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Waste: The Overlooked Resource

Waste Plastics to Fuel

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Energy & Environment Committee

Sunday, July 17th, 2011
Memphis, TN

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The Future

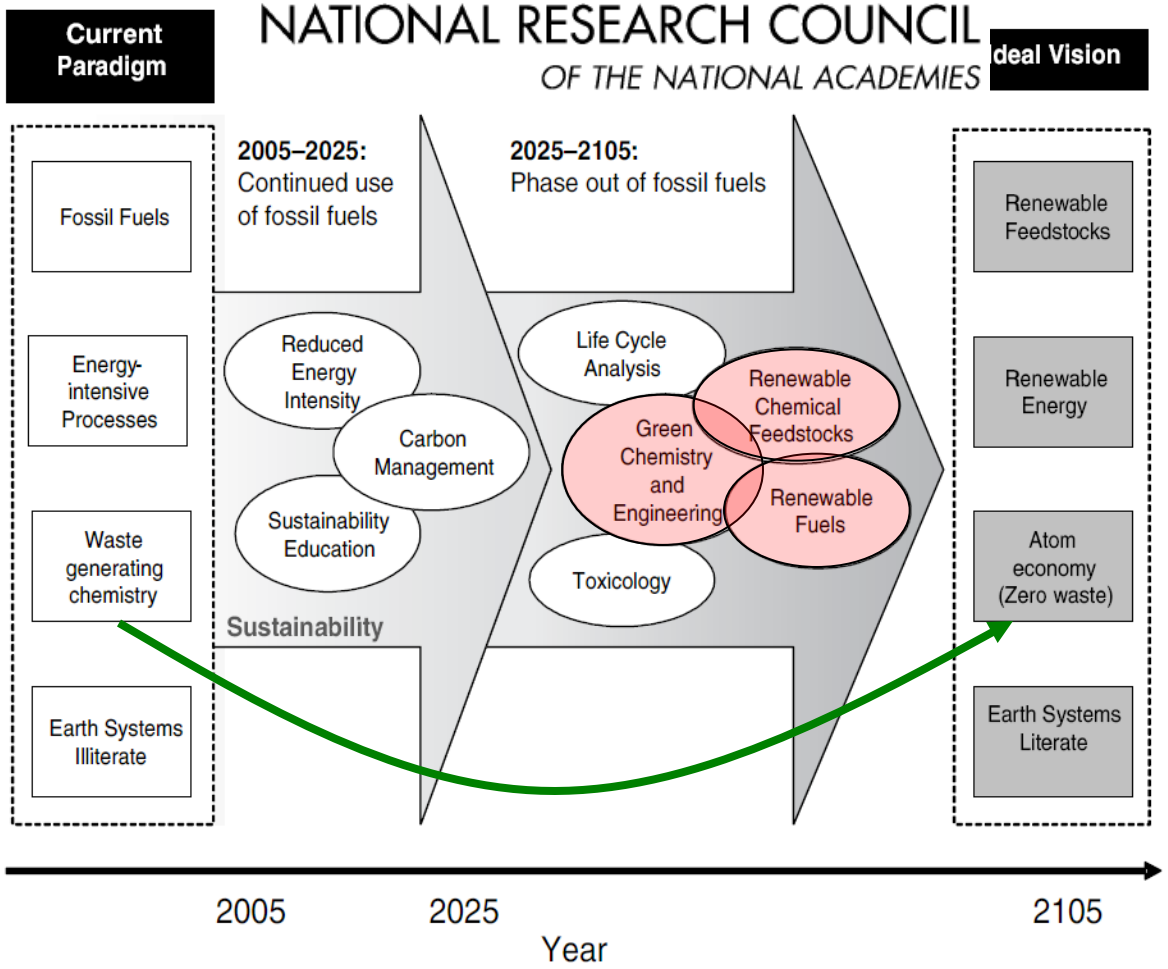

FIGURE ES-1 The Grand Challenges (ovals) for Sustainability (large arrows) that address the transition from current thinking to the ideal vision for the chemical industry over the next 100 years. See text for a more detailed description of figure and the Grand Challenges.

Source: *Committee on Grand Challenges for Sustainability in the Chemical Industry Board on Chemical Sciences and Technology Division on Earth and Life Studies*

- Fossil Fuels will play smaller role
- Renewable / indigenous fuels will become more prominent
- Education needs to continue
- Carbon management is here to stay

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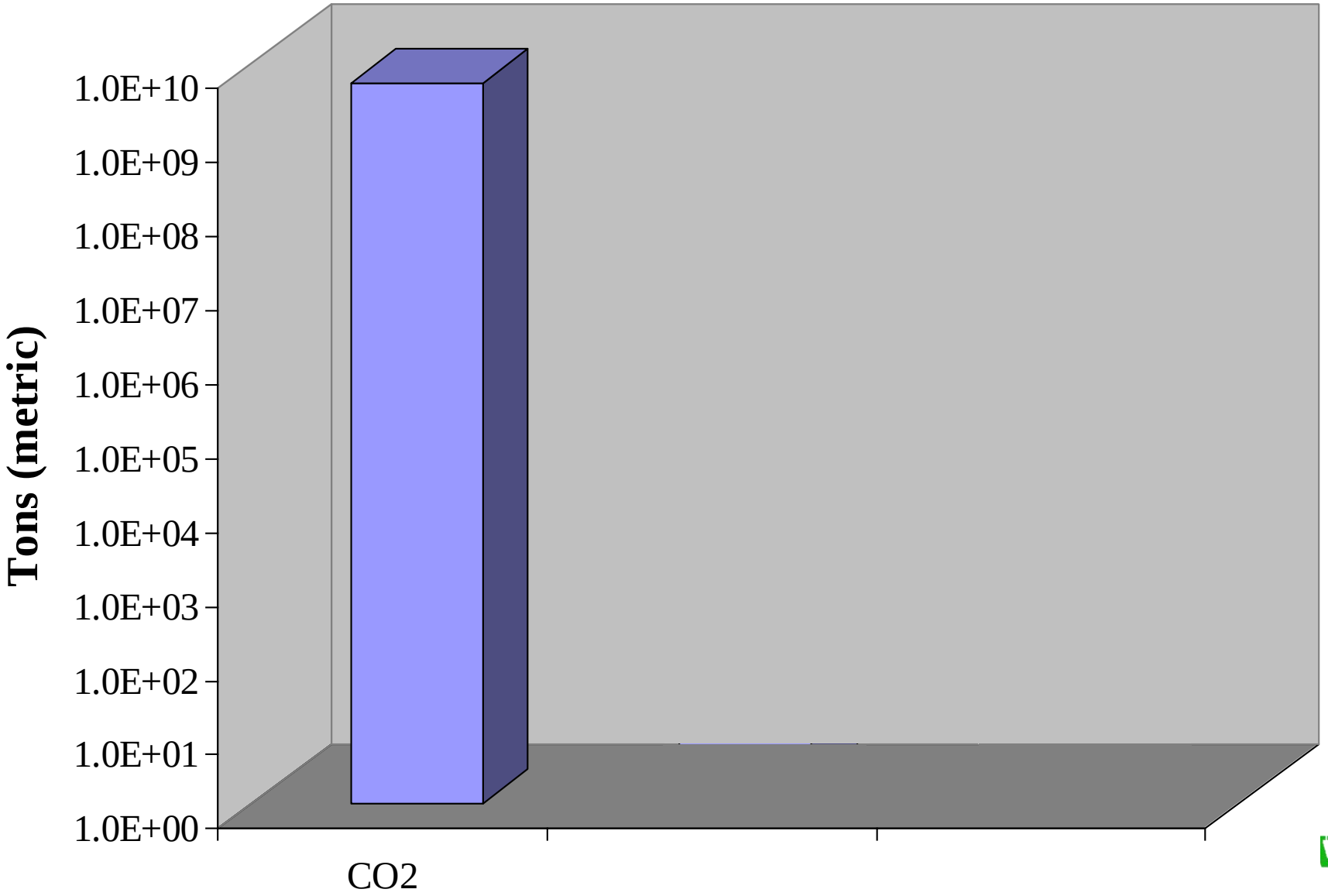
U.S. Wastes



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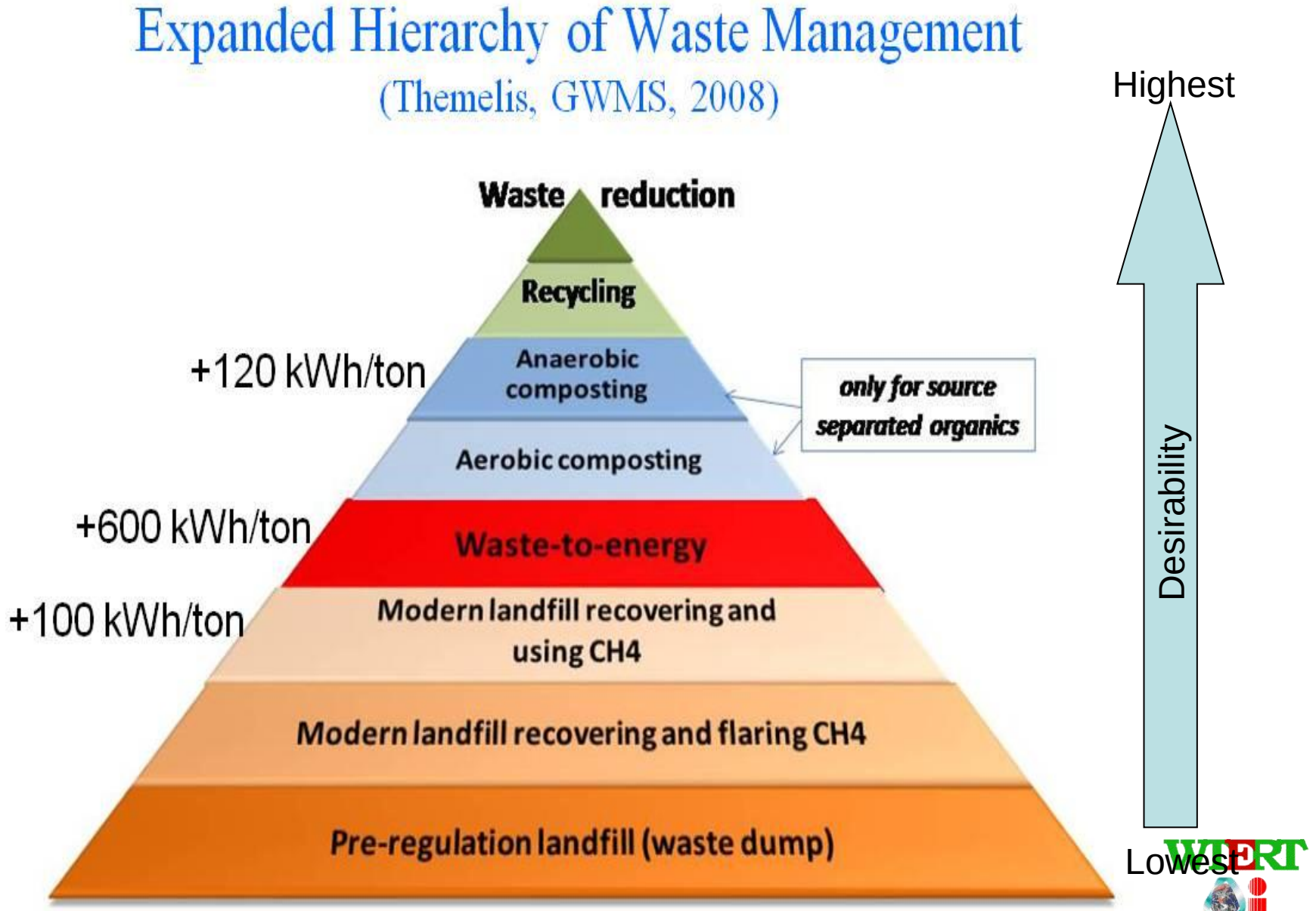
Recommended Methods for Muncipal Solid Waste (MSW)



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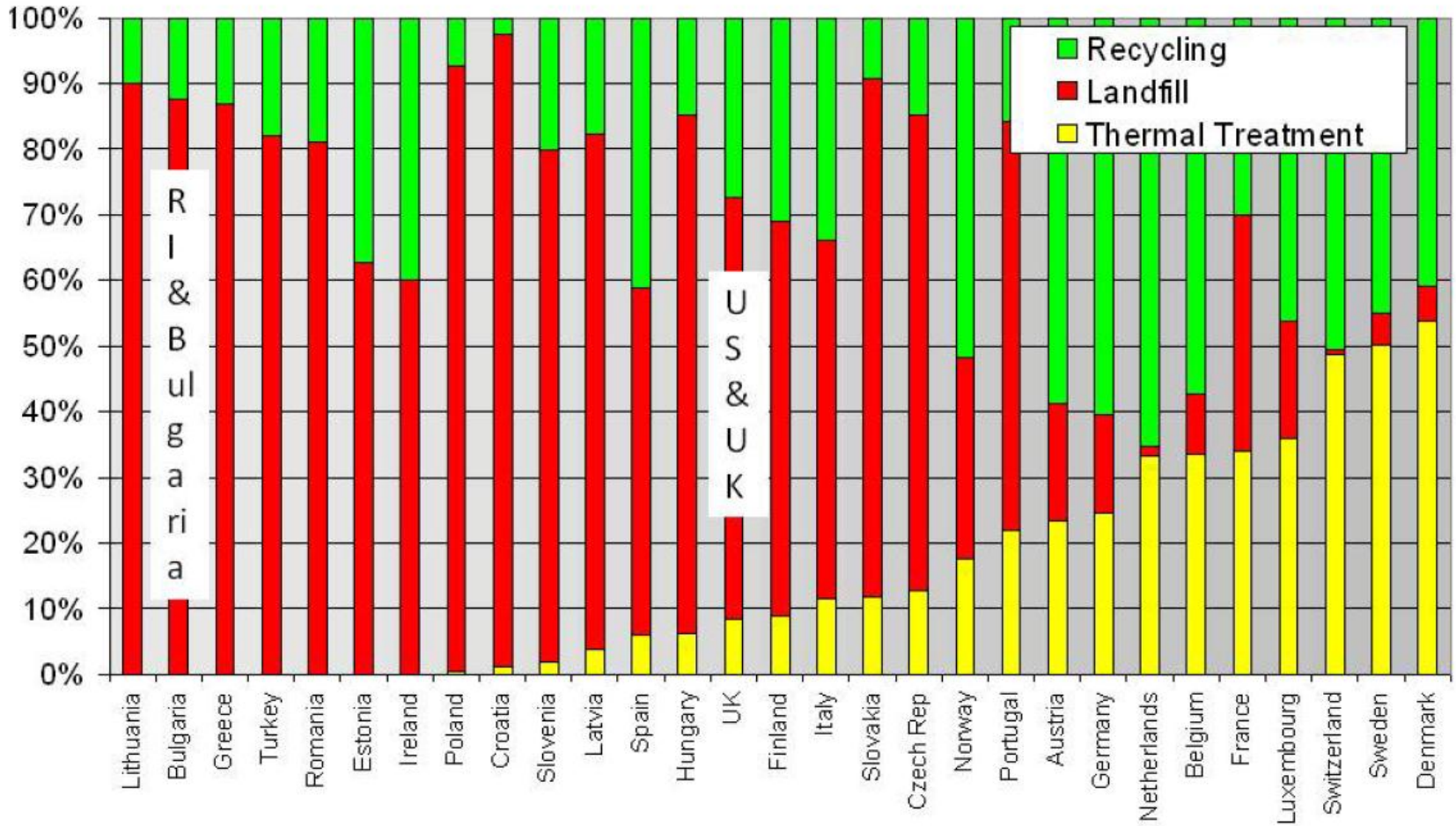
EEC has debunked the myth that WTE interferes with recycling

(e.g., EEC presentation to Rhode Island Assembly Committee)

DISPOSITION OF MSW IN EUROPE, THE U.S. and R.I.



Eurostat analysis by M. Baur, MSZ – U.S. and R.I. data: N.J. Themelis, May 25, 2009

Packaging is a Valuable Resource

Protects products

Extends shelf life of food:

- Prevents food spoilage
- More product shipped w/ less packaging
- Less resources are consumed
- Less emissions are generated
- Reduce impact of climate change

Fosters a safer and healthier society

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Plastics Recycling is growing

- **Nearly 95% of U.S. households have access to plastic recycling programs.**
- **More than 4 billion pounds of plastic are recycled annually.**
- **More than 2.4 billion pounds of plastic bottles were collected for recycling in 2009.**
- **Nearly 40% of U.S. consumers have access to rigid plastic recycling.**

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Multi-Layer, Multi-Polymer Pouch

- **Huge environmental impact reductions versus glass jars**

- **Landfill volume - 95%**
- **GHG - 93%**
- **Energy - 87%**

- **Rapid market growth**
- **Multi-layer means difficult to recyclable (non-economical)**

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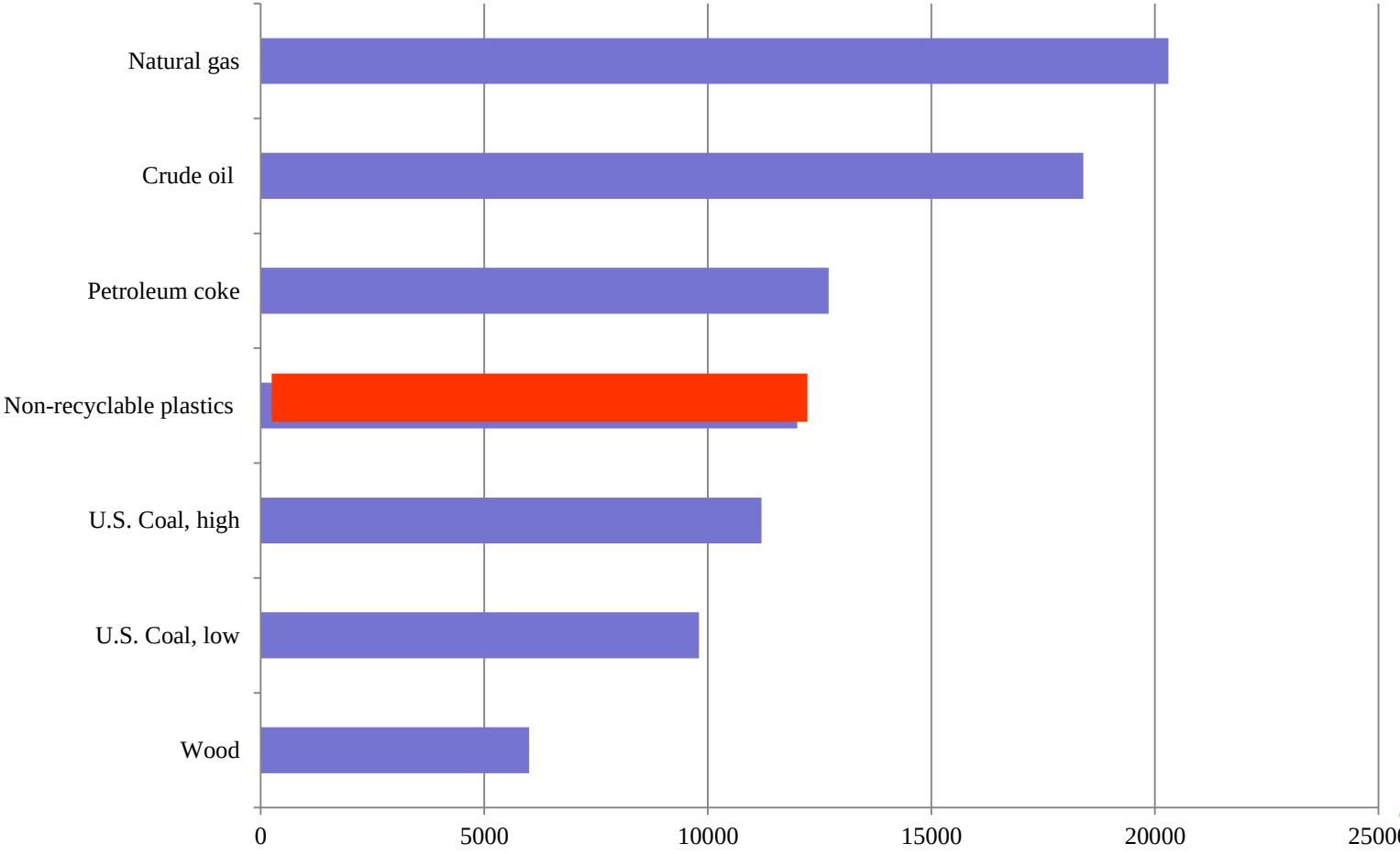
Inherent Energy in Plastics

Energy value of NRP compared to the fossil fuels used in the U.S. (lower heating value, Btu/lb)



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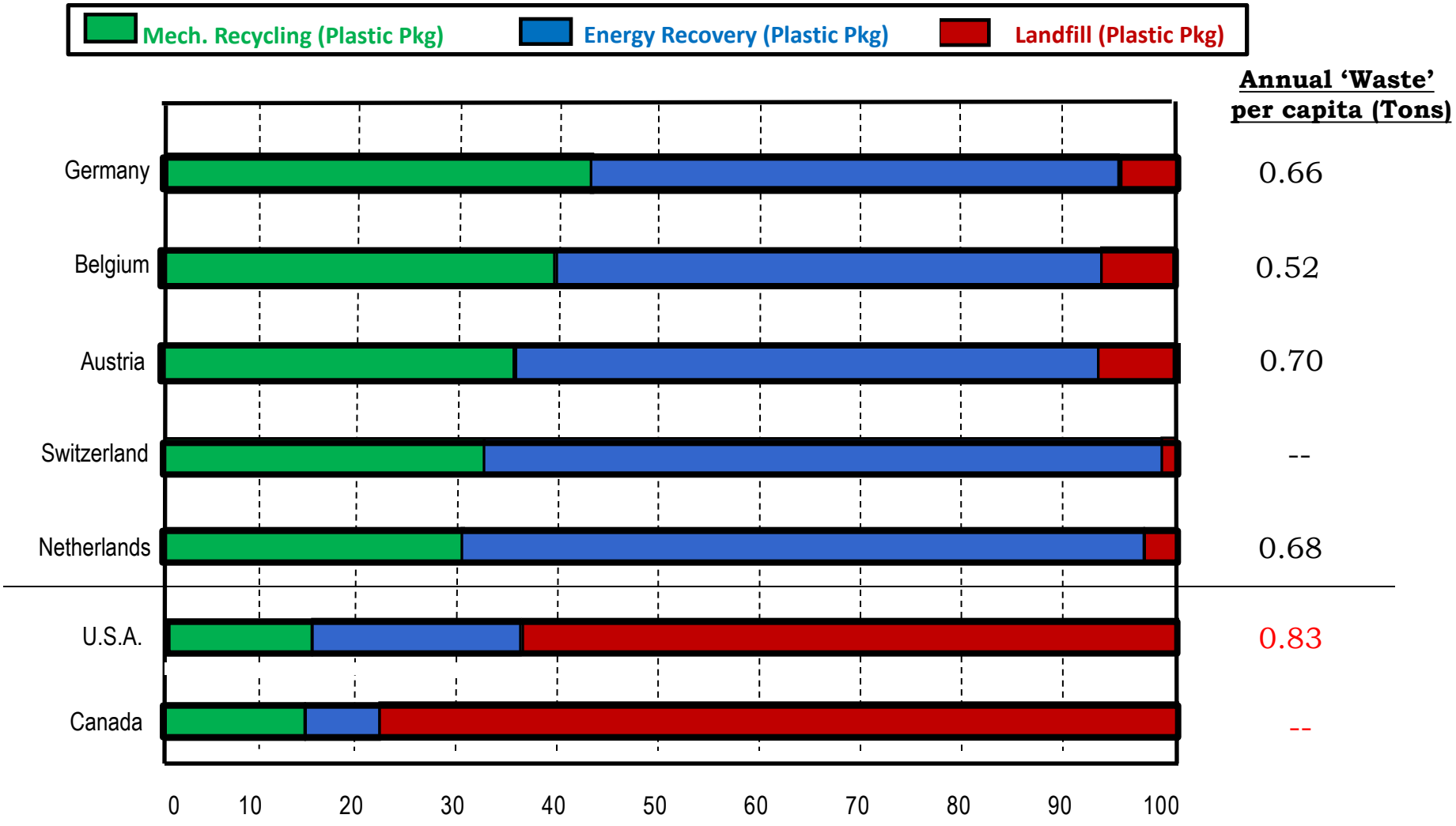
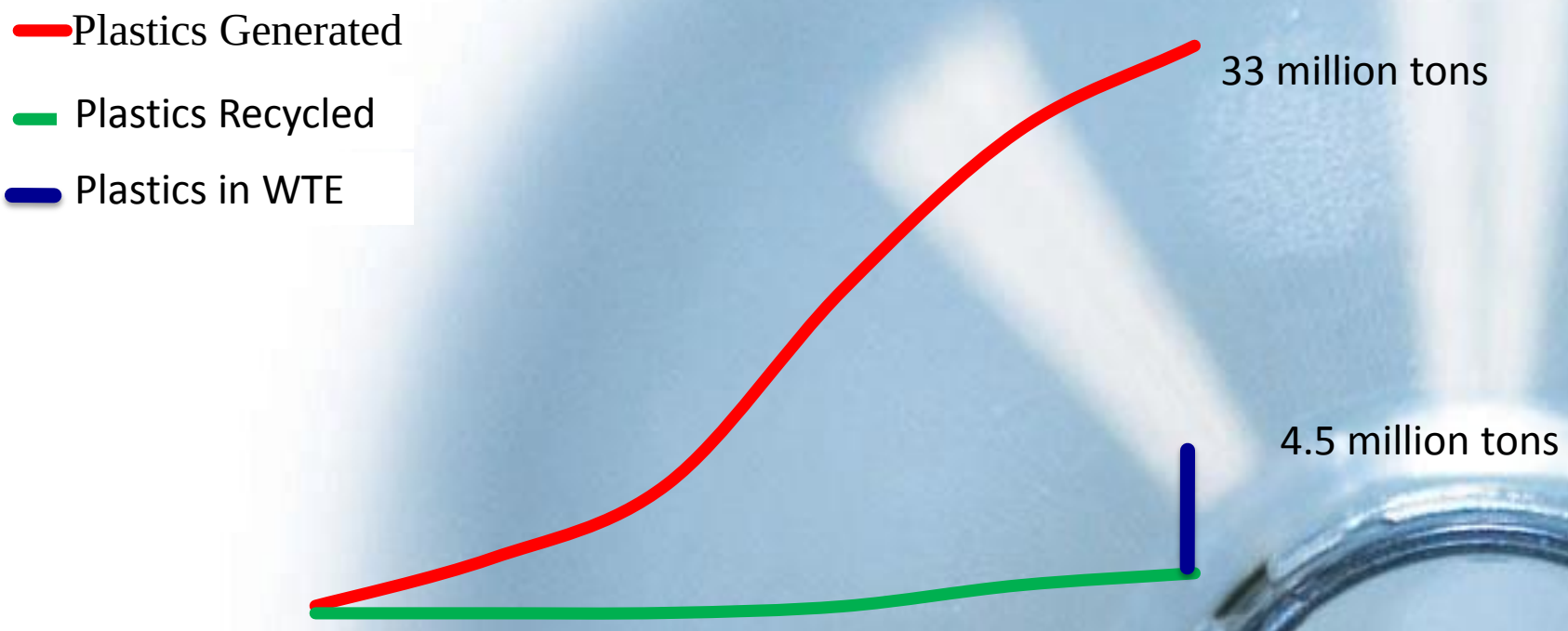
Energy Recovery is Necessary for Higher Diversion



U.S. & Canada – recycling includes composting

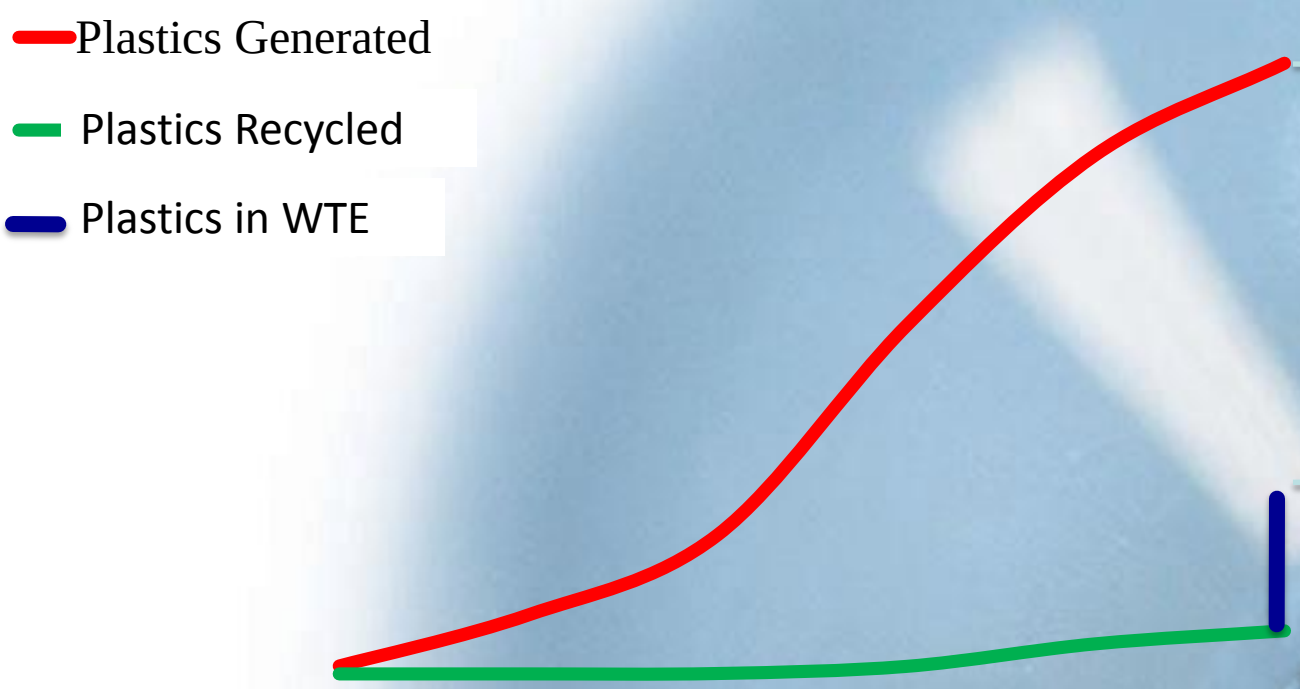
Plastics Generated & Recovered
1960-2008



Source: Jawad A. Bhatti, Earth and Environmental Engineering, Columbia University, Themelis et al, Energy and economic value of non-recycled plastics and municipal solid wastes that are currently landfilled in the fifty states, Earth and Environmental Engineering, Columbia University

Plastics Energy Recovery Opportunity

Energy Equivalents



- 666 billion cubic feet of natural gas
- 35.5 million tons of coal
- 125 million barrels of oil
- 160 million MWH electricity

Source: Jawad A. Bhatti, Earth and Environmental Engineering, Columbia University, Themelis et al, Energy and economic value of non-recycled plastics and municipal solid wastes that are currently landfilled in the fifty states, Earth and Environmental Engineering, Columbia University

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Did you Know?

•Hypothetically, if all of the plastics in MSW that went to landfill in 2009 were converted to oil – we could power 6 million cars for a year!!!

•Hypothetically if all of the plastics that went to landfill in 2009 were captured to create electricity – we could supply enough energy to power 4.5 million households for a year!!!

- Example*: Georgia and Oklahoma ***combined***

•Hypothetically if 100% of all the Municipal Solid Waste landfilled in 2009 was converted to energy – it would supply enough energy to power 16.4 million households!!!

- Example: reduction of 20% of oil imports

*http://www.energystar.gov/ia/partners/promotions/change_light/downloads/State_Households_and_energy_prices.xls

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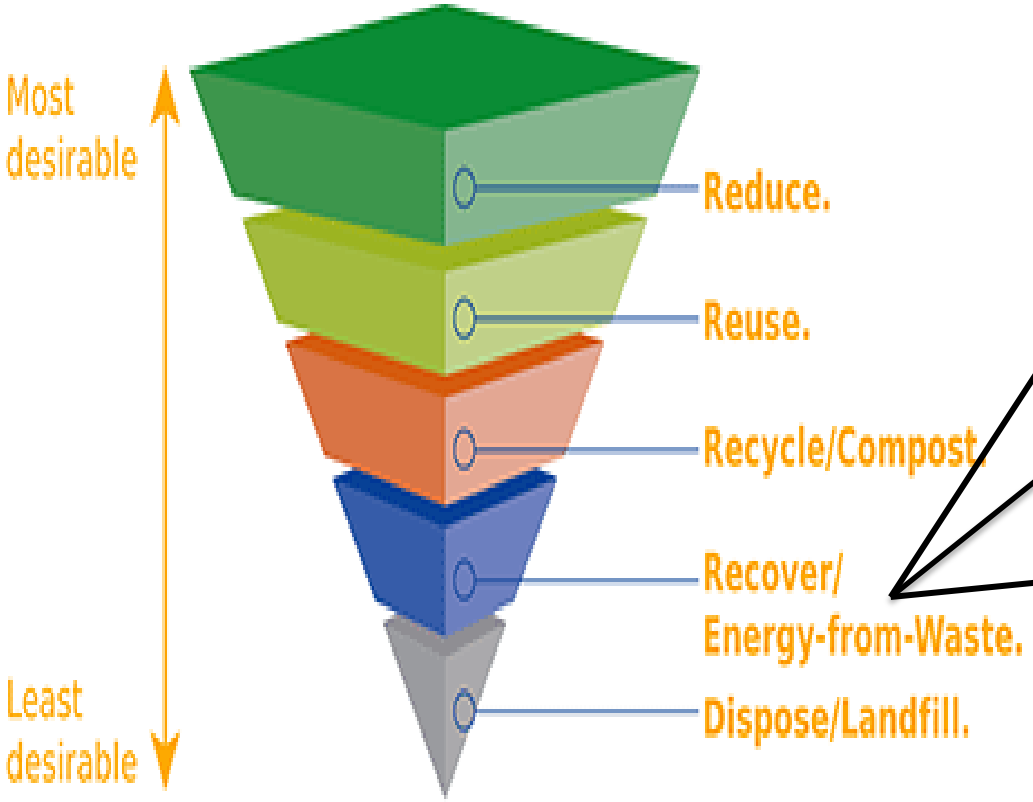
Utilizing All EOL Resource Management Options

EPA's Integrated Solid 'Waste' Management Hierarchy



Emerging Technologies
Eg. Gasification, Pyrolysis, Plasma Arc, Microwave

Solid Recovery Fuel
Eg. Cement / Coal Plants

Combustion with Energy Recovery

Combustion No Energy Recovery

All options are needed to minimize disposal in landfills. Resource conservation is key.

Source: U.S. Environmental Protection Agency

Waste Utilization Efforts

- Military MISER program
  - Trash/Biomass/Solid hydrocarbons to fuels
- American Chemical Society (ACS)
  - Letters to the editor – "chemicals from waste"
    - C&EN April 2006
- Discover Magazine –
  - "DATA" Section : The Ultimate Garbage Disposal
    - How to turn trash into clean energy – Geoplasma Unit
      - 160 MW by 2009, St. Lucie County, Florida
- WTE is attracting interest (confirmed by AIChE and other observations)
  - Coskata ($250 MM), Enerkem ($80 MM) & Ineos ($75 MM) → biomass & MSW to fuels

All are thermal processes

Pyrolysis, Gasification or Combustion

- Normally no air
- Only heat (external or internal)
- Want liquid, Gases not desired
- Pollutants in reduced form (H_2S, COS)
- High Char
- **Scale: ~ 10 tons/day**

- Sub stoichiometric air
- Lower total volumetric flow
- Lower fly ash carry over
- Pollutants in reduced form (H_2S, COS)
- Char @ Low T
- Vitrified Slag @ high T
- **Scale: ~ 100 tons/day**

- Excess air
- Higher volumetric flowrate
- Fly ash carry over
- Pollutants in oxidized form (SO_x, NO_x, etc)
- Bottom ash
- **Scale: ~ 1500 tons/day**

No additional Oxygen (only heat)
Unconverted solid will remain!

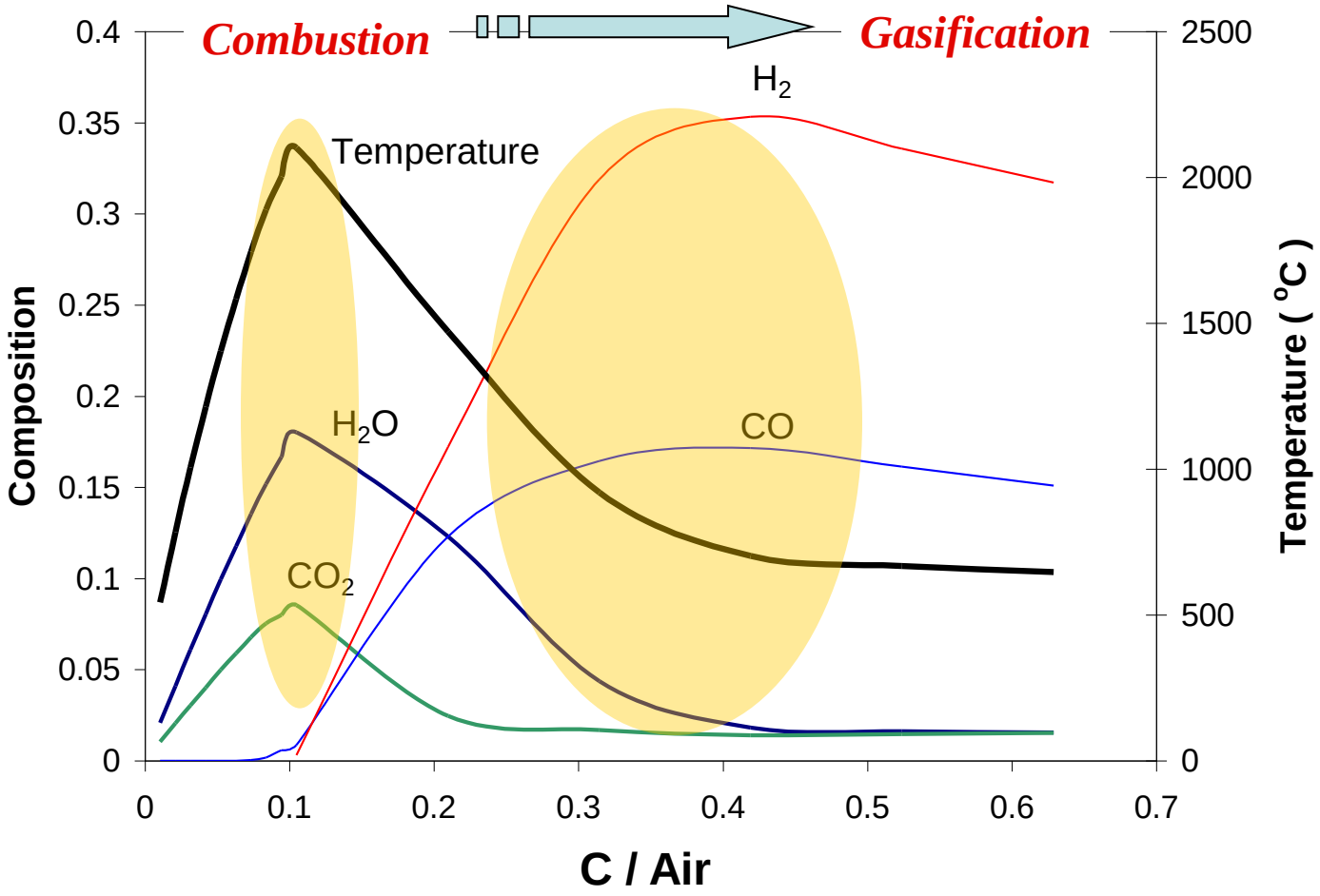
Some additional Oxygen (or air)
Heat added or comes from reactions

Much additional Oxygen (or air)
Heat comes from reactions

Combustion to Gasification

$C + O_2 \xrightarrow{\text{Combustion}} CO_2 + 2H_2O$

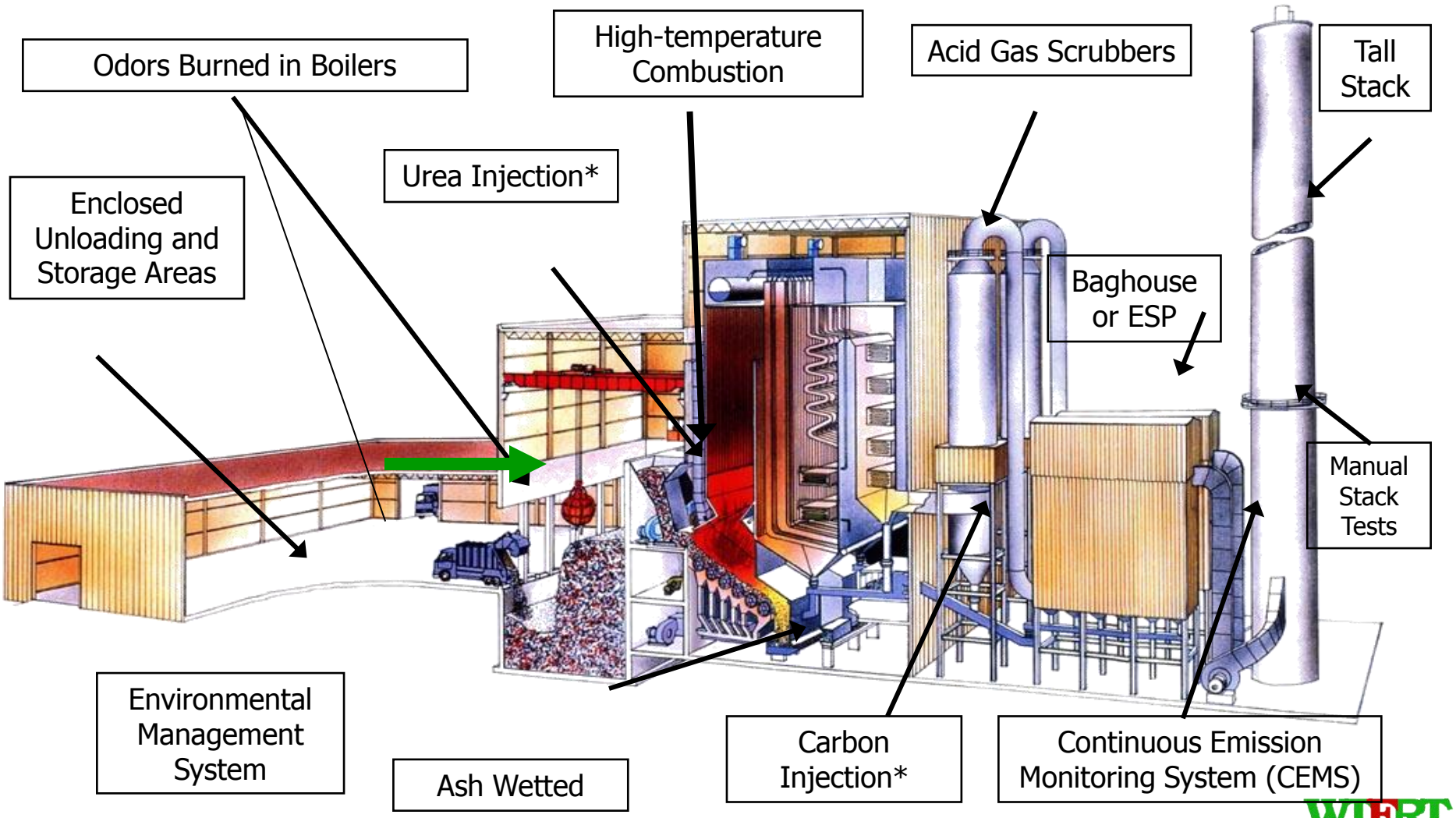
$C + O_2 \xrightarrow{\text{Gasification}} 2H_2 + CO$



C,H,O in waste source → H_2O & CO_2 (combustion) or H_2 & CO (gasificaiton

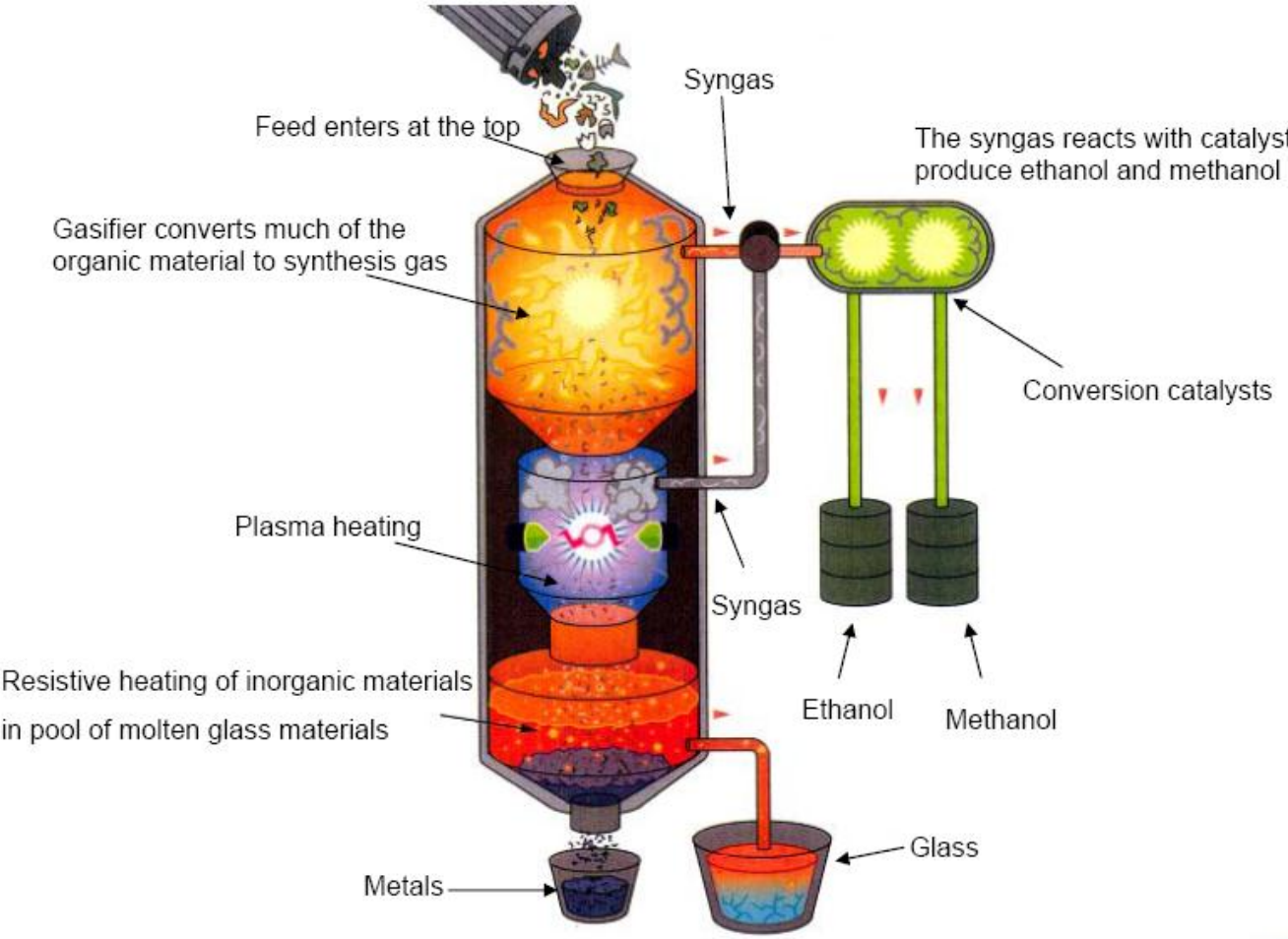
Ref: STANJAN calculations

Traditional Waste-to-Energy Plant



INENTEC Plasma Unit

Liquid Fuels from Municipal/Commercial Waste



Leading Plasma Gasification Solutions

Integration:

- Gasifier
- Plasma Unit
- Thermal Residence Unit

All operated in "sweet spot"

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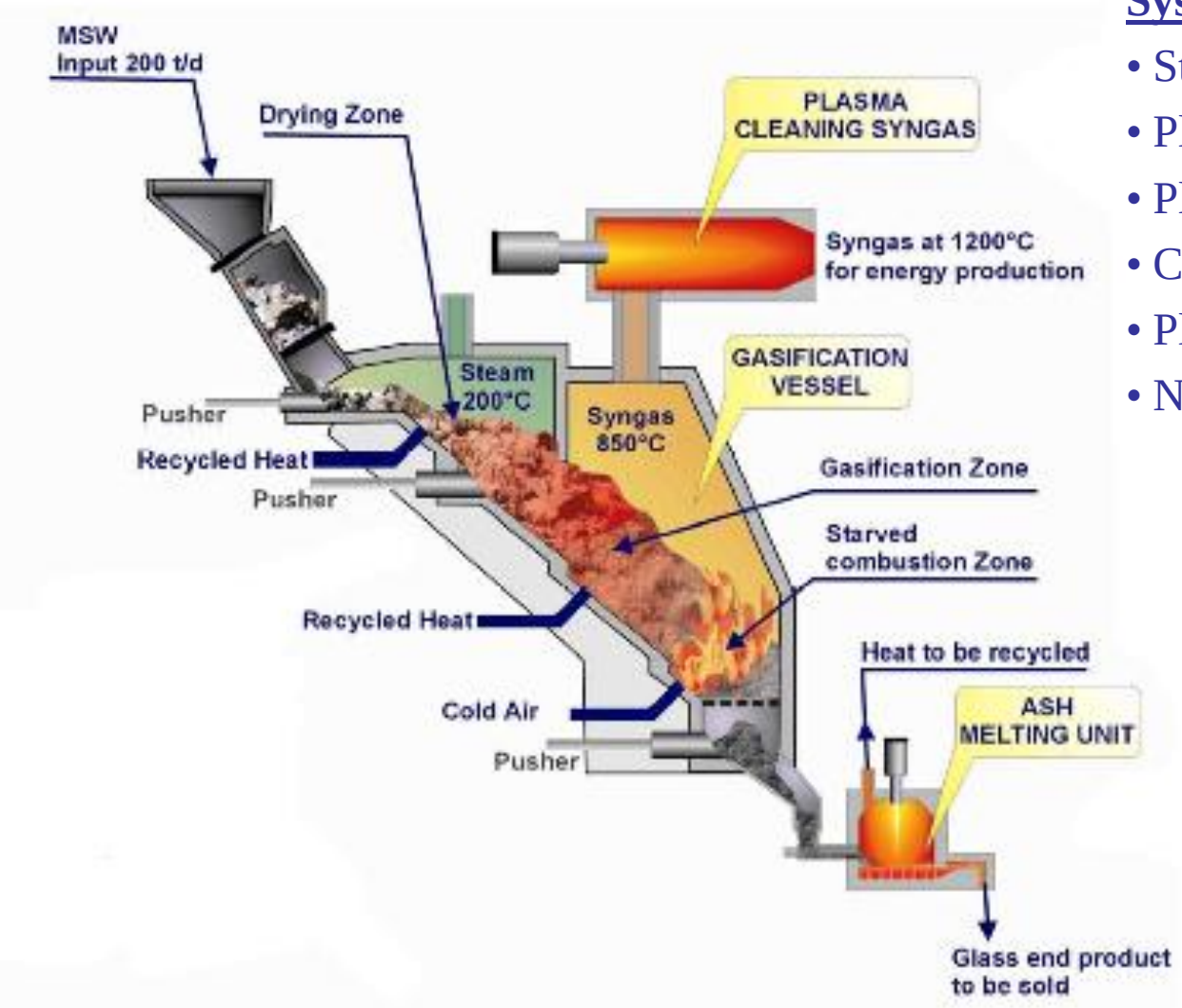
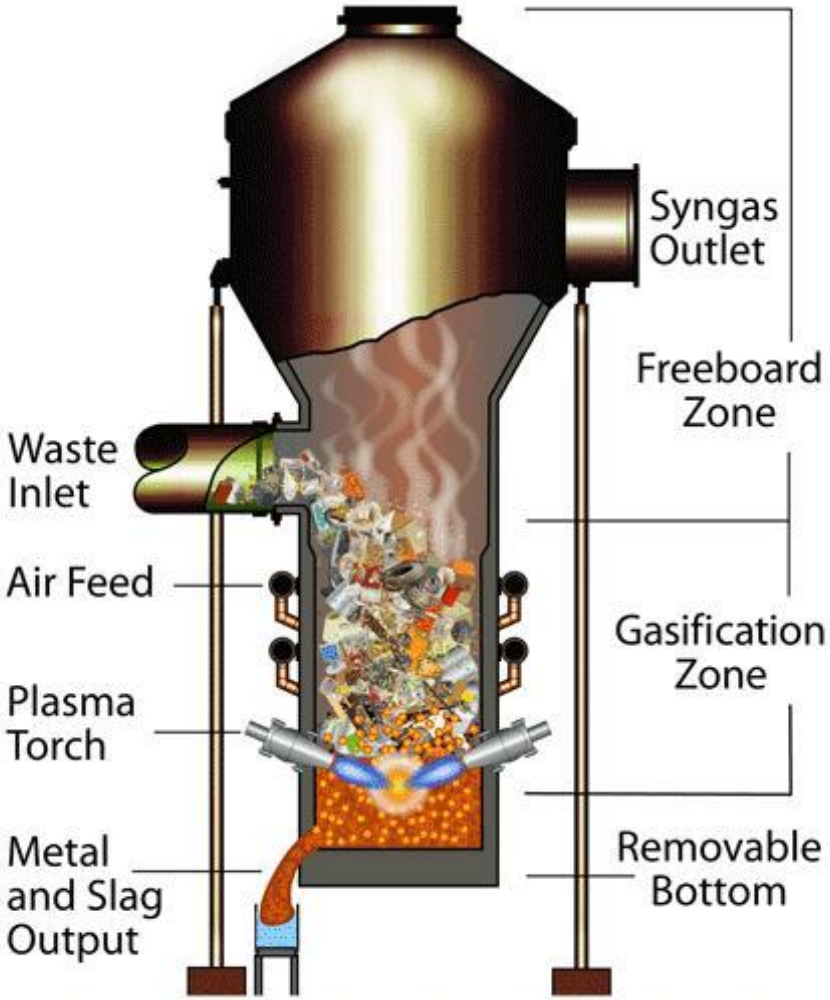
Europlasma



System:

- Stoker Grate Gasifier
- Plasma Unit for Syngas Cleaning
- Plasma Unit for Ash Vitrification
- Commercial Startup → April 2011.
- Plant capacity will be 50,000 tons/y
- Net electrical output → 12 MW

Alter NRG (Westinghouse)



System:

- Metallurgical coke (met coke) injected
  - retain the heat energy from the plasma torches
  - Provide a "skeleton" to support MSW in the gasifier
- Similar to the phenomena occurring in an iron cupola or blast furnace.
- Process can handle any moisture in MSW
- Main commercial plant in Utashinai
  - Originally; 80% ASR / 20% MSW @ 180 tpd
  - Plant operating on 100% MSW @ 150 tpd

Plasma Gasification Field System Summary

Technology	Energy (kWh/ton)	Capital Costs ($/ton)
InEnTec	530	~77 (est)
Alter NRG	617	81
Europlasma	605	86
Plasco	530	86
Grate WTE (US avg)	550	60

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Plastics to Oil

- Complementary to existing Plastics Recycling
- Pyrolysis process heats plastic waste, and turns it into a synthetic oil or diesel fuel.
- Gasification processes waste to synthesis gas (syngas) that can be converted to fuel
- Possible solution for non-recycled plastics e.g. bottle caps, labels, flexible packaging, contaminated jars, food service etc.
- ACC Study: http://plastics.americanchemistry.com/Plastics-to-Oil
  - Identified twenty-two worldwide manufacturers of plastics to oil technology
  - 3 products – Fuel/Oil; Natural Gas; Char
- Pilot facilities in North America
  - Agilyx – Tigard, Oregon
  - Climax Global Energy – Allendale, South Carolina
  - Envion - Montgomery County, Maryland (confirming new loc)
  - GEEP – Barre, Ontario (Electronics Recycler)
  - Plas2Oil (JBI Inc.) – Niagra Falls, New York
  - Vadxx – Cleveland, Ohio
- Potential: ~90 Million Barrels of Oil from plastics in MSW, even more if count post-industrial, commercial waste etc.

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Feedstock and products of pyrolysis (Envion pilot plant, MD)

Feedstock

Oil product

Heavy oil/tar residue

Flexible Packaging Association Fall Executive Conference
Chicago, September 30th, 2010

Here are some ideas

- Do you have an RPS or RFS in your state?
  - If yes, is "energy recovery" from MSW and/or plastics included?
- Is the RPS or RFS limited only to low BTU biomass?
- Do you have incentive programs in your state to help grow alternative energy ventures?
- Do you have policies to incent "recovery" via greater diversion from landfills?
- Are there excessive regulatory and permitting barriers?
- Do you have "beneficial use" provision?
- Do you have a state energy board making strategic planning? – Looking at ALL possible technologies
- Have engineers involved in the RFP
- Don't be afraid to innovate!

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Advancing the Goals of Sustainable Waste Management

What is WTERT

The Waste-to-Energy Research and Technology Council (WTERT) is a top-tier-technical group that brings together engineers, scientists, and managers from industry, universities, and government with the objective of advancing the goals of sustainable waste management globally.

http://www.seas.columbia.edu/earth/wtert/index.html

- **Industry Award:** *World's Best Waste-to-Energy facilities*:
  - **2006 – ASM Brescia, Italy**
  - **2004 – Martin GmbH, Germany**
- **Education Award:** *Person who has advanced Integrated Waste Management globally:*
  - **2006 – Prof. Paul H. Brunner**, Technical University of Vienna
  - **2004 – Prof. George Tchobanoglous**, University of California- Davis

State University of New York, Marine Sciences Research Center (U.S.)

Delft University of Technology, Dept. of Applied Earth Sciences (The Netherlands)

Sheffield University Waste Incineration Centre (United Kingdom)

National Tech. University of Athens (Greece)

University of Patras (Greece)

Institute for Thermal Power Engineering of Zhejiang University (China)

Collage of Mechanical and Energy Engineering Zhejiang University (China)

Chongqing Waste to Energy Technology Research Institute (China)

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Backup

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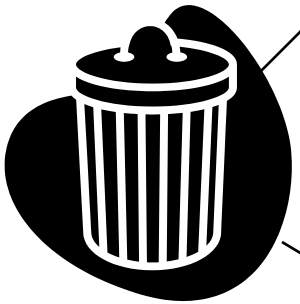
Energy from Waste:
One piece of the global warming solution

249 Million tons of trash (MSW) goes to landfills



29 Million tons of trash goes to EfW

Landfills

Renewable Energy Generated from Landfills - 5 billion kWh

Up to 120 kilowatt hours of electricity per ton of waste

EfW

Renewable energy generated from WTE Facilities - 15 billion kWh

Up to 700 kilowatt hours of electricity per ton of waste

Today's modern EfW facilities avoid 30 million tons per year of CO_2 equivalent by avoiding CO_2 from fossil fuel power plants and methane from landfills.

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Emerging Conversion Technologies

Conversion Technologies	Pyrolysis	Gasification
Feedstock	Plastics only	MSW
End Products	Synthetic Oil Petroleum Wax	Syngas Electricity Ethanol
Conversion efficiency	62-85%	69-82%
Commercial Conversion rates*	10-30 tons per day	75-330 tons per day
Product Energy Value	15,000-19,050 BTU/lbs	11,500-18,800 BTU/lbs

*Source – Research Triangle Institute International

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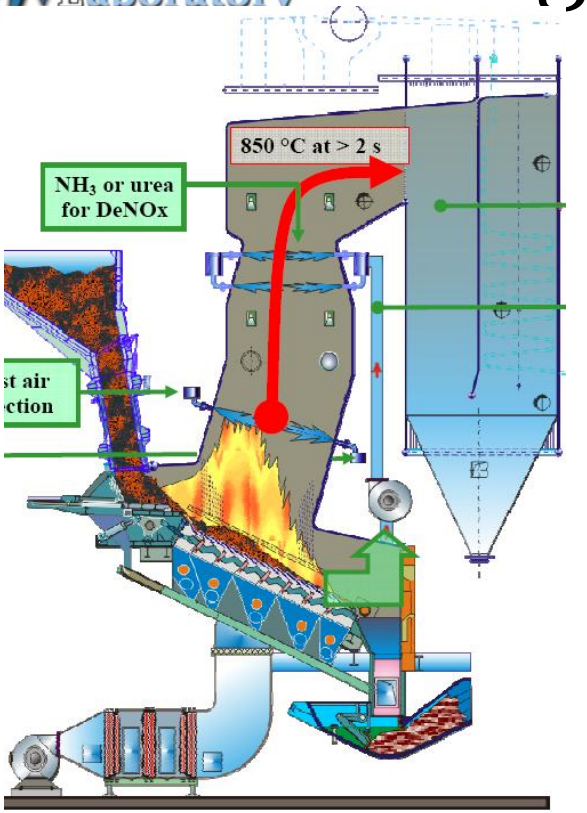
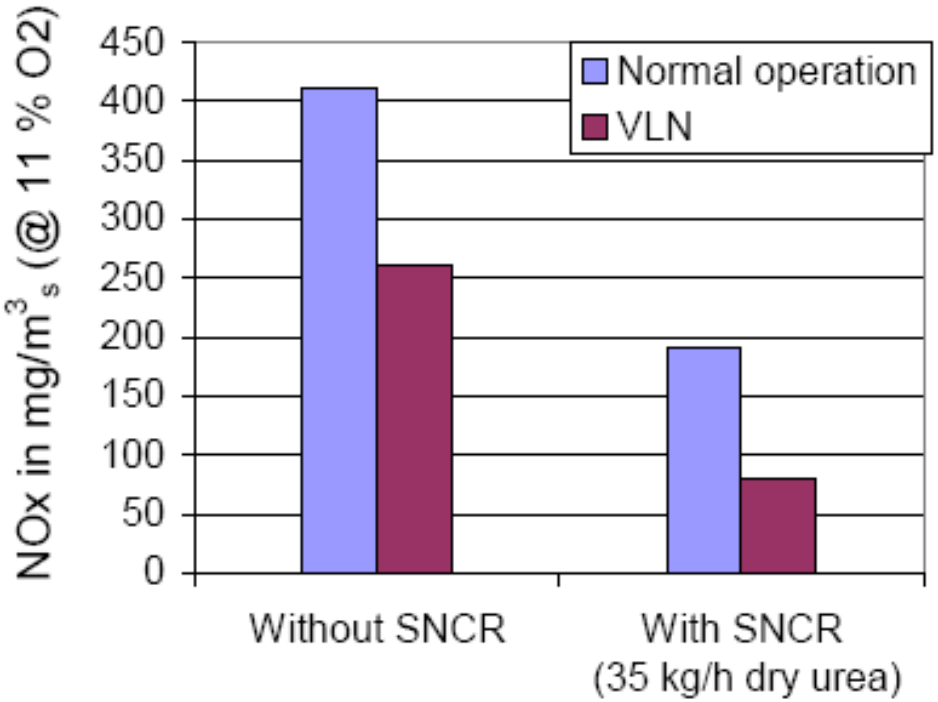
Flue gas recycle: Low NOx



Lower O_2
Lower Temperature
Increased Turbulence → increased mixing
Lower Velocity (maintains 850ºC & 2sec)
Reduced excess air rate ($ savings)

Tested @ Bristol / USA (MSW thoughput 12 t/h)
NOx = 80 mg/m3
Confirmed @ Thiverval / France and Oita / Japan



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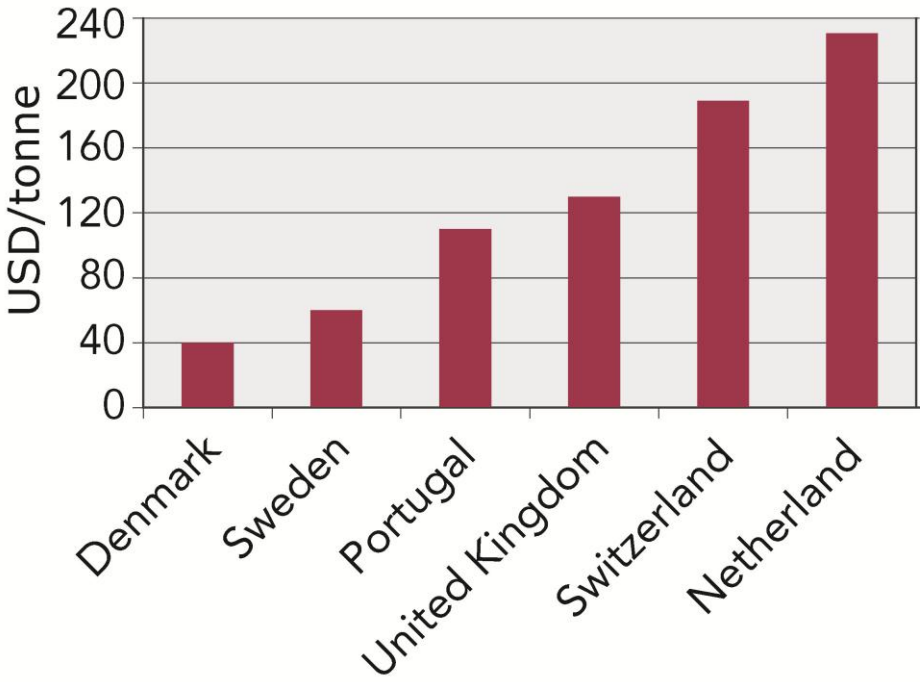
Waste-to-Energy - Economy

WtE prices in Europe



WtE costs are the same as the price of an empty rubbish sack

i.e. about $0.40 US/week per household!

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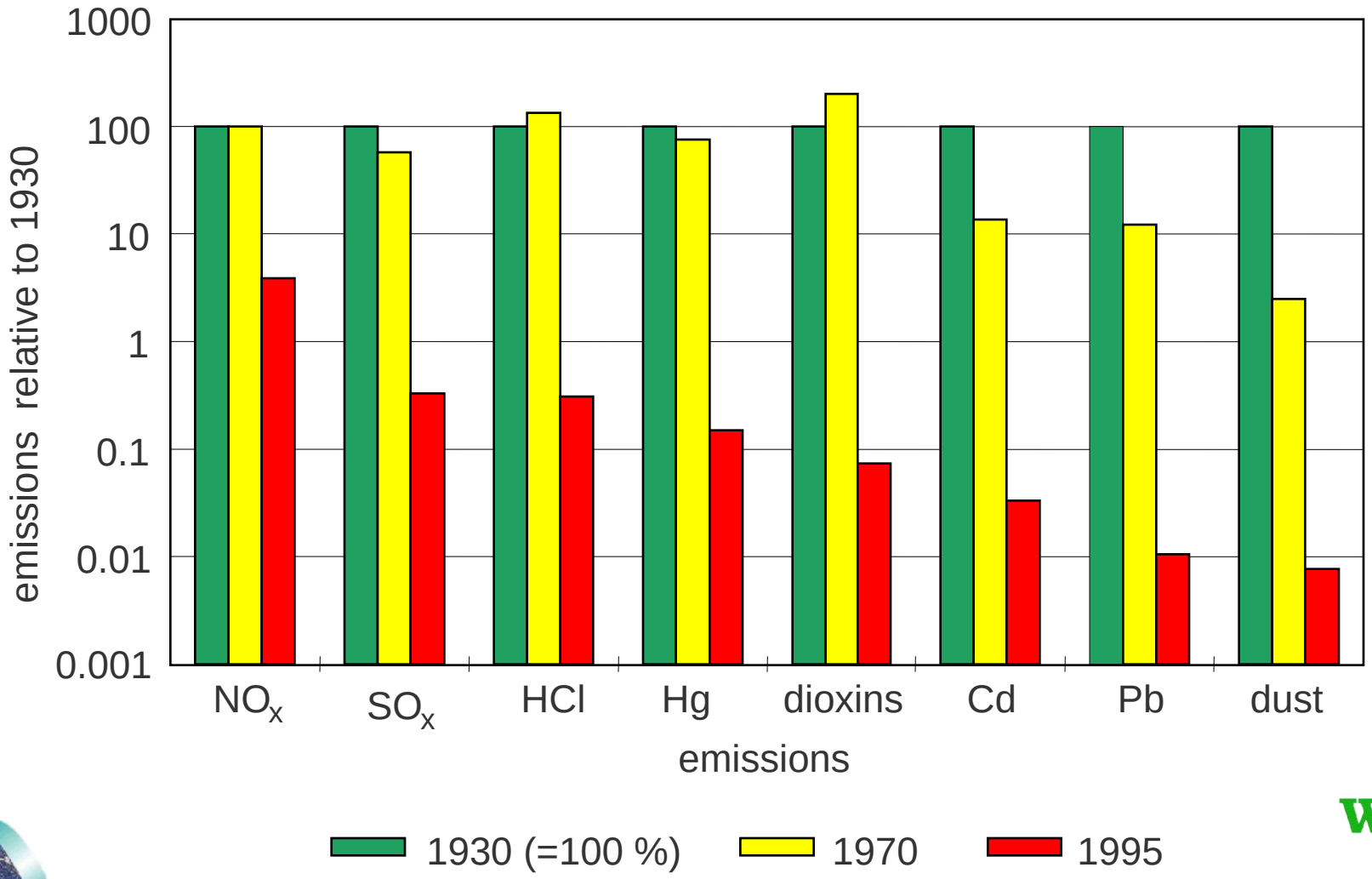
Emissions from MSW incinerators 1930-1995



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Example Waste-to-Energy Facility

Actual vs. Allowable Emissions

	Permit Limit	2003 – 2007 Actual Results	% Below Limit
Particulate (mg/dscm)	**27**	**3.3**	**87.8%**
Dioxin/Furan (ng/dscm)	**30**	**1.7**	**94.3%**
Mercury (µg/dscm)	**28 – NY State (80 – Federal)**	**9.3**	**66.8% (88.4%)**
Lead (µg/dscm)	**440**	**7.6**	**98.3%**
Cadmium (µg/dscm)	**40**	**0.4**	**99.0%**

Note: All concentrations corrected to 7% oxygen.

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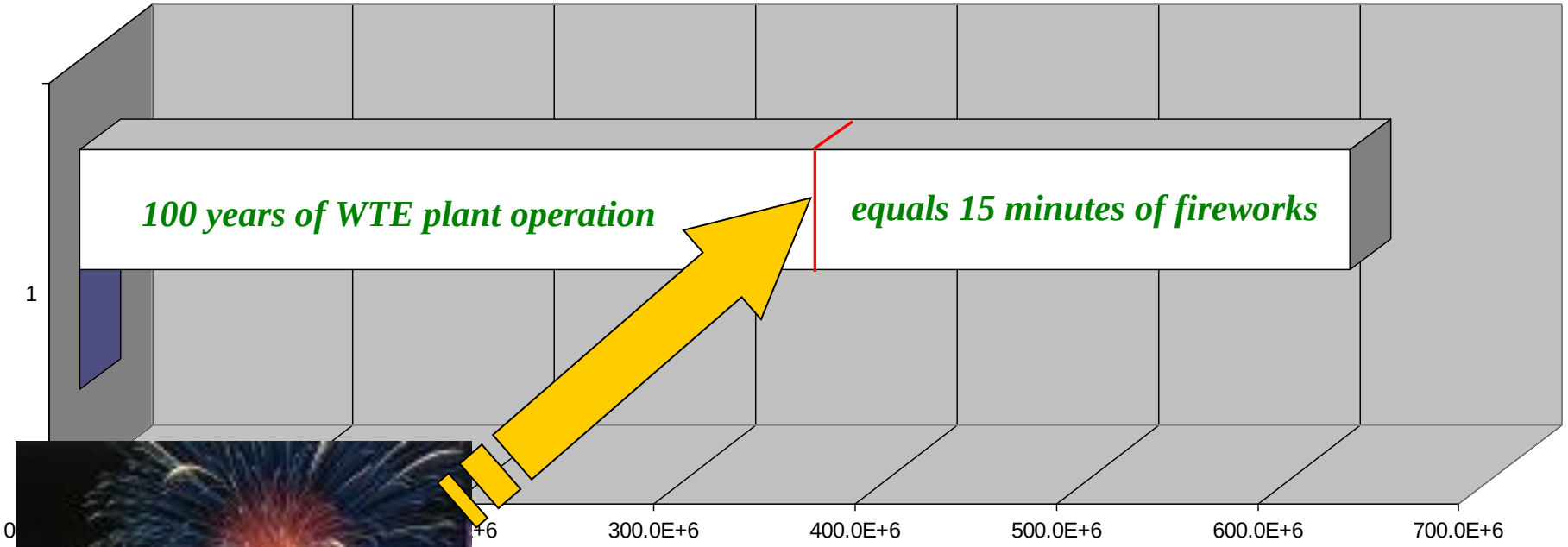
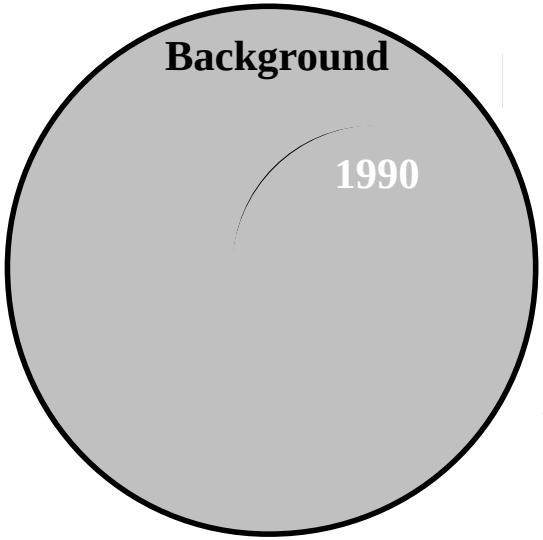
Dioxins Reality





Relative concentrations of dioxins

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Horcholm

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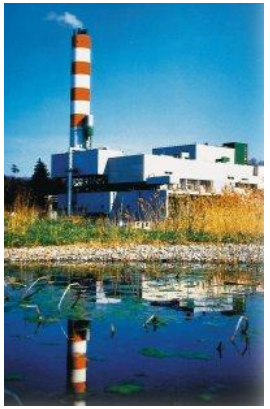
WTE Facilities Today



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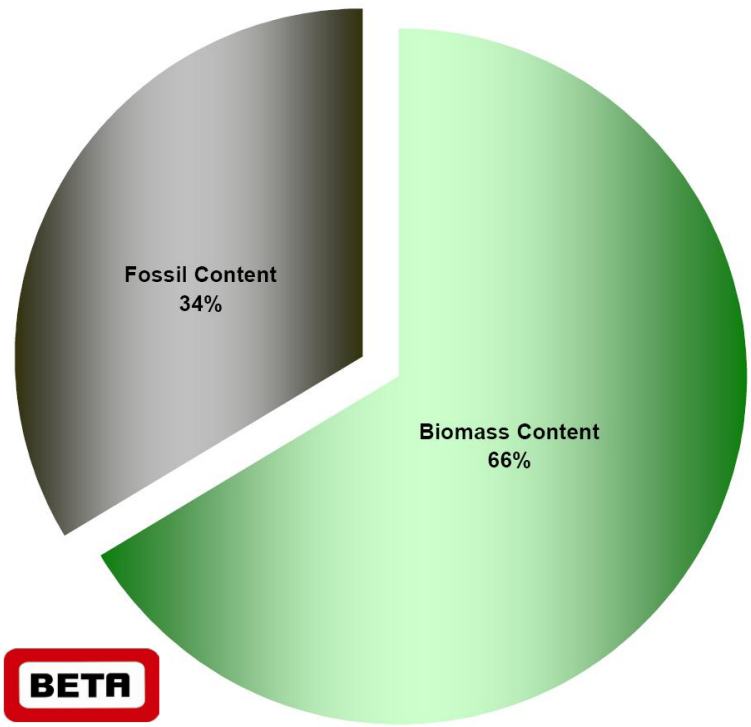
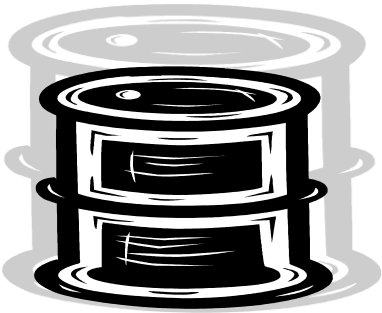
Municipal Solid Waste (MSW)

- ~ 250 million tons of waste generated per year (U.S.)
- Landfills are filling up
- Disposal costs and energy costs are going up
- Greenhouse gas initiatives (RGGI, etc)

•Waste as fuel emits 2/3 less CO_2 than fossil fuel





Potential to replace ~ 20% of oil imports per year

Burning is good (WTE); instead of oil → use waste

- Gasification gives options
  - •choice of products – Heat, fuels, chemicals

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Energy from Waste

- ***WTE conserves fossil fuels by generating electricity.*** ***(Energy)***
  - 1 ton of waste combusted = 45 gallons of oil or 0.28 tons of coal
  - Most WTE facilities in U.S. process between 500 and 3,000 tons of waste per day
  - Electricity for 2.8 million homes
- **WTE facilities process 14% of the MSW in the United States. (Health)**
  - Trash-disposal needs about than 37 million people
- **WTE facilities meet some of the world's most stringent standards. (Environmental, local)**
  - Achieved compliance with new Clean Air Act pollution control standards in 2000
  - EPA data :dioxin emissions now account for less than 0.5% of dioxin emissions
- ***WTE facilities reduce greenhouse gas emissions. (Climate, global)***
  - EPA estimates :WTE facilities prevent 33 million metric tons of CO_2 per year avoided
- ***WTE facilities save real estate. (Land)***
  - They reduce the space required for landfills by about 90%
- ***WTE is compatible with recycling***. ***(Resource Minimization)***
  - Communities served by WTE recycle 35% of their trash, compared to 30% for the general population.
  - Annually removes more than 700,000 tons of ferrous materials
  - Nearly 3 million tons of WTE ash is reused as landfill cover, roadbed, or building material.
- ***WTE facilities provide economic benefits*****. (Economic)**
  - WTE is a $10 billion industry employs ~ 6,000 American workers annual wages ~ $400 million

Boundaries and interfaces of WTE cut across all sustainable fronts

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How can we have zero waste?

What to do with old clothes?

no clothes?

Not everything can be recycled or eliminated

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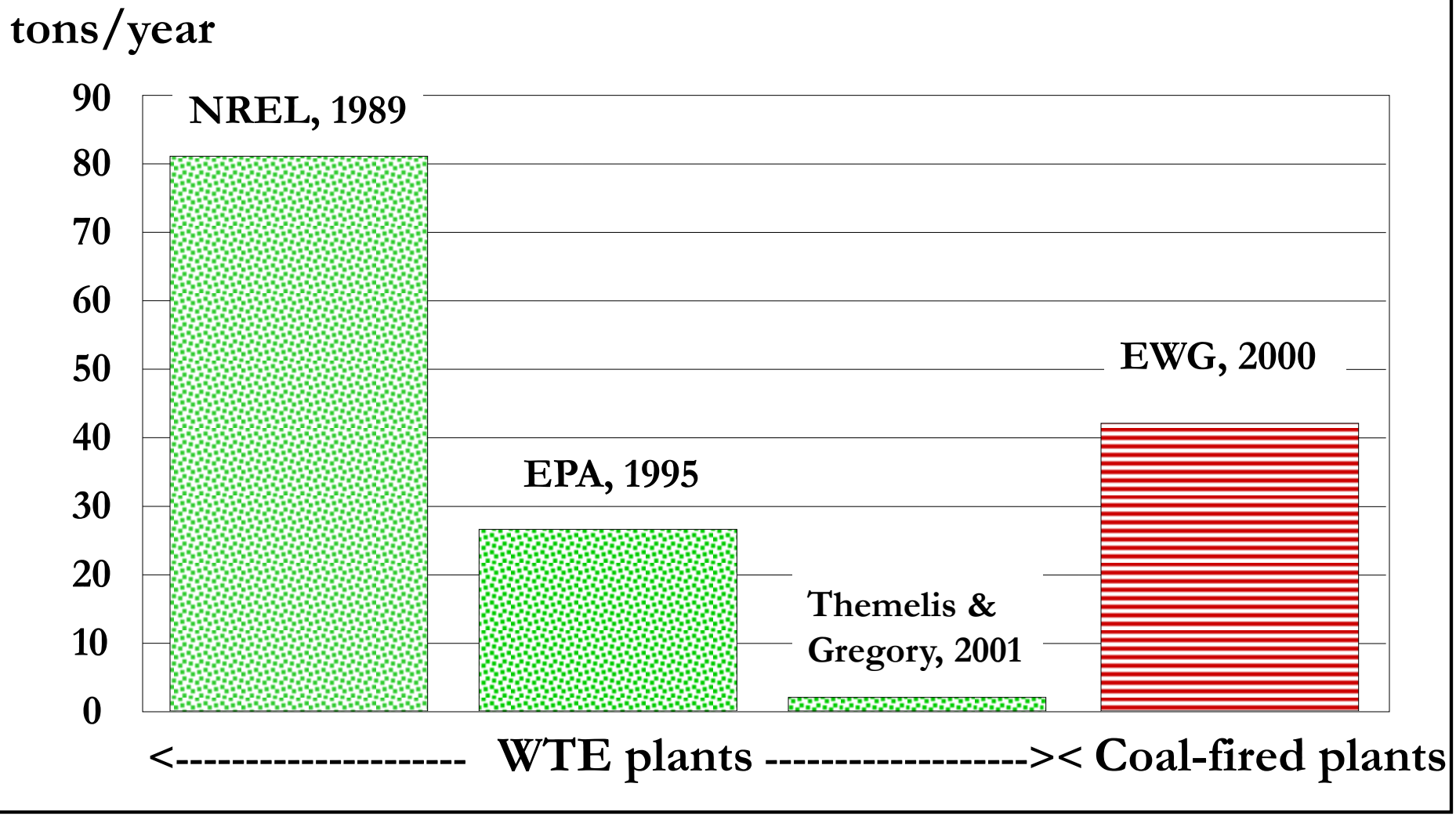
Reduction of mercury emissions from U.S. WTEs



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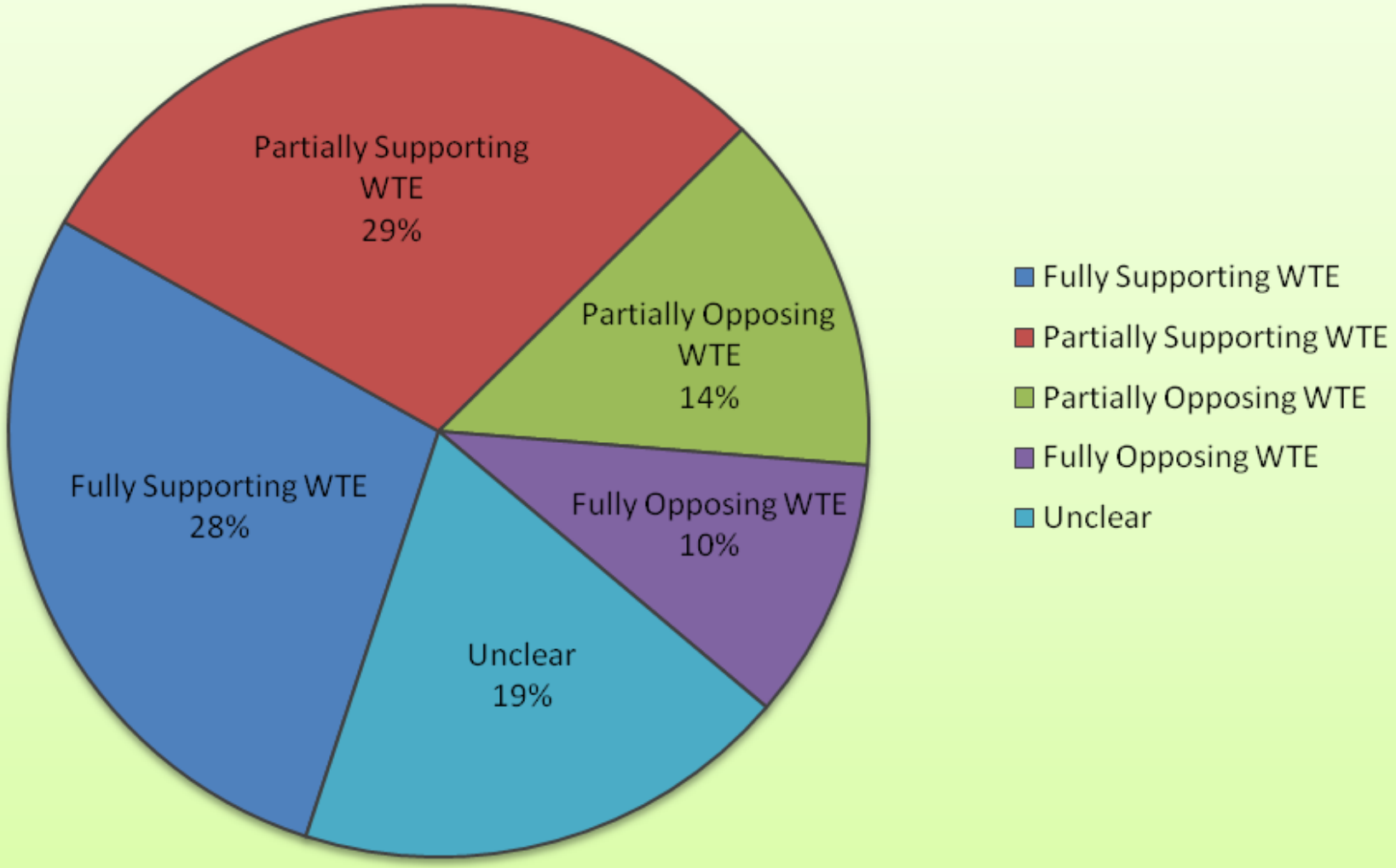
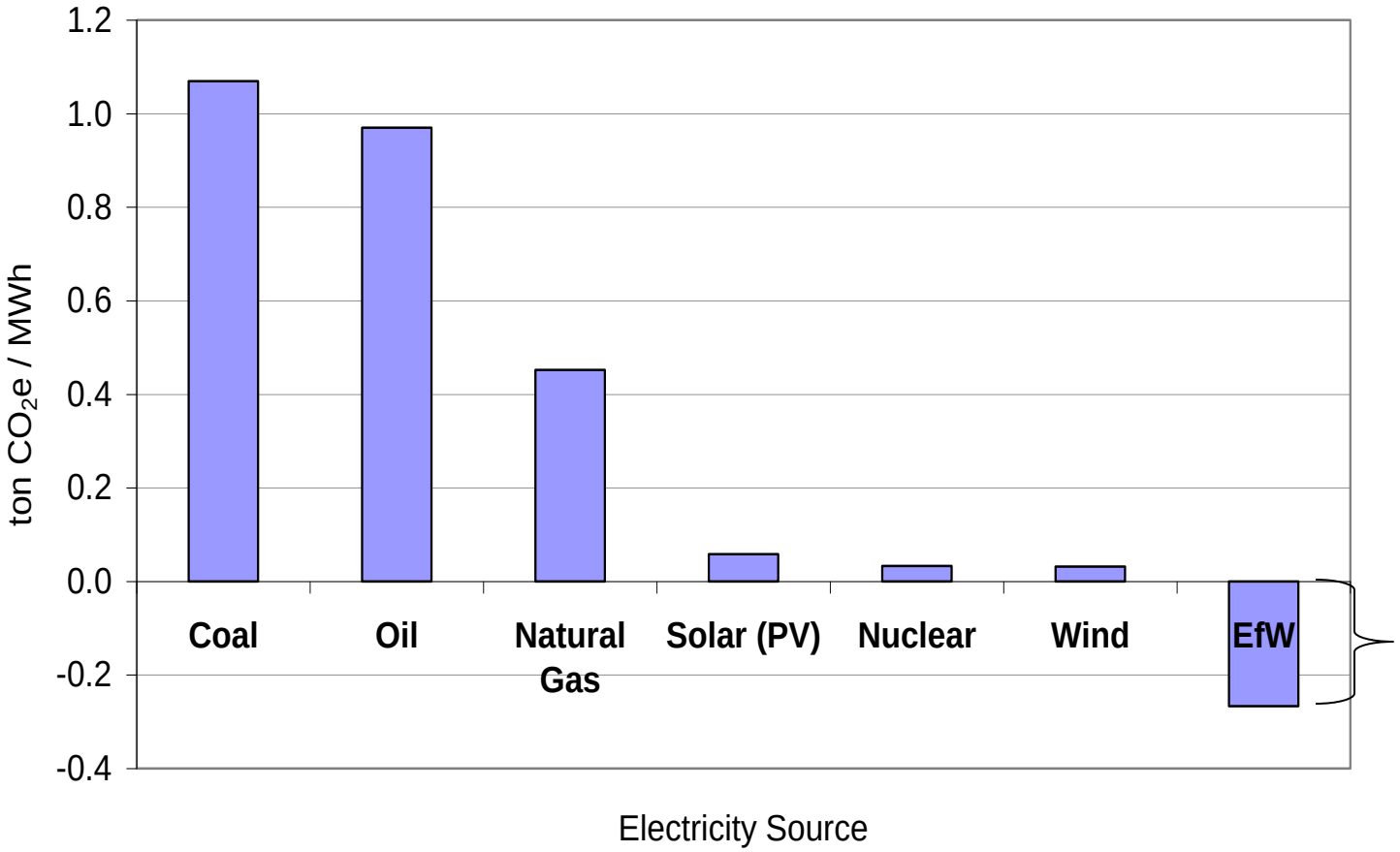
- 104 (57%) comments supported WtE.
- 34 (19%) comments unclear.
- 43 (24%) comments opposed WtE.
- 181 comments in total.



IV. GHG: Electrical Generation

LCA GHG Emissions



EfW reduces GHG emissions when including avoided CH4 from landfills and grid CO2

Sources: WARM v10, U.S. EPA (2006), Hondo, Hiroki, 2005, Life cycle GHG emission analysis of power generation systems: Japanese case

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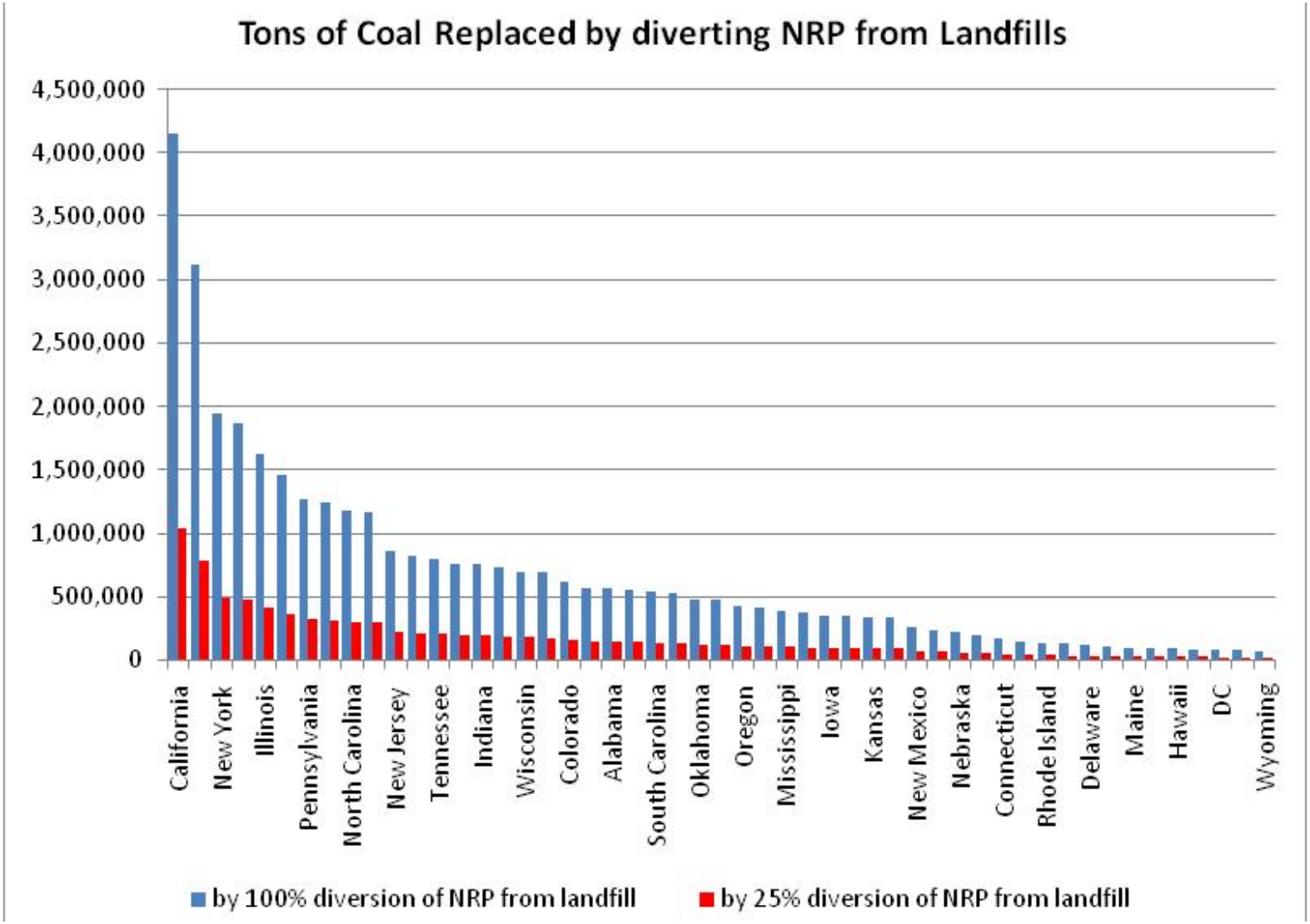

WIERT
Waste-To-Energy Research and Technology Council

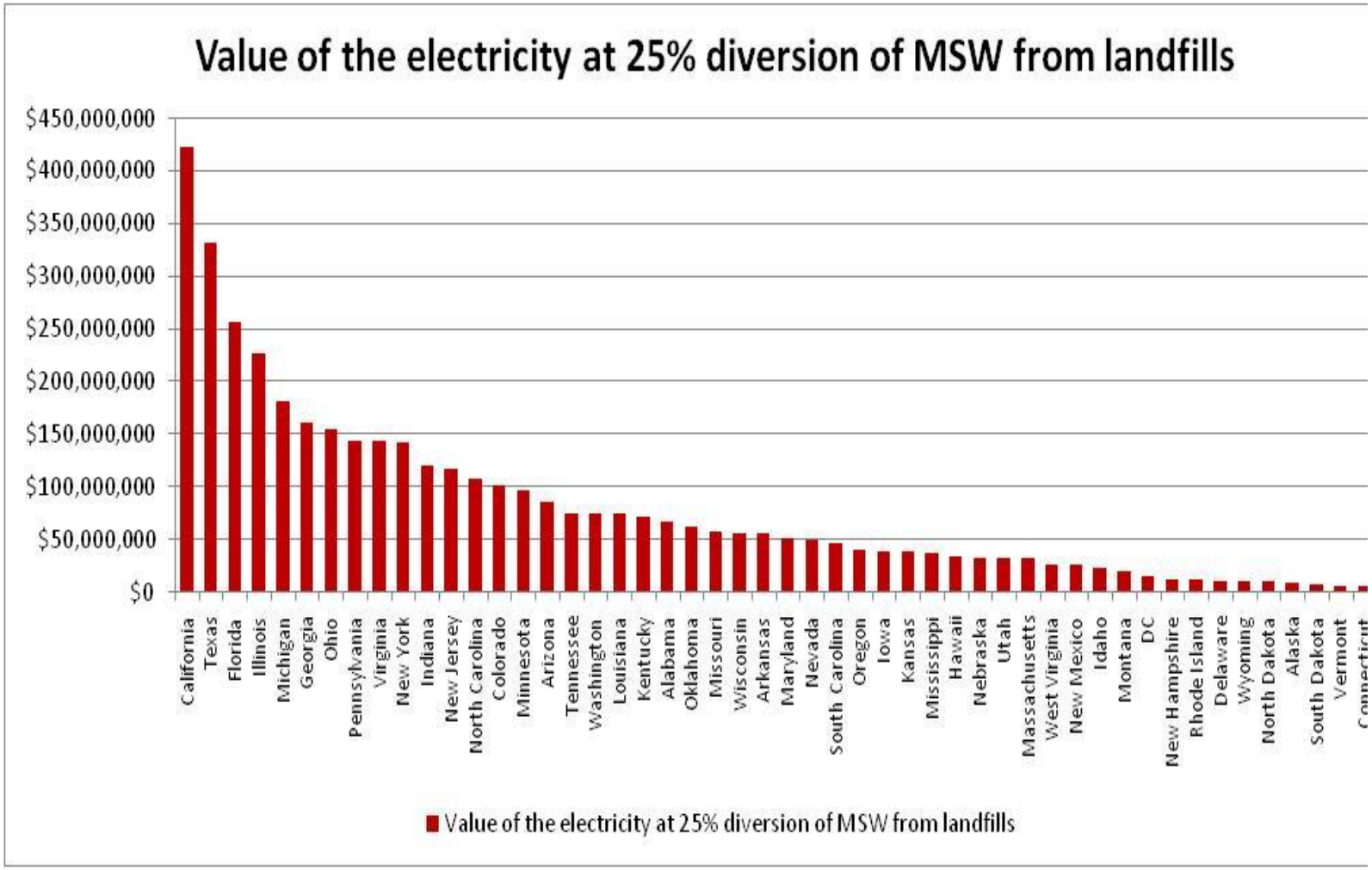

Figure 15. Value of electricity (at $100/MWh) produced by diverting 25% of present landfilling to new WTE facilities