# ENVIRONMENTAL ENGINEERING

## Chapter 6 : Solid Waste

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# Chapter Description

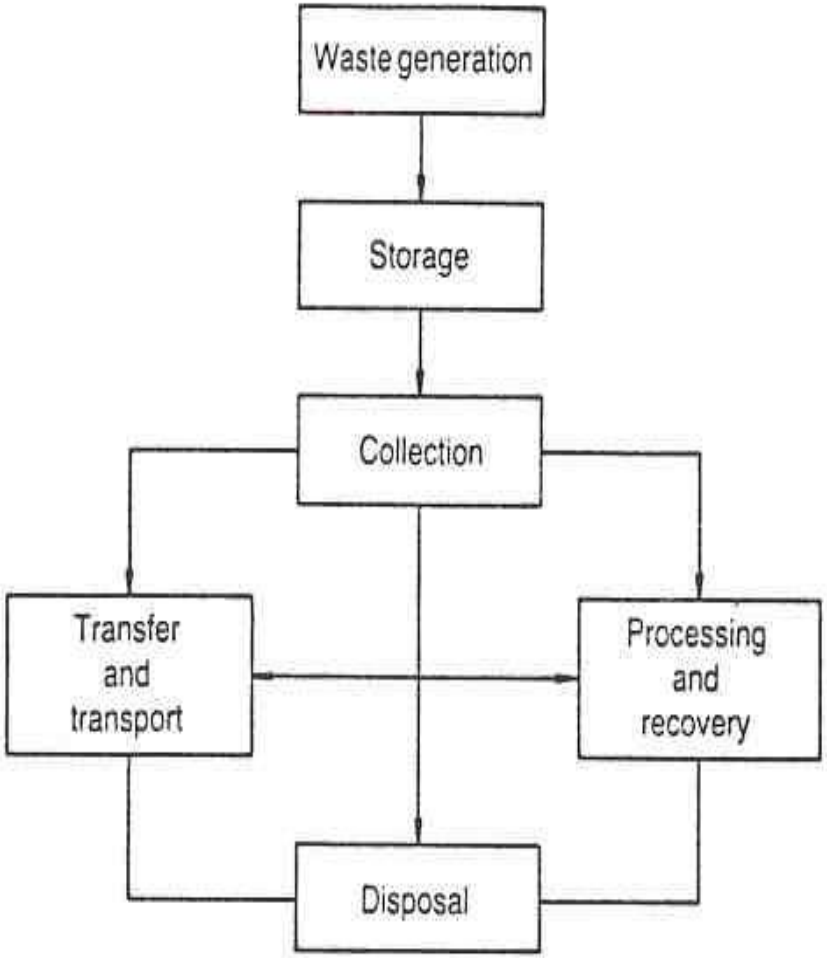
- Topic
  - Type of solid waste
  - Properties of solid waste
  - Solid waste management
- Topic Outcomes
  - Explain the types and properties of solid wastes
  - Identify the solid waste treatment related to on-site handling, storage processing and collection of solid wastes
- References

  - Peavy, H.S., Rowe, D.R. and Tchobanoglous, G., Environmental Engineering, McGraw Hill, 1985.
  - Mackenze, I.D., Introduction to Environmental Engineering, 4th Edition, Davis A. Cornell, Mc Graw Hill, 2008.
  - Sawyer, C.N. Chemistry for Environmental Engineerin. 4th Edition, McGraw Hill, 1994.
  - Martin, T.A. and David, W.H. Fundamental of Environmental Engineering. 2003.
  - Environmental Quality Act 1974 (Subsidiary Legislation), International Law Book, Service June 2002.

# Functional elements

- Activities involved with the management of solid waste from the point of generation to final disposal have been grouped into six functional elements:

1. Waste generation
2. On-site handling, storage and processing
3. Collection
4. Transfer and transport
5. Processing and recovery
6. Disposal




Interrelationship of functional elements comprising a solid-waste management system

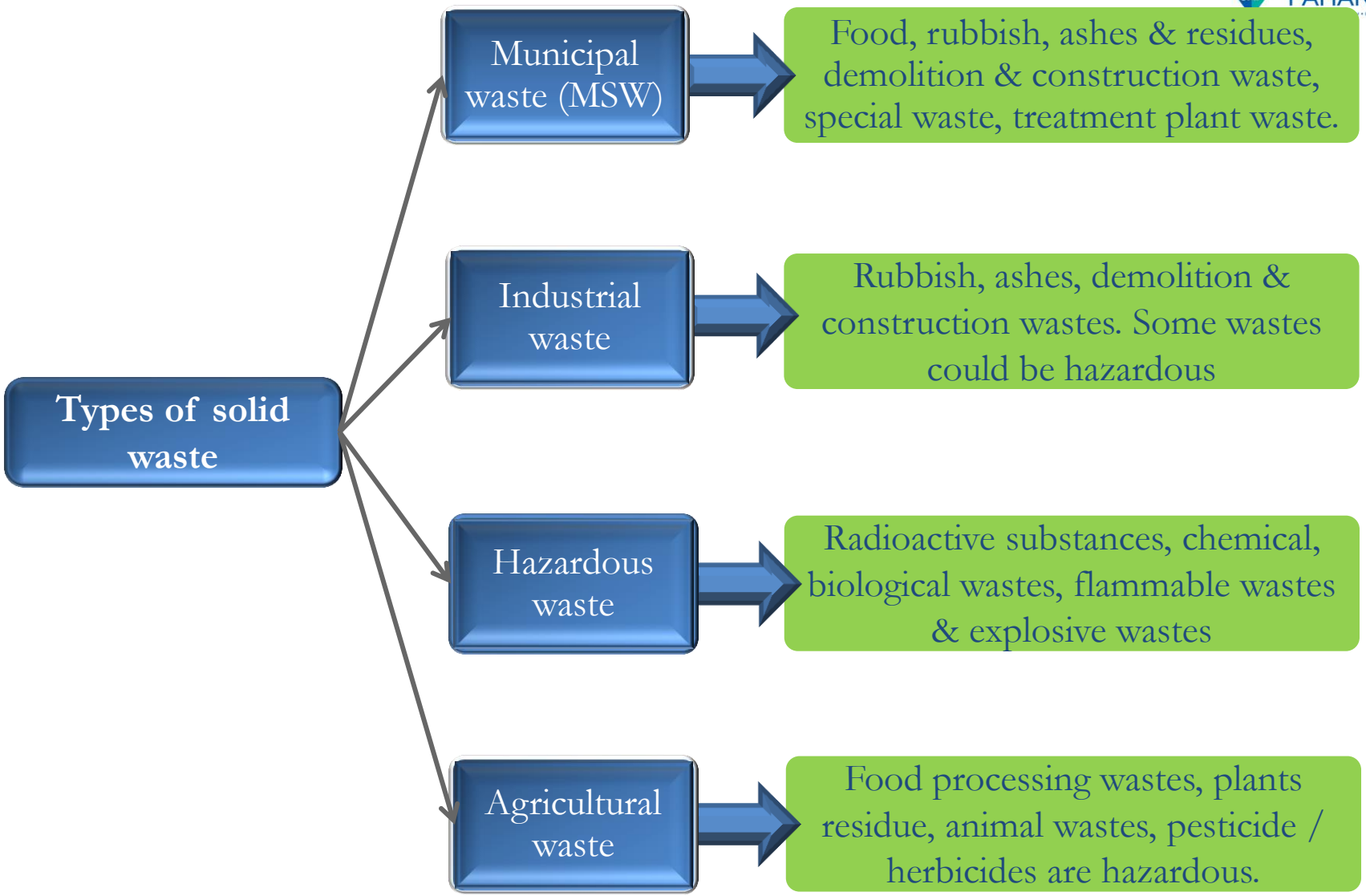
# Table 11-1: Description of the functional elements of a solid waste management system

| Functional element | Description |
|---|---|
| Waste generation | Activity in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. |
| On-site handling, storage & processing | Activities associated with the handling, storage, and processing of solid wastes at or near the point of generation. |
| Collection | Activities associated with the gathering of the solid wastes and the hauling of wastes after collection to the location where the collection vehicle is emptied. |
| Transfer & transport | Activities associated with (1) transfer of wastes from smaller collection vehicle to the larger transport equipment & (2) the subsequent transport of the wastes, usually over long distance, to the disposal site. |
| Processing & recovery | Techniques, equipment & facilities used both to improve the efficiency of the other functional elements & to recover usable materials, conversion products, or energy from solid wastes. |
| Disposal | Activities associated with ultimate disposal of solid wastes, including those wastes collected & transport directly to a landfill site, semisolid waste (sludge) from wastewater treatment plants, incinerator residue, compost, or other substances from the various solid-waste processing plants that are of no further use. |

# Introduction to municipal solid waste (MSW)

Definition

- Waste that is other than emission or effluent and is regarded as inevitable by-product due to human activities, generated a rate and discarded after used when no longer needed by the generator
- Waste is a residual, a used-up product or material of marginal or negative value for the owner that the owner wishes to get rid off (Christenser, 1988)



# Example sources of Municipal solid waste (MSW)

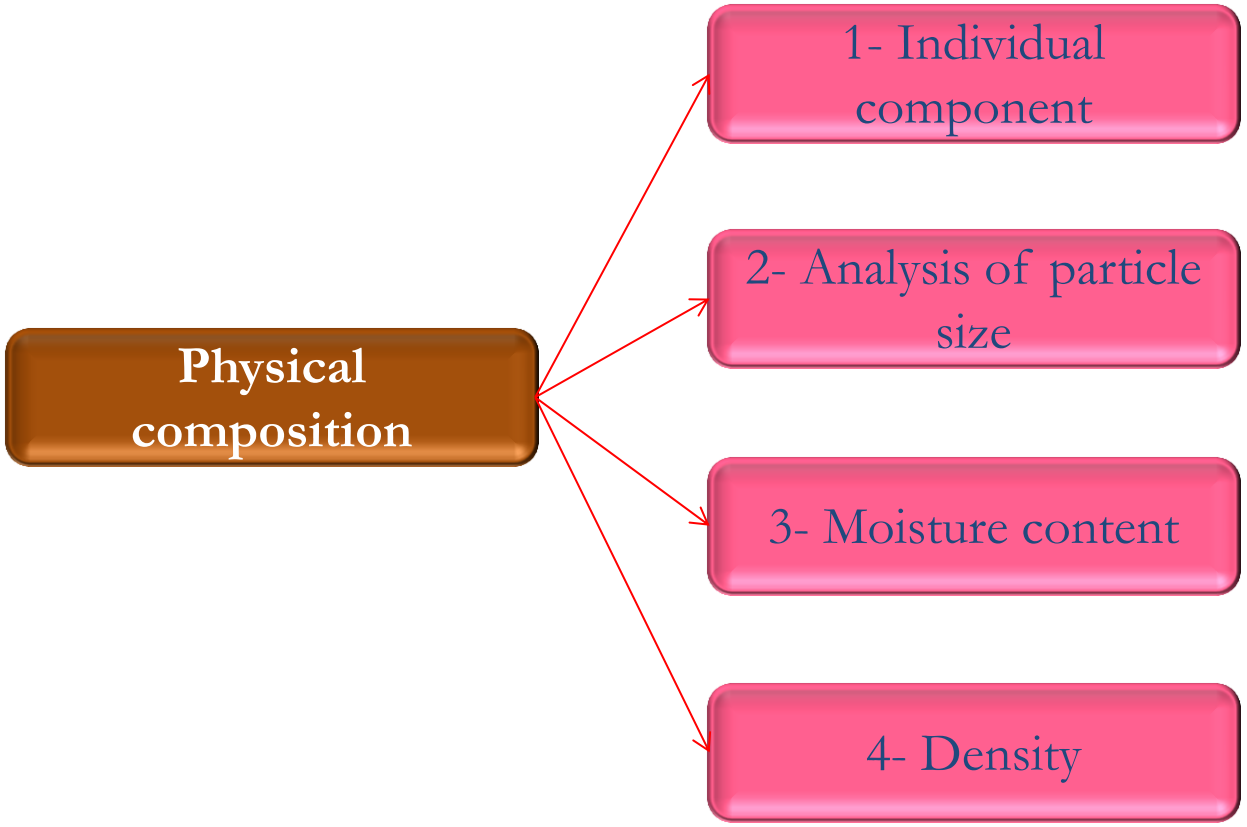
- Residential area – family dwellings.
- Commercial area – markets, offices, hotel, workshop school.
- Open areas – roadside, parks, street, playground beaches.
- Treatment plants sites.
- Industrial activities & construction areas.

Source:https://www.google.com.my/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwiJr4H47OzVAhUHTY8KHXxGBsUQjRwIBw&url

# Hazardous wastes

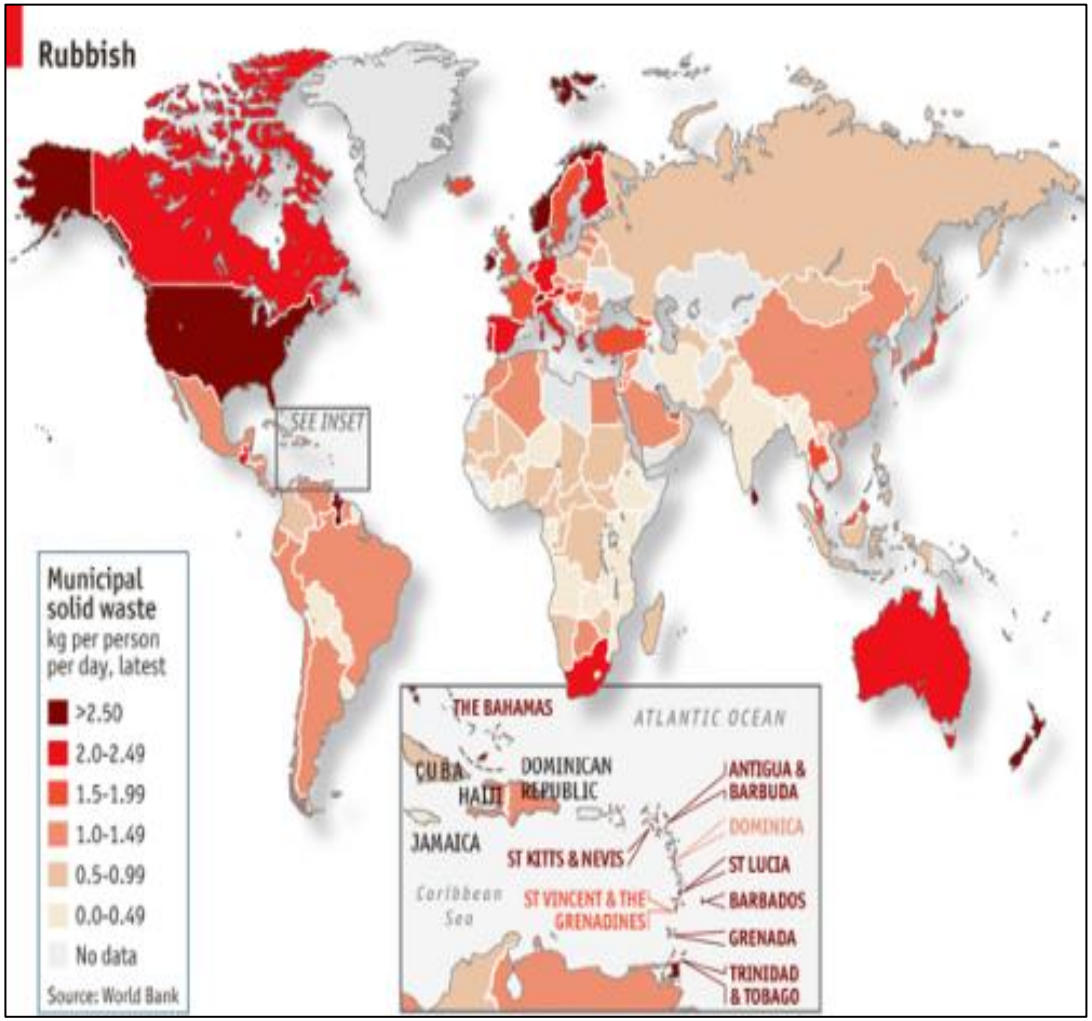
- **Definition:** Wastes that pose a substantial danger immediately or over a period of time to human, plant or animal life.
- Classified as hazardous if it exhibits any of the following characteristics :
  a) Ignitability
  b) Reactivity
  c) Corrosivity
  d) Toxicity

https://www.google.com.my/imgres?imgurl=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2F3%2F3e%2FValleyofdrums.jpg&imgrefurl



# 1- Individual components

- Composition of MSW
- Reflects affluence of society.
- The way of life.
- Economic status.
- Social behavior.




Source: world bank, 2012

Composition of MSW for Malaysia & USA (% by mass)

MSW component

| *Waste* | *Range* | *Typical* | *Malaysia* | *USA* |
|---|---|---|---|---|
| Organic / food | 5-25 | 17 | 32.0 | 10.0 |
| Yard waste | 0-10 | 10 | - | 15.0 |
| Paper | 10-40 | 33 | 29.5 | 38.0 |
| Plastic | 2-8 | 6 | 16.0 | 10.0 |
| Textile / leather | 0-3 | 2 | 3.4 | 7.0 |
| Rubber | 0-1 | 0.5 | 2.0 | - |
| Wood | 1-3 | 2 | 7.0 | - |
| Glass | 4-15 | 5 | 4.5 | 6.0 |
| Ceramic | - | - | 0.4 | - |
| Ferrous metal | 1-3 | 1 | 3.7 | 8.0 |
| Non ferrous metal | 0-1 | 1 | 0.6 | - |
| others | 0-10 | 8 | 0.9 | 3.0 |

(70% of waste in Malaysia can be composed)

# General trends in composition of MSW (% by weight)

| *Component* | *Low income countries* | *Middle income* | *High income* |
|---|---|---|---|
| Food waste | 40-85 | 20-65 | 6-30 |
| Paper / cardboard | 1-10 | 8-30 | 25-60 |
| Plastic | 1-5 | 2-6 | 2-8 |
| Yard wastes | 1-5 | 1-10 | 10-20 |
| Other organics | 2-10 | 2-15 | 4-15 |
| Inorganics | 1-55 | 1-45 | 7-35 |

# 2- Analysis of particles size

- Size of waste component effect the effectiveness of material recovery.
- The use of mechanical separation technique (screens and magnetic separators) can effectively sort the particle size.
- Organic materials, size is important with respect to biological treatment (smaller particles required).
- Reduction in particle size increase the rate of biological transformation and degradation of material.
- Shredding employed to reduce particle size.

# 3- Moisture content

- It is important when waste is to be composted or digested anaerobically in sanitary landfill
- For effective composting and digestion, optimum moisture content is required.
- Moisture content is expressed as mass of moisture per unit mass of wet or dry material

$$moisture\,content\,\% = \left(\frac{a-b}{a}\right)100$$

Where, a = initial mass of sample as delivered

b = mass of sample after drying

# 4- Density

- Knowledge of density required to determine waste compacted volume
- Used for calculating volume of landfill space requirement
- Compacted volume needed to determine collection vehicle capacity
- Density is expressed on as-compacted or as-discarded basis.
- Ratio between as-compacted density, $\rho_c$ to as-discarded density $\rho_d$ is called compaction ratio, r or

$$r = \frac{\rho_c}{\rho_d}$$

# Chemical Composition

- Important in evaluating alternative processing and energy recovery options.
- Energy content or fuel value of waste is the amount of heat that will be released when wastes are combusted.
- Calorific value of wastes decreased with increased in moisture content – if incineration is used, auxiliary fuel is required.

- Potential of waste as fuel alternative is evaluated using proximate analysis and chemical properties.
- Proximate analysis – moisture, volatile matter, ash (residue after burning) and fixed carbon.
- Fusing point of ash.
- Ultimate analysis, % of carbon, hydrogen, oxygen, nitrogen, sulphur and ash.
- Heating value (energy value).

**Table 10-6 Proximate and ultimate chemical analysis of municipal solid waste**

| | Value, percent* | |
|---|---|---|
| | Range | Typical |
| Proximate analysis | | |
| Moisture | 15–40 | 20 |
| Volatile matter | 40–60 | 53 |
| Fixed carbon | 5–12 | 7 |
| Noncombustibles | 15–30 | 20 |
| Ultimate analysis (combustible components) | | |
| Carbon | 40–60 | 47.0 |
| Hydrogen | 4–8 | 6.0 |
| Oxygen | 30–50 | 40.0 |
| Nitrogen | 0.2–1.0 | 0.8 |
| Sulfur | 0.05–0.3 | 0.2 |
| Ash | 1–10 | 6.0 |
| Heating value† | | |
| Organic fraction, kJ/kg | 12,000–16,000 | 14,000 |
| Total, kJ/kg | 8,000–12,000 | 10,500 |

* By mass.
† As-discarded basis.

# Chemical content

- Representative data on the ultimate analysis of typical municipal waste components are presented in Table 10.8. If energy values are not available, approximate values may be determined by using eq. 10.4, known as the *modified Dulong formula*:

$$kJ/kg = 337C + 1428\left(H - \frac{O}{8}\right) + 9S$$

$C$: % *carbon*

$H$: % hydrogen

$O$: % *oxygen*

$S$: % *sulfur*

# Solid Waste Management


| Generation | Collection | Transport/ Transfer | Recovery/ Treatment | Disposal |
|---|---|---|---|---|
| -Generation of solid waste at households / commercial<br>- Sorting waste | -Scheduling of compactors or trucks for waste collection<br>-Providing bins for recyclables | Transportation of waste to sites for transfers, recovery, or disposal | -Secondary sorting of waste, e.g. plastic, glass, paper,aluminium<br>-Treatment and recovery of other waste streams | -incinerator, landfill, or hazardous waste facility, or for recycling |

# Waste separation

Collected **twice** a week

## 1. Food waste

> Fish
> Tea bags
> Meat
> Fruit peels & vegetable discards

## 2. Disposable diapers and others

> Food wrappers
> Disposable napkins
> Wet tissues

## 1. Paper

Encouraged to use blue garbage bags

> Boxes
> Receipts
> Magazines
> Paper
> Cardboard
> Newspaper

## 2. Plastic

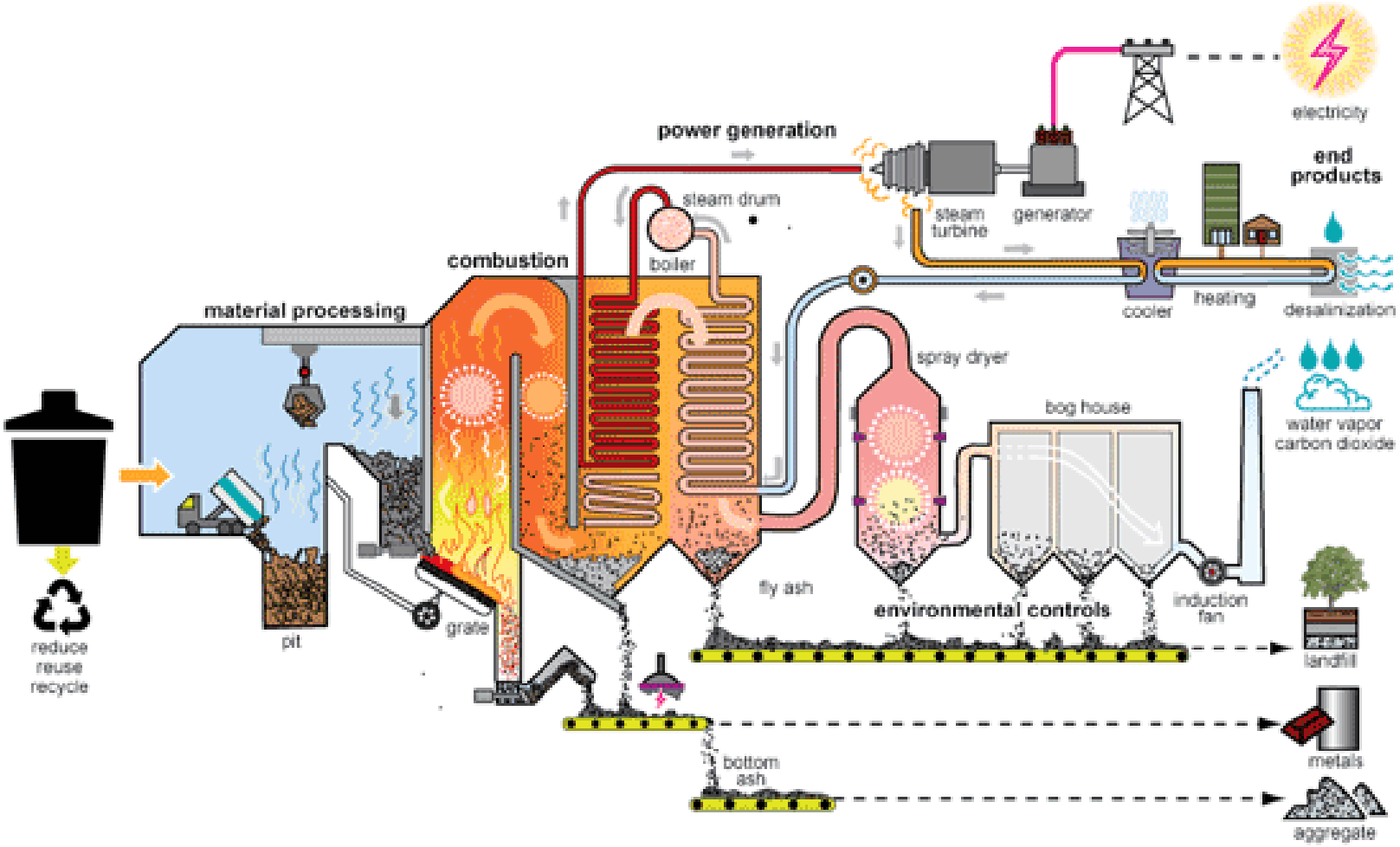
Encouraged to use white garbage bags

Collected **once** a week

> Plastic bags
> Detergent bottle
> Plastic containers
> Food containers
> Beverage bottle
> Cardboard

# Waste To Energy

Waste-to-energy plant




Source: Adapted from the National Energy Educational Development Program

# End of Chapter 6

# Author Information

Credit to the author: Dr Norhanimah Hamidi