The Role of Agriculture in Advancing Carbon Negative Energy

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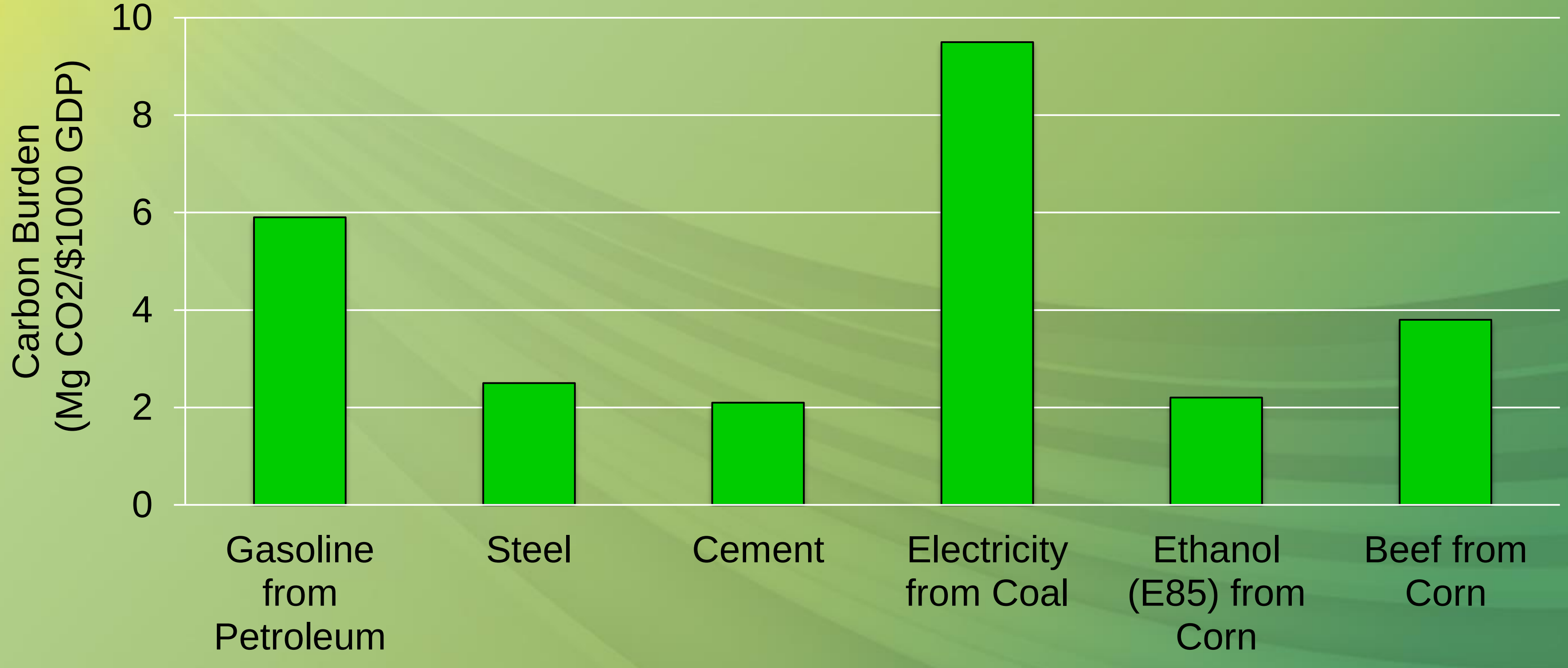
The Global Research Alliance on Agricultural Greenhouse Gases

ISU Field Trip, Sept. 11, 2015

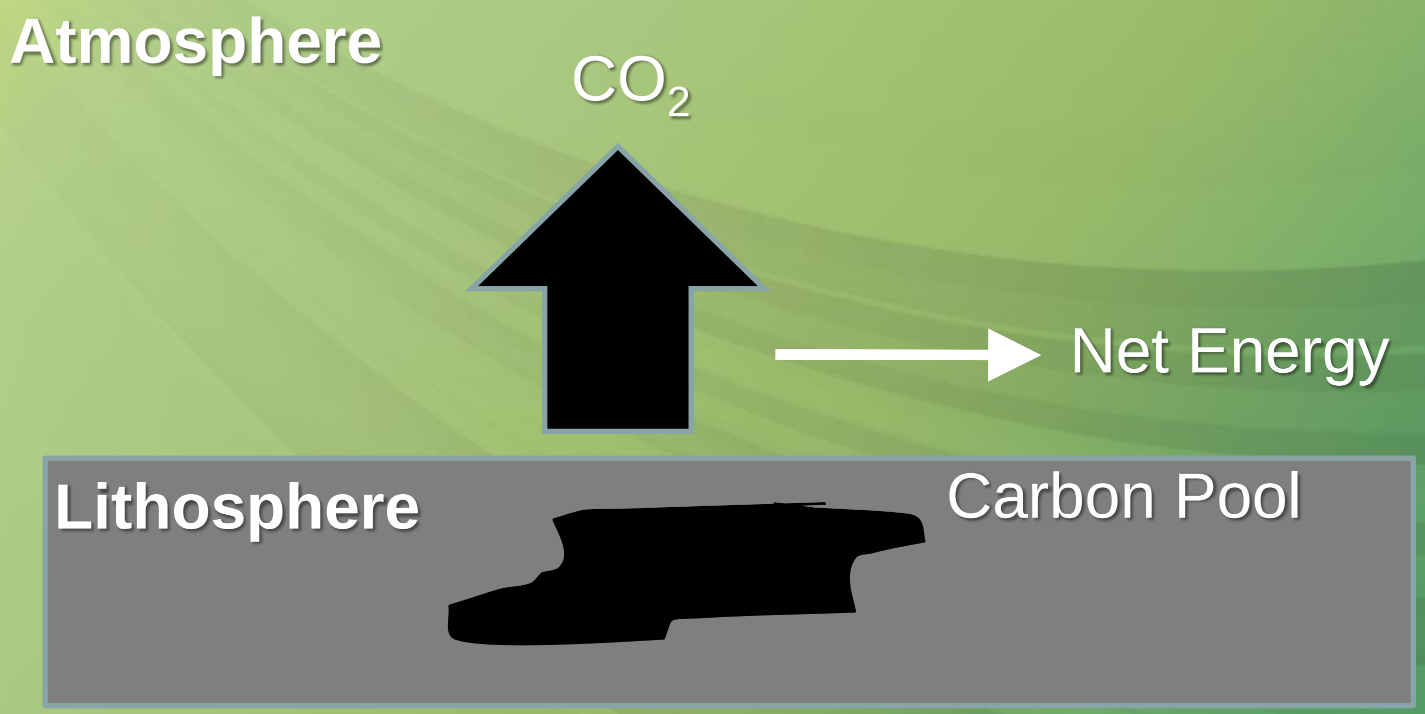
Why have concerns about global climate change not resulted in agreements to reduce greenhouse gas emissions?

All economic activity generates greenhouse gas emissions!



We Live in a Petroleum Economy

Petroleum Economy



Understanding Carbon Management: The Parable of the Coffee Cup

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March 06, 2015, 07:00 am

Managing carbon like coffee cups

By Robert C. Brown

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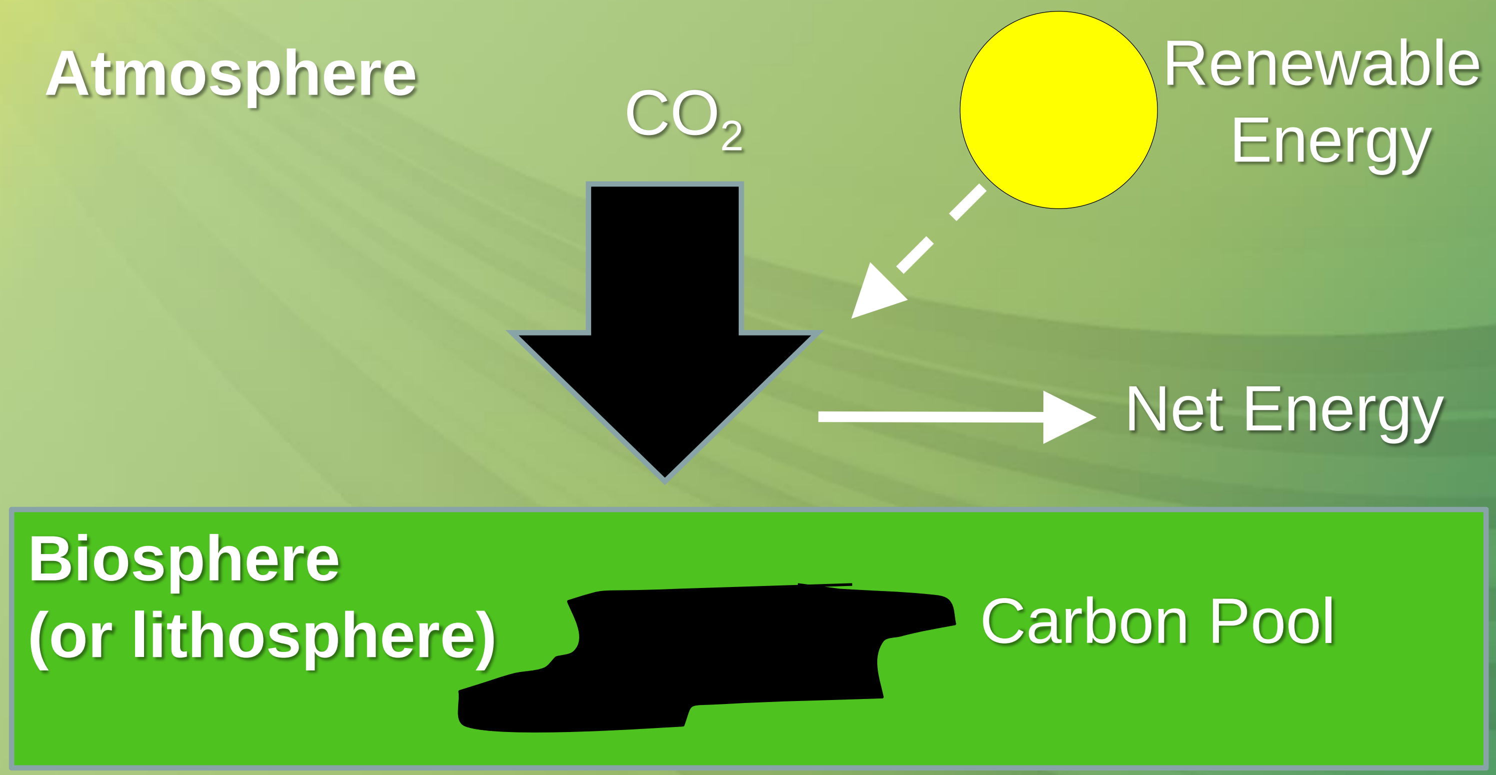
Many people find the role of biofuels in managing greenhouse gases difficult to understand. It can be readily explained over a cup of coffee. Imagine a couple who enjoy cups of coffee every morning. Of course, they wash and reuse the cups.

The husband discovers that Amazon.com will deliver two new coffee cups every morning – how much more convenient than washing cups every day! Soon dirty coffee cups overflow the cupboard. The wife suggests a return to recycling but the husband argues that there is no difference between new and recycled cups, so how does reusing cups help? She explains that although the cups are identical, it matters where they come from. Cups brought into the house are responsible for the problem, not the cups they reuse.

6 12.0107 C NEGATIVE

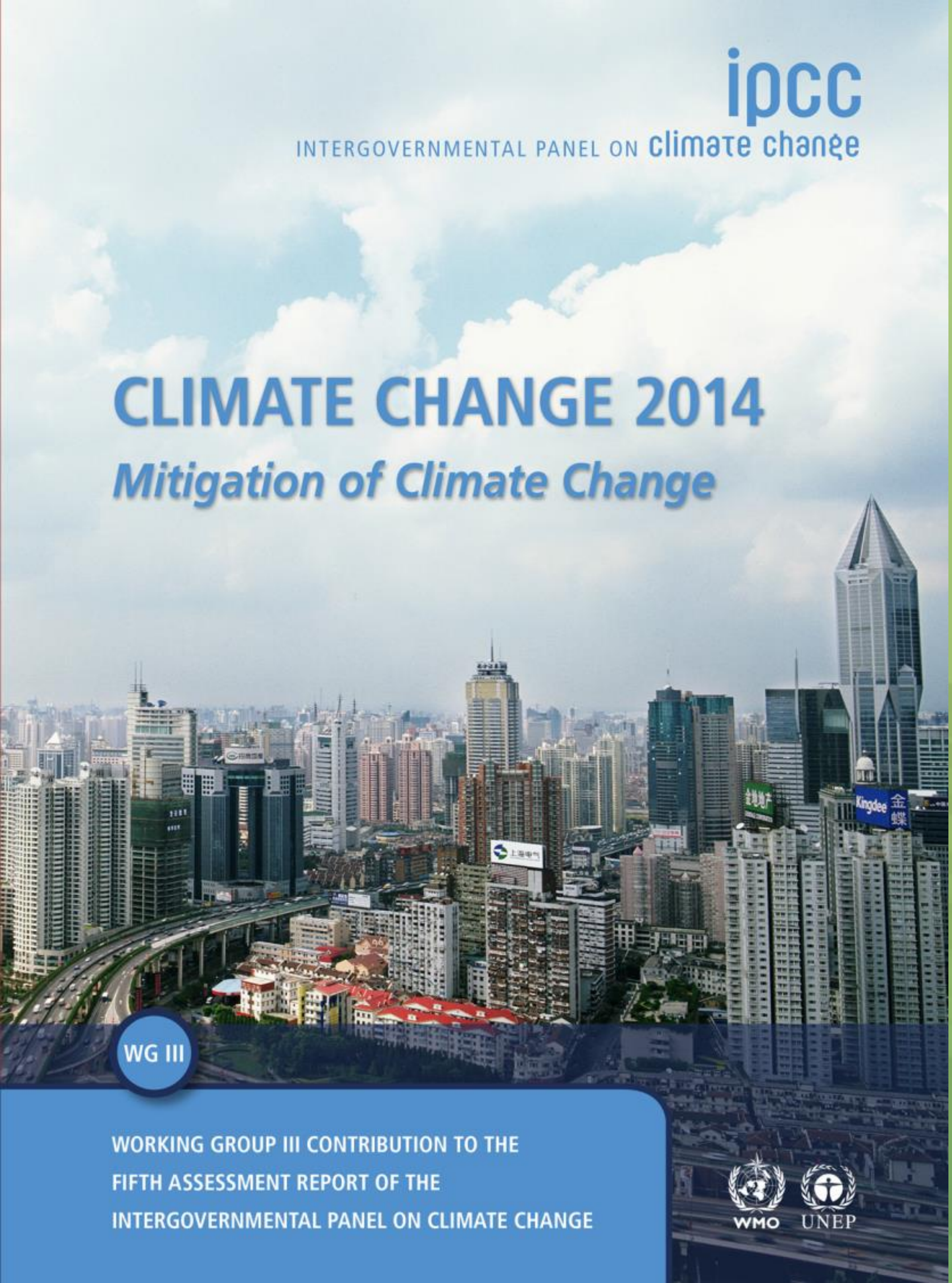
Reversing the Paradigm

Carbon Negative Economy



Key Features of Carbon Negative Technologies

- Fixes carbon from the atmosphere
- Sequesters carbon in the biosphere or the lithosphere (ideally, also providing ecosystem services)
- Ideally, will also generate co-products useful to human society (providing positive contribution to national economies)



- 2014 IPCC Working Group III report highlights carbon negative technologies
- Similar conclusions by Stanford's Global Climate and Energy Project (GCEP) and Imperial College's Grantham Institute of Climate Change

http://www.abc.net.au/news/2014-04-13/ipcc-working-group-iii-report-warns-of-high-cost-climate-change/5387006

Just how might you go about making a “carbon negative” economy?

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Artificial Trees

- Draws air through a sorbent to remove CO_2
- Powered by photovoltaics or wind power

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Mollusk Sequestration of CO_2

Current sequestration from world-wide shellfish farms

Component	Proportion	Weight (tonnes)
Molluscs	-	12,000,000
Shells	0.5	6,000,000
Calcium carbonate	0.95	5,700,000
CO_2	0.44	2,508,000

- Removes CO_2 dissolved in oceans
- Powered by nature
- Would require a 10,000 fold increase in shellfish farming to remove cumulative anthropogenic CO_2 within 50 years

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Biomass Energy Carbon Capture and Sequestration (BECCS)

- Fixes carbon from the atmosphere via photosynthesis in the form of biomass
- Biomass is converted to energy product* and a “storable” carbon product
- Carbon product is sequestered for millennia

*Energy product makes the process economically attractive

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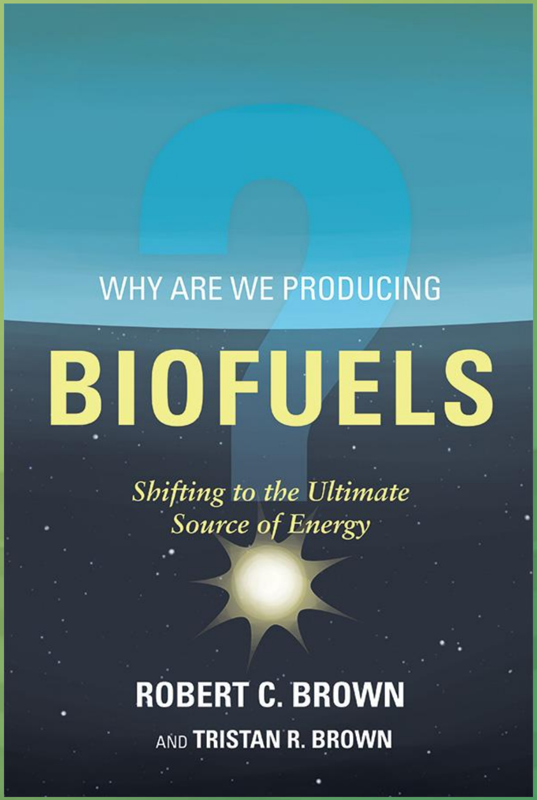
Why Biomass?

We must learn to harvest energy flows in the biosphere to provide society with both food and fuel … in a sustainable manner.

Annual energy resource	Exajoules
Solar	2,700,000
Wind	2,300
Photosynthetic fixation	3,000

Annual energy consumption	
Electricity	60
Primary energy use	470



Two Major Approaches to Biomass Energy Carbon Capture and Sequestration (BECCS)

- Gasification and sequestration of carbon dioxide
- Pyrolysis and sequestration of biochar

BECCS I: Gasification of Biomass

- Gasify biomass to syngas (CO and H_2)
- Generate energy products
  - Water-gas shift syngas to H_2 and CO_2 and burn H_2 for electric power generation; or
  - Convert syngas to hydrocarbon fuels and co-product CO_2
- Sequester CO_2 in geological deposits or oceans for carbon negative energy
- Concept can also be applied to CO_2 emissions from ethanol plants

BECCS I: Concern about CO_2 as carbon sequestration product

BBC NEWS

August 21, 1986
Hundreds gassed in Cameroon lake disaster

At least 1,200 people are feared dead in Cameroon, West Africa, after a cloud of lethal gas escaped from a volcanic lake. The tragedy happened at Lake Nyos, about 200 miles (322 km) northwest of the capital, Yaoundé, during the night.

Most of the victims died in their sleep. The gas killed all living things within a 15-mile (25km) radius of the lake, and the area is still highly contaminated.

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BECCS II: Pyrolysis of Biomass

- Terrestrial plants fix carbon as *biomass*
- Biomass is harvested and pyrolyzed to *bio-oil and biochar*
- Bio-oil is used as energy product for power production or upgraded to drop-in fuels, providing *net economic return*
- Biochar is returned to croplands where it recycles nutrients, improves soil fertility, and *sequesters carbon, making possible carbon negative energy*

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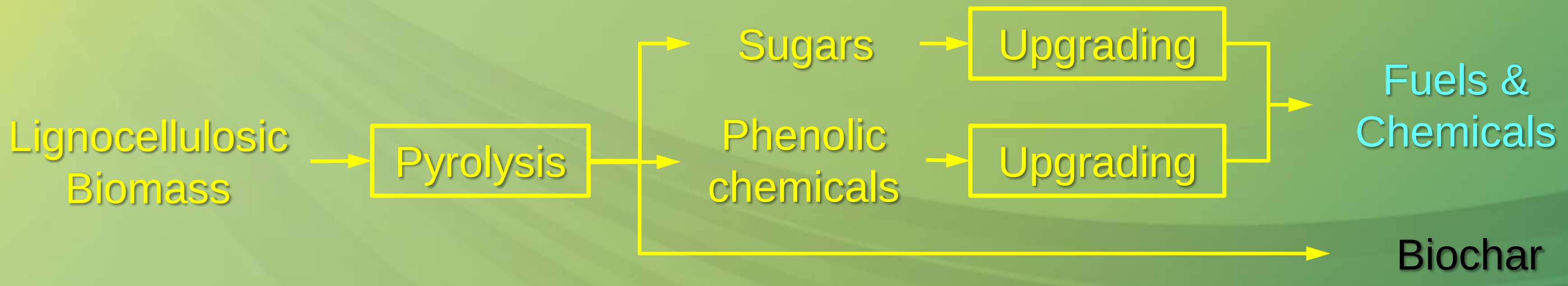
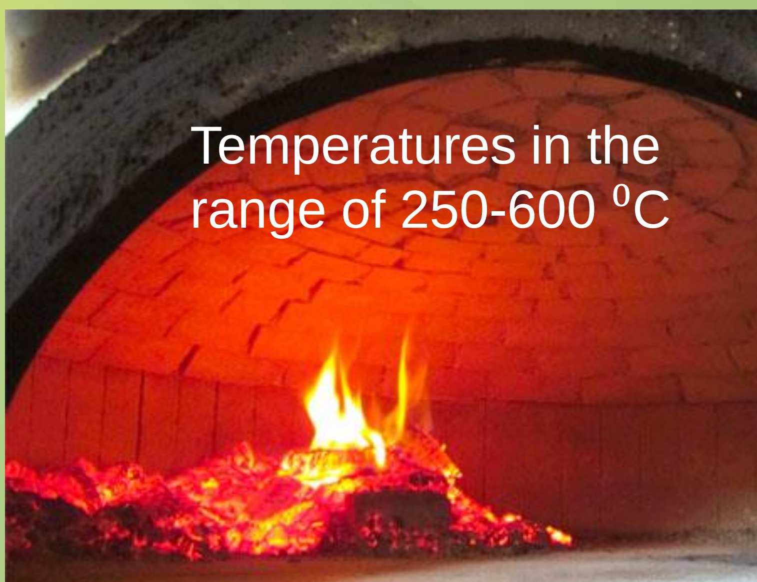
BECCS II: Pyrolysis Pathway to Carbon Negative Energy



Fast Pyrolysis

Rapid (few seconds) thermal decomposition of organic compounds in the absence of oxygen to produce bio-oil and biochar

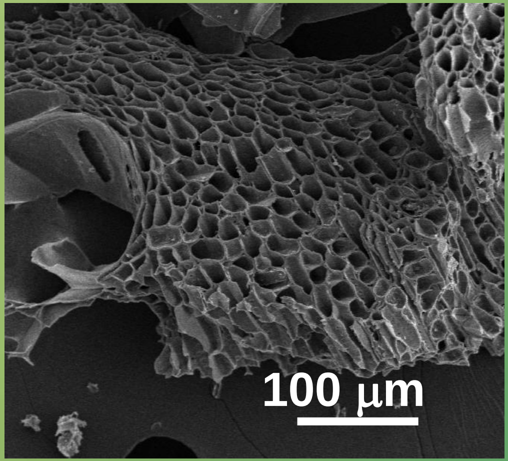


Advantages of Pyrolysis/ Biochar CNE

- Bio-oil can be upgraded to drop-in biofuels or used in electric power generation
- Biochar is a stable and benign carbon sequestration agent
- Biochar provides ecosystem services when sequestered in agricultural lands
- Technology suitable for relatively small-scale facilities

Biochar

- Porous, carbonaceous residue from pyrolysis of biomass
- Recalcitrant to biological degradation
- Impacts on soil quality
  - Increases fertilizer retention
  - Improves water retention
  - Reduces N_2O emissions from soils



Inspiration for Biochar: Terra Preta in Amazon Basin

- Created hundreds of years ago by pre-Colombian inhabitants of Amazon Basin
- Result of slash and char agriculture
- Much higher levels of soil organic carbon
- Far more productive than undisturbed Oxisol soils

Terra Preta Oxisol

Applied to the land, biochar serves as both soil amendment and carbon sequestration agent

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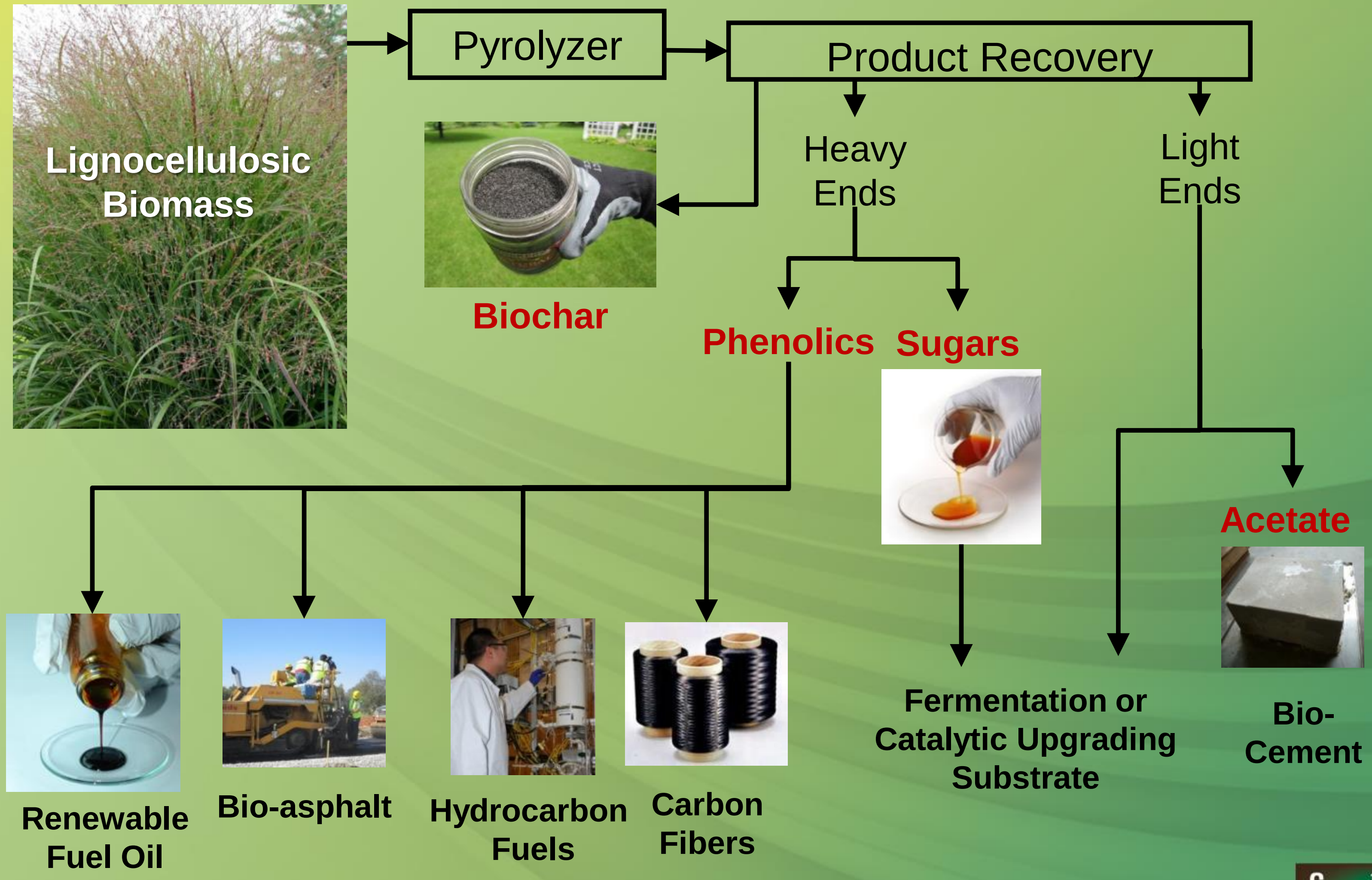
Glaser et al. 2001. Naturwissenschaften (2001) 88:37–41

Challenges to the Pyrolysis/Biochar Pathway to BECCS

- Large-scale biomass production for non-food uses
- Conversion of bio-oil into transportation fuels and other biobased products
- Characterizing biochars and understanding biochar properties, soils, climates, and application practices that optimize yield response

Py Refinery



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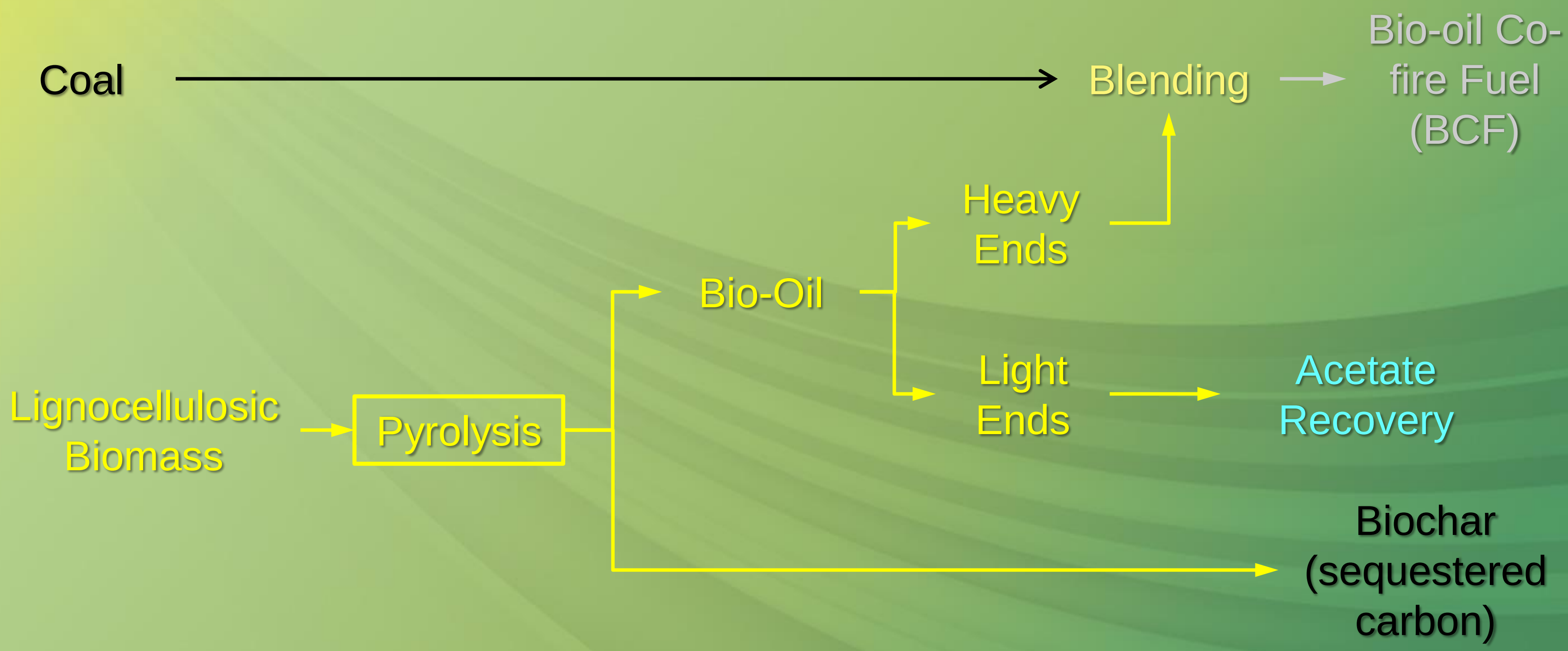
Transitional Pathway to CNE: Coal Power Plants with Ultra-low Carbon Emissions



Bio-Oil Co-Firing Fuel (BCF)

Ground coal mixed with hot "clean phenolic oligomers" (CPO) and cured either as "granola" or pellets

BCF granola

BCF pellets

	Coal	CPO	Biomass	
Heating Value	27.6	24.2	18.4	MJ/kg
Moisture	5.66	16.0	6.24	wt%
Volatiles	33.6	65.4	76.0	wt%
Fixed Carbon	51.9	23.4	17.5	wt%
Ash	8.84	0.05	0.25	wt%
Carbon	73.4	58.9	47.0	wt%
Hydrogen	5.20	6.67	6.41	wt%
Nitrogen	1.51	0.34	0.20	wt%
Sulfur	2.33	0.00	0.01	wt%
Oxygen	11.4	27.8	40.2	wt%

Within uncertainty of measurements, BCF formulated from 70% coal + 30% CPO has heating value identical to coal

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BCF/Biochar Demonstration

- Retrofit 30 TPD pyrolysis unit at Stine Seed Co. to produce fractionated bio-oil and biochar
- Blend heavy ends of bio-oil with coal to produce BCF
- Co-fire BCF at Iowa State University power plant
- Apply biochar to cropland as soil amendment and carbon sequestration agent in partnership with Soybean Promotion Board

Stine Pyrolyzer

ISU Power Plant

Biochar Application

Bio-oil Co-Fire Fuel (BCF) Could Bring Coal-Fired Power Plants in Line with Proposed New Mandates on CO_2 Emissions

- EPA proposed 40% CO_2 reductions from coal-fired power plants by 2025
- BCF consisting of 36 wt% bio-oil and 67 wt% coal would achieve this target

- Cost of electricity based on BCF at an existing coal-fired facility (10% IRR): $0.094/kWhr
- Average cost of electricity for a new conventional coal-fired facility*: $0.096/kWhr

* Assumes coal costs $56.3/Mg, biomass costs $83/Mg and 10% IRR

Backyard Biochar Garden

Red Pots: Biochar
Yellow Pots: Control

Backyard Biochar Garden –2011

Harvested Tomatoes for Week of July 24

Questions?