



EV20001: ENVIRONMENTAL SCIENCE



Lecture #7

# Solid and Hazardous Waste Management

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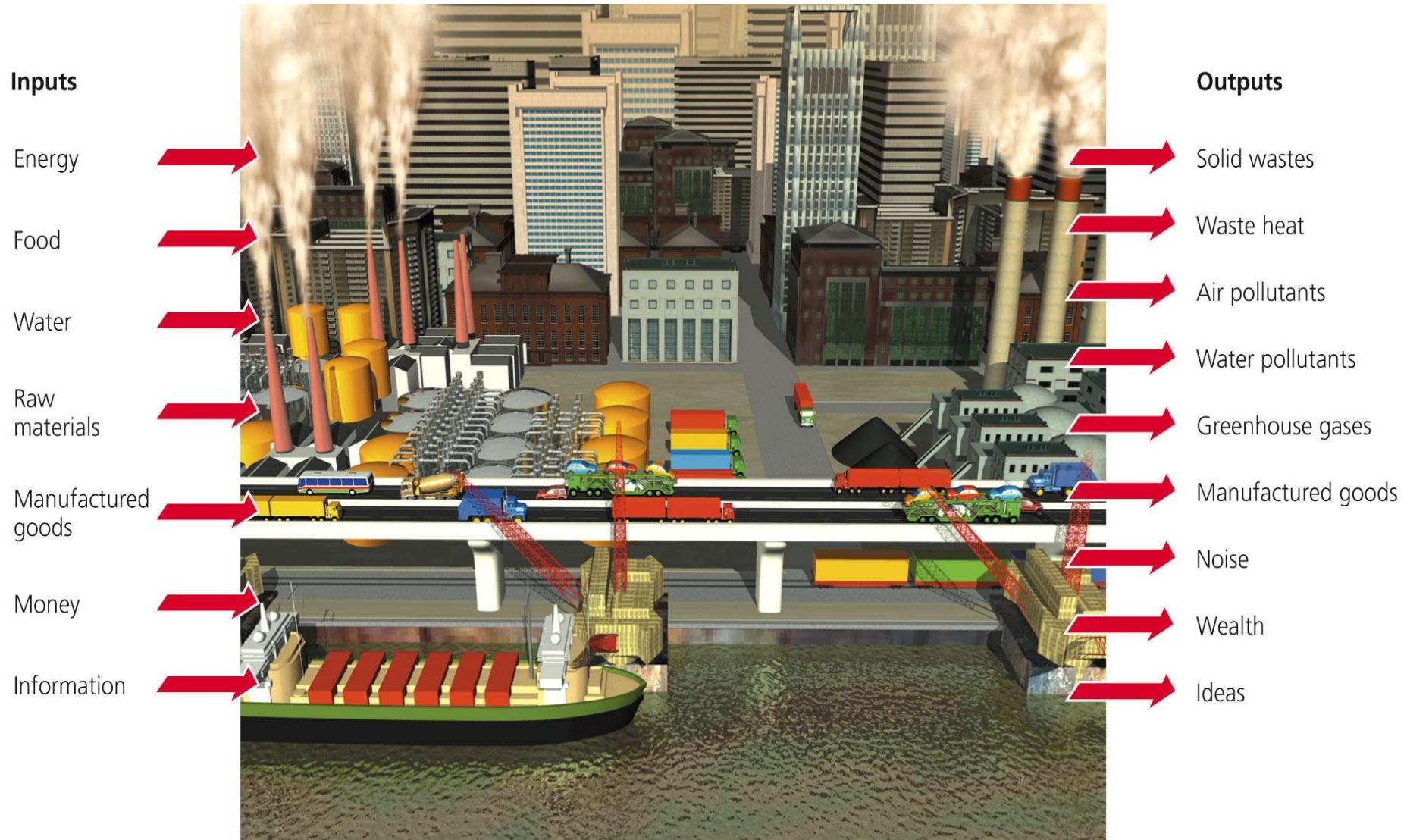
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# We are living unsustainably



- Most urban areas are unsustainable systems.



# Solid waste



- **Solid waste** refers to any unwanted or discarded material resulting from industrial, commercial, mining and agricultural operations, and from community activities.
- Two types of solid waste:
  - **Industrial solid waste** refers to waste produced by mines, agriculture and industries that supply people with goods and services (e.g., chemical solvents, paints, sandpaper, paper products, metals, and radioactive wastes).
  - **Municipal solid waste** comprises the combined solid waste produced by homes and workplaces (e.g., paper, cardboard, waste food, cans, bottles, wood, e-waste, etc.).



# Hazardous waste



- **Hazardous waste** threatens human health or the environment because it is poisonous, dangerously chemically reactive, corrosive, or flammable.
- Examples include industrial solvents, medical waste, car batteries, dry-cell batteries, household pesticide products, ash from incinerators and coal-burning power plants.
- Two types of hazardous waste:
  - **Organic compounds** (such as various solvents, pesticides, polychlorinated biphenyls (PCBs), and dioxins)
  - **Toxic heavy metals** (such as lead, mercury and arsenic)

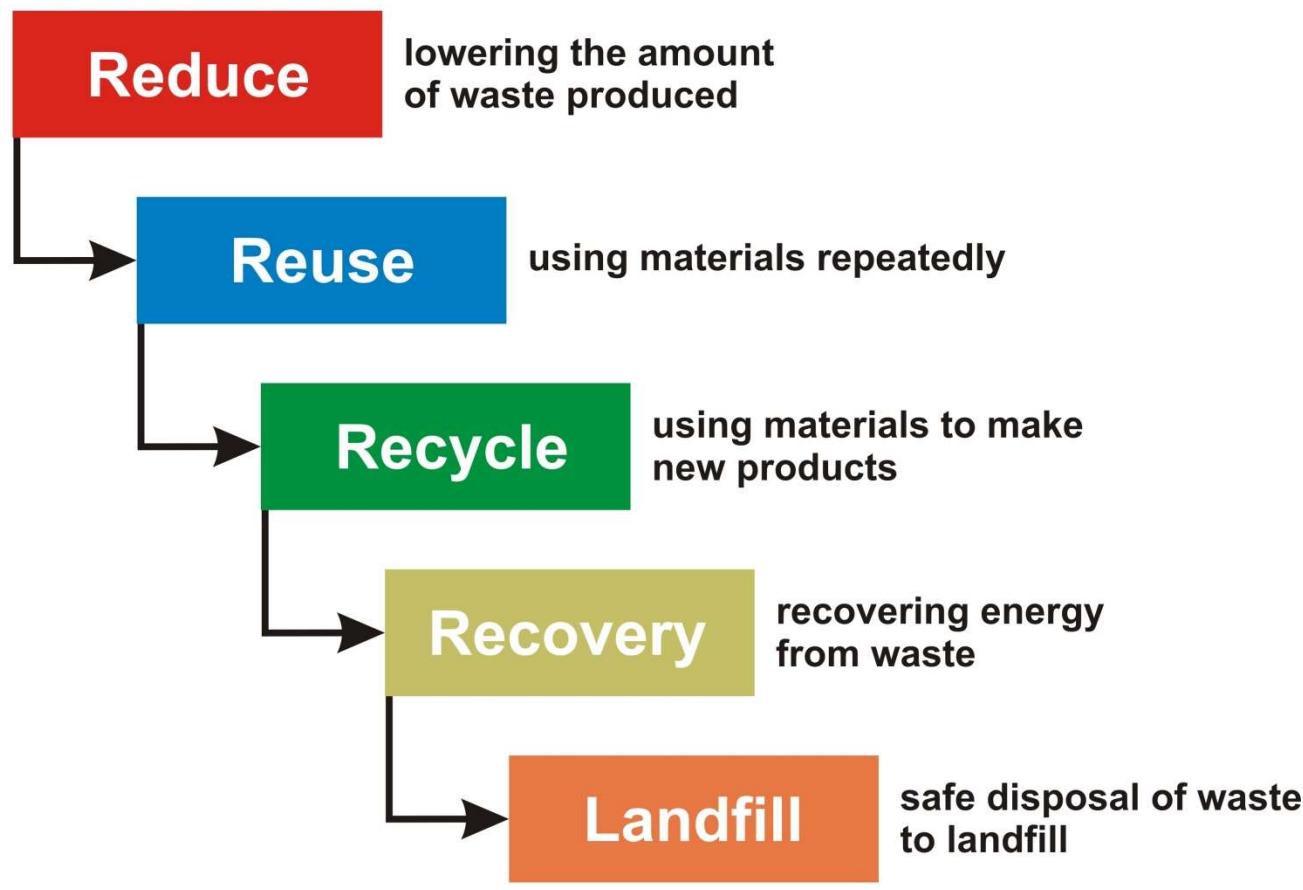


# Managing solid waste



- The waste hierarchy sets out a set of priorities that are based on sustainability with an order of preference for actions to reduce and manage waste.

## Most favoured option



# Dealing with solid waste



- **Waste management**
  - Attempt to manage wastes in ways that reduce their environmental harm
  - Involves mixing wastes together and then transferring them from one part of the environment to another
- **Waste reduction**
  - Involves producing much less waste and pollution
  - Wastes produced are considered to be potential resources that can be reused, recycled, or composted
- **Integrated waste management**
  - Involves a variety of strategies for both waste reduction and waste management



# Waste management

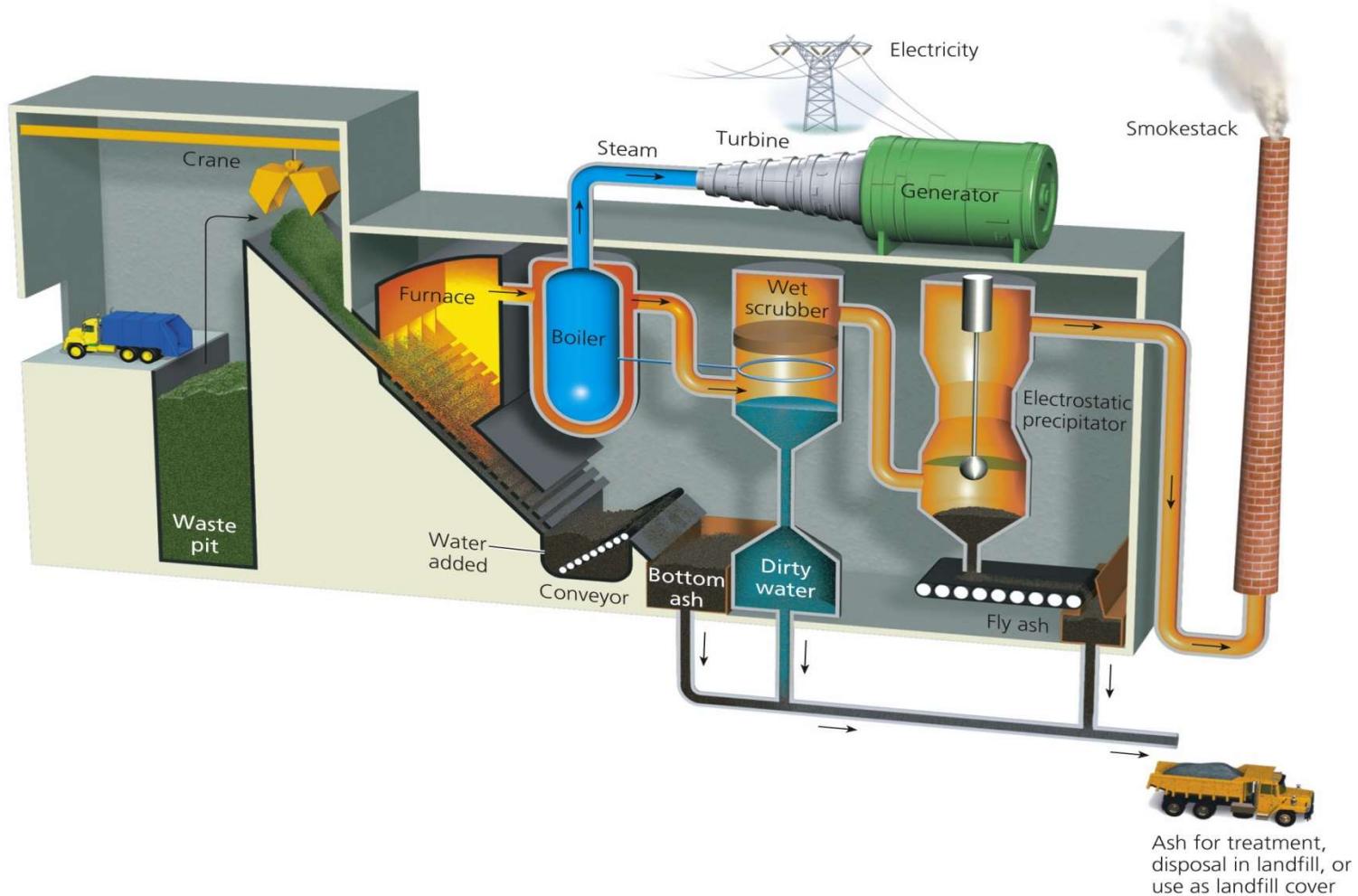


- Does not attempt to reduce the amount of waste produced.
- Involves transferring wastes from one part of the environment to another, usually by **burying** them, **burning** them, or **shipping** them to another location.
- Technologies for burning and burying solid wastes are well developed.
- Burning contributes to pollution and greenhouse gas emissions.
- Buried wastes can eventually contribute to air and water pollution and land degradation.
- Waste management practices are not uniform among countries (developed and developing nations), regions (urban and rural area), and sectors (residential and industrial).



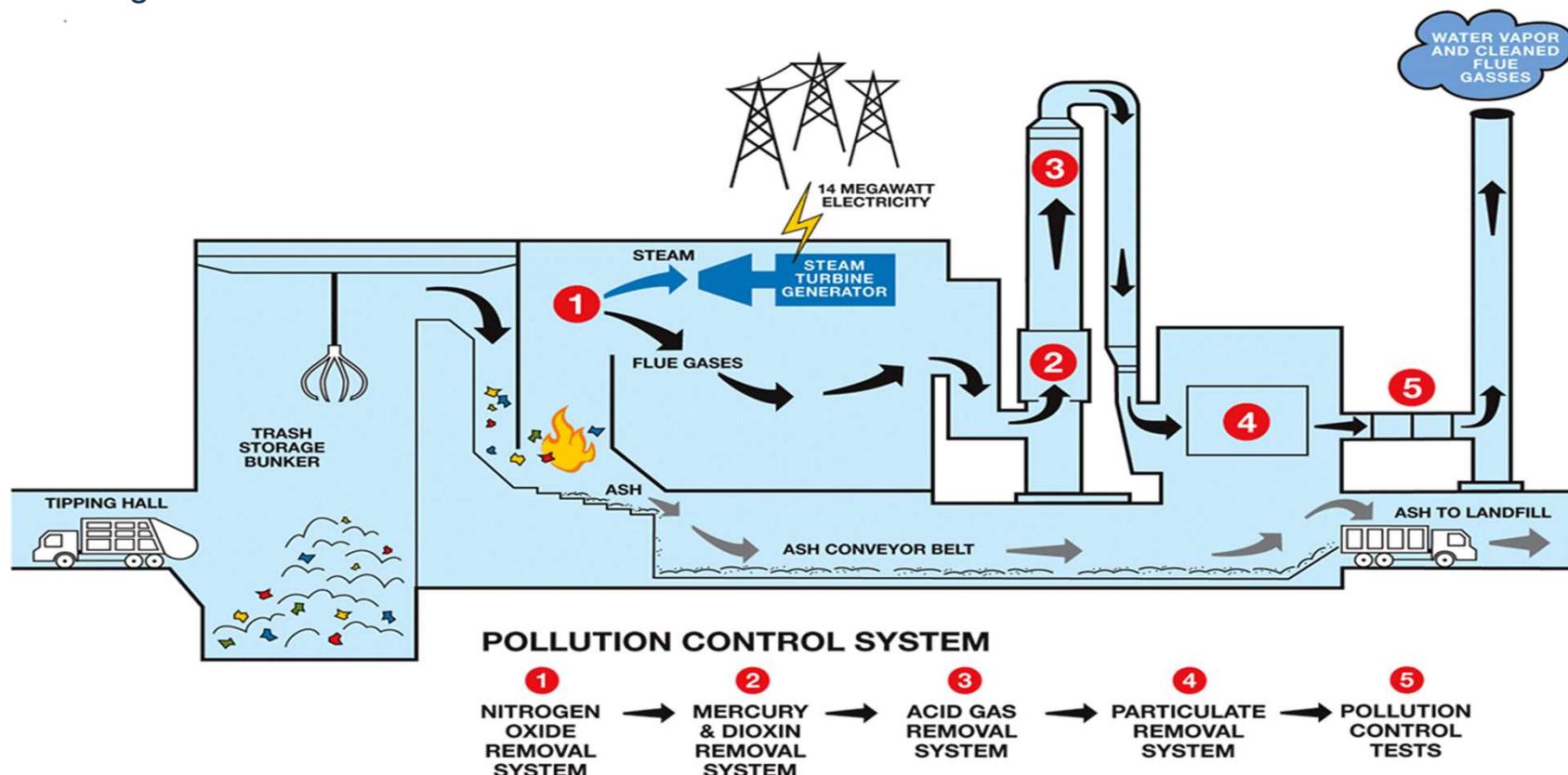
# Burning solid waste (incineration)

- A **waste-to-energy incinerator** with pollution controls that burns mixed solid wastes and recovers some of the energy to produce steam used for heating or producing electricity.





- Despite being an attractive technological option for energy production and waste management, direct combustion of solid waste has been largely criticized since it **emits heavy metals, dioxins and furans**. However, the concerns over the health effects of dioxin and furan emissions have been significantly lessened in recent years by advances in emission control designs and very stringent new governmental regulations that have resulted in large reductions in the amount of dioxins and furans emissions.



# The good and bad of incineration



## Trade-Offs

### Incineration

#### Advantages

Reduces trash volume

Less need for landfills

Low water pollution

Concentrates hazardous substances into ash for burial

Sale of energy reduces cost

Modern controls reduce air pollution

Some facilities recover and sell metals

#### Disadvantages

Expensive to build

Costs more than short-distance hauling to landfills

Difficult to site because of citizen opposition

Some air pollution and CO<sub>2</sub> emissions

Older or poorly managed facilities can release large amounts of air pollution

Output approach that encourages waste production

Can compete with recycling for burnable materials such as newspaper



# Gasification of solid waste

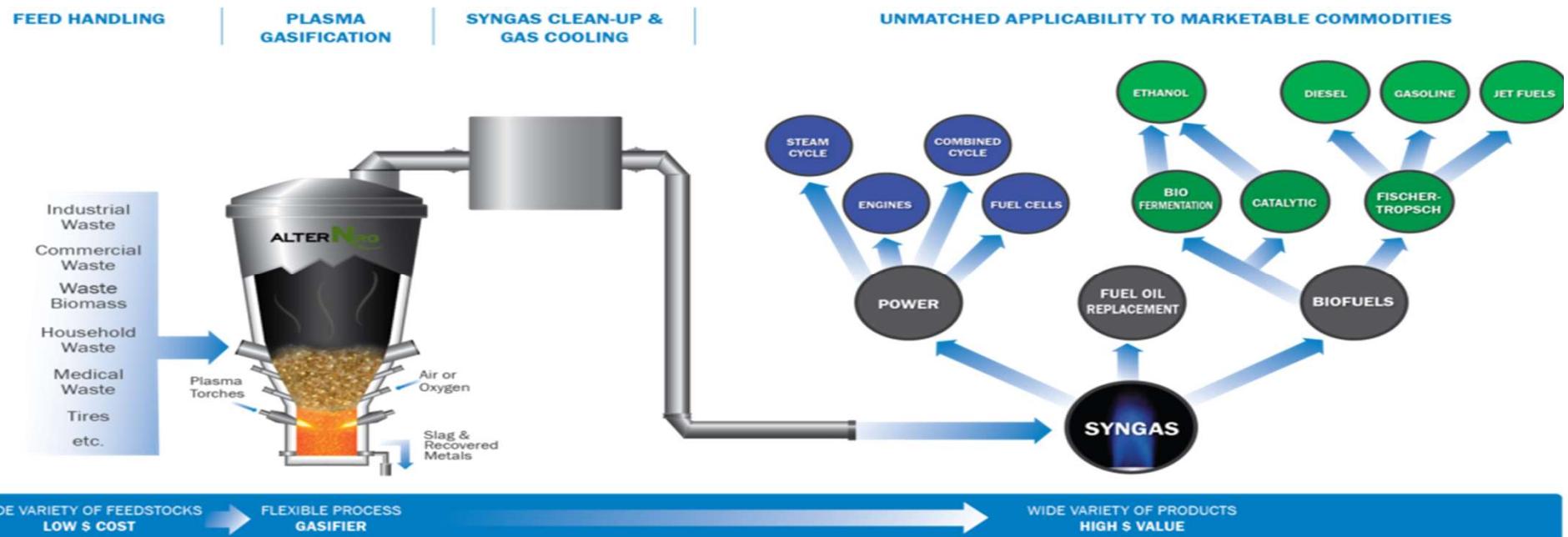
- Gasification involves conversion of waste into **syngas** – a mixture of CO and H<sub>2</sub> – by reacting it with steam or by heating at 1300°C in an oxygen-limited atmosphere. The syngas is then reacted with steam to convert CO to CO<sub>2</sub> and H<sub>2</sub>. Finally, CO<sub>2</sub> is separated from the CO<sub>2</sub>/H<sub>2</sub> mixture, by contact with physical solvents in an absorption column, and the resulting H<sub>2</sub> is burnt to produce power, leaving H<sub>2</sub>O as the main gaseous product emitted to the atmosphere.

## Feed Materials



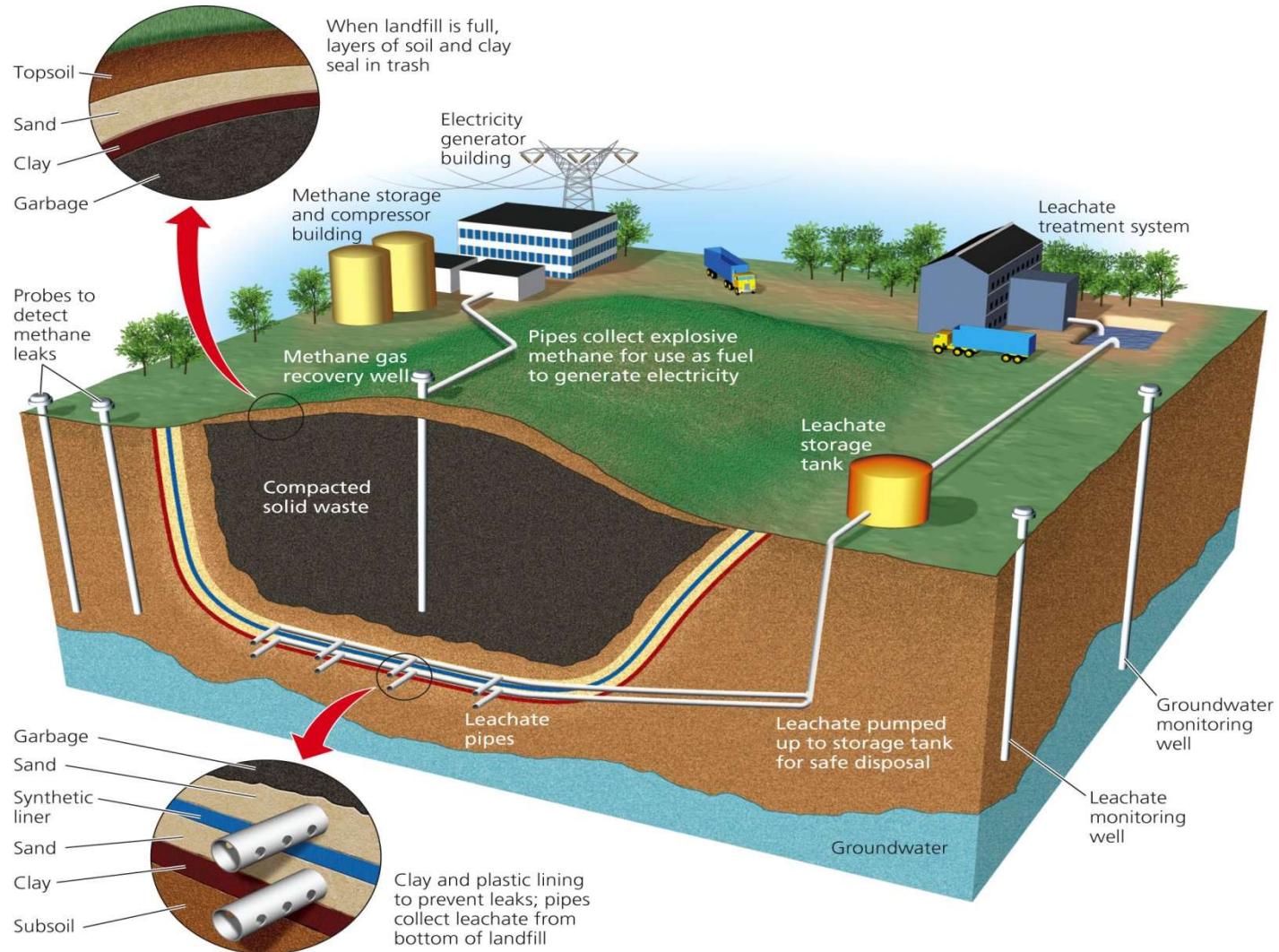
# Plasma gasification

- Plasma gasification uses electrical energy to create high temperature ( $>2000^{\circ}\text{C}$ ) plasma arc for **waste gasification**. The plasma arc effectively breaks down the waste material into elemental molecules and produces syngas and inert vitreous slag as outputs.
- The syngas, which contains dust (particulates) and other undesirable elements like mercury, undergoes a clean-up process to make it suitable for conversion into other forms of energy including power, heat and liquid fuels.
- The slag has the potential for use as rock wool, landfill cover, reclamation purposes, base material for construction, landscaping blocks, asphalt road and pavement aggregate among other possible applications.



# Burying solid waste (sanitary landfills)

- Sanitary landfills are sites where waste is isolated from the environment until it is safe, i.e., when it has completely degraded biologically, chemically and physically.



# The good and bad of sanitary landfills



## Trade-Offs

### Sanitary Landfills

#### Advantages

- No open burning
- Little odor
- Low groundwater pollution if sited properly
- Can be built quickly
- Low operating costs
- Can handle large amounts of waste
- Filled land can be used for other purposes
- No shortage of landfill space in many areas



#### Disadvantages

- Noise and traffic
- Dust
- Air pollution from toxic gases and trucks
- Releases greenhouse gases (methane and CO<sub>2</sub>) unless they are collected
- Slow decomposition of wastes
- Output approach that encourages waste production
- Eventually leaks and can contaminate groundwater



# Waste reduction



- Waste reduction is based on three R's:
  - **Reduce:** consume less and live a simpler lifestyle
  - **Reuse:** rely more on items that can be used repeatedly instead of throwaway items, and buy necessary items secondhand or borrow or rent them
  - **Recycle:** separate and recycle paper, glass, cans, plastics, metal, and other items, and buy products made from recycled materials



# Reusing solid waste



- Reuse involves cleaning and using materials over and over, thus increasing the typical life span of a product.
- Decreases the use of matter and energy resources, cuts pollution and waste, creates local jobs, and saves money.
- Reuse strategies include yard sales, flea market, secondhand stores, and online sites such as e-bay and craigslist.
- Current available technology allows reuse of many items.
- Encourage the use of refillable containers and reusable bags.





# Reusing solid waste

## What Can You Do?

### Reuse

- Buy beverages in refillable glass containers instead of cans or throwaway bottles
- Use reusable plastic or metal lunchboxes
- Carry sandwiches and store food in the refrigerator in reusable containers instead of wrapping them in aluminum foil or plastic wrap
- Use rechargeable batteries and recycle them when their useful life is over
- Carry groceries and other items in a reusable basket, a canvas or string bag, or a small cart
- Buy used furniture, computers, cars, and other items instead of buying new
- Give away or sell items you no longer use



# Recycling solid waste

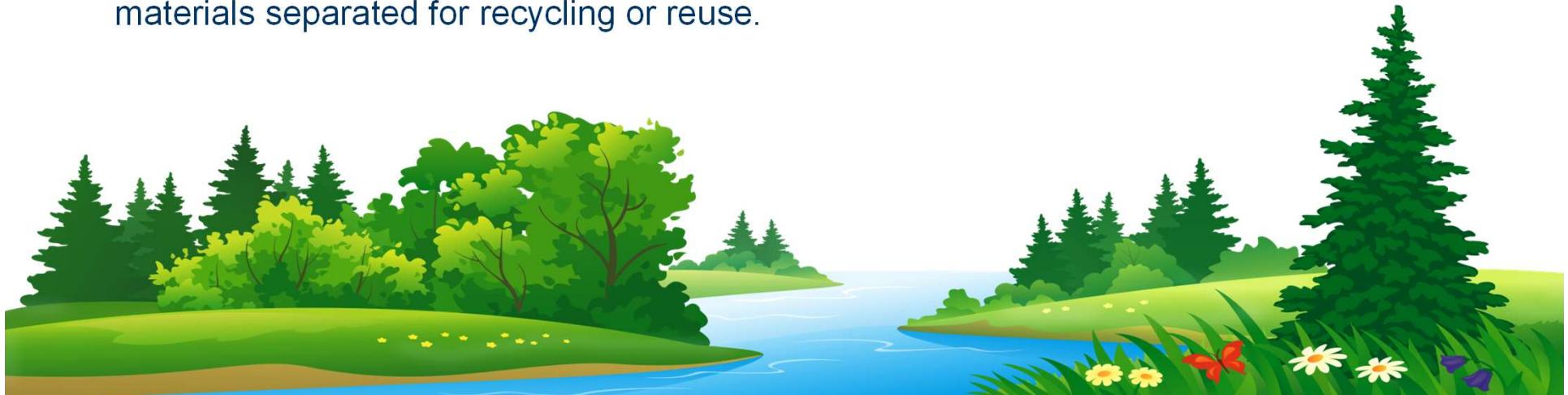
- Recycling involves reprocessing discarded solid materials into new, useful products.
- Two types of wastes can be recycled:
  - Preconsumer / Internal waste: generated in a manufacturing process.
  - Postconsumer / External waste: generated by consumer use of products.
- Such materials can be reprocessed in two ways:
  - Primary / Closed-loop recycling: materials are recycled into new products of the same type. e.g., used aluminum cans can be turned into new aluminum cans.
  - Secondary recycling: waste materials are converted into different products. e.g., used tires can be shredded and turned into rubberized road surfacing.



# Recycling household solid waste



- We can mix or separate household solid wastes for recycling.
- Materials recovery facilities (MRFs) involve machines or workers to separate the mixed wastes to recover valuable materials for sale to manufacturers as raw materials. The remaining wastes are either recycled or burned to produce steam or electricity.
- Source separation approach encourage households and businesses to separate their trash into recyclable categories such as glass, paper, metals, certain types of plastics, and compostable materials, thus saving more energy and reduces environmental pollution.
- Pay-as-you-throw (PAUT) or fee-per-bag waste collection system charges households and businesses for the amount of mixed waste picked up, but does not charge for pickup of materials separated for recycling or reuse.



# Recycling biodegradable solid waste



- Composting is a form of recycling that mimics nature's recycling of nutrients.
- Composting involves using decomposer bacteria to recycle yard trimmings, food scraps, and other biodegradable organic waste.
- The resulting organic material can be added to soil to supply plant nutrients, slow soil erosion, retain water, and improve crop yields.
- Large-scale composting program must be located carefully and odors must be controlled, especially near residential areas.
- Composting programs must also exclude toxic materials that can contaminate the compost and make it unsafe for fertilizing crops and lawns.



# Recycling biodegradable solid waste



- Composting is a form of recycling that mimics nature's recycling of nutrients.
- Composting involves breaking down organic materials such as yard trimmings, food scraps, and other biodegradable wastes.
- The resulting organic material is a dark, crumbly substance rich in plant nutrients, slow soil erosion, retain water, and improve soil structure.
- Large-scale composting operations must be controlled, especially near residential areas. Odors must be controlled, especially near residential areas.
- Composting programs can be effective if managed properly and make it unsafe if managed poorly.

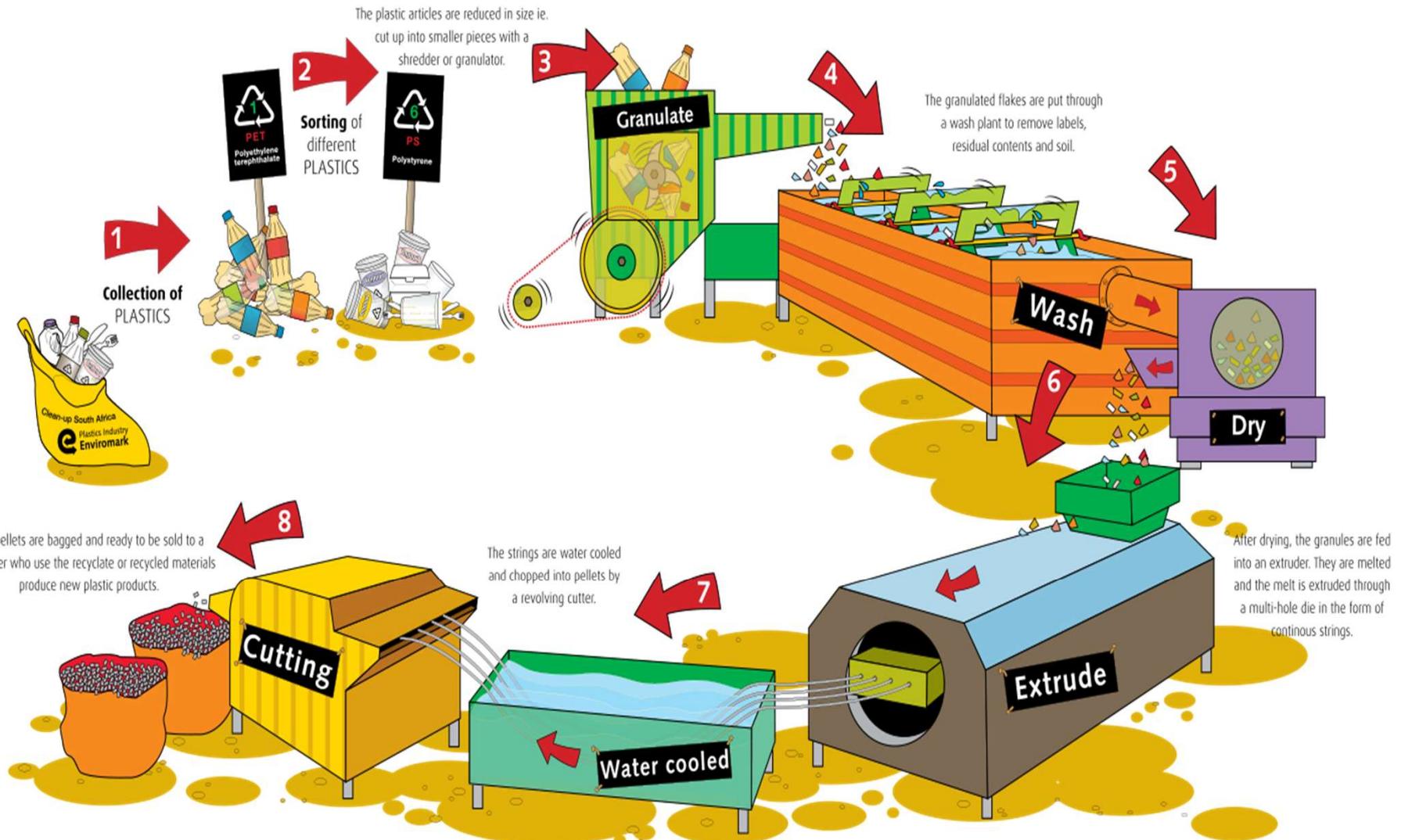


# Recycling plastics

- Conversion of high value engineering plastics from complex streams of goods such as computers, electronics, appliances, and automobiles into pellets.
- Plastic pellets are cheaper than virgin plastics since the processing technology uses 90% less energy than that needed to make a new plastic.
- Also the raw material is cheap or free junk.
- Environment friendly since greenhouse gas emissions are much lower than those from making virgin plastics.
- Recycling waste plastics further reduces the need to incinerate them or bury them in landfills.



# Plastics recycling sequence



# Plastics have several lives



# The good and bad of recycling



## Trade-Offs

### Recycling

#### Advantages

Reduces air and water pollution

Saves energy

Reduces mineral demand

Reduces greenhouse gas emissions

Reduces solid waste production and disposal

Helps protect biodiversity

Can save landfill space

Important part of economy



#### Disadvantages

Can cost more than burying in areas with ample landfill space

May lose money for items such as glass and some plastics

Reduces profits for landfill and incinerator owners



Source separation is inconvenient for some people

# Promoting reuse and recycling



- Governments can encourage reuse and recycling by adopting the following strategies:
  - increase subsidies and tax breaks for reusing and recycling materials.
  - decrease subsidies and tax breaks for making items from virgin sources.
  - greatly increase the fee-per-bag waste collection system.
  - encourage or require government purchases of recycled products.
  - pass laws requiring companies to take back and reuse or recycle packaging and electronic waste discarded by consumers.
  - informing the public about the merits of reuse and recycling.



# Waste reduction

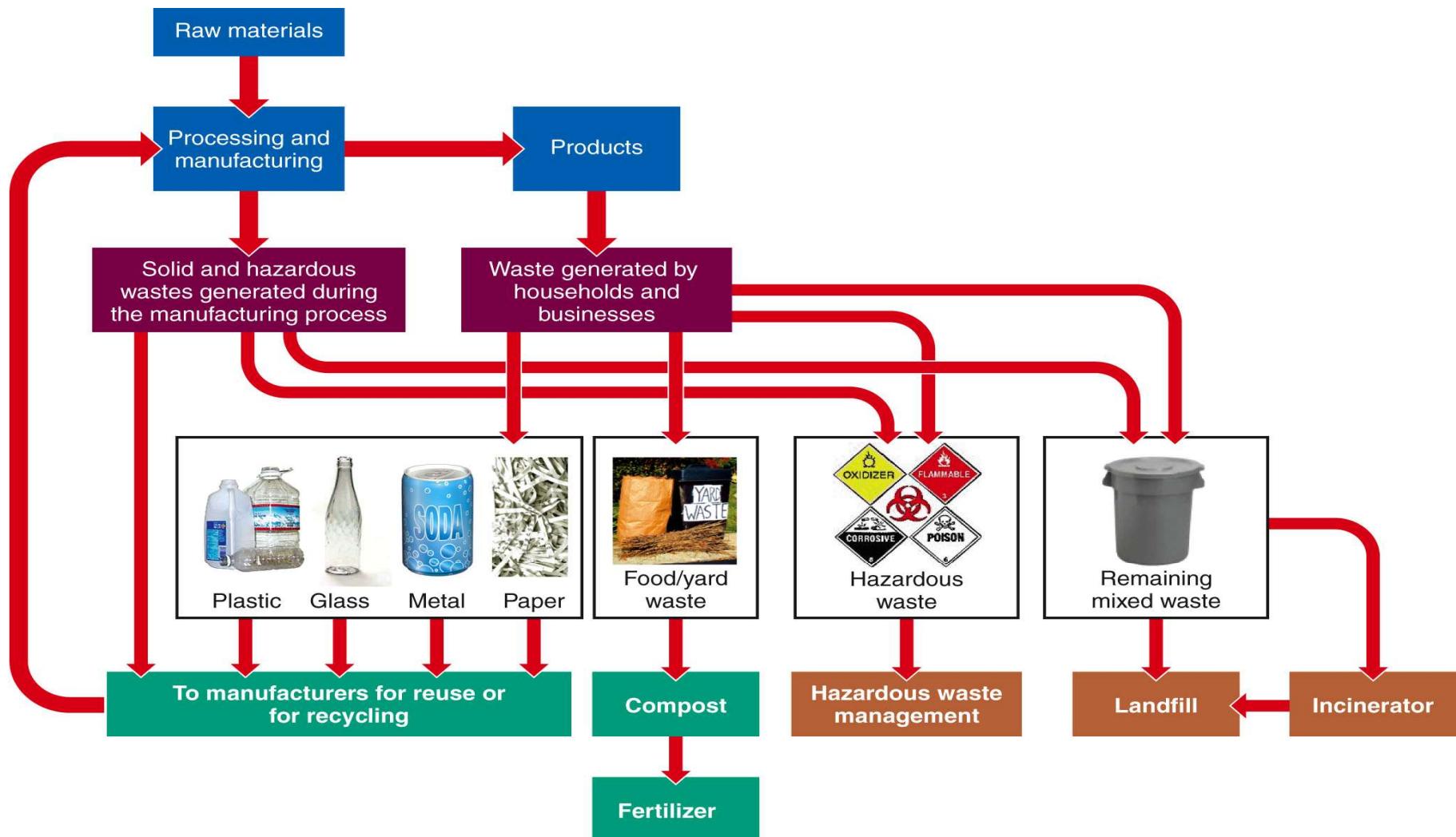


- Seven strategies that industries and governments can use to reduce resource use, waste and pollution:
  - redesign manufacturing processes and products to use less material and energy
  - redesign manufacturing processes to produce less waste and pollution
  - develop products that are easy to repair, reuse, remanufacture, compost or recycle
  - eliminate or reduce unnecessary packaging
  - use fee-per-bag waste collection systems
  - establish cradle-to-grave responsibility laws
  - restructure urban transportation systems



# Integrated waste management

- Wastes are reduced through reuse, recycling, and composting, or managed by burying them in landfills or incinerating them.



# Dealing with hazardous waste



- Priorities suggested by the US National Academy of Sciences for dealing with hazardous waste.

## Produce Less Hazardous Waste

- Change industrial processes to reduce or eliminate hazardous waste production
- Recycle and reuse hazardous waste

## Convert to Less Hazardous or Nonhazardous Substances

- Natural decomposition
- Incineration
- Thermal treatment
- Chemical, physical, and biological treatment
- Dilution in air or water

## Put in Perpetual Storage

- Landfill
- Underground injection wells
- Surface impoundments
- Underground salt formations



# Dealing hazardous waste



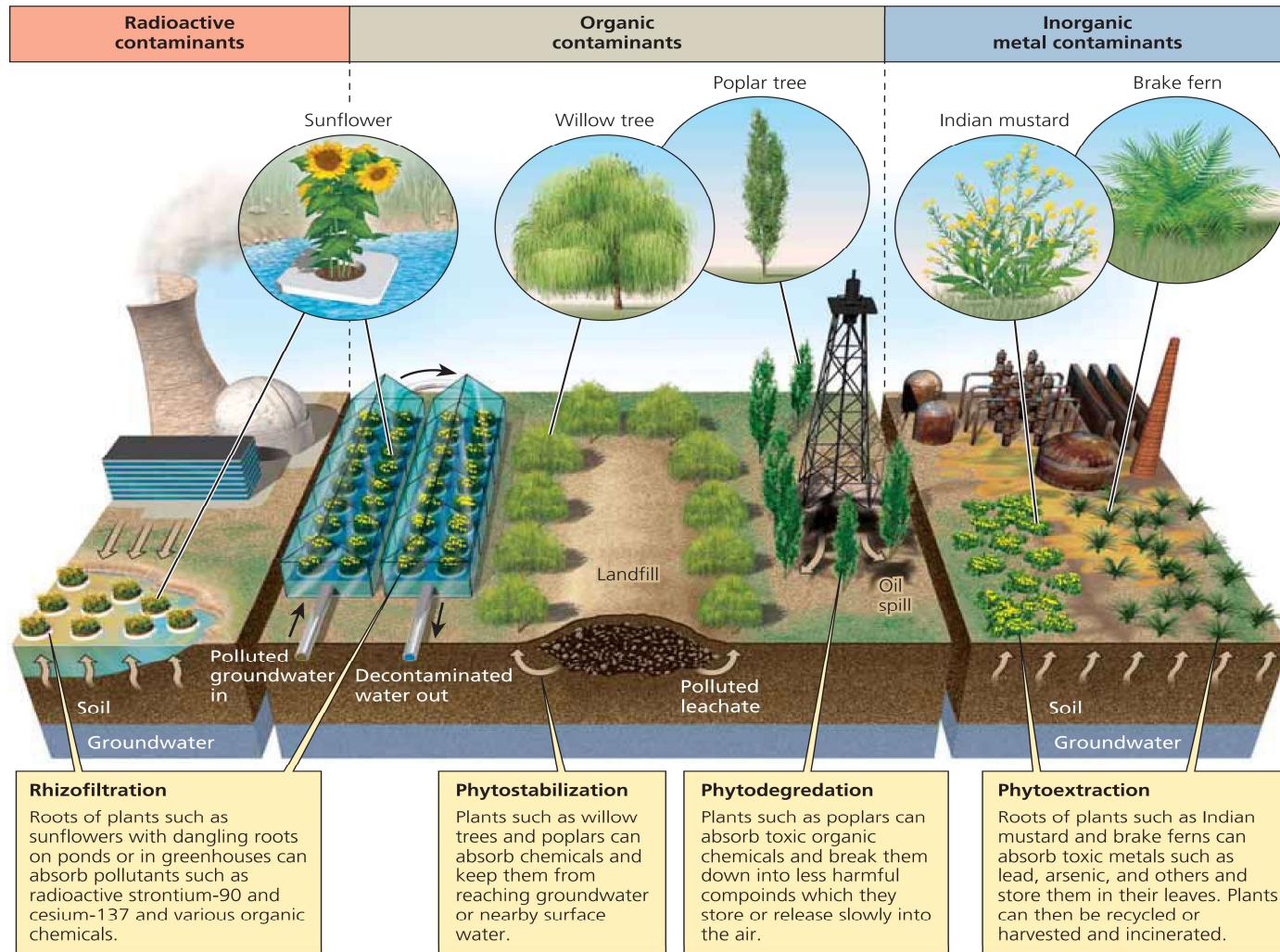
## ■ Detoxification

- **Bioremediation:** bacteria or enzymes help destroy toxic and hazardous waste or convert them to more benign substances.
- **Phytoremediation:** involves using natural or genetically engineered plants to absorb, filter and remove contaminants from polluted soil and water.
- **Incineration:** heating many types of hazardous waste to high temperatures – up to 2000°C – in an incinerator can break them down and convert them to less harmful or harmless chemicals.
- **Plasma arc torch:** passing electrical current through gas to generate an electric arc and very high temperatures can create plasma which can decompose liquid or solid hazardous organic material.



# Dealing hazardous waste

- Various types of plants can be used as pollution sponges to clean up soil and water and radioactive substances (left), organic compounds (center), and toxic metals (right).



# The good and bad of phytoremediation



## TRADE-OFFS

### Phytoremediation

#### Advantages

Easy to establish

Inexpensive

Can reduce material dumped into landfills

Produces little air pollution compared to incineration

Low energy use



#### Disadvantages

Slow (can take several growing seasons)

Effective only at depth plant roots can reach

Some toxic organic chemicals may evaporate from plant leaves

Some plants can become toxic to animals

# Dealing hazardous waste



## ■ Storing hazardous waste

- **Deep-well disposal:** liquid hazardous wastes are pumped under pressure into dry porous rock far beneath aquifers.
- **Surface impoundments:** excavated depressions such as ponds, pits, or lagoons into which liners are placed and liquid hazardous wastes are stored.
- **Long-term retrievable storage:** some highly toxic materials cannot be detoxified or destroyed. Metal drums are used to stored them in areas that can be inspected and retrieved.
- **Secure landfills:** hazardous waste are put into drums and buried in carefully designed and monitored sites.



# The good and bad of deep-well disposal



## TRADE-OFFS

### Deep-Well Disposal

#### Advantages

Safe method if sites are chosen carefully

Wastes can often be retrieved if problems develop

Easy to do

Low cost

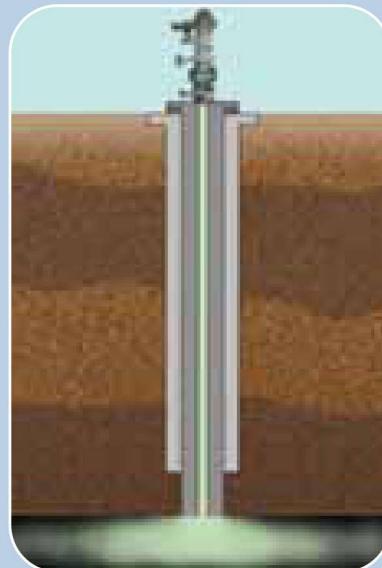
#### Disadvantages

Leaks or spills at surface

Leaks from corrosion of well casing

Existing fractures or earthquakes can allow wastes to escape into groundwater

Output approach that encourages waste production



# The good and bad of surface impoundments



## TRADE-OFFS

### Surface Impoundments

#### Advantages

Low construction costs

Low operating costs

Can be built quickly

Wastes can often be retrieved if necessary

Can store wastes indefinitely with secure double liners

#### Disadvantages

Groundwater contamination from leaking liners (or no lining)

Air pollution from volatile organic compounds

Overflow from flooding

Disruption and leakage from earthquakes

Output approach that encourages waste production





## What Can You Do?

### Hazardous Waste

- Avoid using pesticides and other hazardous chemicals, or use them in the smallest amounts possible
- Use less harmful and usually cheaper substances instead of commercial chemicals for most household cleaners. For example, use vinegar to polish metals, clean surfaces, and remove stains and mildew; baking soda to clean utensils and to deodorize and remove stains; and borax to remove stains and mildew.
- Do not dispose of pesticides, paints, solvents, oil, antifreeze, or other hazardous chemicals by flushing them down the toilet, pouring them down the drain, burying them, throwing them into the garbage, or dumping them down storm drains. Instead, use hazardous waste disposal services available in many cities.

# Transition to a low-waste society



- **Grassroots actions:** Keep large numbers of incinerators, landfills, and hazardous waste treatment plants from being built in local areas.
- **Environmental justice:** Every person is entitled to protection from environmental hazards without discrimination.
- **International treaties:** Calls for phasing out the use of harmful persistent organic pollutants (POPs).
- **New vision:**
  - Everything is connected
  - There is no away, as in to throw away, for the wastes we produce
  - Polluters and producers should pay for the wastes they produce
  - Hazardous waste and recyclable waste should not be mixed
  - Mimic nature by reusing, recycling, or composting

