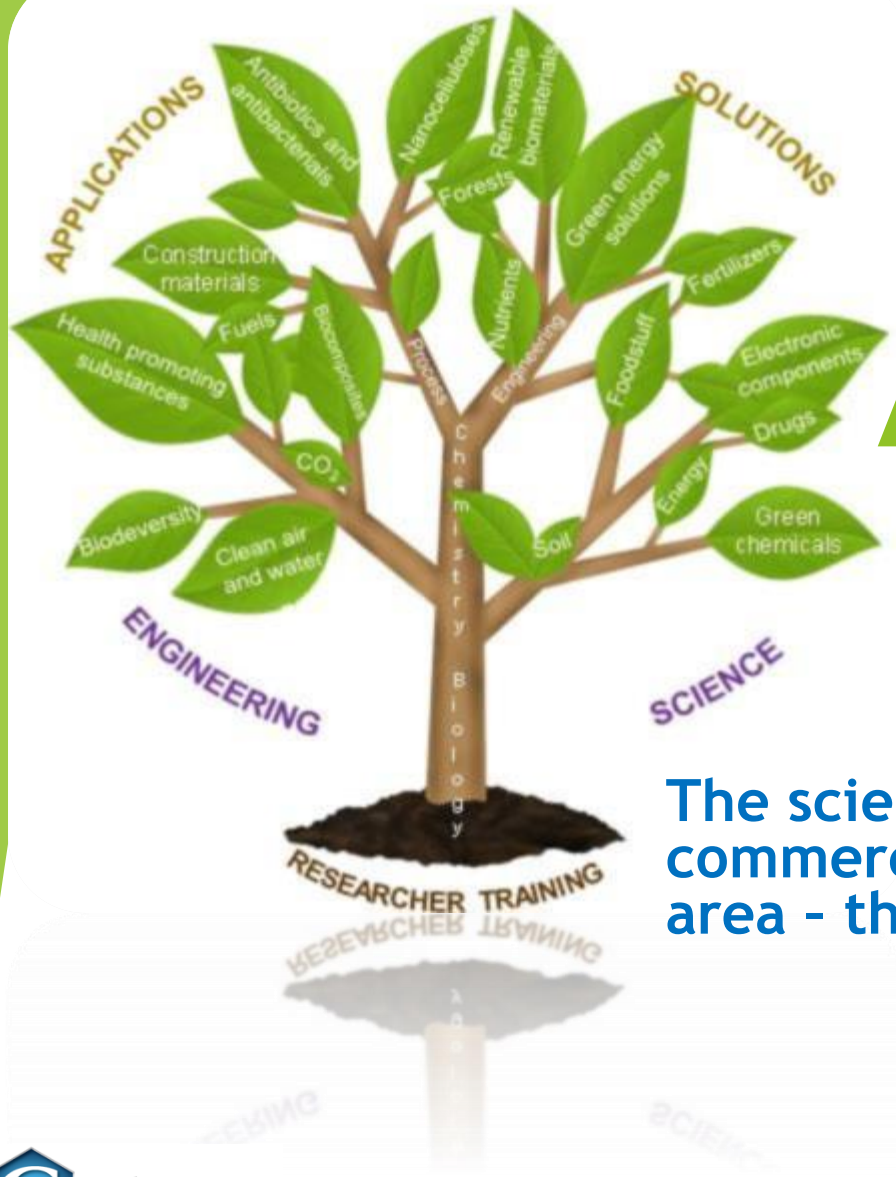


BIOCHAR: A Status Report

The science of biochar and the associated commercial activities are a rapidly evolving area – this perspective is as of the end of 2018

LEE ENTERPRISES CONSULTING, INC.

Hugh McLaughlin, Ph.D., P.E.

(Technical Expert in Pyrolysis, Biochar, Act. Carbon)

Gerald Kutney, Ph.D.

(Business Expert in Pyrolysis, Biochar)

Accredited Members

LEE ENTERPRISES CONSULTING, INC.

Hugh McLaughlin, PhD, PE
dba Hugh McLaughlin, PE

- **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.

Gerald Kutney

SIXTH ELEMENT SUSTAINABLE MANAGEMENT

- **Background:** Dr. Gerald Kutney, Ph.D. in chemistry, has two decades of executive experience with global corporations and entrepreneurial enterprises in the forest bioeconomy. He brings the innovation of research, the financial discipline of big business, and the spirit of entrepreneurship.

- **Projects:** Completed dozens of pro formas, feasibility studies & business plans, related to the forest bioeconomy

- **Expertise:** Includes investor-grade *pro forma* design and analysis, feasibility studies and business plans, technology/venture vetting and audits. Sixth Element works with its clients to prepare for the investment community..

Expertise: World's largest bioeconomy consulting group - over 100 subject matter experts (SME's)- all areas of the bioeconomy.

Approach: Project interdisciplinary teams to meet exact needs of specific projects.

POC: Handle projects with one agreement and single point of contact.

Cost Advantage: Single POC = lower administrative costs = lower project cost.

What is Biochar?

- International Biochar Initiative: "A solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment. …… Biochar can be distinguished from charcoal—used mainly as a fuel—in that a primary application is use as a soil amendment with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases."

- Above 300ºC, carbonization commences and the thermochemical reactions become exothermic (i.e., heat generating). Biomass undergoes major chemical modifications at these higher temperatures, being initially converted into charcoal, a fuel, and subsequently into biochar, the soil amendment, at higher temperatures.

- Biochar has several unique properties, including adsorption capacity (like activated carbon), porosity and voidage (improving soil aeration and water storage), cation exchange capacity and improved nutrient retention, and is derived from carbon dioxide removed from the atmosphere as the biomass grew a plants and trees. Furthermore, biochars resist breakdown in the soil by microbes, providing a stable soil amendment for centuries.

What does Biochar do?

- When applied to soil, biochar acts as an agricultural catalyst by promoting plant growth but is not consumed. Since it is a catalyst, its benefits continue for generations to come without further addition. The biochar holds nutrients and fertilizers longer in the soil and provides other benefits encouraging plant growth. At the same time, the carbon of the original biomass has been chemically modified and is not biologically active; therefore, it will not naturally return its carbon to the atmosphere (i.e., the carbon has been sequestered), which is a benefit for carbon change. In addition, the absorbent qualities of biochar have led to investigations of a number of applications.
- For a review of applications see: http://www.ithaka-journal.net/55-anwendungen-von-pflanzenkohle?lang=en
- 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.
- With increased concern about rising carbon dioxide levels in the atmosphere, biochar represents a proven method to remove carbon dioxide from the air and utilize it in the agricultural systems while providing improved economics of production. Since the biomass starting material is renewable, the cycle can be repeated to provide ongoing carbon dioxide removal. As such, biochar represents the only geo-engineering option that is proven and safe if implemented at a scale sufficient to make a difference in humanities future.

What is the 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: $200 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.

Biochar & Related Product Ventures

Note: “ventures” may be now defunct or never achieved commercial operation

Number of Pyrolysis Ventures by Technology and Region

	European Union	United States	Canada	Rest of World	Total
Torrefaction	63	56	23	17	159
Steam Thermal	2	2	2	1	7
Pyrolysis-slow	120	123	39	140	423
Pyrolysis-fast	39	30	18	13	99
Hydrothermal Liquefaction (HTL)	4	7	1	6	18
Hydrothermal Carbonization (HTC)	17	2	4	0	23
Biomass Gasification	178	154	56	78	466
Total	423	374	143	255	1196

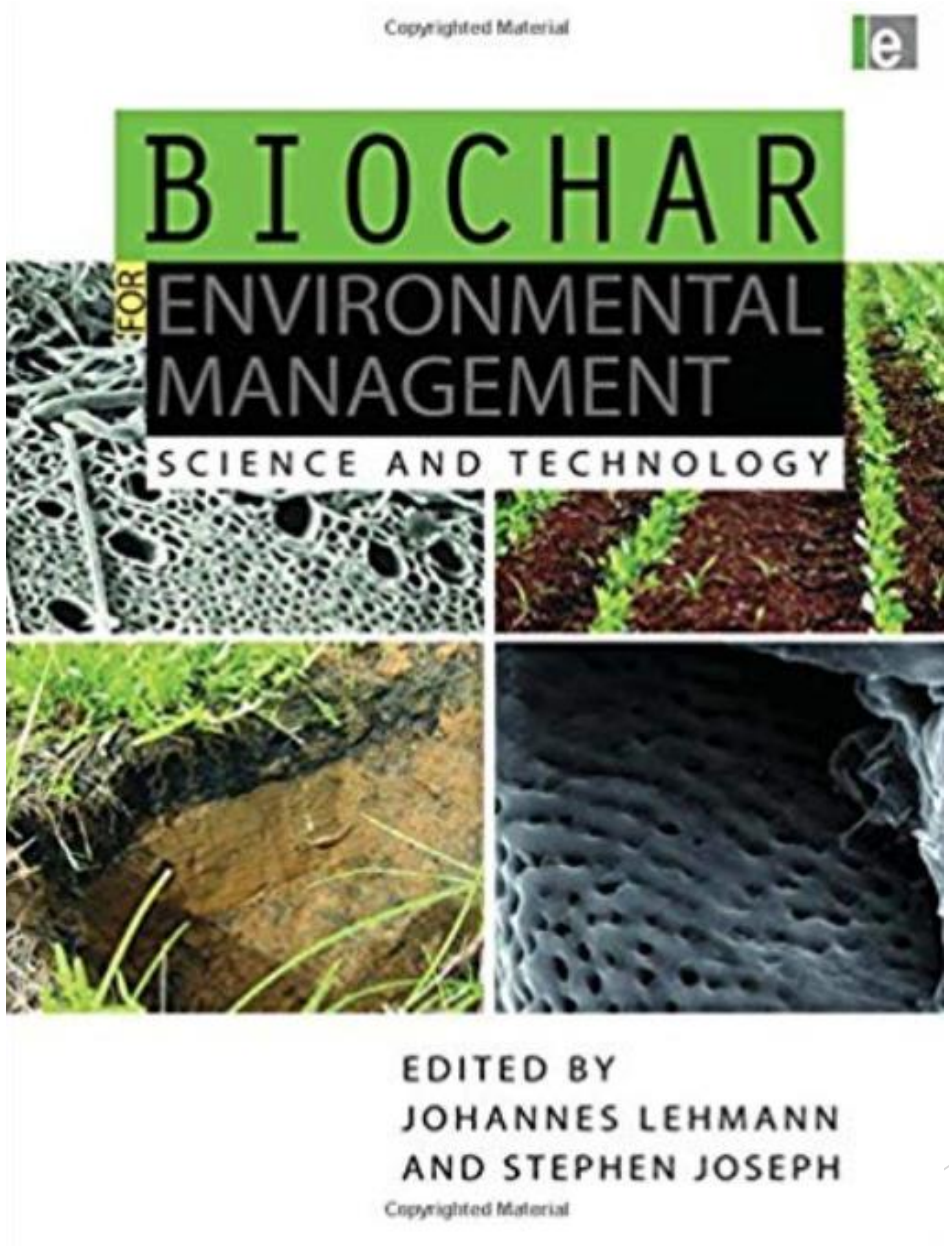
The History and Future of Biochar

- The use of charcoal as a plant growth promoter (a component of *terra preta*) in South America may date back to 400 B.C. One of the first modern studies on the impact of charcoal on agriculture was carried out by Arthur Young (1741-1820) in 1770. During the 19th century, many references appeared on the use of charcoal as a soil additive, and the first observation that charcoal increased crop yields was made by John Lawes (1814-1900). The most famous scientist examining biochar at the time was Justus Liebig (1803-73), "the father of the fertilizer industry."
- Current interest in Biochar is driven by climate concerns and future demands on food production to address the rising world population. Individual demonstrations often reveal significant improvements in farming economics by reduced inputs of fertilizer and improved crop properties of yield and quality.
- The majority of current US biochar production is based on historical industrial processes that consume biomass and generate a high carbon wood ash while generating electricity at small (10 to 20 MW) power plants or adapting charcoal making processes to higher temperatures. Newer processes focused on improved biochar properties and better operating economics are now being demonstrated in the commercial marketplace.

Biochar suffers from the lack of a recognized industry association capable of setting product quality requirements and promoting regulatory acceptance of biochar practices.

Several books and thousands of research papers are being generated around the expanding set of biochar uses. As with any developing science, there is significant variability in the quality of the research and a general lack of consensus on specific conclusions and performance claims.

To date, there have been no significant governmental incentives to promote biochar adoption.




A Sculpture of Biochar?
"Samothrace"
Armand Vaillancour
Ottawa, ON
SIXTH ELEMENT
SUSTAINABLE
MANAGEMENT

Hugh McLaughlin, PhD, PE
dba Hugh McLaughlin, PE
hsmclaughlin@verizon.net
978-448-6414

Gerald Kutney
Sixth Element
gkutney@6esm.com
613-425-0619

Lee Enterprises Consulting
www.lee-enterprises.com
1+ 501 833-8511