Biochar for carbon sustainability and waste management

Stanford / Climate Foundation Biochar Team

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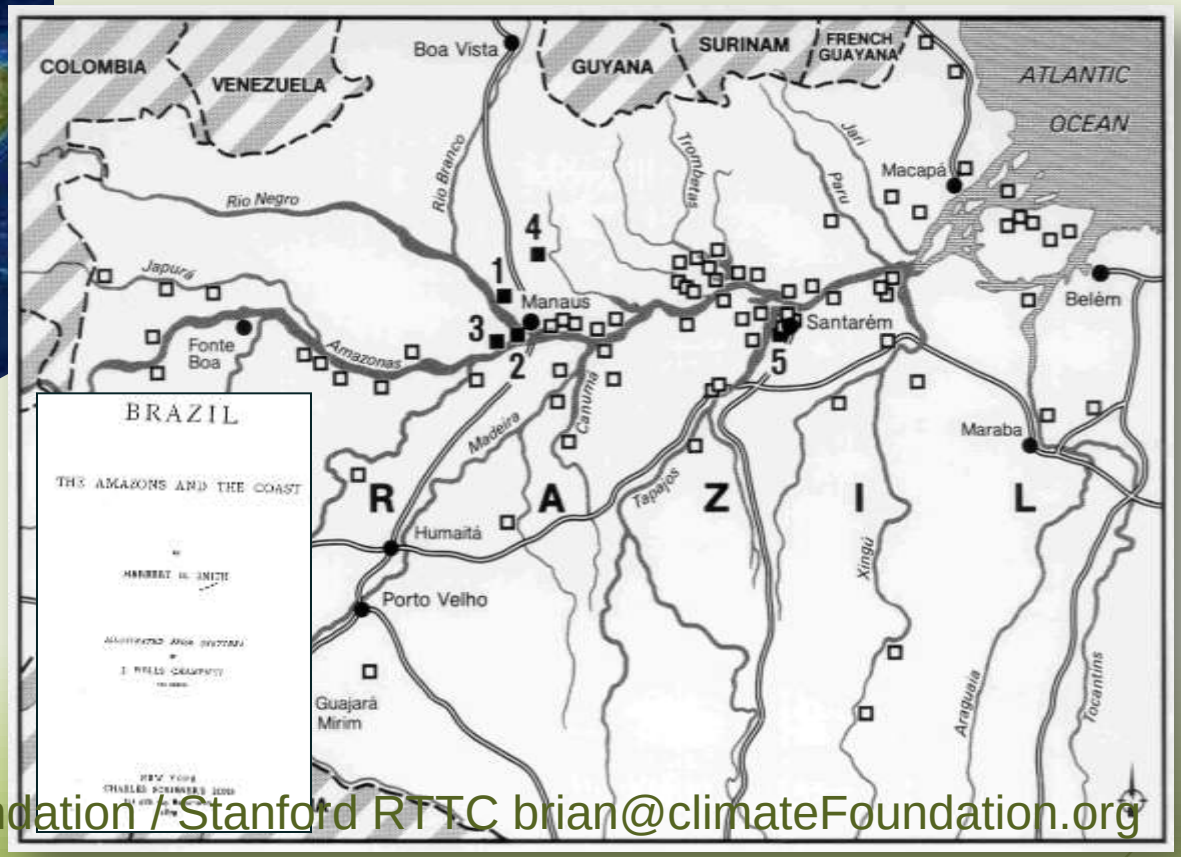
What is Biochar? Prehistorically Proven

Numerous catalogued prehistoric sites with anthropogenically improved soils.



The topsoil from these sites is mined and sold for ~$1/kg

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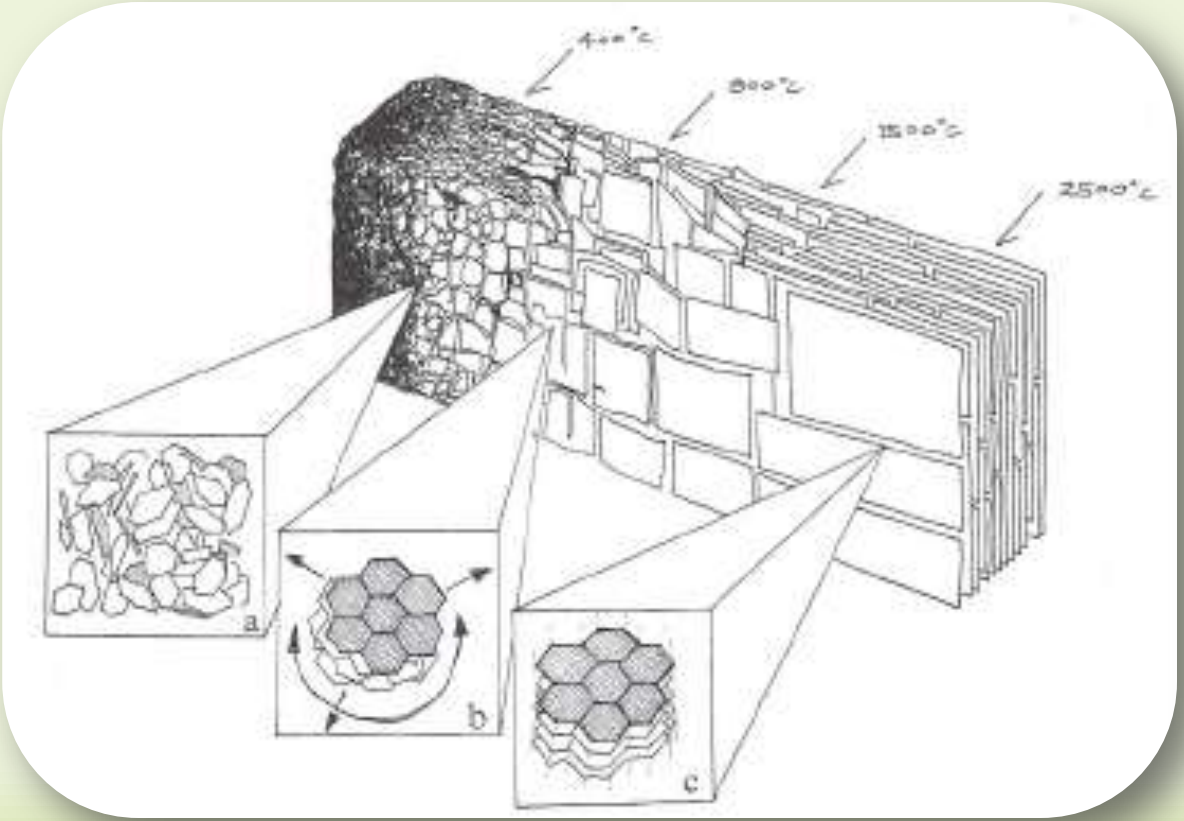
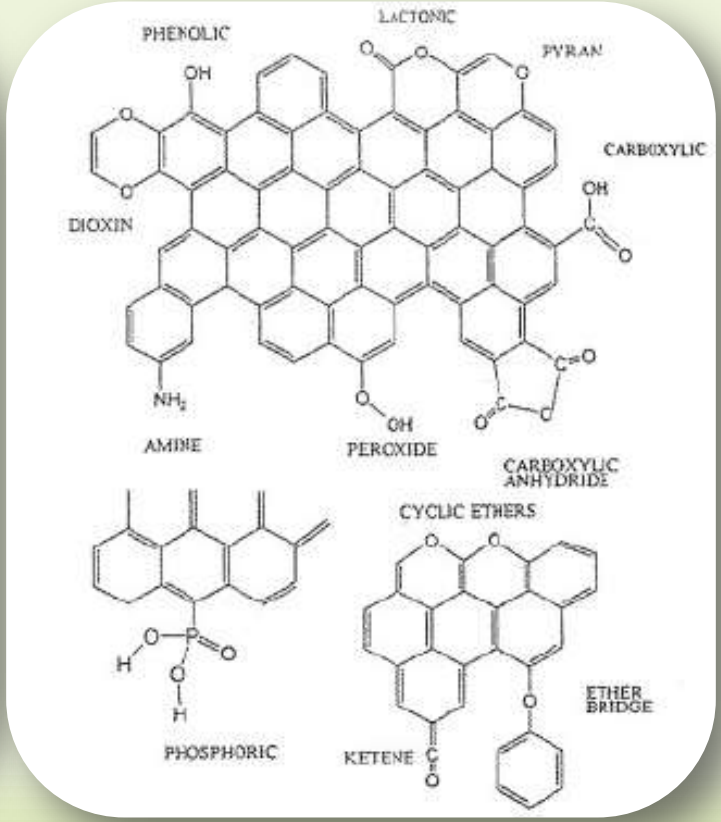
Thermophysical Properties





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Highest Heating Temperature (HHT)

Cation Exchange Capacity (CEC)

Lehman ... *Environmental Management* (2009)

It's all about H, C, N, and O

Cellulose, Hemicellulose, and Lignin can form aromatic sheets…

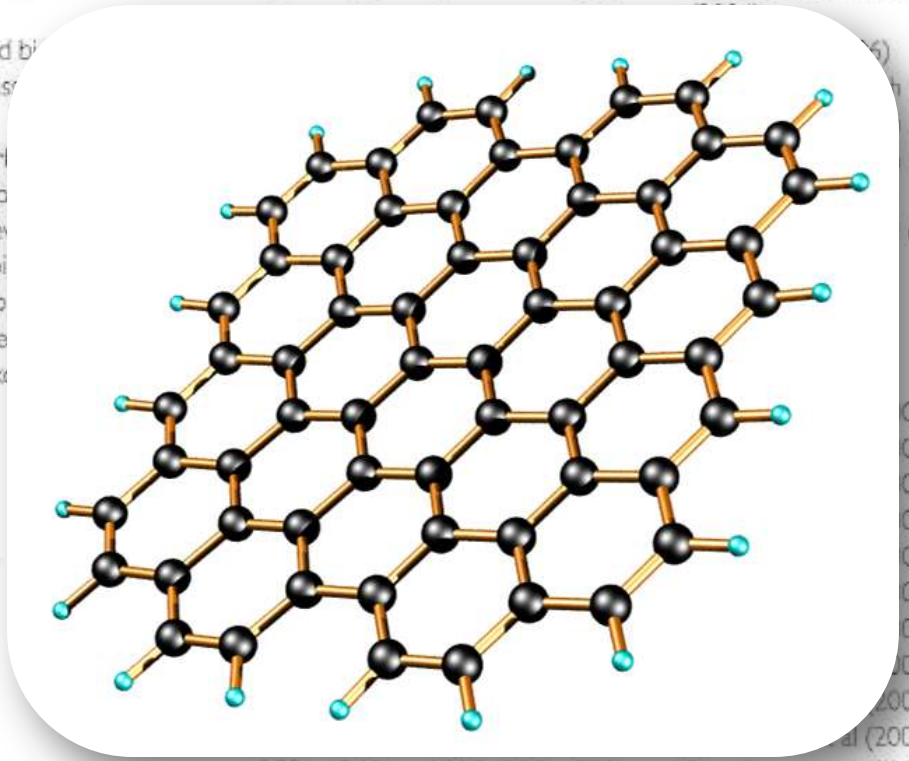
But how much?

$$C_1H_{1.4}O_{0.6}$$

$$C_1H_{1.4}O_{0.6} \xrightarrow{Heat} \Rightarrow$$

$$xH_2 + C_{0.6}O_{0.6} + \tilde{C}_{0.4}$$

33% C by mass



Material	H/C	O/C	C/N	H/O	OC (mg g^{-1})	Reference
200°C wood biochar	1.02	0.61	500	1.67	525	Baldock and Smernik (2002)
250°C wood biochar	0.51	0.44	370	1.15	610	Baldock and Smernik (2002)
300°C wood biochar	0.46	0.4	214	1.12	628	Baldock and Smernik (2002)
350°C wood biochar	0.54	0.32	269	1.7	673	Baldock and Smernik (2002)
Wood biochar	0.07		105		540	Fernandes et al (2003)
Pea-straw biochar	0.08		25		430	Fernandes et al (2003)
Vegetation fire residue	0.17		40		40	Fernandes et al (2003)
Rapeseed cake	0.5	0.3	11		550	Özçimen and Karaosmanoglu
350°C wood bi						
Charred gras						(1995)
Soot						(1995)
Charred bark						(1995)
Hardwood b						
Pyrolysed se						(2004)
Rice straw bi						
Sugar cane b						
Coconut she						
Soybean cak						
Peas 190°C						04)
Peas 220°C						04)
Peas 235°C						04)
Peas 250°C						04)
Peas 270°C						04)
Peas 290°C						04)
Peas 310°C						04)
Peas 340°C						04)
Peas 370°C						004)
Peas 400°C						al (2004)
Peas 440°C	0.55	0.12	14.53	0.29	770	Braadbaart et al (2004)
Peas 500°C	0.45	0.11	17.02	0.25	800	Braadbaart et al (2004)
Peas 600°C	0.30	0.05	13.08	0.35	850	Braadbaart et al (2004)
Peas 700°C	0.22	0.06	20.71	0.23	870	Braadbaart et al (2004)
Cellulosic biochar 300°C	1.76	0.85		0.13	440	Shafizadeh and Sekiguchi (1983)
Cellulosic biochar 350°C	1.05	0.44		0.15	599	Shafizadeh and Sekiguchi (1983)
Cellulosic biochar 400°C	0.74	0.18		0.25	765	Shafizadeh and Sekiguchi (1983)

Lehman … *Environmental Management* (2009)

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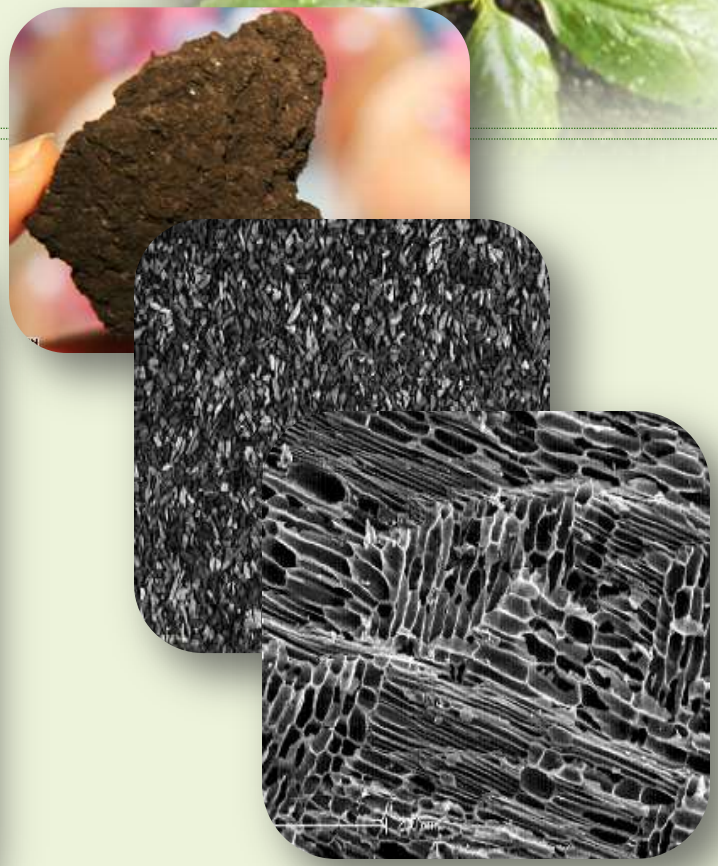
Why is Biochar important?

- Reduces fertilizer use
- Renders soluble nitrate fertilizer insoluble
- Reduces water use
- Reduces runoff
- Multiplies the productivity per unit fertilizer added
- Keeps nutrients near the plant roots longer

Terre Pretan soils are the most productive

Pre-Columbian (950 to 450 BC)



Mychorrizal Fungi

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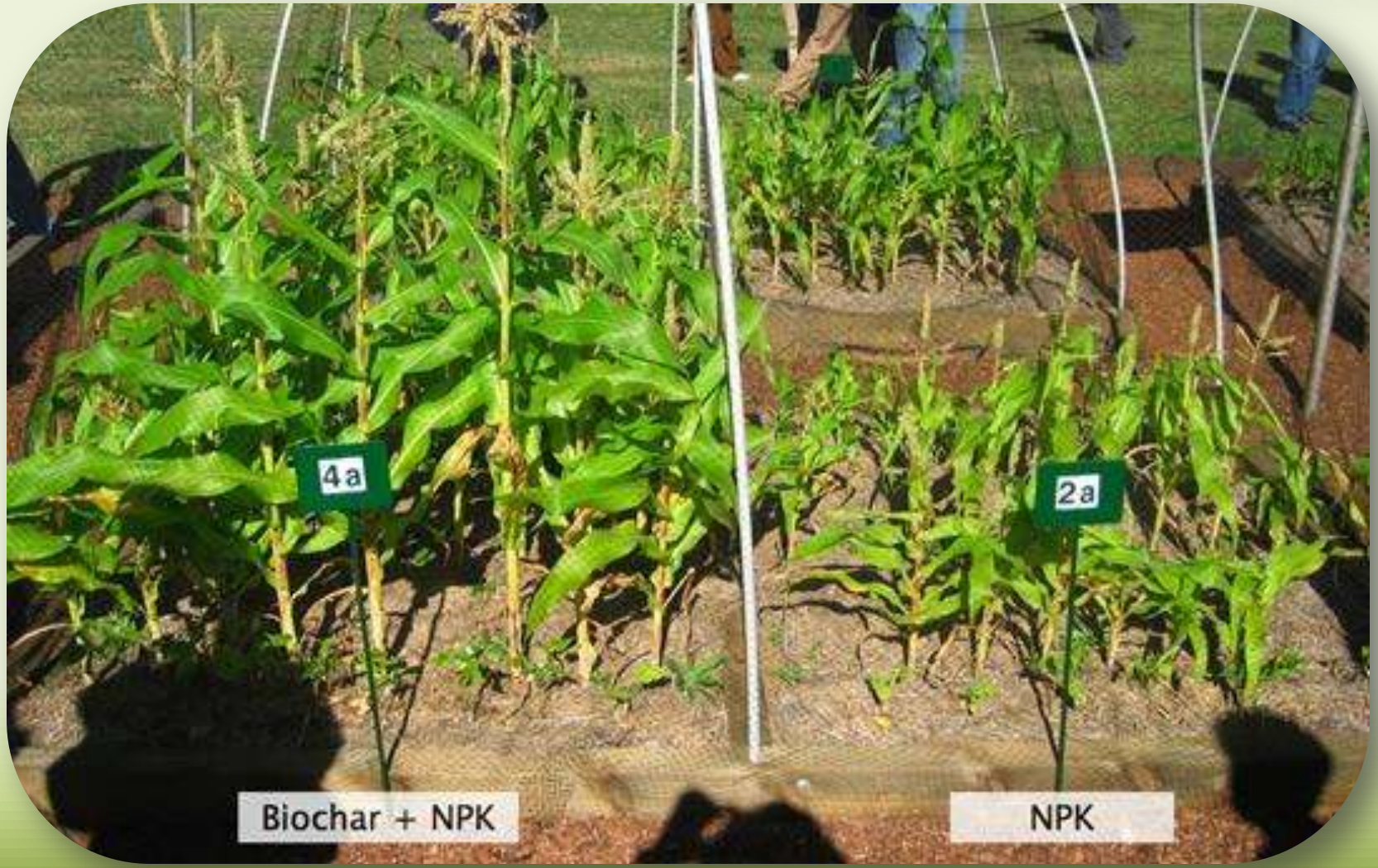
Lehman… *…d Soil* (2003)

BioChar + NPK vs. NPK



Can Biochar be made from human solid waste?

Urine Diverting Dry Toilets

http://envirosan.co.za/products/

Sanergy squat plate UDDT design

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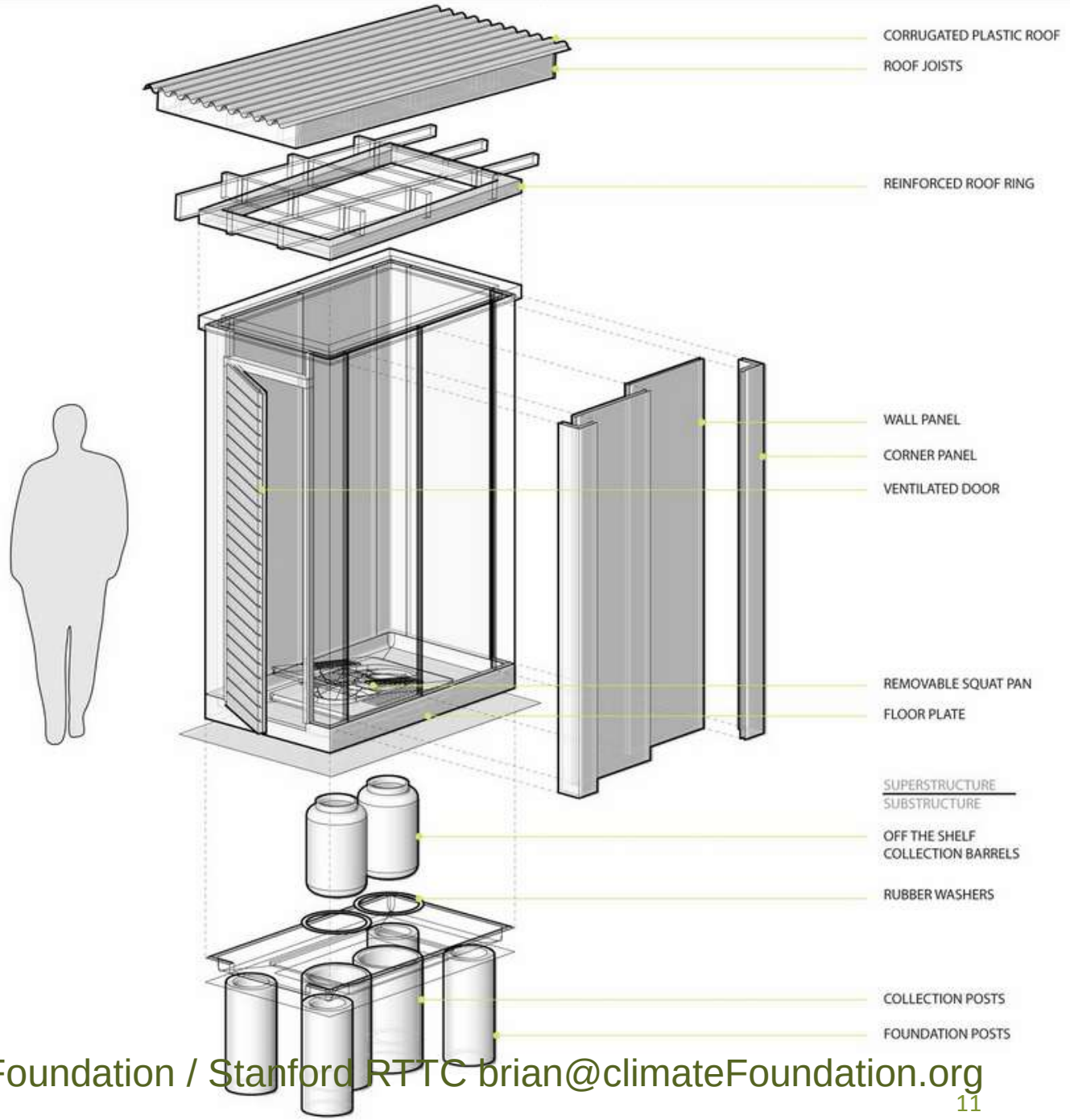
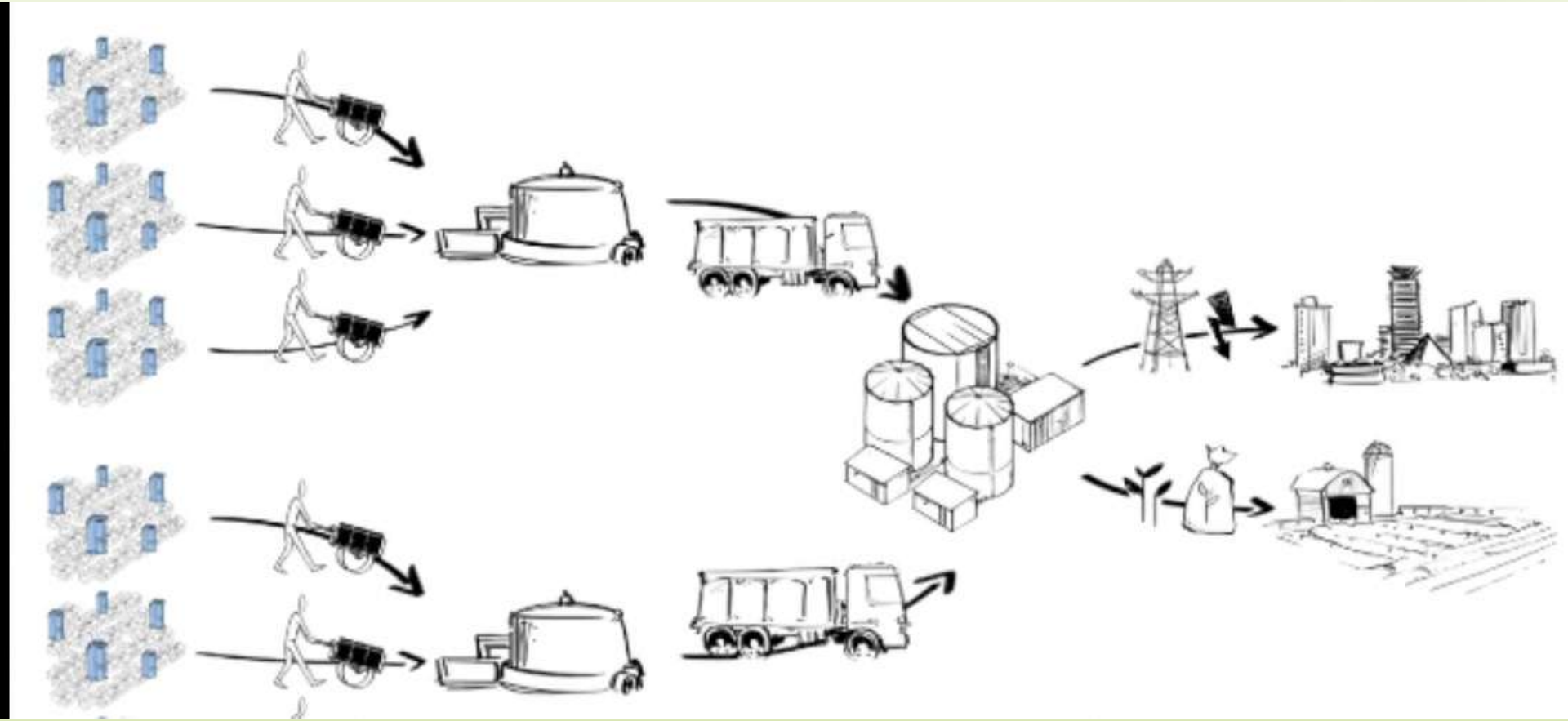
Sanergy Sanitation Units

Sanergy Sanitation Unit

- Material
- Costs of
- <$200
- Per unit

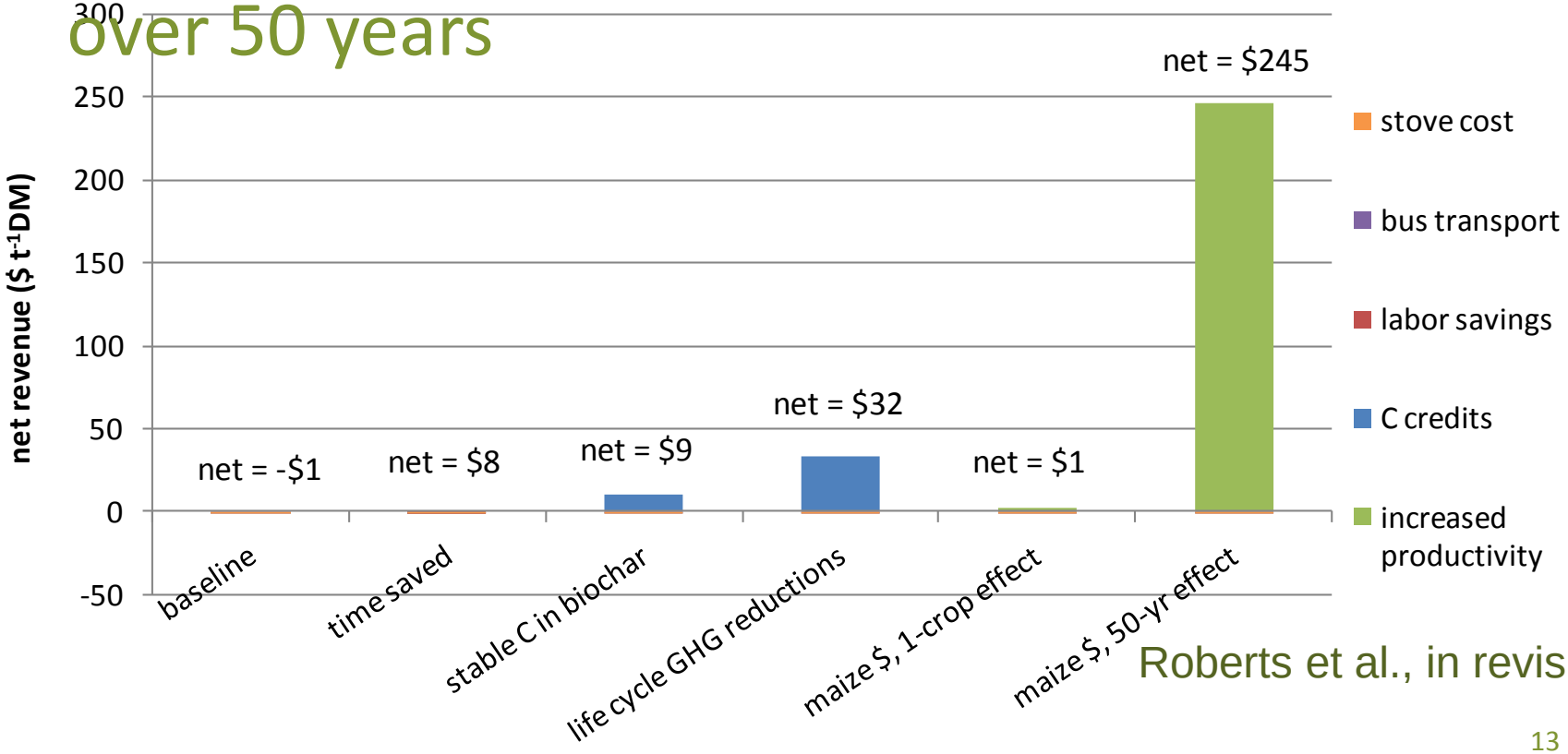


Spreading adoption of UDDTs
Saner.gy business model:



Soil Capital

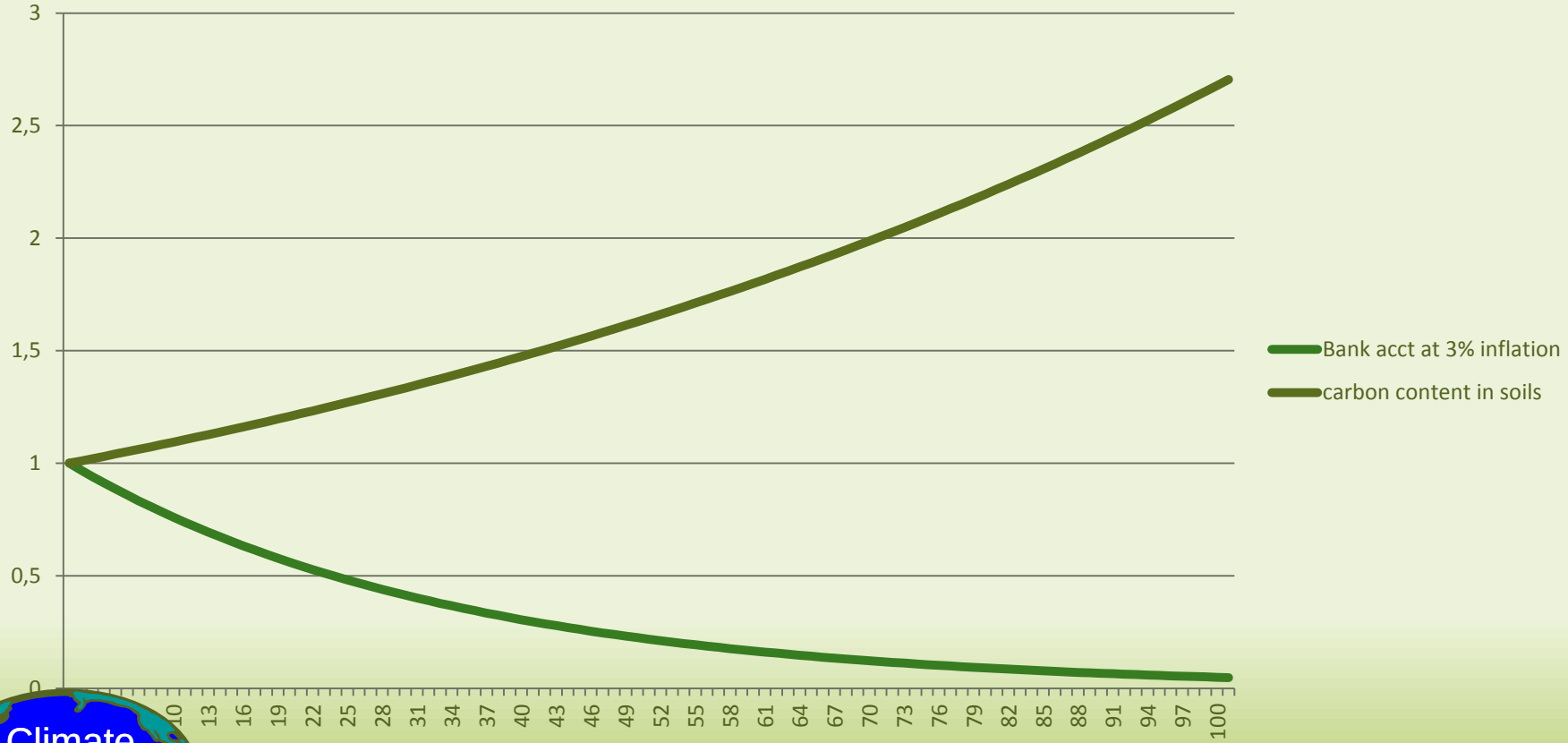
- Cornell Prof. Johannes Lehmann and Dr. Kelli Roberts reported 10x benefit of soil carbon over 50 years



Roberts et al., in revision

Biochar: black gold

- Bank account @ 3% inflation vs. biochar @ 1%



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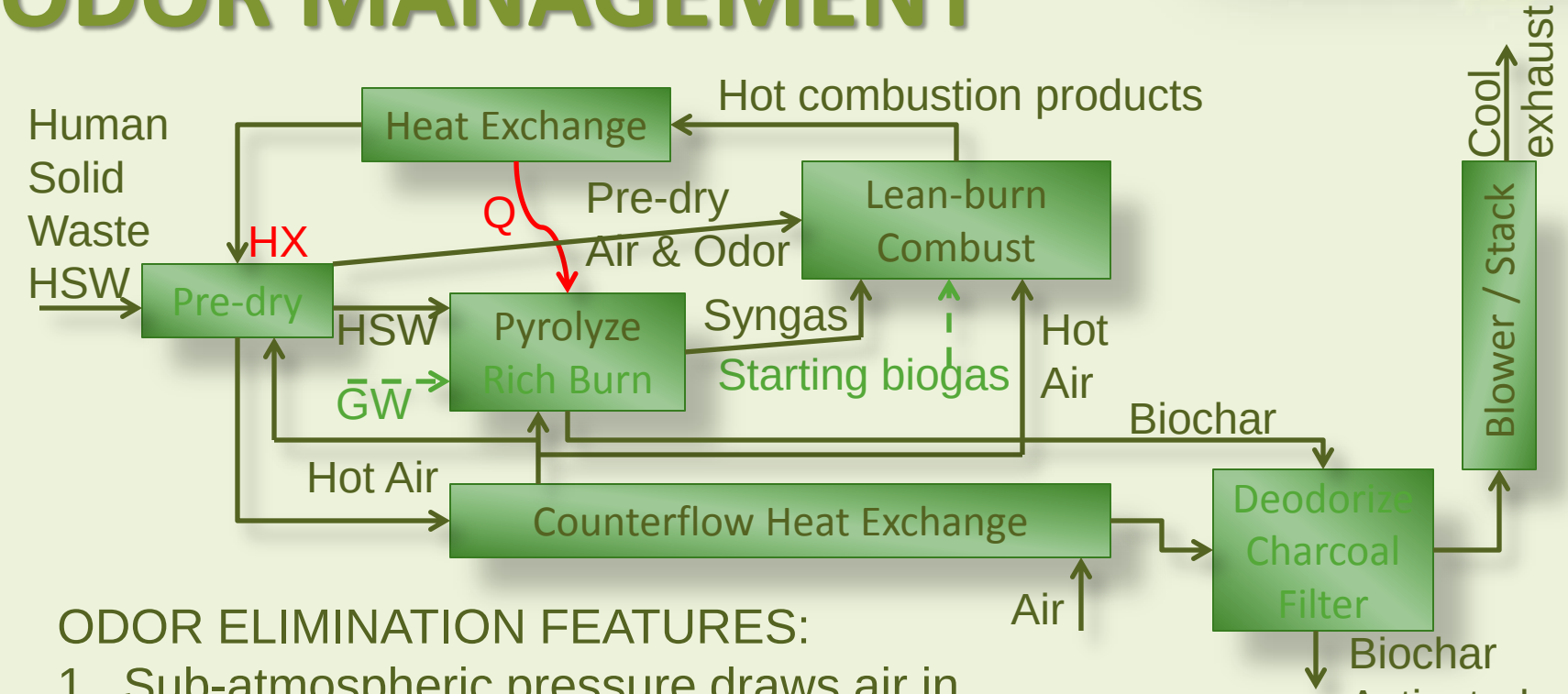
Making Biochar from HSW efficiently and with ODOR MANAGEMENT



ODOR ELIMINATION FEATURES:

1. Sub-atmospheric pressure draws air in
2. Lean burn post-combustion eliminates the odors
3. Biochar activated charcoal filter cleans the exhaust of odors,

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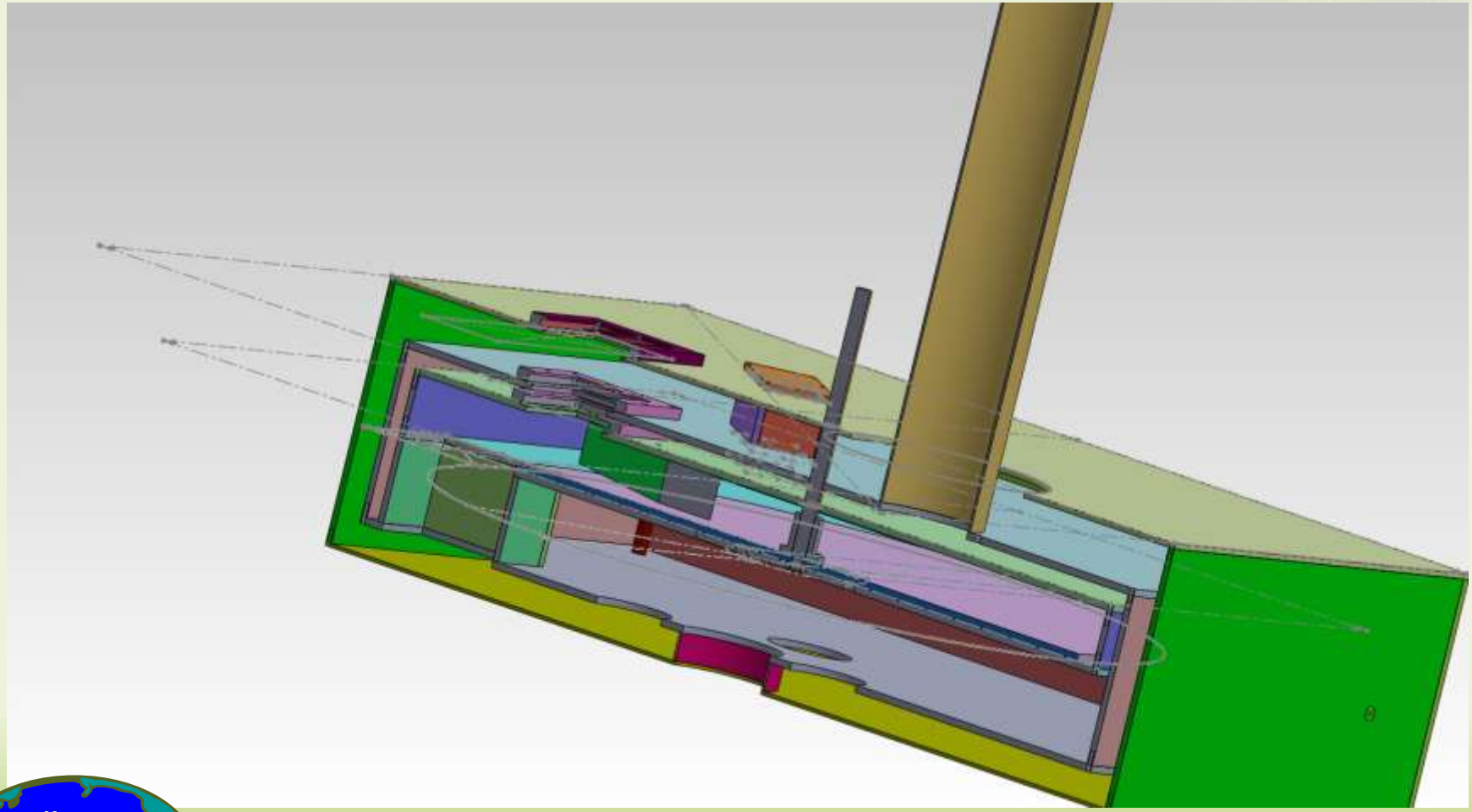
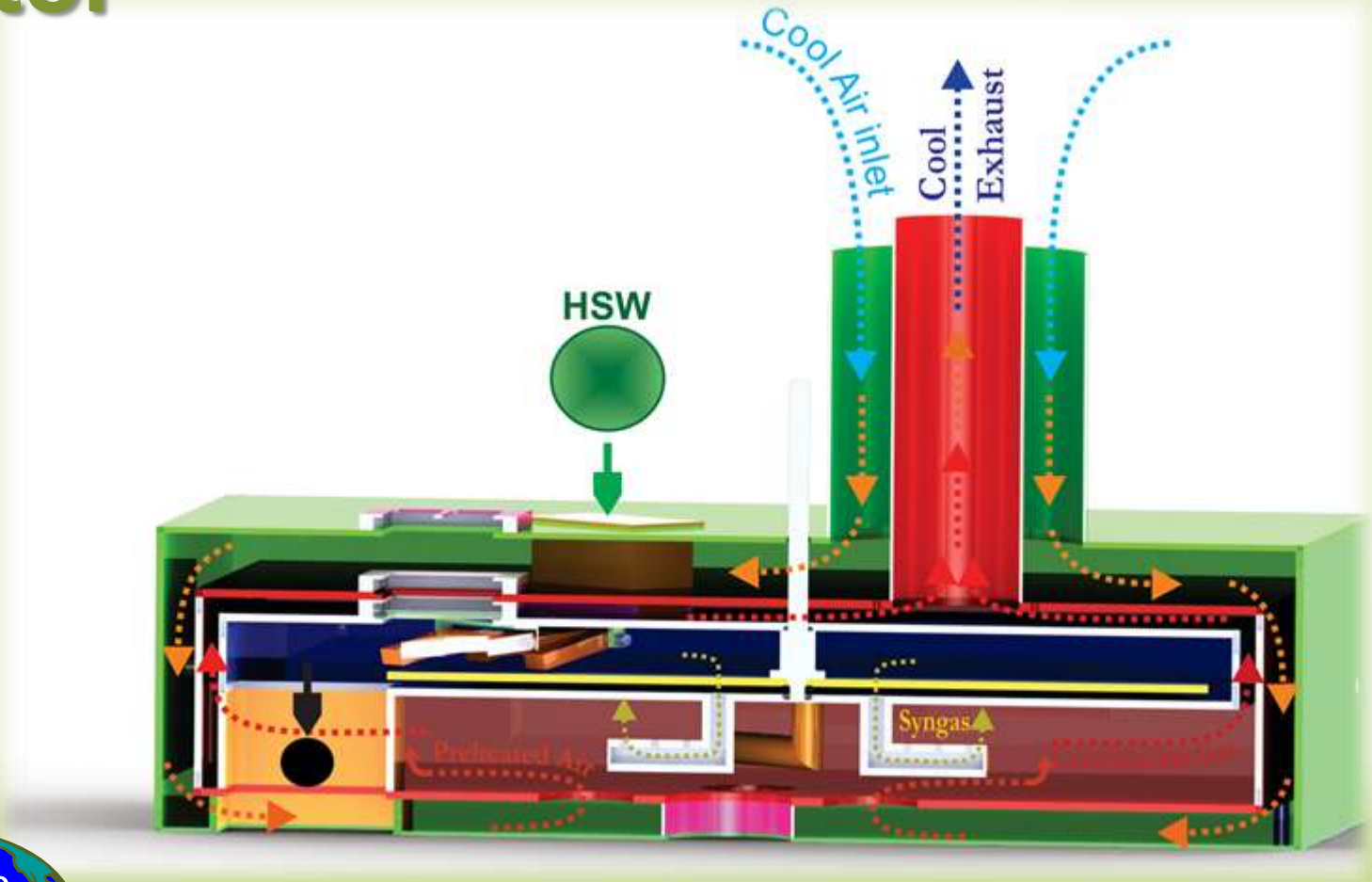
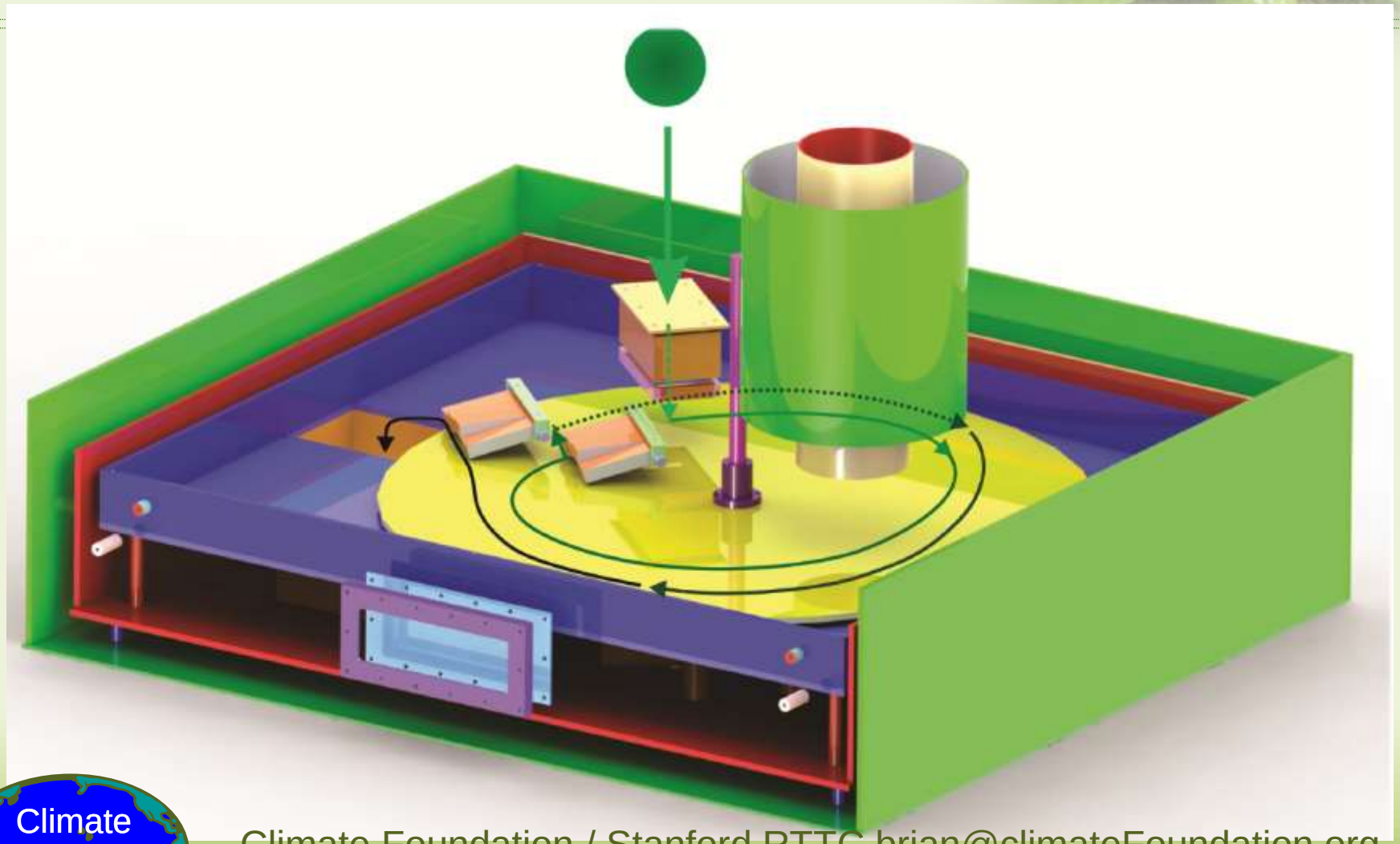
Biochar Reactor Mechanical Design



Rendered cross-sectional view of the biochar reactor



How the pyrolyzing turntable works



Solid Waste Biochar Reactor

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Solid Waste Biochar Reactor

Energy Budget: 60% H2O

- +8.00 MJ/kg heat generated from combustion
- -1.35 MJ/kg heat of vaporization at 60% H2O
- -0.18 MJ/kg thermal capacity to warm water
- -0.14 MJ/kg warming dry fecal solids to 100 C
- -0.52 MJ/kg heating steam and solids to 350C

- +5.81 MJ/kg remaining thermal energy remaining after HSW heating and vaporization


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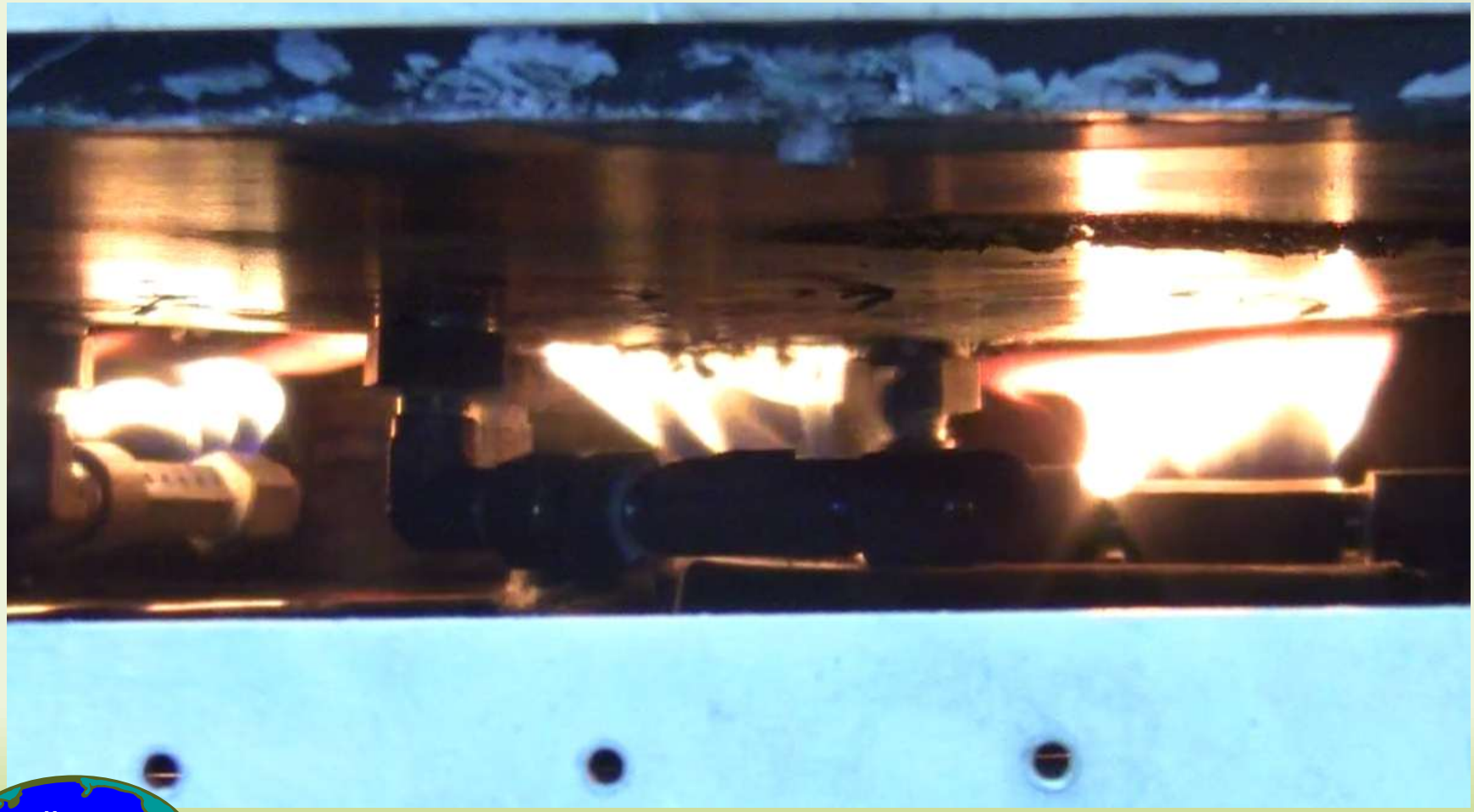
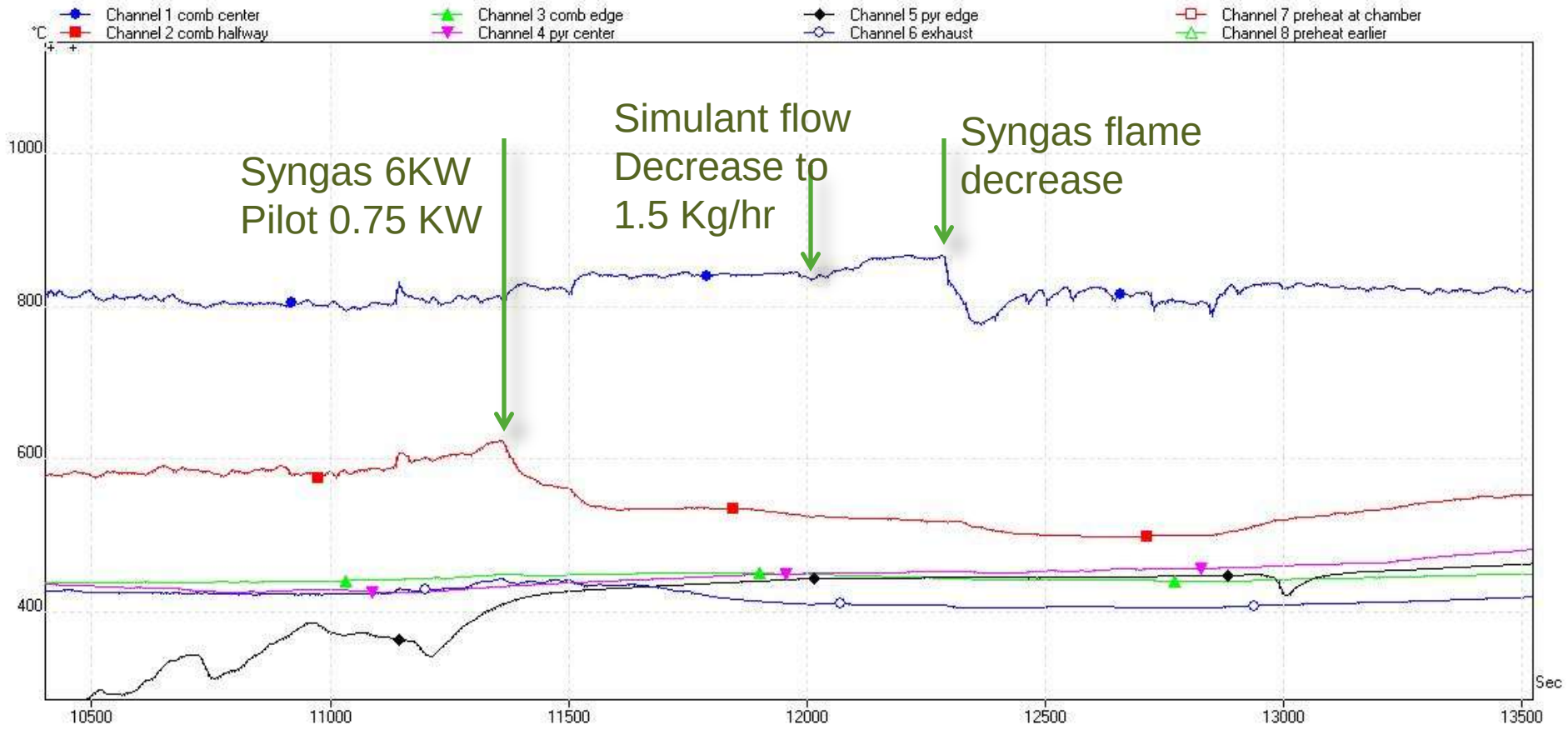
Syngas combustion



Syngas combustion: expanded injector nozzles

Results: NASA Simulant 51% H_2O 3 Kg/hr, decrease to 1.5Kg/hr



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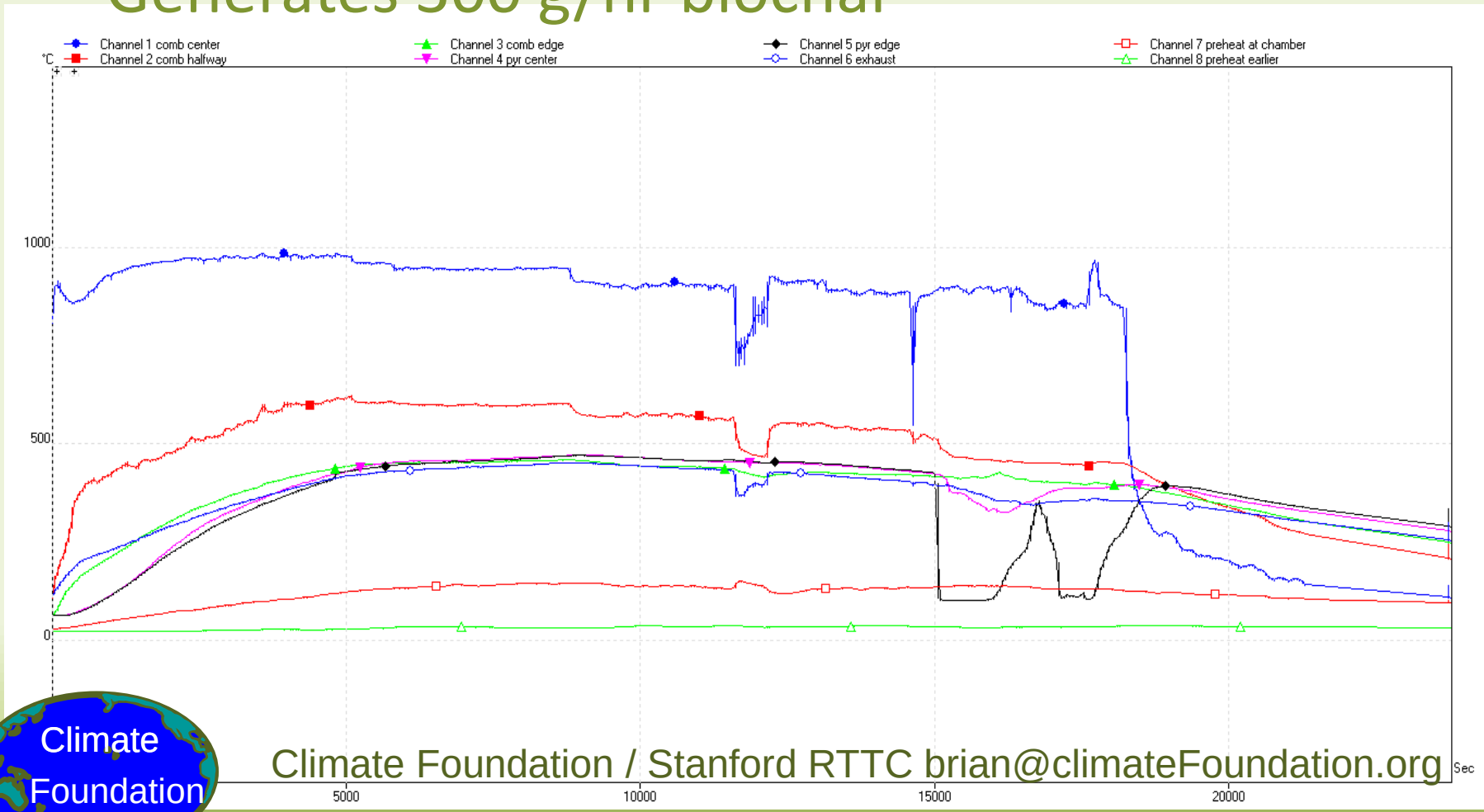
Results: NASA Simulant 60% H_2O 30-minute burn @ 3 Kg/hr

- Generates 300 g/hr biochar



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Showcase: US Biochar 2012

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Results:

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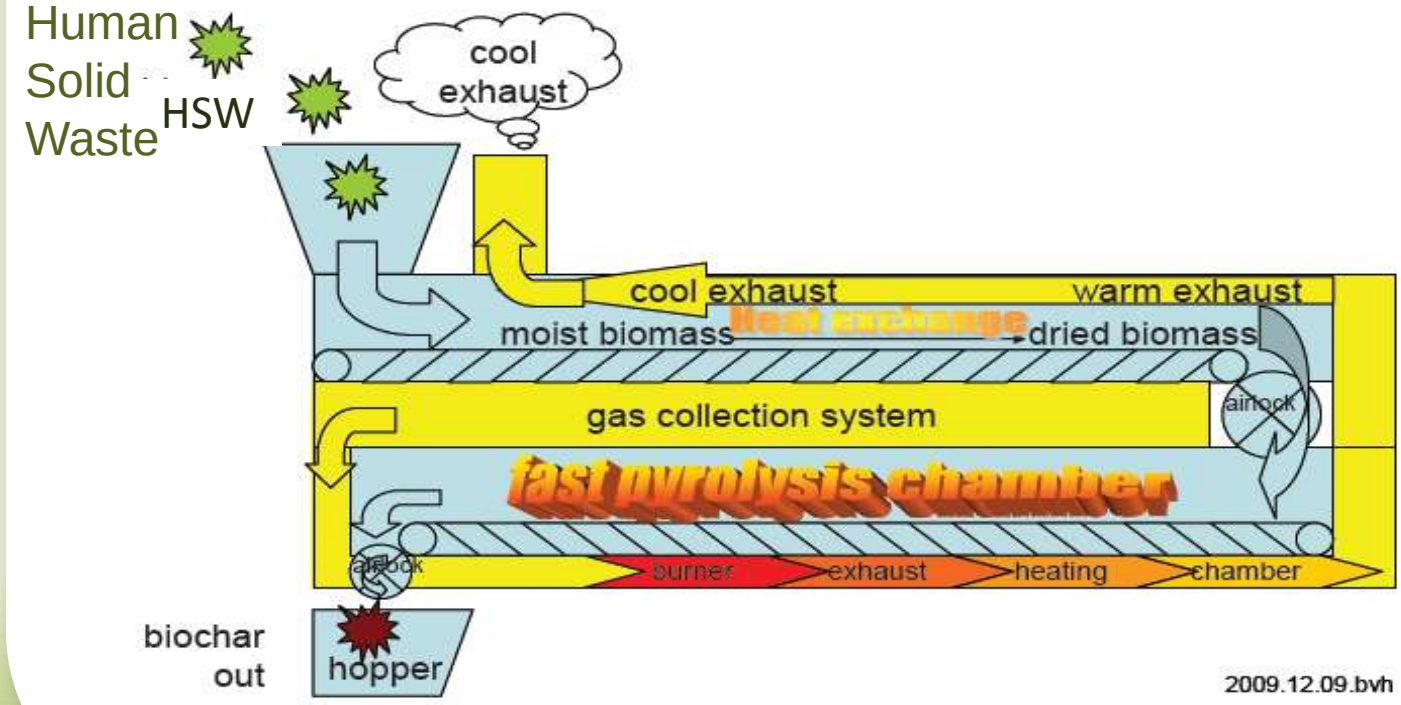
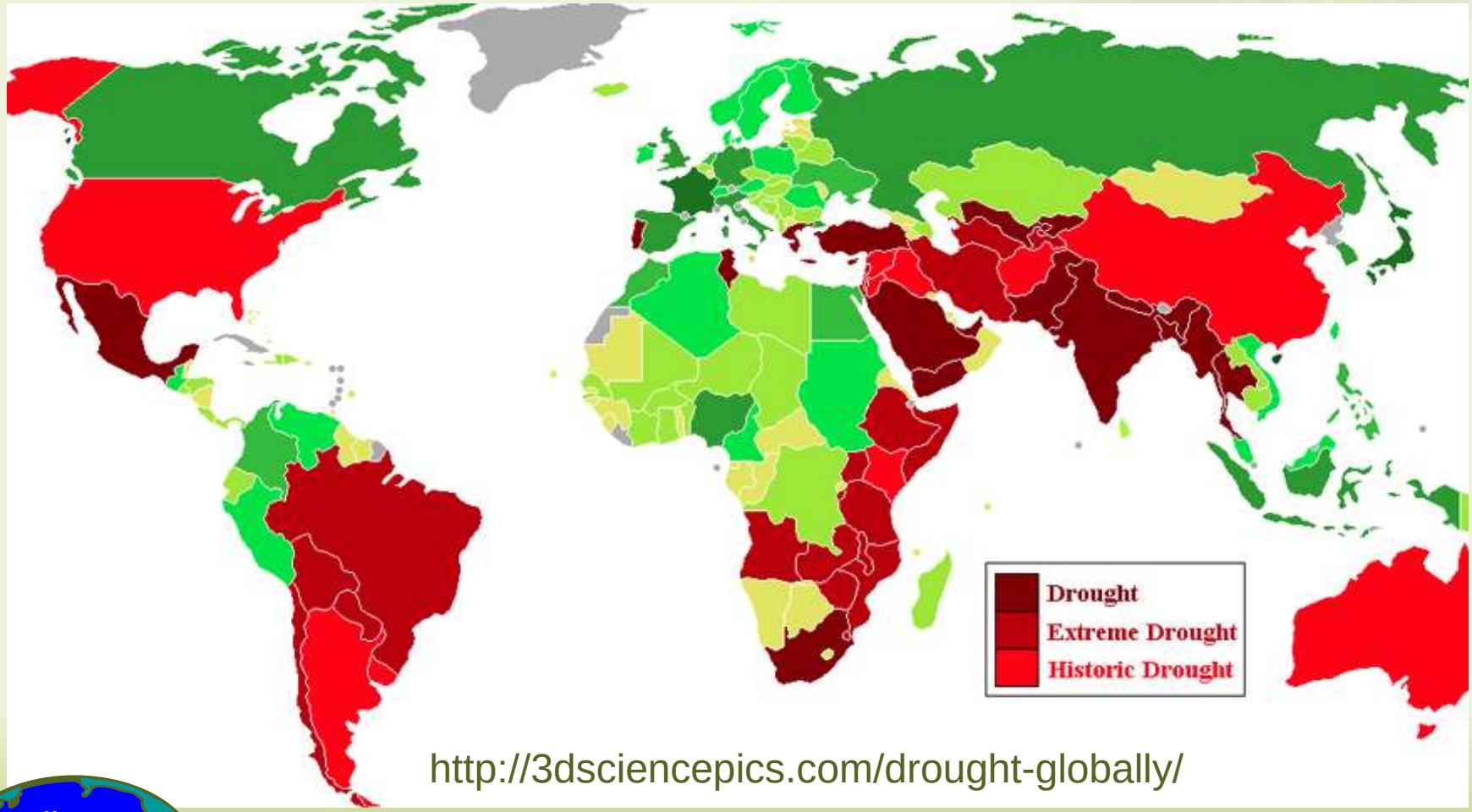
Biochar Reactor to serve thousands in urban slums

Container-based continuous flow pyrolysis with dehydration

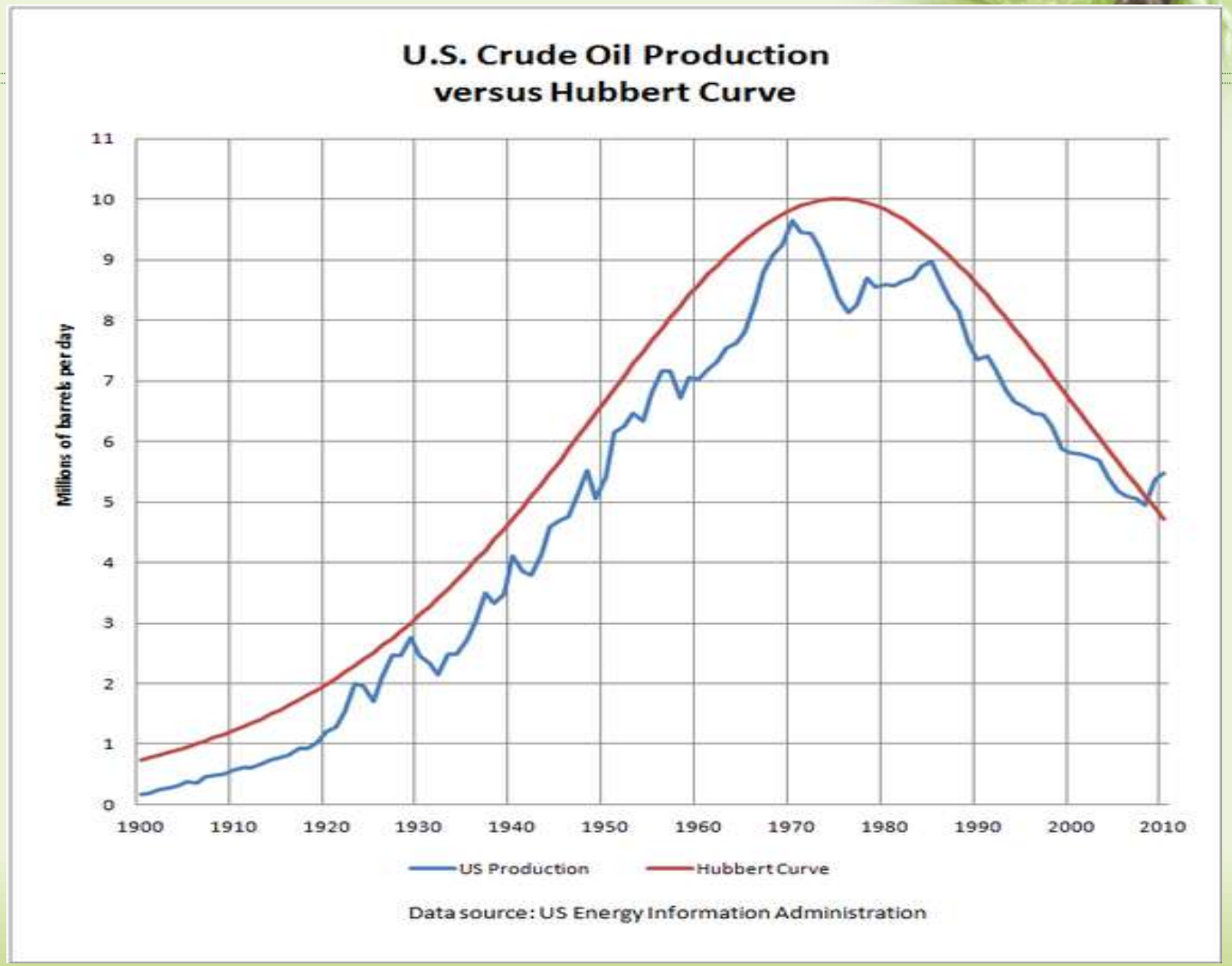


Climate drought nations

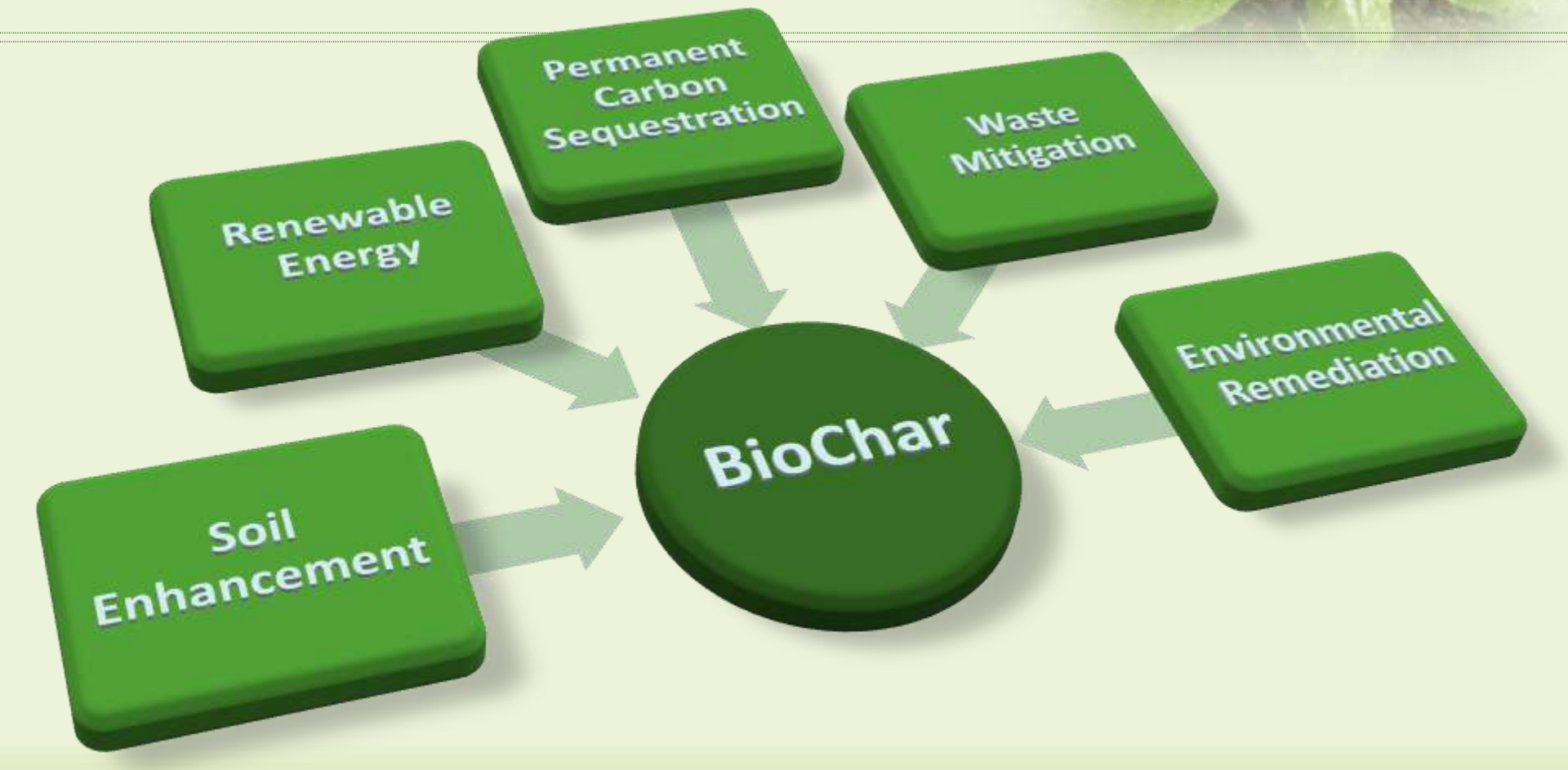


http://3dsciencepics.com/drought-globally/

Peak Oil in US



BioChar Benefits



Biochar rebuilds soil capital with global benefits

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Thanks to the Sponsors of the Climate Foundation / Stanford Biochar Reactor Project

- Gates Foundation RTTC Round 1
- NAFTA NAPECA Commission for Environmental Cooperation
- Haas Business School Award
- Climate Foundation private donors

Reinvent the Toilet Challenge Team

- Paul Csonka- Stanford Postdoc
- Ken Chaney, Climate Foundation
- Randy Hall, Climate Foundation
- Ani Vabhaneni, Saner.gy- Nairobi Kenya
- Graham MacWilliams- Pomona College
- Kieran Stolorz- Student
- Prof. Reginald Mitchell- Stanford University
- Ben Jensen, Mechanical Engineering, Stanford
- Eli Goldstein, Mechanical Engineering, Stanford
- Brian Von Herzen- Climate Foundation

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Biochar Sanitation Pipeline