



The Chemistry of Combustion

And How it Applies to the
Proposed Tire-to-Energy Facility

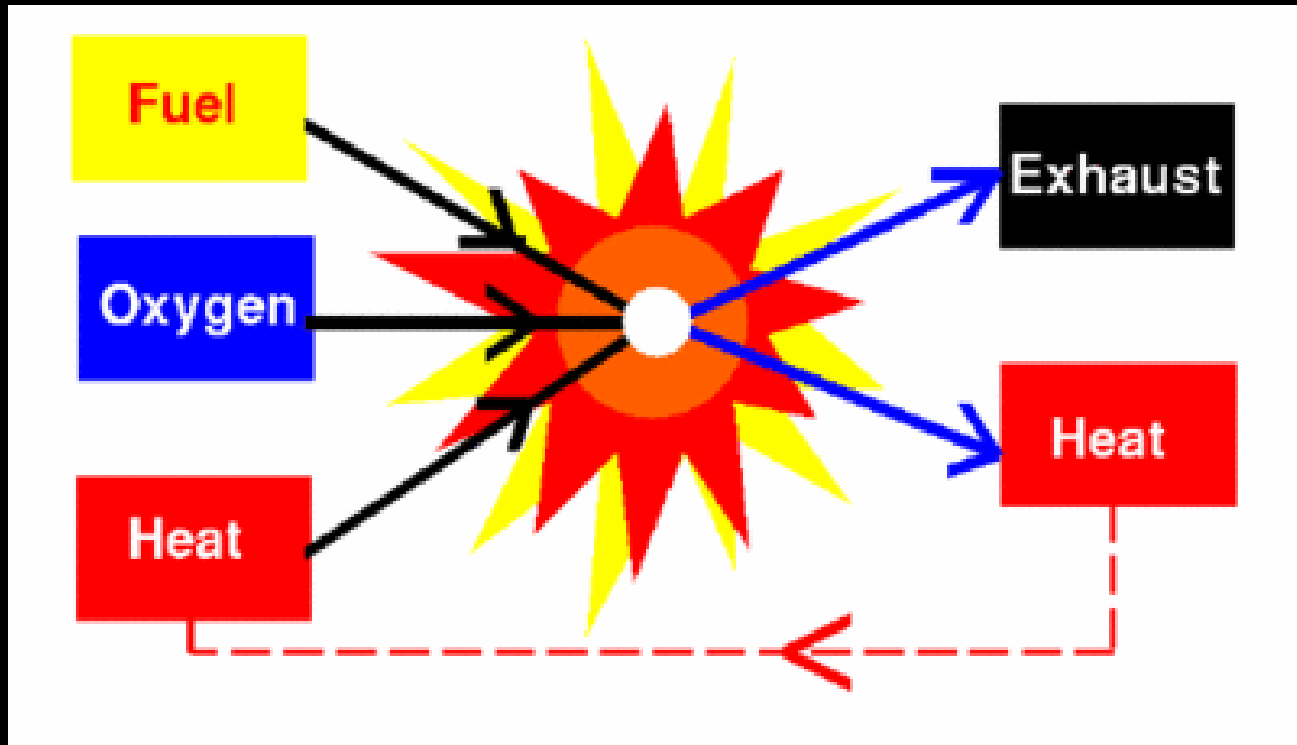
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Combustion

The Oxidation of a Fuel to produce Heat



Complete Combustion

- Carbon \rightarrow CO_2
- Hydrogen \rightarrow H_2O
- Fuel \rightarrow Fossil Fuels \rightarrow Hydrocarbons
 - Ideally, only emission products are CO_2 and H_2O



Main Points

1. *Nothing is Perfect*



Incomplete Combustion

- Partially Oxidized Emissions
 - Carbon monoxide, CO
- Non-Oxidized Emissions
 - Benzene, C₆H₆

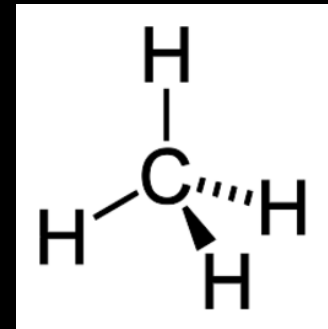
VOCs



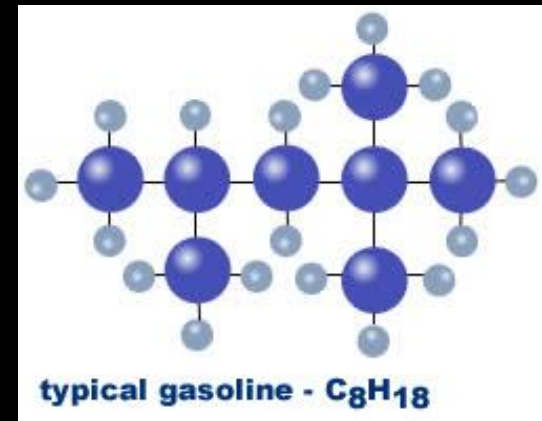
- Nitrogen → NO + NO₂ = NO_x
- Sulfur → SO_x

Fuels

- Natural Gas → Methane, CH_4
 - Cleanest burning fossil fuel



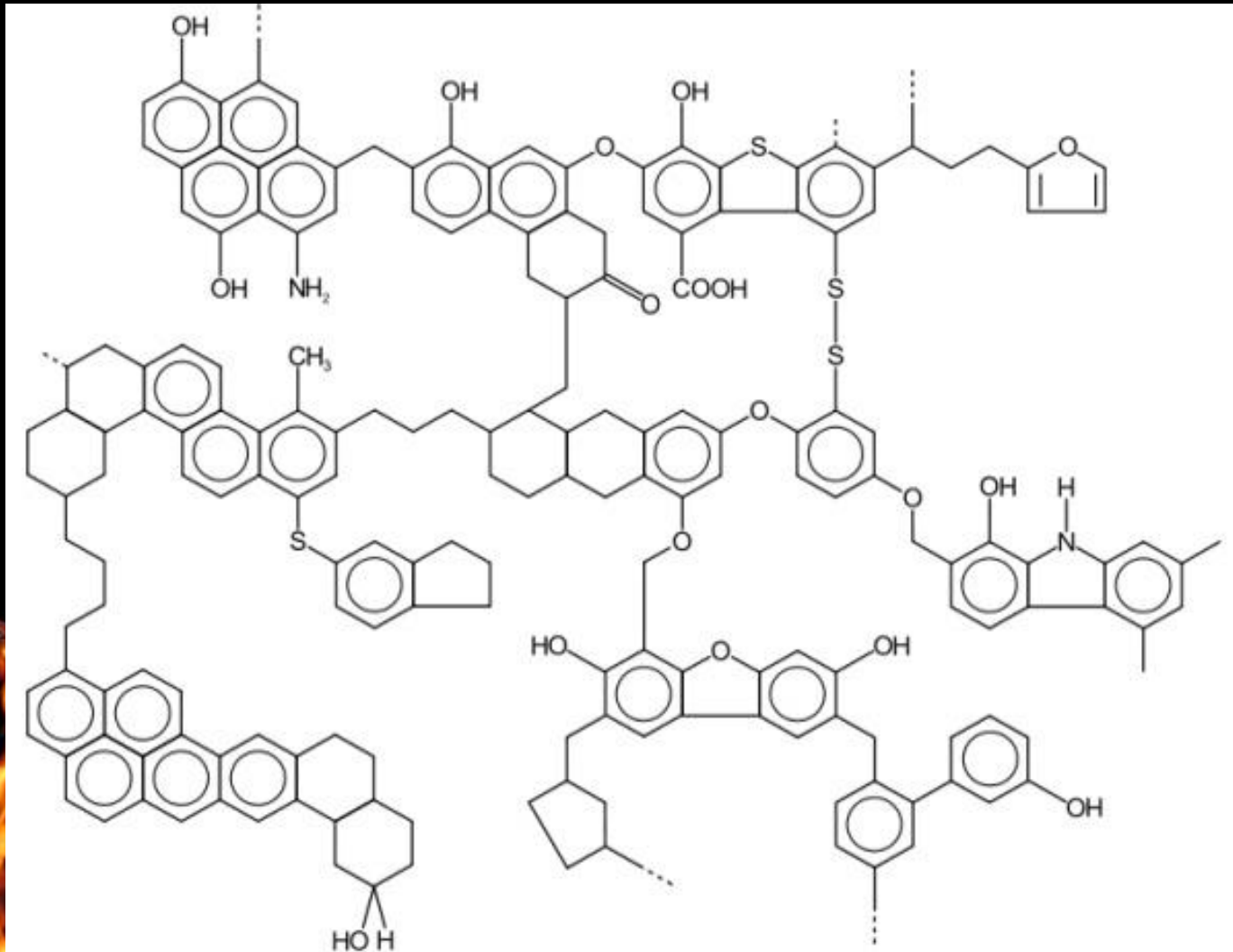
- Gasoline
 - Mixture of hydrocarbons
 - $\text{C}_5 \rightarrow \text{C}_{12}$
 - Octane, C_8H_{18}



- Coal
 - Dirtiest of our fossil fuels
 - On Average 135 Carbons per Molecule



Coal



Main Points

1. *Nothing is Perfect*
2. *More Complex the Fuel,
More Complex the Emissions*

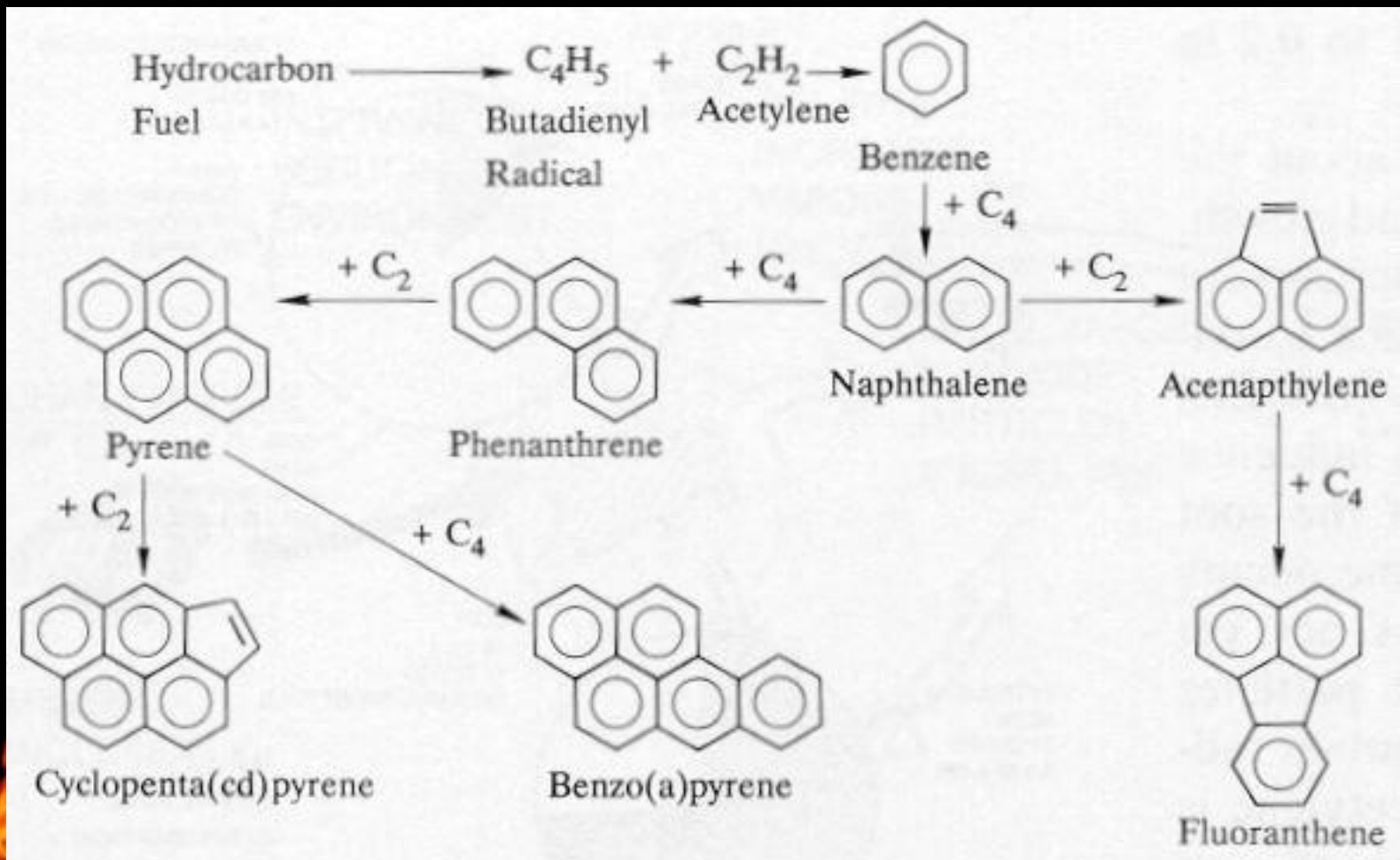


Tire-Derived Fuel

Table 1. Tire and Coal Elemental and Immediate Analyses

	tire	coal
%C (daf)	88.6	80.2
%H (daf)	8.3	6.7
%S (mf)	1.4	5.7
%N (daf)	0.4	1.0
% moisture (af)	0.9	22.0
% ash (mf)	3.8	26.9
% volatiles (ar)	67.3	48.6
% fixed carbon (ar)	31.1	28.4
Calorific value (Kcal/Kg)	9220	4130

Pyrosynthesis



Polycyclic Aromatic Hydrocarbons (PAHs)

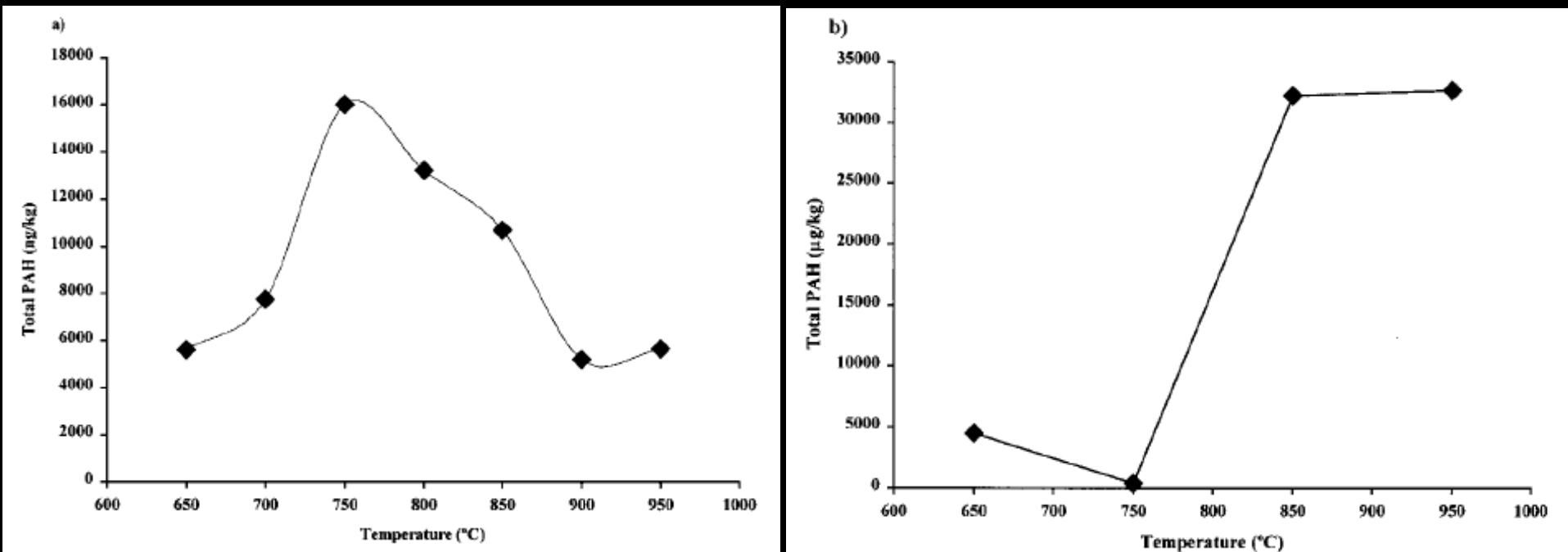
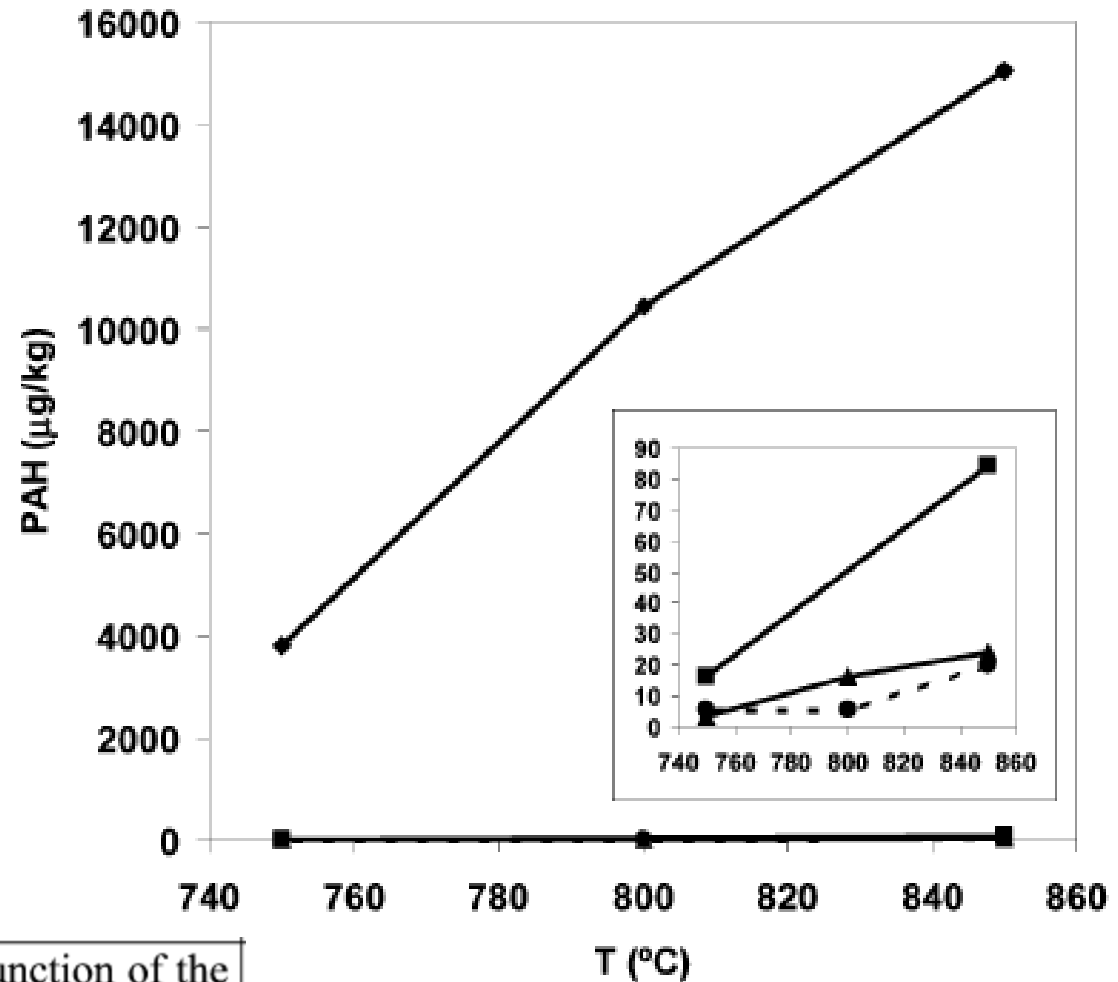


Figure 1. Total PAH ($\mu\text{g}/\text{kg}$) emitted in (a) coal and (b) tire combustion (AFBC, 860 L/h, 20% excess oxygen) as a function of combustion temperature.



Polycyclic Aromatic Hydrocarbons (PAHs)



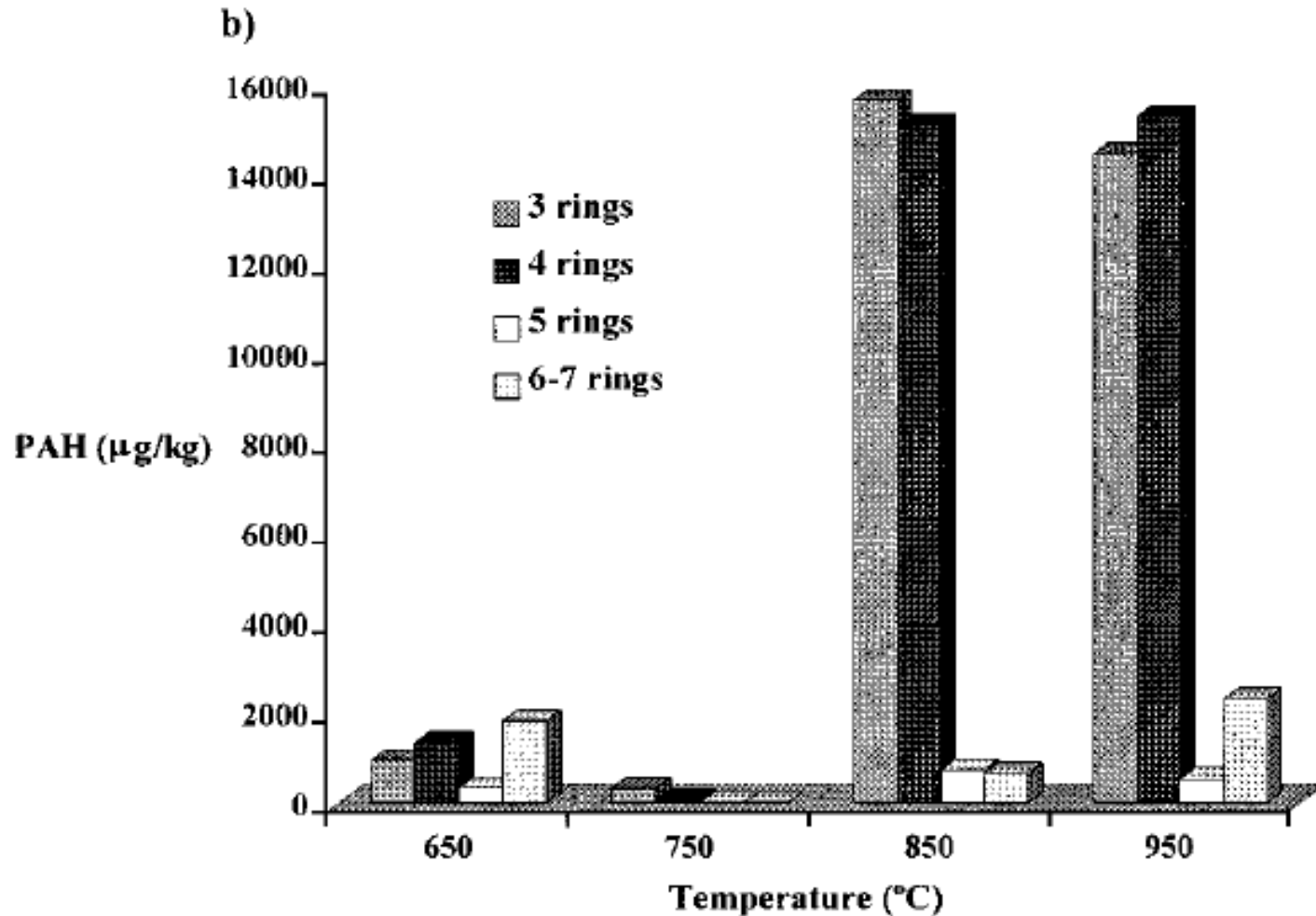
Total PAH collected in filter as a function of the temperature and feed blend
◆—Rubber; ■—Coal; ▲—R:C(10:90); ●—R:C(30:70)

Main Points

1. *Nothing is Perfect*
2. *More Complex the Fuel,
More Complex the Emissions*
3. *Conservation of Mass*



PAH Size



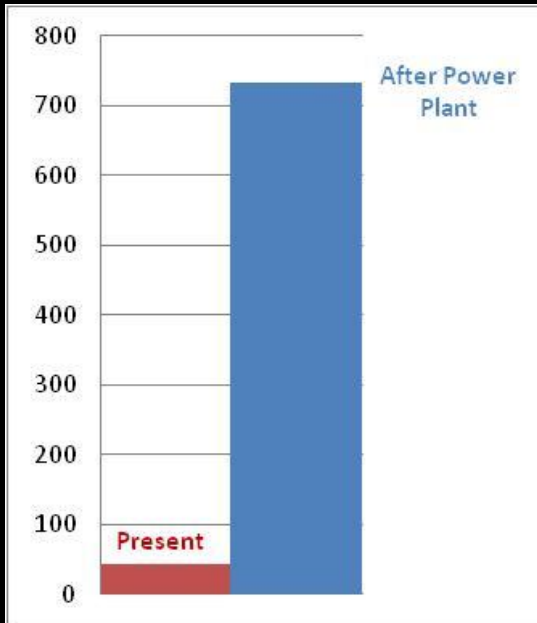
Main Points

1. *Nothing is Perfect*
2. *More Complex the Fuel,
More Complex the Emissions*
3. *Conservation of Mass*
4. *Quantity vs. Toxicity*

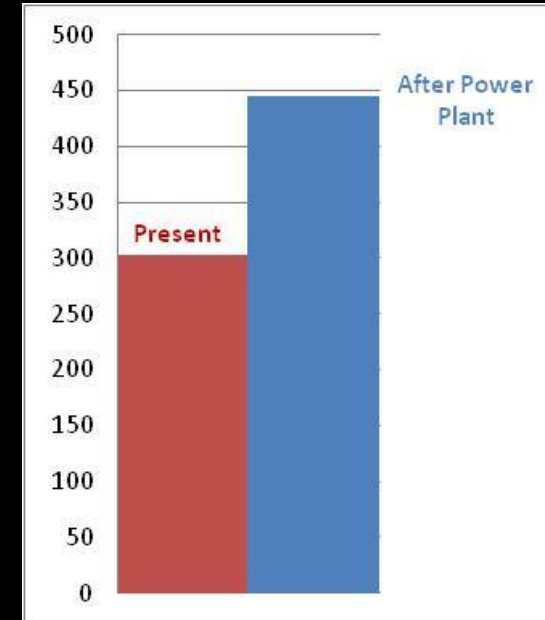


Criteria Air Pollutants

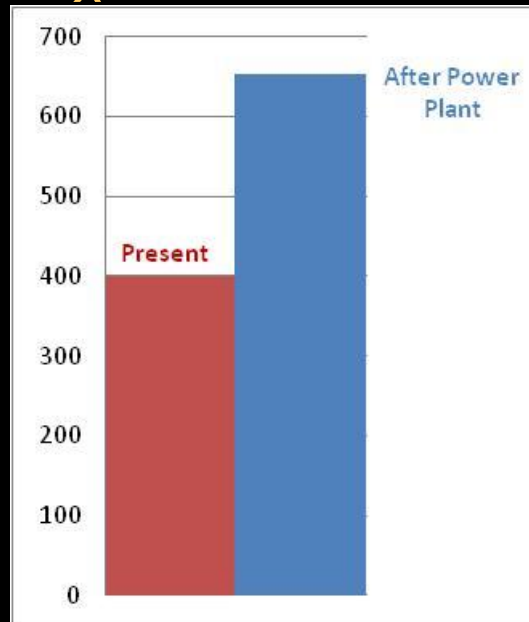
CO



SO_x



NO_x



Present Data taken from *eFACTS** for Crawford County 2009

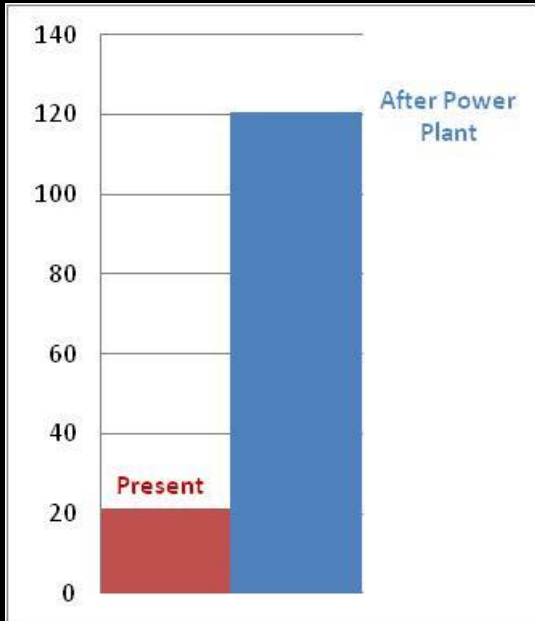
CRE emissions data from DEP Air Permit Application

*Pennsylvania Environment Facility Application Compliance Tracking System

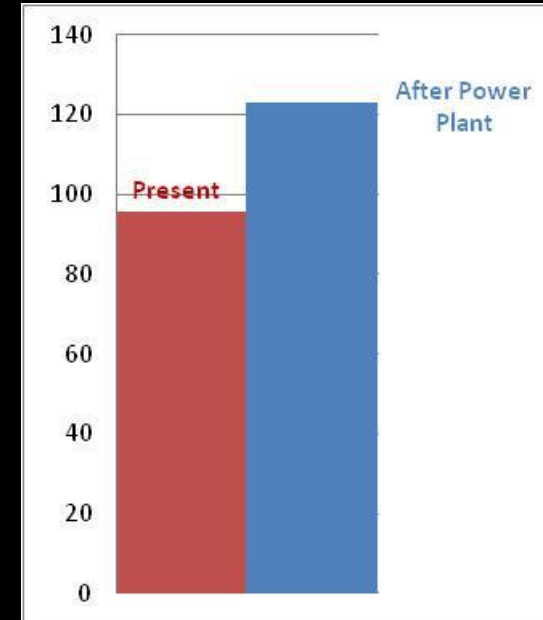


Criteria Air Pollutants

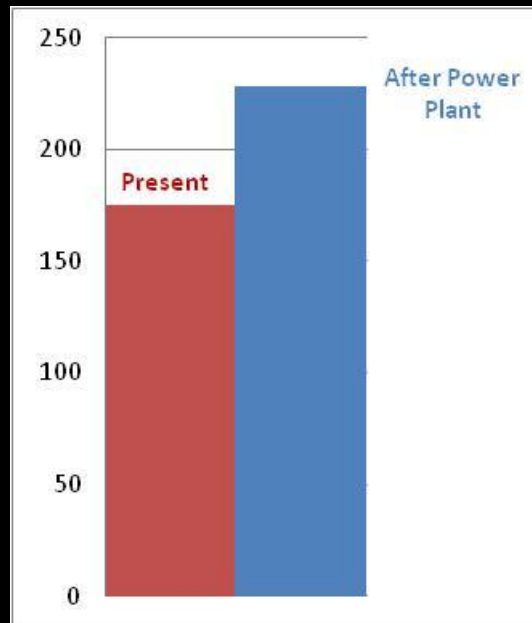
PM10



VOCs



PM2.5



Present Data taken from *eFACTS** for Crawford County 2009

CRE emissions data from DEP Air Permit Application

*Pennsylvania Environment Facility Application Compliance Tracking System



BACT

- “Best Available Control Technology”
- For this facility, applies to:
 - SO_2
 - PM
 - NO_2
 - CO



Table 5.1-1
CFB Facilities Identified on RBLC since 2000

Company	State	Yr.	Fuel	SO ₂ lbs/ MM BTU	NO _x lbs/ MM BTU	Part. lbs/ MM BTU	CO lbs/ MM BTU	VOC lbs/ MM BTU	H ₂ SO ₄ lbs/ MM BTU	HF lbs/ MM BTU	Status
Robinson Power	PA	2005	Waste coal	0.245	0.08	0.012	0.15	0.006			permit expired
Montana Utilities (Gascoyne)	ND	2005	Lignite	0.038	0.09	0.013	0.154	0.005		0.005	
River Hill	PA	2005	Waste coal	0.27	880tpy	125tpy		62.9tpy	0.01	0.0014	no construction
Green Energy	PA	2005	Waste coal	0.156	0.08	0.012	0.20	0.005		0.0014	min. construction
Lamar Utilities	CO	2006	Bit. coal	0.103	0.08	0.012					
Western Greenbriar	WV	2006	Waste coal	0.14	0.10	0.015	0.20				not built
Sunnyside Ethanol	PA	2007	Coal	0.20	0.10	0.01(filter)	0.15	0.005	0.01	0.0014	No construction
Desert Power	UT	2007	Waste coal	0.055	0.08	0.03	0.15		0.0035		Pending
Great River Energy	ND	2007	Lignite	0.06	0.09	0.03	0.15	0.007	0.006		Pending
Entergy	LA	2007	Pet coke/coal	0.15		0.011	0.10	0.005	0.001	0.0008	Pending
Louisiana Gen.	LA	2008	Pet coke/other	0.164	0.076	0.011(filter)	0.11	0.0052	0.0013		Pending
Virginia Electric and Power	VA	2008	Coal/Waste coal	0.035	0.070	0.012	0.15	0.005	0.0035		Pending

BACT

“EPA has consistently supported the position that facilities that utilize distinct fuel sources are not similar facilities for the purposes of the BACT analysis.”

“This being the case, it is difficult to assess various emissions limitations because of the lack of similar units combusting TDF.”



Circulating fluidized bed combustion

