WTERT research on resource recovery from wastes by gasification

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WTERT 2010 Bi-Annual Meeting at Columbia University
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Summary (from WTERT 2004)

- **Developing Novel Technologies for Improved MSW Applications**

  Efficiency Gains

  Emission Reductions

  Dynamic Control

- **Drawing on Expertise**

  Chemical Mechanism Development

  High Temperature Kinetics

  Catalytic Reactor Design

- **Posters**

  Catalytic Rubber Gasification (Kwon)

  Waste Plastic Gasification to Useful Chemicals (Llewelyn)

  Greenhouse Gas Reforming (Castaldi)

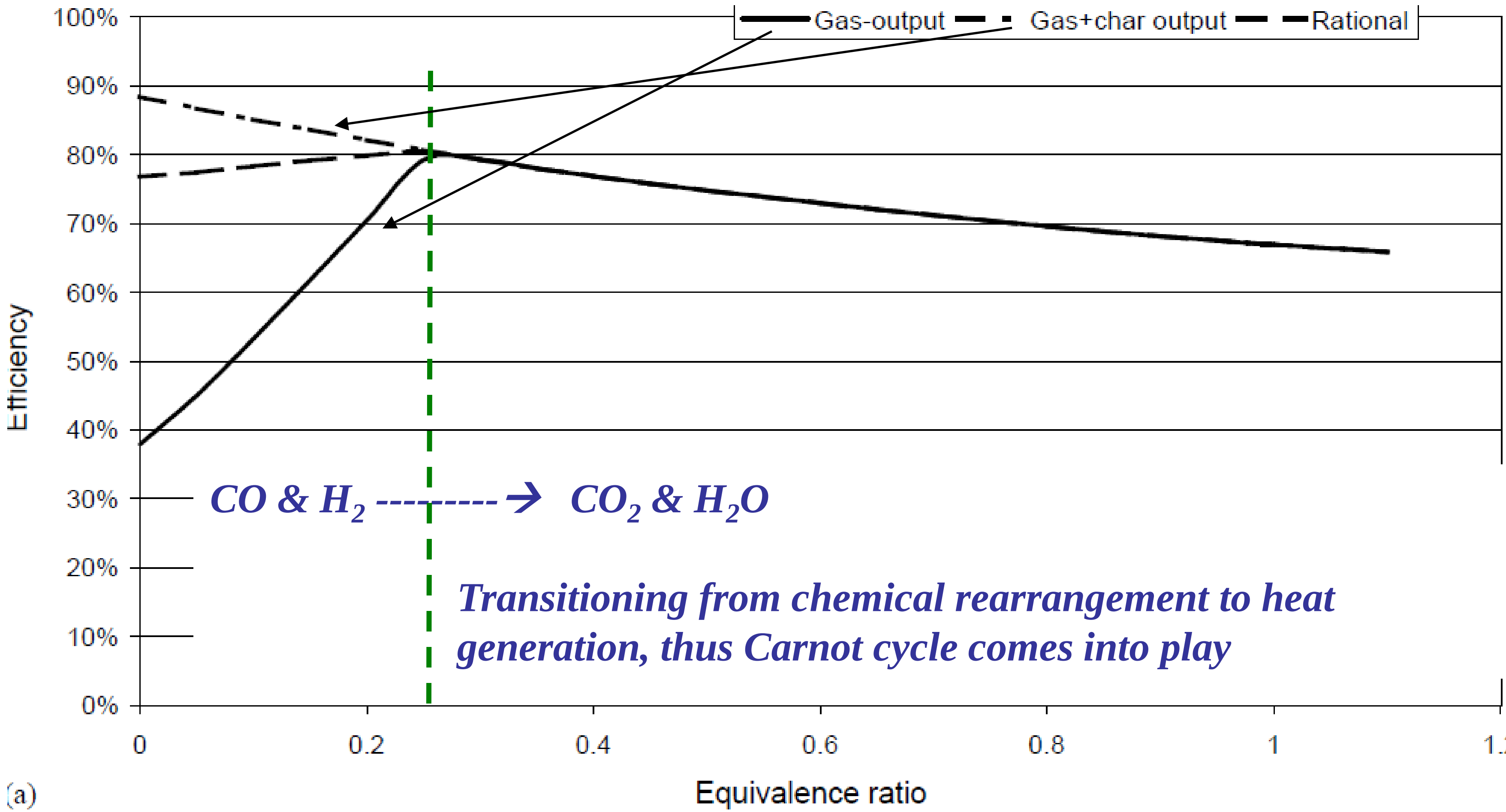
  Corrosion Phenomena in WTE Facilities (Albina)

  Size and Shape Analysis of Particles in WTE Facilities (Nakamora)

  Breaking Down Municipal Solid Waste for Combustion (Whitworth)

Gasification	Combustion
• Sub stoichiometric air	• Excess air
• Lower total volumetric flow	• Higher volumetric flowrate
• Lower fly ash carry over	• Fly ash carry over
• Pollutants in reduced form (H_2S, COS)	• Pollutants in oxidized form (SO_x, NO_x, etc)
• Char – Low T	• Bottom ash
• Slag – vitrification – high T	

Thermodynamic Efficiency Analysis



Source: M. J. Prins et al. / Chemical Engineering Science 58 (2003) 1003 – 1011

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Enhanced Char Burnout: CO_2

Walnut Shells: **0% CO_2**

Walnut Shells: **30% CO_2**

Douglas Fir: **0% CO_2**

Douglas Fir: **30% CO_2**

~20% biomass remaining

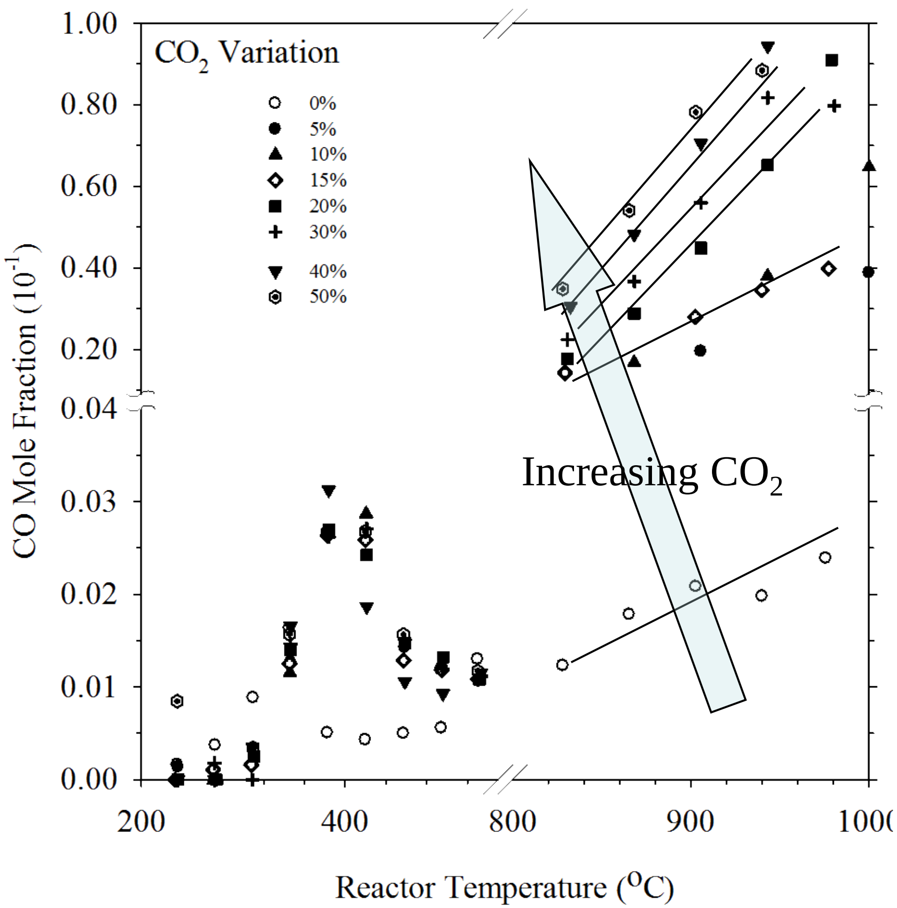
<2% remaining as inorganic ash

- Identical time on stream, reaction temperature profile, total flow rate
- ***Physical evidence of more efficient gasification with CO_2***

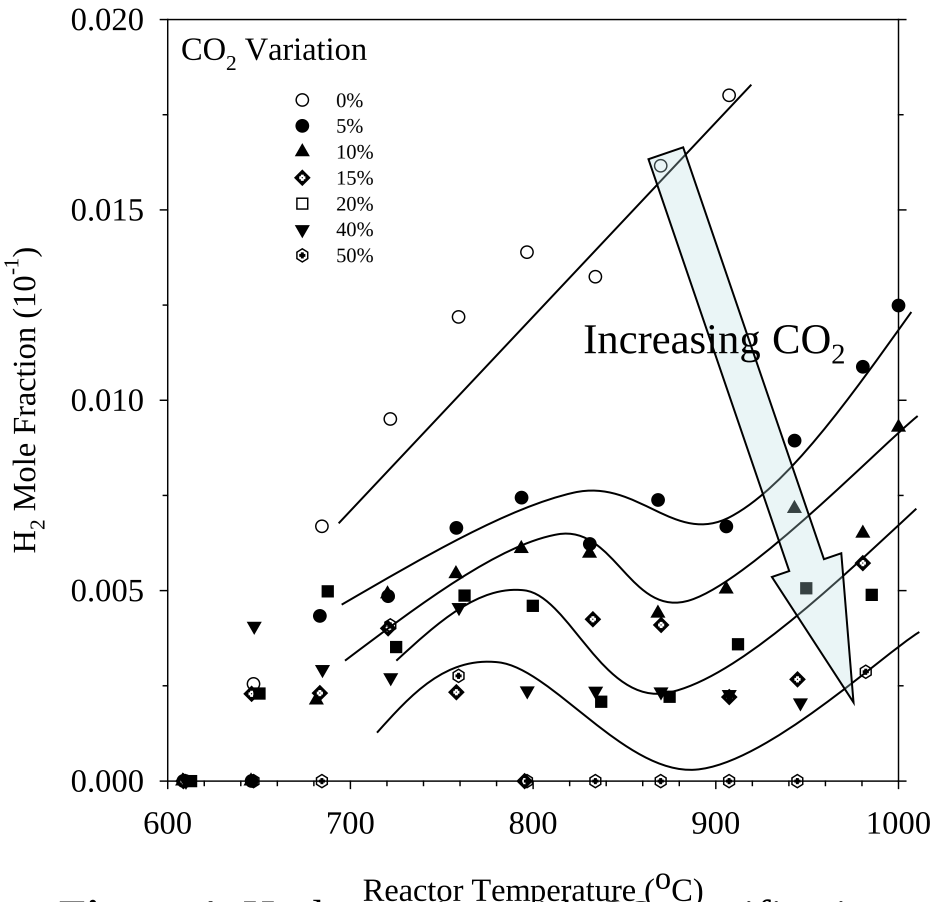
Observed for 100's samples tested

WTERT
Waste-To-Energy Research and Technology Council

CO_2 impact on gasification products



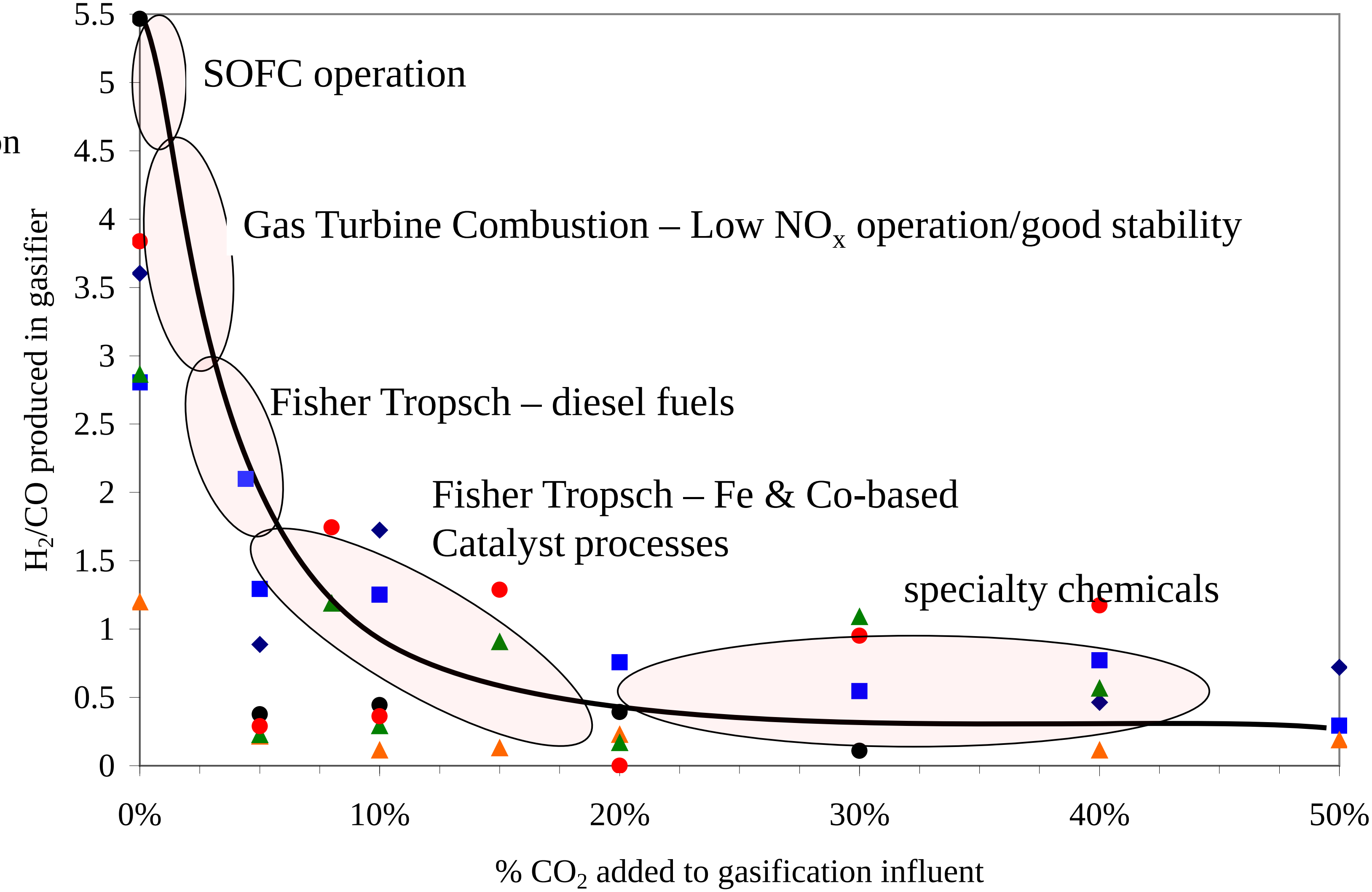
CO ***increases*** *with* CO_2



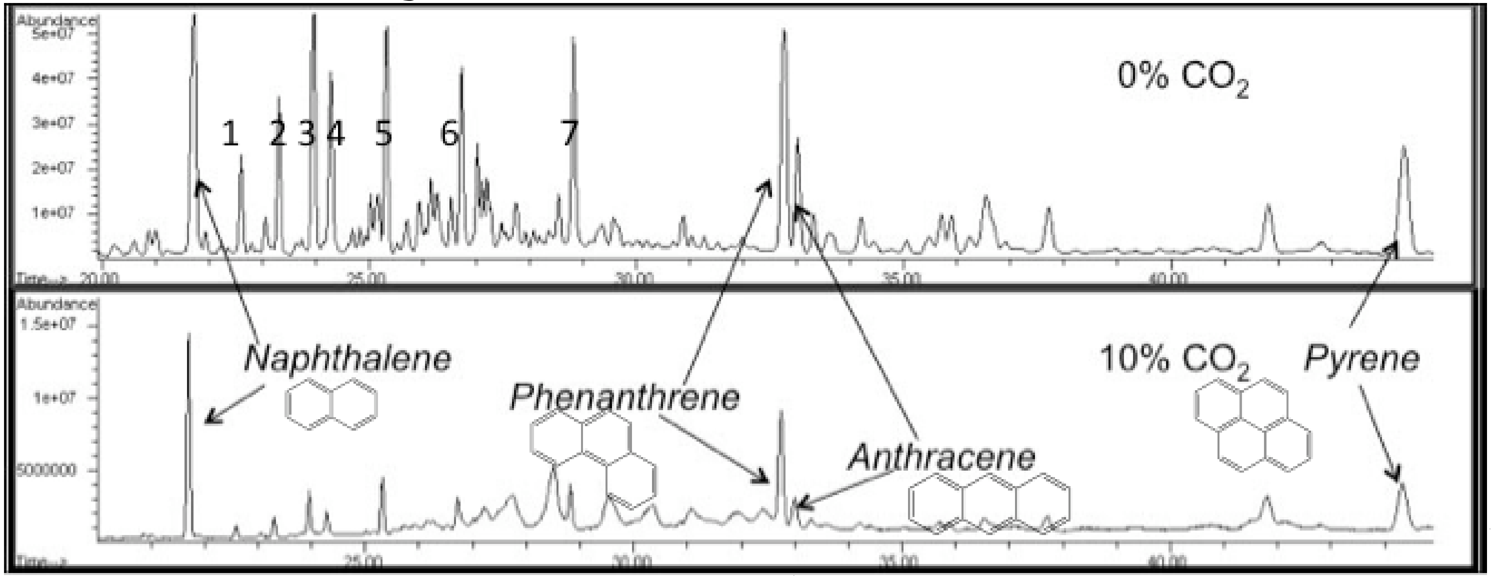
H_2 ***decreases*** *with* CO_2

H_2/CO (Syngas) Tuning

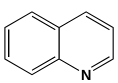
- Fuels
- Chemicals
- Combustion
- Fuel cells



Fuel Synthesis from Waste Streams



Peak Identification

1


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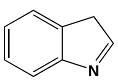

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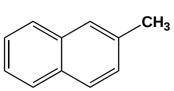

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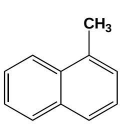

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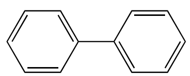

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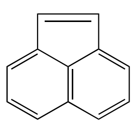

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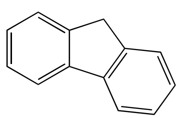
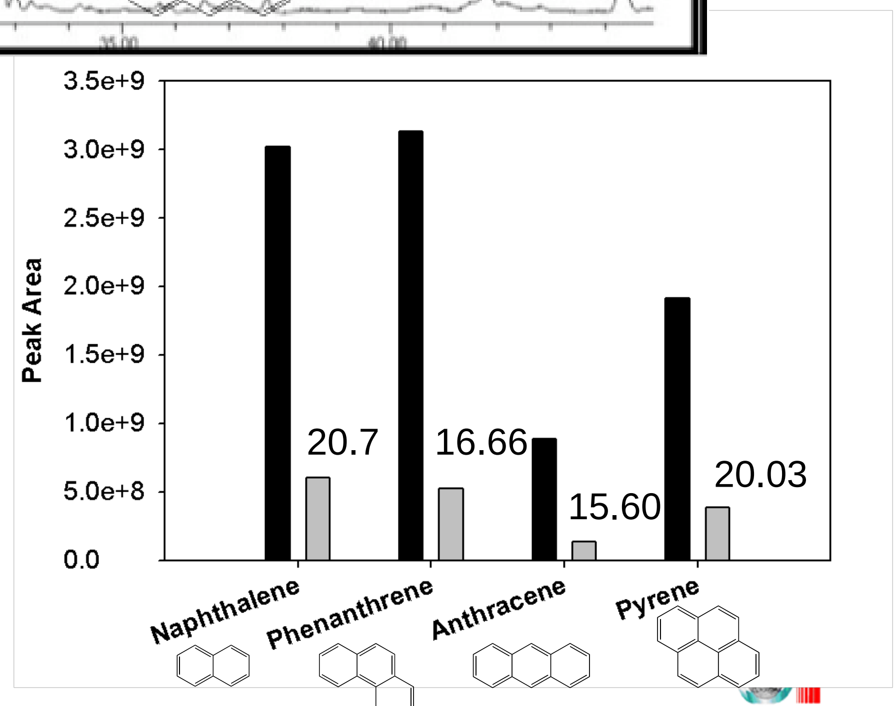
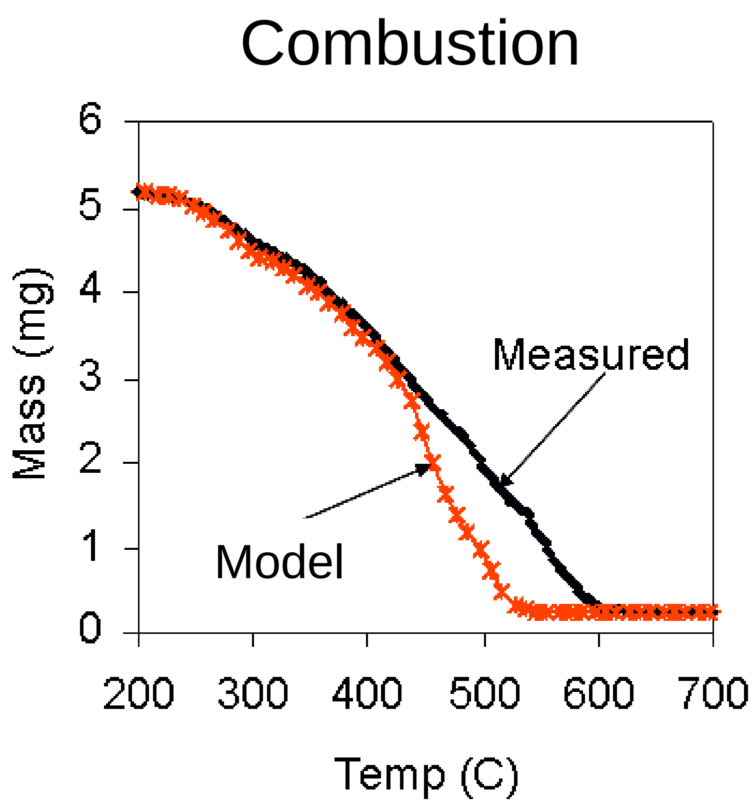
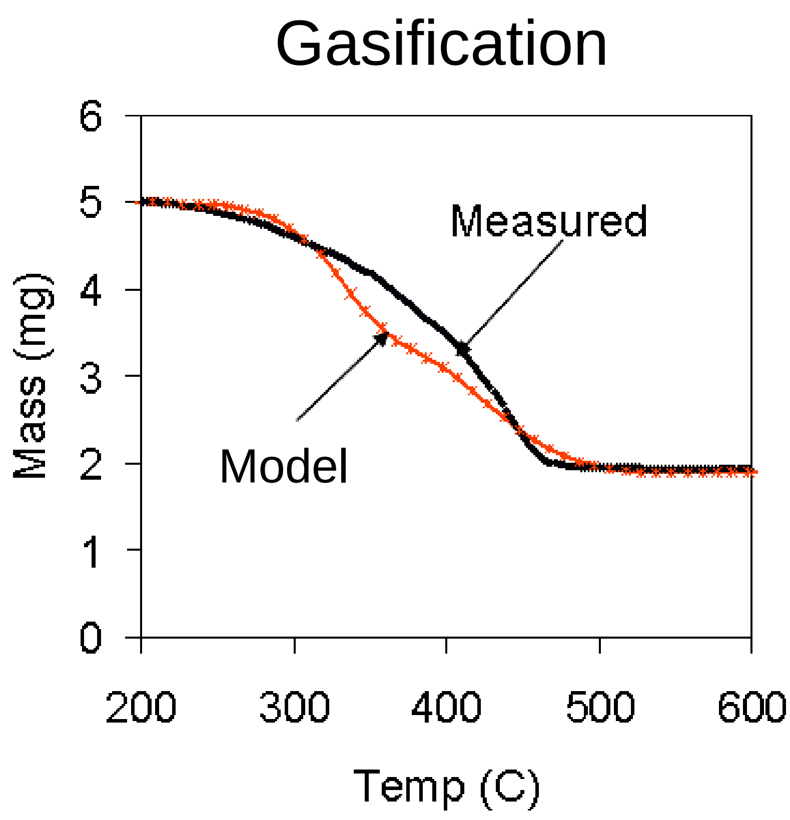




Experiment & Simulation Comparison





Experiment & Simulation “Scale Up”

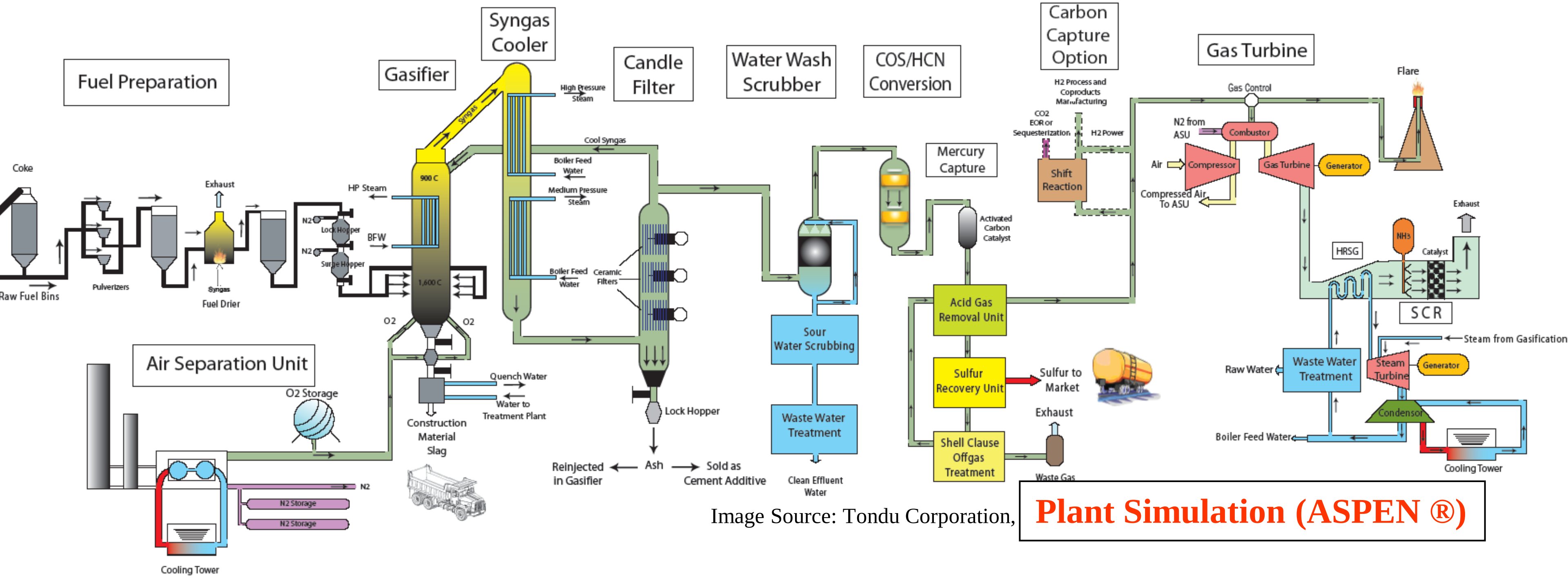
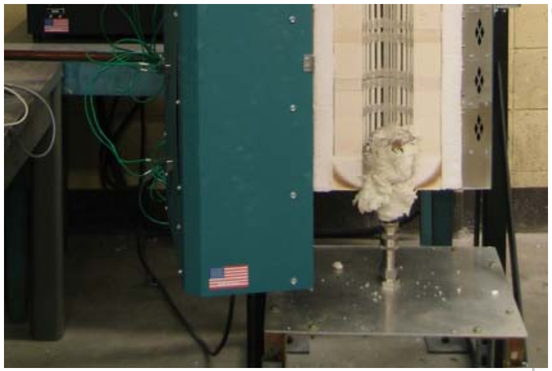
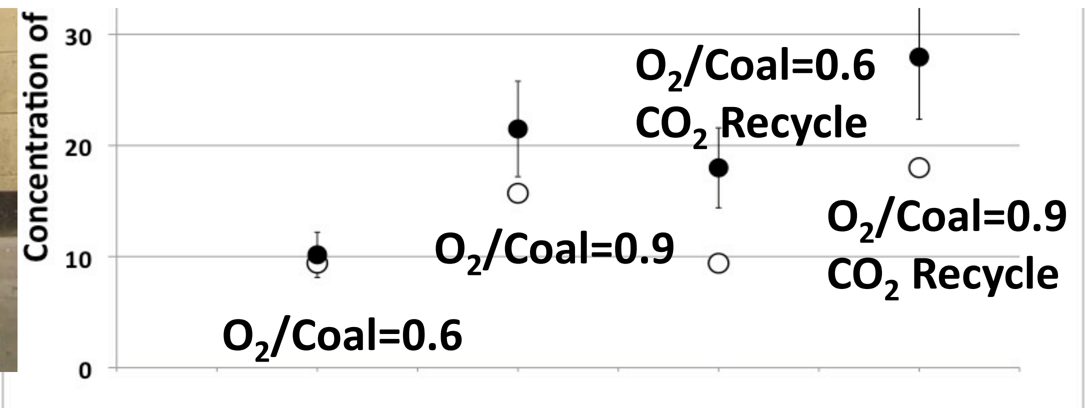


Image Source: Tondu Corporation,

Plant Simulation (ASPEN ®)



Drop tube (~ 2 g/min)



Evaluation of Field Systems

- Technical and Economic Analysis

  MS Thesis – Caroline Ducharme "*Technical and economic analysis of Plasma-assisted Waste-to-Energy processes*"

- Mass and energy balances were developed for each process
  - Company data & engineering estimates
  - Economic analysis comparison to grate combustion systems

- Plasma Technologies
  - InEnTec
  - Europlasma
  - Alter NRG
  - Plasco

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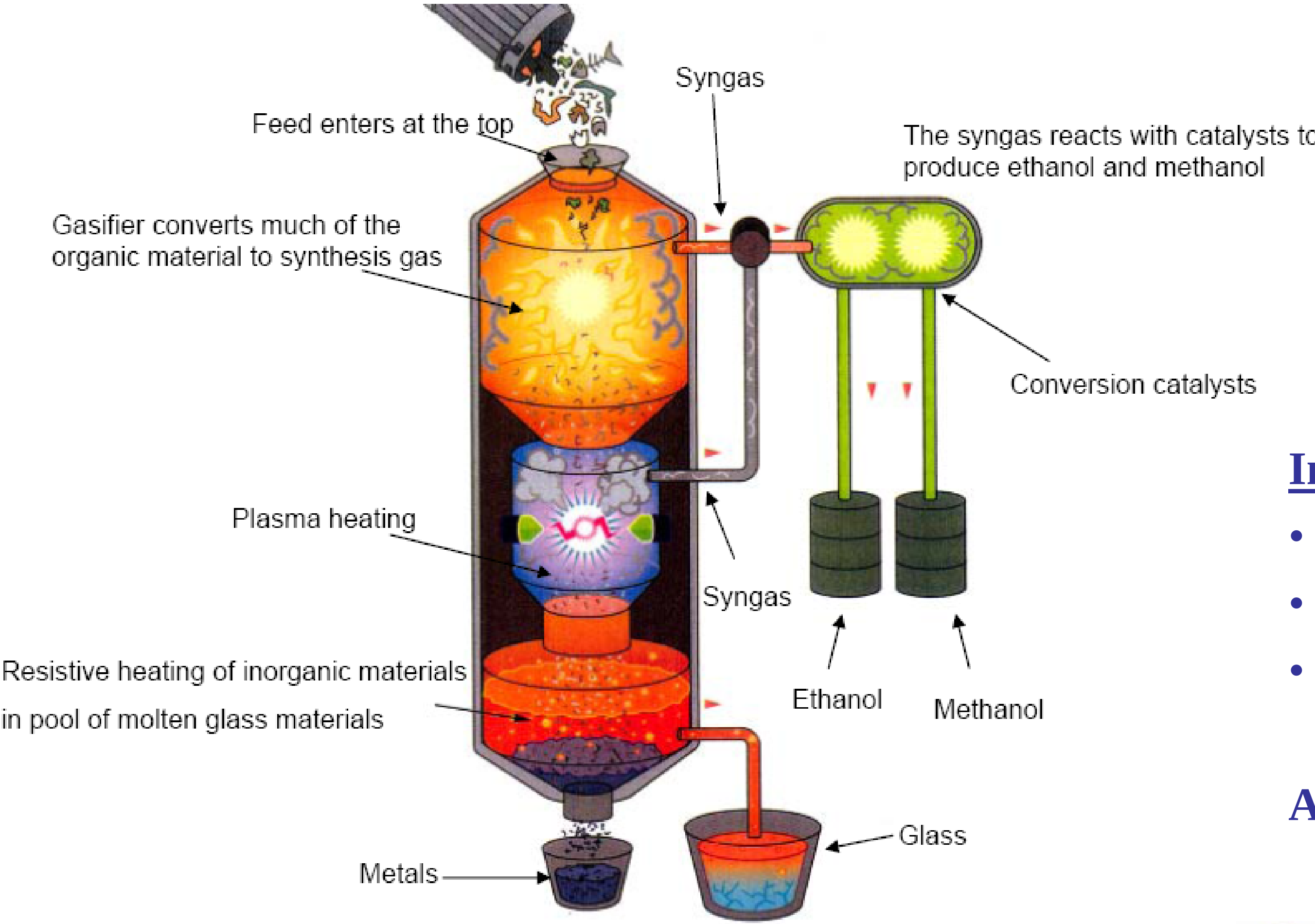
INENTEC Plasma Unit

Liquid Fuels from Municipal/Commercial Waste



Leading Plasma Gasification Solutions

Integration:

- Gasifier
- Plasma Unit
- Thermal Residence Unit

All operated in "sweet spot"

InEnTec

WTERT

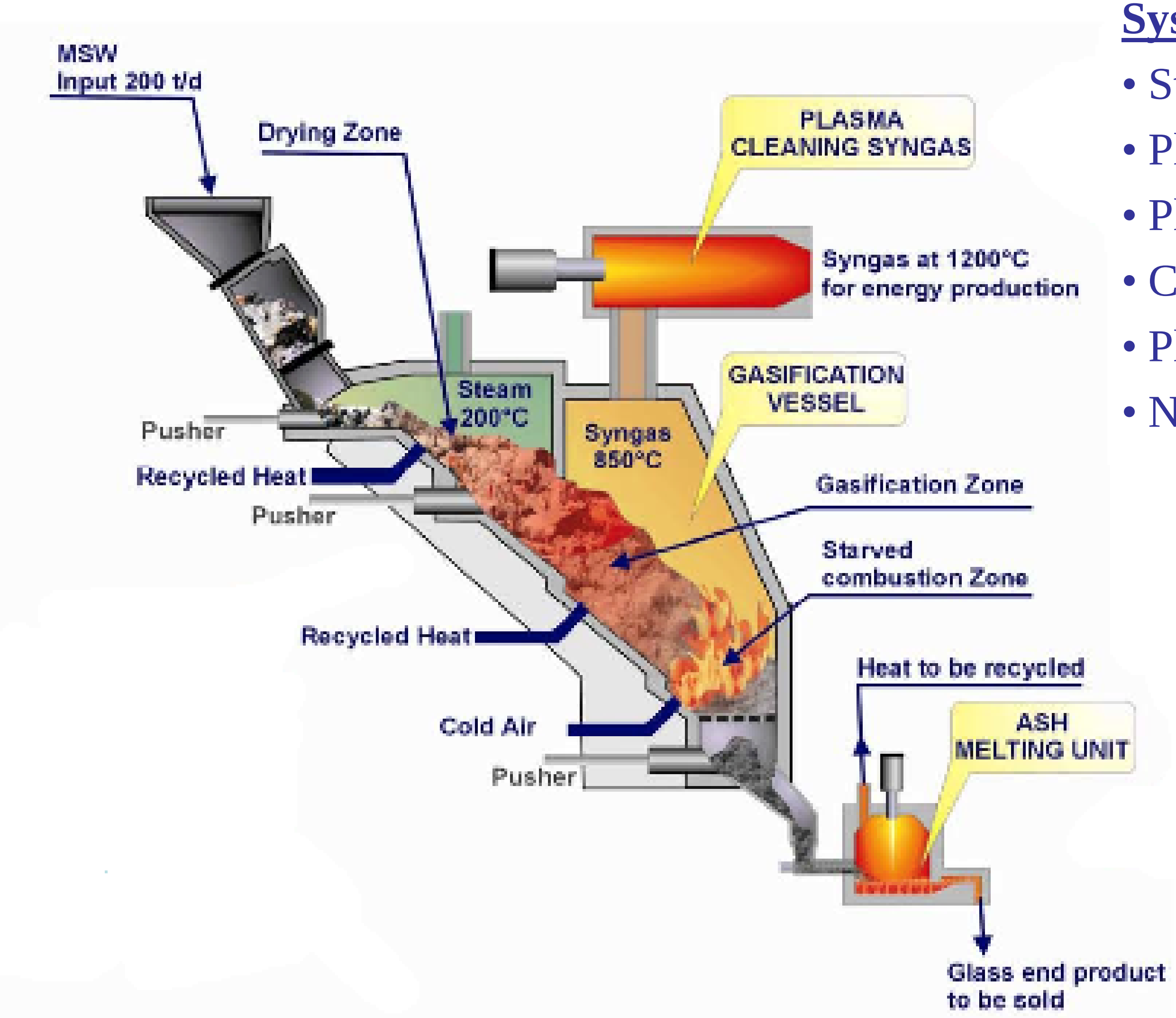
Waste-To-Energy Research and Technology Council

WasteManagement & InEnTec

S4 Energy Solutions

- Joint Venture Formed to Commercially Deploy Gasification of Waste
- 50/50 Joint Venture Between WM and InEnTec
- Venture Officially Launched in February 2009
- JV to Operate in Collaboration with, but Independent of JV Partners

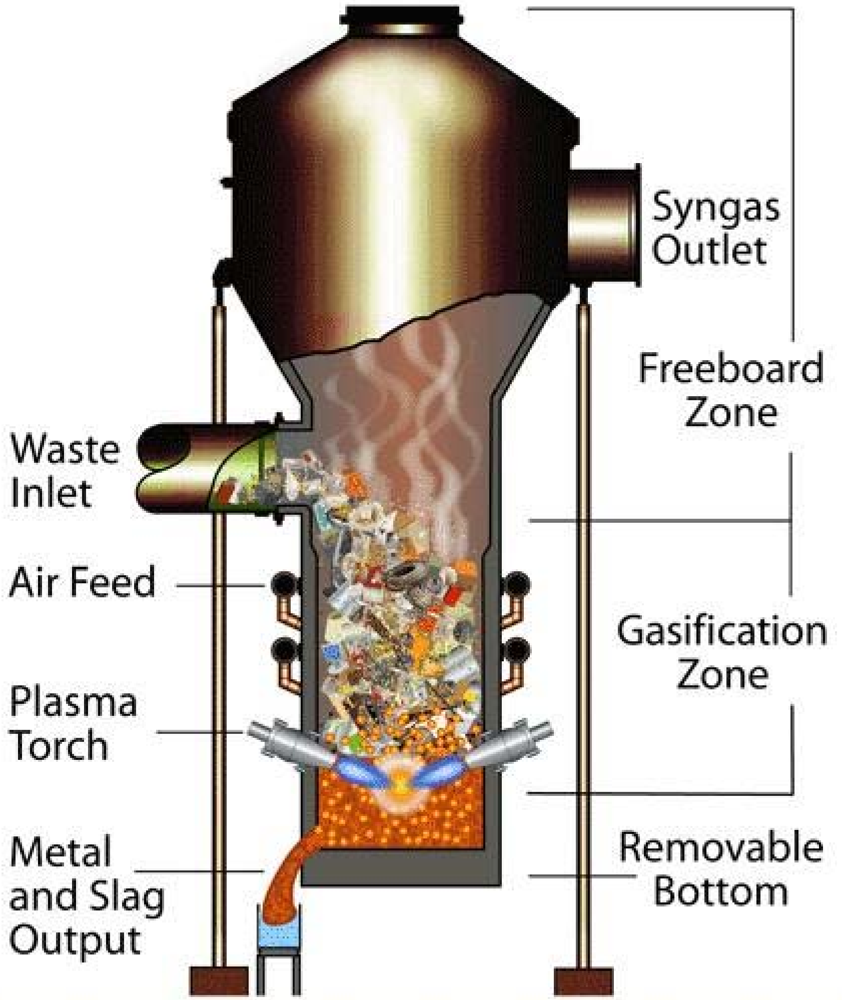
Europlasma



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)



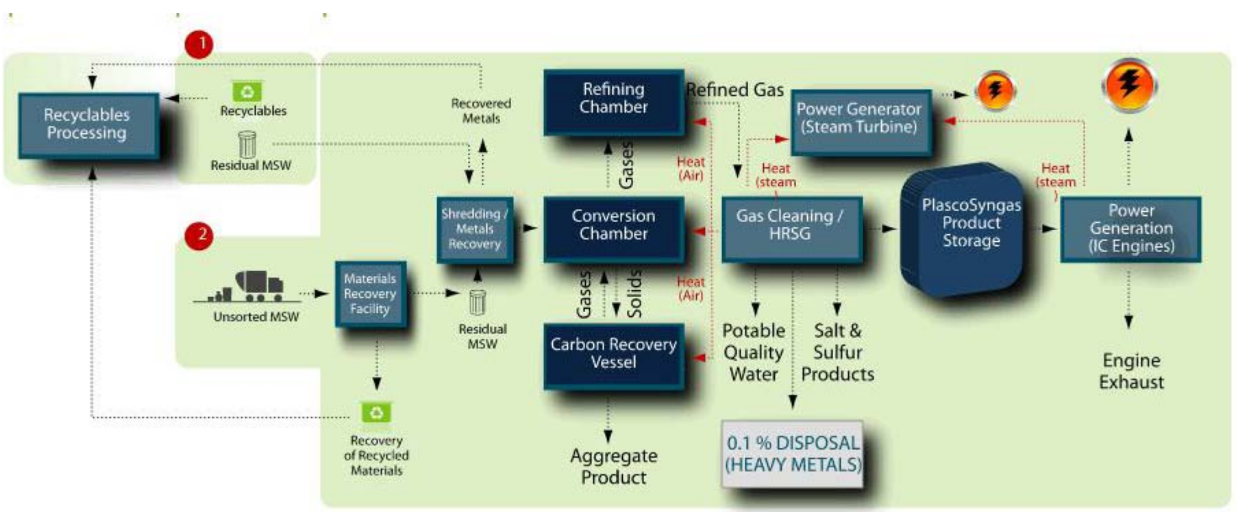
System:

- 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

Plasco

System:

- Demonstration plant in Ottawa built in 2008
- Two stages process:
  - Horizontal Traditional gasification @ 700°C
  - Syngas Production: plasma torches @ 1200°C.
- Electricity production
  - syngas GT combustion
  - Waste heat for combined cycle.



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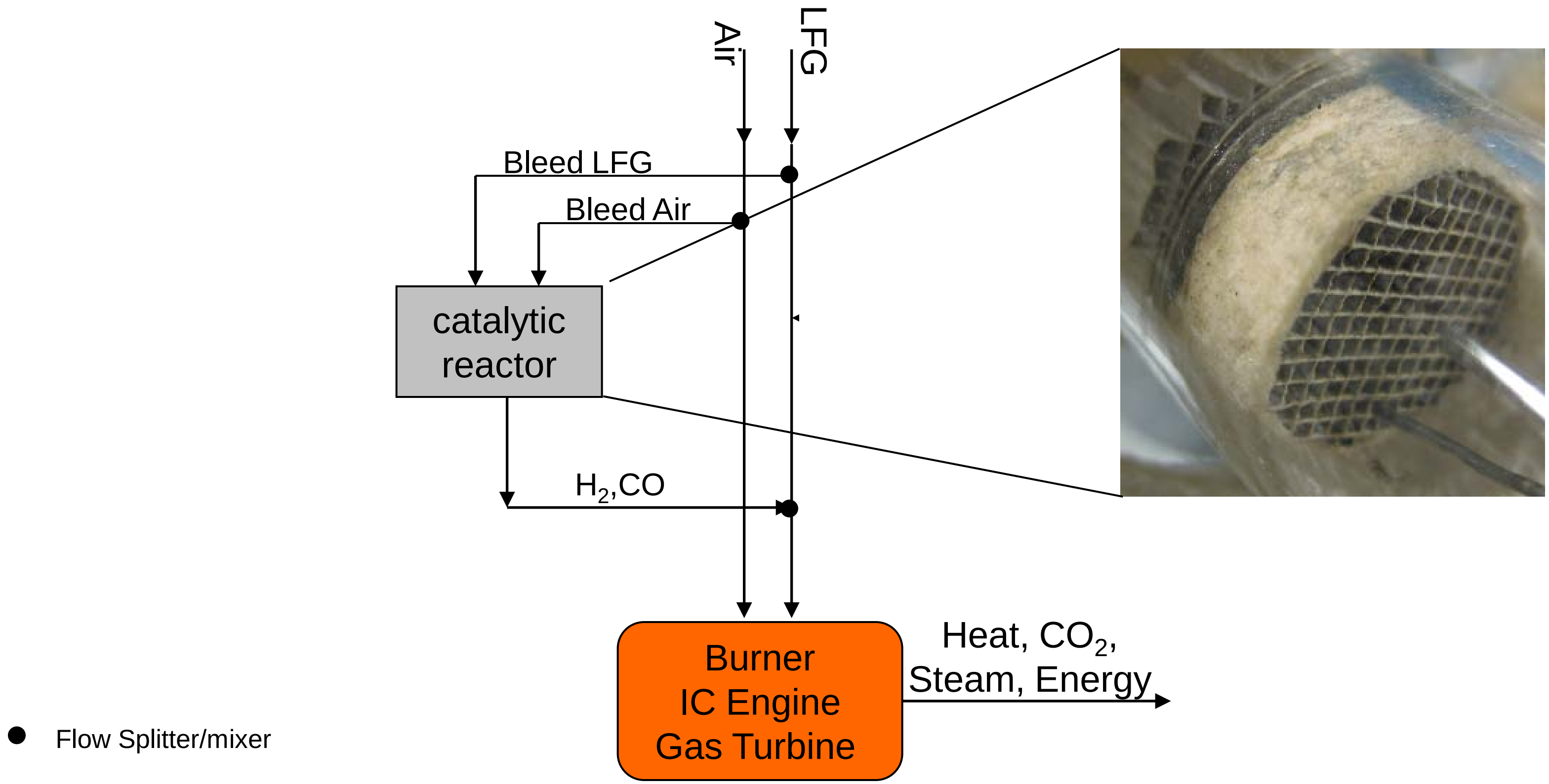
Plasma Field System Summary

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

Landfill Gas Utilization



More reactive system; Reduce/eliminate secondary fuel usage

Kohn, M., et al.” *App. Catal. B: Environ*, (94), **2010**, 125-133.
Barrai, F.; et al. *Catalysis Today* **2007,** 129, (3-4), 391-396.

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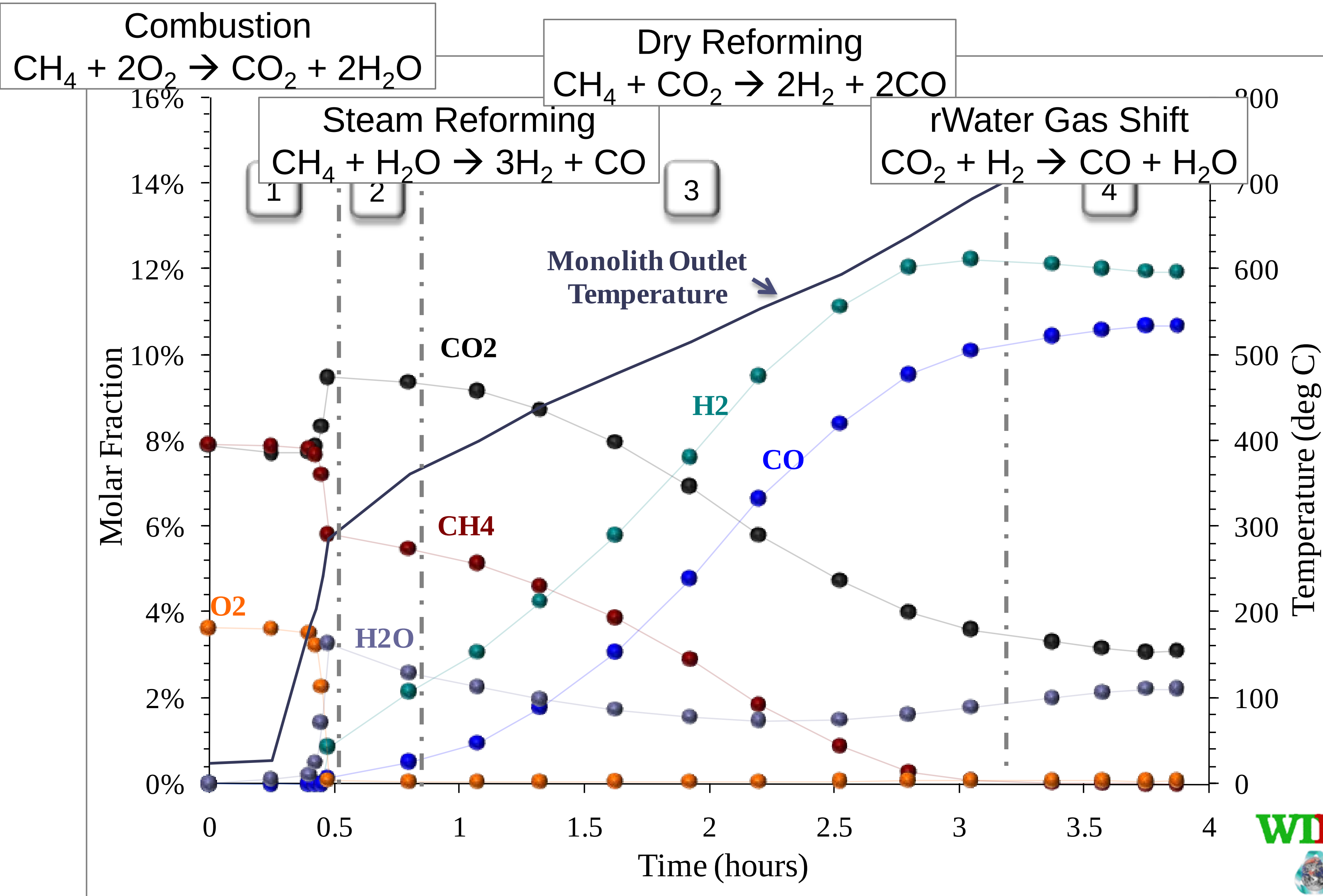
LFG Catalytic Reaction Regions



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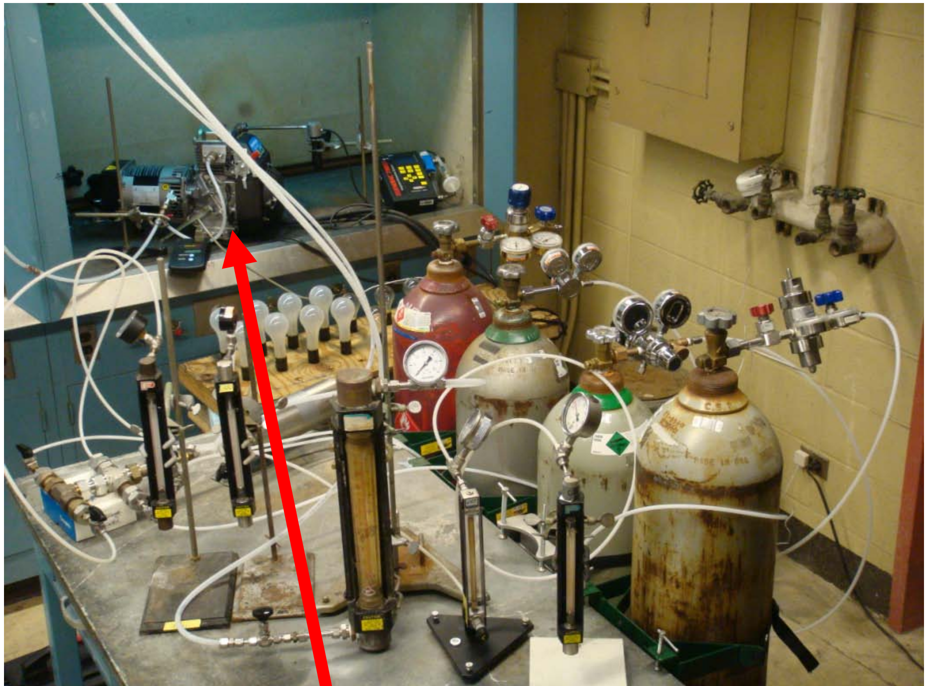
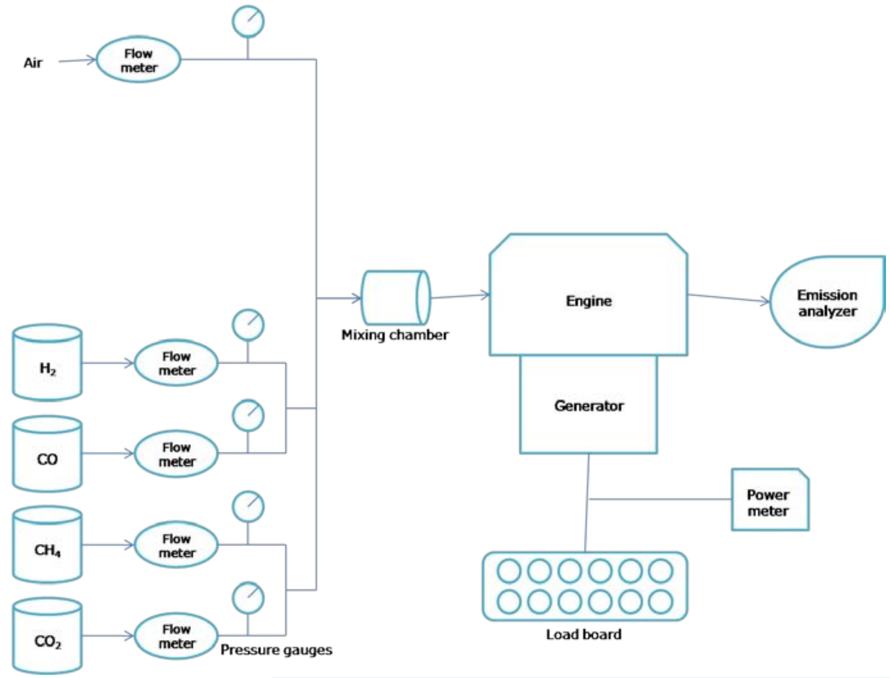
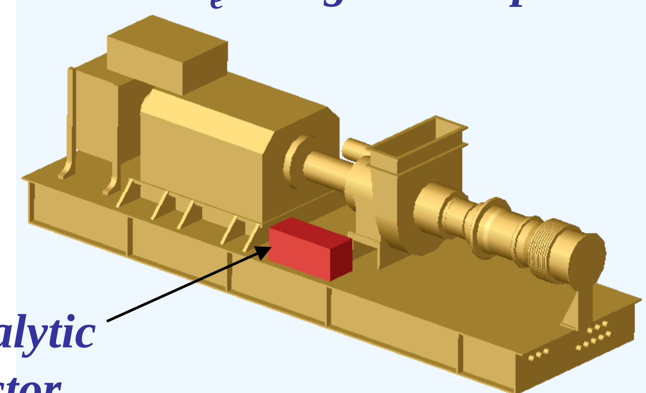
Test Apparatus @ CCL





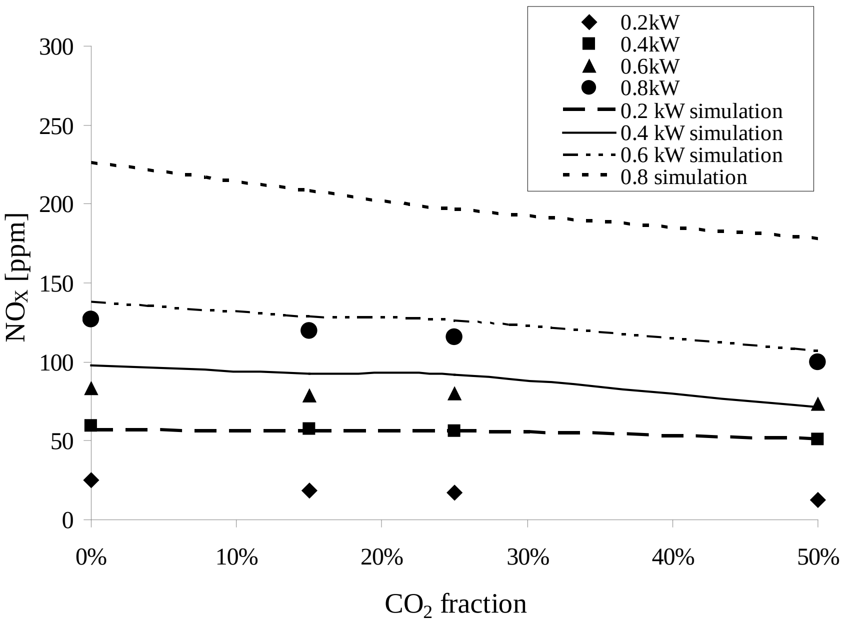
2 kW_e Laboratory test engine

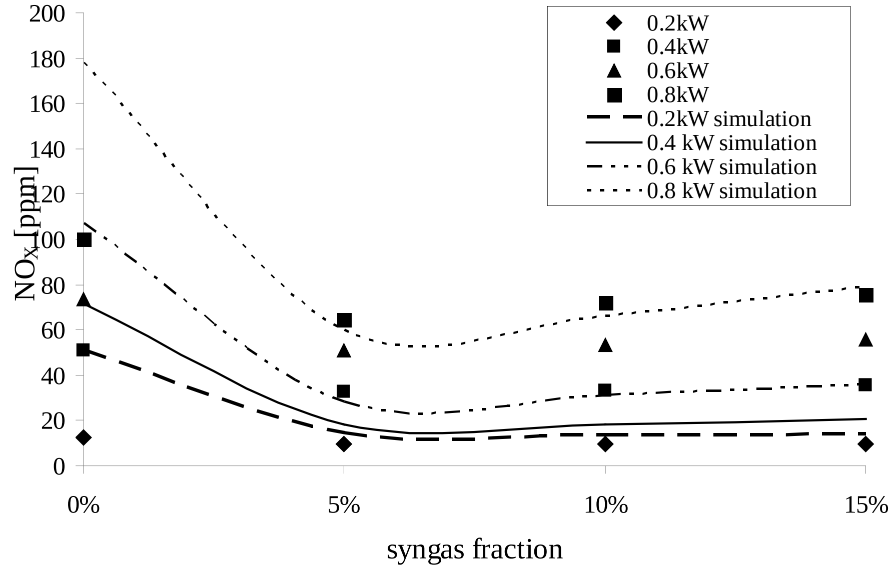
200 kW_e Design Concept



Catalytic reactor

LFG and Syngas impact on NO_X





CO_2 reduction of N radical concentration

$N + CO_2 \rightarrow NCO + O$

Reduce prompt mechanism by reacting with fuel radicals

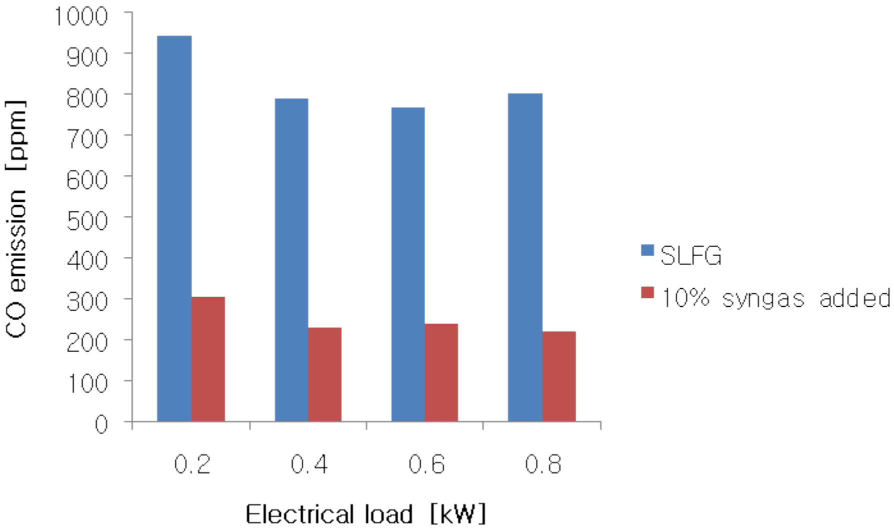
$CH_x + CO_2 \rightarrow CHO + CO$

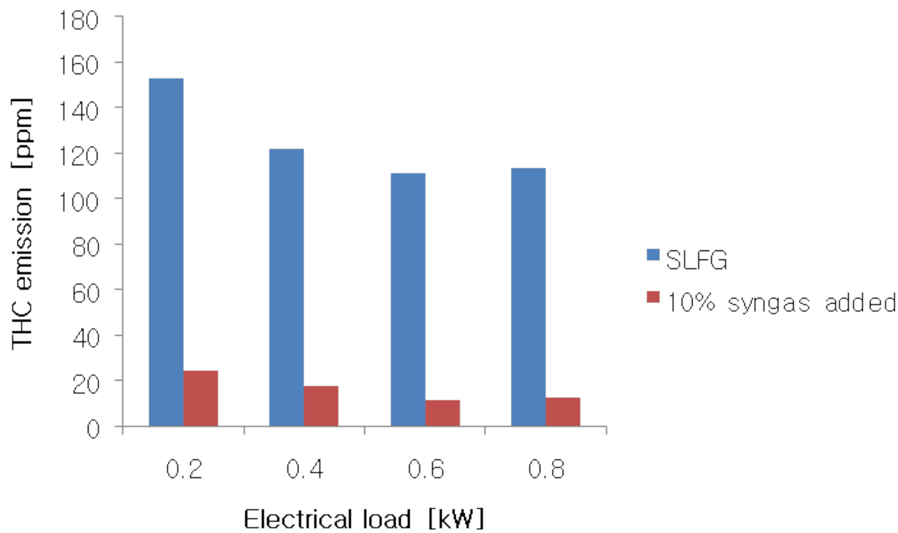
CO2 also serves as diluent – reduces concentrations

$R_{CHN} = kC_{CHN}\, C_{CHN}$ *is reduced*

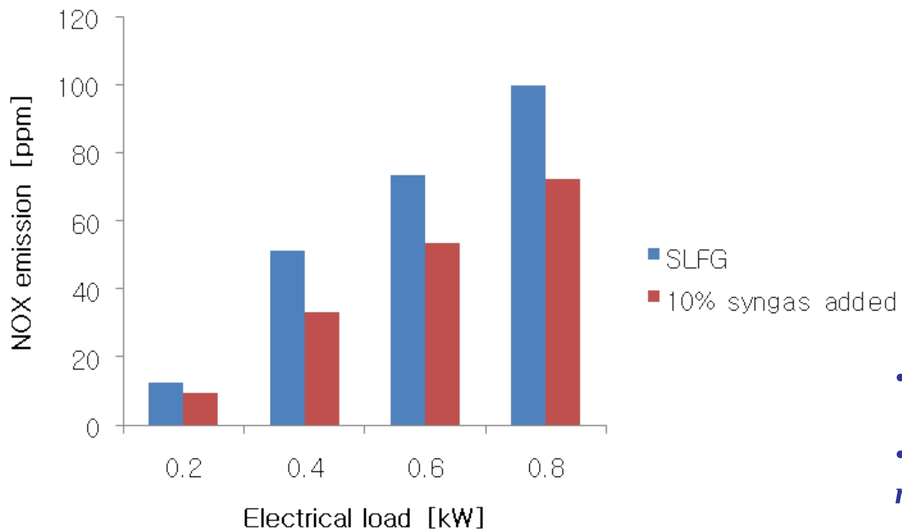
$R_{N2O} = kC_{N2}\, C_O$

Test data from Honda Engine on LFG





Test data shows lower emissions possible across all loads utilizing syngas produced from LFG



•SLFG = simulated landfill gas

•10% syngas added = SLFG mixed with 10% syngas

Looking over the horizon

- Next generation combustors – higher energy density
  - Low NOx operation
  - Approach 3+ MW m^{-2}
- Liquefaction of wastes (T ~ 300 – 500 ºC)
  - Removal of O_2
- In-situ reduction of corrosive gases
  - Injection of halogen scavengers
- Novel uses of ash – catalytic and property adjustment
- LFGTE Applications and LFG to fuels
  - Casella Energy to implement in DE

Combustion & Catalysis Laboratory

Acknowledgments

- **Collaborators**
  - Tuncel Yegulalp, Columbia Univ.
  - Robert Farrauto, BASF Catalysts, LLC.
- **Students**
  - Alex Frank (WTE Modeling – **Poster**)
  - Natali Ganfer (LFGTE Engine Testing – **Poster**)
  - Naomi Klinghoffer (Beneficial Use of Ash - **Poster**)
  - McKenzie Primerano (LFGTE Catalyst Testing – **Poster**)
  - Garrett Fitzgerald (Hydrates – **Poster**)
  - Caroline Ducharme (Plasma Gasification)
  - Amanda Simson
  - Federico Barrai
  - Kelly Westby (ugrad)
- **Visiting Scholars**
  - Jin Yuqi, Zhejiang University
  - John Dooher, Adelphi University
  - Zhixiao Zhang, Hangzhou University
- **Post-Docs**
  - Eilhann Kwon
  - Heidi Butterman

ATK

BASF The Chemical Company

EPRI ELECTRIC POWER RESEARCH INSTITUTE

WM WASTE MANAGEMENT

COVANTA ENERGY for a cleaner world

VEOLIA ENVIRONNEMENT

You, the audience for listening

Please visit CCLlabs.org

WTERT Waste-To-Energy Research and Technology Council

- *Most HC fuels ($C_xH_yO_zN_aS_b$) exist above lines*
- *Need oxygen source or hydrogen to get below*
  (CO_2, O_2, air H_2O, H_2)

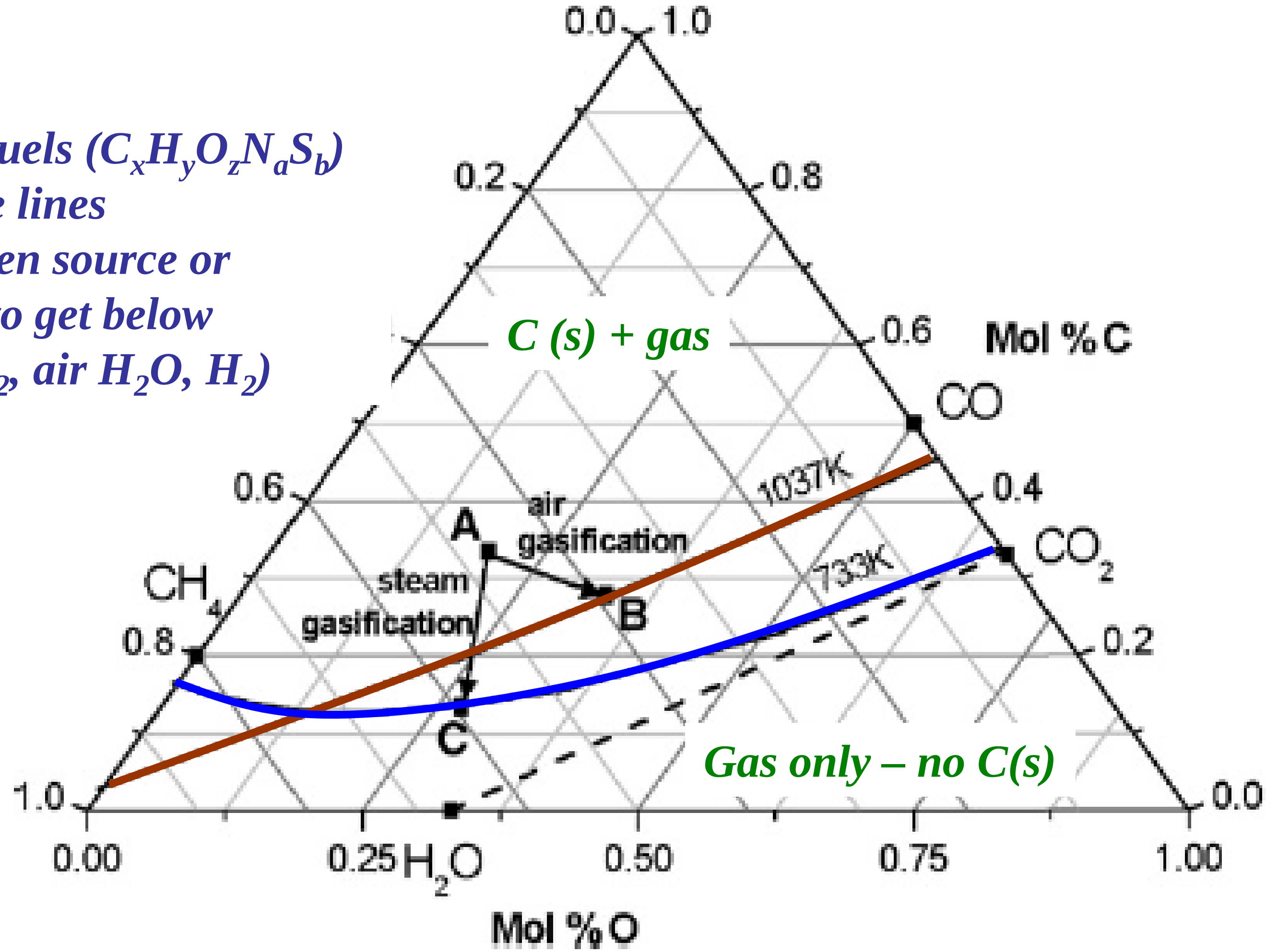
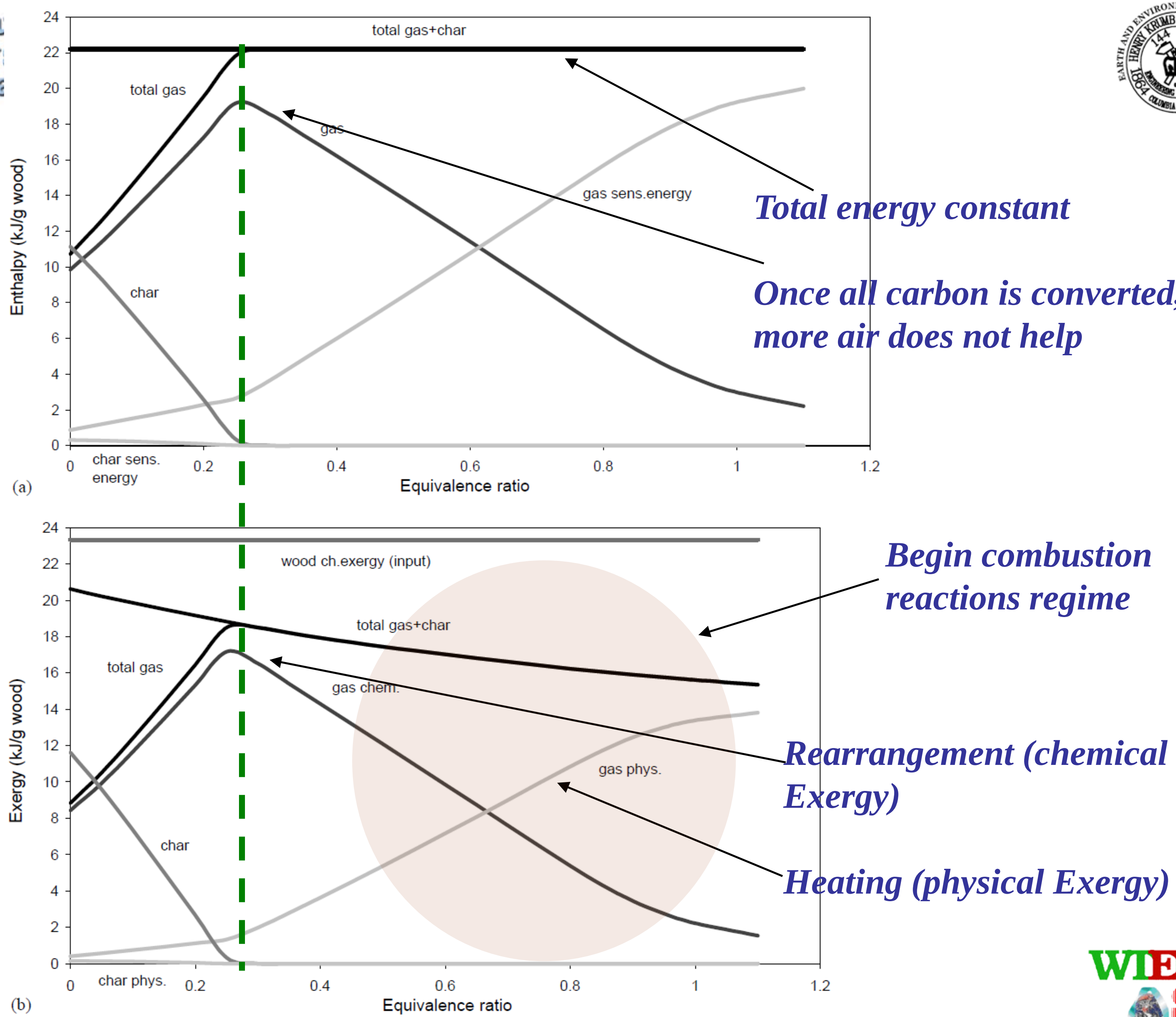


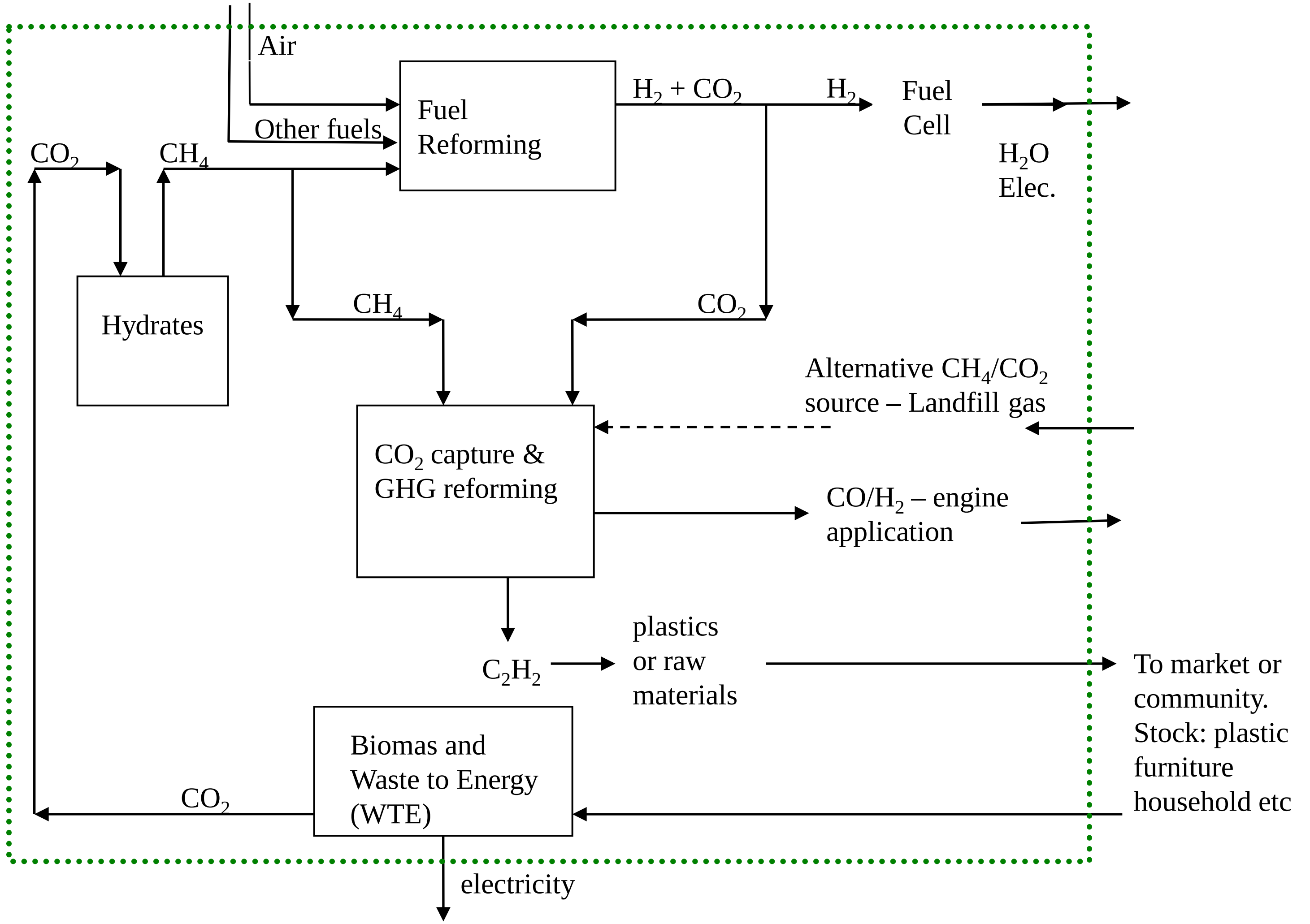
Fig. 1. Molar triangular diagram indicating (A) biomass feed, (B) biomass in equilibrium with air at carbon boundary, (C) biomass in equilibrium with steam of 500 K at carbon boundary.

M. J. Prins et al. / Chemical Engineering Science 58 (2003) 1003 – 1011



. 2. Distribution of energy and exergy to the product gas and char for biomass conversion by air: (a) energy (b) exergy.

Combustion & Catalysis Lab (CCL)



Resources for energy production will continue to be in demand

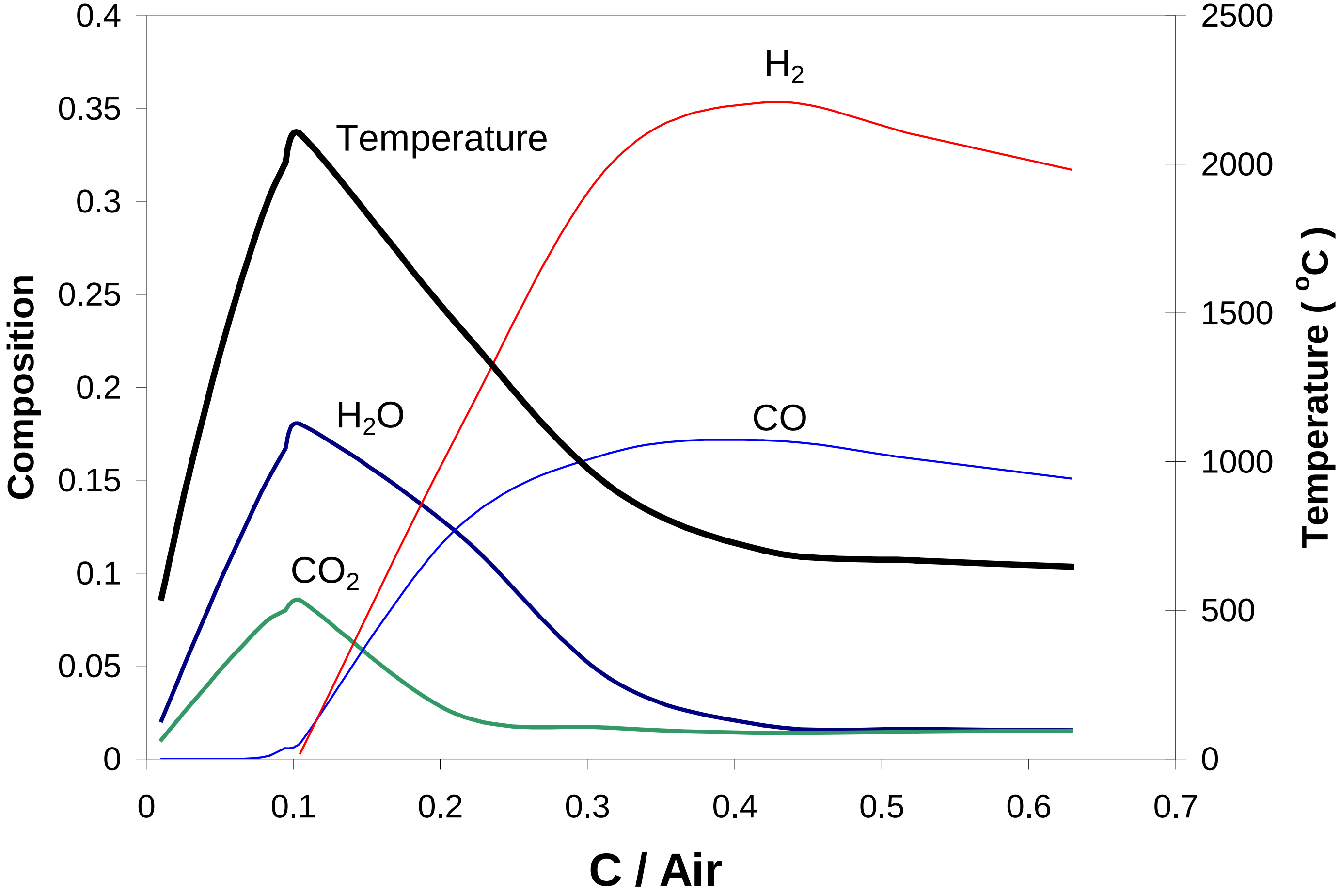
"The nature of environmental issues is changing from a regulatory to a resource focus"

R. MacLean, Env. Protec. April 2003, P.12

Stiochiometry & Equilibrium

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

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



Ref: STANJAN calculations