10th Annual LEA/CIWMB Conference
October 15-18, 2007
San Diego, CA

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EMERGING TECHNOLOGIES AND ISSUES

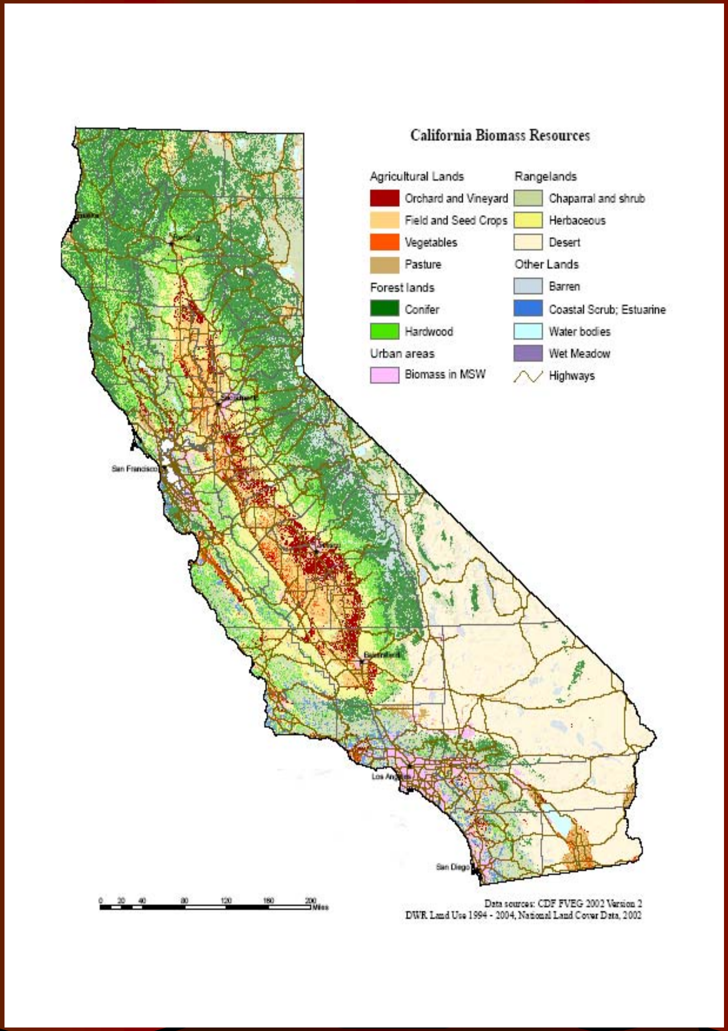
What are They

Are they Safe??

Outline

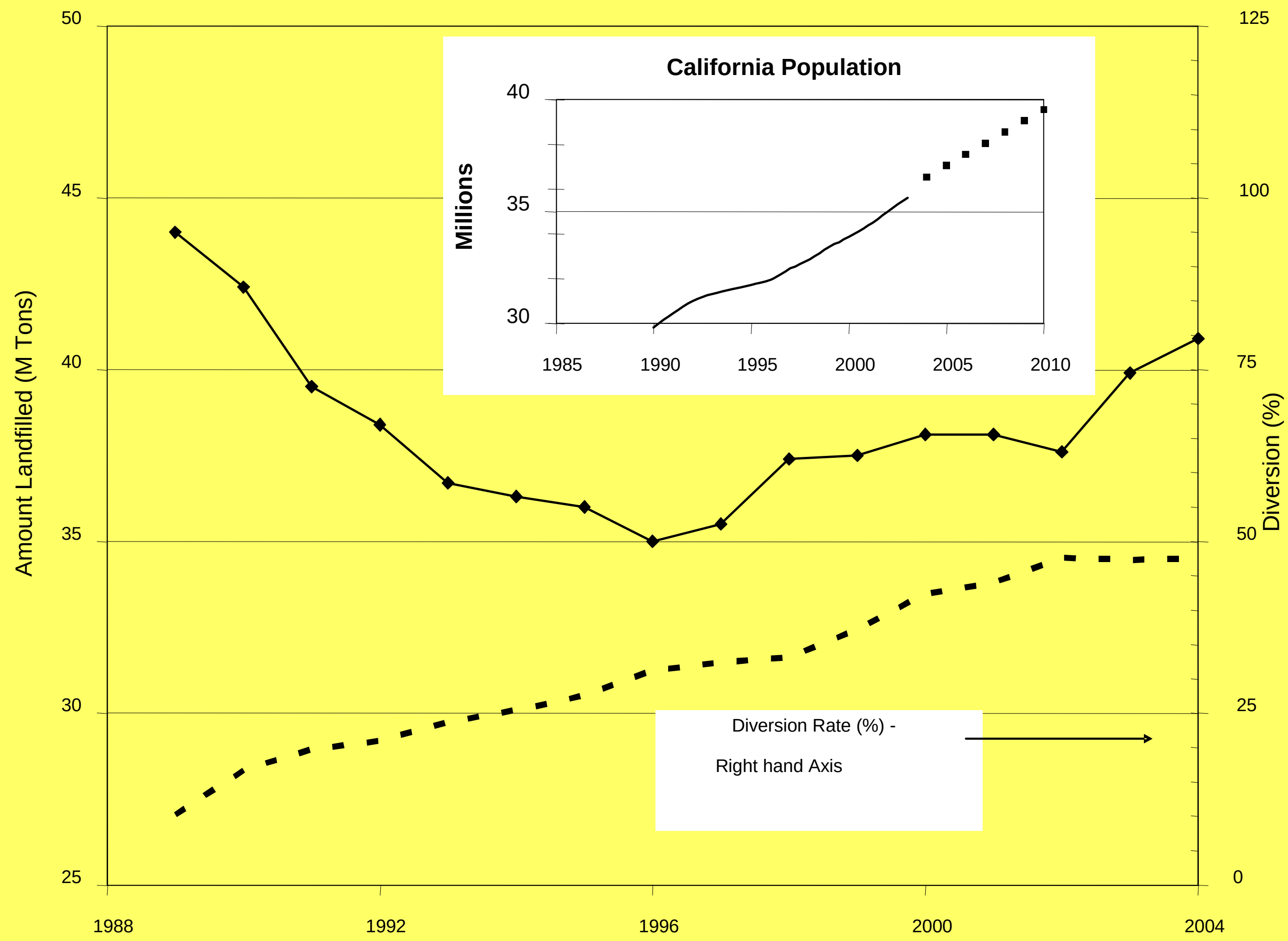
- Overview
- Technology Types
  - Pyrolysis
  - Gasification
  - Anaerobic Digestion
  - Fermentation
- Issues

Biomass Resources in California



- Gross resources are 80 billion bone dry tons annually
- Three principal resources are agriculture, forestry, and waste
- Forestry in northern and central mountains
- Agriculture in Central Valley
- Waste in Los Angeles and San Francisco Bay Area

Total Disposal vs. Statewide Diversion

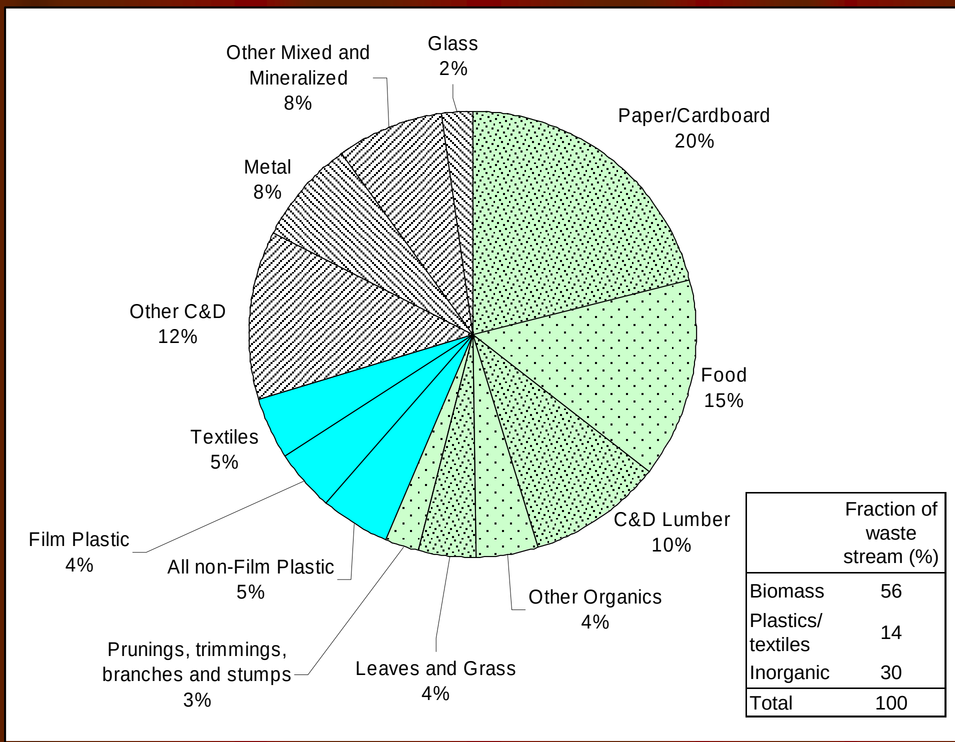


Potential Feedstock

Waste Management & Energy Production

- 42 Million TPY Disposed
- Reduce Reliance on Landfills
- Alternatives to Natural Gas
- Achieve 20% Threshold of Renewable Energy by 2017
- Achieve Governor's EO on Biofuels

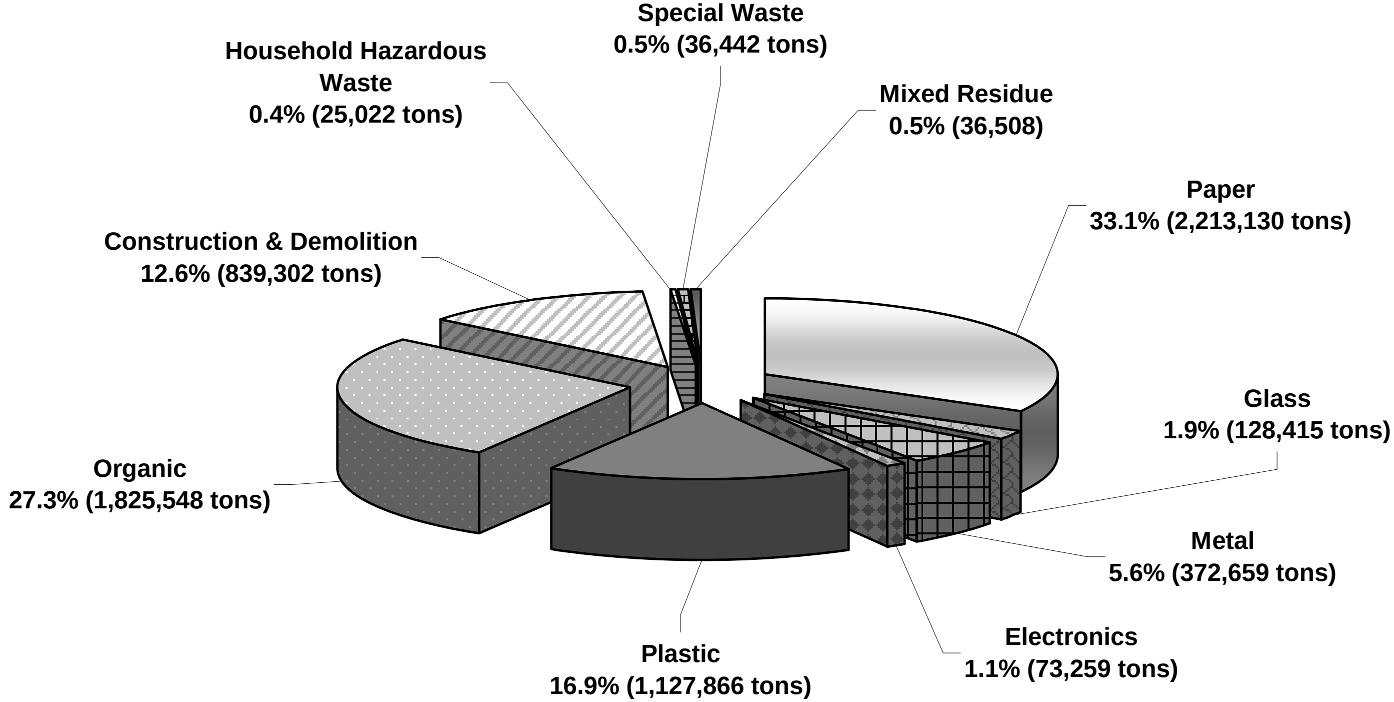
Waste Characterization in California



- 42 million tons disposed in 2005
- 23 million tons biological in origin
- 5.7 tons plastic and textiles

Available Residuals – Mixed Waste (6.7 Million Tons)

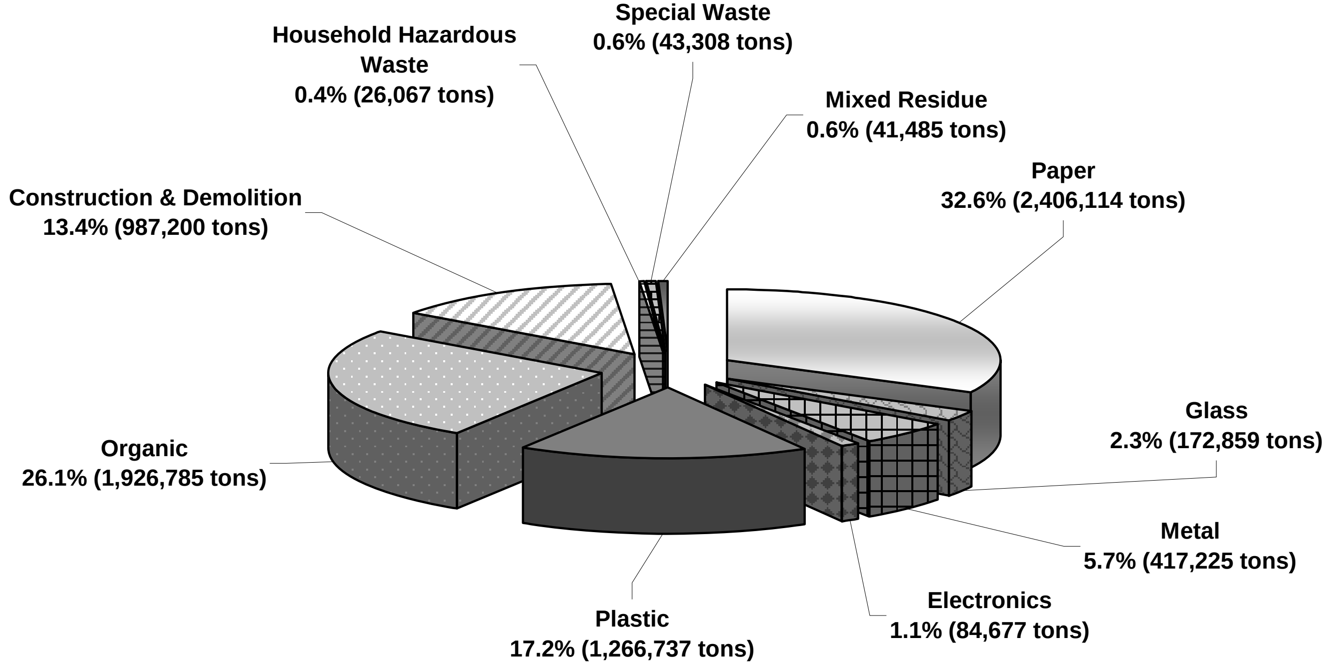
Figure H
Summary of Composition of Residuals - MRFs Receiving Mixed Waste, 2005



Total Residual Weight is 6,678,151 tons
Note: Percentages calculated by weight as the average proportion of each material type to the total residual weight

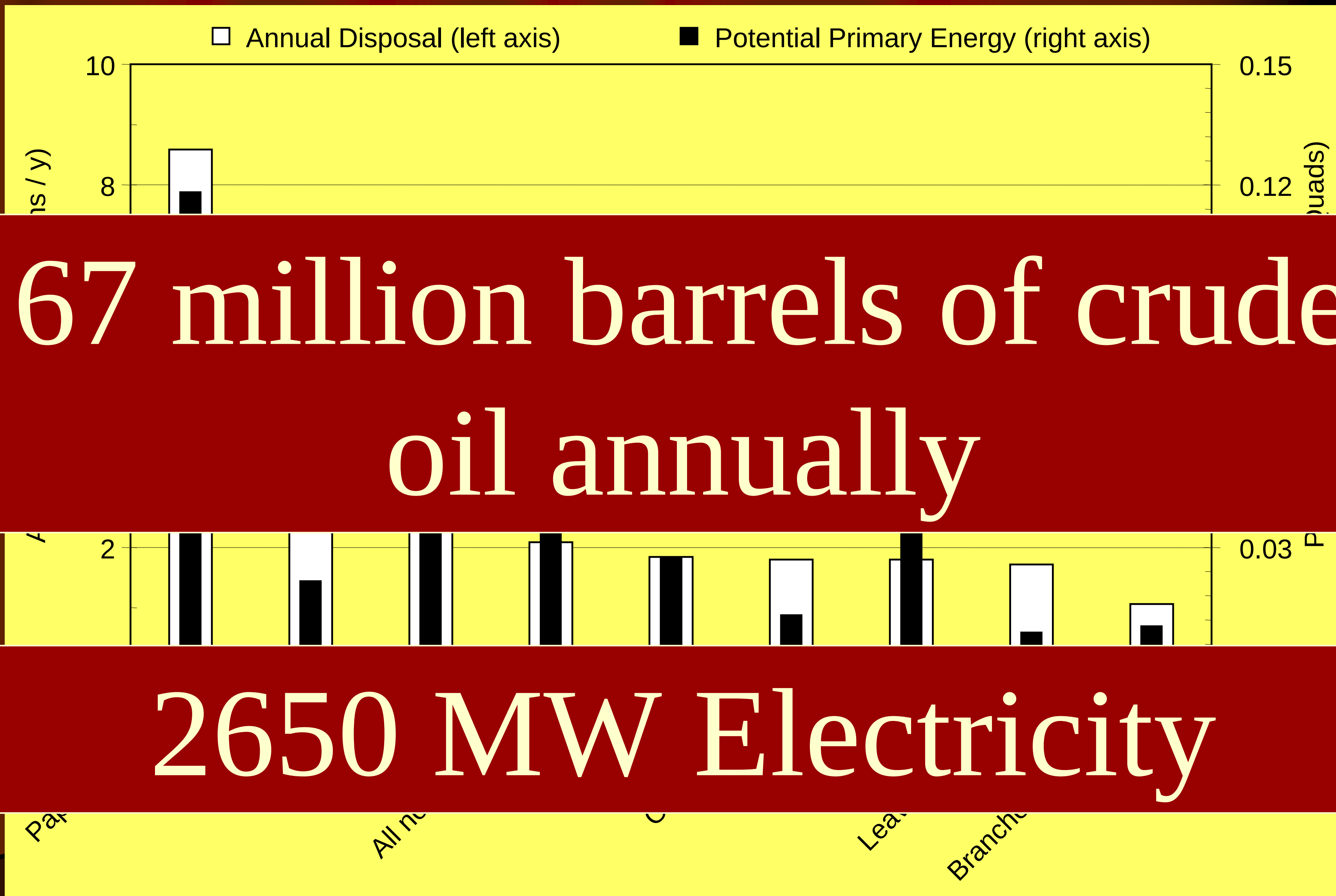
Available Residuals – Overall (7.4 Million Tons)

Figure J
Summary of Composition of Residuals - Overall MRFs, 2005



Total Residual Weight is 7,372,456 tons
Note: Percentages calculated by weight as the average proportion of each material type to the total residual weight

Waste Distribution (Mass/Energy)



67 million barrels of crude oil annually

2650 MW Electricity

WHAT ARE THEY??

CT Major Categories

Thermochemical Processes

- Pyrolysis
  - Very little air/oxygen added or none at all
  - 750º F to 1500º F
- Gasification
  - Some air/oxygen used but less than for incineration
  - Begins at 1300º F

Technology	**Primary Product**	**Secondary Product**	**Residue**
Gasification	Fuel Gas Synthesis Gas	Fuels, Chemicals, Power	Char, Ash
Pyrolysis	Fuel Gas Synthesis Gas Pyrolytic oils	Fuels, Chemicals, Power	Char, Ash

Gasification

- Carbon in waste or biomass reacts with steam and oxygen
- (from air) at sub-stoichiometric conditions

Primary reactions:

$C + O_2 \rightarrow CO_2$ (exothermic)

$C + H_2O \rightarrow CO + H_2$ (endothermic, water gas)

$C + CO_2 \rightarrow 2\ CO$ (endothermic)

$CO + H_2O \rightarrow CO_2 + H_2$ (exothermic, generator gas)

- Resulting synthesis gas (syngas) can be used for:
  - energy production in IC engines or turbines
  - synthesis of chemicals
  - hydrogen production

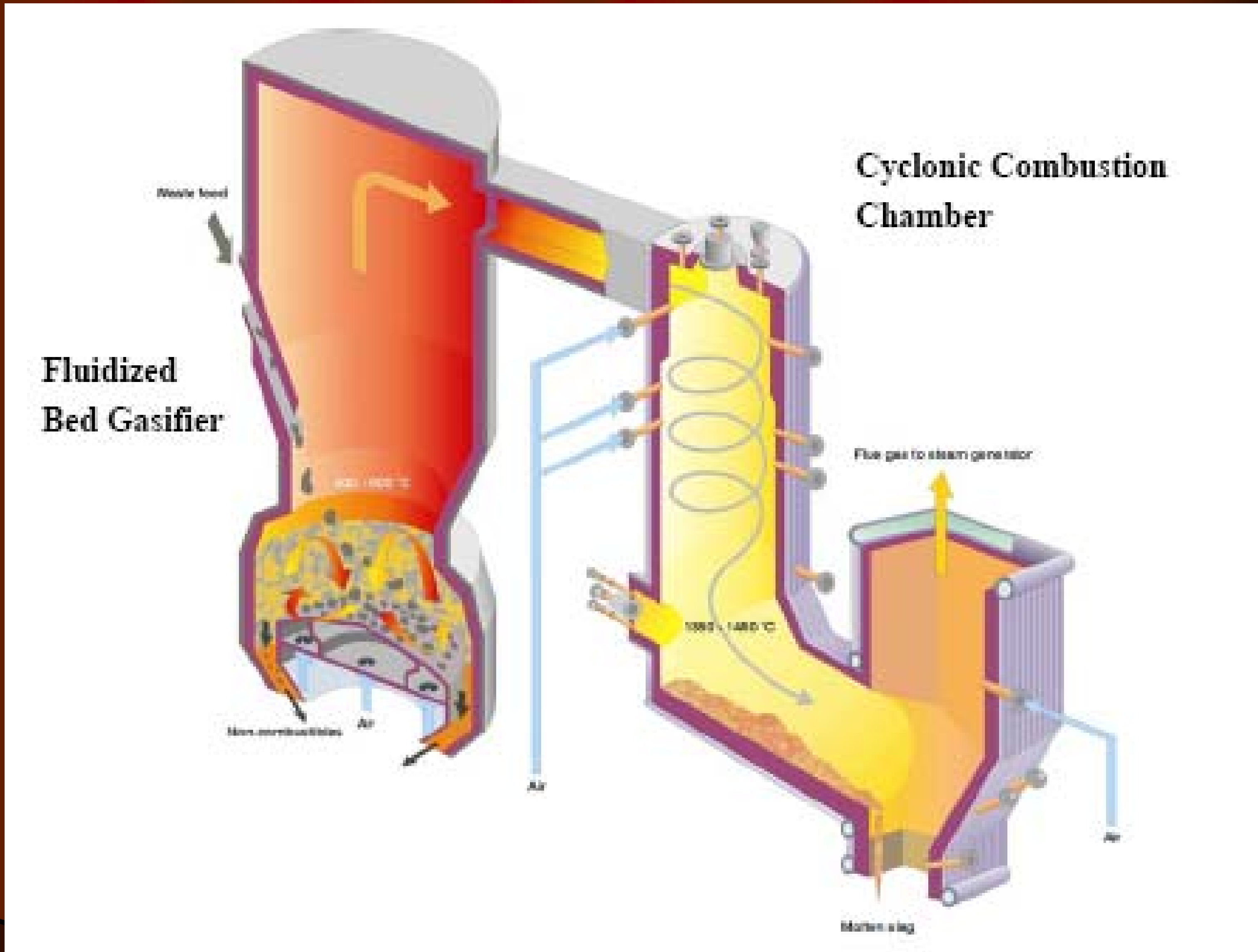
Pyrolysis

- Endothermic reaction of organic fraction of waste, biomass, or liquid waste in the absence of oxygen at high temperature and pressure
- Organic matter is transformed to a gas, liquid, and a solid (char)
- Temperature and pressure levels affect the relative ratios of gas, liquid, and solid

GASIFICATION

- "Cooks" feedstock at high temps
- No combustion
- Yields gases that are turned into electricity or fuel

Typical Gasification Process



Kurashiki Facility

Kurashiki Facility

Kawaguchi Facility

Kawaguchi Facility

Kawaguchi Facility

CT Major Categories

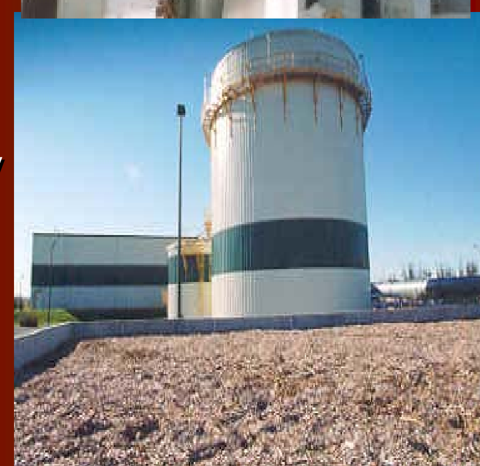
Biochemical Processes

- Anaerobic Digestion
  - Bacteria breaks down feedstock
  - No oxygen
- Fermentation
  - Also anaerobic process
  - Microbes used to produce ethanol

Technology	**Primary Product**	**Secondary Product**	**Residue**
Anaerobic Digestion	Biogas	Heat, Electricity, Fuels, Soil Amendment	Lignin, inorganics
Fermentation	Ethanol		Lignin, inorganics

ANAEROBIC DIGESTION

- Bacteria “digest” feedstocks
- Mesophilic or Thermophilic temperatures
- Yields gases and residues
- Gases into electricity
- Residues into fertilizer

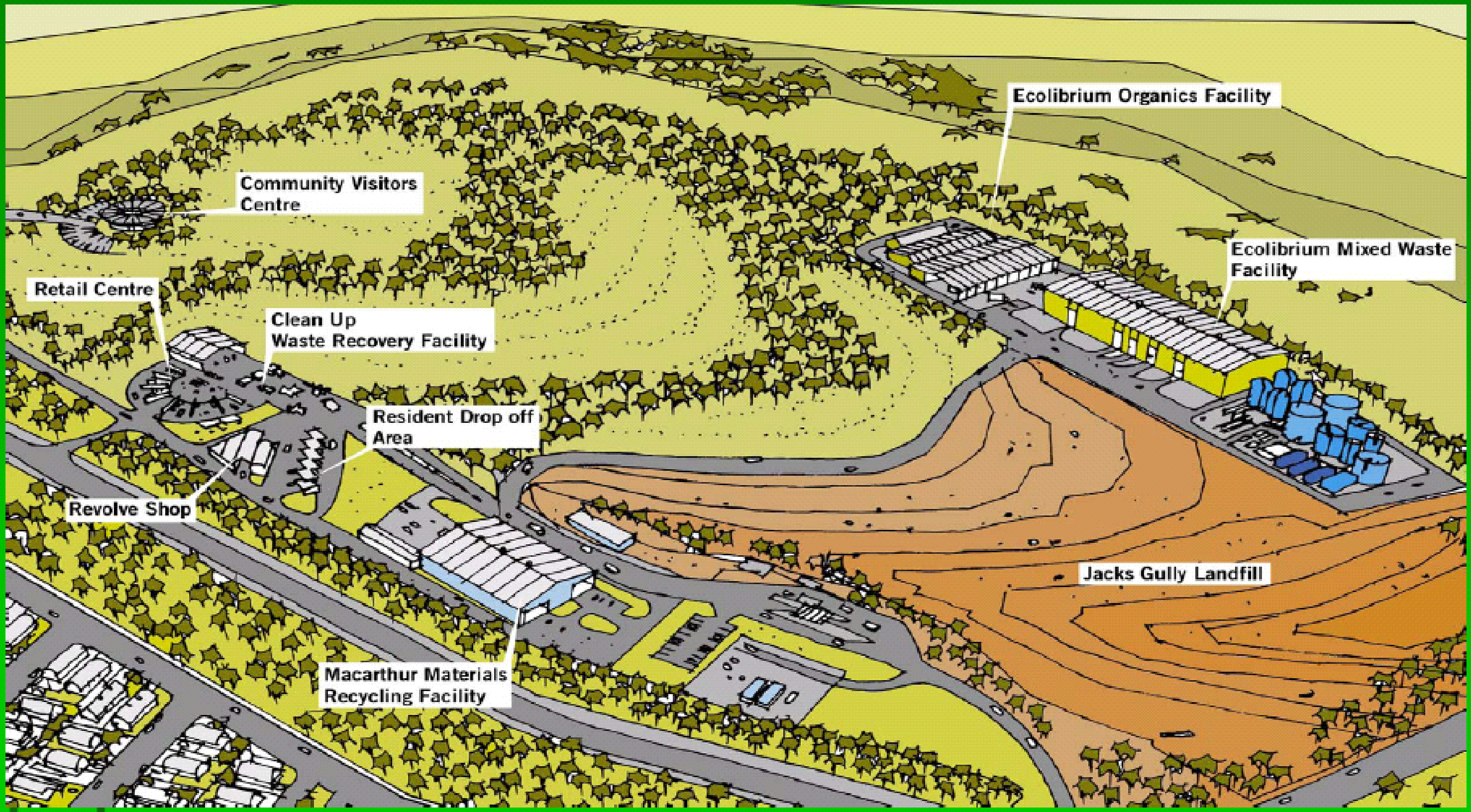


Arrow Bio - Israel

Arrow Bio - Israel

Arrow Bio - Israel

Arrow Bio – Australia Facility



Dranco Anaerobic Digestion Facility - Belgium

Digester Feedstock

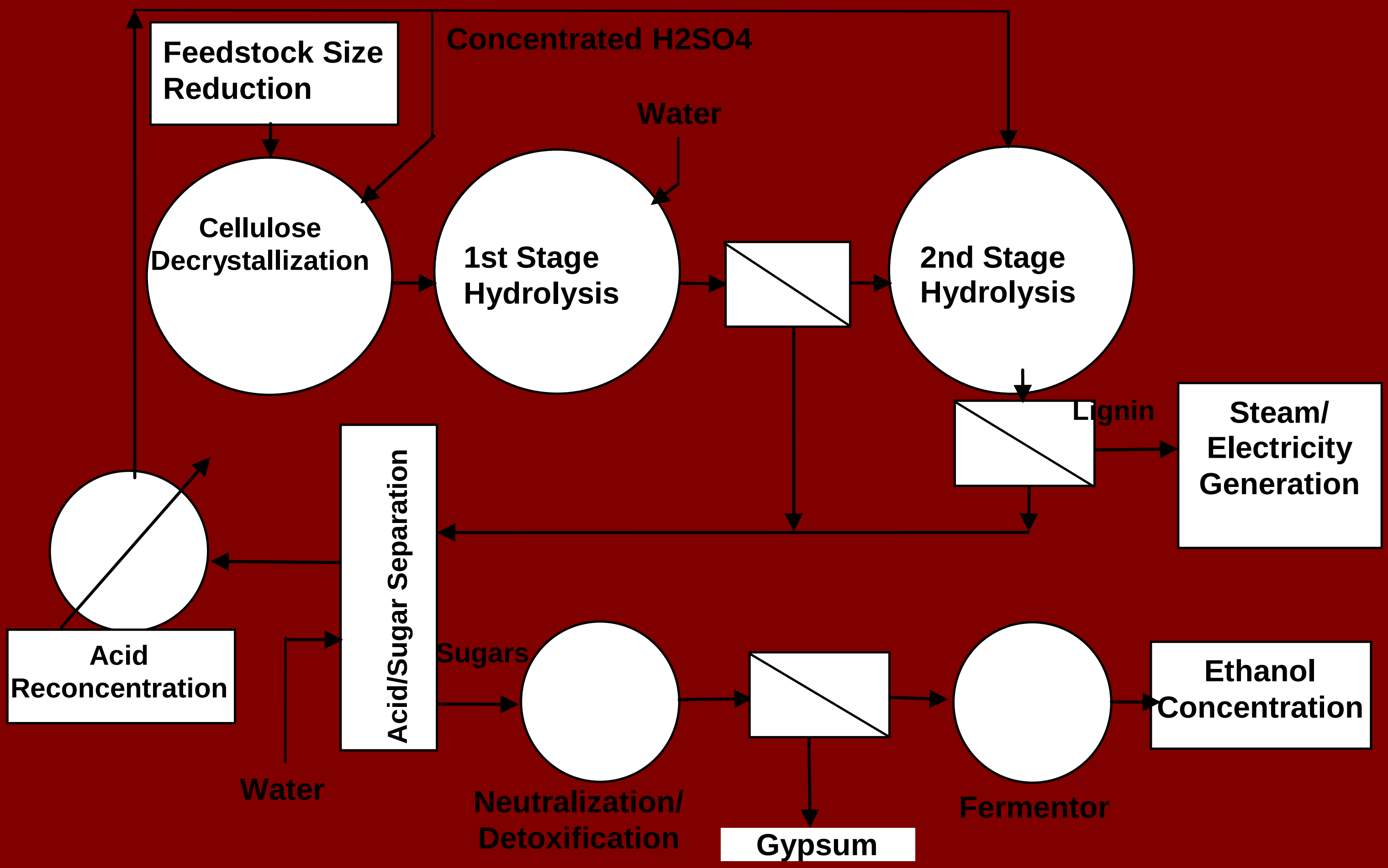
Hydrolysis/Fermentation

- Breaks feedstocks into sugars, then "brews" products
- Uses acid or enzyme pre-treatment
- Yields ethanol, citric acid, other products

Hydrolysis

- Acids or enzymes
- Processing involves several steps:
  - feed preparation (addition of nutrients and sterilization to microorganisms)
  - treatment of organic residues (cellulose)
  - hydrolysis of cellulose
  - glucose separation

Typical Hydrolysis/Fermentation Process



FEEDSTOCKS

- Mostly cellulose-based = plant material
  - Organic part of solid waste (wood, yard, etc.)
  - Low-grade paper part of solid waste
  - Ag and forest residues
  - Some also can take plastics
- Each technology needs certain characteristics
- Which feedstocks best for which technologies?

What Are The Issues

- Perception of Technologies
  - Incinerators in disguise?
- Permitting Issues
  - Solid Waste Facilities?
  - Manufacturing Facilities
- Cost
- NIMBY/BANANA

Perception of Technologies

- Some technologies labeled “Incinerators in Disguise”
- Technologies will harm existing recycling infrastructure
- Technologies less efficient than recycling

Permitting Issues

- Are they solid waste facilities
- Are they manufacturing facilities
- Are they recycling facilities

Cost

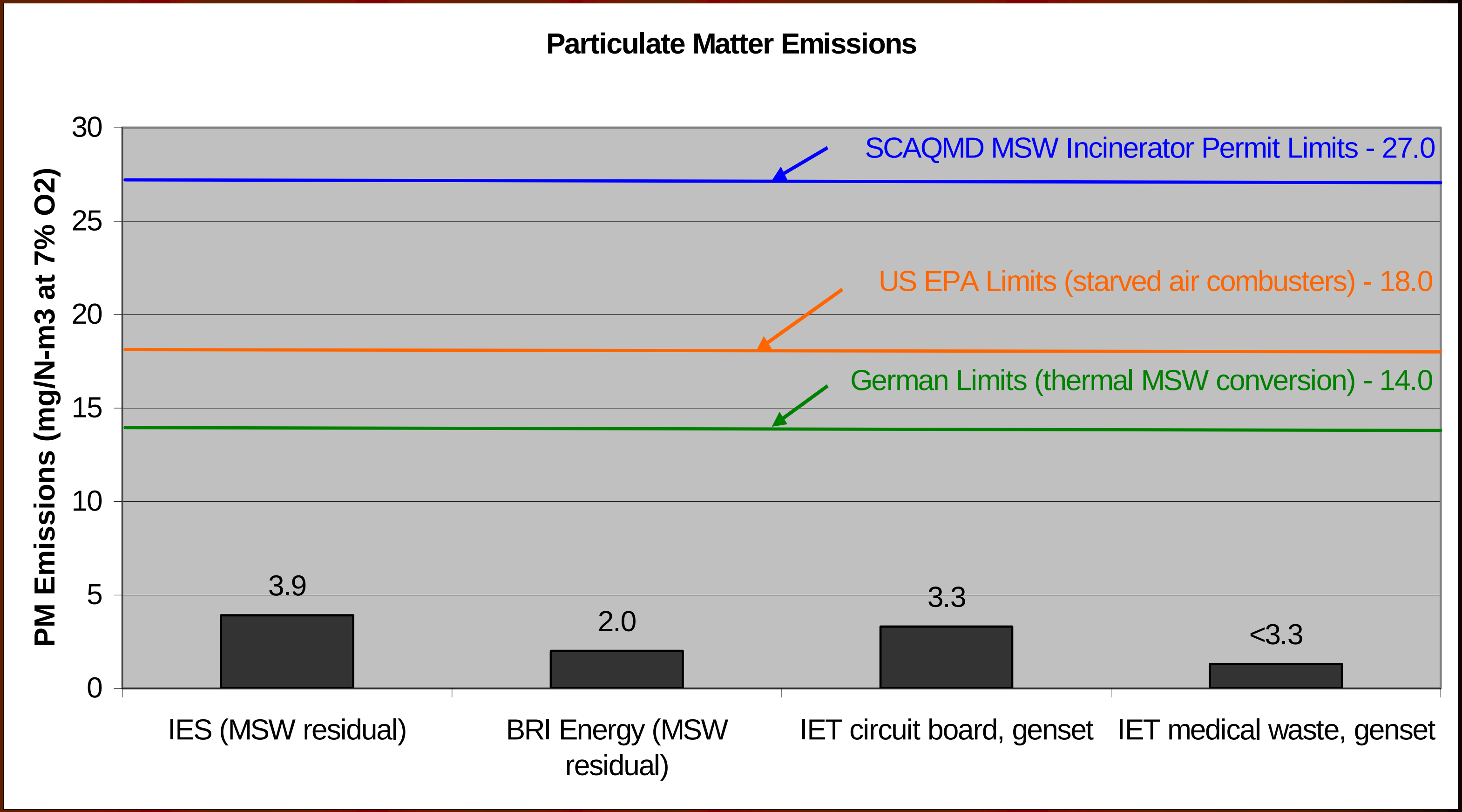
- Technologies expensive
- Average tip fee in California currently approximately $40 per ton
- Cost of facilities range from $50 to $175 per ton - Depending on throughput

NIMBY/BANANA

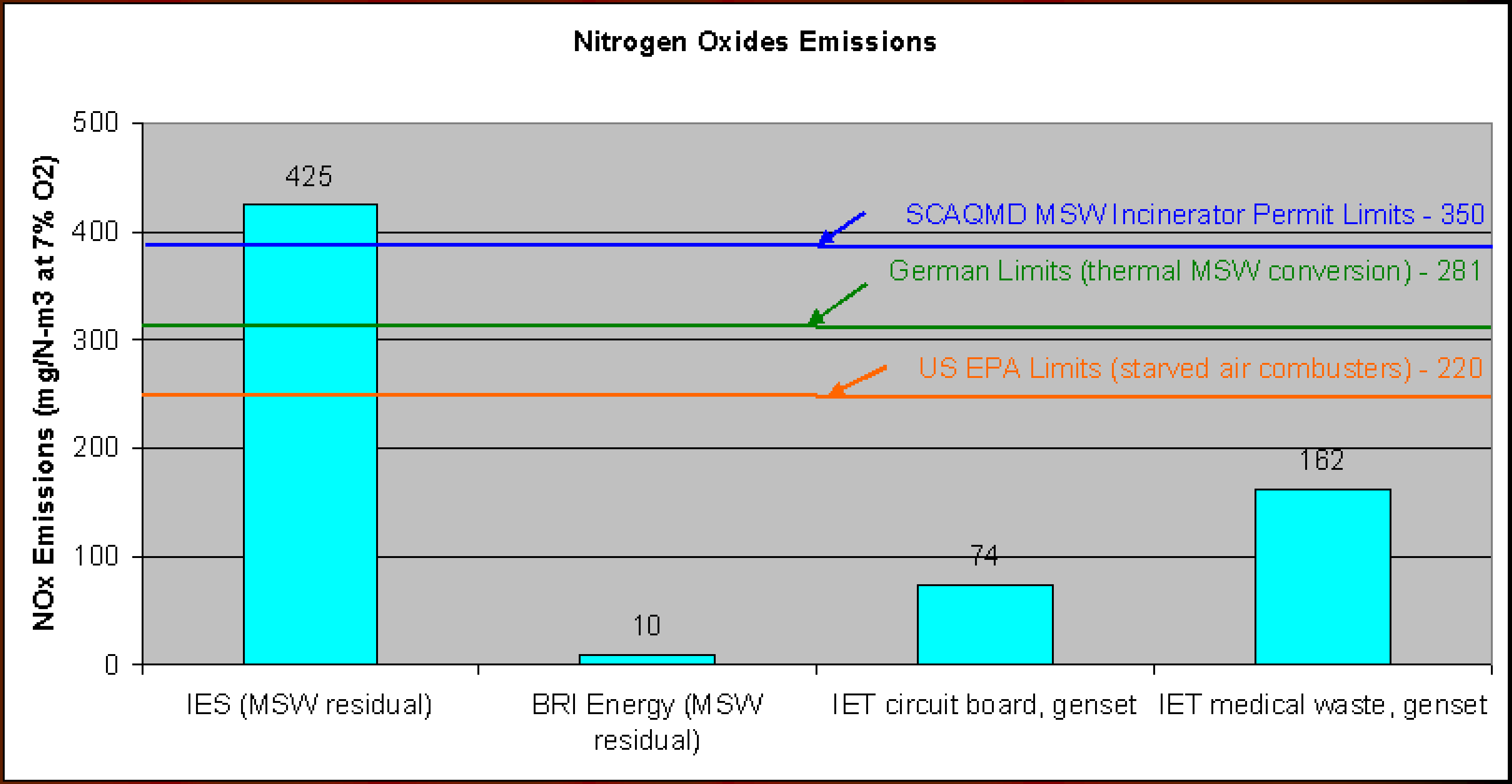
- Public opposition to anything
- Fear of technologies
- Support for renewables but not for technologies to produce renewables

Are They Safe??

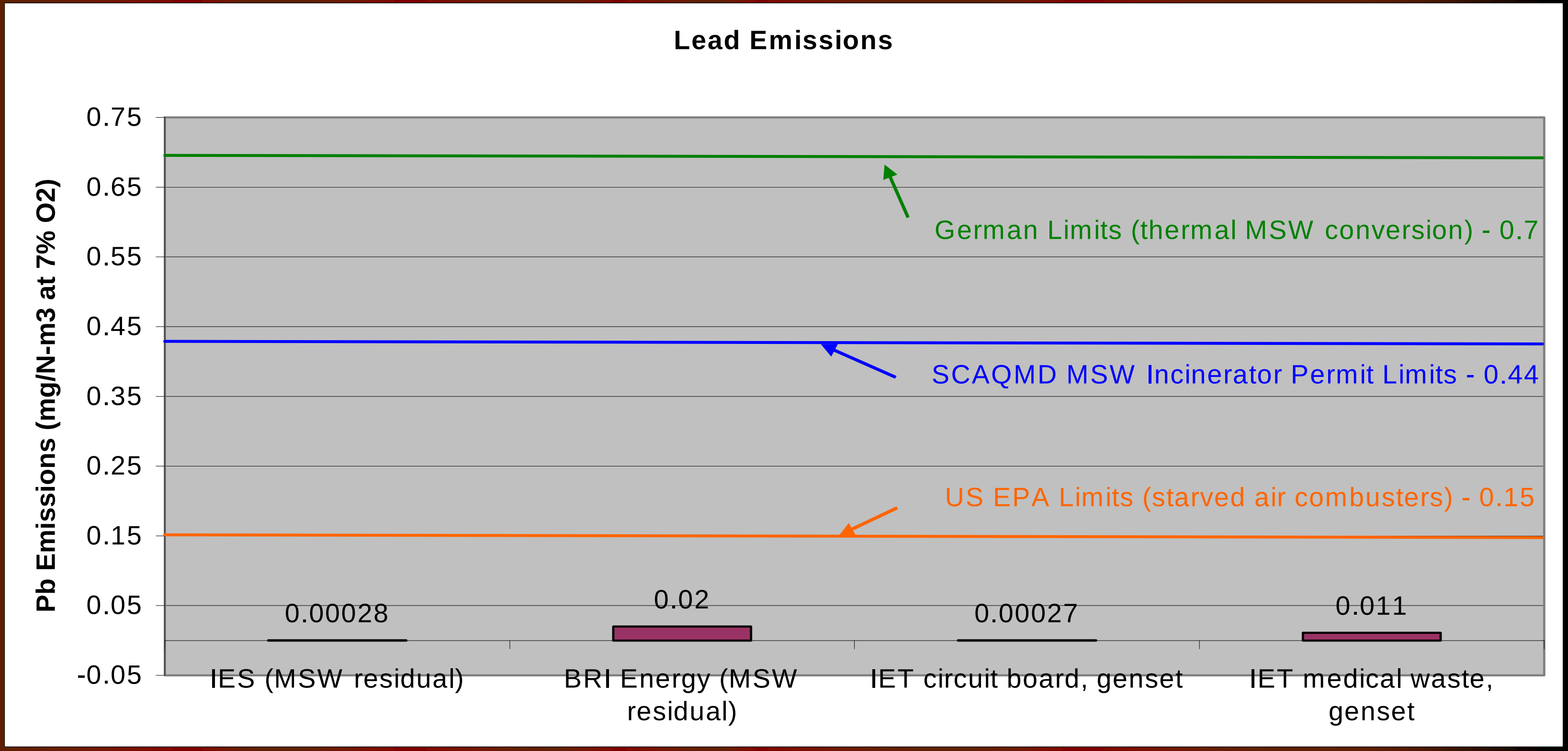
Emissions Results – Particulate Matter



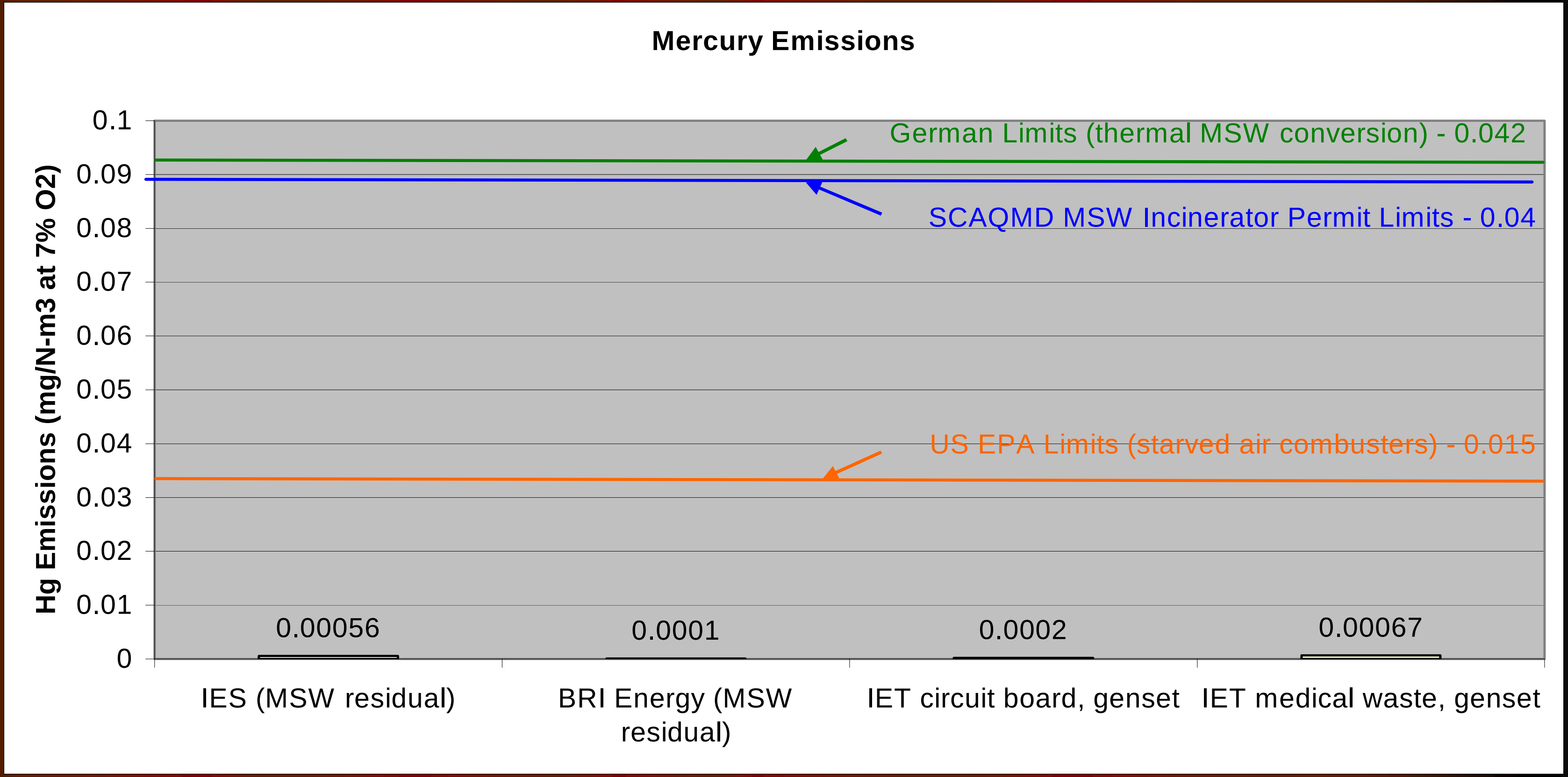
Emissions Results - NOx



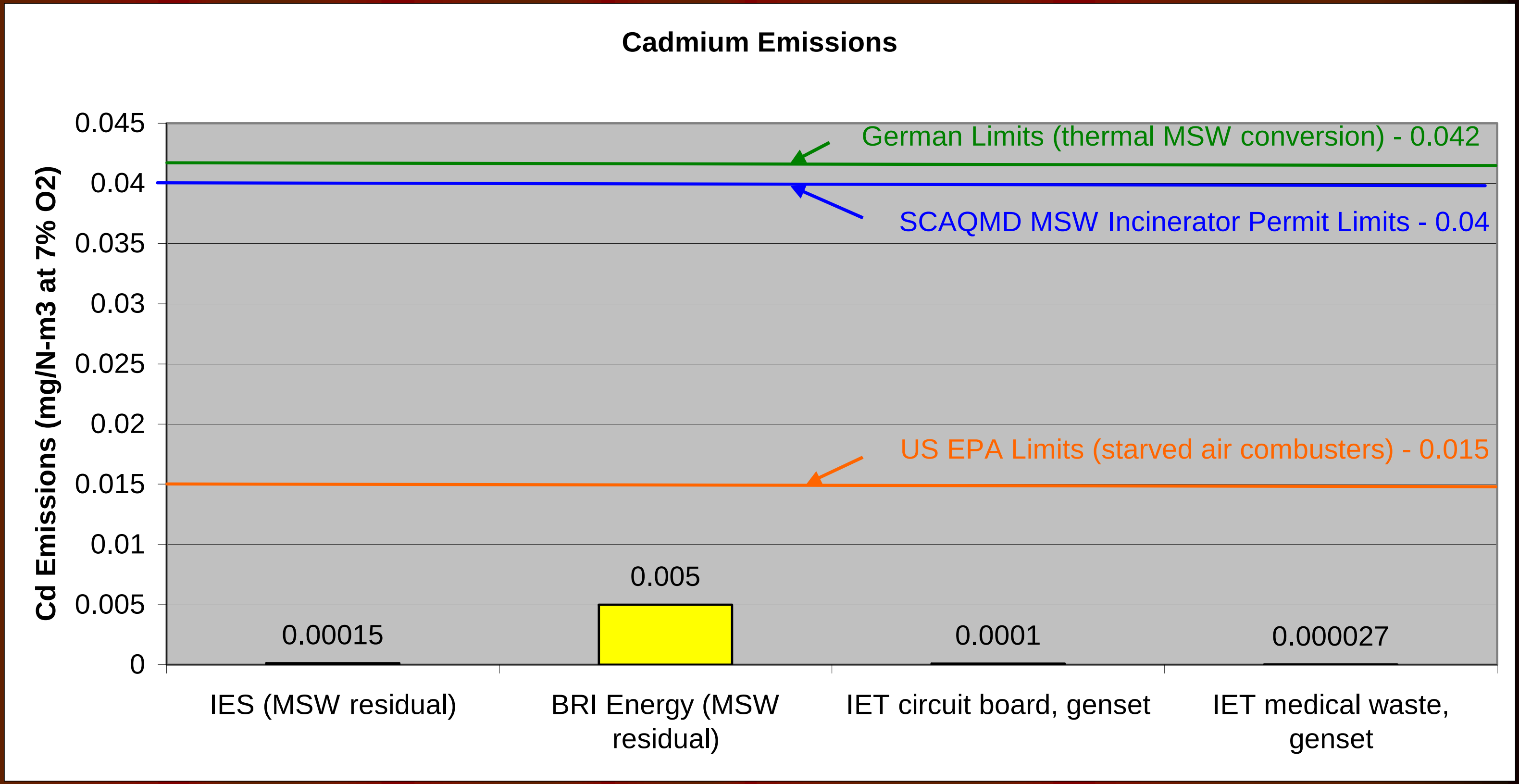
Emission Results - Lead



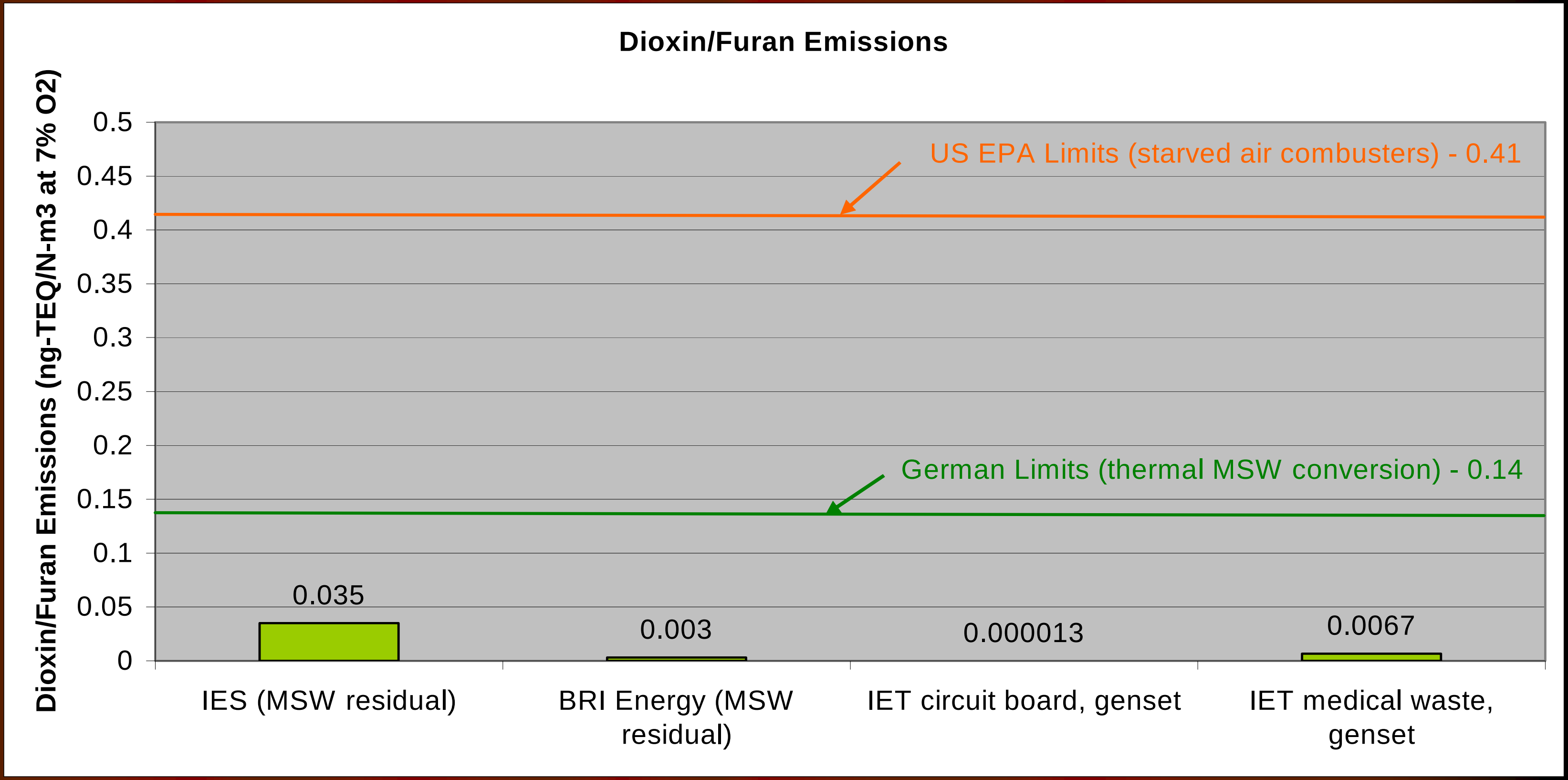
Emissions Results - Mercury



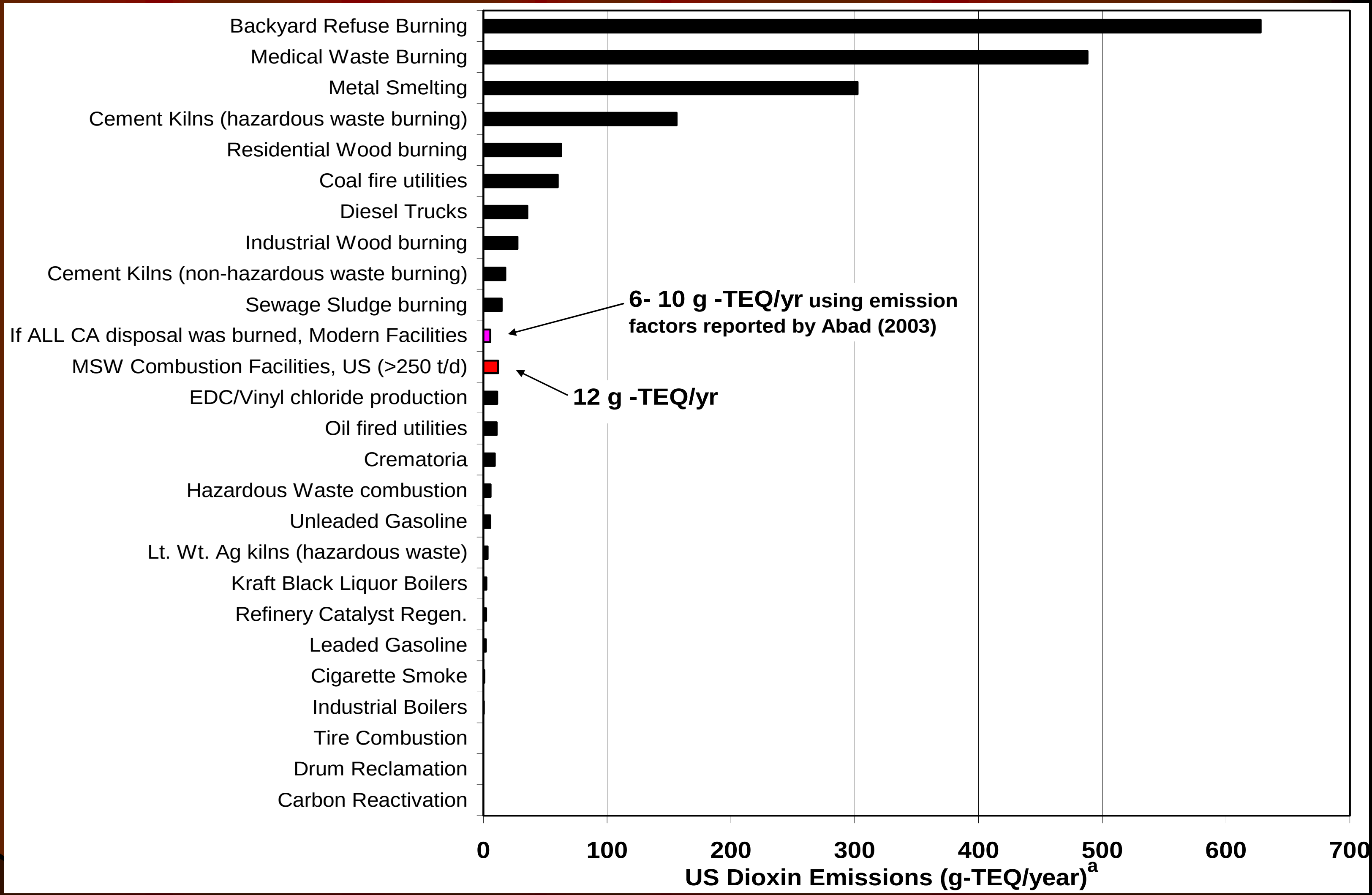
Emission Results - Cadmium



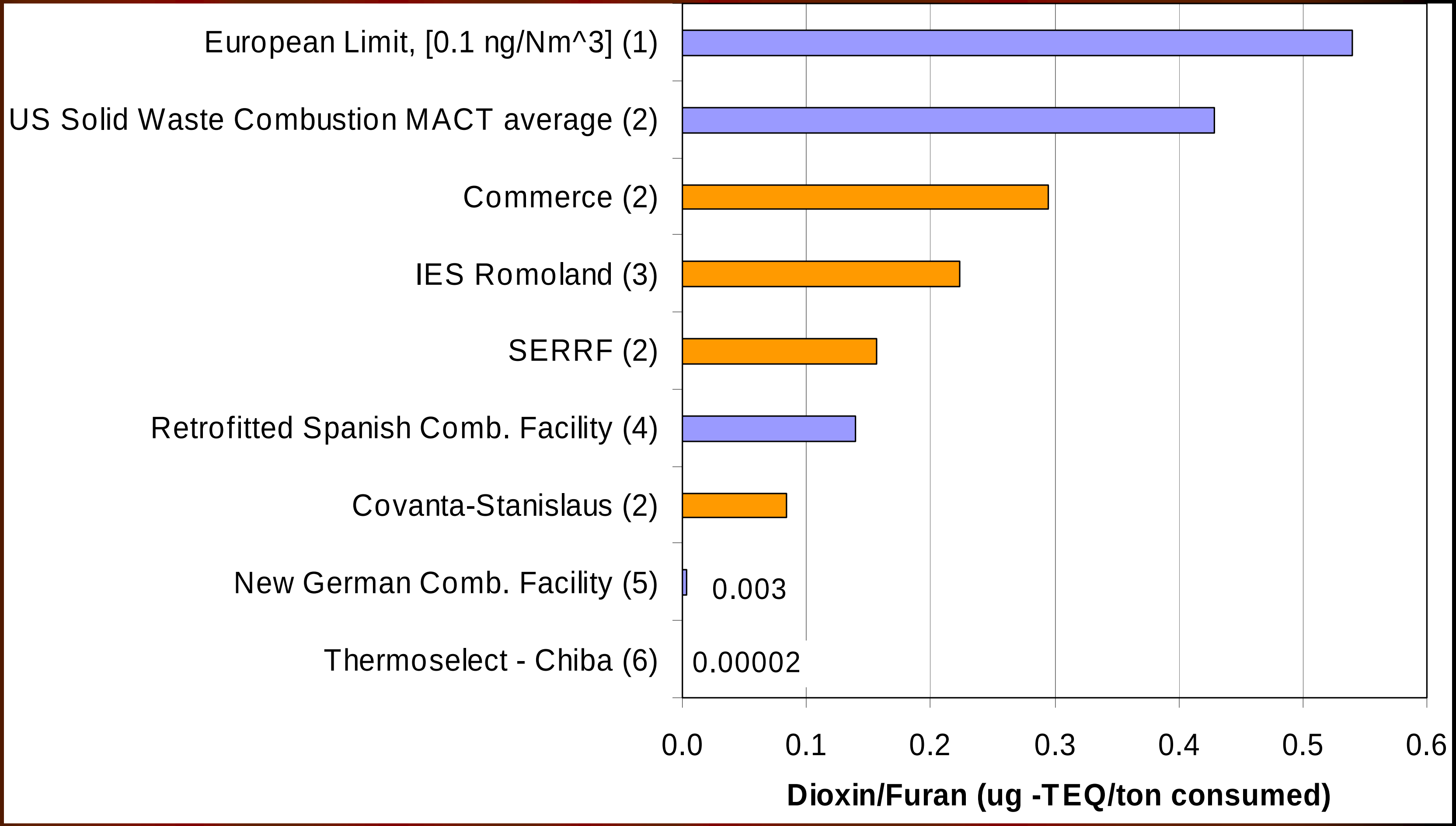
Emissions Results – Dioxins/Furans



US Dioxin Inventory



Dioxin emission factors for several technology types



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