BIOMASS PYROLYSIS

CDI

by

Fred L. Jones
Cogen Designs, Inc.

Waste Disposal Options

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- Landfilling
- Incineration
  - Mass Burn
  - Refuse Derived Fuel (RDF)
- Gasification
- Pyrolysis
  - High Temperature
  - Low Temperature

Pyrolysis

$$C_6H_{12}O_6 \xrightarrow{\text{Heat}} H_2,\ CO,\ H_2O,\ CO_2,\ C_1H_{1.8}O_{.28}\ \text{(Oils)},\ C_1H_{1.03}O_{.13}\ \text{(Coal)}$$

$$C_6H_{12}O_6 = 6\,C + 6\,H_2O$$

LTMP Renewable Fuels Process

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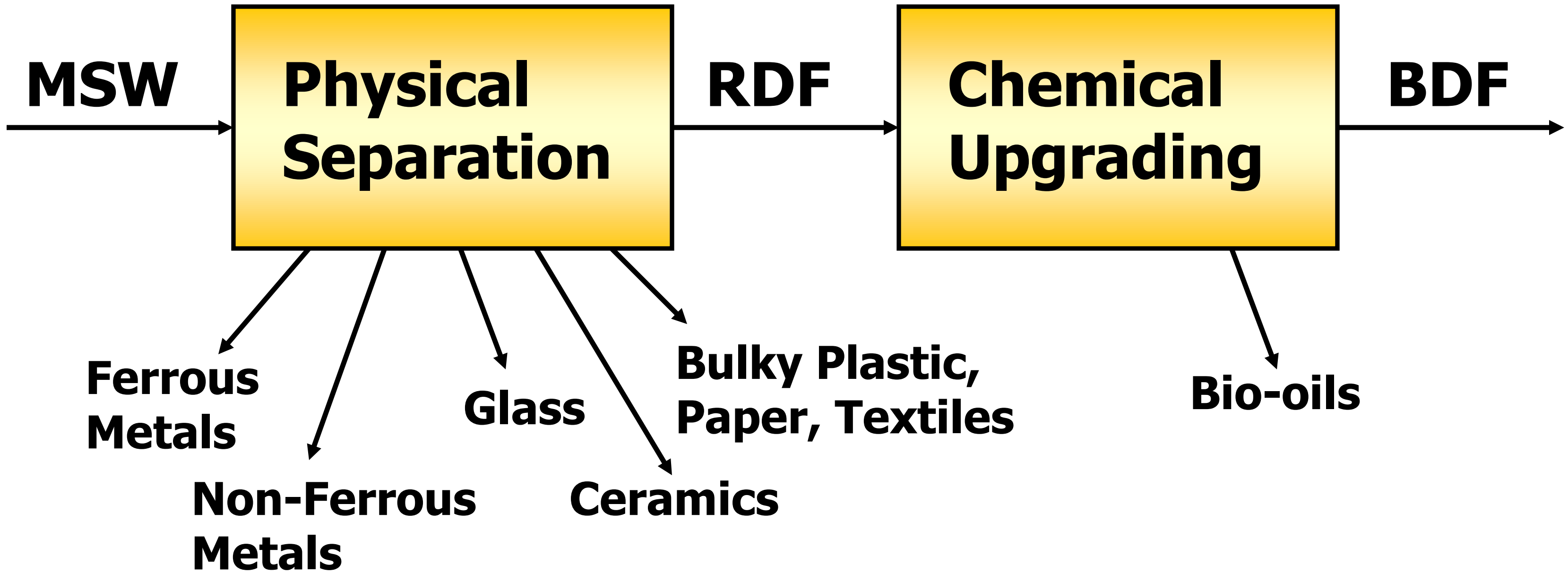

Fuel Upgrading

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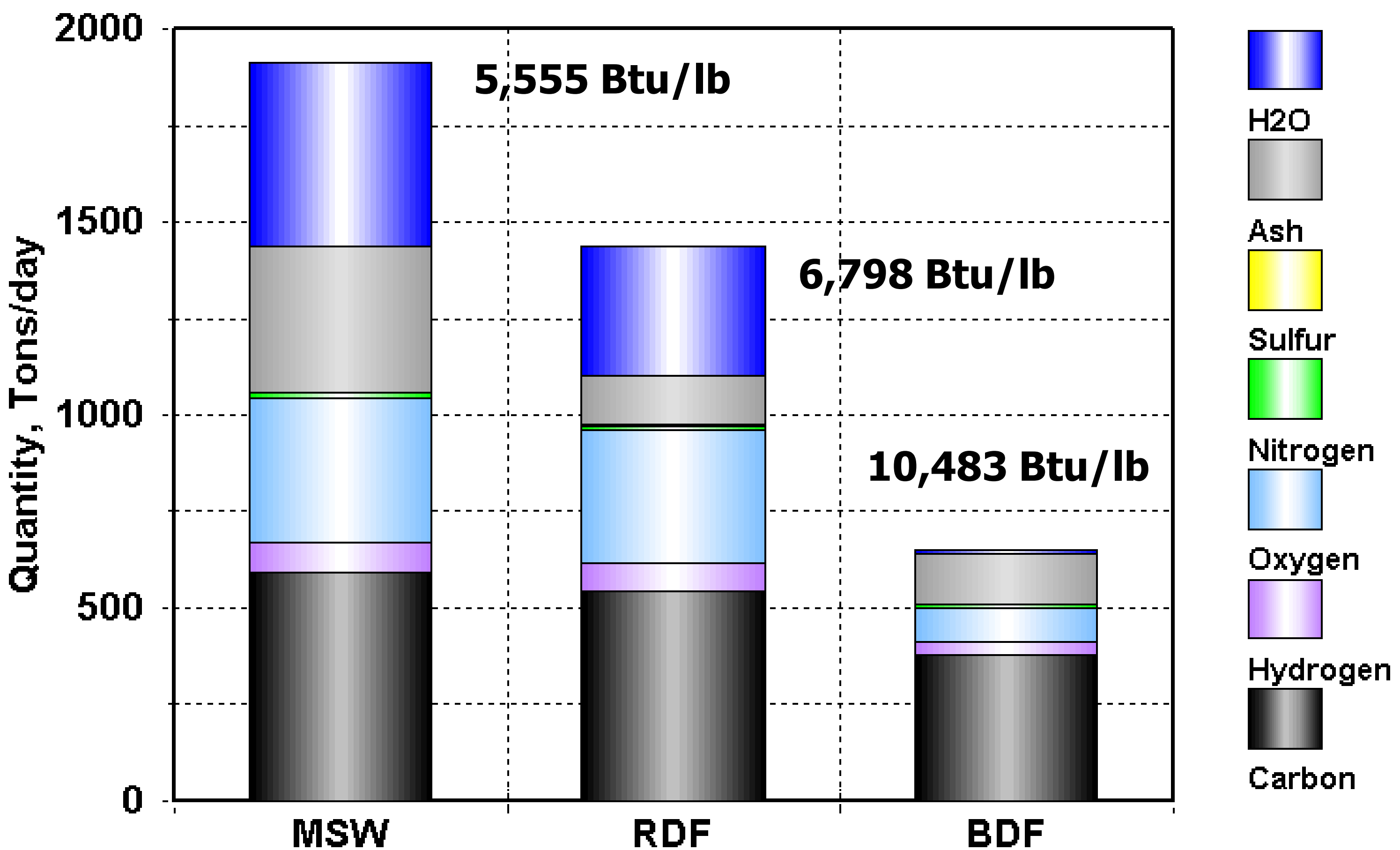

Waste to BDF

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Shredded Waste

Biomass-Derived Fuel

Why Displace Coal?

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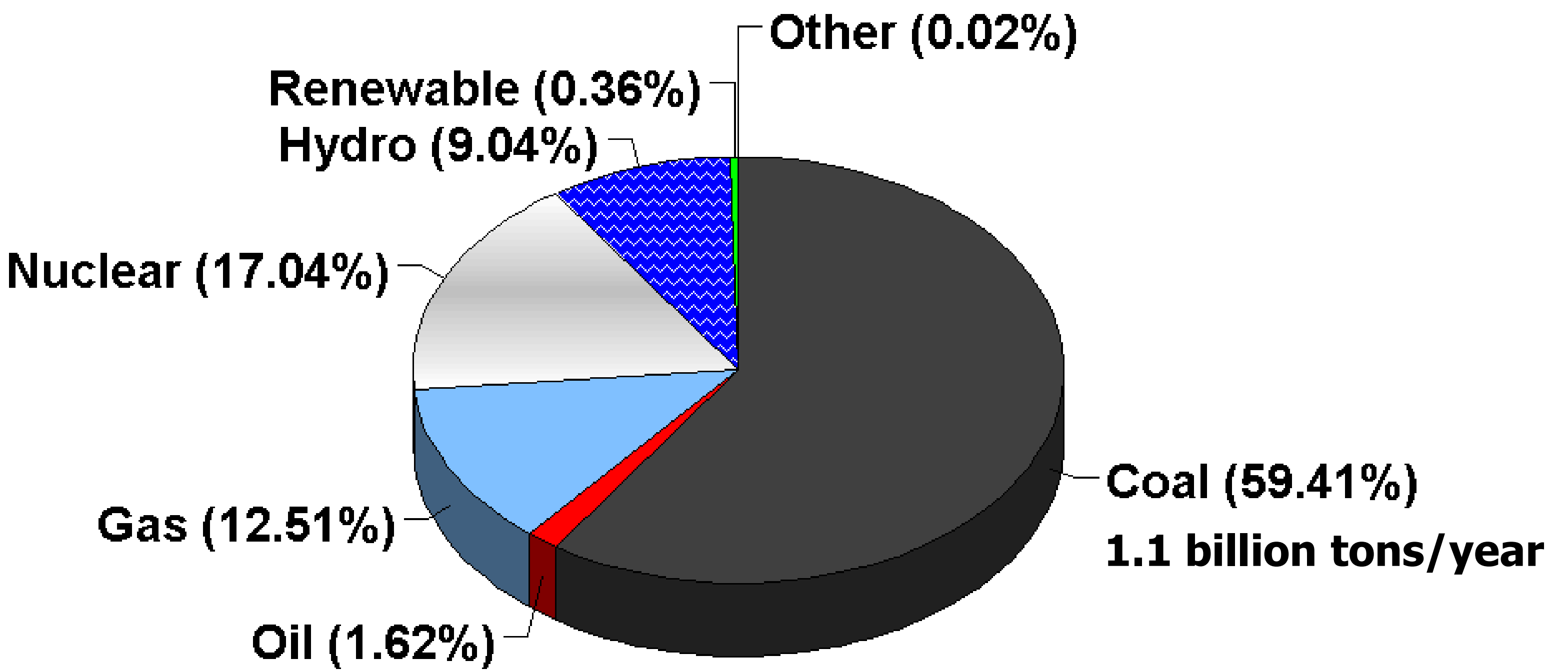
Electric Utility Fuel Use



Source: US EIA

Burning Biomass-Derived Fuel

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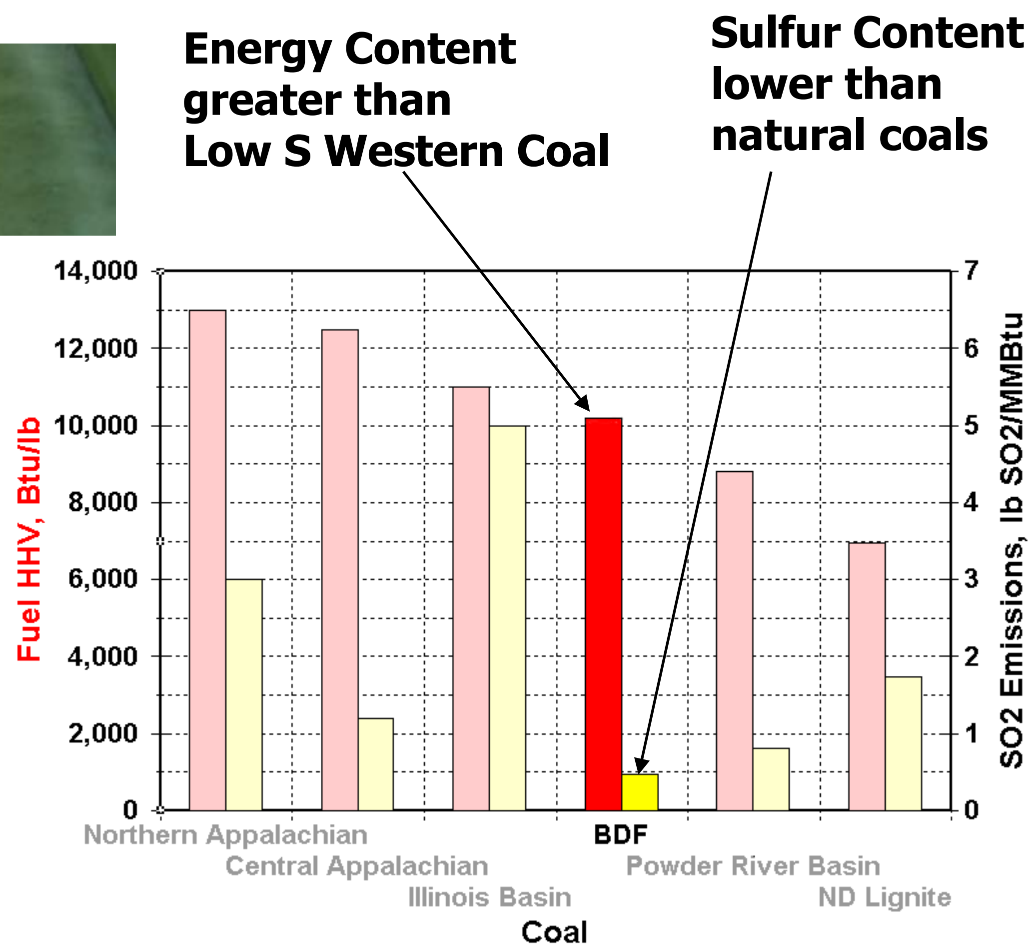
Easy ignition
Stable combustion
High carbon conversion



LTMP Pyrolysis Process

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- Based on low temperature twin screw extruder/mixer technology
  - Forty years of experience in similar applications, over 1,200 commercial extruder/mixer units in service.
  - Mixer produces highly consistent product quality
  - Process can operate on a wide variety of organic waste materials

Feedstock Range

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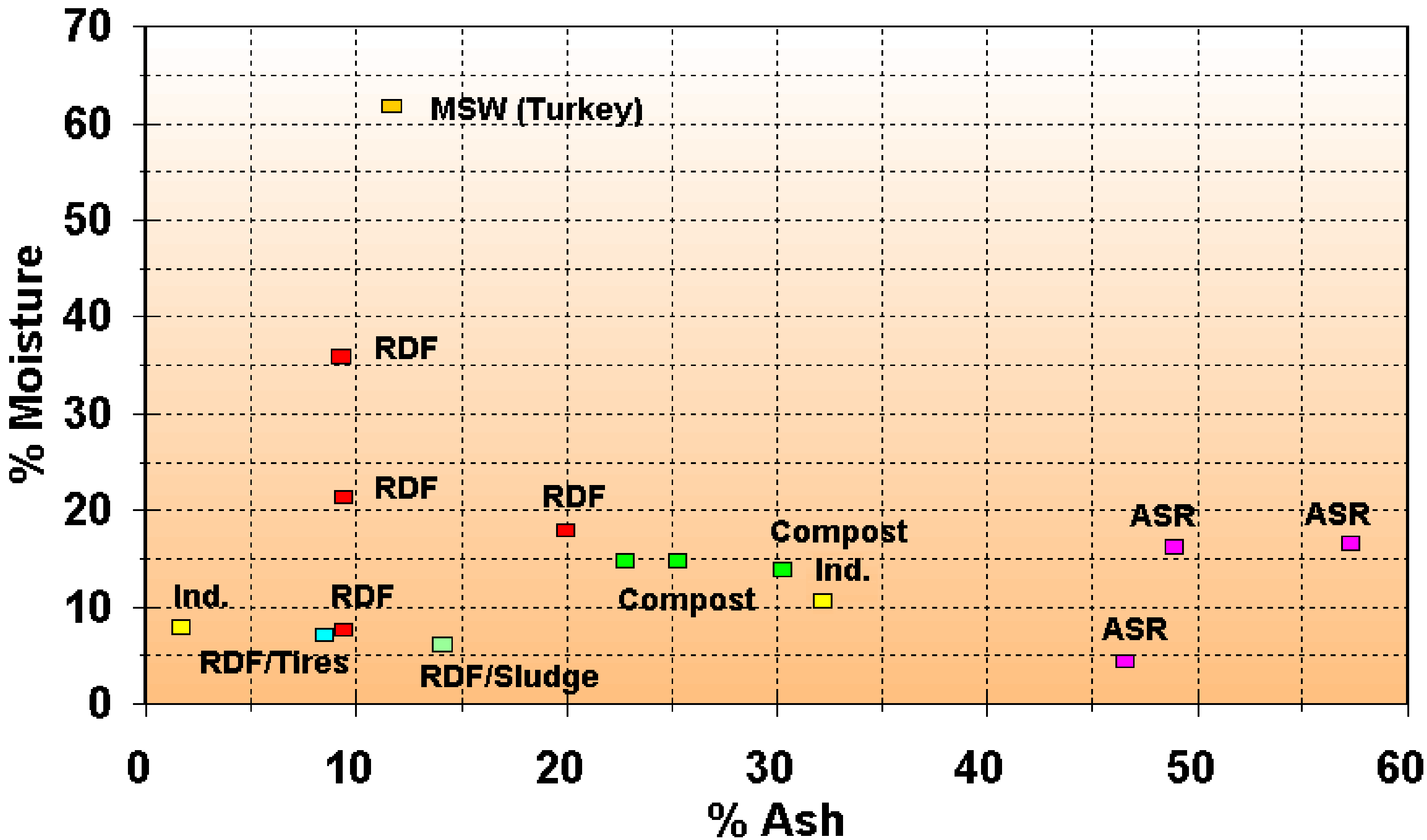

Pyrolysis Reactor

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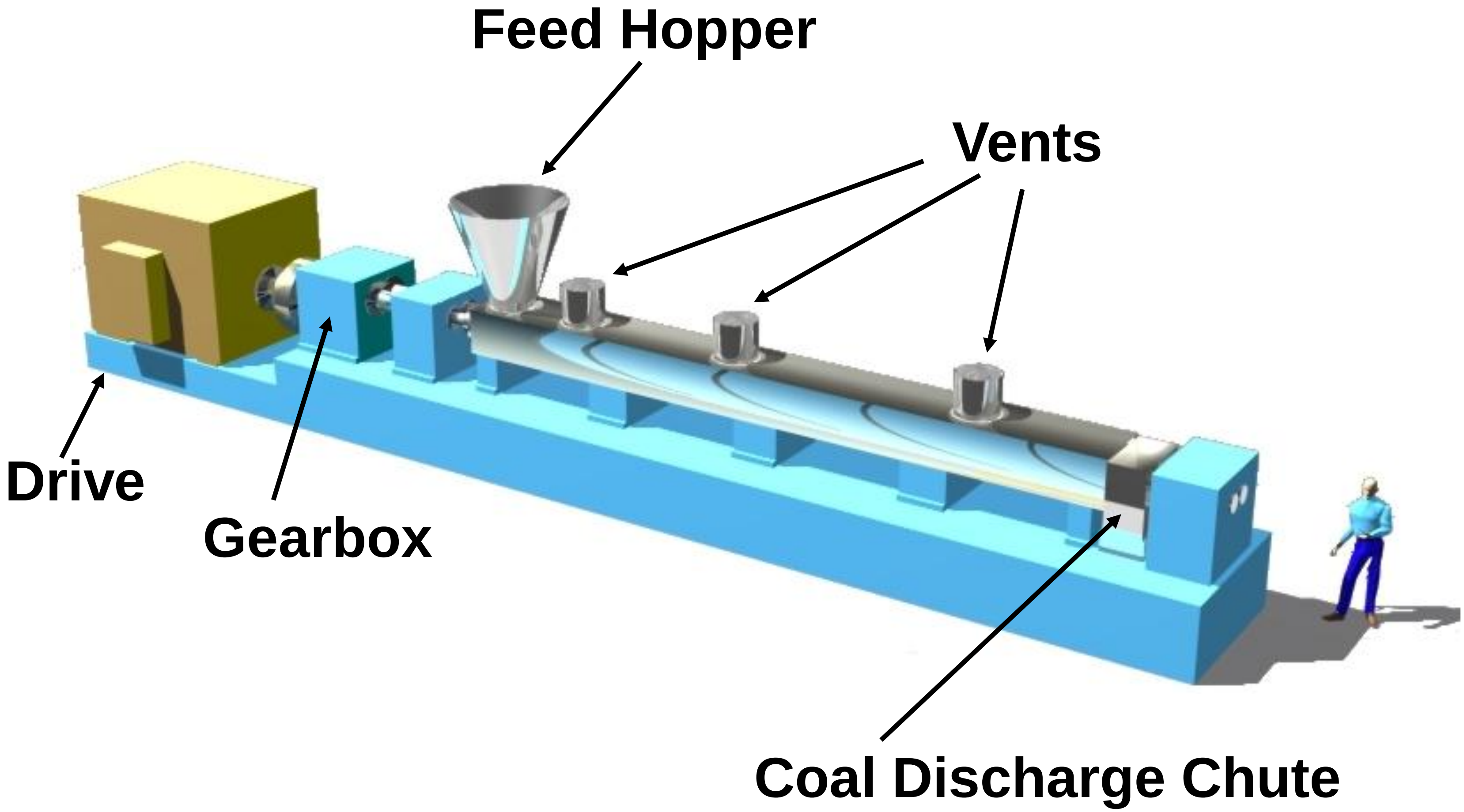

8 Tons/hr Capacity

Internal Augers

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~25 Tons/hr Capacity

BDF Production Process

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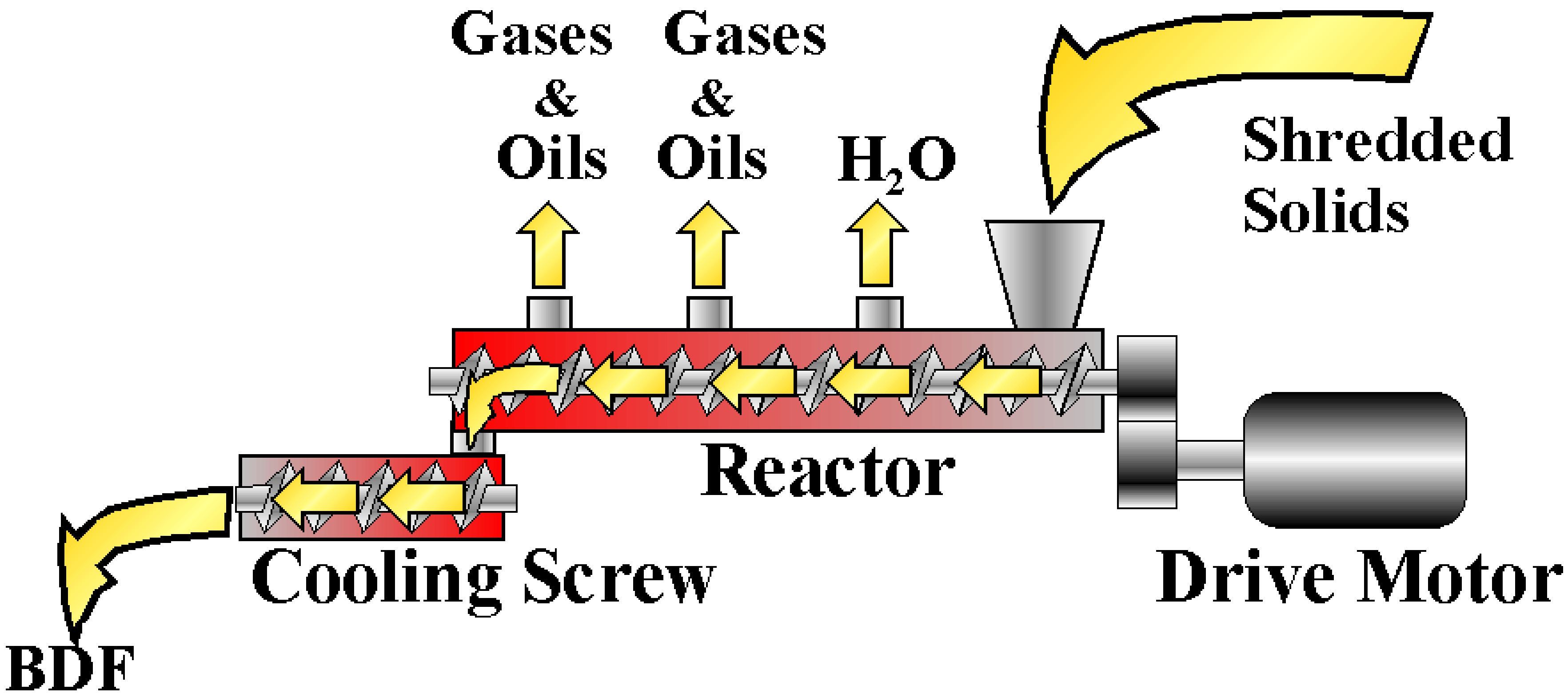
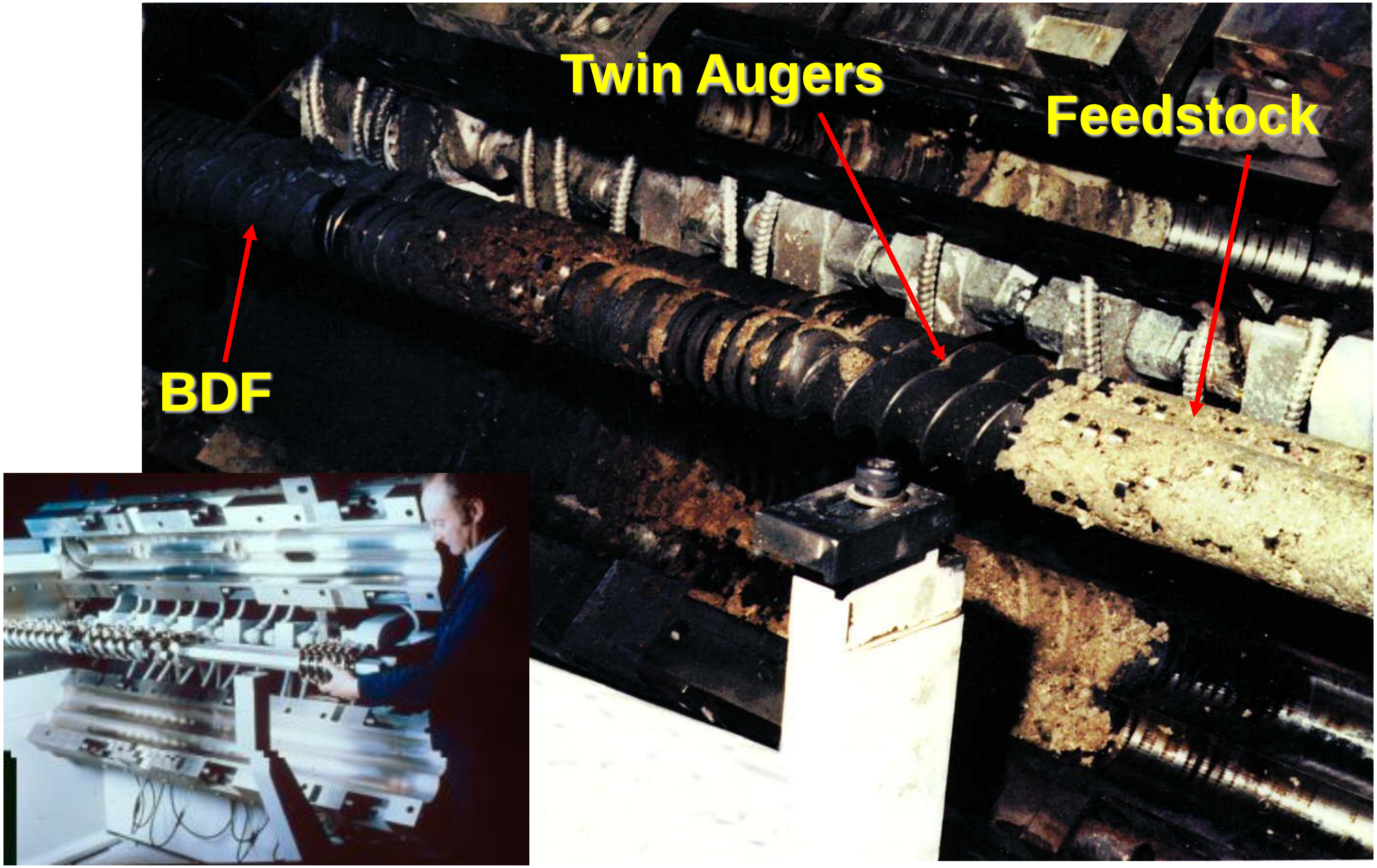


Pyrolysis at Work



Large Capacity Machines

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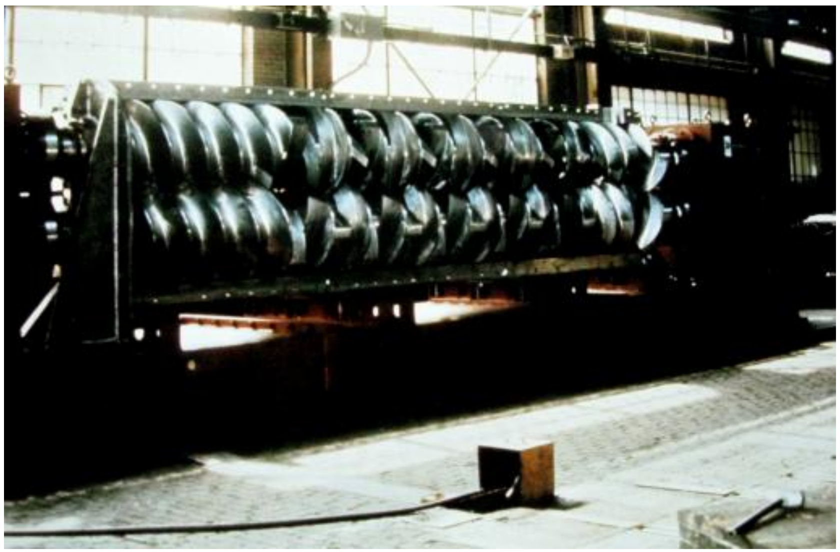
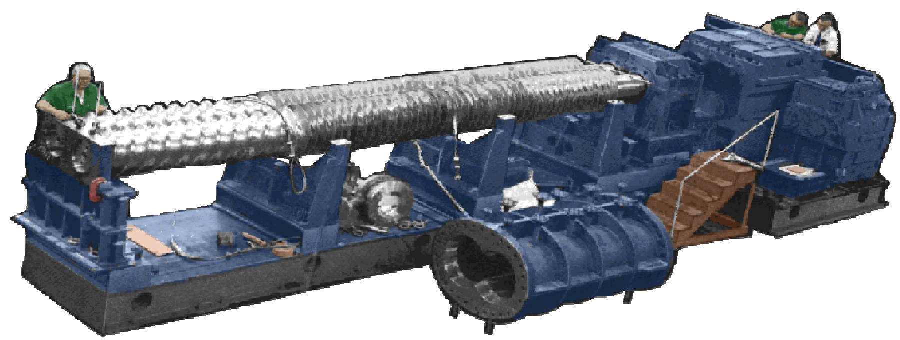


Similar Unit --
Designed for cellulose
Vertical vs horizontal
35" Diameter Augers
100 tph vs 8 tph

Similar Unit --
Designed for Kevlar
Horizontal Configuration
31" Diameter Augers
75 tph vs 8 tph



Unique Reactor Properties

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- No incineration, combustion or burning
- No air or oxygen added
- No flame
- No external heat addition
- No circulating solids
- 550°F max. operating temperature
- Single step to end product - no refining needed

Dioxin Formation

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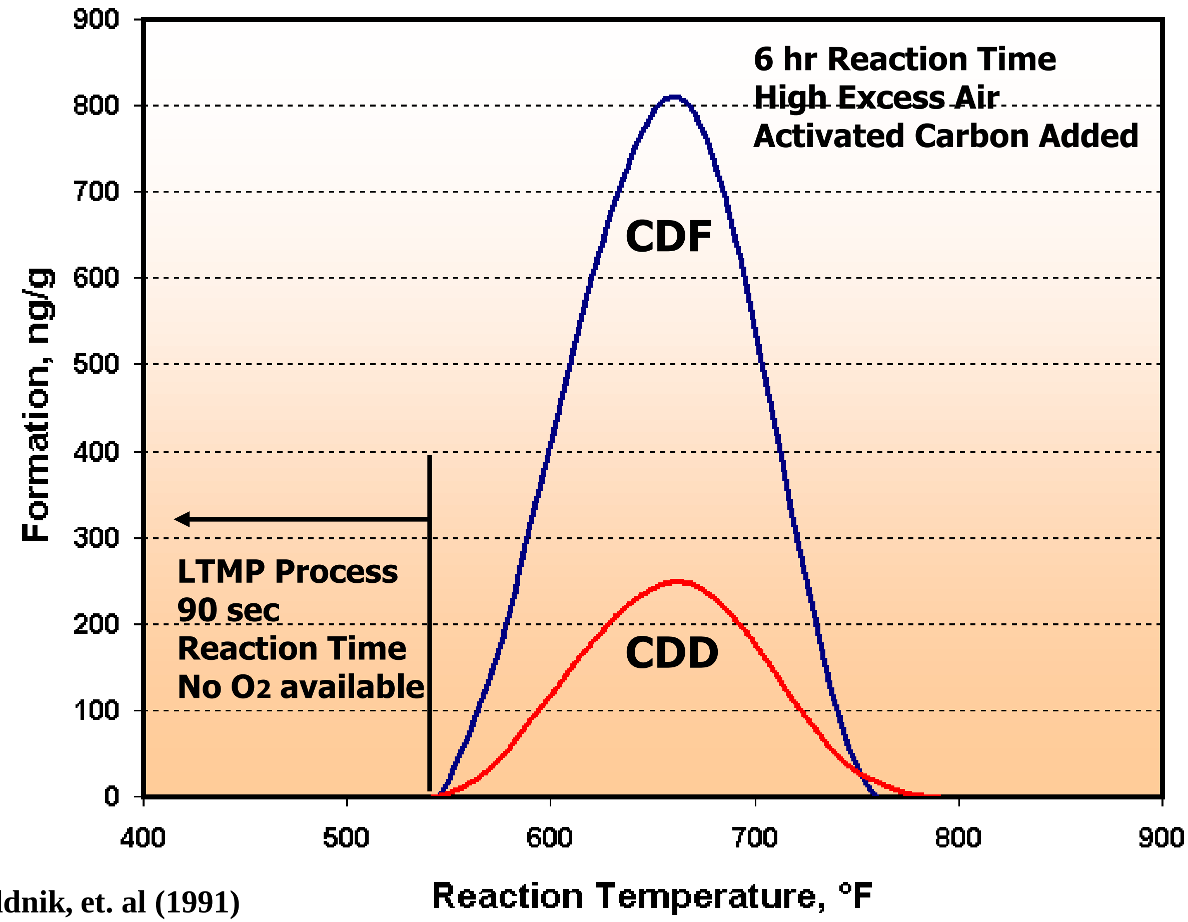

Sources: USEPA, Addnik, et. al (1991)

Incineration vs. LTMP

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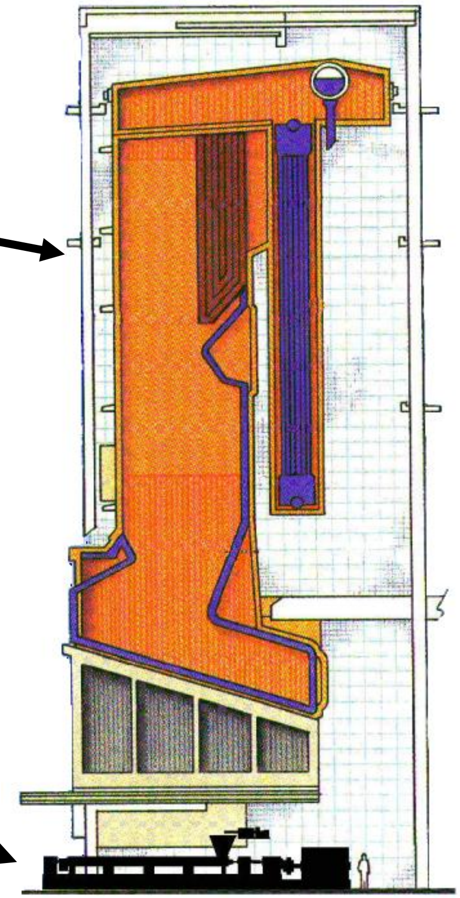

200 Tpd Incinerator

200 Tpd LTMP Reactor

Incineration vs Pyrolysis

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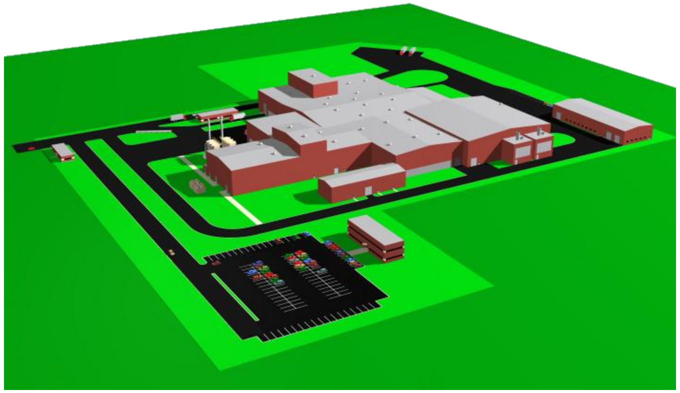
Detroit Incinerator, Michigan

LTMP Pyrolysis, Illinois



Waste Quantity — 3,200 UST/d*
Waste Moisture — 18%
Net Power Generation — 65 MW
Generating Efficiency — 16.9%

Waste Quantity — 1,232 UST/d*
Waste Moisture — 24%
Power from Syncoal — 35 MW
Generating Efficiency — 19.2%

***7 day/wk average**

RDF Preparation

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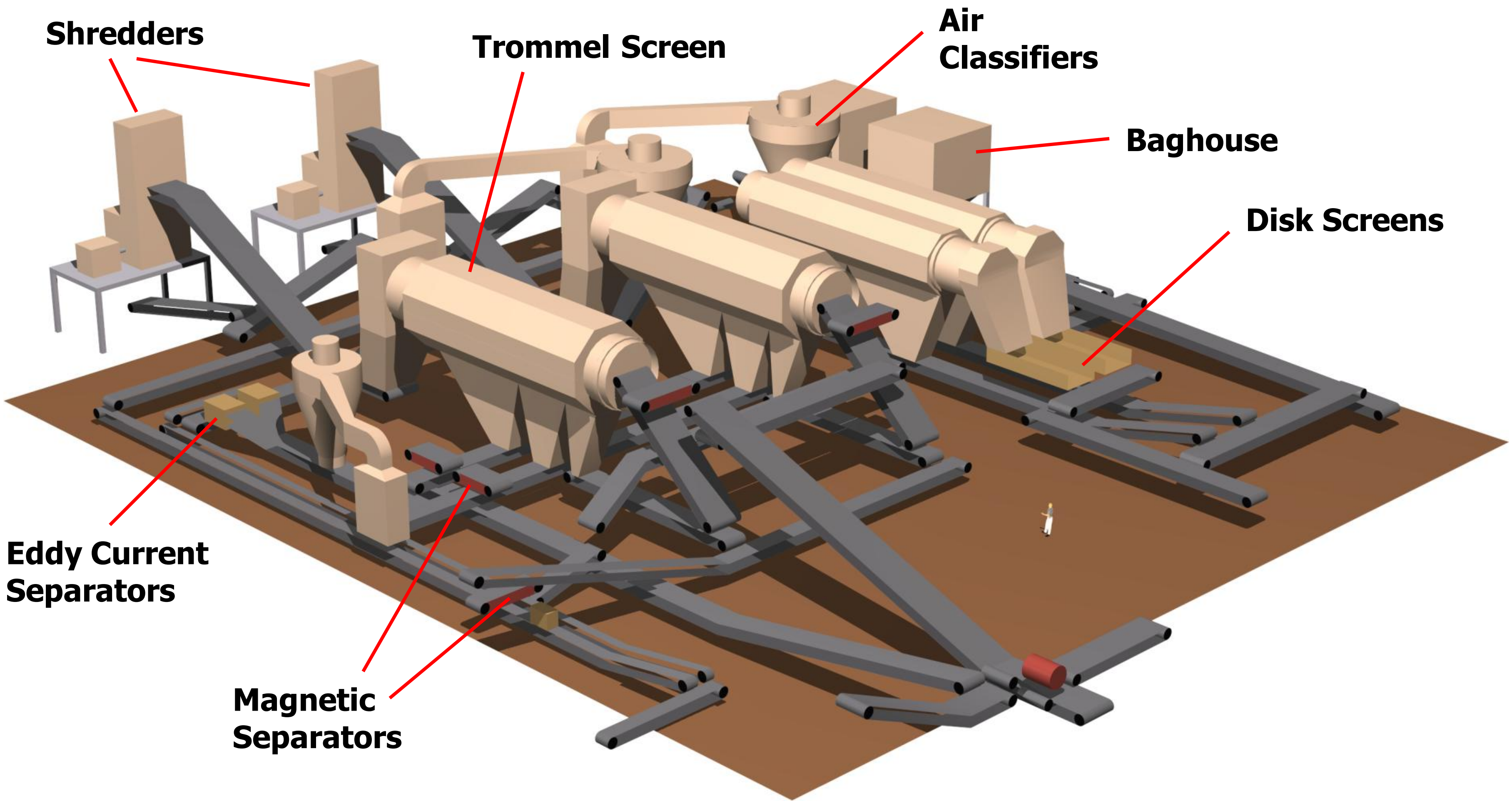

Pyrolysis Area

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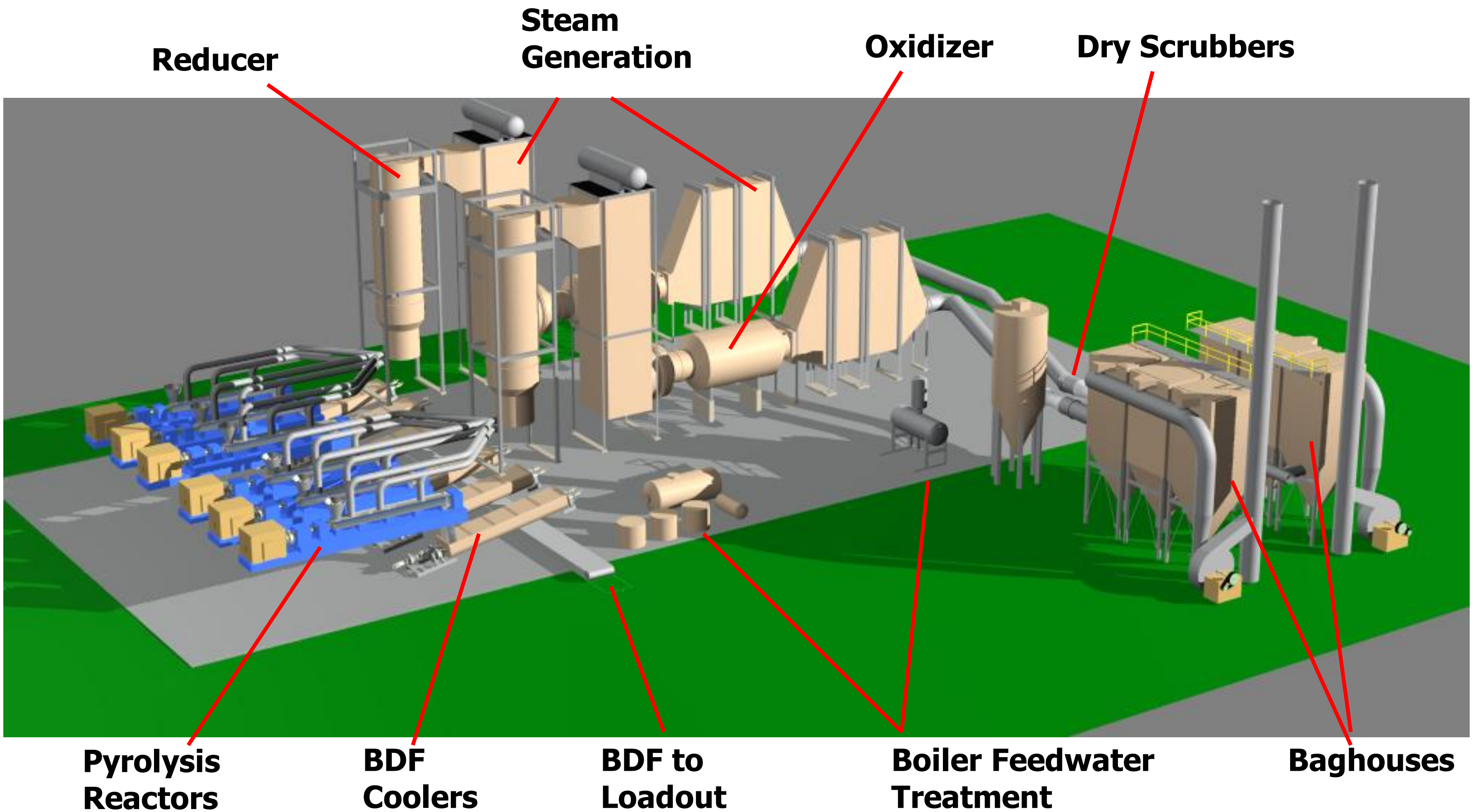
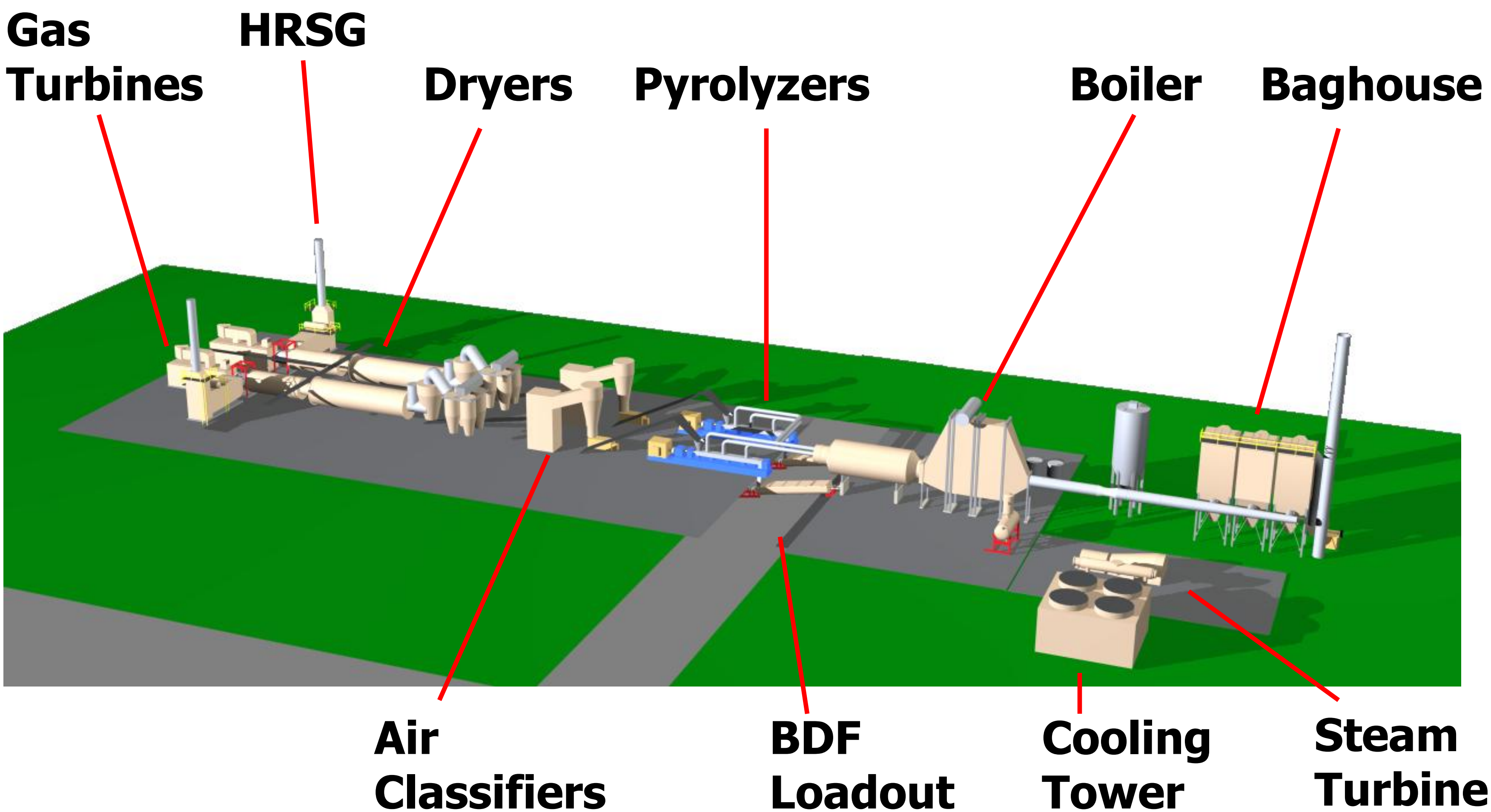


Pyrolysis Area - High Moisture



Incineration vs Pyrolysis

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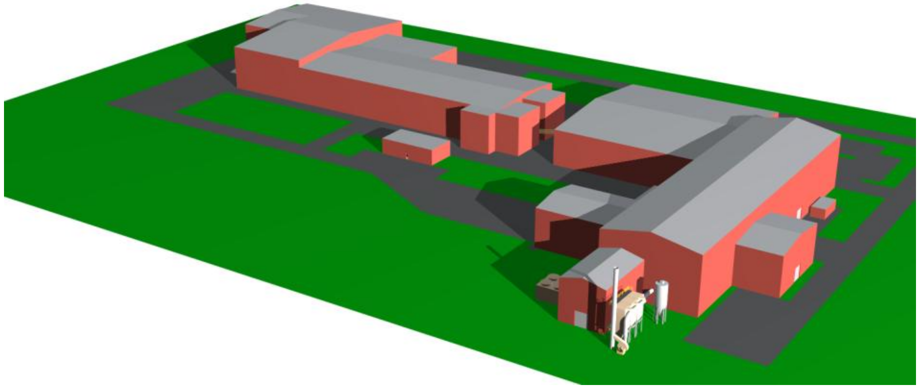
Kajang Incinerator, Malaysia*

Waste Quantity — 1,100 UST/d
Waste Moisture — 56%
Net Power Generation — 5 MW
Generating Efficiency — 6.4%

LTMP Pyrolysis, Santiago



Waste Quantity — 1,500 UST/d
Waste Moisture — 54%
Power from Syncoal — 25 MW
Generating Efficiency — 19.2%

***Renewable Project of the Year 2010 -- "Power Magazine"**

Process Comparisons

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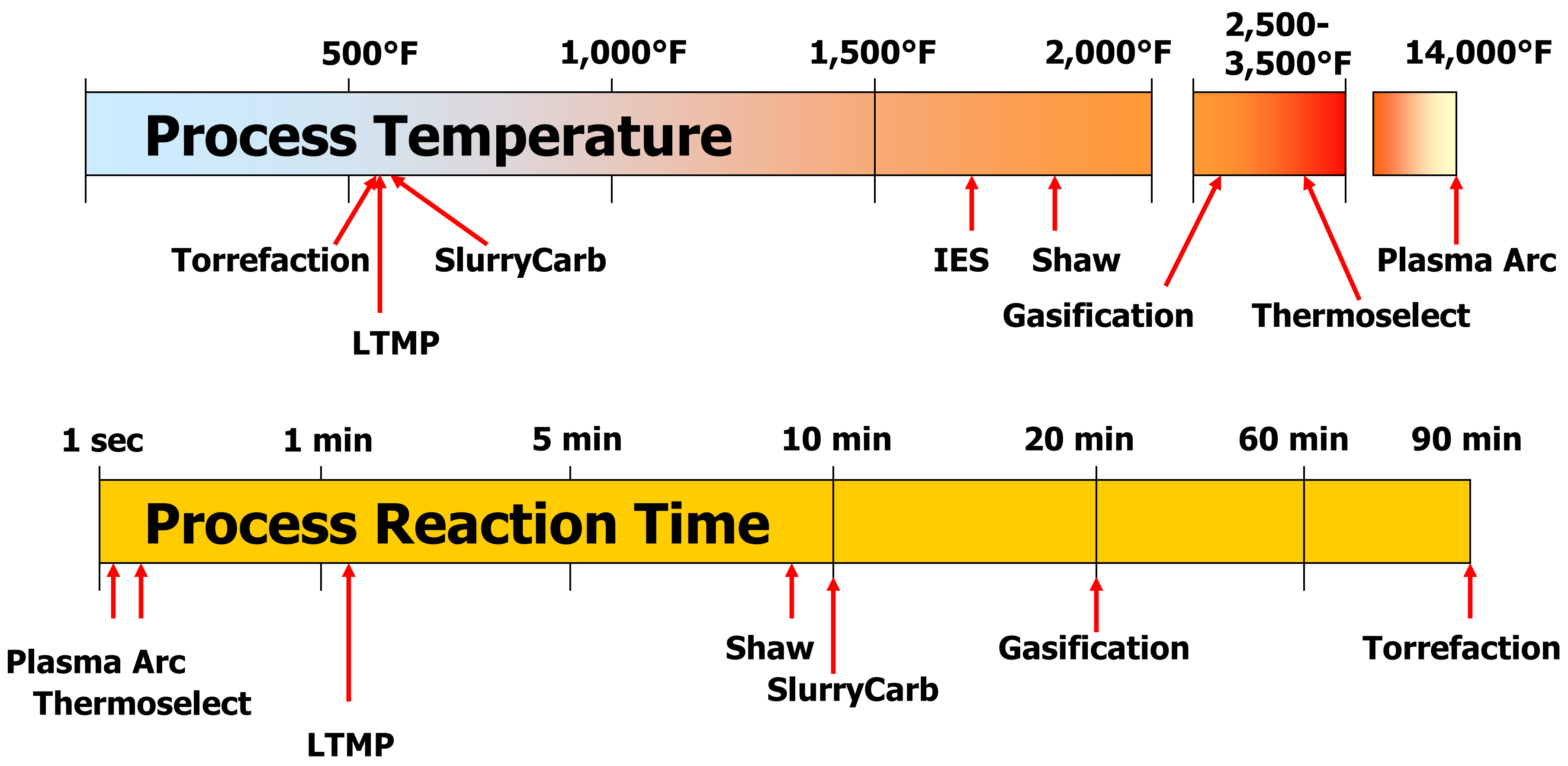
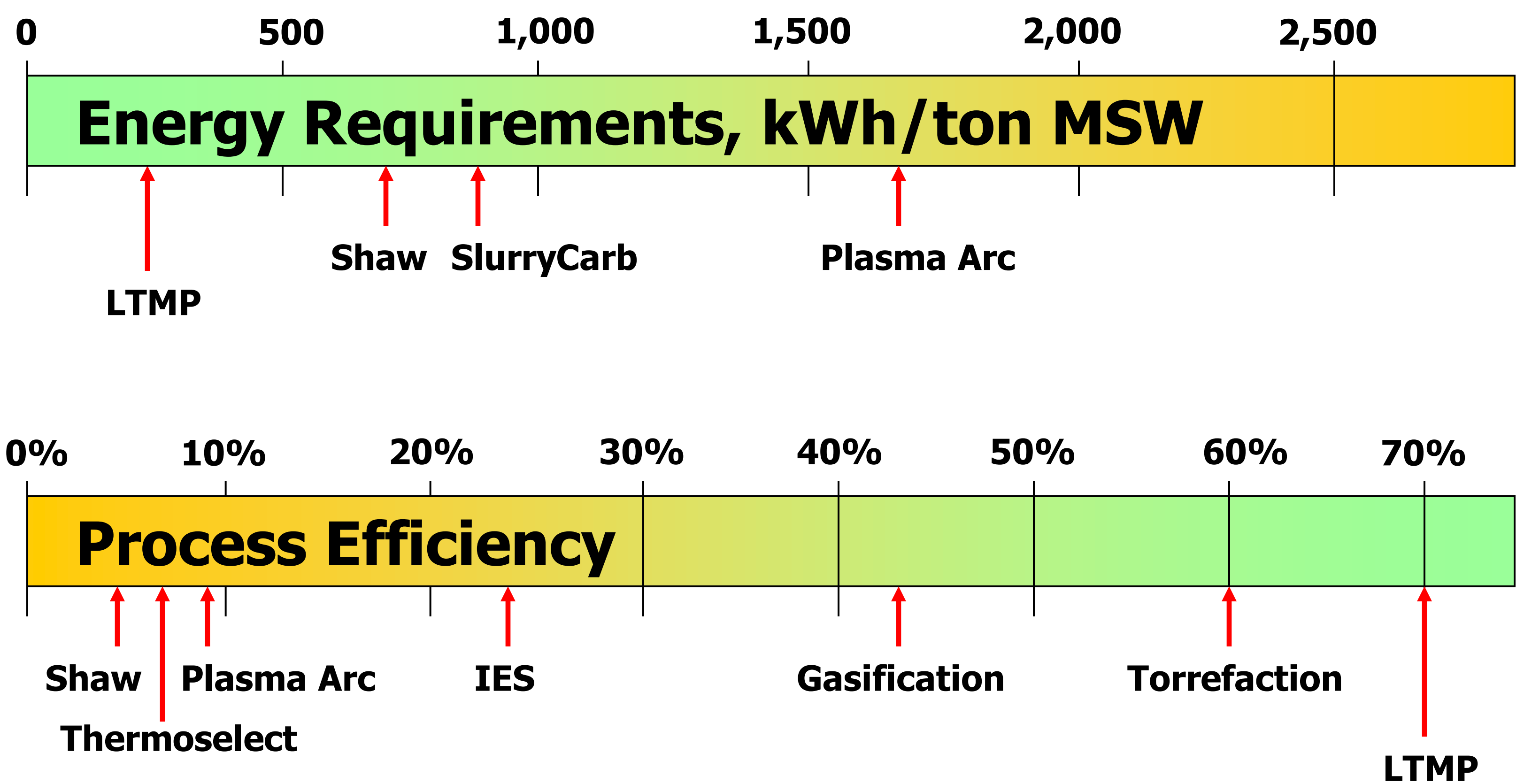


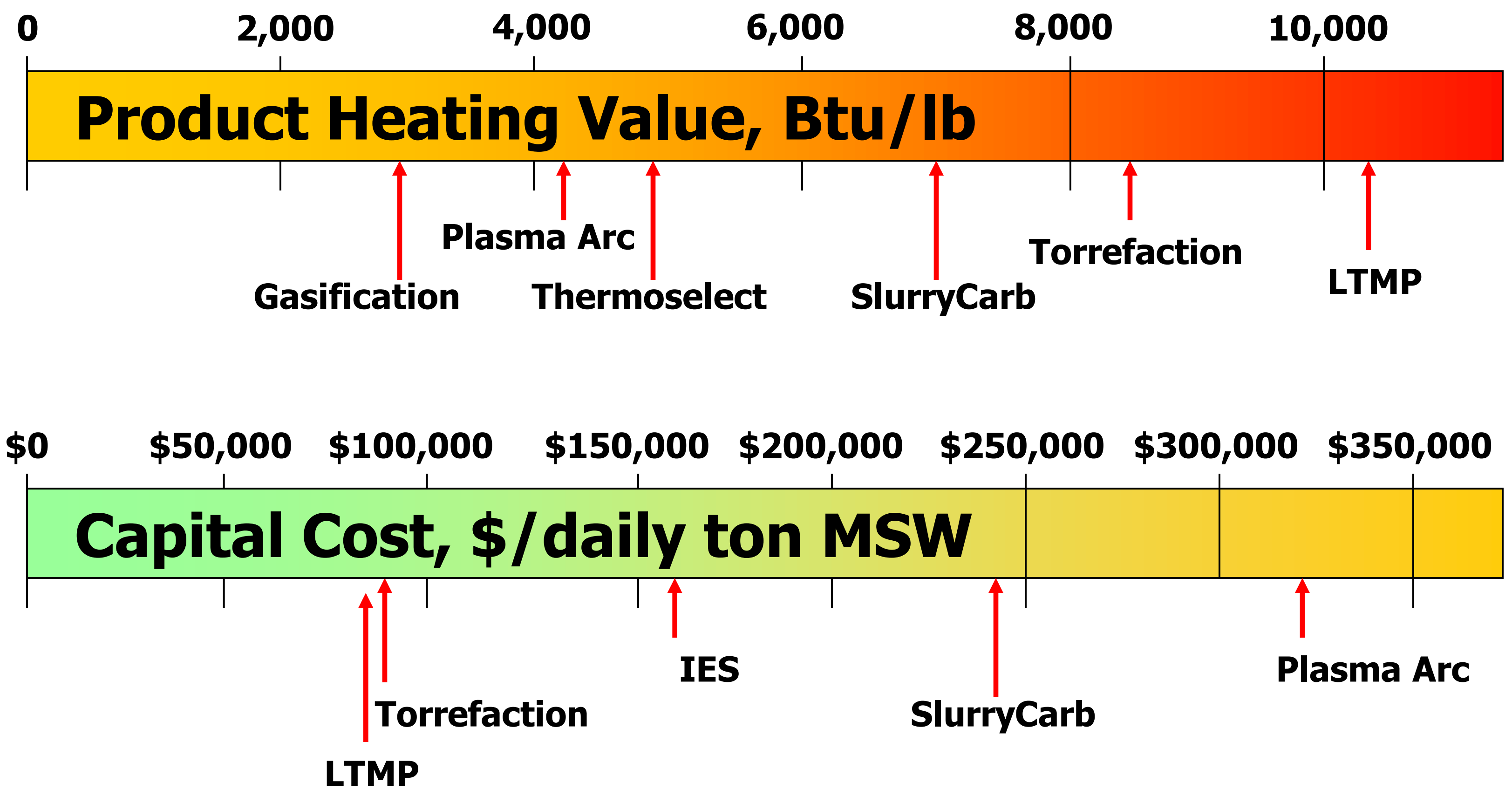
Process Comparisons

CDI



Process Comparisons

CDI



Net Energy Production

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	Net Electric/ Fuel Output	1,000 TPD 100% Availability
Thermal		
Gasification	400 kWh/ton	16 MWe
Pyrolysis	450 kWh/ton	19 MWe
Plasma Arc	400 kWh/ton	16 MWe
Anaerobic Digestion	125 kWh/ton	5 MWe
Acid Hydrolysis	31 gal EtOH/ton (260 kWh/ton)	11 mm gal/yr (11 MWe)
LTMP Carbonization	0.38 ton BDF/ton (785 kWh/ton)	137,000 tpy BDF (33 MWe)

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Comparative Emissions

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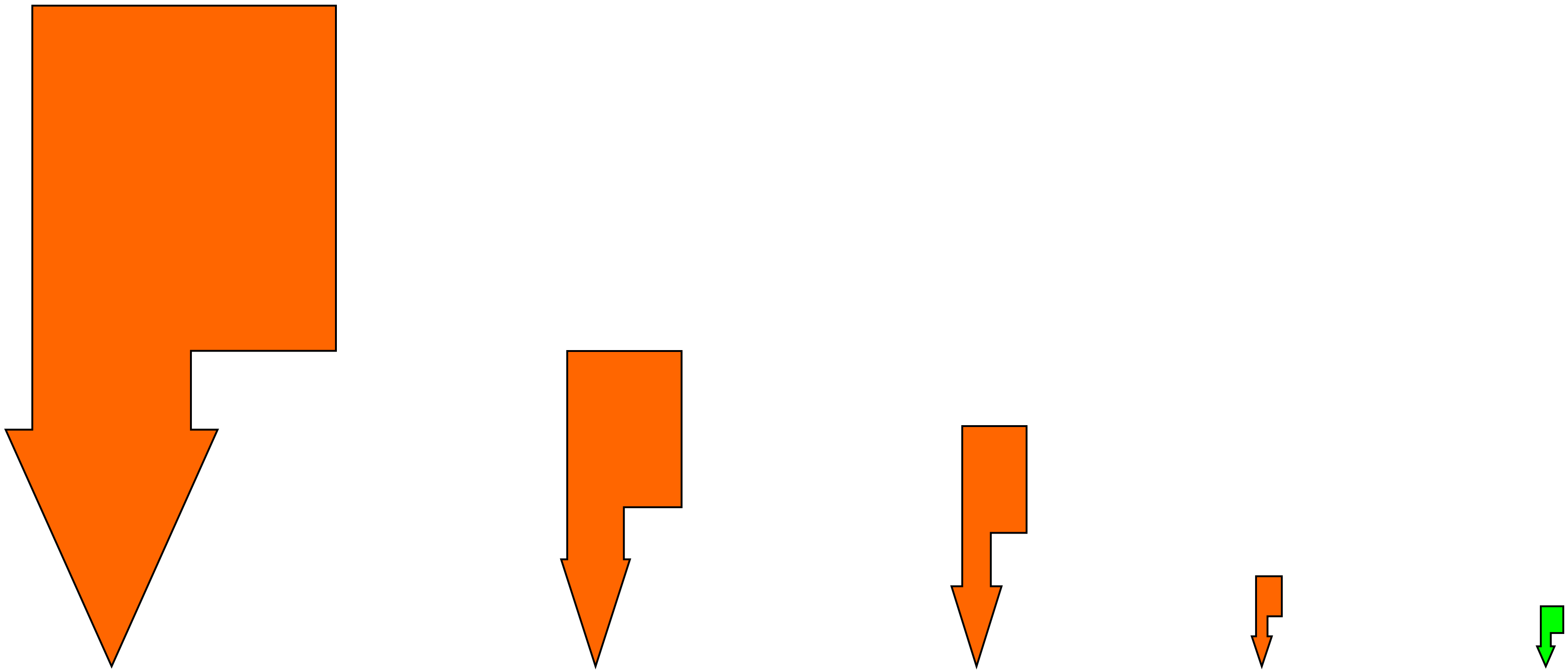

Utility	Refinery	Incinerator	Large Hospital	BDF Production
Emissions, Tons/year 37,000	5,000	2,400	370	234*

*minor source

Sources of Greenhouse Gases

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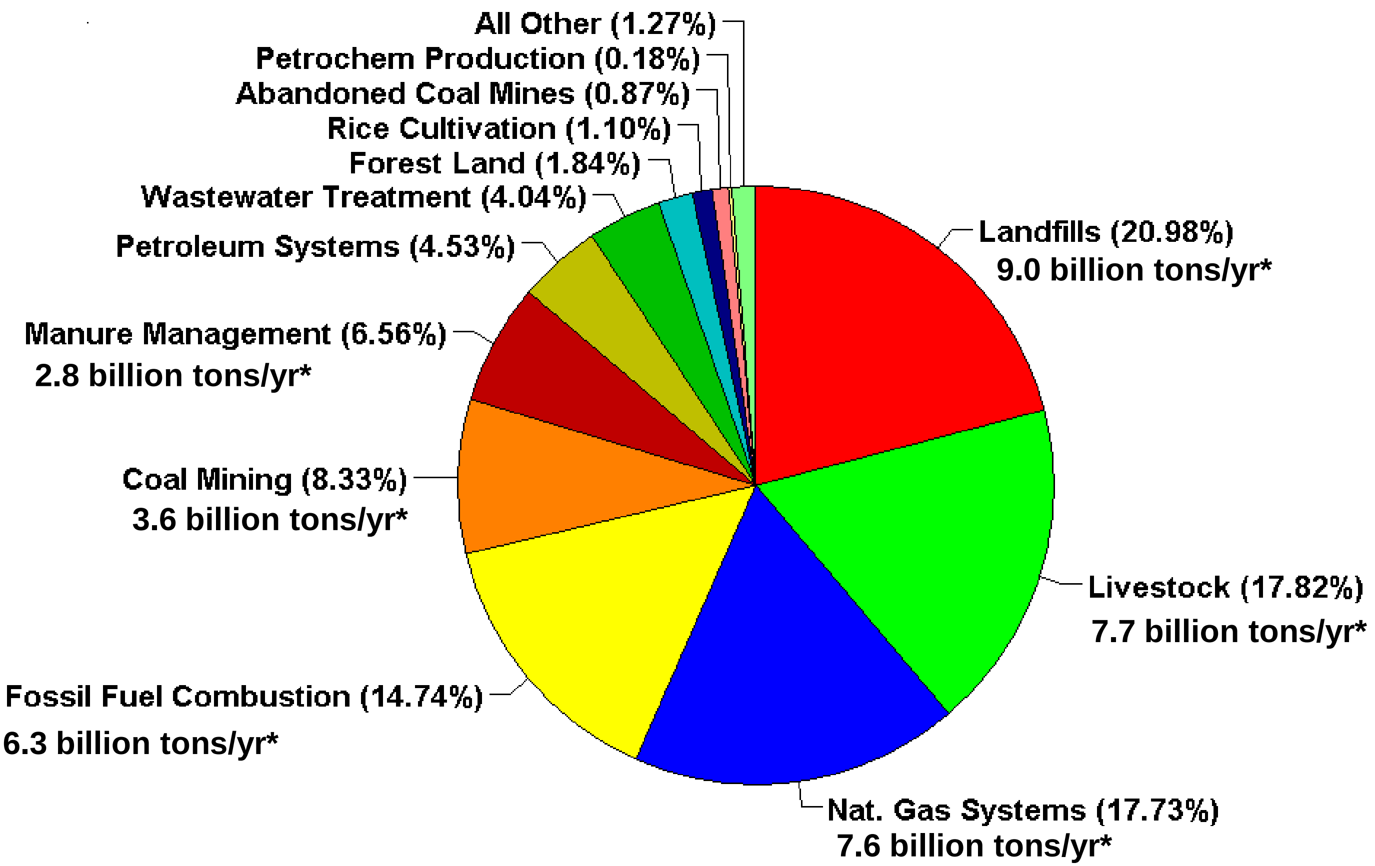
US EPA Data



*CO_2 Equivalent

Greenhouse Gas Reduction

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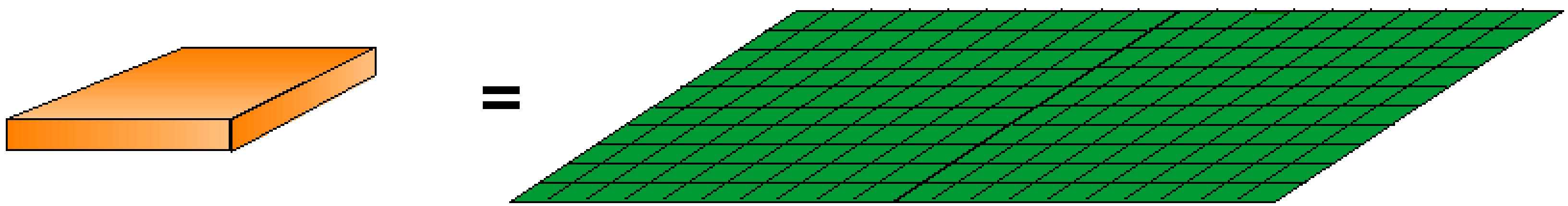
LTMP Plant vs Forest Land



200 Square Miles

	1 LTMP Plant	1 Acre Forest Land
Capacity	1,600 Tons/day MSW 450,000 Tons/yr MSW	
CO_2 Reduced*	1.5 million Tons/yr	12 Tons/yr

***All Greenhouse gases, as CO_2**

Source: MI United Conservation Club

Dioxin Emission Factors

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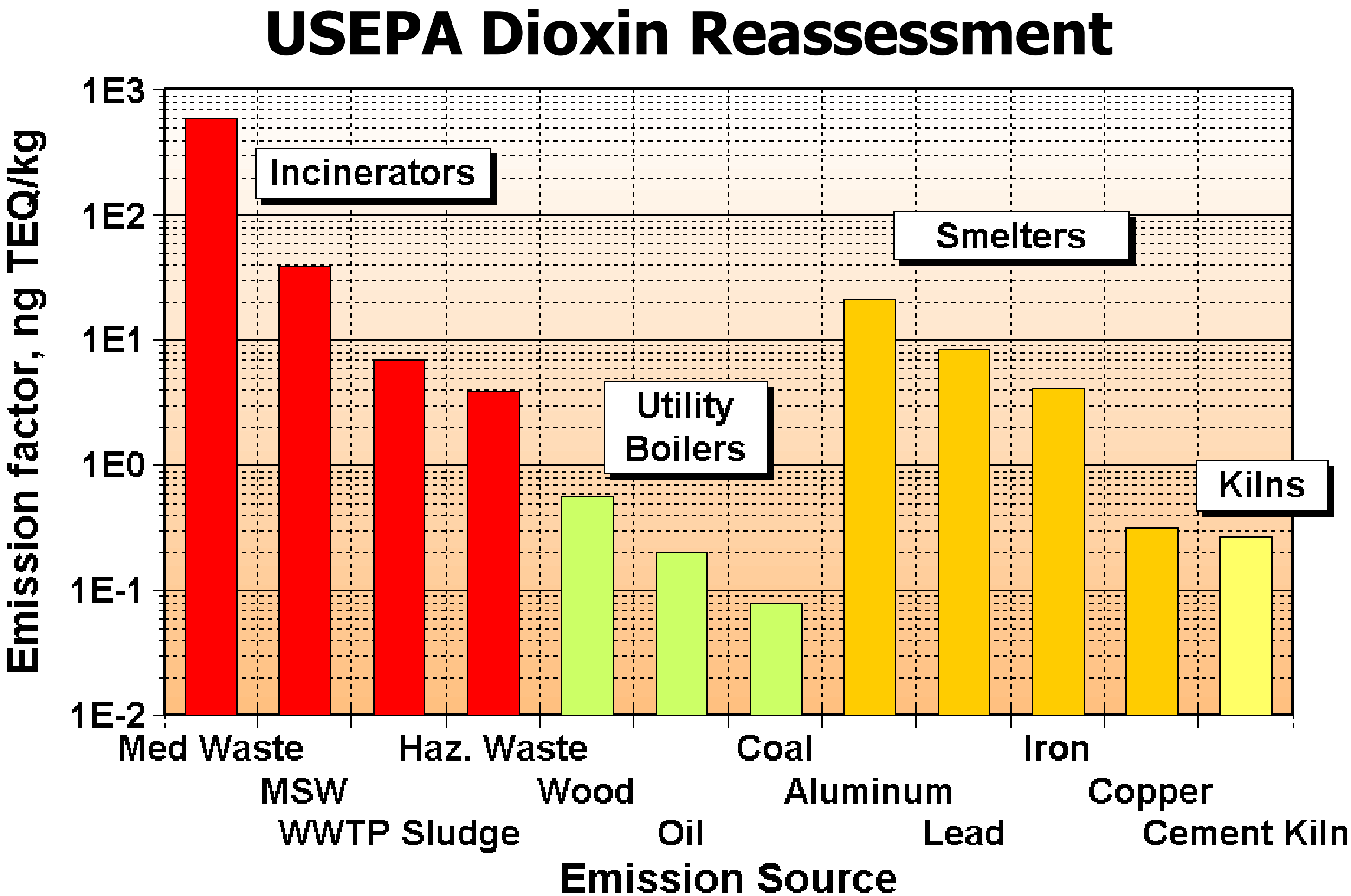

Environmental Impact

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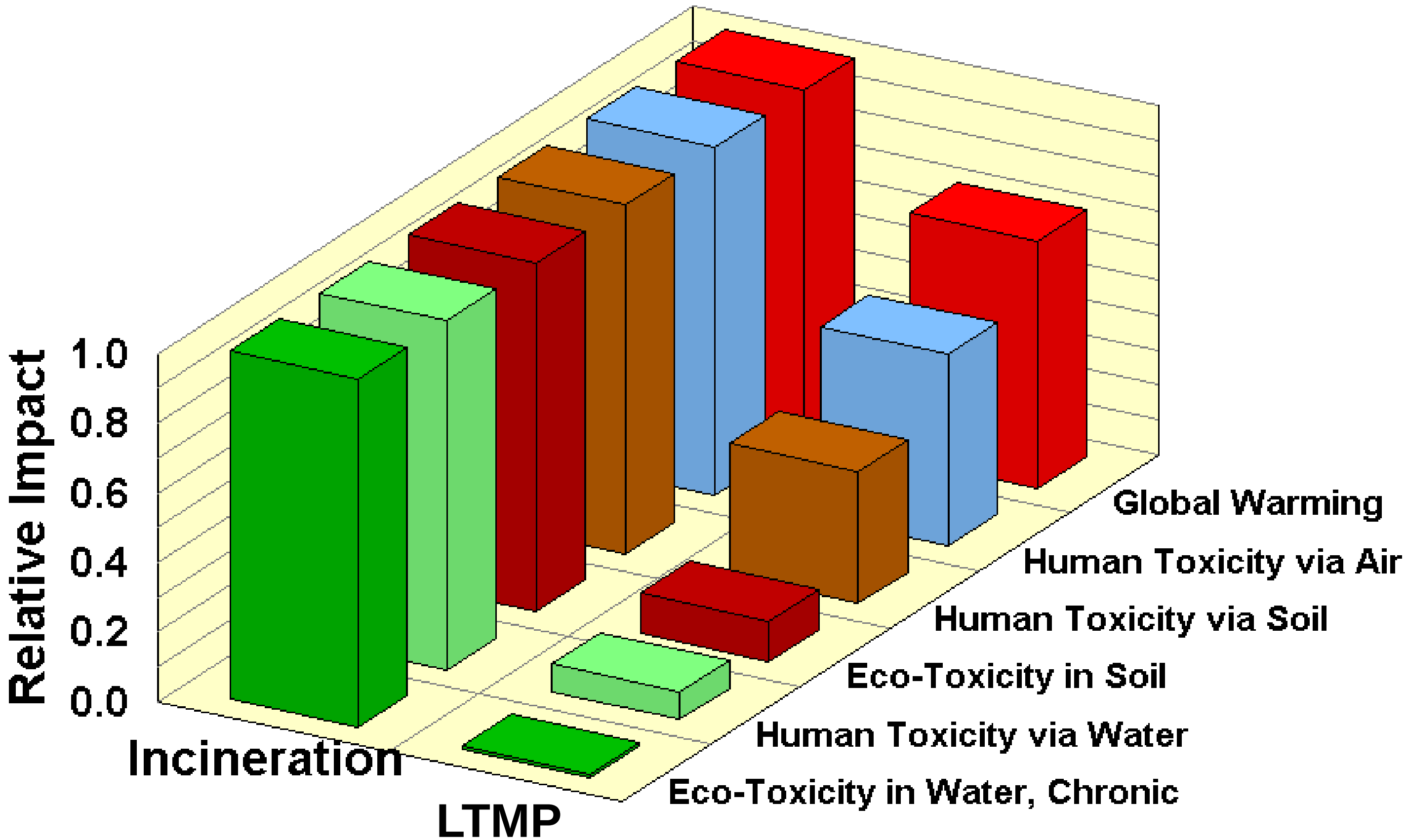
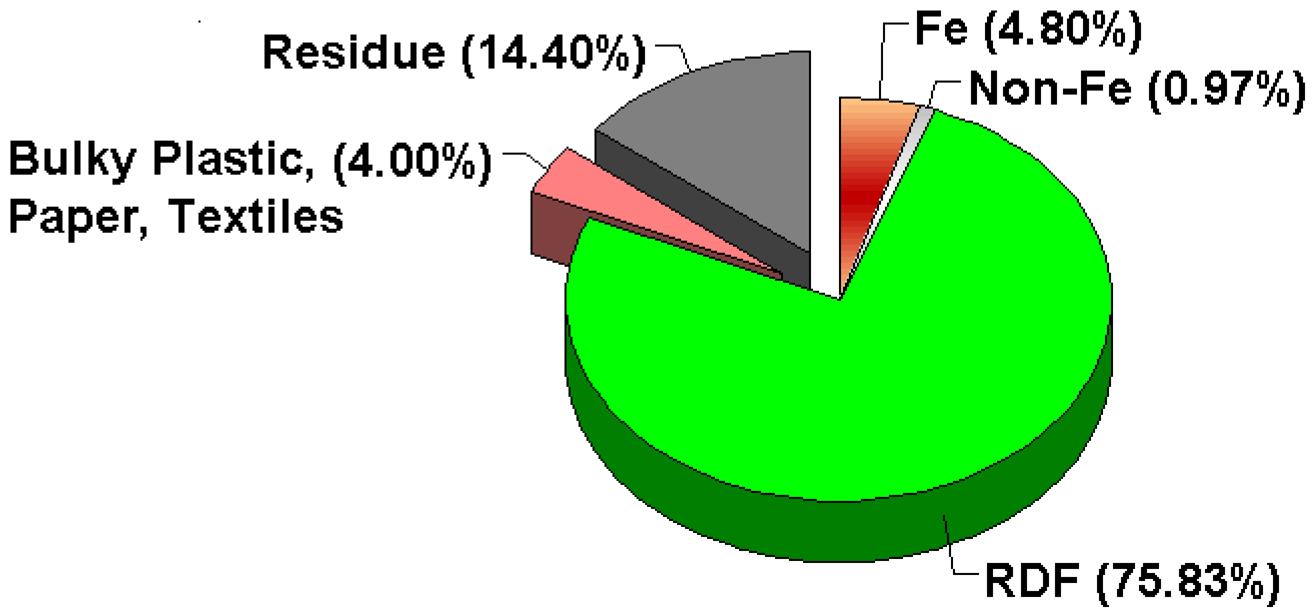
LTMP Carbonization vs Incineration*



Source: Technical University of Denmark, Nov. 2007

***Includes impact of BDF Use**

Recycling Performance



81.6% Recovery

Recycling Goals

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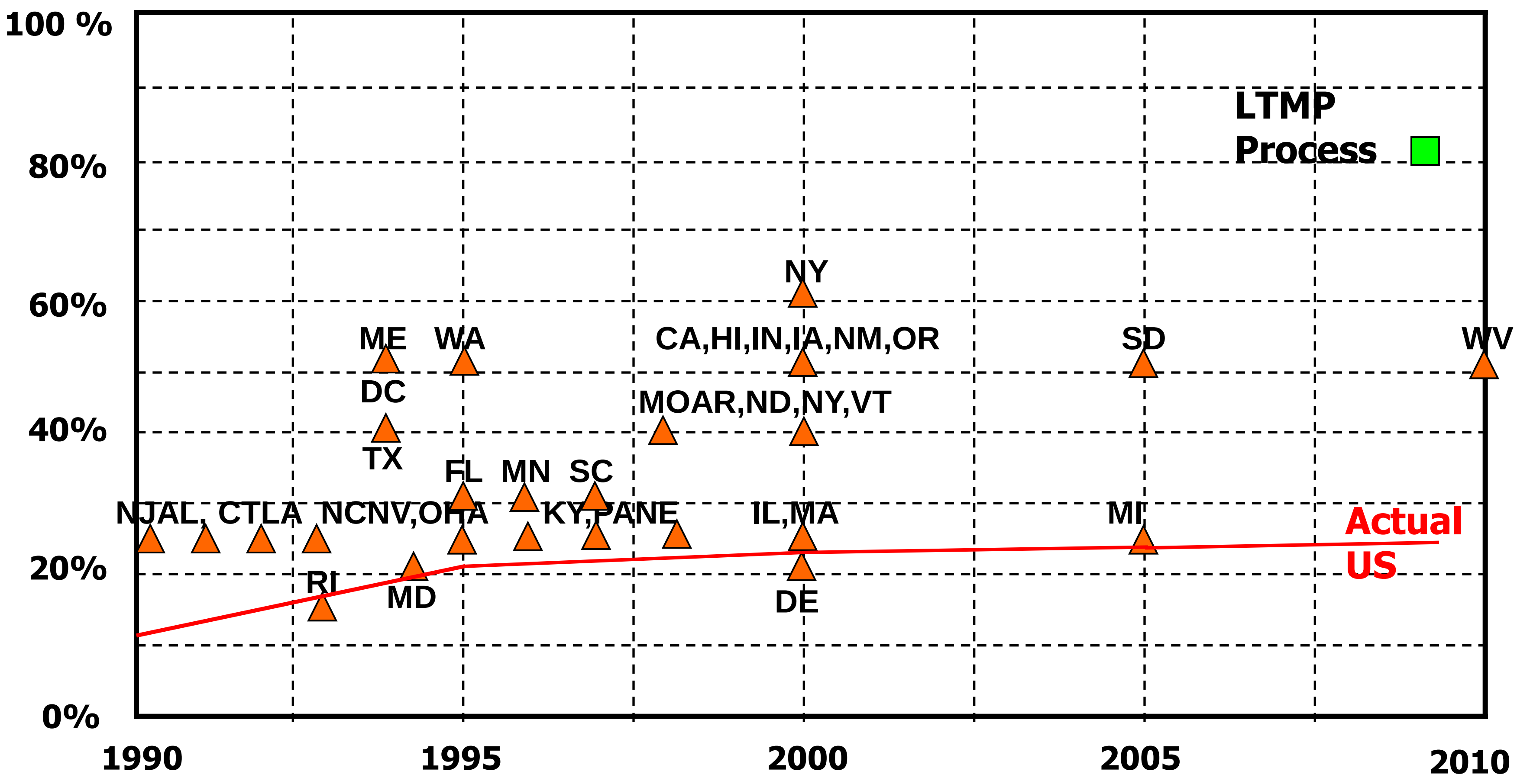
Comparison with LTMP Process



Feed Coal Samples

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PRB Coal

BDF (Syncoal)

Bit. Coal Mix

Coal Analyses

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	BDF	PRB Coal	Bit Blend
Proximate			
VM, %	53.14%	30.04%	29.46%
H_2O, %	1.82%	30.47%	11.49%
Ultimate			
C, %	57.49%	49.52%	67.88%
H, %	5.67%	3.39%	4.26%
O, %	11.41%	11.31%	6.27%
N, %	1.06%	0.71%	1.29%
S, %	0.29%	0.23%	1.75%
HHV, Btu/lb	10,236	8,264	11,628
Hg, ug/g	0.04	0.07	0.134
Lb CO_2/MMBtu	205.8	219.6	213.9
Stack Losses,%*	12.8%	14.7%	11.3%
Comb. Eff'y,%*	87.2%	85.3%	88.7%

***15% XS Air, 350°F Stack Temperature**

Coal Mercury Content

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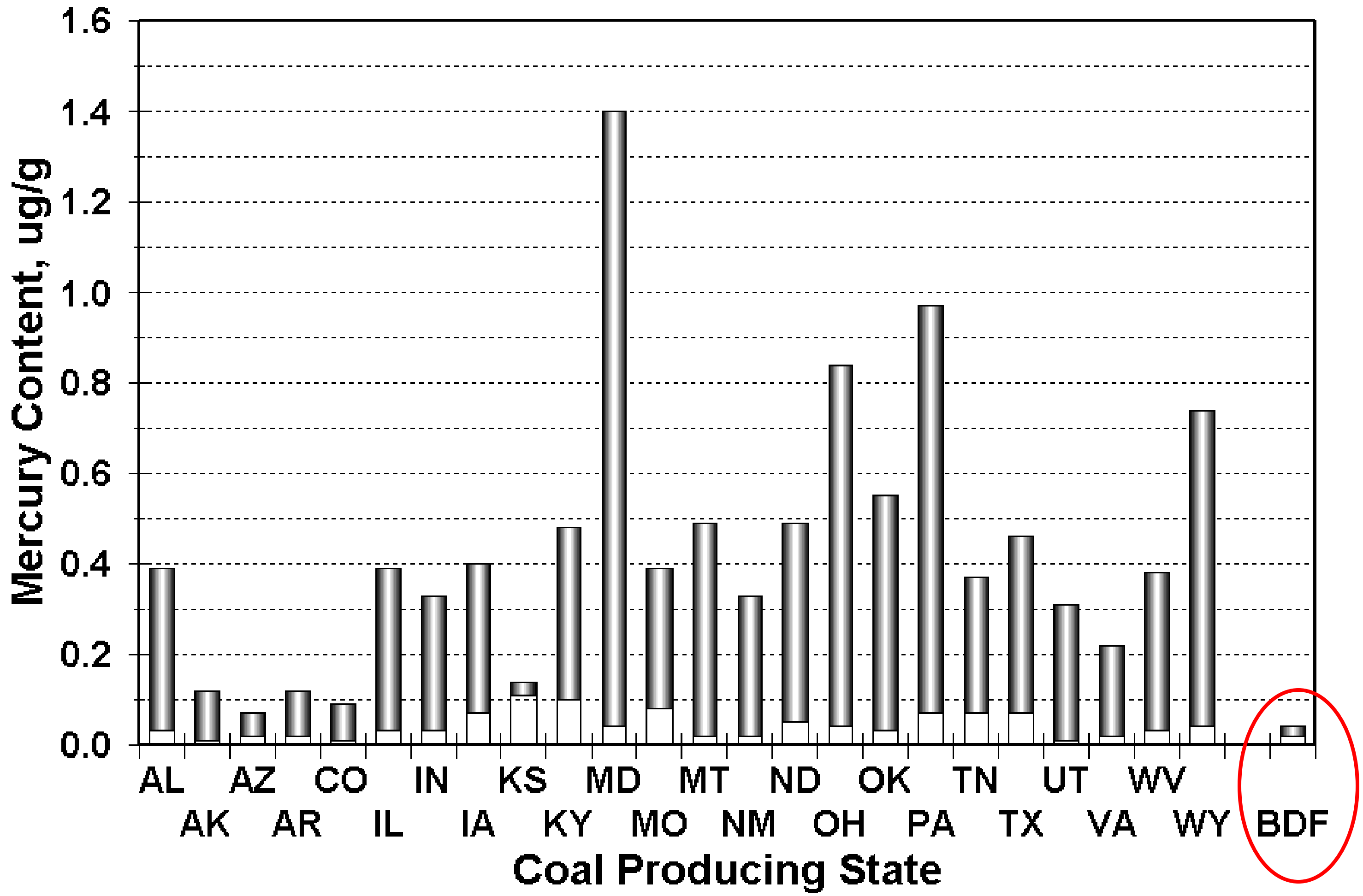

Thermogravimetric Analysis

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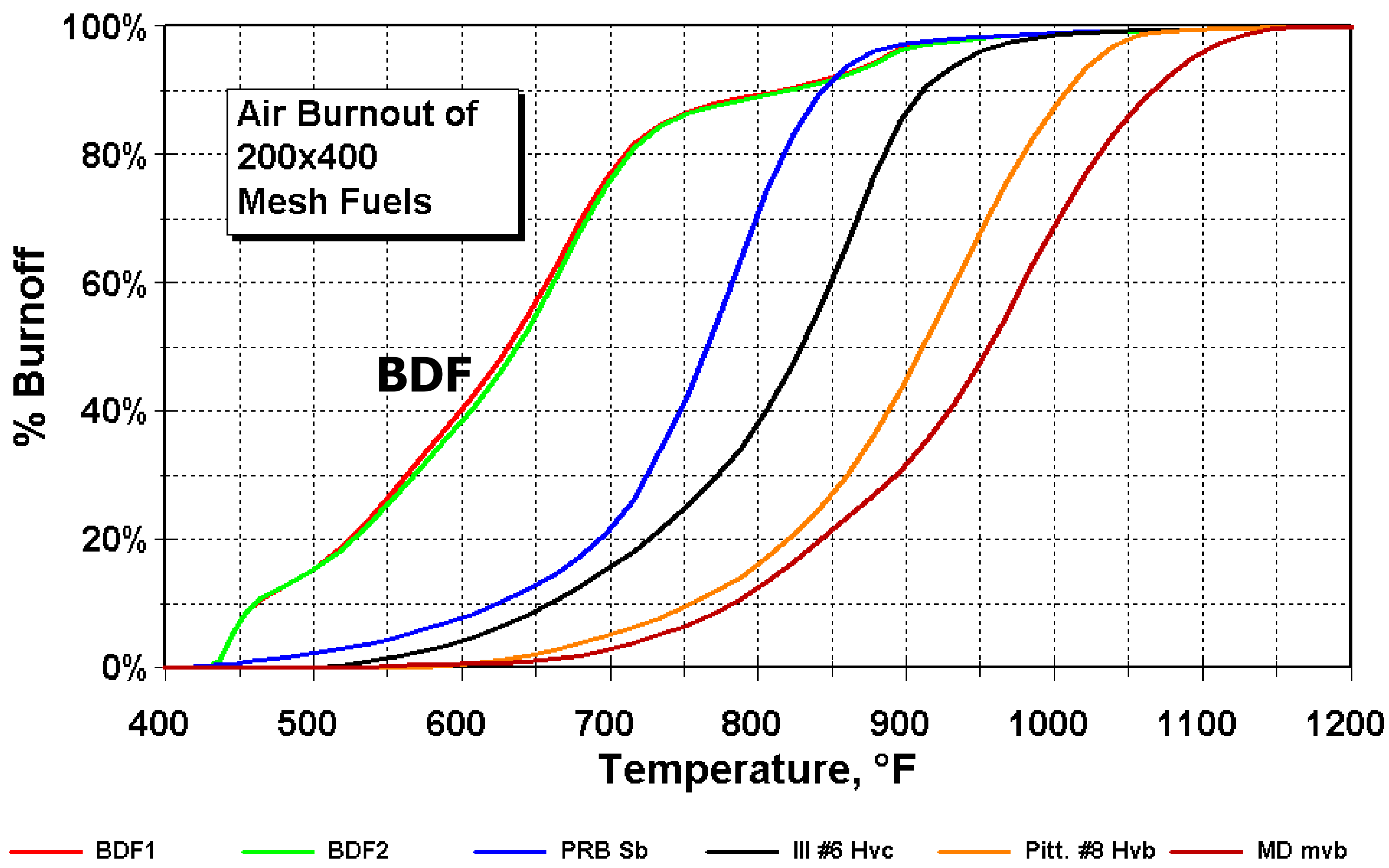
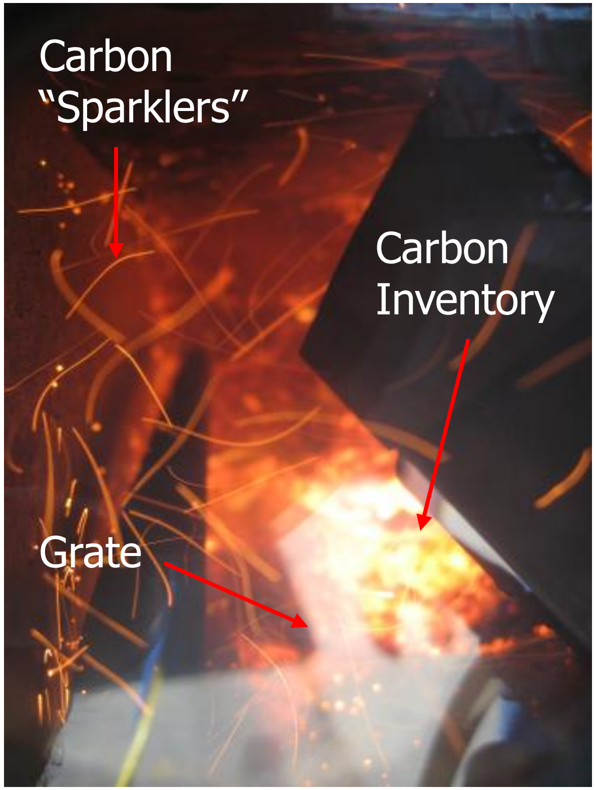
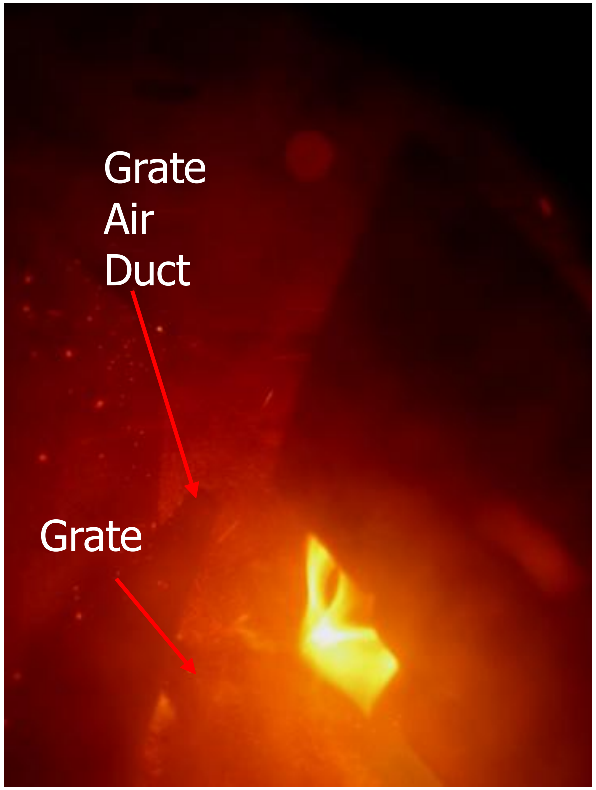


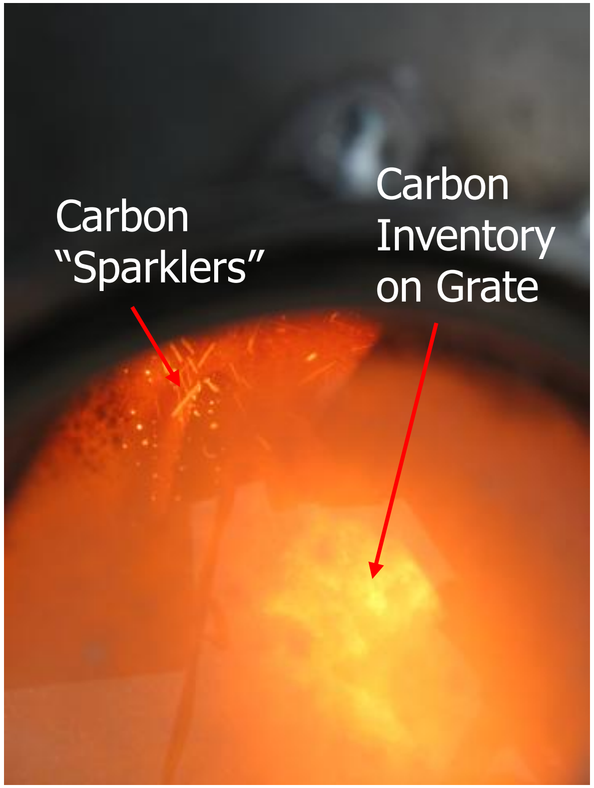
Furnace Views



PRB Coal



BDF (Syncoal)



TES Coal Mix

Carbon Burnout

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BDF Ash


Bit. Coal Ash

Emission Reductions

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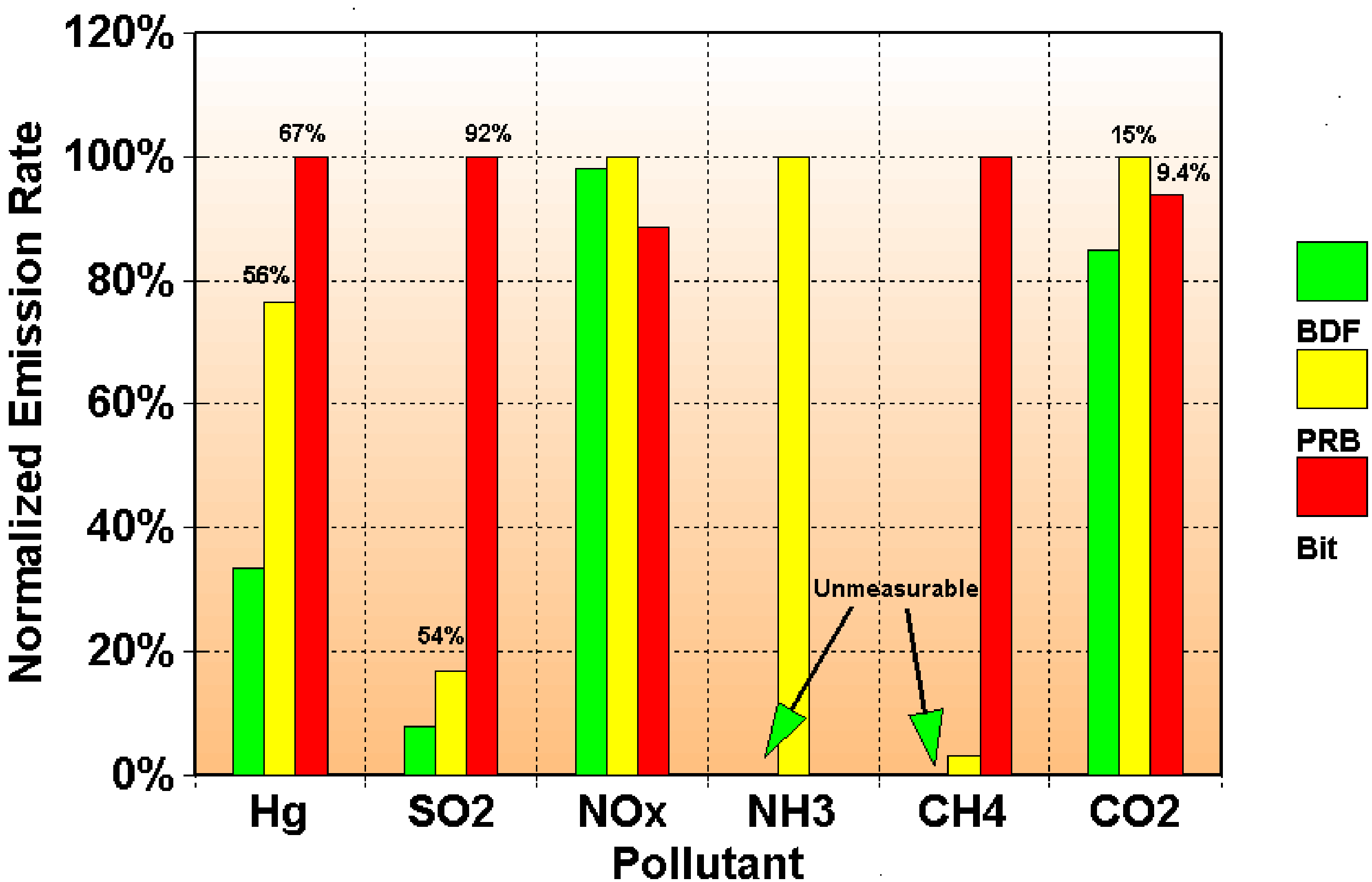

Stack H_2O Content

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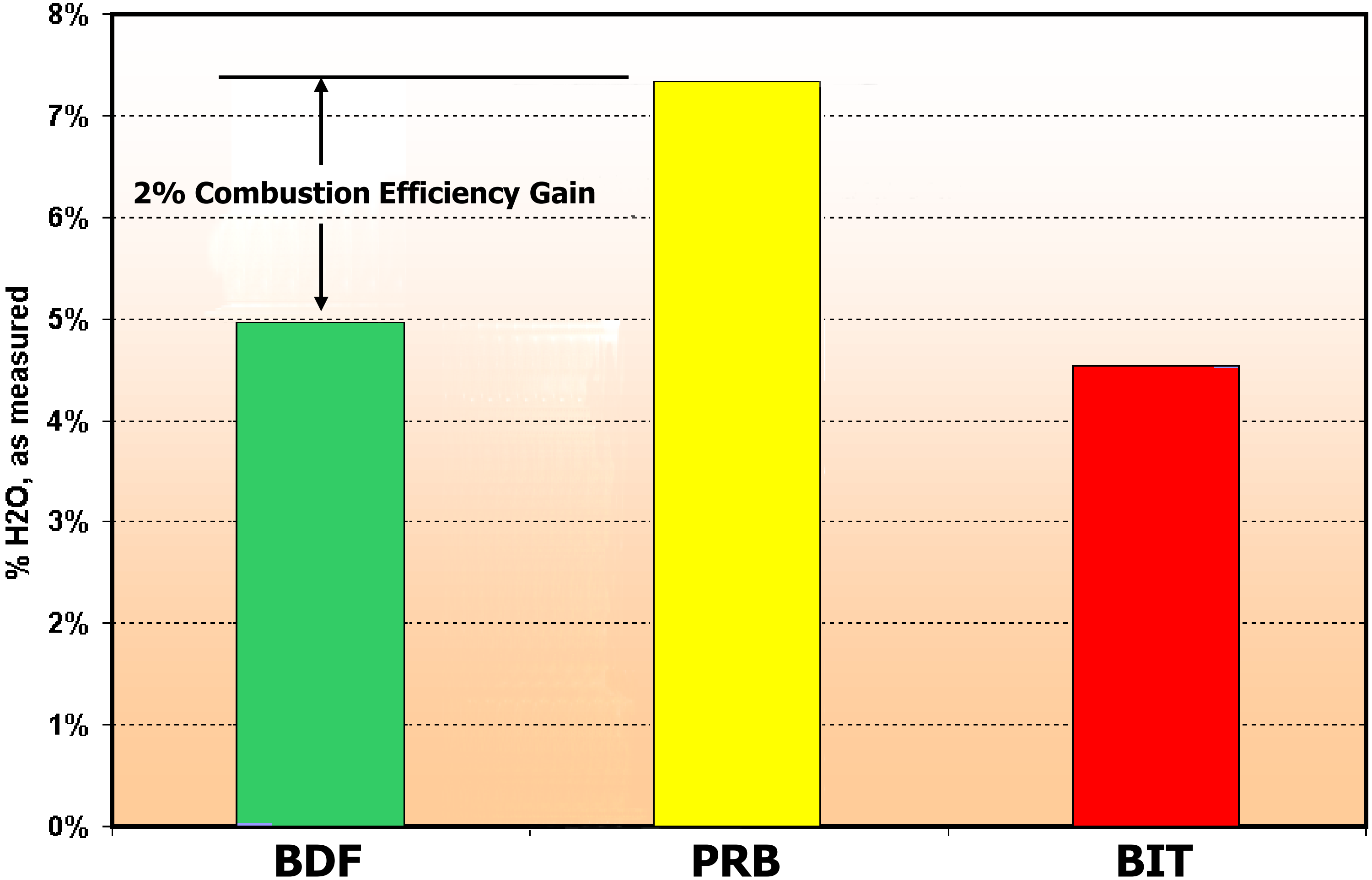

Boiler Efficiency

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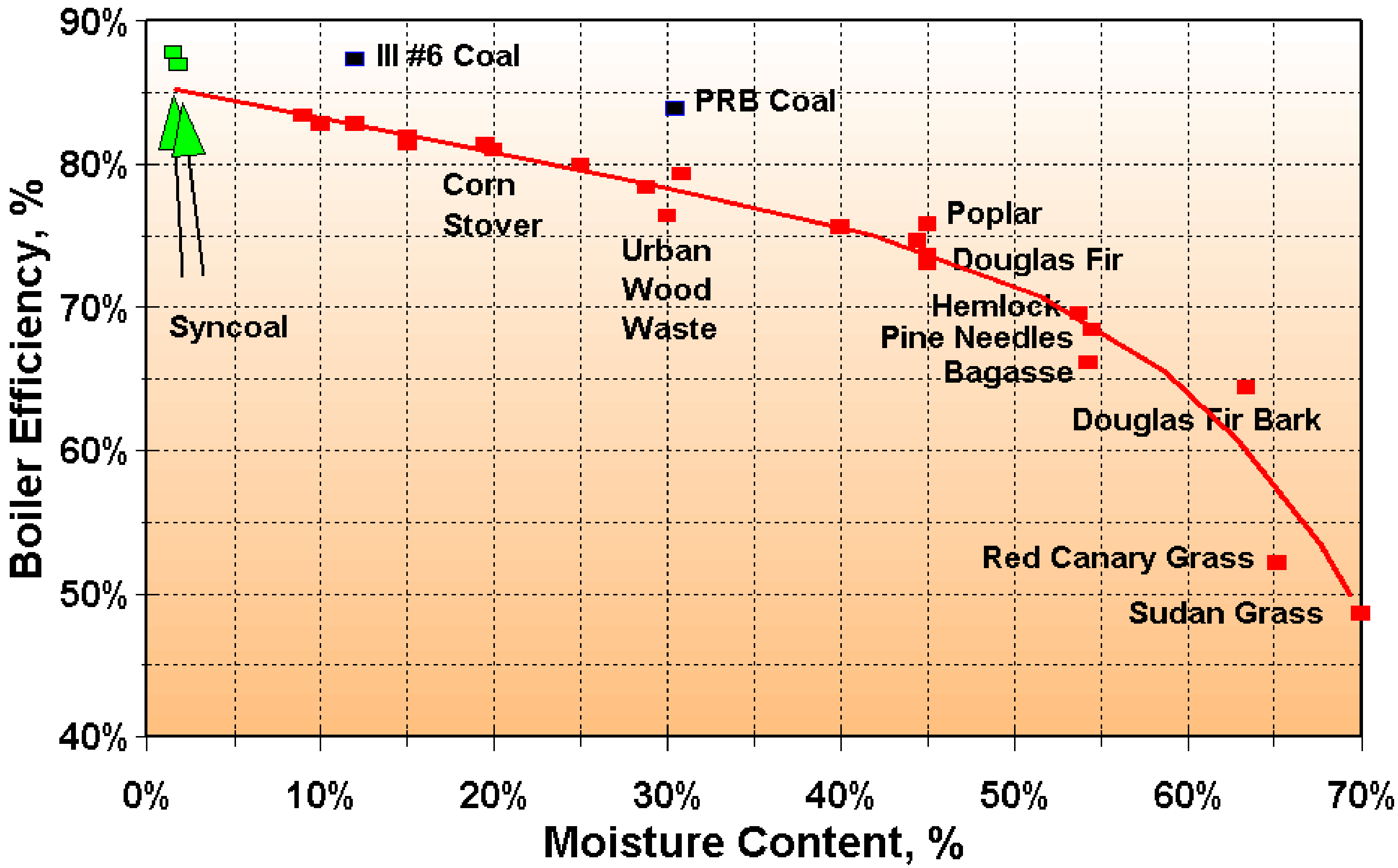

Power Generation

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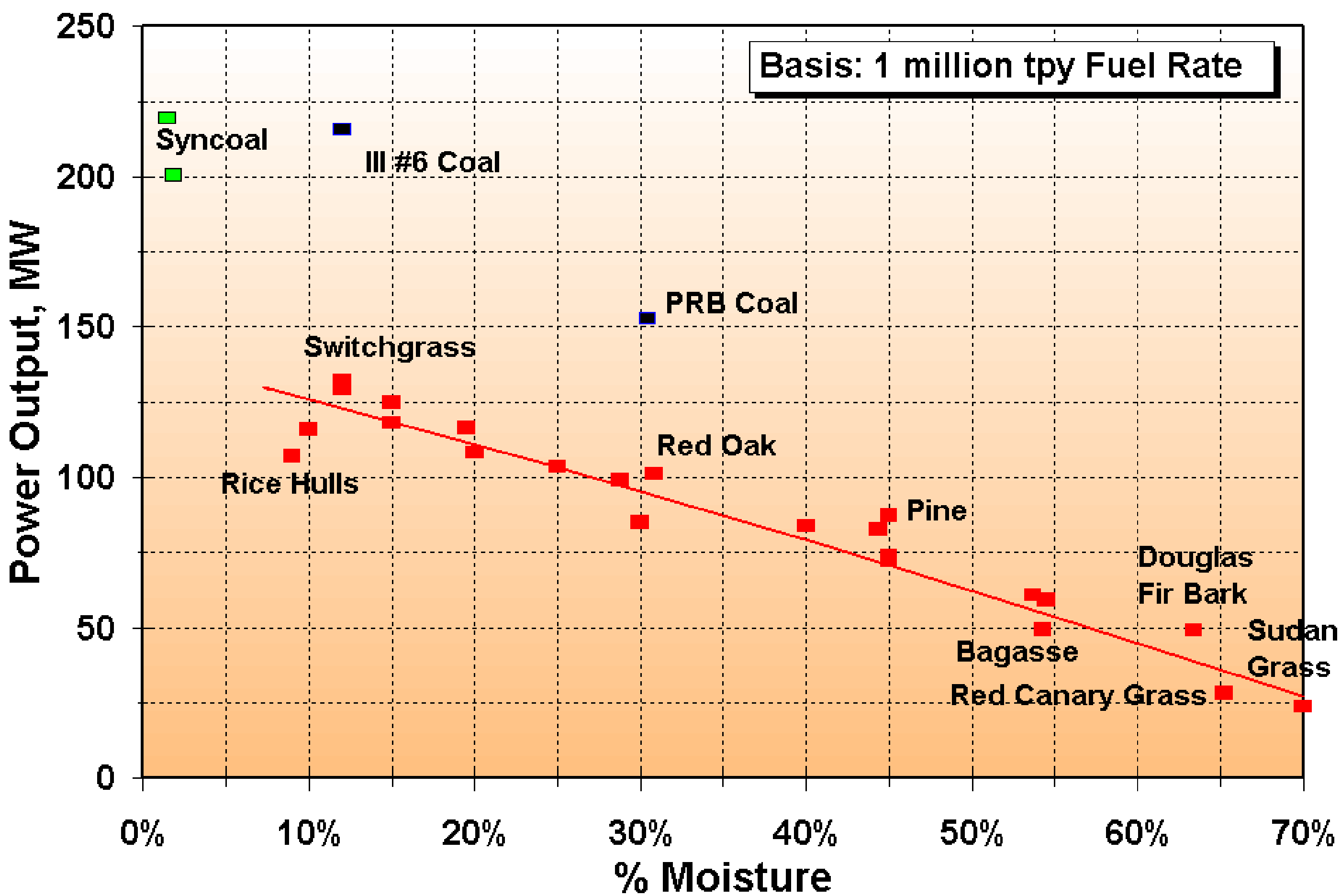

CO_2 Emissions

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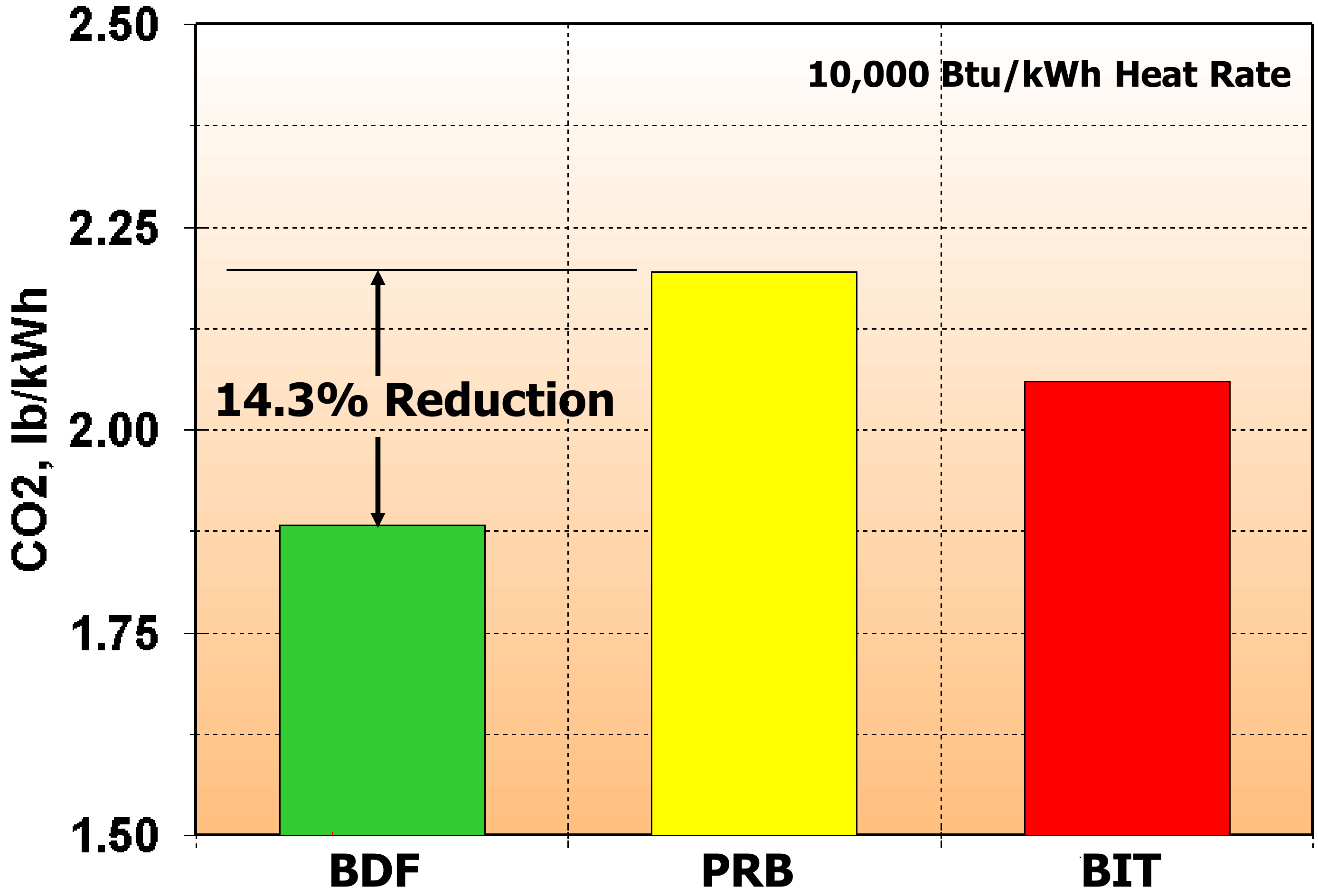

Grindability

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80/20 Coal/BDF blend
Grindability comparable to Western coals
Pulverizer stays clean
No sample compaction

Moisture Pickup

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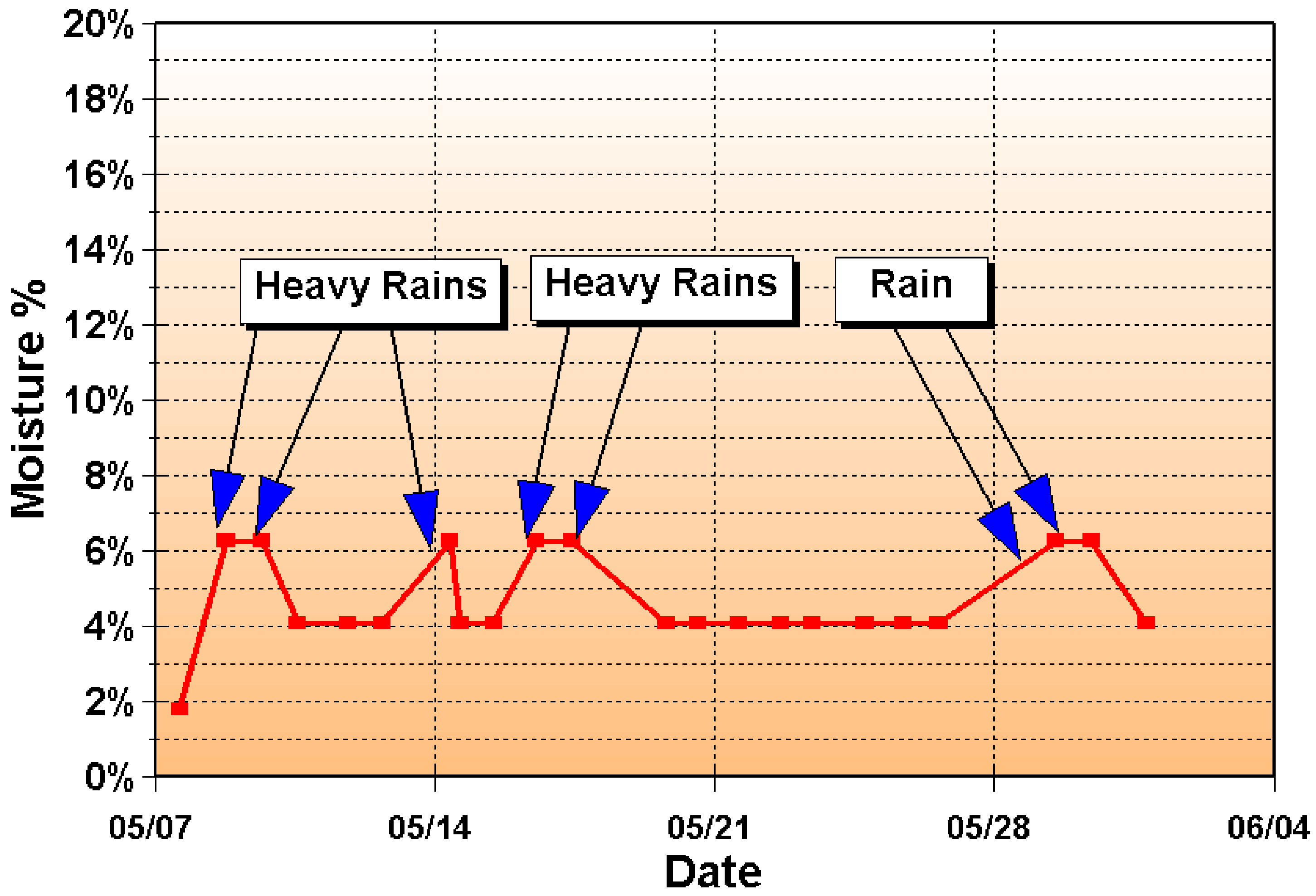

BDF/Biomass Comparison

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	Wood Pellets	BDF
Rail Transportation	Closed hopper only	Same as coal
Fuel Unloading	Bottom dump only – no rotary	Same as coal
Fuel Storage	Enclosed storage only	Same as coal
Moisture Pickup	Serious – becomes mush	Same as coal
Dust Generation	Very dusty – explosion potential	Same as coal
Grindability	Poor 1 - 3 mm	Same as coal 0.075 mm
Mill Clearing Cycle	60+ minutes	Same as coal 5-10 minutes
Primary Air Flow	Much higher – must be cold air	Same as coal

BDF/Biomass Comparison

CDI

	Wood Pellets	BDF
Steam conditions	Decreased superheat, reheat temperatures	Same as coal
Cl Corrosion	Serious - may require doping with sulfur	Same as coal
Plant Capacity	17% Derating	Same as coal
Plant Heat Rate	4% Efficiency Loss	2% Efficiency Gain
CO_2 Emissions	8% Increase	15% Reduction
SO_2 Emissions	Reduction	50-93% Reduction
Hg Emissions	50% Reduction	55-70% Reduction
Heat Value	8,297 Btu/lb	10,400 Btu/lb

BDF Ash Analyses

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Ash Minerals	
SiO_2	39.31%
Al_2O_3	12.35%
Fe_2O_3	4.87%
CaO	22.66%
MgO	2.46%
TiO_2	2.08%
K_2O	2.02%
Na_2O	5.23%
SO_3	2.60%
MnO_2	0.20%
P_2O_5	1.71%
SrO	0.05%
BaO	0.16%

Trace Elements (TCLP)	Sample	QL	Reg. Limit
As, mg/L	BQL*	0.20	5.0
Ba	BQL	5.00	100.0
Cd	BQL	0.10	1.0
Cr	BQL	0.10	5.0
Pb	0.47	0.10	5.0
Hg	BQL	0.00057	0.2
Se	BQL	0.20	1.0
Ag	BQL	0.10	5.0

*Below Quantitative Limit

Bio-oil Boiler Fuel

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Vents 2/3 - Bio-Oil

Oil Characteristics

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	MeOH	EtOH	**Bio-Oil**	Biodiesel	No. 2	No. 6
C	37.48%	52.14%	**60.84%**	76.14%	87.18%	85.60%
H	12.58%	13.13%	**8.76%**	11.25%	12.50%	9.70%
O	49.93%	34.73%	**29.20%**	12.10%		1.80%
N			**0.58%**	0.20%	0.02%	0.10%
S			**0.18%**	0.20%	0.30%	2.30%
Ash			**0.06%**			0.50%
Btu/lb (HHV)	9,750	12,800	**12,026**	16,095	19,430	18,300
Btu/gal	64,250	84,100	**112,202**	118,300	140,090	143,655
SpGr, lb/gal	6.63	6.61	**9.33**	7.35	7.21	7.85
Visc @ 60°F	0.59	1.19	**5.09**	7.50	3.30	450

Chloride Content

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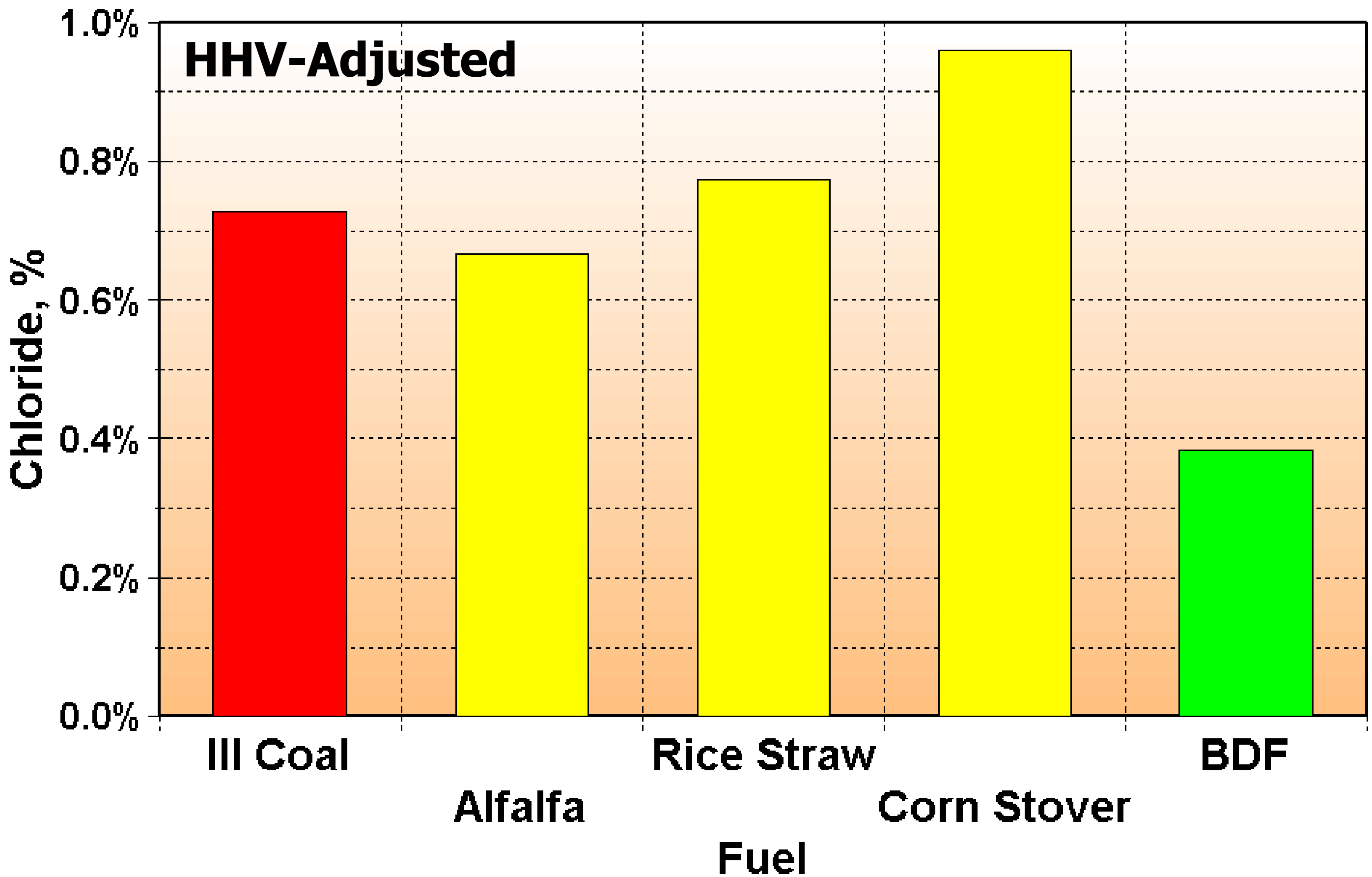

Source: "Chloride Issues with Biomass Co-firing in PC Boilers," Duong & Tillman

Syncoal Production Cost

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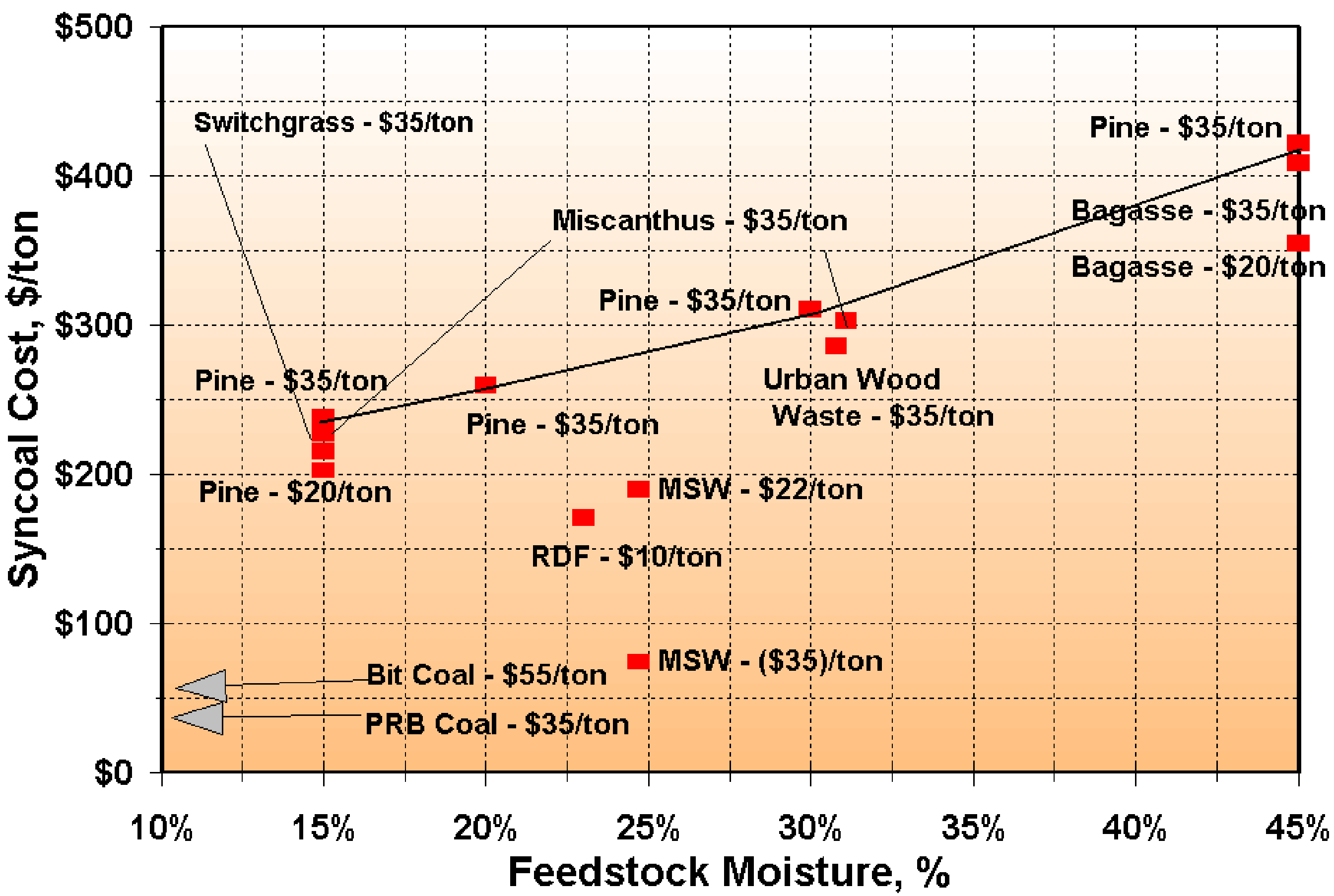
Stand-Alone Plant



MSW as a Renewable Resource

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On August 18, 2009 the Massachusetts Department of Energy Resources (DOER) announced that **only waste-based biofuels will qualify toward fulfilling its biofuel requirements** "until further notice." The announcement ... excludes using other renewable and sustainable biomass feedstocks, such as agricultural crop residues and algae.

MSW/BDF as a Renewable Resource

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- Overwhelmingly agricultural biomass
- Continuously produced - little seasonality
- No diversion of existing crop lands required
- Produced at energy use centers - low transport costs
- Collection (“harvesting”), distribution systems already in place
- BDF makes MSW/biofuels compatible with existing energy technologies
- BDF burns cleaner than the fossil fuel it displaces
- BDF process offers huge GHG benefits

Before/After

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Completed Project Site

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