Informational Meeting Session No. 2

February 28, 2017
King County Council Chamber

Introduction
Kathy Lambert, King County Councilmember
Integrated Solid Waste Management Systems Anchored by Modern Waste-to-Energy

A Review of Recent Installations and Existing Facility Operations from Around the World

Sustainable Waste Management Solutions for the 21st Century

Presentation to:
King County and Regional Public /Private Organizations
February 28, 2017
Seattle, WA
CDM Smith’s World Waste-to-Energy Experience

DB/DBO Vendor Procurement
Technology Evaluation
Other WTE Projects

British Columbia, Canada, Vancouver

Ontario, Canada, Brampton

Pennsylvania
Lancaster County, York County

New York
Babylon, Onondaga County, Huntington, Westchester County, New York, Erie-Niagrs County, Oyster Bay

New Hampshire
Durham, Manchester, NH/VT SWP

Maine
Auburn, Portland

Canada, Nova Scotia
Halifax

Massachusetts
Fall River, North Andover, Braintree, Saugus, Haverhill

Connecticut
Bristol, Hartford, Wallingford, Windham

New Jersey
Essex County, Bergen County, Mercer County, Middlesex County

Virginia
Fairfax County, Prince William County

Florida
Bay County, Tampa, Dade County Aviation, Key West, Lee County, Palm Beach County, Hillsborough County, Pinellas County, Pasco County, Vero Beach, St. Lucie County
Presentation Outline

- Evolution of the WTE into the Resource Recovery Industry
- Capital and O&M Cost of WTE Facilities
- Revenue Streams from WTE Facilities
- Options for Enhanced Revenues
- Economic and Environmental Benefits of WTE
- Greenhouse Gases and Carbon Offset Potential of WTE
- Case Studies of Several Florida WTE Projects
- Conclusion
U.S. / Europe Waste Management Hierarchy

- Waste Prevention
- Re-use
- Recycling
- Maximize Recovery of Energy and Materials
- Minimize Landfill Waste Disposal
WTE Benefits Include Waste Sterilization, along with 90% Volume and 75% Weight Reduction

Input

Waste in, stabilized and inert ash out!

Output
Modern WTE Trends...Improved Efficiency and Sustainability, Yet Lower Power Payments!

**Increasing Trends**
- Advanced ferrous and non-ferrous metal recovery
- Advanced combustion controls
- Higher boiler/TG availability and gross/net electric generation
- Use of reclaimed water for cooling
- Higher Heating Value (HHV) of MSW
- Compliance with stringent emission limits & GHG reporting
- WTE facility expansions and attention to aesthetics/LEED®/innovation
- Evolution of integrated solid waste management/eco-campus

**Decreasing Trends**
- Air pollution emissions
- Chemical reagent consumption
- Water consumption
- Lower payments for electricity sold to electric grid
## Evolution of WTE Technology

<table>
<thead>
<tr>
<th>Element</th>
<th>Incineration</th>
<th>1st Generation WTE</th>
<th>2nd Generation Modern WTE</th>
<th>3rd Generation Advanced RR</th>
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</thead>
<tbody>
<tr>
<td>Aesthetics</td>
<td>Industrial</td>
<td>Industrial</td>
<td>Enhanced</td>
<td>Enhanced Plus</td>
</tr>
<tr>
<td>Steam Conditions</td>
<td>None</td>
<td>600 psi</td>
<td>835/ 1350 psi</td>
<td>850 / 1400 psi</td>
</tr>
<tr>
<td>Net Electrical Generation</td>
<td>0</td>
<td>475</td>
<td>570/ 725</td>
<td>575-600/ 750</td>
</tr>
<tr>
<td>Combustion Control</td>
<td>Basic</td>
<td>Computer Based</td>
<td>Advanced</td>
<td>Optimized</td>
</tr>
<tr>
<td>Air Pollution Control</td>
<td>None</td>
<td>Electrostatic Precipitators</td>
<td>Scrubber / Fabric Filters with Activated Carbon</td>
<td>Scrubber / Fabric Filters with Activated Carbon, Very Low NOx</td>
</tr>
<tr>
<td>Ferrous Recovery</td>
<td>None</td>
<td>Electromagnets 2.0 – 2.5%</td>
<td>Permanent Magnets 2.5%</td>
<td>Rare Earth Magnets 3.5%</td>
</tr>
<tr>
<td>Non-ferrous Recovery</td>
<td>None</td>
<td>None</td>
<td>Eddy Current Separators (ECS)</td>
<td>High Strength ECS (90% recovery)</td>
</tr>
<tr>
<td>Beneficial Reuse of Ash Residue</td>
<td>None</td>
<td>None</td>
<td>Within Landfill Campus</td>
<td>Multiple Uses</td>
</tr>
</tbody>
</table>
Examples of Enhanced Architectural Design

Palm Beach County FL

Hamburg, Germany

Copenhagen Denmark
Focus on Good Housekeeping...
Top Floor of Refuse Storage Building
Focus on Good Housekeeping...
Middle Deck Level of Boiler Building
Metals “Liberated” by Combustion and Recovered by Stronger Magnets and ECS – 2nd Generation

Plus 6” Ferrous Metals

Minus 6” Ferrous Metals

+3/8” Non-ferrous Metals

Close-up of Non-ferrous Metals

Dense aluminum “nuggets”
Advanced Metal Recovery Goal is to Recover the “Fine Fractions” of Metals and Minerals
Samples of “Fine” Minerals and Metals from Ash

Percent of Estimated Value of Non-Ferrous Metals in Ash

- Aluminum 34%
- Gold 28%
- Copper 23%
- Iron 10%
- Silver 3%
- Zinc 2%
- Lead 1%

Credit: InAshCo
3rd Generation Resource Recovery can Help Communities Achieve Future “Zero Waste” Goal

- MSW to Landfill
- WTE without Metal Recovery
- WTE with Metal Recovery
- WTE with Metal Recovery and Bottom Ash Recycling

Evolution of WTE Industry
### Major Elements of WTE Capital and O&M Cost

#### Capital Costs
- Cost of land
- Project development cost
  - Engineering
  - Permitting
  - Procurement
  - Legal
- WTE facility / process cost (including spare parts)
- Financing cost
  - Interest rate
  - Term of loan

#### O&M Costs
- Contractor labor and service fee (includes profit)
- Air pollution control system chemical reagents (carbon, lime, urea, ammonia)
- Water treatment reagents (acid, caustic)
- Utilities (natural gas, electricity, potable water, raw water, reclaimed water, sanitary sewer)
- Disposal of bypassed or non-processible waste
- Disposal of ash residue
U.S. Massburn WTE Capital Cost History
Upward Trend, or has it Turned the Corner?

Capital Cost
($ per Ton / Day Capacity)

Start of Construction


RDF

Palm Beach County New
WTE Project Bid Prices

Capital Cost of WTE
Representative Massburn WTE **Annual Expenses**
Illustrative Purposes Only, from Prior Project Analysis

**Approximate ratio of capital to O&M cost is ~50/50**

- **Capital Debt Service @ 6%**: 70.0%
- **O & M Cost**: 50.0%
- **Ash Disposal Cost**: 10.0%
- **Reagent Costs**: 0.0%

In Europe, this expense has been minimized, and in some cases, become a revenue!
Major Revenue Streams from Modern WTE (Listed in Approximate Order of Value)

- Value of power used internally (behind the meter)
  - Allows owner to realize full retail value
- Net electricity sold to grid
  - Percentage of electrical revenues shared with operator (10%)
- Steam / hot water sales (CH&P)
- Ferrous and non-ferrous metals
  - Percentage of electrical revenues shared with operator (50%)
- Special Waste Programs
  - Liquid and solid wastes
- Attributes of renewable energy generation
  - Renewable Energy Credits (RECS)
  - Carbon offsets (CO$_2$e - Currently sold on voluntary markets)
Representative Massburn WTE Annual Revenues
Illustrative Purposes Only, from Prior Project Analysis

Energy sales dominate WTE revenues

Non-ferrous metal revenues are ~ 3 to 4 times the value of ferrous metal revenues
WTE Capacity Factor is the Highest Among Renewable/Fossil Energy Options (Base Load)

- Nuclear: 90-92%
- **Waste-to-Energy (WTE):** 88-95%
- Baseload Coal: 80-90%
- Landfill Gas: 80-95%
- Biomass: 60-85%
- Natural Gas Combined Cycle: 60-80%
- Thermal solar (parabolic trough): 40%
- Wind: 20-35%
- Photovoltaic solar (southern latitudes): 18-20%
- Photovoltaic solar (northern latitudes): 12-15%

WTE helps provide **fuel diversity and resiliency for base load power production on the regional electrical grid!**
Benefits of WTE to Regional Electrical Grid

- Centrally located distributed energy
  - Typically located in close proximity to urban electrical demand
  - Distributed source of generation, with minimal line losses
- Reliable base load source of renewable energy
  - Supports proper operating voltages on local electrical grid
- Delays need to permit and construct new units as aging and uneconomical large fossil units are retired
- Improves “fuel” diversity to local electrical grid for reliability during interruptions in fuel or hydro water supply
- Compatible with Microgrid Concept
  - Improves resiliency of critical municipal infrastructure (power, water, wastewater, public works, emergency and disaster management, etc.)
Opportunities for Enhanced WTE Revenues

- Maximize availability
- Maximize energy production
- Internal use of energy
  - Treatment of water and/or wastewater
  - Drying and processing WWTP biosolids
  - Other “behind the meter” uses (Public Works, recycling facilities)
- Combustion of special wastes in need of assured destruction
- Advanced recovery of metals and minerals
- Sale of bottom ash
  - Aggregates for use in asphalt or concrete pavements / products
  - Feedstock for manufacturing of Portland cement
- Recover and use of waste heat (municipal and industrial uses, host community benefits)
Pasco County Florida WTE Facility (26 years old)
Continuous Improvement in Facility Availability

Credit: Pasco County, FL
Current Value of Recovered Non-Ferrous Metals in Bottom Ash is ~60% of Total Recoverable Value

Assuming 0.4% Non-ferrous Metal per Ton MSW

Annual Revenues ($ / Year)

Scrap Price
- $2,000/Ton
- $1,500/Ton
- $1,000/Ton
- $500/Ton

WTE Facility Capacity (Tons per Day x 100)
Net Electrical Generation Rates for Proven WTE (not including Emerging Technologies)

High pressure boiler can increase electrical production by ~30%
World’s Largest WTE Facility (2020) in China to include Desalination Water Plant and Solar PV

- 5,000 mtpd (5,600 tpd)
- 125 MW nameplate electrical
- **132 mgd water production**
- Shenzhen, China (population of 20 Million)

Credits: Schmidt Hammer Lassen Architects and Gottlieb Paludan Architects

Options for Enhanced Revenues
Low pressure steam used for heating of grassed areas for early greening in spring, along with space heating and hot water needs. Steam also delivered to local district heating system, significantly increasing net thermal efficiency!
Special Wastes in Need of Secure Means of Disposal!

- **Wastewater treatment plant residuals and biosolids**
  - Discarded fats, oils and grease (FOG)
- **Local and regional wastes in need of “secure means of disposal”**
  - Unsalable manufactured products
  - Out-of-spec or out-of-date
  - Discarded pharmaceuticals
  - Industrial liquid and solid wastes
  - International wastes (USDA regulated garbage)
  - Auto shredder residue (ASR)
- **Construction and demolition wastes**
- **Recycling facility residues**
- **Bulky Wastes, used tires, used motor oils and lubricants**
Significant Annual Revenues from Supplemental Waste Program in Lancaster County Pennsylvania

Addition to WTE Tipping Building for Supplemental Waste Program
Opportunities for Local Ash Recycling

• Beneficial use of bottom ash
  – Construction aggregate
    • Road base
    • Structural fill
    • Flowable fill
    • Asphalt and concrete pavements
  – Feedstock for manufacture of Portland cement
    • Source of alumina, ferric oxide, lime and silica (primary ingredients)

• Beneficial use of combined ash
  – Construction aggregate
    • Road base
    • Structural fill
    • Flowable fill
Europe Continues to Advance the Art and Science of Enhanced Recovery of Metal and Minerals, along with Beneficial Reuse of Ash

Advanced screening technology for various size ranges of ash

Multiple magnets and eddy current separators

Impact breaker for large clinkers, ash washing
This is What Fresh Bottom Ash Looks Like
Pasco County Ash Reuse - First in Florida to Receive FDEP Authorization for Beneficial Reuse Beyond the Limits of the Solid Waste Campus

FDEP approved beneficial reuse in December 2014 for three applications
1. Bottom ash as road base
2. Bottom ash as aggregate in asphalt
3. Bottom ash as aggregate in concrete
WTE Bottom Ash Recycling Opportunity as a Raw Material for Production of Portland Cement

WTE Bottom Ash is a good match to provide the four primary ingredients.

<table>
<thead>
<tr>
<th>Component</th>
<th>Portland Cement</th>
<th>Clinker</th>
<th>Typical WTE Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂)</td>
<td>18-24</td>
<td>22-24</td>
<td>24</td>
</tr>
<tr>
<td>Aluminia (Al₂O₃)</td>
<td>4-8</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Ferric Oxide (Fe₂O₃)</td>
<td>2-5</td>
<td>0-3</td>
<td>3</td>
</tr>
<tr>
<td>Lime (CaO)</td>
<td>62-67</td>
<td>68-71</td>
<td>37</td>
</tr>
</tbody>
</table>

Source: Defending the Character of Ash, Richard W. Goodwin, 1992
Explore Opportunities for Recycling Bottom Ash at Local Cement Kilns

United States and Canadian Portland Cement Plant Locations
Plant Identification as of May, 2004
Plant Data as of December 31, 2002

Options for Reduced Costs
Sensitivity Analysis (2,400 TPD, 3 Cents/kWh, Project Financed at 4.5% for 30 Years)
Illustrative Purposes Only, from Prior Project Analysis

Impact of Variables on Fee

Change in Assumptions

Reduction in Base Case Tipping Fee

$ / Ton

- $0.07/kWh Electric Revenue
- $1.5% Less Interest
- 10% Less Capital Cost
- 8% Less Capital Cost
- 10% Less O&M Cost
- $15/MWh REC Revenue
- 6% Less Capital Cost
- 8% Less O&M Cost
- 6% Less O&M Cost
Extending Financing Term from 20 to 30 Years Reduces Tipping Fee by ~ $10.60 per Ton
Illustrative Purposes Only, from Prior Project Analysis

WTE Tipping Fee (3,000 tpd @ 90% Availability)

Economic Benefits of WTE
Reason to Finance Infrastructure Debt over Longer Periods of Time

• WTE technology has proven 45-50 service life when properly operated and maintained
• Reduces annual financing costs by a meaningful amount (~$10.60 per ton)
• Attractive for bond financing of investment grade “PPP infrastructure projects”
• Users of the system pay their fair share over the longer finance period!
Long-term Benefit of WTE... Cost Stabilization and Local Economic Development

- Long-term tipping fee savings and rate stabilization
- Economic development via procurement of goods and services from local vendors
- Creation of high quality jobs during design, construction, operation, and maintenance period

WTE & Greenhouse Gas Avoidance

- **Avoided methane emissions from landfills.** When a ton of solid waste is delivered to a waste-to-energy facility, the methane that would have been generated if it were sent to a landfill is avoided. While some of this methane could be collected and used to generate electricity, some would not be captured and would be emitted to the atmosphere.

- **Avoided CO₂ emissions from fossil fuel combustion.** When a megawatt of electricity is generated by a waste-to-energy facility, an increase in carbon dioxide emissions that would have been generated by a fossil-fuel fired power plant is avoided.

- **Avoided CO₂ emissions from metal recycling.** Waste-to-energy plants recover more than 700,000 tons of ferrous metal for recycling annually. Recycling metals saves energy and avoids CO₂ emissions that would have been emitted if virgin materials were mine and new metals were manufactured, such as steel.

- **Waste-to-energy plants are tremendously valuable contributors in the fight against global warming.** According to the U.S. EPA MSW Decision Support Tool, nearly one ton of CO₂ equivalent emissions are avoided for every ton of municipal solid waste handled by a waste-to-energy facility.

  Credit: Ted Michaels, President Energy Recovery Council, March 17, 2011
Potential Carbon Offsets Attributable to Modern WTE Facilities – Avoided Methane is the Largest

Nearly one ton of CO2 equivalent emissions are avoided for every ton of municipal solid waste processed by a modern WTE facility.

Credit: Ted Michaels, President Energy Recovery Council, March 17, 2011
Annual Avoided CO₂ Emissions from WTE (May be 4 times than first reported by EPA)

Avoided CO₂ Emissions per Year

- Avoided CO₂ Emissions (tons/year)
- Size of WTE Facility (tpd)

4.0 tons CO₂e per ton MSW
2.0 tons CO₂e per ton MSW
1.0 ton CO₂e per ton MSW

Greenhouse gases and carbon offset potential of WTE
Case Study Pasco County, Florida WTE
1,050 TPD Massburn – 30 MW Net Electrical Output
(serving average needs of 17,000 households)

• Construction: 1989-1991
• $90M capital cost
• Current O&M cost ~ $42/ton+
• Electricity revenues shared 10%
• Metal revenues shared 50%
Case Study - Hillsborough County Florida WTE
1,800 TPD Massburn – 46 MW Net Electrical Output (serving the average needs of 25,000 households)

- Original 1,200 TPD construction: 1987 @ $80M
- 600 TPD expansion completed: 2009 @ $125M
- Current O&M cost ~$44/ton+
- Electricity revenues shared 10%
- Metal revenues shared 50%

Compatible with the urban landscape
Commercial/industrial development has occurred around facility over the past 30 years!
Hillsborough County Florida WTE
First to Internally Power Water Resource Facilities

- 1,800 TPD WTE Facility
- 12 MGD AWTP Facility
- 2 MW
- ~ 5 MW to Public Works Campus (Future)
- 37 MW currently sold to Grid
Significant Potential Savings to Public Works by Internally Using Electricity from WTE Facility

Potential Net Savings to Public Works
(1,800 TPD WTE with 4 cents / kWh spread)

Current internal use ~5%
Future internal use ~15%

Potential Annual Savings

$- $2,000,000 $4,000,000 $6,000,000 $8,000,000 $10,000,000 $12,000,000 $14,000,000 $16,000,000

Percent of Electricity Used Internally

0 20 40 60 80 100
Case Study - Pinellas County Florida WTE
3,000 TPD Massburn – 75 MW Net Electrical Output
(serving average needs of 40,000 households)
## Summary of Tampa Area Annual Solid Waste Rates with ISWM Systems Anchored by WTE Facilities

<table>
<thead>
<tr>
<th>County</th>
<th>Population</th>
<th>Collections per Week</th>
<th>Tipping Fee ($/ton)</th>
<th>Collection ($/HH/Yr)</th>
<th>Disposal ($/HH/Yr)</th>
<th>Overall Cost ($/HH/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasco</td>
<td>470,000</td>
<td>2 Trash 1 Recycling  No Separate Yard Waste Pickup</td>
<td>$56.70</td>
<td>Open Market ($150 max)</td>
<td>$62.00</td>
<td>$212.00</td>
</tr>
<tr>
<td>Pasco</td>
<td>470,000</td>
<td>2 Trash 1 Recycling  No Separate Yard Waste Pickup</td>
<td>$56.70</td>
<td>Open Market ($150 max)</td>
<td>$62.00</td>
<td>$212.00</td>
</tr>
<tr>
<td>Hillsborough</td>
<td>950,000</td>
<td>2 Trash 1 Recycling  1 Yard Waste</td>
<td>$68.16</td>
<td>$131.43 (Franchise System)</td>
<td>$91.32</td>
<td>$222.75</td>
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<tr>
<td>Pinellas</td>
<td>925,000</td>
<td>2 Trash EOW Recycling  No Yard Waste (St. Petersburg)</td>
<td>$37.50</td>
<td>$208.00 Varies among 27 cities Data for City of St. Petersburg</td>
<td>$95.40</td>
<td>$303</td>
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</table>

HH: Household

Case Studies of Florida WTE Projects
Benefits Realized by the Florida Communities with ISWM Systems Anchored by WTE

- **Maximizes production of renewable energy**
  - 575 kWh/ton of MSW processed
  - Higher thermal efficiency with Combined Heat and Power (CHP)
- **Significantly lower environmental impacts than landfills**
  - Less CO$_2$ and greenhouse gas emissions
  - Stabilized and inert ash disposal volume is minimized (90% volume reduction and 75% weight reduction)
  - Opportunities for recycling ash as aggregates and feedstock for cement
- **Greatest economic impact to local economy**
  - Long-term careers and high quality jobs
  - Significant impact during construction and long-term operation for purchase of goods and services
- **Minimal land use impacts**
  - Can meet the current and future needs of a community on 15-45 acres

- **ISWM Systems anchored by WTE allowed each community to responsibly manage their waste, within their jurisdiction!**
My Vision of an Integrated Campus for Management of Municipal Resources
Benefits of Waste to Energy

- Least environmental impact for power plants according to EPA (February 2003)
- Converts 4 million tons of Florida garbage/year to 534 megawatts of Power/day
- NCRRF has processed 13M tons of waste since the 1980’s – saving 13M barrels of oil
- Reduces expended landfill volume by 60%
- More favorable than landfills for greenhouse gas emissions according to EPA (September 2006)
Evaluating the Feasibility of Waste Conversion Technologies Requires a Serious Commitment

- High-Impact Decisions:
  - Capacity – target/max/min tpd, MSW source(s), etc.
  - Location – in region/out-of-region, transportation, etc.
  - Technology – massburn, gasification, emerging technologies, anaerobic or co-digestion, waste-to-biofuels, etc.
  - Procurement – funding, transparency, equitable comparison, etc.
  - Triple-Bottom-Line (TBL) Baseline – what is WTE being compared to?

- Economic
  - Capital
  - Annual O&M
  - Total Lifecycle
  - Offsets
  - Revenues

- Environmental
  - Regulations
  - Permitting
  - Carbon Impacts
  - Health & Human Risk Assessment

- Social
  - Job Creation
  - Community Integration
  - Being a Good Neighbor
Thank You for the Opportunity to Share!

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Question and Answer Session

Resources

- Scott DuBoff - GSB
- Paul Hauck – CDM Smith
- Jimmy Jia - DEM
- Philipp Schmidt-Pathmann - Neomer
- Curt Thalken - Normandeau
- Tay Yoshitani

Thank you!
Additional Slides for Q&A

- Options for Integrated Resource Management Systems
- Photos of WTE Plants from Around the Globe
- Advanced Recovery of Metals
- Economic Benefits of WTE to Local Community
Options for Integrated Resource Management Systems

- Representative Slides
Future WTE Projects Could Include Material Recovery, Advanced Recycling, and Emerging Waste Conversion Processes

Options for Recycling:
1. Single Stream MRF
2. Multi Stream MRF
3. Dirty MRF
4. C&D Recycling

Options for WTE Basement Area:
1. Maintenance Shop
2. Ash Processing
3. Special Recycling

Options for Integrated Resource Management Systems
Massburn WTE Integrated with Anaerobic Digestion and Composting

Options for Integrated Resource Management Systems
Co-digestion of Organic Waste with Wastewater Biosolids for Generation of Biomethane Gas

Options for Integrated Resource Management Systems
Synergies for EfW on Wastewater Sites...Similar Opportunities may exist on Power Plant Sites

- Co-digestion (Organic waste and FOG)
- Biogas Use (CHP and CNG)
- Heat Recovery Effluent
- PV Solar Energy
- Energy from Waste Facility
- Reclaimed Water
- Biosolids to Fertilizer

Options for Integrated Resource Management Systems
Co-Digestion
Des Moines Wastewater Reclamation Authority
Hauled Waste - Regional
Integrated Campus can Include C&D Recycling for Commodities and “Engineered Aggregates”

Public Works Recycling Complex

- Construction & Demolition Wastes
  - wood wastes
  - plastic
  - paper
  - shingles
  - tires

- Municipal Solid Waste
- Industrial Wastes
  - slag/ash
  - contaminated soils
  - sludge
  - other problematic wastes

Options for Integrated Resource Management Systems
Integrated Campus for Management of Municipal Waste Can Include Water Resources
World’s Largest EfW Facility (2020) in China to include Desalination Water Plant and Solar PV

- 5,000 mtpd (5,600 tpd)
- 125 MW nameplate electrical
- 132 mgd water production
- Shenzhen, China (population of 20 Million)

Schmidt Hammer Lassen Architects and Gottlieb Paludan Architects
Catawba County, NC Resource Recovery Park Site Layout

- Lumber & Pallet Partners
- Wood Gasification
- Research Center
- Biosolids Processing Facility
- Digesters for Sludge, Animal and Food Waste for Energy
- Biofuel Research- Algae and Fuel Crops
- Total Project Cost- $20.7 Million
Palm Beach County, FL
Regional Biosolids Palletization Facility (600 wtpd)

- 5 utilities partnered with Solid Waste Authority (SWA)
- Landfill gas used for drying

Provides long-term regulatory certainty
Palm Beach County Florida
Regional Biosolids Processing Facility on ISWM Campus

Landfill gas used for drying of WWTP biosolids
Supplemental Waste Program
Lancaster County Pennsylvania

Examples of WTE Facilities from Around the World
Copenhagen Denmark WTE (under construction) with Public Ski Slope around Stack
If an EfW Facility Can be Located in the Center of Paris, It Can be Located Anywhere!
Marchwood England 2007
500 TPD WTE Facility Under Dome

Located 1 hour south of London on a marine port
Ineos Bio-Energy Center (2012)
Indian River County, FL

Phase 1 - 8 mmgpy ethanol from vegetative waste
Phase 2 – 50 mmgpy ethanol from RDF
What does a Co-Digestion Facility Look Like?
Courtesy of Harvest Power Orlando

- 120,000 tpy capacity processing food waste and WWTP biosolids into biomethane
- 3.2 MWe plus heat for drying granular biosolids product (5,000 mt/year)
- Facility commissioned in December 2013
Spittelau WTE facility in Austria
Resource Recovery
Nuremberg, Germany

- Compact layout, close to the city
- Heat for district heating and industrial purposes
- Transport of waste by truck and rail
- Modern architecture
Lee County Florida
Integrated Campus with Regional Landfill

SWANA 2009 WTE Excellence Gold Award

Examples of WTE Facilities from Around the World
Advanced Recovery of Metals

- High strength magnets for recovery of ferrous metals
  - Large, medium and fine fractions
- Eddy Current Separators for recovery of non-ferrous metals
  - Large, medium and fine fractions
  - Separation of aluminum, brass, bronze, copper and stainless steel
  - Recovery of precious (gold, silver) and rare-earth metals
High Tech Magnets for Optimized Recovery of Ferrous and Non-ferrous Metals

High Strength Drum Magnet for Ferrous Metals

Samples of Non-ferrous Metals Recovered by Eddy Current Separator
Aluminum, brass, bronze, copper... even gold and silver!
Recovery of Metals from WTE Bottom Ash can Play a Significant Role in Community’s Recycling Program

- Two thirds of metals generated by residential households end up in the mixed waste mainly because they are not targeted for recycling in source-separation recycling programs.

- Recycling of metals from WTE bottom ash can account for more recycling tonnages than typically diverted via source separation recycling programs.

- Conventional EfW ash processing systems typically target the recovery of native metals greater than 12 millimeters (0.47 inches) in size.

- Advanced metal recovery systems utilizing recently developed new technologies improve the metal recovery rates by targeting metals less than 12 millimeters (0.47 inches) in size.
Initial Metal Recovery Operation
Bulky Ferrous Metals Greater than 5-6” in Size

Everything imaginable... including the kitchen sink

...and engine blocks!
Second Metal Recovery Operation
Ferrous Metals Less than 5-6” in Size

Minus 5-6”
Ferrous

Plus 5-6” Bulky Ferrous
Third Metal Recovery Operation
Non-ferrous Metals "Liberated" by Combustion
Non-ferrous Metals Liberated by Combustion and Recovered by Eddy Current Separator

Aluminum, brass, bronze, copper... even gold and silver!

Dense aluminum "nuggets"
Value of Non-Ferrous Metal Recovered from WTE Bottom Ash

WTE Non-ferrous Metal Recovery Annual Revenues
(assuming 0.4% Nfe / Ton MSW)

Scrap Price
$2000/Ton
$1500/Ton
$1000/Ton
$500/Ton

Annual Revenues ($ / Year)
$0
$1,000,000
$2,000,000
$3,000,000
$4,000,000
$5,000,000
$6,000,000

WTE Facility Capacity (TPD x 100)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Advanced Recovery of Metals
Coins Separated from Recovered Non-ferrous Metals in Palm Beach County, FL
Europe Continues WTE Advancements with Recovery of “Fine” Recyclables from Bottom Ash

- Fine minerals (< 0.07 inch)
- Mineral aggregates (> 0.07 inch)
- Non-ferrous concentrate
- Ferrous concentrate
Recovered Aluminum Products
Light Non-ferrous Metals from WTE Bottom Ash

Aluminium scrap product (fine)
- 0.04 – 0.14 inch
- 70 - 75% pure metal scrap

Aluminium scrap product (middle)
- 0.14 – 0.4 inch
- 75 - 80 % pure metal scrap

Aluminium scrap product (coarse)
- 0.4 – 0.75 inch
- 85 - 90 % pure metal scrap
Heavy Non-ferrous Metals from WTE Bottom Ash

Primarily brass and copper

Heavy non ferrous scrap

- 0.04 – 0.75 inch
- 95-99 % pure metal scrap
Inashco Centralized Upgrading Facility (Belgium)

Central Upgrading Facility located in Sluiskil, the Netherlands, where non-ferrous recovered metals are processed into high value heavy and light non-ferrous metal scrap products.
Economic Benefits for 1,000 tpd WTE Facility
Economic Benefits During Construction for 1,000 tpd WTE Facility

- Over $200M in total construction cost
- $60M construction payroll
- 300 total jobs over 2 year construction period
- Procurement of $40-50 M in local goods and services
- Increased demand for local business
Economic Benefits During WTE Operation Period (45-50 years)

- High quality jobs/careers
  - 30-35 full-time permanent jobs
- Payroll dollars increase
  - Over $2M in annual payroll
- Retail sales increase
  - Local procurement of Operations and Maintenance supplies
  - Bank deposits increase
  - Local tax base expands
- Oversight of waste disposal operations and management
- Protection from out-of-county surcharges
## Typical Goods and Services Procured During Operation and Maintenance Period (45-50 years)

<table>
<thead>
<tr>
<th>Office and Plant Supplies</th>
<th>Sub-contracted Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Calibration gasses</td>
<td>- Boiler water treatment monitoring</td>
</tr>
<tr>
<td>- Carpentry services</td>
<td>- Building services</td>
</tr>
<tr>
<td>- Chemical reagents (lime, carbon, urea, water chemicals)</td>
<td>- Catering services</td>
</tr>
<tr>
<td>- Electrical supplies</td>
<td>- Cooling tower water treatment monitoring</td>
</tr>
<tr>
<td>- Fire protection</td>
<td>- Electrical testing</td>
</tr>
<tr>
<td>- Fuel (gasoline, diesel, propane)</td>
<td>- Janitorial / cleanup services</td>
</tr>
<tr>
<td>- Janitorial supplies</td>
<td>- Landscaping maintenance</td>
</tr>
<tr>
<td>- Lab supplies</td>
<td>- Medical testing</td>
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<tr>
<td>- Lubricants</td>
<td>- Mobile equipment maintenance</td>
</tr>
<tr>
<td>- Mechanical supplies</td>
<td>- Residue hauling</td>
</tr>
<tr>
<td>- Mobile equipment</td>
<td>- Pest and vector control</td>
</tr>
<tr>
<td>- Office equipment and supplies</td>
<td>- Plant equipment rental</td>
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<tr>
<td>- Safety and first aid</td>
<td>- Printing services</td>
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<tr>
<td>- Tools</td>
<td>- Refractory repair</td>
</tr>
<tr>
<td>- Welding supplies</td>
<td>- Scaffolding rental</td>
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<tr>
<td><strong>Environmental Testing</strong></td>
<td>- Specialty cleaning</td>
</tr>
<tr>
<td>- Air emission testing</td>
<td>- Temporary labor</td>
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<tr>
<td>- Ash residue testing</td>
<td>- Uniform services</td>
</tr>
<tr>
<td>- CEM maintenance / troubleshooting</td>
<td>- Welding repairs and Non-destructive testing</td>
</tr>
<tr>
<td>- Water quality testing</td>
<td></td>
</tr>
</tbody>
</table>
MSW – Ash – Recovered Metal Photos
Typical Mass Burn WTE Flow Diagram

Evolution of WTE
Typical Massburn EfW Facility Cross-Section

Based upon B&W Volund technology employed at the newest EfW facility in US (Palm Beach County, FL)
Massburn is the Dominant EfW Technology in the US (~75%)

Massburn technology requires no pre-processing of waste materials
Minimizing Landfill Disposal of EfW Ash Residue

~ 90% volume and 75% weight reduction, plus ~3% metal recovery
Initial Metal Recovery Operation
Bulky Ferrous Metals Greater than 5 – 6 Inches

Everything imaginable... including the kitchen sink
Second Metal Recovery Operation
Ferrous Metals Less than 5 – 6 Inches

Minus 5-6” Ferrous

Plus 5-6” Bulky Ferrous
Third Metal Recovery Operation
Non-ferrous Metals “Liberated” by Combustion
Sample of Non-ferrous Metals Recovered from Bottom Ash by Eddy Current Separator

Aluminum, brass, bronze, copper... even gold and silver!

Dense aluminum “nuggets”
Enhanced Recovery of Recyclable Products from Bottom Ash “Fines” (European Experience)
Enhanced Recovery of Aluminum Metals from Bottom Ash “Fines”

Aluminium scrap product (fine)
- 0.04 – 0.14 inch
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Aluminium scrap product (coarse)
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Proven Waste Conversion Technologies
Heavy Non-ferrous Metals Separated from Non-ferrous Metals Recovered from Bottom Ash Fines

Primarily brass and copper

Heavy non ferrous scrap
- 0.04 – 0.75 inch
- 95-99 % pure metal scrap
Massburn WTE Trends
Higher Steam Pressures and Net Electric Generation

Net Electric Output (kWh/ton) vs Steam Pressure (psig)

- 1st Generation ~ 600 psig
- 2nd Generation ~ 835 psig
- Next Generation ~ 1,350 – 1,450 psig

Options for Enhanced Revenues
Increase in Annual Electrical Payments with High Pressure Boilers

Note: higher O&M costs also accompany higher pressure units

Price Paid for Electricity

- 8 cents/kWh
- 7 cents/kWh
- 6 cents/kWh
- 5 cents/kWh
- 4 cents/kWh
- 3 cents/kWh

Size of WTE Facility (TPD)

Million Dollars per year

Options for Enhanced Revenues
Options for Improved Benefits from WTE

- Process and recycle leachate from local landfill(s) for use as WTE process water
- Process WWTP biosolids for beneficial Reuse
  - Low pressure steam for drying biosolids
  - Electricity for microwave drying of WWTP biosolids
- Capture rain water from facility roofs for use as process makeup water
- Mine existing unlined landfill(s) and process combustibles in WTE
- Use of steam or hot water in local recreational / fitness center (host community benefit often employed in Europe and Asia)
Palm Beach County, Florida New WTE Facility Incorporating Gravity Rainwater Harvest
First 2” of Rain Provides ~16% of Annual Water Demand

2 MG Tank
Machine for “Halving” Tires on Rims
Supplemental Fuel for Pasco County Florida WTE
Chipped Tires - Supplemental Fuel for Pasco County Florida WTE Facility

Note: One ton of tires displaces three tons of MSW due to higher heating value of rubber
Explore Incentives / Needs of Regional Electric Grid
North American Electric Reliability Corporation (NERC) Regions
Western Electricity Coordinating Council (WECC)

Western Interconnection Balancing Authorities (38)
- AESO - Alberta Electric System Operator
- AVA - Avista Corporation
- AZPS - Arizona Public Service Company
- BANC - Balancing Authority of Northern California
- BCRA - British Columbia Hydro Authority
- BPAT - Bonneville Power Administration - Transmission
- CFE - Comisión Federal de Electricidad
- CHPD - PUD No. 1 of Chelan County
- CIISO - California Independent System Operator
- DEAA - Arlington Valley, LLC
- DOPD - PUD No. 1 of Douglas County
- EPE - El Paso Electric Company
- GCPCD - PUD No. 2 of Grant County
- GRID - Gridforce
- GRIF - Griffith Energy, LLC
- GRMA - Sun Devil Power Holdings, LLC
- GWA - NaturEner Power Watch, LLC
- HGMA - New Harquahala Generating Company, LLC
- IID - Imperial Irrigation District
- IPCD - Idaho Power Company
- LDWP - Los Angeles Department of Water and Power
- NEVP - Nevada Power Company
- NWMT - NorthWestern Energy
- PACE - PacifiCorp East
- PACW - PacifiCorp West
- PGE - Portland General Electric Company
- PNM - Public Service Company of New Mexico
- PSCO - Public Service Company of Colorado
- PSEI - Puget Sound Energy
- SCL - Seattle City Light
- SRP - Salt River Project
- TEPC - Tucson Electric Power Company
- TIDC - Turlock Irrigation District
- TPWR - City of Tacoma, Department of Public Utilities
- WACM - Western Area Power Administration, Colorado-Missouri Region
- WALC - Western Area Power Administration, Lower Colorado Region
- WAUUW - Western Area Power Administration, Upper Great Plains West
- WWA - NaturEner Wind Watch, LLC

Options for Enhanced Revenues
Explore Opportunities for Regional Electrical Generation with Western Electricity Coordinating Council (WECC)

- Reactive power advantages for electrical generation in urban areas
- Fuel diversity for improved resiliency
- Grid balancing needs
Small Power Purchase Agreements (PPA) in Florida
...Timing is Everything, but the Trend is Downward!

Capacity Payments for Two WTE Projects
(in adjacent counties 2009)
Opportunities to Reduce Cost of Modern WTE

• Optimization of the combustion process
• Value Engineering and optimization of facility and processes for balance of plant
  – Processing of ash for advanced recycling of metals at a remote location
  – Appropriately sized refuse receiving and storage areas
  – Need for redundancy of critical systems
  – Reduce parasitic load
    • High efficiency motors and systems
    • Variable frequency drives
  – High efficiency ceramic based thermal insulation
Optimization of the Combustion Process

- Expert systems to optimize the combustion process
- Improve Boiler efficiency
  - Reduction of excess air
  - Reduction of flue gas temperature at boiler outlet
  - Installation of an external superheater
  - Steam production at higher pressure and temperature
  - Design of boilers to allow intermediate steam reheating
  - Supplementary gas turbine to preheat combustion air
  - Additional superheater located above lower end of combustion grates (B&W Steam Boost)

Options for Reduced Costs