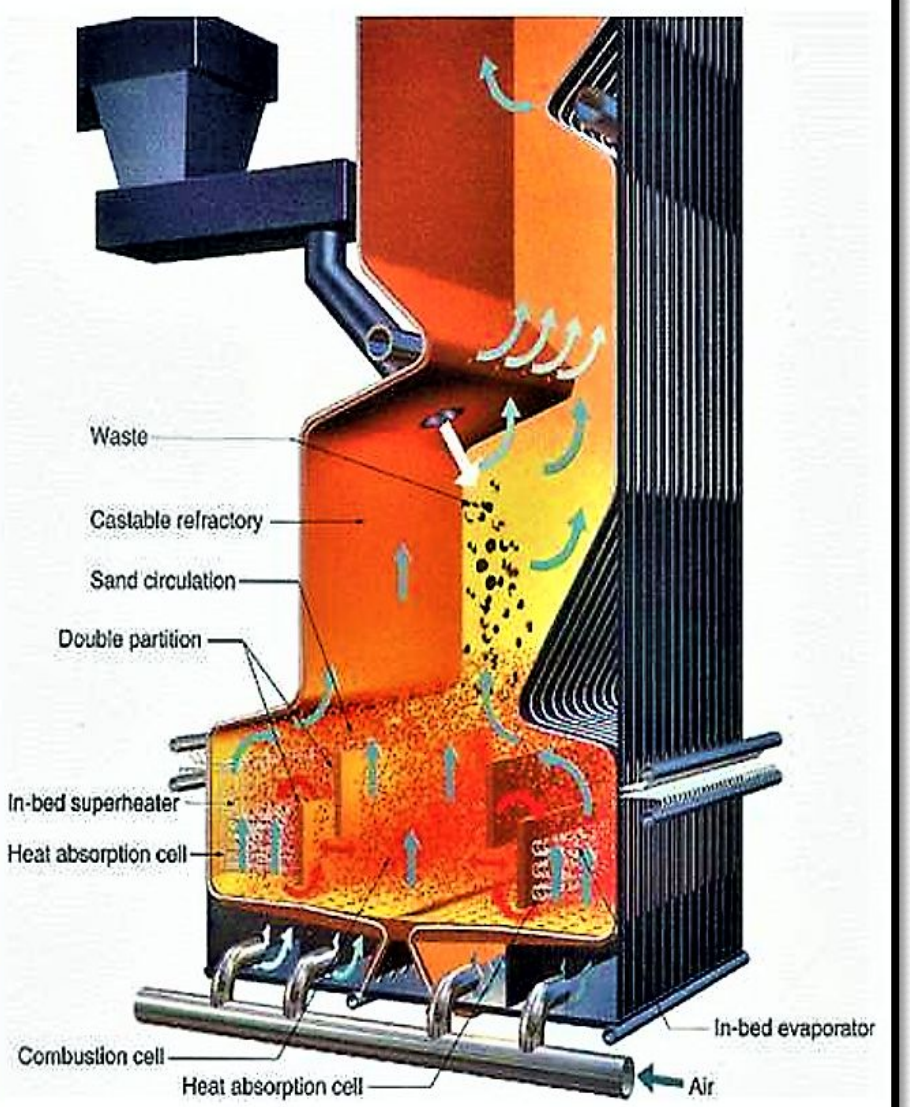

Conversion Technology
PYROLYSIS
GASIFICATION
COMBUSTION
Primary Products
char
tars & oils
gas
heat
Product Recovery
EXTRACTION
UPGRADING
SYNTHESIS
Energy Recovery
GAS TURBINE
ENGINE
BOILER
Secondary Products
chemicals
gasoline
methanol
ammonia
electricity

Incineration

- Waste is an unwanted material that is of no use to the owner and hence is disposed off in open area.
- Disposal onto the land or water body is not the solution as they create huge problem to the environment and health of the human beings. Moreover, the polluter pay principle of environmental protection act has forced the industries to treat the waste prior to disposal.
- Thermal treatment uses high temperature to degrade or destruct the waste. They are designed to thermally degrade the waste and recover energy in the form of heat or electricity.
- Its main purpose is to reduce the impact of residual waste on the environment.
- Incineration is a type of combustion where waste is oxidized at high temperature of 900 – 1200 ^{0}C to produce carbon dioxide, water and a residue ‘ash’.
- Though incineration reduces 90% of waste by volume, it generates huge amount of gaseous and particulate pollutants.

Incineration - process





Advantages

- Less requirement of landfills: Incineration reduces almost 95% of waste volume. The ash that is left out as residue is taken to landfills for disposal. The landfill space is reduced.

- Incineration can be carried out near the point of waste collection: Incinerators are compact units and hence can be set up at the source of waste generation or in transfer stations. They are can be used as decentralized systems.

- Substantial reduction of weight up to 75% and volume up to 90% of solid waste.

- Waste is reduced into biologically sterile ash product: High temperatures of 900-1100^{0}C kills pathogens and other harmful organisms present in the waste, thereby sterilizing them. The residue (i.e) ash left out after incineration is biologically sterile.

- Incineration process does not produce methane gas unlike landfill.

- Waste-to-energy (production of electricity and heat).Waste incineration can be a source of low cost energy to produce steam for electric power generation, industrial process heating or hot water for district heating thereby conserving primary fuel resource.

- The bottom ash residue is considered non-injurious and can be used for materials recovery or as secondary aggregates in construction.

- It is the best practicable environmental option for many hazardous wastes such as highly inflammable, volatile, toxic and infectious wastes.

Disadvantages

- Emissions from the incinerators
- High investment, operation and maintenance costs
- Also due to high capital investment, the incinerator must be tied to long term waste disposal contracts thereby limiting the choice of waste disposal options.
- An inorganic residue produced by the incineration process further needs safe and proper disposal.
- Loss of organic substances such as kitchen waste or green waste from gardening: When comingled wastes are incinerated, the organic or biodegradable substances that can be degraded by simple biological routes are lost. Organic substances can be recovered and used as fertilizer

- Incinerating plants are producers of heavy metals, which are injurious even in minor amounts.
- Although, modern incinerators comply with existing emission legislation, there is some public concern that the emitted levels may still have adverse effect on health
- The incineration is designed on the basis of a certain calorific value for the waste. Removal of materials such as paper and plastics for recycling may reduce the overall calorific value of the waste and consequently may affect the incinerators performance.
- Local communities have always opposed the presence of incinerating plant in the locality.
- Operation requires skilled operators

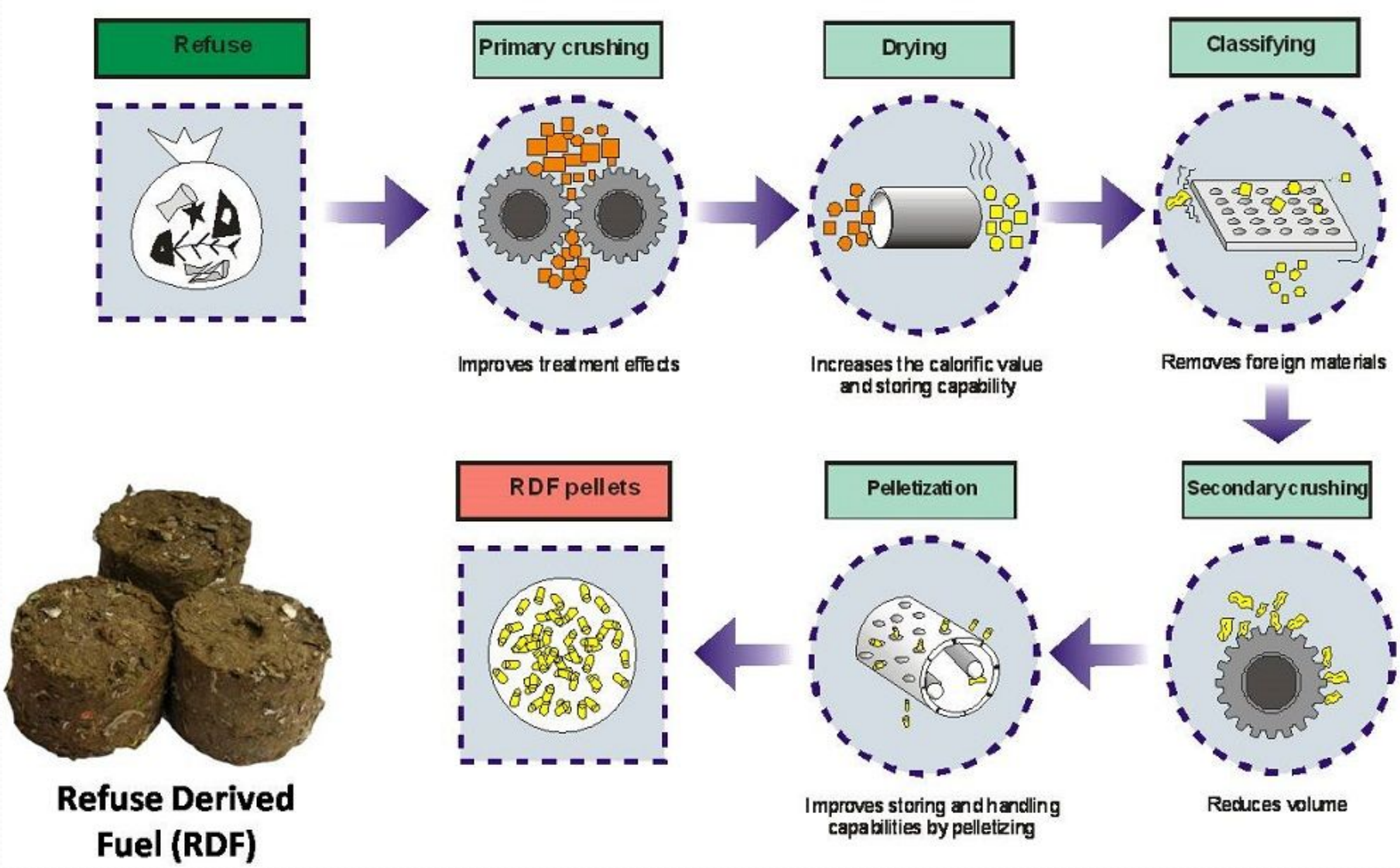
Application of Incineration

- In places where waste management is being practiced for a number of years.
- The municipal solid waste is disposed of in controlled or secured landfills.
- Stable supply of combustible waste is required. Large scale systems require minimum of at least 50,000 metric tons/year.
- Calorific value of waste is very important to achieve efficient incineration. Calorific value should at least be around 7 MJ/kg and should not be lower 6 MJ/kg.
- The community where the incinerators are installed should be willing to bear the cost tipping fees, and tax-based subsidies.
- Recruitment of skilled staff is required

Incineration system

- Mass burn incinerators
- Modular incinerators
- Fluidized bed incinerators
- Rotary kiln
- Starved air or pyrolytic kiln.
- Refuse derived

Refuse-derived fuel




BEFORE
AFTER

Starved air incinerators

- They are smaller than modular incinerators with capacity ranging from 5 to 100 tonns per day.
- In the pyrolytic chamber the waste is chemically decomposed by the action of heat in the inert atmosphere.
- During heating, a gas is generated which is when ignited becomes self-supporting in air.
- Carbon and hydrogen that is formed is sent to second combustion chamber where they are subjected to 200% excess air.
- Hydrogen and carbon monoxide is converted to carbon dioxide.
- During this process NOx is not formed. In the second chamber turbulence and mixing occurs due to gas that enters from the first chamber.

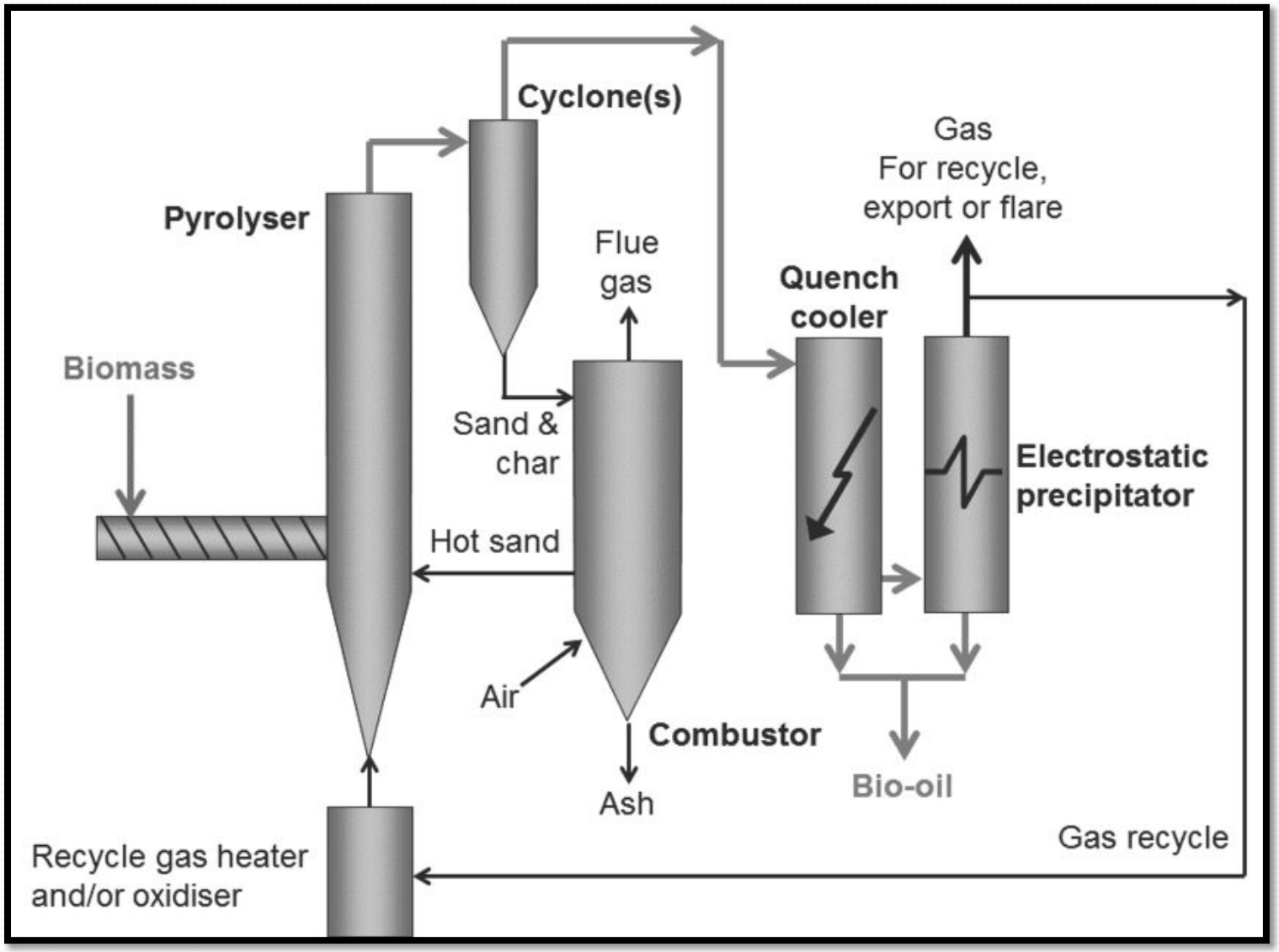
Advantages

- It is a controlled combustion process
- Low release of volatile organic compounds and carbon monoxide
- Release of low particulate matter in flue gas
- low combustion temperature in the primary chamber aids in pollution control by minimizing the vaporization of the metallic components of the waste
- Fast construction time
- Relatively low construction cost
- Flexibile

Disadvantages

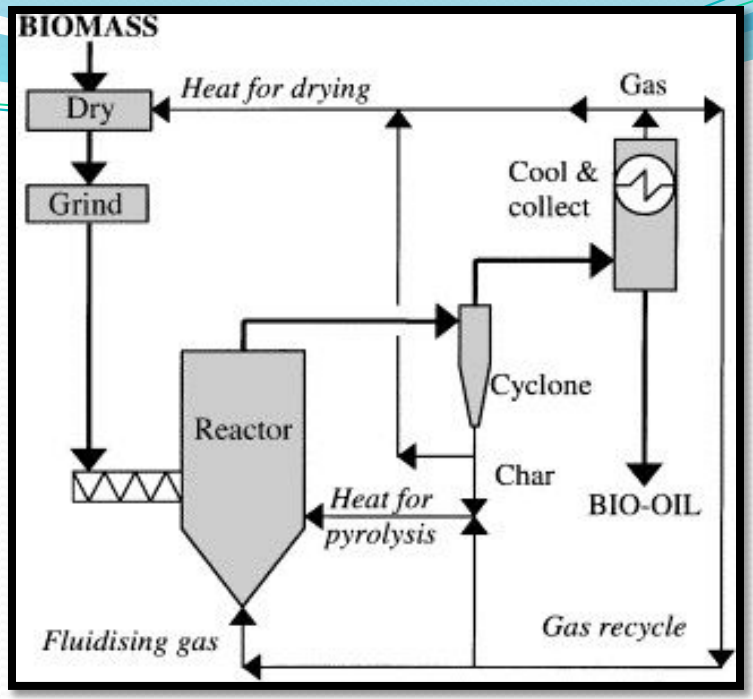
- Limited size
- Lower thermal efficiency
- Higher maintenance costs and
- Shorter equipment life

Pyrolysis


Cyclone(s)
Gas
For recycle,
export or flare
Pyrolyser
Flue
gas
Quench
cooler
Biomass
Sand &
char
Electrostatic
precipitator
Hot sand
Air
Combustor
Ash
Bio-oil
Gas recycle
Recycle gas heater
and/or oxidiser

Products of Pyrolysis

- Char
- Oil
- Gases



Types of Pyrolysis process

- Slow pyrolysis
- Fast/flash pyrolysis
- Vacuum pyrolysis

Types of pyrolysis reactors

- Fixed bed reactors
- Batch reactors
- Fluidized bed reactors
- Spouted bed reactor
- Rotary kiln reactor
- Microwave assisted reactors
- Plasma reactors
- Solar reactors

Advantages

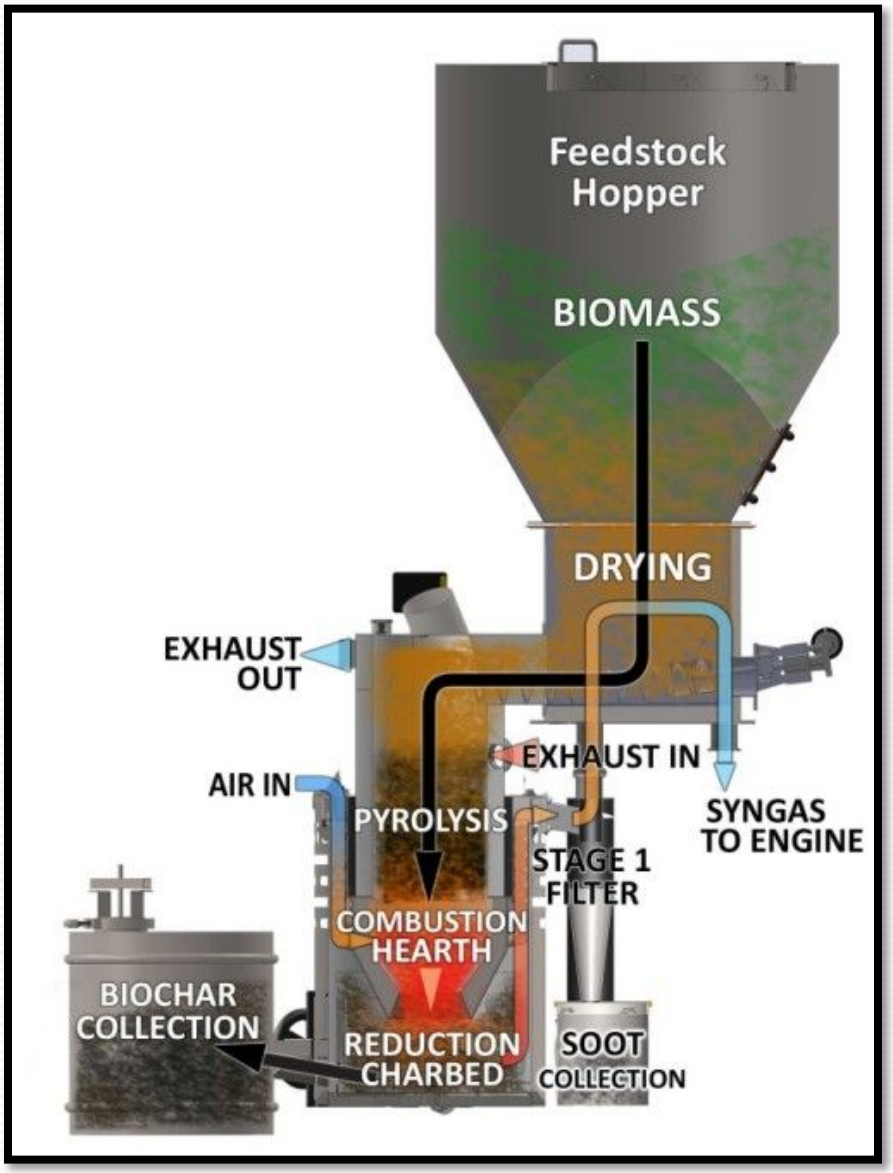
- It degrades the biodegradable wastes and plastics using high temperatures
- Energy is recovered as heat or electricity from waste. When compared to mass burning, energy and other value added products are recovered by advanced thermal treatment process, the pyrolysis.
- High temperature involved in pyrolysis kills the pathogens and other harmful organisms in the solid waste
- The water volume of the waste content is reduced
- The gas produced during the thermal degradation of waste is used as fuel. It minimizes the use of external fuel if the producer fuel is used for pyrolysis operation

- Biochar produced during pyrolysis can be used as a soil amendment or as activated carbon. Biochar sequesters carbon and increases the fertility of soil.
- The bio-oil can be combusted directly in boilers and engines
- It degrades the complex pollutants present in the solid waste
- It favours the recycling of mixed plastics, soiled plastics (agricultural plastics, mulch/silage/greenhouse films and dripper/irrigation tube), plastic laminates, packaging materials that are difficult to be treated by traditional recycling methods
- Minimizes the volume of waste and residual waste sent to the landfills
- Pyrolysis plants are flexible due to their modular nature. The number of pyrolysis units can be added or reduced according to the requirement. Moreover, these units are easy to be built.
- Pyrolysis units produce low air pollutant emission levels unlike incineration

Disadvantages

- Pyrolysis unit can be used only for residual waste, failing which it will undermine the advantages of recycling and composting.
- Feedstock of pyrolysis needs pre-treatment or pre-processing.
- High capital and operational cost as they are energy intensive
- Requires skilled operators for operating the units
- Air pollution control devices are required to control air emissions
- The ash generated during the thermal degradation might contains heavy metals and hence need safe disposal.

Gasification

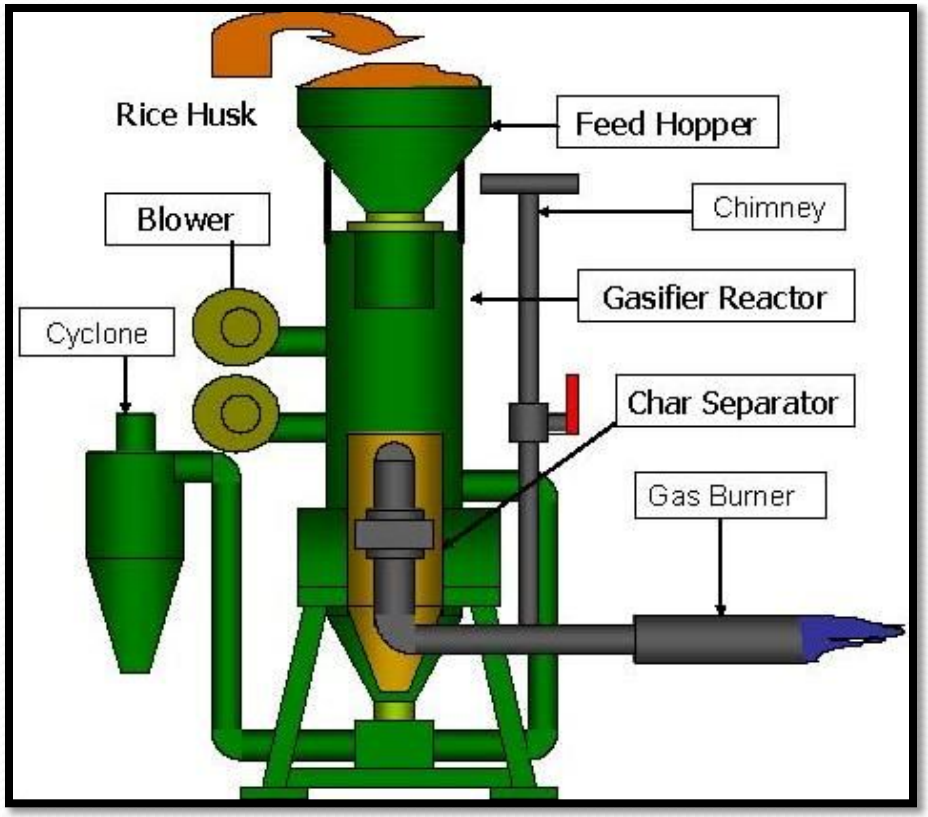


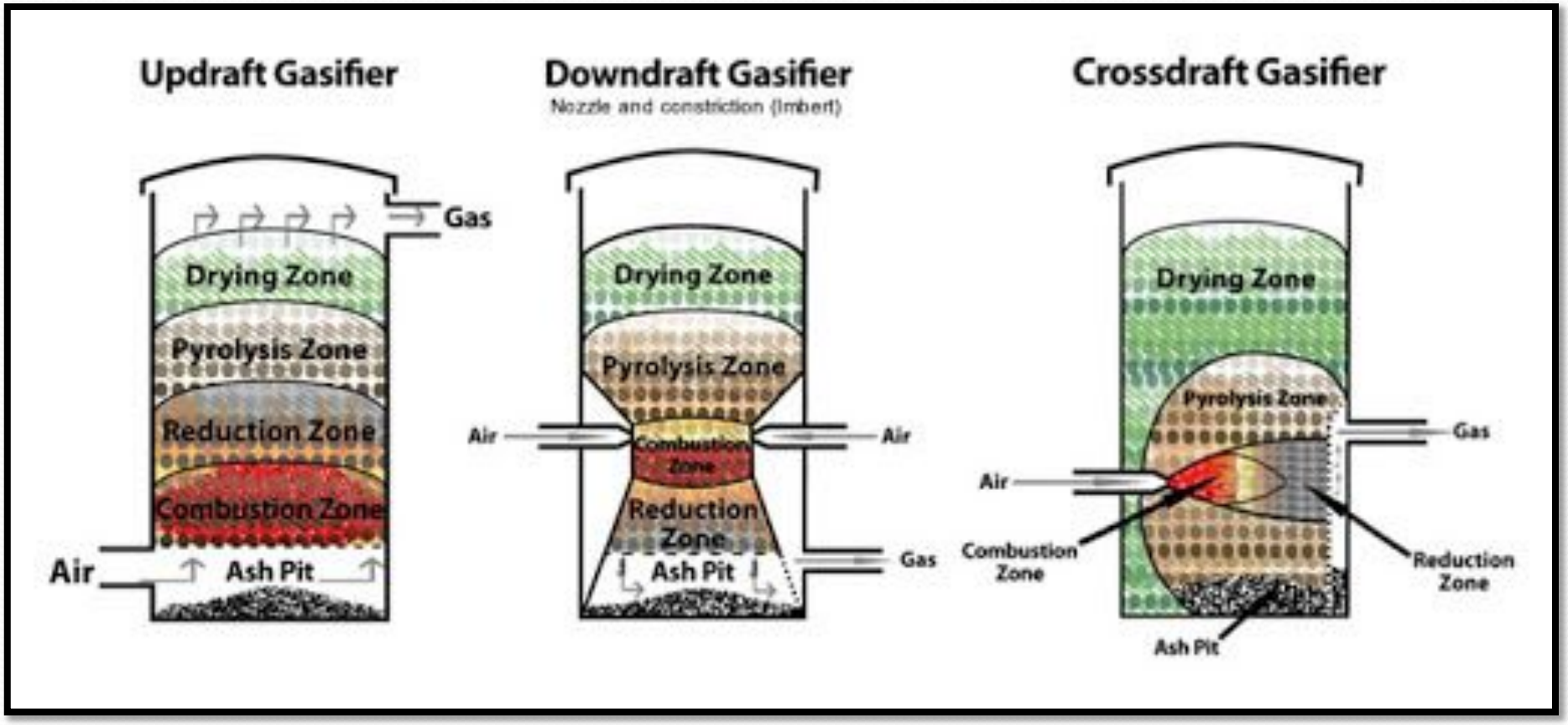
Types of Gasification

- Air Gasification
- Oxygen Gasification
- Steam Gasification
- Gasification with hydrogen
- Thermal depolymerization
- Plasma Gasification

Types of Gasifiers

- Fixed beds
  - Updraft gasifiers
  - Downdraft gasifiers
    - Slagging fixed bed gasifier
    - Fluidized bed gasifiers
    - Entrained flow gasifiers
    - Rotary kiln gasifiers




Updraft Gasifier
Gas
Drying Zone
Pyrolysis Zone
Reduction Zone
Combustion Zone
Air
Ash Pit
Downdraft Gasifier
Nozzle and constriction (Imbert)
Drying Zone
Pyrolysis Zone
Air
Air
Combustion Zone
Reduction Zone
Ash Pit
Gas
Crossdraft Gasifier
Drying Zone
Pyrolysis Zone
Gas
Air
Combustion Zone
Reduction Zone
Ash Pit

Advantages

- Requirement of landfill space is reduced
- Reduces the transportation cost of waste being taken to landfills
- Minimizes the methane emission from landfills during the decomposition of waste
- Reduces the risk of contamination of water bodies (surface and ground water)
- Syngas, a usable energy product is produced
- End product is a high commercial value fertilizers and chemicals
- Enhances existing recycling programs
- Reduces the use of fossil fuels

- Tar, a valuable product is produced
- The volume of the waste is reduced
- Plastics that cannot be recycled can be brunt in gasification process
- Low oxygen environment limits the formation of dioxins and large quantities of SOx and NOx.
- Requires small and less expensive gas cleaning equipment due to less gas production
- Lower gas volume also means a higher partial pressure of contaminants in the off-gas and hence favours complete adsorption and particulate capture

Disadvantages

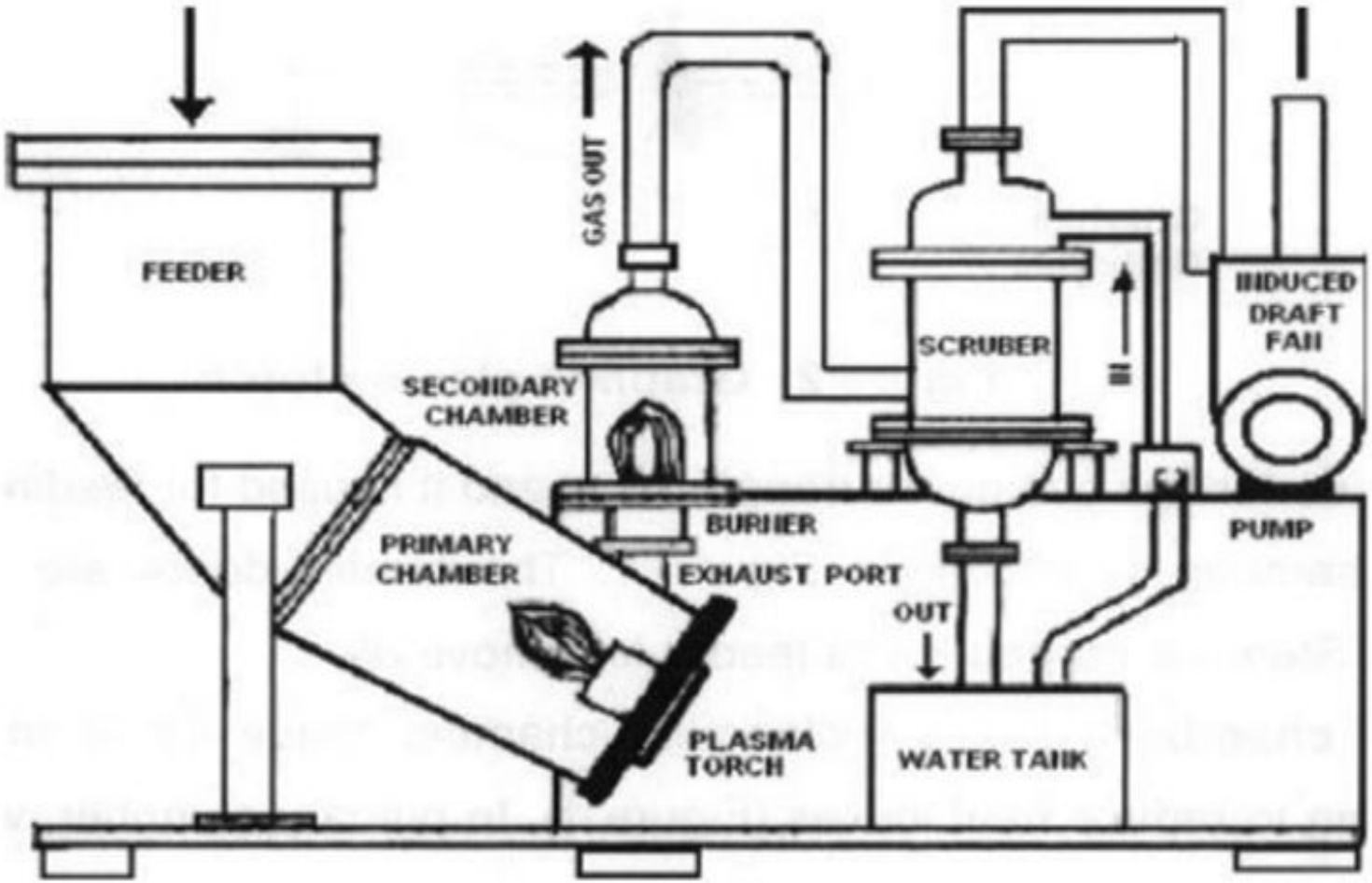
- The tars, heavy metals, halogens and alkaline compounds that are released in the gas often causes environmental and operational problems.
- Tar produced during the process is high molecular weight organic gases. It possesses potential to destroy the sulfur removal systems, ceramic filters etc. They also lead to formation of slag in the boilers and on the refractory surfaces of the gasifiers.
- Presence of alkalis in the waste might affect the turbines during combustion
- Likewise, halogens will corrode the walls of gasifiers and might lead to acid rain when emitted.

Incineration and Gasification

Incineration	Gasification
Incineration burns the waste at high temperature in the presence of excess air to produce carbon dioxide, heat and ash.	In gasification waste is not used as a fuel, it is used as a feed stock for thermochemical conversion. The process takes place in the limited supply of oxygen resulting in the production of syngas (carbon monoxide and hydrogen), tar and other high value commercial products namely transportation fuels, chemicals, fertilizers etc.
The plastics during incineration results in the generation of dioxins and furans. Formation and reformation of dioxins and furans occur in the incinerator. They end up in incinerator exhaust by following three pathways: • Decomposition of larger molecules to smaller ones • reformation of smaller particles to bigger ones • Remaining as such without undergoing any change	For the formation and reformation of dioxins and furans, oxygen is very essential which is not available in gasification. Hence dioxin formation is not possible in gasification. Moreover, at that temperature, the dioxins are broken down to syngas. Also the clean up of syngas removes the metal particulates and hence dioxin reformation becomes impossible.

Incineration	Gasification
The heat is used to make steam and in turn generate electricity.	Syngas that is produced during the process is cleaned before use. The cleaned gas can be used for electricity generation, hydrogen production, transportation fuels. Certain chemicals and fertilizers are also produced during the process.
Ash produced during incineration needs safe disposal in landfills. They are also considered safe for using it as a cover material in landfills	Emission control devices are required for particulate and gaseous pollutant removal
Emission control devices are required for particulate and gaseous pollutant removal	Devices are used to remove tar from the gas.

PLASMA PYROLYSIS



Components

- Plasma torch & power supply
- Feeder
- Primary chamber
- Secondary chamber
- Scrubbers
- Induced draft fan and chimney

ADVANTAGES OF PLASMA PYROLYSIS

- The process conditions are maintained such that it eliminates the possibility of formation of toxic dioxins and furans molecules (in case of chlorinated waste).
- The conversion of organic waste into non toxic gases (CO_2, H_2O) is more than 99%.
- The extreme conditions of plasma kill stable bacteria such as bacillus stereo-thermophilus and bacillus subtilis immediately.
- There are no liquid industrial effluents and no floor washings as it is a dry process.
- Segregation of the waste is not necessary, as the very high temperatures ensure treatment of all types of waste without discrimination.
- Plasma can provide permanent treatment for difficult contaminants and waste.
- Plasma has the potential for significant reductions in the cost and the time required for treatment of municipal and industrial wastes.

DISADVANTAGES OF PLASMA PYROLYSIS

- Large initial investment costs, relative to that of alternatives, including landfill and incineration.
- Operational costs are high relative to that of incineration.
- Little or even negative net energy production.
- Wet feed stock results in less syngas production and higher energy consumption.
- Frequent maintenance and limited plant availability.
- For some technologies, the plasma torch plume requires reduced diameter of the sampler orifice over time, necessitating frequent maintenance.