RDECOM

US ARMY NATICK SOLDIER RD&E CENTER

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Small Scale Waste to Energy Conversion for Military Field Waste

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JSEM Conference – May 2008

- **Mission Areas**
  - Individual Protection
  - Collective Protection
  - Airdrop / Aerial Delivery
  - DoD Combat Feeding
  - Supporting Science and Technology
  - Warrior Systems Technology Integration

DoD Combat Feeding

- **Combat Rations**
- **Field Food Service Equipment**
- **Combat Feeding Systems**

- **S&T Thrusts Areas:**
  - Energy & Equipment
  - Food Safety / Biosensors
  - Novel Preservation & Stabilization
  - Novel Nutrient Delivery
  - Revolutionary Packaging
  - M&S / Logistics

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R&D Objective

- **Objective:**
  - Develop and demonstrate technologies that treat solid waste as a resource, producing useful energy while minimizing field waste
- **Capability Provided:**
  - Onsite conversion of solid waste into electricity and high-quality heat for field-feeding and organizational equipment
  - Reduced logistics tail in terms of fuel consumed and trash backhauled

WEC Vision: A Paradigm Shift

TODAY: Waste is a Liability

- **Waste disposal costs time & money**
  - Expensive logistical burden
- **Reliance on host nation support is problematic**
  - Overwhelm local capabilities
  - Human health and environment
- **Waste footprint usable by the enemy**
  - Signature
  - Force protection

VISION: Waste is Power

- **Paradigm shift**
  - Waste less a liability, more a resource
- **Convert field waste into useful power and heat for field-feeding and organizational equipment**
- **Positive Impact**
  - Reduced military waste footprint
  - More self-sufficient forces
  - Improved force protection

The unfortunate reality at base camps…

Example:
Solid Waste Disposal at ASG Eagle Base (Bosnia)

Open burn box with no emissions control

<u>Energy wasted</u>!

Mounds of leftover partially burned trash

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Energy Potential of Waste

90 lbs
mixed waste

has energy content equivalent to…

5 gal
JP-8

…and more than 50% can be recovered

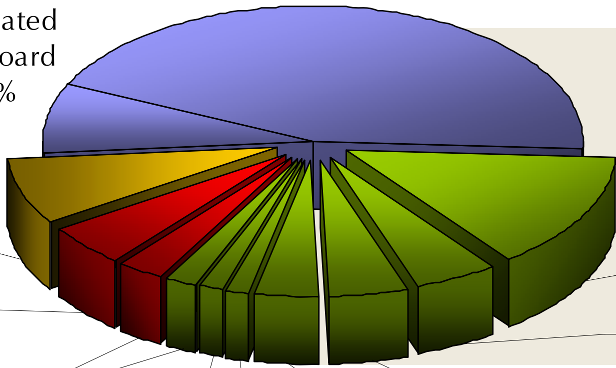
Waste generated feeding 300 troops a single UGR dinner

Waste Stream Data Comparison

	Army Field Feeding System (Fort Campbell, April 1995)	Force Provider Training Module (Fort Polk, June 2000)	AF Bare Base* (Derived from PSAB data)	ASG Eagle Base Camp (excluding wood)	ASG Eagle Base Camp (including wood)
Study Population	**210**	**164**	**1182**	**3700**	**3700**
Paper & Cardboard	**45%**	**38%**	**53%**	**49%**	**12%**
Plastic	**8%**	**12%**	**26%**	**34%**	**8%**
Food	**14%**	**40%**	**2%**	**4%**	**1%**
Misc	**12%**	**7%**	**10%**	**8%**	**2%**
Metal & Glass	**21%**	**3%**	**6%**	**5%**	**1%**
Wood	**–**	**–**	**3%**	**–**	**76%**
Per Capita (lbs/person/day)	**3.2**	**4.1**	**13.2**	**3.0**	**12.6**
Fuel Potential	**79%**	**97%**	**94%**	**95%**	**99%**

* This data is estimated, and the methodology used was not specified.

Operational Ration Packaging



MRE Packaging

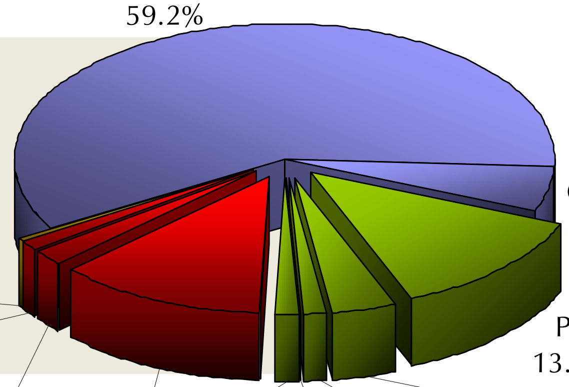
(0.61 lb/man-meal)

- Using available data to provide best estimate of component materials
- Many materials are bound in laminates and therefore inseparable

UGR H&S Packaging

(0.49 lb/man-meal)

- Data represents an average of Dinner Menu 2 and Menu 7, and may not be representative of all UGR menus



Does not address materials associated with enhancements (e.g., milk, yogurt, and fresh produce), beverage bottles, and other items not included in these operational rations

WEC: What to Process?

What portion of the waste stream should be targeted?

- The most energetic constituents represent a small fraction of the overall trash disposal burden
- Maximizing waste destruction leads to larger, more expensive equipment and diminishing returns with respect to power generation

Force Provider Waste Characterization Data

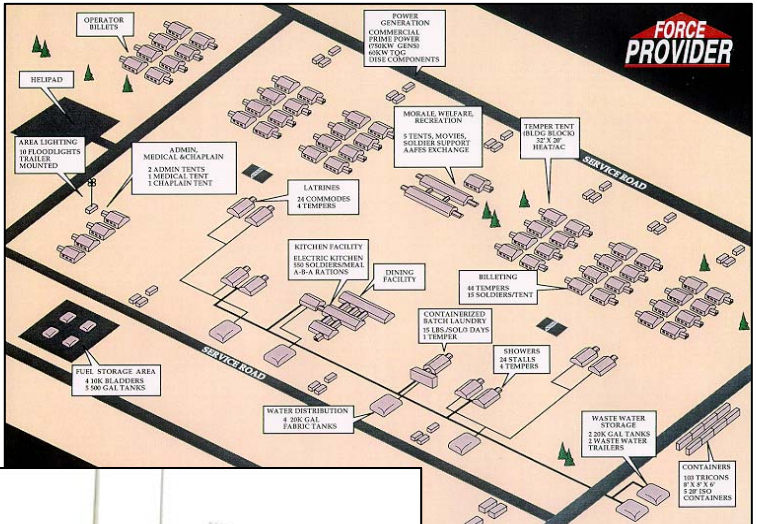
Paper & Cardboard	36%
Food	23%
Slop Food	16%
Plastic	11%
Cooking Oil	5%
MRE	5%
Metal & Glass	2%
Miscellaneous	1%

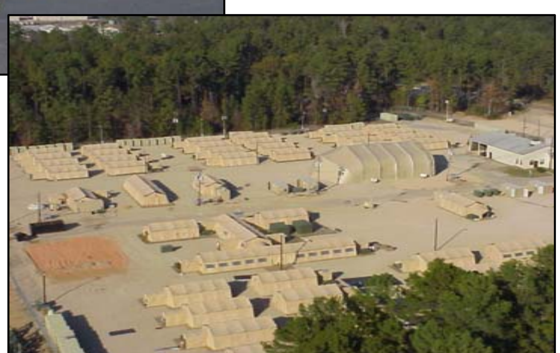
Fort Polk, June 2000
4.1 lbs / person / day

Waste Constituent	wt%	lbs/day	BTU/lb	lbs/hr*	kWe*
Plastic	11	250	17400	14	14
Plastic & Paper	47	1050	10000	59	34
All But Wet Food	82	1850	7950	104	48
All Waste	100	2250	6750	125	50

* Based on 18 hours/day operation, assuming 20% conversion efficiency to electricity.

Initial Target: Force Provider





- **Force Provider is the critical life support element for Army bare base camps**
- **Force Provider supports 550 personnel (+50 operators) with:**
  - Climate Controlled Billeting
  - Quality Food Service (1800 meals/day “A” rations)
  - Laundry Service (200 lbs/hour)
  - Showers & Latrines (one 10 minute shower/day)
  - Morale, Welfare and Recreation Facilities
- **Power, 24 60kW TQGs (1.1 MW Continuous)**
- **Water Storage & Distribution (80K gals/3 days)**
- **Fuel Storage & Distribution (20K gals/3 days)**
- **Waste Water Collection (30K gals/day)**
- **System Support Packages—30 days repair parts**
- **Transportable—air, rail, land, sea (containerized)**
  - ~81 TRICONs, 10 ISOs and rolling stock

Force Provider Daily Usage Data

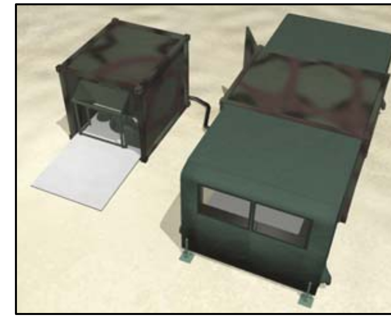
System	Capacity	Power	Fuel (gal/day)	Water Supply (gal/day)	Gray Water Produced (gal/day)	Black Water Produced (gal/day)
Containerized Latrine System (CLS)	Four CLSs per module each with 6 commodes, one urinal and a two bay sink	38 kW	n/a	2700	n/a	3465
Containerized Batch Laundry (CBL)	200 pounds/hour	100 kW	25	5200	5200	n/a
Containerized Shower System (CSS)	Two CSSs per module, each with 12 stalls, avg 10 minutes/ shower per person per day	55 kW	12	11000	11000	n/a
Food Service Facility	1800 A meals per day	120 kW	25	1925	1375	n/a
Power Generation	27 60kW-TQGs, 18 operating at all times; 1,080 kW	n/a	2186	n/a	n/a	n/a
	TOTAL	**313**	**2248**	**20825**	**17575**	**3465**

Trash: Approx. 2500 lbs per day

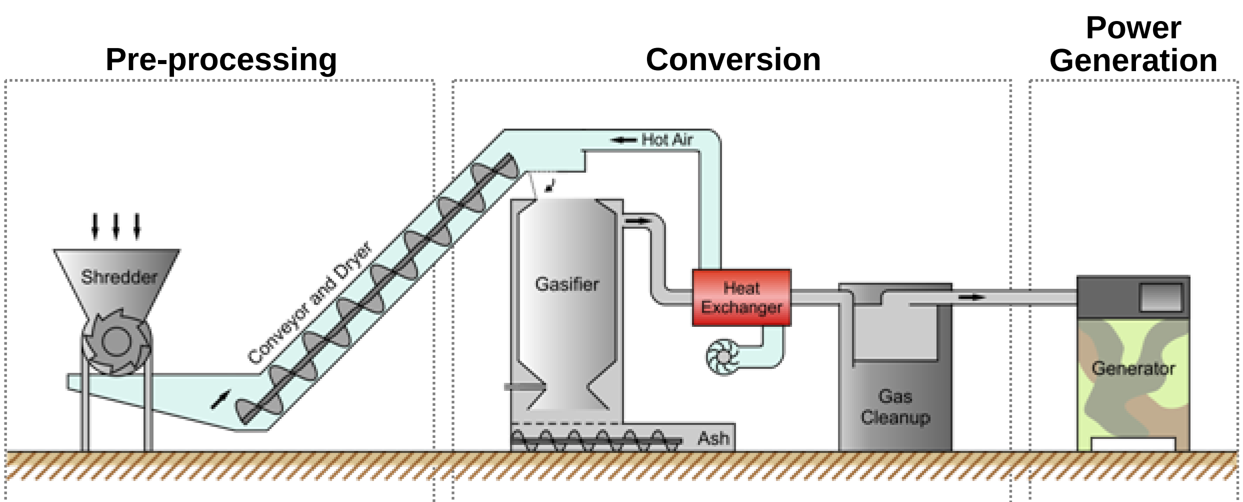
WEC Process Concept

A thermo-chemical WEC process concept can be broken down into three general areas:

- **Pre-processing.** Solid waste is sized and, if necessary, homogenized, dried, and/or pelletized.
- **Conversion.** The prepared feedstock is gasified, and the fuel gas product is cooled and cleaned.
- **Power Generation.** The fuel gas is used in a generator to make electricity.



WEC system concept with field kitchen



A generic WEC gasification process

Leveraging DARPA & SBIR

- **SBIR — <u>Onsite Field-feeding Waste to Energy Converter</u>**
  - Goals:
    - Convert mixed waste into electricity and heat
    - Process 1500 lbs/day field-feeding solid waste
    - Package in ISO container for compatibility with Force Provider
  - Two Phase II efforts recently completed

- **SBIR — <u>Solid Waste Pre-processor for Field WEC</u>**
  - NSRDEC partnered with ARL
  - Goals:
    - Size, dry, mix, and densify feedstock into homogeneous product
    - Ultimately package together with WEC gasifier
  - One Phase II effort in progress

- **DARPA — <u>Mobile Integrated Sustainable Energy Recovery</u>**
  - Goals:
    - Convert packaging wastes into fuel/electricity
    - Retain 70% of the waste energy content, 10% residual waste
  - One Phase IA effort in progress

Research & Development Performers

Community Power Corporation

Stratified Downdraft Gasifier

GENERAL ATOMICS

Supercritical Water Depolymerization

SBIR
ARL
DARPA

INFOSCITEX
Research, Development, & Commercialization

Solid Waste Pre-processor

GREEN
LIQUID & GAS TECHNOLOGIES

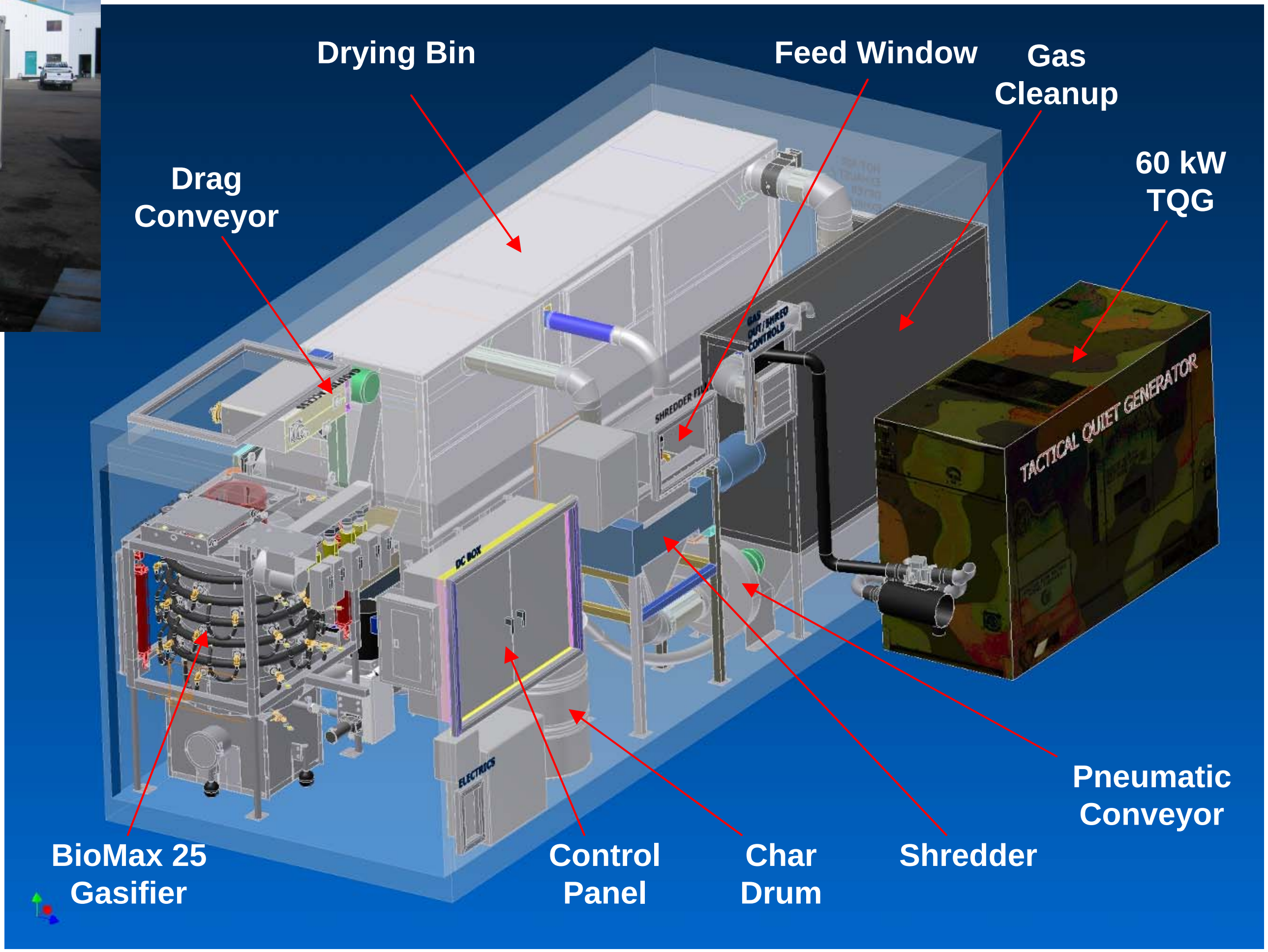
Indirectly Heated Pyrolyzer/Gasifier

Downdraft Gasifier

Community Power Corporation, Littleton CO

- **Approach: Stratified Downdraft Gasifier**
  - an innovative design with electronic instrumentation and active air controls to optimize the process
- **Reduces dry feedstock to fuel gas and char/ash**
  - the clean producer gas can be used in an internal combustion engine
- **BioMax® pre-commercial system converts woody biomass into electricity and heat**
  - markets include small industrial, agro-processing, and rural electrification
- **SBIR Phase I awarded in December 2004**
- **SBIR Phase II awarded in January 2006**
- **Initial technology demonstration performed in April 2008**

Downdraft Gasifier



Containerized WEC with major sub-systems identified

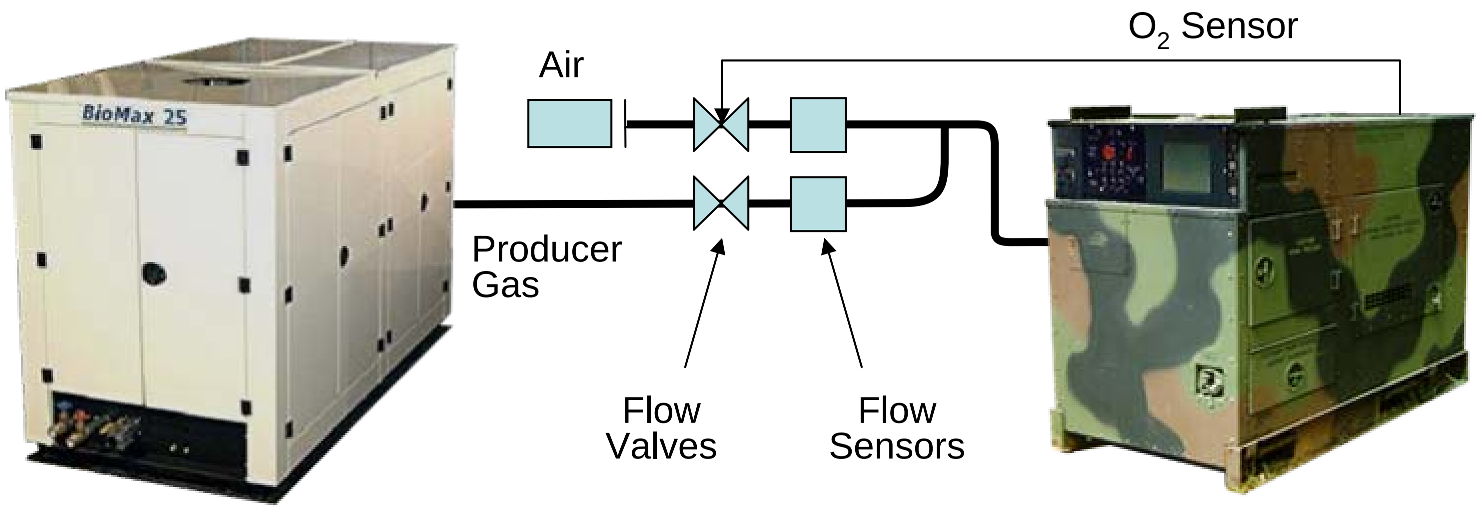
Routine Operation and Maintenance

- **Automatic Operation**
  - Computer controlled
  - Transports feedstock from shredder to drying bin to gasifier
  - Adapts to feedstock and electrical load changes
  - Identifies faults
  - Alerts and instructs operator
  - Logs data

- **Operator Requirements**
  - Minimal computer skills
  - Some mechanical aptitude
  - High school education
    - Example: BioMax® 15 operated by Ag students at North Park High School in Walden, CO

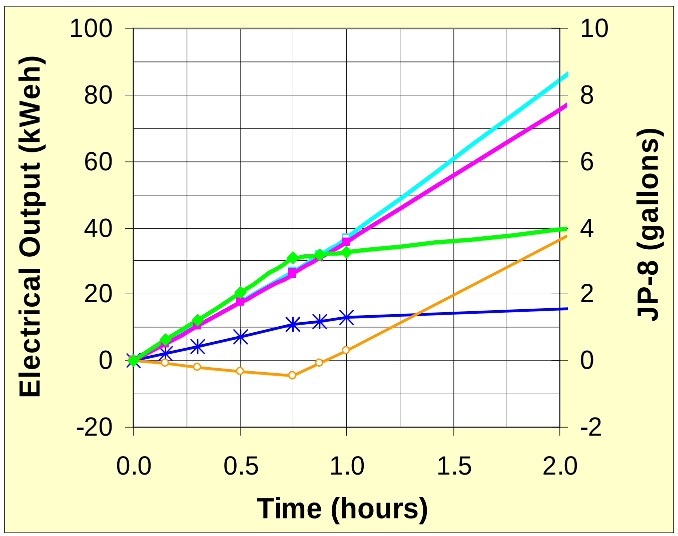
- **Operator's Duties**
  - Load the shredder
  - Respond to operator alerts
  - Remove sack of char from char drum
    - About daily
  - Perform routine maintenance
    - Weekly as required

Diesel Engine Fumigation with Producer Gas

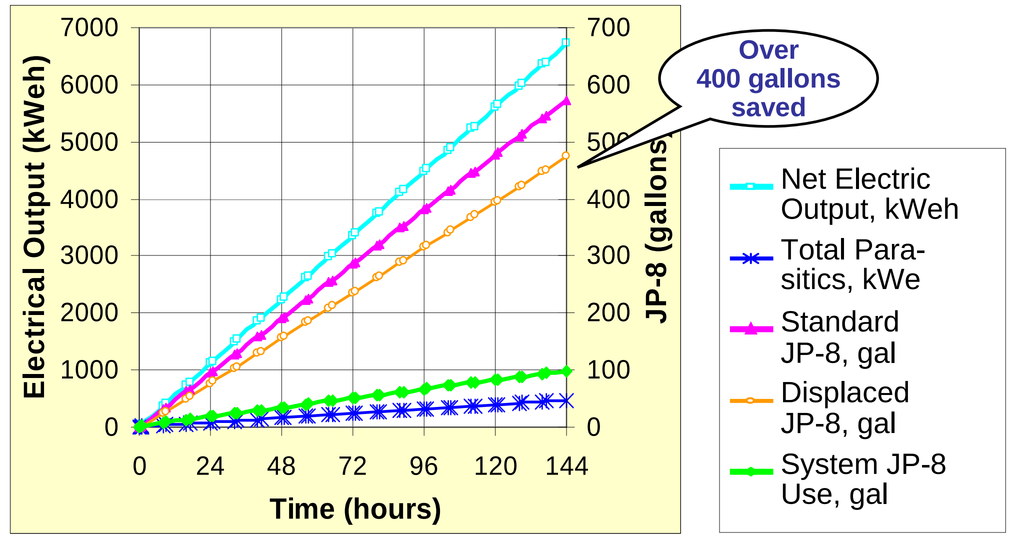


- Gasifier-engine interface module doesn’t require modifications to 60kW Tactical Quiet Generator set
- Combustion air flow valve operates via PID control
- Producer gas valve adjusts flow according to demand
- Demonstrated 80% displacement of JP-8 fuel with producer gas

Projected Energy Timeline for WEC System



Startup



One Week

Projected operation with a 60 kW TQG delivering 50 kWe while running on producer gas and JP-8 pilot fuel. During 45-minute warmup, JP-8 fuel is used exclusively.

Parasitic electrical requirement is:
- –8.5 kWe during warmup
- –2.5 kWe during operation
- –extra 6 kWe during shredding

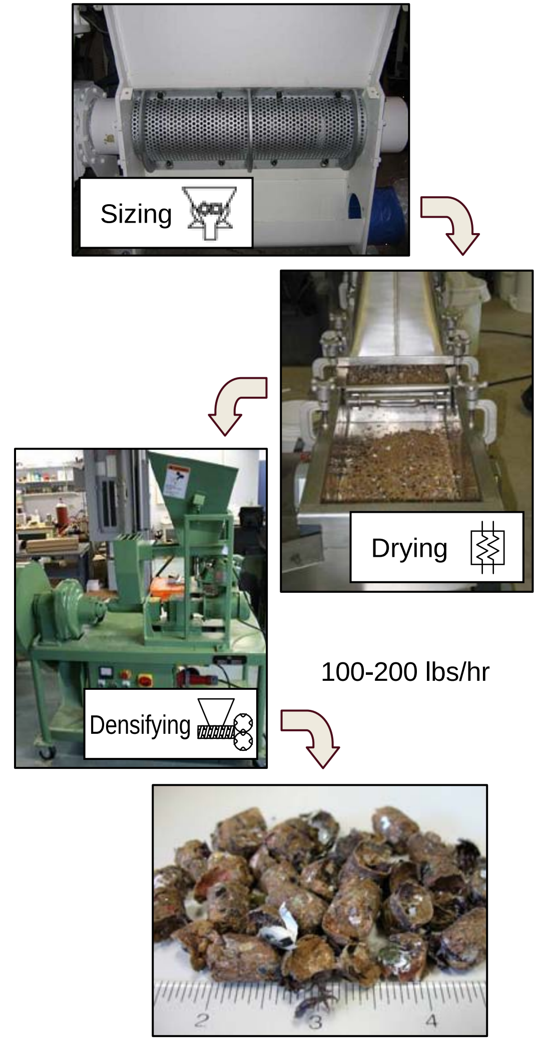
Accounting for parasitic losses and the contribution of the JP-8 pilot fuel:

- WEC is up to 22% efficient at converting trash into electricity
- Each gallon of JP-8 used has 5.8x payback

Solid Waste Pre-processor

INFOSCITEX Research, Development, & Commercialization, Waltham MA

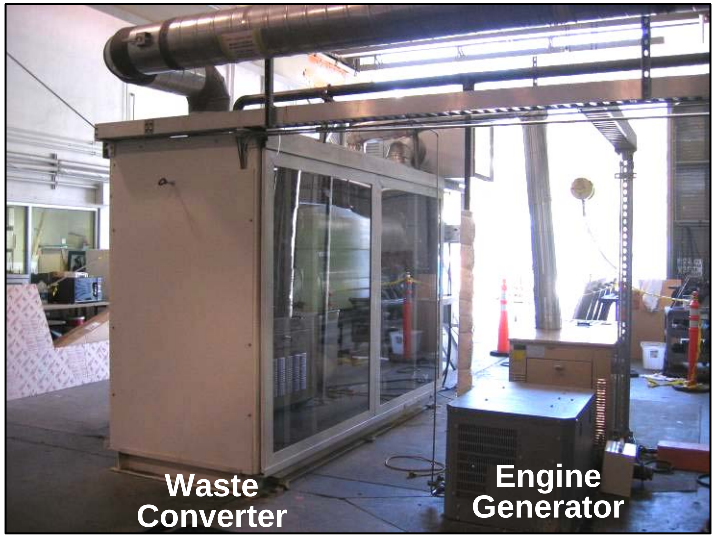
- **Approach: Waste Pelletizer**
  - integrates a shredder, dryer, and pelletizer to produce a homogeneous product with minimal parasitic losses
- **Converts solid waste into a fuel feedstock for WEC gasifier**
  - pellets appropriate for short-term storage and automatic feeding with suitable physical properties for gasification
- **Proof-of-principle demonstrated with Unitized Group Ration (UGR) and Meal, Ready-to-Eat (MRE) materials**
- **SBIR Phase I awarded Nov 2005**
- **SBIR Phase II awarded Sep 2006**



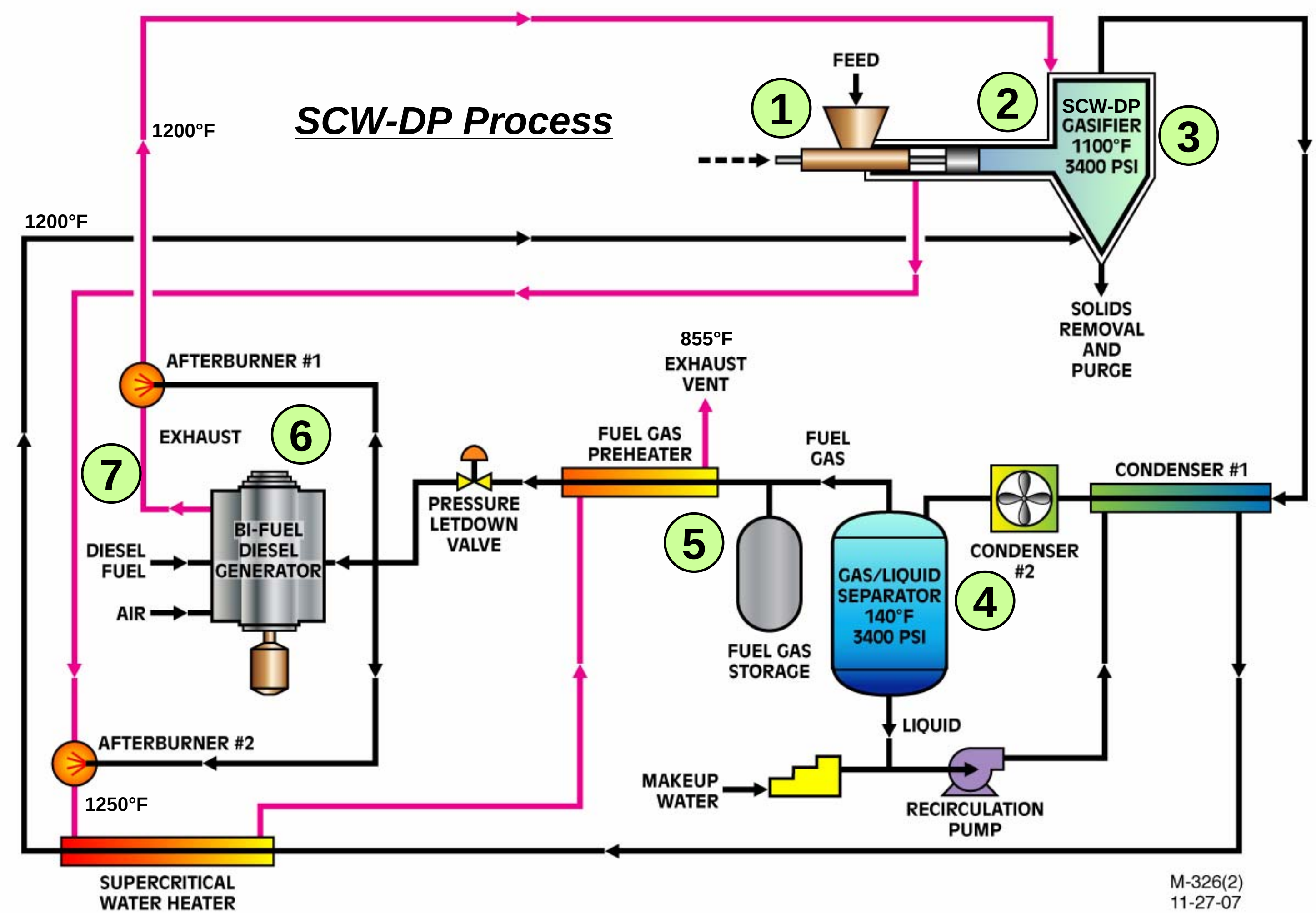
Waste Pellets

GENERAL ATOMICS, San Diego CA

- **Approach: Supercritical Water (SCW) Depolymerization**
  - hydrothermal process that uses a high-pressure, high-temperature reactor to break down polymeric and cellulosic materials
- **Converts wastes into fuel gases**
- **SCW process has desirable properties**
  - clean, high heating value gas product
  - no need for feedstock drying
  - ease of heat recovery
- **SCW processes previously proven for hazardous waste destruction and biomass gasification**
- **DARPA MISER Phase I awarded August 2004**
- **DARPA MISER Phase IA awarded March 2007**



Supercritical Water Depolymerization

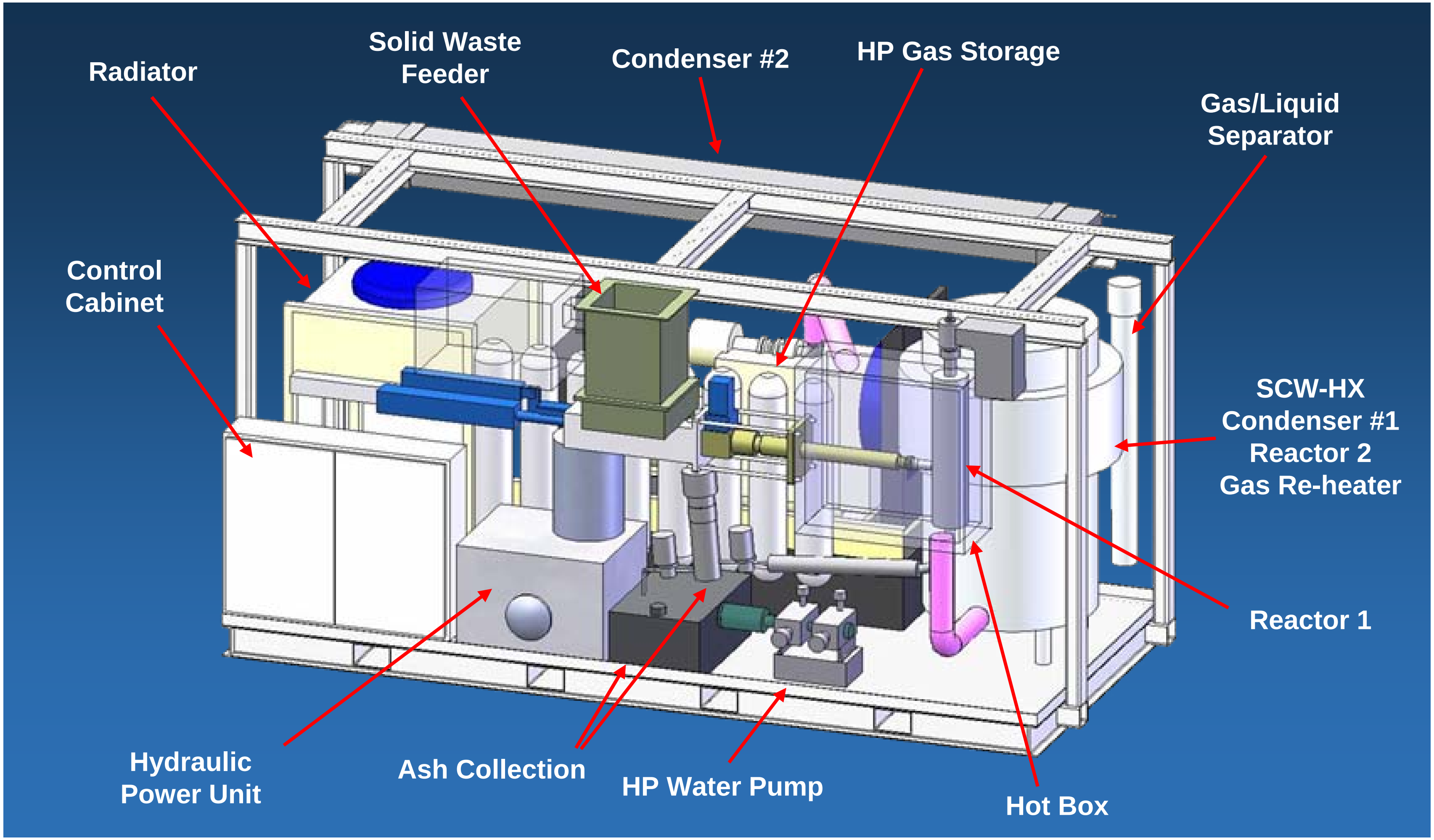


1. Solid waste fed into the reactor
2. Feedstock broken down into gases and residual liquid and solids
3. Fuel gas, SCW, and liquid organics exit overhead; solids drop into vessel
4. Gas and liquid products cooled and separated; liquids are further re-circulated
5. Fuel gas stored or fed directly to a generator
6. Bi-fuel generator used to produce electric power
7. Generator exhaust provides system heat; some product gas used in afterburners for additional heat

Based on GA's MISER system processing 60-100 lb/hr mixed waste:

- Projected 19% efficiency converting mixed waste into electricity
- Each gallon of JP-8 used has more than 5x payback

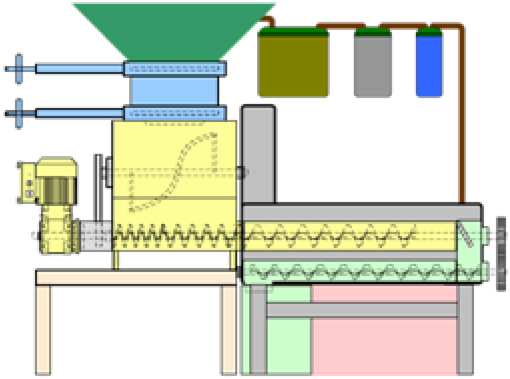
Supercritical Water Depolymerization



Layout for GA's 60 kW MISER Phase IA System

Indirectly Heated Gasifier

GREEN LIQUID & GAS TECHNOLOGIES, Gainesville FL



- **Approach: Indirectly Heated Gasifier**
  - gasification by high-temperature pyrolysis, which reduces dilution of the output gas with nitrogen, carbon dioxide, and water vapor.
- **Converts feedstock to gas, oils, and ash/char**
  - produces a pyro-gas with medium heating value, similar to natural gas
- **Concept demonstrated with Unitized Group Ration (UGR) and Meal, Ready-to-Eat (MRE) waste**
- **SBIR Phase I awarded in December 2004**
- **SBIR Phase II awarded in February 2006 (DARPA funded)**
- **Prototype demonstrated in March 2008**

Return on Investment

- **ROI / Benefits of WEC:**
  - Reduced logistics for waste management and fuel
    - Reduce field-feeding solid waste by 75-90%
    - Reduce field kitchen energy requirements by 50% or more
  - Improved safety, reduced signature, and reduced DNBI while protecting the environment
  - Early economic analysis predicted an ROI of 2.6:1
    - Assuming deployment with field kitchens, $200K unit cost, 15-year system life, mission of 78 days/year, fuel value of $1.50/gal
    - Save over $500K per WEC, with 10-year payback for fleet
    - Base camp application should see higher ROI
    - Updated analysis will be prepared as more accurate cost, performance, maintenance, and mission details emerge

The Road Ahead

- **Planned Activities for FY08, FY09, and Beyond:**
  - Complete development of WEC prototypes
    - Downdraft Gasifier
      - Extended testing to characterize performance and maintenance
      - Field demonstration at kitchen site
    - Pre-processor
      - Complete development of full-scale prototype pre-processor
      - Demonstration in conjunction with gasifier
    - Supercritical Water Depolymerization
      - Complete full-scale prototype for plastics (and collect data for mixed waste)
      - Full-scale prototype for mixed waste (DARPA Phase II decision in FY08)
  - Investigate WEC inputs and outputs in a bare base setting
    - Waste characterization study and packaging analysis
    - Logistics study
  - Develop metrics for comparing competitive systems
    - Mass & energy balance, energy timeline
  - Secure additional funding (e.g., ESTCP, TTI) to bridge the gap between technology demonstration and transition to procurement
    - Integrate gasifier, pre-processor, and generator

**Meeting Today's Challenges…
Providing Tomorrow's Solutions™**