Imagining the Next 25 Years… Opportunities to Enhance Benefits and Reduce Costs of Waste Management

Sustainable Waste Management Solutions for the 21st Century

NC-SWANA Annual Conference

Wrightsville Beach, NC

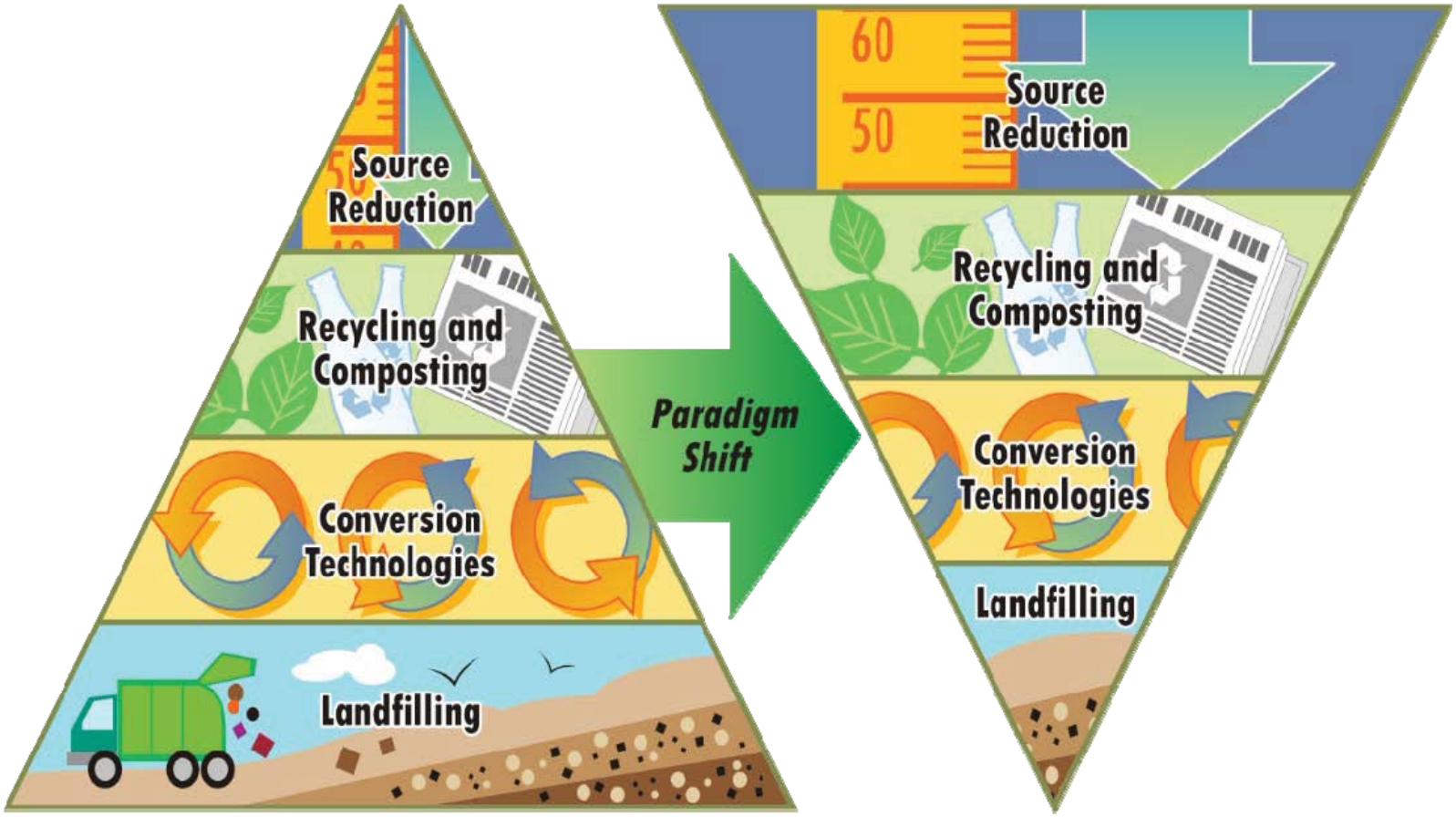
Wednesday, October 19, 2016

2:15- 3:00 pm

Presentation Outline

- **Emerging paradigms for management of municipal wastes (aka "municipal resources")**
- Proven waste conversion technologies
- Emerging waste conversion processes
- Examples of operating Energy from Waste (EfW) facilities in the U.S. and Europe and China
- Imagining a sustainable future

Intended Consequences of the Integrated Solid Waste Management Hierarchy



Hierarchy of Preferred Solid Waste Management Strategies

Paradigm Shift for the 21st Century

The Three Rs of Recycling…Plus Two More!

Options for Recovering Value from MSW

Conversion Technology	Power		Fuels/Chemicals				Soil Amendments/ Aggregates	
	Steam/Heat	Electric	Syn Gas	Bio Methane	Chemicals	Fuels	Aggregates	Mulch/ Compost
Thermal	Yes	Yes	Yes		Yes	Yes	Yes	
Biological/ Chemical	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Physical						Yes	Yes	Yes

Range of Revenues from Processing of MSW

Product	Yield from 1 ton MSW	Value of Product	Revenue per Processed Ton
Electricity	500-650 kWh	$0.05 / kWh	$25-$33 + RECs + Carbon Offsets (??)
Synthetic Crude	barrel	$40 / barrel	$40
Bio-Diesel	35 gallons	$2.00 / gallon	$70 + RINs
Recyclables	0.8 – 1.0 ton	$75 - $150 / ton	$60 - $150
Ethanol	50 – 100 gallons	$2.00 / gallon	$100 – $200 + RINs

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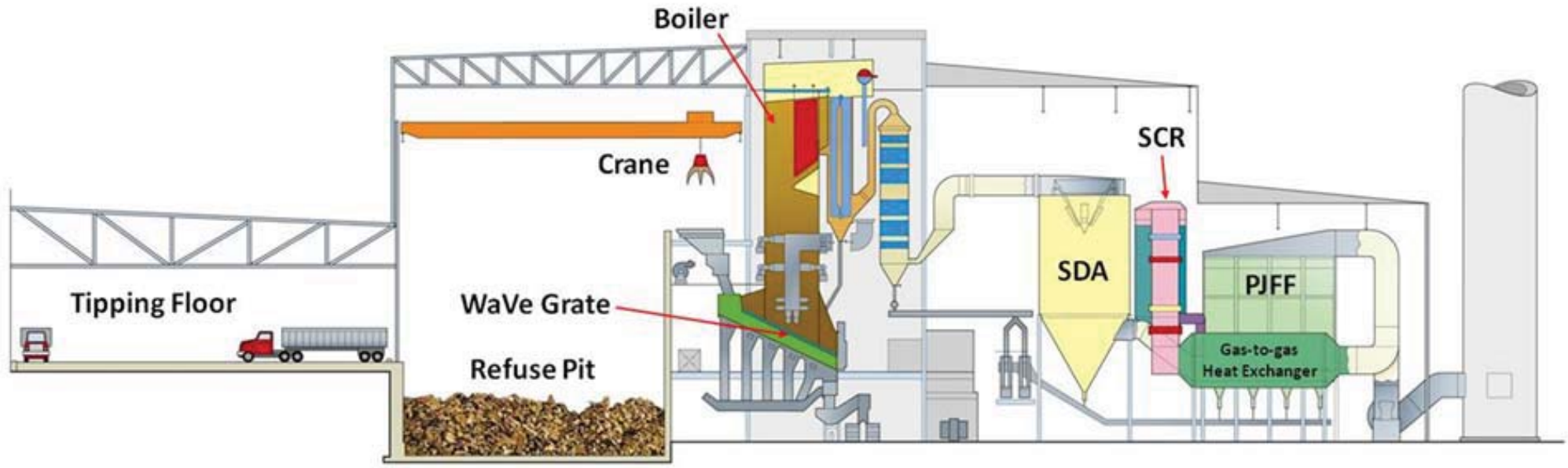
EfW Capacity Factor is the Highest Among Renewable/Fossil Energy Options (base load)

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

EfW can help provide fuel diversity for base load power production on the U.S. electrical grid!

Typical Massburn EfW Facility Cross-Section



Based upon Volund technology employed at the newest EfW facility in the U.S. (Palm Beach County, Florida)

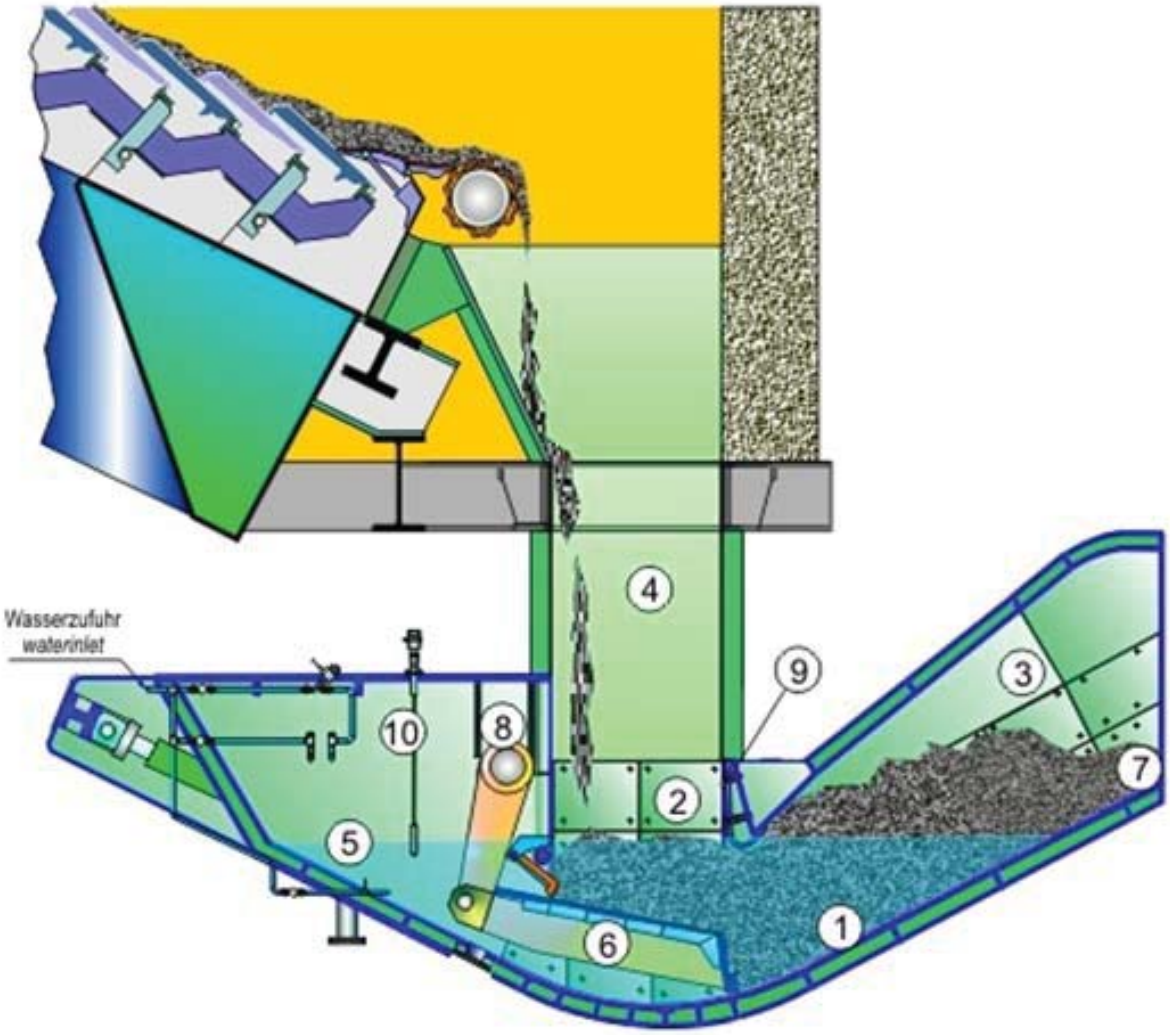
Massburn is the Dominant EfW Technology in the U.S. (~75%)

Pasco County FL - 1,050 TPD Massburn EfW Facility Refuse Storage Pit with 7 Day Fuel Storage Capacity

Proven Waste Conversion Technologies

Typical Massburn EfW Ash Discharger (Wet)

1 Discharger tub
2 Inlet section
3 Outlet chute
4 Connecting piece
5 Water level
6 Discharge ram
7 Drop-off edge
8 Drive shaft
9 Air sealing wall
10 Electrically-controlled level metering system

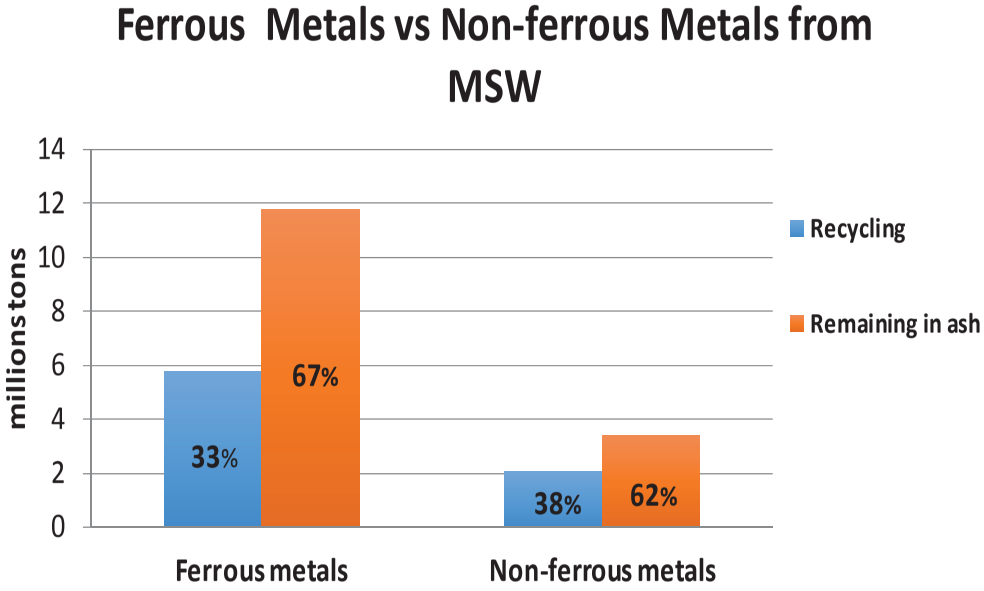


EfWs Contribution to Minimizing Waste to Landfill

~ 90% volume and 75% weight reduction, plus ~3% metal recovery

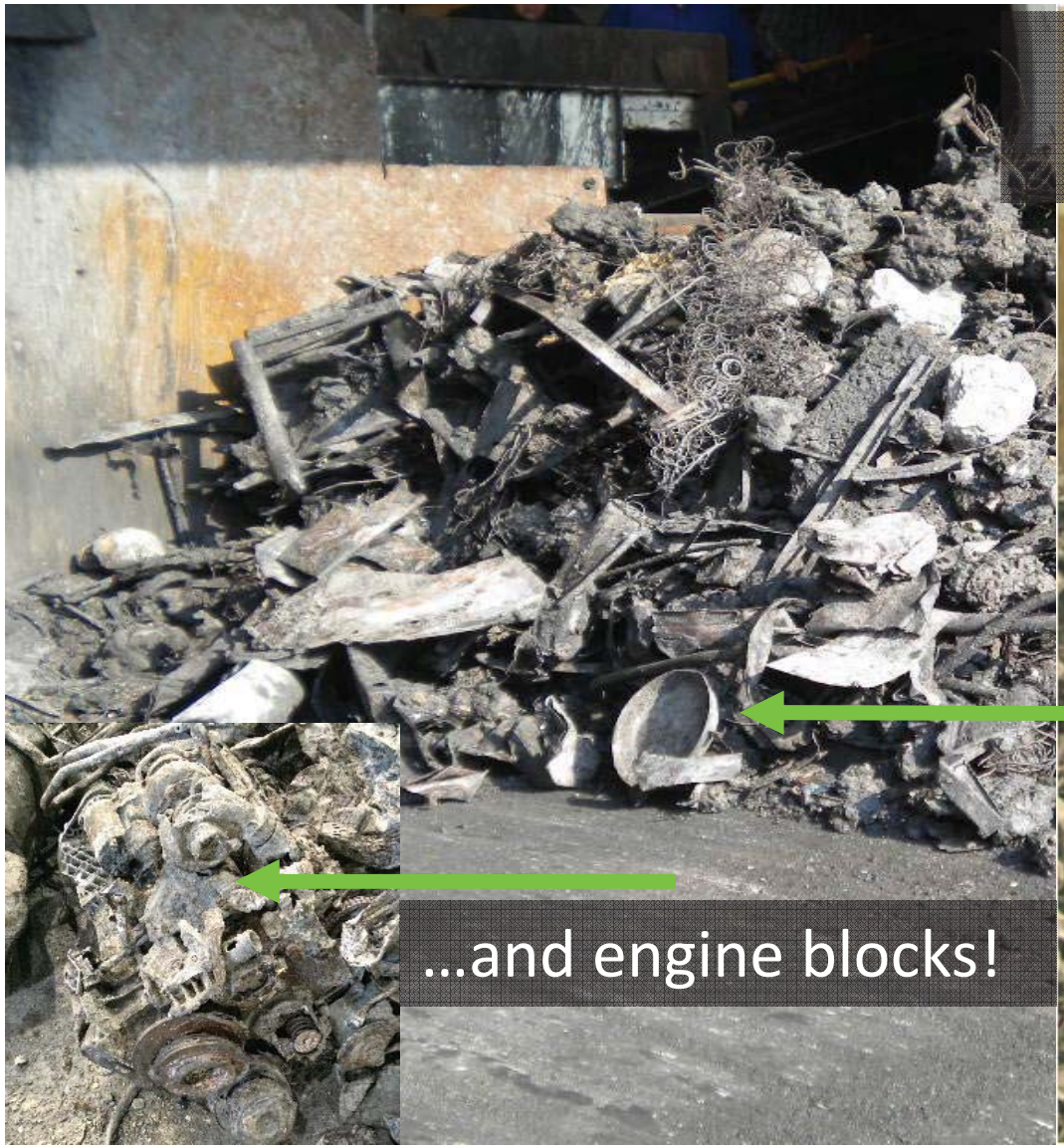
Recovery of Metals from EfW Bottom Ash can Play a Significant Role in Community's Recycling Program

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

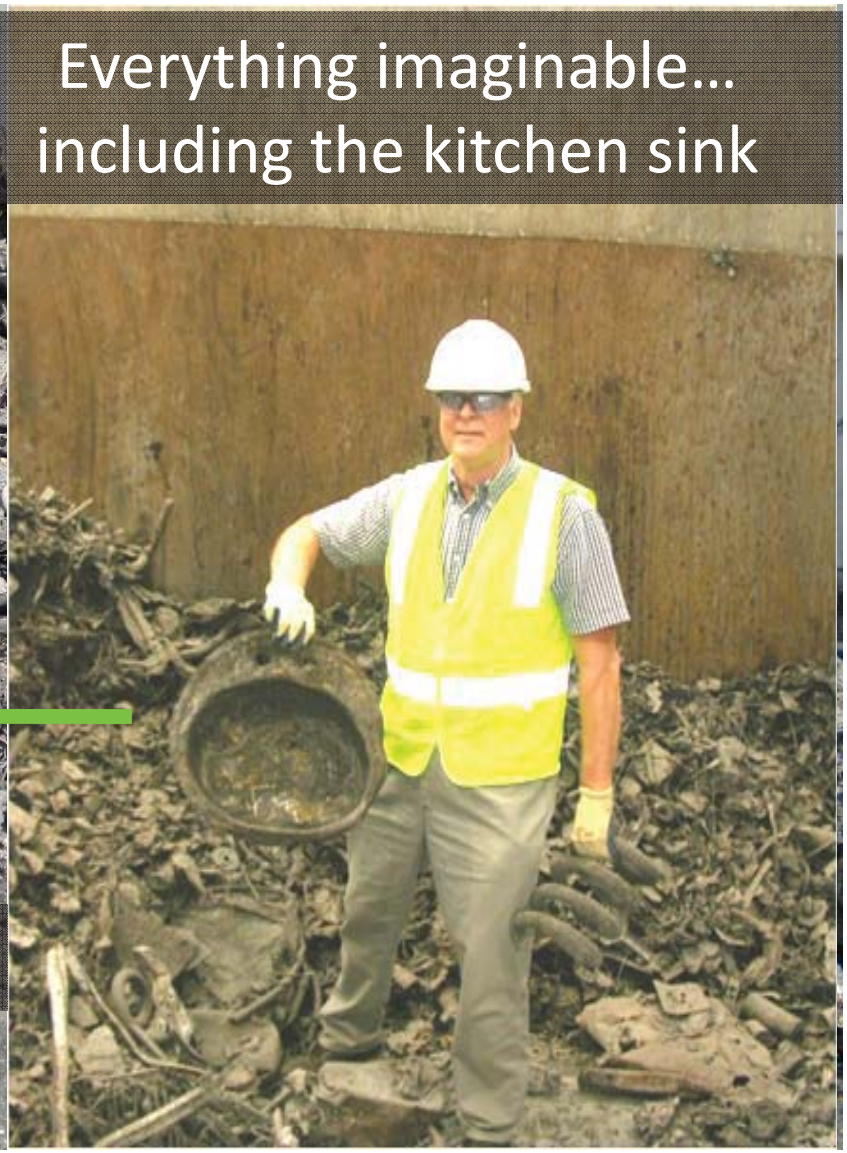


- Recycling of metals from EfW bottom ash can account for more recycling tonnages than typically diverted via source separation recycling programs.
- Conventional EfW ash processing systems typically target the recovery of native metals greater than 12 millimeters (0.47 inches) in size.
- Advanced metal recovery systems utilizing recently developed new technologies improve the metal recovery rates by targeting metals less than 12 millimeters (0.47 inches) in size.

Initial Metal Recovery Operation
Bulky Ferrous Metals Greater than 5-6” in Size



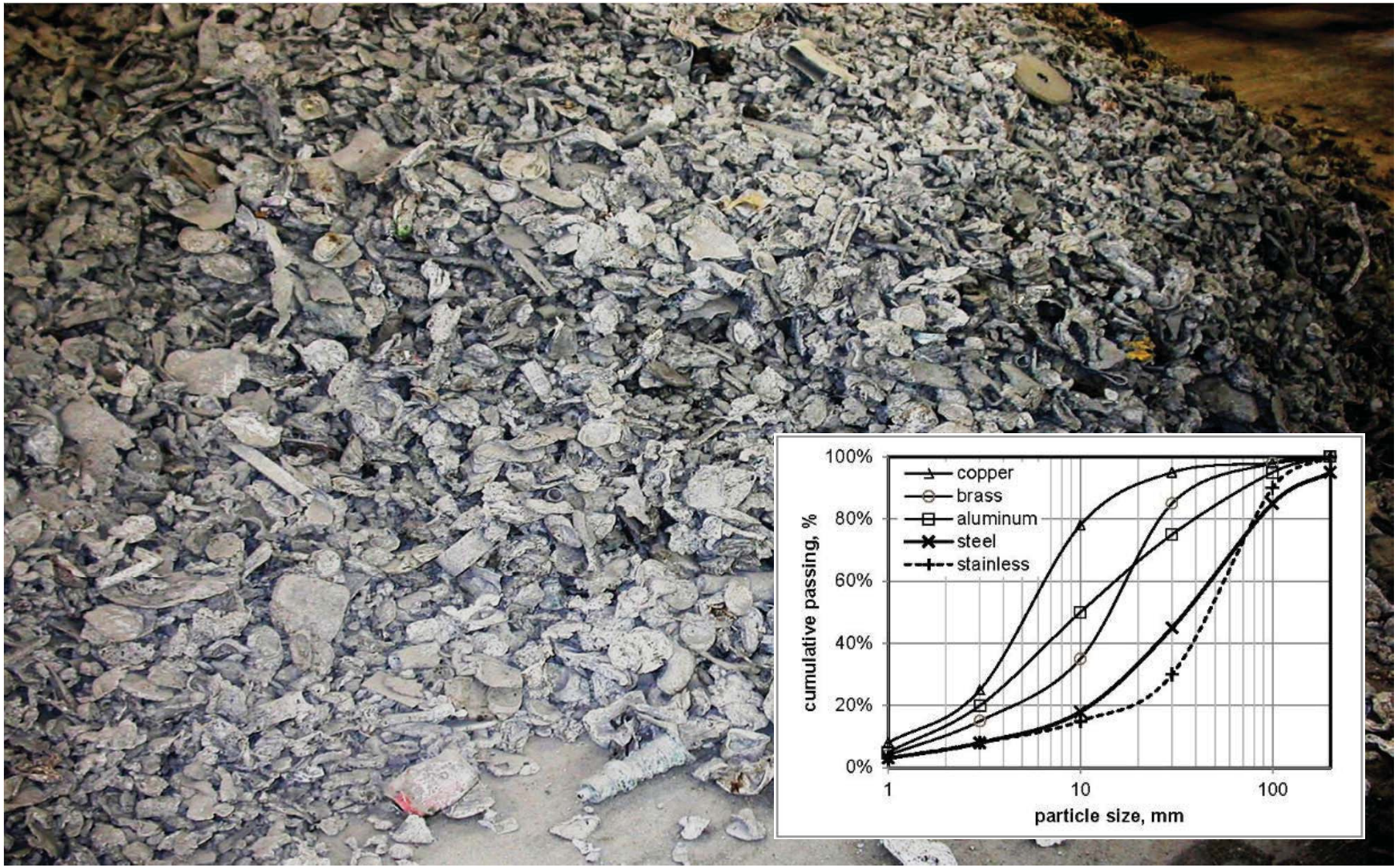
…and engine blocks!



Everything imaginable…
including the kitchen sink

Second Metal Recovery Operation
Ferrous Metals Less than 5-6” in Size

Third Metal Recovery Operation
Non-ferrous Metals “Liberated” by Combustion



Non-ferrous Metals Liberated by Combustion and Recovered by Eddy Current Separator

Coins Separated from Recovered Non-ferrous Metals in Palm Beach County, FL

Recovered Recyclable Products from EfW Bottom Ash (European Experience)

Fine minerals
(< 0.07 inch)

Mineral aggregates
(> 0.07 inch)

Non-ferrous concentrate

Ferrous concentrate

Recovered Aluminum Products
Light Non-ferrous Metals from EfW Bottom Ash

Aluminium scrap product (fine)

- 0.04 – 0.14 inch
- 70 - 75% pure metal scrap

Aluminium scrap product (middle)

- 0.14 – 0.4 inch
- 75 - 80 % pure metal scrap

Aluminium scrap product (coarse)

- 0.4 – 0.75 inch
- 85 - 90 % pure metal scrap

Heavy Non-ferrous Metals from EfW Bottom Ash

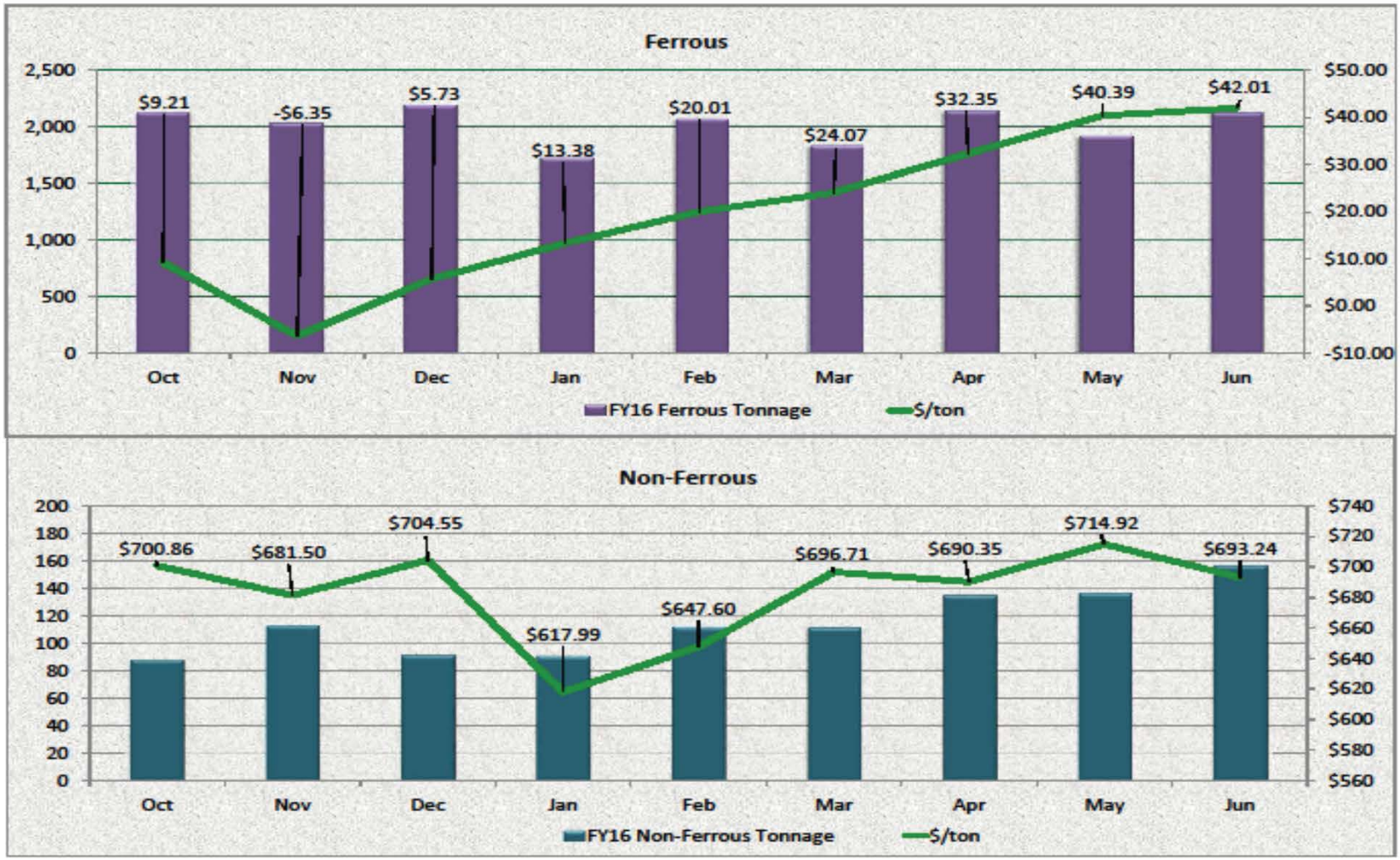
Primarily brass and copper

Heavy non ferrous scrap

- 0.04 – 0.75 inch
- 95-99 % pure metal scrap

Inashco Centralized Upgrading Facility (Belgium)

Today's Reality
Fickle Recycling Metals Markets



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

EfW Can Help Meet Waste Diversion Goals

- **MSW to Landfill**

EfW without Metal Recovery

EfW with Metal Recovery

EfW with Metal Recovery and Bottom Ash Recycling

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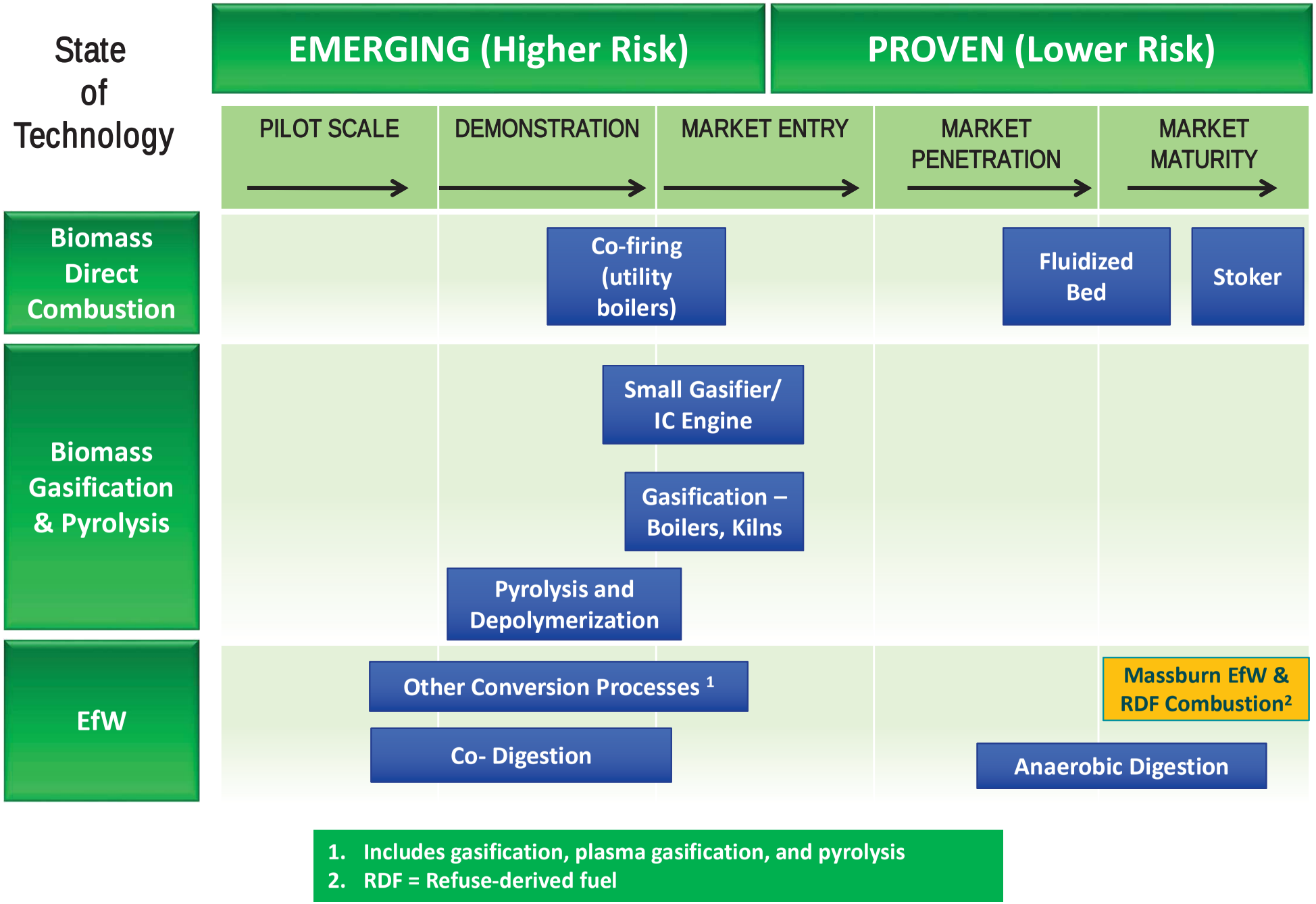
Ineos New Planet BioEnergy Facility
Indian River County, FL

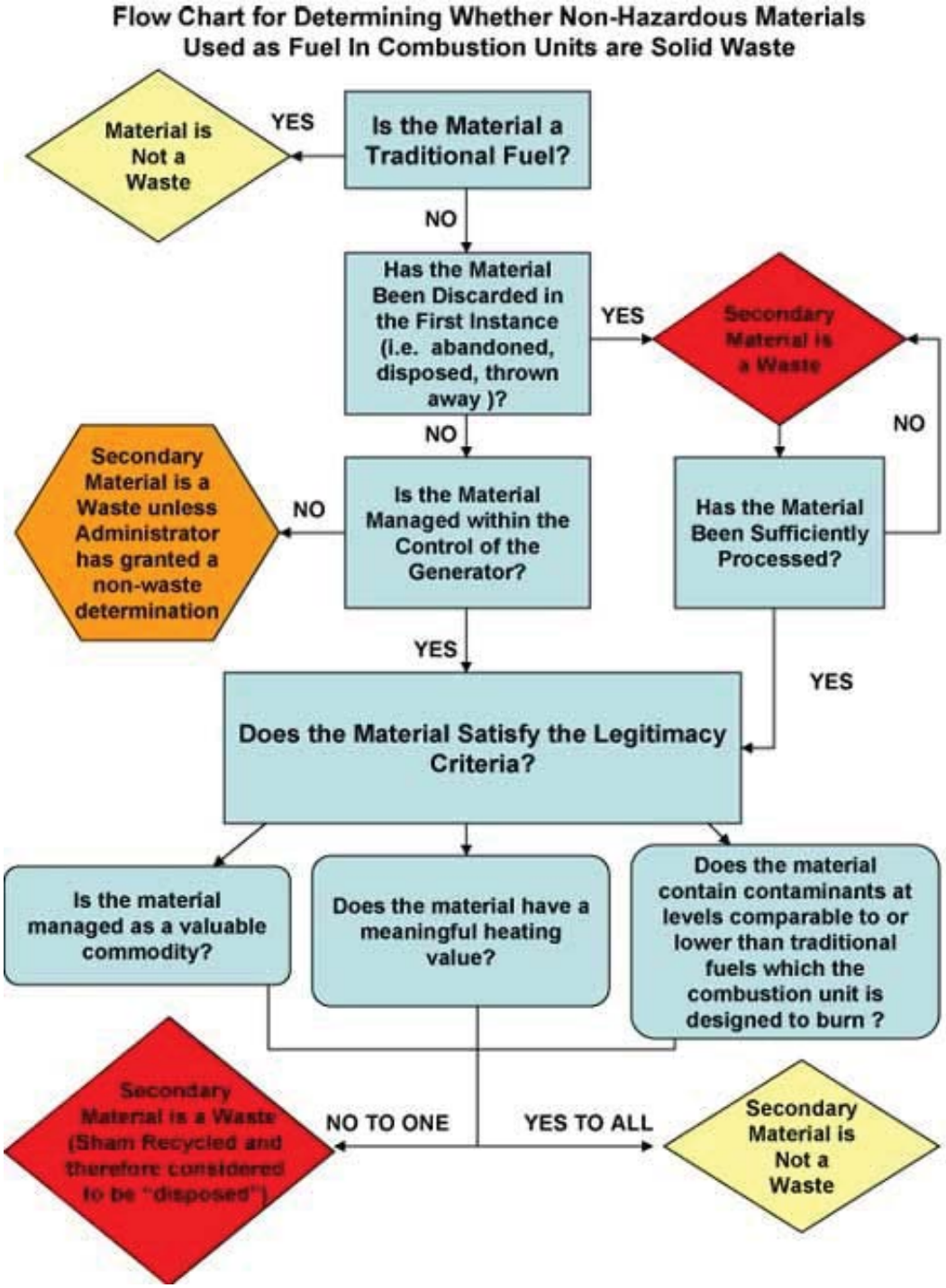
Ultimate Waste Conversion Technology
Wishful Thinking – But It's Not That Easy!


State of Technology
EMERGING (Higher Risk)
PROVEN (Lower Risk)
PILOT SCALE
DEMONSTRATION
MARKET ENTRY
MARKET PENETRATION
MARKET MATURITY
Biomass Direct Combustion
Co-firing (utility boilers)
Fluidized Bed
Stoker
Biomass Gasification & Pyrolysis
Small Gasifier/ IC Engine
Gasification – Boilers, Kilns
Pyrolysis and Depolymerization
EfW
Other Conversion Processes 1
Co- Digestion
Massburn EfW & RDF Combustion2
Anaerobic Digestion
1. Includes gasification, plasma gasification, and pyrolysis
2. RDF = Refuse-derived fuel

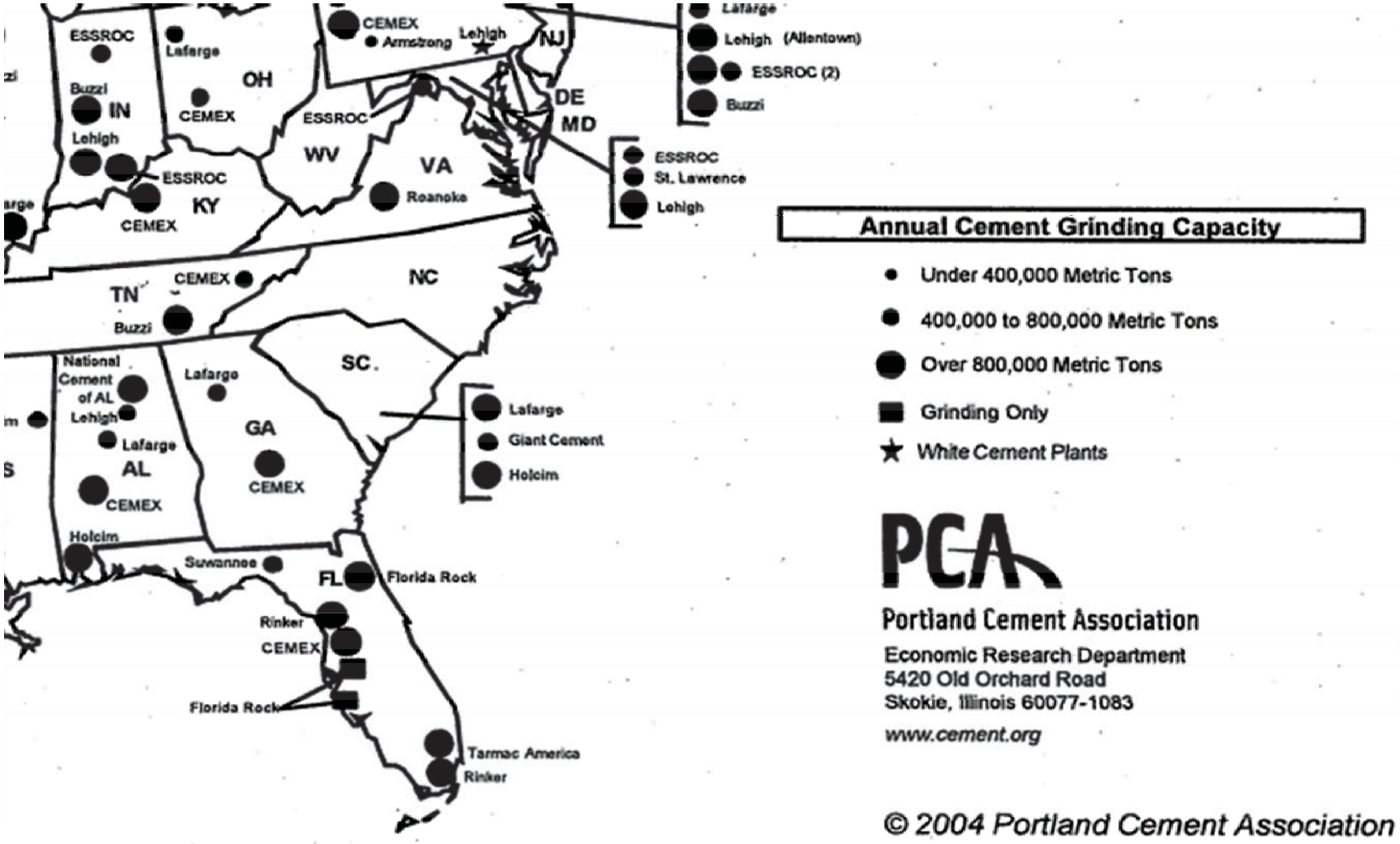
EPA Clarified Definition of "Solid Waste" (2011)

Engineered Fuel may Displace Coal in Power Plants, Cement Kilns, and Industrial Boilers

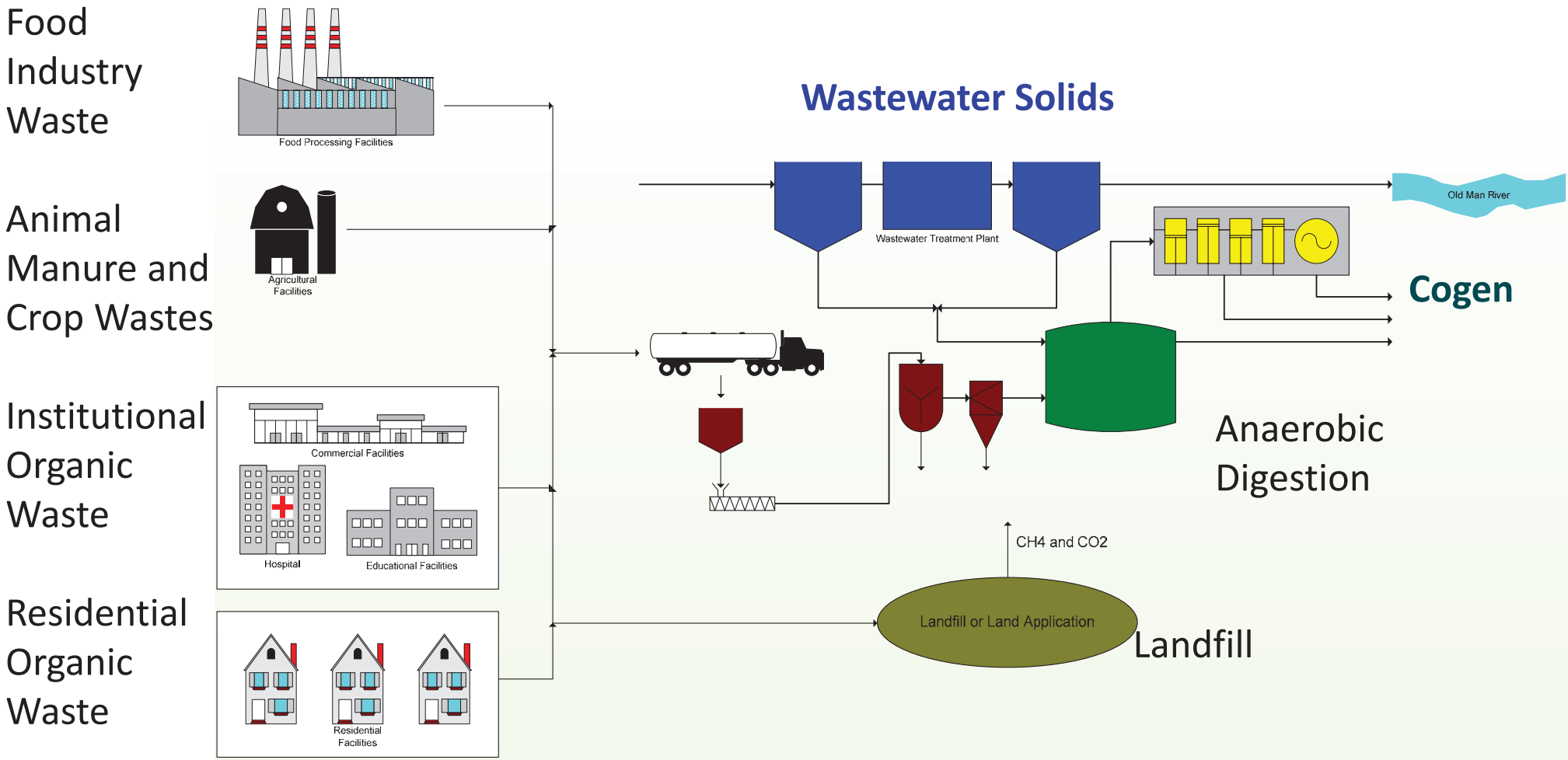
- Qualifies under EPA criteria
- 7,000 – 8,000 BTU/LB
- Low chlorides and sulfur
- Uniform product size
- Successfully combusted for decades in EfW/RDF boilers
  - Xcel's Redwing Station repowering (1986)
  - Xcel's French Island Station repowering (1987)
  - Palm Beach County RDF facility (1991)



Potential Sites for Co-firing of Engineered Fuel at Cement Kilns



Co-digestion of Organic Waste with Wastewater Biosolids for Generation of Biomethane Gas

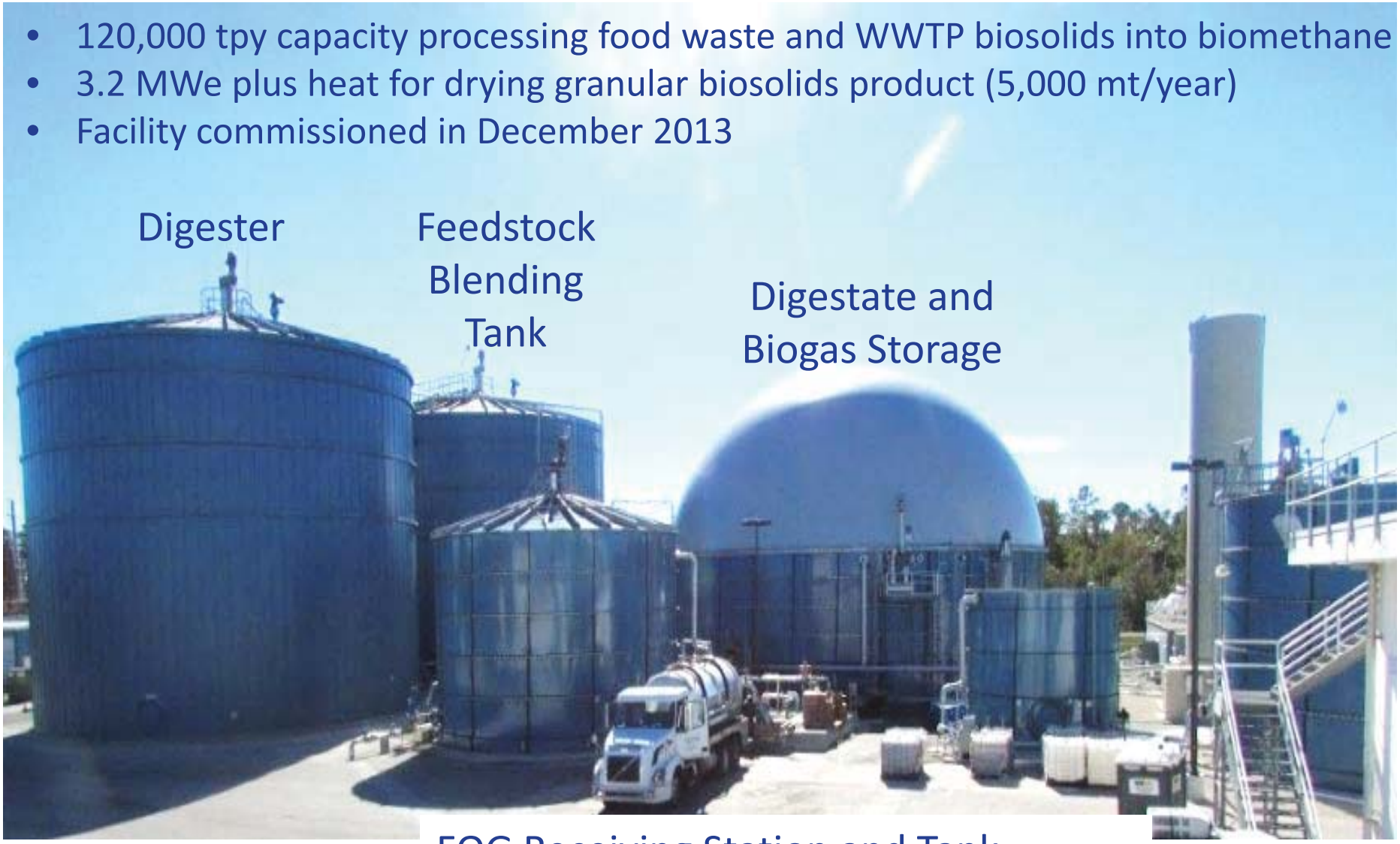


Co-Digestion 101...It's Not Rocket Science, but Requires Knowledge of Biology and Chemistry

- Organic Compounds
  - Digestion is a biological process that uses organic compounds as an energy source. Inorganics are not readily metabolized.
- Carbon : Nitrogen Ratio
  - Ideal C:N ratio between 20 and 30 for stable digestion
  - Higher nitrogen concentrations can cause ammonia toxicity
- Trace Nutrients
  - Micronutrients are essential (phosphorus, magnesium, iron, molybdenum, nickel, and cobalt)
- Absence of Inhibitory Compounds
  - Disinfectants, antibiotics, and heavy metals can negatively influence digester populations

What does a Co-Digestion Facility Look Like?
Courtesy of Harvest Power Orlando

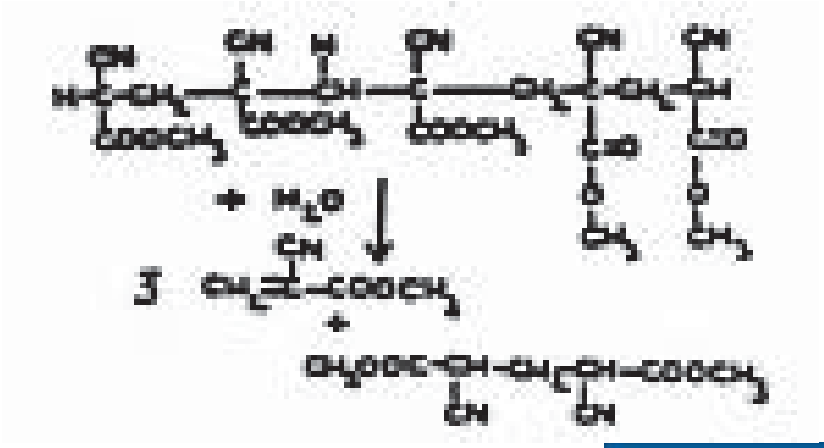
- 120,000 tpy capacity processing food waste and WWTP biosolids into biomethane
- 3.2 MWe plus heat for drying granular biosolids product (5,000 mt/year)
- Facility commissioned in December 2013



FOG Receiving Station and Tank

Des Moines Iowa Co-Digestion Project...40% of Feedstock from Region for Additional Revenue

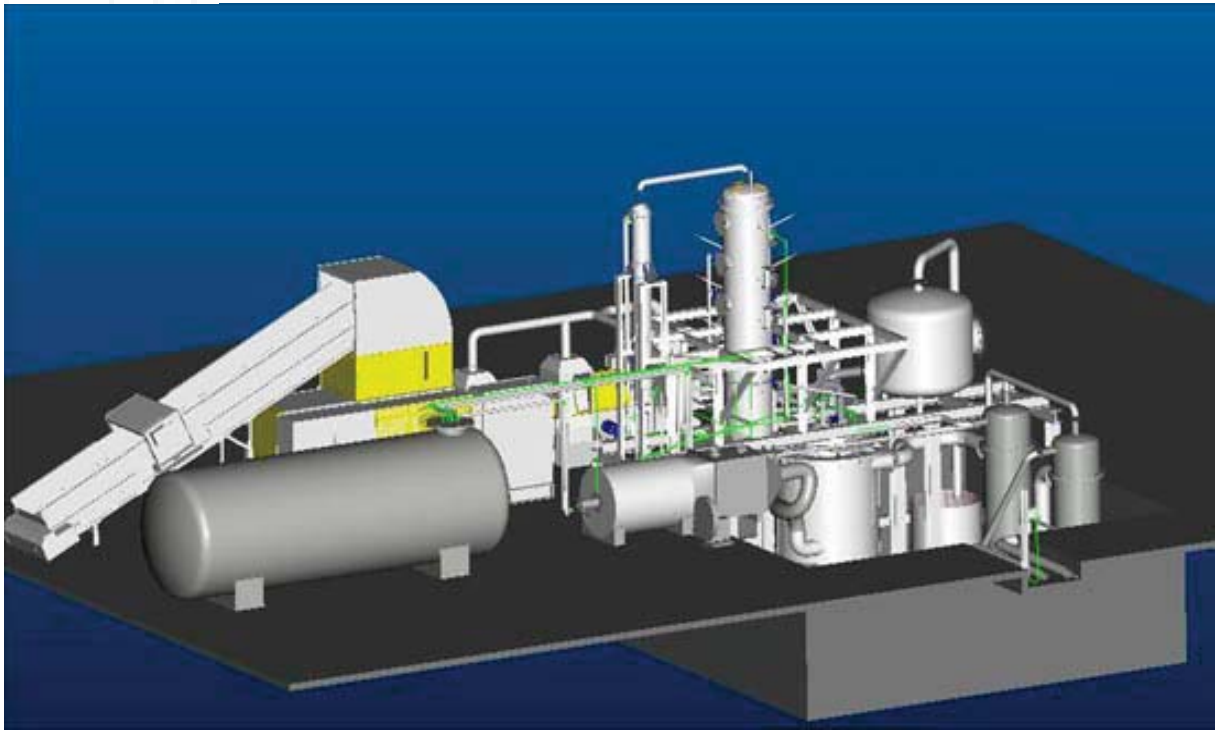
Thermal and Catalytic Depolymerization of Carbonaceous Wastes



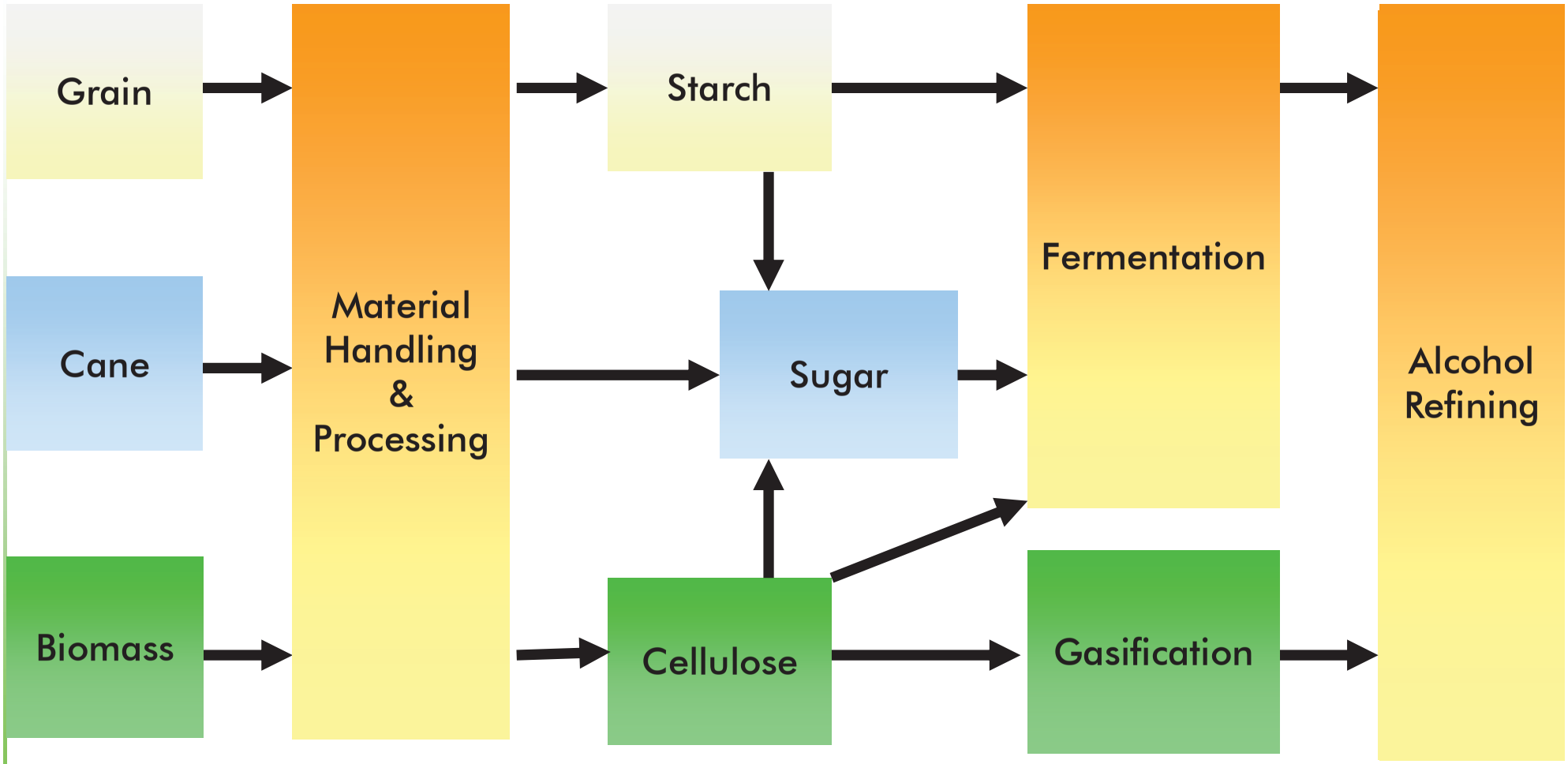
For Production of Synthetic Diesel / Bio Oils

Vadxx Waste Plastics to Diesel Project

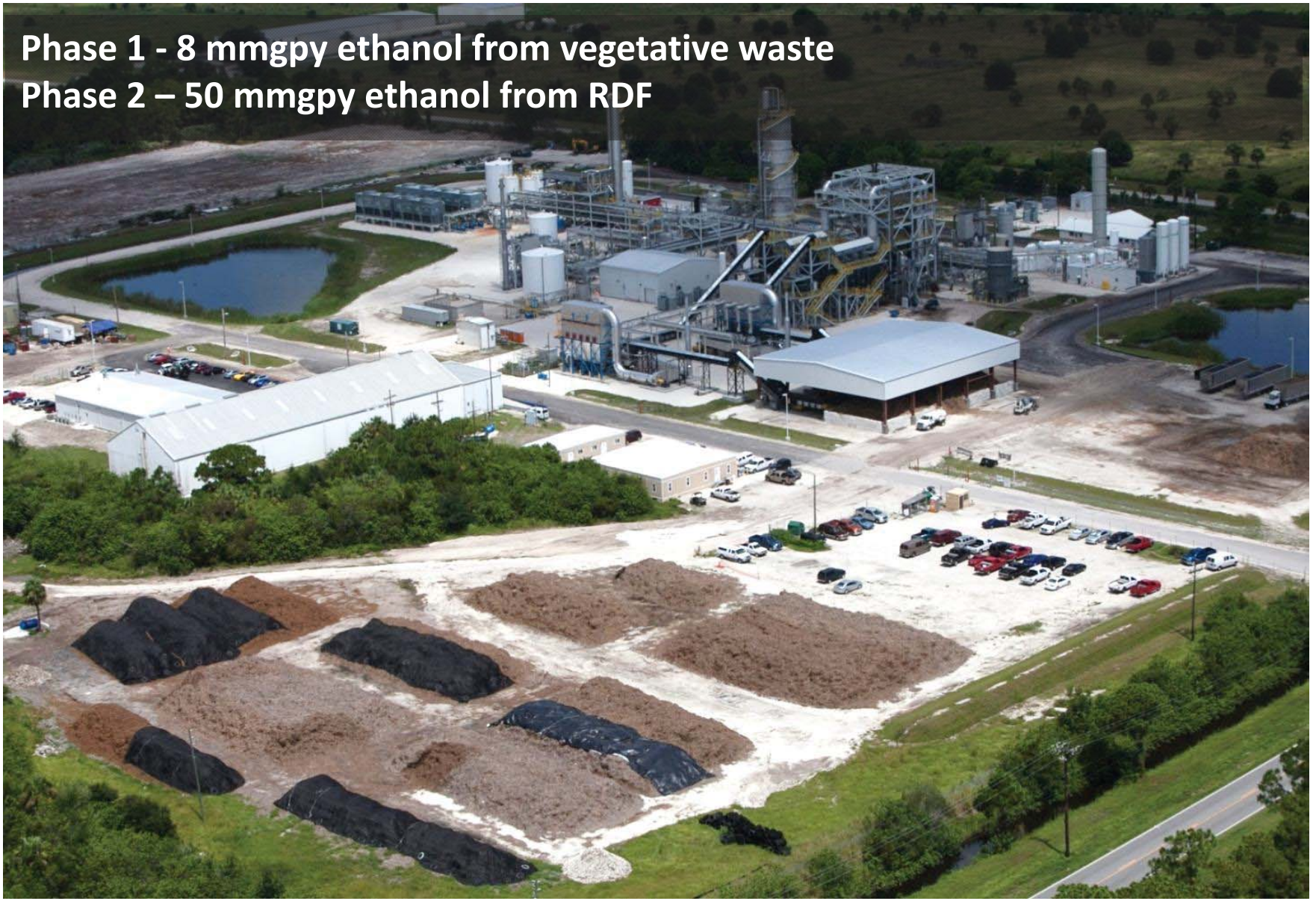
- Akron, OH
- Startup / acceptance test commenced in summer of 2015
- 20,000 tons/year feedstock into 100,000 bbls/yr diesel/naptha



Biomass-to-Ethanol Production Pathways

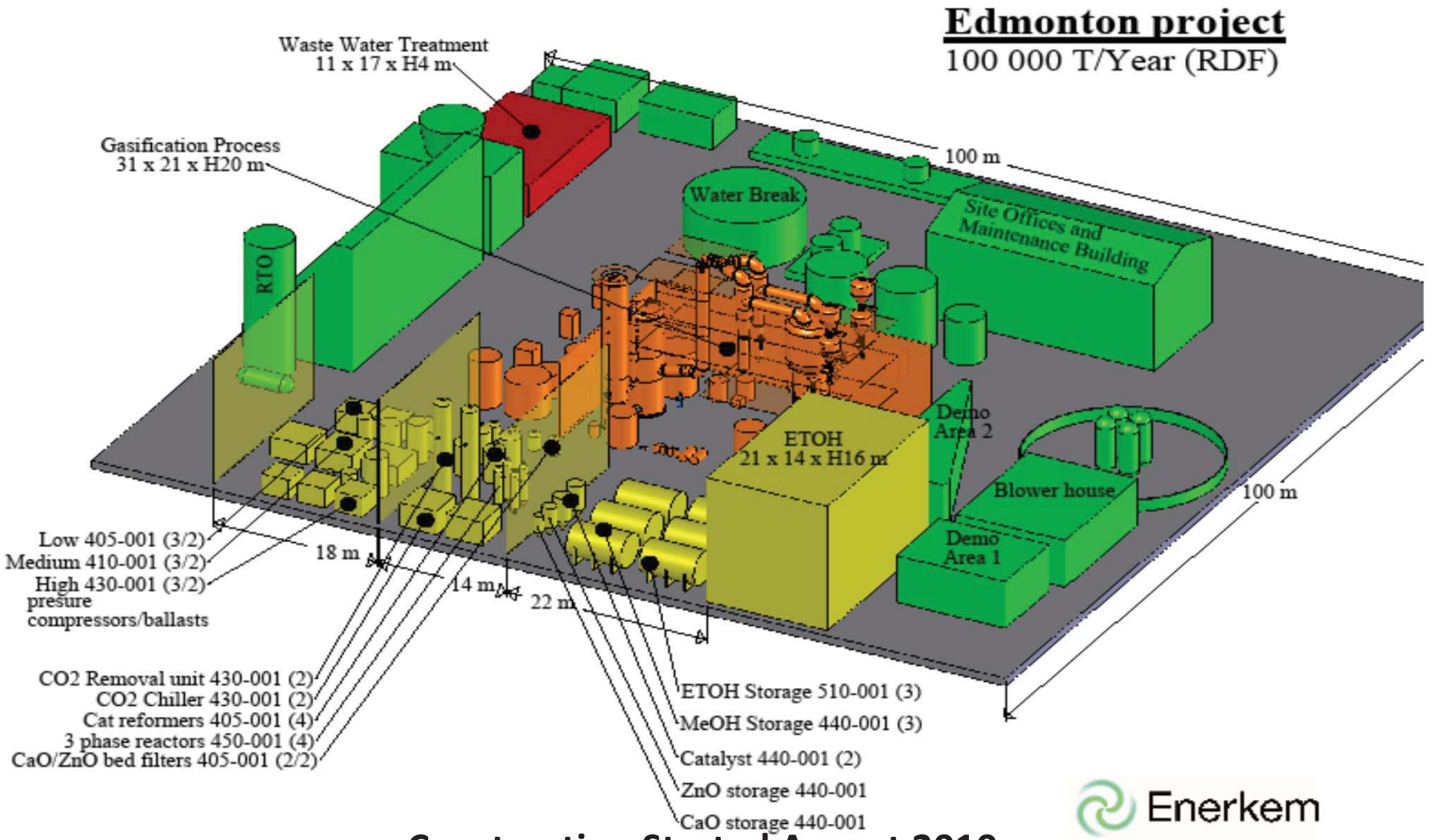


Ineos Bio-Energy Center (2012)
Indian River County, FL



Biochar as a Soil Amendment… Solution to Carbon Sequestering Technology?

North America's First Commercial Scale Cellulosic Ethanol Facility (10 MGY)

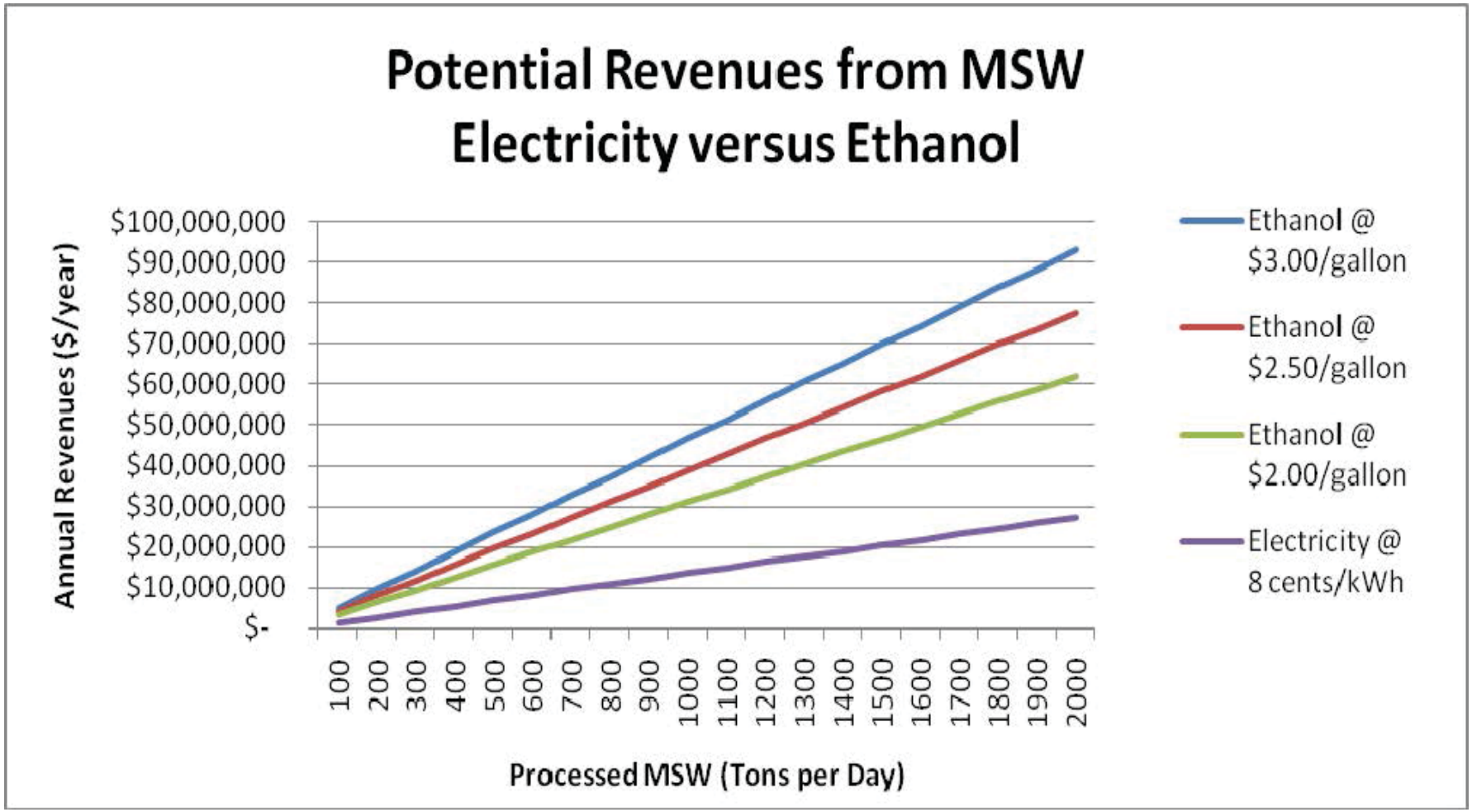


Construction Started August 2010

Currently in startup processing at 50% throughput

Only Time Will Tell…
Enhanced Revenues of Ethanol from MSW

- Potentially 2-3 times the revenue stream of electricity



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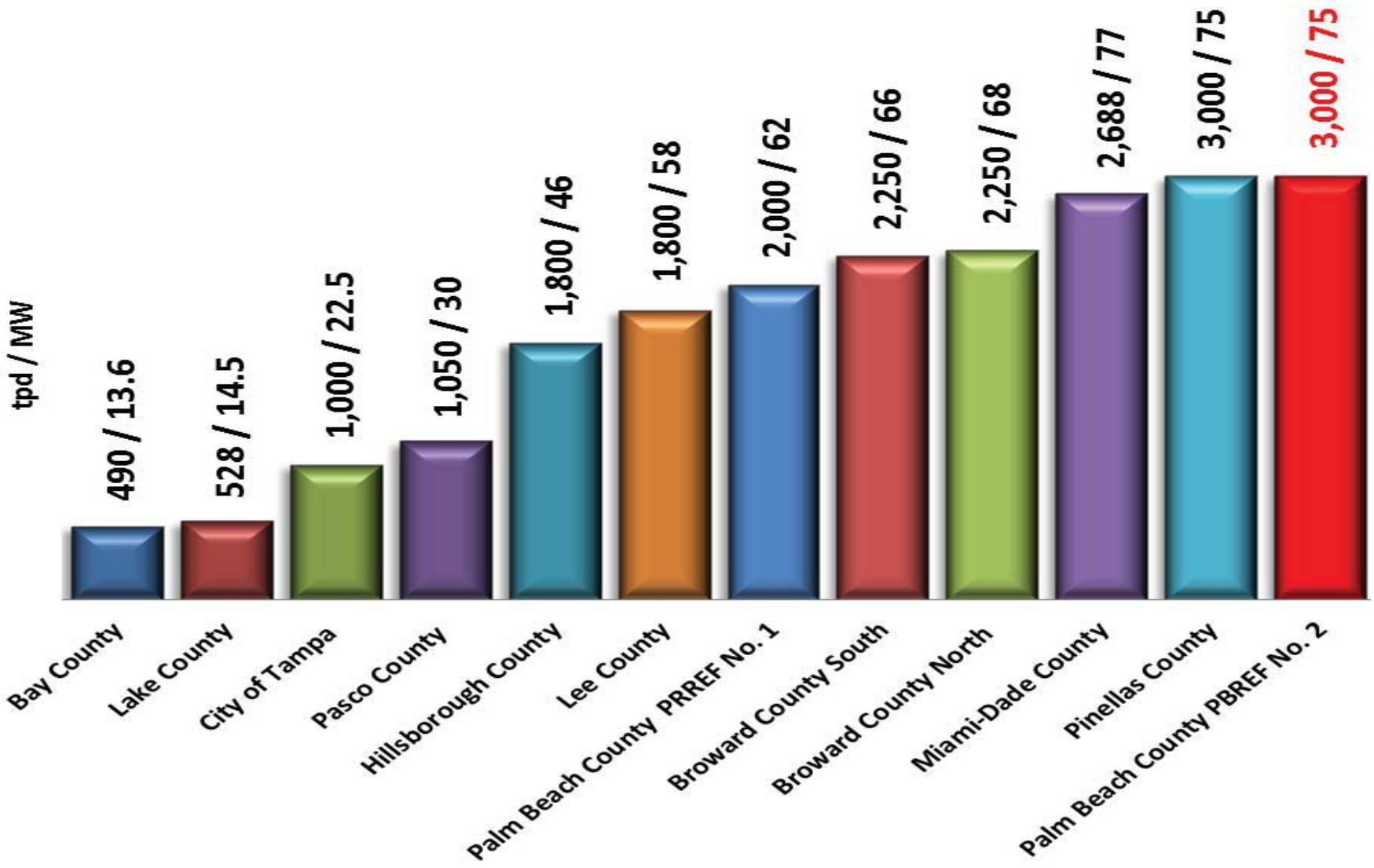
Florida WTE Facilities:
12 Facilities – 607 MW of Renewable Electricity



City of Tampa Energy from Waste Facility 1,000 TPD – 22.5 MW Electrical Output

- Original construction: 1975
- Rebuilt as EfW: 1985
- Retrofit for Clean Air Act (CAA) Amendments: 1998-2001

- **Portions of this facility are 40 years old and on their third life!**

Hillsborough County Resource Recovery Facility
1,800 TPD – 46 MW Electrical Output

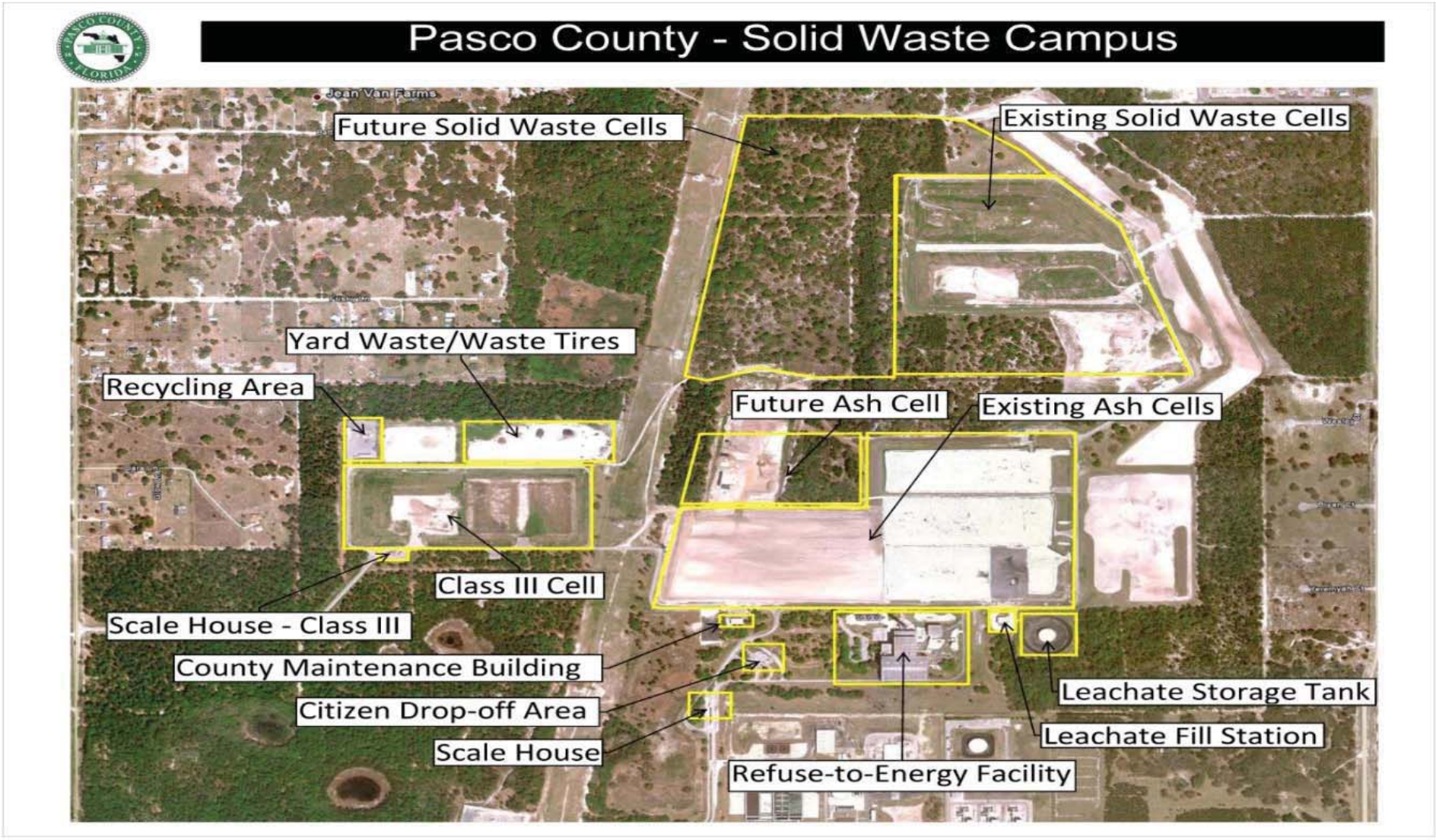
- Original 1,200 TPD construction: 1987
- 600-TPD expansion completed: 2009
- Enhanced architecture

Compatible with the urban landscape!

Commercial/industrial development has occurred around facility over past 27 years

Pasco County Resource Recovery Facility
1,050 TPD – 30 MW Electrical Output

Pasco County Florida
ISWM Located on an Integrated Campus



Lee County Florida
Integrated Campus with Regional Landfill

Palm Beach County EfW Facility

Incorporates enhanced aesthetics and sustainability features

Palm Beach County Florida
Integrated Campus with Two EfW Facilities

- Raw waste and ash landfill
- C&D debris landfill
- 2,000 tpd RDF EfW facility
- 3,000 tpd Massburn EfW facility
- Recycling facilities
- Household hazardous waste drop-off facility
- Compost facility (retired)
- Biosolids drying / pelletizing facility

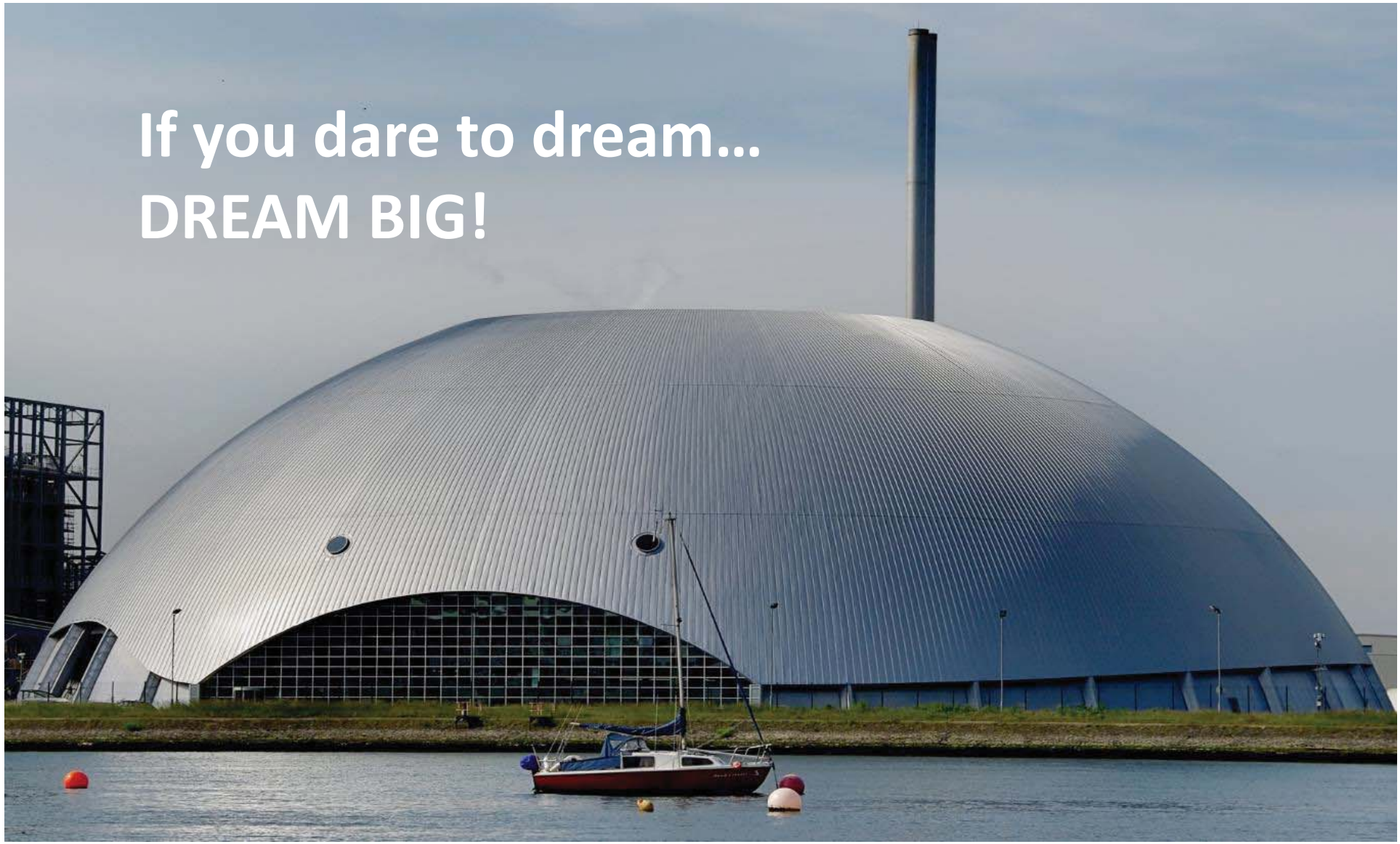
Hennepin County, MN EfW Facility Compatibility with Urban Re-development

Supplemental Waste Program
Lancaster County Pennsylvania

Lancaster County Pennsylvania
Public Outreach and Education is a Full-time Job

If an EfW Facility Can be Located in the Center of Paris, It Can be Located Anywhere!

Marchwood England 2007
EfW Facility Under Dome



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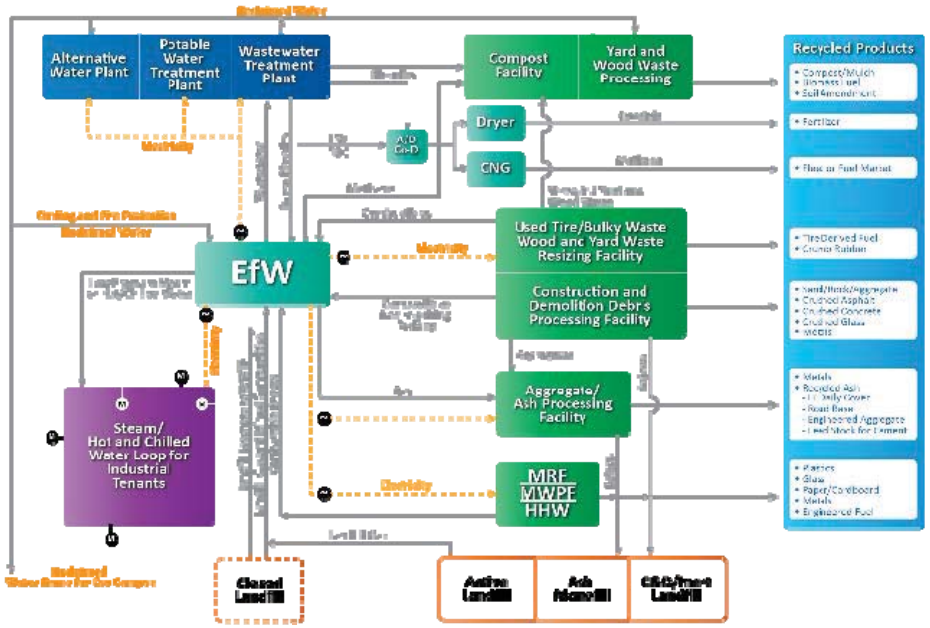
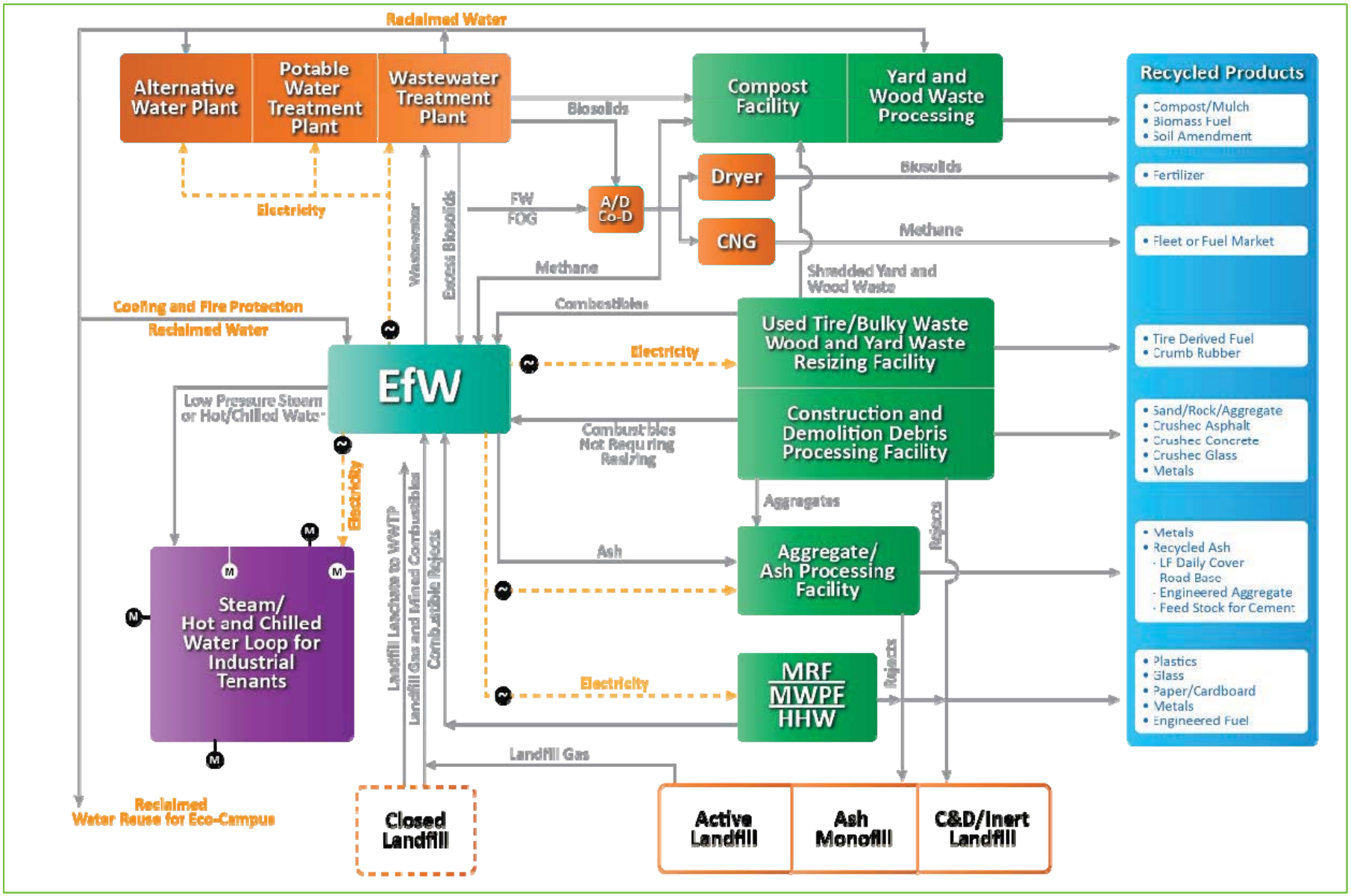
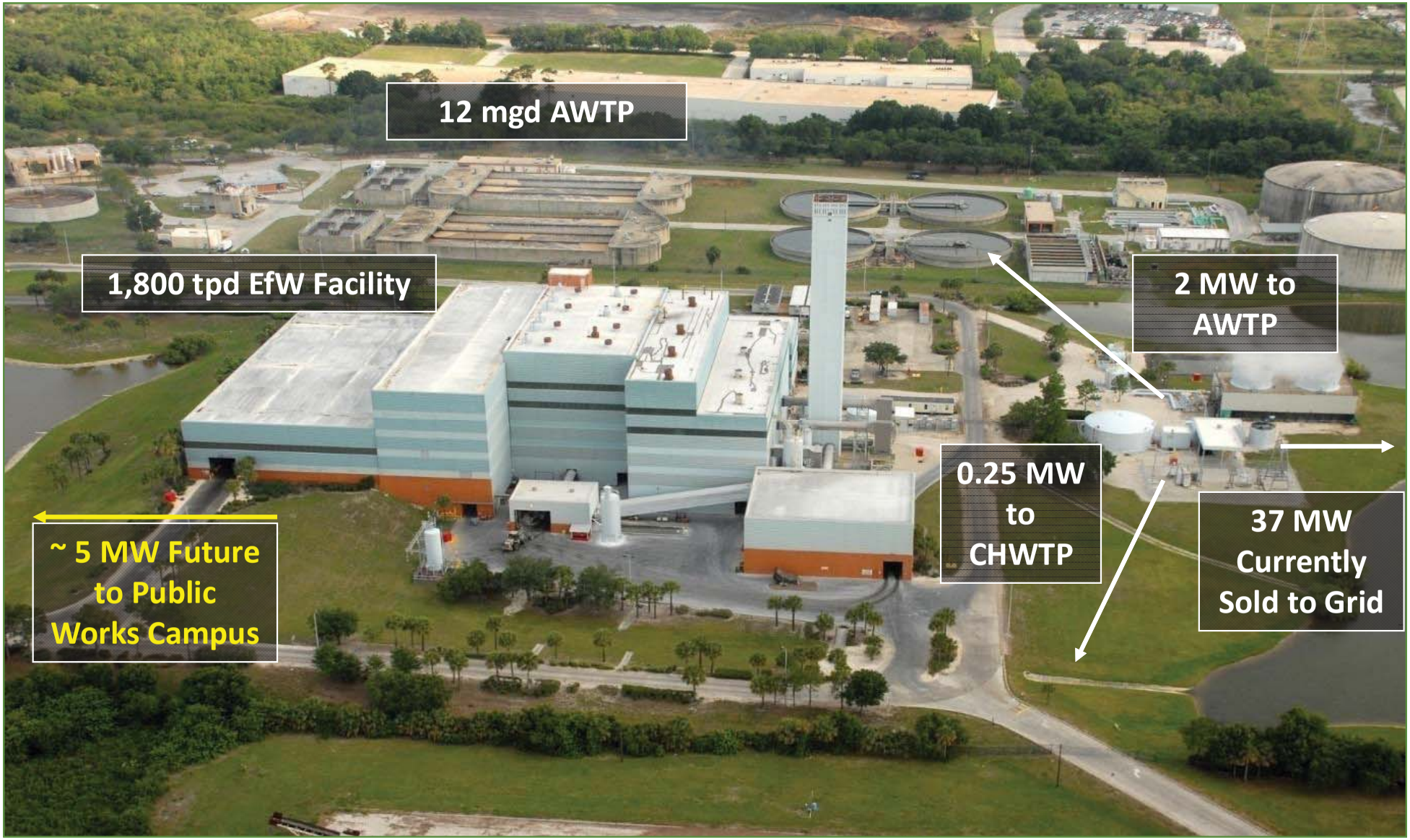


Integrated Campus for Management of Municipal Waste Can Include Water Resources



Hillsborough County, FL
EfW and Water Resources Synergy

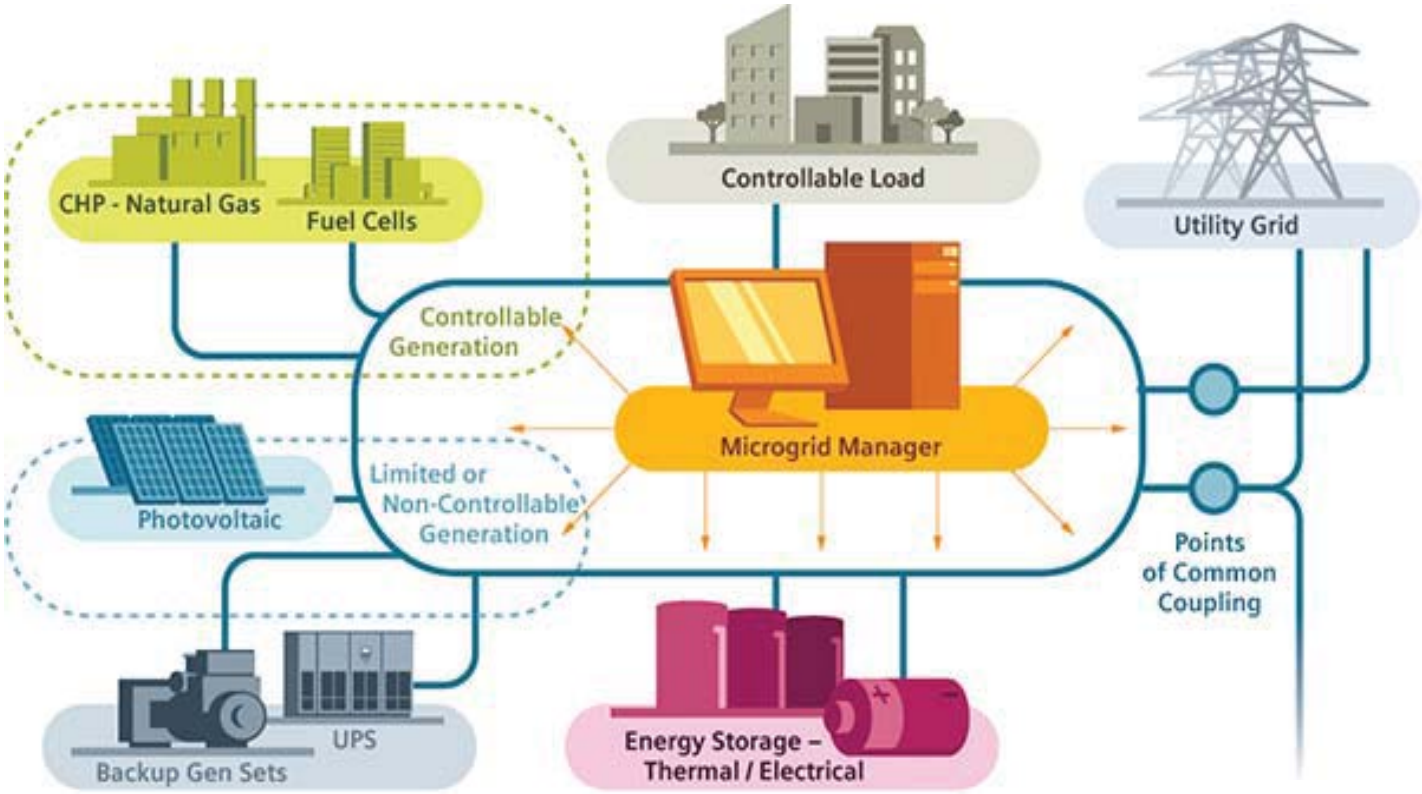


Additional Public Works Facilities may be Powered by Electricity from EfW in the Future

Similar to "microgrid" concept promoted by DOE

Microgrid Concept

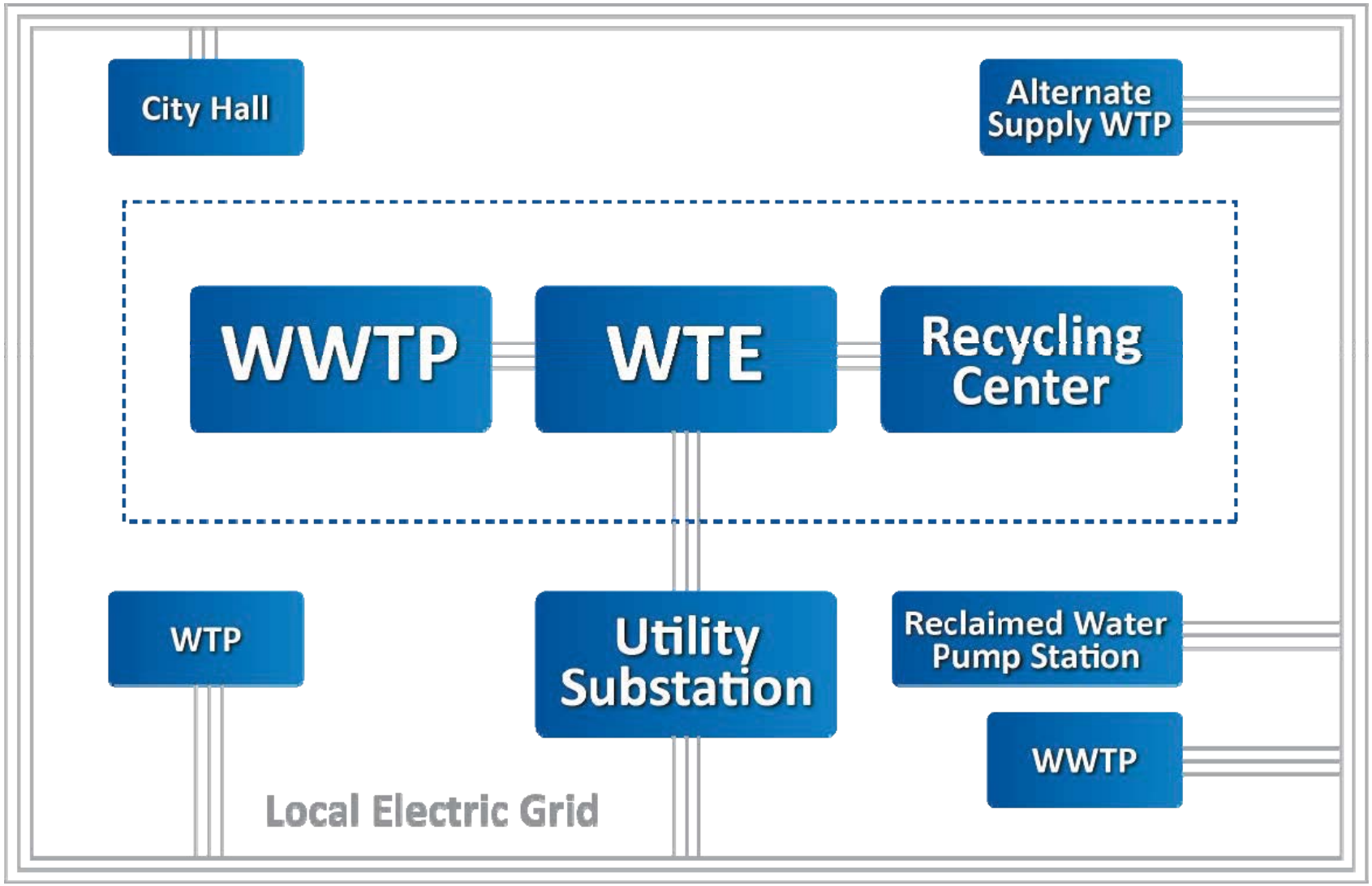
A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and that connects and disconnects from such grid to enable it to operate in both grid-connected or “island” mode (DOE)



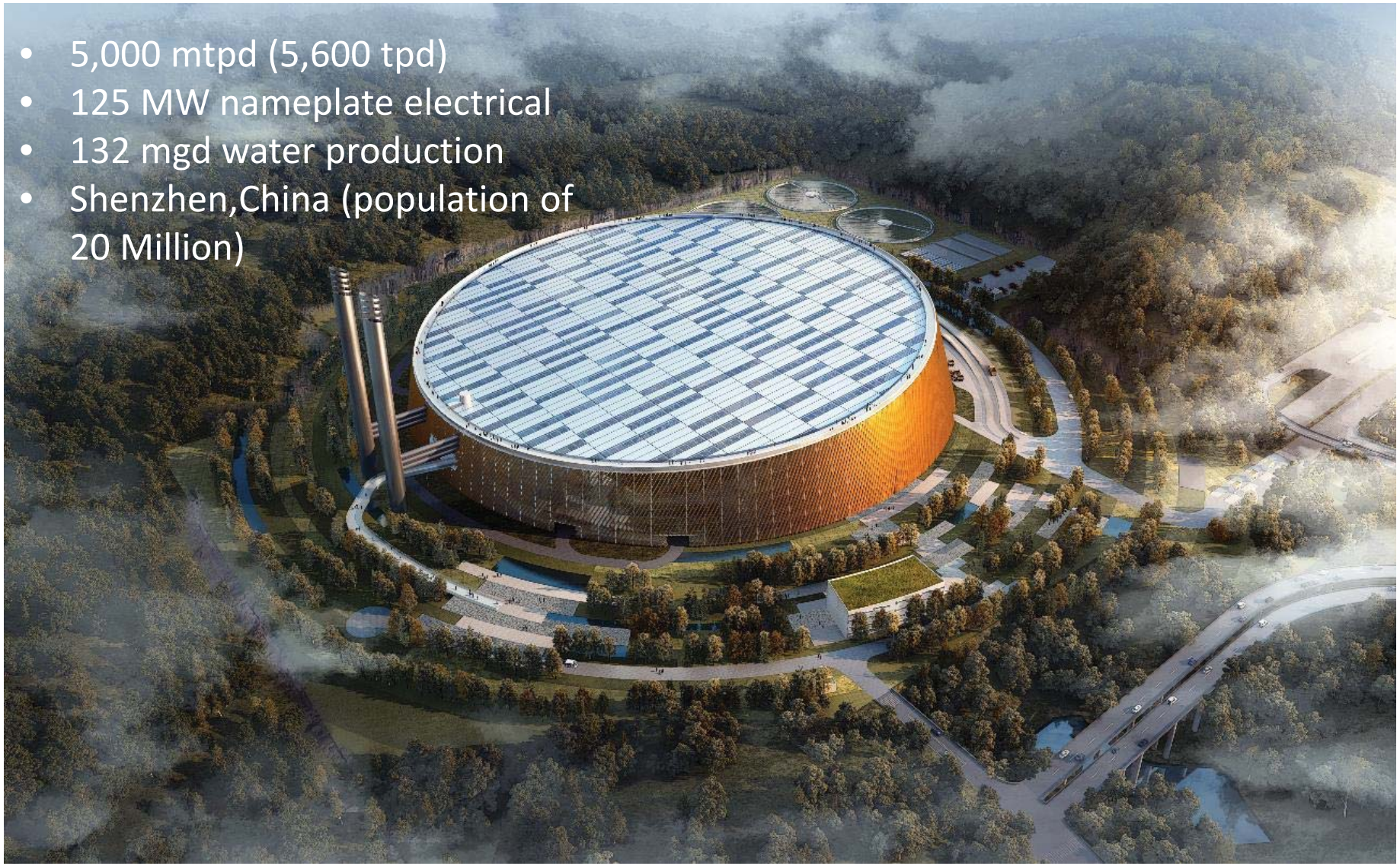
Siemens USA

EfW facilities on existing municipal utility sites may be ideal candidates for Microgrids. Existing utility sites often have adequate buffer, and are located within the urban core, where power is needed!

Net Metering of EfW Electricity in the US...Will Require Legislation to Overcome IOU Resistance

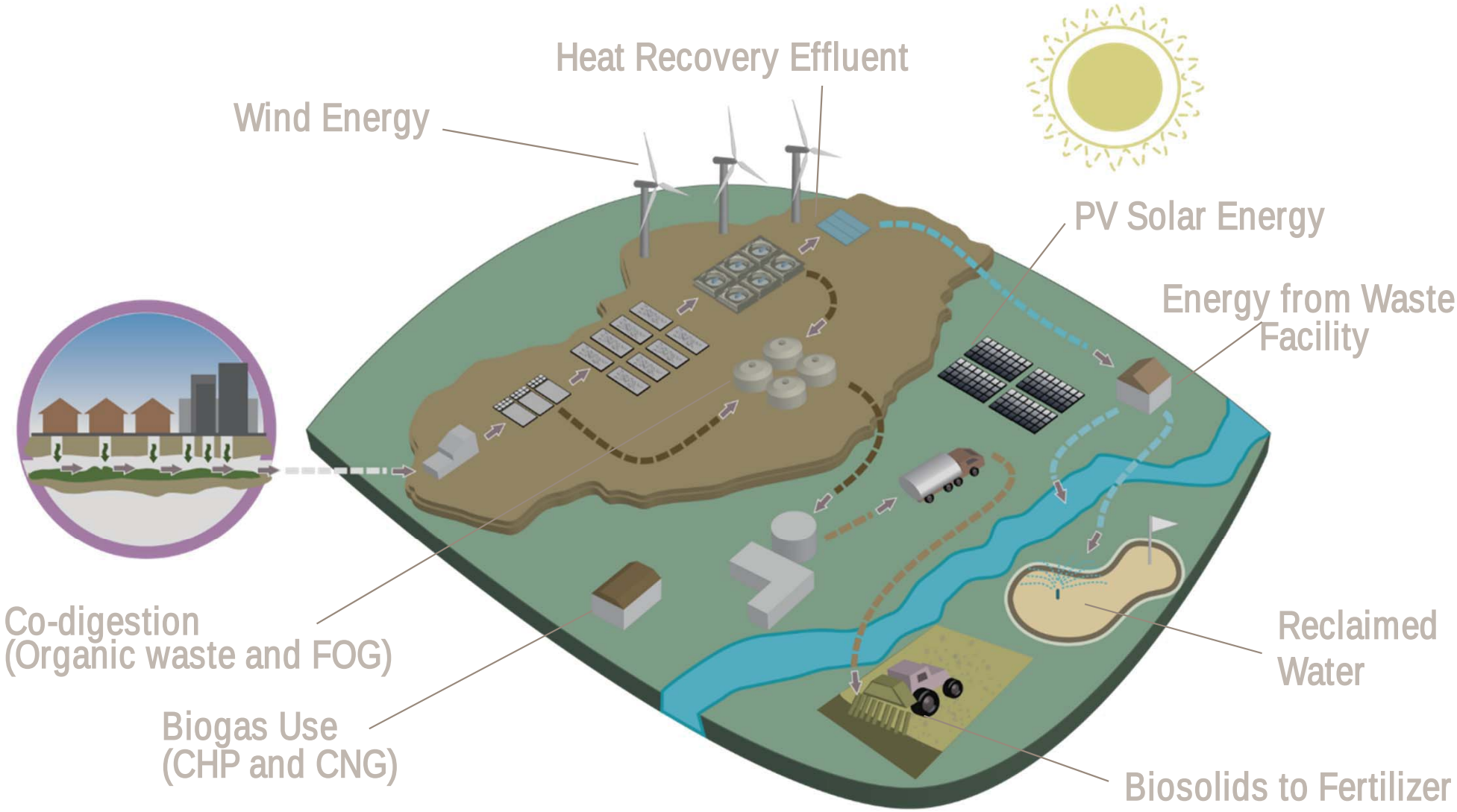


World's Largest EfW Facility (2020) in China to include Desalination Water Plant and Solar PV

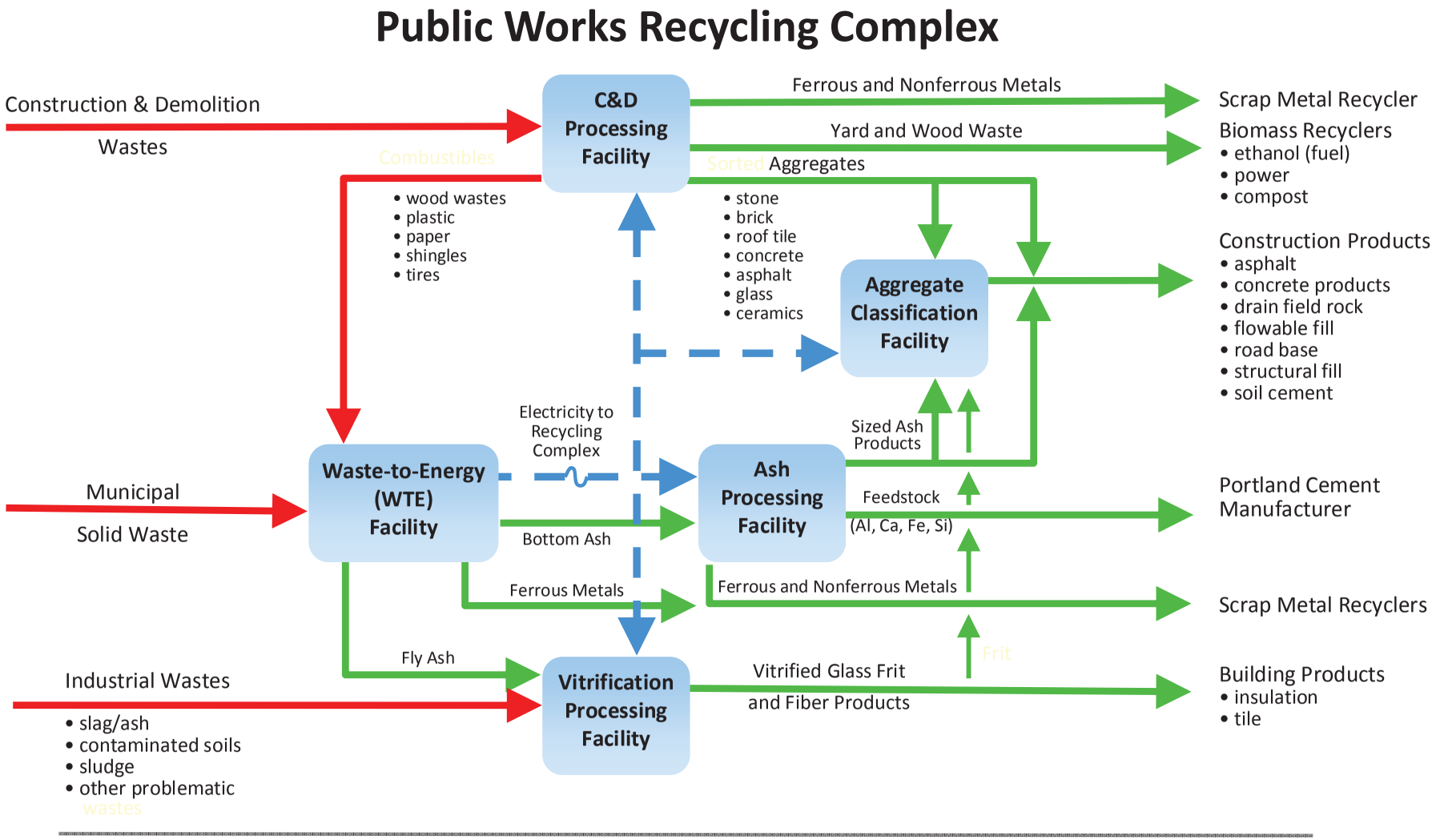


Schmidt Hammer Lassen Architects and Gottlieb Paludan Architects

Excellent Renewable Energy Project Opportunities on Wastewater Treatment Sites



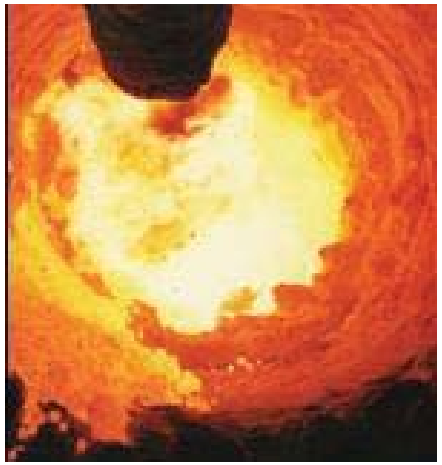
Integrated Campus can Include C&D Recycling for Commodities and "Engineered Aggregates"



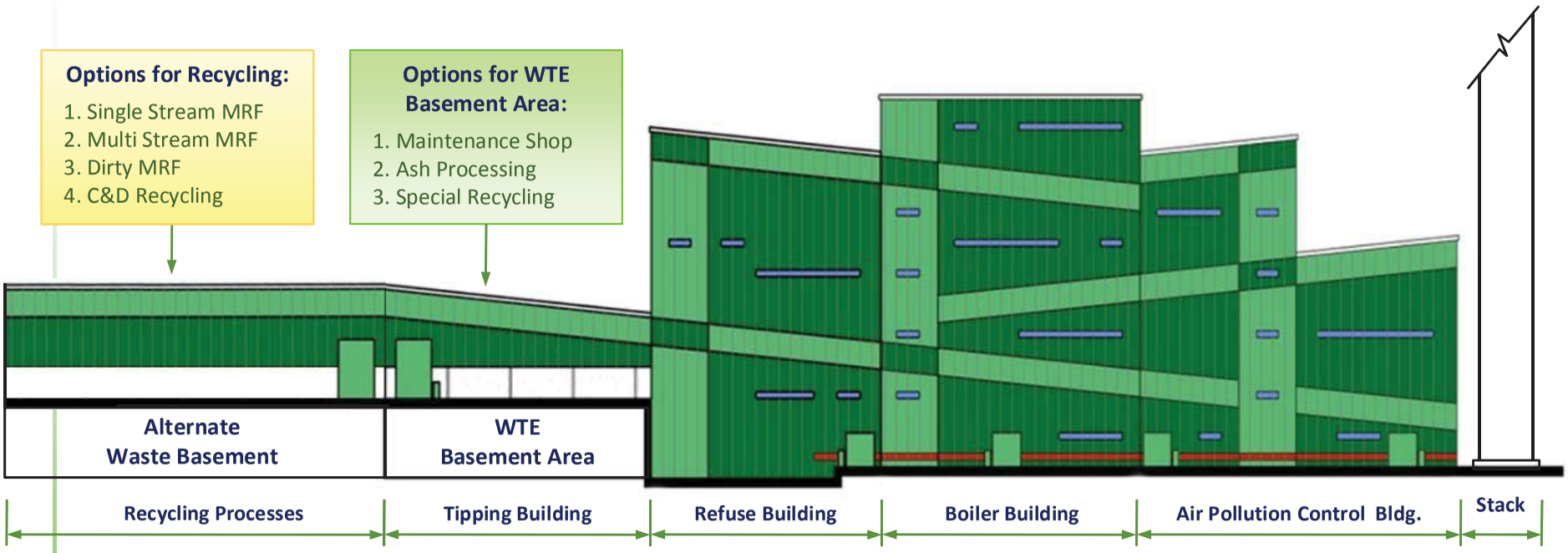
St. Lucie County, Florida
C&D Recycling Facility

EfW Bottom Ash Recycling Opportunity
Raw Material for Production of Portland Cement

Component	Portland Cement	Clinker	Typical WTE Ash
Silica (SiO_2)	18-24	22-24	24
Aluminia (Al_2O_3)	4-8	5	6
Ferric Oxide (Fe_2O_3)	2-5	0-3	3
Lime (CaO)	62-67	68-71	37

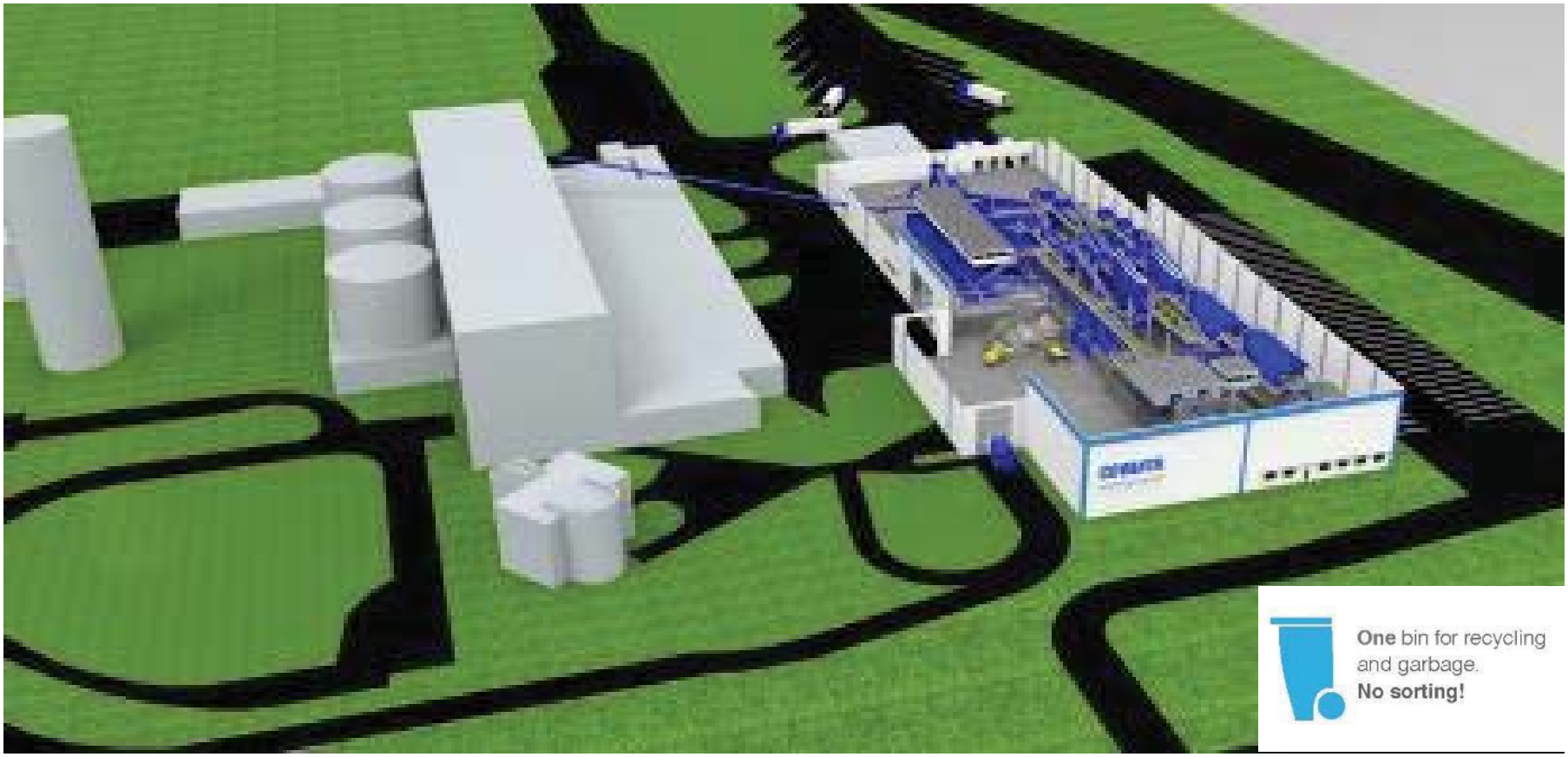


Future EfW Projects Could Include Material Recovery, Advanced Recycling, and Emerging Waste Conversion Processes

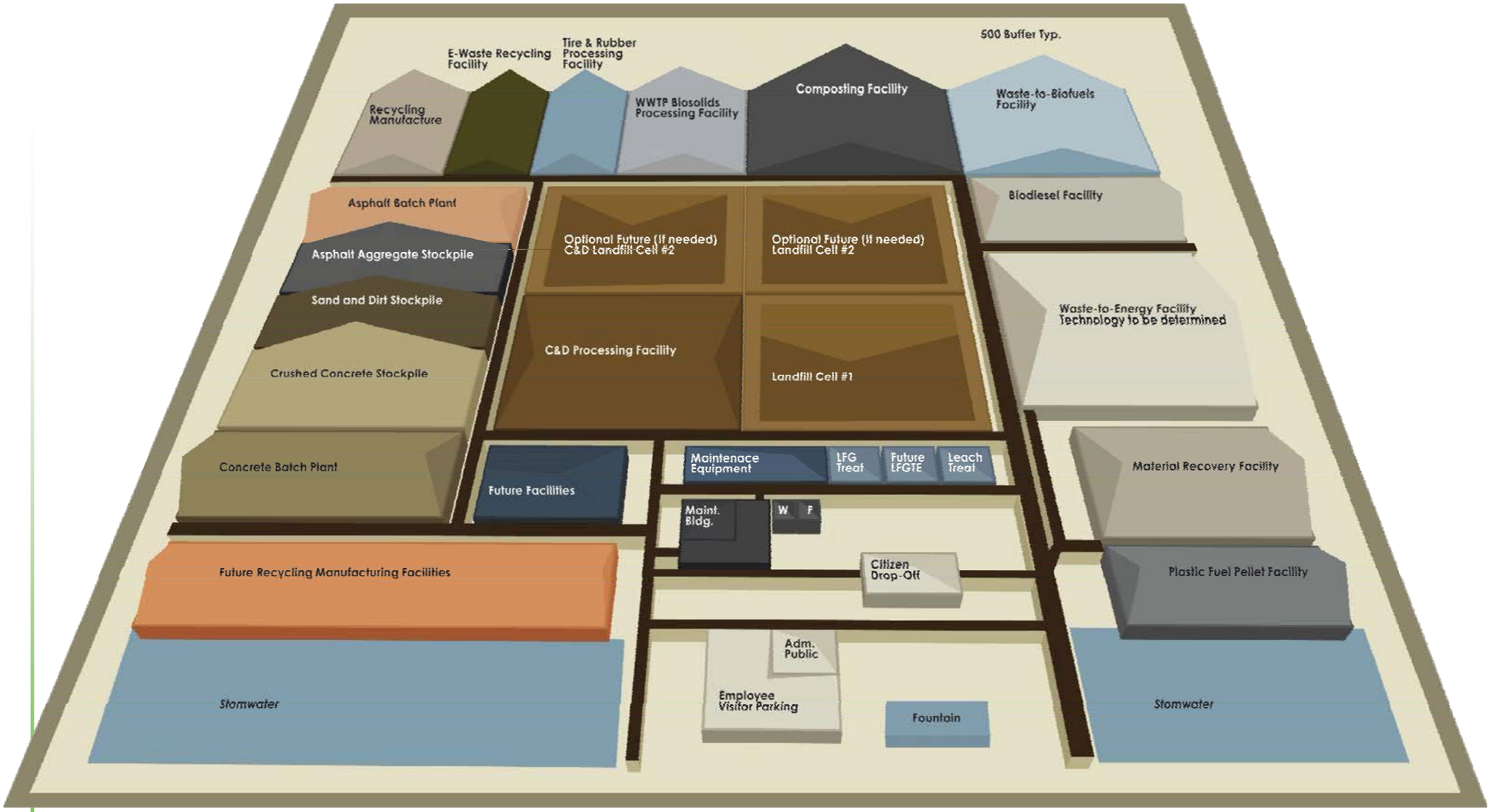


Advanced Recycling Center Co-located with EfW

- To be located adjacent to existing Covanta EfW facility in Indianapolis
- Currently in permitting stage
- One bin / one truck option



Future Eco-Recycling Campus Should Include Recycling Industries

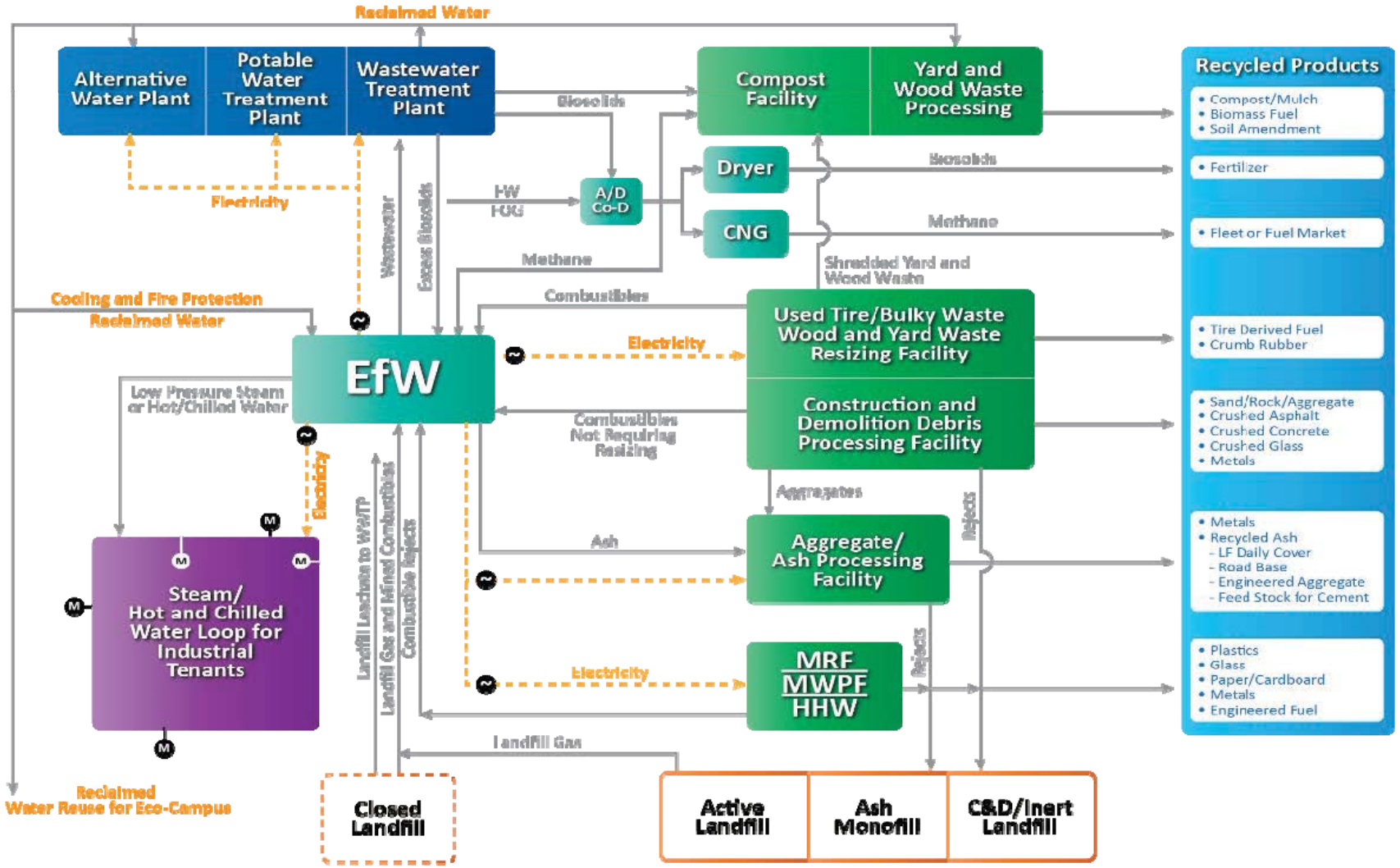


Opportunities to make the Transition from Waste Management to Resource Management

- **Thermal Processes**
  - EfW (massburn, high pressure, advanced metal recovery)
  - Gasification (thermal, plasma, vitrification)
  - Internal use of power (public works, utilities), net metering of electrical power
  - Bottom and combined ash recycling (aggregates, road base, feedstock for Portland cement)
- **Material Recovery Facilities**
  - Single stream, dual stream, mixed waste processing, advanced recycling centers
  - Commodities, engineered fuel as substitute for coal, RDF as feedstock for biofuel production, residuals to massburn EfW
- **Yard and Wood Waste Processing Facilities**
  - Mulch, biomass fuel, compost as soil amendment
  - Enhanced compost (with food waste, biosolids (WWTP, A/D, Co-D), ethanol residuals, micro-nutrients, minerals and biologicals)
- **Co-Digestion and Anaerobic Digestion Facilities**
  - WWTP biosolids with FOG, food waste, high strength industrial wastes (out of spec sugars, starches, and alcohols)
- **Biofuels/Bio-products Manufacturing Facilities**
  - Biomass versus RDF for production of ethanol, heating fuel, higher alcohols, hydrogen, jet fuel, low sulfur diesel, methanol, DME, synthetic gasoline, synthetic natural gas (CNG and LNG)
- **C&D Recycling Facilities**
  - Commodities, dry wall (gypsum soil amendment), glass cullet (fiberglass insulation, cullet)
  - Engineered aggregates (manufactured from asphalt, brick, concrete, rock, stone, sand, glass cullet)
- **Electronic Waste Recycling Facilities**
  - Recovery of metals (ferrous, non-ferrous, precious, rare earth), plastics and polymers

The Future…
We'll See It, When We Believe It!

Integrated and Sustainable Resource Management!



Replacing Apathy with Action

- NIMBY…Not in My Back Yard
- NIMEY…Not in My Election Year
- BANANA…Build Absolutely Nothing Anywhere Near Anyone
- NUMBEE…Not Using My Bucks Ever, Either
- **NIMBI…Now I Must Become Involved!**
- **NYMBI…Now You Must Become Involved!**

Thank You for the Opportunity to Share... and Imagineer!

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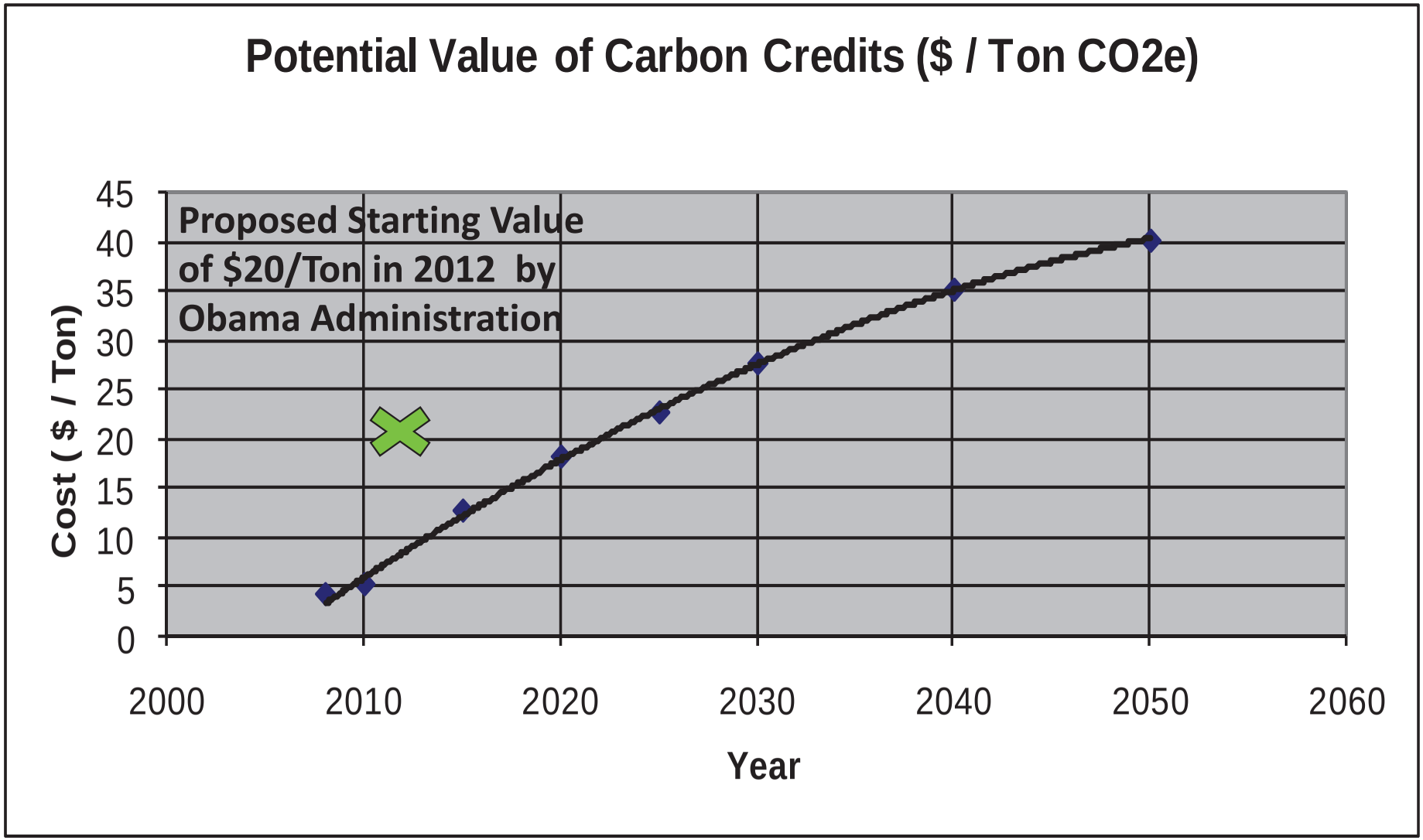
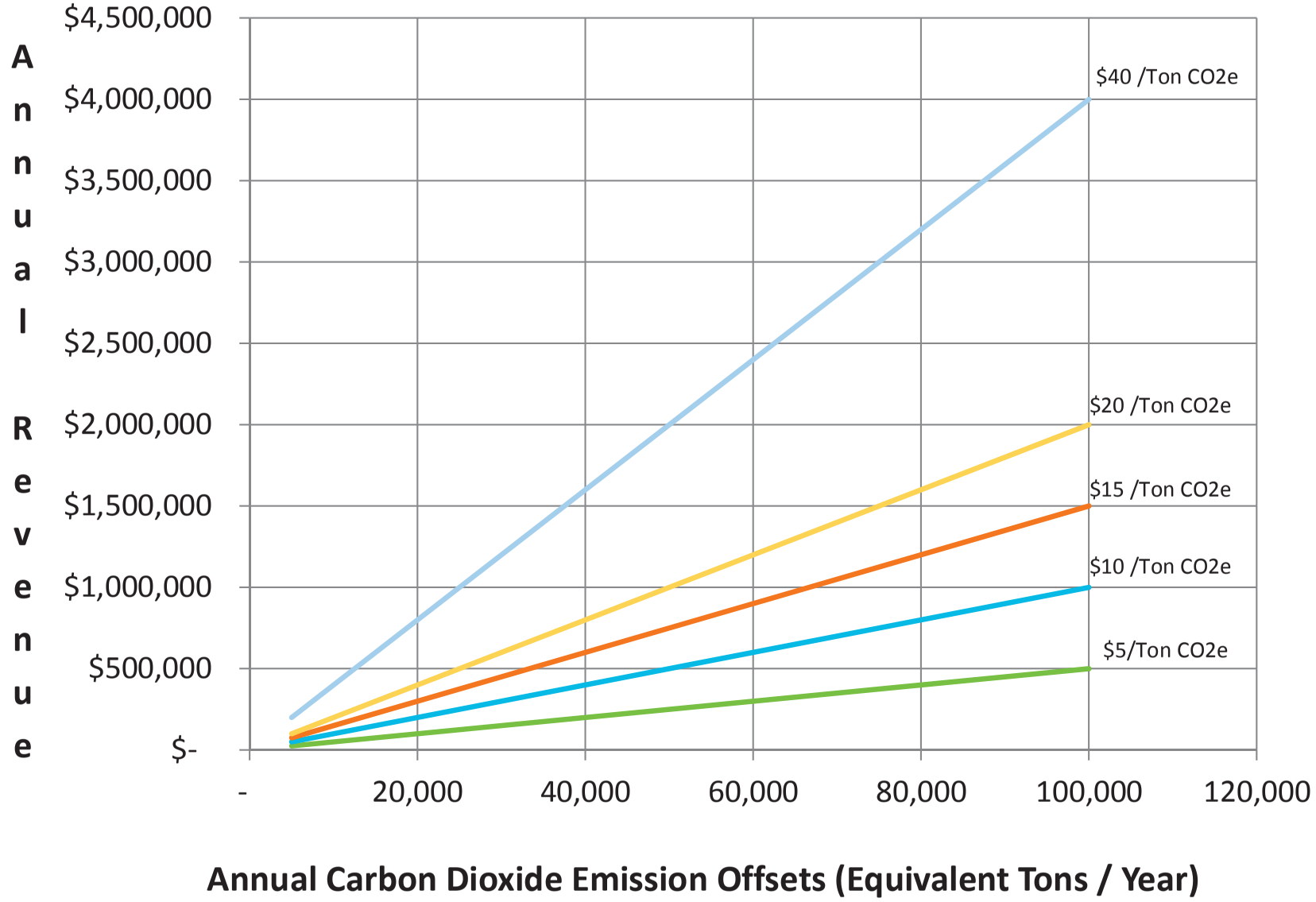
Projected Value of Carbon Credits

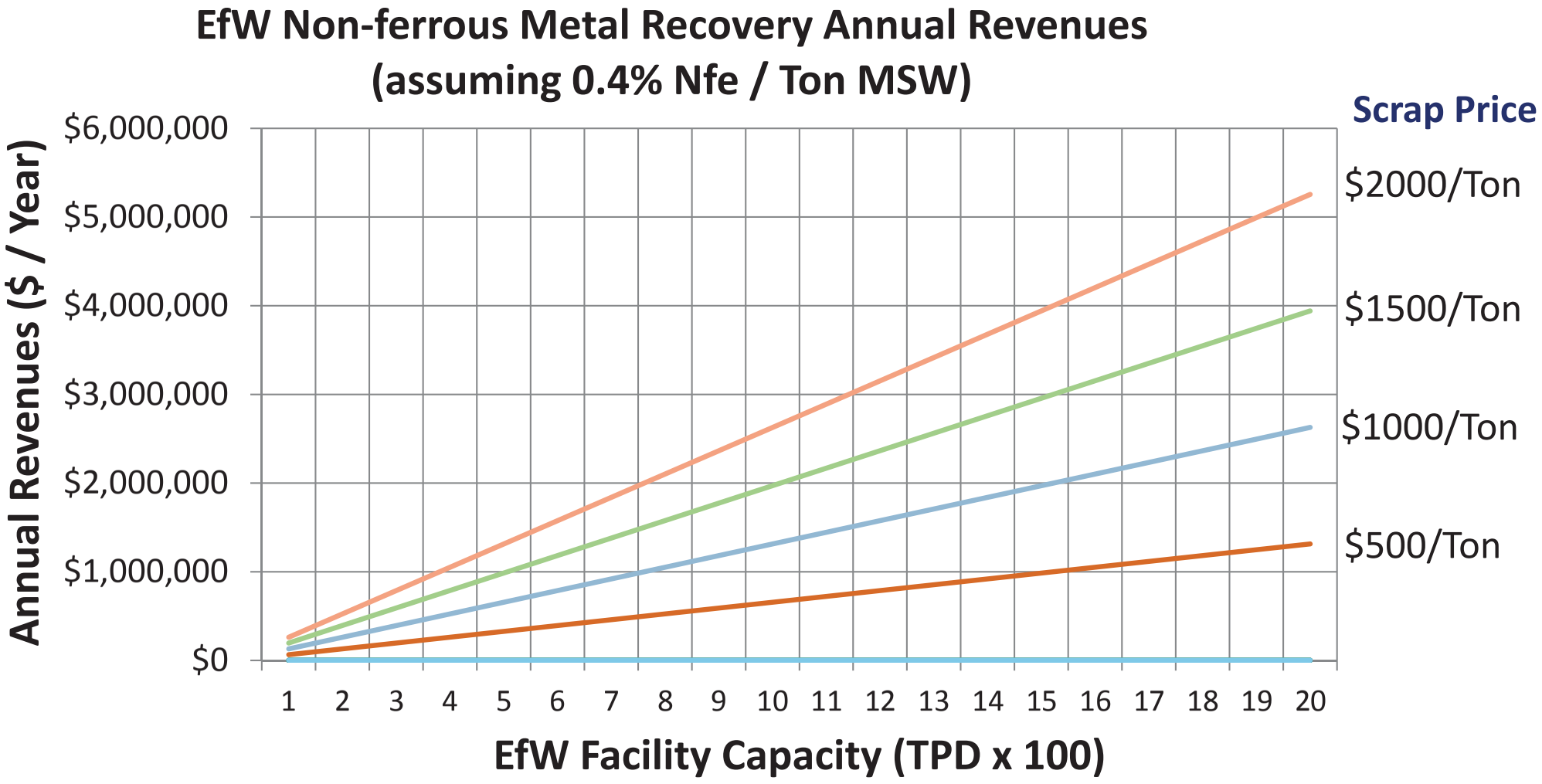


Value expected to rise over time in regulated carbon market!

Potential Revenues from Sale of Carbon Offset Credits



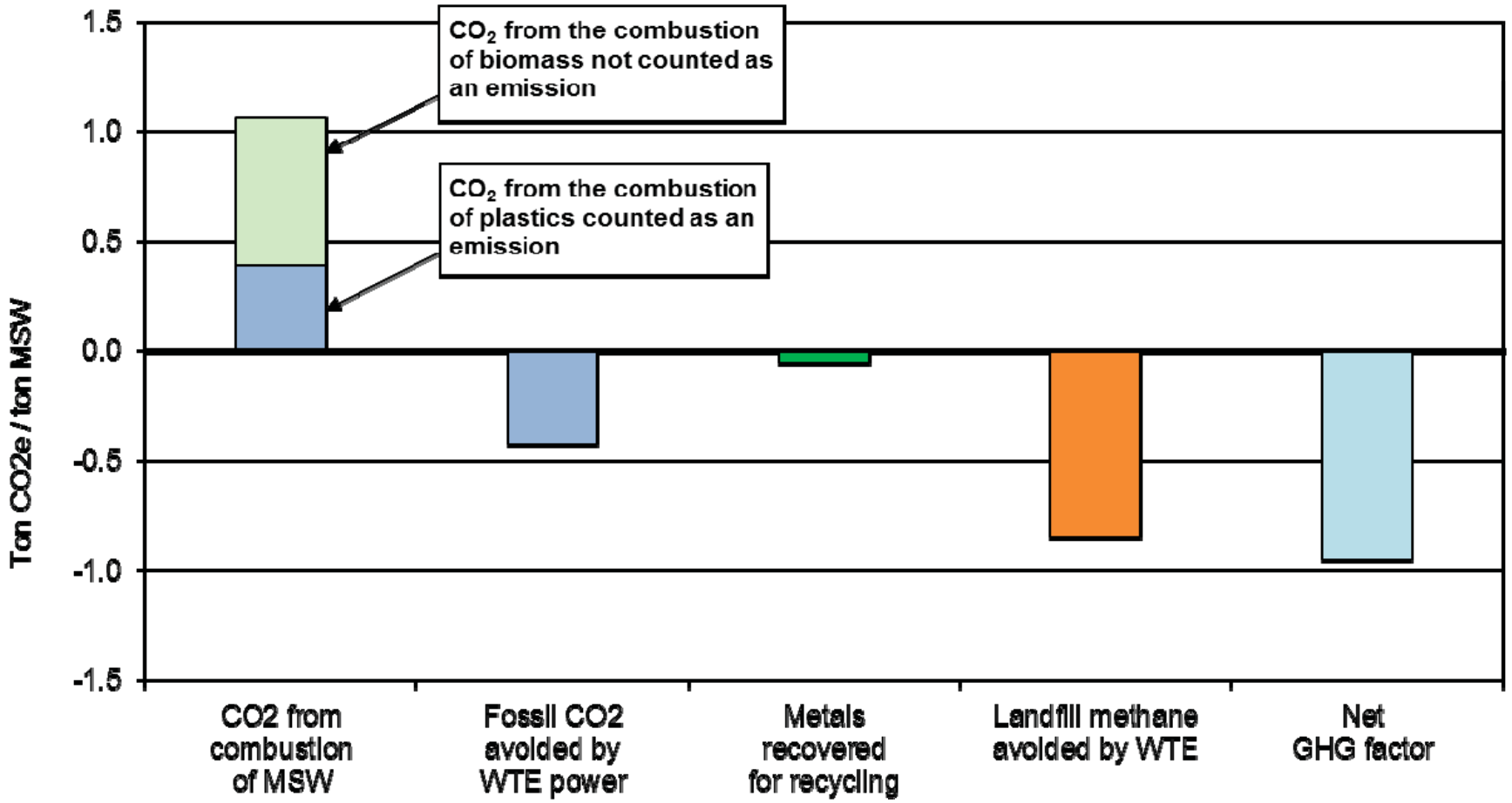
Value of Non-Ferrous Metal Recovered from EfW Bottom Ash



WTE & Greenhouse Gas Avoidance

- **Avoided methane emissions from landfills.** When a ton of solid waste is delivered to a waste-to-energy facility, the methane that would have been generated if it were sent to a landfill is avoided. While some of this methane could be collected and used to generate electricity, some would not be captured and would be emitted to the atmosphere.
- **Avoided CO_2 emissions from fossil fuel combustion.** When a megawatt of electricity is generated by a waste-to-energy facility, an increase in carbon dioxide emissions that would have been generated by a fossil-fuel fired power plant is avoided.
- **Avoided CO_2 emissions from metal recycling.** Waste-to-energy plants recover more than 700,000 tons of ferrous metal for recycling annually. Recycling metals saves energy and avoids CO_2 emissions that would have been emitted if virgin materials were mine and new metals were manufactured, such as steel.
- Waste-to-energy plants are tremendously valuable contributors in the fight against global warming. According to the U.S. EPA MSW Decision Support Tool, nearly one ton of CO_2 equivalent emissions are avoided for every ton of municipal solid waste handled by a waste-to-energy

Carbon Offsets Attributable to Modern EfW Facilities



Nearly one ton of CO_2 equivalent emissions are avoided for every ton of municipal solid waste processed by a modern EfW facility