Waste Conversion Technologies 101

Presented by:
Lori Scozzafava & Steve Simmons
Gershman, Brickner & Bratton, Inc. (GBB)

February 15, 2017
WELCOME

By Kevin Roche- SWANA NNE Chapter President, CEO/General Manager
Outline

Welcome – Kevin Roche
Introduction
MSW Overview
Waste Conversion Technologies
Project Development
Q&A - Discussion
INTRODUCTION

By Lori Scozzafava, GBB
GBB  Quality – Value – Ethics – Results

- Established in 1980
- Solid Waste Management and Technology Consultants
- Helping Clients Turn Problems into Opportunities
GBB’s Waste Consulting Services

- Economic, technical and environmental reviews
- Procurements
- Due diligence third-party reviews
- Waste characterization and sourcing
- Process planning and conceptual designs
- Independent feasibility consultant
Lori Scozzafava
GBB Vice President, Operations Officer

Experienced senior level executive with over 25 years of solid waste management industry experience.

• 15 years in high profile leadership roles, influencing regional / national policy in multiple environmental areas:
  - Solid Waste Association of North America
  - US Composting Council
  - Composting Council Research & Education Foundation

• Extensive project management, recycling & composting expertise

• Received several industry recognitions:
  - One of the top Women in Environmental Management (Waste & Recycling News)
  - One of seven “Up-and-Coming” professionals in recycling & composting industries (Resource Recycling magazine)
Steve Simmons

- GBB Senior Vice President
- Over 30 years of experience
- Has visited/investigated 40+ waste/biomass plants worldwide
- Technologies reviewed include fluid bed gasifiers, plasma gasifiers, pyrolysis, RDF boilers and others
- Experience with designing, building and operating waste to energy facilities
### OVERVIEW

| Morning Session I | • MSW Management Overview  
|                   | • Overview of Conversion Technologies |
| Morning Session II| • Mixed Waste Processing Technologies  
|                   | • Organic Waste Processing Technologies |
| Afternoon Session I| • Thermal Processing Technologies |
| Afternoon Session II| • Project Development  
|                   | • Conclusions and Q&A |
Before We Start

What is important to you today?
MSW MANAGEMENT OVERVIEW
MSW Composition

Composition of the MSW as generated, before recycling

- Paper & Paperboard, 27.0%
- Food Scraps, 14.6%
- Yard Trimmings, 13.5%
- Plastics, 12.80%
- Metals, 9.1%
- Rubber, Leather & Textiles, 8.4%
- Wood, 6.2%
- Glass, 4.6%
- Other, 3.3%

Composition of the MSW as disposed, after recycling and composting

- Paper & Paperboard, 15.1%
- Food Scraps, 21.1%
- Yard Trimmings, 9%
- Plastics, 17.7%
- Metals, 9.1%
- Rubber & Leather & Textile, 11%
- Wood, 8.0%
- Glass, 5%
- Other, 4.4%

Source: US EPA, 2015
U.S. Waste Generation Methodology

- EREF estimates 347 million tons MSW managed in 2013 using “bottom up” approach
- EPA estimates 254 million tons MSW in 2013 using “material balance” approach
- Approximately 220,000,000 total tons (~600,000 TPD) of MSW disposed at landfills in 2013... diverting this material would provide...
  - Nation-wide investment opportunity of $120 billion
  - 50,000 jobs created across the country
History of US MSW Composition

Source: USEPA, 2013
## US MSW Composition Change

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<tr>
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<tbody>
<tr>
<td>Paper</td>
<td>39.2%</td>
<td>34.2%</td>
<td>27%</td>
<td>-31.1%</td>
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<tr>
<td>Plastic</td>
<td>9.1%</td>
<td>11.8%</td>
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<td>Metals</td>
<td>7.6%</td>
<td>7.6%</td>
<td>9.1%</td>
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<tr>
<td>Glass</td>
<td>6.2%</td>
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<td>4.6%</td>
<td>-25.8%</td>
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<tr>
<td>Organics</td>
<td>28.1%</td>
<td>30.7%</td>
<td>34.3%</td>
<td>22.1%</td>
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</table>

# US MSW Organic Waste Composition Change

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<tbody>
<tr>
<td>Food Waste</td>
<td>6.2%</td>
<td>11.9%</td>
<td>14.6%</td>
<td>135.5%</td>
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<tr>
<td>Wood</td>
<td>7.6%</td>
<td>5.7%</td>
<td>6.2%</td>
<td>-18.4%</td>
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<tr>
<td>Yard Trimings</td>
<td>14.3%</td>
<td>13.1%</td>
<td>13.5%</td>
<td>-5.6%</td>
</tr>
<tr>
<td>Total Organics</td>
<td>28.1%</td>
<td>30.7%</td>
<td>34.3%</td>
<td>22.1%</td>
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# U.S. Waste Management Infrastructure

<table>
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<tr>
<th>Technology</th>
<th>Number</th>
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<tbody>
<tr>
<td>Transfer Stations</td>
<td>3,350</td>
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<tr>
<td>Material Recovery Facilities (MRF)</td>
<td>586</td>
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<tr>
<td>Curbside Recycling Programs</td>
<td>9,000+</td>
</tr>
<tr>
<td>Mixed Waste Processing Facilities &amp; Hybrid MRFs</td>
<td>70*</td>
</tr>
<tr>
<td>Composting</td>
<td>2,300</td>
</tr>
<tr>
<td>Anaerobic Digestion</td>
<td>21</td>
</tr>
<tr>
<td>WTE</td>
<td>77</td>
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<tr>
<td>Landfills</td>
<td>1,908</td>
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*Excludes facilities that solely produce RDF*
MSW Disposal: Over 50% is Still Landfilled

EPA Estimate:
251 million tons (2013)

BioCycle State of Garbage 2013 results:
389 million tons (2011)
**California** – MSW allowed as engineered fuel to power cement kilns; new goal of 75% diversion

**Rhode Island** - beginning Jan. 1, 2016, required separation of organic waste including food scraps and composting or other beneficial reuse

**Vermont** – Universal Recycling Act requires diversion of food waste, yard waste, and wood debris from landfill, continued EPR and e-waste laws

**Massachusetts** – ban on disposal of food and yard waste, policies to encourage growth of AD

**Connecticut** - Ban of commercial food waste from landfills for generators of two or more tons of food waste

**New Jersey** – S-771 would require any large generator located within 25 miles of an authorized organics recycling facility to divert their material for processing

**Florida** – Waste-to-energy is considered recycling
OVERVIEW OF THE MSW CONVERSION TECHNOLOGIES
Increased Interest in Renewable WTE Technologies

476 Technology/Project Development Companies

- 28 Aerobic Composting
- 106 Anaerobic Digestion
- 30 Ethanol Fermentation
- 117 Gasification
- 30 Plasma Gasification
- 31 Pyrolysis
- 63 WTE: mass burn, modular, dedicated boilers, and RDF
- 69 Others (e.g., thermal cracking, hydrolysis, steam reforming, agglomeration, depolymerization)

157 Commercial or Demonstration CT Facilities

- 70 Anaerobic Digestion
- 57 Gasification
- 10 Plasma Gasification
- 12 Pyrolysis

International WTE market for new construction estimated at $11 billion per year

Source: VisionGain
Modern Integrated Waste Management Systems are Complex

- MSW
- Organics
- Food Scraps

Mixed Waste Processing

- Materials For Recycling
- Organics

Refuse Processed Fuel

- Energy Recovery
- Residue
- Landfill

- Steam
- Power
- Biofuel

- Oil Refineries
- Dedicated RE-Boilers
- Paper Mills

WWTP

Composting

Anaerobic Digestion

- Biogas
- Trucks and/or gas grid

Soil Amendment

- Residue
- Landfill
Conversion Systems may have Multiple Technologies, Pathways and Products

**Conversion Technology**
- Pyrolysis
- Gasification
- Combustion
- Anaerobic Digestion
- Aerobic Composting

**Primary Product Conversion**
- Char
- Tars & Oils
- Syngas
- Steam
- Biogas
- Digestate
- Compost

**Product Conversion**
- Extraction
- Upgrading
- Synthesis
- Turbine
- Engine
- Conditioning
- Aerobic Composting

**Secondary Product**
- Chemicals
- Gasoline
- Ethanol/Methanol
- Ammonia
- Electricity
- CNG/LNG
- Heat
- Compost

*Feedstock* *may be pre-processed*

Source: GBB 2017
Conversion Technologies have Different Risk Profiles

<table>
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<tr>
<th>Alternative</th>
<th>Risks/Liability</th>
<th>Risk Summary</th>
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<tr>
<td>Processing for Recyclables and Fuel</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
<tr>
<td>Composting</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
<tr>
<td>Mass Burn Combustion</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
<tr>
<td>RDF Combustion</td>
<td>Proven technology; limited U.S. commercial experience</td>
<td>Moderate to Low</td>
</tr>
<tr>
<td>Anaerobic Digestion</td>
<td>Proven technology; limited U.S. commercial experience</td>
<td>Moderate to Low</td>
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<tr>
<td>Pyrolysis and Gasification</td>
<td>Previous failures at scale; no operating experience with large-scale operations in the U.S.; full-scale demonstrations nearing operation</td>
<td>High</td>
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Source: Gershman, Brickner & Bratton, Inc. 2017
Traditional Mass Burn Combustion is on the Decline

<table>
<thead>
<tr>
<th>Year</th>
<th>Numbers of Plants</th>
<th>Reference</th>
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<tbody>
<tr>
<td></td>
<td>RDF</td>
<td>MB</td>
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*MWC type: MB = Mass burn, MOD = Modular excess air, RDF = Refuse-derived fuel*
Organic Waste Management

- Growing interest in managing organic waste separately from the municipal waste stream.
- Higher recycling and diversion goals
- From private initiatives only to bigger involvement of the public sector
- More world leading technology developers coming to the US
- Legislative support
- Financial support for infrastructure development
- Wastewater treatment plants interested in using excess AD capacity for food waste
States Leading the Way on Organics

- **California**
  - AB 1826 – Legislation signed into law September 28, 2014
  - AB 939- Integrated Waste Management Act
  - AB 32- Global Warming Solutions Act

- **Connecticut:**

- **Massachusetts**
  - Regulation 310 CMR 19.000 Takes Effect October 1, 2014 (disposal ban)

- **Minnesota**
  - Statute 115A.151 Recycling Requirements; Public Entities; Commercial Buildings; Sports Facilities (2015)

- **Rhode Island:**
  - SB 2315 – Signed into law June 30, 2014

- **Vermont**
Local Initiatives on Organic Waste

• Austin, Texas:
  – Resolution 20121213-097 – Passed December 13, 2012

• New York City, New York:
  – Local Law 146-2013 – Legislation Passed on December 30, 2013

• San Francisco, California:
  – Ordinance Number 100-09 – Regulation Effective November 10, 2009

• Seattle, Washington:
  – Ordinance Number 1122844 - Legislation Passed on December 2, 2008 - Curbside Compostable Waste Collection
  – Ordinance Number 123307 - Legislation Passed on May 20, 2010 - Compostable Food Service Ware
  – Ordinance Number 124582 - Legislation Passed on September 22, 2014 – Disposal as Garbage

• Washington, DC:
  – Sustainable DC Omnibus Amendment Act of 2014
  – Sustainable Solid Waste Management Amendment Act of 2014
Food Waste Diversion Programs...

• Current status of Food Waste Diversion Programs:
  – 198 Food Waste Programs in 2013
  – (CA – 33%, WA – 29%, MN – 12%)

• Multi-Family Collection Cost (Seattle) - $1.38 per HH per MO or $14 per cubic yard

• Diversion rate (Seattle):
  – Multi-family: 1.6 lbs. per week
  – Single-family: 8.3 lbs. per week

• Processing Systems
  – AD ($60-100 per ton)
  – AD @ WWTPs
  – Composting
  – Organics processing in Biocells
Food Waste Diversion Programs...

- **Impacts to landfills**
  - Less air space utilized when food waste out
  - LFG recovery rates go down 20%
  - GHG emissions significantly lower

- **Impacts to WTE Facilities**
  - HHV significantly increases when food waste out
    - Vancouver: 25 to 50% diversion of food waste increased HHV 4 to 9%
  - Increased HHV lowers throughput of tons per day by same percent that HHV increased; energy output remains the same
  - Need to consider potential impact on WTE when planning a food waste diversion program
Anaerobic Digestion Development Drivers

- High recycling and diversion goals (up to 80%)
- Zero waste goals
- Food waste disposal bans/mandates-VT, CT, CA, MA and RI
- Recognition of the food waste as a feedstock for AD plants and biogas production
  - Biogas as a fuel from organic waste included in the RFS2 under advanced fuel qualifying for the D3/D5 RINs
- Financial support for infrastructure development
MIXED WASTE PROCESSING (MWP) TECHNOLOGIES

- Mixed Material Recovery Facilities
- Refuse Derived Fuel Facilities
- Mechanical Biological Treatment Approach
Advanced Systems Start with Waste Processing

MSW
- Organics
- Materials For Recycling
- Food Scraps

Mixed Waste Processing
- Organics

Refuse Processed Fuel
- Energy Recovery
  - Residue
    - Landfill
    - Steam
    - Power
    - Biofuel

WWTP
- Composting
- Anaerobic Digestion

- Soil Amendment
- Biogas

- Residue
  - Trucks and/or gas grid
  - Oil Refineries
  - Dedicated RE-Boilers
  - Paper Mills

For Recycling

Fuel

Power

Recycling
An MWP Facility is More than a MRF

• Recovers additional recyclables from mixed waste
• Focus on additional containers and removal of organics
• Best viewed as a complement to single stream recycling, not a replacement
But They May Have Many Common Elements

Ballistic Separator

Heavy-Light Air Separator
But They May Have Many Common Elements

Optical sorting
Mixed Waste Processing Report

The Evolution of Mixed Waste Processing Facilities
1970-Today

Prepared for:
The American Chemistry Council

Prepared by:
Gershman, Brickner & Bratton, Inc.

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April 7, 2015

Technologies Processing
Mixed MSW...the early years
RDF Burning in Coal-Fired Utility Boilers (1970s)

Union Electric Co.
St. Louis, MO
1972, 300 TPD

Americology – WEPCO
Milwaukee, WI
1977, 1200 TPD
Gasification and Pyrolysis
(1970s into early 1980s)

- Baltimore, Maryland
- San Diego, California
- South Charleston, West Virginia
- Disney World
Monsanto Baltimore – 1000 TPD
Pyrolysis Kiln (late 1970s through 1980)
Charleston, WV – 100 TPD
Union Carbide Purox System (1970s)
Current Mechanical Biological Treatment (MBT) Practice
MBT

- Originated in Germany in 1999 (now 36 operating MBTs)
- 330 plants in EU most in: Germany, Austria, Italy, Switzerland and the Netherlands; UK catching up
- Includes:
  - Mechanical sorting of recyclables and organics
  - Food scraps and green waste processed through AD and composting units; mulching too
  - Residuals converted to high BTU refuse-derived fuel (RDF)
- Only 0.4% of waste goes directly to landfills in Germany and 81% of household waste goes to MBT Plants
- RDF key to MBT diversion results
  - 54% to dedicated boilers, 16% to coal plants, 11% to cement kilns and 19% to others

Source: Mechanical Biological Treatment of Municipal Solid Waste. UK Department for Environment Food & Rural Affairs (DEFRA). February 2013
81% of German household waste goes to MBT Plants; 0.4% goes to LF
Waste Management Centre Pohlsche Heide, Germany
MBT with partial flow anaerobic dry digestion

- Publicly owned, privately operated
- The complex has MBT, landfill, WWTP, composting and tunnel anaerobic dry digestion plant for organic waste, and convenience center
  - mixed waste sorting for materials and RDF (double grind)
  - biogas with CHP and biogas to gas grid
  - composting for soil amendment and fertilizer products
  - residue to landfill
Minden, Germany
Small Sized Industrial RDF With Combined Heat and Power Plant

- Facility takes 35,000 tons of RDF per year from MBT
- BASF, chemical company, next door, uses for process steam
- RDF pays to be combusted as a fuel
  - 35 - 65 Euro per ton
MWPF Project: Sun Valley CA (LA Area)
Athens Disposal

- Privately Owned/Operated Project
- MWPF – 1,500 TPD (300,000 TPY)
- 80,000 Sq. ft. Building w/200kw rooftop solar
- 70 TPH Bulk Handling Systems Equipment (BHS) Processing and Recovery System
- Capital Price: Est. $50 Million
- Opened: October 12, 2014

Photo: Athens Website
Montgomery, AL – Infinitus

- High-tech 80,000 square feet “state-of-the-art” Mixed Waste Processing Facility
- $35 Million capital cost
- First “One Bin for All” in 21st Century in the U.S.
- Bulk Handling System:
  - One-line, 40 ton per hour input for 100,000 tons per year
  - 60% material recovery guarantee (including organics)
- Commercial operations began April 2014
- Temporarily closed October 2015

Source: GBB 2014
MWP Can Complement Traditional Mass Burn Combustion

- Waste management systems may be out of capacity
- Curbside recycling rates have stalled
- WTE expansions not economically feasible
- Mixed waste processing can lead to:
  - An increase in material recovery
  - Removal of low energy organics which improve boiler efficiency
  - Lower emissions
  - Reduced boiler maintenance expense
  - Enhanced system economics
Processing Technology Vendors

- Mustang Renewable Power Ventures, LLC
- AMUT GROUP
- Infinitus ENERGY
- RRT
- BHS
- LINDNER America LLC
- STADLER America
- CP mfg.
- M MACHINEX
- Van Dyk recycling solutions
- Vecoplan
MWP’S Produce and Engineered Fuel

- MSW
- Organics
- Mixed Waste Processing
- Materials For Recycling
- Food Scraps
- WWTP
- Composting
- Anaerobic Digestion
- Refuse Processed Fuel
- WTE Facility
  - Residue
  - Steam
  - Power
  - Landfill
  - Oil Refineries
  - Dedicated RE-Boilers
  - Paper Mills
- Biogas
- Soil Amendment
- Trunks and/or gas grid
- Residue
- Landfill
Engineered Fuels for Industrial Use

- Industry requires energy for thermal processes
- Predominate source today is fossil fuel based, coal / natural gas,
- Traditional renewables such as wind and solar can not produce industrial thermal energy
- Forestry Biomass is useful but can be controversial
- Waste derived biomass can be an excellent source (partially renewable)
- Engineered fuel is commonly accepted in the EU
Mechanical Biological Treatment (MBT)

Source Separated Recyclables

Mixed MSW

Source Separated Organics

Mechanical- Biological Treatment Plant (MBT)

**Mechanical** (grinding, screening, recyclables separation, palletizing)

**Biological** (bio-drying, aerobic composting, anaerobic digestion)

Products:
- Recyclables
- Compost
- Biogas/ Electricity
- RDF/EF

Over 330 MBT facilities in operation throughout Europe
Berkeley County, WV MBT Facility

- Uses High Efficiency Mechanical Biological Treatment (HEBioT) process
  - Front end sorting of MSW to remove high value recyclables
  - Remaining material is processed by mixed waste composting to create Solid Recovered Fuel (SRF)
- SRF marketed to cement kilns valued at ~$30/ton
  - EPA approved alternative to coal to reduce emissions
Entsorga Process

MSW → Preprocessing → 12-14 day biological stabilization → Final sizing → Fuel

500 TPD

Oversized → Biofilter → Oversized

Air → Aerobic Processing → Aerobic Processing
Entsorga Wilshire, UK
Hampden, ME Enzymatic Hydrolysis - AD

• Mechanically separates MSW for processing
  – Front end separation of high valuable recyclables
  – Enzymatic hydrolysis of cellulose organics produces high value sugars
  – Anaerobic digestion of soluble organics produces biogas

• Groundbreaking October 27, 2016
  – Contracting with Municipal Review Committee (representing 187 local communities) for MSW feedstock
DISCUSSION

Q&A
Morning Break
ORGANIC WASTE PROCESSING TECHNOLOGIES

- Composting
- Anaerobic Digestion
Organics Management

- MSW
  - Mixed Waste Processing
  - Organics
    - Food Scraps
      - WWTP
      - Composting
      - Anaerobic Digestion
        - Soil Amendment
        - Biogas
          - Trucks and/or gas grid
          - Residue
            - Landfill
            - Steam
            - Power
            - Biofuel

- Organics Management:
  - Energy Recovery
    - Residue
      - Landfill
    - • Oil Refineries
      - • Dedicated RE-Boilers
      - • Paper Mills

- Processed Fuel
  - Energy Recovery

- Processing
  - Mixed Waste Processing

- Fuel
  - Energy Recovery

- Refuse
  - Mixed Waste Processing

- Biogas
  - Residue

- Power
  - Energy Recovery
Circular Economy

Source: Ellen MacArthur Foundation
Municipal Solid Waste (MSW)
Residential MSW Composition from Actual Waste Sorts

30% Residue
- Other Residue (2) 27%

30% Recyclables
- Organics (1) 22%
- Glass 7%
- PET 3%
- OCC 4%
- Other Fibers 21%
- HDPE-(Natural) 1%
- HDPE-(Colored) 1%
- Mixed Plastic 4%
- Aluminum 2%
- Ferrous 3%
- Bags and Film 5%

10% Wildcard

30% Organics and Fines
- Other Residue (2) 27%

Source: Compilation of Sort Data from Fayetteville, NC and Fort Worth, TX

(1) Contains Food Waste, Soiled Paper, and Yard Trimmings
(2) Includes C&D, Diapers, Textiles, Electronics and Other Residue
Managing Organic Waste

Source Separated Organics

Aerobic Composting

Anaerobic Digestion
ANAEROBIC DIGESTION DEFINITION:

Microbial decomposition of organic matter into methane, carbon dioxide, inorganics and organic nutrients in an oxygen depleted environment.
What is Anaerobic Digestion?

**Anaerobic Digestion**

- Microbial decomposition of organic matter
- Oxygen depleted environment
- Methane, inorganic nutrients and non-digested organics
Biochemical Reactions

Hydrolysis
Breakdown of complex molecules
Products: soluble sugars, amino acids, glycerol and long-chain carboxylic acid

Acid-forming stage
Fermentation: soluble organics (glucose) to ethanol and propionate
Acetogenesis: glucose, ethanol, propionate & bicarbonate to acetate

Methanogenesis
Methane generation from:
- acetate
- methanol
- carbon dioxide
Anaerobic Digestion in Nature

- Responsible for the carbon cycle in the ecosystem
- Natural Vs. Man-made sources of methane 30%:70%

Animal intestines, manure

Wetlands
Rice Fields
AD Feedstocks

Other Sources for Organic Materials

- Grocers
- Restaurants and Cafeterias
- Urban Farms
- Food Processing Industries
- Curbside Collections

Source: Seattle Public Utilities

Source: Getty Images
Classification of AD Technologies

**Number of reactors in series**

**Single Stage**
- Feedstock
  - Anaerobic Digestion
    - Hydrolysis
    - Acid Forming
    - Methane production
  - Products
    - Biogas
    - Digestate

**Multi Stage**
- Feedstock
  - AD Stage I
    - Hydrolysis
    - Acid Forming
  - AD Stage II
    - Methane production
  - Products
    - Biogas
    - Digestate

**Operating Temperature**
- Thermophilic (120-150°F)
- Mesophilic (70-104°F)
Classification of AD Technologies II

**Feedstock Introduction**
- Continuous flow
- Plug flow
- Batch

**Solids Content**
- **Low Solids**
  - Pumpable material (“wet”)
  - <15% Solids content
- **High Solids**
  - 25-30% - pumpable (“wet”)
  - >50% - stackable (“dry”)

- **Zero Waste Energy Batch reactors**
- **Eisenmann Plug Flow Reactor**
Feedstock → Pre-Processing → Anaerobic Digestion → Post-Processing → Applications

- Recyclables
- Digestate → Composting (Aerobic)
- Methane → Gas Cleaning
- Soil Amendment/Mulch → Electricity/RNG
Pre-Processing Organics for AD

- **Pre-Processing for Wet Digestion**
  - More Intensive to break down organic material, remove residue, and achieve the correct solids content (Processor Dependent)

- **Pre-Processing for Dry Digestion**
  - Source Separated may need yard waste mulch added to achieve stackability
  - MSW needs equipment to separate from other materials but can then be processed directly
Pre-Processing of Feedstocks

Source Separated (Dry AD)  
Source Separated (Wet AD)

Source: GBB Visit to Zero Waste  
– Monterey, CA

Source: Kompogas
Pre-Processing of Feedstock

Mechanical Separation from MSW

Organic Fines After Screening

Prior to Loading in Bunkers (Dry)

Source: GBB Visit to Republic Newby Island /ZeroWaste San Jose
AD Process – Gas Production

Source: GBB Visit to ZeroWaste
Monterey, CA

Source: GBB Visit to Quasar –
Wooster, Ohio
AD Process – Digestate

Dry AD

Wet AD

Source: GBB Visit to Zero Waste – Monterey, CA

Source: Kompogas
Post-Processing of Digestate

• Wet Digestate
  – Requires dewatering and may need additional drying

• Dry Digestate
  – Screening (Separation by Size)
  – Air Classification (Separation by Weight)
  – Optical Units (NIR, X-Ray)
Processing of the Digestate

Some Equipment Used

Mobile Screen

Source: GBB Visit to Zero Waste – Monterey, CA

Densimetric Table

Source: Van Dyk
Applications - Compost

Source Separated Organics

Maturing Windrows

Screened Final Compost

Source: GBB Visit to Zero Waste – Monterey, CA
Aerobic Composting in the United States

- Aerobic decomposition of biodegradable waste
- 4,914 composting operations in 43 states
- 19.4 million tons of organics diverted for composting (reported by 33 states)
- Average amount of organics processed at a composting plant: 5,155 TPY
- >20 states have yard waste bans from landfills

Source: Institute for Local Self-Reliance & BioCycle, July 2014
Applications – Soil Amendment

MSW Sourced Organics

Maturing Windrows

Screened Final Product

Source: GBB Visit to Zero Waste – San Jose, CA
Applications – Methane Gas

IC Engine/Electricity and Heat

Renewable Natural Gas (RNG)

Source: GBB Visit to Zero Waste – Monterey, CA

Source: CleanEnergy
AD Facilities and Market Leaders

- ~ 20 facilities operating in the U.S.
- Privately financed, owned and operated
- Commercial food waste
- Organics from MSW
- Mixed with yard waste
AD CASE STUDIES
Projects Under Development & Construction

Total: 26
Under Development: 16
Under Construction 10

Yellow - under development
Green - Under construction
Harvest Power- Orlando Energy Garden, FL

- Wet AD
- 120,000 tons/yr commercial food waste and biosolids
- Energy Output: 7 MW (CHP: 3.2 MW electrical, 3.8 MW thermal)
- Product Output: 5,000 MT/yr granular fertilizer
GREENWASTE/ZANKER PROJECT - San Jose, CA

- State-of-Art dry AD facility
- 16 SMARTFERM AD digesters
- Four In-Vessel composting Units
- Capacity of 90,000 TPY of commercial organic waste - biggest in the world
- 1.6 MW power output
CR&R Perris, CA

- CR&R services 2.5 million people in Los Angeles, Orange, Imperial, Riverside and San Bernardino counties
- Phase I to process 80,000 tpy of organics
- Full build out 320,000 tpy of organics
- AD system by Eisenmann
- RNG to fuel CR&R fleet balanced injected into pipeline system
Heartland Biogas, LLC in Weld County, Colorado, by AgEnergy USA, LLC in partnership with EDF Renewable Energy: Manure and food waste
Prince William County, VA

- GBB assisted County with RFP to build, finance, own, operate.
- Wet Anaerobic digestion
- Aerated composting of digestate and yard waste
- On-site greenhouses for growing organic food
- Sale of high grade compost
• US company established in 2006 in Cleveland, OH
• Initially European technology
• Integrated Anaerobic Digestion System (iADs)- patent pending technology developed at Ohio State University
• Over $150M in Executed Projects
  – 14 Operational Digesters (OH, NY, MA, ME)
  – Capacity to annually manage 700,000 tons of organic waste
• Municipal, Industrial & Agricultural Ads
• Mature US Supply Chain
• US company based in Lafayette, CA
• Dry Anaerobic Digestion licensee for:
  – KompoFERM
  – SmartFERM
• Plants:
  – Monterey Regional Waste Management District, Marina, CA
  – Zero Waste Energy Development Co., San Jose, CA
  – Blue Line Transfer/SSF Scavengers, South San Francisco, CA
  – 3 plants under construction and development
One of the world leaders in AD
- Dry anaerobic digestion
- 75 plants around the world
- Plant under construction in San Luis Obispo County, CA
- 400 years of accumulated operating experience
Facilities and Market Leaders

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System Economics

- **Tipping fees at operating plants:**
  - $40-$100/ton
  - Cleaner the feedstock lower the tipping fee

- **Capital expenses**
  - Different for different types of AD
  - $300-$500 per installed annual ton of capacity

- **Operating Expenses**
  - 2-3% of the Capital Expenses per ton processed
Revenue Sources

• Electricity/ biogas sale
• Digestate/ fertilizer sale
• RINs
• Low Carbon Fuel Standard (LCFS), CA
  – Metric Tons of Carbon Dioxide equivalent (MTCO2e) avoided
  – $85-$100 per credit
• RECs (eligibility depends of the state)
  – $20/MWh – PJM value
• Production Tax Credit-
  – Section 45: Open/closed-loop Biomass (electricity)
  • 1.15 cents/kWh (x2 for closed loop)
Renewable Identification Numbers (RINs)

- Tradable environmental attribute under the US Renewable Fuel Standard
- Energy equivalent to one gallon of ethanol
- Multiple categories depending upon feedstock
- Wide range of values
- Cellulosic feedstock has the highest value, currently over $2.00 per gallon
Capital Funding

• **Investment Tax Credit** -
  – Section 45: Open/closed-loop Biomass (electricity)
    • 30% of qualifying property (capital costs)
    • Must “commence construction,” safe harbor 5% or complete “Physical work of a significant nature” by December 31, 2016
  – H.R.5489 — Agriculture Environmental Stewardship Act of 2016 (non-electricity)
    • 30% ITC for:
      – Non-Electricity Biogas Systems (heat, fuel)
      – Nutrient Recovery Systems
  – Loan Guaranteed
  – Private investment sources
AD RENEWABLE ENERGY COMPARATIVE ANALYSIS
Source: James Potter, AgEnergyUSA, President

CAPACITY FACTOR
- Solar 14%
- Wind 22% (worldwide)
- AD 95%

COMPARATIVE ANALYSIS-THE REAL ENVIRONMENTAL BENEFITS
- It takes 7 times as much solar capacity to achieve the same amount of AD produced energy
- For example 100 MW’s of AD Projects, you would need 700 MW’s of solar to produce the same amount of renewable energy.
- This is $400 million in AD projects versus $2.5 billion in solar (to achieve the same energy production level)
- 4,900 acres for solar versus 200 acres for AD
- AD Projects result in significantly greater CO2 reductions than solar
AD Systems

**Pro’s**
- Can produce multiple products
  - Electricity
  - Liquid fuels
  - Compost
- Operating experience
- Lower capital required versus thermal processes
- Compatible with waste streams that are not easily processed by thermal processes

**Con’s**
- Feedstock quality control paramount
- Process controls can be challenging
- Odors can be difficult
PROSPECTS OF AD IN THE U.S.
Significant Attention

• Biogas Opportunities Roadmap
  – By USDA, US-EPA, USDE- August 2014
  – Progress Report- December 2015
  – Part of the White House Climate Action Plan- Strategy to Reduce Methane Emissions

• U.S. EPA Sustainable Materials Management Program Strategic Plan (2017-2022)
  – Develop infrastructure (composting and AD plants)
  – Promote opportunities across the entire food life cycle to reduce wasted food from landfills
  – Improve and standardize measurement of wasted food.

• ReFED- Rethink Food Waste
  – A Roadmap to reduce U.S. food waste by 20%
  – Assessed Technical and Economic Impact of 27 Solutions
Significant Funding Opportunities

- Amazon
- Apple
- Google green
- Microsoft
- Sterne Brothers & Co.
- Stifel
Opinion of Future Trends

• Stand alone AD facilities
• AD facilities as part of Mechanical Biological Treatment Facilities or together with composting, MRF’s or WTE facilities
• As projects like Prince William County become reality the public sector will feel more comfortable and willing to accept more risk
• More experienced AD project developers
OrganEcs-A Cost Estimating Tool for Managing Source Separated Organics

• Provides planning-level assistance for estimating the costs associated with constructing and operating an organic waste management project for SSO
  – Open air composting with and w/o forced aeration
  – high-tech wet and dry AD
  – low-tech wet anaerobic digestion

• Developed with cost & operating data from published reports, technology vendors, industry professionals

• GBB is beta-testing the tool
Biogas Wastewater Assessment Technology Tool (BioWATT)

- ERG through the World Bank and GMI
- Provide a quick and preliminary assessment of wastewater-to-energy projects
- Evaluated Technologies:
  - Conventional activated sludge (CAS) with anaerobic digester (plus optional co-digestion)
  - Trickling filter (TF) with anaerobic digester (plus optional co-digestion)
  - Upflow anaerobic sludge blanket (UASB) reactor
  - Covered anaerobic pond
- Free download:
  - [http://www.globalmethane.org/tools-resources/tools.aspx#five](http://www.globalmethane.org/tools-resources/tools.aspx#five)
Steering Committee

- Natural Resources Defense Council
- Atticus Trust
- The Fink Family Foundation
- The David and Lucile Packard Foundation
- Ahearn Family Foundation
- Closed Loop Fund

Advisory Council (select members)

- Waste Management
- Wal-Mart
- US EPA Region 10
- Marriott International
- World Resources Institute
- California State Board of Food and Agriculture
- Harvard Food Law and Policy Clinic
- City of Seattle
- Grocery Manufacturers Association
- Biocycle
DISCUSSION

Q&A
Lunch
THERMAL PROCESSING TECHNOLOGIES

- Mass-Burn Combustion
- RDF Combustion
- Gasification
- Pyrolysis
Energy Recovery

- MSW
- Organics
  - Mixed Waste Processing
  - Materials For Recycling
  - Food Scraps
    - WWTP
    - Composting
    - Anaerobic Digestion
      - Soil Amendment
      - Biogas
        - Trucks and/or gas grid
      - Residue
        - Landfill
  - Organics
  - Energy Recovery
    - Power
    - Biofuel
    - Steam
    - Residue
      - Landfill
- Oil Refineries
- Dedicated RE-Boilers
- Paper Mills
Combustion Mass Burn/Dedicated Boilers

- Excess air for complete combustion
  - Starved air with some modular mass burn
- Products: steam, power, hot water, and/or chilled water; also metals, aggregates, and ADC
- Feedstocks
  - MSW
  - Special wastes
  - Biosolids

Combustion: is a high-temperature exothermic redox chemical reaction between a fuel (the reductant) and an oxidant, usually atmospheric oxygen, that produces oxidized, often gaseous products, in a mixture termed as smoke. Combustion in a fire produces a flame, and the heat produced can make combustion self-sustaining...

Traditional Mass Burn Combustion
Mass Burn Grate System
Modular Mass Burn Combustion
1980s: RDF – Dedicated Boiler Facilities (20 operating today)

- Rochester, MA
- Hartford, CT
- West Palm Beach, FL
- La Crosse, WI
Xcel and Great River Energy (GRE)
RDF Production With Remote Boilers
(825,000 TPY – 59 MW)

Elk River RRF
COUNTIES:
Dakota
Ramsey
Washington
Benton
Hennepin
Sherburne
Stearns

Newport RDF Facility

Great River Energy Plant

Xcel Energy Wilmarth Plant
Typical Industrial RDF Boiler

Source: Outotec
Traditional Combustion Based WTE Over Past 30 Years

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>RDF</td>
<td>105</td>
<td>162</td>
<td>102</td>
<td>86</td>
<td>77</td>
</tr>
<tr>
<td>MB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MWC type:** MB = Mass burn, MOD = Modular excess air, RDF = Refuse-derived fuel.
WTE Facility Closures

Harford, MD

Harrisonburg, VA

Portsmouth, VA

Nashville, TN

Wallingford, CT
Newest Traditional WTE: Solid Waste Authority of Palm Beach County, FL

- 3,000 TPD Mass Burn facility (1,040,000 TPY)
- Babcock & Wilcox
- 130 MW renewable power; enough for over 86,000 houses
- $668 million construction price
- $20.5 million first year O&M cost
- Advanced emissions controls, ferrous and non-ferrous metals recovery

Source: SWA of Palm Beach County
Copenhagen, Denmark – Ski Slope Plant

- 400,000 TPY
- Electricity and steam for district heating
Emissions Control Technology

- Powdered Activated Carbon (PAC) injection for mercury & dioxin/furan reduction
- Spray Dry Absorber (SDA) with individual lime/water feeds for acid gas removal
- Pulse Jet Fabric Filter (PJFF) for particulate and heavy metals removal

Source: Michael D. Fick
Babcock & Wilcox, Project Director
Selective Catalytic Reduction (SCR)

- First U.S. WTE plant designed with SCR system
  Injection of vaporized aqueous ammonia upstream of catalyst for NOx removal
- Low temperature catalyst in a low dust environment
- Flue gas reheat and heat recovery systems integrated directly into the power cycle
- Total of 56 municipal WTE projects currently operational/under construction or in the preparatory stage.
- An aggregate daily waste processing capacity of 47,700 tonnes and power generation designed capacity of 974.5MW,
Retrofit of Spittelau Waste to Energy Plant (Vienna, Austria) Overview

Source: Stefan Fazekas, Wien Energy (Austria), Material Flow and Data Manager

- Initially constructed in early 1970’s
- 250,000 Tonnes per year capacity
- Power: 9.5 MW to power grid
- District heat/cooling generation: 58MW
- Grate firing, incineration, steam boiler
- Central location:
  - Lessens waste trucks transport
  - Optimal integration into district heating and cooling networks
- Artist designed façade and stack a tourist attraction!
2 new boilers
580/752 psi/°F

Fabric filer with activated carbon replacing electrostatic precipitator

DeNox-facility with low temperature catalyst and heat-shift system

New and larger turbine and generator

Source: Stefan Fazekas, Wien Energy (Austria), Material Flow and Data Manager
Timeline of Retrofit: January 2012 – June 2015

- 2012: Construction
- 2013: Turbine/Generator Installation
- September 2013: Plant Shutdown (6 months)
- June 2015: Startup and Electricity Generation

Cost of Retrofit: $156.3 million

- Furnace: $74.4 million
- Water Steam-System & Turbine: $20 million
- SCR: $14 million
- EMSR, Instrumentation and Control System: $21.1 million
- Engineering & Construction: $26.8 million
Next generation WtE plants

- SHOCK PULSE GENERATORS
- RADIANT SUPERHEATER
- Enhanced ONLINE CLEANING
- HEAT EXCHANGER SWITCHING
- Enhanced SNCR
- LOW NOx STAGED COMBUSTION
- MICC
- SNCR
- REVERSE-ACTING GRATE VARIO
- Optimized CLADDING
- DRY ASH HANDLING SYSTEM
- SYNCOM/SYNCOM-PLUS
- INTERMEDIATE SUPERHEATING

130 bar / 440 °C
14 bar / 320 °C

G
Martin Advancements

- Organic Waste Processing - Thoni Systems
- Grate Technologies
  - Reverse acting/horizontal types
- Boiler design
- Combustion Concepts & Controls
- Online cleaning concept - Explosion Power
- Dry bottom ash processing
Martin GhmB Very Low NOx VLN Process

Implemented on an industrial scale
- Coburg, Denmark 2011
- Honolulu, USA 2012
- Buchs, Switzerland 2013
- Durham, CAN 2014
- Bazenheid, Switzerland 2014

Source: Ralf Koralewska
Martin GMBH, Research and Development Technology
Very Low NOX-GM
WtE plant St. Gallen, Switzerland
## Air Emissions Acceptance Test Results

<table>
<thead>
<tr>
<th>Tests</th>
<th>Maximum Concentration</th>
<th>Test Results *</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x}</td>
<td>50 ppm</td>
<td>30 – 31 ppm</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>24 ppm</td>
<td>11 – 21 ppm</td>
</tr>
<tr>
<td>CO</td>
<td>100 ppm</td>
<td>16 – 24 ppm</td>
</tr>
<tr>
<td>Opacity</td>
<td>10%</td>
<td>0.4 – 2.4 %</td>
</tr>
<tr>
<td>VOCs</td>
<td>7 ppm</td>
<td>0.2 – 2.7 ppm</td>
</tr>
<tr>
<td>PM</td>
<td>12 mg/dscm</td>
<td>0.6 – 2.5 mg/dscm</td>
</tr>
<tr>
<td>Pb</td>
<td>125 μg/dscm</td>
<td>0.5 – 8.1 μg/dscm</td>
</tr>
<tr>
<td>H\textsubscript{2}SO\textsubscript{4}</td>
<td>5 ppm</td>
<td>Non-detectable &lt; 0.01 ppm</td>
</tr>
<tr>
<td>HCl</td>
<td>20 ppm</td>
<td>1.5 – 2.1 ppm</td>
</tr>
<tr>
<td>HF</td>
<td>3.5 ppm</td>
<td>Non-detectable &lt; 0.1 ppm</td>
</tr>
<tr>
<td>Dioxins/Furans</td>
<td>10 ng/dscm</td>
<td>0.2 – 0.4 ng/dscm</td>
</tr>
<tr>
<td>Hg</td>
<td>25 μg/dscm</td>
<td>0.6 μg/dscm</td>
</tr>
<tr>
<td>Cd</td>
<td>10 μg/dscm</td>
<td>0.3 – 2.5 μg/dscm</td>
</tr>
<tr>
<td>NH\textsubscript{3} slip</td>
<td>10 ppm</td>
<td>2.2 – 5.5 ppm</td>
</tr>
</tbody>
</table>

*Corrected to 7% O\textsubscript{2} dry basis*
Hitachi Zosen INOVA updates

1. Keeping costs down by sourcing local
2. Increased Energy Recovery
3. Increased material recycling
Combustion Systems

Pro’s
• It works!
• It is well demonstrated
• There is a large base of experienced, well financed, technology providers and system developers
• Financeable

Con’s
• It is expensive in today’s energy market
• Perceived to be highly polluting
• Perceived to compete with recycling
The Sustainable Waste Management Ladder

Earth Engineering Center, Columbia University (based on Eurostat 2008 data)

Source: Earth Engineering Center, Columbia University, 2009
GASIFICATION TECHNOLOGY
What is gasification?

Gasification is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. Wikipedia
The Gasification Process

Indirect heat is pyrolysis

MSW | AIR/OXYGEN

GASIFIER

ASH/SLAG BYPRODUCT

SULFUR BYPRODUCT

GAS CLEAN-UP

CLEAN SYNGAS

TO POWER

TO PRODUCTS
Gasification System Types

1. Fixed Bed Thermal Gasifiers

- Up-draft
  - Drying
  - Pyrolysis
  - Gasification
  - Partial combustion
- Down-draft
- Cross-draft
Gasification System Types

2. Fluidized Bed Gasifiers/ bubbling bed/ circulating Bed

- Low Btu Gas (LBG) or Medium Btu Gas (MBG)
- Staged (in vessel ignition)
- Boiler or Process Burner
- IC Engine or Turbine
- Gas to Liquids or Other Process

Diagram:
- Feedstock
- Air or Steam & Oxygen
- Ash
Gasification System Types

3. Plasma Assisted Gasifiers
Gasification Output Pathways

Steam & Power
- Boiler
- Gas Turbine
- Combined Cycle
- IC Engine
- Fuel Cells

Power Generation
- Refinery
- Hydrotreating
- Transportation Fuels
- Fuel Cells
- Chemicals
- Fertilizers

Transportation Fuels
- Hydrogen
- Syngas
- Methanol
- Formaldehyde
- Methyl Acetate
- Acetic Anhydride
- Acetic Acid
- VAM
- PVA
- Ketene
- Diketene & Derivatives
- Ethyl
- Propylene
- Wax
- Fischer-Tropsch
- Diesel/Kerosene
- Gasoline
- Naptha
- DME
- Gasoline
- Polyolefins
- Oxy Chemicals
- Acetic Esters
- PVA
- Diketene & Derivatives
- Steam & Power
- Gas Turbine
- Combined Cycle
- IC Engine
- Fuel Cells

The diagram illustrates various pathways from gasification to different end products such as fuels, chemicals, and power generation.
Gasification Technology Offerors

- AlterNrg
- Enerkem
- BlueFire Ethanol
- ENTECH Renewable Energy Solutions
- Chinook Energy
- Fulcrum Bioenergy
- Covanta Energy
- InEnTec
- Plasco Energy Group
- INEOS Bio
# Biomass to Liquid Fuel Technologies

<table>
<thead>
<tr>
<th>Company</th>
<th>Technology</th>
<th>Product</th>
<th>Status</th>
<th>Featured plants in N. America</th>
<th>No. of commercial plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enerkem</strong></td>
<td>Gasification</td>
<td>Methanol/Ethanol</td>
<td>Commercial</td>
<td>Demo: Westbury, CAN Commercial: Edmonton, CAN Development: Varennes, CAN and Rosemont, MN</td>
<td>1</td>
</tr>
<tr>
<td><strong>INEOS Bio</strong></td>
<td>Gasification</td>
<td>Ethanol/Electricity</td>
<td>Shutdown</td>
<td>Vero Beach, FL</td>
<td>None</td>
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<tr>
<td><strong>Fulcrum Bioenergy</strong></td>
<td>Gasification</td>
<td>Ethanol</td>
<td>Demo</td>
<td>Reno, NV, sierra biofuels</td>
<td>None</td>
</tr>
<tr>
<td><strong>Fibright</strong></td>
<td>Enzymatic Fermentation</td>
<td>Ethanol</td>
<td>Demo</td>
<td>Demo: Lawrenceville, VA Commercial: Blairstown, IA – 6 Construction: Hampden, ME</td>
<td>None</td>
</tr>
</tbody>
</table>
• 330 TPD refuse derived fuel
• 10 million gallons/year of ethanol
• Produces cellulosic methanol, ethanol (planned for 2017), syngas, and chemical intermediates
• Edmonton Waste Management Centre:
  – Refuse Derived Fuel Facility
  – Enerkem Waste-to-Biofuels Facility
  – Advanced Energy Research Facility

Source: SWANA Northern Lights 2013, Bud Latta, Processing and Disposal Waste Management Services, City of Edmonton
### Project Status - Edmonton Waste-to-Biofuels Facility, Alberta, CA

#### Financing
- Privately financed by capital and ownership investments
- Waste Management of Canada
- EB Investments
- Alberta Innovates
- City of Edmonton

#### Owner/operator
- Public-Private Partnership: Enerkem Alberta Biofuels LP
- Builds, owns, and operates Waste-to-Biofuel facility
- City of Edmonton and Alberta Innovates own/operate co-located facilities

#### Waste Stream
- City of Edmonton provides 110,000 tons MSW annually
- 25 year contract
- Pre-processed in RDF facility
- Tip fee $45/Ton

---

Sources: Biofuelsdigest.com/bdigest/2014/10/22/enerkem-alberta-municipal-waste-to-fuels-juggernaut-in-pictures
http://www.durhamyorkwaste.ca/pdfs/project/complaint/20140822_July2014DYECProjectTeamLog.pdf
Concord Blue/Lockheed Martin – Oswego, NY

- 8 TPD demonstration facility
  - Will be operated as hybrid production unit / R&D unit / sales and marketing tool
- Produces 250 kW using wood waste and C&D derived fuel
- Plans to transition material to MSW in future

Source: GBB Site Visit 2016
AlterNRG – Tees Valley, UK

• 1,000 tons-per-day Plasma gasification facility
  – Front end MWPF
  – AlterNRG (Westinghouse) plasma reactor technology

• Co-located processing for Tees Valley 1, and Tees Valley 2

Source: AlterNRG
- Gasification followed by alcohol synthesis
- Sierra BioFuels- commercial plant under construction in Reno, Nevada
  - 200,000 MSW
  - 10.5 million gal of jet fuel/year

**2013 STATUS:**
- Permitting completed
- Feedstock and off-take agreements
- USDA $105 million loan guarantee
- Secured $175 million for construction
- Expected startup in 2015

**2017 STATUS**
- EPC Contract with Abengoa (Stalled)
- Fuel offtake agreement with Cathay Pacific Airways
- Commercial operation expected in 2017
• Gasification followed by biocatalyst fermentation and distillation

• **Plant:**
  – Vero Beach, Indian River County, FL-commercial demonstration facility
    • process ~150,000 TPY of yard, wood and vegetative wastes
    • produce 8 million gal/year ethanol and 6 MW (gross) of electric power
Gasification followed by biocatalyst fermentation and distillation

**Plant:**
- Vero Beach, Indian River County, FL - commercial demonstration

- process ~ 150,000 TPY of yard, wood, and vegetative wastes
- produces ~ 8 million gal/year ethanol and 6 MW (gross) of electric power

*Indian River BioEnergy Center*
Gasification followed by plasma torches to refine the syngas product

2013 Status

- Plants:
  - Commercial-scale demonstration, 94 TPD- Train Road, Ottawa, CA
  - Recently signed contract with the City of Ottawa to build new 3-line plant to process 109,500 t/year of the city MSW
• Gasification followed by plasma torches to refine the syngas product

2013 Status

• Plants:
  • Commercial 94 TPD - Train Road, Ottawa, CA
  • Recently signed contract with the City of Ottawa to build new 3-line plant to process 109,500 t/year of the city MSW
• Thermal conversion in the absence of oxygen
• Non-recyclable plastics to oils, fuels
• Plastics-to-Oil Technologies Alliance formed by ACC

Source: RES Polyflow
Gasification Systems

Pro’s
- Can produce multiple products
  - Electricity
  - Liquid fuels
  - Renewable chemicals
- Operating experience with select feedstocks, but not MSW
- Production of products greatly reduces on-site emissions
- Less extensive air emission control systems
- Perceived to be more compatible with recycling

Con’s
- It is expensive in today’s energy market
- Not well demonstrated with MSW, (at least not in the USA)
- May be tagged as “An incinerator in disguise”
DISCUSSION

Q&A
Afternoon Break
CONVERSION TECHNOLOGIES
PROJECT DEVELOPMENT

- Associated Risks
- Building Blocks
- Legislation
- Financing opportunities
- Lessons learned
Modern Integrated Waste Management Systems are Complex

- MSW
- Organics
- Mixed Waste Processing
- Refuse Processed Fuel
- Energy Recovery
  - Steam
  - Power
  - Biofuel
  - Residue
  - Landfill
  - Oil Refineries
  - Dedicated RE-Boilers
  - Paper Mills
- Food Scraps
- Materials For Recycling
- Organics
- WWTP
- Composting
- Anaerobic Digestion
- Biogas
- Soil Amendment
- Trucks and/or gas grid
- Residue
- Landfill
Reasons Project Developments Fail

- Technology risk
- Regulatory push back
- Lack of political will
- No financing
- Costs too high
- Inadequate waste supply
- Hurts recycling
- No sites
- No sites
Laying the Foundation of a Successful Project

- Develop and articulate an integrated strategy
- Clearly define project objectives and opportunities
- Develop internal economic and risk profile
- Clearly define roles and responsibilities
- Knowledgeable and trustworthy advisor
# Project Building Blocks

<table>
<thead>
<tr>
<th>Regulatory impetus and incentives</th>
<th>Limited or high disposal costs</th>
<th>Waste Supply</th>
<th>Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site with good logistics that can be permitted</td>
<td>Landfill for residues</td>
<td>Contractor with resources and proven technology</td>
<td>Capital</td>
</tr>
<tr>
<td>Ability to pay service fees</td>
<td>Finance</td>
<td>Compatibility with High Level of Recycling</td>
<td>Political Will</td>
</tr>
</tbody>
</table>
Collecting Data to Plan and Design Waste Processing Facilities

Characterizing the solid waste stream is key!

Waste characterization data provides

- Technical Specifications for Feedstock
- Potential Material Recovery Rate
- End-product value (recyclables and ACT outputs)
Executing a Waste Characterization

Characterization Protocol & Health and Safety Plan

Unique to each waste sort – GBB used “targeted” methodology for City of Fayetteville

Data analysis

Field work
<table>
<thead>
<tr>
<th>Category</th>
<th>Sort Material List</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>Newsprint</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Office Paper</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Corrugated Cardboard, Kraft Paper</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Paperboard</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Other Dirty Paper</td>
<td>5</td>
</tr>
<tr>
<td>Plastic</td>
<td>PET</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>HDPE</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Polystyrene</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>LDPE</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Other Rigid Plastic</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Mixed Dirty Plastic</td>
<td>11</td>
</tr>
<tr>
<td>Glass</td>
<td>Clear</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Green</td>
<td>13</td>
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<tr>
<td></td>
<td>Brown</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>16</td>
</tr>
<tr>
<td>Metals</td>
<td>Ferrous</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Non-Ferrous</td>
<td>18</td>
</tr>
<tr>
<td>Organics</td>
<td>Yard Waste</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Food Waste</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Misc. Organics</td>
<td>21</td>
</tr>
<tr>
<td>Special Wastes</td>
<td>Rubber</td>
<td>22</td>
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<td></td>
<td>Textiles</td>
<td>23</td>
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<tr>
<td></td>
<td>HHW</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Tires</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Appliances &amp; Batteries</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Used Oil</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>C &amp; D</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Fines</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Misc. Nonorganics</td>
<td>30</td>
</tr>
</tbody>
</table>
Sorting Tables

Weighing and Sizing Station

Material Collection Tarp
Sell the Procurement
...Pre-Develop Project Building Blocks

• Include a site
• Address recycling as part of future solution
  – In certain states, organics too
• Show understanding of cost implications and how it will be funded
• Offer waste supply strategy and commitment
• Include service agreement showing risk posture
• Involve internal decision-makers and stakeholders
• Have internal team with resources and advisors
Barriers to Implementation

- Public acceptance:
  - Emissions
  - Public health concerns
  - Political will
  - Conversion does not always mean recovery

- Level of preprocessing necessary:
  - Increases cost

- Costs are Uncertain:
  - Limited operating experience (new technologies)
  - Value of products
  - Volatility of product values
  - $ for RINS/RFs uncertain
  - Loans/grants needed for new technologies

- Legislative and regulatory uncertainty:
  - Renewable fuel requirement
  - Shifting diversion and recovery requirements

- Limited operating experience:
  - No commercial scale plants
  - Pilot and demonstration scale operations experience
Public / Private Partnership

- **Bondholders**
  - **IDA**
  - **Debt/Equity**

- **Public Sector**
  - **Owner/Operator**
    - **WSA**
      - **Haulers**
    - **Permit**
      - **Permitting agencies**

- **Owner/Operator**
  - **Compost**
  - **Fuel and Energy Markets**

- **Fuel and Energy Markets**
  - **OA**
  - **DA**

- **Public / Private Partnership**
  - **DEBT/EQUITY**
  - **OWNER/OPERATOR**
  - **HAULERS**
  - **PERMITTING AGENCIES**
  - **WSA**
Public Finance Structure
Private Finance Structure
# Technologies and Risk

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Risks/Liability</th>
<th>Risk Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Waste Processing</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
<tr>
<td>Composting</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
<tr>
<td>Mass Burn Combustion</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
<tr>
<td>RDF Combustion</td>
<td>Proven technology; limited U.S. commercial experience</td>
<td>Moderate to Low</td>
</tr>
<tr>
<td>Anaerobic Digestion</td>
<td>Proven technology; limited U.S. commercial experience</td>
<td>Moderate to Low</td>
</tr>
<tr>
<td>Pyrolysis and Gasification</td>
<td>Previous failures at scale; no operating experience with large-scale operations in the U.S.; full-scale demonstrations nearing operation</td>
<td>High</td>
</tr>
<tr>
<td>Landfill Gas Recovery</td>
<td>Proven commercial technology</td>
<td>Low</td>
</tr>
</tbody>
</table>

*Source: Gershman, Brickner & Bratton, Inc. 2016*
## Energy/Fuel Product Values - Key and Cyclical

<table>
<thead>
<tr>
<th>Converting MSW to...</th>
<th>Product</th>
<th>Yield from 1 Ton MSW</th>
<th>Value Per* Production Unit</th>
<th>Revenue Per Input Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power</td>
<td>500-650 kWh</td>
<td>@ $0.06 / kWh</td>
<td>$30-$39</td>
</tr>
<tr>
<td></td>
<td>Synthetic Crude</td>
<td>1 barrel</td>
<td>@ $50 / barrel w/o subsidies**</td>
<td>$50</td>
</tr>
<tr>
<td></td>
<td>Ethanol</td>
<td>40 gallons</td>
<td>@ $2.5 / gallon w/o subsidies**</td>
<td>$100</td>
</tr>
<tr>
<td></td>
<td>Bio- Diesel (w/subsidies)</td>
<td>35 gallons</td>
<td>@ $3.57 - 4.00 / gallon***</td>
<td>$125 to 140</td>
</tr>
</tbody>
</table>

* 2015 market values  
** Subsidies apply only to biogenic fraction of the feedstock  
***Includes Renewable Identification Numbers (RINs) and from California Low Carbon Fuel Standard (LCFS) subsidies
Plant sizing: Step 1 what is the waste?

- Municipal waste streams can have seasonal variation
  - Quantity
  - Energy value

<table>
<thead>
<tr>
<th></th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
<td>95%</td>
<td>90%</td>
<td>95%</td>
<td>100%</td>
<td>105%</td>
<td>110%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHV</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

- Mild dry winter / tourists
- Hot wet summer
Step 2: How much energy is available?

For 300,000 TPY:

- **A Maximum (25 MWe)**
- **B Minimum (19 MWe)**
- **C Average (22 MWe)**
Drivers for Interest in Conversion Technologies

- High recycling and diversion goals (up to 80%)
- Zero waste goals
- Negative perspective towards conventional WTE
- Food waste disposal bans/mandates-VT, CT, CA, MA and RI
- Financial support for infrastructure development
- Availability of private financing
Legislation and Regulations

• Will more states ban food scraps from disposal?
• Will North American landfill disposal become more expensive?
• Permitting needs to be streamlined/rational
• Several states stepping up recycling/diversion goals and producer responsibilities
• USEPA needs to help lead the way with RFS2 and EF rules
• Will there be local leadership willing to make changes to their waste management systems at generally higher costs?

• Waste is very recyclable and it is also very renewable!
• Less waste to landfills is better!
CONCLUSIONS & EXPECTATIONS

- Summary and conclusions
- What can be expected in the U.S. with the new administration
Economics are Holding Back WTE in the US

- Landfill capacity abundant and relatively cheap
  - *We don’t tax landfills like in Europe and UK*
- Energy values are low and declining
  - RECs not always available for MSW-power
  - Power alone not enough
    - Cogeneration/CHP applications improve revenues
- Bottom line: WTE costs too much for most communities
  - Are there savings to find in the collection part of your system?
Opinion of Trends for Future

• More mixed waste processing (MBT is coming to North America!)
  – Added recycling side-benefit
  – Most conversion technologies require pre-processing for feedstock preparation
  – Cement kilns and coal-fired boilers potential RDF users
  – CNG from AD projects and municipal fleet use

• New conversion technology facilities and “One-bin” key to watch

• ‘Environmentalists’ and ‘Zero Waste’ proponents fight non-recycling only alternatives
Legislation and Regulations

- Will more states ban food scraps from disposal?
- Will North American landfill disposal become more expensive?
- Permitting needs to be streamlined/rational
- Several states stepping up recycling/diversion goals and producer responsibilities
- USEPA needs to help lead the way with RFS2 and EF rules
- Will there be local leadership willing to make changes to their waste management systems at generally higher costs?

- Waste is very recyclable and it is also very renewable!
- A lot less waste to landfills is better!
DISCUSSION
Q&A
Thank You

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