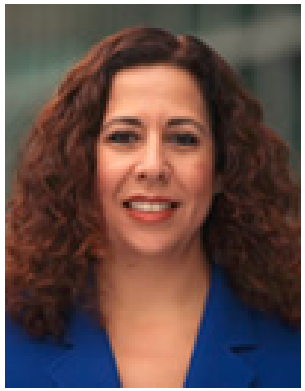
Waste to Energy Options for Base Camps: Efficient Tar Management and Rotary Kiln Gasification

December 4, 2014

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions

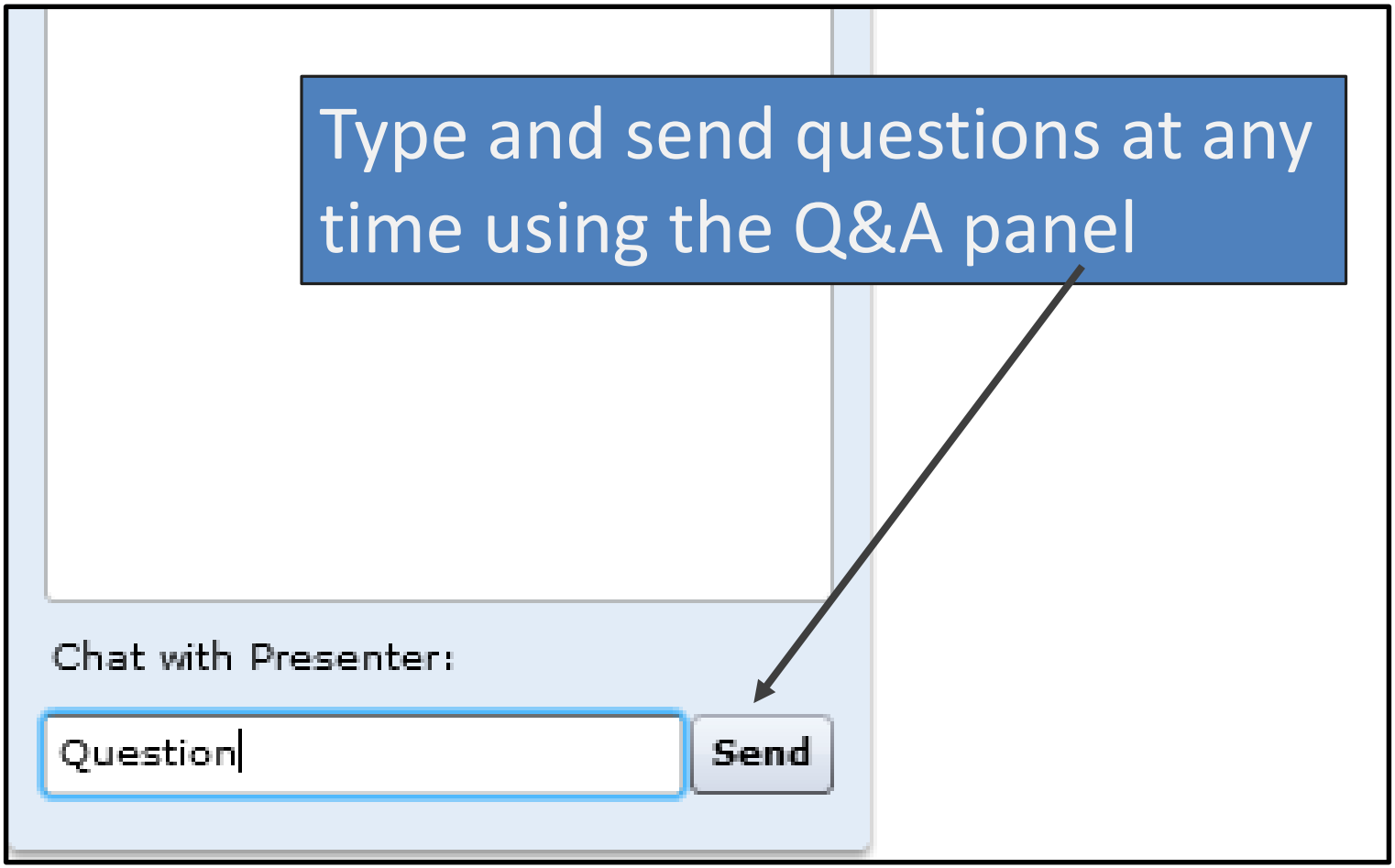
Rula Deeb, Ph.D.
Webinar Coordinator



Webinar Agenda

- Webinar Overview and ReadyTalk Instructions
  Dr. Rula Deeb, Geosyntec (5 minutes)
- Overview of SERDP and ESTCP, and webinar series goals
  Dr. Robin Nissan, SERDP and ESTCP (5 minutes)
- Introduction to the Topic
  Leigh Knowlton, U.S. Army Natick Soldier Research Development and Engineering Center (10 minutes)
- Investigating Efficient Tar Management for Deployable Waste-to-Energy Systems
  Patrick Scott, Lockheed Martin (25 minutes + Q&A)
- Rotary Kiln Gasification of Solid Wastes for Base Camps
  Steven Cosper, U.S. Army Engineer Research and Development Center (25 minutes + Q&A)
- Final Q&A session

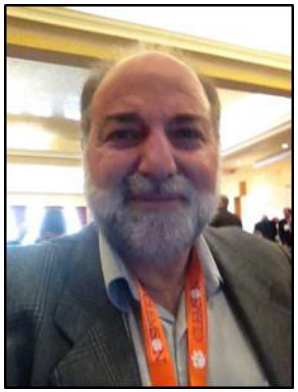
How to Ask Questions



SERDP and ESTCP Overview

Robin Nissan, Ph.D.

Weapons Systems and Platforms Program Manager



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SERDP

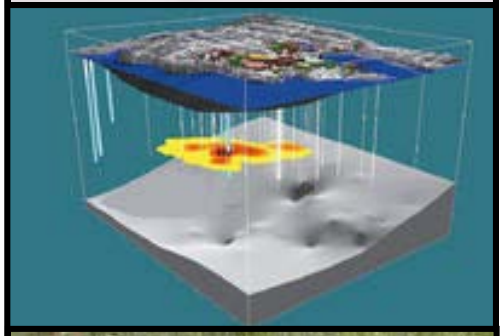
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

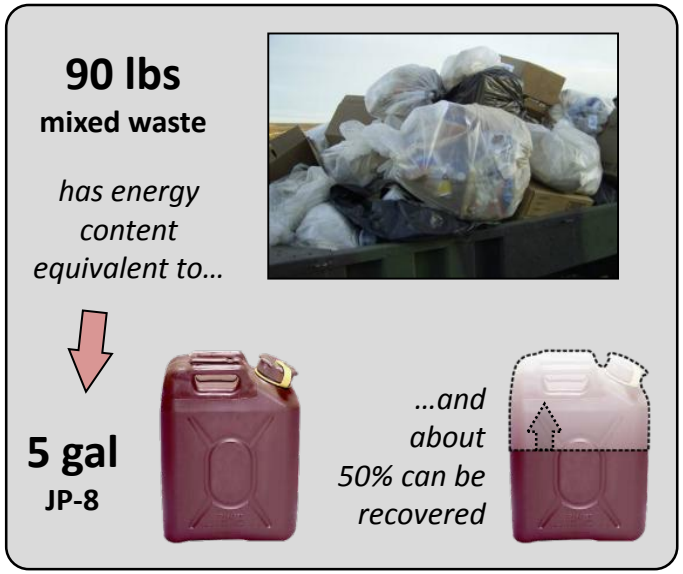
Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Climate Change
5. Weapons Systems and Platforms



Weapons Systems and Platforms

- Major focus areas
  - Surface engineering and structural materials
  - Energetic materials and munitions
  - Noise and emissions
  - Waste reduction and treatment in DoD operations
  - Lead free electronics



SERDP and ESTCP Webinar Series

DATE	WEBINARS AND PRESENTERS
December 18, 2014	**Energy Audits: From Clipboard to Cloud** • Mr. Oliver Davis (concept3D, Inc.) • Ms. Cara Brill (FirstFuel)
January 8, 2015	**DNAPL Source Zone Management** • Dr. Paul Johnson (Arizona State University) • Dr. Charles Newell (GSI Environmental)
January 22, 2015	**Sustainable Materials** • Dr. Andrew Guenthner (Air Force Research Laboratory, Aerospace Systems Directorate) • Dr. Benjamin Harvey (Naval Air Warfare Center, Weapons Division) • Dr. John La Scala (U.S. Army Research Laboratory)
February 5, 2015	**Acoustic Methods for Underwater Munitions** • Dr. Joseph Bucaro (Naval Research Laboratory) • Dr. Kevin Williams (APL University of Washington)

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

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Introduction to the Topic

Leigh Knowlton
U.S. Army Natick Soldier Research Development and Engineering Center

Waste to Energy Conversion for Small Contingency Bases

Leigh Knowlton
U.S. Army Natick Soldier Research Development and Engineering Center

Background

Army NSRDEC Waste to Energy Vision (2004)

- TODAY: **Waste is a liability**
  - Waste disposal is an expensive logistical burden
- VISION: **Waste is power**
  - Paradigm shift: waste is less a liability, more a resource
  - Convert waste into energy for organizational equipment
- Energy potential of field feeding waste
  - Field feeding generates 3-4 pounds of waste per person each day
  - Most of the trash is carbonaceous, a potential fuel source
  - 90 lbs of mixed waste has energy content equivalent to 5 gallons of fuel; about half of that might be recovered

Contingency Basing
Solid Waste Reduction in Theater

- Solid waste management in Afghanistan (by site, OEF data from 2011)
  - 67% burn pits
  - 25% other (including backhaul)
  - 8% incinerators
- Waste generation rate
  - Field foodservice alone: 3-4 lbs/person/day
  - Force Provider: 2 TPD or 6.7 lbs/person/day
  - OEF planning: 10 lbs/person/day, 18 with PX or bazaar
  - US Army LIA 2012 study: 9 to 25 lbs/person/day
- Current WTE does not meet mission requirements for small contingency bases

Waste to Energy Conversion for Contingency Basing Logistics Reduction

Technical Problem	• Deployed forces produce enormous amounts of solid waste −Planning factor for small bases is 10 lbs/person/day • Current solid waste handling has negative impacts on mission −Logistics, environment, health, safety, energy, etc.
Technical Barrier	• Current small scale WTE is too large, expensive, and has feedstock limitations • Small incinerators consume a lot of fuel (up to 50% by weight of the waste)
Capability Sought	• Practical and efficient technology to eliminate or reduce solid waste for small contingency bases (150-1000 PAX)
Result / Product	• Demonstration of waste remediation capability for small bases −Provide a viable alternative to burn pits and fuel-hungry small incinerators −Reduce logistics and improve safety while protecting the environment • Objective of 90% reduction of organic waste with minimal energy requirement −Reduce or eliminate the use of burn pits
Requirement	• Capability Production Document (CPD) for Force Provider Expeditionary −Contains performance goals as threshold and objective requirements
Acquisition Program	• Army Product Manager Force Sustainment Systems −Force Provider Expeditionary

Force Provider Expeditionary Requirements for Solid Waste Management

- **Solid Waste Management Capability, <u>Individual Modules</u>** (150 PAX)
  - The FPE (Force Provider Expeditionary) shall incorporate an integrated waste management (reduction, reuse, recycling, treatment, or disposal process) <u>add-on capability</u> that can <u>safely process 1,000 lbs or more of mixed solid organic waste in a single day on site (T)</u> and <u>the energy associated with the management process shall be converted to usable energy including fuel, heat or electric power (O)</u>.

- **Solid Waste Management Capability, <u>Modules Collocated</u>** (600 PAX)
  - The FPE (Force Provider Expeditionary) shall incorporate an integrated waste management (reduction, reuse, recycling, treatment, or disposal process) <u>add-on capability</u> that can <u>safely process two tons of mixed solid organic waste in a single day on site (T)</u> and <u>the energy associated with the management process shall be converted to usable energy including fuel, heat or electric power (O)</u>.

Rationale: On a daily basis, approximately 5–8 lbs/person/day of mixed solid waste is produced on a FPE site that must be properly managed through reduction, reuse, recycling, treatment, or disposal. Most of the waste is nonhazardous solid waste. The threshold requirement is a substantial improvement over the current practice of burn pits and backhaul. The Objective requirement of exportable energy will further improve the economics of onsite waste remediation.

(Force Provider Expeditionary CPD Approved 27 FEB 14)

In Pursuit of a Solution...
Army NSRDEC Involvement in WEC Efforts

System / Project Name	Technology	Contractor	Proponents	Start	End	Demo
Onsite Field-feeding Waste to Energy Converter (OFWEC)	Downdraft Gasification	Community Power Corporation	Army NSRDEC	2005	2008	
Onsite Field-feeding Waste to Energy Converter (OFWEC)	Indirectly Heated Pyrolytic Gasification	Green Liquid & Gas Technologies	Army NSRDEC / DARPA	2005	2008	
Military Encampment Waste to Electrical Power System (MEWEPS)	Downdraft Gasification	NextEnergy / Community Power	Army TARDEC	2008	2009	Camp Grayling
High Energy Density Waste to Energy Converter (HEDWEC)	Downdraft Gasification	Community Power Corporation	Army ARL, NSRDEC; NREL	2009	2013	
Onsite Field-feeding Waste to Energy Converter III (OFWEC III)	Downdraft Gasification	Community Power Corporation	Army NSRDEC	2010	2011	Fort Irwin
Mobile Integrated Sustainable Energy Recovery (MISER)	Supercritical Water Gasification	General Atomics	DARPA / Army NSRDEC	2005	2009	
Mobile Integrated Sustainable Energy Recovery (MISER)	Liquid Anode Fuel Cell	Celltech Power	DARPA / Army NSRDEC	2005	2006	
Green Energy Machine (GEM)	Downdraft Gasification	Infoscitex	Army ARL, ECBC, TACOM; ESTCP	2004	2012	Edwards AFB
Pyrolysis Waste Destruction System (PWDS)	Pyrolysis, Gasification, and Combustion	QinetiQ	Army PdM FSS / FCT	2009	2011	Fort Irwin
Tactical Garbage to Energy Refinery (TGER)	Downdraft Gasification, Fermentation	Defense Life Sciences	Army ECBC / REF	2004	2008	Iraq
Tactical Garbage to Energy Refinery 2.0 (TGER 2.0)	Indirectly Heated Gasification, Fermentation	SAIC / Defense Life Sciences	Army ECBC	2011	2012	APG

Army NSRDEC Current WEC Efforts

US ARMY RDECOM

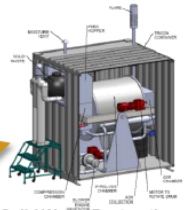
Waste to Energy Converter (WEC) for Small Contingency Bases

US ARMY NATICK SOLDIER RD&E CENTER

6-10 lb/person/day field waste

Waste to Energy Conversion

Efficient Solid Waste Disposal



Solid Waste Destruction System (SWDS)

150-600 PAX

600-1000 PAX

Solid waste generates power (export 1+ MWh daily)

Battalion-scale Waste to Energy Converter (BWEC)

Solid waste powers incineration latrine

Expeditionary Waste Mitigation Box (XwBox)

Schedule

Milestones	FY14	FY15	FY16	FY17	FY18
BWEC (2 TPD) R&D	5				
Demonstration (600+ PAX)		6			
SWDS (0.5 TPD) R&D	4	5			
Xw-Box (0.5 TPD) R&D		5			
SERDP S&T	4				
Demonstrations (150+ PAX)			6		
JDW2E Follow-on R&D					7
Technology Transition					

Milestone Indicators: TRL: ◆ Milestone Timeline: ▬

Purpose:

- Provide a practical and efficient capability for onsite disposal of the solid waste generated by small contingency bases (150-1000 PAX)
  - Current CB disposal practices are expensive, consume land, energy, and manpower, are hazardous to human health and the environment, and degrade mission effectiveness
- Minimize solid waste with minimal resource expenditure, with objective to export useful energy
- Reduce logistics and improve safety for the Warfighter

Results/Products:

- Technology demonstration of WEC suitable for Force Provider and other small contingency bases
  - Containerized, deployable, semi-autonomous
  - Processes non-hazardous mixed solid waste
  - Recovers enough energy for 50% self power, objective to export electrical power
  - Benign residuals and emissions

ROI/Payoff:

- Reduce logistic burden of contingency basing
  - Reduce two costly burdens: waste & fuel
  - "Trucks off the road" = force protection
- Reduces carbonaceous solid waste by 90% (e.g., 4000 lbs would be reduced to 400 lbs char/ash)
- Viable alternative to fuel-hungry small incinerators
- Transition to PdM FSS and/or JDW2E in FY16

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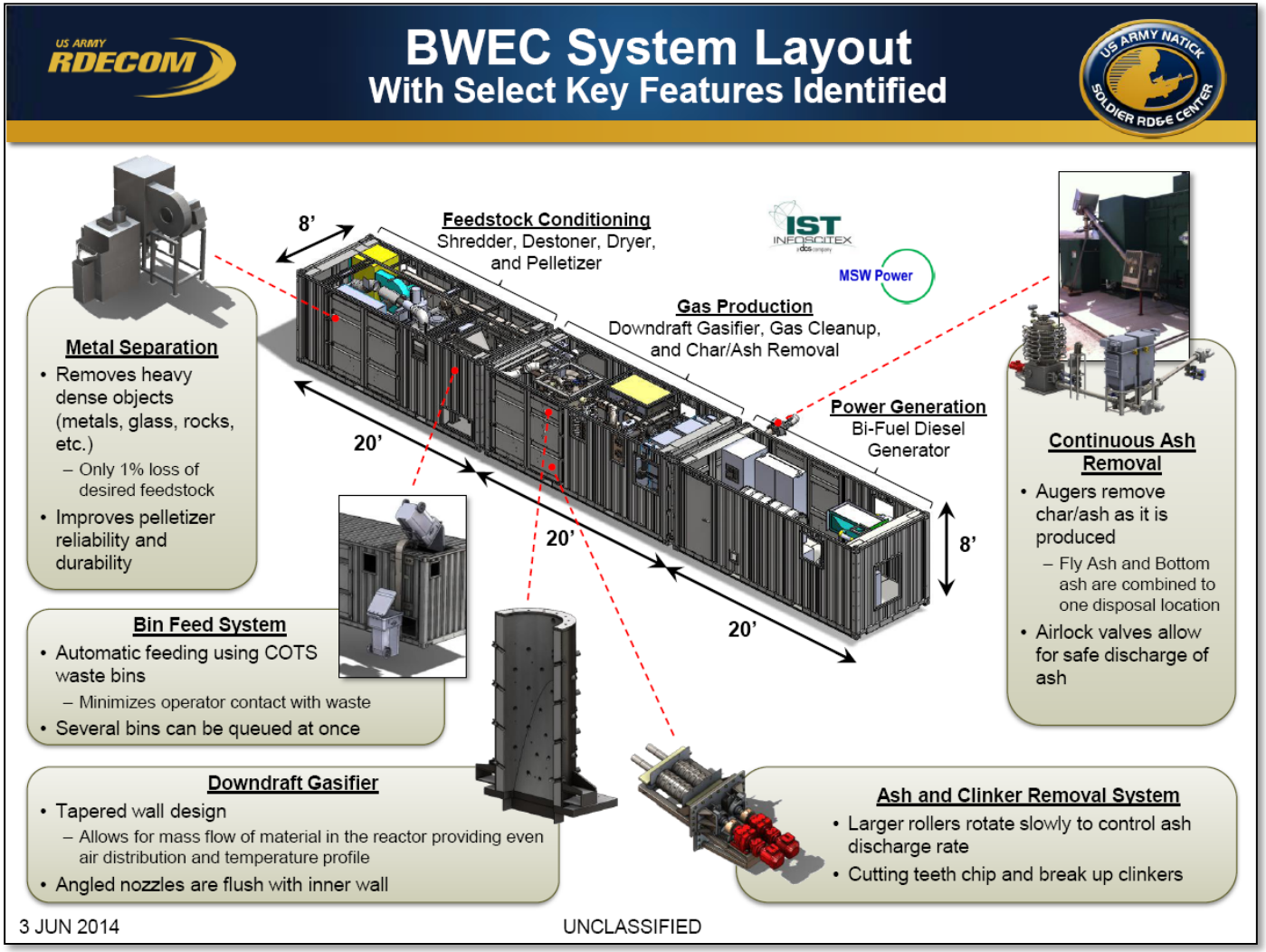
Army NSRDEC Battalion-scale Waste to Energy Converter (BWEC)



Performance Barriers
Small-scale WTE / Waste Destruction

- WTE being shown feasible, but performance barriers remain
  - Expensive, large, and heavy
  - Low technical maturity, difficult to maintain
  - Feedstock limitations and/or presorting requirements
  - Too inefficient, leading to poor ROI
- COTS incineration technologies are not an ideal solution
  - Difficult to permit and may exceed emissions regulations
  - High fuel usage
- No major breakthroughs expected without Government investment
  - Comparatively little demand in the commercial sector
  - ROI highest where the fully burdened cost of fuel or waste is high

SERDP WPSON-12-03

Waste to Energy Converters for Overseas Contingency Operations

- **Objective:** Develop innovative approaches to decrease the size and increase the efficiency of battalion-scale WEC systems based on gasification or pyrolysis processes

- **Performance Criteria:** (for a battalion-scale WEC, from PdM FSS and Base Camp System of Systems Working Group)
  - Process 1–3 tons per day of mixed solid waste into exportable energy (fuel or electricity)
  - Non-hazardous residuals (char/ash)
  - Threshold efficiency: system self-sufficient (without adding fuel or power)
  - Objective efficiency: system 50% efficient (net chemical energy recovered, accounting for parasitic energy requirements)
  - Minimal labor (manual waste segregation highly undesirable)
  - Packaged in 2x 20-foot ISO containers (objective of 1x, including feedstock conditioning and power generation)

Keep in Mind...

When you've seen one base camp…

You've seen <u>one</u> base camp!

Investigating Efficient Tar Management from Biomass and Waste to Energy Gasification Processes

Patrick Scott
Lockheed Martin-MST

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Investigating Efficient Tar Management from Biomass and Waste to Energy Gasification Processes

SERDP Project Number WP-2236

Patrick Scott, Lockheed Martin-MST

Agenda – Efficient Tar Management

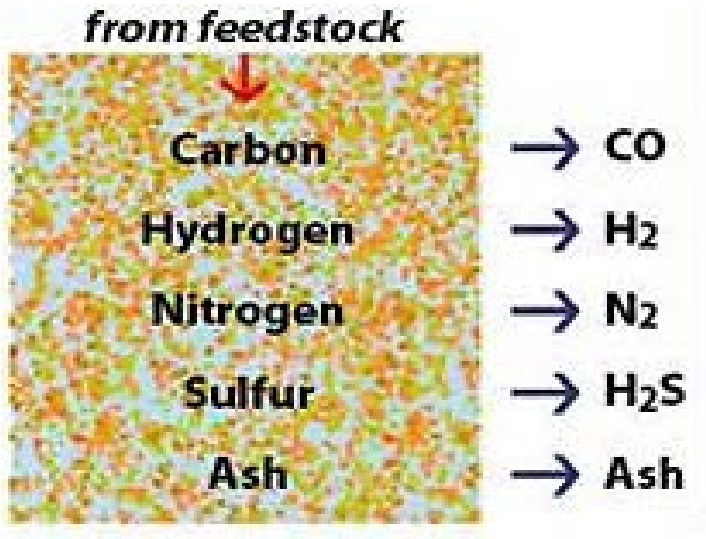
- Research drivers: Waste, health and energy
- History of gasification and current status
- Key concept of this research
- Approach
- Results and conclusions

Research Driver

- Forward operating base waste disposal
  - Burn pit solution → Health and environmental problem
    - VA position: No research proving problem
    - Website to document and make a claim
    - PBS broadcast 11/17/14

Research Driver

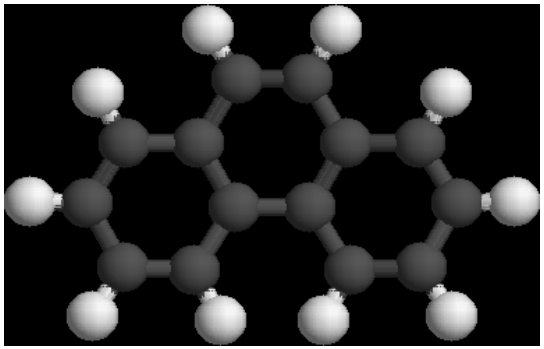
- Forward operating base waste disposal
  - Organic waste = Energy opportunity
    - Gasification: Carbonaceous matter → CO and H_2
      - Partial combustion to CO_2 and H_20
      - CO and H_2 → Internal Combustion Engine (ICE – spark or diesel)
      - ICE drives generator



+ Tars (Historic fight)

Gasification History

- Tar cracking
  - Temperature: 1200°C
  - Catalyst + temperature: 800°C
  - Plasma (temperature) or activation
    - Corona discharge, direct arc, gliding arc
      - Still need considerable temperature

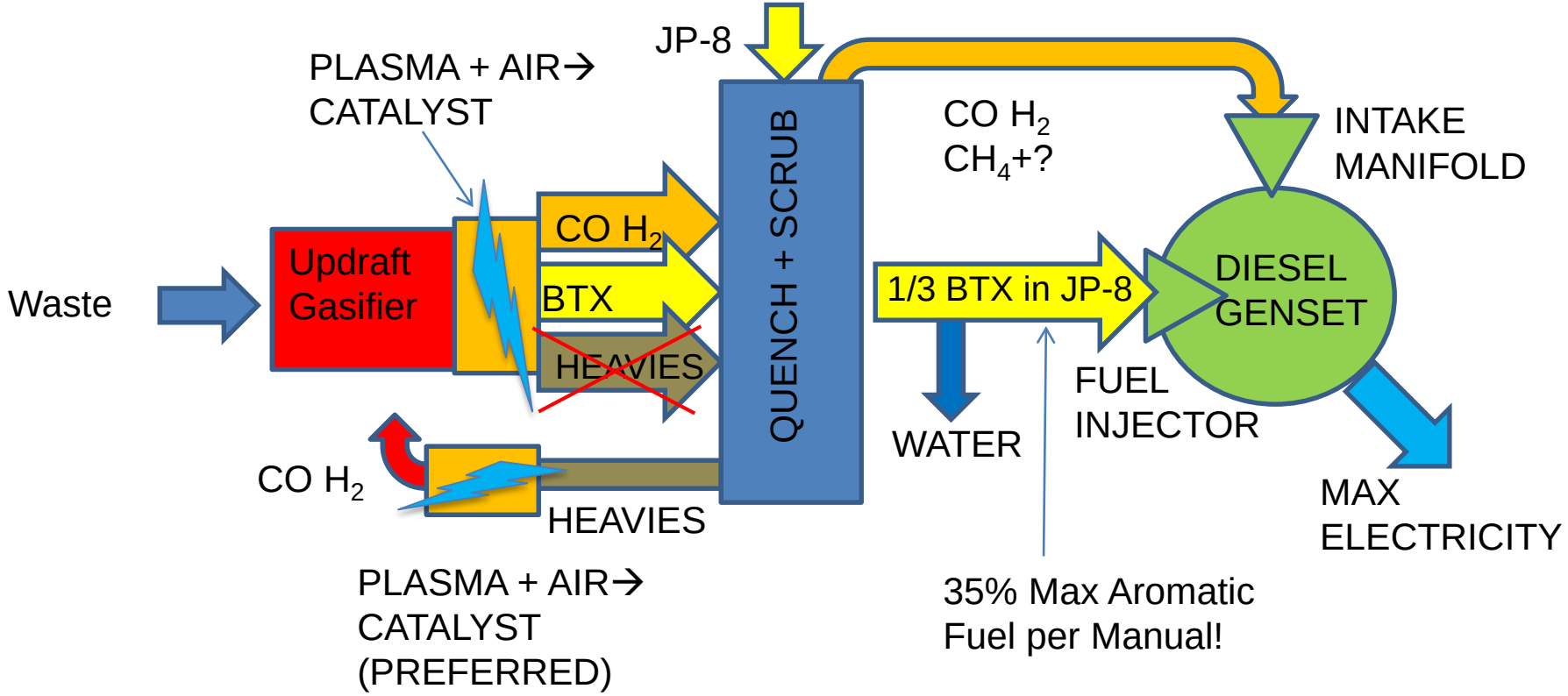


Phenanthrene (tar)

CO H_2

Key Concept of Research

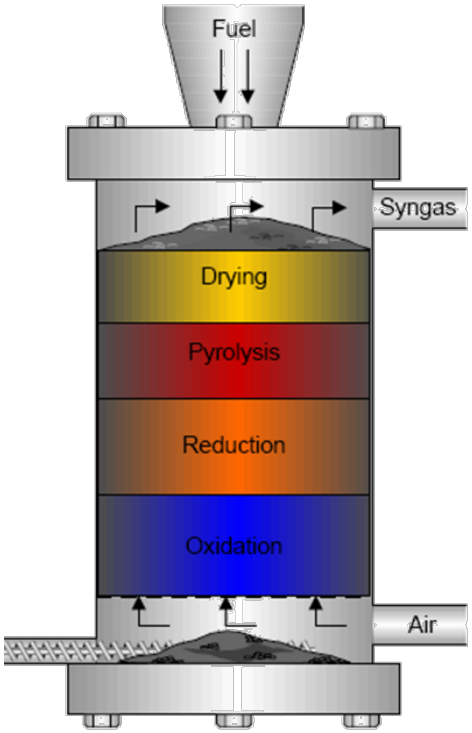
- Maximize waste energy delivery to engine
  - Gasify and scrub with fuel for genset



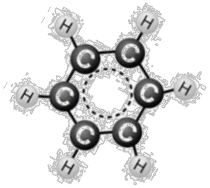
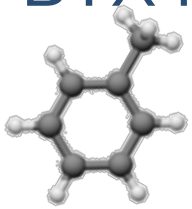
Key Concept of Research

- Examination of tars
  - Raw tar from updraft gasifier or pyrolyzer
    - 70% benzene, toluene, xylene (BTX), etc.
      - Flammable liquids
    - 30% polyaromatic hydrocarbon (PAH), sugars (heavies), waxes

UPDRAFT GASIFIER: HIGH TARS, LOW PARTICULATES, 90% CONVERSION



Key Concept of Research

- Thermodynamically 190% better to burn benzene in engine vs. cracking to CO and H_2
  - Modify w/plasma and catalysis to BTX not CO H_2
    - Benzene 
    - Toluene 
    - Less parasitic nitrogen going to engine
      - Better to fuel with liquid vs. vapor
    - Cracking is high temperature!
      - Complicates and requires expensive material – MINIMIZE IT!

Key Concept of Research

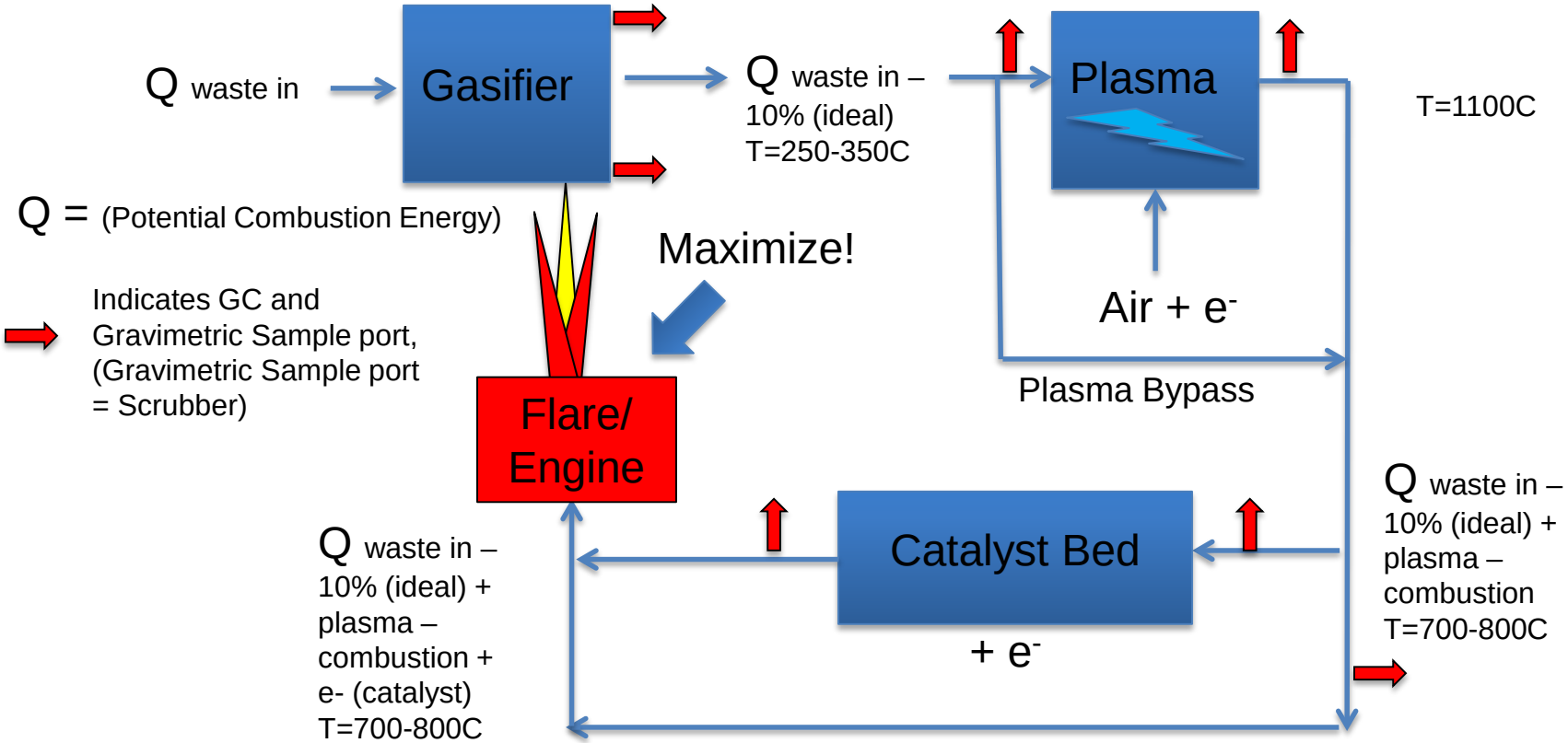
- Generate, characterize, modify to use in diesel engine
  - National Renewable Energy Lab - Catalyst experts
    - Produce CO and H_2 when fresh
    - Makes BTX forever
  - Drexel University - Gliding Arc Plasma
    - Minimal electrical energy input
    - Add air to combust and preheat stream for catalyst bed

Approach

- Design/build gasifier that can operate up or downdraft
  - Feed with double dump
  - Updraft for rich tar stream, filled with untapped energy
  - Updraft/down flow re-heats stream to reduce condensation problems

Pilot Plant Approach

- Energy balance

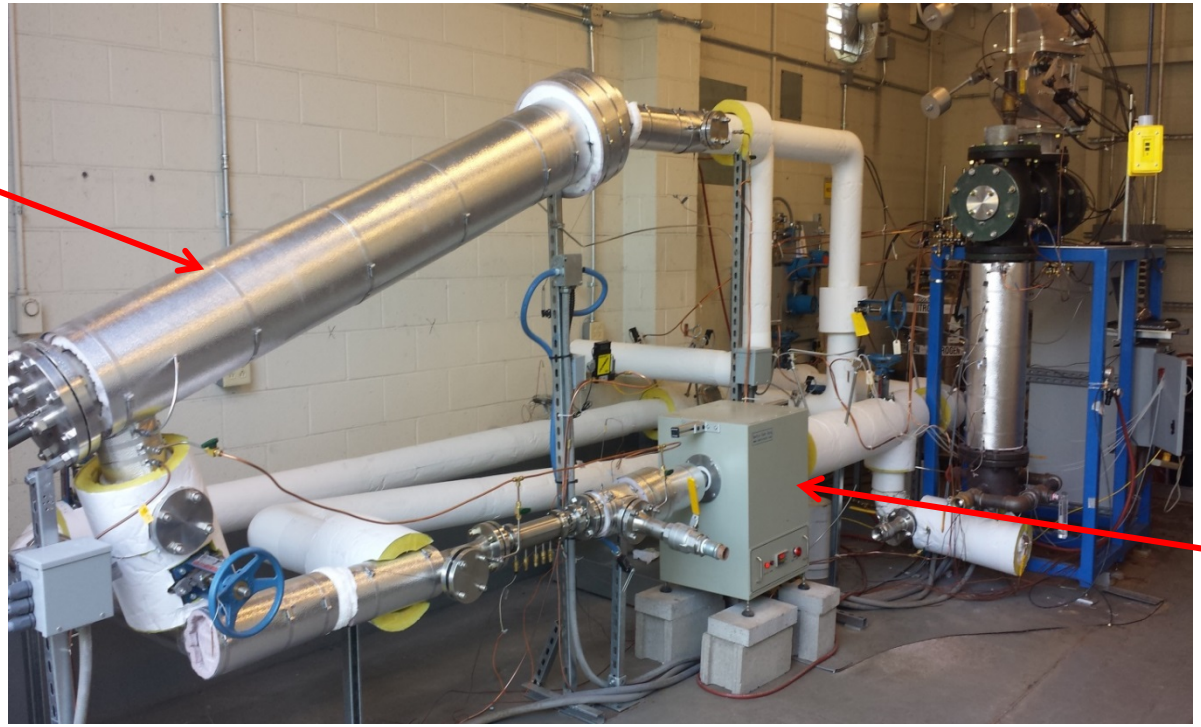


Q at sample port = DH Comb (Syngas + Light Tar – Gravimetric Tar)

Pilot Plant Approach

- Add plasma, catalyst bed, heat trace and PLC
  - Details: Preheat for plasma + hydrogen for catalyst
    - 1000°C plasma, 800°C catalyst

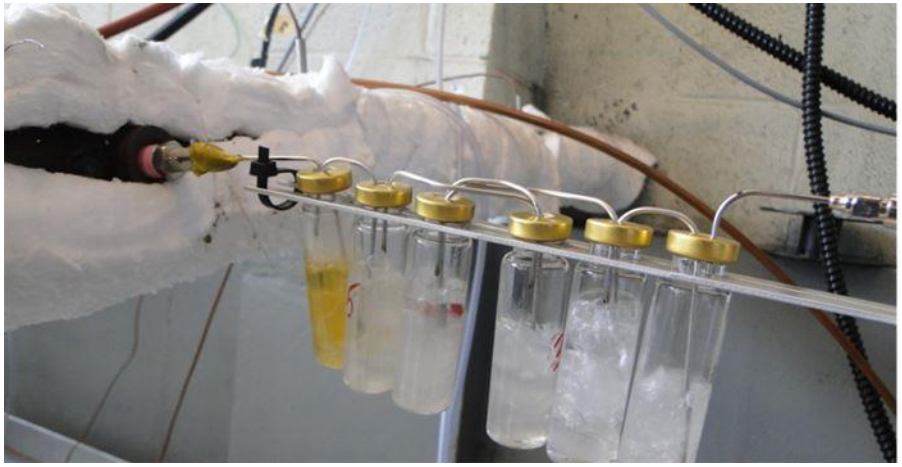
Catalyst bed w/ electric heaters

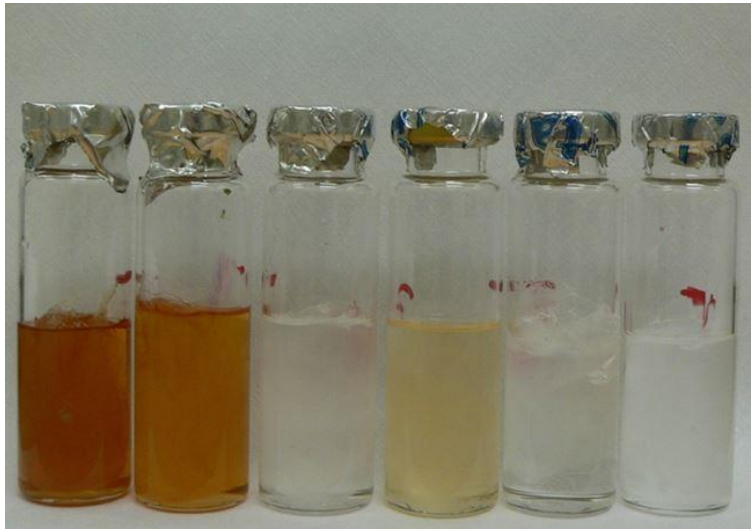


Tube furnace preheater and plasma

Approach

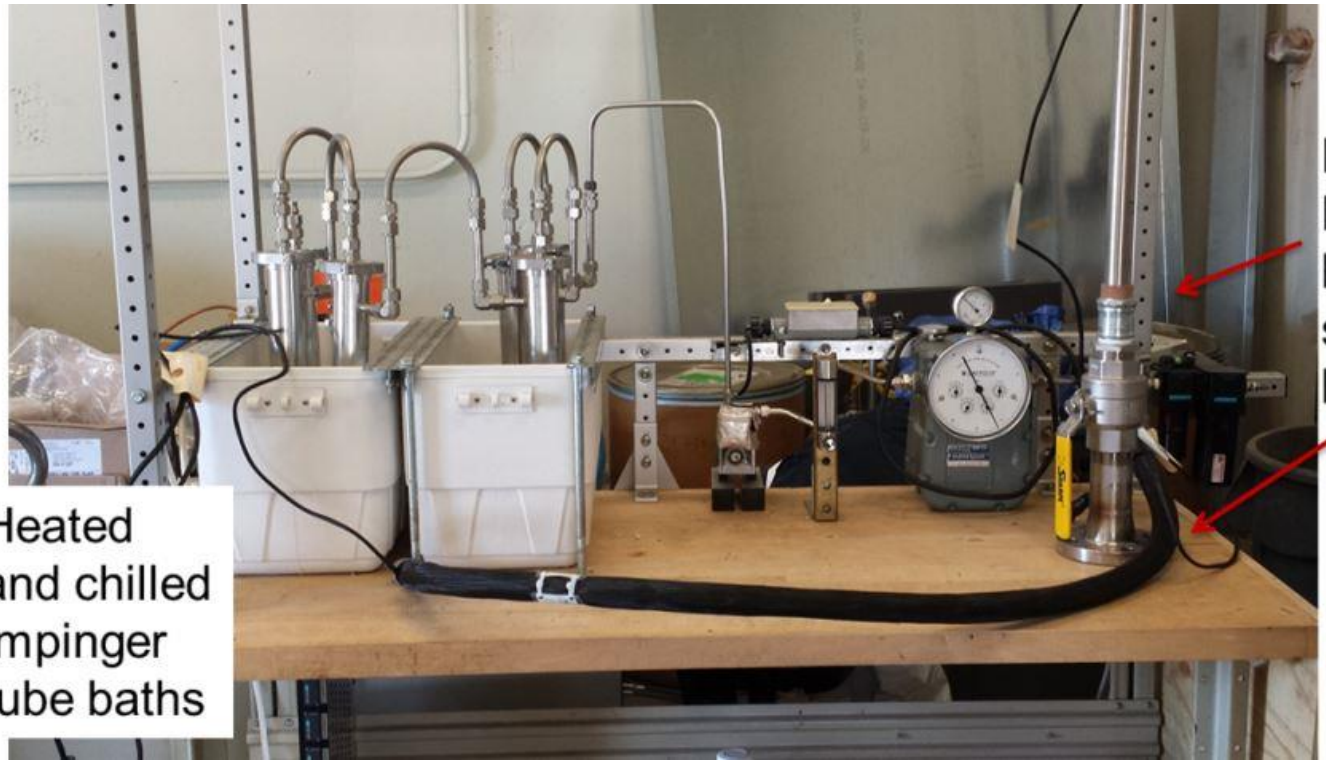
- Sample ports at each process step
  - Gas chromatography MS/TCD/FID analytical





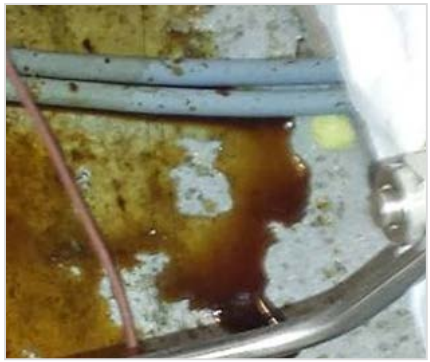
Approach

- Sample ports at each process step
  - Gravimetric tar (weight)



Results

- Tars generated and flared
  - Feed (with difficulty)
    - 70% wood, 10% paper/cardboard, 10% plastic, 10% dog food
  - Results: Lots of tar!

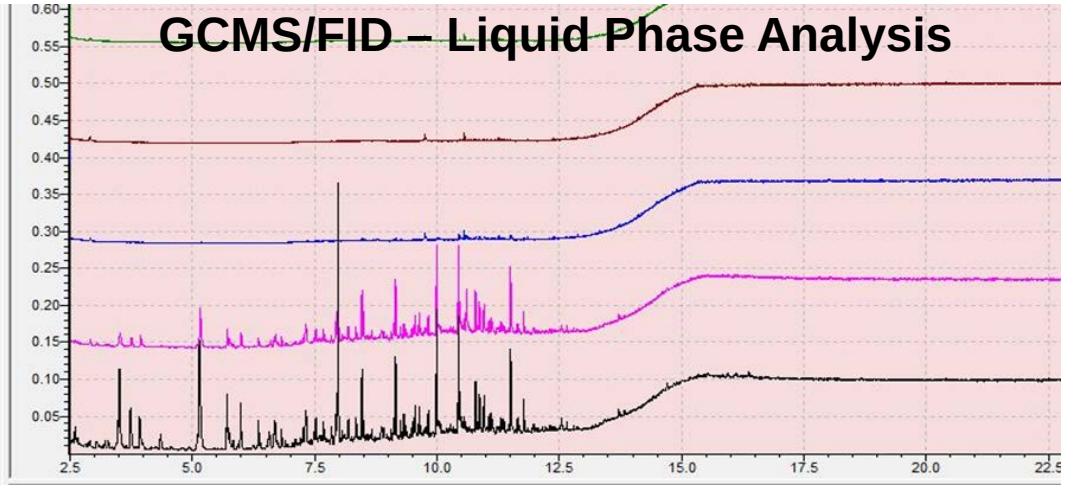


Liquid from sample port

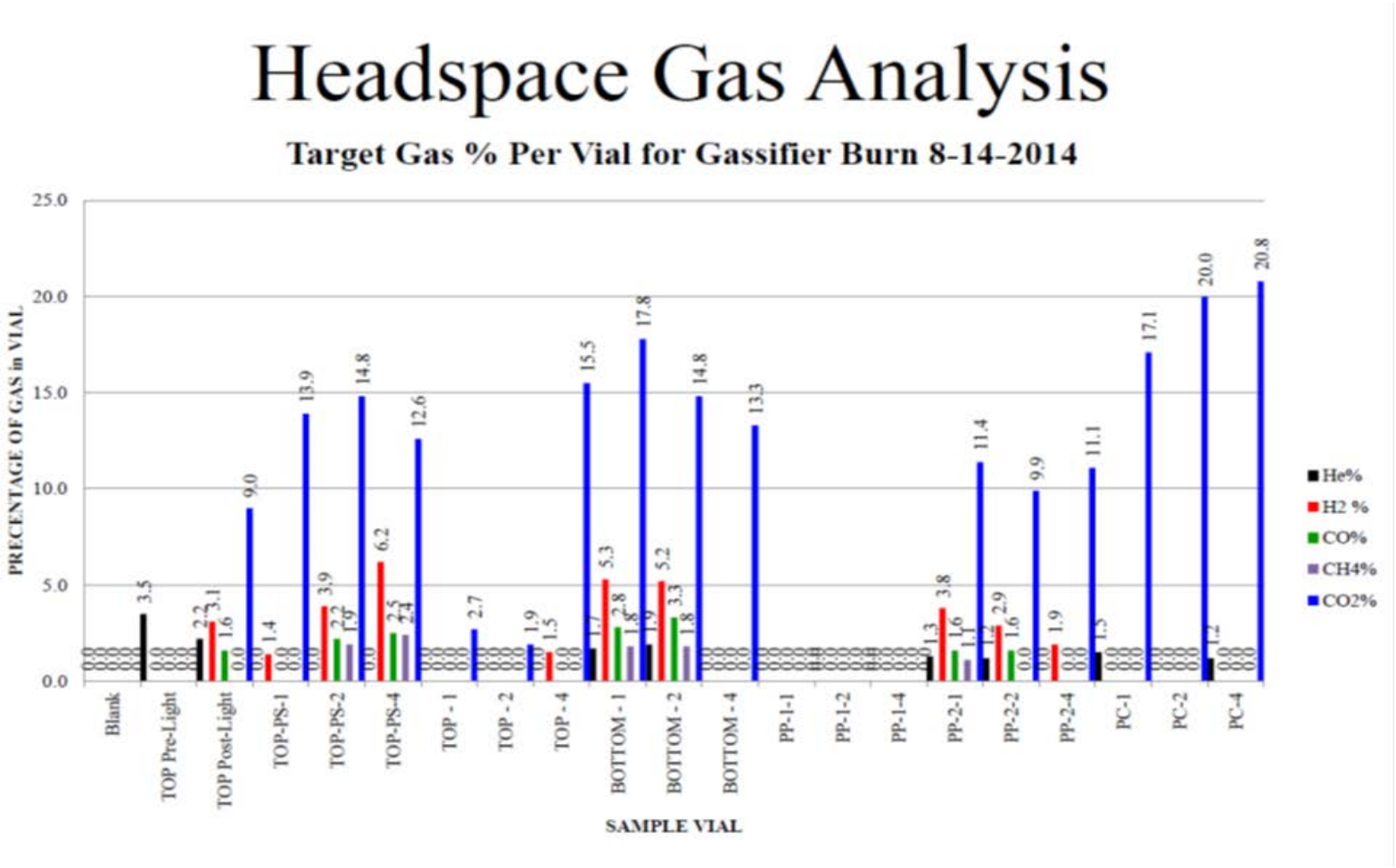
Stalagmite at flare

Results

- Tars generated, sampled and reduced
  - Air flow is 10% of complete combustion (ultimate and proximate analysis)
  - Gravimetric reduction 110 g/m^3 to 3 g/m^3
  - Not sufficient testing to show heavy →BTX
  - H_2, CO 2-6%

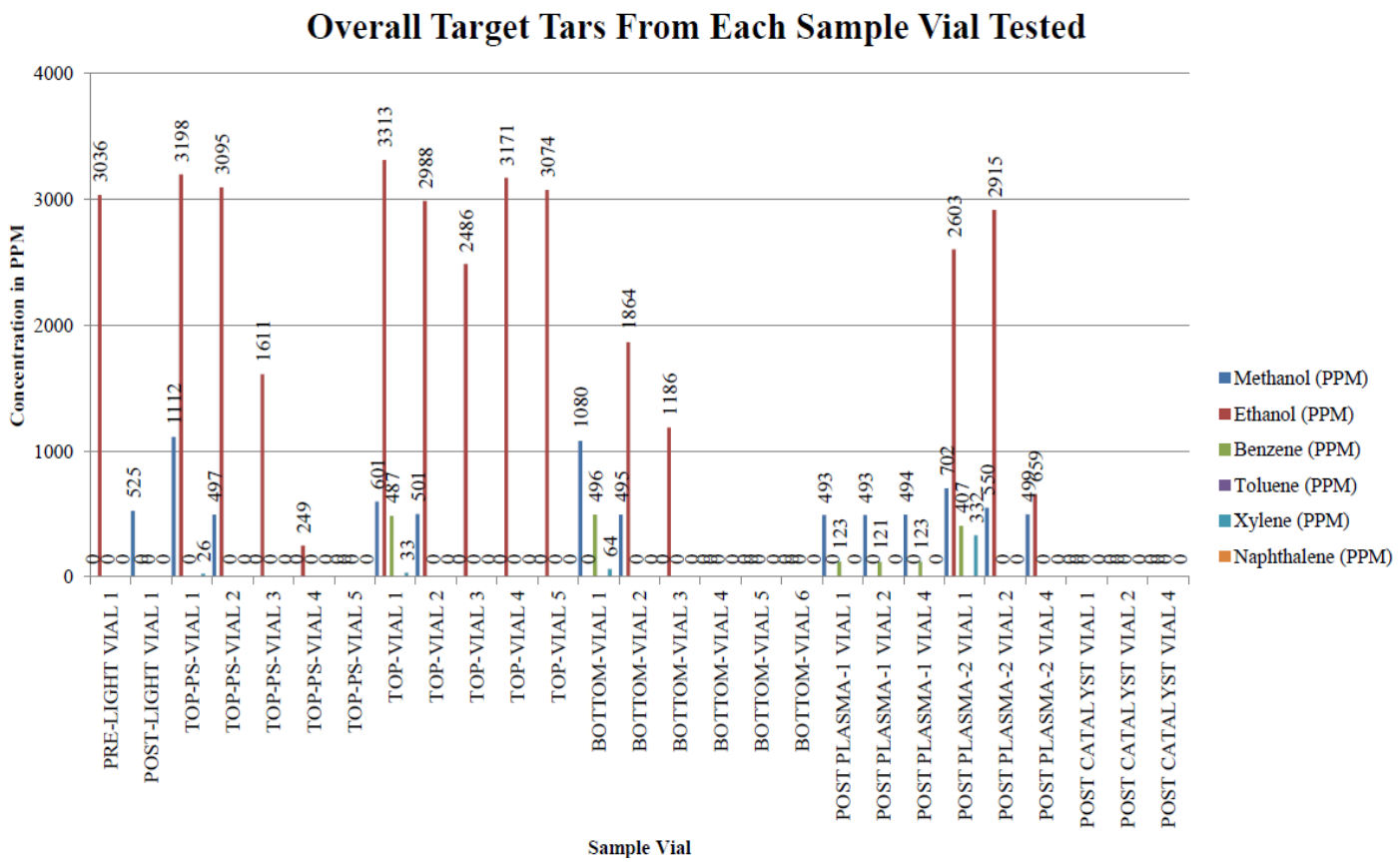


Preliminary Results



Preliminary Results

Overall Liquid Tar Analysis



Results

- Mock tar laden fuel test
  - 18 kW diesel genset
    - 20 kW loadbank
  - Spike JP-8 fuel with toluene
    - Less toxic than benzene
  - Slight derate noted
    - (RPM below spec; motor shut down at 16-17 kW)
  - Aromatic content 35% max per engine manual

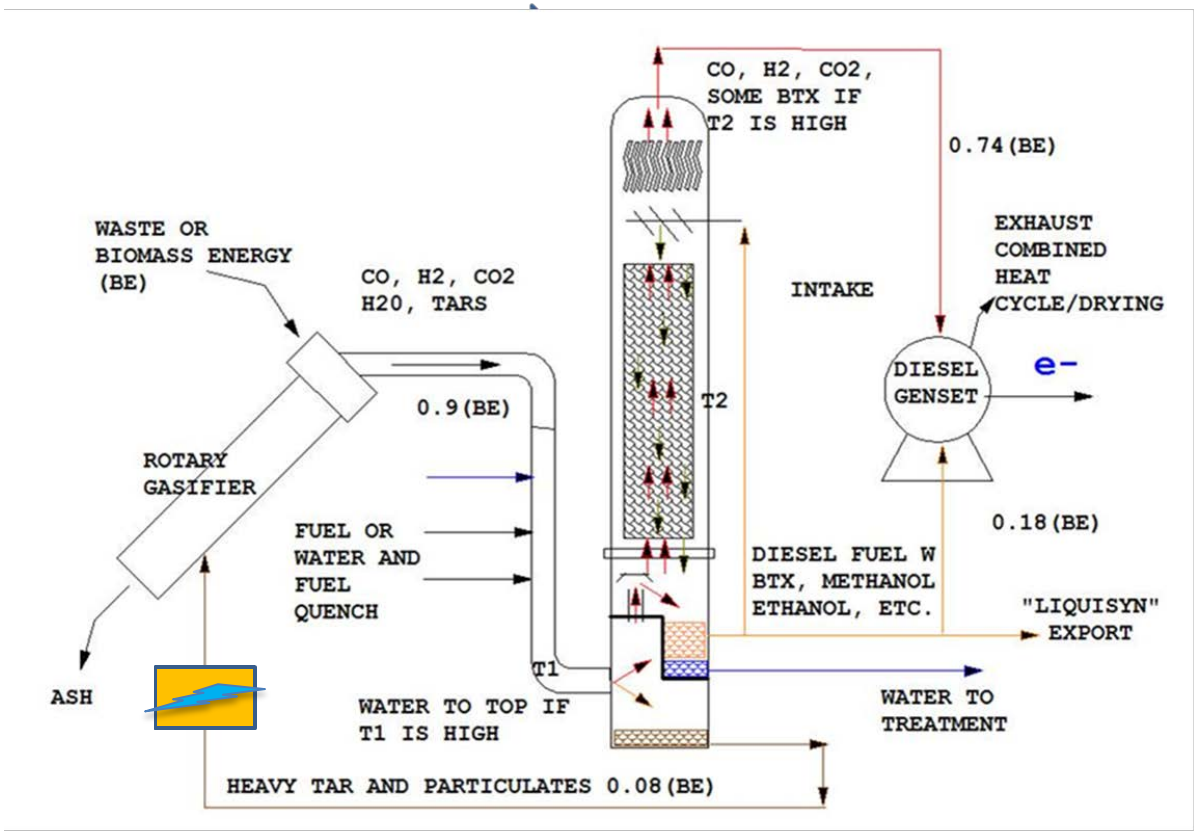
Conclusions

- Hard: Integrating and debugging mini pilot plant is challenging
  - Plasma and catalyst bed stretch for FOB
- Scrubber passing light tars to engine is key
  - Heavies returned to gasifier
    - Plasma + catalyst only on them if they pass through
- Path to efficient waste to energy where diesel fuel is used for electricity

Conclusions – Path Forward

- Fuel based scrub of updraft gasifier output to meet waste disposal needs
  - Enable highest conversion of waste to energy (low temperature process)
  - Enable waste destruction in safer manner (test engine output)

Fuel Based Scrubber for Integration to Diesel Engines. Pat Pend 13/400,905



Rotary Gasifier Shown is from SUNY Cobleskill for DOE Proposal

For additional information, please contact

Patrick Scott
pat.scott@lmco.com; 607-751-3540

Q&A Session 1

Inclined Indirect Flaming Pyrolysis Rotary Gasifier

Stephen Cosper
USACE-ERDC-CERL

Inclined Indirect Flaming Pyrolysis Rotary Gasifier

SERDP WP-2211

Stephen Cosper, USACE-ERDC-CERL

Agenda

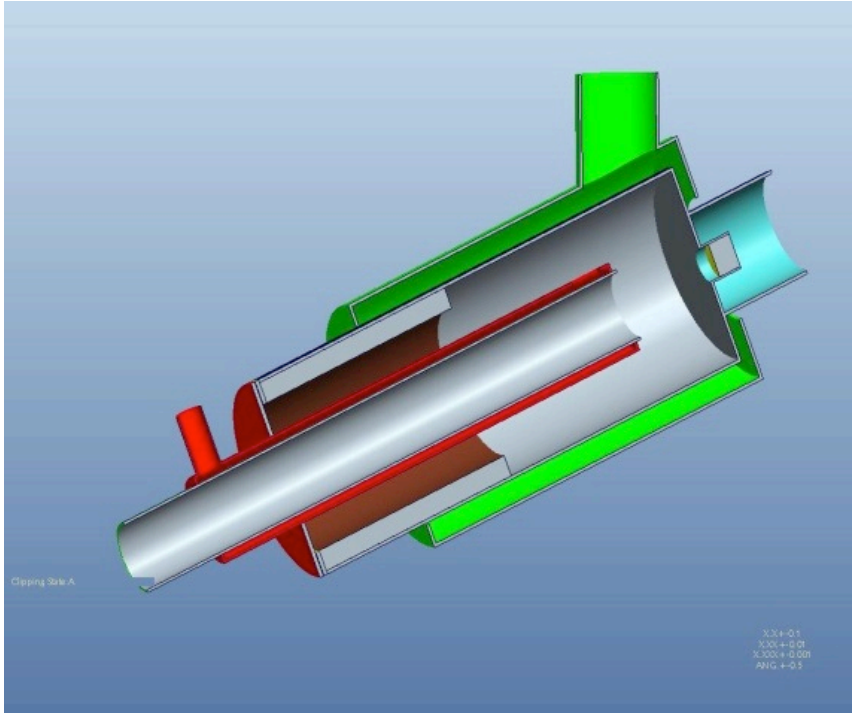
- Project criteria
- Approach
- Technology description
- Current results
- Work in-progress

Background

- Recent waste surveys indicate a range of 9 to 25 pounds per capita, per day
- Burn pits are the default solution, even in very large camps
- Health concerns, Congressional interest, pushing for alternatives
- Mixed success with incinerators; no waste-to-energy fielded

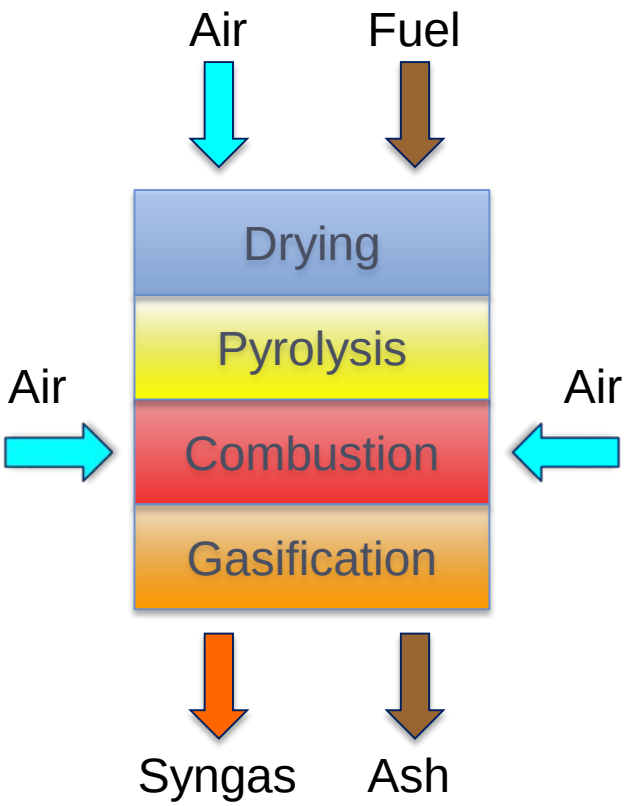
Objective

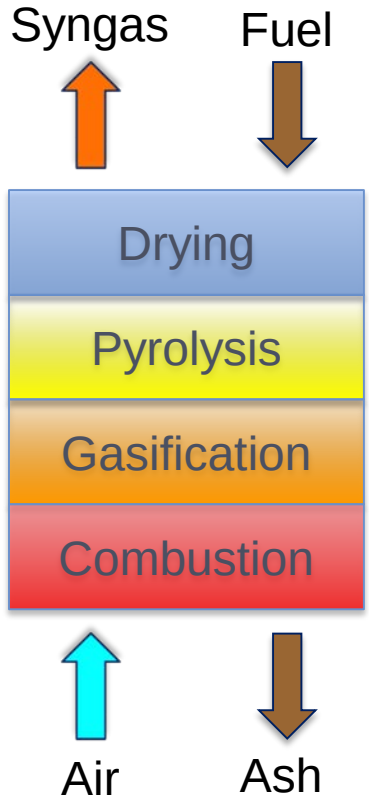
- Clear need for safe, effective waste management
- Energy recovery very attractive
- Create a design for a deployable waste-to-energy-system with the following criteria:
  - Based on gasification
  - One to three tons/day capacity, with minimal sorting
  - Self-powered, with net-positive exportable electricity
  - Size to fit two, 20-ft containers



Technical Approach

Updraft (Countercurrent)

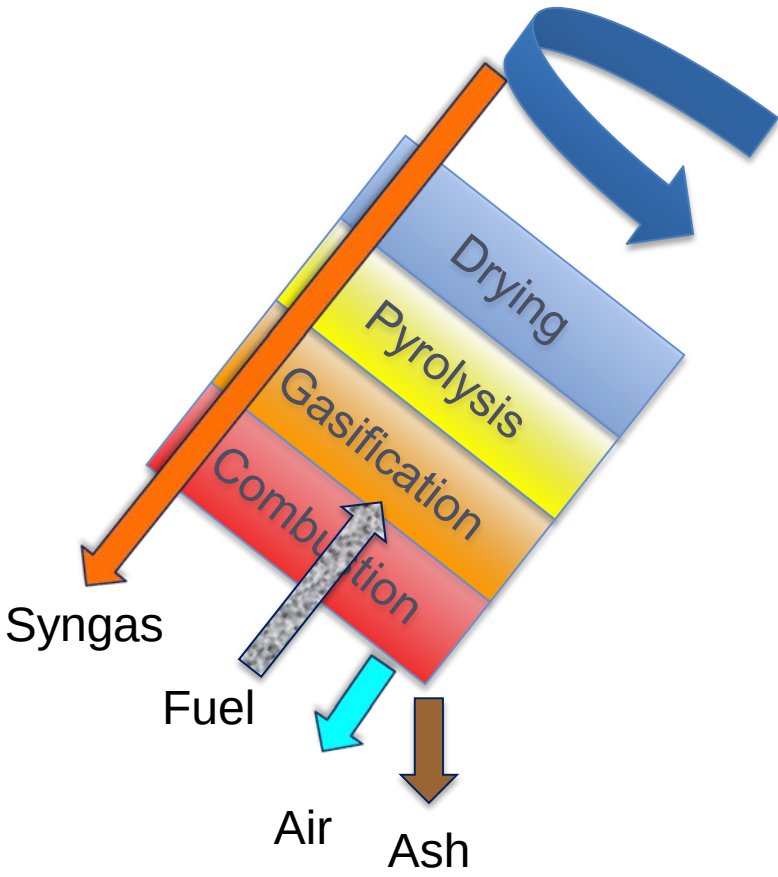




- Countercurrent gasification has a number of inherent characteristics that would be beneficial for a WEC
  - High thermal efficiency
  - Less sensitive to fuel pretreatment
  - Reduced particulate entrainment
  - Low-reactivity ash produced from final-stage combustion

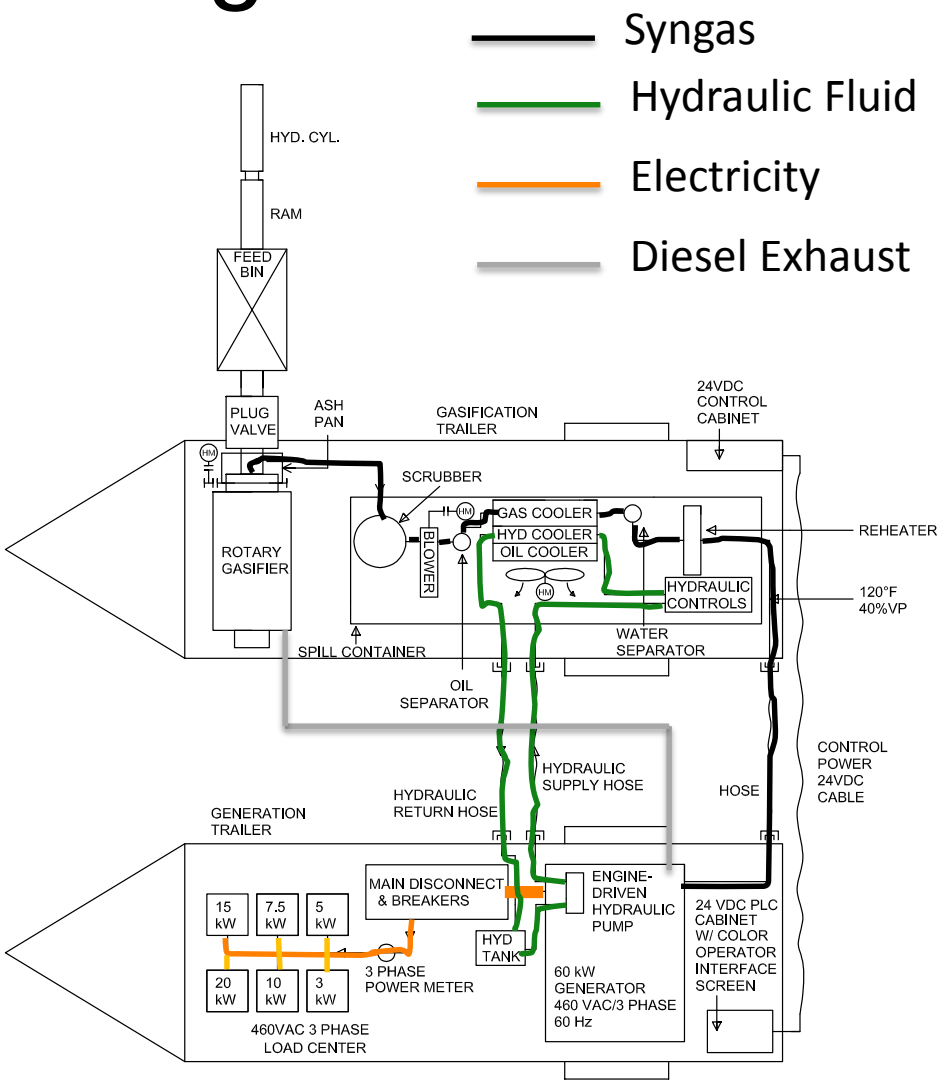
Technical Approach – Rotary System

- System works like a modified updraft gasifier
- Waste fed from bottom, placed at hot, burning char layer
- Syngas collected through concentric tube, not directly exposed to char bed
- Rotates at ~1rpm



Initial design

- Initial hardware design and layout
- Experimental layout on two trailers to mimic portability requirements of SON
- 1st trailer has hydraulic waste compression, gasifier, gas treatment
- 2nd has electronic control system, 60kW genset, hydraulic pump and controls, experimental electric load center



Waste Feed

Main Reactor

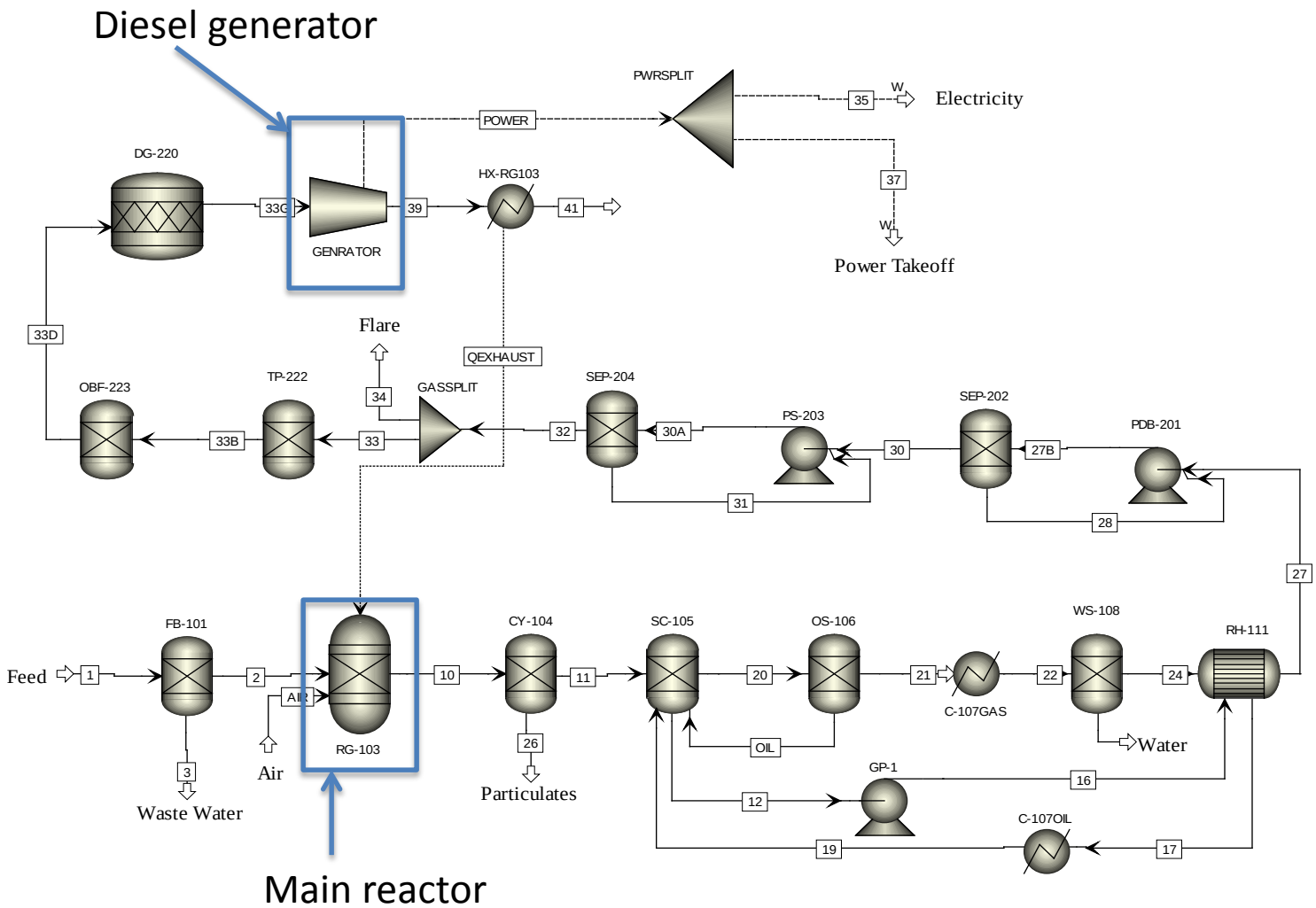
Oil Quench and Ethylene Glycol Polisher

Genset and Load Bank

Aspen Plus Chemical Process Simulator

- Used extensively in commercial power industry
- Capabilities
  - Mass and energy balances
  - Phase and chemical equilibrium
  - Reaction kinetics
  - Unit operations library
  - Physical, chemical, and thermodynamic properties databases
- Model purpose
  - Verify liquid fuel savings
  - Generate a base model that can be used for future designs and sensitivity studies, if necessary

ASPEN Model Layout



Modeling Methodology

- Simplifying assumptions
  - Producer gas composition base on literature values
  - Gasifier heat duty calculated by Aspen Plus
  - Did not model tars or particulates
  - Assumed gas cleanup steps work as designed

Feedstock Characteristics

Wet biomass feed rate, lb/hr	200
Feedstock moisture content, wt%	50%
Dry biomass feed rate, lb/hr	100
Ultimate Analysis (dry basis, wt%)	
Carbon	50.88%
Oxygen	41.9%
Hydrogen	6.04%
Nitrogen	0.17%
Chlorine	0%
Sulfur	0.09%
Ash	0.92%
Proximate Analysis (dry basis, wt%)	
Moisture	0%
Fixed Carbon	15.29%
Volatile Matter	83.84%
Ash	0.87%
Gasifier equivalence ratio	0.38
Gasifier air flowrate, lb/hr	235

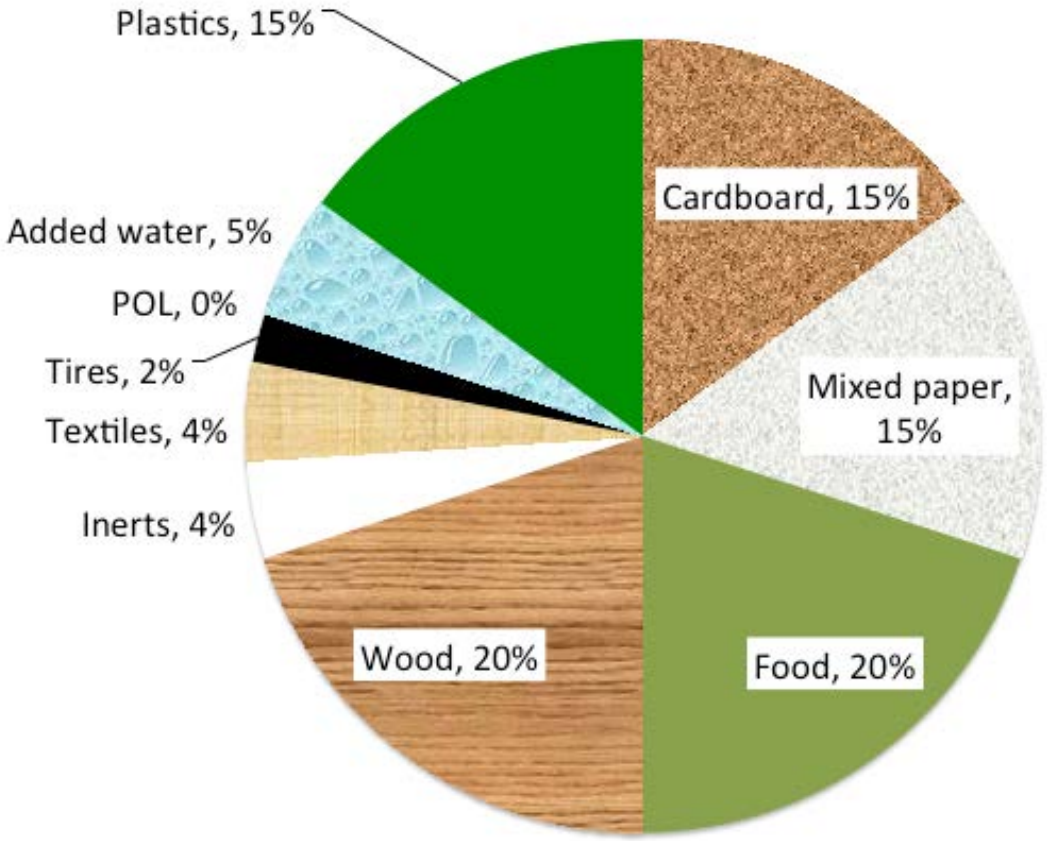
ASPEN Overall Results

- Overall conclusions
  - Using conservative estimates for feedstock composition and genset efficiency, significant liquid fuel savings is possible
  - Using optimistic estimates, liquid fuel savings may approach maximum producer gas operating limits of the diesel engine

Wet Biomass Feed Rate, lb/hr (50% moisture)	**200**	**300**
Power (electricity) produced, net	20.6 kW	53.5 kW
Percent of electricity derived from producer gas (liquid fuel savings)	34.3%	89.2%

“Standard” Waste Composition

- Based on LIA field survey, 2013
- Variations to include
  - 50% food
  - 50% plastics
  - 50% POL



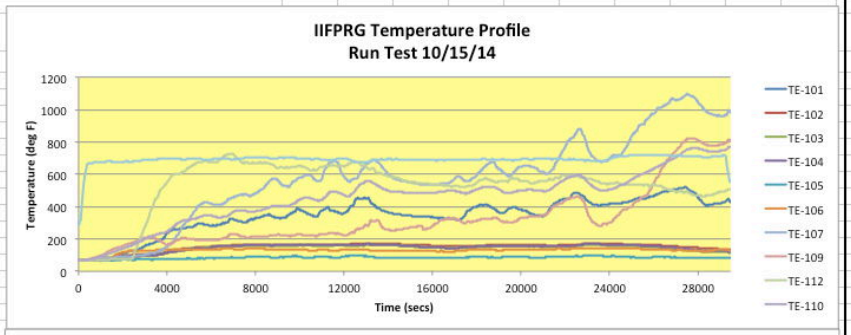
Dashboard

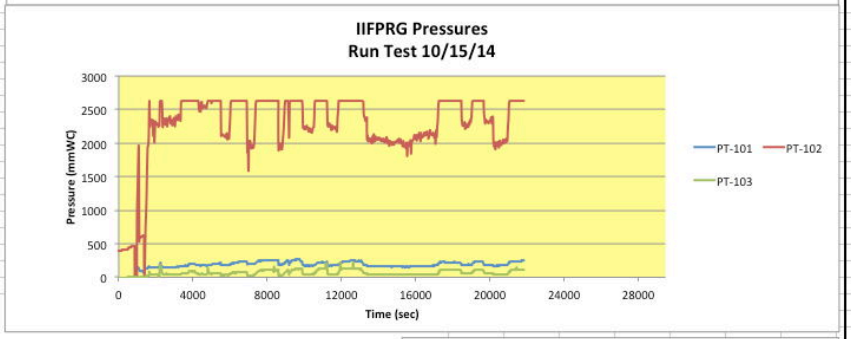
SUNY RF The Research Foundation for The State University of New York

SUNY Cobleskill

IIFPRG Hot Testing Data Report

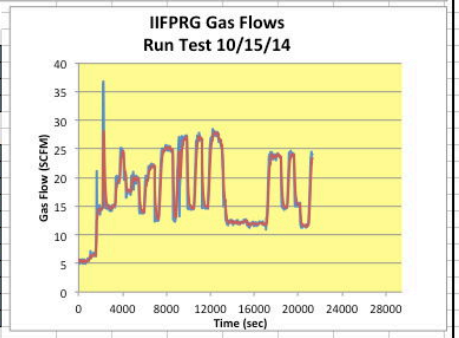
Test Date:	2014-10-15			
Test Specification Reference Number:	TSS-101514-01			
Feedstock:	SERDP Long Term Mix			
Nominal Test Duration: (Engine Run Hours)	8.25			
Generator:	60 kW Nominal			
Engine:	John Deere 5030HF270			
Procedure Start Time:	09:13			
Procedure End Time:	17:28			
Steady State Test Timing				
Test Start Time:	10:37	HH:MM		
Test Start Time (data seconds):	4800	Seconds		
Test End Time:	16:28	HH:MM		
Test End Time (data seconds):	25830	Seconds		
Total Test Duration:	21030	Seconds		
Total Test Duration:	5.84	Hours		
Feedstock				
Total Wet Feedstock Processed:	313.0	lbs	142.0	kg
Average Feedstock Wet Feed Rate:	53.6	lbs/hr	24.3	kg/hr
Average Feedstock Moisture Content (wet basis):	5.0%			
Average Feedstock Dry Feed Rate:	50.9	lbs/hr	23.1	kg/hr
Average Moisture Feed Rate:	2.7	lbs/hr	1.2	kg/hr
Total Condensate Recovered at Condenser:	(156.0)	lbs	-70.7	kg
Average Condensate Capture Rate:	(26.7)	lbs/hr	-12.1	kg/hr
Total Moisture Recovered:	-996.7%			
Feedstock High Heating Value:	7,200	BTU/lb	16,749	kJ/kg
Total Gross Heating Value of Processed Feedstock:	7,708	MBTU	8,132	MJ
Average Heating Rate of Processed Feedstock:	366,515	BTU/hr	386,673	kJ/hr
Syngas				
Average Syngas Flow:	19.5	SCFM	30.7	Nm^3/hr
Average Syngas High Heating Value:	#DIV/0!	BTU/scf	#DIV/0!	KJ/Nm^3
Average Syngas Specific Gravity:	0.95			
Total Mass of Syngas Produced:	486.4	lbs	220.6	kg
Average Syngas Energy Content:	#DIV/0!	BTU/hr	#DIV/0!	kJ/hr
Net Gasifier Efficiency	#DIV/0!			
Tar				
Syngas Total Tar Content at Gasifier Exit:	N/A	PPM	N/A	mg/Nm^3
Syngas Total Tar Content at Engine Intake:	N/A	PPM	N/A	mg/Nm^3
Ash				
Total Bottom Ash Recovered (Dry):	0.0	lbs	0.0	kg
Average Bottom Ash Recovered:	0.0	lbs/hr	0.0	kg/hr
Unburnt Carbon in Bottom Ash:	0.0%			
Quencher				
Quencher Start Level (PDT-102)	12.5	IWG	318	mmWC
Quencher End Level (PDT-102)	15.3	IWG	388	mmWC
Total Pyrolysis Oil Accumulation in Quencher	2.8	Gallons	10.5	Liters
Pyrolysis Oil Accumulation in Quencher	0.5	Gal/hr	1.8	L/hr
Pyrolysis Oil High Heating Value	94,000	BTU/gal	26,201	KJ/L
Total Heating Value of Pyrolysis Oil	44,840	BTU/hr	47,306	KJ/hr
Energy Balance				
Total Energy of Feedstock Input	366,515	BTU/hr	386,673	kJ/hr
Total Energy of Syngas Output	#DIV/0!	BTU/hr	#DIV/0!	kJ/hr
Total Energy of Pyrolysis Oil Output	44,840	BTU/hr	47,306	kJ/hr
Recoverable Energy Output	#DIV/0!	BTU/hr	#DIV/0!	kJ/hr
Net Gasifier Efficiency	#DIV/0!			





Test Average Pressures	mmWC	IWC
Gasifier Outlet (PT-101)	213	8.4
Static Press. At Scrubber Outlet (PT-102)	2,418	95.2
Static Press. At Flow Orifice (PT-103)	85	3.3
Diff. Press. At Flow Orifice (PDT-101)	10	0.4

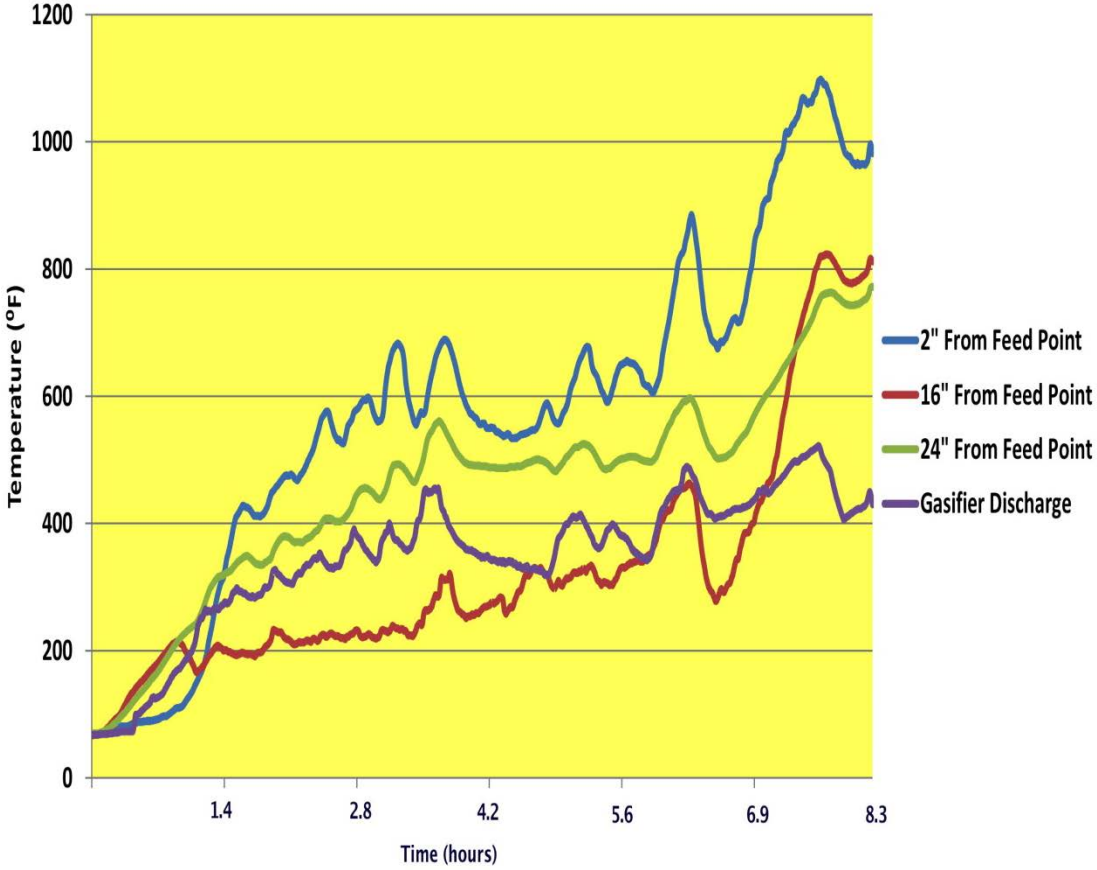
Test Average Temperatures	Deg. F	Deg. C
Syngas at Gasifier Outlet (TE-101)	371.4	188.6
Oil at Scrubber Quench (TE-102)	163.6	73.1
Scrubber Oil (TE-103)	155.2	68.4
Syngas at Scrubber Exit (TE-104)	158.7	70.4
Syngas at Condenser Outlet (TE-105)	88.3	31.3
Syngas at Reheat Outlet/Flow Orifice (TE-106)	134.7	57.0
Gasifier Internal 2" uphill of Feed Pt. (TE-107)	606.6	319.2
Gasifier Internal 8" uphill of Feed Pt. (TE-108)	290.8	143.8
Gasifier Internal 16" uphill of Feed Pt. (TE-109)	600.9	316.1
Gasifier Internal 24" uphill of Feed Pt. (TE-110)	477.0	247.2
Burning Char Bed (TE-112)	695.6	368.7



Report | GCReport | Calcs | IMPORT | GASQ0 | GASQ1 | GASQ2 | GENQ0 | GENQ1 | Feed Rate | SS Graphs | Slide Show | Emissions | Exhaust Temps

Temperature Monitoring Reactor

- Thermocouples down the length of reactor
- Steady state gas discharge temperature about 400°F
- Temperature peaks indicate time to add waste
- High temps at end of run indicate allowing waste layer to burn down

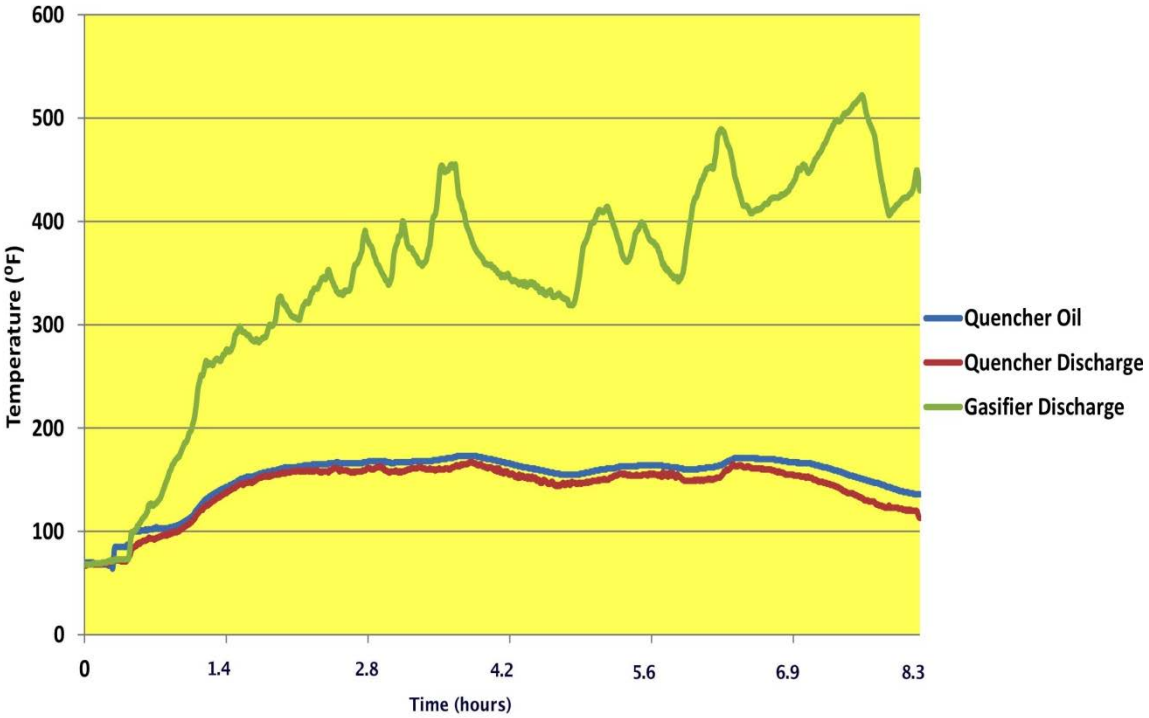


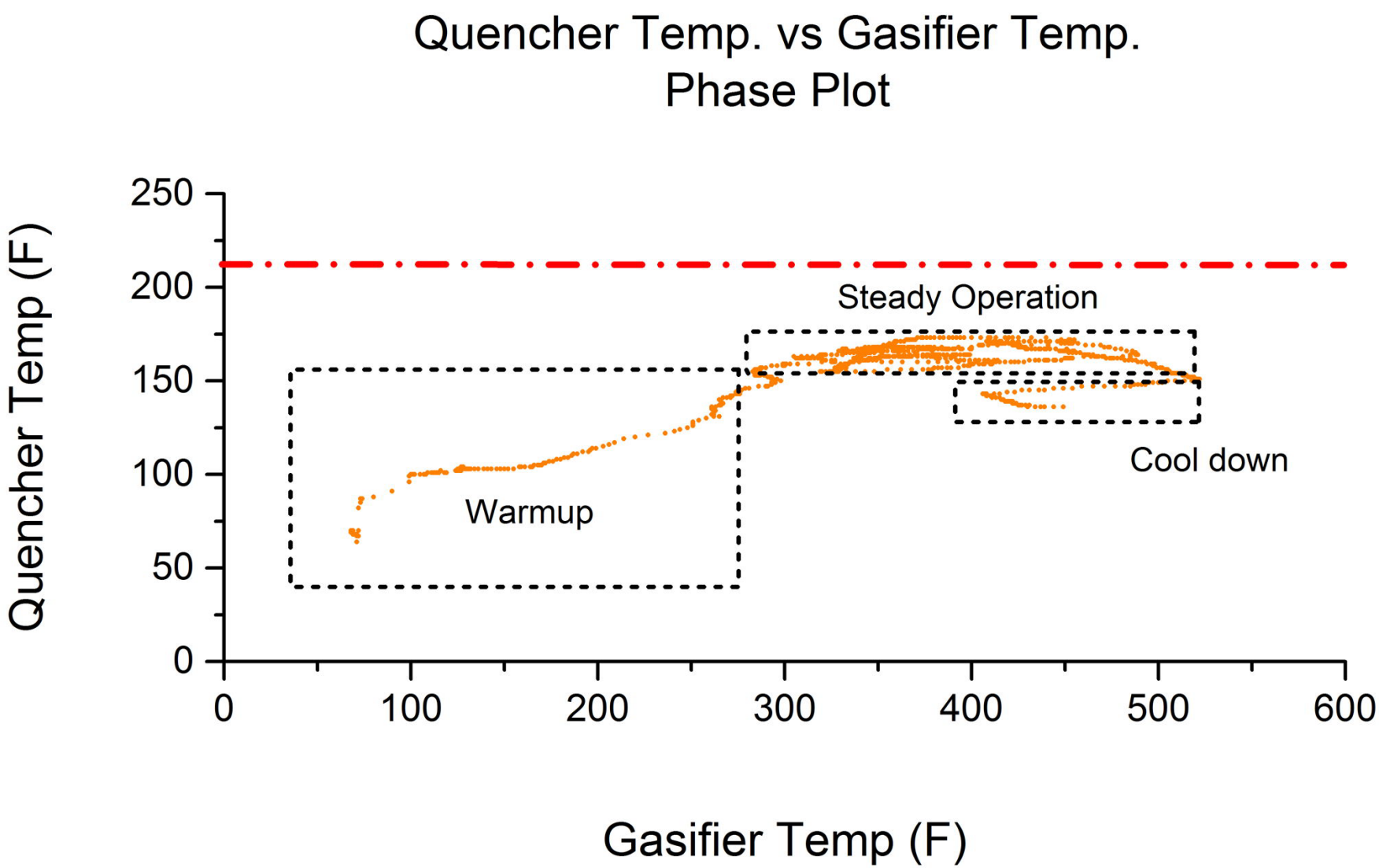
Quencher Tank / Pyro Oil Recycling

- Pyrolysis oils produced in reactor
- Accumulate in quencher tank
- Excess fed back into reactor
  - Eliminates a waste stream
  - Enriches syngas

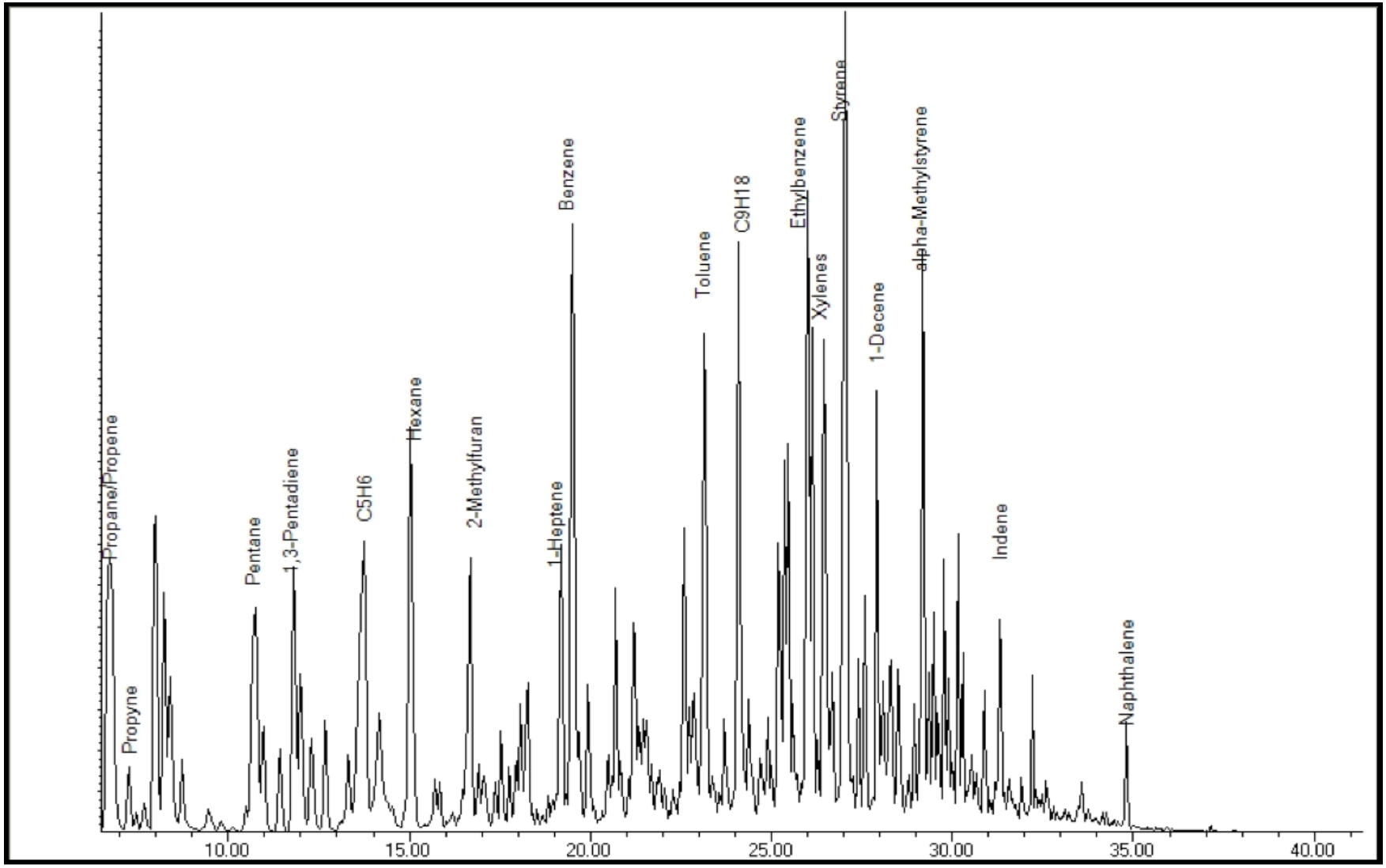
Quencher Oil Temperature

- Incoming syngas ~400°F
- Pyro-oil remains constant due to water emulsion
- Temp remains below boiling point of water



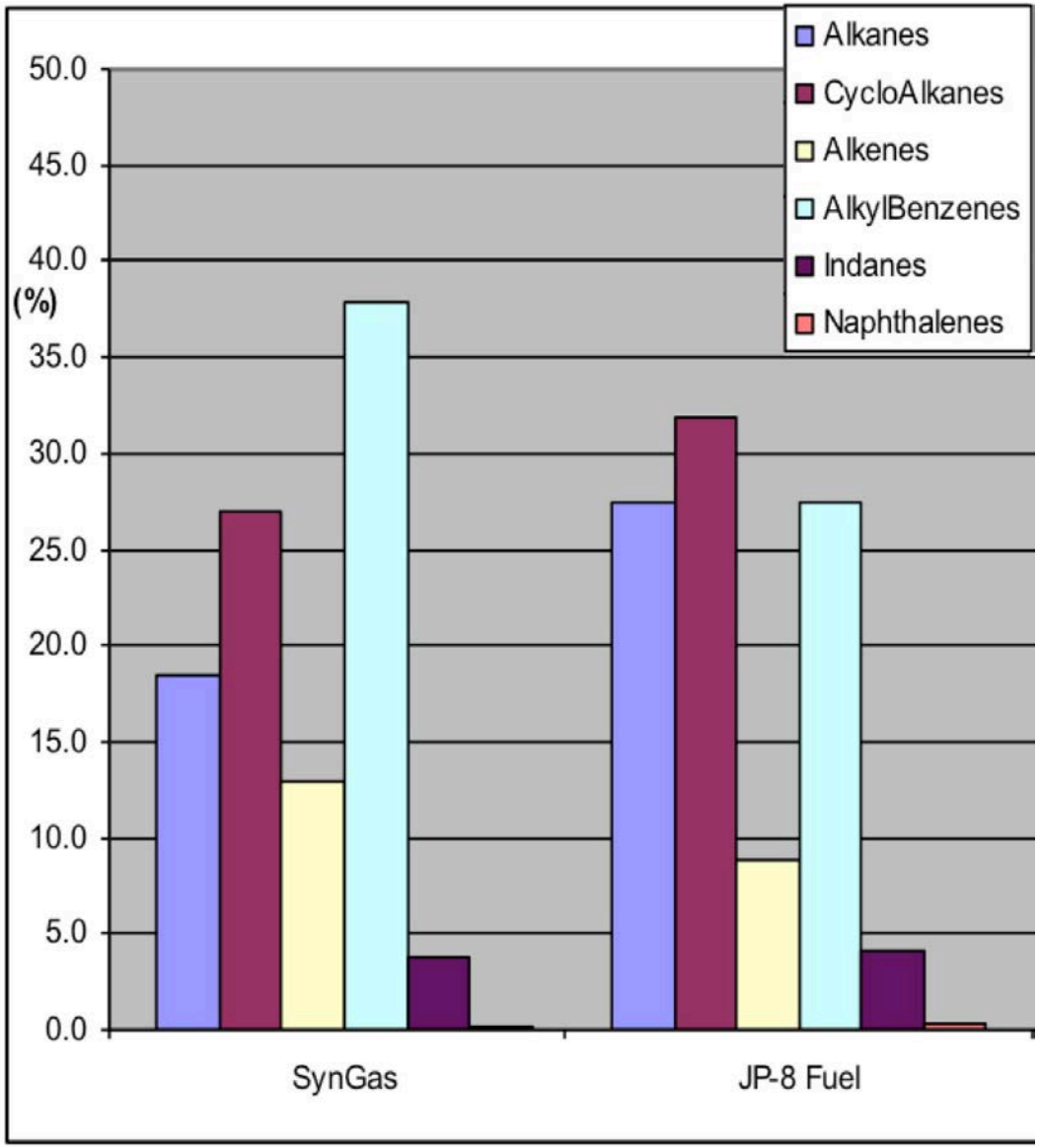

Quencher Temp. vs Gasifier Temp.
Phase Plot
Quencher Temp (F)
250
200
150
100
50
0
0
100
200
300
400
500
600
Gasifier Temp (F)
Steady Operation
Cool down
Warmup

Syngas Chromatogram



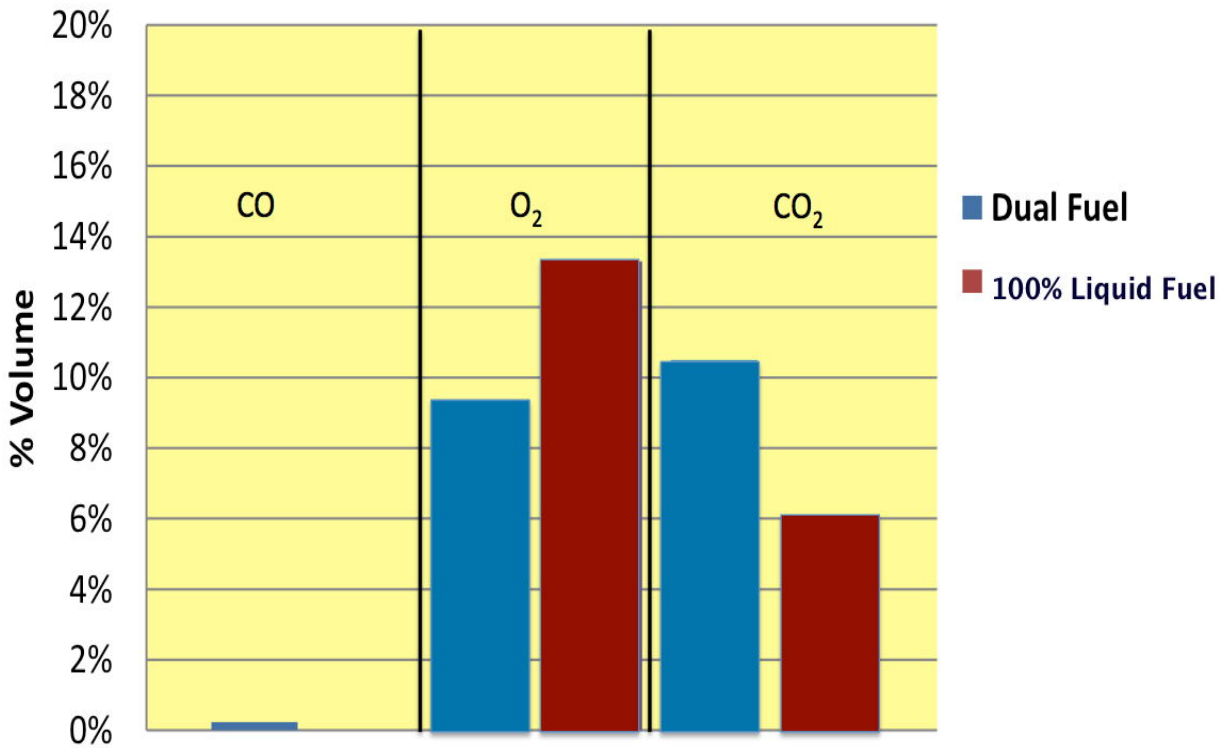
Syngas vs JP8 profile

- Syngas composition (derived from “standard” waste mix)
- Similar chemical profile to jet fuel and kerosene



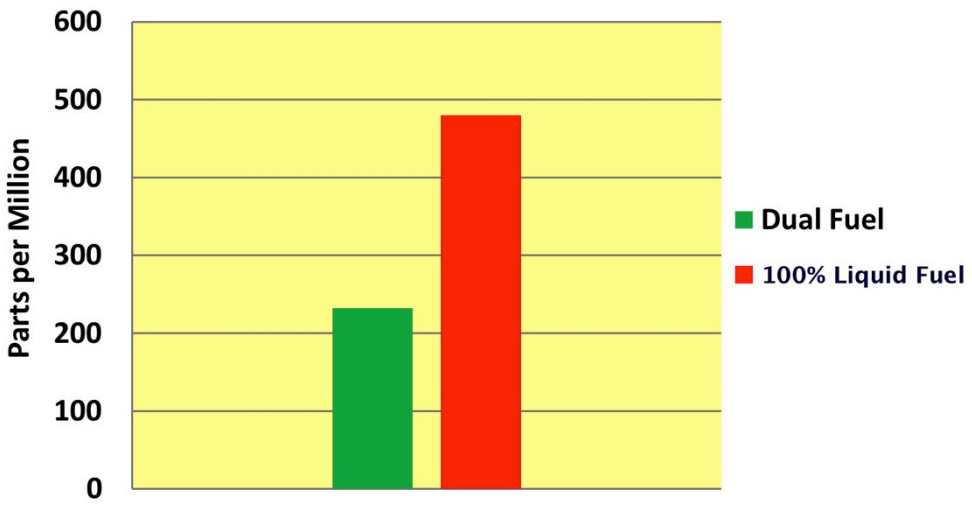
Emissions on Standard Mix

- Minor variation
- More CO on syngas
- Less O_2 as syngas displaces air

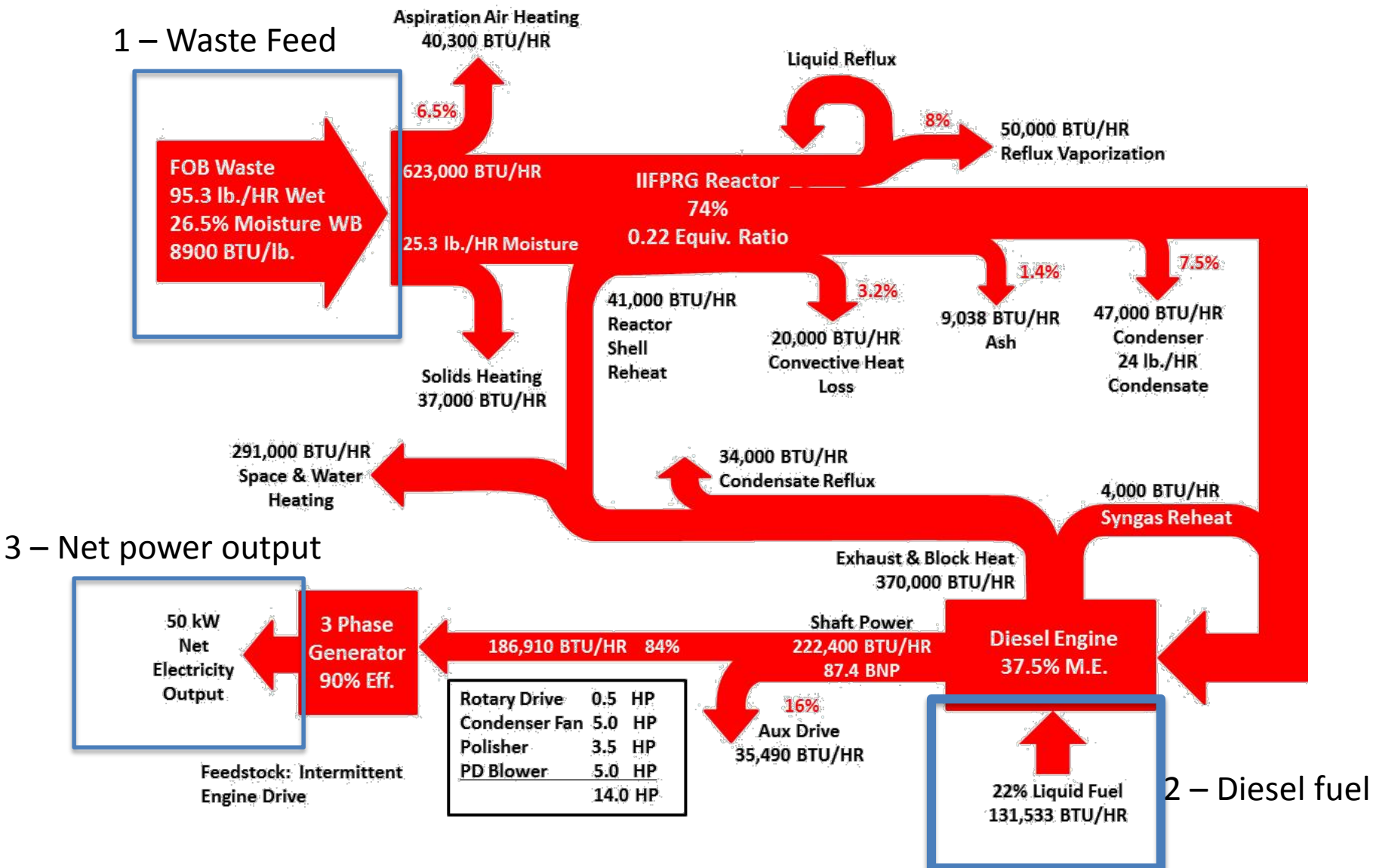


NO_X Emissions

- About 50% reduction in NO_X due to:
  - Less N_2 into engine
  - Cooler combustion temperatures



Sankey Diagram – Experimental Results



Work In Progress

- Continued testing with varied waste mixes
- GC analysis of syngas and exhaust, for energy calculations, and to identify any problematic species
- Deployable design, 3D model

Conclusions

1. Proof of concept established within original Statement of Need
2. Efficiently handles a variety of wastes with no pre-processing
3. Novel approaches to waste drying and gas filtering make this system robust and efficient

For additional information, please visit:

https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Waste-Reduction-and-Treatment-in-DoD-Operations/(list)/1/

Speaker Contact Information:

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Q&A Session 2

The next webinar is on December 18

Energy Audits: From Clipboard to Cloud

http://www.serdp-estcp.org/Tools-and-Training/Webinar-Series/12-18-2014

Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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