The Science of Biochar

The Need-to-Knows and the Opportunity Landscape

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- **Background:** Dr. Hugh McLaughlin, PhD, PE has degrees in Chemistry and Chemical Engineering. He provides direct technical support to internal corporate research programs and stand-alone technical analysis for existing and emerging chemical processes, typically for due diligence by private investors and financial institutions, especially in the renewable chemicals and energy spaces.

- **Projects:** Over the course of a career spanning four decades within the Chemical Processing Industries, Dr. McLaughlin has participated in virtually any aspect of taking an idea from conception to commercial scale operating facilities, participating in process engineering and product development efforts, including start ups.

- **Expertise:** One of the leading technical experts on Activated Carbon properties and uses, in addition to leading the development of basic science in the emerging Biochar marketplace. He is the principal author on several seminal publications on Biochar Characterization and the underlying material properties.

About Lee Enterprises Consulting

◆ *SEASONED, INDEPENDENT, PROFESSIONAL EXPERTISE* ◆

- **OUR TEAM:** We are the world's largest bio consulting group with over 100 subject matter experts.
- **OUR PROJECTS:** Our members have completed thousands of projects in anaerobic digestion, biofuels, biomaterials, chemicals, DSP, feedstocks, fermentation, gasification, pyrolysis, synthetic biology, and water/ wastewater treatment.
- **OUR ADVANTAGE:** We provide independent third-party expertise that provides cost-effective, interdisciplinary teams with a single point of client contact without hiring additional full-time employees.
- **OUR CLIENTS:** Our clients include biofuels companies, biochemical companies, investors, banks, entrepreneurs, plant owners, law firms, biotechnology providers, energy companies, and engineering firms.

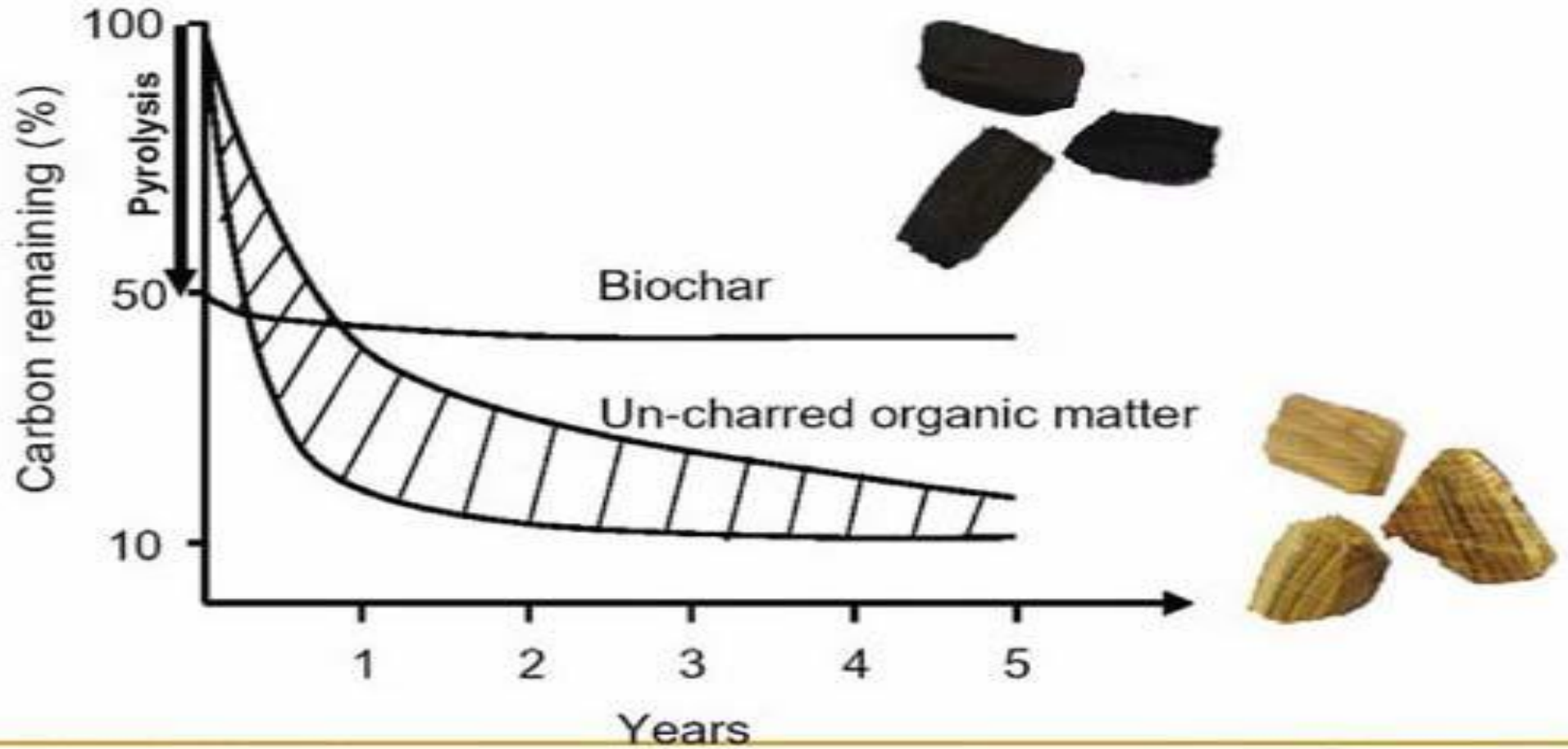
The science of Biochar is maturing and the marketplace is developing around proven crop responses. Climate disruption is driving many applications where the status quo is just not working any more.

In this webinar, we'll cover the need to knows, how to assess the needs, fill the knowledge gaps, analyze the markets and technology readiness, confirm results, and prepare for success in biochar.

the need to knows

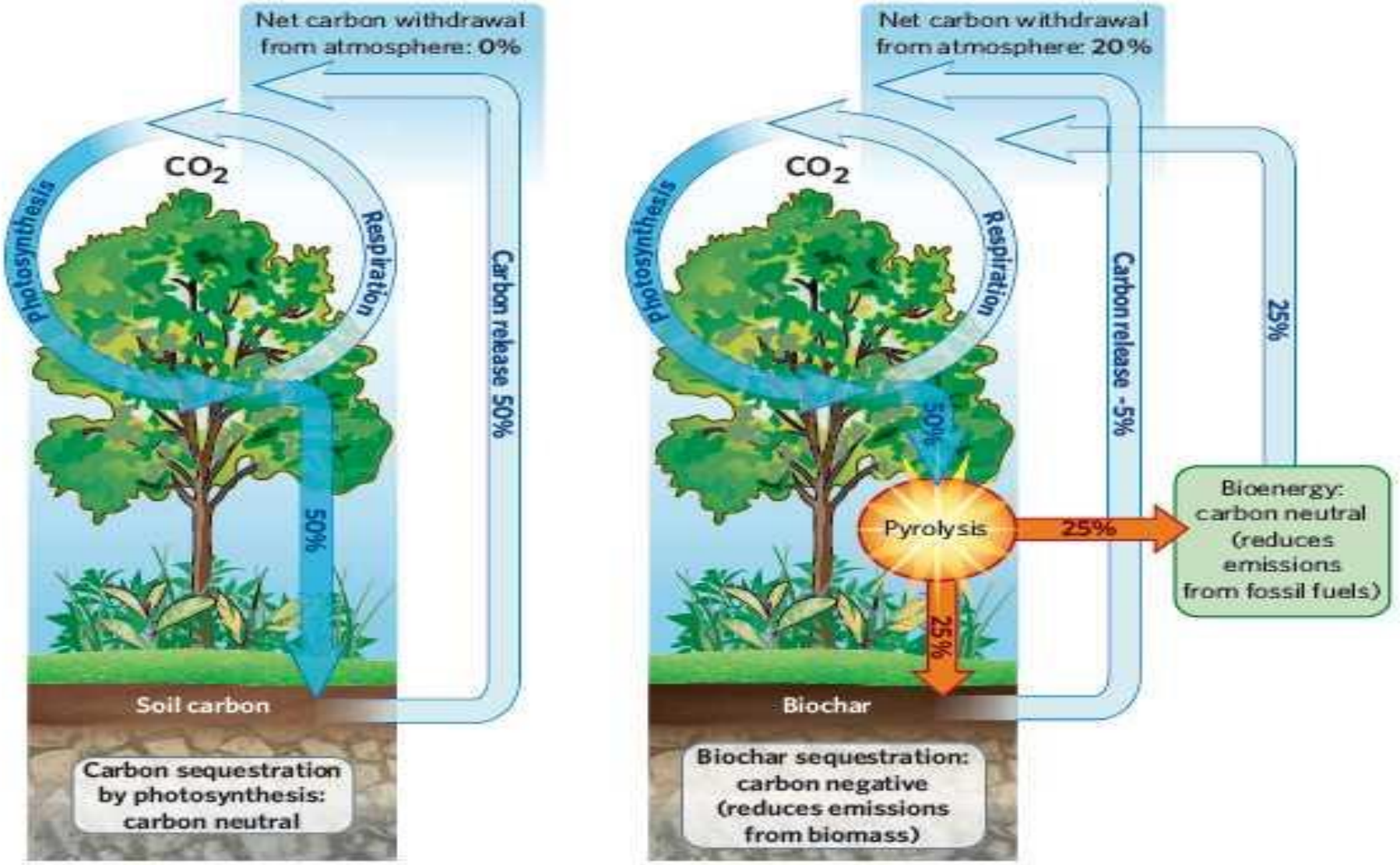
- This section summarizes the core phenomena that make Biochar unique – as a material and as a possible solution to food production and climate change.
- Biochar is created by pyrolyzing - heating in an oxygen deficient atmosphere - biomass, principally plant residues, converting them into biochar and generating a larger portion of volatiles.
- Biochar is similar to Charcoal, but significantly different. **Charcoal is a fuel. Biochar is any other use except fuel.**

The essential stability of biochar

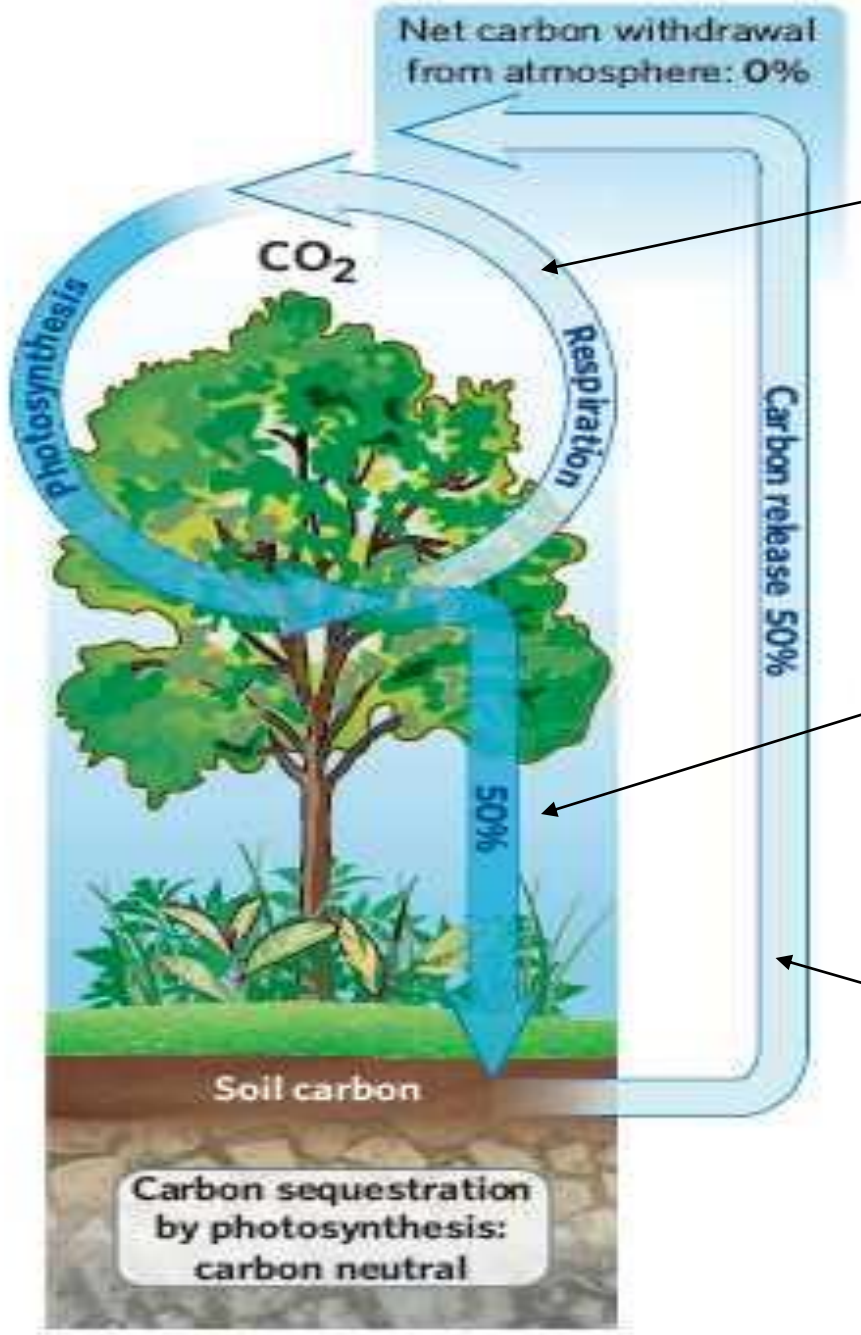


Lehmann et al., 2006, *Mitigation and Adaptation Strategies for Global Change* 11, 403-427

Cornell University



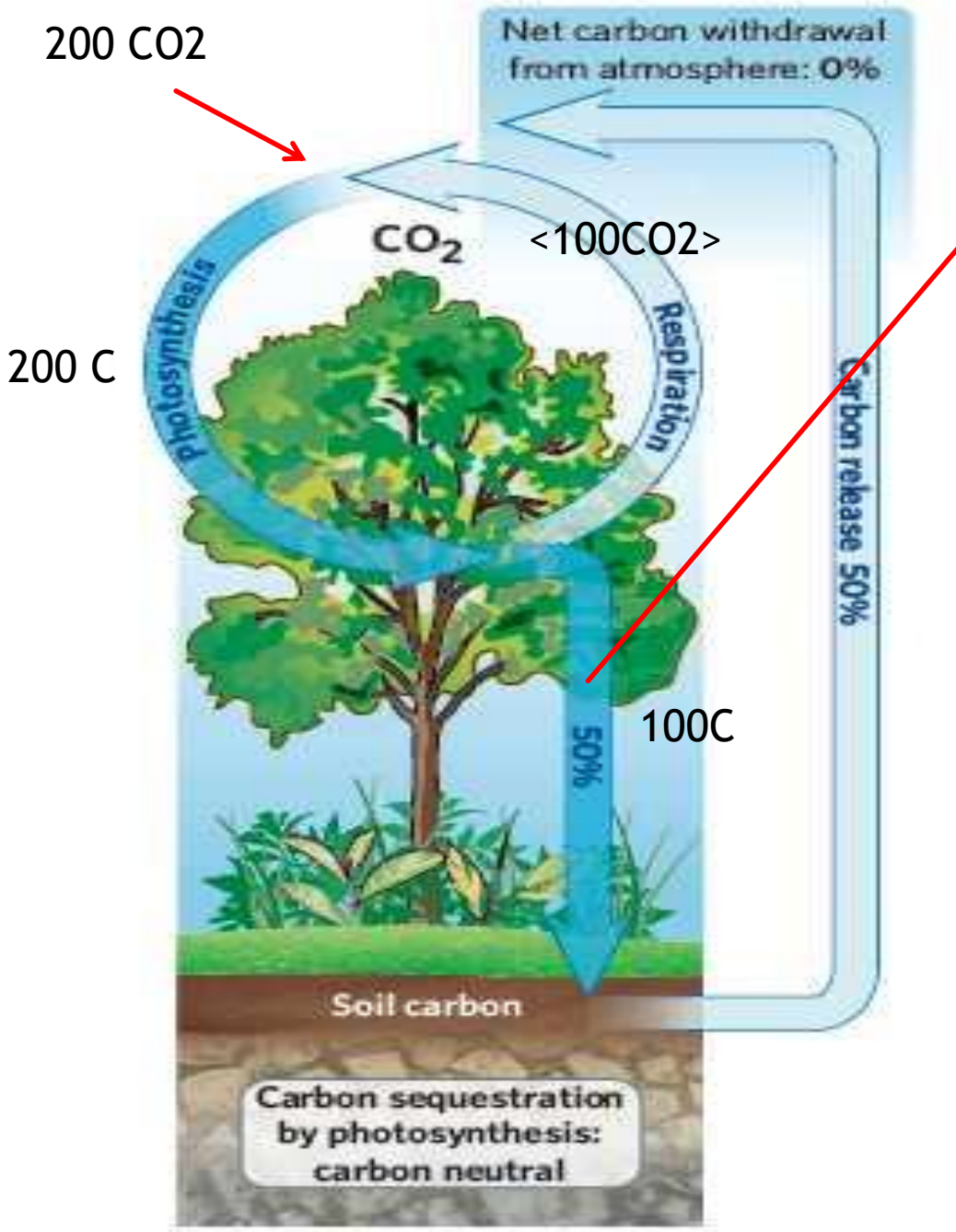
So given a certain amount of carbon that cycles annually through plants, half of it can be taken out of its natural cycle and sequestered in a much slower biochar cycle (see graphic). By withdrawing organic carbon from the cycle of photosynthesis and decomposition, biochar sequestration directly removes carbon dioxide from the atmosphere.



This is the tree as it grows. About one half of the carbon dioxide uptake results in additional carbon atoms in biomass

This is when biomass dies and becomes **detritus:** such as leaves and tree death

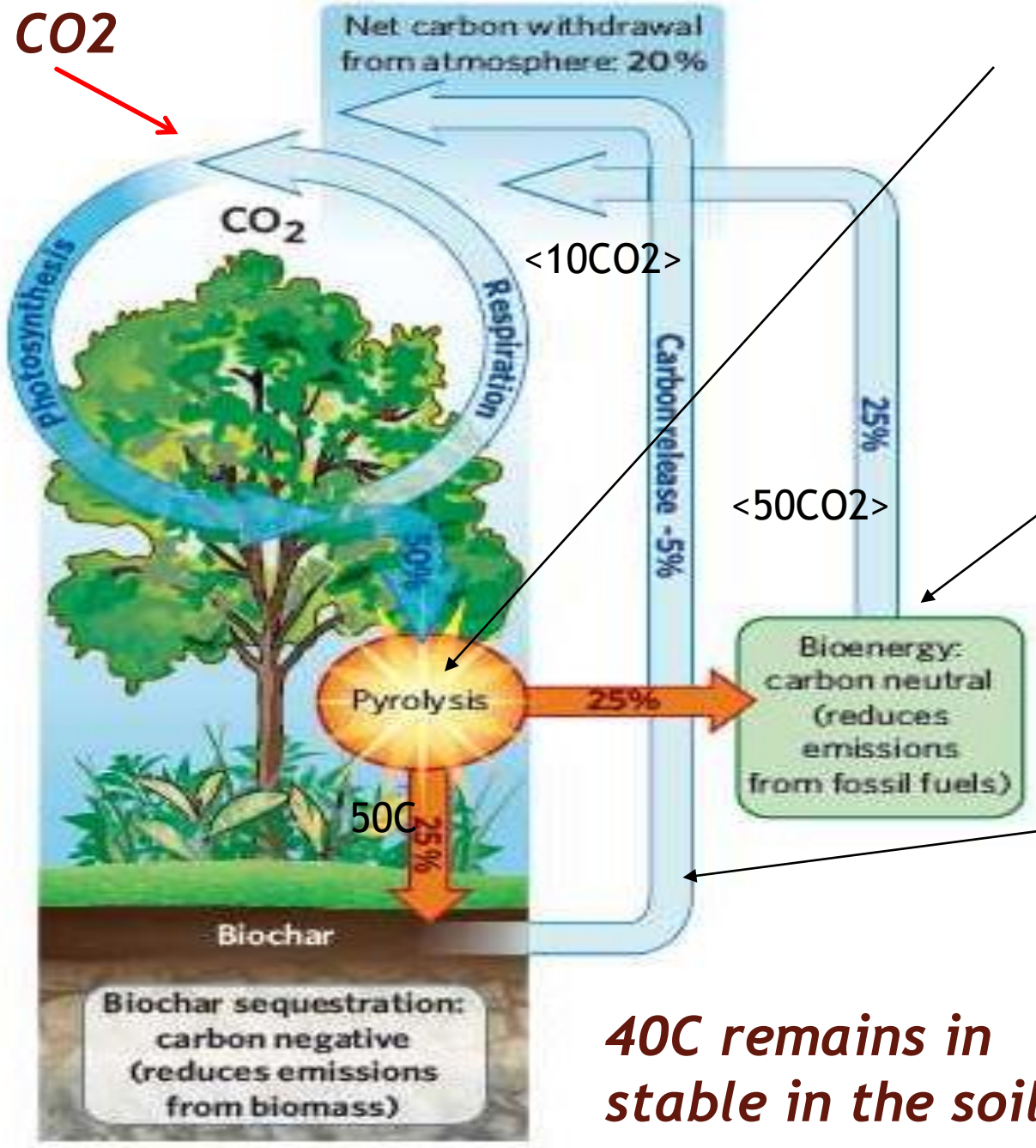
This is due to microbial breakdown of dead biomass – 95% in one to twenty years



Fate of Reduced "Fixed" Carbon

- After the plant takes care of energy requirements of procuring a balanced diet, the excess carbon is directed to seeds, biomass growth or stored as sugars for the next season.
- Sugars are excreted into the soil biota in exchange for plant nutrients (NPK and micro-nutrients).
- If NPK are available, the plant does not "waste" sugars on soil. microbes and puts that carbon into plant priorities = more plant growth
- Without plant sugars, soil microbes attack each other and soil carbon decreases, leading to sterile soil.

200 CO2



Pyrolysis and Carbonization convert biomass into biochar: one half of the carbon atoms are released as volatiles and one half converted to biochar

The volatiles contain carbon atoms that the tree removed from the atmosphere as it grew = carbon neutral

A minority of biochar is slowly oxidized by soil microbes; **the majority is stable for hundreds to thousands of years**

40C remains in stable in the soil

Focusing on the Pyrolysis step and Carbonization Reactions

as found in Antal & Gronli, The Art, Science and Technology of Charcoal Production, *Ind. Eng. Chem. Res.* 2003, *42*, 1619-1640, on page 1621, Klason and co-workers (1908, 1925) report:

For the carbonization of “wood”, at 400 Celsius:

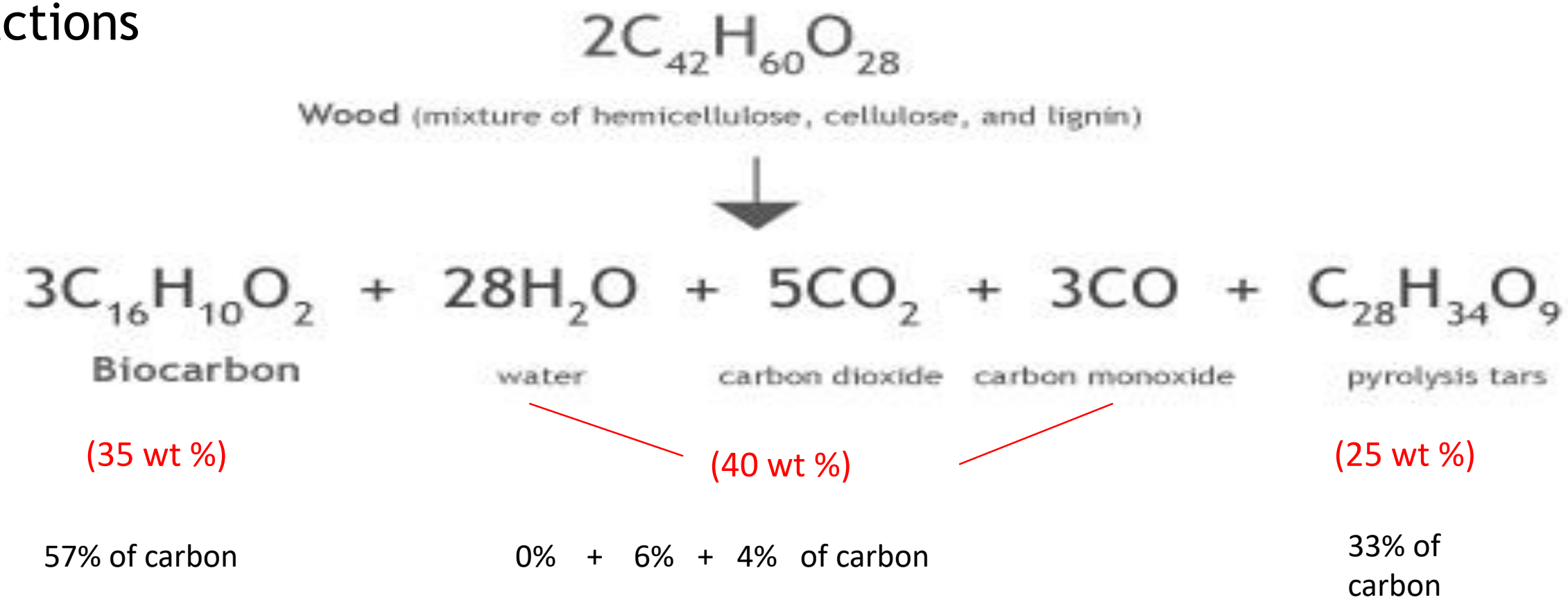
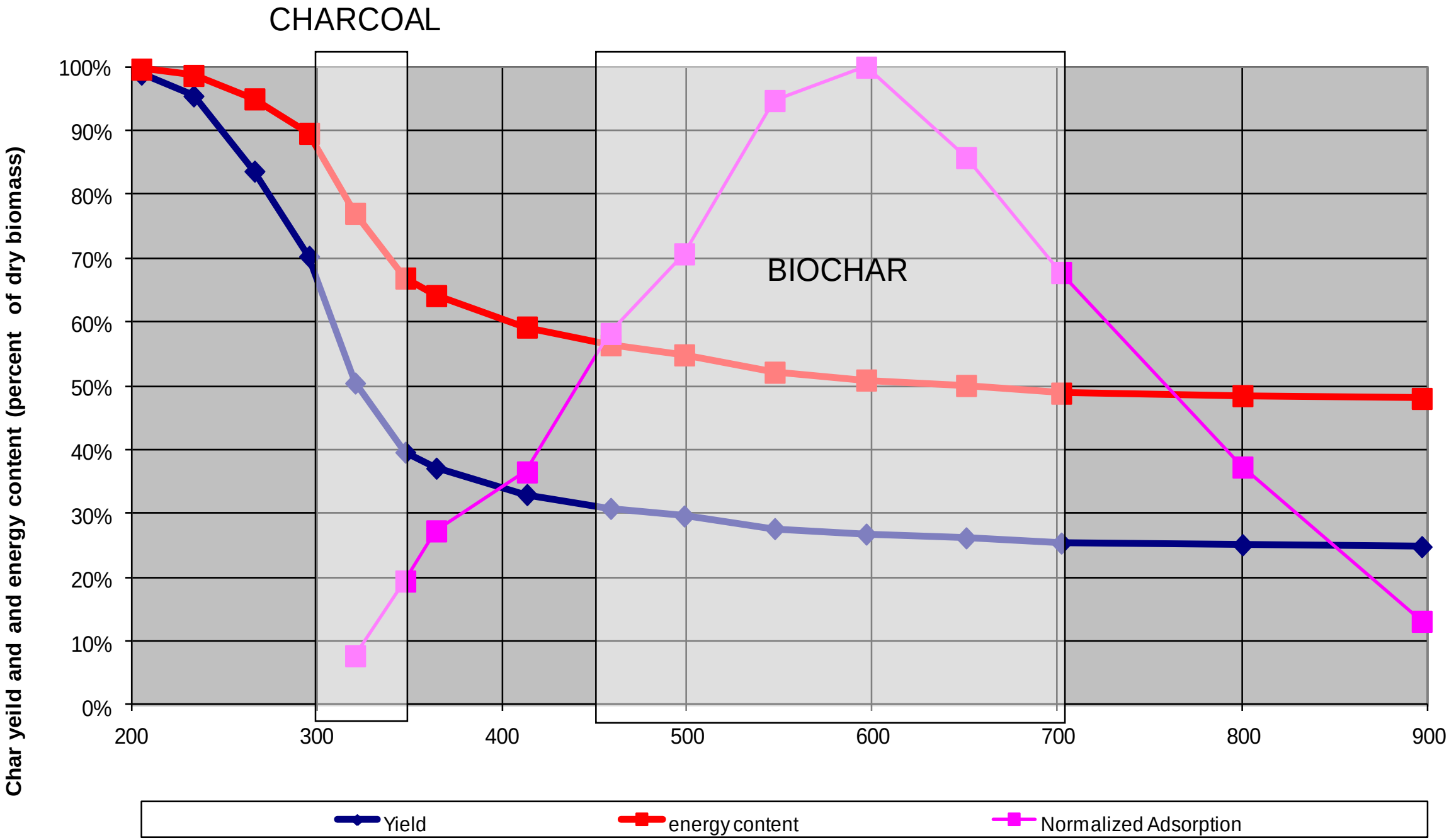


Figure 3: Normalized Adsorption and Adsorption Yield



how to assess the needs

- Biochar is a Permanent Soil Amendment - it modifies how the soil interacts with the soil biology and plant. Biochar fixes soil deficiencies, improves the soil, and is not consumed over time.
- If nothing is wrong in the growing system, then there is nothing Biochar can fix - it will not show an improvement. Don't bother.
- Biochar makes soil more efficient at meeting the crops needs, requiring less of the other inputs: water, fertilizer, etc.
- More efficient soil means less energy from the plant to meet its needs, leaving more energy for plant health and growth.
- Better plant health means higher quality and quantity of produce .

fill the knowledge gaps

- The research on Biochar has exploded over the past 5 years. Biochar continues to amaze, but has demonstrated many of the core value propositions: better soil moisture dynamics requiring less moisture input; less fertilizer leaching allowing less fertilizer inputs; better plant health and improved crops.
- The typical knowledge gaps are the expertise to assemble and operate the biomass-to-biochar process. The actual conversion step, the pyrolyzer, is usually easiest since it is engineered and supplied by others. It is the river of incoming biomass than requires site-specific expertise to address, then focus on the smaller river of biochar leaving.
- Markets are local to regional and profit margins disappear with distance. Don't invent technology; invent a company that services a market need and makes money - then fill in the details.

analyze the markets

One company has dominated the media awareness of Biofuels and Biochar for the past decade. After pivoting from biofuels to biochar several years ago, they have pursued a campaign of demonstrating crop responses to their biochar product line called Cool Terra. ***See their web site***

- Biochar research is expanding rapidly and identifying many new uses for biochar in diverse areas such as feed supplements in animal forage and structural components in building materials like concrete and modified plastics.
- For a review of applications see: http://www.ithaka-journal.net/55-anwendungen-von-pflanzenkohle?lang=en

What is the current market for Biochar?

- No official statistics on biochar. Biochar marketplace is like an iceberg – only a small portion is visible in the open marketplace, due to the lack of tax incentives and subsidies to stimulate use, but would also require reporting. As such, existing biochar transactions are often B-to-B and are not publicized, since that would stimulate competition by others.
  - U.S. (USBI): 45,000 to 100,000 tons
    - Projected Growth Rate = 20% to 25%
    - Major markets: CA, NWUS, CO
  - Canada (USBI): 3,000 tons
  - China (IBI): 250,000 tons, principally by conversion of crop residues to avoid field burning and improve fertilizer efficiency
- Pricing: $300 to $600 per ton - variable (also many specialty products which are proprietary formulations)
- Due to the need to remove carbon dioxide from the atmosphere and the outlet in existing agricultural processes, the market potential is unlimited.

analyze the technology readiness

- The production of Charcoal is older than human civilization, literally. Biochar has different properties than charcoal, but any method that makes charcoal can make biochar – of lower quality.
- Charcoal was once a dominate solid fuel – until coal (18th Century).
- Several modern industrial processes make a high carbon solid residue. These are existing processes that happen to produce a solid byproduct that has favorable properties when used as biochar. One example is the 1980's biomass power plants, all 10 to 30 megawatts, that can recover "high carbon wood ash" from cyclones.
- Because biochar is new, no legacy plants were designed with quality biochar properties in mind, but "rather be lucky than good" still applies.
- As biochar consumption increases, existing sources will not expand and additional capacity will have to be brought on line.

Modern options that create biochar:

- “Purpose built” biochar options are coming to the Marketplace
  - STCT: http://www.bcteinc.com/
  - Community Power Corporation: http://www.gocpc.com/
  - Biochar Solutions: http://www.biocharsolutions.com/
  - Biochar NOW: http://www.biocharnow.com/
  - KARR Eco-Friendly Solutions: http://karrgroupco.com/
  - NextChar: https://www.nextchar.com/
  - **with more out there and many more to follow**

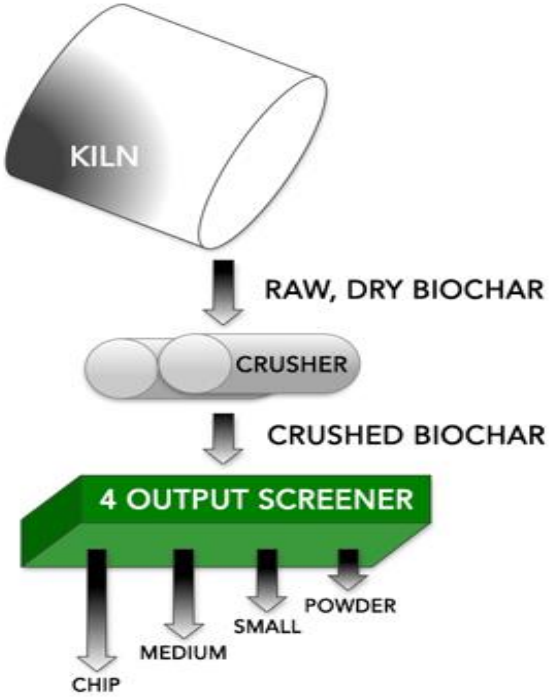

STCT: http://www.bcteinc.com/index.html

Community Power Corporation: http://www.gocpc.com/

Biochar Solutions: http://www.biocharsolutions.com/

Biochar NOW: http://www.biocharnow.com/

BIOCHAR NOW CRUSHING AND SCREENING WORKSTATION



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confirm results

- The biggest challenge in biochar adoption is educating your customer. If that customer is using biochar in a crop, then the demonstration time is measured in growing seasons. The larger the scale, the more credible the conclusions. Think about how to prime a pipeline of similar customers with your reproducible biochar. Matching supply to seasonal demand is challenging.
- Biochar suffers from the lack of a recognized industry association capable of setting product quality requirements and promoting regulatory acceptance of biochar practices.
- To date, there have been no significant governmental incentives to promote biochar adoption. Even carbon sequestration credits are difficult to quantify and saleable on voluntary markets only.

prepare for success in biochar

- Currently, Biochar Ventures are not-bankable in the sense that the business will not serve as collateral for the business loan. That would change with government backing (unlikely in today's political priorities) or establishment of significant market presence. The current situation represents an opportunity for non-traditional money. At some point, the situation will switch.
- The challenge in the biochar marketplace is not competition between producers or technology suppliers, it is completing the supply chain - connecting biomass supplies to a conversion technology to end users. There are few external drivers, even global climate concerns do not convert into significant monetary streams or credits.
- Biochar is coming, but the specific timing is local and dependent on immediate circumstance and small-scale initiatives. *Just like the PC was*.

Options for Profitability

- Biochar brings in a biomass stream, converts it to biochar and creates a new material with unique properties. If Profit results from Revenue Generated less Cost of Production, then Biochar has the following scenarios:
  - **Tipping fees from incoming biomass streams – pyrolysis destroys many historical properties in the biomass.**
  - **Pyrolysis generates significant excess heat, which can be used for heating – but NOT electricity, except at scale.**
  - **Raw Biochar is an adsorbent *or* a unique structural material.**
  - **Conditioned Biochar is a permanent soil amendment, modifying soil-plant dynamics and sequestering atmospheric carbon for centuries.**

Conclusions

- Biochar is a new and unique material to the values of today's world - especially when food security and carbon dioxide levels are factored in.
- Biochar is proven both in production technology and delivering value in the marketplace. The technology risk is minimal, the marketplace is almost infinite, and the action is dictated by site-specific economics.
- It is the next *bio-material of scale* in a world where only corn-to-ethanol and biodiesel have made it so far.
- per Lee Iacocca: *Lead. Follow. Or get out of the way.*