National Renewable Energy Laboratory
Innovation for Our Energy Future

Tribal Leader Forum: Waste-to-Energy Introduction

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NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC

Presentation Outline

- Waste-to-energy Introduction
- Feedstocks
- Recycling
- Conversion Products and Pathways
- Major Equipment
- WTE Economics and Opportunities

Waste-to-Energy Introduction

The issues, for much of the world:

- Waste disposal is a major expense
- High energy prices
- Limited landfill space

The opportunity

- Waste as an alternative fuel source through
  - Landfill gas methane collection
  - Waste to energy

Benefits

- Reduces electricity cost
- Helps to meet renewable energy mandates
- Improves waste management and reduces land filling
- Environmental benefits

WTE Highlights

Waste-to-energy (WTE) is considered renewable energy

WTE offers firm, dispatchable power

There are no commercial WTE projects that have been constructed in the US using advanced generation technologies (e.g. gasification/plasma, pyrolysis)

WTE projects receive income from energy sales and tipping fees

WTE Introduction--QUIZ

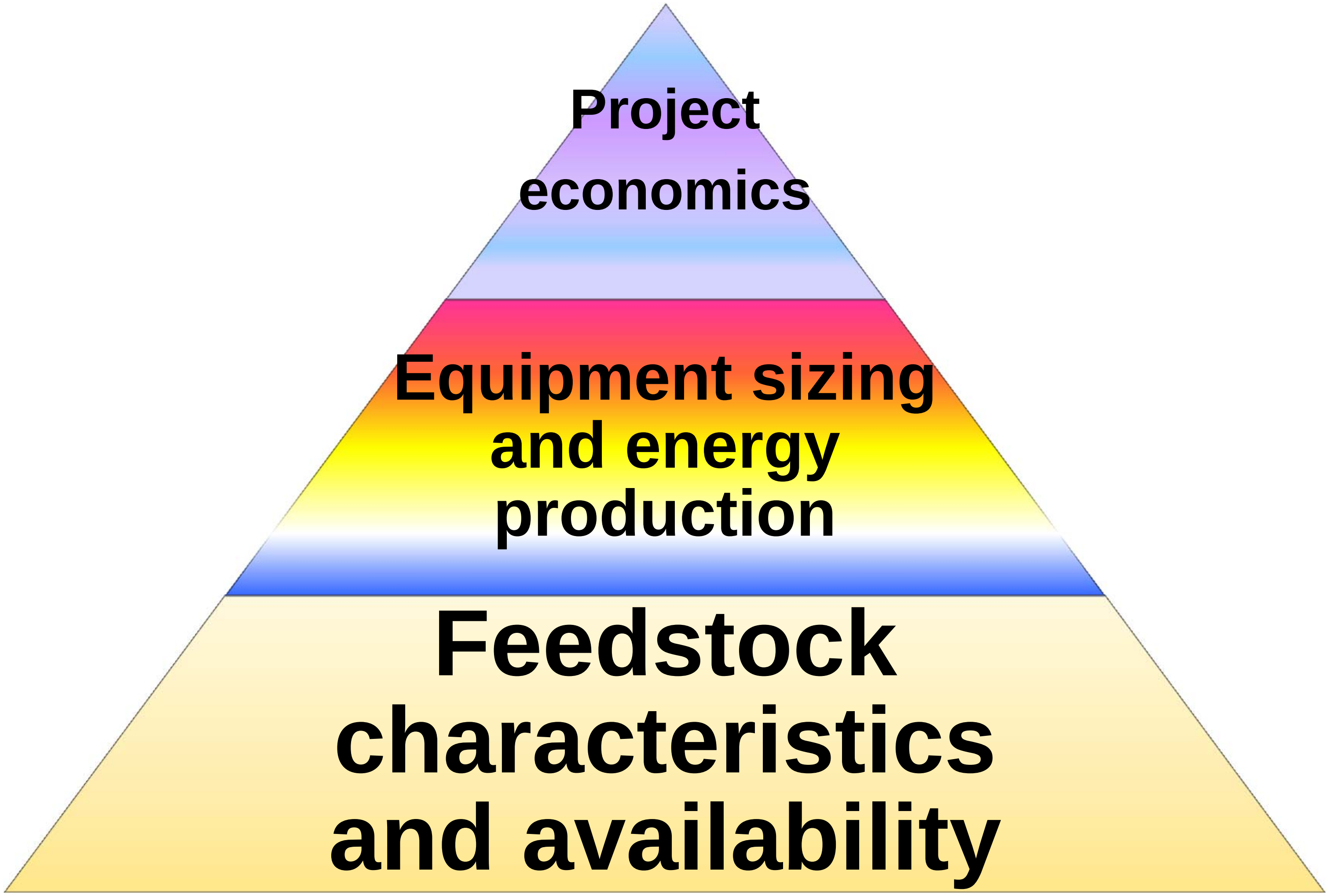
List three benefits of WTE

- Reduces electricity cost
- Helps to meet renewable energy mandates
- Improves waste management and reduces land filling
- + Other environmental benefits

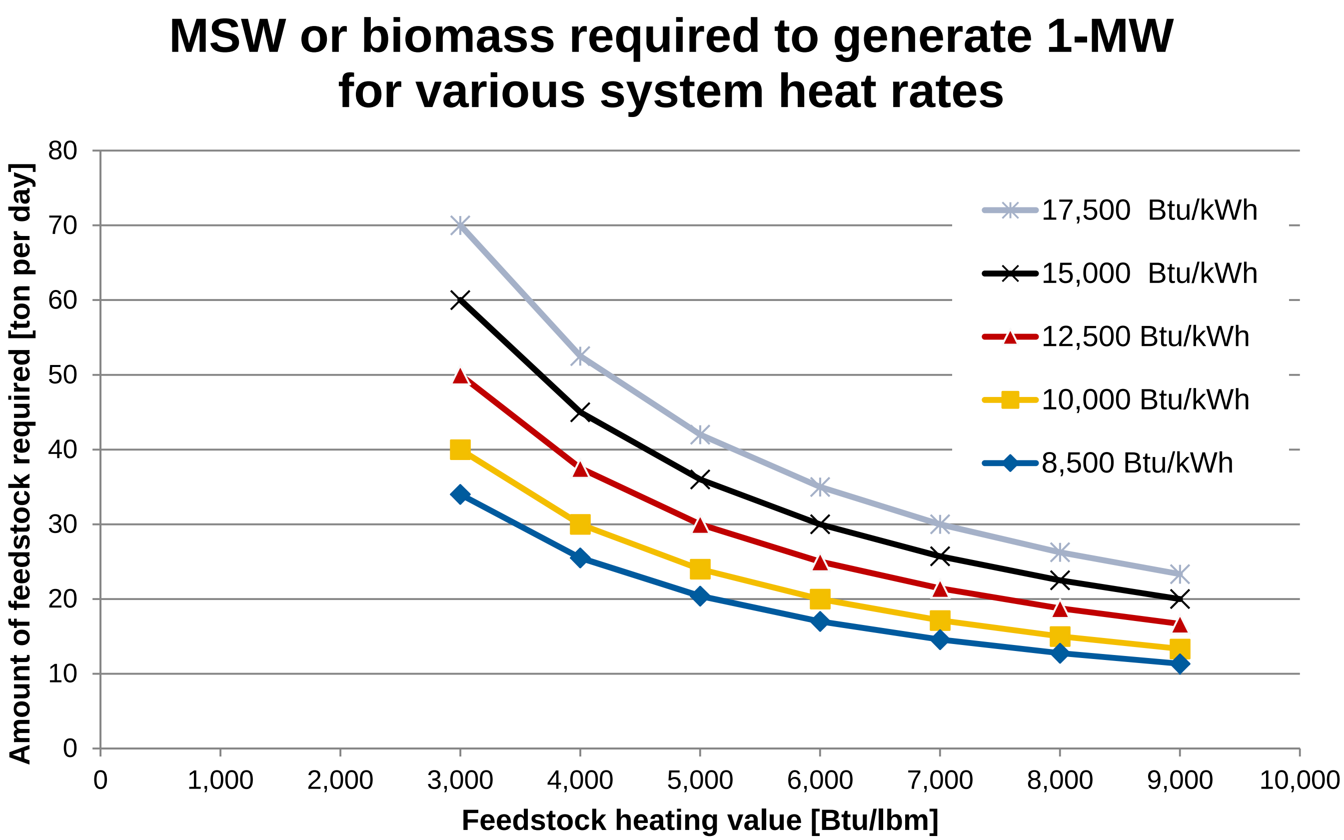
Feedstocks

An accurate feedstock resource estimate is the basis for estimating the performance and economics of a biomass- or waste-to-energy project.

Biopower Pyramid



Capacity Sizing Chart

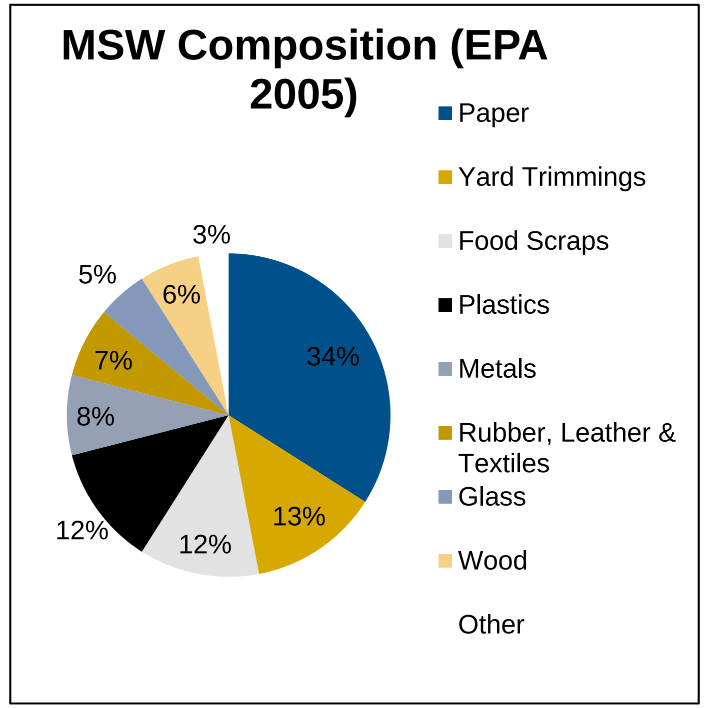


Tons per day at various heat rates and energy contents to generate 1 MW gross

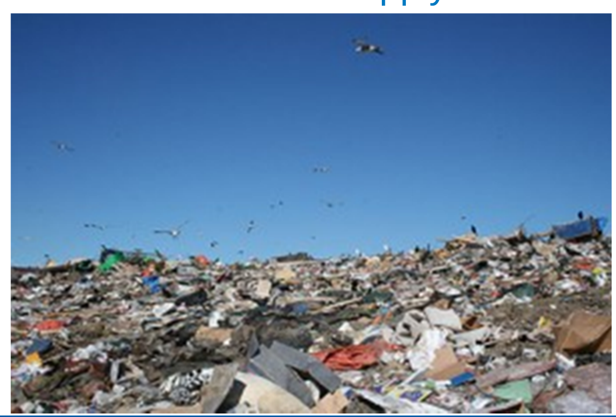
MSW Properties

Municipal solid waste (MSW) is a heterogeneous mixture

Organic material is the primary fuel source for energy projects	Can be composted
Inorganic / inert materials	Many can be recycled
MSW is a low-energy content fuel	Average of 5,900 Btu per pound (US)
WTE systems can be co-fired with other feedstock	



Sustainable Supply



Refuse Derived Fuel (RDF)

RDF is feedstock derived by processing of municipal solid waste

The American Society for Testing and Materials has established classifications RDF-1 to RDF-7

- RDF-1: Municipal solid waste used as a fuel in as-discarded form
- RDF-2: MSW processed to coarse particle size, with or without ferrous metal separation, such that 95% by weight passes through a 6-inch square mesh screen.
- RDF-3: Shredded fuel derived from MSW and processed for the removal of metal, glass, and other entrained in-organics. The particle size of this material is such that 95% by weight passes through a 2-inch square mesh screen. Also called "fluff" RDF.

Resource Assessment

How much waste is available?

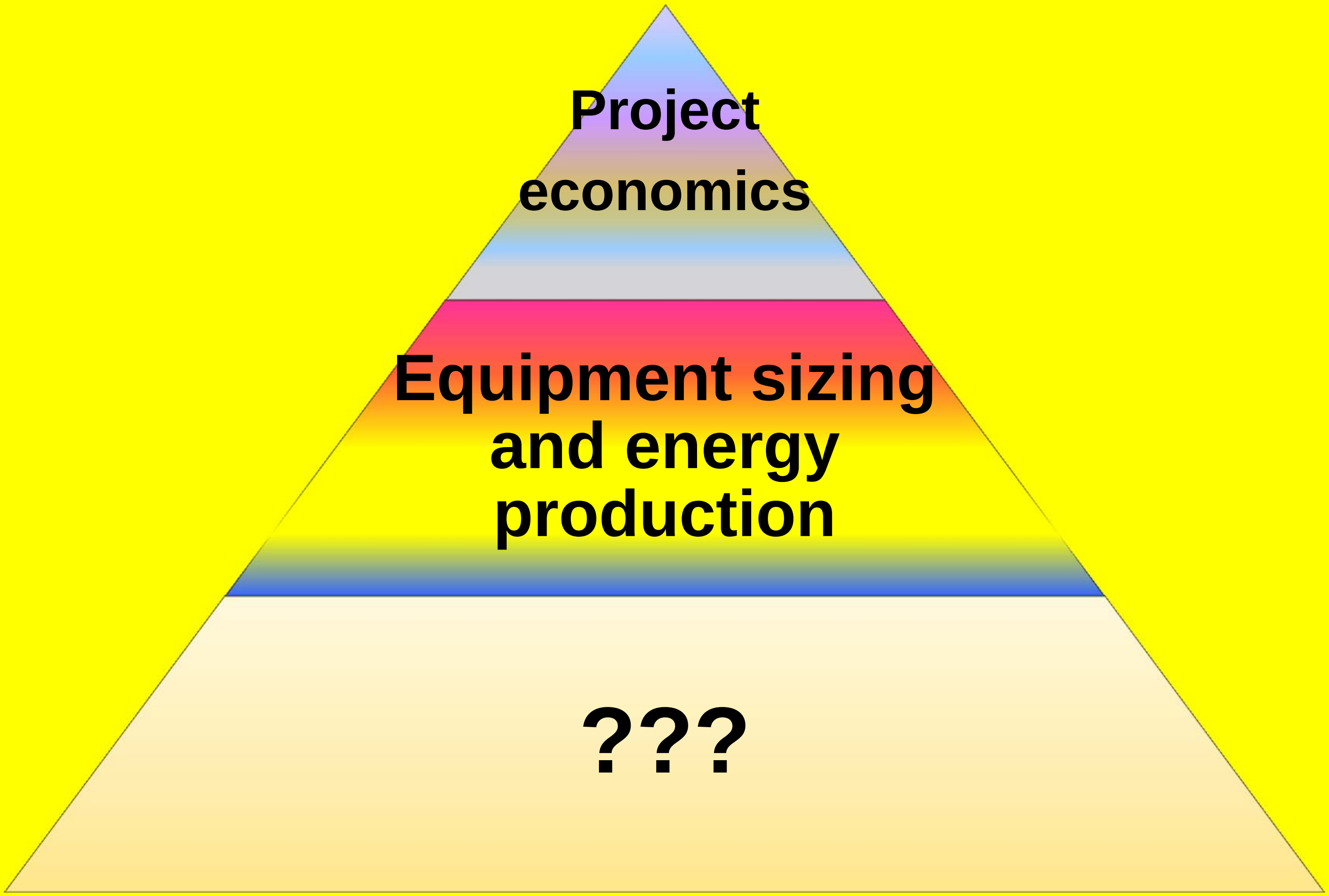
What types of waste are available?

- Municipal waste
- Commercial / Industrial Waste
- Tires
- Sewage sludge
- Wood waste
- Medical waste

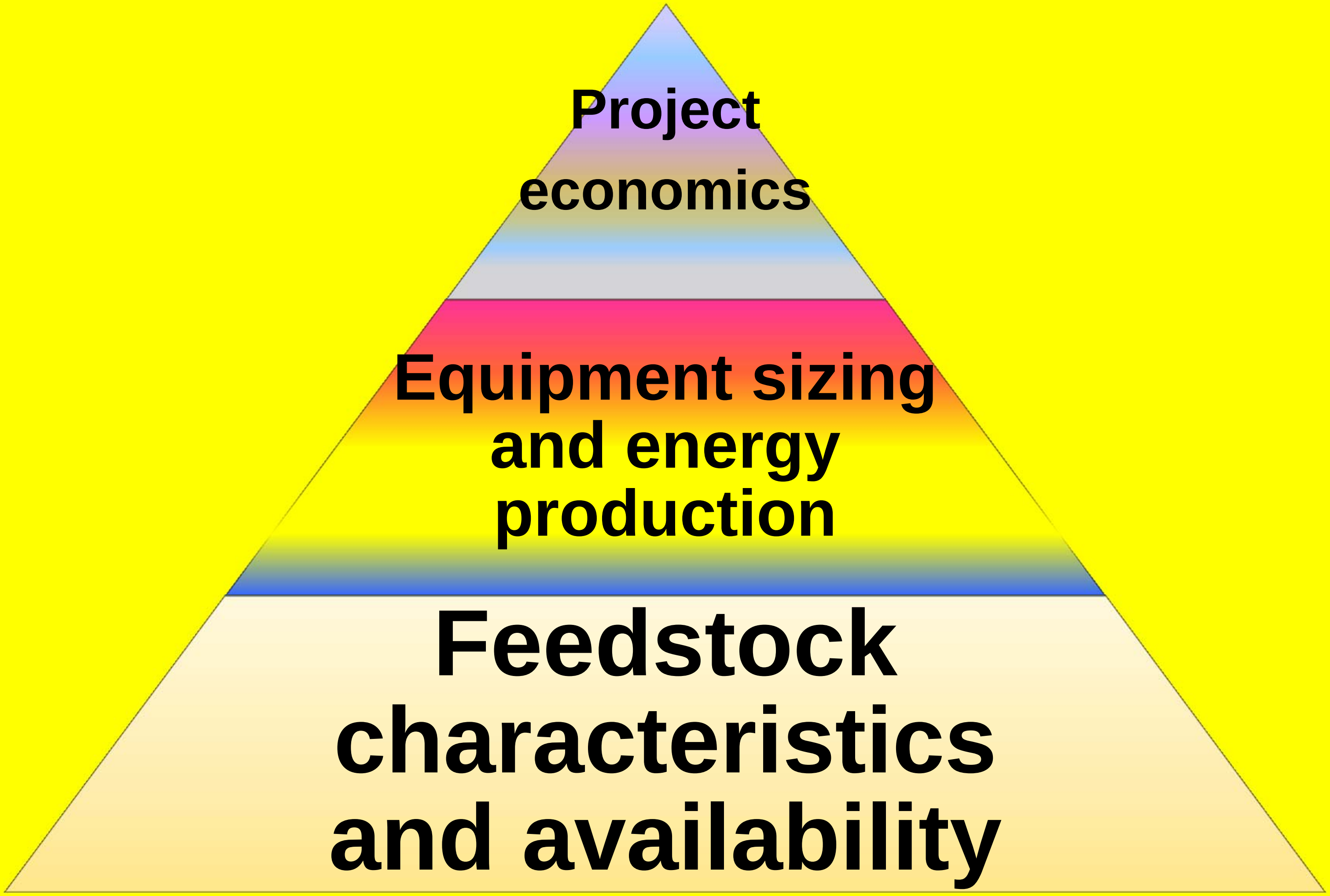
Who controls the waste and where it goes?

How far away is the waste?

Biopower Pyramid--QUIZ



Biopower Pyramid--ANSWER



Recycling

Typical recycled materials

- Paper
- Plastics
- Glass
- Metals
- Miscellaneous

Paper

High-grade paper

- White copy and computer paper
- Letterhead
- White notebook paper
- White envelopes

Mixed office paper

- Colored paper
- File folders
- Sticky notes
- Boxboard (such as cereal boxes)
- Junk mail
- Catalogues
- Paper bags
- Packing/wrapping papers
- Greeting cards

Newspaper

- Coated paper
- Magazines

Glossy paper

Corrugated cardboard

Plastics

#1 – PET (Polyethylene terephthalate)

- Soda bottles
- Bottles for liquor, liquid cleaners, detergents, and antacids

#2 – HDPE (High-density polyethylene)

- Water, juice, and milk jugs
- Bottles for laundry detergent, fabric softener, lotion, motor oil, and antifreeze

#3 – PVC or vinyl (Polyvinyl chloride)

- Bottles for cooking oil, salad dressing, floor polish, mouthwash, and liquor
- "Blister packs" used for batteries and other hardware and toys

#4 – LDPE (Low-density polyethylene)

- Grocery bags
- Trash bags
- Film products

#5 – Polypropylene

- Packaging such as yogurt containers, shampoo bottles, and margarine tubs
- Cereal box liners, rope and strapping, combs, and battery cases

#6 – Polystyrene

- Styrofoam coffee cups, food trays, and "clamshell" packaging
- Some yogurt tubs, clear carry-out containers, and plastic cutlery
- Foam applications [Note: Polystyrene used for foam applications is sometimes called EP or
- expanded polystyrene]

#7 – Other

- Applications that use some of the above six resins in combination
- Collection of individual resins as mixed plastics

Glass

- Clear glass
- Green glass
- Brown glass

Metals

Aluminum

- Cans
- Foil

Tin-Coated Steel Containers

- Food packaging (e.g., canned food)

Bimetal Containers

- Example includes tin-plated steel cans with an aluminum “pop top”

Non-Ferrous Metals

- Scrap metal that does not contain iron (e.g., copper and brass)

Ferrous Metals

- Iron
- Iron-containing metal scrap
- Steel

Batteries

Lead-acid batteries

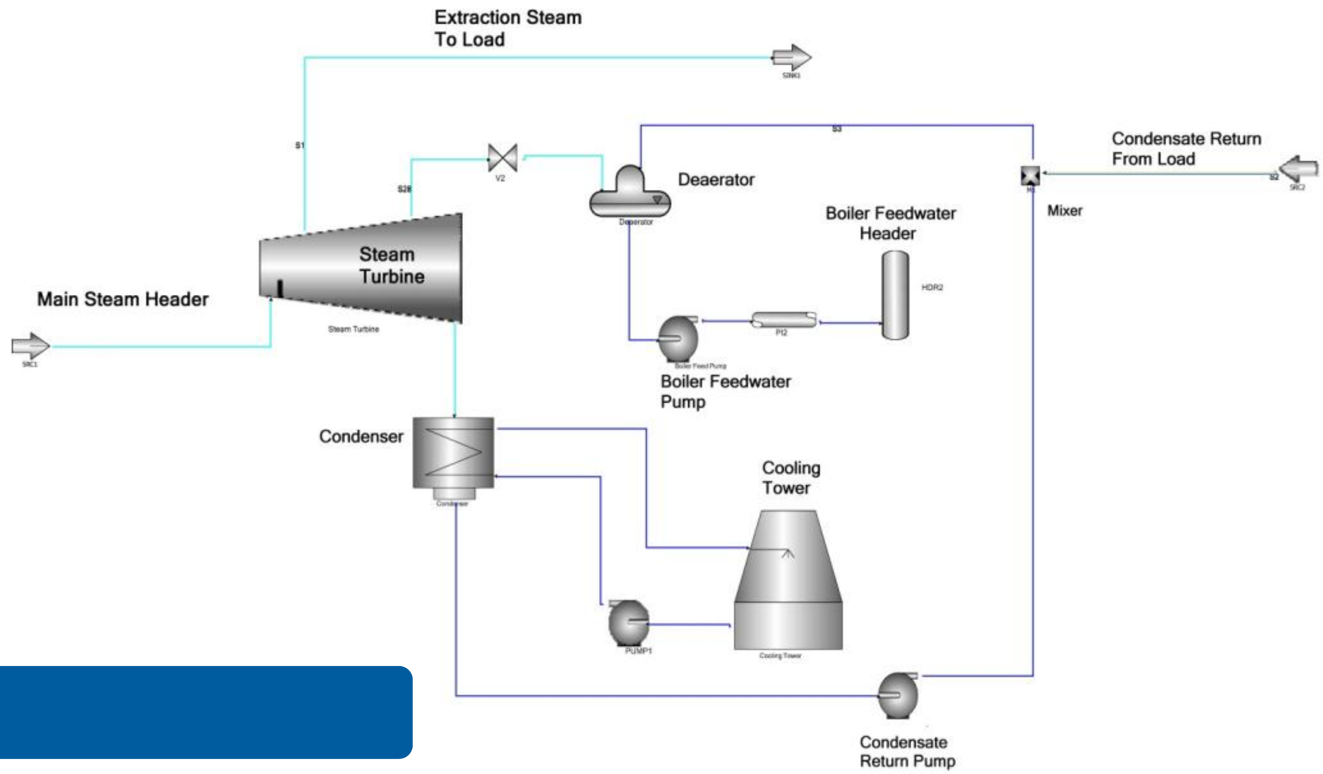
Household batteries

Recycling—QUIZ—Which of these can also be used for energy?

Typical recycled materials

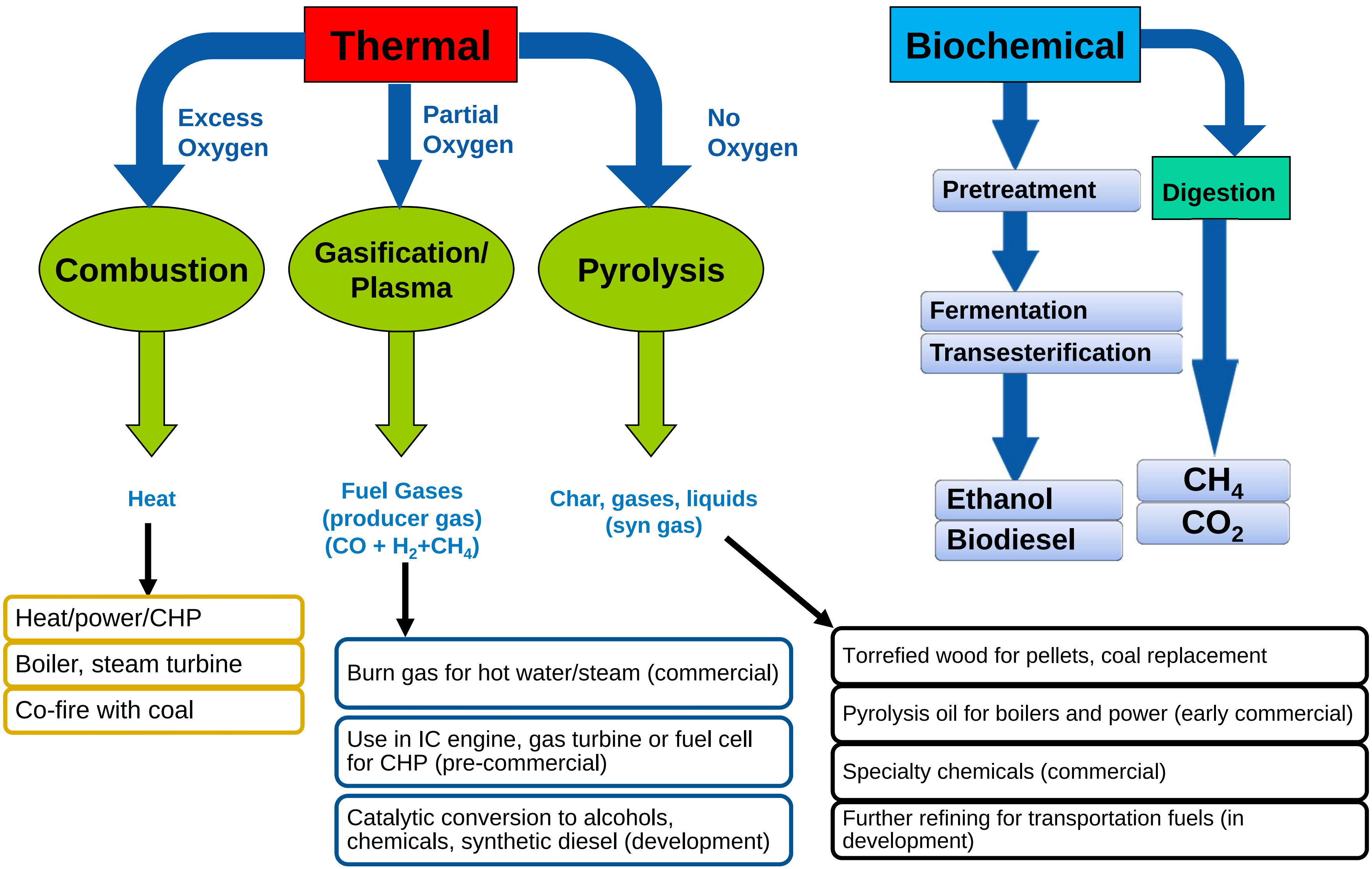
- Paper ←
- Plastics ←
- Glass
- Metals
- Miscellaneous

Primary Bioenergy Products



- Electricity
- Heat
- Combined heat and power (CHP)

Waste-to-energy Pathways



Thermochemical Technologies

Thermochemical technologies include:

- Combustion
- Gasification (and plasma gasification)
- Pyrolysis

Combustion

Thermal conversion in an atmosphere of excess oxygen

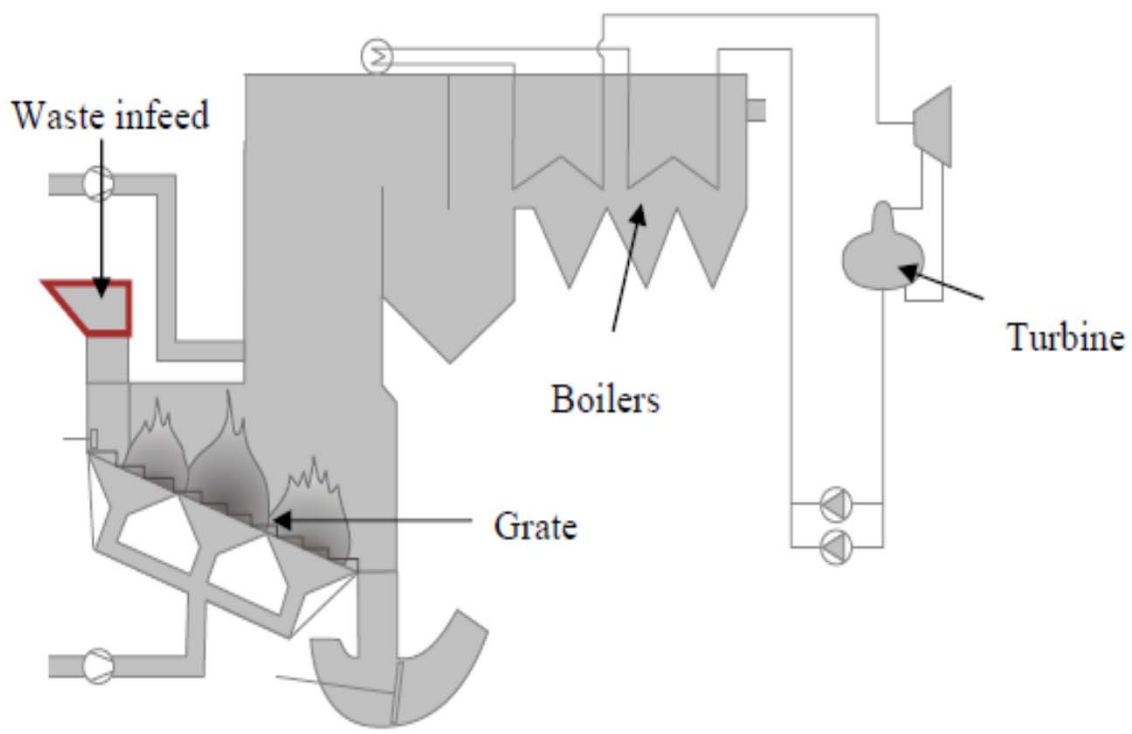
- Commercial technology
- Inefficient but reliable
- Emissions need to be controlled
- Large water requirements

Combustion Overview

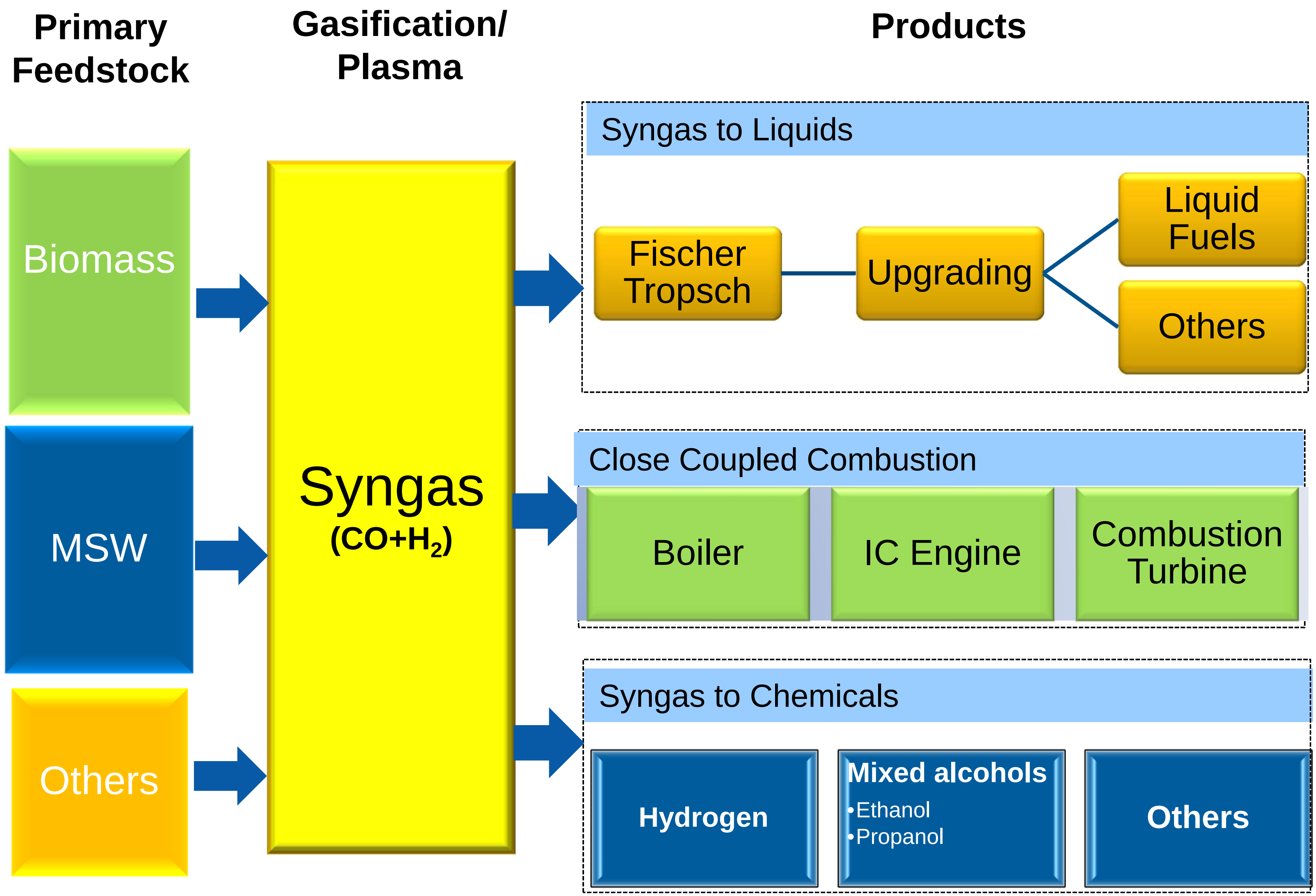
In the US, 88 existing commercial facilities in 25 states combust 26.3 million tons of MSW per year.

Typical minimum for economic feasibility is 500 tons per day (tpd)

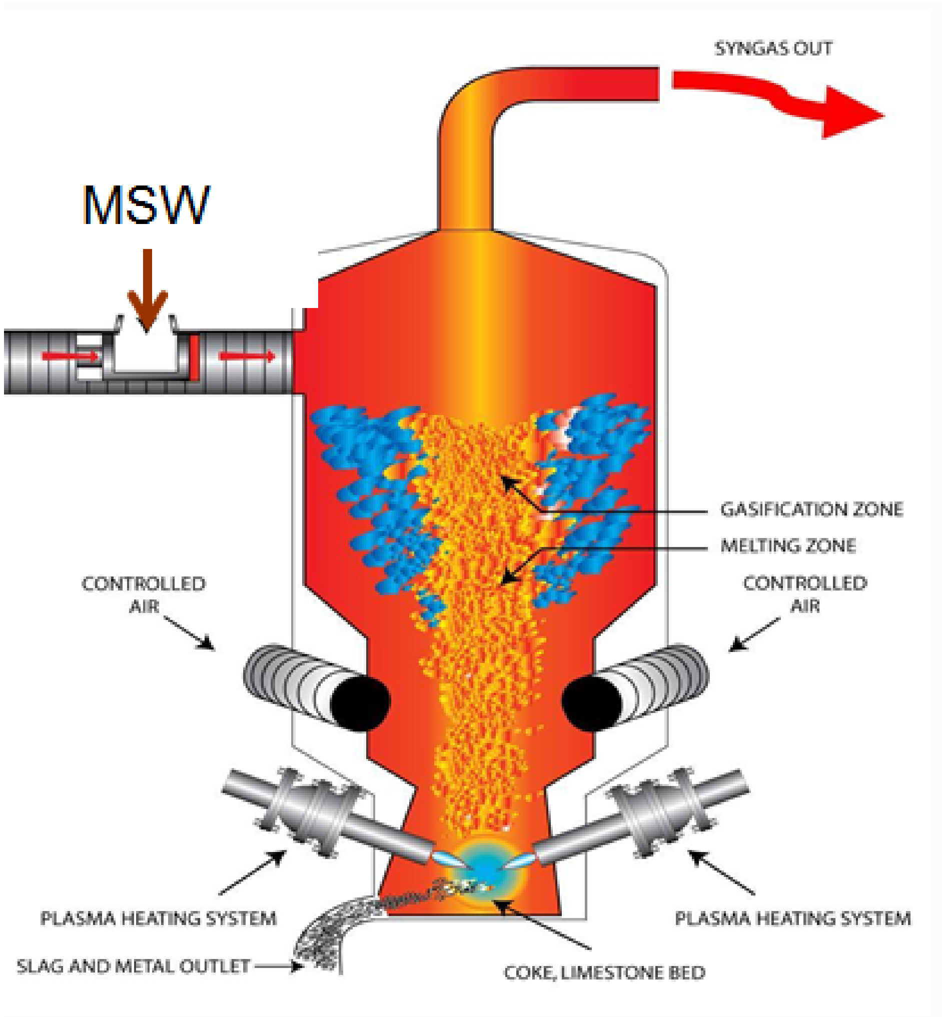
Typical Mass Burn WTE Layout



Gasification Technologies

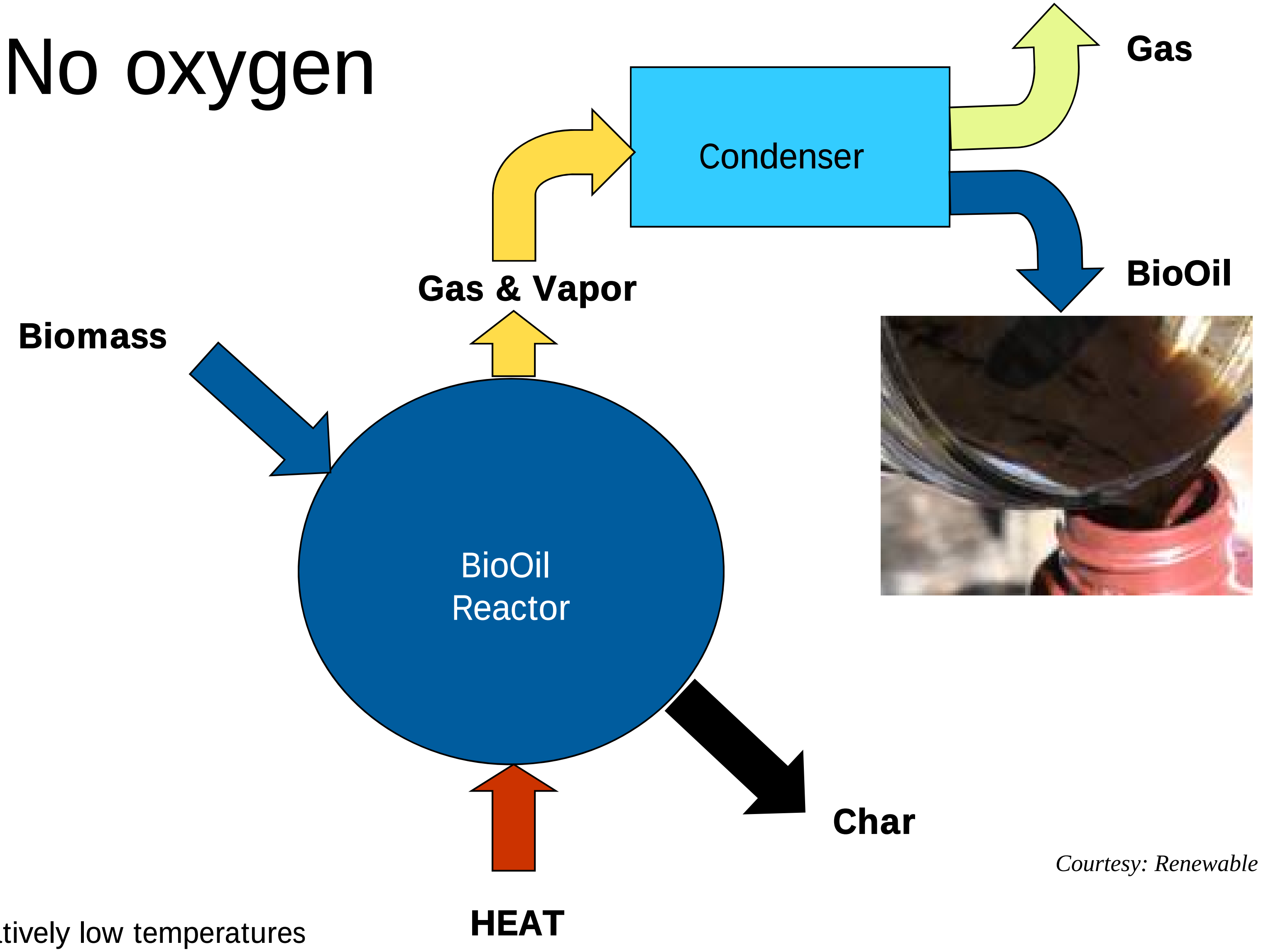


Plasma Reactor



Pyrolysis

No oxygen



Courtesy: Renewable Oil International

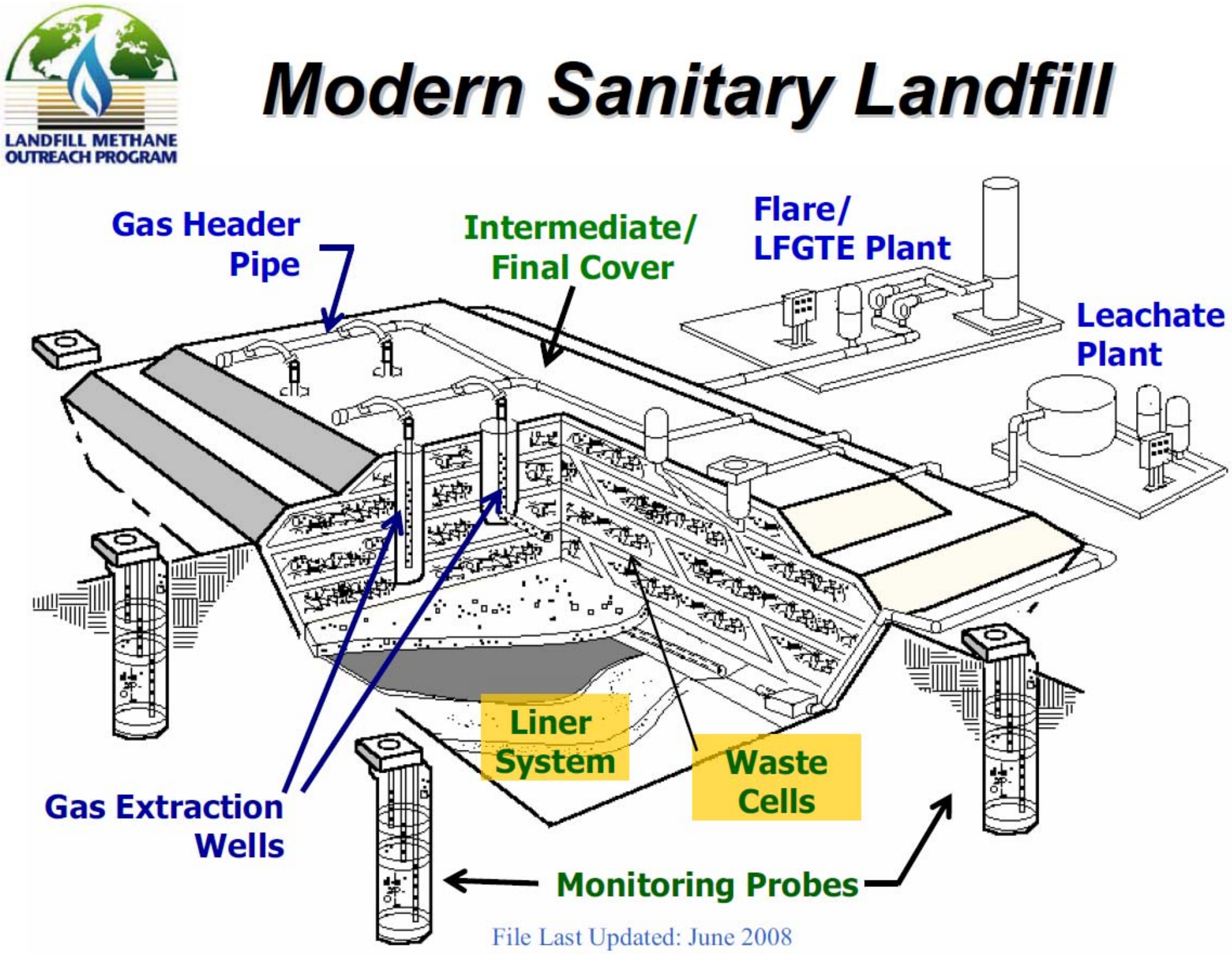
Relatively low temperatures

Biochemical Conversion Technologies

Landfill-Gas-to-Energy (LFG or LFGtE)

Anaerobic Digestion (AD)

Landfill-Gas-to-Energy

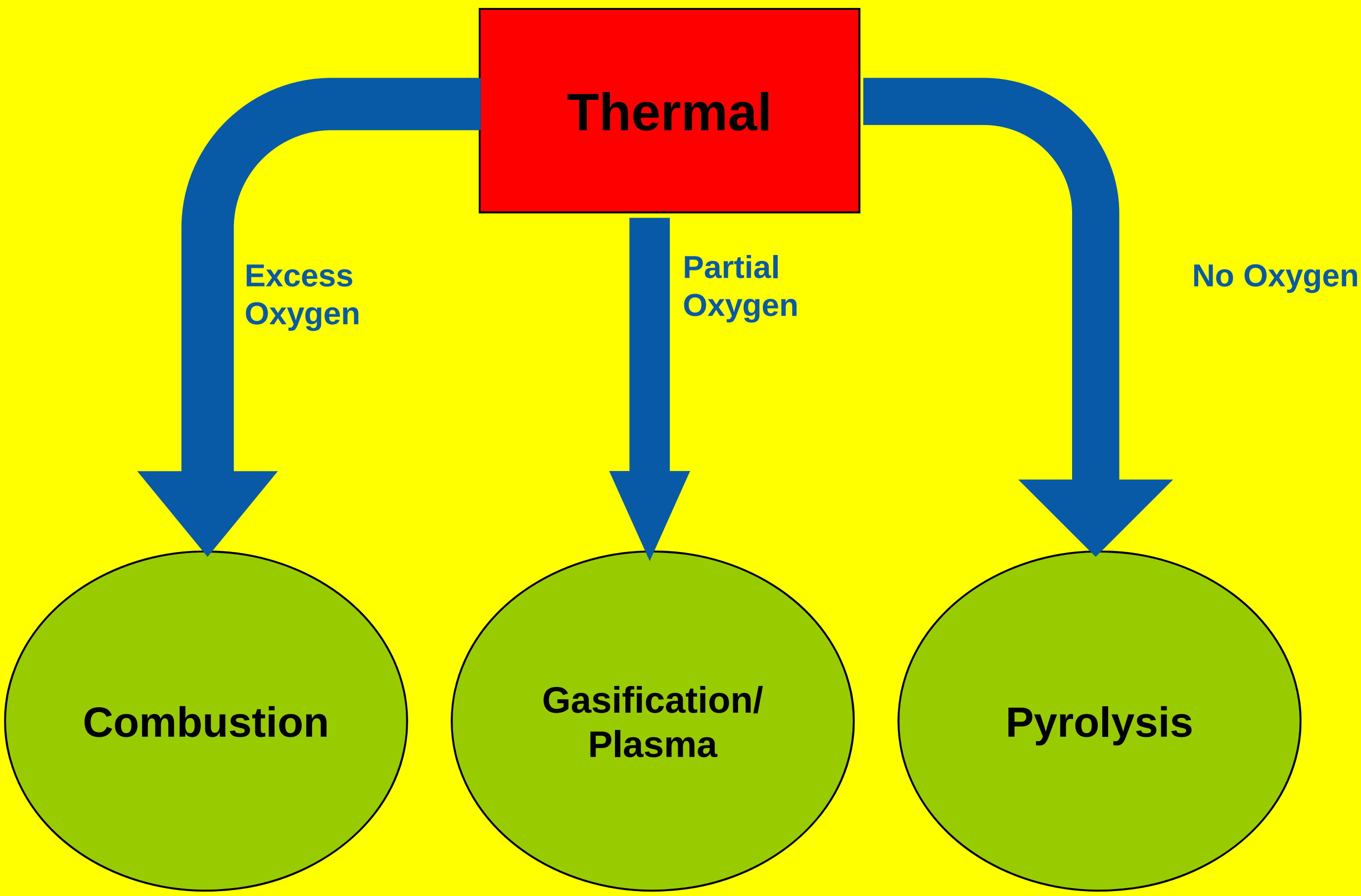


Anaerobic Digestion

Two-phase thermophilic anaerobic digestion of MSW, Anyang City, S. Korea
From CADDET Technical Brochure No. 66

- Breaks down organic material in absence of oxygen
  - Sewage, food waste, waste grease, organics from waste stream
- Produces low to medium Btu biogas and residues
- Emerging technology in U.S, widespread in Europe, Asia
- Limited cost data available at this time
- Possible opportunity at sewage treatment plant
- Scalable

WTE Pathways--QUIZ



Materials Handling

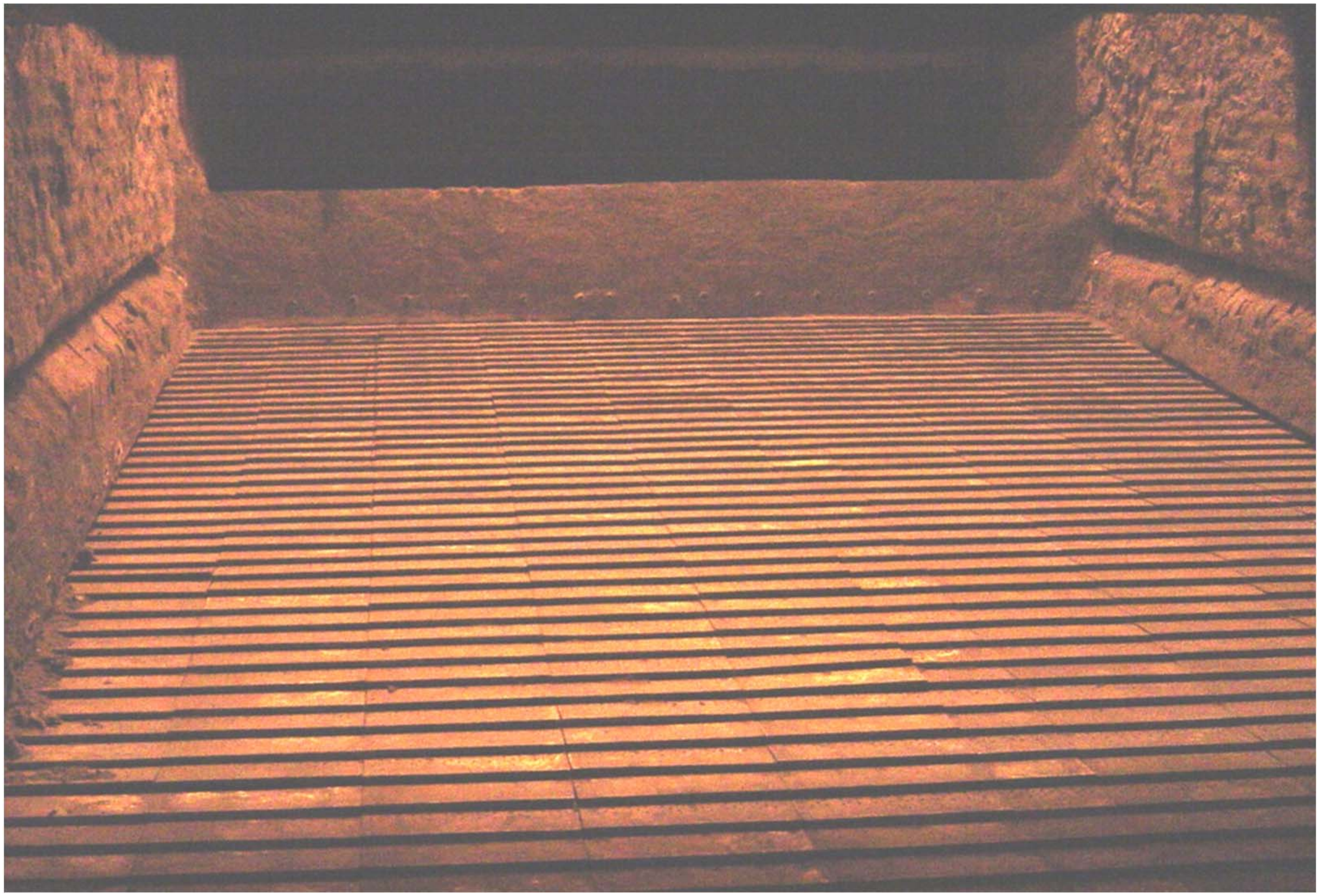
Pit and Grapple Arrangement

Trommel Screen

Used to separate materials by size

Primarily for WTE pre-sorting

Sloping Grate Furnace

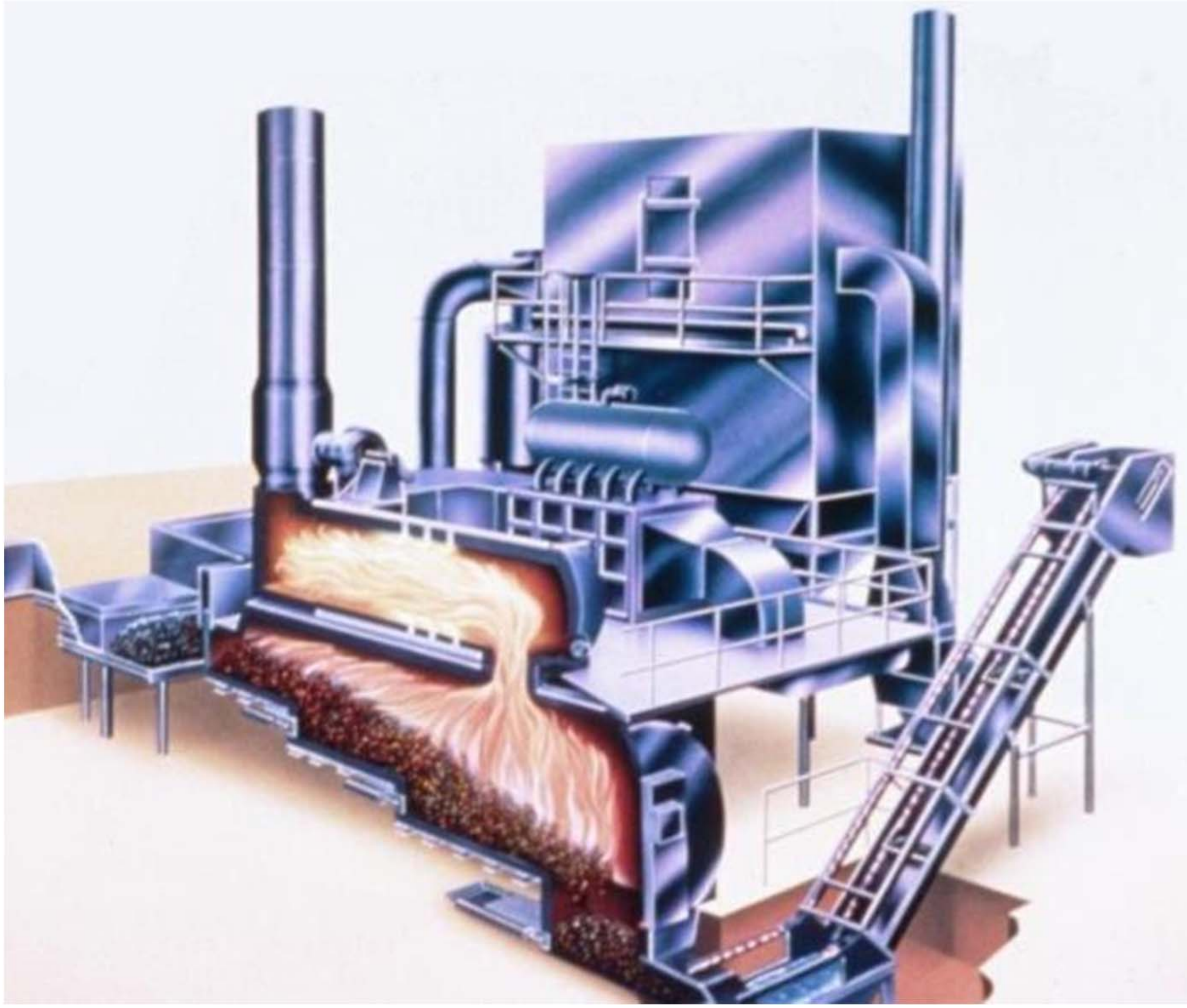


Roller Grate Furnace

Reciprocating Grates

Reciprocating Grate Furnace

Stepped Hearth Grate



QUIZ—What is this?

Roller Grate Furnace

State of WTE Technology - large

Large scale (>300 tpd) combustion units commercially viable

- Almost all commercial power systems are combustion/steam turbine
- Efficiencies in 15% – 30% range power only, (60%-70% CHP)
- 550-650 kWh per ton MSW
- Stokers and fluidized bed
- 1-110 MW (average is ~20)
- Installed costs $4,000/kW
- Smaller systems (< 5 MW) challenging economics
- Residual material (ash) about 10% by volume, 20% by weight
- LCOE = $0.06 - $0.20/kWh (depends on tipping fee revenue)

State of WTE Technology - small

Small scale (10-300 tpd) advanced conversion technologies in demonstration phase

- More efficient than combustion, 30%- 40%
- Syngas (CO + H2 + CH4) can be used in IC engines, gas turbines, steam turbines or to make liquid fuels
- Installed cost $6,000 per kW, and up
- Residual material:
  - about 10% by volume
  - 20% by weight
- LCOE: $0.15 - $0.20+ per kWh
- (LCOE depends on tipping fee revenue)
- Reduced water usage
- 600-800 kWh per ton MSW

IES 30 ton per day unit Mecca, CA

State of WTE Technology - mobile

Expeditionary scale (0.5-3 tpd) WTE entering limited demonstration phase

- Demonstration projects beginning at Ft Irwin, Aberdeen Proving Grounds, Edwards AFB
- 250-600 kWh per ton MSW

Community Power Corp: MEWEPS System

WTE Economics

WTE facilities are expensive to construct

- Emissions control equipment requirements are a primary driver

Operation and maintenance costs are relatively high, approximately $100/MWh of generation

- MSW fuel is hard on system components, requiring replacement earlier than systems using other fuels

Revenue is generated from selling electricity and from fees charges for the disposal of solid waste (tipping fee)

- Due to economies of scale, larger plants (>500tpd) can compete with local electricity rates and tipping fees
- Tipping fees in the U.S. range from $15/ton in Oklahoma to $92/ton in Vermont

Evaluating WTE Opportunities

Waste stream

- Large-scale, commercially proven, systems require >300 ton per day (tpd) of MSW
- Small-scale, yet-to-be proven systems can operate with less feedstock, but economics are marginal

Potential sites

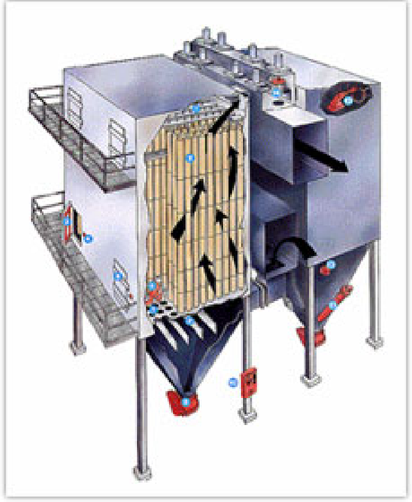
- WTE is typically favorable in cities, islands, and other areas with land constraints, due to high costs to build new landfills
- Tipping fees over $70/ton could support WTE

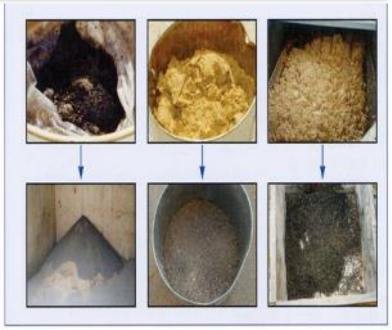
Energy price

- Over $.12/kWh is favorable for WTE

Air Emissions and Ash

Ash	By-product of conversion process	15-25% by weight of MSW and 5-15% of the volume
	Fly ash (top)	Particles and residues removed from flue gas and pollution control devices
	Bed ash (bottom)	Silica (sand, quartz), CaO, Fe_2O_3, and Al_2O_3
		Potential re-use
		Concrete, bricks, artificial reefs
Air	Modern air pollution control technology removes most contaminants	
	Scrubbers, baghouse, ESP, etc.	
	Varies by WTE technology, fuel composition, and controls used	





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