Waste-to-Energy Options and Solid Waste Export Considerations

Presentation to King County
November 6, 2017
Agenda

- Introduction
- King County Solid Waste Existing Conditions
- Best Fit WTE Option
- Financial Analysis
- Solid Waste Export Considerations
- Recommendations
- Next Steps
Task 3 Presentation
WTE Existing Conditions, Best Fit WTE Option and Financial Analysis

Sustainable Waste Management Solutions for the 21st Century

Paul Hauck, P.E.
CDM Smith
November 2017
My Career in Solid Waste and Waste-to-Energy

Construction Manager
1989-1992
$90M, 1,050 TPD
32 MW gross electrical

Consulting Engineer
WTE Facility Operations
1996 - Present
U.S. and European Waste Management Hierarchy are in Close Agreement

- Waste Prevention
- Re-use
- Recycling
- Maximize Recovery of Energy and Materials
- Minimize Landfill Waste Disposal
No Matter How You Look at it, WTE Occupies the Third Step of the Waste Management Hierarchy
## 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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<td>Industrial</td>
<td>Industrial</td>
<td>Enhanced</td>
<td>Enhanced Plus</td>
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<td>835/ 1350 psi</td>
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<td>570/ 725</td>
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<td>Advanced</td>
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<td>Electrostatic Precipitators</td>
<td>Scrubber / Fabric Filters with Activated Carbon</td>
<td>Scrubber / Fabric Filters with Activated Carbon, Very Low NOx</td>
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<td><strong>Ferrous Recovery</strong></td>
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<td>Electromagnets 2.0 – 2.5%</td>
<td>Permanent Magnets 2.5%</td>
<td>Rare Earth Magnets 3.5% +</td>
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<td><strong>Non-ferrous Recovery</strong></td>
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<td>Eddy Current Separators (ECS)</td>
<td>High Strength ECS (90% recovery)</td>
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<td><strong>Beneficial Reuse of Ash Residue</strong></td>
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<td>Within Landfill Campus</td>
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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
Benefits of WTE to Regional Electrical Grid Reliability and Resiliency

- 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 fossil units are retired

- Improves “fuel” diversity to local electrical grid for reliability during interruptions in fuel or hydro water supply (pending legislation by DOE for power plants with 90 day fuel supplies)

- Compatible with Microgrid Concept
  - Improves resiliency of critical municipal infrastructure (power, water, wastewater, public works, emergency and disaster management, etc.)
King County’s Estimated Waste Projection (assumes 57% recycling rate from 2018 - 2078)
Waste Conversion Technology Evaluation Criteria

- State of technology (15 points)
- Technical performance (10 points)
- Technical resources (5 points)
- Facility siting and public acceptance (5 points)
- Environmental criteria (15 points)
- Environmental criteria – sustainability (10 points)
- Financial resources (10 points)
- Project economics (20 points)
- Overall project risks (10 points)
### Highest Ranked Proven Technology Determined to be Combustion on Movable Grates with Waterwall Boilers

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<thead>
<tr>
<th>Criteria Number</th>
<th>Criteria Description (Major / Minor)</th>
<th>Possible Points</th>
<th>Massburn</th>
<th>RDF WTE</th>
<th>ATR</th>
<th>Waste Cokes</th>
<th>Thermal Catalytic</th>
<th>Plasma Arc</th>
<th>Gasification</th>
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<td>Economic realities</td>
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<td>Technical risk</td>
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<td>Procurement issues</td>
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</tbody>
</table>

|                          | Total Score                           | 100 | 95 | 85 | 95 | 42 | 37 | 39 | 38 | 72 |

**Total Score:** 95 85 95 42 37 39 38 72
B&W Volund Dynagrate™ Employs Special Alloy Steel with Expert Combustion Controls

Credit: B&W Volund
Typical Combustion WTE Flow Diagram

Renewable Electricity

CO₂ emissions
60% biogenic, 40% anthropogenic
Typical Combustion WTE Facility Cross-Section

Illustration of B&W Volund technology employed in Palm Beach County Florida
WTE Benefits Include Waste Sterilization, along with 90% Volume and 75% Weight Reduction

Input

Waste in, stabilized and inert ash out!

Output
Energy Balance: Traditional Waste To Energy Process

Waste

Waste: 116.4 MW

WTE Boiler

Steam: 96.8 MW

Losses: 19.6 MW

Steam Turbine

Losses: 61.8 MW

Power Output: 35 MW

Total Losses: 81.4 MW

Power Output (Net): 31 MW

Parasitic Consumption: 4 MW
Two Approaches Considered for Size of WTE Option 1A – Maximize Use of WTE Capacity

- Maximize capacity of WTE at start of commercial operation
- **Advantages include:**
  - Allows unit to be operated optimally at its design condition
  - Smaller WTE facility results in lower capital cost
  - Provides incentive for future recycling programs to accommodate growth in waste generation
- **Disadvantages include:**
  - Excess bypass waste requiring alternate disposal grows annually
  - Eliminates opportunity for regional project
  - Eliminates opportunity for marketing of special waste program
Sizing of WTE Facility
Option 1B – Eliminate Bypass Waste

- Eliminate bypass waste throughout the duration of commercial operation period

- Advantages include:
  - Reduces reliance, cost and environmental impacts associated with alternate disposal method
  - Provides capacity to accommodate future growth
  - Excess capacity may be marketed to neighboring communities

- Disadvantages include:
  - Unused capacity in early years of operation may prevent units from being operated optimally at its design condition
  - One or more combustion unit may need to be operated at reduced load, or shutdown for a day on weekends
  - Larger WTE facility results in higher capital cost than Option 1A
  - Reduces incentives for future recycling programs
Scenario 1B - 20 Year Planning Horizon (No Bypass Waste/29% Excess Capacity Year 1)

Facility in Year 2028: 4 Units; Size: 1,000 tpd
Total Capacity: 4,000 tpd
Scenario 2B - 30 Year Planning Horizon
(No Bypass Waste/45% Excess Capacity Year 1)

Facility in Year 2028: 4 Units; Size: 1,125 tpd
Total Capacity: 4,500 tpd
Scenario 3B - 50 Year Planning Horizon (No Bypass Waste / 28% Excess Capacity Year 1 34% Excess Capacity Year 26)

Facility in Year 2028: 4 Units; Size: 1,050 tpd
Facility Expansion in Year 2053: 2 Units; Size: 1,050 tpd
Total Capacity: 6,300 tpd
Reference WTE Facilities (large capacity)

- Shenzhen, China (5,612 tpd total capacity)
  - 6 B&W Volund Massburn units @ 920 tpd under construction
- Palm Beach County, Florida (3,000 tpd total capacity)
  - 3 B&W Volund Massburn units @1,000 tpd in operation since 2015
- Honolulu, Hawaii (900 tpd total capacity for expansion unit)
  - 1 Martin Massburn unit @ 900 tpd in operation since 2012
- Pinellas County Florida (3,150 tpd overall capacity)
  - 3 Martin GmbH Massburn units @ 1,050 tpd in operation since 1985
- Delaware Valley, Pennsylvania (3,510 tpd overall capacity)
  - 6 O’Connor Rotary Combustors @ 585 tpd in operation since 1992

NOTE: the last two WTE projects in the U.S. (Palm Beach County and Honolulu) were implemented by communities with existing RDF WTE facilities, and they chose massburn technology for expansion.
Additional Benefits of WTE
Implemented by WTE Owners in N.A.

• Combined heat and power (CHP) applications
  – Hennepin County, MN; Indianapolis, IN; Durham York, BC; Dublin, IR

• Internal use of electricity
  – Hillsborough County, FL; Lee County, FL

• Recycling of landfill leachate / stormwater in WTE process
  – Pinellas County, FL

• Co-combustion of tires (5%), used oils (5%), auto shredder residue, WWTP biosolids (10%), bulky and construction wastes
  – Honolulu, HI

• Co-combustion of construction and demolition waste
  – Lee County, FL

• Co-combustion of special wastes in need of assured destruction (USDA regulated garbage, medical waste, solid waste and liquid waste)
  – Honolulu, HI; Tulsa, OK; Huntsville, AL, numerous other facilities
Pinellas County FL Industrial Water Treatment Plant
Recycles Leachate/Stormwater for use in WTE Process

100 MG Leachate / storm water pond

Landfill

WTE

Water Treatment Plant
Summary of Features for Best Fit WTE Option
(refer to Final Report Table)

- Advanced combustion on movable grate with waterwall boiler
  - Expert combustion control system
  - Medium steam pressure, net generation of 609 kWh/ton

- Advanced air pollution control system
  - Spray Dryer Absorber (SDA), Fabric Filter (FF) with catalytic filters
  - Injection of urea/ammonia for NOx control
  - Injection of powered activated carbon for mercury / dioxin control
  - Injection of pebble lime slurry for acid gas control

- Advanced metal recovery system
  - Optimized recovery of ferrous and non-ferrous metals
  - Recovery of minerals and glass for local recycling opportunities

- Rainwater harvesting, air cooled condenser and zero liquid discharge to minimize demand on local water supplies

- Fully enclosed, architecturally pleasing buildings and landscaping
Typical Combustion WTE Facility Cross-Section

Based upon B&W Volund technology employed at Palm Beach County Florida
Reference Facility – Palm Beach County FL (enhanced aesthetics and sustainability features)
Palm Beach County FL WTE Facility
3,000 TPD – 75 MW Net Electrical Output

- $670M capital cost

Sky Bridge from Education Center to WTE Facility
New 3,000 tpd WTE Facility Located Adjacent to Existing 2,000 tpd RDF WTE Facility
LEED Platinum Education Center
Fully Enclosed
Waste Receiving Building with 24 Truck Bays
Efficient and Safe Network of Roads and Driveways

- Designed to minimize truck delivery times, and provide safety to system users and visitors by avoiding co-mingling of waste delivery and ash hauling trucks with passenger vehicles.
Palm Beach County WTE Facility Emission Control Technology

Flue gas from boiler

Activated Carbon Injection

Spray Dryer Absorber

Cold Side SCR

Heat Recovery HX

Pulse Jet Fabric Filter

Credit: Babcock and Wilcox
# Palm Beach County Florida Emission Profile

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Maximum Permit Concentration</th>
<th>Test Results*</th>
<th>Control Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₂</td>
<td>50 ppm</td>
<td>30 – 31 ppm</td>
<td>SCR</td>
</tr>
<tr>
<td>SO₂</td>
<td>24 ppm</td>
<td>11 – 21 ppm</td>
<td>SDA</td>
</tr>
<tr>
<td>CO</td>
<td>100 ppm</td>
<td>16 – 24 ppm</td>
<td>Optimized combustion design</td>
</tr>
<tr>
<td>Opacity</td>
<td>10%</td>
<td>0.4 – 2.4%</td>
<td>Fabric filter</td>
</tr>
<tr>
<td>VOCs</td>
<td>7 ppm</td>
<td>0.2 – 2.7 ppm</td>
<td>Optimized combustion design</td>
</tr>
<tr>
<td>Particulate Matter (PM)</td>
<td>12 mg/dscrn</td>
<td>0.6 – 2.5 mg/dscrn</td>
<td>Fabric filter</td>
</tr>
<tr>
<td>Pb</td>
<td>125 μg/dscrn</td>
<td>0.5 – 8.1 μg/dscrn</td>
<td>Fabric filter</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>5 ppm</td>
<td>Non-detectable &lt; 0.01 ppm</td>
<td>SDA</td>
</tr>
<tr>
<td>HCl</td>
<td>20 ppm</td>
<td>1.5 – 2.1 ppm</td>
<td>SDA</td>
</tr>
<tr>
<td>HF</td>
<td>N/A</td>
<td>Non-detectable &lt; 0.1 ppm</td>
<td>SDA</td>
</tr>
<tr>
<td>Dioxins/Furans</td>
<td>10 ng/dscrn</td>
<td>0.2 – 0.4 ng/dscrn</td>
<td>PAC, SCR</td>
</tr>
<tr>
<td>Hg</td>
<td>25 μg/dscrn</td>
<td>0.6 μg/dscrn</td>
<td>PAC</td>
</tr>
<tr>
<td>Cd</td>
<td>10 μg/dscrn</td>
<td>0.3 – 2.5 μg/dscrn</td>
<td>Fabric filter</td>
</tr>
<tr>
<td>NH₃ slip</td>
<td>10 ppm</td>
<td>2.2 – 5.5 ppm</td>
<td>Optimized SCR design</td>
</tr>
</tbody>
</table>

*Corrected to 7% O₂ dry basis

PAC = Powdered activated carbon  
SCR = Selective catalytic reduction  
SDA = Spray dryer absorber

Credit: Babcock and Wilcox
Global WTE Overview

• More than 2,000 WTE facilities in operation 2017
• China is building on average 50 WTE facilities per year (already more than 450)
• Europe has more than 600
• US has 77 facilities
WTE EU – MVR, Hamburg, Germany

- One of the most advanced Thermal Treatment Facilities to date – Combined Heat and Power
- 1,000 tons per day
- State of the Art Fluegas Treatment
- 18 Year proven track record
- City/State of Hamburg & surrounding area = zero waste to landfill area with start up of operations in 1999
- Advanced bottom ash processing
WTE EU – Rothensee, Germany

- First facility was so successful that a second identical one was build right next to it
- Total capacity 2,000 tons per day
- Combined Heat and Power
WTE EU – Copenhagen ‘Copenhill’, Denmark

- One of the newest facilities
- 1,850 tons per day
- 28% Electrical Efficiency
- Bottom Ash processing
- Combined Heat and Power
- Ski slope, Hiking and Climbing
- Integral part of the goal to make Copenhagen the first zero-carbon City by 2025
WTE EU – Brescia, Italy

- Largest combustion line for biomass worldwide
- Avoids 760 kg of CO2 per ton of waste over state of the art landfill
- Energy Efficiency (Electric) > 27%
- Combined heat and power
- Tipping Fee $65/ton
- 1,600 tons per day
WTE EU – Giubiasco, Switzerland

- Start of operations 2009
- Recipient of Architectural Awards
- Surrounded by Vineyards and Farmland – within 500 feet of residential area
- In valley surrounded by mountains
- Treats solid waste and waste water (sewage)
WTE EU – Amsterdam, The Netherlands

- 4,200 tons per day (largest European WTE facility) from Amsterdam and 27 neighboring municipalities
- Highest energy recovery at over 30% electric
- Bottom Ash Utilization
- Metal Recovery
- Combined Heat and Power
- Part of an integrated waste management system that has over 60% recycling
- Can supply power for 320,000 households
World first Carbon Capture & Storage at Oslo waste-to-energy plant

- Pilot test completed in 2016
- Plant to proceed to full scale production
500,000 tons of Bottom Ash used as carrying layer for most advanced container terminal in the world in Hamburg Germany:
Cruse Terminal Hamburg – Built on Bottom Ash
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.

- Conventional WTE 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.

Credit: SWANA Advanced Research Foundation
Impact of Metal Recovery and 95% Bottom Ash Recycling on Overall King County Recycling Rate

- **Without WTE**: Assumed 57% Recycling Rate
- **Current 52% Recycling Rate**
- **59.7% WTE with Advanced Metal Recovery**
- **70.6% WTE with Advanced Metal Recovery and Ash Recycling**
Metals “Liberated” by Combustion and Recovered by Stronger Magnets and ECS – 2\textsuperscript{nd} Generation

Plus 6” Ferrous Metals

Minus 6” Ferrous Metals

+3/8” Non-ferrous Metals

Close-up of Non-ferrous Metals

Dense aluminum “nuggets”
European Advanced Bottom Ash Treatment
Main Process-Steps

Section A: Screening; Separation and Ferrous Washing
Section B: Washing and Screening
Section C: Separation of Non-Ferrous
Section D: Separation, Cleaning Glass
Section E: Glass

Crude Bottom Ash

Ferrous Metals
Fine Particles (recycled to combustion process)
Non-Ferrous Metals
Bottom Ash Aggregate
3rd Generation WTE (Advanced Resource Recovery)
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
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

Credit: InAshCo
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

Credit: InAshCo
Enhanced Metal Recovery Improves 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
Explore Opportunities for Recycling Bottom Ash at Local Cement Kilns
Residue Utilization: Pasco County Florida
Bottom Ash Test Road Project - May 2014

- Three test sections were constructed
- 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
Raw Material for Production of Portland Cement

<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>
Key Parameters used for “Conservative” Financial Analysis

- Capital cost (adjusted for inflation, seismic, 8.6% sales tax, owner costs, $5M site acquisition, $15M advanced metal recovery equipment and building, $1.35M electrical interconnection, and 5% contingency)
  - Scenario 1 (4 units at 1,000 tpd) = Base cost of $237,812/tpd (2017) escalated to $341,000 /tpd (2028)
  - Scenario 2 (4 units at 1,125 tpd) = Base cost of $221,576 /tpd (2017) escalated to $318,000 /tpd (2028)
  - Scenario 3 (4 units at 1,050 tpd) = Base cost of $230,943 /tpd (2017) escalated to $332,000 /tpd (2028)

- Sales price of electricity = $0.0491 ($2028) based upon Mid-C Medium scenario of Northwest Power and Conservation Council 7th Power Plan

- Electric sales price escalated at 2% inflation (2037-2078)
Key Parameters used for “Conservative” Financial Analysis

- Net electric generation = 609 kWh/ton
- 90/10 electrical revenue sharing (owner/contractor)
- Ferrous metal recovery rate of 4.0 percent and sales price of $50/ton ($2017)
- Non-ferrous metal recovery rate of 0.8 percent and sales price of $750 ($2017)
- 50/50 metal recovery revenue sharing (owner/contractor)
- No revenues assumed from sale of RECs, VCU's or recycling of bottom ash
- Ash transportation and disposal cost of $54.44/ton
- Debt service interest rate of 5%
- Construction period of 42 months at 2% interest
- Cost to issue bonds at 1%
Key Parameters used for Financial Analysis

- WTE O&M service fee in year 1
  - 20-year scenario (4,000 tpd) = $23.00/ton
  - 30-year scenario (4,500 tpd) = $22.00/ton
  - 50-year scenario (4,200 tpd) = $22.50/ton

- County annual management costs = $210,000/year

- Annual environmental consulting costs = $350,000/year
## Key Escalation Factors for “Conservative“ Financial Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Other Revenue - Inflation</td>
<td>1.50%</td>
<td>2015 to 2017 actual increase for non-ferrous revenue - Pinellas Electric</td>
</tr>
<tr>
<td>Operating Costs - Labor Inflation</td>
<td>3.20%</td>
<td>County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, blended labor</td>
</tr>
<tr>
<td>Operating Costs - Equipment Inflation</td>
<td>2.80%</td>
<td>County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, general inflation</td>
</tr>
<tr>
<td>Operating Costs - Other Inflation</td>
<td>2.80%</td>
<td>County Financial Planning Assumptions and Guidance (2017-2026) for 2026 and all future years, general inflation</td>
</tr>
<tr>
<td>Operating Costs - Reagent Inflation</td>
<td>3.00%</td>
<td>BLS Chemical Indexes WPU061 - Average of increase 2010-2017</td>
</tr>
<tr>
<td>Contract Operating Costs - Combined Inflation</td>
<td>2.90%</td>
<td>Equals the average of above</td>
</tr>
<tr>
<td>WTE Capital Cost - Labor Inflation</td>
<td>2.68%</td>
<td>Engineering News Record, Skilled Labor Index – average of 2012-2016</td>
</tr>
<tr>
<td>WTE Capital Cost - Equipment Inflation</td>
<td>1.72%</td>
<td>Engineering News Record, Materials Index – average of 2012-2016</td>
</tr>
<tr>
<td>WTE Capital Cost - Other Inflation</td>
<td>2.20%</td>
<td>Bureau of Labor Statistics – Machinery &amp; Equipment (WPU114) – average increase 2010-2016</td>
</tr>
</tbody>
</table>
20-Year Analysis Net Cost and Cost per Ton (69% reduction upon retirement of debt)

*A 20 year scenario does not consider additional investment, beyond year 20, if the County’s solid waste projection continues to grow as planned*
20-Year Scenario Net Cost per Ton 2017$ for Comparison with Current Disposal Costs

20 Year Alternative - Comparison of Current Cost/Ton with 2017$ for Years 1 & 20

- Year 1 (2028$): $139,558,000
- Year 1 (2017$): $126,34
- 20-Year (2048$): $52,292,000
- 20-Year (2017$): $37.49

Annual Net Costs Tip Fees $/Ton
30-Year Analysis Net Cost and Cost per Ton
(47% reduction upon retirement of debt)

*A 30 year scenario does not consider additional investment, beyond year 30, if the County’s solid waste projection continues to grow as planned
30-Year Scenario Net Cost per Ton 2017$
for Comparison with Current Disposal Costs

30 Year Alternative - Compare Current Cost per Ton with 2017$ and View Change Between Years 1, 20 and 30

Annual Net Costs $/Ton

Year 1 (2028$) $120,676,000 $109.25
Year 1 (2017$) $82,480,000 $74.67
20-Year (2048$) $147,830,000 $105.98
20-Year (2017$) $85,528,000 $61.32
30-Year (2058$) $89,363,000 $55.20
30-Year (2017$) $18,412,000 $11.37
50-Year Analysis Net Cost and Cost per Ton
(25% reduction upon retirement of debt)
50-Year Scenario Net Cost per Ton 2017$
for Comparison with Current Disposal Costs
Summary of Year 1 Revenues - Electrical Sales are the Primary Source of Offsetting Revenues

Revenue based upon following sharing:
- Electrical: 90% County / 10% Contractor
- Metals: 50% County / 50% Contractor
Summary of Year 1 Costs – Capital and Debt Service is the Primary Cost Element

- Debt Service: $116,205,000 (67%)
- Contractor O&M: $35,758,000 (21%)
- KC Project Management Cost: $16,181,000 (9.4%)
- Wastewater Disposal: $3,762,000 (2.2%)
Sensitivity Analysis of Enhanced WTE Revenues or Reduced Costs

- Combustion of special wastes in need of assured destruction
  - Fill all of unused capacity
  - Market 10% of capacity (400 tpd)
- Internal use of all energy valued at 6 cents/kWh ($2017)*
  - Treatment of water and/or wastewater, drying and processing WWTP biosolids, other “behind the meter” uses (Public Works, recycling facilities)
- Recycle bottom ash (75% assumed)*
  - Aggregates for use in asphalt or concrete pavements / products
  - Feedstock for manufacturing of Portland cement
- Local ash disposal in lieu of remote landfill
- Additional electrical revenue (+ 1 cent / kWh)
- Sale of Renewable Energy Credits ($10/REC)
- Reduced O&M inflation rates by 0.5%
- Reduced financing interest rate by 0.5%

*Would require statutory change. The probability of this occurring is considered low without a push from the King County Council and/or State Legislature.
Example of Successful Supplemental Waste Program in Lancaster County Pennsylvania

Addition to Tipping Building for Supplemental Waste Program
Special Wastes in Need of Secure Disposal can be a Significant Source of Revenues

- 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)

- Wastewater treatment plant residuals and biosolids
  - Discarded fats, oils and grease (FOG)

- Used tires

- Used motor oils and lubricants
Hillsborough County FL WTE...First to Internally Power Water Resource Facilities (no interruption during Hurricane Irma)

~ 5 MW to Public Works Campus (Future)

1,800 TPD WTE Facility

12 MGD AWTP Facility

2 MW

37 MW Currently Sold to Grid
Additional Public Works Facilities may be Powered by Electricity from WTE in the Future

Similar to “microgrid” concept promoted by DOE
## Summary of Sensitivity Analysis

<table>
<thead>
<tr>
<th>Option</th>
<th>Net Gain ($)</th>
<th>Reduction in Base Cost (%)</th>
<th>Reduction in Tipping Fee ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplemental Waste Revenue (maximized to fill all excess capacity)</td>
<td>$56,705,879</td>
<td>40.7%</td>
<td>$51.34</td>
</tr>
<tr>
<td>Supplemental Waste Revenue (400 tpd – 10% of total capacity)</td>
<td>$27,594,000</td>
<td>19.8%</td>
<td>$24.98</td>
</tr>
<tr>
<td>Internal use of electricity at 6 cents/kWh</td>
<td>$19,178,162</td>
<td>13.7%</td>
<td>$13.76</td>
</tr>
<tr>
<td>Recycle 75% of Bottom Ash</td>
<td>$11,211,129</td>
<td>8.0%</td>
<td>$10.15</td>
</tr>
<tr>
<td>Local ash disposal vs. out-of-county</td>
<td>$8,204,162</td>
<td>5.9%</td>
<td>$7.43</td>
</tr>
<tr>
<td>Additional 1 cent/kWh on electrical sales</td>
<td>$7,903,978</td>
<td>5.7%</td>
<td>$7.16</td>
</tr>
<tr>
<td>Renewable Energy Credits at $10/REC</td>
<td>$6,397,356</td>
<td>4.6%</td>
<td>$5.79</td>
</tr>
<tr>
<td>Reduced O&amp;M inflation factors by 0.5%</td>
<td>$3,226,754</td>
<td>2.3%</td>
<td>$2.92</td>
</tr>
<tr>
<td>Reduced financing interest rate by 0.5%</td>
<td>$1,981,800</td>
<td>1.4%</td>
<td>$1.79</td>
</tr>
</tbody>
</table>
Summary of Sensitivity Analysis
Net Gain and Reduction in Cost/Ton

- Supplemental Waste Revenue (maximized): $51.34
- Supplemental Waste Revenue (400 tpd): $24.98
- Internal use of electricity at 6 cents/Kwh: $17.36
- Recycle 75% of Bottom Ash: $10.15
- Local ash disposal vs. out-of-county: $7.43
- Additional 1 cent/Kwh on electrical sales: $7.16
- Renewable Energy Credits at $10/REC: $5.79
- Reduced O&M inflation factors by 0.5%: $2.92
- Reduced financing interest rate by 0.5%: $1.79
## Sensitivity Analysis – Best Case
(20 Year Scenario)

### Options for Improved Revenues and Reduced Cost of WTE to King County Rate Payers

<table>
<thead>
<tr>
<th>Option</th>
<th>Improved Revenues</th>
<th>Reduced Cost</th>
<th>Option 1 (Best Combination)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplemental Waste Revenue (maximized to fill available capacity)</td>
<td>Yes</td>
<td></td>
<td>$56,705,879 40.7% $51.34</td>
</tr>
<tr>
<td>Internal use of all electricity (valued at 6 cents/kWh in 2017$)*</td>
<td>yes</td>
<td></td>
<td>$19,178,162 13.7% $17.36</td>
</tr>
<tr>
<td>Recycle 75% of bottom ash*</td>
<td>Yes</td>
<td></td>
<td>$11,211,129 8.0% $10.15</td>
</tr>
<tr>
<td>Sale of RECs at $10/Rec</td>
<td>Yes</td>
<td></td>
<td>$6,397,356 4.6% $5.79</td>
</tr>
<tr>
<td>Reduced O&amp;M Inflation Factors by -0.5%</td>
<td>Yes</td>
<td></td>
<td>$3,226,754 2.3% $2.92</td>
</tr>
<tr>
<td>Reduced Construction Financing Interest Rate by -0.5%</td>
<td>Yes</td>
<td></td>
<td>$1,981,800 1.4% $1.79</td>
</tr>
<tr>
<td><strong>Total Combined Benefits</strong></td>
<td></td>
<td></td>
<td><strong>$98,701,080 70.8% $89.37</strong></td>
</tr>
</tbody>
</table>

### Possible Tipping Fee: $36.92

*Would require statutory change. The probability of this occurring is considered low without a push from the King County Council and/or State Legislature.
## Sensitivity Analysis – Optimistic Case
(20 Year Scenario)

<table>
<thead>
<tr>
<th>Option</th>
<th>Improved Revenues</th>
<th>Reduced Cost</th>
<th>Net Gain ($/year)</th>
<th>Reduction in Base Case Cost (%)</th>
<th>Reduction in Tipping Fee ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplemental Waste Revenue (400 tpd - 10% of capacity)</td>
<td>Yes</td>
<td></td>
<td>$27,594,000</td>
<td>19.8%</td>
<td>$24.98</td>
</tr>
<tr>
<td>Recycle 75% of bottom ash</td>
<td></td>
<td>Yes</td>
<td>$11,211,129</td>
<td>8.0%</td>
<td>$10.15</td>
</tr>
<tr>
<td>Additional 1 cent/kWh on electric power sales</td>
<td>Yes</td>
<td></td>
<td>$7,903,978</td>
<td>5.7%</td>
<td>$7.16</td>
</tr>
<tr>
<td>Sale of RECs at $10/Rec</td>
<td></td>
<td>Yes</td>
<td>$6,397,356</td>
<td>4.6%</td>
<td>$5.79</td>
</tr>
<tr>
<td>Reduced O&amp;M Inflation Factors by -0.5%</td>
<td></td>
<td>Yes</td>
<td>$3,226,754</td>
<td>2.3%</td>
<td>$2.92</td>
</tr>
<tr>
<td>Reduced Construction Financing Interest Rate by -0.5%</td>
<td></td>
<td>Yes</td>
<td>$1,981,800</td>
<td>1.4%</td>
<td>$1.79</td>
</tr>
<tr>
<td><strong>Total Combined Benefits</strong></td>
<td></td>
<td></td>
<td><strong>$58,315,017</strong></td>
<td><strong>41.8%</strong></td>
<td><strong>$52.80</strong></td>
</tr>
</tbody>
</table>

**Possible Tipping Fee:** $73.49
Sensitivity Analysis
Options Under Control of King County
(20 Year Scenario)

<table>
<thead>
<tr>
<th>Option</th>
<th>Improved Revenues</th>
<th>Reduced Cost</th>
<th>Option 3 (Items Controlled by KC)</th>
<th>Net Gain ($/year)</th>
<th>Reduction in Base Case Cost (%)</th>
<th>Reduction in Tipping Fee ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplemental Waste Revenue (400 tpd - 10% of capacity)</td>
<td>Yes</td>
<td></td>
<td></td>
<td>$27,594,000</td>
<td>19.8%</td>
<td>$24.98</td>
</tr>
<tr>
<td>Disposal of all ash into local ash monofill</td>
<td>Yes</td>
<td></td>
<td></td>
<td>$8,204,162</td>
<td>5.9%</td>
<td>$7.43</td>
</tr>
<tr>
<td><strong>Total Combined Benefits</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$35,798,162</strong></td>
<td><strong>25.7%</strong></td>
<td><strong>$32.41</strong></td>
</tr>
</tbody>
</table>

Possible Tipping Fee: $ 93.88
Conclusions from Financial Analysis

- Conservative analysis was conducted for this project
  - High escalation factors may not come to fruition
    - Variable costs doubled during first 20 years
  - Large capacity WTE facility at year 1 (oversized by 28%-45%)
    - WTE facility doesn’t reach capacity until end of financing period
    - Excess capacity remains unused for growth in future waste generation
  - Modest sales price of primary WTE products:
    - Electricity sold at $49.09/MWh in 2028$, inflated by 2% per year
    - Non-ferrous metals sold at $750/ton (2017$), inflated by 1.5% per year
    - Ferrous metals sold at $50/ton (2017$), inflated by 1.5% per year
    - No revenue from sale of RECs or VCOs assumed
    - No revenue from sale of recyclable bottom ash assumed

- Refined analysis should be conducted in future Feasibility Study
  - Start construction earlier
  - Potentially lower capital and O&M costs
  - Potentially higher revenues
  - Report all costs in 2017$
Thank You for the Opportunity to Share! Feel Free to ask Questions

Paul Hauck, PE
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Suite 875
Tampa, Florida 33607

Telephone:
813.281.2900

E-mail:
hauckpl@cdmsmith.com
Solid Waste Export Considerations

Curt Thalken, PE
November 6, 2017
Regional SW Disposal Options
### Remaining Permitted Capacity

<table>
<thead>
<tr>
<th>Landfill</th>
<th>Permitted Acres(^1)</th>
<th>Remaining Capacity (tons)(^2)</th>
<th>Currently Receiving (tons/year)(^3)</th>
<th>Remaining Capacity at current fill rate (years)(^4)</th>
<th>CHRLF Tons(^5)</th>
<th>Projected Tons/year w/CHRLF redirected (new fill rate)</th>
<th>Years remaining at new fill rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbia Ridge</td>
<td>760</td>
<td>329,000,000</td>
<td>2.6 to 2.7 mill</td>
<td>120-140</td>
<td>1.1-2.2 mill</td>
<td>3.7-4.9 mill</td>
<td>67-88</td>
</tr>
<tr>
<td>Roosevelt</td>
<td>915</td>
<td>162,000,000</td>
<td>2.2 to 2.4 mill</td>
<td>70-100</td>
<td>1.1-2.2 mill</td>
<td>2.3-4.7 mill</td>
<td>35-70</td>
</tr>
<tr>
<td>Finley Buttes</td>
<td>510</td>
<td>131,859,000</td>
<td>500,000–700,000</td>
<td>200+</td>
<td>1.1-2.2 mill</td>
<td>1.6-2.9 mill</td>
<td>45-82</td>
</tr>
<tr>
<td>Simco Road</td>
<td>810</td>
<td>208,000,000</td>
<td>365,000 ±</td>
<td>150-200+</td>
<td>1.1-2.2 mill</td>
<td>1.4-2.5 mill</td>
<td>83-148</td>
</tr>
</tbody>
</table>

**Sources:**

1. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco–City of Boise Solid Waste Strategic Plan (2007)
3. Metro Transportation and Disposal Evaluation–Phase I Results (2017); Simco (estimated)
5. Cedar Hills Regional Landfill (CHRLF) 2028-2078 Solid Waste Tonnage Forecast (2016), KCSWD
Critical Segments

- Tacoma to Kalama/Longview (137% capacity by 2028)
- Kalama/Longview to Vancouver (143% capacity by 2028)
- Vancouver, WA to Pasco (100% capacity by 2028)
- Pasco to Spokane (100% capacity by 2028)
- Spokane to Sandpoint, ID (100% capacity by 2028)
Figure 4.2  Washington’s Rail System Utilization, 2010


Note: Directional running of trains is assumed on the Stampede Pass route (Auburn-Pasco via Yakima), which was implemented by BNSF in 2012.
Figure 4.3  Washington’s Rail System Utilization, 2035

Legend

Network Attributes


Note: Directional running of trains is assumed on the Stampede Pass route (Auburn-Pasco via Yakima), which was implemented by BNSF in 2012.
Consider Waste to Energy as a viable option for solid waste management in long range SWD plans
  - The “Best Fit Technology” for King County is a thermal treatment system
    - Combustion on a movable grate with a waterwall boiler to recover heat for production of steam and electricity (massburn system)
    - Thermal recycling innovations and design features

Conduct a WTE Feasibility Study

Develop a Public Education Program
“Best Fit” WTE overview including key recycling and disposal components of an Integrated Solid Waste Management System

- Analysis of Existing Conditions to determine compatibility with a WTE-anchored system
- Visit Palm Beach County, FL campus and other similar integrated solid waste management facilities
- Comparative Analysis for cost effectiveness of integrated WTE system vs. out of county landfill
Analysis of options for appropriately sizing WTE facility and ancillary treatment, recovery, recycling and disposal needs

- Potential solid waste quantities and composition
- Evaluate potential for treatments such as a stand alone anaerobic digestion facility and uses of bio-methane
- Evaluate recycling technologies/processes and advanced material recovery options
- Meet with other cities/counties for regional participation
Feasibility Study Components

Design/Permitting/Construction Requirements
- Analysis of environmental regulation and permitting process including criteria, permit requirements and potential schedule

Siting and Architectural Options
- Develop siting criteria, identify potential sites
- Evaluate potential sites for WTE, ash monofill and bypass/backup disposal facilities and rank preliminary sites
- Form architectural committee to evaluate design features
Feasibility Study Components

- Environmental Opportunities
  - Availability of fairly-priced energy, metals and materials markets
  - Evaluate integration of technologies for small amounts of bypass waste

- Economic Cost Assessment
  - Analysis of financial alternatives
  - Meet with local municipal and private utilities for interest in PPAs or financial participation in WTE project

- Conclusions, Recommendations and Implementation Plan
  - Key Tasks and Schedule for siting/design/build and key infrastructure systems
Next Steps - Public Education

- Develop public education approach
  - Identify committees and representation
- Identify and maintain a library of technical information, environmental data, architectural preferences, and public policies
- Identify type and schedule of public workshops
- Identify approach for maintaining historical project information (meeting agendas and minutes) and establishing methods for ensuring transparency
Integrated Campus for Management of Municipal Resources