Biochar conversion of human solid waste
Brian von Herzen PhD
Climate Foundation

Climate Foundation team: Brian Von Herzen, Hamish Fallside, Laura Talsma, Pau Csonka, Sampath Kumar, Andrew Larsen, Prasino Group, Cornell University, Sanergy, T.R. Miles, Inc.
brian@ClimateFoundation.org

USBI
Amherst, October 2013
Kofi Annan

Eat one vegetarian meal per week.
You are what you eat

western diet: 120g/day of poop
unrefined diet (mostly vegetables): 400g/day.

Both produce 14-18 MJ/kg of dry fuel
1 kg of beef: 20,000 kg of water
1 kg of wheat: 200 kg of water

Colon cancer is a western disease

Net present value of mostly veggie diet:
costs less, uses 100x less water,
greater longevity and health
Gates Foundation Reinvent the Toilet Challenge

2.5 billion people without access to adequate sanitation

Sanitize waste for a nickel per poop
Do it without external electricity or water

Town of 1000 people: $50/day, $15k per year
$150k per decade
Poo pyrolyzer economics

Prevailing wage in Nairobi is $4/day
$1k per year

could spend $100k on capital equipment
or could hire ten people for a decade

Creating jobs lifts the local economy
Favors low capital intensity and “right-sizing” technology-- TLUD++ ?
Biochar Real Estate:

Adsorption surface area conserved over time:
Metric: not m2/g, but $/square meter

<table>
<thead>
<tr>
<th>Material</th>
<th>Price/ton</th>
<th>Area m2/g</th>
<th>Cost/sq km</th>
</tr>
</thead>
<tbody>
<tr>
<td>activated carbon</td>
<td>$2500/ton</td>
<td>1000</td>
<td>$2.50/ sq km</td>
</tr>
<tr>
<td>bulk biochar</td>
<td>$650/ton</td>
<td>400</td>
<td>$1.62/ sq km</td>
</tr>
<tr>
<td>wood ash</td>
<td>$50/ton</td>
<td>700</td>
<td>$.07/ sq km</td>
</tr>
<tr>
<td>manure biochar</td>
<td>$15/ton, due to tipping fees</td>
<td>200</td>
<td>$.07/ sq km</td>
</tr>
</tbody>
</table>
Contents

• Climate Foundation

• Biochar reactor for sanitation
  o Biochar reactor development
    ▪ Preprocessing/drying
    ▪ Gasification
  o Field lab at Sanergy
  o Biochar market development

• Timeline & future results
Terrestrial carbon balance
  o In collaboration with Gates Foundation and Hertz Foundation
  o **Reinvent The Toilet Challenge**
    Biochar Reactor Phase 1: Small-scale solid waste to biochar reactor
    ~2 kg/hr input flow
  o **Reinvent The Toilet Challenge**
    Biochar Reactor Phase 2: Scaled solid waste to biochar reactor
    serving ~40 kg/hr input flow

Ocean carbon balance projects
  o Ocean Pumps
  o Coral reef cooling
  o Local ocean acidification reduction
Climate Foundation Partners

Reactor Development

Feedstock & biochar characterization

Biochar market development

SANERGY
Building Sustainable Sanitation in Urban Slums

Vertical sanitation infrastructure
Prototype field test site
Time series feedstock analysis

Climate Foundation
Project Lead

Tide Technocrats Systems
Engineering - Bangalore

Cornell University
Department of Crop and Soil Sciences
Biochar characterization

The Prasino Group
Biochar applications market research
Biochar for Sanitation

• Sanitized flow: high temperatures kill pathogens
• Fast processing: hours versus weeks for compost
• Energetics balance: 16-24 MJ/kg from dry fuel
  o Selecting belt-drying solutions for efficiency
• Valuable end product:
  o Soil amendment
  o Fuel - briquette
  o Soil remediation
Sanitation service model

- Toilets
- Waste Collection
- Field Laboratory
- Waste Processing
- Agricultural Products

Community scale - serve 1,000’s of people
Taxonomy of Waste

Optional additives including green waste, MSW, biomass

ASW = Accidental Solid Waste
ISW = Incidental Solid Waste
HSW = Human Solid Waste = Faeces + ASW + I
NDU = Non-Diverted Urine
MSW = Municipal Solid Waste
Biochar Reactor Overview

- Shredding / Mixing
- Efficient Belt Drying
- Updraft Pyrolysis
- Biochar Collection
- Modified Pyrolyzer and Reformer
- Volatile Oxidation
- Dryer & Exhaust Condensing Heat Exchanger
- Electricity Generation
- Odor Management

ISO Containerized Biochar Reactor

HSW from UDDT
Phase 1 RTTC Biochar Reactor
Phase 1 pyrolysis reactor

Internal views of the pyrolysis chamber during assembly, and the sealed reactor after assembly. The heat exchanger connection is seen on the left side of the reactor lid.
USBI 2012 Sonoma demonstration

The complete prototype (left); example biochar output from the machine (right).
Biochar Reactor Overview

Input Hopper

Dryer

Post-processor

Pyrolyzer
Belt Drying recovering the heat of condensation
courtesy Thermal Energy International, Inc.
Belt dryer implementation
## Energetics of Poo Pyrolysis

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Energy Component</th>
<th>Energy Value 1</th>
<th>Energy Value 2</th>
<th>Energy Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass % sawdust</td>
<td>5%</td>
<td>boiling water and heating wood</td>
<td>-4.46</td>
<td>-3.122</td>
<td>-0.20482</td>
</tr>
<tr>
<td>Water</td>
<td>0.7 kg</td>
<td></td>
<td>-4.46</td>
<td>-3.122</td>
<td>-0.20482</td>
</tr>
<tr>
<td>Dry poo</td>
<td>0.3 kg</td>
<td></td>
<td>16</td>
<td>4.8</td>
<td>-0.102</td>
</tr>
<tr>
<td>Sawdust</td>
<td>0.05 kg</td>
<td></td>
<td>16</td>
<td>0.8</td>
<td>-0.017</td>
</tr>
<tr>
<td>Total mass material</td>
<td>1.05 kg</td>
<td>gross exotherm</td>
<td>2.478</td>
<td>-0.32382</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>heating enthalpy</td>
<td>-0.32382</td>
<td>MJ</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>net exotherm</td>
<td>2.15418</td>
<td>MJ</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>per unit mass</td>
<td>2.052</td>
<td>MK/kg input material</td>
<td></td>
</tr>
<tr>
<td>30% electric conversion</td>
<td></td>
<td></td>
<td>-0.6156</td>
<td>MJ (energy transfer)</td>
<td></td>
</tr>
<tr>
<td>Heat output</td>
<td></td>
<td></td>
<td>1.4364</td>
<td>MJ/kg</td>
<td></td>
</tr>
</tbody>
</table>
Field lab, Nairobi with Sanergy

- Human solid waste analysis at Sanergy
  - Calorimetry, moisture levels
  - Samples from Sanergy toilets on rotating daily basis
  - Time series analysis across geography
  - Small scale biochar production for Cornell studies
Biochar characterization

- “Humanure Biochar” to be analyzed at Cornell
  - Measure across range of pyrolysis temperatures
  - Properties: pH, CEC, surface area, N retention
  - Compare with other biochars, humanure compost
  - Soil studies, initial focus on Kenya
  - Inoculation and effects on plant growth
  - Pathogen analysis: validate safety aspects
Biochar market development

- **Soil Amendment**
  - Smallholder Farmers
  - Commercial Farmers
  - Organic Farmers

- **Energy**
  - Household Charcoal
  - Industrial Processing

- **Soil Remediation**
  - Environmental Remediation

- **Other Markets**
  - Cover material for waste mgt.
  - Odor abatement
  - Water filtration
  - Nitrification substrate
  - Pyrolysis substrate

- **Filters**
  - Adsorption
  - Energy content
  - Nutrient substrate