Outline

• Millenium Development Goals
• Rain and Grey Water System (Subsystem 1)
• Biodigestor (Subsystem 2)
• Pyrolysis (Subsystem 3)
• Integrated System (Closed Loop)
• Challenges/Conclusions
MILLENIUM DEVELOPMENT GOALS

The 8 Millennium Development Goals

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Global partnership for development
INTERGRATED HMW DEVELOPMENT

SUBSYSTEM 1: RAIN & GREY WATER

SUBSYSTEM 2: BLACK WATER + ORGANIC WASTE

SUBSYSTEM 3: CARBON SEQUESTRATION

Energy, water, environment efficient community

Solar power

Isolation

Electricity

Generator

Heat + cook

Bio-gas

Bio-reactor: anaerobic digestion

Rain water store

Gray water sump

Filters

Communal green areas and gardens

Water

Bio-char

Terra-astra

Soil mixture

Bio-char pyrolysis kiln

Waste heat

Syngas

Useful minerals

Residues

Allen, invasive plants & wood rests

Organic waste

Refinery

Useful minerals

Sewage
SUBSYSTEM 1
RAIN AND GREY WATER
Household electricity use

- 50% of heat loss through roof
- Double Glazing windows
- Insulate hot water tank/solar geyser
- Lag hot water pipes
- Draught proof strips around roof and door

DSM Action Points:
- SWH
- Ceiling Insulation
- CFL Lighting
- Low Flow Shower-heads
- Refrigeration
Rain Water Storage

Low annual rainfall of 407 mm

Mediterranean weather

Leaf Beater, 2000 l tank, outlet tap – with 0.37 kW pressure pump
Grey Water system

Kitchen water diverted to black water system, due to heavy fatty contents that is damaging to plant life.

Maxi garden system.

Save 50% on water consumption

Attach outlet to permanent garden drip irrigation system.

Solar-powered pumps possible.
Water system costs

Cost analysis: Rain Water system - R 4750
  Grey Water system - R 3495
Total water integration costs - R 8245

For R 250 water account, DSM savings will amount to break-even within 5 years, not including rain-water harvest.
Walker Bay to Cape Agulhas
SUBSYSTEM 2
BLACK WATER AND ORGANIC WASTE
(BIODIGESTION)
SELECTED AD TECHNOLOGY

• Primary & secondary digester
• 1000 m³ each
• Calculations based on following assumptions
  – 5000 households
  – 60 m³/day sewage effluent
ILLUSTRATION OF TECHNOLOGY

Biodigester – 1,000 m³

Location: Georgian Bluffs/Chatsworth, Canada
AD Supplier: CH\textsubscript{FOUR} Biogas Inc., Canada
Commissioned: October 2010

Gas Generator - 100 kW

Gas Generator and Boiler Container
## ESTIMATION OF BIOGAS YIELD

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Biogas m³/tonne of substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septage</td>
<td>13.1 (calculated est.)</td>
</tr>
<tr>
<td>Sewage Sludge</td>
<td>15</td>
</tr>
<tr>
<td>Pig slurry</td>
<td>22</td>
</tr>
<tr>
<td>Cattle slurry</td>
<td>26</td>
</tr>
<tr>
<td>Chicken manure</td>
<td>54</td>
</tr>
<tr>
<td>Cattle manure (fresh)</td>
<td>77</td>
</tr>
<tr>
<td>Sheep manure (fresh)</td>
<td>162</td>
</tr>
<tr>
<td>Corn silage</td>
<td>204</td>
</tr>
<tr>
<td>Grease trap residues</td>
<td>285</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>361</td>
</tr>
<tr>
<td>Corn stalks</td>
<td>557</td>
</tr>
<tr>
<td>Oil seed residues</td>
<td>624</td>
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</tbody>
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Source: Henderson Paddin (2009)
ACTUAL USABLE ENERGY OUTPUT

**Biogas produced (m³/day)**

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Sewage</td>
<td>786.0</td>
</tr>
<tr>
<td>Organic waste</td>
<td>654.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,440.0</strong></td>
</tr>
</tbody>
</table>

**Electricity Produced/Annum**

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<tbody>
<tr>
<td>Biogas reqd for 1 kWh elec (m³)</td>
<td>0.4</td>
</tr>
<tr>
<td>Gas Generator Rated Power (kW)</td>
<td>150</td>
</tr>
<tr>
<td>Electricity produced per year (kWh)</td>
<td><strong>1,314,000.0</strong></td>
</tr>
</tbody>
</table>
MASS & ENERGY FLOW

Households

Generator

Heat

3240 kWh/day

Biodigester

Organic waste
2200 kg/day

1440 m³/day

Sewage
60 m³/day

Digestate

Soil Mixture

TERA

PETRA

Refinery

Water

Treated biosolids

Residues

Soil Mixture
ECONOMICS

Capital Costs
Primary digester (35 days storage): 1,000 m³  R1,050,000
Primary digester (35 days storage): 1,000 m³  R1,050,000
Balance of Plant  R3,200,000
Project Costs  R730,000
Total  R6,030,000

Operational Costs (10% of capital costs)  R603,000

Revenue from electricity (@R1/kWH)
Electricity produced per year (kWh)  1,314,000
Revenue from electricity (@R1/kWH)  R1,314,000

Payback Period (@12 discount rate)  5yrs

• Additional income possible from nominal tipping fees: disposal of waste fats and other food processing wastes.

⇒ Project is financially feasible
ENVIRONMENTAL

• Mitigation of GHG (particularly $\text{CH}_4$)
• Cleaner electricity with possible combined heat and power (CHP)
• Improvement of sanitation
• Promotion of tertiary treatment of effluent
• Usage/recycling of organic waste (ease of load on landfill)
SOCIAL

• Local jobs created
  – Several tens temporary construction jobs
  – At least two permanent jobs on sight (assuming two shifts)

• Skilling and training (in construction areas and O&M)

• Local value chain created – supply of feedstock (organic waste)
SUBSYSTEM 3
CARBON SEQUESTRATION
(PYROLYYSIS)
SLOW PYROLYSIS TECHNOLOGY OPTIONS

- Agoda, SA
- Best Energies, Australia & US
- Rodim Wood Chemical, SA
- Pyreg, Germany
Pyreg bio-char plant (120:40 kg/h)
A **PYREG**® pyrolysis plant housed in a standard shipping container processing Green Waste as the Biomass feedstock to produce high quality Biochar.
PYROLYSIS PROCESS

Schematic Diagram of a Pyrolysis Process to Produce Biochar
Pyreg Heat Flow Chart

Biomass heat potential 100%

Pyrolysis Coke Discharged 66%

Pyrolysis Gas 34%

Biomass Humidity/Pyrolysis Gas Heat 38%

Exhaust Humidity/Exhaust Heat 38%

Useful Heat 34%

Useful Heat Expelled 30%

Pyrolysis Reactor

Combustion Chamber

FLOX®-Furnace 72%

Exhaust Heat Loss 4%
Component Gases of Pyrolysis Gas showing their respective Mass & Calorific Values
(CV: 8.95MJ/Kg, Density: 1.283Kg/m³)

Carbon Efficiency: 62%

CO₂ Balance PYREG Processes (biomass into biochar, green waste C₁₀ H₁₄ O₇, Humidity 100%)
DESCRIPTION

- It is a continuous process
- The process is energy and carbon negative
- Rated energy input 0.5MW
- Has 3 inclined twin screw Pyroreactors
- One combustion chamber
- Plus auxiliaries e.g. conveyors, fans, control panel, hoppers
- Annual throughput capability 1000t, yielding 350t of biochar plus clean waste heat
- Configured to operate in and around a 6m long shipping container
- Weighs 8.5t
- Meets and beats all the stringent EU/German emission directives/regs
- Excess pyrolysis gas exported to neighboring bio-gas power plant
**BIOCHAR VALUE CHAIN**

**Feedstocks**
- Alien invasive plants, biomass, waste (1000t/a, 0.5MW)

**Pre-treatment**
- Harvesting, stack, air dry 50% to 30%, mobile chipper: 0.3kW diesel
- Transport: 1.7 kW diesel

**Initial conversion**
- Pyrolysis <= Energy In: 3.5kW electrical

**Final conversion**
- Combustion => Energy Out

**Final Product**
- Bio-char (350t/a)
- Pyrolysis gas: 150kW Energy to power plant

› 80% energy efficient (50kW electrical)
ENVIRONMENT

• Energy:
  – 66% converted to bio-char
  – 34% pyrolysis:
    • 30% pyrolysis gas to bio-gas power plant
    • 4% waste

• Waste disposal:
  – Meets & beats all EU/German emission directives

• Carbon balance
  – Up to half of carbon is sequestered
BIOCHAR IN CARBON CYCLE

The Carbon Cycle

- Photosynthesis
- Atmospheric CO₂
- Biomass
- Biomass Decomposes or Burns 99% of Carbon Released as CO₂

Almost all of the carbon returns to the air

Green plants remove CO₂ from the atmosphere via photosynthesis and convert it into biomass. Virtually all of that carbon is returned to the atmosphere when plants die and decay, or immediately if the biomass is burned as a renewable substitute for fossil fuels.

The Biochar Cycle

- Photosynthesis
- Atmospheric CO₂
- Biomass
- Biochar
- Pyrolysis
- Syn-Gas or Bio-Oil

Up to half of the carbon is sequestered

Green plants remove CO₂ from the atmosphere via photosynthesis and convert it into biomass. Up to half of that carbon is removed and sequestered as biochar, while the other half is converted to renewable energy co-products before being returned to the atmosphere.

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BENEFITS OF BIOCHAR IN SOIL

- Enhanced plant growth
- Suppressed methane emission
- Reduced nitrous oxide emission (estimate 50%)
- Reduced fertilizer requirement (estimate 10%)
- Reduced leaching of nutrients
- Stored carbon in a long term stable sink
- Reducessoilacidity: raisessoilpH
- Reduces aluminum toxicity
- Increased soil aggregation due to increased fungal hyphae
- Improved soil water handling characteristics
- Increased soil levels of available Ca, Mg, P, and K
- Increased soil microbial respiration
- Increased soil microbial biomass
- Stimulated symbiotic nitrogen fixation in legumes
- Increased arbuscularmycorrhizal fungi
- Increased cation exchange capacity
ECONOMY

• Mass balance:
  – Pyreg annual capacity = 1000 t, 928 052 t available (Stafford, CSIR study), biomass from vegetable gardens can be used when AIP stock depleted
  – Pyreg annual production = 350 t

• Capital investment = R3.5M

• Quantified return on investment
  – Bio-char price @ R2220/t
  – Annual income = R700k (Assuming 10% operating costs)
  – Pay back period = 5 years

• Actual return
  – Bio-char feed rate 1 to 5 kg/m² @ 2 year intervals
  – 350 t/year = 7 to 35 ha/year => 14 to 70 ha for a cycle of 2 years
SOCIETY

• Jobs will be created to:
  – harvest & transport the AIP woody biomass manually (15 people)
  – operate the bio-char plant (3 shifts over 24h=> 6 people)
  – work in communal green areas & gardens (15 people)
  – process & sell produce from areas allocated to vegetables/fruit (5 people)

• Food will be produced
  – 14 to 70 ha better quality soil available, some allocated to food crops

• Water supply will be increased
  – from removal of AIP

• Health will be improved
  – From better quality food due to soil improvement from bio-char and increased water

• Education improved
  – From training for jobs mentioned above and increase of income
CLOSING THE LOOP

Subsystem 1

Water

Subsystem 2

Organic Waste

Sewage

Compost/minerals

Biochar

Subsystem 3

Biomass

Mass + water losses

Mass + water losses

Electricity

Heat???
CHALLENGES (CONCLUSIONS)

• Decentralised (@household) water & grey water system:
  – Requires community collaboration
  – Upfront cost may be a barrier, and payback is usually difficult to explain (as in case of SWH)

• Centralised AD Biodigester
  – @ household level easy to supply heat & cooking requirements
  – Centralising creates challenge of distribution
    • Piping infrastructure to housing expensive (make project unviable)
    • May look at central gas depot (requires feasibility assessment)

• Centralised Pyrolysis
  – Harvesting of invasive species must not encourage planting of those species
THANK YOU