A Business Model That Emulates Biology for the Development of Bioenergy and Carbon Mitigation Technologies

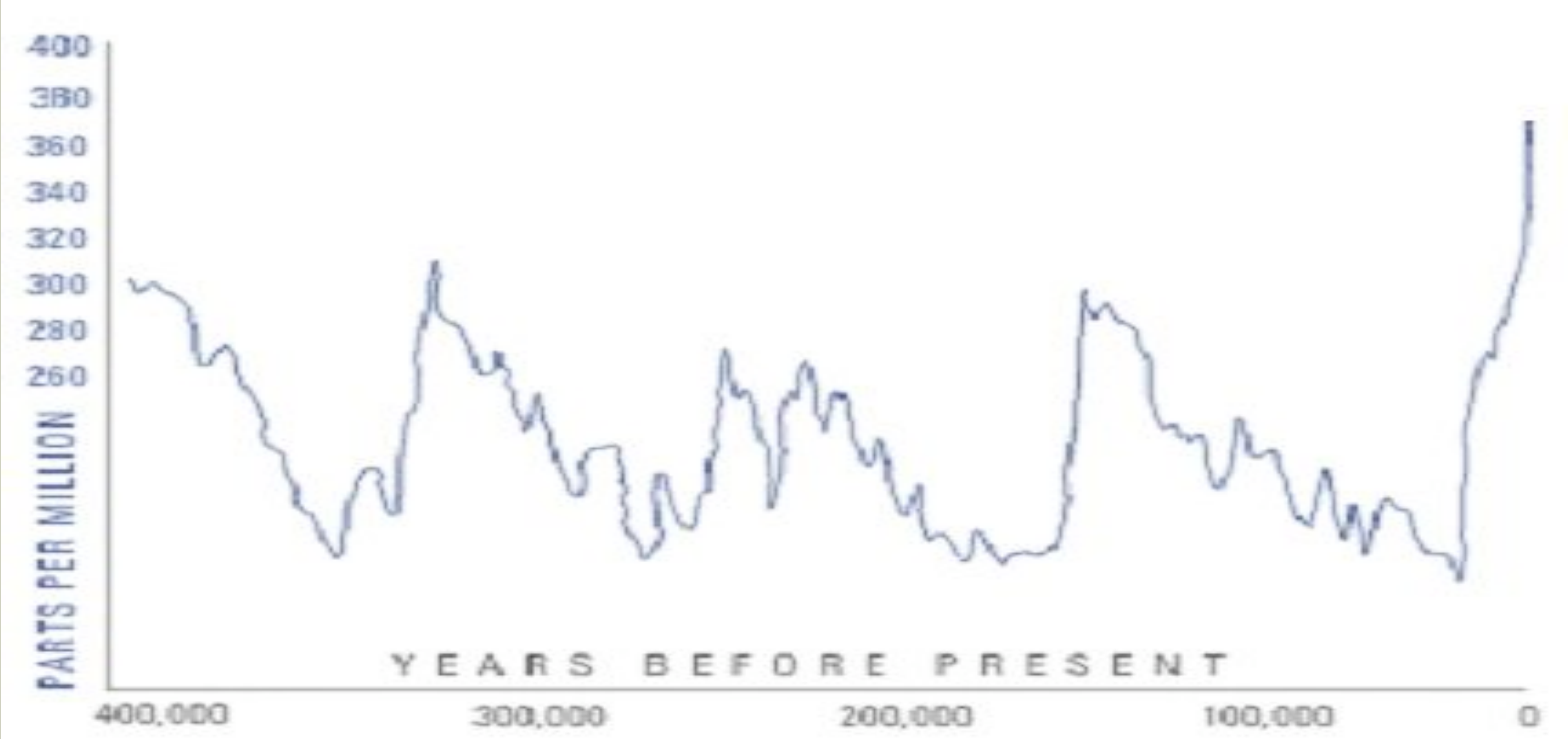
Danny Day

Eprida, Inc.

April 17, 2008

BESD Seminar, ORNL

Is the problem really anthropogenic greenhouse gas buildup?

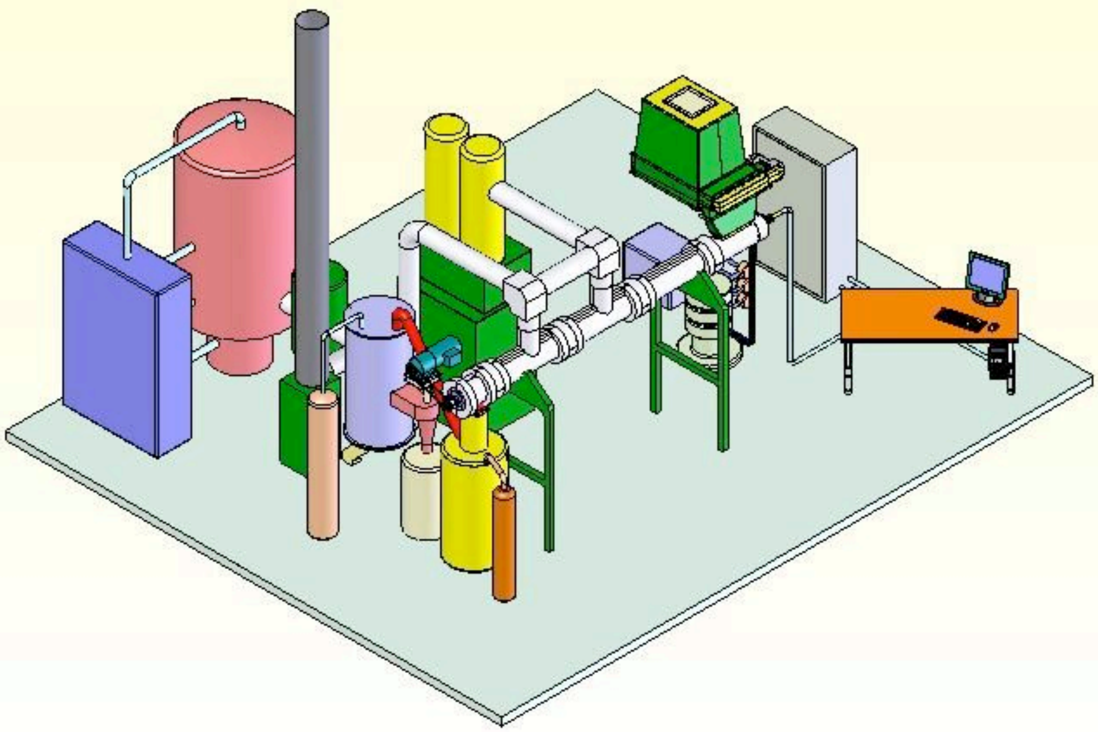


or the stumbling steps of a brand new species evolved to stabilize this recurring imbalance?

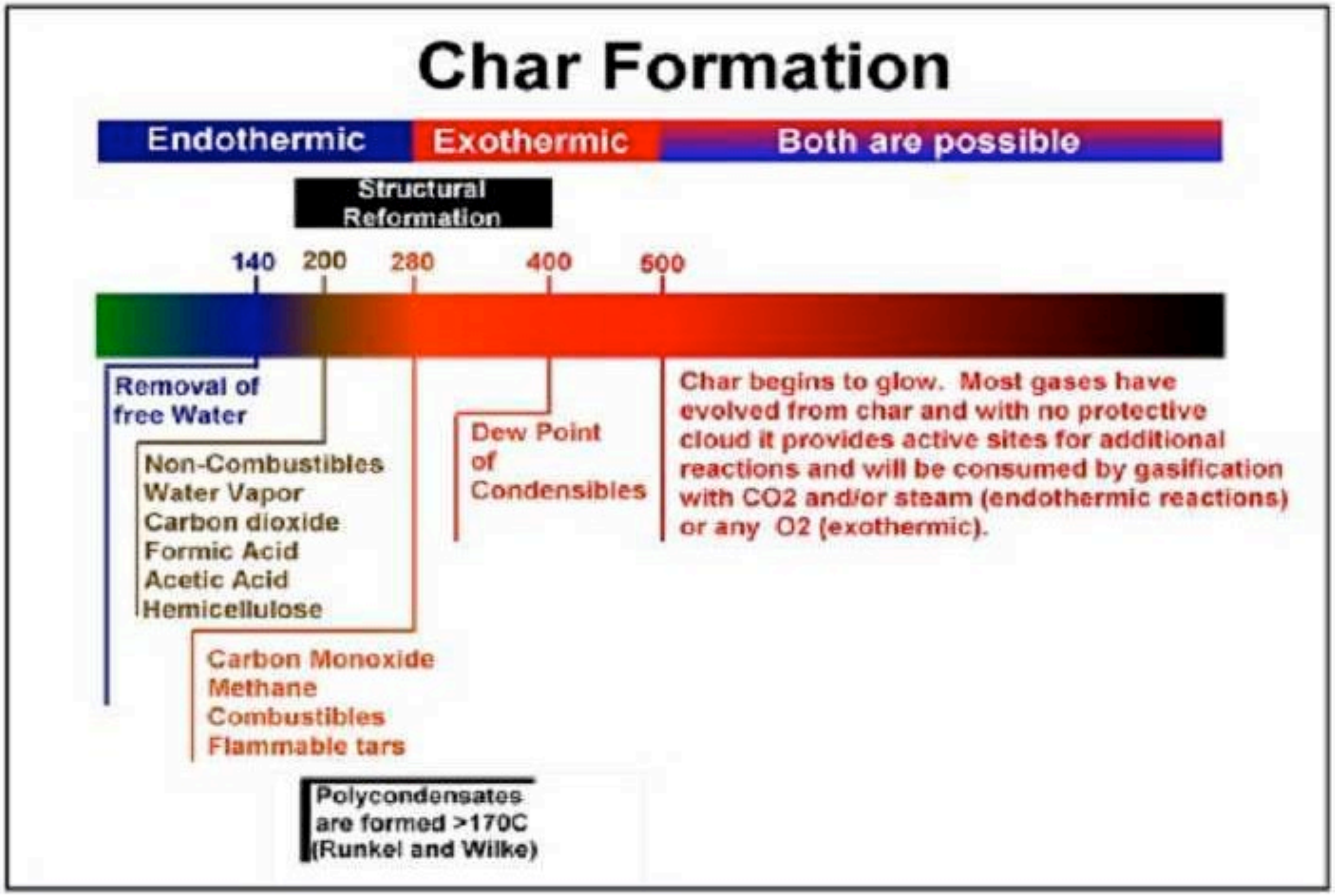
How do we transform the daily habits/thoughts of billions.

- By choosing those systems which create local income and stabilityat the lowest possible economic rung.
- By adopting those technologies which retain profits/gain inside local communities
- By supporting those which can be scaled in numbers rather than size.
- By supporting those which are multi-purpose, cost-effective, people-centered using local initiatives and skills.

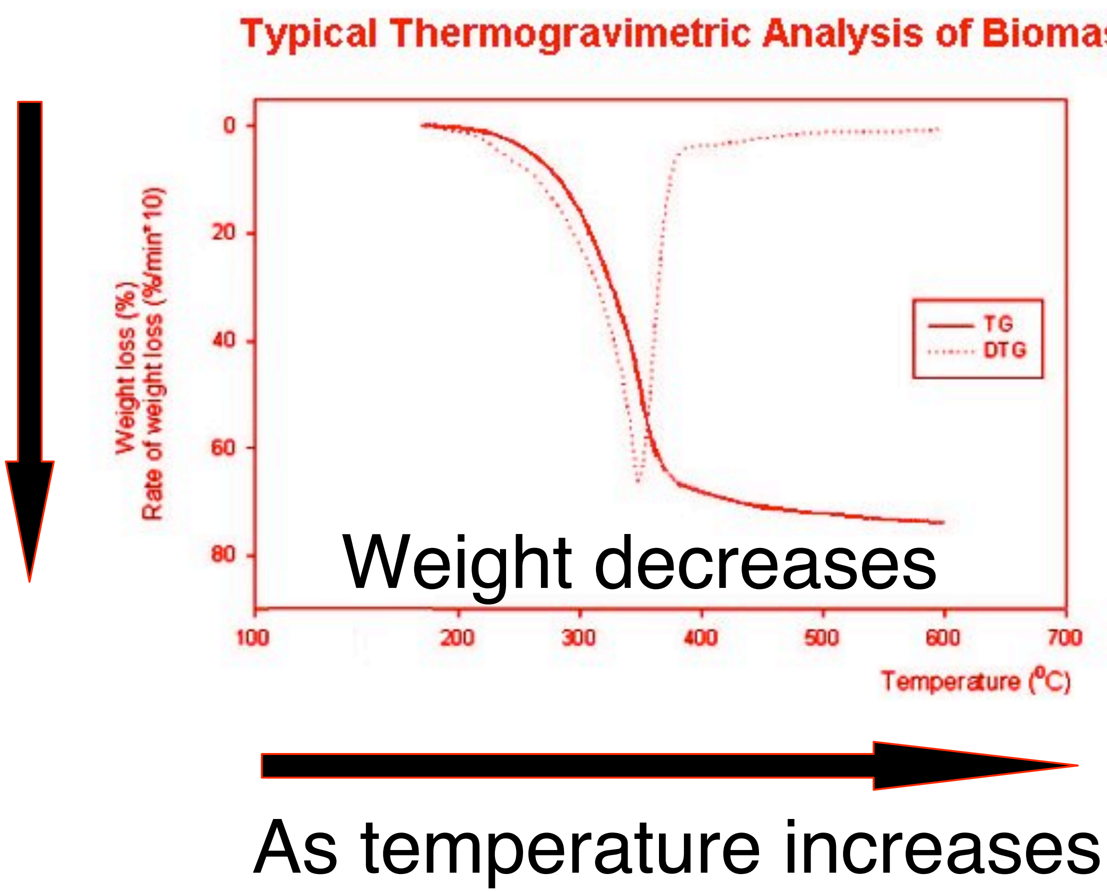
A large number of farm/coop biomass systems which produce fuel, fertilizer, high-value extractables and increased soil fertility may be part of the solution.



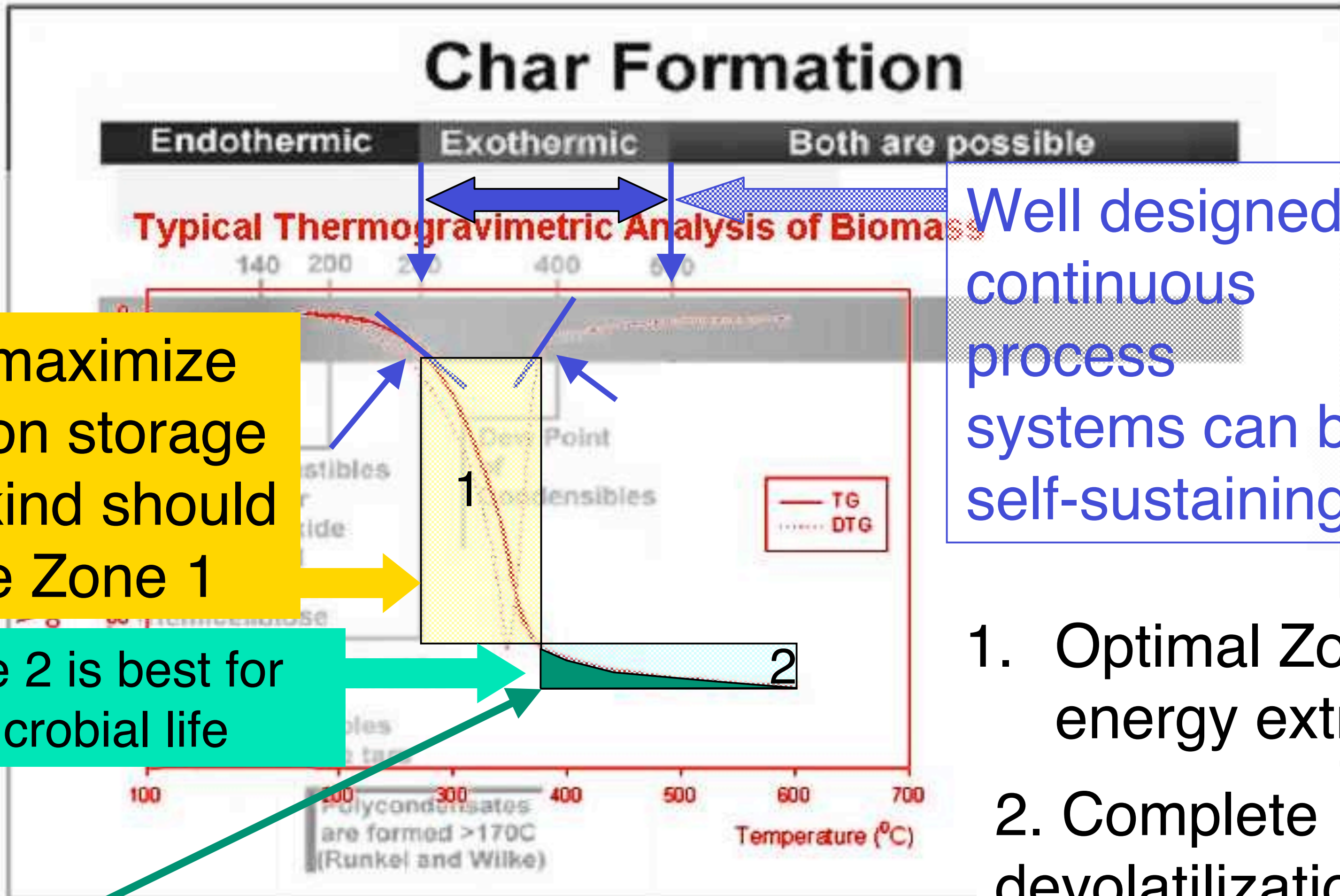
Progression of Pyrolysis



Typical TGA of Pyrolysis



Progression of Pyrolysis



To maximize carbon storage mankind should use Zone 1

Zone 2 is best for microbial life

Well designed continuous process systems can be self-sustaining

1. Optimal Zone for energy extraction

2. Complete devolatilization

Requires addition of energy (and/or oxygen)

Our investment for a sustainable planet

Ancient Amazonians left behind widespread deposits of rich, dark soil, say archaeologists. Reviving their techniques could help today's rainforest farmers better manage their land

The Real Dirt on Rainforest Fertility

IRANDUBA, AMAZÔNAS STATE, BRAZIL— Above a pit dug by a team of archaeologists here is a papaya orchard filled with unusually vigorous trees bearing great clusters of plump green fruit. Below the surface lies a different sort of bounty: hundreds, perhaps thousands, of burial urns and millions of pieces of broken ceramics, all from an almost unknown people who flourished here before the conquistadors. But surprisingly, what might be most important about this central Amazonian site is not the vibrant orchard or the extraordinary outpouring of ceramics but the dirt under the trees and around the ceramics. A rich, black soil known locally as *terra preta do Indio* (Indian dark earth), it sustained large settlements on these lands for 2 millennia, according to the Brazilian-American archaeological team working here (see sidebar).

Fruits of labor. Soils enhanced centuries ago underlie a flourishing papaya orchard near Iranduba, Brazil.

Throughout Amazonia, farmers prize terra preta for its great productivity—some farmers have worked it for years with minimal fertilization. Such long-lasting fertility is an anomaly in the tropics. Despite the exuberant growth of rainforests, their red and yellow soils are notoriously poor: weathered, highly acidic, and low in organic matter and essential nutrients. In these oxisols, as they are known, most carbon and nutrients are stored not in the soil, as in temperate regions, but in the vegetation that covers it. When loggers, ranchers, or farmers clear the vegetation, the intense sun and rain quickly decompose the remaining organic matter in the soil, making the land almost incapable of sustaining life—one reason ecologists frequently refer to the tropical forest as a "wet desert."

Because terra preta is subject to the same punishing conditions as the surrounding oxisols, "its existence is very surprising," says Bruno Glaser, a chemist at the Institute of Soil Science and Soil Geography at the University of Bayreuth, Germany. "If you read the textbooks, it shouldn't be there." Yet according to William I. Woods, a geographer at Southern Illinois University, Edwardsville, terra preta might cover as much as 10% of Amazonia, an area the size of France. More remarkable still, terra preta appears to be the product of intensive habitation by precontact Amerindian populations. "They practiced agriculture here for centuries," Glaser says. "But instead of destroying the soil, they improved it—and that is something we don't know how to do today."

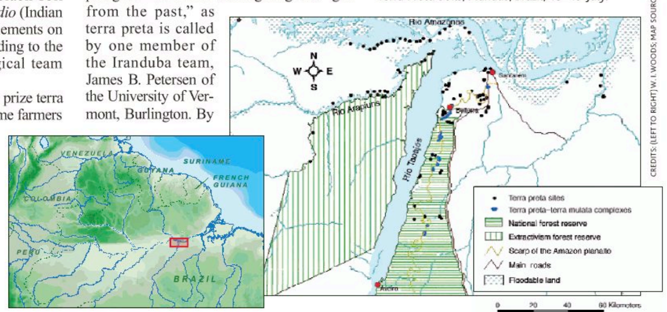
In the past few years, a small but growing group of rsearchers—geographers, archaeologists, soil scientists, ecologists, and anthropologists—has been investigating this "gift from the past," as terra preta is called by one member of the Iranduba team, James B. Petersen of the University of Vermont, Burlington. By understanding how indigenous groups created Amazonian dark earths, these researchers hope, today's scientists might be able to transform some of the region's oxisols into new terra preta. Indeed, experimental programs to produce "terra preta nova" have already begun.

The research is still in an early stage, but last month attendees at the first large-scale scientific congress* devoted to terra preta argued that its consequences could be enormous, both for Amazonia and for the world's hot regions in general. Population pressure and government policies are causing rapid deforestation in the tropics, and poor tropical soils make much of the clearing as economically nonviable in the long run as it is ecologically damaging. The existence of terra preta, says Wim Sombroek, former director of the International Soil Reference and Information Center in Wageningen, the Netherlands, suggests "that some kind of sustainable, intensive agriculture is possible in the Amazon, after all. If we can learn the principles behind it, we may be able to make a substantial contribution to human welfare and the environment."

The good earth

Terra preta is scattered throughout Amazonia, but it is most frequently found on low hills overlooking rivers—the kind of terrain on

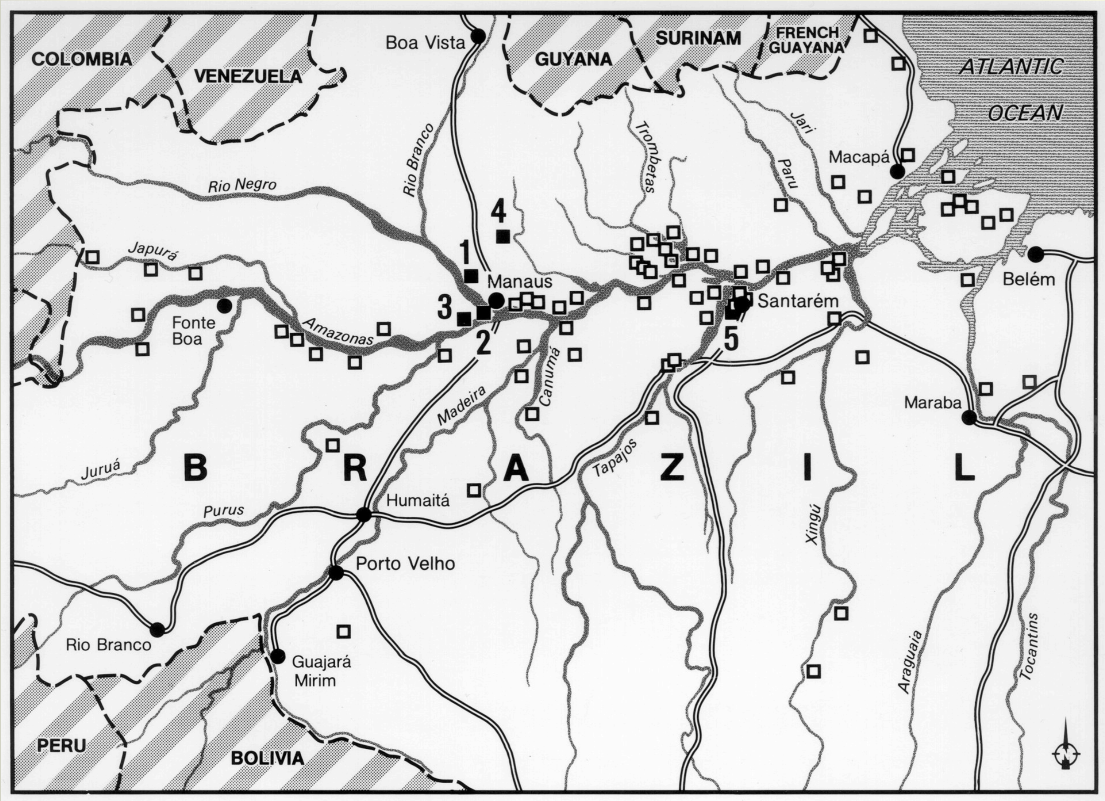
* First International Workshop on Anthropogenic Terra Preta Soils, Manaus, Brazil, 13–19 July.



CREDITS: (LEFT TO RIGHT) W. I. WOODS; MAP SOURCE: ADAPTED FROM NIMUENDAJU, ROOSEVELT, MEGGERS, SOMBROEK, FALESI, IMAFLORA, WOODS, AND MCCANN

Science Magazine
August 2002

Terra Preta: A 2000 Year Old Soil Experiment



(Steiner, 2002)

- Man-Made Soil Plots
- Average size 20 ha
- Carbon dated at 800 B.C-500 A.D
- High Carbon Content (9%)
- Local farmers prize terra preta which yields as much as three fold crop yields as surrounding infertile tropical soils.

Terra preta sites are so valued they are dug up and sold for potting soil

Charcoal Research in Japan and Asia

Bark Charcoal and Fertilizer

Effect of bark charcoal and fertilizer on the plant growth and soil properties in south Sumatra (Yamato 2004 unpublished)

Charcoal has Benefits for Existing Forests

Recovering of Pine Tree from Wilting by Charcoal Treatment after a year

Ogawa 1999, Kansai Environmental

Charcoal has Benefits for Existing Forests
Results of Charcoal Treatment after a year

Ogawa 1999, Kansai Environmental

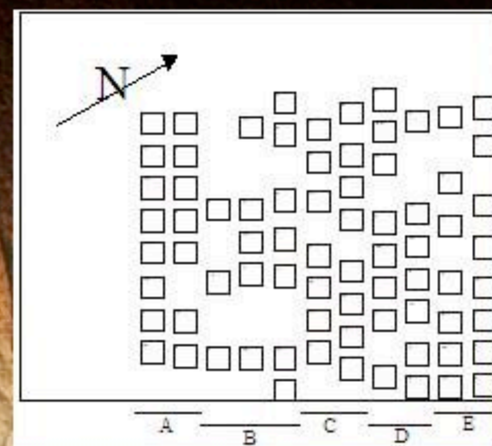
The growth of pine root and mycorrhiza formation started at 5 to 6 months after treatment

3 Year Field Trial Studies

Project ⌨ Introduction ⌨ **Experiments, Trials & Results** ⌨ Application

Experiments

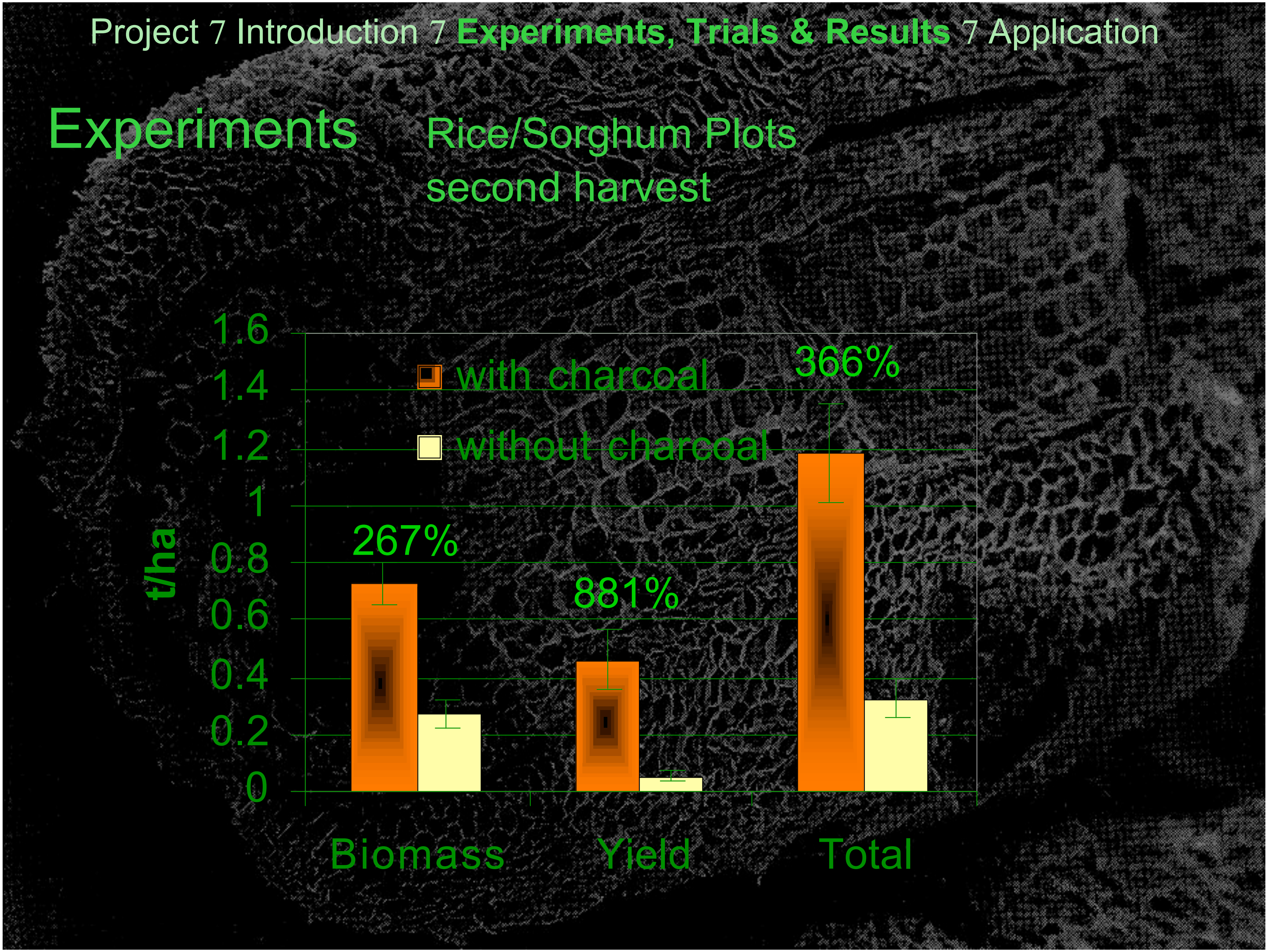
Rice/Sorghum Plots
Setup



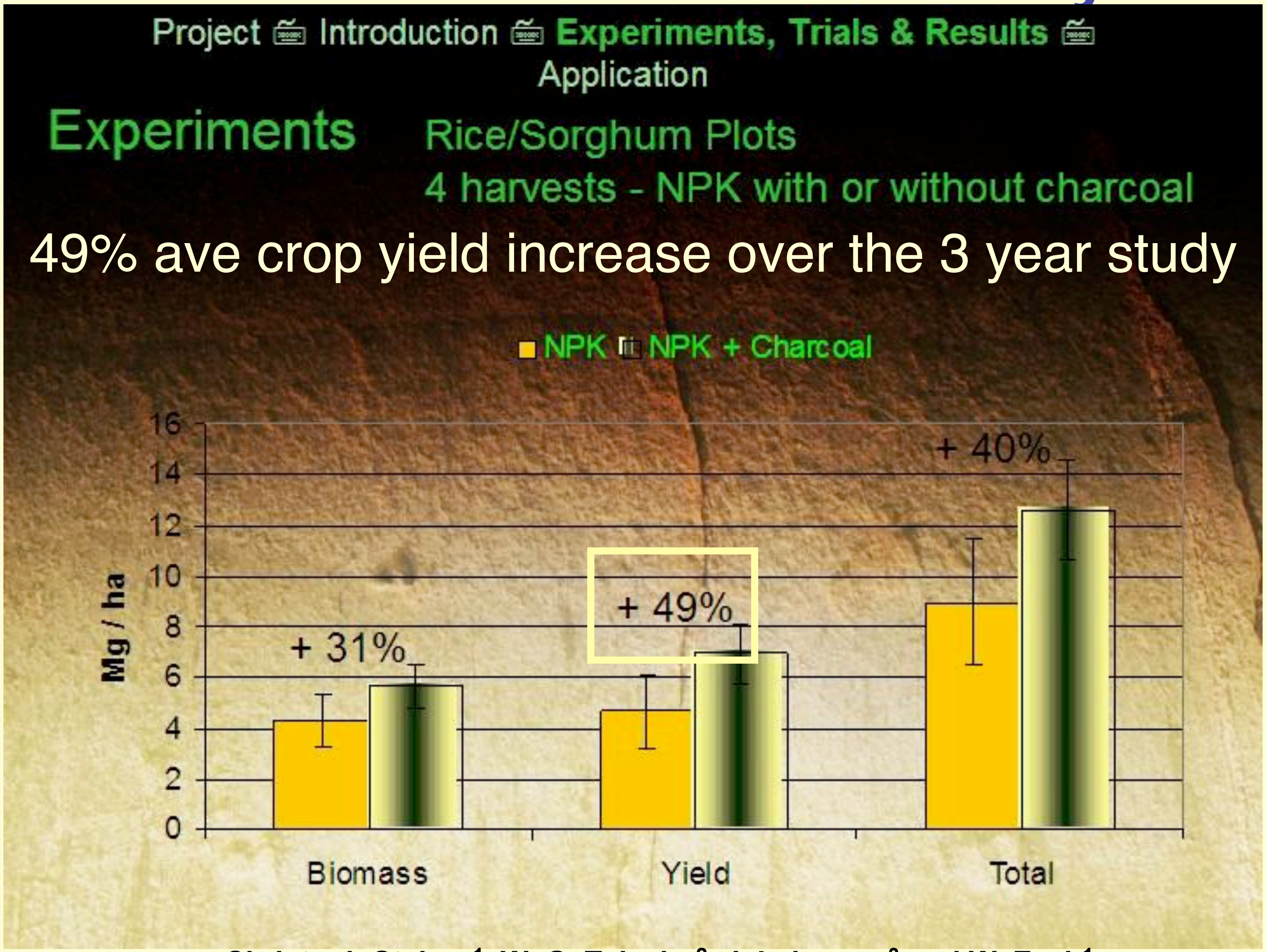
- 15 treatments with 5 repetitions
- Experimental area 40 x 40 m
- Plot-size: 2 x 2 m
- Litter and roods removed
- Distance between the plots 1m and to secondary forest 6m

Christoph Steiner[1], W. G. Teixeira[2], J. Lehmann[3] and W. Zech[1]

1 *Institute of Soil Science, University of Bayreuth, Germany*- 2 *Embrapa Amazonia Ocidental, Manaus, Brazil*
-3 *Department of Crop and Soil Sciences, Cornell University, USA*


Project 7 Introduction 7 Experiments, Trials & Results 7 Application
Experiments
Rice/Sorghum Plots
second harvest
with charcoal
without charcoal
t/ha
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
267%
881%
366%
Biomass
Yield
Total

3 Year Results Summary



Christoph Steiner[1], W. G. Teixeira[2], J. Lehmann[3] and W. Zech[1]

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Adding Charcoal to the ground seems easy enough but the impact is far from simple.

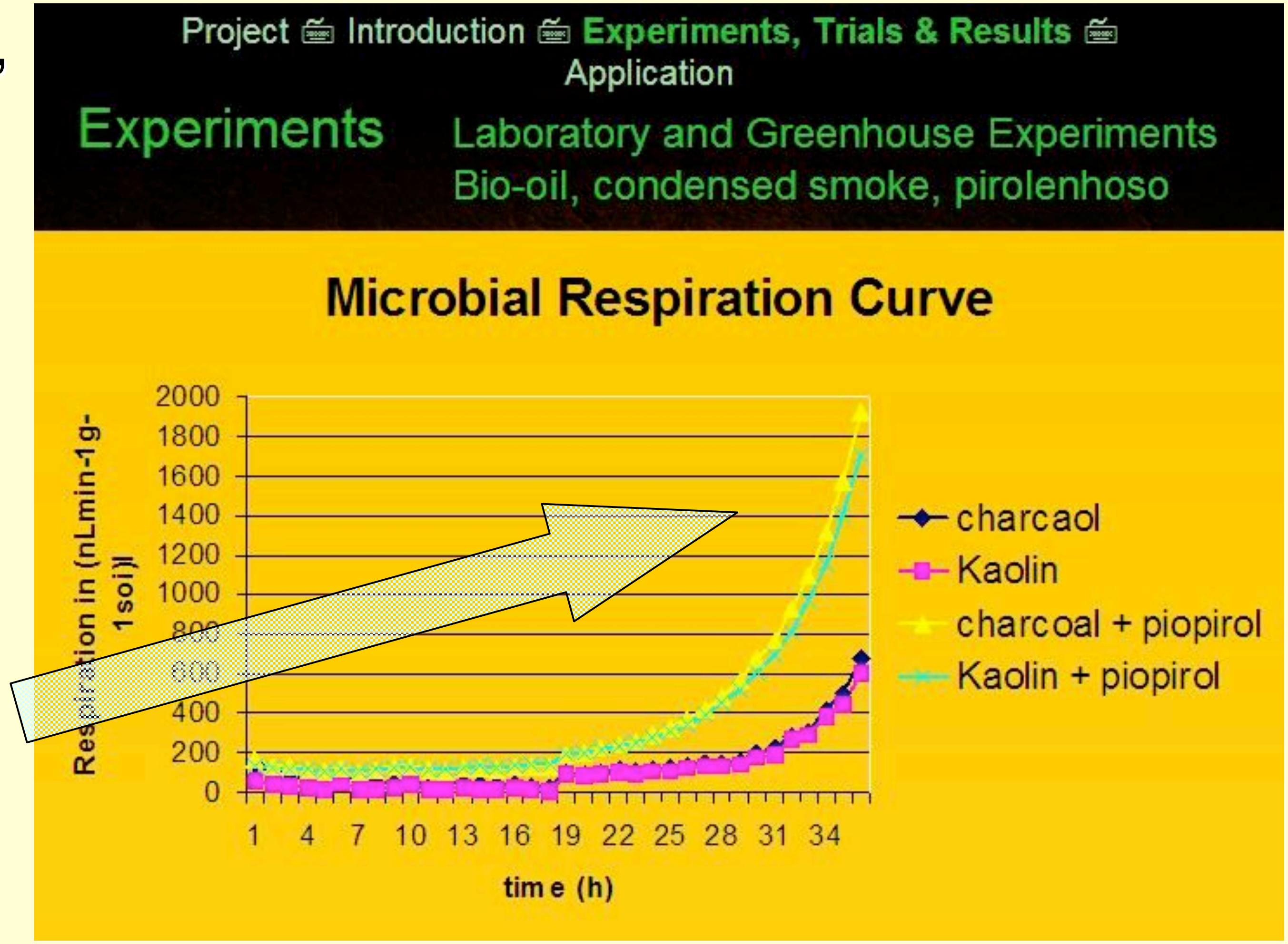
Nature has spent billions of years evolving ecosystems to utilize charcoal and its byproducts.

We are just now uncovering the science behind this fascinating story and the possibilities may yet provide solutions to many of our most intractable problems.

The answer is in the smoke

In this experiment, condensed smoke was added to charcoal and kaolin.

The impact was the same as adding glucose to these materials.

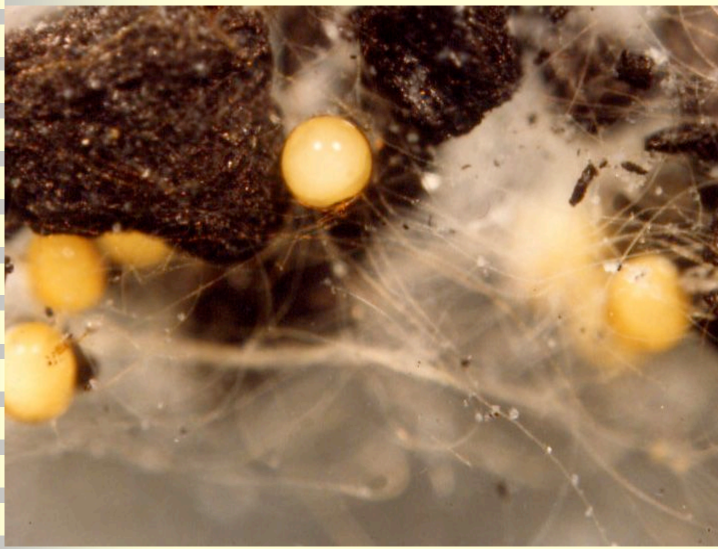


C. Steiner, M. Garcia, B. Förster and W. Zech

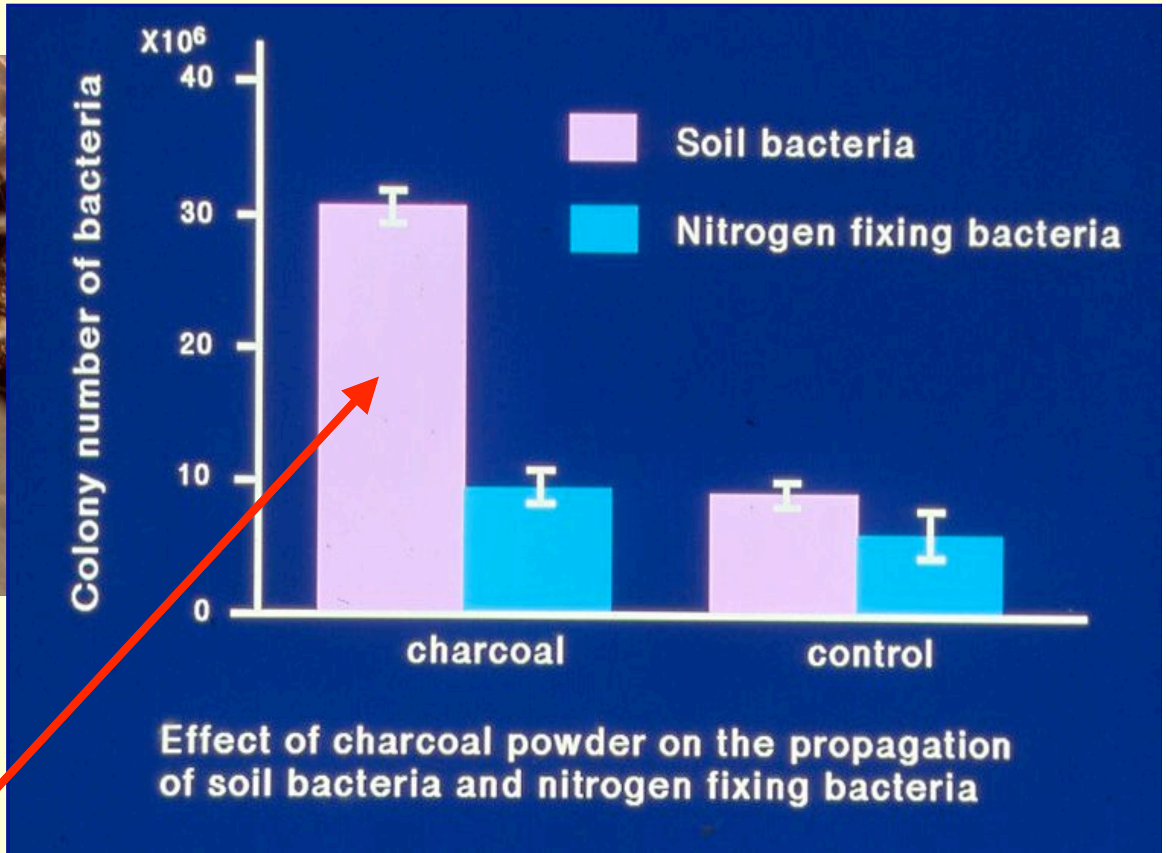
Nature's Thermal Reactors

Pressures up to 300psi
Results in highly diverse organic compounds
And the unknown multitude of evolutionary bacterial life forms which benefit from those compounds.

Charcoal provides a preferred habitat for soil micro organisms



The germination rate of G. margarita was higher than that on soil (Ogawa 1991)

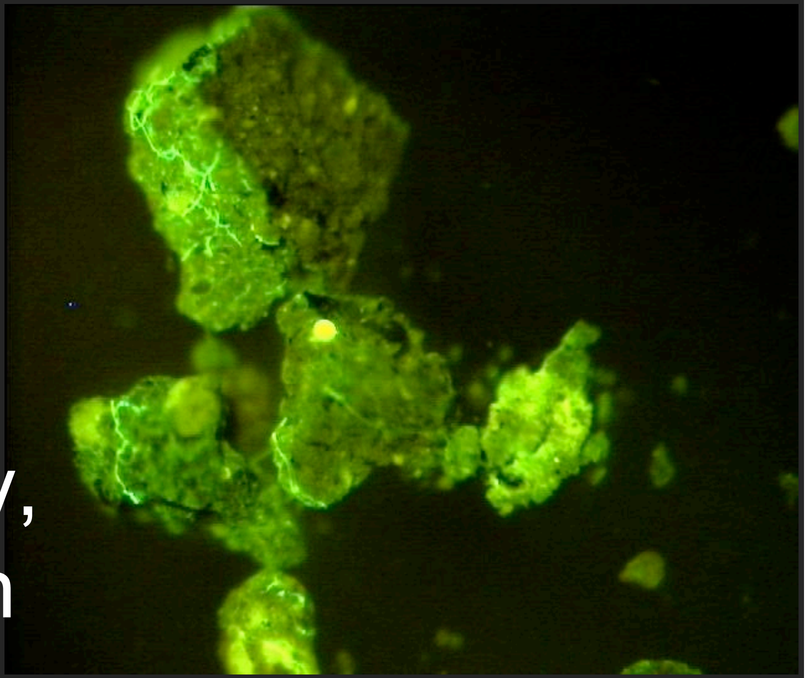


Bacterial populations show marked increase with charcoal addition (Beijerinckia, Ogawa 1992)

Note the 3 fold increase

Fertile Soil is "aggregated"

- AM Fungi produce a glue Glomalin, which aggregates small soil particles
- This increases water and air holding capacity, resulting in soil tilth with increased biomass yields.

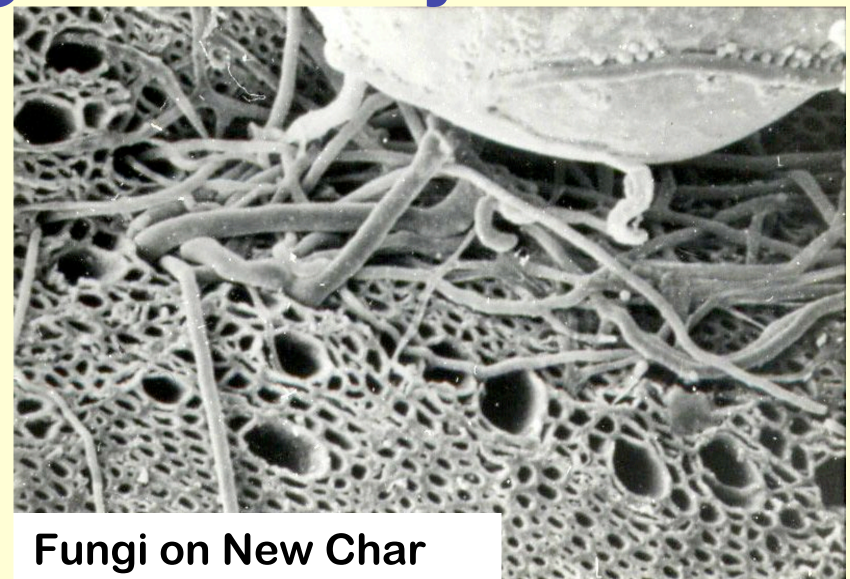


Charcoal is sought out by AMF

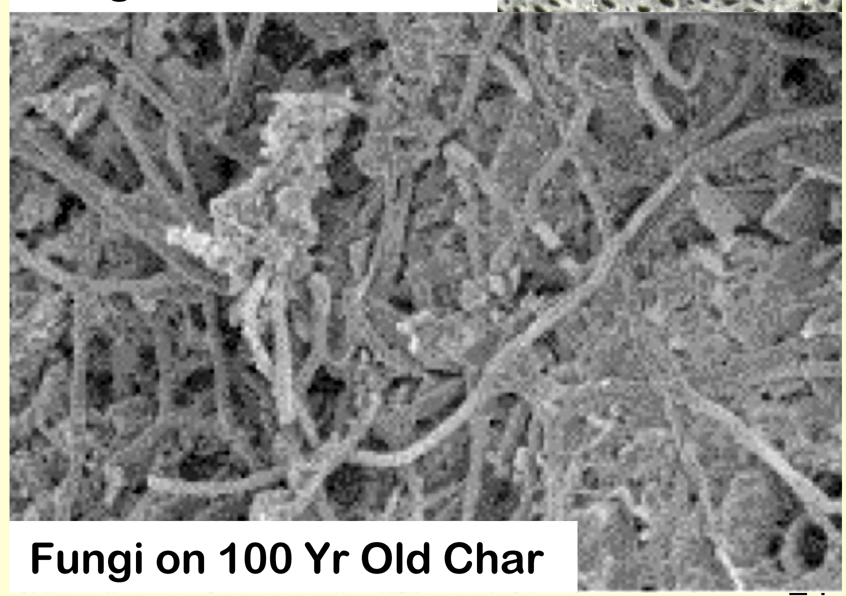
Charcoal addition to the soil provides nutrient and water storage center for mycorrhizal fungi

Their hyphae invade charcoal pores and support spore reproduction

Ogawa
Kansai Environmental

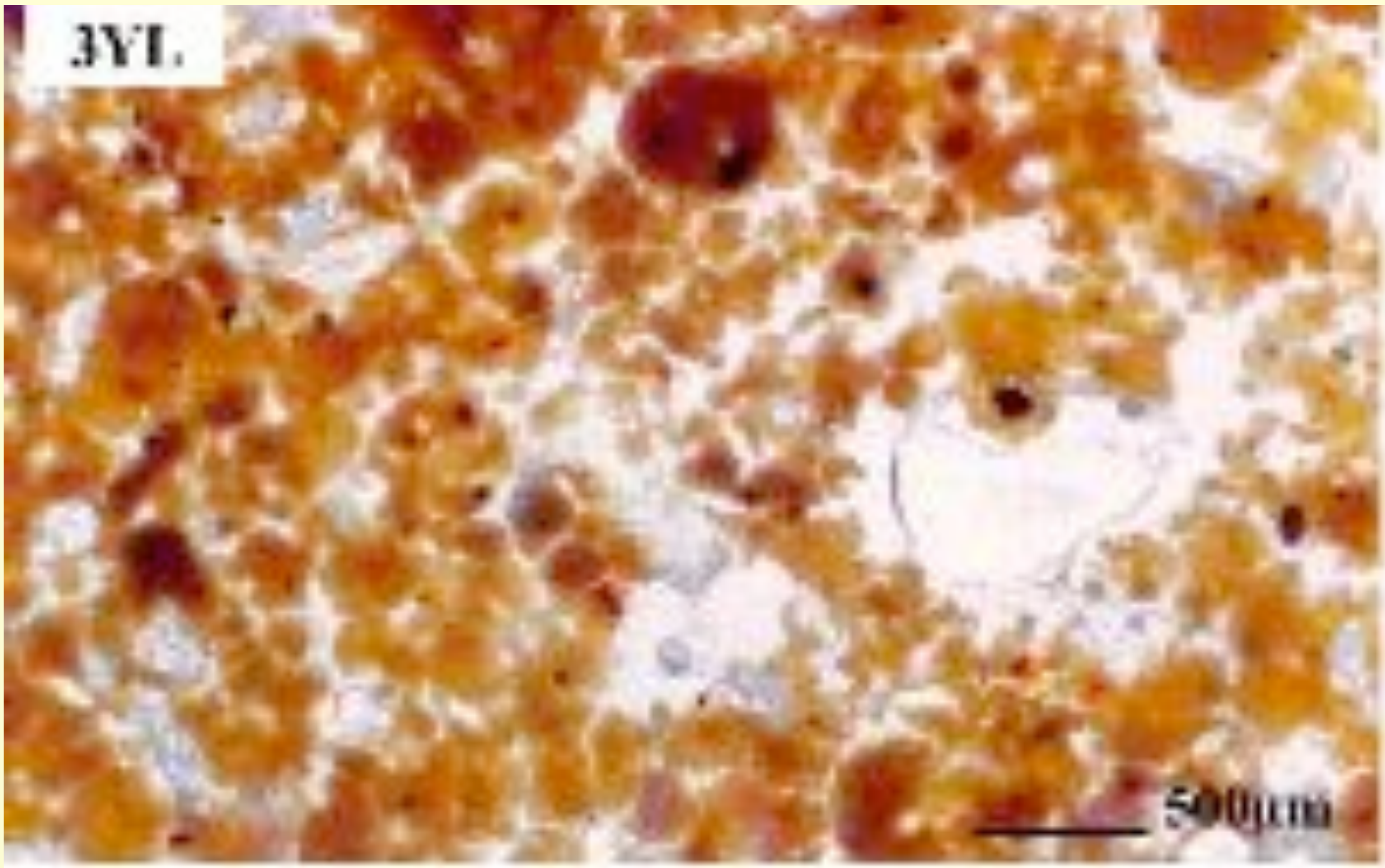


Fungi on New Char

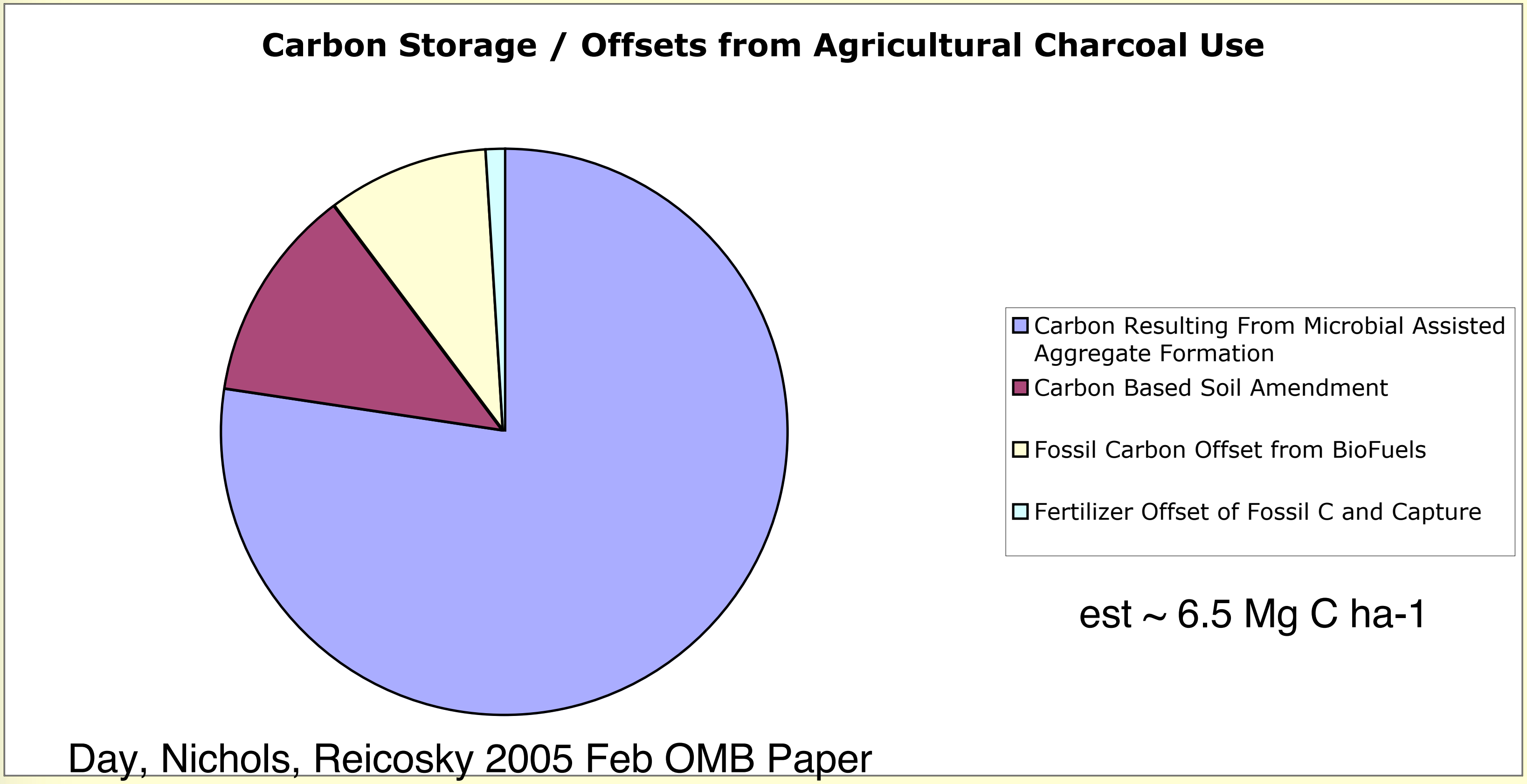


Fungi on 100 Yr Old Char

Char seeds aggregates formation which absorbs dissolved organic matter through wetting and drying cycles to build humus as a long term beneficial carbon storage



Utilizing 1/3 of Crop Productivity for Bioenergy and Carbon based fertilizers and no-till

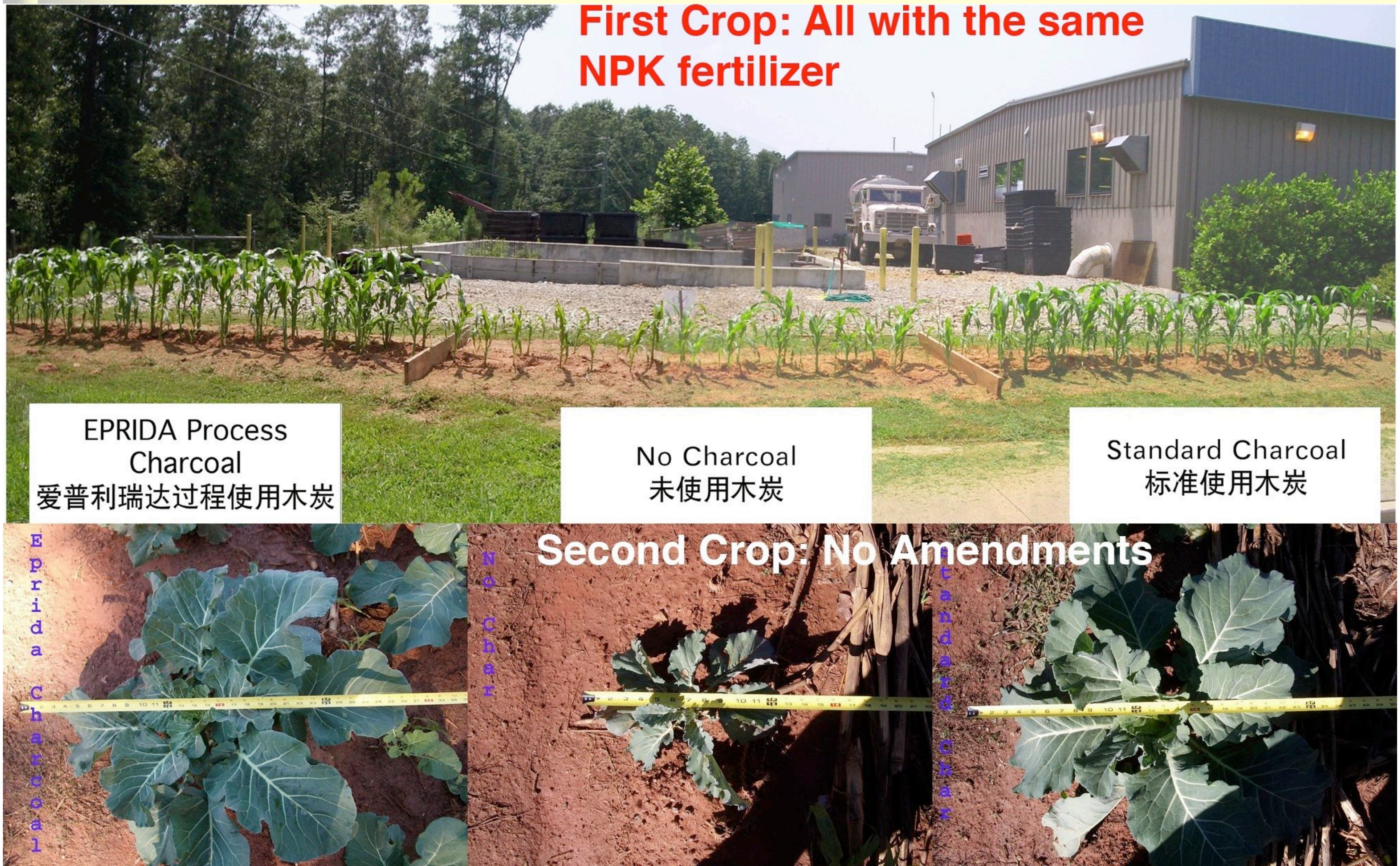


Land required to offset 1.9 Gt C/yr = 2.2E+8 ha (3xTexas)

What is the difference in ECOSS charcoals?


EPRIDA Process
Charcoal
爱普利瑞达过程使用木炭
No C
未使


EPRIDA Process Charcoal
爱普利瑞达过程使用木炭
No Charcoal
未使用木炭
Standard Charcoal
标准使用木炭


First Crop: All with the same NPK fertilizer
EPRIDA Process Charcoal
爱普利瑞达过程使用木炭
No Charcoal
未使用木炭
Standard Charcoal
标准使用木炭
Second Crop: No Amendments
Eprida Charcoal
No Char

Global Charcoal Research

With NPK and Charcoal — With NPK

Manaus, Brazil - Terra Preta Research, 2001
Christoph Steiner, University of Bayreuth
Institute of Soil Science and Soil Geography

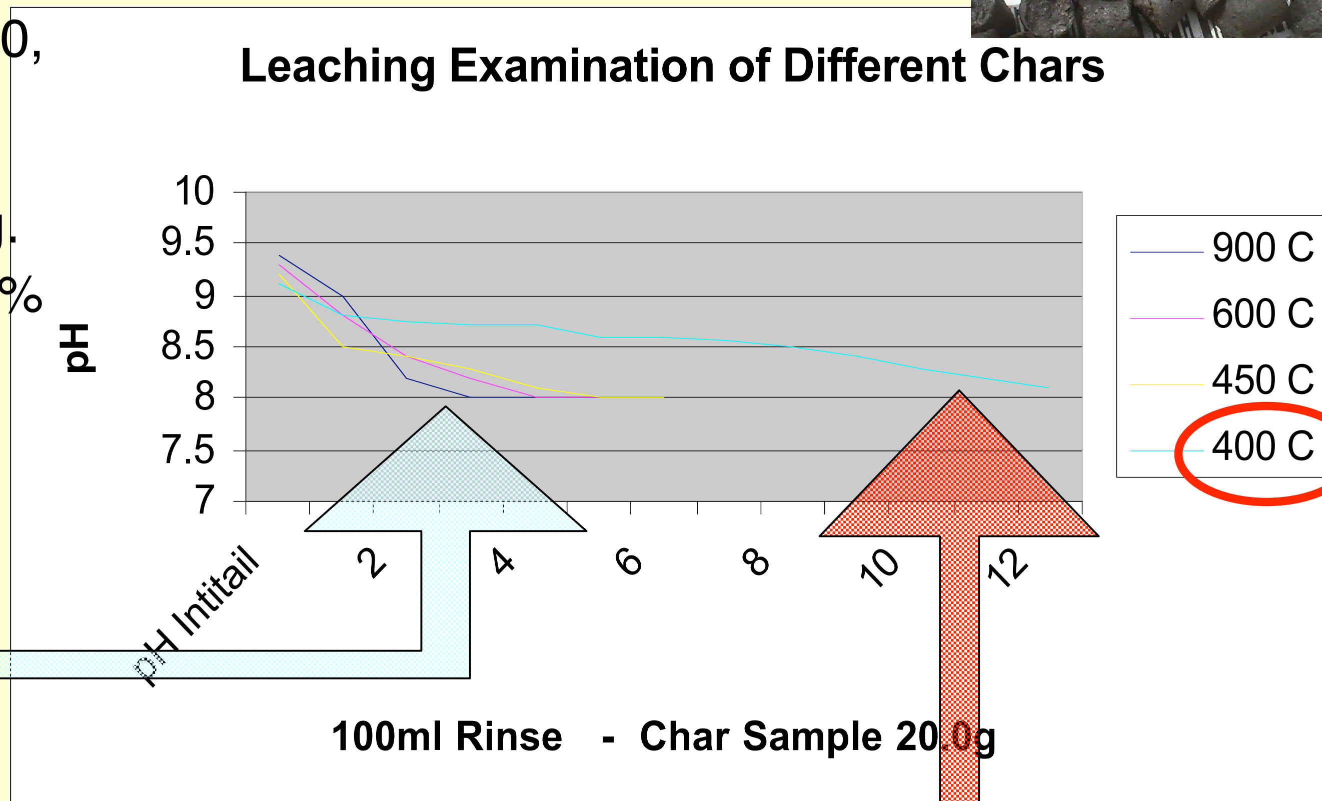
(Taiwan, 2001)
Food and Fertilizer
Technology Center
for the Asian and
Pacific Region

Other charcoal benefits

- Surface oxidation of the char increased the cation exchange capacity (Glaser)
- Char increased available water holding capacity by more than 18% of surrounding soils (Glaser)
- Char experiments have shown up to 266% more biomass growth (2^{nd} Yr Steiner) and 324% (Kishimoto and Sugiura)
- Plant nitrogen uptake doubled in charcoal amended soils (Steiner)
- Charcoal has proven to help reduce farm chemical runoff (Yelverton)

We conducted leaching experiments on a variety of chars

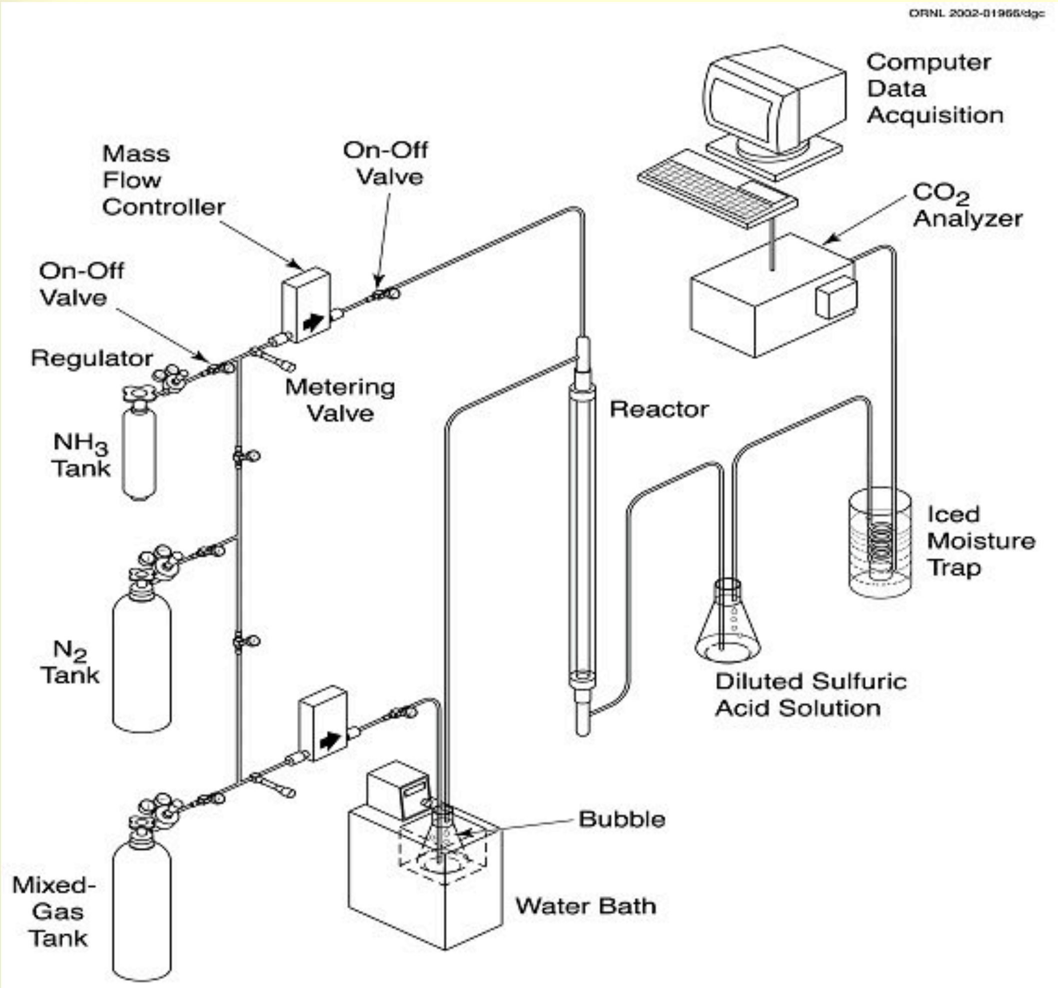
- Chars were produced at 900, 600, 500, 450, and 400C.
- Crushed and sieved to #30 mesh, wt 20g.
- Soaked 5 min. in 48% NH_4NO_3 solution.
- Each rinse = 100 ml water 8.0 pH

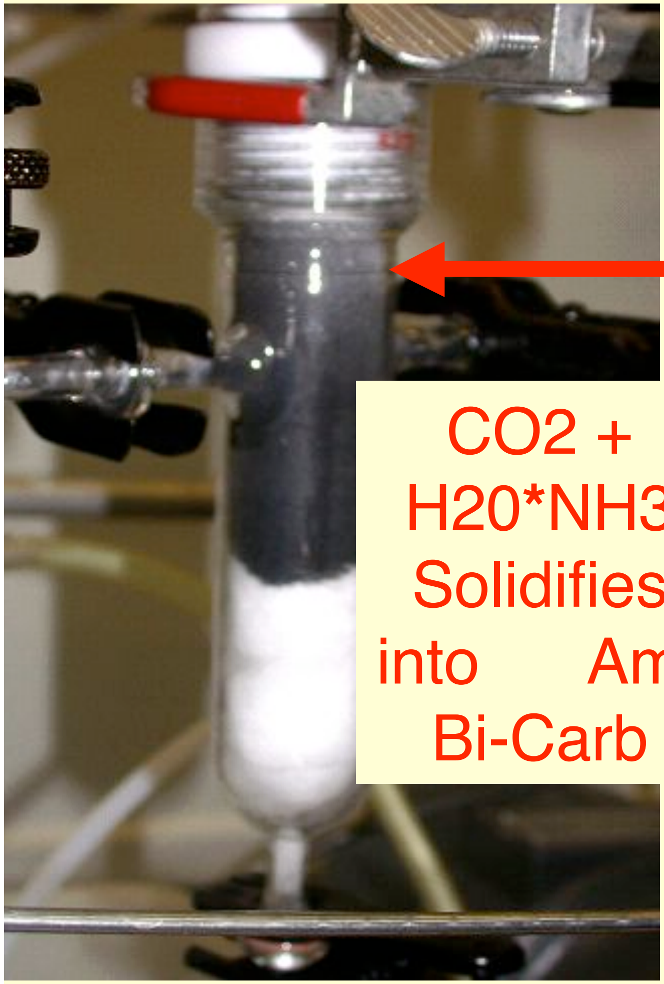


Most stabilized after a few rinses

But at chars produced 400 C very gradually released its ammonia

Bench Scale NH_3-CO_2-Char Experiment





CO2 + H20*NH3 Solidifies into Am-Bi-Carb

Chemical Pathways for Simultaneous Removal of Major CO_2 and ppm Levels of NO_x and SO_x Emissions by Innovative Application of the Fertilizer Production Reactions

CH_4 or

CO

Typical Composition
of the
Resulting Nitrogen Compounds

97.5% Ammonium Bicarbonate
2% Ammonium Sulfate
0.5% Ammonium Nitrate

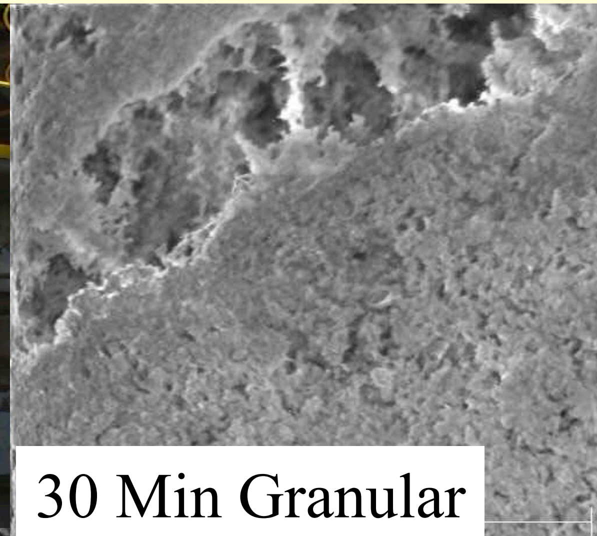
NO_{xx}+S

SO

tory

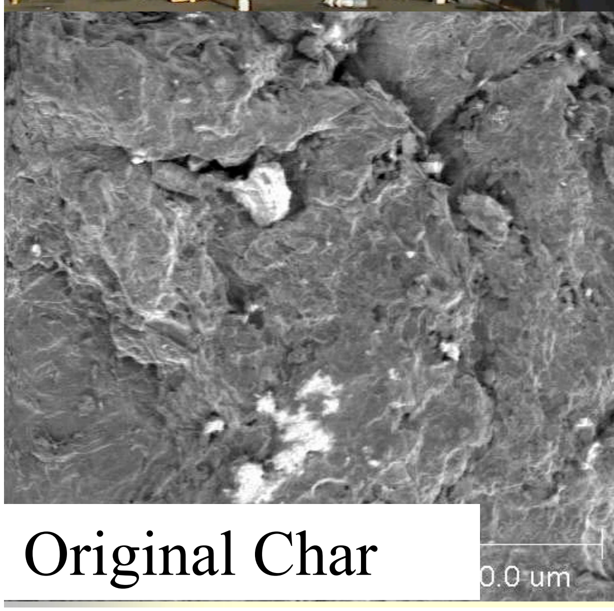
US Patent 6,447,437

- Operated at ambient pressure and temperature
- CO_2 separation is not required

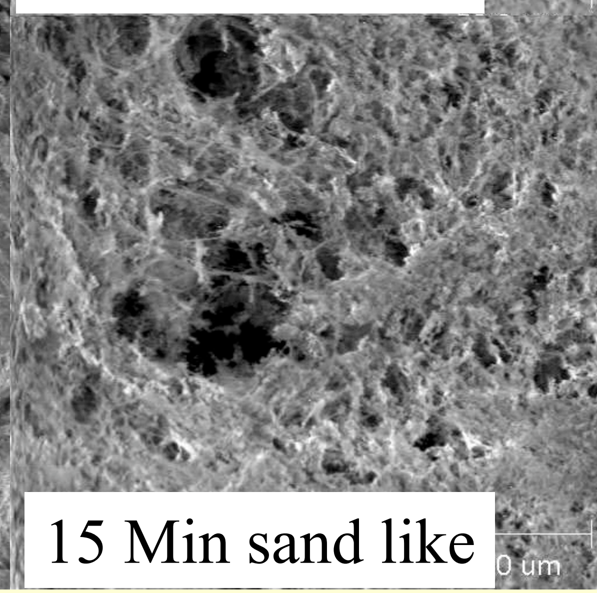


30 Min Granular

Large Granule ECOSS



Original Char



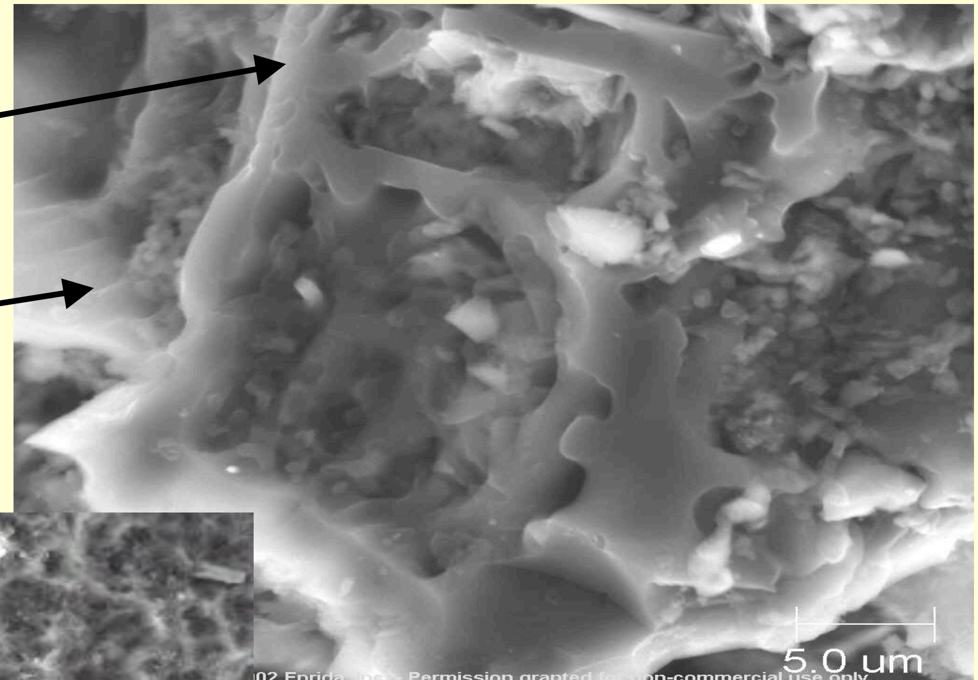
15 Min sand like

Char ECOSS - Sand like

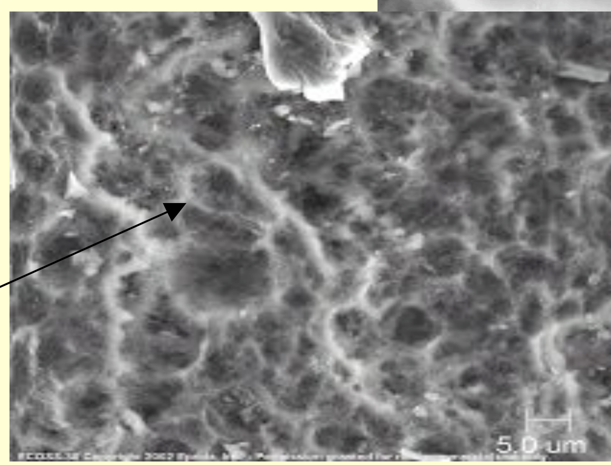
Crushed Interior 2000x SEM

The residual cell structure of the original biomass is clearly visible

The ABC fibrous buildup has started inside the carbon structure

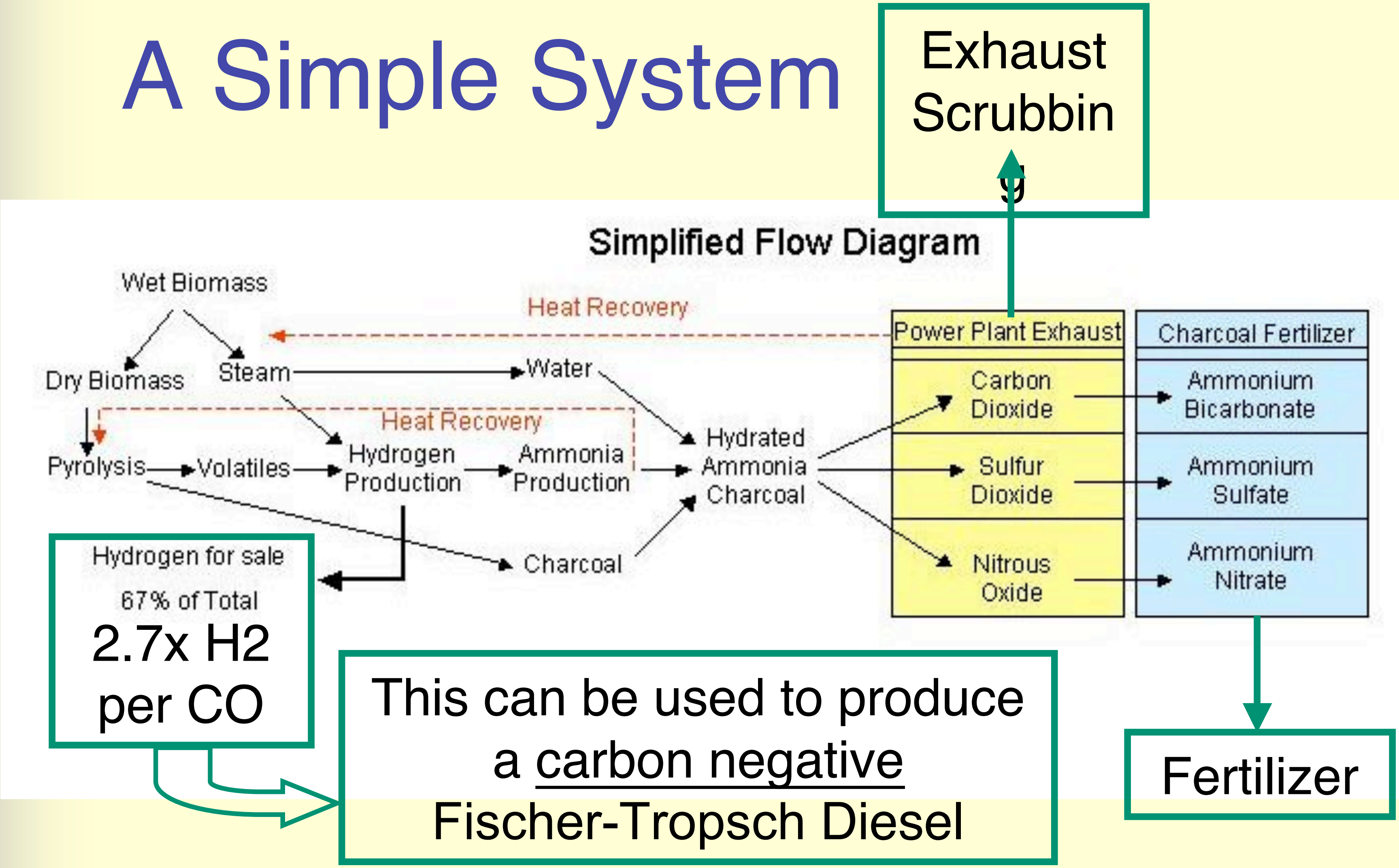


After complete processing, interior is full



Trace minerals are returned to the soil along with essential nitrogen.

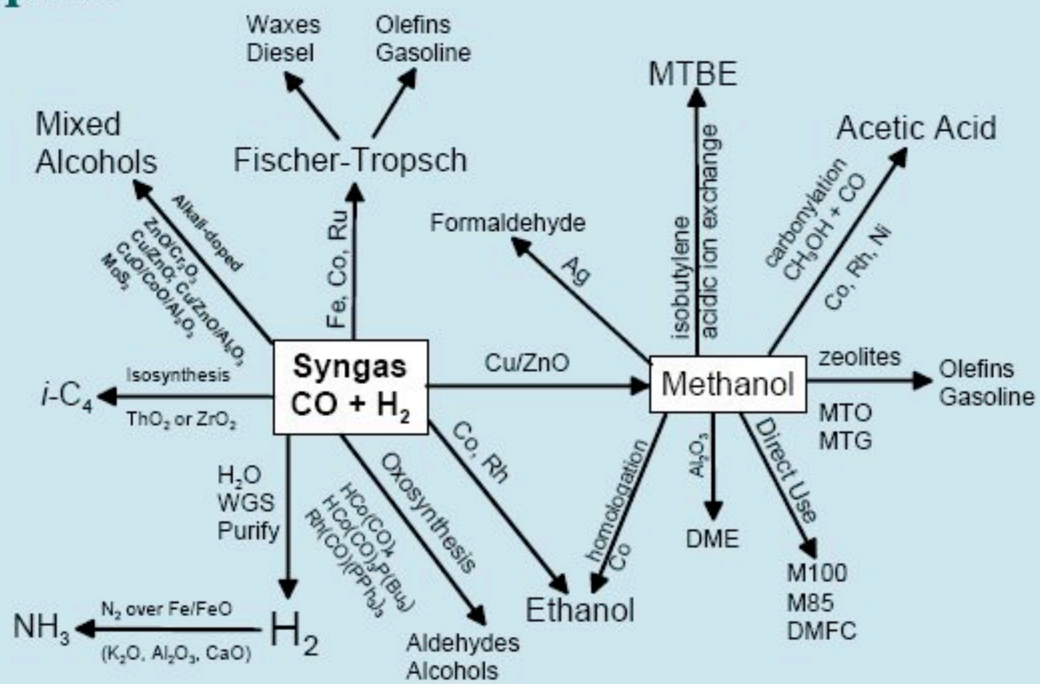
A Simple System



Profit Centers

Potential Syngas Products

- Hydrogen
- Methanol and MeOH derivatives (NH3, DME, MTBE formaldehyde, acetic acid, MTG, MOGD, TIGAS)
- Fischer Tropsch Liquids
- Ethanol
- Mixed alcohols
- Olefins
- Oxosynthesis
- Isosynthesis
- **Ammonia**

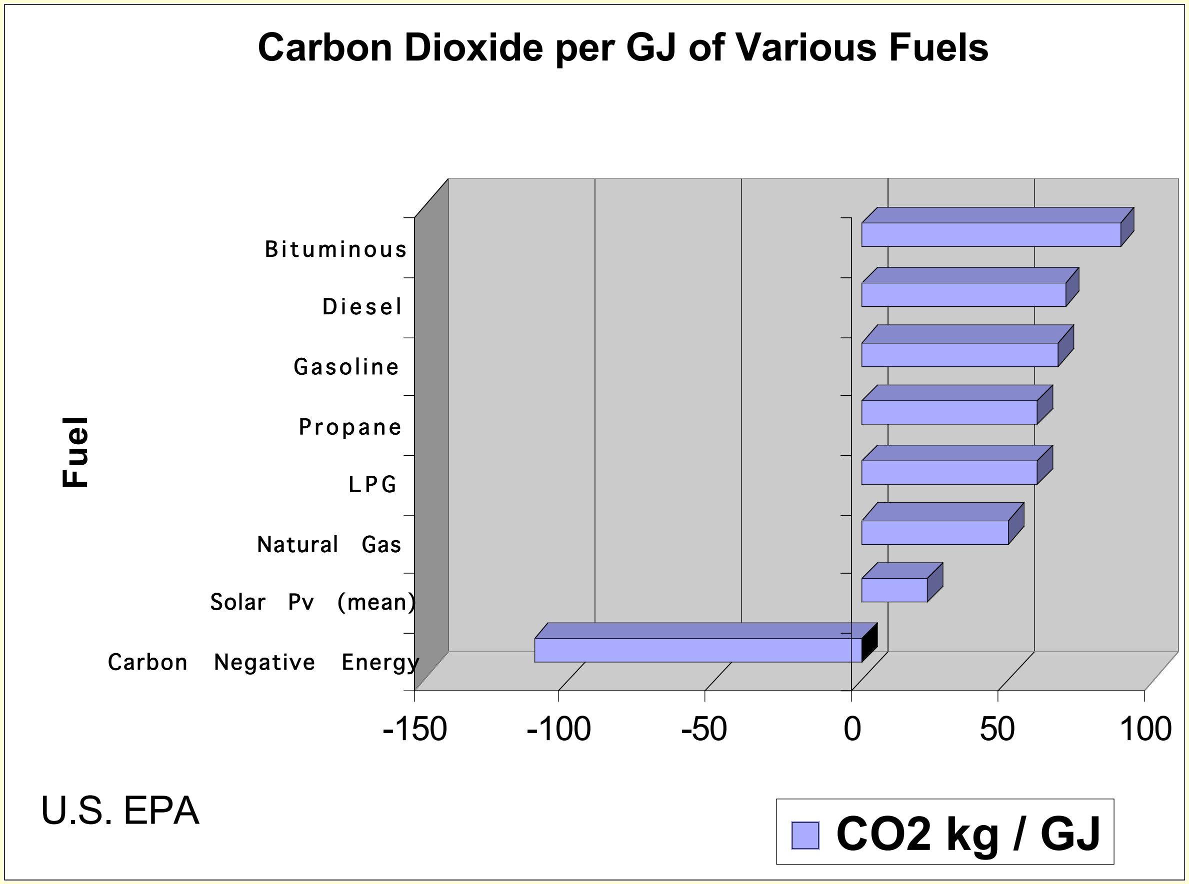


Remember Co-Products = Sustainability

Can biomass streams be as competitive fossil fuels?
Yes.

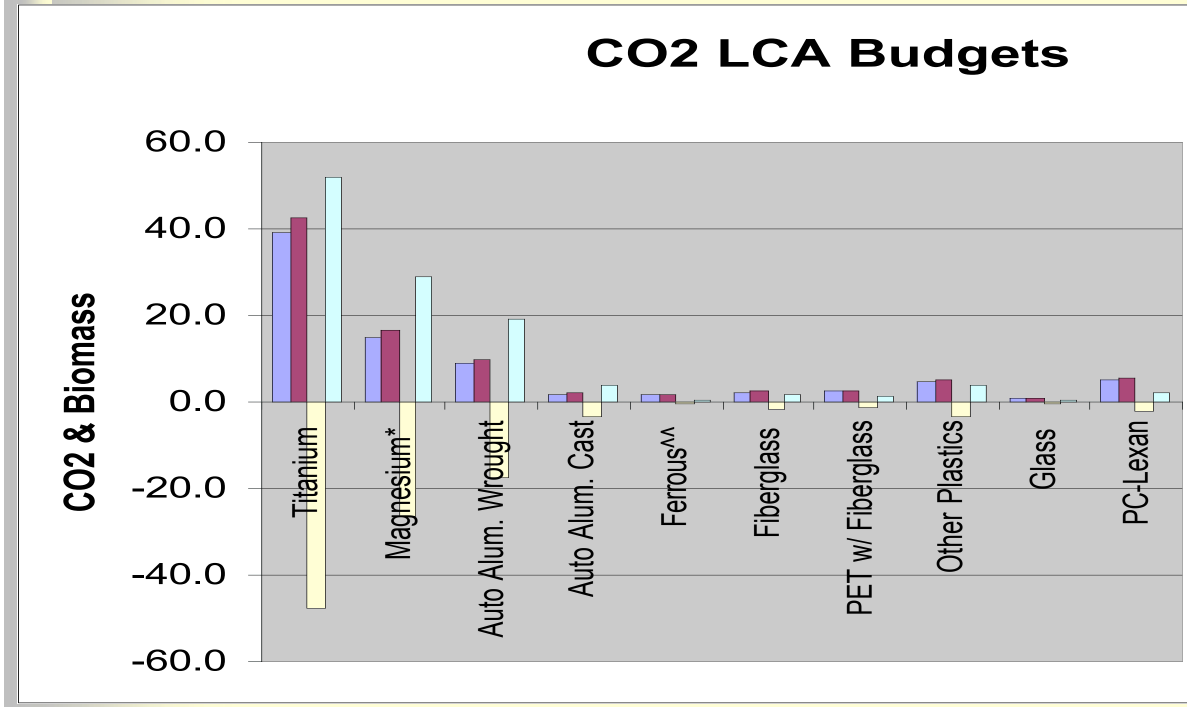
- Biomass becomes more competitive as as fuel prices rise
- Profits are made on co-products not just fuels.
- Proportionate funding of research and commercial support
- Homogenous standards and testing

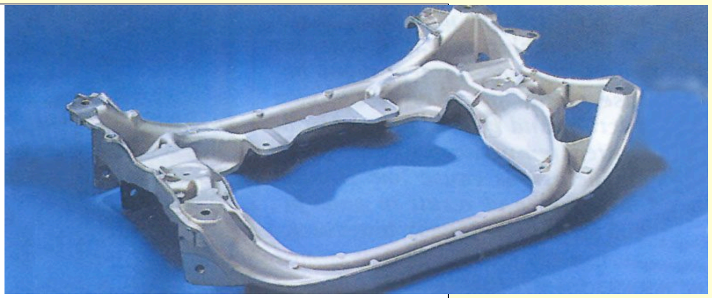
Agricultural use offers Carbon Negative Energy



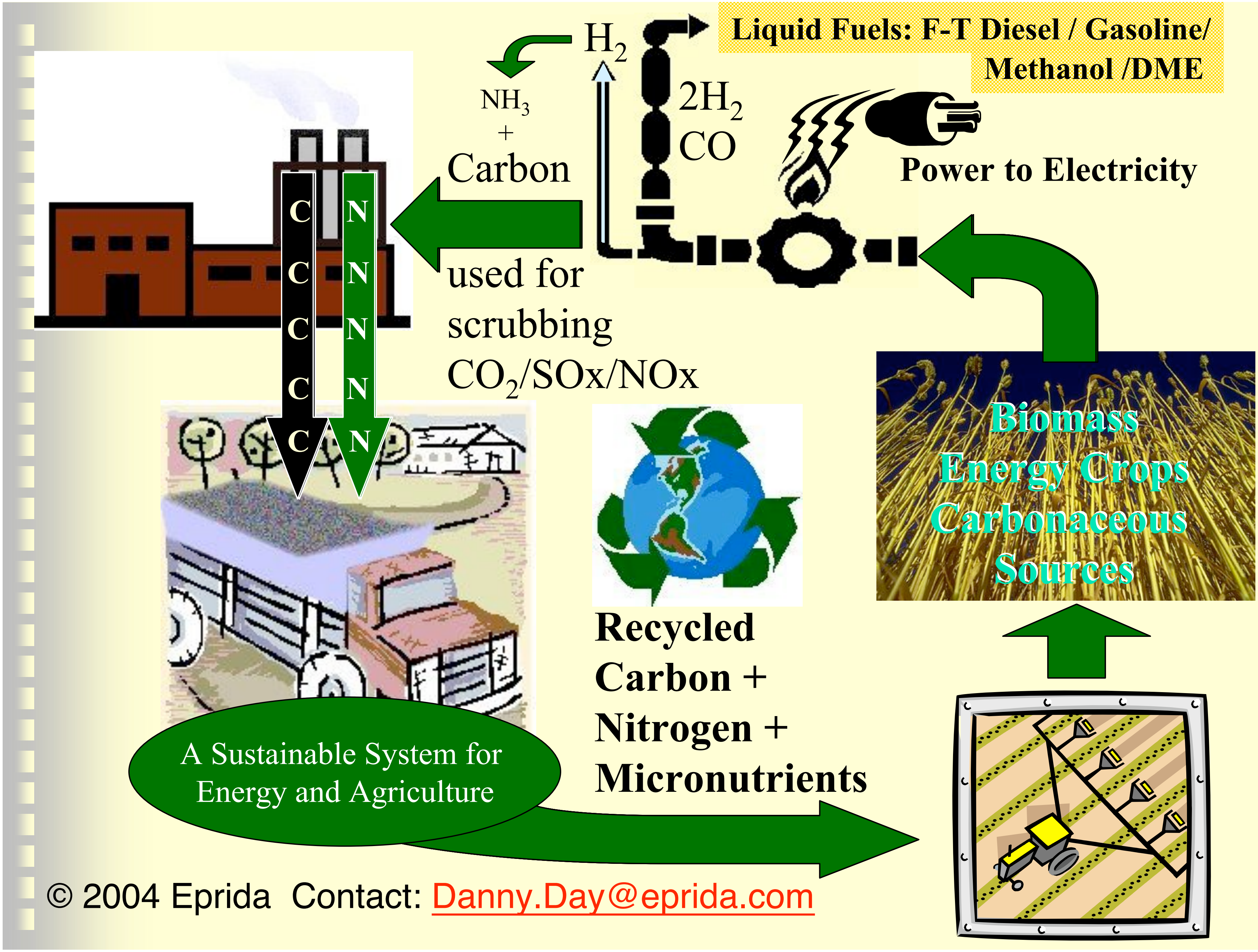
Special thanks to Stefan Czernick and Mathew Realff

The Opportunity





Materials that represent sequestered atmospheric carbon



Liquid Fuels: F-T Diesel / Gasoline/ Methanol /DME
H_2
$2H_2$
CO
NH_3
+
Carbon
used for scrubbing CO_2/SOx/NOx
Power to Electricity
C C C C C
N N N N N
Biomass
Energy Crops
Carbonaceous
Sources
Recycled Carbon + Nitrogen + Micronutrients
A Sustainable System for Energy and Agriculture
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Thank You

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