Tribal Leader Forum:
Waste-to-Energy Introduction

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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
List three benefits of WTE
• Reduces electricity cost
• Helps to meet renewable energy mandates
• Improves waste management and reduces land filling
• + Other environmental benefits
An accurate feedstock resource estimate is the basis for estimating the performance and economics of a biomass-or waste-to-energy project.
Biopower Pyramid

- Feedstock characteristics and availability
- Equipment sizing and energy production
- Project economics
Capacity Sizing Chart

MSW or biomass required to generate 1-MW for various system heat rates

Tons per day at various heat rates and energy contents to generate 1 MW gross
Municipal solid waste (MSW) is a heterogeneous mixture composed of various materials. Organic material is the primary fuel source for energy projects and can be composted. Inorganic / inert materials, which include many that can be recycled, make up a significant portion of MSW. MSW is a low-energy content fuel, with an average energy content of 5,900 Btu per pound (US). WTE systems can be co-fired with other feedstock, making MSW a versatile resource.

The MSW Composition (EPA 2005) shows the percentage distribution of different materials in MSW:
- Paper: 34%
- Yard Trimmings: 13%
- Food Scraps: 12%
- Plastics: 12%
- Metals: 8%
- Rubber, Leather & Textiles: 7%
- Glass: 6%
- Wood: 5%
- Other: 3%

Sustainable Supply
Refuse Derived Fuel (RDF)

RDF is feedstock derived by processing of municipal solid waste.

- 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.

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

- Project economics
- Equipment sizing and energy production
- Feedstock characteristics and availability
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
#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
## Metals

<table>
<thead>
<tr>
<th>Metals Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aluminum</strong></td>
<td>• Cans • Foil</td>
</tr>
<tr>
<td><strong>Tin-Coated Steel Containers</strong></td>
<td>• Food packaging (e.g., canned food)</td>
</tr>
<tr>
<td><strong>Bimetal Containers</strong></td>
<td>• Example includes tin-plated steel cans with an aluminum “pop top”</td>
</tr>
<tr>
<td><strong>Non-Ferrous Metals</strong></td>
<td>• Scrap metal that does not contain iron (e.g., copper and brass)</td>
</tr>
<tr>
<td><strong>Ferrous Metals</strong></td>
<td>• Iron • Iron-containing metal scrap • Steel</td>
</tr>
</tbody>
</table>
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

**Thermal**
- **Excess Oxygen**
  - Combustion
    - Heat
    - Heat/power/CHP
    - Boiler, steam turbine
    - Co-fire with coal
  - Gasification/Plasma
    - Fuel Gases (producer gas) $(CO + H_2 + CH_4)$
  - Pyrolysis
    - Char, gases, liquids (syn gas)
    - Burn gas for hot water/steam (commercial)
    - Use in IC engine, gas turbine or fuel cell for CHP (pre-commercial)
    - Catalytic conversion to alcohols, chemicals, synthetic diesel (development)

**Biochemical**
- **No Oxygen**
  - Pretreatment
    - Digestion
  - Fermentation
  - Transesterification
  - Ethanol
  - Biodiesel
  - CH$_4$
  - CO$_2$
  - Torrefied wood for pellets, coal replacement
  - Pyrolysis oil for boilers and power (early commercial)
  - Specialty chemicals (commercial)
  - Further refining for transportation fuels (in development)

**Partial Oxygen**
- Gasification/Plasma
- Pyrolysis

**Innovation for Our Energy Future**
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

Primary Feedstock
- Biomass
- MSW
- Others

Gasification/Plasma
- Syngas (CO+H₂)

Products
- Syngas to Liquids
- Syngas to Chemicals
- Close Coupled Combustion
  - Boiler
  - IC Engine
  - Combustion Turbine
- Fischer Tropsch
- Upgrading
- Liquid Fuels
- Others
- Hydrogen
- Mixed alcohols
  - Ethanol
  - Propanol
- Others
Plasma Reactor
Pyrolysis

No oxygen

Biomass

BioOil Reactor

Gas & Vapor

Condenser

Gas

BioOil

Char

Relatively low temperatures

HEAT

Courtesy: Renewable Oil International
Landfill-Gas-to-Energy

Modern Sanitary Landfill

Gas Header Pipe
Intermediate/Final Cover
Flare/LFGTE Plant
Leachate Plant
Gas Extraction Wells
Liner System
Waste Cells
Monitoring Probes

File Last Updated: June 2008
Anaerobic Digestion

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

Thermal

- Excess Oxygen
- Partial Oxygen
- No Oxygen

Combustion
Gasification/Plasma
Pyrolysis
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
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
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

<table>
<thead>
<tr>
<th>By-product of conversion process</th>
<th>15-25% by weight of MSW and 5-15% of the volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash (top)</td>
<td>Particles and residues removed from flue gas and pollution control devices</td>
</tr>
<tr>
<td>Bed ash (bottom)</td>
<td>Silica (sand, quartz), CaO, Fe$_2$O$_3$, and Al$_2$O$_3$</td>
</tr>
<tr>
<td></td>
<td>Potential re-use</td>
</tr>
<tr>
<td></td>
<td>Concrete, bricks, artificial reefs</td>
</tr>
</tbody>
</table>

## Air

<table>
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<tr>
<th>Modern air pollution control technology removes most contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrubbers, baghouse, ESP, etc.</td>
</tr>
<tr>
<td>Varies by WTE technology, fuel composition, and controls used</td>
</tr>
<tr>
<td>Reference</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
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</tbody>
</table>
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