

Waste-to-Energy

(An Introduction)

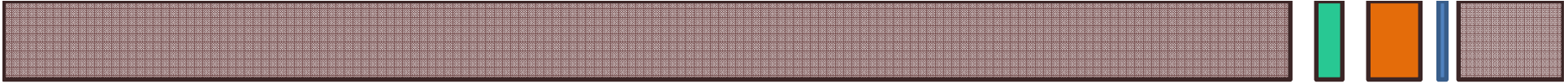
By

Moustafa M. Elsayed

Professor & Consultant, EGEC

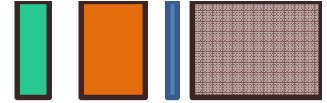
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- Municipality Solid Waste
- Solid Waste Management
- Hazardous Waste
- Landfills
- Zero Waste
- Established Waste Treatment Technologies
- New Waste Treatment Technologies
- Waste Calorific Values
- Environmental Concerns
- Waste Burning
- Plasma Gasification



Municipality Solid Waste

Municipality Solid Waste



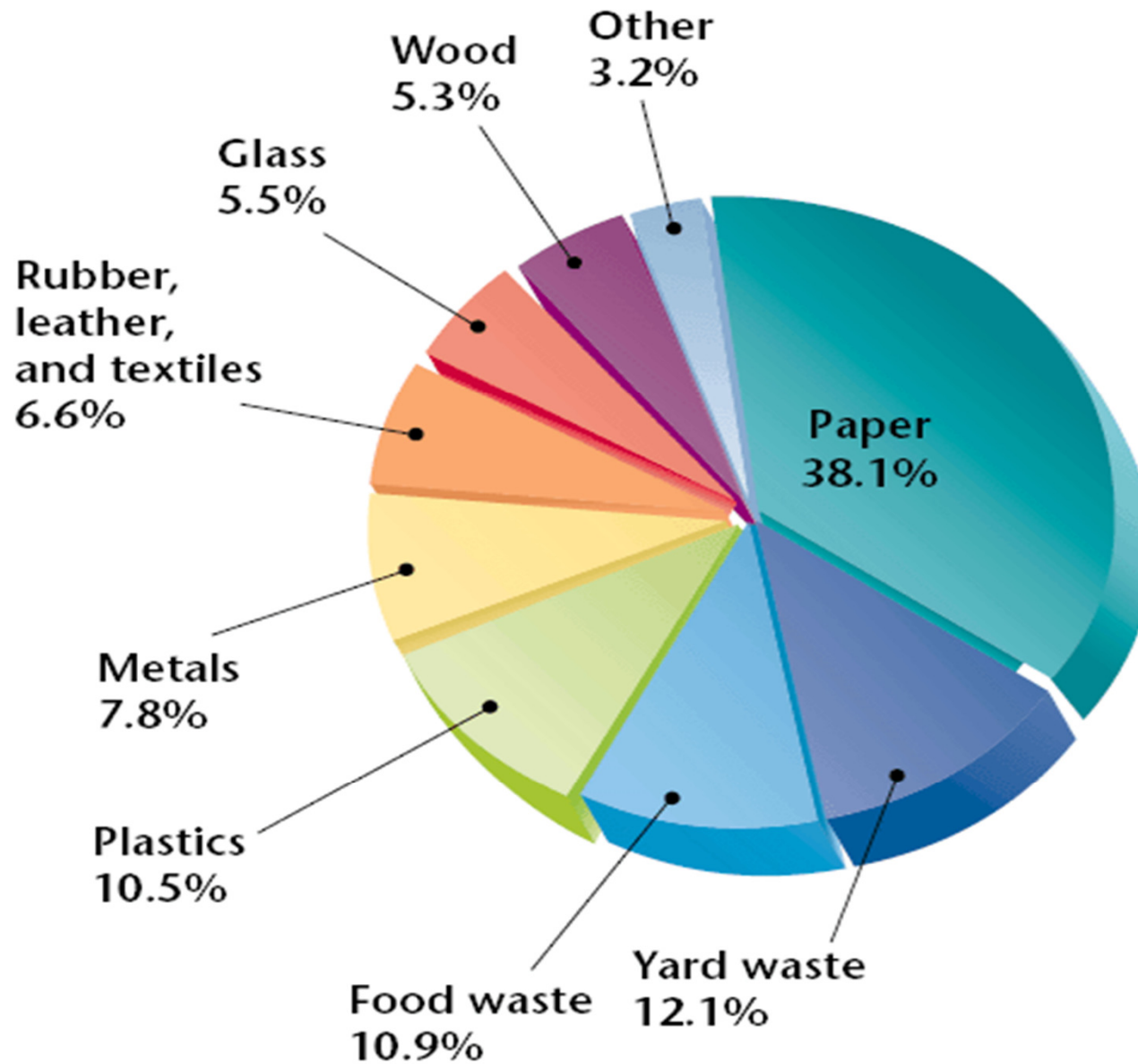
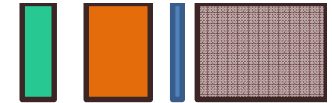
Municipality Solid Waste: Typical Composition - 1

Average waste component for Petaling Jaya (% by weight)

Composition	Residential					Shops	Institutional	Wet markets	Total arithmetic average
	High income	Medium income	Low income	Squatters	Average for residential				
Paper, cardboard and paper products	20.3	16.0	13.2	11.5	15.3	49.8	58.5	19.8	27.0
Vegetable and putrescibles (food and animal waste)	40.1	45.4	55.6	66.0	51.8	11.0	2.9	34.4	36.5
Rags, jute, hessian and textile, carpets, rugs, leather, etc.	1.6	2.1	4.6	5.5	3.5	4.7	0.9	2.4	3.1
Ferrous metals	2.4	2.8	3.4	3.3	3.0	2.7	1.0	5.1	3.0
Non-ferrous metals	4.4	0.3	0.2	0.0	1.6	0.2	1.0	0.2	0.9
Glass	6.5	4.5	5.6	0.4	4.3	1.2	0.9	2.7	3.1
Plastics	20.4	23.6	16.0	7.8	17.0	17.8	19.1	9.9	16.4
Rubber products	0.0	0.2	0.1	0.6	0.2	12.6	0.2	2.0	2.0
Timber products and waste	4.1	0.5	1.2	4.9	2.7	0.0	15.5	23.0	7.0
Other incombustible, ceramics, etc.	0.2	0.1	0.1	0.0	0.1	0.0	0.0	2.3	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

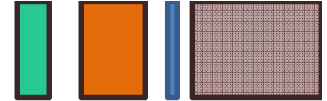
Source: Masterplan for Solid Waste Management for PJ Municipality (1990-2010).

Municipality Solid Waste: Typical Composition- 2

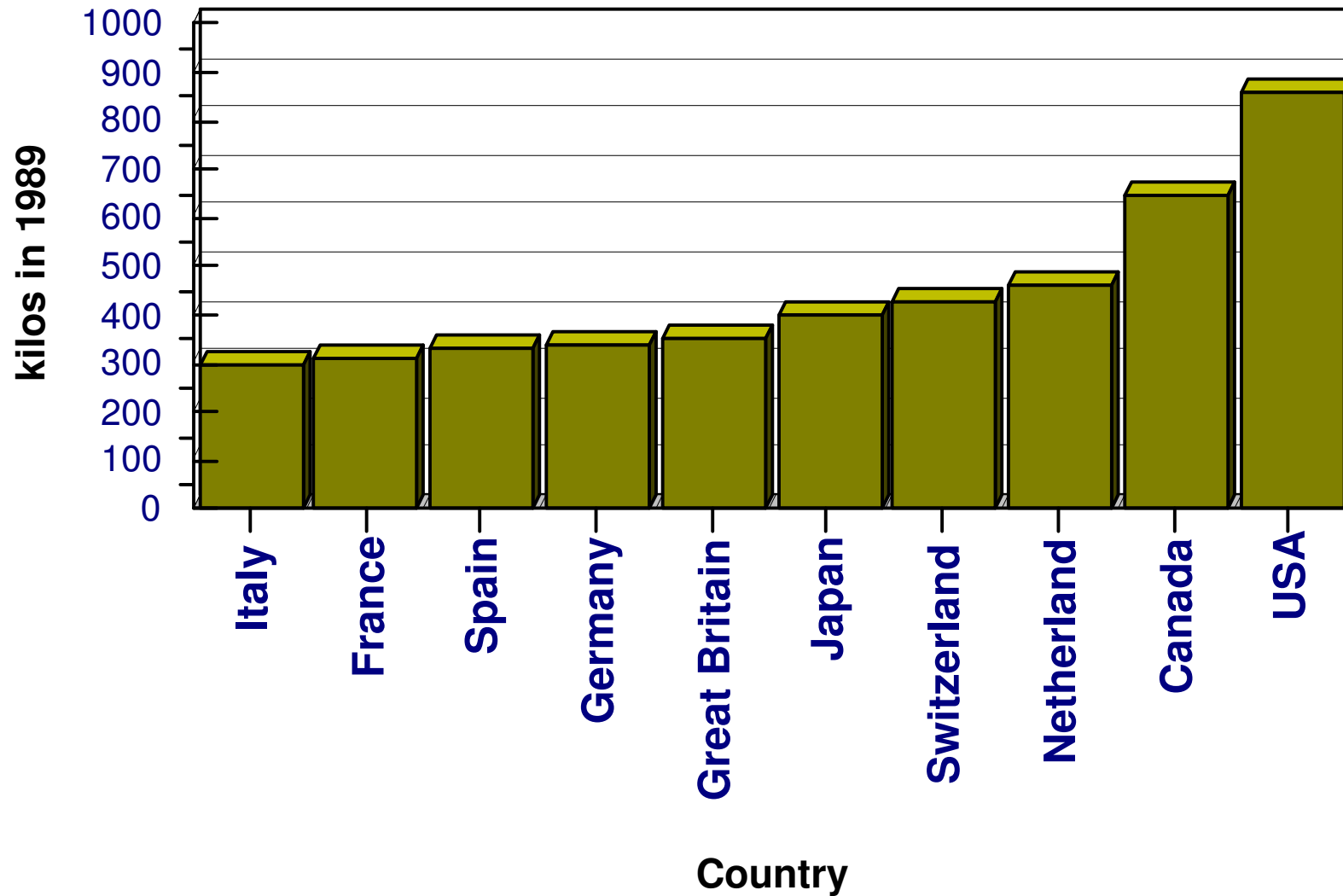


Source: U.S. Environmental Protection Agency.

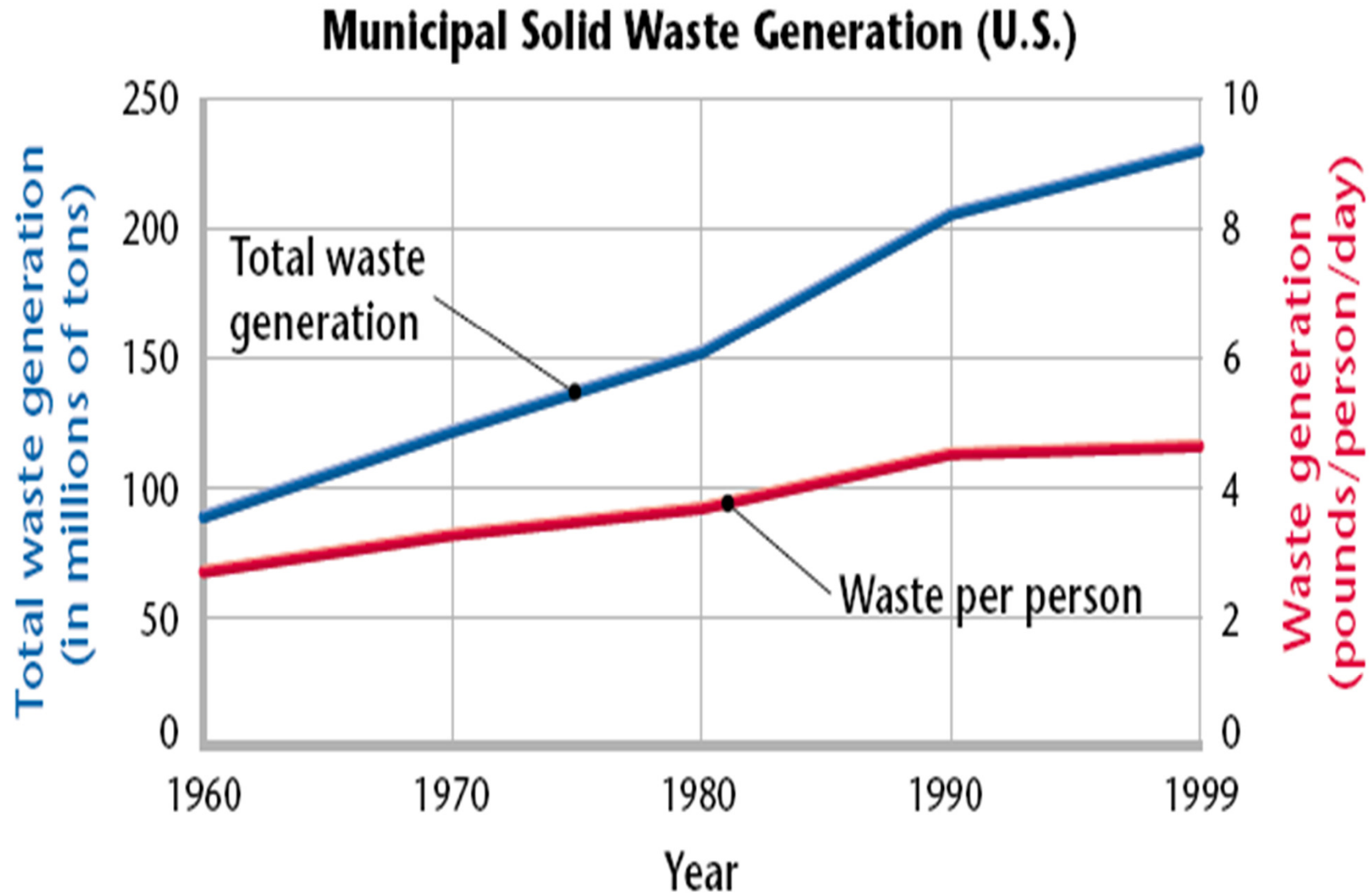
Municipality Solid Waste: Generation



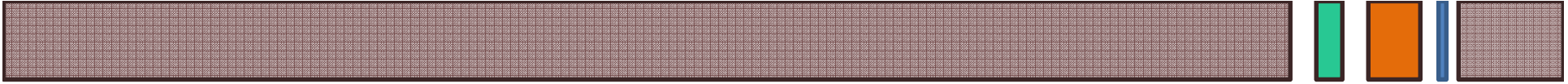
ANNUAL WASTE ACCUMULATION PER INHABITANT IN KILOS



Municipality Solid Waste: Generation



Source: U.S. Environmental Protection Agency.



Solid Waste Management

Solid Waste Management: Alternatives

- Reduce
 - Nude products (no packaging)
 - Long life products to avoid replacement
- Reuse
- Recycle
- Burning
- Burying
- Shipping



What Can You Do?

Reuse

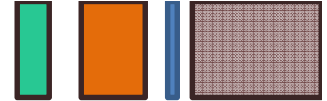
- Buy beverages in refillable glass containers instead of cans or throwaway bottles.
- Use reusable plastic or metal lunchboxes.
- Carry sandwiches and store food in the refrigerator in reusable containers instead of wrapping them in aluminum foil or plastic wrap.
- Use rechargeable batteries and recycle 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.
- Use reusable sponges and washable cloth napkins, dishtowels, and handkerchiefs instead of throwaway paper ones.

Reuse

- Beverages in refillable glass containers.
- Reusable or metal lunchboxes.
- Refrigerator reusable containers instead of wrapping in aluminum foil or plastic wrap.
- Rechargeable batteries.
- Groceries and other terms in reusable basket, a canvas or string bag, or a small cart.
- Reusable sponges and washable cloth napkins, dishtowels, and handkerchiefs instead of throwaway paper ones



Recycling



- Cost Effective Recycling

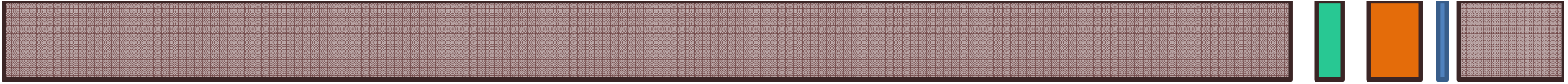
- Paper Products
- Aluminum
- Steel



- Expensive Recycling

- Glass
- Some Plastics





Hazardous Waste

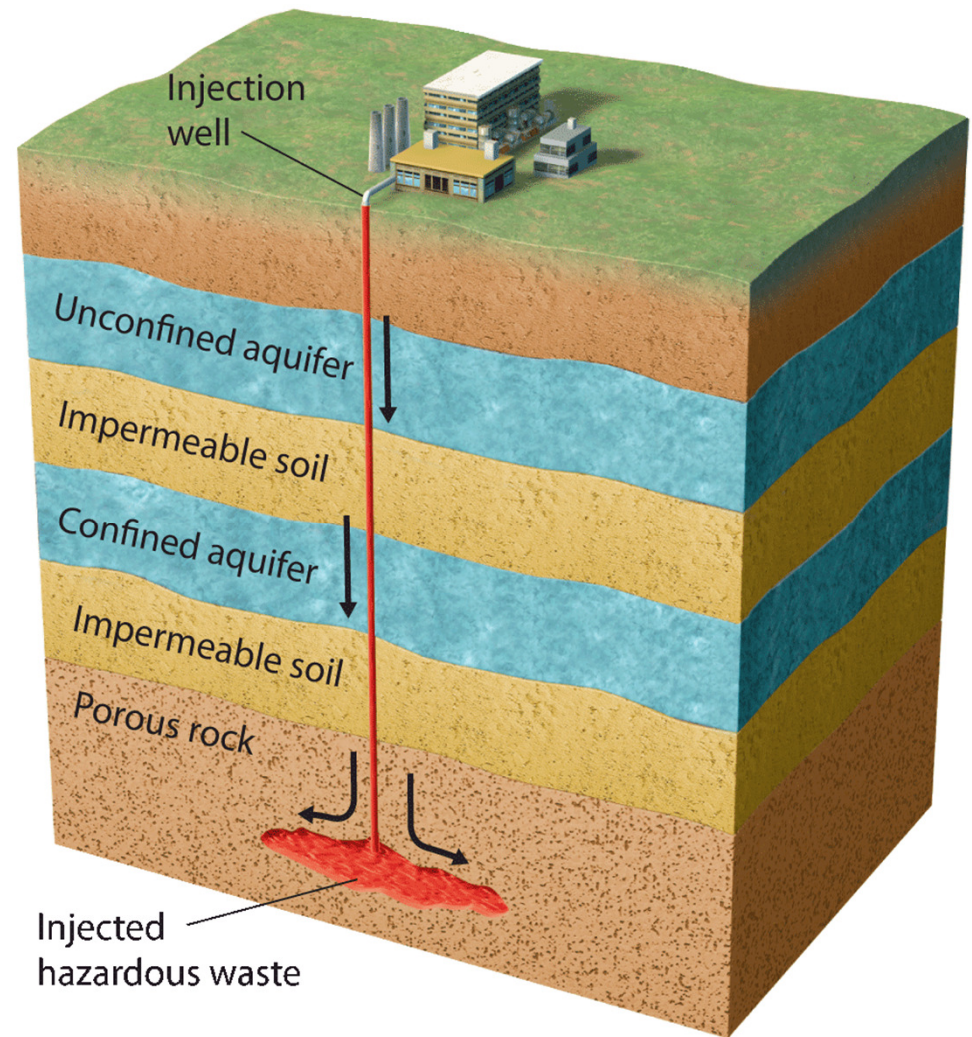
Hazardous Waste: Overview

- Any discarded solid or liquid that is toxic, ignitable, corrosive or reactive enough to explode or release toxic fumes.
- Ignitable: Can catch fire
- Corrosive: Can damage or destroy metals
- Reactive: can explode or produce fumes when combined with water
- Toxic: when inhaled, ingested, or touched
- Examples: batteries, cleaning agents, paints, and pesticides.

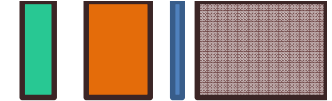


Hazardous Waste: Disposal

- Landfills: Specifically designed to keep hazardous waste contained
- Surface impoundment: Liquid waste poured into shallow lined pits; water evaporates and solid waste is transported elsewhere
- Deep-well injection (see diagram on right): Wastes injected into deep, confined porous rock layers



Hazardous Waste: Surface Impoundments



Trade-Offs

Surface Impoundments

Advantages

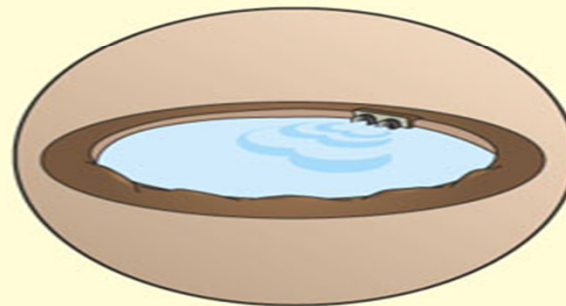
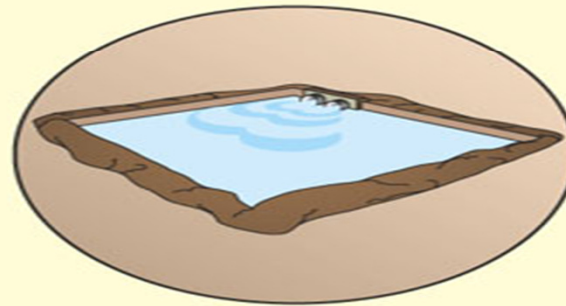
Low construction costs

Low operating costs

Can be built quickly

Wastes can 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

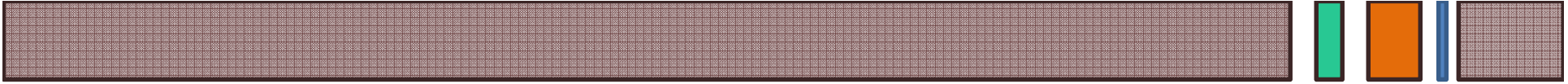
Disruption and leakage from earthquakes

Promotes waste production

E-Waste

- E-waste is the general category of outdated or eliminated electronic goods
- Broken TV parts ,CPU & CRT monitors of computers, cell phones etc. are examples
- A computer contain notable amount of toxic materials
- A desk top PC contains 57g of lead, 2.5g of barium,0.01g of arsenic 0.8g of antimony ,and other toxics
- If incinerated , they produce volatilized heavy metals & causes public health hazards





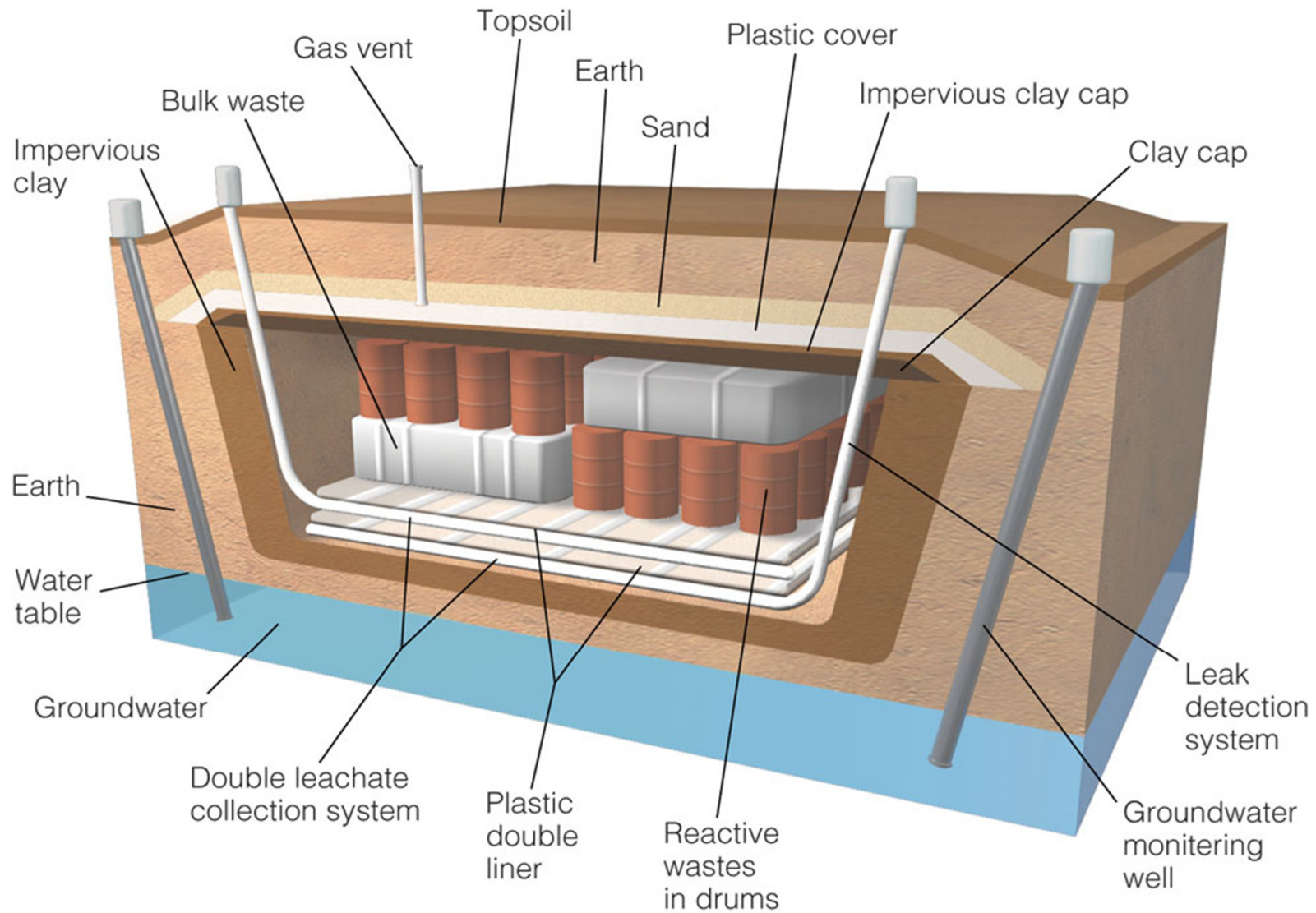
Landfills

Hazardous Waste: Landfills

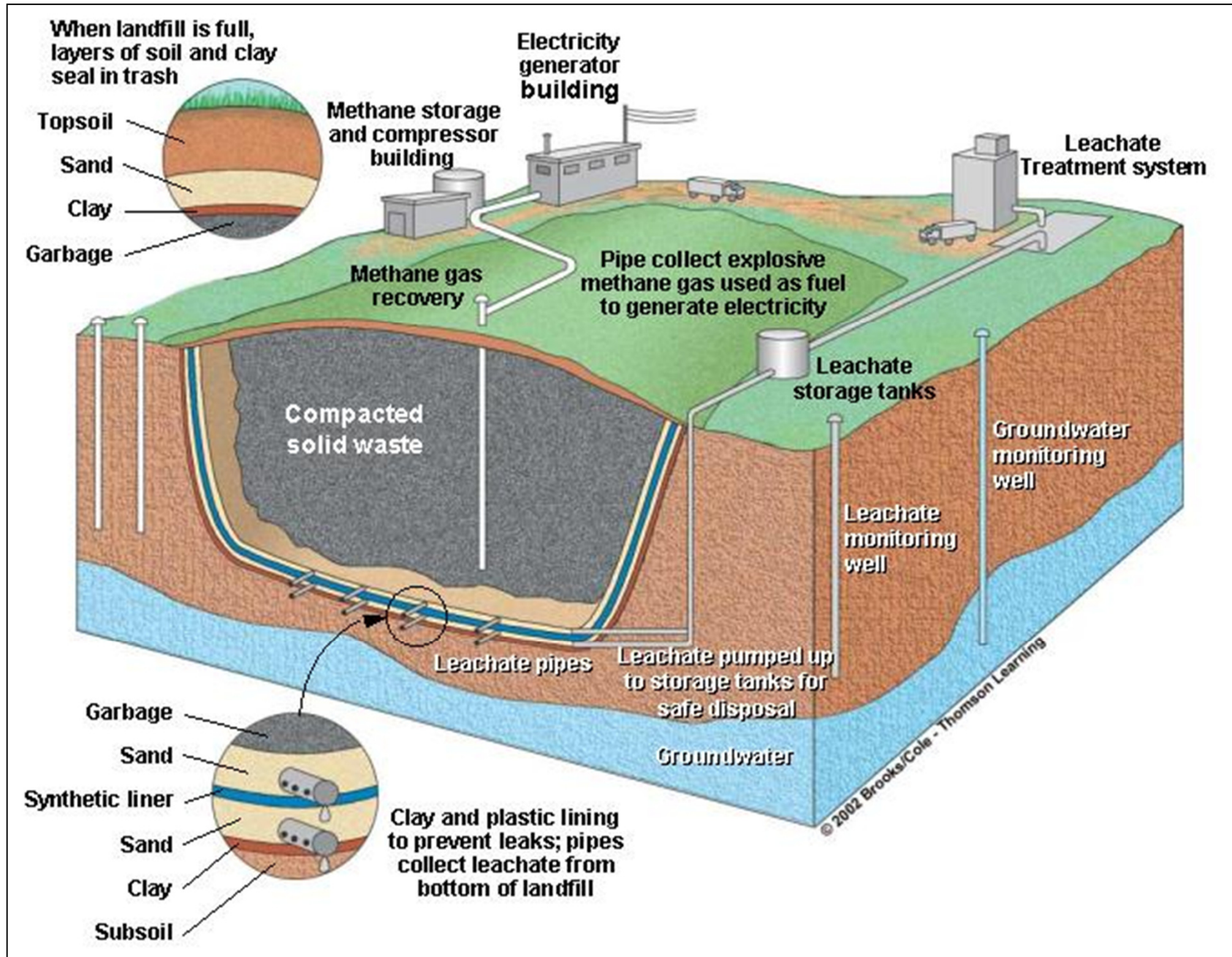
- Inexpensive, but dangerous solution
- Sooner or later uncontrolled chemical reactions will occur
- Creation of explosive methane gases
- Great danger to ground water and the environment



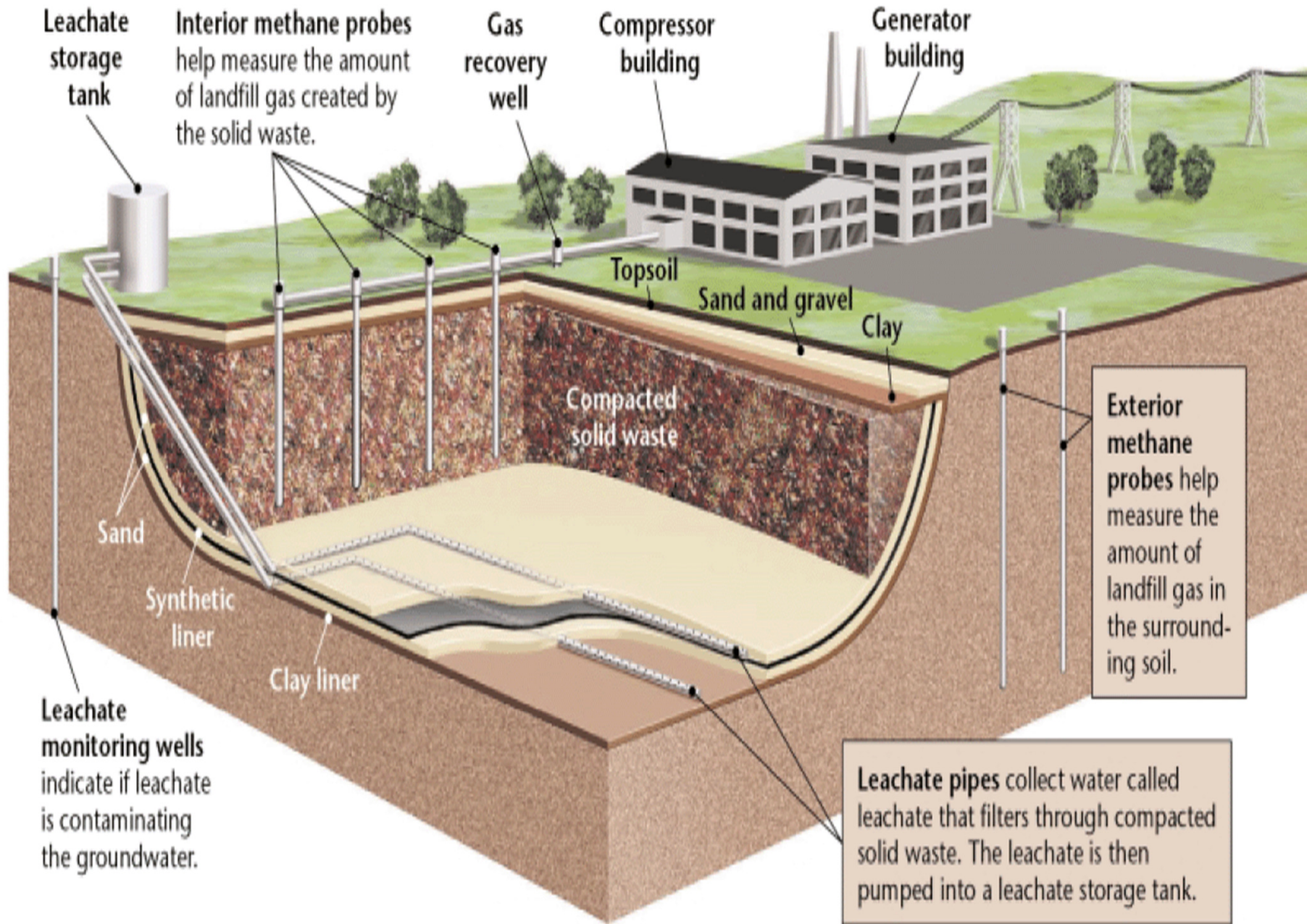
Hazardous Waste Landfills



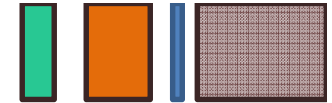
Sanitary Landfills



Sanitary Landfills



Sanitary Landfill: Pros & Cons



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 volatile organic compounds

Releases greenhouse gases (methane and CO₂) unless they are collected

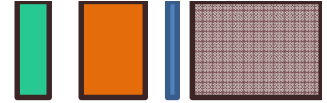
Groundwater contamination

Slow decomposition of wastes

Discourages recycling and waste reduction

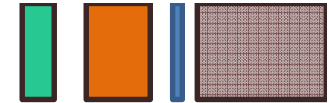
Eventually leaks and can contaminate groundwater

Sanitary Landfill: Costs



- Cost: Approximately about US\$ 40/ton

Solid Waste Management- Europe Treatment

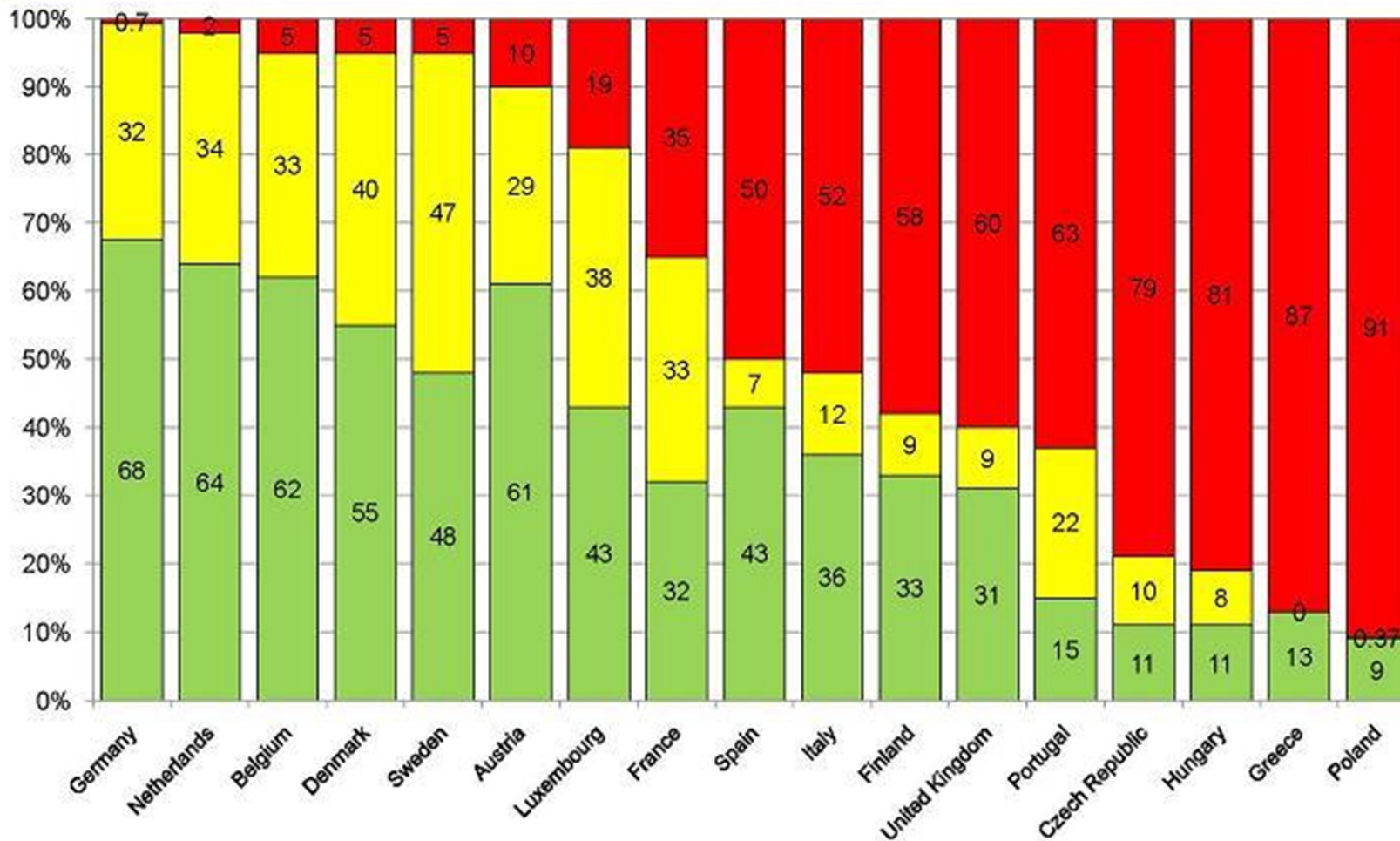


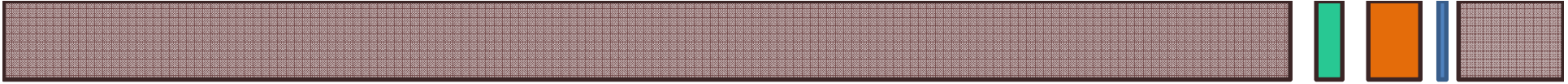
Treatment of MSW in the EU 27 in 2006

Source: EUROSTAT



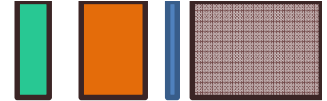
■ Recycling (Incl. Composting)
 ■ Waste-to-Energy
 ■ Landfilling





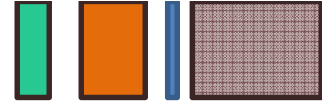
Established Waste Treatment Technologies

Waste Treatment Technologies: Established

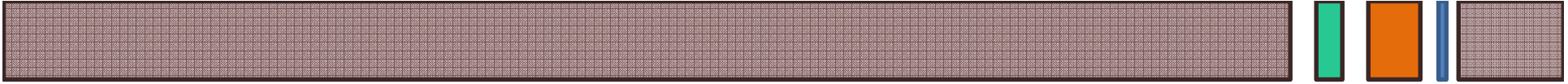


- Composting
- Incineration
- Landfills

Waste Treatment: Anaerobic Digestion

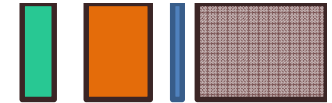


- A series of processes in which microorganism break down biodegradable material in the absence of oxygen.
- It is used for industrial or domestic purposes to manage waste and/or to release energy.
- Much of the fermentation used industrially to produce food and drink products, as well as home fermentation, uses anaerobic digestion.
- Silage is produced by anaerobic digestion. It is used as part of the process to treat biodegradable waste and sewage sludge.
- As part of an integrated waste management system, anaerobic digestion reduces the emission of landfill gas into the atmosphere. Anaerobic digesters can also be fed with purpose-grown energy crops, such as maize.



Waste Calorific Values

Waste Calorific Values - 1



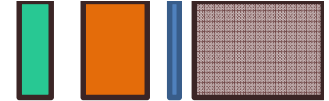
Secondary Energy Material

approx. kcal/kg

approx. kW/kg

Braun coal	4,500	5.2
Cardboard	3,800	4.4
Citrus peels	4,500	5.2
Car tires	8,300	9.6
Household waste (presorted)	4,500	5.2
Hospital waste	6,780	7.8
Manure (dried)	3,760	4.4
Neoprene	7,100	8.2
Nylon	7,570	8.8
Oil sludge	8,800	10.2
Paper	4,400	5.1
Paraffin	10,340	12.1

Waste Calorific Values - 2



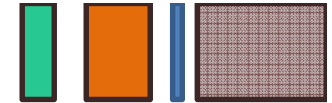
Secondary Energy Material

approx. kcal/kg

approx. kW/kg

Polyethylene	10,990	12.7
Polypropylene	11,030	12.8
Polystyrol EPS	9,800	11.3
Rubber	5,600	6.5
Sewage sludge (dried)	3,300	3.8
Tar and refinery residues	9,200	10.7
Tar acid	5,600	6.5
Textiles	4,000	4.6
Wood	4,200	4.8

Waste Calorific Values – Electrical Equivalent

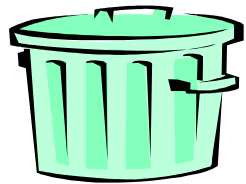


1 CONTAINER



1 HOUR

The energy of 1 container of yogurt (0.3 ltr) keeps a light bulb glowing for 1 hour



The waste put into a dust bin over 1 year contains enough energy to heat water



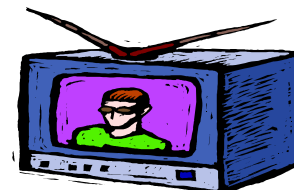
for

500 bath



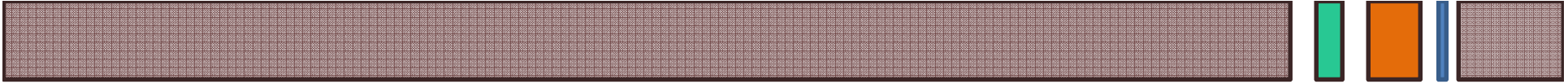
or

3,500 showers



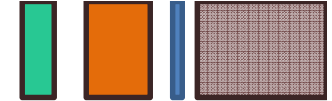
or

keep the TV on for 500 hours



Environmental Concerns

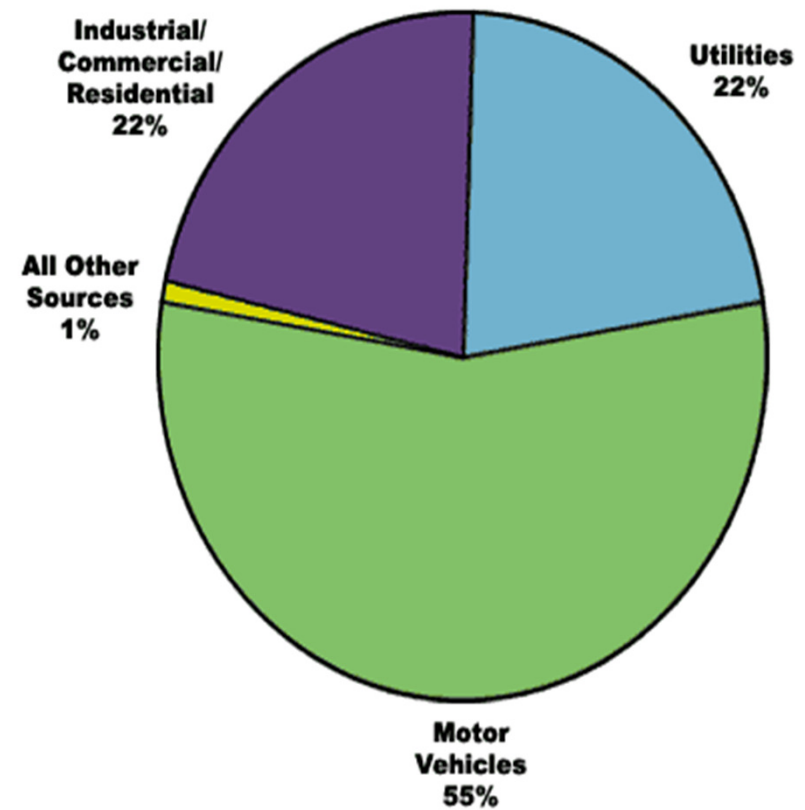
Environmental Concerns – Waste to Energy



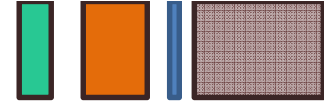
Air Emissions of Waste-To-Energy and Fossil Fuel Power Plants
(Pounds per Megawatt Hour)

Facility Type	Carbon Dioxide	Sulfur Dioxide	Nitrogen Oxides
Coal	2,249	13	6
Oil	1,672	12	4
Natural Gas	1,135	0.1	1.7
Waste-To-Energy	837	0.8	5.4

Manmade Sources of NOx Emissions - 2003

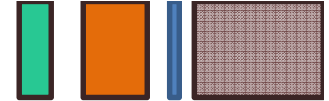


Environmental Concerns – Dioxins 1

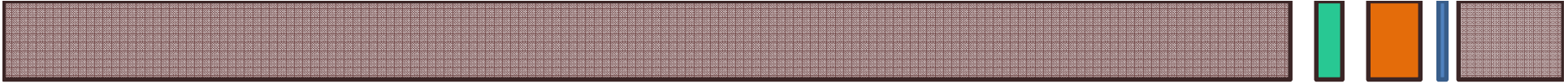


- These are super toxic chemical that can cause immune to nervous system damage.
- Dioxins are by-product of manufacture, molding, or burning of organic chemical.
- Dioxins toxicity is second to radioactive waste.
- In the incinerators Dioxins are destroyed due to high temperatures of over 1000° C
- Dioxins accumulate in the food chain, mainly in the fatty tissue of animals.
- More than 90% of human exposure is through food, mainly meat and dairy products, fish and shellfish.
- Dioxins are highly toxic and can cause reproductive and developmental problems, damage the immune system, interfere with hormones and also cause cancer.

Environmental Concerns - Dioxins 2



- All people have background exposure, which is not expected to affect human health. However, due to the highly toxic potential of this class of compounds, efforts need to be undertaken to reduce current background exposure.
- Prevention or reduction of human exposure is best done via source-directed measures, i.e. strict control of industrial processes to reduce formation of dioxins as much as possible.
- Dioxins are unwanted by products of a wide range of manufacturing processes including smelting, chlorine bleaching of paper pulp and the manufacturing of some herbicides and pesticides.
- In terms of dioxin release into the environment, uncontrolled waste incinerators (solid waste and hospital waste) are often the worst culprits, due to incomplete burning.



Waste To Energy Technologies

Thermal

Yields heat, fuel oil, or syngas from both organic and inorganic wastes

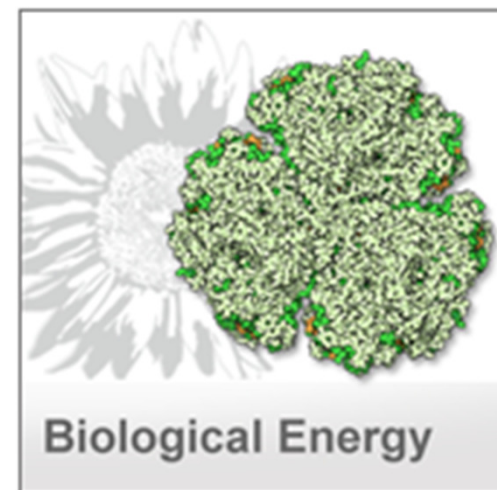
- Combustion
- Pyrolysis
- Thermal gasification
- Plasma-arc gasification



Biological

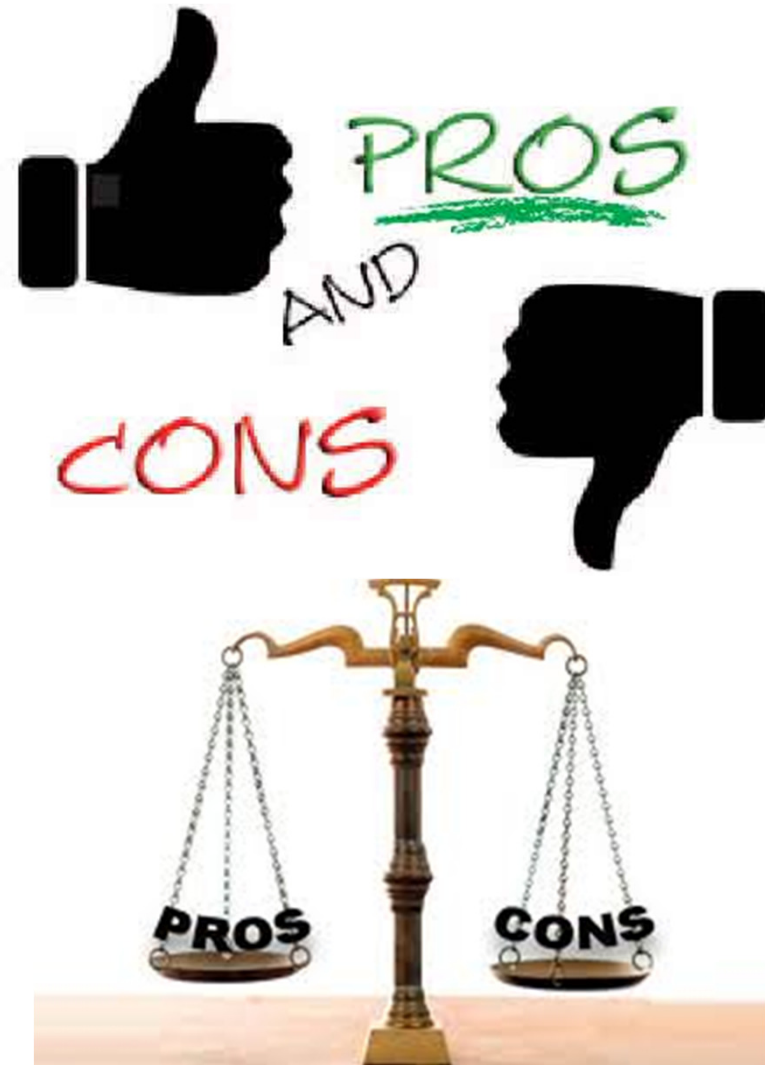
Bacterial fermentation is used to digest organic wastes to yield fuel

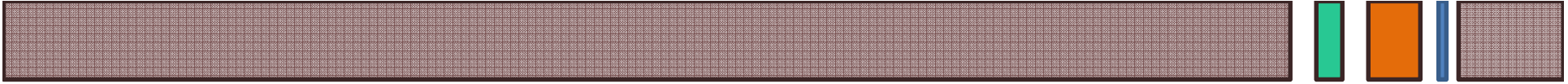
- Fermentation
- Methane capture/landfill gas



Waste-To-Energy Payoff

- WTE technologies solve problem of land use and pollution from landfills.
- WTE technologies solve problem of environmental perils of fossil fuels.
- WTE systems can be expensive.
- WTE is often limited in the types of waste they can use efficiently.





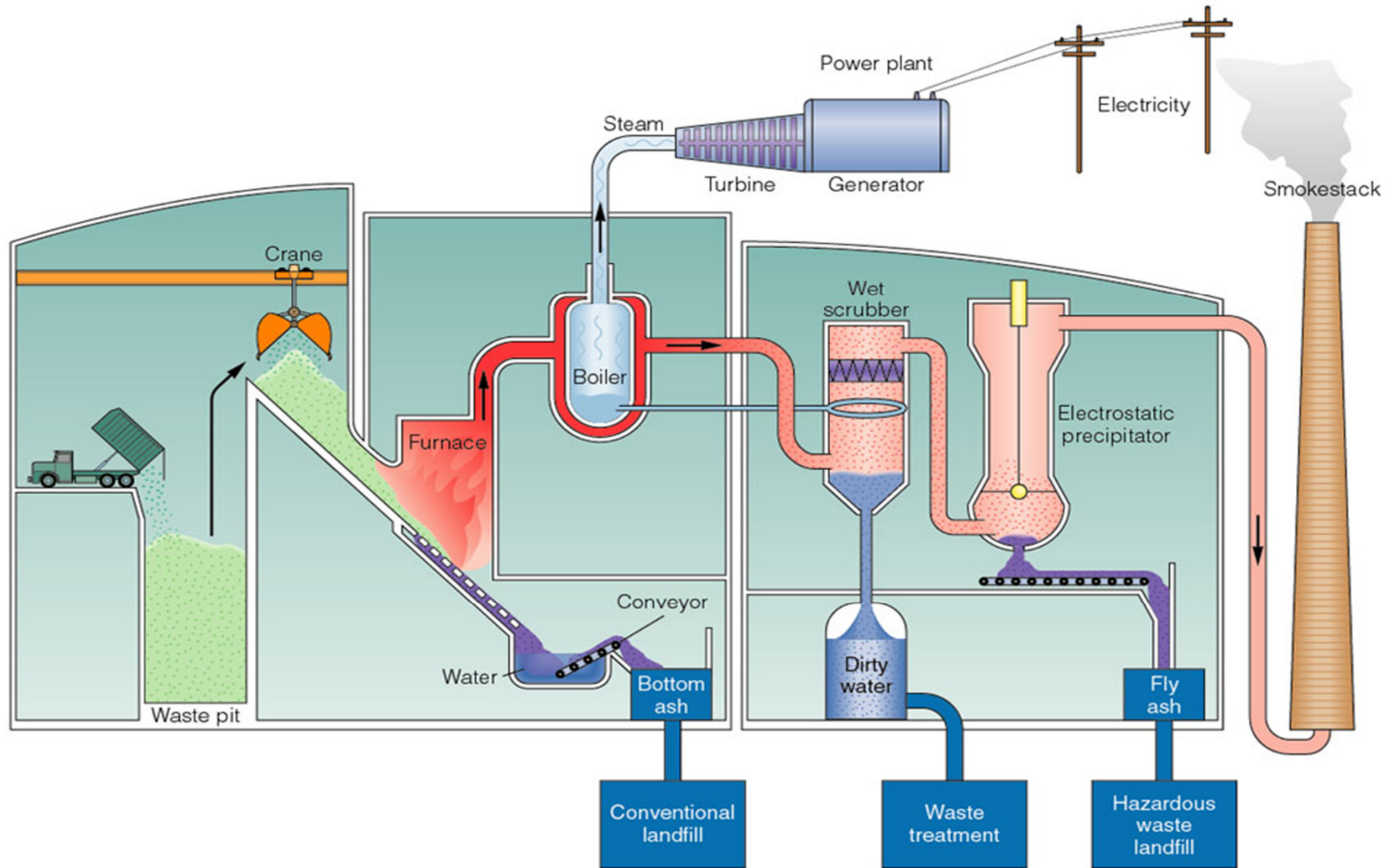
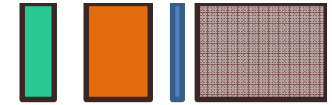
Waste Burning

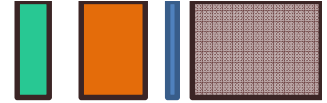
Waste Burning: Incinerator History



- 1865 - The first waste incinerator was built in Michigan
- 1874 - The “Destructor” was Britain’s first attempt to burn waste to produce energy
- 1905 - New York uses wastes incinerator to create electricity and light the Williamsburg Bridge
- 1930’s – Incinerators became too expensive, making waste dumps a more viable option

Waste Burning: Energy Plant (Incinerator)





Trade-Offs

Incineration

Advantages

Reduced trash volume

Less need for landfills

Low water pollution

Quick and easy



Disadvantages

High cost

Air pollution (especially toxic dioxins)

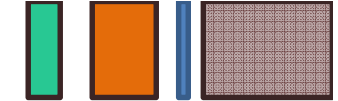
Produces a highly toxic ash

Encourages waste production

Discourages recycling and waste reduction

Waste Burning: Costs ???

- Problematic disposal of created ashes (approx. 25% of input)
- Incinerating waste reduces its weight by up to 75% and volume by up to 90%.
- Costs vary between US\$ 200.-/ton and US\$ 600.-/ton



Covanta Onondaga LP. Jamesville, New York

Case Study

The Onondaga County Resource Recovery Facility began commercial operation in February 1995, for the Onondaga County Resource Recovery Agency (OCCRA), which controls the waste flow in the County and the greater Syracuse region.

The facility processes 990 tons per day of municipal solid waste, generating up to 39.5 megawatts of electricity that is sold to Niagara Mohawk Power Corporation. The facility is equipped with an air-cooled condenser used for condensing turbine exhaust.



Technical Data

Facility Address:

5801 Rock Cut Road
Jamesville, NY 13078
(315) 498-4111

Site:

12 acres

Commercial operation:

25 February 1995

Energy from Waste System:

Three 330 ton-per-day dry waterwall furnaces with Martin® reverse-reciprocating grates and ash handling system.

Boiler design:

865 psig/830°F superheater outlet conditions

Air Pollution Control Equipment:

Semi-dry flue gas scrubbers injecting lime, fabric filter baghouses, nitrogen oxide control system, mercury control system and continuous emissions monitoring (CEM) system

Rated Refuse Capacity:

990 tons per day

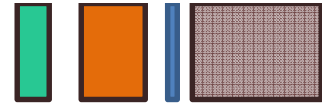
Energy Generation of Rated Capacity:

39.5 megawatts from one condensing steam turbine generator

Sold to:

Niagara Mohawk Power Corporation

Methane Capture



Organic waste is put into storage tanks. The decomposition process releases methane gas that can be siphoned off and stored. The same process creates methane pockets in landfills.

It is considered to have a double benefit because it prevents the methane that would be released from the landfill and also providing a cleaner burning alternative to more conventional fossil fuels.

Often used for small scale projects.

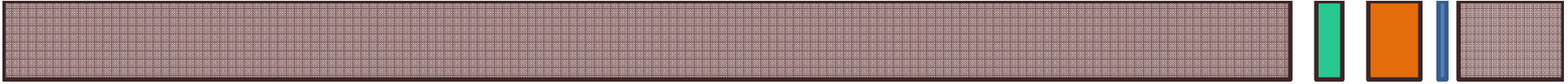
High Temperature Gasification

The process uses thermal decomposition to chemically breakdown waste and create a hydrogen rich synthetic gas.

The technology uses induction heating (similar to a microwave) as opposed to burning.

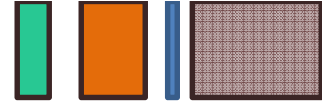
Along with the synthetic gas, the process also creates a ash like by product that can be reused.

The company advancing the technology claim that the process has a relatively small carbon footprint and that the process limits the toxicity of the ash.



Plasma Gasification

Plasma Gasification – Definition 1



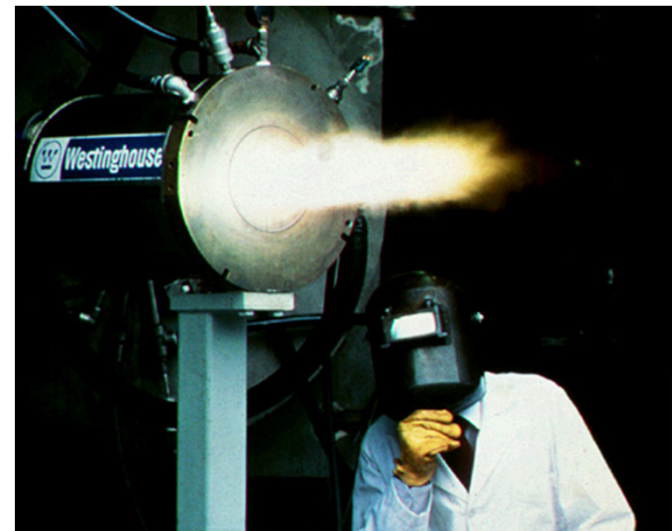
What is Plasma?

- Superheated gas where positive and negative charges are separated (ionized)
- Sun and lightning are natural plasma
- Man-made Plasma is created by passing electricity through a gas (air) causing a change in the state of the gas and a significant temperature increase often exceeding 10,000°F.

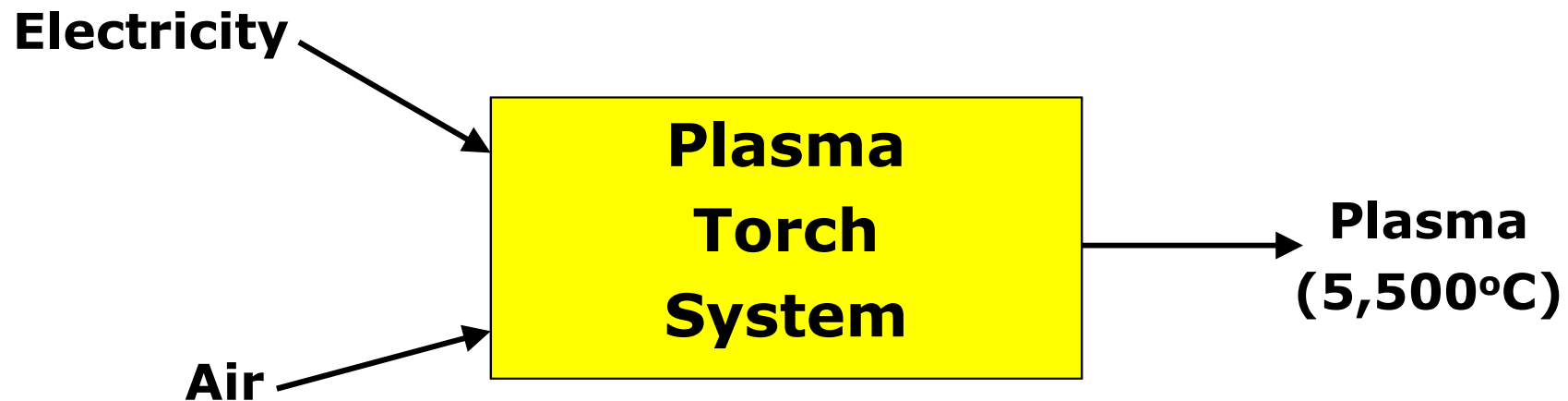


What is Gasification?

- Process that converts carbon-containing materials (MSW, biomass, coal, etc.) into a synthesis gas
- Syngas = carbon monoxide and hydrogen
- Syngas is a “cleaner” fuel than the original solid feedstock, resulting in cleaner emissions (reduced NO_x, SO₂)

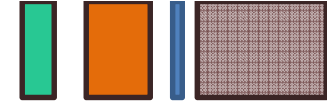


Plasma Gasification is not combustion
(Plasma Gasification is Not Incineration)



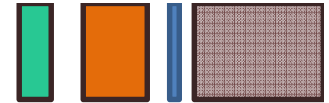
Plasma Gasification converts solid fuel or organic waste into a clean gaseous fuel

Plasma Gasification: Comparison with Burning



Plasma Gasification	Incineration
Occurs in the absence or near absence of oxygen, prohibiting combustion.	Excess air is induced to ensure complete combustion.
Gases resulting from degradation of organics are collected and used for production of various forms of energy and/or industrial chemicals.	All potential energy converted to heat.
Products of degradation largely converted to inert (non-hazardous) glass-like slag of a volume 6% to 15% of the original solids volume.	Combustion results in ash (as much as 30% of original solids volume) that must often be treated as hazardous waste.
Emissions substantially lower than those resulting from incineration.	Far greater emissions of GHG and other pollutants than with thermal gasification systems.

Plasma Gasification: Technology Experience



Location	Population	Materials	Capacity (TPD)	Start Date
Bordeaux, France	1.01 million	Ash from MSW	10	1998
Morcenx, France	4,993	Asbestos	22	2001
Bergen, Norway	213,000	Tannery waste	15	2001
Landskrona, Sweden	27,889	Fly ash	200	1983
Jonquiere, Canada	54,872	Aluminum dross	50	1991
Ottawa, Canada	1.1 million	MSW	85	2007
Alpoca, W. Virginia	613	Ammunition	10	2003

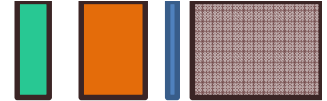
Plasma Gasification: Technology Experience

Location	Population	Materials	Capacity (TPD)	Start Date
Anniston, Alabama	24,276	Catalytic converters	24	1985
Madiso, Pennsylvania	510	Biomass, const. waste	18	2009
U.S. Army	--	Chemical agents	10	2004
Miham -Mikata, Japan	28,817	MSW/Sewage sludge	28	2002
Utashinai, Japan	5,221	MSW/ASR	300	2002
Kinura, Japan	40,806	MSW Ash	50	1995
Kakogawa, Japan	268,565	MSW Ash	30	2003

Plasma Gasification: History

- Plasma arc technology was used in industries in late 1800s to obtain high temperatures
- It was⁵⁵ used in 1900s in chemical industries for manufacturing acetylene from natural gas
- Used in 1960s by NASA to recreate high heat of re-entry encountered by space crafts
- The concept of Plasma Gasification was introduced by Dr. S. L. Camacho in a patent in 1973.
- Recently in 2000s pilot scale research at MIT ;10,000°C plasma –arc was used to melt waste material into lava like liquid

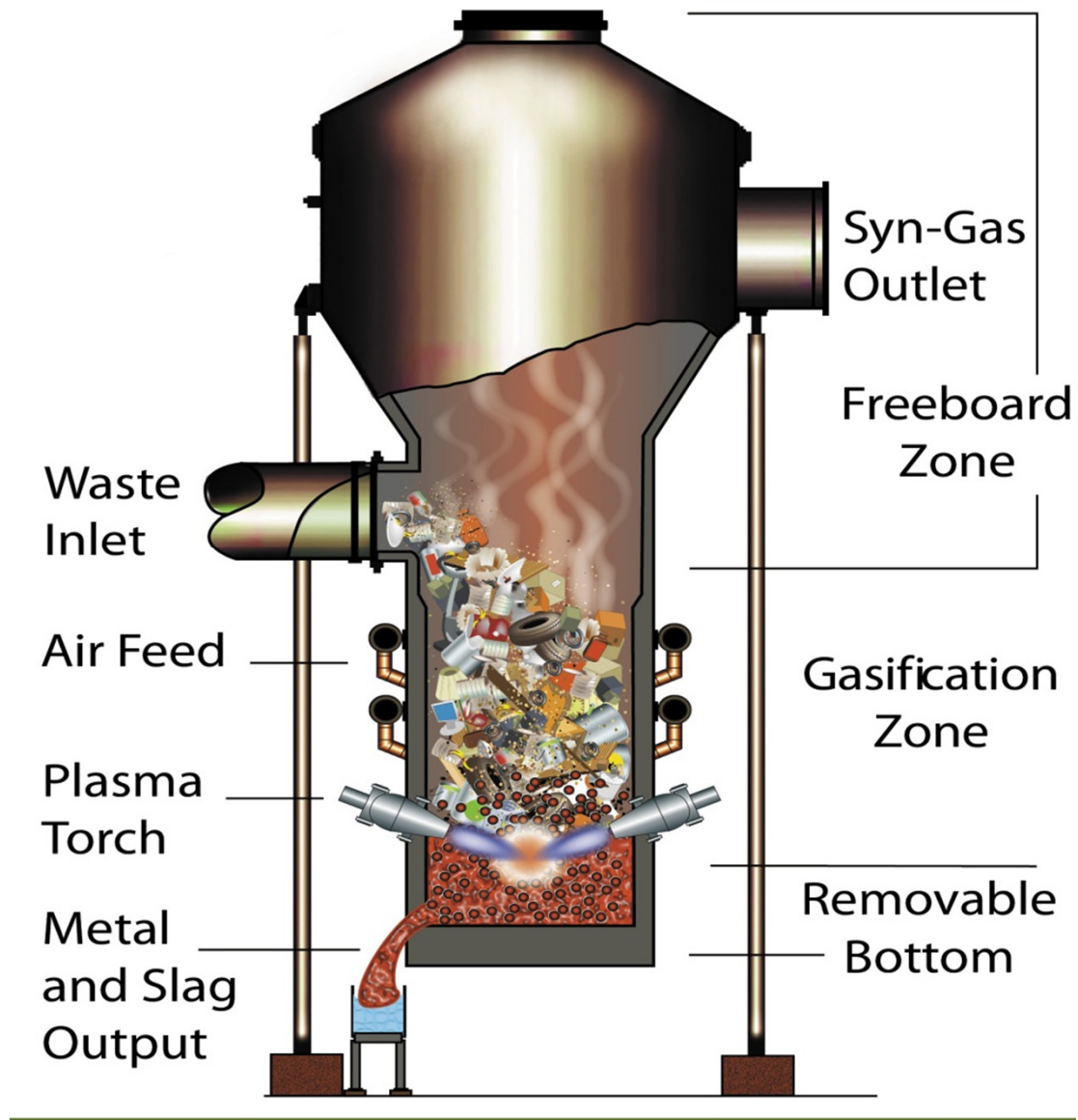
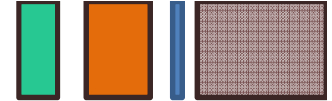
Plasma Gasification: Roundup



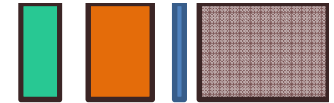
- Reduces emissions from existing coal fired plants by as much as 60% to 95%.
- A 120 mega watt facility will consume on average 3,000 tons of garbage per day.
- Could use old landfills, completely cleaning up and beautifying landscape.
- An affordable, cost-effective solution compared to other alternative energy solutions.



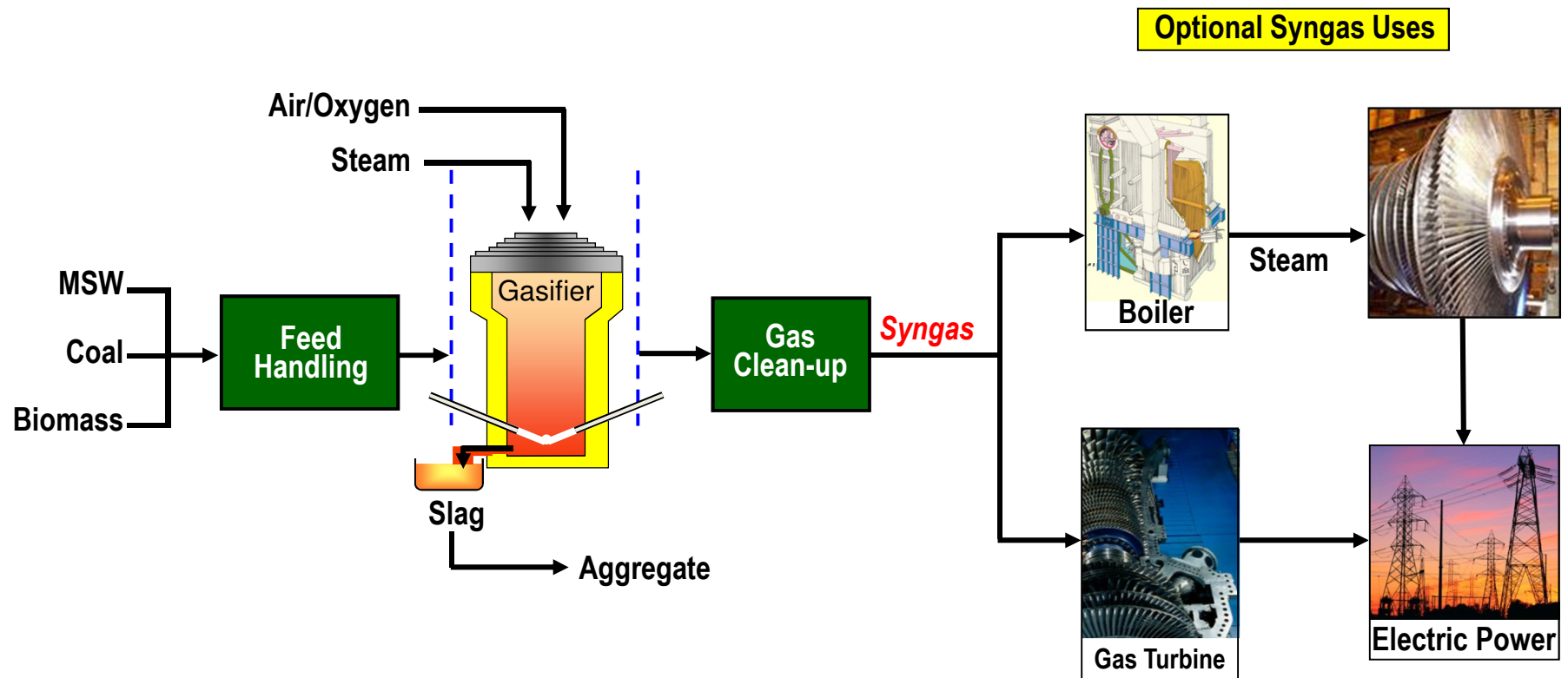
Plasma Gasification – Reactor Cross Section



Plasma Gasification: Process



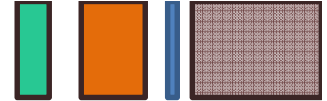
Variety of Feedstocks → Flexible Process → Variety of Energy Products



Low \$ Cost

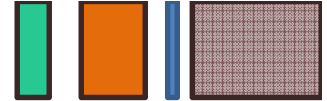
Gasifier

High \$ Value



- Metals and other inorganic materials have no energy content.
- Sorting MSW to recover recyclable commodities such as paper, metals, and high-value plastics can be a more effective way to recover energy.
- Capturing recyclables can represent a potential revenue stream.
- Wastes with high concentrations of halogen can lead to emissions of difficult-to-capture hydrogen halides and hydrogen sulfide.

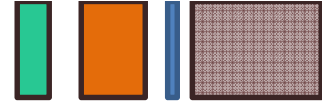
Plasma Gasification: Possible Input



- Asphalt shingles
- Used roadway asphalt
- Oil sands
- Sewage sludge
- Harbor sludge
- Composite materials
- Wood
- Treated wood
- Solvents/paints
- Mixed solid waste
- Steel beams
- Copper piping
- Steel, aluminum, and copper wire
- Concrete
- Stone
- Bricks
- Low-level radioactive waste

Plasma Gasification: Products

- Synthesis gas (a low to medium calorific value gas composed of carbon monoxide and hydrogen).
- A glass-like (vitrified) slag in 1/6th to 1/16th the volume of the original waste processed (volume depends on proportion of inorganics processed).
- Metals (if present in sufficient volume), Sulfur , and Chlorine

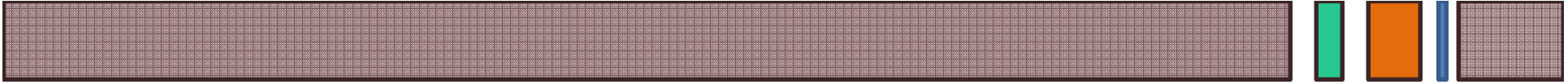


- Potential emissions include particulate matter, nitrogen oxide, sulfur dioxide and trioxide, mercury, dioxins and furans, and hydrochloric acid.
- Hydrogen halides, hydrogen sulfide, and metals are also sometimes emitted.
- Emissions are typically well within established limits and standards of the most developed countries.

Plasma Gasification: Cost



- Example 1: 3000 tons/day of MSW costs \$300 million and generates 120 MW of electricity
- Example 2: 2000 tons/day of MSW costs \$250 million and generates 900 kW of electricity
- Y2010 Approximate cost: \$5000 per kW of generated electricity (higher than conventional cost of gas fired combined cycle power plants)



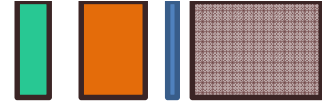
The Zero Waste Concept

Zero Waste Concept: Overview



- Redesign of resource life cycles so that all products are reused.
- Guide people to change lifestyles and practices
- It means to eliminate the volume and toxicity of waste and materials.

Low Temperature Conversion



- LTC is a multi-stage thermo catalytic decomposition process operating in a closed system no open flame.
- LTC decomposes organic materials into their basic elements and converts these into a clean high grade methane gas.
- Final products obtained are gas and/or electricity optionally the produced gas can be converted to liquid fuel.

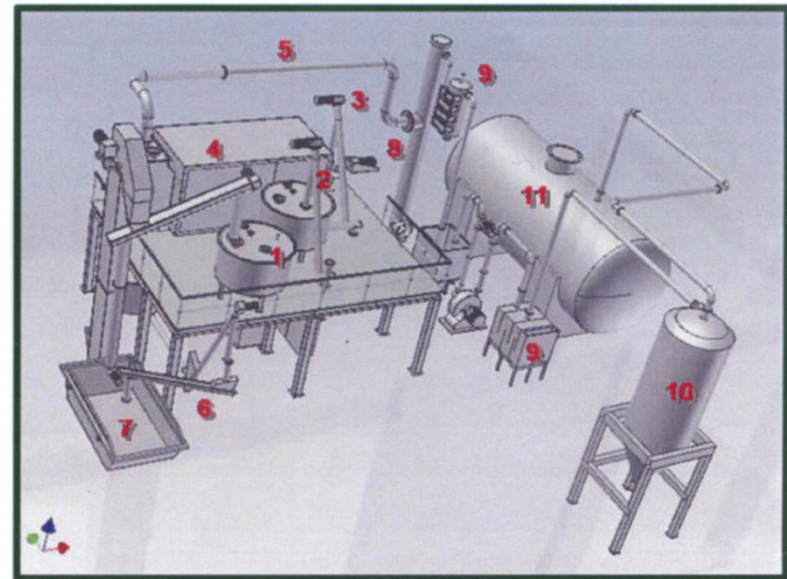
Prairie Biogas

System Components

1. Shredder
2. Pyromex Induction Heating System
3. Syngas-burning Engine

The Process

- Pretreatment
- Pyrolysis (syngas & heat)
- Electricity Generation
- Heat Production



Feedstocks

- Wood chips
- Sewage Sludge
- Farm Waste
- Plastic waste
- Waste from leather and fur industry
- Tannery waste
- Fly ash from power plants
- Paper and cardboard
- Plastic packaging material
- Used oils and hydraulics
- Tires
- Medical & Hospital waste
- Natural fiber products
- Shredder waste
- Plastic and rubber

Plasco Conversion System

Waste to Syngas \longrightarrow Syngas to Electricity

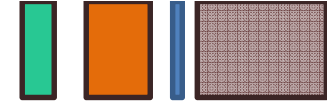


Plasco Plant

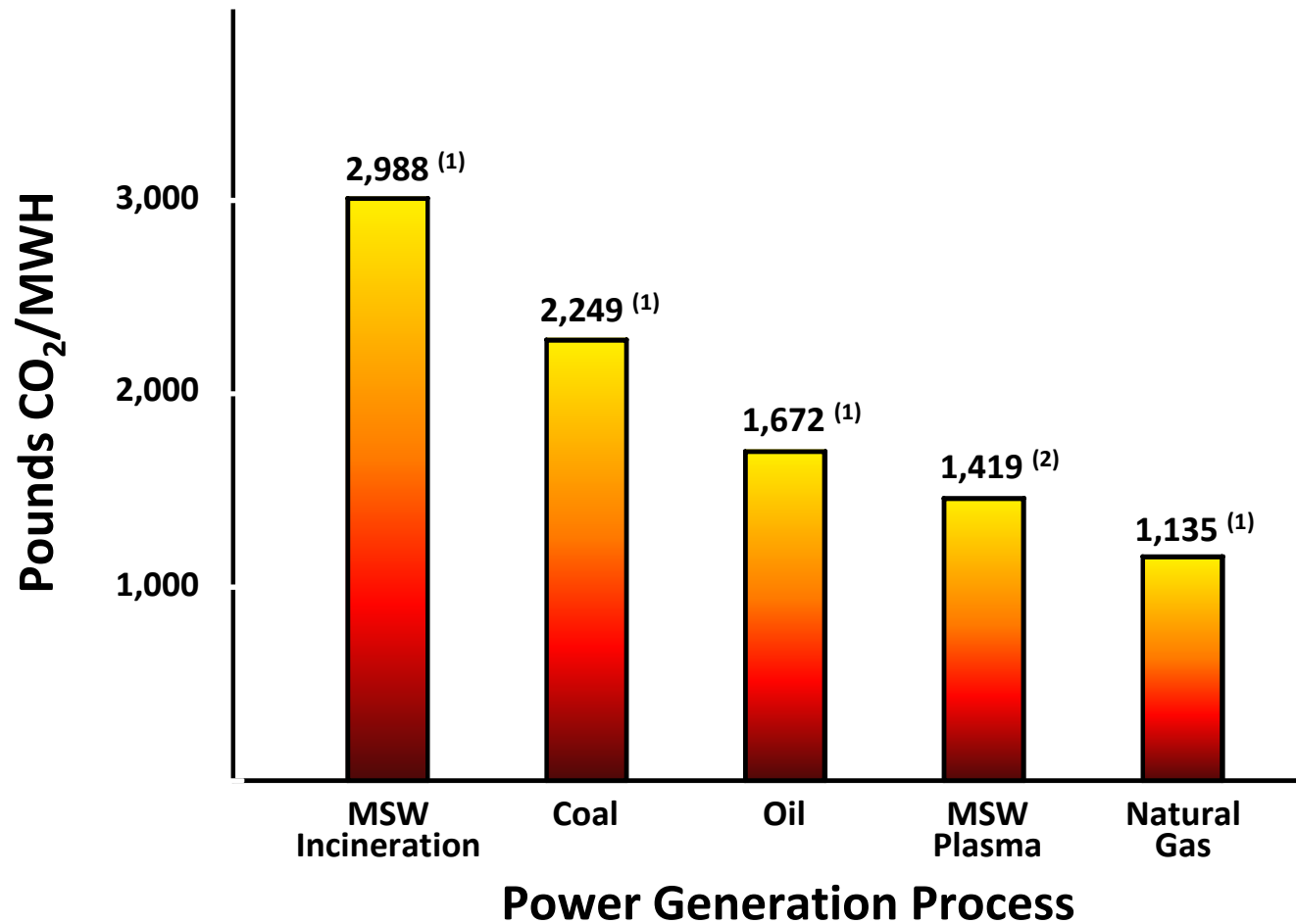


One ton of waste...

1. 1400 kWh electricity
2. 55 days of household use
3. 150 kg of vitrified slag (sold as aggregate)
4. 5 kg sulphur (soil enhancement)
5. 1.3 kg heavy metals and filter screenings
6. 300 litres of potable water
7. 5 – 10 kg salt

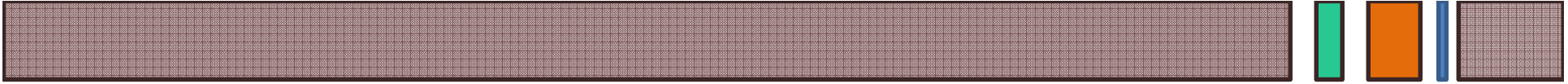


Pounds of CO₂ Emissions per MWH of Electricity Produced



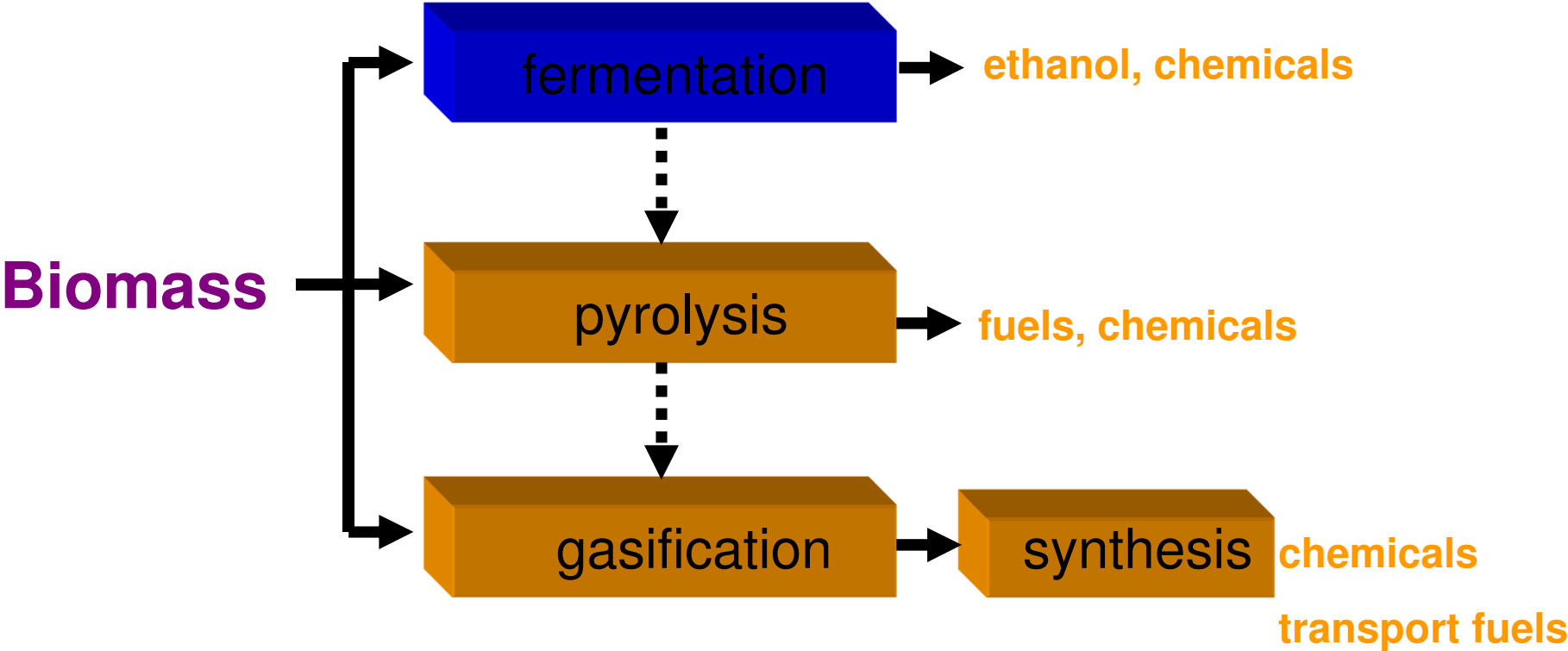
(1) EPA Document: www.epa.gov/cleanenergy/emissions.htm

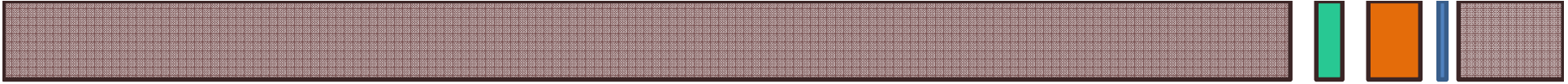
(2) Complete Conversion of Carbon to CO₂; MSW Material & Heat Balance, Westinghouse Plasma Corp.



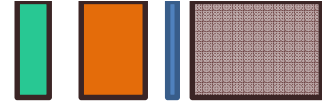
Agricultural Waste to Energy

Concept for the use of biomass

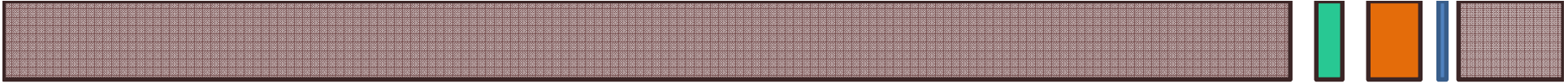




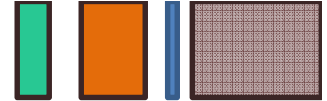
Gasification



- Gasification means oxidation of a substance to produce a gaseous mixture containing two or all of the following: oxides of carbon, methane and hydrogen
- Partial oxidation process using air, pure oxygen, oxygen enriched air, hydrogen, or steam
- Produces electricity, flues (methane, hydrogen, ethanol, synthetic diesel), and chemical products
- Temperature > 700 deg. C.



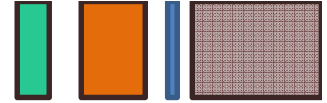
Pyrolysis



- This is a thermochemical decomposition of organic material at elevated temperatures without the participation of oxygen.
- The word is coined from the Greek-derived elements pyro "fire" and lysis "separating".
- Preprocessed material is fed into the pyrolysis reactor where an indirect source of heat elevates the contents to a temperature between 600 and 1,200 deg. C to produce raw syngas overhead and a bottom ash, carbon char, and metals from the reactor.
- Syngas cleanup to remove carry-over particulate matter from the reactor, sulfur, chlorides/acid gases (such as hydrochloric acid), and trace metals such as mercury.

Pyrolysis

- Pyrolysis” means, the thermal degradation of a substance in the absence of any oxidising agent (other than that which forms part of the substance itself) to produce a char and one or both of gas or liquid
-

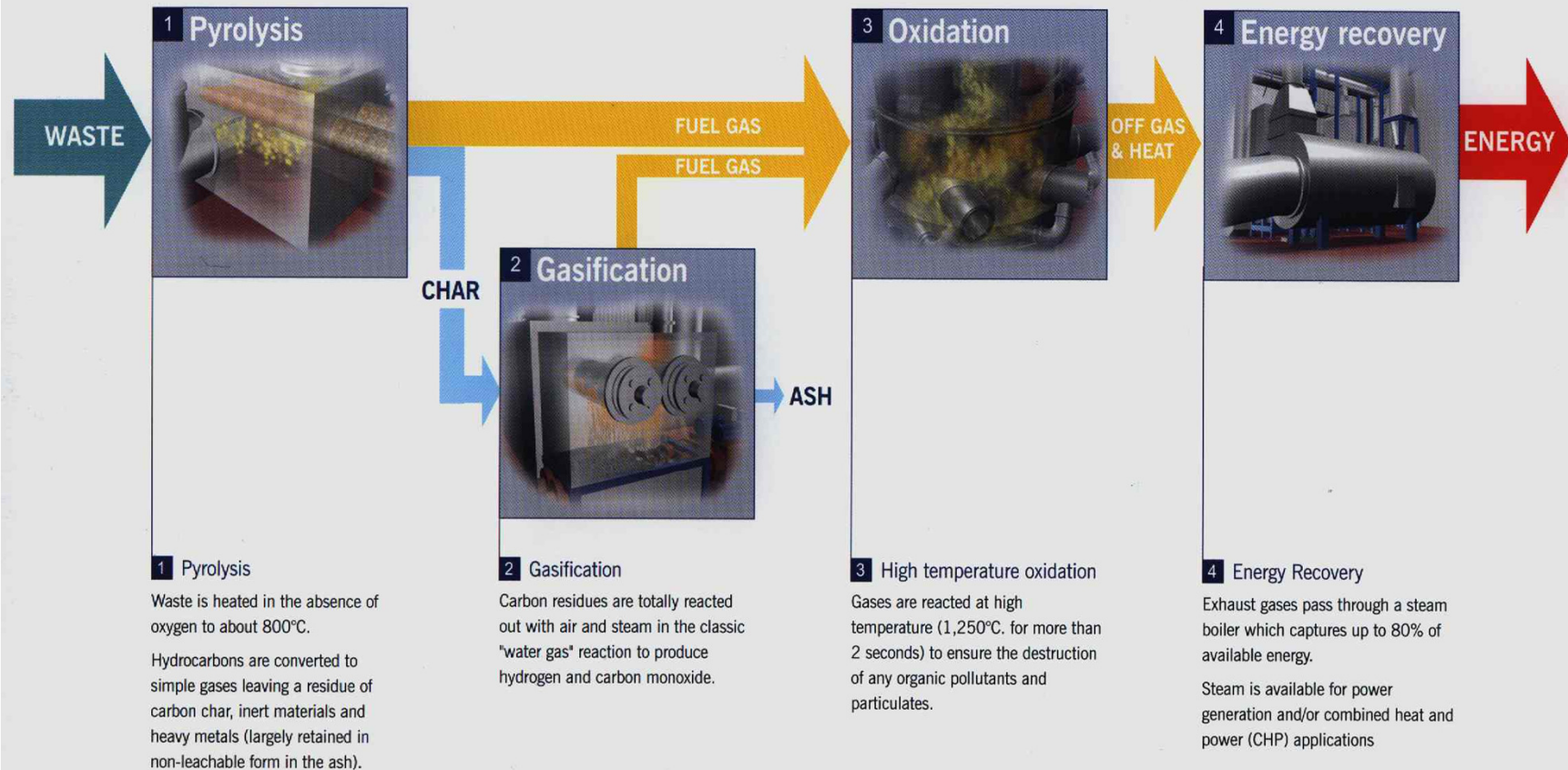


- Pyrolysis uses heat to break down organic materials in the absence of oxygen, producing a mixture of combustible gases (primarily methane, complex hydrocarbons, hydrogen, and carbon monoxide), liquids, and solid residues.
- A beneficial byproduct of pyrolysis is a kind of charcoal called “biochar,” which can be used as a fertilizer and can also be used to absorb CO₂ and other emissions from coal-fired power plants.

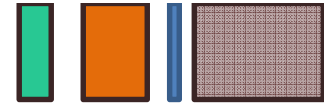
Combined Pyrolysis & Gasification

COMPACT POWER'S COMBINED PROCESS

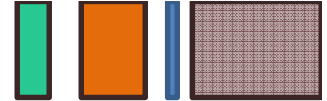
A revolutionary technology for processing a wide range of waste that remains after recycling and composting to create heat and power.



Combined Pyrolysis & Gasification



Capital equipment- million	6.3
Total project development costs- million	8.4
Design configuration	MT8
Annual throughput capacity- tpa	30,000
Gross electrical output- MWe	2.4
Heat output- MWh	10
Gate fee required- £/tonne	40



Feedstock

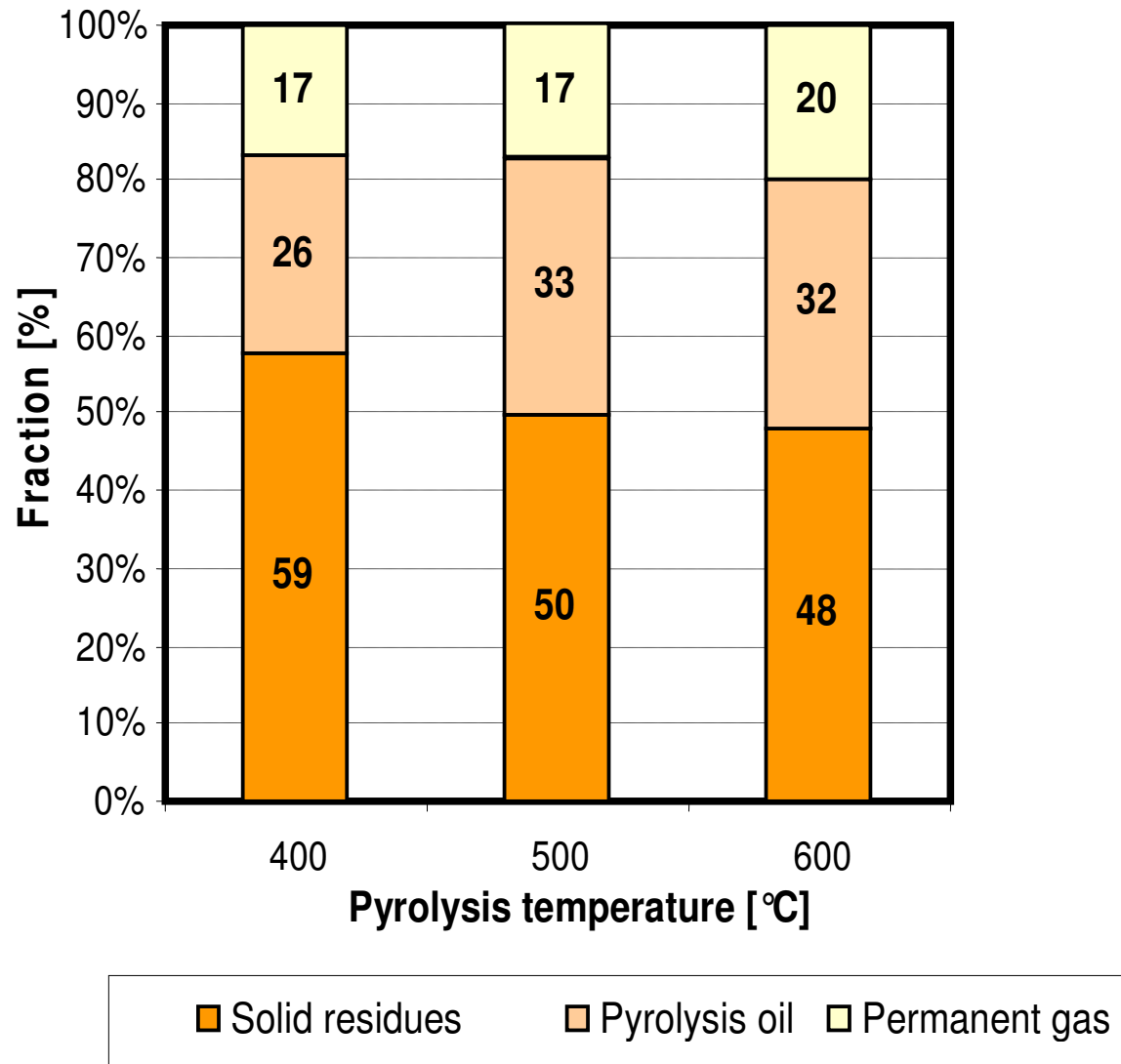
- Municipal Solid Waste (MSW)
- Waste plastics
- Medical waste
- Rubber and tyres
- Car fluff
- E-waste
- Biomass /wood
- Organic sludge (sewage /oil / paper sludge)
- Others
-

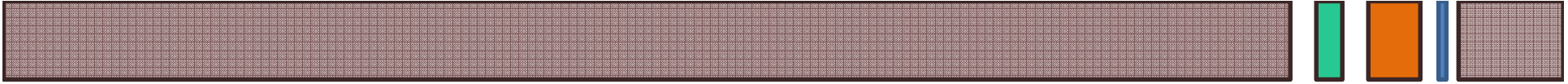
Products

- Electrical energy
- Thermal energy
- Carbon black
- Pyrolysis oil used for (after appropriate post-treatment): liquid fuels, chemicals, adhesives, and other products
- Non-oxidized metals

Pyrolysis: Products Analysis

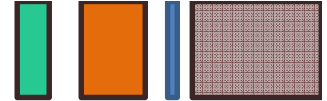
- Amount and composition of products depend on process parameters such as the temperature and the dwell time.
- This graph applies for tyre pyrolysis.





Technology Comparison

TECHNOLOGY SELECTION CONSIDERATIONS



ENVIRONMENT

- CO₂ Control
- Dioxins Control
- Emission Control
- Landfill Control

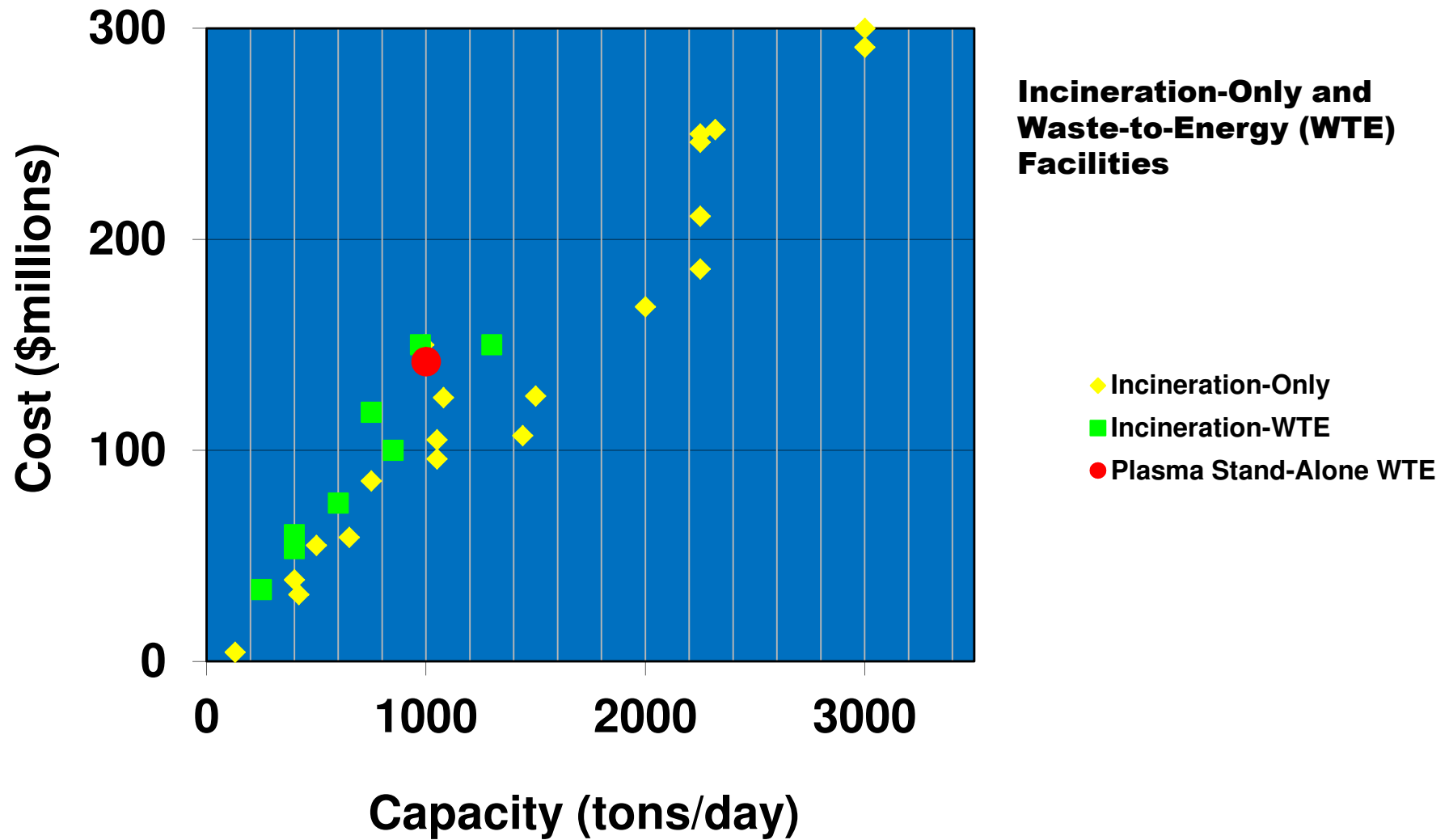
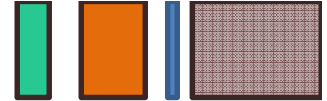
ECONOMY

- Cost Control
- Profit
- Growth

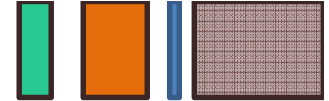
ENERGY

- Energy Recovery
- High Efficiency
- Utilization / Sale

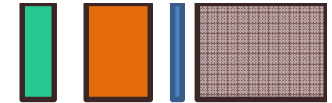
Capital Costs: Incineration vs. Plasma Gasification



Capital Cost

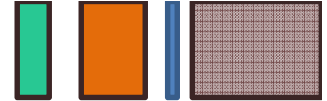


Treatment method	Cost(Euro / Ton)
Landfill burial	150-160
Traditional incineration	100-140
Pyrolysis / thermolysis	90-150
Plasma without syngas utilization	100-120
Plasma with syngas utilization	70-90



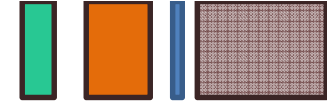
Temperature Range

Technology	Temperature Range (° C)	
Plasma Arc Gasification	4,000	7,000
Conventional Gasification	700	1,500
Pyrolysis Gasification	700	1,500
Pyrolysis	650	1,200
Incineration	500	1,200



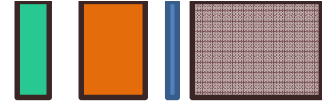
Net Energy to Grid Using MSW

Technology	Production to Grid
Plasma Arc Gasification	816 kWh/ton
Conventional Gasification	685 kWh/ton
Pyrolysis Gasification	685 kWh/ton
Pyrolysis	571 kWh/ton
Incineration	544 kWh/ton



Economic Assessment

Parameter	Plasma Arc Gasification	Conventional Gasification	Pyrolysis/ Gasification	Pyrolysis	Incineration
Capital investment at 6%, 20 years	\$101,583,800	\$80,337,800	\$102,593,400	\$86,936,900	\$115,997,700
Plant capacity (tons MSW/day)	500	500	500	500	500
Energy production (kWh/ton MSW)	816	685	685	571	544
Operation and maintenance, capital budget, cost of ash	\$7,483,400	6,871,800	\$7,711,100	\$7,193,700	\$8,216,600
Tipping fee (\$/ton MSW) (revenue)	\$35.00	\$35.00	\$35.00	\$35.00	\$35.00
Green tags (revenue)	2 ¢/kWh	2 ¢/kWh	2 ¢/kWh	2 ¢/kWh	2 ¢/kWh
Production energy sales (revenue)	6.50 ¢/kWh	6.50 ¢/kWh	6.50 ¢/kWh	6.50 ¢/kWh	6.50 ¢/kWh
By-product	0.2	0.2	0.2	0.21	0.2



Open Discussion

