Imagining the Next 50 Years…

Proven and Emerging Waste Conversion Technologies for Management of Municipal Solid Waste (aka Municipal Resources)

USF Stavros Center

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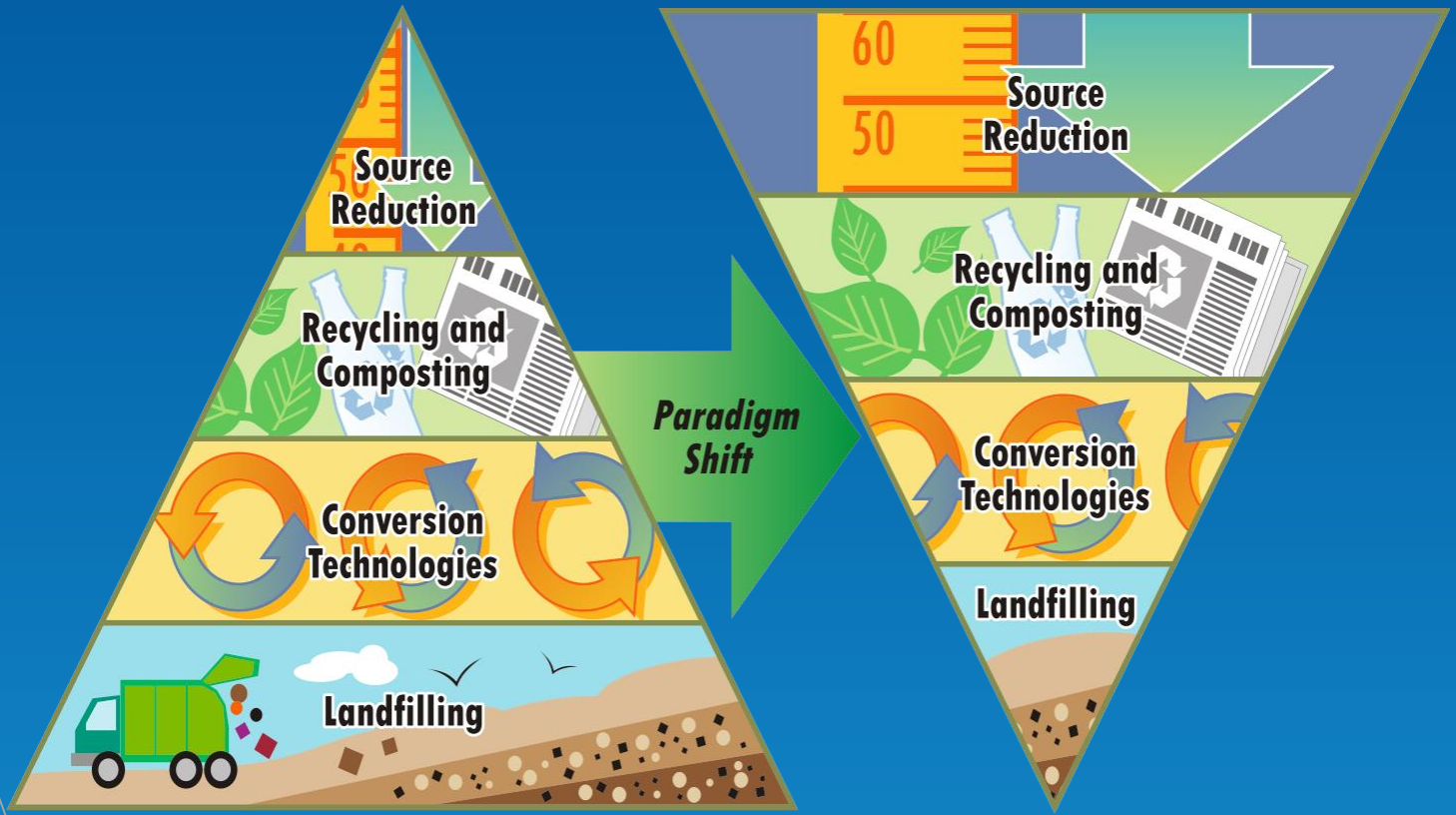
Presentation Outline

- Introduction to Municipal Solid Waste (MSW)
- Proven Waste Conversion Processes
- Emerging Waste Conversion Processes
- Examples of WTE in Florida, U.S. and the World
- Suggestions for Teachers of Future Innovators

Let's Talk Trash!
Average American Municipal Solid Waste Data

- Average Generation 4.48 pounds / person / day (0.82 tons per year)
  - Responsible or 36,000 pounds of CO_2 emissions per year, or ~2,830,000 pounds over a lifetime of 78.6 years
    - Equivalent to burning 1,418,000 pounds (709 tons) of coal
    - Equivalent to driving 3,171,000 miles in a passenger vehicle
- 35% current national recycling rate (~40% in Florida, 2018 data)
- 52% of municipal solid waste (MSW) is disposed of in landfills
  - >3,000 active landfills
- ~ 70 active Waste-to-Energy facilities processing ~8% of MSW

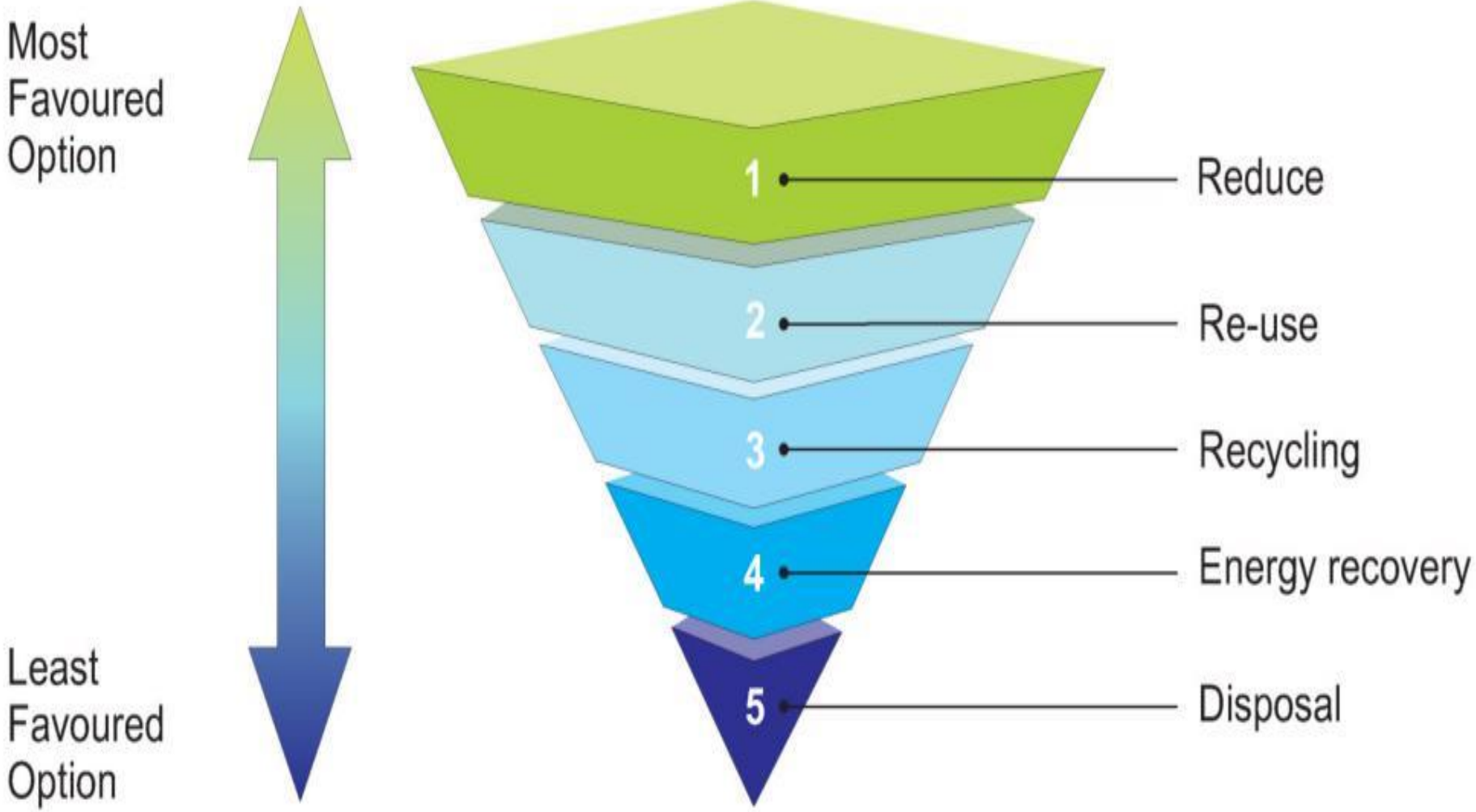
Intended Consequences of the Integrated Solid Waste Management Hierarchy



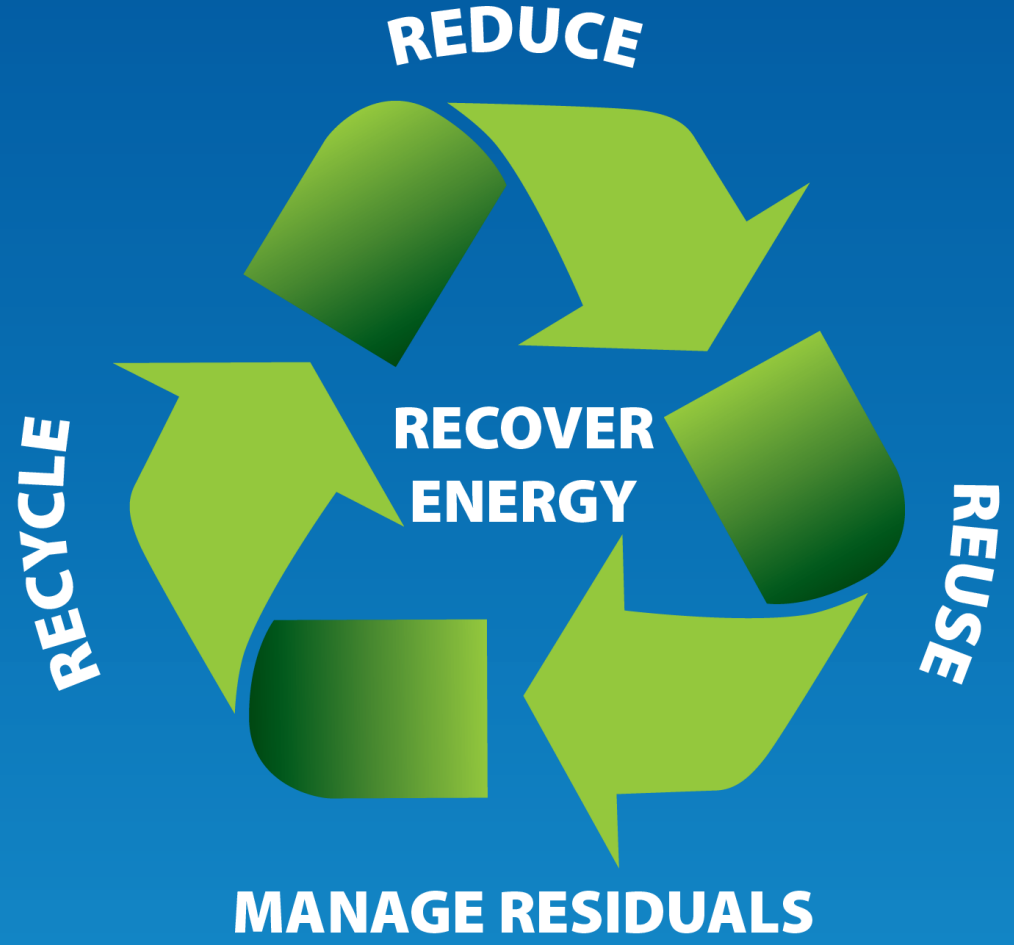
Hierarchy of Preferred Solid Waste Management Strategies

Paradigm Shift for the 21st Century

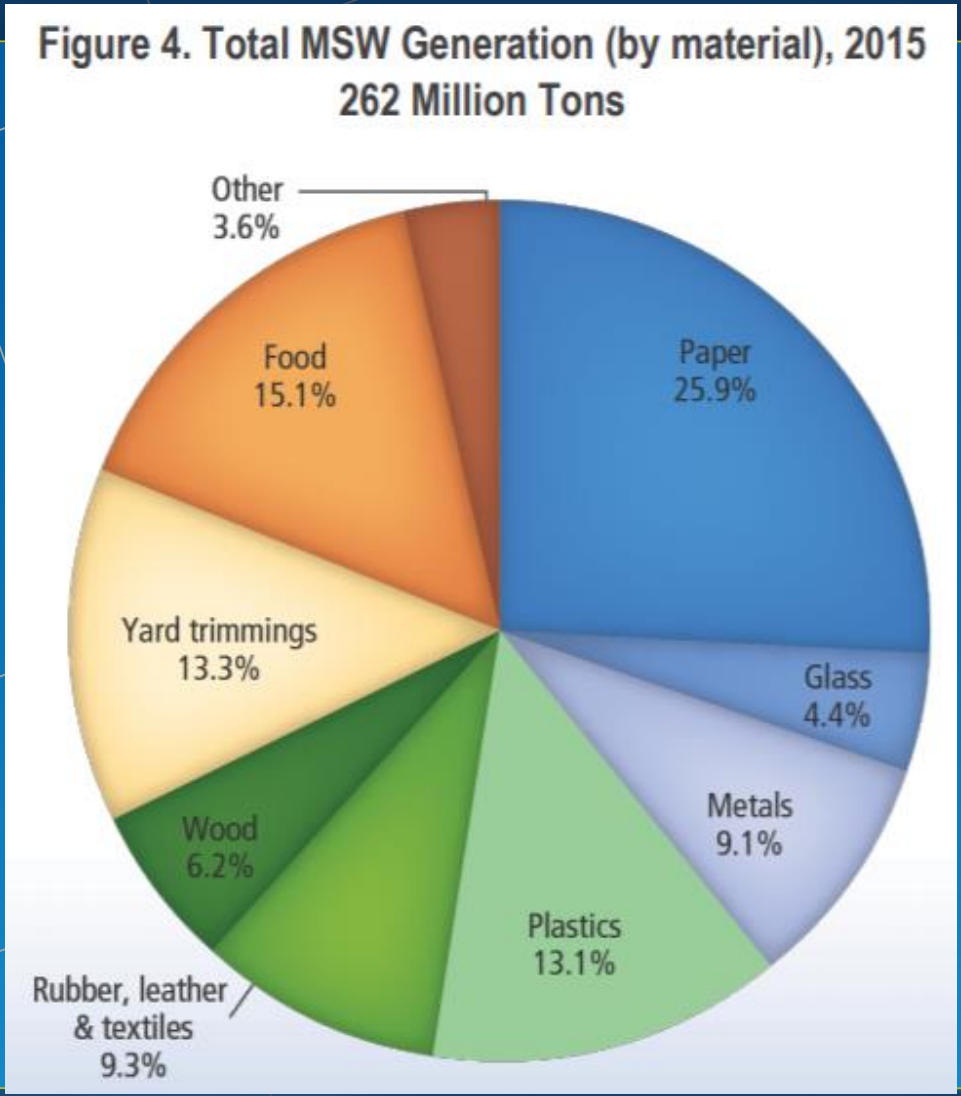
Solid Waste Management Hierarchy



The Three Rs of Recycling…Plus Two More



What's In Our Municipal Solid Waste?



Most materials can be recycled somewhere, in some way, but <u>NOT</u> always in your curbside cart

Future Trends:

- Reduction in Old Newsprint (ONP) and glass
- Growth in plastics and corrugated fibers
- Growth in composite materials for packaging and products
- Reduction in single use plastics?

Key Impacts of Waste Management Options

- Cost
- Pollutants (NO_x, SO_x, VOCs, PM_{10}, CO, HCl, Hg, Pb, Cd)
  - Collection
  - Processing
  - Disposal
- Greenhouse gases (CO_2, CH_4, N_2O)
- Socio-demographics
  - Jobs, tax base, environmental justice
- Energy consumption and/or savings
- Traffic, vehicle collisions, and wear and tear on roadways

Benefits of Recycling

- Reduces waste sent to landfills and uncontrolled emissions
- Conserves natural resources
- Prevents pollution by reducing the need to mine new raw materials
- Saves energy which reduces greenhouse gas emissions (CO_2, CH_4, N_2O)
- Increases economic security
  - High quality jobs and careers in U.S. recycling and manufacturing industries
  - 10 times more jobs in recycling than disposal

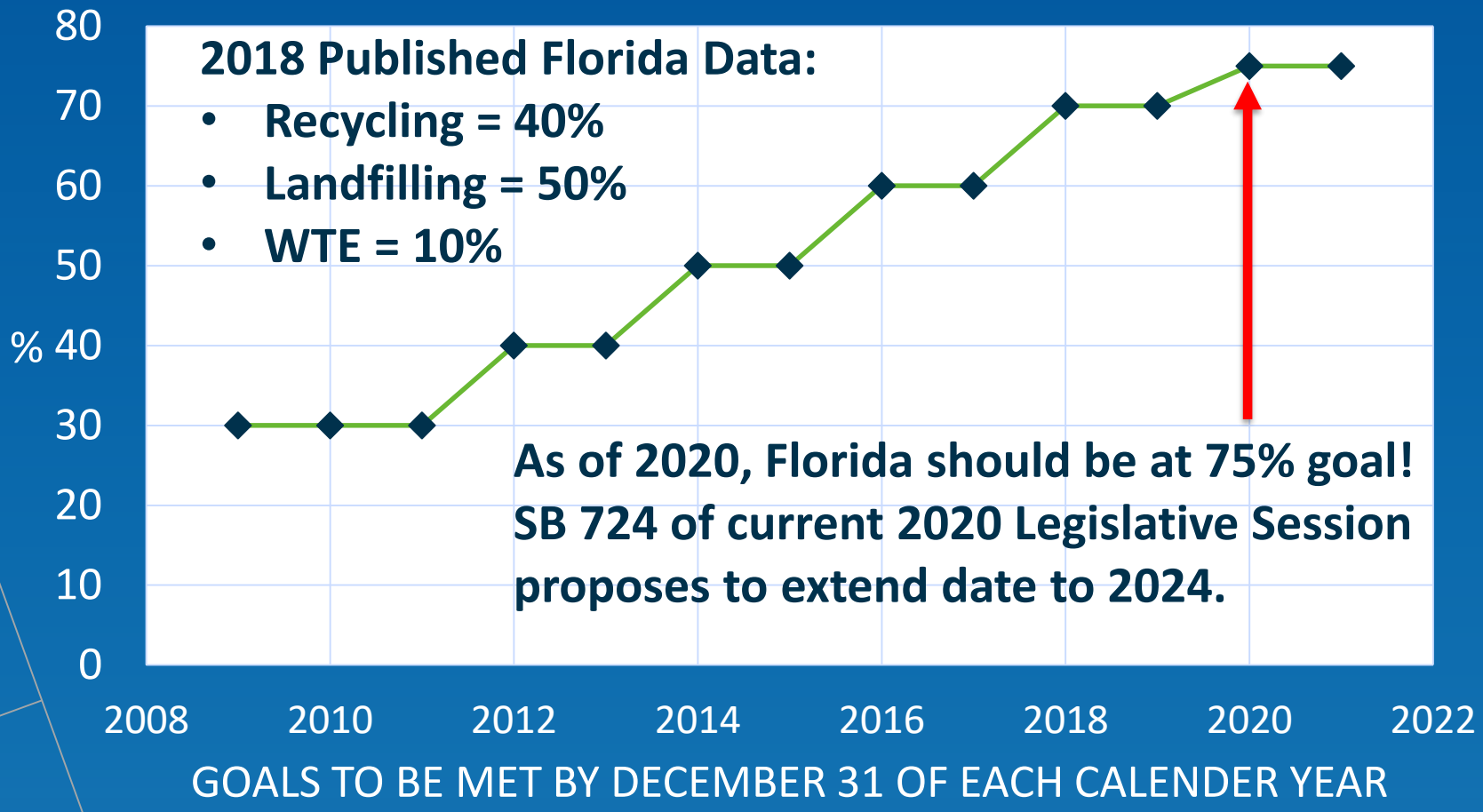
Energy Savings Due to Recycling

- Aluminum – 94%
- Plastic – 90%
- Steel – 75%
- Lead – 75%
- Paper – 40%
- Glass – 25%

Fun Facts – Annual Waste Collection

- Hillsborough County (includes City of Tampa)
  - Collects ~ 3.3 mtpy
  - WTE processes ~ 920,000 tpy (~28%)
- Pasco County
  - Collects ~ 1.2 mtpy
  - WTE processes ~ 350,000 tpy (~30%)
- Pinellas County
  - Collects ~ 2.3mtpy
  - WTE processes ~1,000,000 tpy (~43%)
- NYC generates ~ 33 mtpy of MSW with only 700,000 tpy of recyclables and no WTE facilities

Schedule to Meet Florida's 75% Recycling Goal (based upon 2010 H. B. 7243)



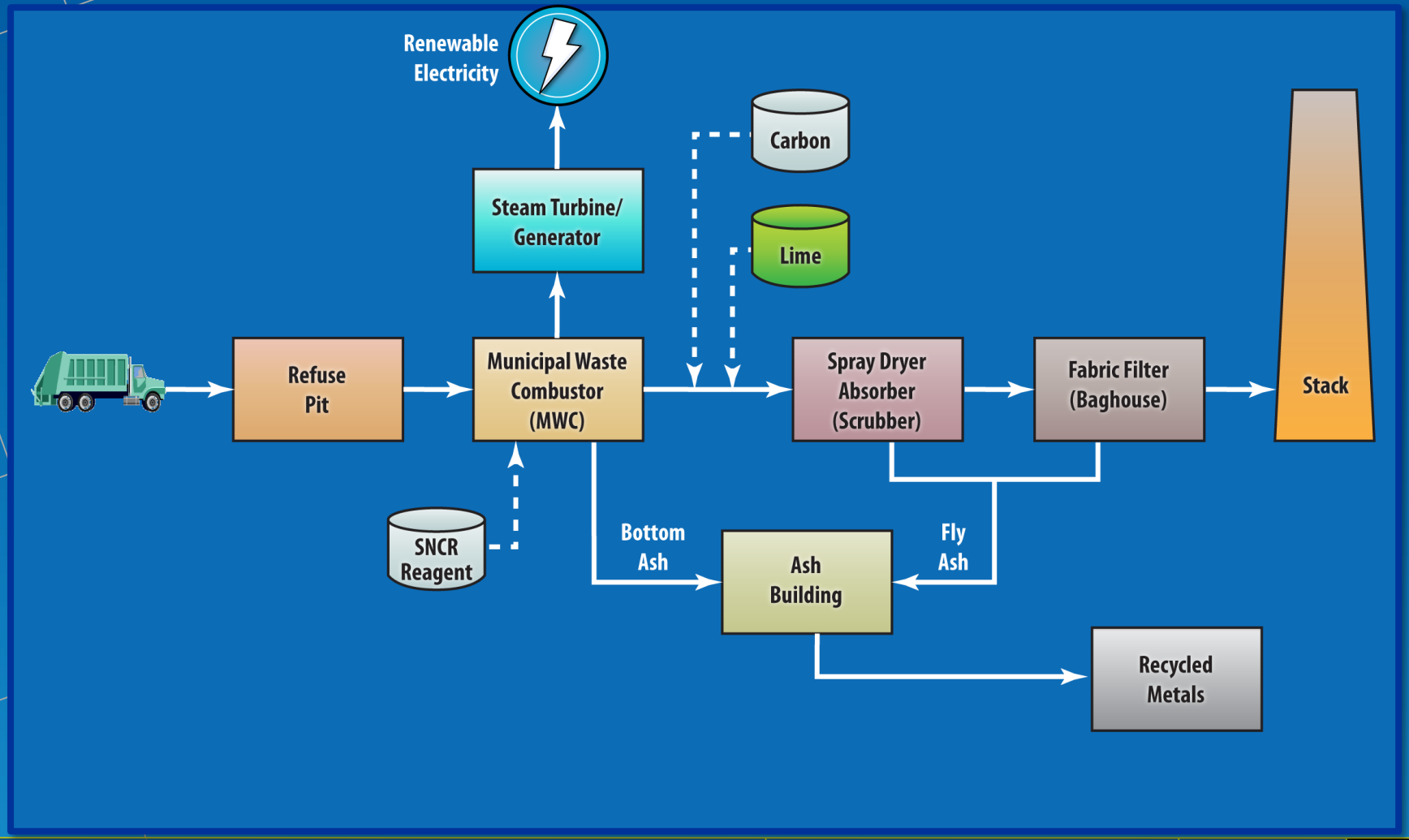
Recycling Technology Trends

- New Material Recovery Facilities (MRFs) will be more mechanized
- Robotics and Artificial Intelligence (AI)
  - Robotic sorting machines are learning to identify different types of materials, remove them from conveyor belts of mixed materials at rapid speed and deposit them into appropriate categories for further sorting
- U.S needs to develop home-grown recycling infrastructure
  - Mixed papers and No. 3-7 plastics
  - Food waste

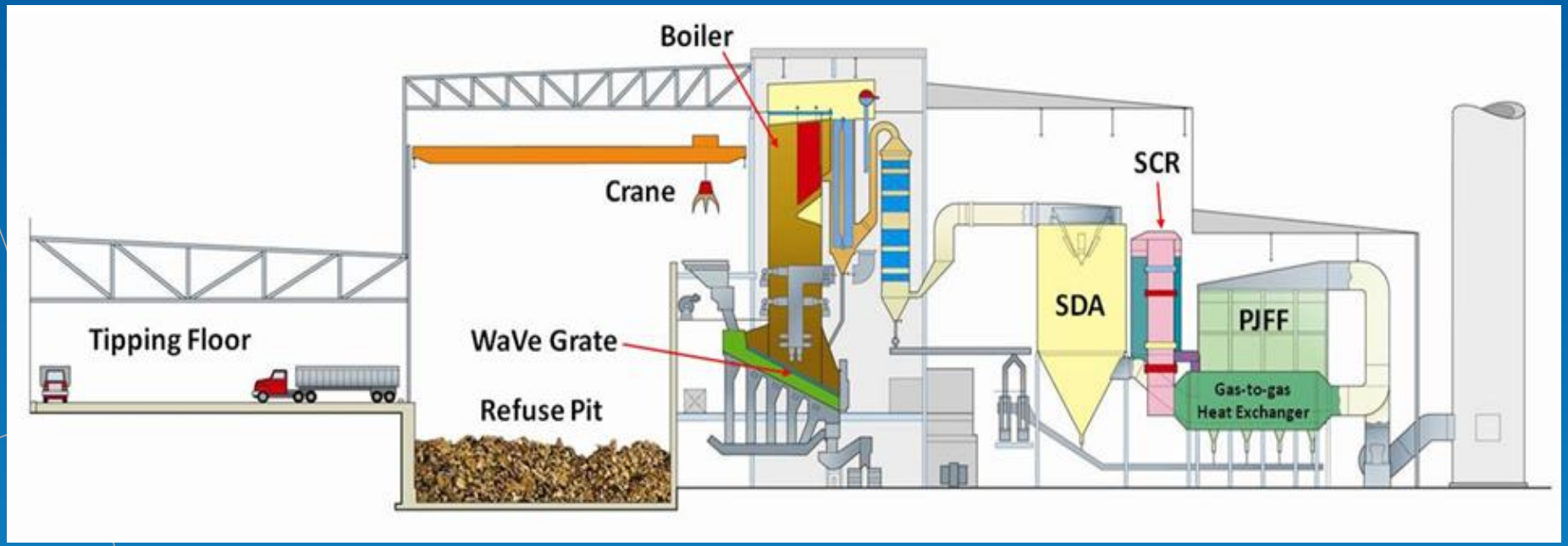
Key Advantages of Modern Waste-to-Energy (WTE) Technology

- Aesthetically pleasing
- 90% volume reduction
- Stabilized ash residue
- Recovery of energy
- Recovery of metals
- Waste treatment reduces or eliminates future landfill liabilities (note that U.S. does not require waste to be stabilized prior to disposal as in Europe)
- Control over future disposal capacity and pricing

Typical Mass Burn WTE Flow Diagram



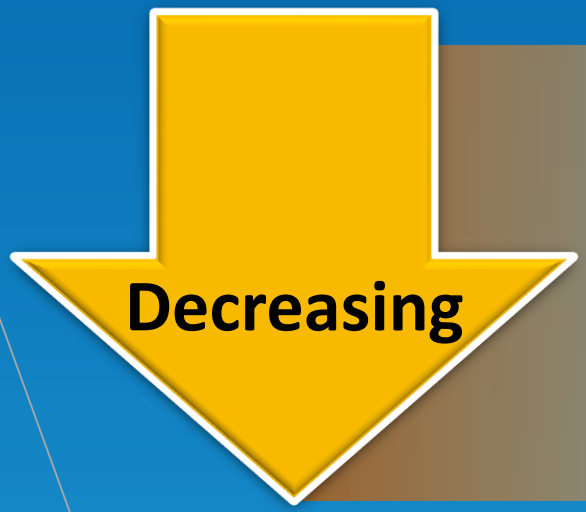
Typical Massburn WTE Facility Cross-Section



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

Modern WTE Trends…
Advancing Efficiency, Aesthetics, and Sustainability!

- Many successful operations for 20-25 years
- WTE facility expansions and new construction
- Attention to aesthetics/LEED®/innovation
- More stringent emission limits and GHG reporting
- MSW Higher Heating Value (HHV)
- Boiler/T-G availability
- Use of reclaimed water for cooling
- Gross/net electric generation
- Non-ferrous metal recovery



- Resistance to WTE in established communities
- Air emissions
- Reagent consumption
- Water consumption
- Payments for environmental attributes of renewable electricity

Historical Emission Trends Since 2000 CAAA from Large and Small Municipal Waste Combustors

Pollutant	1990 Emissions (TPY)	2005 Emissions (TPY)	Percent Reduction
CDD/CDF TEQ Basis *	44	15	99+%
Mercury	57	2.3	96%
Cadmium	9.6	0.4	96%
Lead	170	5.5	97%
Particulate Matter	18,600	780	96%
HCL	57,400	3,200	94%
SO_2	38,300	4,600	88%
NOx	**64,900**	**49,500**	**24%**

Source: EPA, August 2007

* Dioxin/furan emissions are in units of grams per year toxic equivalent quantity (TEQ), using 1989 NATO toxicity factors; all other pollutant emissions are in units of tons per year

WTE Capacity Factor is Among Highest Renewable / Fossil Energy Options (24/7/365)

• Hydroelectric	10-99%
• **Waste-to-Energy (WTE)**	**85–95%**
• Baseload Coal	80-90%
• Landfill Gas	80-95%
• Biomass	60-85%
• Natural Gas Combined Cycle	60-80%
• Thermal solar (parabolic trough)	40%
• Wind	20-40%
• Photovoltaic solar (southern latitudes)	18-20%
• Photovoltaic solar (northern latitudes)	12-15%

WTE can help provide fuel diversity for base load power production to local grid!

Capacity Factor = actual kWhrs produced divided by kWhrs that would have been produced if operated at design capacity

Modern Waste-to-Energy Reduces Greenhouse Gas (GHG) Emissions

- 1 Ton MSW Combusted Avoids 1 Ton of CO_{2e} Emissions
  - = Carbon Dioxide emissions from fossil portion of MSW
  - – Avoided Landfill Methane Emissions

  - – Avoided CO_2 from Displaced Fossil Fuel Electricity
  - – Avoided CO_2 from Metals Production using Recovered Ferrous and Non-ferrous Metals

Dominant WTE Technology in U.S. is Massburn Combustion (aka Advanced Thermal Recycling)

Modern WTE Facility Operators Focus on Good Housekeeping!

WTE Minimizes Waste Disposed in Landfills

~ 90% volume and 75% weight reduction plus 2.8 % metal recovery

First WTE Metal Recovery Operation
Ferrous Metals > 6-inch Size

Second WTE Metal Recovery
Liberated Ferrous and Non-ferrous Metals

Ferrous metals <6” in size (everything…including the kitchen sink)

Non-ferrous metals (+3/8 -2”) (aluminum, brass, bronze, copper, gold, silver, stainless)

Sample of Non-ferrous Metals Liberated and Recovered After Combustion

Aluminum, brass, bronze, copper, and stainless

Most of these items are NOT ACCEPTED in curbside programs

Dense aluminum nuggets

Coins Separated from Non-ferrous Metals
Palm Beach County, Florida

Recovered Recyclable Products from WTE 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 WTE Bottom Ash

Aluminium scrap product (fine)

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

Aluminium scrap product (middle)

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

Aluminium scrap product (coarse)

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

Heavy Non-ferrous Metals from WTE Bottom Ash

Heavy non ferrous scrap

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

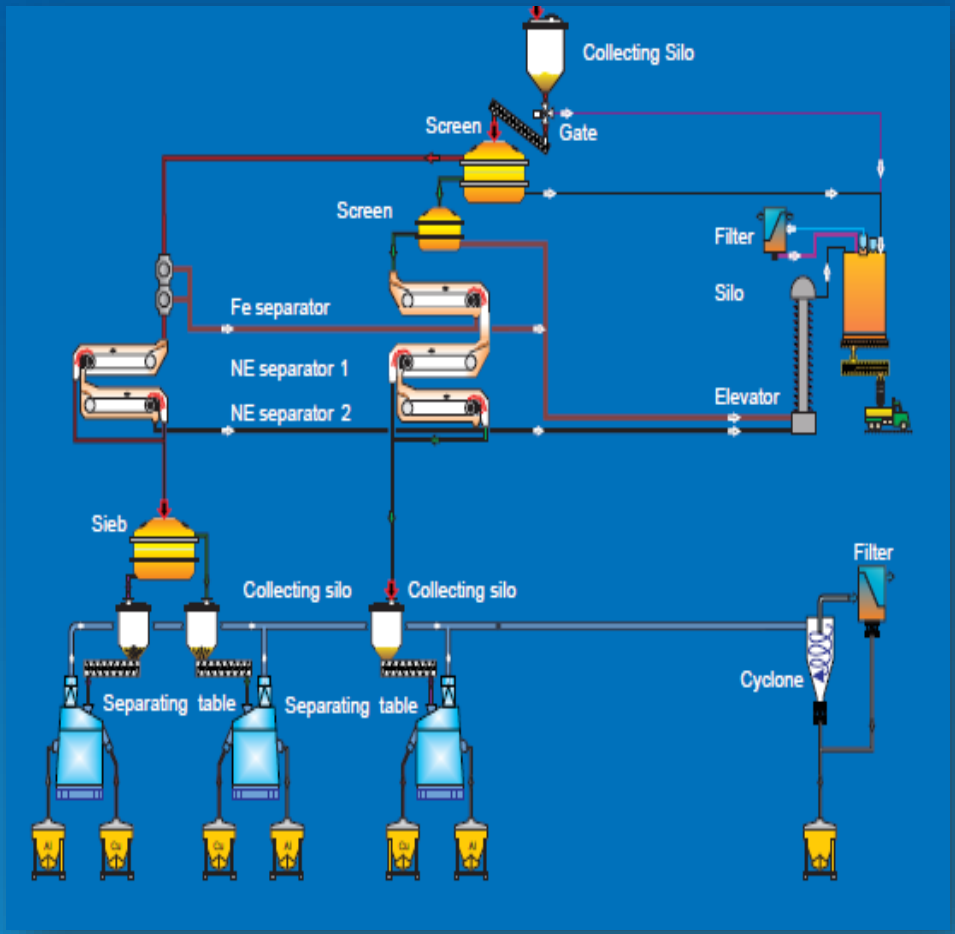
WTE Bottom Ash Recycling
Raw Material for Production of Portland Cement

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

Source: Defending the Character of Ash, Richard W. Goodwin, 1992

Future Recovery of Rare-Earth Metals from WTE Ash Residue

- Driven by China's control over rare earth metals supply
- European innovations in WTE ash management
  - Advanced metal recovery technology optimizes recovery of ferrous, non-ferrous and precious metals
  - Rare Earth Metal recovery under development



WTE Can Help Communities Meet Future Goals for "Zero Waste" to Landfill!

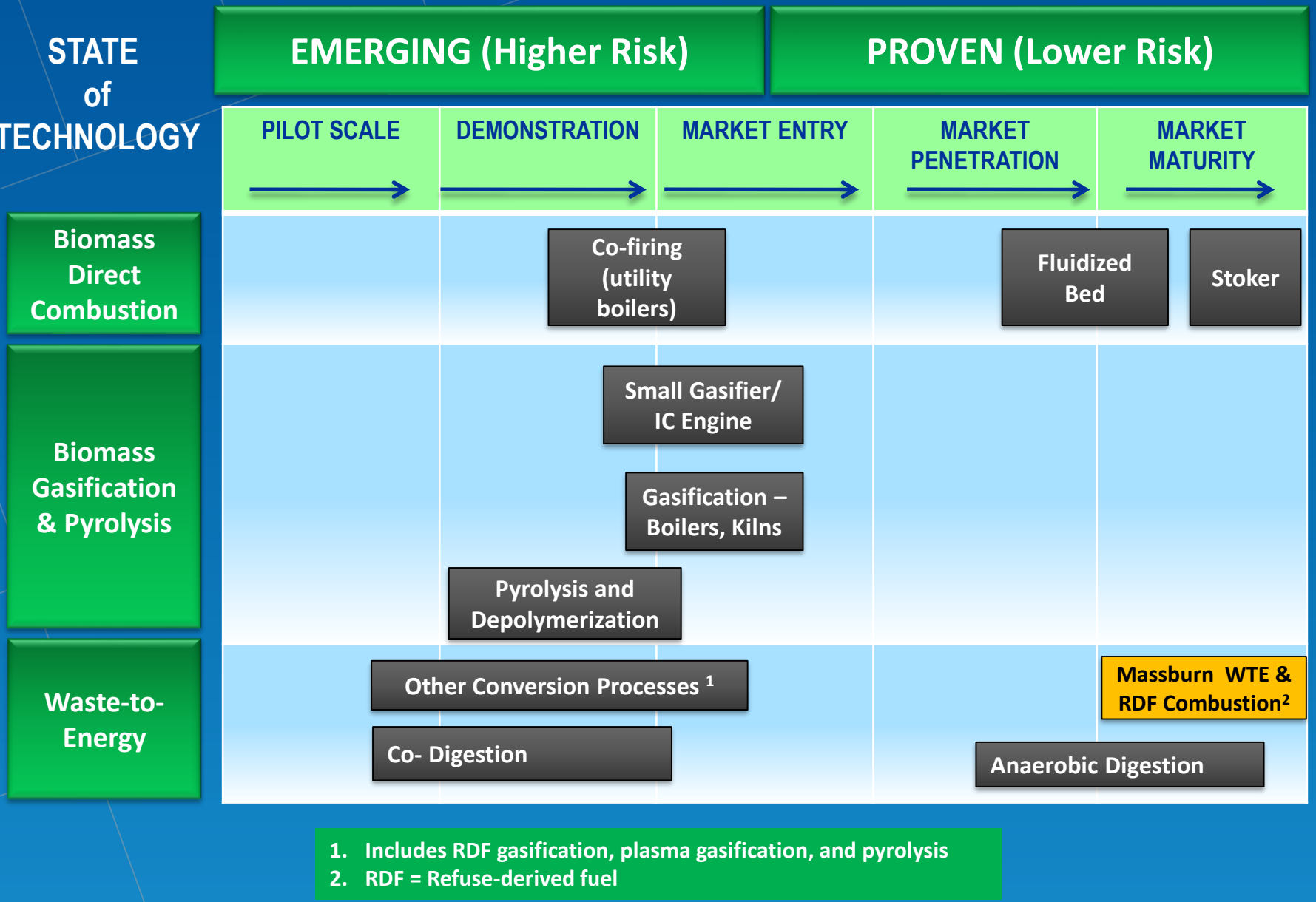
MSW to Landfill

WTE without Metal Recovery

WTE with Metal Recovery

WTE with Metal Recovery and Bottom Ash Recycling

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



1. Includes RDF gasification, plasma gasification, and pyrolysis
2. RDF = Refuse-derived fuel

Range of Revenues from Conversion 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
Synthetic Crude	1 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

Future Chemical Recycling By-products...It's Not Just About Ethanol!

- Butanol
- Ethanol
- Heating Fuel
- Higher Alcohols
- Aviation and Jet Fuel
- Low Sulfur Diesel
- Methanol DME
- Synthetic Gasoline
- Synthetic Natural Gas (CNG / LNG)

Options for Organic Waste

- Current practice:
  - Most landfilled (21,000,000 tons per year)
  - Some composted
  - Very little digested
- 2,000 Anaerobic Digesters in U.S.
  - Most located on farms (animal waste)
  - A few standalone digesters for food waste
  - Two primary by-products
    - Biogas for energy (pipeline gas, electricity/heat for on farm application)
    - Soil amendment of residuals
- Co-Digestion is being developed in several U.S. Cities
  - NYC, LA, SF, SLC, Philadelphia

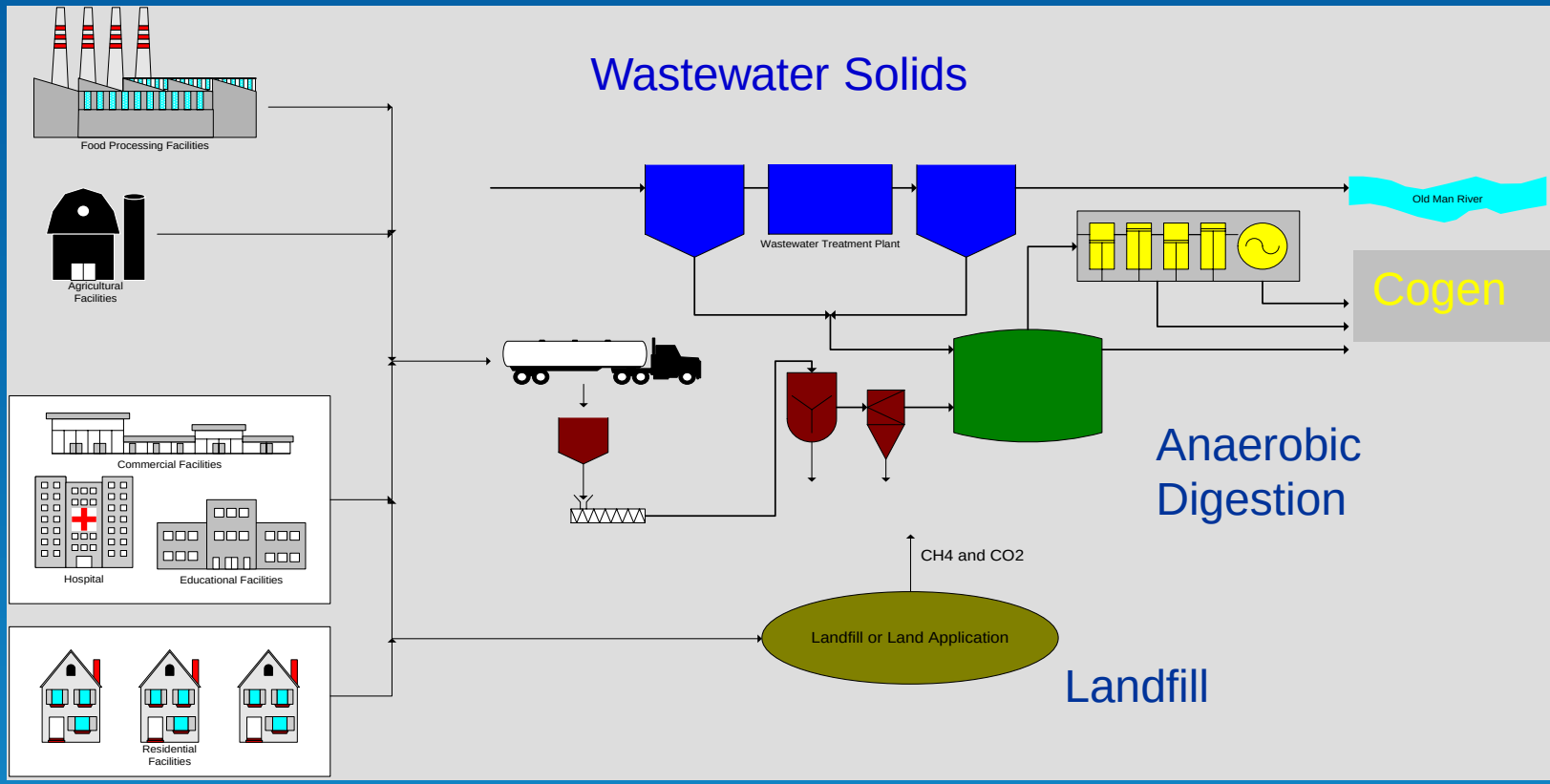
Co-digestion of Organic Waste with Wastewater Biosolids

Food Industry Waste

Animal Manure and Crop Wastes

Institutional Organic Waste

Residential Organic Waste



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

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

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

Ineos Bio-Energy Center (2012)
Indian River County Florida

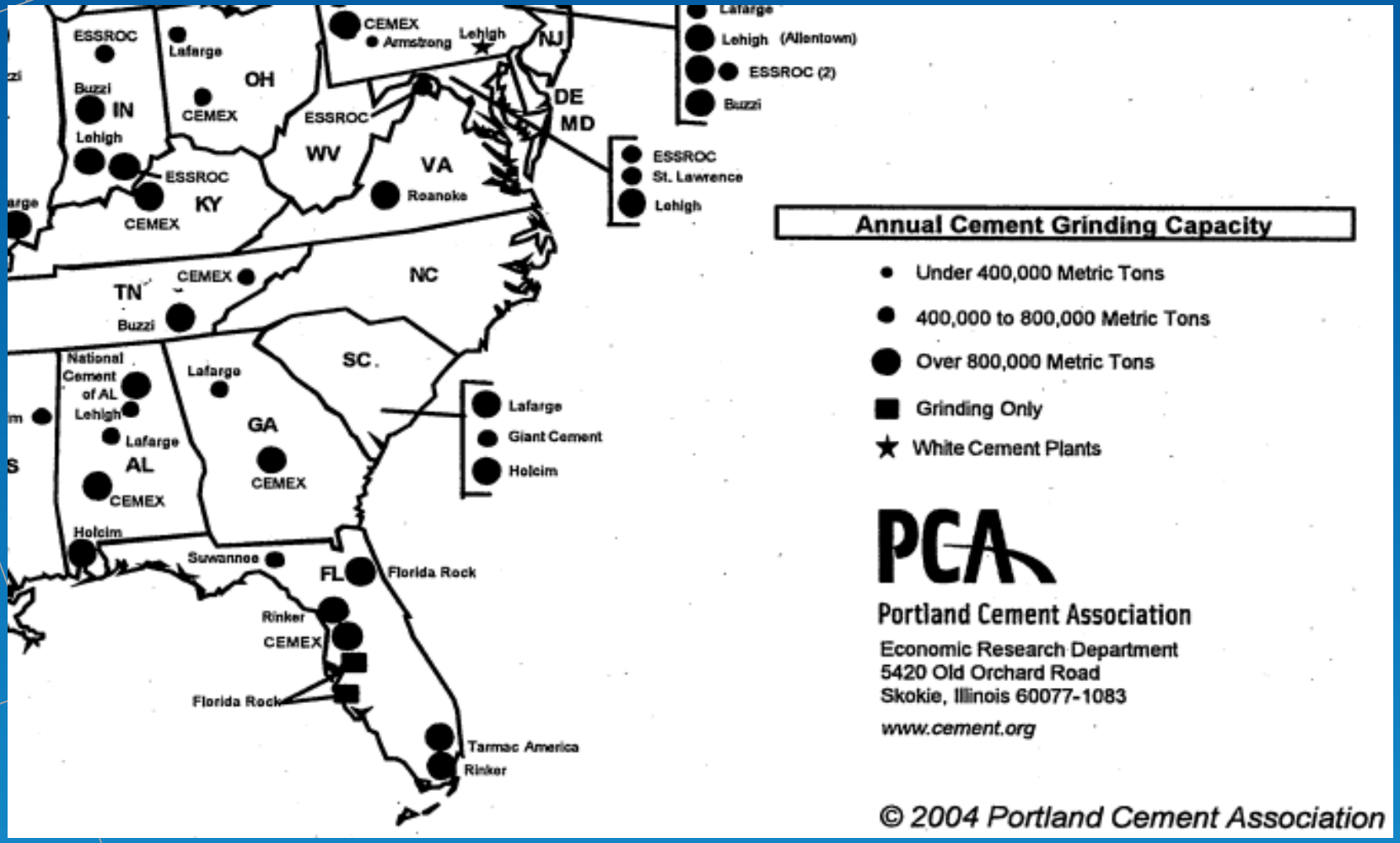
400 direct jobs in construction, engineering and manufacturing

Injected more than $25 million dollars directly into the Florida economy

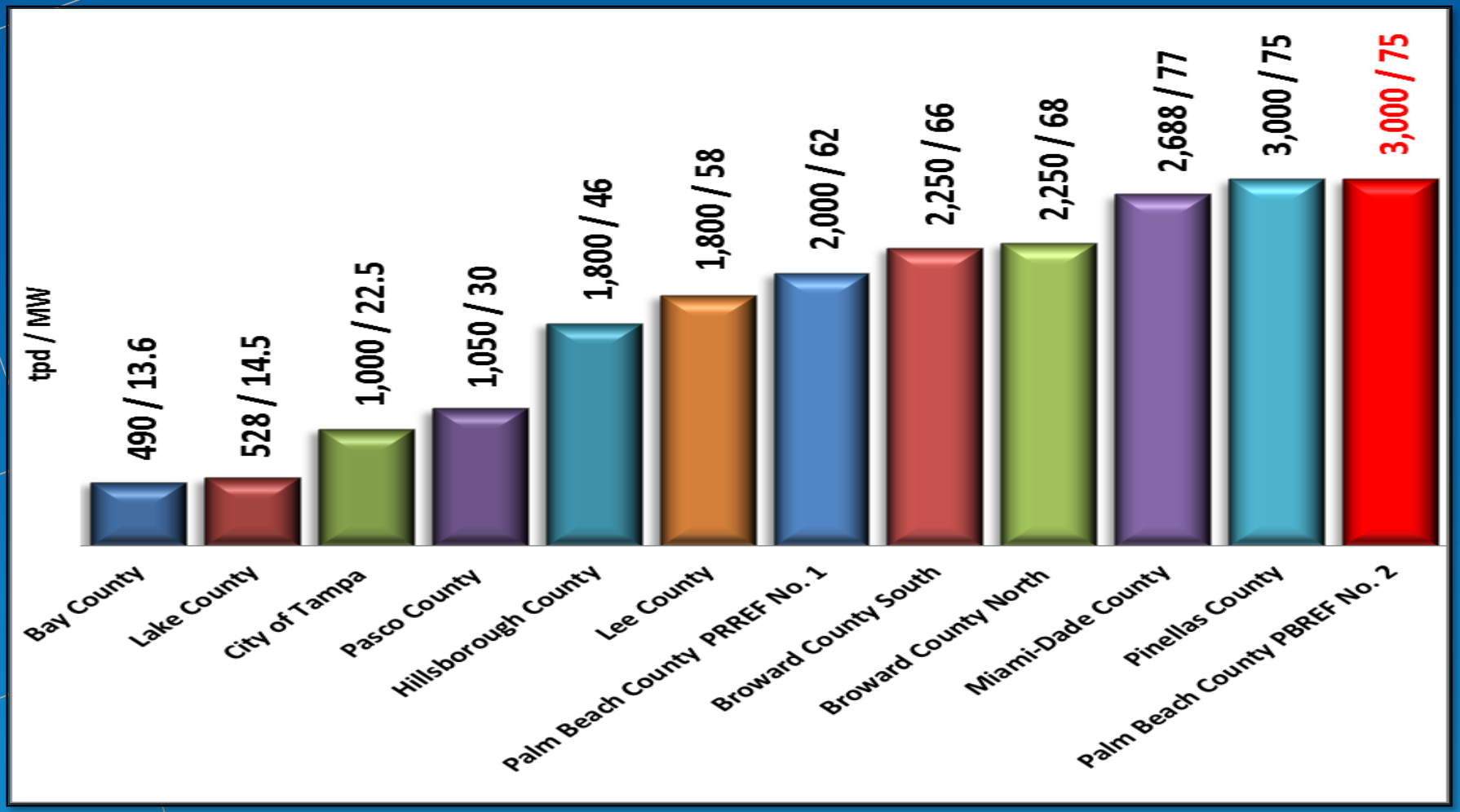
60 full-time employees

$4 million annually in payroll to the local community

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



Florida Waste-to-Energy Facilities
12 Facilities with 607 MW of Renewable Electricity



City of Tampa WTE Facility
Located on Public Works Campus

City of Tampa WTE Facility
1,000 TPD Massburn – 22.5 MW

- Original construction: 1975
- Rebuilt as WTE: 1985
- Retrofit for CAAA: 1998-2001

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

City of Tampa - Public Works
Recycled Asphalt Pavement

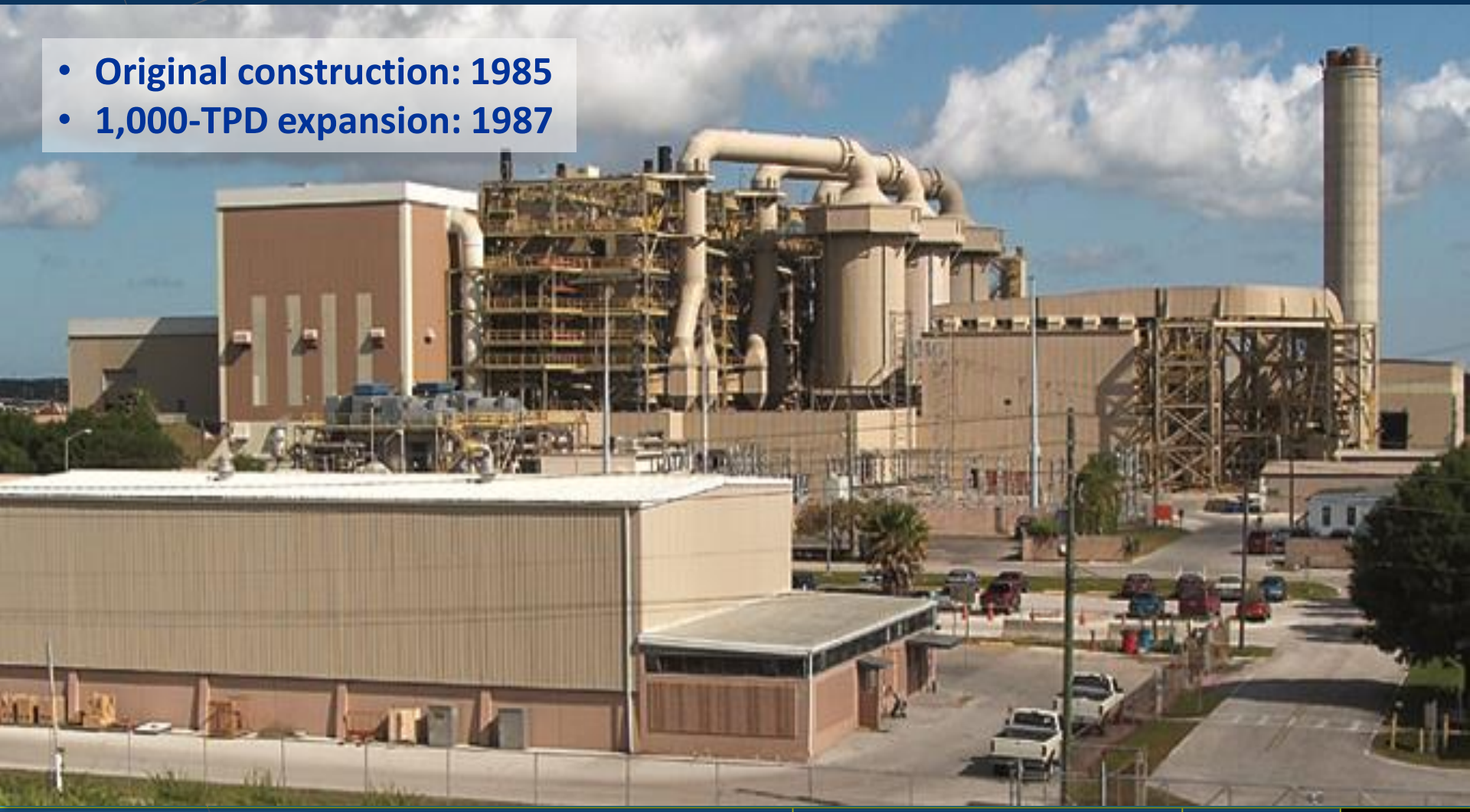
City of Tampa Public Works
Recycling Used Ceramics

Toilet bowls and household ceramics stockpiled at City of Tampa Public Works yard for later crushing and sizing to <1/2 inch

Pinellas County WTE Facility Located on Integrated Solid Waste Management Campus

Pinellas County WTE Facility

3,000 TPD Massburn – 75 MW Net Electrical Output



- **Original construction: 1985**
- **1,000-TPD expansion: 1987**

Hillsborough County WTE Facility Located on Public Works Campus

Hillsborough County WTE Facility

1,800 TPD Massburn – 46 MW Net Electrical Output

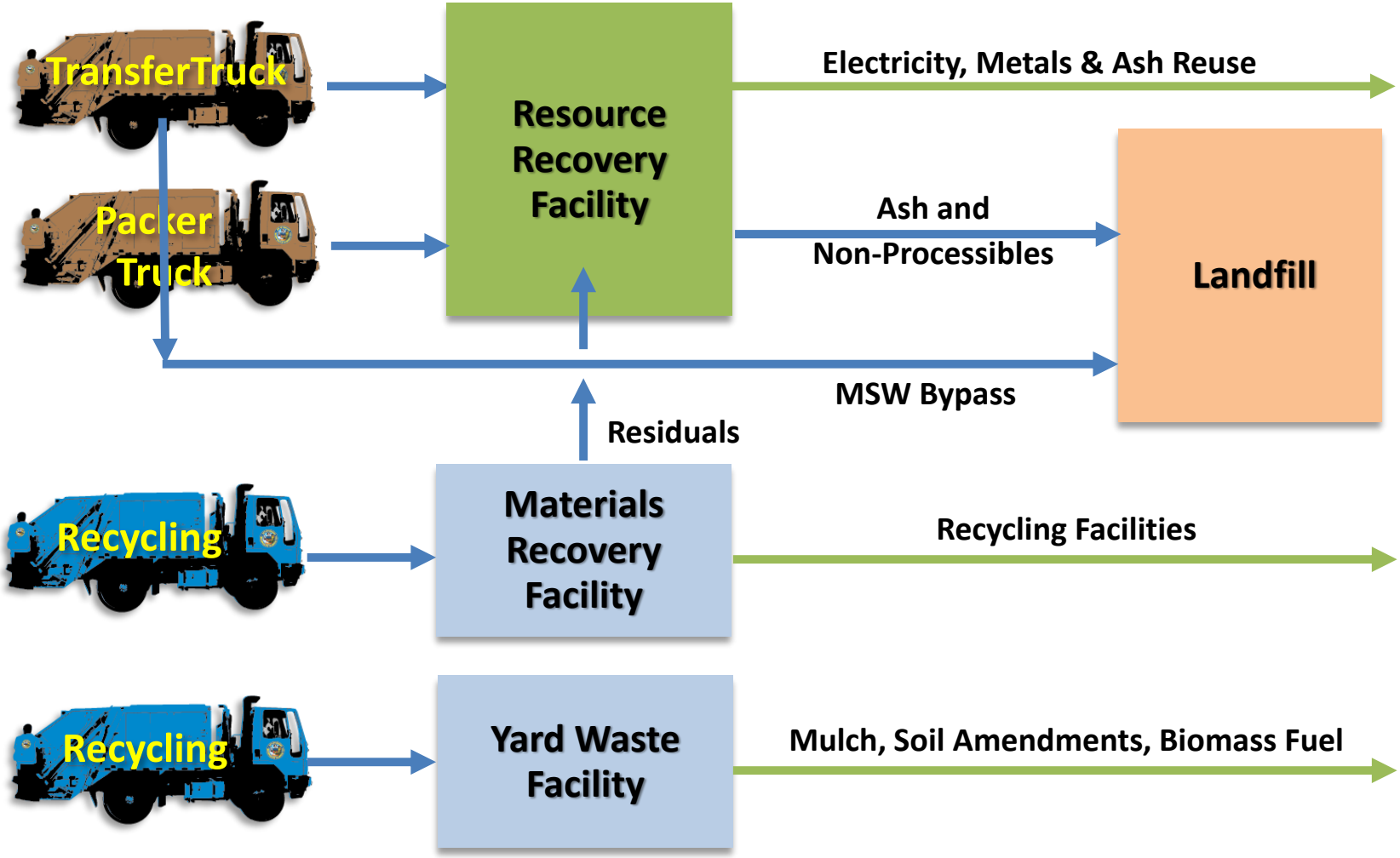
Original 1,200-TPD construction: 1987
600-TPD expansion completed: 2009

Compatible with the urban landscape

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

Hillsborough County Florida
WTE and WWTP Synergy

Hillsborough County
Integrated Solid Waste Management System



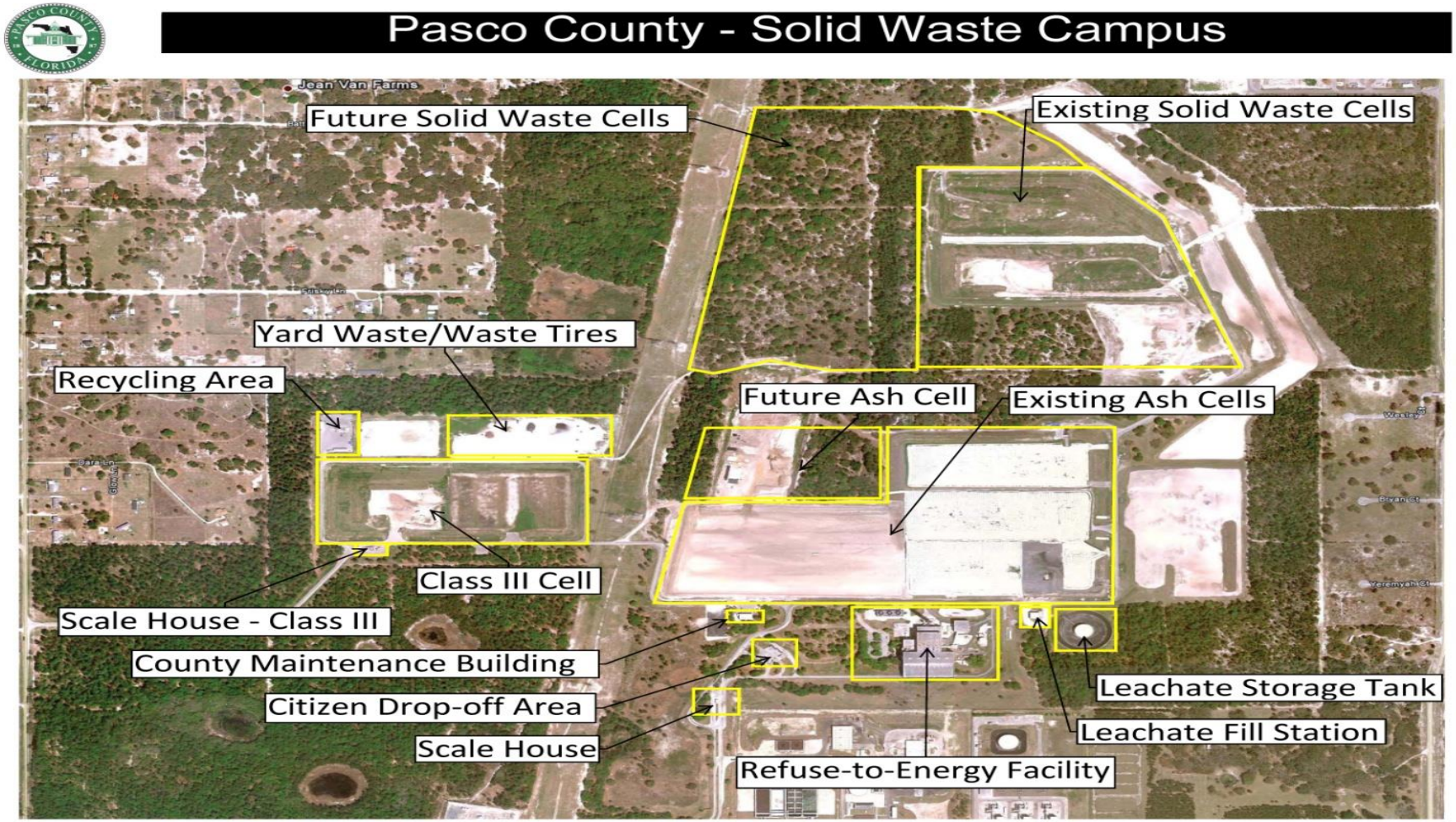
Hillsborough County ISWM
Taking Advantage of Former Landfill Sites

Hillsborough County ISWM
Waste Tire Collection and Processing Center

Pasco County WTE Facility Located on Integrated Utility Campus

- Raw Waste Landfill
- C&D Landfill
- Ash Monofill
- 1,050 TPD WTE Facility
- Citizen Drop-off Facility
  - Recyclables
  - Yard waste and tires
  - Household Hazardous Waste
- Adjacent WWTP (8-mgd)

Pasco County Integrated Solid Waste Management and Utility Campus



Pasco County Florida WTE

1,050 TPD Massburn – 30 MW Net Electrical Output

Machine for "Halving" Tires on Rims
Supplemental Fuel for Pasco County WTE

Chipped Tires
Supplemental Fuel for Pasco County WTE Facility

Lee County WTE Facility Located on Integrated Solid Waste Campus

Lee County WTE Facility
1,800 TPD – 58-MW Electrical

- **Original construction: 1994**
- **636-TPD expansion completed: 2006**

Palm Beach County WTE Facilities (2) Located on Integrated Solid Waste Management Campus

- **Raw waste and ash landfill**
- **Construction and demolition debris landfill**
- **2,000 tpd RDF WTE facility**
- **3,000 tpd Massburn WTE facility (2015)**
- **Recycling facilities**
- **Household hazardous waste drop-off facility**
- **Compost facility**
- **Biosolids drying / pelletizing facility**

Palm Beach County
Rendering of New 3,000 TPD Massburn WTE

Sustainability and enhanced aesthetics have been integrated into the design of this facility, the first new WTE facility in the US since 1996

Palm Beach County

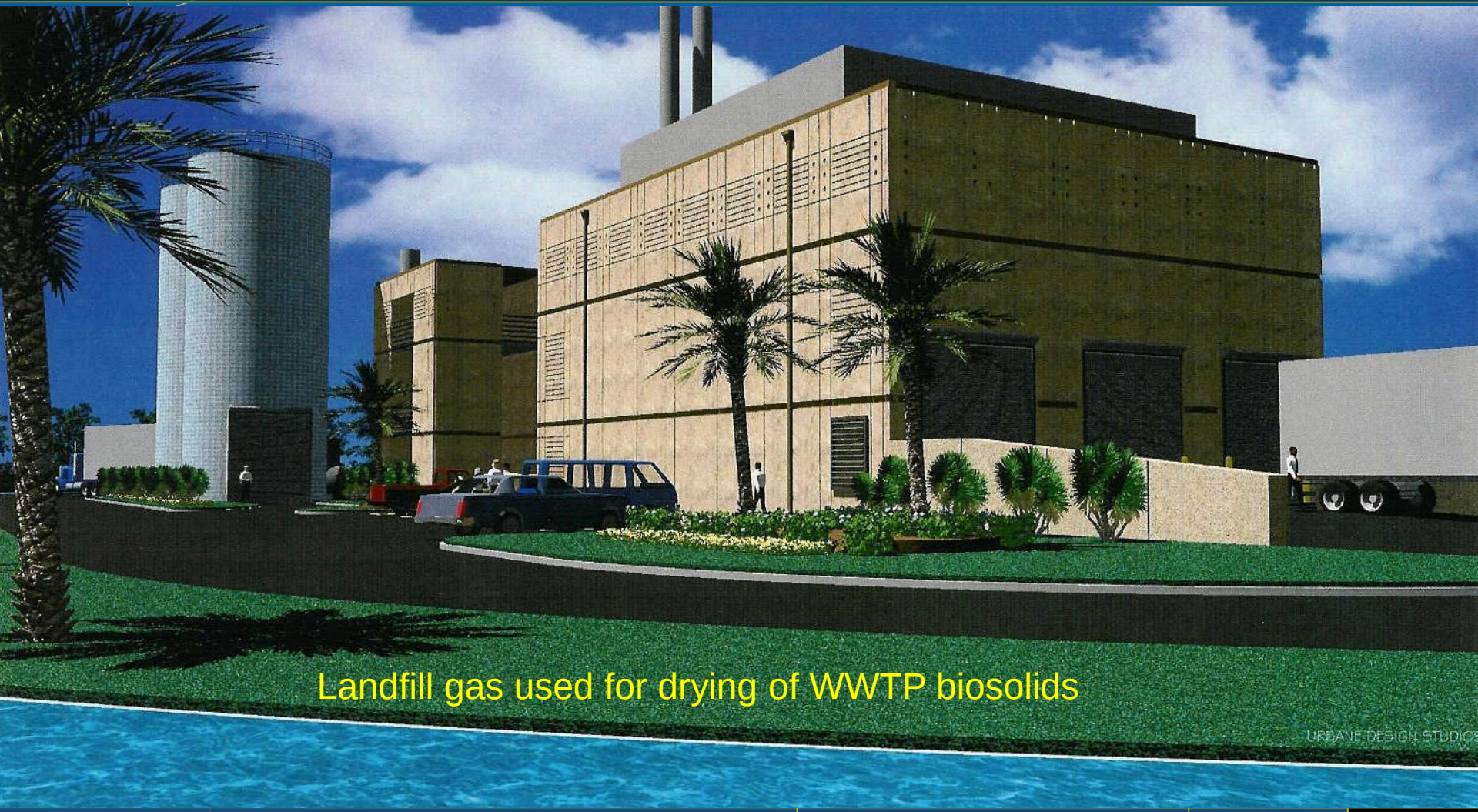
Incorporating Rainwater Harvest (First 2” of Rain)

Palm Beach County

Visitors Center with Elevated Tour Walkway

Palm Beach County

Regional Biosolids Processing Facility on ISWM Campus



Supplemental Waste Program
Lancaster County Pennsylvania

Opportunities to Generate Revenues at Modern WTE via Special Waste Program

- Co-combustion of Special Wastes:
  - WWTP biosolids
  - Used tires
  - Carpet
  - Construction and Demolition (C&D) combustibles
  - Bulky waste
  - Off-spec / out of date / confidential materials (assured destruction)
  - USDA regulated garbage (international waste)
  - Auto shredder residue
  - Expired pharmaceuticals
  - Special industrial waste
  - Marine and fishing waste
  - Liquid waste

Windmills on Landfill
Lancaster County Pennsylvania

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

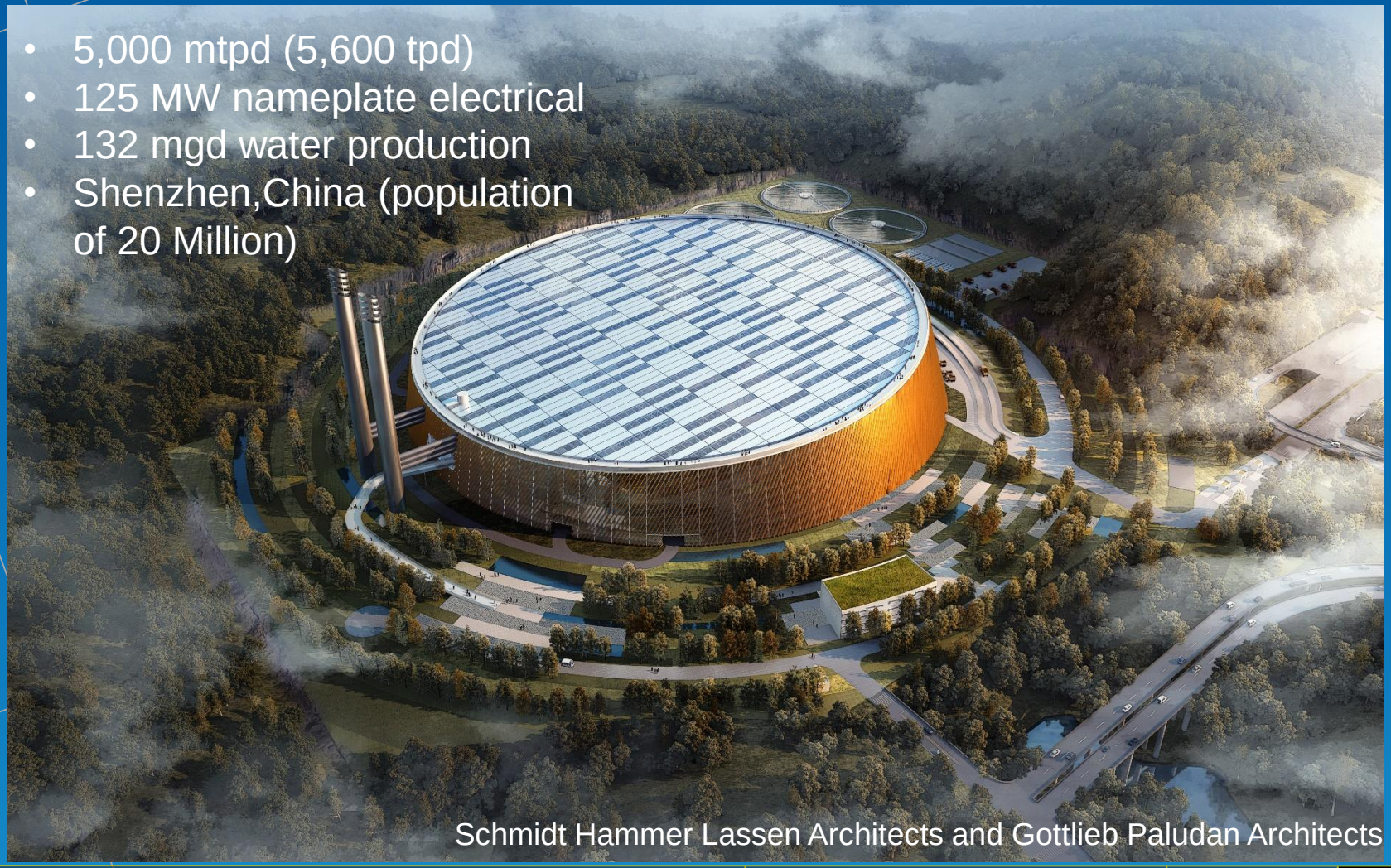
Hennepin County Minnesota WTE
WTE is Compatible with Urban Development!

Isséane Waste to Energy Facility in Paris France

(partially underground to blend in with local development)

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

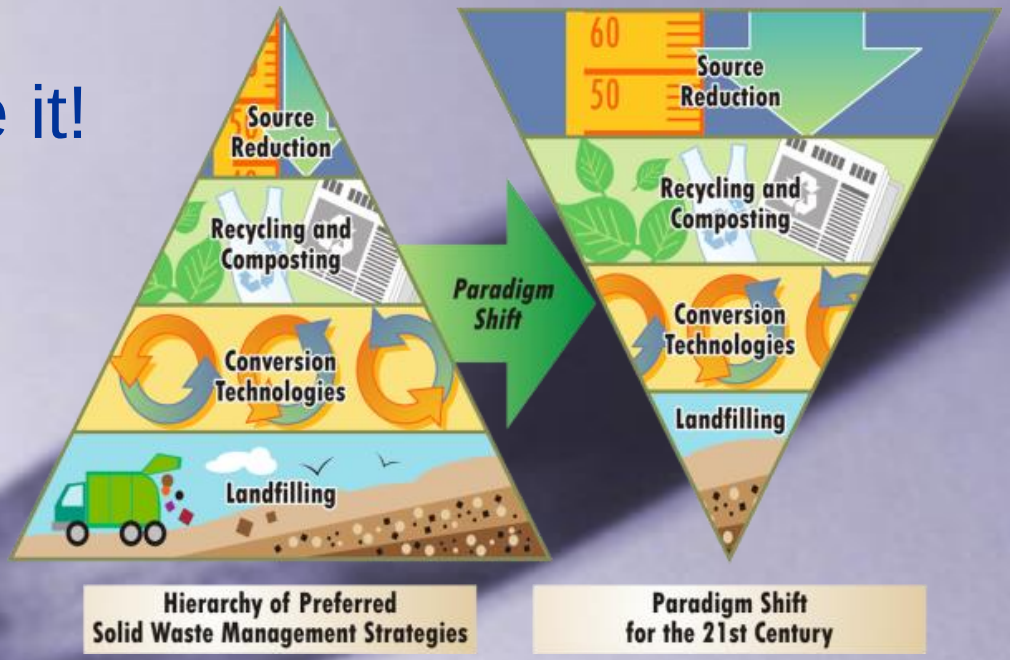
- 5,000 mtpd (5,600 tpd)
- 125 MW nameplate electrical
- 132 mgd water production
- Shenzhen,China (population of 20 Million)



Schmidt Hammer Lassen Architects and Gottlieb Paludan Architects

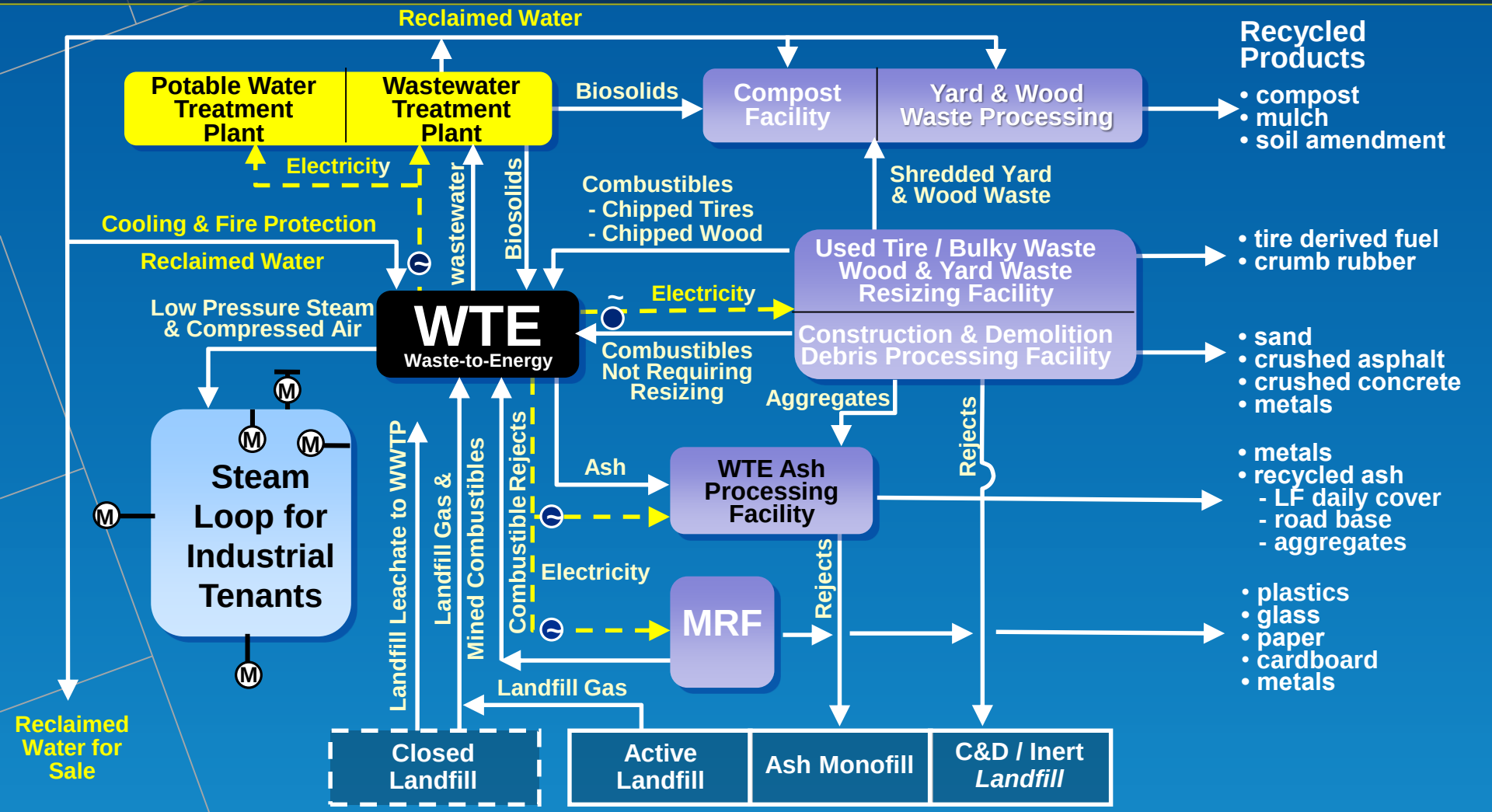
The Future for Integrated Sustainable Waste Management

We'll see it…
when we believe it!



Teaching future generations to make Transition from Waste Management to "Resource Management"

Campus for Management of Municipal Resources... Solid Waste, Recycling, and Water Resources



Teaching the Next Generation…We are all Waste Generators and it's only Waste…if we Waste it.!

- Waste Management must morph into Resource Management
- Reduce use of fossil fuels (coal, oil, natural gas) by accounting for all environmental costs and replace with clean energy (solar, wind, bioenergy, and biochemicals)
- Cheap and plentiful fossil fuels are essential for our current way of life, rapid changes could have negative consequences. Need to develop equitable way to alleviate pain of higher cost of energy!
- Circular economy must replace outdated linear economy model of "take, make, waste". A circular economy is one that is restorative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. – Ellen MacArthur Foundation

Replace 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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