



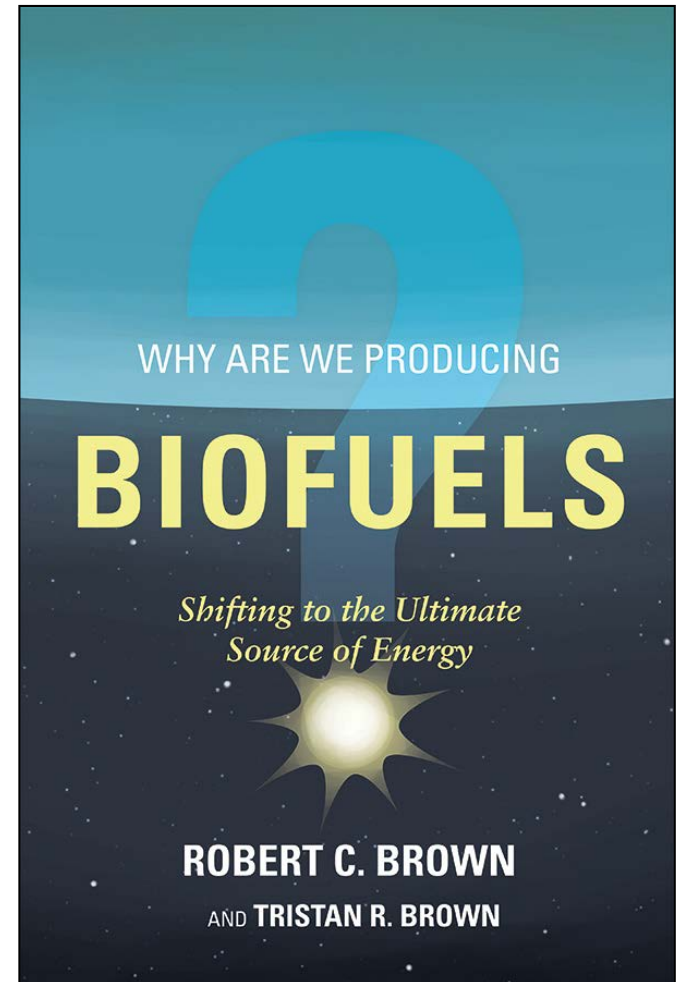
The Role of Biofuels in Carbon Management

Robert C. Brown
Iowa State University
August 14, 2018

Why Are We Producing Biofuels?

We have few other alternatives to:

- Develop sustainable transportation fuels;
- Dramatically reduce greenhouse gas emissions from transportation;
- Achieve cost-effective carbon dioxide removal and sequestration from the atmosphere.



Biofuels: Plenty of options

Conventional

Ethanol from starch crops

Ethanol from sugar crops

Biodiesel from oil crops

Biodiesel from waste oil

Advanced

Butanol from starch crops

Butanol from sugar crops

Ethanol from cellulosic crops

Green diesel from waste oil

Green diesel from algae

Drop-in biofuels from
cellulosic crops

Biofuels: Plenty of criticism

“Biofuels are bad because_____”

Claim: There is no difference between the CO₂ emitted from burning ethanol and burning gasoline.

Fact: Managing carbon requires an understanding of its source.

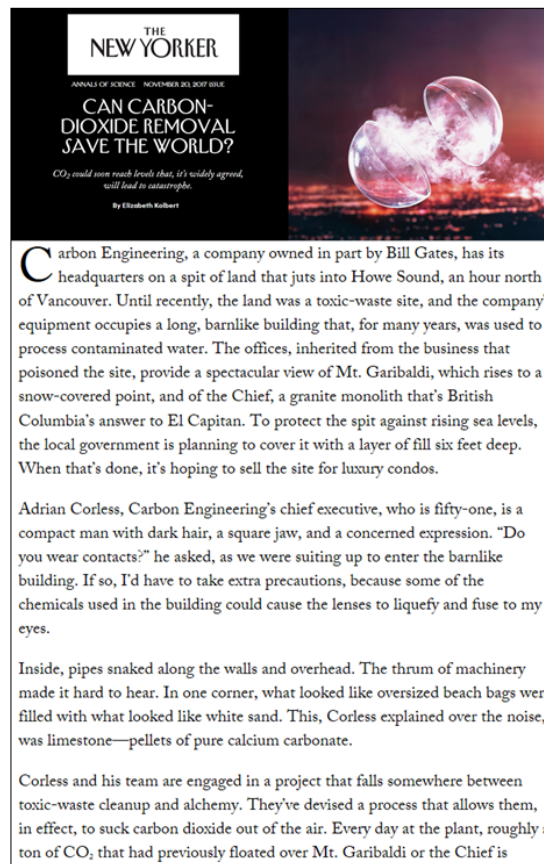


The screenshot shows a blog post from 'THE HILL' Congress Blog. The header features the 'THE HILL' logo in large white letters on a blue background, followed by a smaller image of the US Capitol dome and the text 'CONGRESS BLOG THE HILL'S FORUM FOR LAWMAKERS AND POLICY PROFESSIONALS'. Below this is a Twitter feed icon and a date stamp: 'March 06, 2015, 07:00 am'. The main title of the post is 'Managing carbon like coffee cups' by Robert C. Brown. Social media sharing icons for Facebook, Google+, Twitter, LinkedIn, and a dropdown menu are visible, along with a 'COMMENTS 0' button. The post text begins with: '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.'



Climate policies increasingly call for Carbon Dioxide Removal and Reliable Sequestration (CDRRS)

- 2014 IPCC Working Group III report highlights carbon negative energy
- 2015 Climate Summit in Paris concludes that nations should work toward a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases



Carbon Engineering, a company owned in part by Bill Gates, has its headquarters on a spit of land that juts into Howe Sound, an hour north of Vancouver. Until recently, the land was a toxic-waste site, and the company's equipment occupies a long, barnlike building that, for many years, was used to process contaminated water. The offices, inherited from the business that poisoned the site, provide a spectacular view of Mt. Garibaldi, which rises to a snow-covered point, and of the Chief, a granite monolith that's British Columbia's answer to El Capitan. To protect the spit against rising sea levels, the local government is planning to cover it with a layer of fill six feet deep. When that's done, it's hoping to sell the site for luxury condos.

Adrian Corless, Carbon Engineering's chief executive, who is fifty-one, is a compact man with dark hair, a square jaw, and a concerned expression. "Do you wear contacts?" he asked, as we were suiting up to enter the barnlike building. If so, I'd have to take extra precautions, because some of the chemicals used in the building could cause the lenses to liquefy and fuse to my eyes.

Inside, pipes snaked along the walls and overhead. The thrum of machinery made it hard to hear. In one corner, what looked like oversized beach bags were filled with what looked like white sand. This, Corless explained over the noise, was limestone—pellets of pure calcium carbonate.

Corless and his team are engaged in a project that falls somewhere between toxic-waste cleanup and alchemy. They've devised a process that allows them, in effect, to suck carbon dioxide out of the air. Every day at the plant, roughly a ton of CO₂ that had previously floated over Mt. Garibaldi or the Chief is



BONN
Cutting emissions will not be enough to keep global warming in check. Greenhouse gases must also be scrubbed from the air



SWEDEN'S parliament passed a law in June which obliges the country to have "no net emissions" of greenhouse gases into the atmosphere by 2045. The clue is in the wording. This does not mean that three decades from now Swedes must emit no planet-heating substances; even if all their electricity came from renewables and they only drove Teslas, they would presumably still want to fly in aeroplanes, or use cement and fertiliser, the making of which releases plenty of carbon dioxide. Indeed, the law only requires gross emissions to drop by 85% compared with 1990

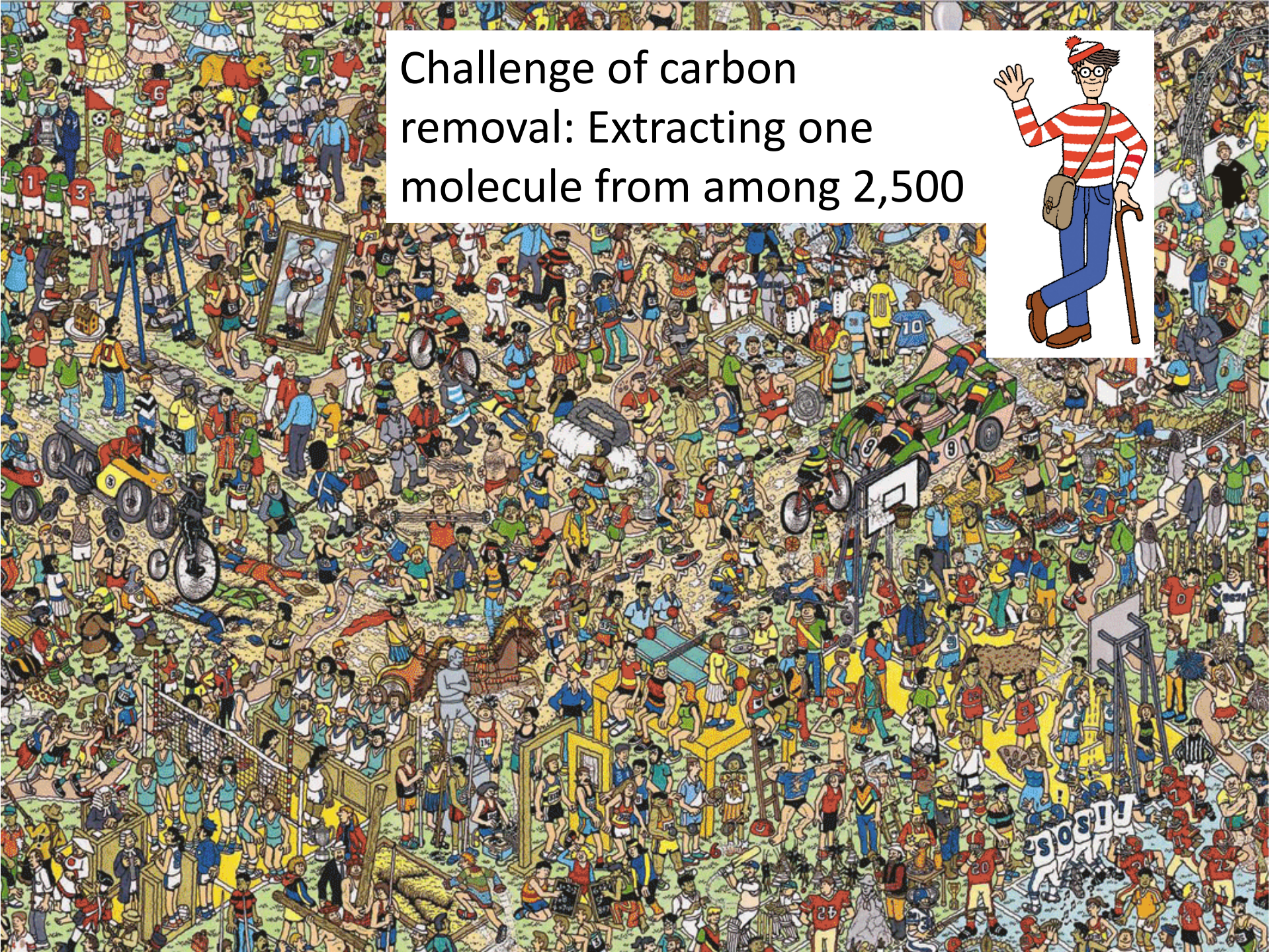
Carbon reduction vs carbon removal

- Carbon *reduction* – reduce the rate at which carbon dioxide enters the atmosphere



- Carbon *removal* – remove carbon dioxide from the atmosphere

Challenge of carbon
removal: Extracting one
molecule from among 2,500



Some Ideas for Carbon Dioxide Removal and Reliable Sequestration (CDRRS)

Direct Air Capture



- Draws air through a sorbent to remove CO₂
- Powered by photovoltaics or wind power

Mollusk Sequestration of CO₂

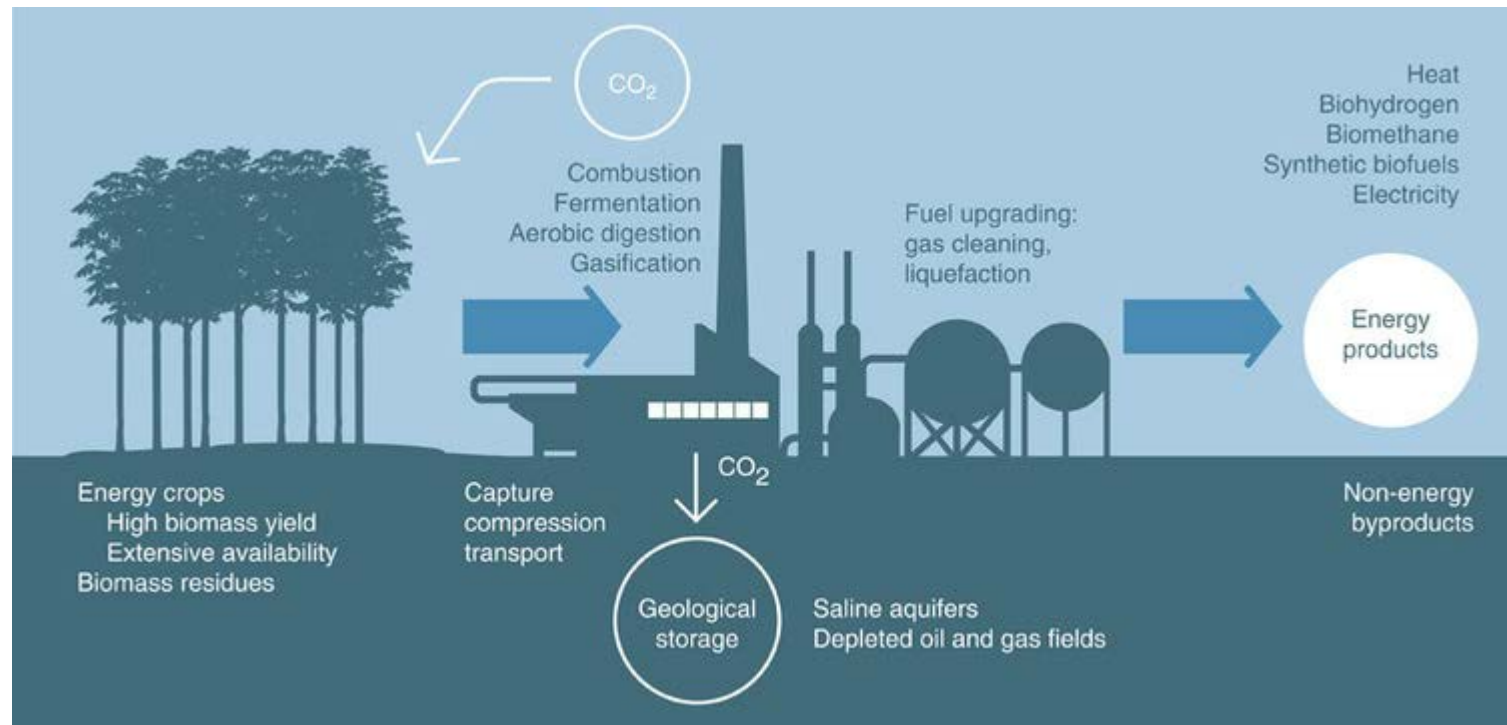


Current sequestration from world-wide shellfish farms

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 CO₂ dissolved in oceans
- Powered by nature
- Would require a 10,000 fold increase in shellfish farming to remove cumulative anthropogenic CO₂ within 50 years

Biomass Energy Carbon Capture and Sequestration (BECCS)



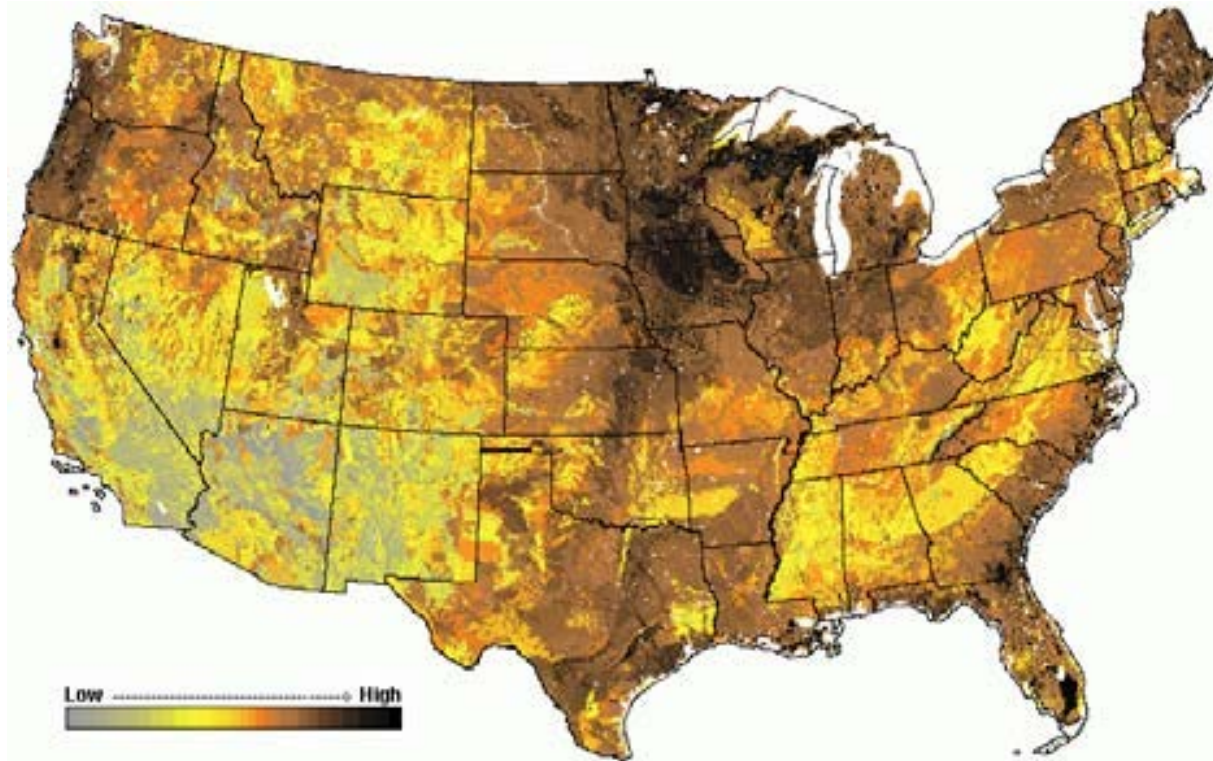
<http://www.centerforcarbonremoval.org/blog-posts/2015/11/3/theme-of-the-month-november-beccs>

Surely agriculture can come up with
carbon removal strategies!



Let's store it in soils, like Iowa already does...

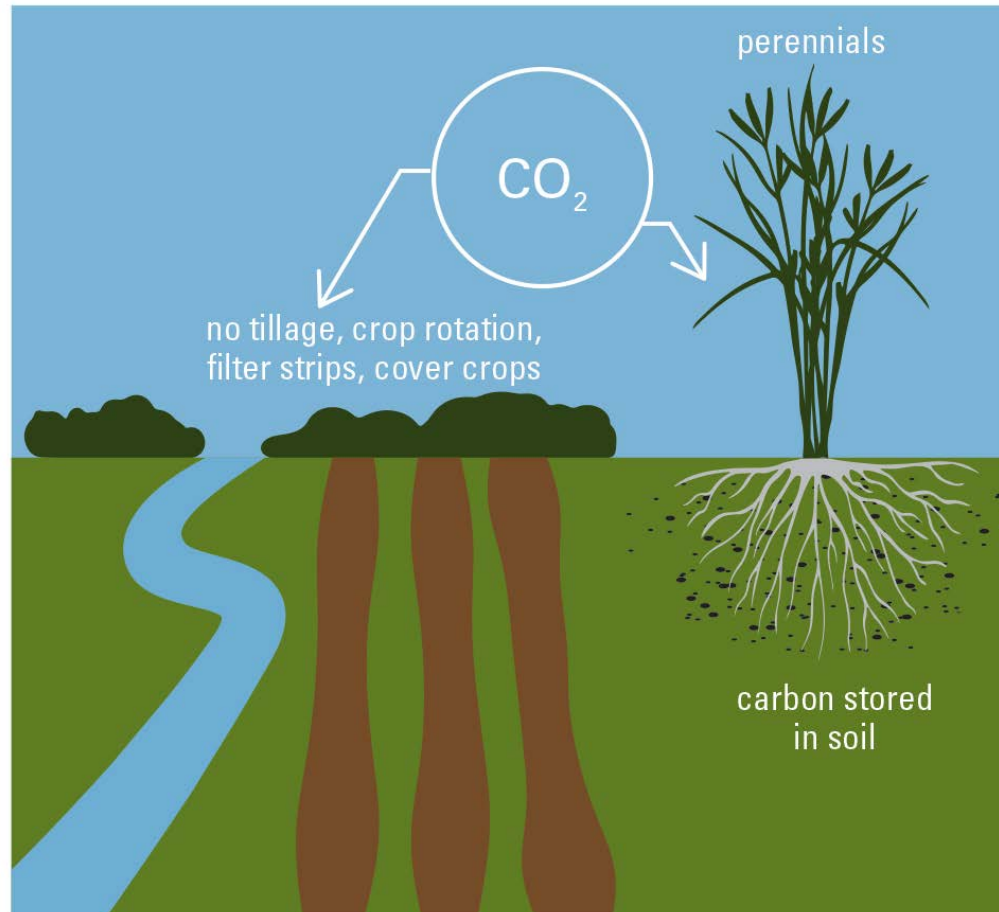
Soil organic matter in the U.S.



Hargrove and Luxmore (1988)

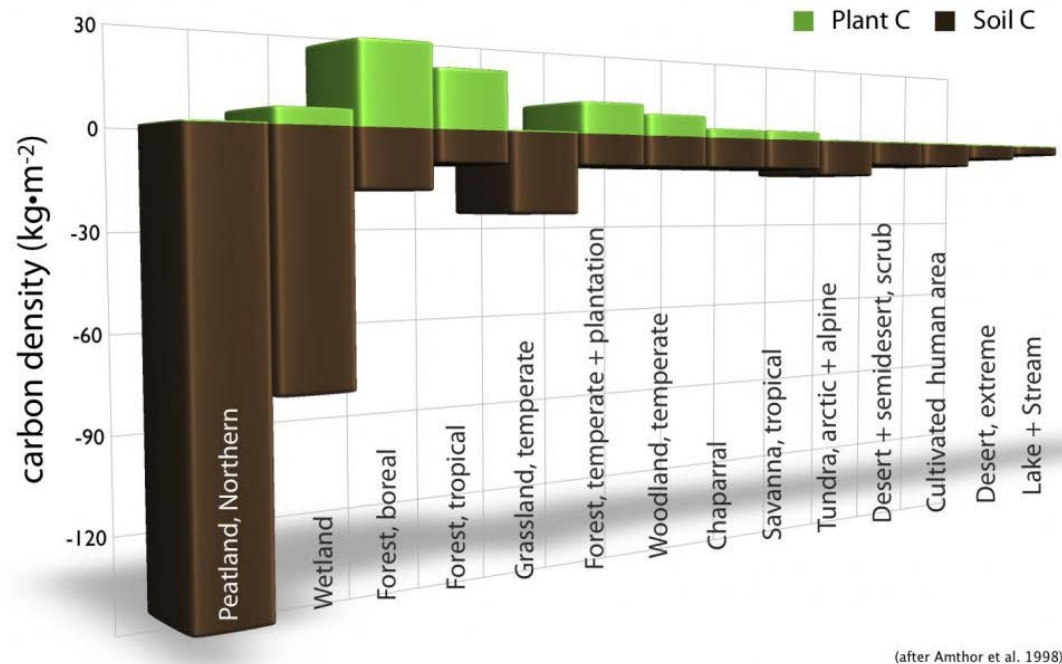
Agriculture-based Carbon Dioxide Removal and Reliable Sequestration (Ag-CDRRS)

Soil Carbon Management

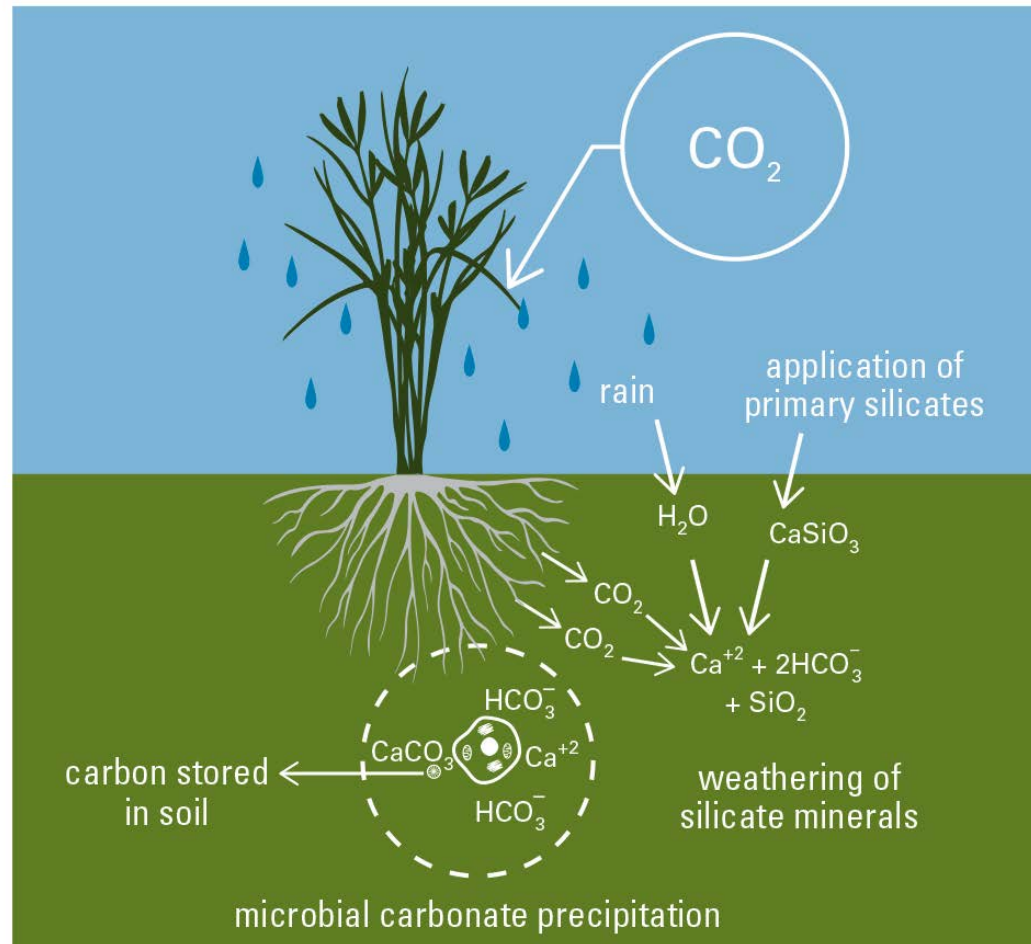


Terrestrial ecosystems store most of their carbon in soils

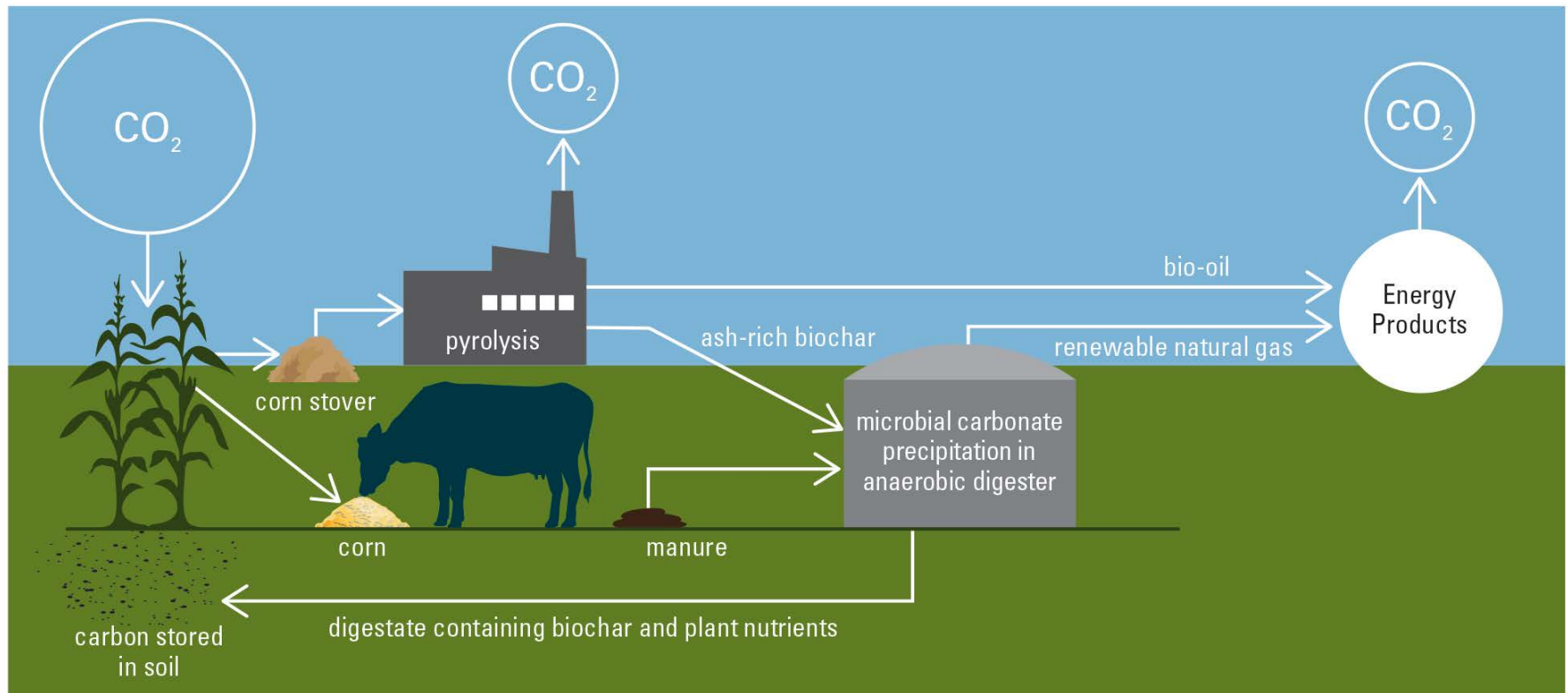
Eighty one percent in of the carbon in the earth's biosphere is stored in the soil while only nineteen percent is stored in plants (IPCC, 2000)



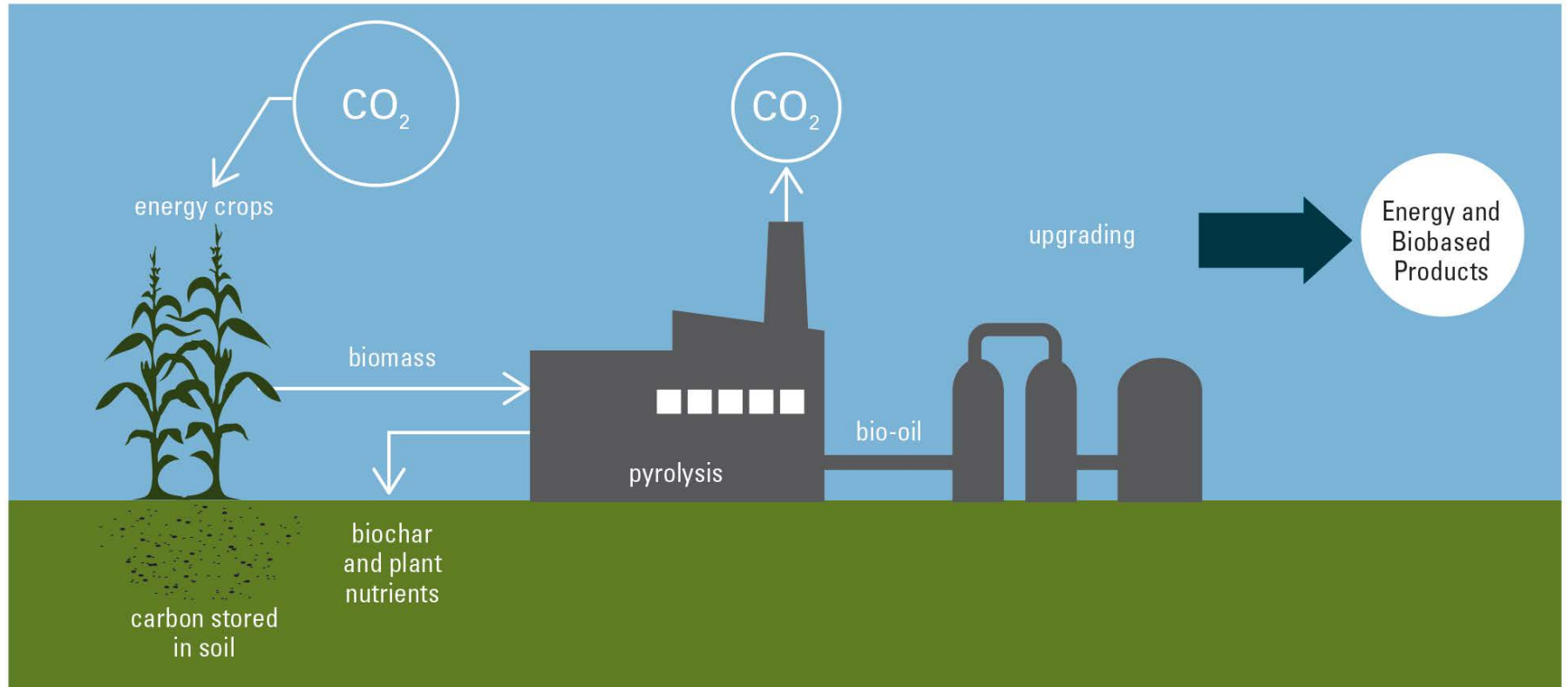
Microbial Carbonate Precipitation (MCP) in Soils



Microbial Carbonate Precipitation (MCP) in Anaerobic Digestion

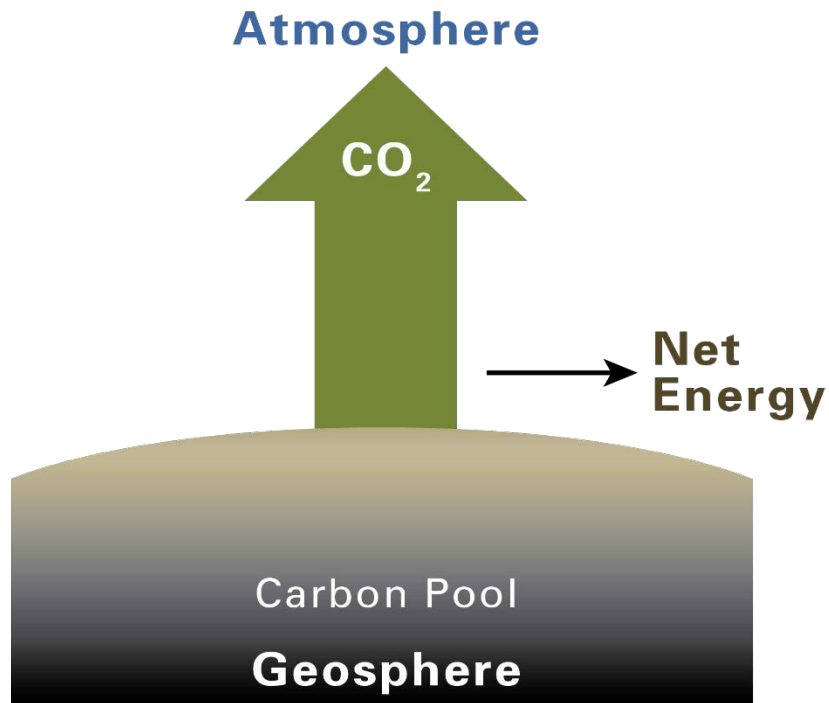


Pyrolysis-Biochar Platform

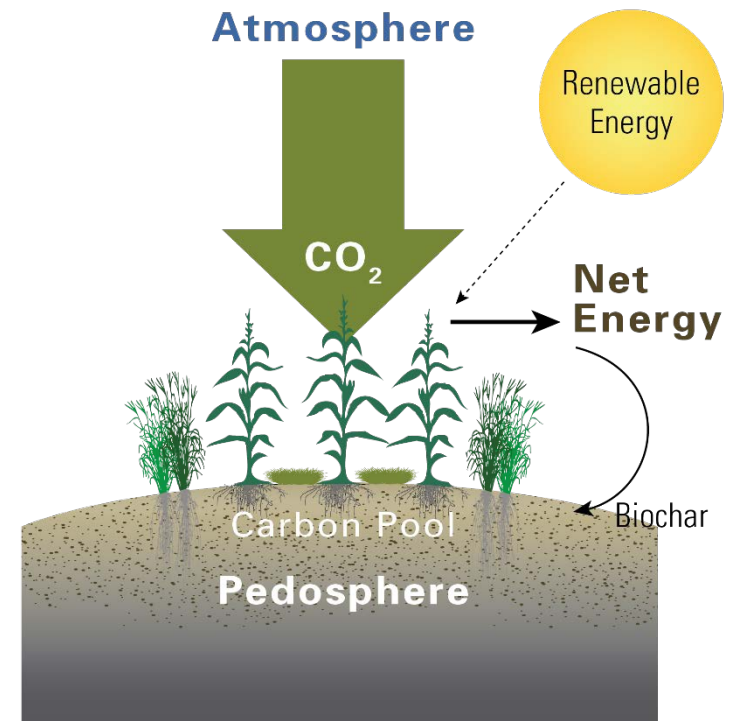


The pyrolysis-biochar platform stores carbon in soils as biochar...

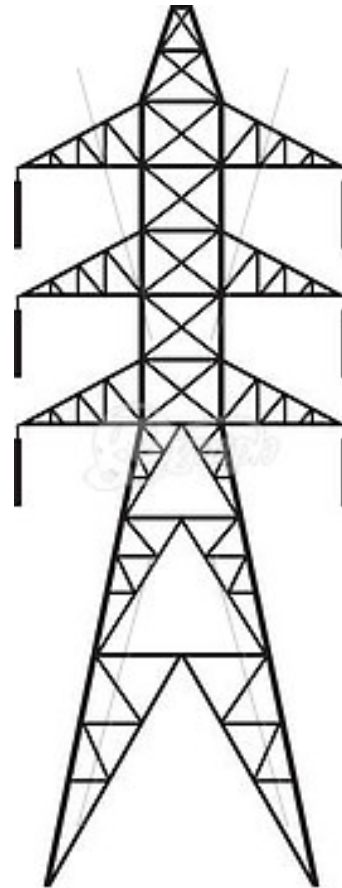
Carbon Positive Energy



Carbon Negative Energy



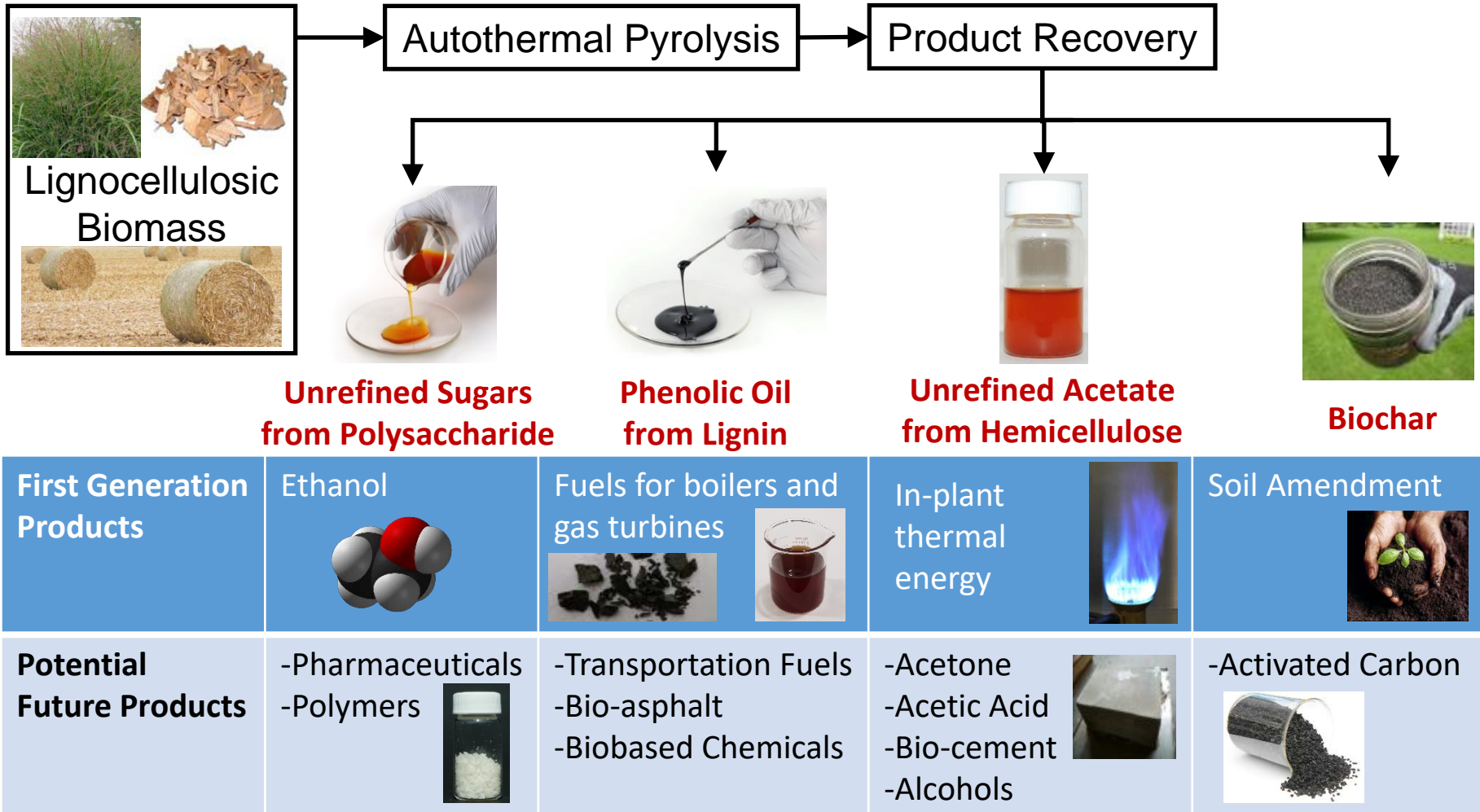
...while supplying carbon negative energy for transportation and power



Key features of carbon negative energy

- Fixes carbon from the atmosphere
- Sequesters carbon in the biosphere (potentially providing ecosystem services) or the geosphere
- Generates energy products that contribute to the nation's economy

ISU strategy for obtaining energy products from biomass: Py refinery

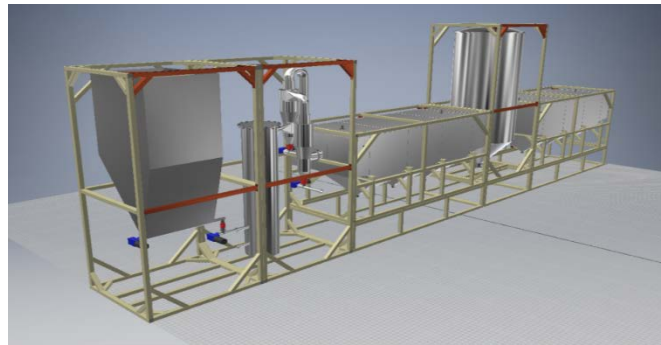


Pyrolysis demonstration project

- Partners: Iowa State University, Easy Energy Systems and Stine Seed Company
- Technology: Modular Energy Production Systems (MEPS) based on ISU pyrolysis technology
- Approach: Pilot scale research to guide design of 50 tpd demonstration plant
- Products: Pyrolytic sugars, fuel oil substitute and biochar



Pilot plant (15-20 kg/h) used to design demonstration plant



Modular Energy Production System
Demonstration plant (50 tpd)

Pyrolytic sugar



Fuel oil
substitute



Biochar Application

Summary

- Biofuels is an opportunity to provide sustainable liquid fuels for transportation, reduce greenhouse gas emissions compared to petroleum and even achieve carbon negative energy
- Carbon removal is increasingly recognized as important for mitigating global climate change – pyrolysis-based biofuels offers a pathway to carbon negative energy
- ISU is demonstrating Py Refineries for production of sugars and phenolic oil with multiple energy and material applications and biochar for carbon negative energy