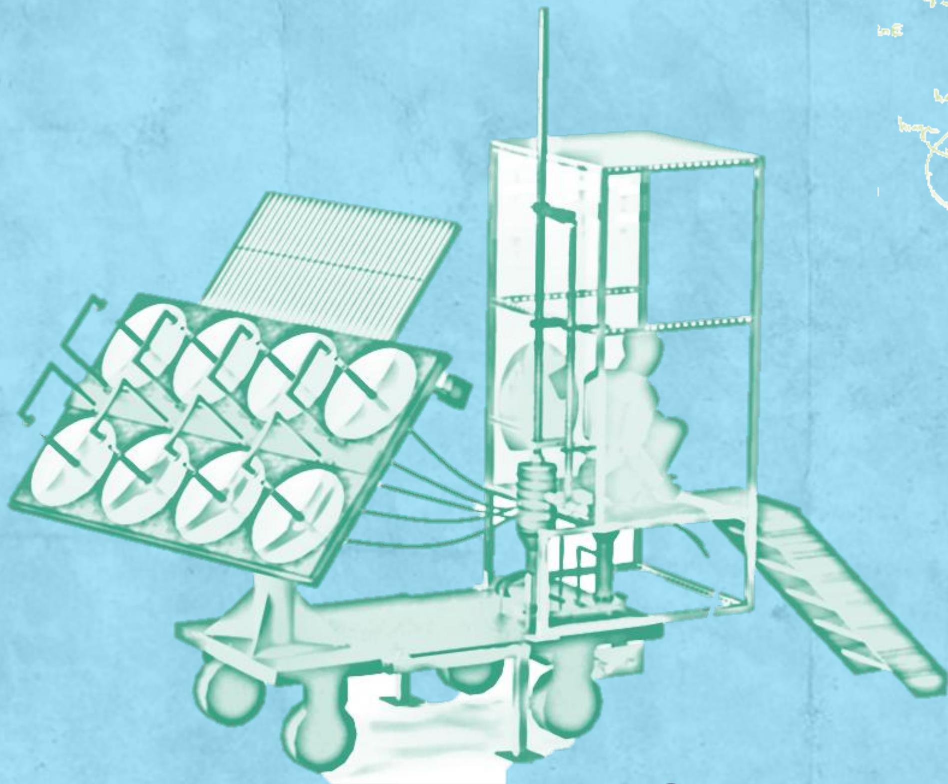
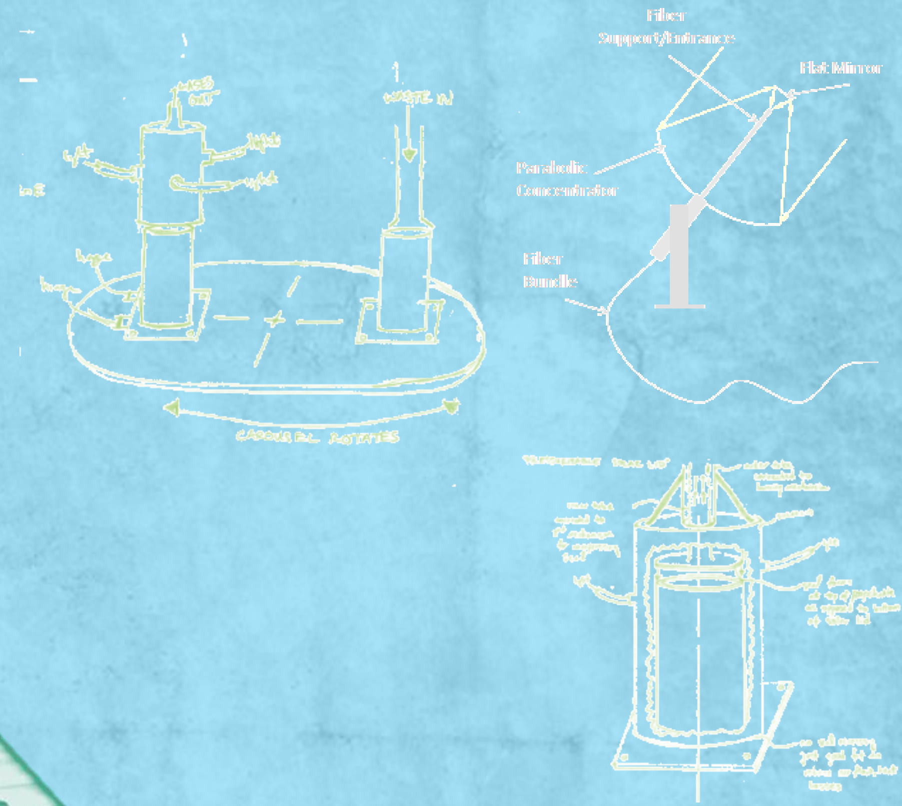
Sol-Char Sanitation

UNIVERSITY OF COLORADO **BOULDER**





Applications of Concentrated Solar-Energy in Innovative Sanitation Solutions

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FSM3

Hanoi, Vietnam

January 19-22, 2015

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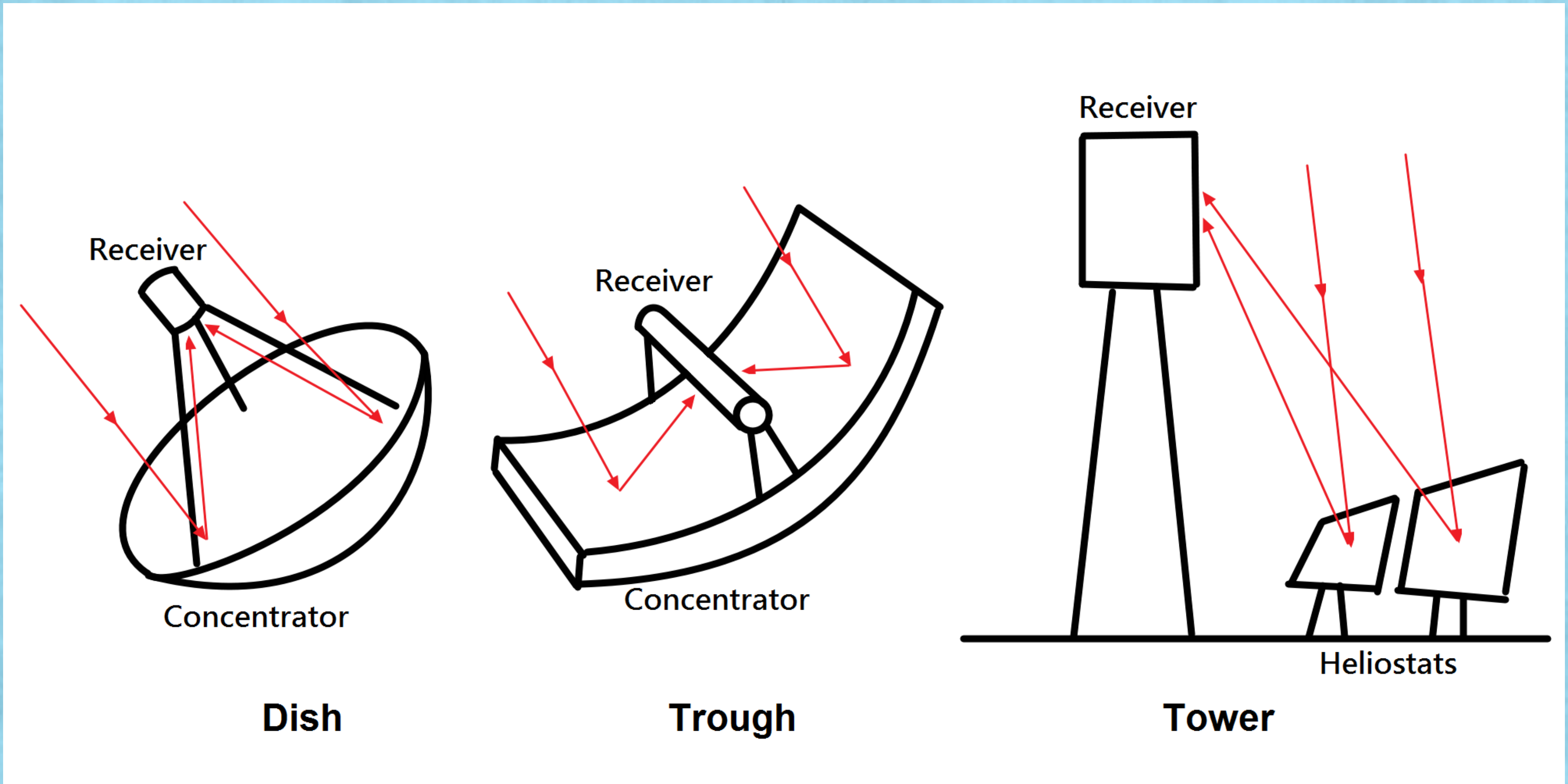
Overview: Sol-Char Sanitation Team

- SolChar: Al Weimer, R. Scott Summers, Al Lewandowski, Rita Klees, Richard Fisher, Tesfayohanes Yacob, Ryan Mahoney, Barbara Ward, Cori Oversby
- BrightSpace: Joseph DiMasi, Kevin Keilbach, Lauren Hafford, James Barry

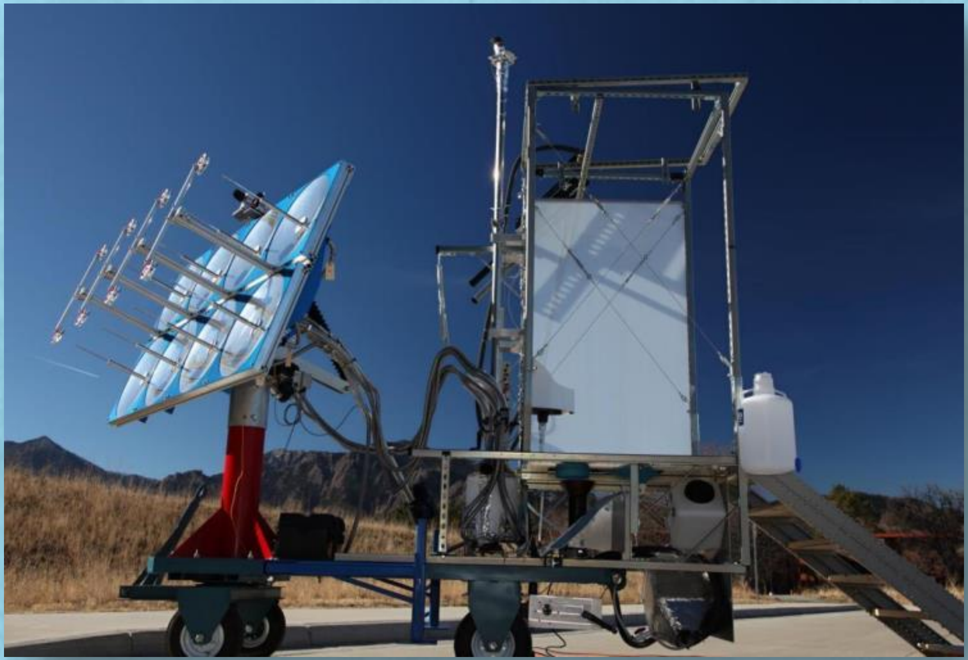
Types of Concentrated Solar Energy

- Three primary methods for concentrating and transmitting solar energy



http://solarpowers.info/know-concentrated-solar-power/

Sol-Char Concept Overview



Phase I
Reinvent The Toilet Challenge

Parabolic dishes concentrate solar energy

Fiber optics transmit energy to a pyrolysis reactor

Reactor thermally inactivates human waste

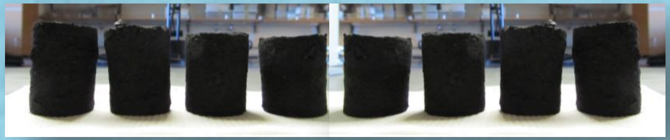
Useful end products are created

The Sol-Char toilet uses concentrated solar power to transform human waste into valuable end products

No water, No grid electricity, No external inputs, Creates useful byproducts

Advantages of Phase I Design

- Completely solar-based design
- Fiber optics decouple solar concentrators from the reactor
- High temperature applications safely contained within the reactor chamber
- Batch design allows for disinfection and waste stabilization in a single processing step
- System generates valuable end products
  - Char – solid fuel, soil amendment, adsorbent
  - Disinfected urine – fertilizer
  - Excess heat – home use or water heating



Key Challenges Identified in Phase I

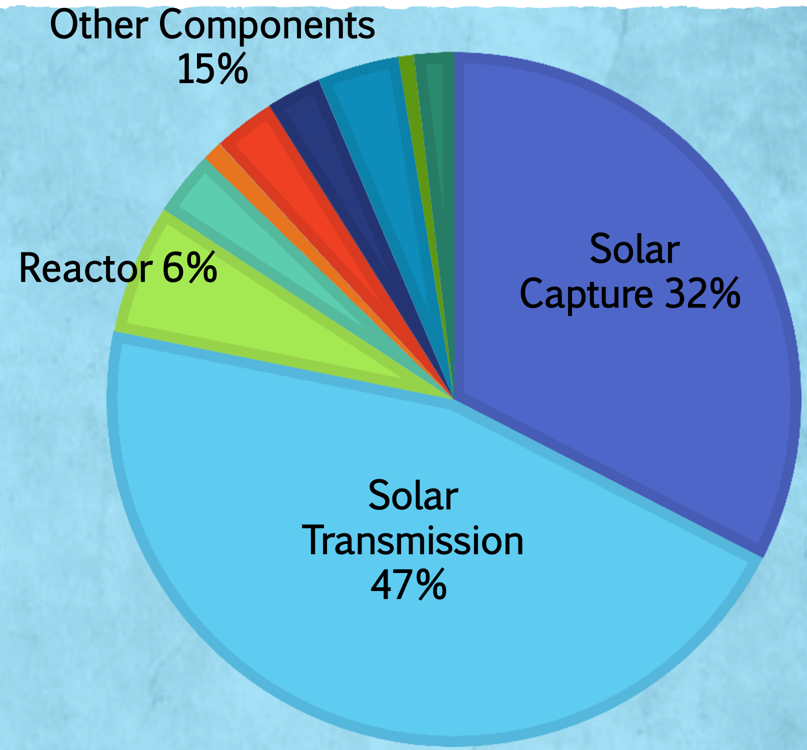
High Cost of Solar Concentrator

High Cost of Solar Transmission

Limited number of people served

Inability to process waste on cloudy or high pollution days

Durability and security concerns



Cost Breakdown for Phase I Design at production scale

- Production-scale unit cost: ~$11,900
- Most expensive components:
  - Fiber optics
  - Solar concentrators

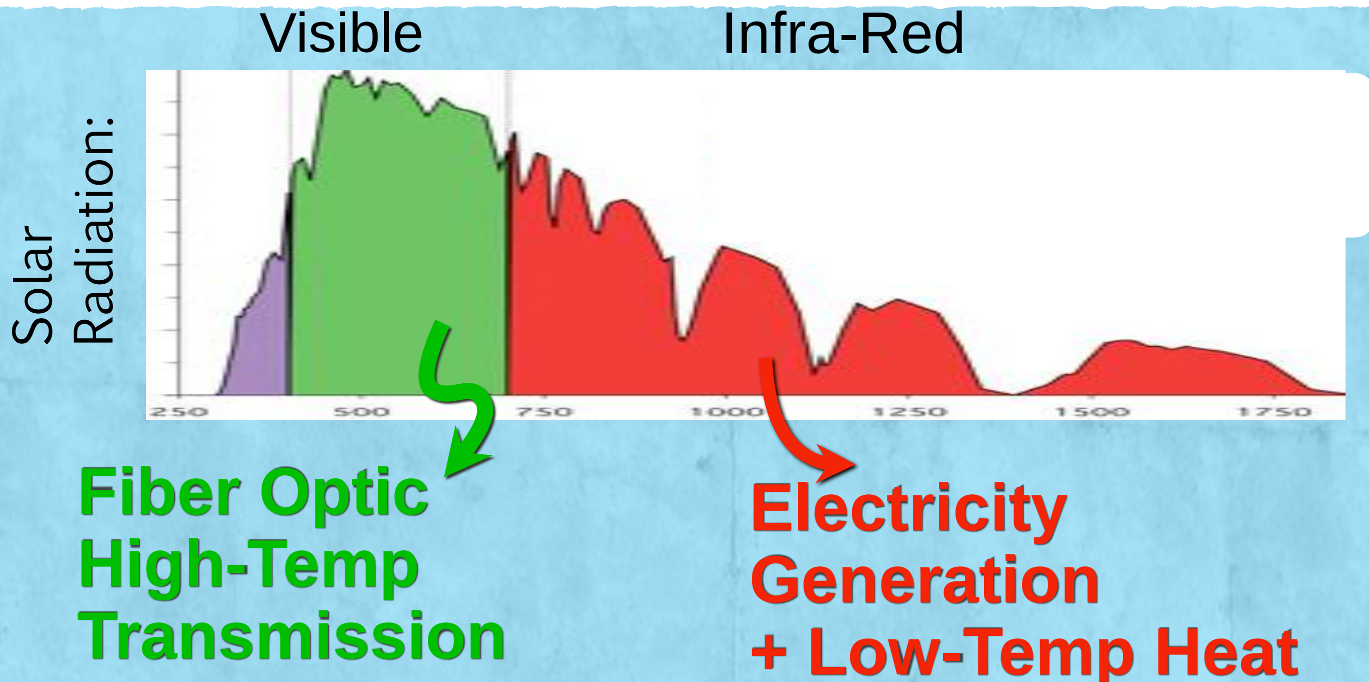
PI Challenges→ PII Advances

Technology Addresses Key P1 Program Challenges

	Colorado (CU) Phase 1 Key Program Challenge:	BrightSpace Partner Technology Enables:
1	High Cost of Solar Transmission	Fiber Optic Technology reduces Cost/Power by 10x.
2	High Cost of Solar Capture	Cost/Collection Area reduced by up to 8x from prior approach. New collectors utilize high volume production process with 30+ year lifetime
3	Limited # of People Served	High-density energy utilization services up to 100 people/day in single, standard (8'x8'x20') "Shipping Container" design.
4	Inability to Process Waste on Cloudy Days	Electrical 'co-generation' provides up to 15 kW-hrs of electricity with battery backup for offline (cloudy) operation. Higher energy density supports longer thermal storage.
5	Durability/Security Concerns	Protected collectors and rooftop mounting decrease failure modes. Caged system protection for Security. Low-profile.

BrightSpace

Phase II Technology Approach

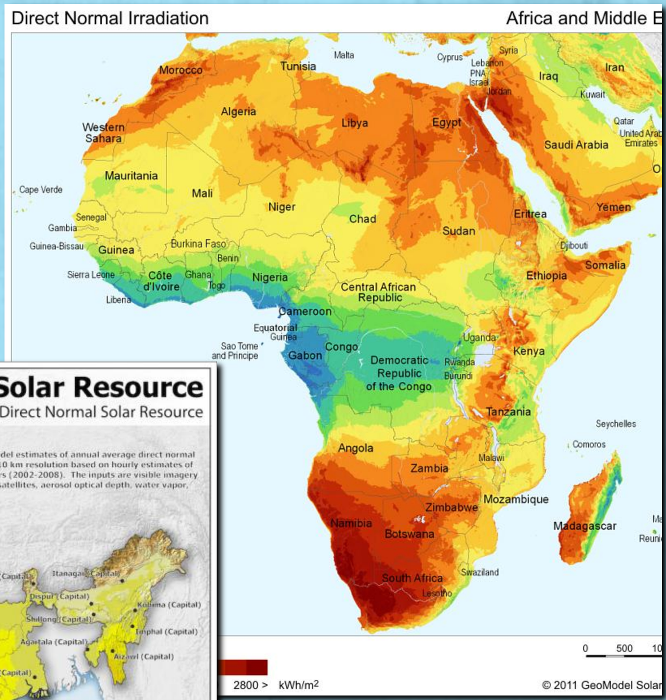


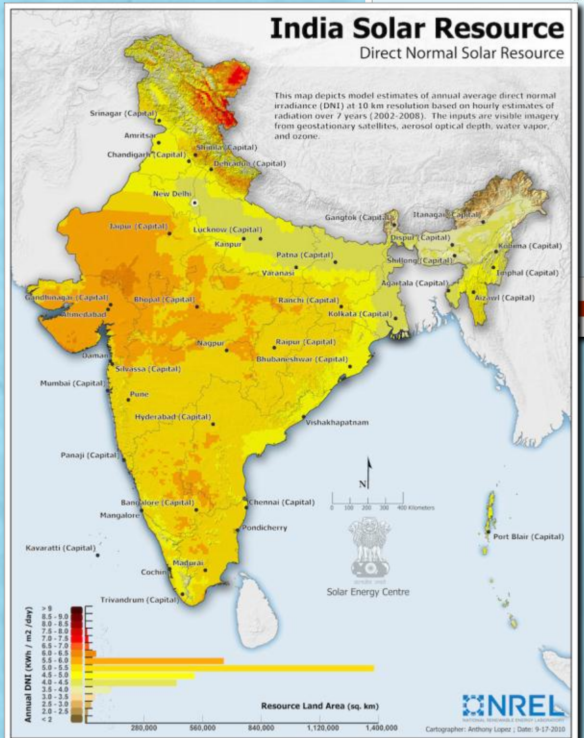
- Collects Solar Energy & Split Spectrum:
  - *Visible Portion - transmit through Fiber Optic Cables for Daylighting in Buildings*
  - *Infrared Portion - convert into electricity, up to 30% efficiency*
- Designed around Low-Cost and Long-Lifetime:
  - *For Commercial Buildings - require low cost, and high energy density*
  - *Breakthrough technology minimizes costs of collection, transmission & conversion*
  - *20-30 year lifetime for installations and minimizing service*

BrightSpace

FYI about ‘DNI’

- “D.N.I.”
  - *= “Direct Normal Insolation”*
  - *Solar energy, per m², per day*
  - *Measured in “kWhrs/m²/day”*
- CU P1 assumed 3.2
  - *Overly conservative*
  - *<u>Much</u> better in Africa & India!*
- Real Values:
  - *<u>India</u>: 75% of country 5.0~6.0*
  - *<u>South Africa</u>: mostly 6.0~7.0*
  - *<u>East Africa</u>:   mostly 5.0~6.0*
  - *<u>West Africa</u>: mostly 4.0~5.0*





Cost Reduction

		Univ. of Colo. Phase I	BrightSpace Approach	Improvement
Fiber Transmission				
Cost / Optical Power	*($/$W_o$)*	6.25	0.63	10x
Unique fibers to reactor for even heating	*(#)*	8 fused bundles	*24 or 48 cables (w/ many fibers each)*	*(a lot)*
Solar Capture Area				
Cost of Solar Collection Area	*($/$m^2$)*	$25(film) + $100 (substrate & framing) = $125	$15 ~ $30	**4-8x**

Power Delivery Comparison

(Assumptions: 1k/yr production, 800kJ/person/day, DNI = 5.0)

		Univ. of Colo. Phase I	BrightSpace Small	BrightSpace Large
# of Collectors	*(#)*	8	24	48
Peak Power / Collector	*(W_o)*	93	115	115
Total System Peak Fiber Power Delivery	*(W_o)*	750	2,730	5,470
Daily Fiber Light Energy	*(MJ)*	13.4	52.4	104.8
PreHeat / Disinfection 50°C Energy *(@50% eff)*	*(MJ)*	0	32.5	65
Total Energy Delivered	*(MJ)*	13.7	84.9	169.8
# of People Serviced	*(#)*	6	38	76
10yr - $/Person/Day	*($)*	**$0.45**	**$0.02**	**$0.02**
Electricity Generation/Day	*(kW-hrs/d)*	none	5	10

Collector System Options

(Assumptions: CU P1 Reactor Efficiency = 35%, 800kJ/person/day)

Small System Scenario

- *24 Solar Collectors*
- *Fits Over Container Footprint*
- *Electricity Generation:*
  - *3~7.5 (kWhr/day)*

Large System Scenario

- *48 Solar Collectors*
- *Extend Footprint w/ Rain Awning*
- *Electricity Generation:*
  - *6~15 (kWhr/day)*

DNI	People Served *(#)*	Cost of Use / Person / Day *($)*	Electric Generated *(kW-hrs/d)*
3.0	23	*$0.034*	3.2
4.0	31	*$0.025*	4.2
5.0	38	*$0.020*	5.3
6.0	46	*$0.017*	6.4
7.0	54	*$0.014*	7.4

DNI	People Served *(#)*	Cost of Use / Person / Day *($)*	Electric Generated *(kW-hrs/d)*
3.0	46	*$0.032*	6.4
4.0	62	*$0.024*	8.5
5.0	76	*$0.019*	10.6
6.0	92	*$0.016*	12.7
7.0	108	*$0.014*	14.8

Phase II Approach – Tailored Treatment

Treatment Level 1:

DISINFECTED FECAL SLUDGE
for safe transport and disposal

DISINFECTED URINE
for liquid fertilizer

Treatment Level 2:

DRIED FECAL SLUDGE
for fertilizer or industrial fuel

DISINFECTED URINE
for liquid fertilizer

Treatment Level 3:

CHAR
for soil amendment or briquetting

DISINFECTED URINE
for liquid fertilizer

Business Model Evolution

Providing Electricity, Showers, Char, etc. allows new Opportunities

Services Encourage Adoption

- *electricity - enabling product*
- *hot showers*
- *biochar/briquettes for sale*
- *size provides village 'center', and enables private business caretaker and security resources*
- *could scale up or down*
- *'poop credits' offered at use   to reduce cost of other   desired services encourage adoption*

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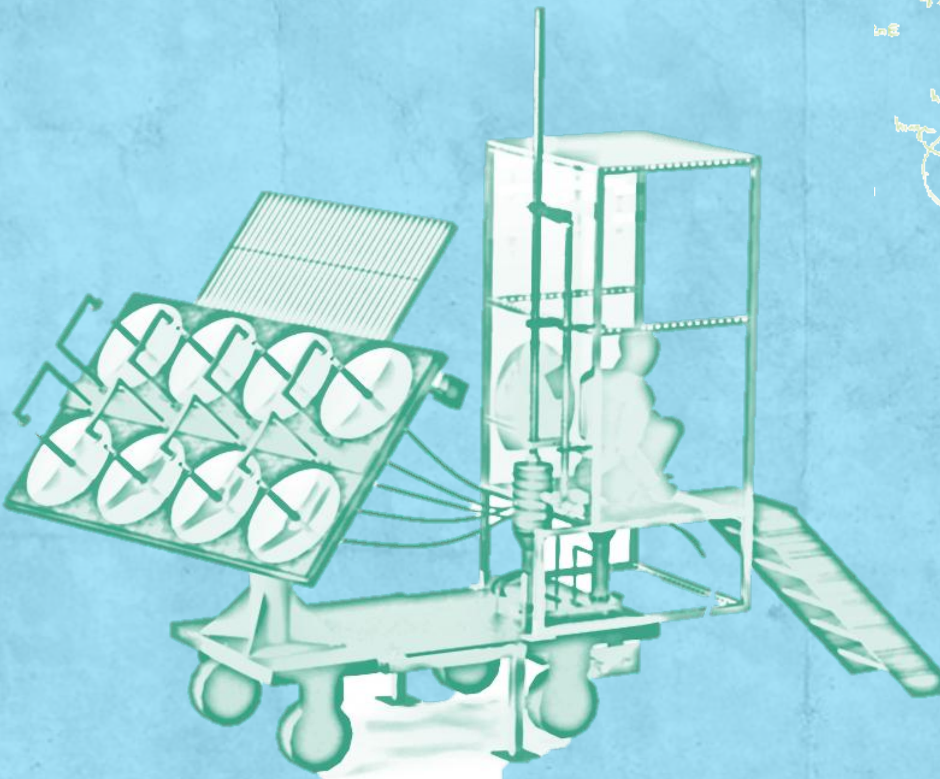

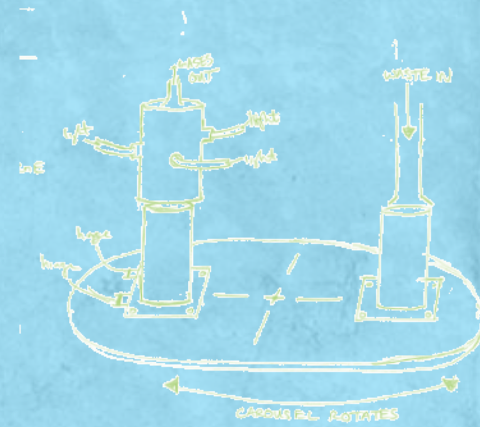

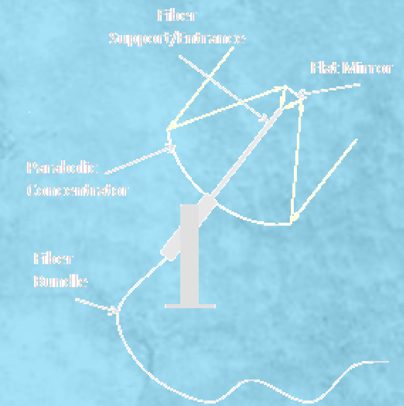

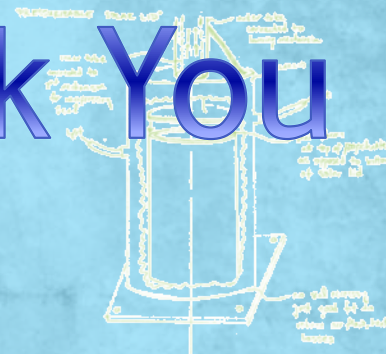

Thank You

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Phase II Approach – Design Considerations

Available Sunlight
- Year-round
- Seasonal sun
- Atmospheric pollution

User Scale
- Family, private use
- Household shared
- Public shared
- Municipal treatment

Setting
- Urban,
- Peri-urban/Informal settlements
- Rural

Markets for End Products
- Agricultural
- Household energy
- Industrial energy

Supply Chain Maturity
- Mature: available machine shops, electronics shops, skilled technicians
- Immature: needs transportation infrastructure for imports







Proved concept and developed a working research prototype. Phase I success!

Need to partner with industry/research to reduce costs and improve efficiency.

Consider modular treatment system with flexibility in treatment levels to improve economics, and provide useful end products.