I. Covanta
II. Municipal Solid Waste (MSW)
III. Energy from Waste (EfW) Technology
   • Combustion
   • Energy Recovery
   • Emissions Control
   • Ash Management
IV. EfW – Sustainability
V. New Technologies
VI. Questions - anytime
I. Covanta – Energy from Waste Leader

Covanta Holding Corporation (NYSE: CVA)

Largest EfW operator in the world
- North America, Asia & Europe
- 4,200 employees

45 EfW facilities owned and/or operated
- 20 million tons of waste per year
- 9 million MW-hr of renewable energy/yr

Strong balance sheet & stable business
- 2010 revenue $1.6 billion
- 2010 cash flow = $320 million
• Corporate Headquarters Morristown, NJ
• 40 EfW facilities (240 TPD to 3,000 TPD)
  • 23 Martin Mass Burn
  • 4 Refuse Derived Fuel (RDF)
  • 4 O’Connor Rotary Mass Burn
  • 4 Fisia DBA Mass Burn
  • 3 Enercon Mass Burn
  • 1 Steinmuller Mass Burn
  • 1 Aireal Mass Burn
• 13 Transfer Stations
• 3 Ashfills and one landfill
• 7 Biomass to electricity facilities
• 5 Landfill gas to energy facilities
• 2 Hydro electric facilities
• Recently broke ground on Durham / York project in Ontario – 1st new facility in 10+ years
International Portfolio

• Europe
  • Office outside Birmingham, England
  • UK – developing new EfW projects
  • Italy – Trezzo EfW Facility
  • Ireland – Dublin EfW Project development

• Asia
  • Office in Shanghai, China
  • Chongqiing, China – Sanfeng/Covanta JV
  • Own / operate 4 EfW facilities
II – Municipal Solid Waste (MSW)

A typical

Contains enough energy to power a 50 watt light bulb for 48 hours.

Paper
Cardboard
Plastics
Leather & Rubber
Textiles
Wood
Ceramics, Stones, Dirt
Food Waste
Yard Waste
Metals
Glass
MSW Composition

Elemental Components:

- Carbon ~ 30 wt%
- Hydrogen ~ 4
- Oxygen ~ 25
- Nitrogen ~ 0.5
- Sulfur ~ 0.1
- Chlorine ~ 0.5
- Water ~ 20
- Ash ~ 20

Ash Elements:

- Si
- Zn
- Ca
- Cu
- Al
- Pb
- Fe
- Cr
- K
- Ni
- Na
- As
- P
- Cd
- Mg
- Hg

HHV ~ 5000 Btu / lb - VERY VARIABLE
2007
280 Million Tons Generated

1960
88 Million Tons Generated

**TRASH TALK:**

In 50 Years:
- U.S. Total Waste ~ Tripled
- U.S. Waste per Person ~ Doubled
- U.S. = 0.9 ton/person/year - decreasing
- E.U. = 0.5 ton/person/year - stable
- China = 0.25 ton/person/year - increasing
U.S. Annual MSW HHV Trend

The Waste Management Hierarchy

- European directive in 2008 established the hierarchy as the best overall environmental solution – regulatory requirement
- The U.S. EPA has the same hierarchy – but not regulated by law

- Reduce. Then what can’t be reduced
- Reuse. Then what can’t be reused
- Recycle/Compost. Then what can’t be recycled or composted
- Recover. Using state-of-the-art combustion processes to generate clean, renewable energy, and then
- Dispose. Of that which has no other use and must be landfilled.
EfW Complements Recycling

Waste Management Trend in Germany
1996 to 2007

- The EU goal of diverting MSW from landfills has increased both recycling and EfW
- Communities in the U.S. with EfW have higher recycle rates
- EfW provides direct recycling thru Fe/NonFe recovery
III. Energy-from-Waste (EfW) Technology

- Also known as:
  - Waste-to-Energy (WTE)
  - Municipal Waste Combustion (MWC)
- Power plant that combusts MSW and other non-hazardous wastes as fuel
- Generation of renewable electrical power and/or steam

U.S. EPA has stated that Energy from Waste is one of the cleanest sources of electrical power available today.
COVANTIA Energy-from-Waste Process

Refuse volume is reduced 10:1
Refuse weight is reduced 4:1

Not to Scale (typical layout)
Covanta Montgomery County, MD Facility
EfW Technology Challenges

- Grate Technology
- Boiler Design
- Combustion Control
- Emissions Control
- Ash Management
EfW Grate Technology

Key Design Parameters:
- Air distribution control
- Degree of stoking of MSW
- MSW bed depth control
- MSW residence time control

Bar chart showing the number of facilities for different technologies:
- Inclined Horizontal Sity2000: 56 facilities
- RDF: 4 facilities
- DBA: 4 facilities
- Rotary "Oconner": 11 facilities
- Multiple Hearth: 13 facilities
- Stein-mueller: 8 facilities
- Aireal: 5 facilities
- Von Roll: 3 facilities
- Martin: 2 facilities
Martin GmbH Reverse Reciprocating Grate
Deutsche Babcock Anlagen (DBA) Roller Grate
EfW Boiler Design

Steam Conditions Set by Corrosivity - Chloride Molten Salts

Design Considerations:

• Tube metal temperature
  • Waterwalls
  • Superheaters
  • Economizers

• Flue gas velocity

• Fouling
  • Tube spacing
  • Cleaning systems

• Tube protection
  • Refractory
  • Alloy coatings
  • Shielding

• MSW and energy value
  • Energy efficiency – boiler outlet temp.
  • Tube life
Mass Burn Martin Horizontal Boiler

Lee County – 3 x 900 TPD Boilers
Mass Burn DBA Vertical Boiler

Hempstead – 3 x 900 TPD Boilers
Shredded Refuse-Derived-Fuel (RDF) Boiler

SEMASS – 3 x 1,000 TPD Boilers
Boiler Corrosion – Impact of SO₂/HCl
EfW Combustion Control

- No measure of feed waste flow or heating value
- Large MSW HHV variations
- Control targets – constant steam flow, excess oxygen, furnace temperature limits
- Variables – ram feeder speed, grate speed, underfire air flow and distribution, overfire air flow
- Empirical “Trash Factor” input based on waste quality – moisture content
HHV Trend vs. Precipitation

Month

JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC

HHV (Btu/Lb)

5,400
5,000
4,600
4,200
3,800
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0

Precipitation (inch)
EfW Boiler Firing Diagram
EfW Emissions Control

- Automated combustion controls
- Staged combustion and SNCR for NOx control
- Activated carbon for mercury and dioxins
- Scrubber / baghouse for PM, SO2, HCl, Hg, dioxins
- Continuous monitoring and reporting

All existing EfW facilities in U.S. are subject to Federal MACT standards. EPA is in process of implementing new MACT standards for EfW
Covanta Low NOx Technology (Staged Combustion)

- Automated controls integrated with EfW control system
- NOx: 150 - 180 ppm without SNCR
- NOx: 60 - 90 ppm with SNCR
- Installed in 20 Covanta boilers
Spray Dry Adsorbers for HCl / SO2 Removal

- Injection of Ca(OH)$_2$ slurry and water
  - Ca(OH)$_2$ slurry for acid gas control
  - Water for outlet temperature control

- Acid gases absorbed onto droplets then react with dissolved lime to form salts
  - Ca(OH)$_2$ + SO$_2$ → CaSO$_4$
  - Ca(OH)$_2$ + 2 HCl → CaCl$_2$

- Droplets dry leaving salt residue

- Complex mechanism but rate limiting step is gas phase mass transfer of acid gases to droplet surface
Baghouses – More Than Particulate Control

- Flue gas passes through thousands of long, thin bags
- Cake forms on outside of bag enhancing particulate capture and adsorption
- Contributes to fine particulate, acid gas, mercury & dioxin control
- Bags are cleaned by pulses of high pressure air
- Advances in baghouse design targeting formation and retention of consistent filter cake
- Development of new bag materials improving performance
EfW facilities operate with average emissions far below EPA permitted limits.

**Graph:**
- **US EPA MACT Limit (%):**
- **Chemicals:** Mercury, Cadmium, Lead, Particulates, Hydrochloric Acid, Sulfur Dioxide, Nitrogen Oxides, Dioxins/Furans, Nitrogen Oxides w/VLN, Carbon Monoxide

**Legend:**
- EfW Emission Performance Exceeds MACT
New MACT – Emission Control in Existing Plants

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Particulate (mg/dscm)</th>
<th>Cadmium (ug/dscm)</th>
<th>Lead (ug/dscm)</th>
<th>Mercury (ug/dscm)</th>
<th>Dioxin (ng/dscm)</th>
<th>SO2 (ppm)</th>
<th>HCl (ppm)</th>
<th>NOx (ppm)</th>
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<td>Current MACT</td>
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<td>35</td>
<td>400</td>
<td>50</td>
<td>30</td>
<td>30</td>
<td>25</td>
<td>205</td>
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<tr>
<td>Anticipated New MACT</td>
<td>5 - 10</td>
<td>0.5 - 3</td>
<td>10 - 30</td>
<td>5 - 10</td>
<td>5 - 10</td>
<td>8 - 16</td>
<td>8 - 16</td>
<td>140 - 160</td>
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</table>

- New MACT regulations not yet defined but emission limits will likely be 5 to 10 times lower
- The presence of any mercury and dioxins continue to be a negative for EfW growth
New Plant Emission Control Approach

Circulating Dry Scrubber / Baghouse Systems

- Inlet flue gas cooled with water quench if necessary
- Fly ash / scrubber residue recycle ratio as high as 50 - contains unused reagents (lime and carbon)
- High solids loading and internal recirculation in dry scrubber yields high surface area for mass transfer
- Uses dry hydrated lime
- Make-up hydrated lime and carbon added to recycled residue or separately to CDS reactor

Shown to achieve superior emissions in Europe
EfW Ash Management

- Mass burn ash distribution ~ 85% bottom; 15% fly
- Bottom ash processed to recover ferrous and non-ferrous metals
- Screened bottom ash has potential for beneficial use as natural aggregate substitute
  - Common in Europe
  - No current use in U.S. due to lack of regulations
- Fly ash contains high chlorides and heavy metals – not fit for reuse
- In US fly ash is mixed with bottom ash for disposal
  - Ash must be characterized using TCLP
IV. Sustainability

EfW Reduces Greenhouse Gas Emissions

EfW is a demonstrated GHG mitigation technology.
EfW Recovers More Power than Landfilling

EfW provides more renewable electrical power than any other waste disposal option.

EfW recovers additional ferrous and non-ferrous metals (post recycling), saving the energy of production.
V. Advanced Technologies

- Gasification
- Bio-Fuels
Gasification

• Conversion of carbonaceous material into gaseous products containing CO & H₂, by reactions with O₂, CO₂ and H₂O

Chemistry of gasification is sound

Challenge is Gasification of MSW – Economic Viability

– Heterogeneous make-up of MSW
– Heat balance – partial combustion vs. external energy (e.g. plasma)
– Syngas purity – trace impurities
– Syngas variability – process control
MSW Gasification

- Continued market interest in gasification technologies
- Perception of higher energy efficiency and less environmental impact
- No commercial operating MSW gasification projects in North America, but several commercial projects in development or construction

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Feedstock</th>
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</thead>
<tbody>
<tr>
<td>Enerkem</td>
<td>Fluidized bed gasification to syngas; Air based</td>
<td>Biomass, RDF</td>
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<tr>
<td>AlterNRG</td>
<td>Moving bed, plasma torch gasification, O2 enriched air</td>
<td>RDF, Biomass</td>
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<tr>
<td>S4 Energy</td>
<td>Moving bed thermal gasification followed by plasma</td>
<td>RDF</td>
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<td>gasification – O2 enriched air, Syngas to bio-fuels</td>
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<td>Plasco</td>
<td>Plasma-enhanced gasification – Air based, Syngas to</td>
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<td>gas engine</td>
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<td>Ze-gen</td>
<td>Molten metal gasification, Air or O2 enriched air</td>
<td>C&amp;D, Biomass</td>
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<td>Chinook</td>
<td>Batch pyrolysis</td>
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<tr>
<td>Energos</td>
<td>Close-coupled gasification/combustion</td>
<td>MSW</td>
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</table>
MSW Gasification – Two Types of Processes

1. GASIFICATION / COMBUSTION – Goal of Improved Emissions and Higher Energy Efficiency

- MSW
- Low Temperature Gasification
  - Low Quality Syngas
  - Post Combustion
  - Reduced NOx, CO & gas flow
- Conventional Boiler, APC, Power Gen

2. GASIFICATION TO SYNGAS – Goal of Combined-Cycle Power or High-Value End-Products

- MSW
- High Temperature Gasification
  - High Quality Syngas
- Syngas Cleaning
  - Combined Cycle Power
  - Liquid Fuels Production
  - Hydrogen Production
Gasification at Adiabatic Conditions
MSW Gasification – Conclusion

• Many gasification processes on the market and several projects under construction or in extended start-up – none commercial

• Gasification has potential for incremental improvements in power efficiency and emissions

• MSW gasification technically feasible but many challenges still to be overcome

• Economics very uncertain
## Bio-Fuels Technologies

Many technologies entering market based on thermal and catalytic cracking of waste plastics and biomass to liquid fuels

<table>
<thead>
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<th>Feedstock</th>
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<td>Plastics</td>
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<td>Environ</td>
<td>Vacuum Thermal Cracking</td>
<td>Plastics</td>
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<tr>
<td>Polymer Energy</td>
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<td>ETS (UK)</td>
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<td>KiOR</td>
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</tr>
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Thank You!