# ENERGY FROM MUNICIPAL SOLID WASTE (MSW)

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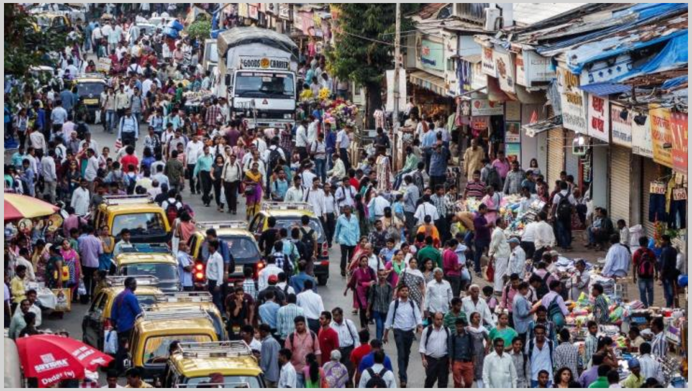
# INTRODUCTION

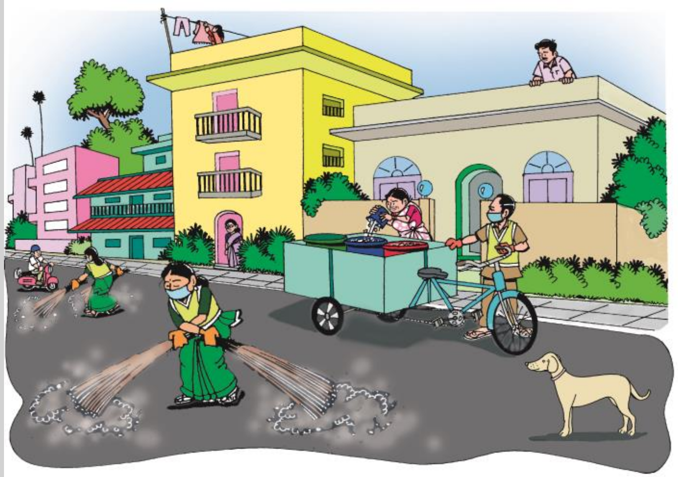
- The population of urban India is 336 million as per 2011 census, which accounts for 27.8% of the total population.
- Global experience shows that when a country's urban population reaches almost 25% of the overall population, the pace of urbanization accelerates.
- With the rapid urbanization and uncontrolled growth of population, solid waste generation and management has become a major social and environmental issue.
- Municipal bodies in India provide solid waste management services. Though it is an essential service, but is given low priority due to lack of financial resources, institutional weaknesses, improper choice of technology and public apathy towards MSW.



- The current practices of the uncontrolled dumping of waste on the outskirts of towns and cities have created a serious environmental and public health problem.
- Since the global energy crisis of the 1970s, there has been a trend towards use of alternative energy sources to replace fossil fuel worldwide.
- The fuel potential of many wastes is a valuable resource and considerable interest has been devoted to it recently to exploit its potential. However, it has been found out that the energy content that could be practically recovered from the wastes would be a small percentage of the total energy required in any nation. This suggests that energy recovery from wastes will only serve as a supplement to the total energy required.

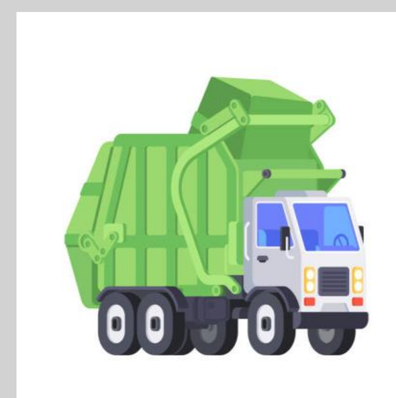





SCHOOL


Om
Go Green
Waste
Management



# DEFINITIONS OF WASTE

- ***Waste*** is defined as any unwanted material intentionally thrown away for disposal. However, certain wastes may eventually become resources valuable to others once they are removed from the waste stream.
- The ***domestic waste*** (also known as *rubbish*, *garbage*, *trash*, or *junk*) is unwanted or undesired material generated by the normal activities of households including, but not limited to, food wastes, food packaging, glass bottles, plastics, clothing, newspapers and magazines.
- ***Industrial waste*** is a type of waste produced by industrial factories, mills, and mines. Toxic waste and chemical waste are two specific designations of industrial waste.
- ***Electronic waste (e-waste)*** is a waste type consisting of electronic products that were used for data processing, telecommunications, or entertainment in private households and businesses that are now considered obsolete, broken, or irreparable. E-waste includes computers, entertainment electronics, mobile phones, and other items discarded by their users.

- Knowledge of the sources and types of waste in an area is required in order to design and operate appropriate solid waste management systems.
- There are eight major classifications of solid waste generators: residential, industrial, commercial, institutional, construction and demolition, municipal services, process, and agricultural (Table 1).
- The boundaries of MSW are not yet clear. The term is normally assumed to include all of the wastes generated in a community with the exception of solid wastes from industrial processes and agriculture.
- In India, Korea, Turkey, Taiwan, and Japan, MSW includes part of the waste from industrial sources, depending on waste types.
- In Hong Kong, industrial waste is officially included in MSW.

| Table 1: Sources and Types of Solid Wastes | | |
|---|---|---|
| **Source** | **Typical waste generators** | **Types of solid wastes** |
| Residential | Single and multifamily dwellings | Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, consumer electronics, batteries, tires, and household hazardous wastes |
| Industrial | Light and heavy manufacturing, fabrication, construction sites, power and chemical plants | Housekeeping wastes, packaging food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes |
| Commercial | Stores, hotels, restaurants, markets, office buildings, etc. | Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes |
| Institutional | Schools, hospitals, prisons, government centers | Same as commercial |

| Table 1: Sources and Types of Solid Wastes (Contd.) | | |
|---|---|---|
| **Source** | **Typical waste generators** | **Types of solid wastes** |
| Construction and demolition | New construction sites, road repair, renovation sites, demolition of buildings | Wood, steel, concrete, dirt, etc. |
| Municipal services | Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants | Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge |
| Process | Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing | Industrial process wastes, scrap materials, off-specification products, slag, tailings |
| Agriculture | Crops, orchards, vineyards, dairies, feedlots, farms | Spoiled food wastes, agricultural wastes, hazardous wastes (*e.g.* pesticides) |

# WASTE GENERATION

- There has been a significant increase in the generation of MSW in India over the last few decades.
- The national level data do not exist for MSW generation, collection and disposal due to lack of a nation wide inventory, the growth of solid waste generation over the years can be studied for a few selected urban centres.
- In its 2009-10 Annual Report the Ministry of New and Renewable Energy (MNRE) has estimated that approximately 55 million tonnes of MSW are generated in urban areas of India annually which are estimated to increase at a rate of approximately 1-1.33% annually.
- This increase along with the population increase has tremendously swollen up the figures of total waste generation quantum **(Table 2)** adding to the problems of local municipalities, responsible for managing it.
- In general, the daily per capita generation of MSW in our country ranges from about 100 gm in small towns to 500 gm in large towns.

| Table 2: Waste Generation Statistics | | |
|---|---|---|
| **Year** | **gm / capita / day** | **Total urban municipal waste (million tonnes / year)** |
| 1971 | 374 | 14.9 |
| 1981 | 432 | 25.1 |
| 1991 | 460 | 43.5 |
| 1997 | 490 | 48.1 |
| 2047 (expected) | 945 | 300 |

- The quantity of waste generated in India and other developing countries is still much less than that generated by developed countries.
- However, it should also be noted that not all MSW is counted due to the activities of the informal sector and self-disposal in developing countries.
- The informal sector plays important roles in collecting recyclable materials in developing countries such as India, China, the Philippines, and Turkey.
- It is difficult to know the amounts of materials collected and recycled by the informal sector, and how much is thus absent from official waste composition data; it is simply assumed that the overall volumes collected by the informal sector are about 10-15% in China and 15-20% in India.
- However, the fact that the volume of waste collected by the informal sector is not usually counted in official statistics for waste generation is often overlooked.

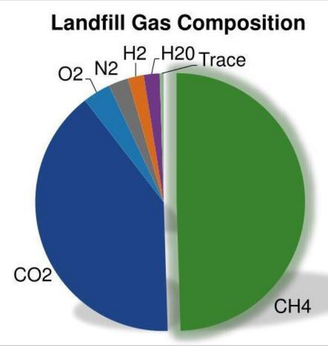
# MSW CHARACTERISTICS

- Characteristics of MSW collected from any area depends on factors such as food habits, cultural traditions of inhabitants, lifestyles, climate, etc.
- **Table 3** presents the changes in the relative share of different constituents of waste over a period of three decades.
- The organic matter percentage has remained almost static at 41%, but the recyclables have increased from 9.56% to 17.18%.
- The increased consumption of recyclable waste can be largely attributed to changing lifestyles and increasing consumerism.
- Amongst various recyclables, plastics have had a quantum jump from 0.69% to 3.9%, more than a five fold increase within twenty years.
- Plastics due to their unique properties of flexibility, high impact strength, resistance to corrosion, rigidity have replaced the valuable resources like wood and metals.
- As the use of convenience foods and packaging grows, the composition of waste tends to change in the direction of higher heating values, and hence becomes more suitable for energy recovery.

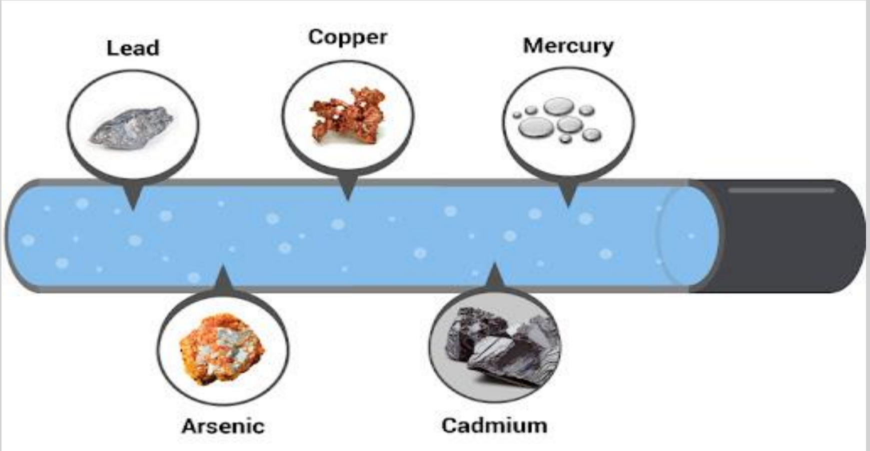
| Table 3: Physico-chemical Characteristics of Wet MSW ... | | |
|---|---|---|
| **Component** | **1971-1973 (40 cities)** | **1995 (23 cities)** |
| Paper | 4.14 | 5.78 |
| Plastics | 0.69 | 3.90 |
| Metals | 0.50 | 1.90 |
| Glass | 0.40 | 2.10 |
| Rags | 3.83 | 3.50 |
| Ash and fine earth | 49.20 | 40.30 |
| Total compostable matter | 41.24 | 41.80 |
| Calorific value (kcal/kg) | 800-1100 | < 1500 |
| Carbon-nitrogen ratio | 20-30 | 25-40 |

# DISPOSAL OF MUNICIPAL SOLID WASTE

- The disposal of MSW has been a problem ever since mankind ceased roaming the earth in search of food, and settled in small communities.
- The domestic waste of these primitive folk was dumped around their mud huts, thus providing nourishment for domestic animals.
- MSW is mostly collected by the municipalities and transported to disposal sites, which are normally the low lying areas on the outskirts of the city.
- The open dumping of the waste affects the surrounding ecosystem.
- It results in bad odor, bacteria growth, and the slow release of landfill gas.
- Landfill gas (50–60% $CH_4$) contributes significantly to global warming.
- The waste is left unattended at the disposal site; it attracts birds, rodents, fleas, and other pests to the waste.




- The plastic content is picked up by rag pickers for recycling either at primary collection centers or at disposal sites.
- Plastics are recycled mostly in factories operating without adequate technologies to process them in a safe manner. This exposes the workers to toxic fumes and unhygienic conditions.
- The rag picking is a non-formalized kind of work, so all the recyclables, particularly polyethylene bags, do not get collected and many are found littered everywhere, ultimately reaching the drains and water bodies to choke them.
- In addition, there is a risk of rainwater penetrating and leaching soluble heavy metal salts into the subterranean water supply, thus representing a potential and unseen health hazard.



- Around 48 million tonnes of solid waste was generated in 1997 and it is expected to increase to 300 million tonnes per annum by 2047.
- The estimated requirement of land for disposal would be 169.6 $km^2$ in 2047 as against 20.2 $km^2$ in 1997.
- The availability of landfill sites suitable for meeting environment, legislative requirements or political acceptability is declining, and the cost of landfilling is increasing, so that landfill is no longer the cheap disposal option for MSW as it once was.
- The choice of a disposal site is more a matter of what is available than what is suitable.
- Attention has been focused now on alternative techniques directed toward ..
    a) minimizing the amount of waste material to be landfilled,
    b) ensuring that the remaining landfilled material will be as environmentally acceptable as it can be; and
    c) extracting some useful component of the MSW that can be economically employed, offsetting partly the cost of disposal.

# ENERGY FROM WASTE

- Combustion with energy recovery is a logical choice when landfill space is either very limited or nonexistent.
- Combustion can achieve a waste reduction of as much as 95% by volume and 75% by weight, and it will usually be in the form of biologically inert inorganic ash or fines.
- In several countries, the waste to energy option is the major means for the disposal of municipal waste.
- Japan burns about 75%, Switzerland burns about 60%, and France and Germany each burn approximately 40% of their waste.
- Energy from municipal waste can be extracted by a variety of thermal routes, viz. incineration, pyrolysis, gasification, etc.



# INCINERATION OF MUNICIPAL SOLID WASTE

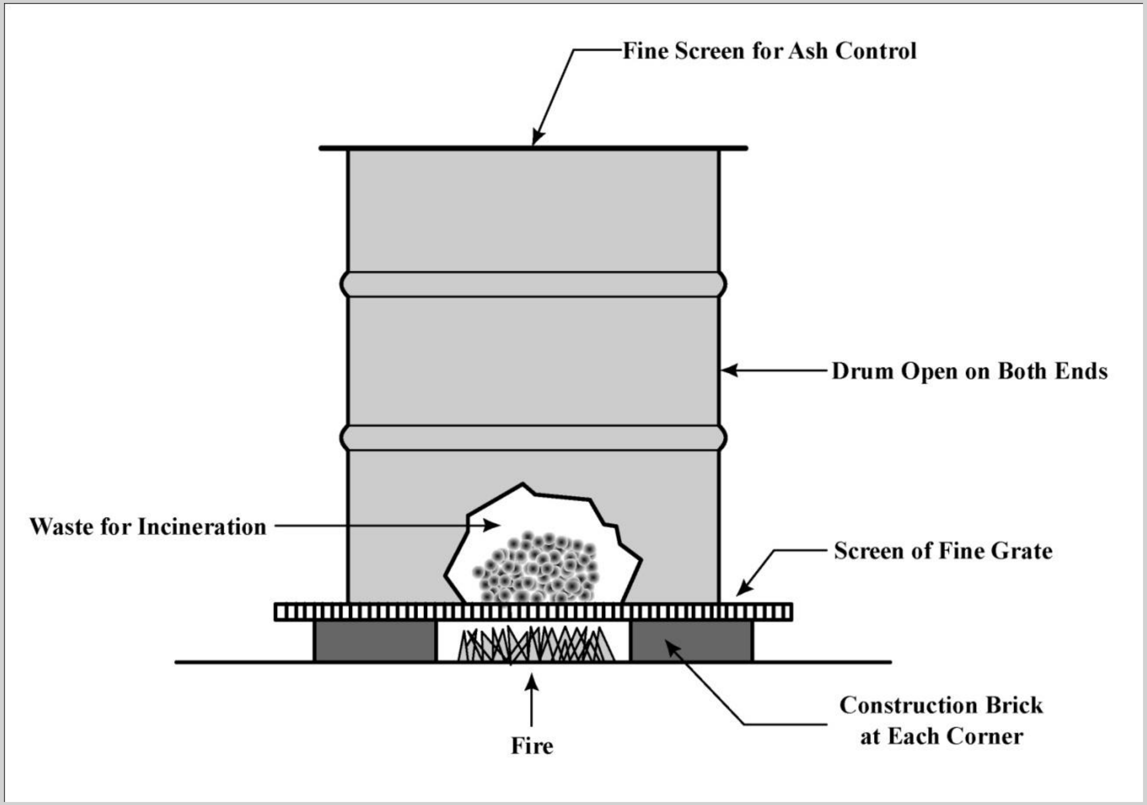
- Incineration has long been applied as a thermal destruction method to a wide variety of wastes, such as household wastes (often referred to as municipal wastes), industrial wastes, medical wastes, sewage, and the hazardous wastes generated by industry.
- The major benefit of incineration is that the process actually destroys most of the waste rather than just disposing of or storing it.
- Modern incineration systems use high temperatures, controlled air, and excellent mixing to change the chemical, physical, or biological character or composition of waste materials.
- The new systems are equipped with state-of-the-art air pollution control devices to capture particulate and gaseous emission contaminates.

# TYPES OF INCINERATORS

- There are many different types of incinerator plant designs:
  a) simple fixed grate
  b) moving grate
  c) rotary-kiln
  d) fluidized bed
- The type of incinerator and the choice of combustion chamber depend on the characteristics of the waste that needs to be incinerated, the quantity of waste needed to burn per hour, and the specific needs of the plant (if any).
- The waste can be specified by its calorific value, Chlorine content, density, and homogenicity.
- The rotary-kiln incinerator is the most widely used type in industrial applications due to its ability to effectively burn different types of waste and the rotating nature of the kiln that helps in even and complete combustion of all waste.

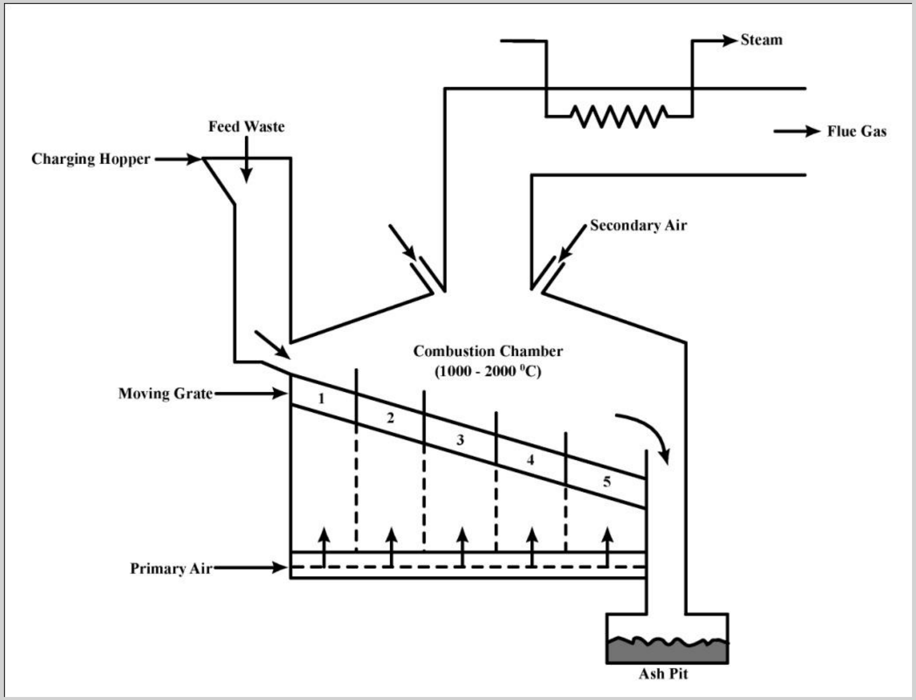
# Simple fixed grate incinerator

- This is an old and basic model that consists of a brick-lined cell with a fixed metal grate over a lower ash pit, with one opening at the top or side opening for loading of the waste material and another opening at the side for removing incombustible solids called clinkers.

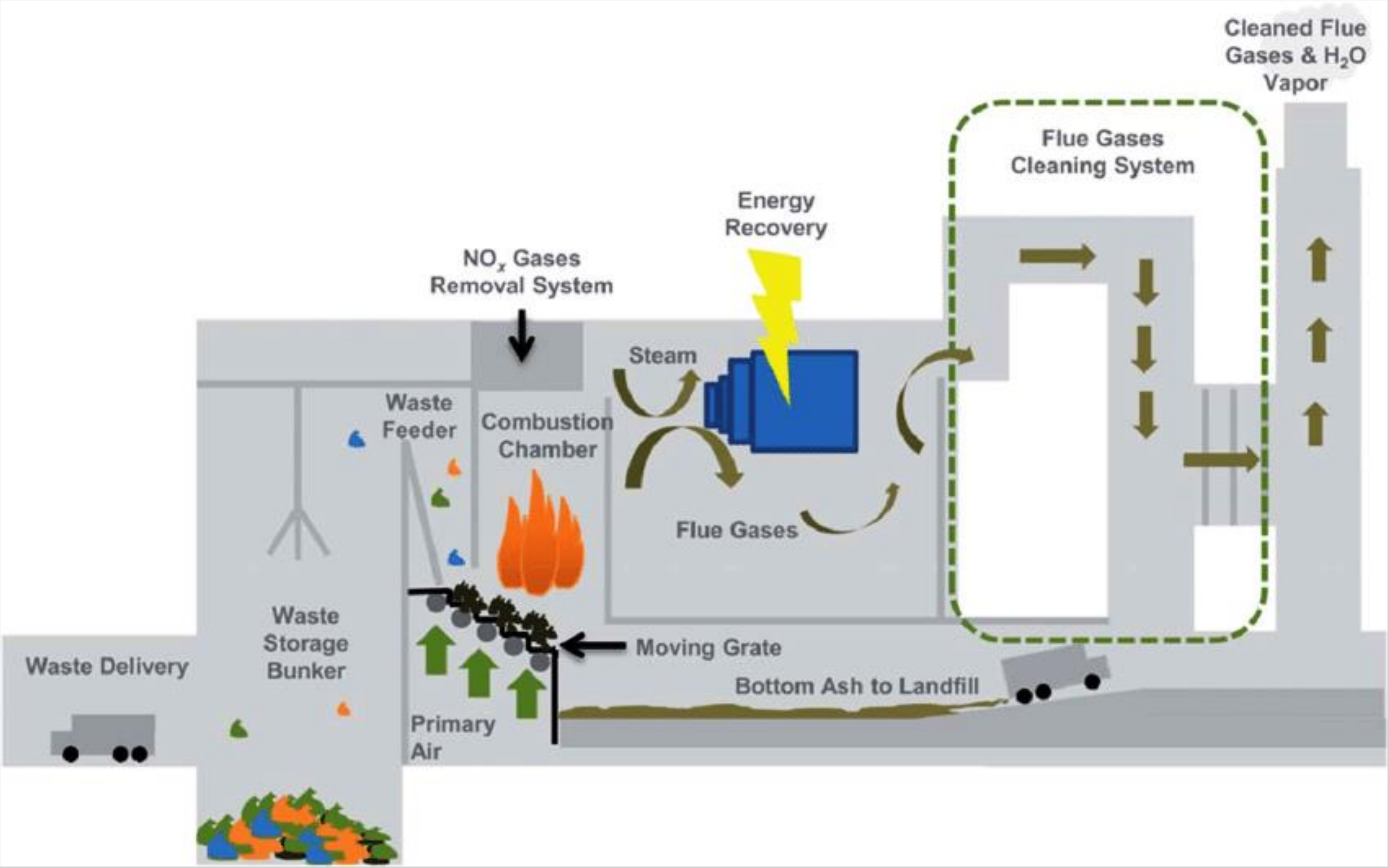


# Moving grate incinerator

- A moving grate incinerator is typically designed for thermal destruction of MSW, thus they are sometimes referred to as MSW Incinerators.
- The moving grate enables the movement of waste through the combustion chamber to allow more efficient and complete combustion.



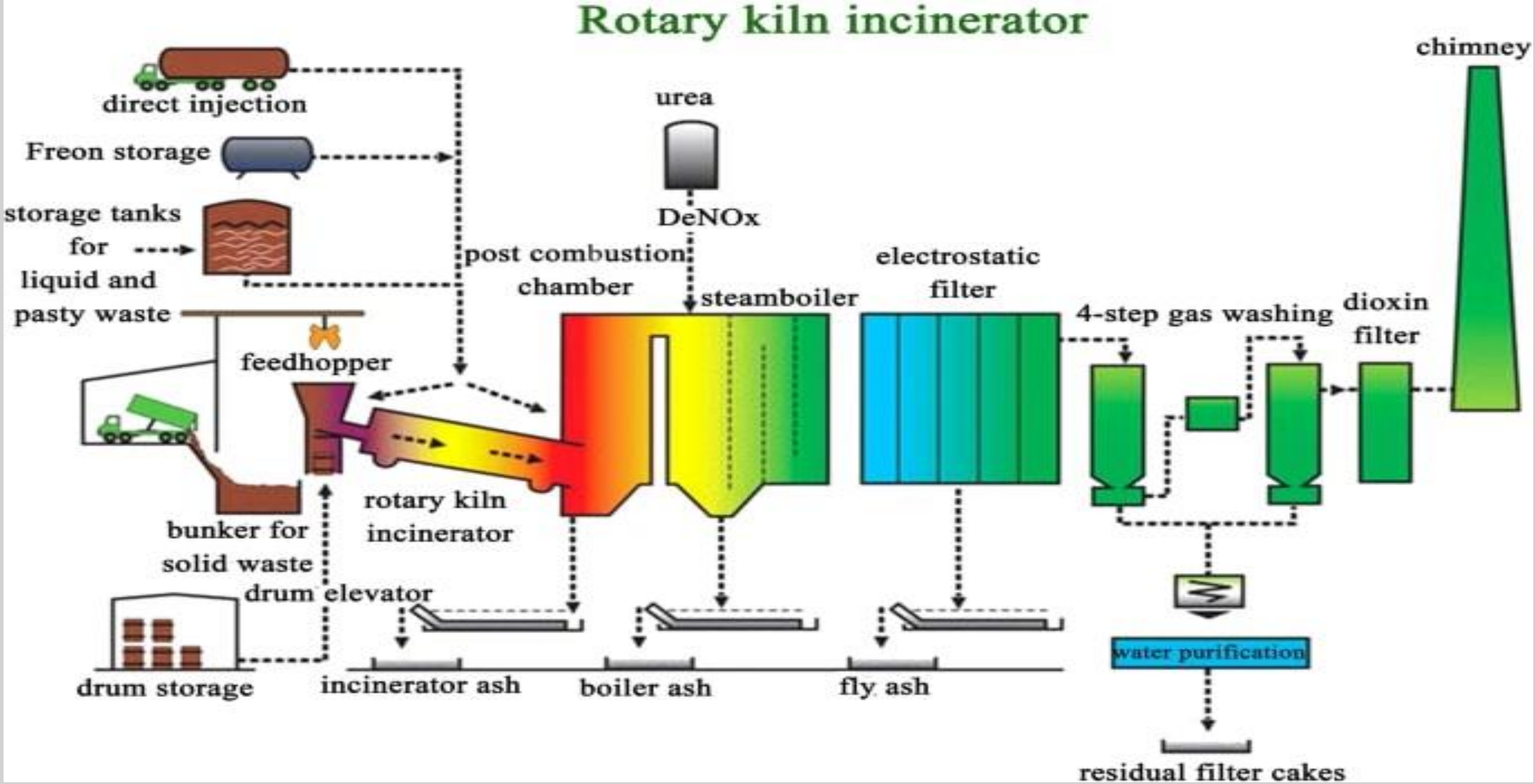

- A single moving grate boiler can handle up to 35 metric tons/hr of waste and can operate 8,000 hr/year with single stop for inspection and maintenance of about one month duration.

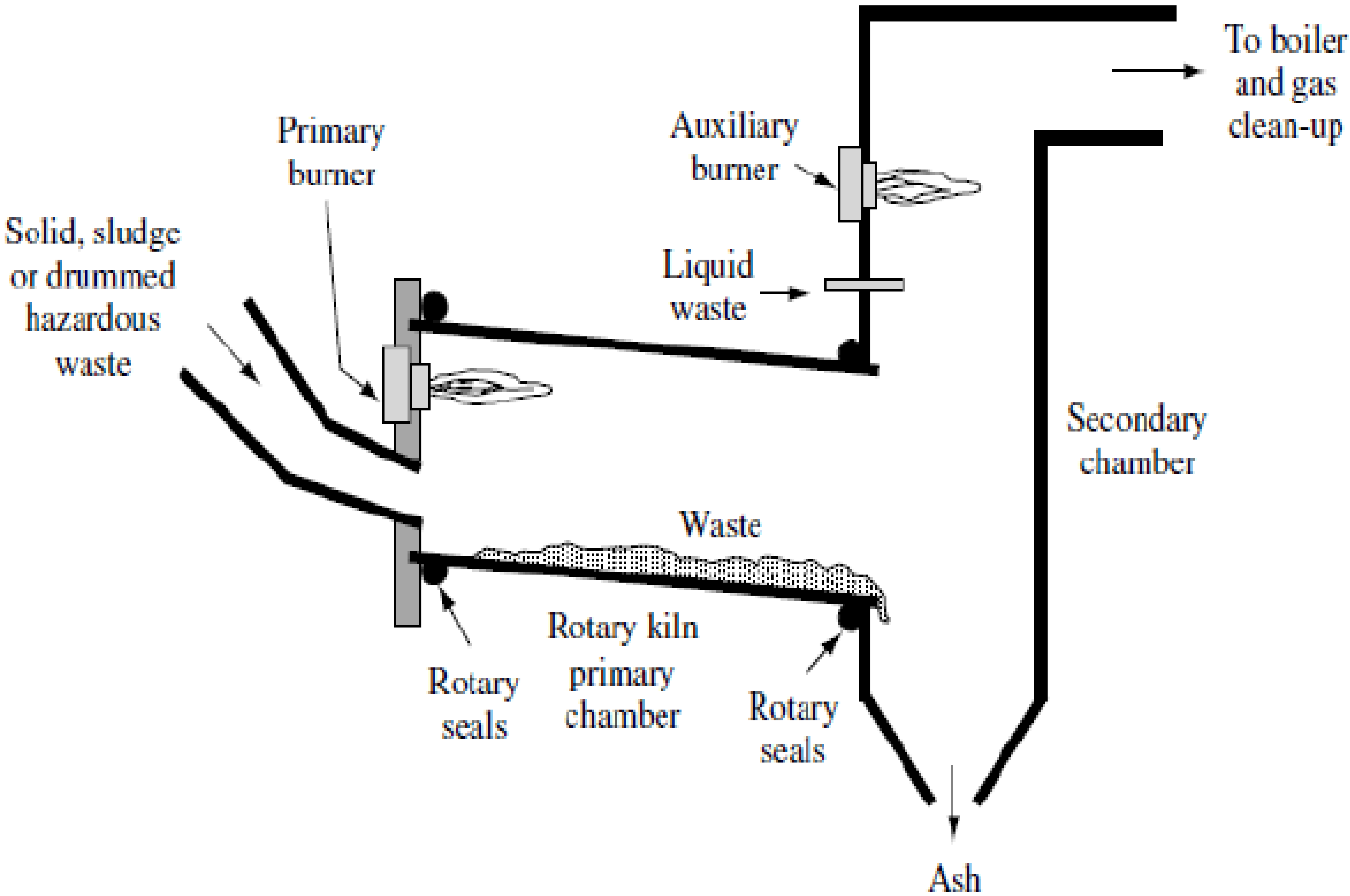

Cleaned Flue Gases & $H_2O$ Vapor
Flue Gases Cleaning System
Energy Recovery
$NO_x$ Gases Removal System
Steam
Waste Feeder
Combustion Chamber
Flue Gases
Waste Storage Bunker
Waste Delivery
Moving Grate
Bottom Ash to Landfill
Primary Air

- Feed waste is introduced by a crane through the "throat" at one end of the grate, from where it moves down over the descending grate to the ash pit at other end.
- Primary combustion air is supplied through the grate from below. This air flow has the additional purpose of cooling the grate itself.
- Cooling is important for the mechanical strength of the grate. Several moving grates are water cooled internally.
- Secondary combustion air is supplied into the boiler at high speed through nozzles over the grate. It facilitates complete combustion of flue gases by introducing turbulence for better mixing and by ensuring surplus oxygen.
- Incinerator must be designed to ensure that the flue gases reach the temperatures of 800-1000°C for 2-3 seconds with 40-60% excess air to ensure proper breakdown of toxic organic substances.
- It requires oil fueled backup auxiliary burners, in case the heating value of the waste becomes too low to reach this temperature alone.
- The flue gases are then cooled by heat transfer and heat the steam to typically 400°C at a pressure of 40 bars for electricity generation in the turbine.
- At this point, the flue gas has a temperature of around 200°C, and is passed to the flue gas cleaning system.

# Rotary-kiln incinerator

- Rotary-kiln incinerators are used to destroy solid as well as liquid wastes generated by municipalities and industrial plants.
- A rotary-kiln incinerator consists of a primary and a secondary combustion chamber.

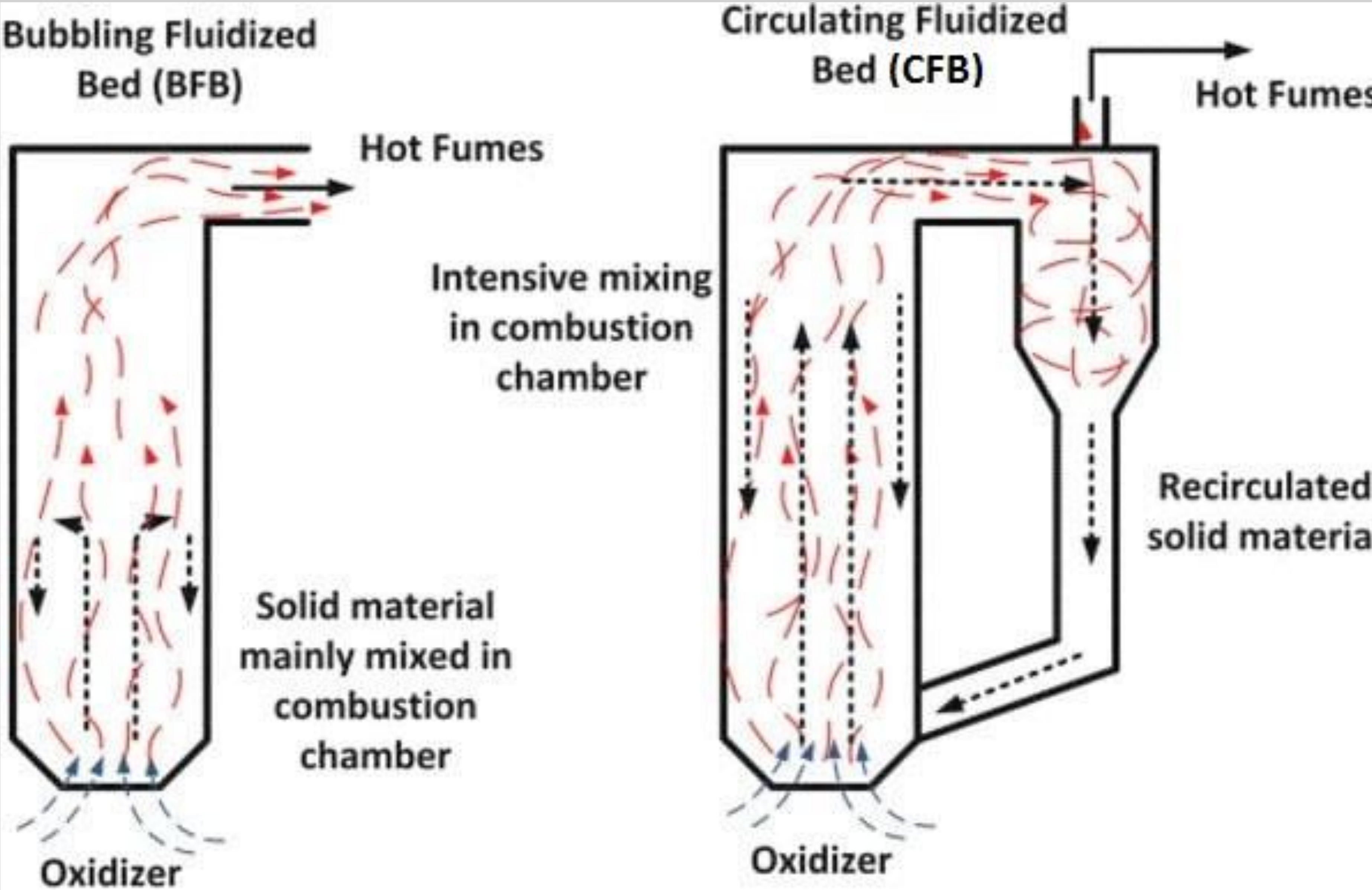



To boiler and gas clean-up
Primary burner
Auxiliary burner
Solid, sludge or drummed hazardous waste
Liquid waste
Secondary chamber
Waste
Rotary kiln primary chamber
Rotary seals
Rotary seals
Ash

- The primary combustion chamber is an inclined refractory lined cylindrical shell that is rotated to provide a tumbling and lifting action to the solid waste materials. This exposes the surface of the waste material evenly to the flames coming from fuel burning in the rotating kiln.
- In the primary combustion chamber, the organic compounds in the solid wastes are converted to gases through volatilization, destructive distillation and partial combustion reactions.
- The unburned volatiles from the primary combustion chamber enter the secondary combustion chamber along with hot combustion products, where additional oxygen is introduced to complete the combustion.
- The clinkers spill out at the end of the cylinder.
- A tall flue gas stack, fan, or steam jet supplies the needed draft.
- Ash drops through the grate, but many particles are carried along with the hot gases.
- The particles and any combustible gases may be combusted in an "afterburner".

# Fluidized bed incinerator

- In a fluidized bed incinerator, the MSW is combusted within a chamber that contains a high temperature zone/bed of a fluidized, granular, non-combustible medium, such as sand.
- The sand particles are fluidized within the combustion zone through the nullification of the downward acting gravitational force by the upward acting aerodynamic lifting force provided by the combustion air stream made to permeate the bed.
- The basic objective of this design is to achieve the complete or near complete combustion of the solid fuel particles by their intimate contact with high temperature sand particles having high surface-to-volume ratio.
- The refuse-derived fuel is the usual form of solid waste that is supplied to fluidized bed incinerators.
- There are two design variables of fluidized bed techniques for incineration of municipal waste, namely, the bubble fluidized bed (BFB) and circulating fluidized bed. (CFB).


Bubbling Fluidized Bed (BFB)
Hot Fumes
Solid material mainly mixed in combustion chamber
Oxidizer
Circulating Fluidized Bed (CFB)
Hot Fumes
Intensive mixing in combustion chamber
Recirculated solid material
Oxidizer

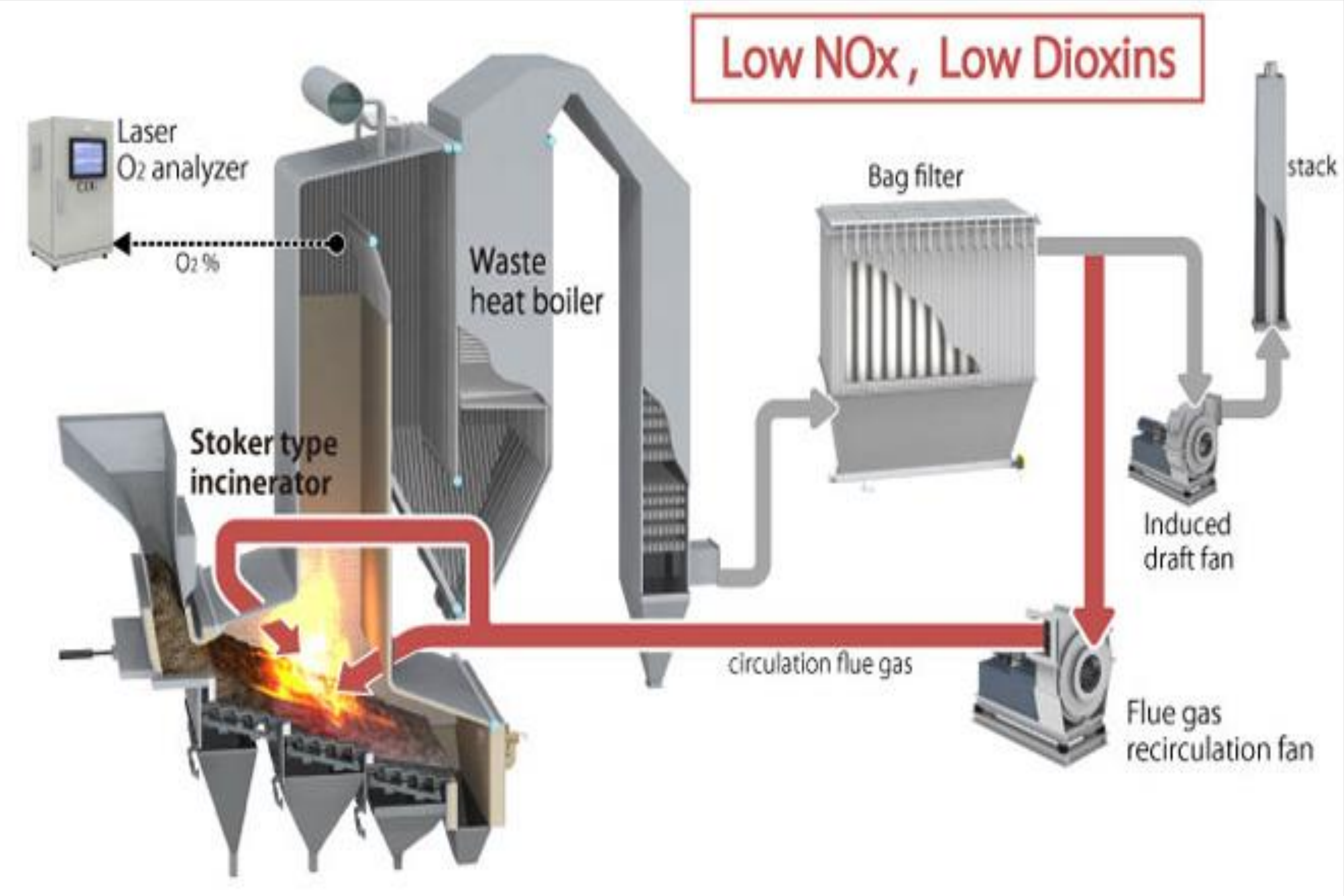
- BFB has a primary air flow of 0.9-3.1 m/s which makes the bed of fuel and inert material fluidize.
- CFB has a flow of primary air between 4.9-9.1 m/s. The high flow rate makes the bed circulate in the furnace.
- A cyclone separates sand particles from the exhaust fumes which are then recirculated to the furnace through a particle trap.
- CFB has an economic advantage over BFB when the energy output requirements are greater than 45,000 kg steam/hr.
- Bed temperature is nearly same in both designs, but in CFB designs it is constant along the furnace height, while in BFB designs large difference between bed and freeboard temperature can exist due to the volatile combustion in freeboard.
- Heat generation is more uniform in CFB, the combustion efficiency is greater, and $SO_2$ and $NO_x$ emissions are smaller than in BFB boilers.
- The majority of commercial fluidized bed systems combusting low-grade fuels are of the circulating bed design.

# Flue Gas Cleaning

- Ideally, an incinerator should convert simple hydrocarbons into nothing other than carbon dioxide and water. However, in practice, the waste contains chemicals that escape pollution control devices through airborne emissions, or concentrate in the ash residue, which is typically disposed of in landfills or stockpiled above the ground. Some of these pollutants are:
  a) Particulate matter, heavy metals, acid gases, oxides of nitrogen and products of incomplete combustion, including chlorinated organic compounds and, as with all combustion devices, large quantities of carbon dioxide. Carbon dioxide is considered to be one of the major contributors to global climatic changes.
  **b) Acid gases:** These are formed during combustion when certain elements in waste come in contact with oxygen or hydrogen. Sulphur dioxide and hydrogen chloride are two of the gases released into the atmosphere, contributing to the acidification of rain or fog and consequently metal corrosion, and the erosion of limestone and marble buildings.

c) **Dioxins and furans:** 'Dioxins' and 'furans' are generic terms for a group of over 200 chemical compounds, which are formed as unintended byproducts when chlorinated substances are burned in a temperature range of 200-800°C. These are extremely toxic substances which produce a variety of adverse effects in humans and animals even at extremely low doses. These compounds accumulate in magnified concentrations as they move up the food chain, concentrating in fat and breast milk. Municipal and medical waste incineration has been listed as the primary source of dioxin production worldwide.

- The selection of the flue gas cleaning system depends primarily on the desired emission level.
- The available air pollution control systems can be grouped as basic, medium, or advanced emission control.
- The basic emission control only reduces the particulate matter, is simple to operate and maintain, and the investment cost is relatively low.
- By applying relatively simple dry or semidry scrubbers, medium level emissions can be controlled.
- The state of the art flue gas cleaning systems used in developed countries are very complex, and they increase installation and treatment costs.



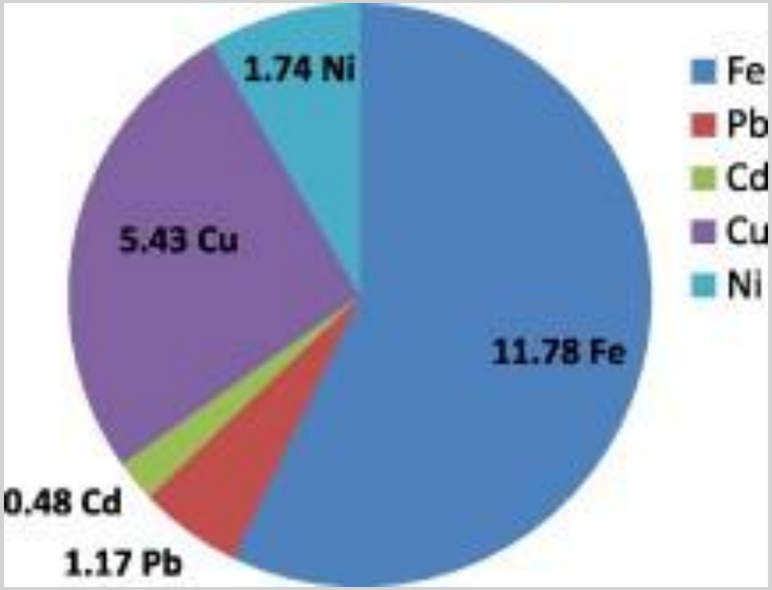
Low NOx , Low Dioxins
Laser
O2 analyzer
O2 %
Waste
heat boiler
Bag filter
stack
Stoker type
incinerator
Induced
draft fan
circulation flue gas
Flue gas
recirculation fan

# Incineration Residues

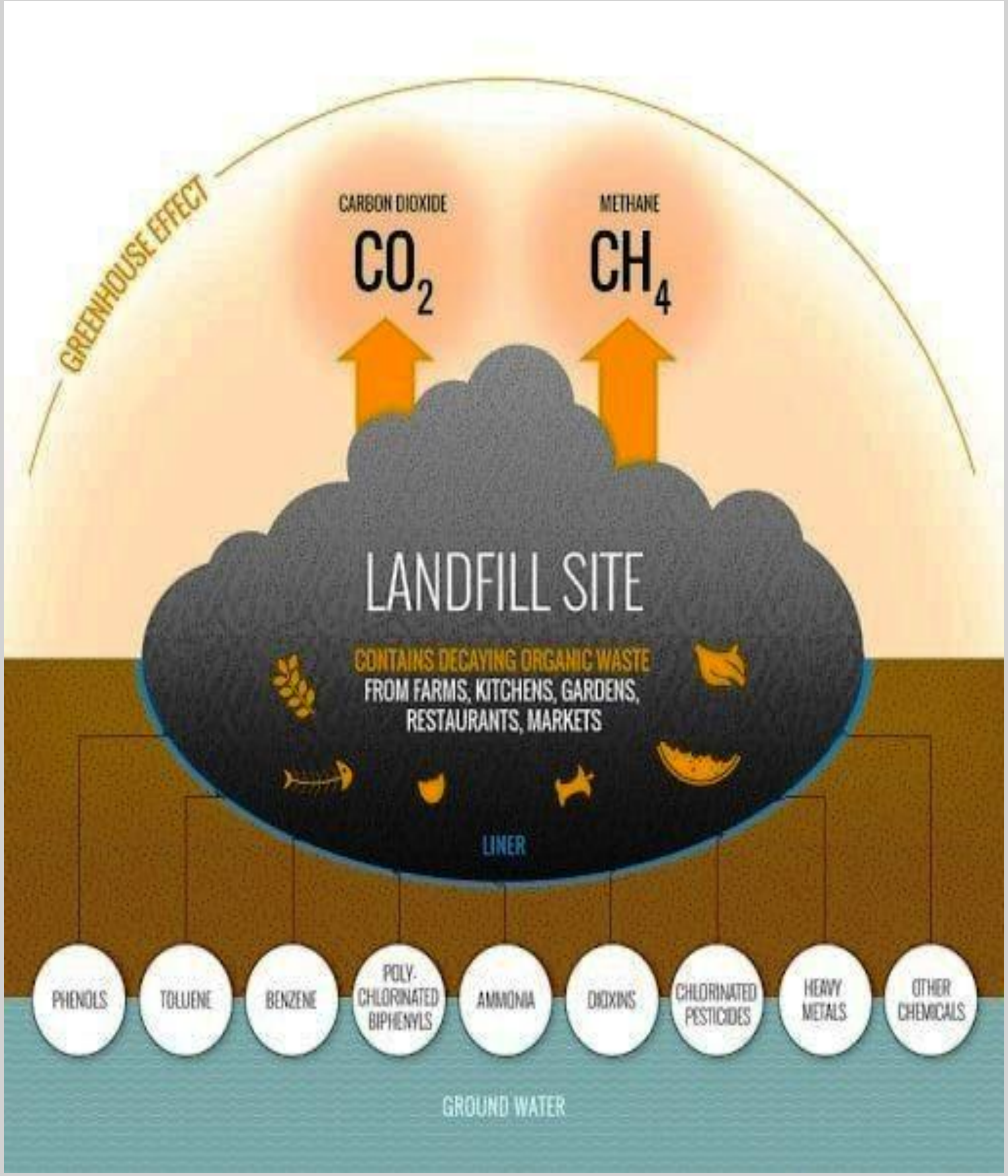
- The main residue from MSW incineration is slag.
- In addition to the slag, the plant generates residues from dry, semidry, or wet flue gas cleaning processes.
- The slag from a well-operated waste incinerator will be well burnt out, with only a minor content of organic material.
- Besides, the heavy metals in the slag, which are normally leachable, will to some extent become vitrified and thus insoluble.
- Much of the slag may therefore be used as road construction material or something similar after sorting.
- The other residues require proper disposal where leaching with rainwater can be prevented.
- Proper disposal of fly ash and other flue gas residues is also important.
- The fine particle size of the residues calls for special precautions during handling at the plant and the landfill.

# Advantages of Incineration

- Most attractive feature of the incineration process is its ability to reduce the original volume of combustibles by 80-95% and thus, the demand for landfill space.
- Incineration plants can be located close to the center of waste generation, thus reducing the cost of waste transportation.
- The use of ash from MSW incinerators for environmentally appropriate construction further reduces the need for landfill capacity.
- In particular, incineration of waste containing heavy metals should be avoided to maintain a suitable slag quality. However, ordinary household waste does contain small amounts of heavy metals which do not readily leach under field conditions.



- All waste disposal methods eventually decompose organic materials into simpler carbon molecules such as carbon dioxide and methane.
- Incineration provides the best way to eliminate methane gas emissions from waste management processes.
- Further, the energy from incineration can be a substitute to fossil fuel combustion.
- Waste incineration may be advantageous when a landfill cannot be sited because of lack of suitable sites or long transportation distances resulting in higher costs.

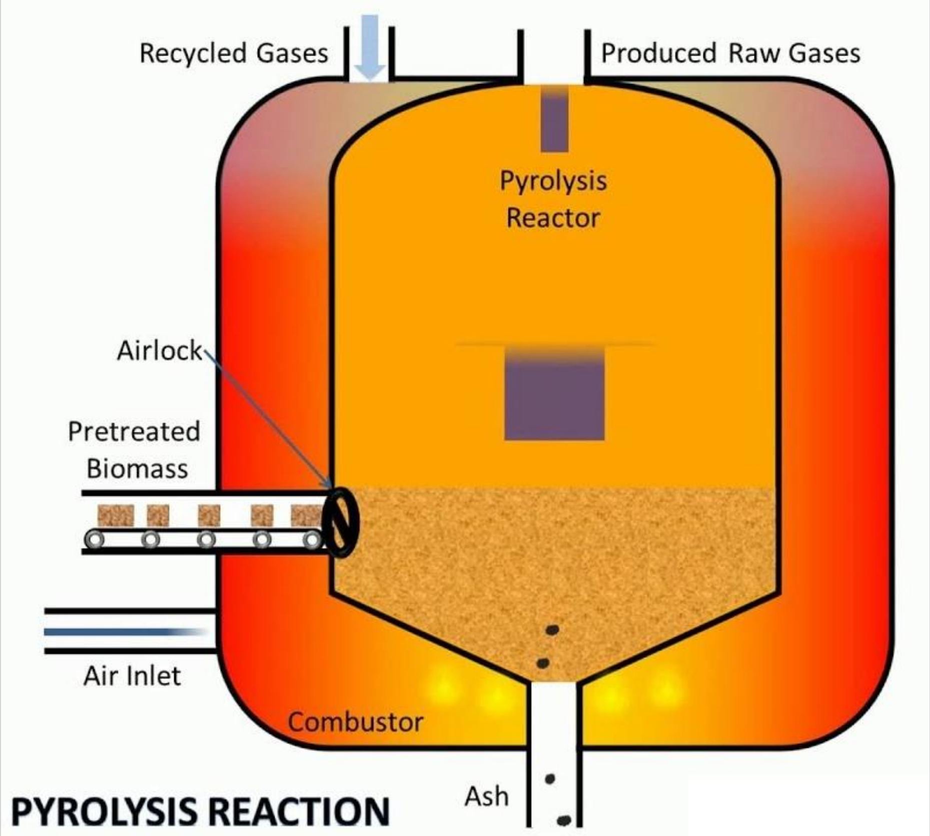


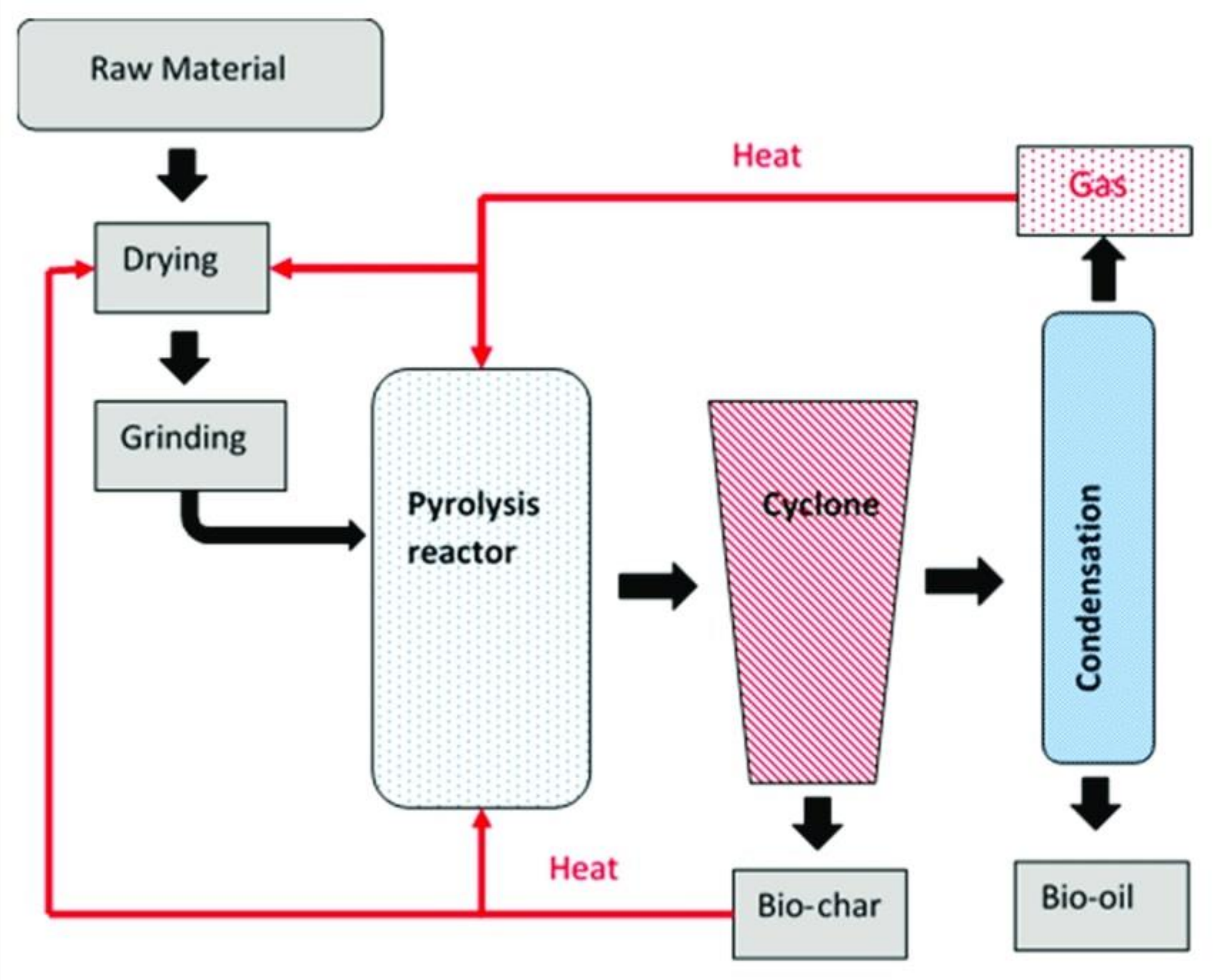
# Disadvantages of Incineration

- Incinerators are capital intensive to build and relatively expensive to run.
- The complexity of a plant requires a certain level of qualified and trained technical staff to operate and maintain.
- Furthermore, waste incineration is only applicable if a certain quantity of waste is generated with a definite quality irrespective of the season.
- The supply of hot water or steam requires that the plant be located adjacent to the potential user.
- Moreover, it is seldom possible to use the energy all the time. Also, most industrial users require a guaranteed supply, which means that a backup boiler will be needed.
- The incineration of MSW generates a variety of pollutants (such as carbon dioxide, heavy metals and particulates) that contribute to environmental and human health impacts such as climate change, smog, acidification, asthma, and heart and nervous system damage.

# PYROLYSIS

- Pyrolysis is the high temperature conversion of organic material in the absence or near absence of oxygen into products that may be gaseous, liquid, or solid, or a combination of all three forms.
- The system pressure influences the reaction and, therefore, the characteristics of the reaction products.
- Pyrolysis differs from incineration in that it is an endothermic reaction and takes place in an oxygen-free or low-oxygen atmosphere.
- Since it is endothermic, a considerable amount of energy input is required to attain the high temperatures required to volatilize the organic compounds.

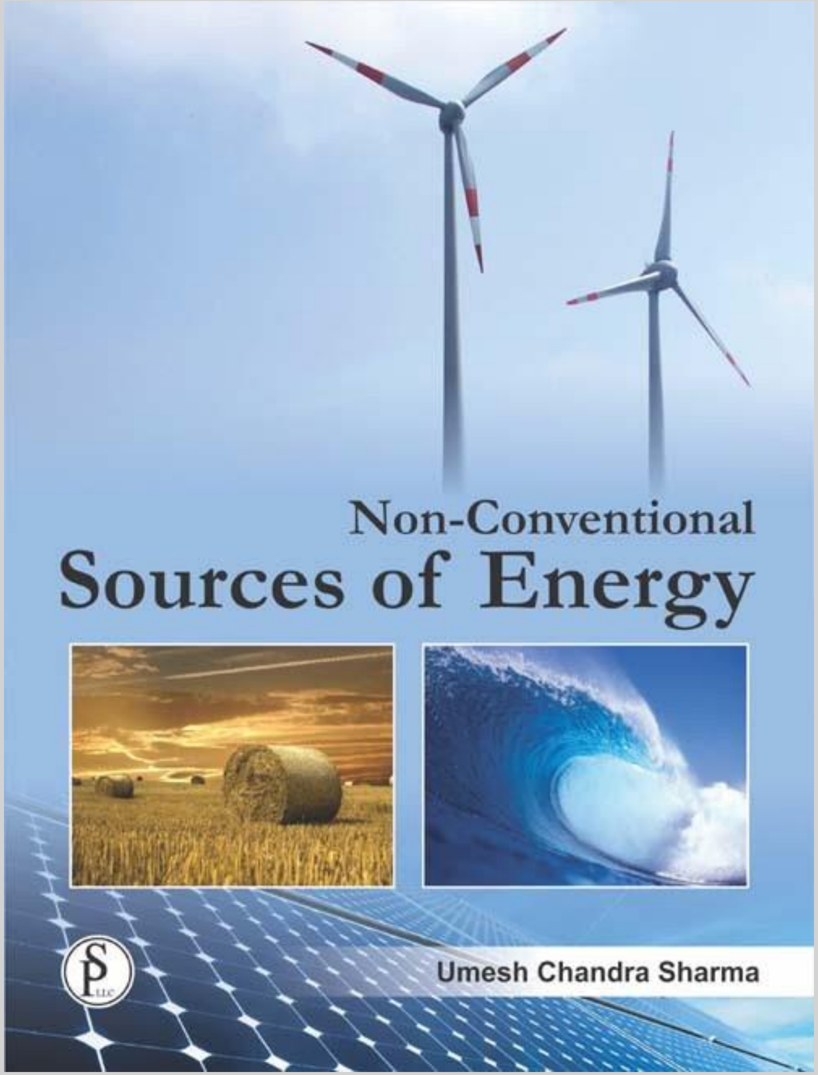



Raw Material
Drying
Grinding
Pyrolysis reactor
Heat
Gas
Cyclone
Condensation
Heat
Bio-char
Bio-oil

# OTHER METHODS

- The other thermal conversion processes are thermal gasification and liquefaction.
- Gasification is a high temperature conversion process that is optimized to produce a fuel gas with a minimum of liquids and solids.
- Gasification consists of heating the feed material in a vessel with or without the addition of oxygen. However, in case of liquefaction, the reactions are shifted in favor of a high yield of liquid byproducts.
- The details of these methods can be found in discussion covering technologies to convert biomass into useful energy.

# REFERENCE

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Thank You