Biochar: Background & Early Steps to Market Development

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For more information contact:

Waste 2 Resources
P.O. Box 47600
Olympia, WA 98504-7600

Phone: (360) 407-6900

Washington State Department of Ecology - www.ecy.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
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by
Mark Fuchs, Manuel Garcia-Perez, David Sjoding

Waste 2 Resources
Washington State Department of Ecology
Olympia, Washington

Table of Contents

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Introduction

Biochar has been the subject of ever expanding regional, national and international interest and excitement over the past 10 years. The interest is from enthusiasts from a broad spectrum including individuals, business entrepreneurs in manufacturing and applications, research scientists, and staff in local, state and federal government. Enthusiasm originates from research of in-situ soils in the Amazon Basin called Terra-Preta de Indio, or the Black Earth's of the Amazon (Figure 1). These anthropogenic soils are extremely productive in climatic conditions where adjacent extremely weathered non-anthropogenic soils are of low fertility, and contain little organic matter and low nutrients for plant growth. Carbon dating shows the black carbon or biochar in terra-preta is over thousands of years old and yet biochar is still present. Although terra-preta de Indio is the best known example of a broad range anthropogenic examples of biochar, black earth soils are found globally. A significant report of rangeland soils management on the Illinois Plain describes how native tribes used range land fires to encourage preferred grazing habitat (grasses, forbs and shrubs) and to limit tree establishment. The report further describes Illinois Plain soils also as very deep, well mixed and extremely fertile (Krug and Hollinger, 2003). Japanese farmers have practiced char additions for soil improvements for many years (Ogawa and Okimori, 2010). Downie, et al. (2011) have also found bio-chars in highly fertile temperate Australian soils.

Figure 1. Photo demonstrating native (left) and anthropogenically modified Amazon soils.

Ground Swell of Interest

Biochar has been used in an expanding number of applications:

- Merle Ott wheat ranch - restore soil carbon lost over 50 years of farming.
- Sorb PCB and toxic organics in water runoff.
- In-situ cleanup of organic contaminants in stream sediments.
- Clean up heavy metals including ubiquitous zinc from rubber tires.
- Filter suspended mineral matter from runoff.
- Capture nutrients from wastewater treatment and digesters.
- Filter N & P in discharges, lessoning phyto-plankton blooms and ocean acidification.
- Renewable industry - pyrolytic recovery of thermal energy and fuels.
- Individual persons can sequester carbon.
- Compost yard odor control, adsorb gas and liquid phase nutrients (N, S, P).
- Support soil stabilization and revegetation in critical and highly disturbed areas.
- Replace vermiculite in nursery potting media.
- Sequester carbon from the atmosphere and store it in stable form in soils.
- Carbon market sales.

Globally, biochar is being explored to improve soils for crop production, and to sequester carbon by storing atmospheric CO_2 fixed by plants in stable form. Biochar has also been demonstrated to have numerous environmental applications and eco-system uses.

Recent applications of biochar are evolving and new markets are being created. A spray on fiber mat and seed layer, PermaMatrix, was used to help establish vegetation on an industrial site with drastically disturbed soils (Figure 2). Biochar was admixed (10%) with the fiber mat. The area without vegetation (center, Figure 2) did not receive the biochar mixture. Biochar is currently being used as a filter media to adsorb contaminants in rainwater and stormwater runoff (Figures 3 and 4). Kearns (2012) used biochar as a final media in a potable water system.

Figure 2. Soils reclaimed with PermaMatrix mixed with 10% biochar.
(From Tom Miles, Washington Future Energy Conference, 2010.)

Figures 3 and 4. Roof drain using Biochar for filtering zinc from roof runoff (From Tom Miles, Washington Future Energy Conference 2010.

Purpose

Biochar is a fast developing industry regionally, and globally. This paper has been written to bring focus on five current regional industry needs:

1. Identify business opportunities, applications and uses, and market development opportunities for Washington and the Pacific Northwest Region to become an international leader in the biochar industry.
2. Create the case for a business feasibility plan for the development of a biochar industry.
3. Identify private business and agency staff that will support an ongoing effort for industry development.
4. Identify training needs for the industry.
5. Support the development of an industry trade association.

What is Biochar?

The International Biochar Initiative (IBI) describes Biochar as: "*a solid material obtained from the carbonisation of biomass.*" IBI goes on to state: "*Biochar may be added to soils with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases. Biochar also has appreciable carbon sequestration value. These properties are measurable and verifiable in a characterisation scheme, or in a carbon emission offset protocol.*" For this market development effort, biochar is meant to include carbonized biomass that *may be used for energy production and that may provide environmental and agricultural products and services.*

Carbonisation also called pyrolysis occurs when biomass is heated to temperatures of between 400^0C and 600^0C driving off volatile organic compounds and leaving a media rich in fixed carbon with enhanced microbial stability and with a structure resembling the cellular skeleton of the biomass with micro and macro pores that enhance the surface area of the material.

Gasification is the partial oxidation of biomass feedstock into permanent gases and tars and ash/char. Gasification occurs between 700^0 C and 1400^0C. Resulting char contains higher percentages of ash components, much of which is silica when the feedstocks are grasses (Brewer et al., 2009). Char in this case has lower surface area, and a more compressed ring structure (Brewer et al., 2009) leading to lower sorption properties. However, the relative percent increase in ash compounds (iron, manganese and alkalines) provides some opportunities to develop biochar products for environmental applications.

As in the case of activated carbons which were developed for specialized industrial applications, bio-char from carbonization can be designed to provide enhanced environmental services and products. However, biochar should be able to be produced at a percentage of the cost of activated carbon. Lower biochar production costs would allow for a broader range and much larger volume of applications and many new markets in environmental and ecological services.

Washington and the Regional Context: The Biochar Challenge, Why the Pacific Northwest?

Washington has the entrepreneurial wisdom, technical and research strength, and agency capacity for developing a biochar industry utilizing local biomass resources. A coordinated effort of interested stakeholders is needed to drive the industry development. Stakeholders include: biochar reactor technology developers/manufacturers, environmental and agronomic applications businesses, distributors, government agencies, NGO's, and researchers. All of them will be required to support biochar commercialization. While a trade association would be best for this effort, no entity exists.

The biochar industry could grow taking the example of the wood pellet industry which began in the 1980's in response to the need for clean burning solid fuel devices as an alternative to fuel oil for heating homes and small businesses. Nationally, the wood pellet industry now has numerous appliance manufacturers, hundreds of distributors and employees many 100's of installers, not to mention over 80 wood pellet mills nearing a half billion dollars of capital investment. All of this began in Washington and the Pacific Northwest. Biochar industry development will occur globally. With pyrolysis business ventures and biochar applications expanding across the nation, why should leaders in the Pacific Northwest conduct a coordinated effort to develop this industry? Regionally, we are at the right time and right place with the technical capability to lead this global industry. Our capability to lead the biochar market sector development comes from the following strengths:

1. Entrepreneurial capability to develop the production technology and field uses in environmental, agricultural and industrial applications.
2. Pacific Rim location for marketing technology capability and intellectual property.
3. Resource base in our woody refuse and our forest resources to create sustainable carbon negative solutions and provide technology and capacity for a regional bio-economy.
4. Regional strength in our research centers' scientists, engineers and extension specialists to conduct the laboratory and field work to support new applications and develop new markets for stable, highly porous and adsorptive carbon for expanded environmental ecological and soils uses.
5. Non-governmental Organization leadership with the regional carbon strategy through the Northwest Biocarbon Initiative, (Climate Solutions), and activities of International Biochar Initiative (IBI) and US Biochar Initiative (USBI) have expanded rapidly.

How do we achieve broad commercialization?

A broad industry development plan is needed to identify opportunities and acknowledge challenges for broad biochar adoption. In a recent article (http://www.biochar-international.org/gettingthebiocharindustryuptospeed), Dr. Jerry Whitfield a pioneer in the US commercialization of wood pellet stoves in the 1980, discussed what can we learn from the pellets business that could help speed up the bio-char industry. He noted that the wood pellet stoves were successfully commercialized because of the existence of companies looking for contracts to commercialize wood pellet and the public pressure to reduce the emission from woodstoves that triggered legislation in Oregon and Washington to limit wood burning. Although environmental concerns triggered the invention of wood pellet stoves, the advantages of the wood pellet stoves over other forms of heating was the major reason for the market success of this technology. The new devises used a superior fuel that could be delivered in clean 40 lbs sacks. Dr. Whitfield found similarities between the nascent bio-char industry and the wood pellet stove industry but noted that while **the pellet industry was essentially one-dimensional the bio-char industry is multi-dimensional (multiple end uses and products) in the potential uses of its main product**. *He noted and strongly cautioned that while the multi-dimensional nature and diversity of markets for the bio-char industry could eventually increase the market scope and decrease risk when competing for well established markets (agriculture and energy), it could also blur focus at the initial stages when small, but profitable specialty markets (example, horticultural, nurseries, greenhouses, small organic farms, and activated carbon substitutes) have to be conquered.* An initial focus on serving small markets is recommended with studies to demonstrate improved crop yields and "designer" biochar products for environmental applications. Support is also needed to implement standards like the ones recently proposed by the IBI (http://www.biochar-international.org/characterizationstandard).

Current Technology and Applications

Current pyrolysis technologies can recovery heat for CHP, conditioning building space and for thermal industrial applications and oil for further refining. However, the refineries do not currently exist. So, commercial biochar production will likely occur as a result of pyrolysis for heat production with biochar as a co-product. In the future, condensable liquid fuel recovery may be supported by bio-oil refinery capacity. Although, there are very few studies on the combustion of pyrolysis vapors, its combustion products are expected to be much cleaner than those generated when the whole biomass is combusted.

Biochar production in Washington and the region is currently undergoing first phase development. New technologies are being built and tested, while other technologies which have already been tested are brought to the Pacific Northwest. Companies are taking both fast (fine ground biomass, pyrolized in seconds) intermediate and slow pyrolysis (larger particles, baked for minutes) approaches to the production of bio-oil heat and char. Several regional examples of technologies and uses of biochar are provided in the paragraphs that follow.

1. Thompson Timber is using a Fluidyne Pacific Class gasifier to make gas from wood chips to fire a pyrolysis reactor. The result is a fossil fuel-free hybridized system using gasification as the thermal drive for a pyrolytic retort. This system provides the option for the company to make different kinds of biochar under different temperature regimes using different feedstocks. The retort can make up to 100 lbs of biochar/hour (http://www.biochar-international.org/profiles/Thompson_Timber).

2. Whitfield Biochar in Burlington, WA has a commercial scale 600,000 btu/hr continuous flow Auger pyrolyser called Whitfield Continuous Feed Biochar Reactor. It is designed to produce heat from lower calorific feedstocks that do not compete with high value wood chips. It can handle a range of feedstock particle sizes typical of wood pellets. The reactor is able to deliver predictable, repeatable, and consistent results at controlled temperatures to within 1 percent of the set point, typically 500^{o}C and well controlled biomass residence time in the reactor (www.whitfieldbiochar.com).

3. Three Dimensional Timberlands (3DT) has the exclusive rights for the Pacific Northwest Region to a continuous feed molten salt, vacuum pyrolysis process capable of up to 3 metric tons of feedstock/hour. This is a vacuum pyrolysis process that has been developed by Christian Roy in Quebec, Canada. Feedstock sources will be slash, salvage, and similar low grade materials. The technology is described as an intermediate pyrolysis method that can treat wood chips up to 1 inch that results in a balanced return of bio-oil, biochar and non-condensable gases used to drive the thermal requirement (http://threedimensionaltimberlands.com/index.html).

4. Environmental applications using biochar are being developed by companies such as The Remediators, TRMiles and Sunmark Environmental Services. As is shown in the photo's and discussion in Figures 2 and 3, biochar is being used as an aid to establish vegetative cover on contaminated soils which would normally not support plant growth, and as a filter for roof drain runoff. The Remediators CEO Howard Sprouse finds that his company is exploring and demonstrating that biochar has numerous applications in the field for vegetation establishment, ecosystem restoration and in various environmental cleanup settings. Information can be found at the following links: http://www.theremediators.com/index.html, http://www.trmiles.com/ and http://sunmarkenvironmental.com/.

The number of pyrolysis companies in the United States is growing very rapidly (Table 1). Likewise the number of companies commercializing bio-char for environmental services and products (mostly carbon sequestration and soil amendments) is also growing rapidly (Table 2). USBI has a list of other commercial producers and retailers for biochar (www.biochar-us.org/).

Table 1. Companies commercializing Bio-char Making Technologies in the United States (Taken from: Miles 2012, http://terrapreta.bioenergylists.org/company).

Company	Location	Website
Agri-Tech Producers	South Carolina, (university spin-off)	www.agri-techproducers.com/
Amaron Energy	Utah	www.amaronenergy.com
Ambient Energy LLC	Washington	www.ambientnrg.com
Avello Bioenergy	Iowa State	www.avellobioenergy.com/
Biochar Products	Oregon	www.biocharproducts.com/
Biochar Solutions	Colorado	www.biocharsolutions.com/
Whitfield Biochar	Washington	www.whitfieldbiochar.com/
Biz Solutions	Utah	www.pyrogreen.com/
Carbon Brokers International	Colorado	www.carbonbrokersinternational.com/
Carbon Char		www.carbonchar.com/
Carbon Resources	California	www.carbonresources.com/
Eprida	Georgia	www.eprida.com/home/index.php4
Full Circle Biochar	San Francisco	www.fullcirclebiochar.com/
GEK (BEK) Gasifier, All Power Labs	California	www.terrapreta.bioenergylists.org/company
Genesis Industries	California	www.egenindustries.com/
HM3	Oregon	www.hm3e.com/contact/index.php
ICM	Kansas	www.icminc.com/services/gasifiers/
New England Biochar	Vermont	www.biochar-international.org/Newenglandbiochar
Pyrolyzer LLC	Florida	www.pyrolyzerllc.com/
3DT	Oregon	www.threedimensionaltimberlands.com/

Table 2. Companies commercializing bio-char in the Unites States (Taken from: Rasmussen 2011, http://terrapreta.bioenergylists.org/buy_biochar).

Company Name	Location	Website
Aztec Wonder	Missouri	www.aztecwonder.com/
Biocharm	California	www.biocharm.com/
Biochar Products	Oregon	www.biocharproducts.com/
Biochar Solutions	Colorado	www.biocharsolutions.com/
Biochar Merchants		www.biocharmerchants.com/
Blue Sky Biochar	California	www.blueskybiochar.com/
CharGROW		www.carbonchar.com/
Carbon Brokers International	Colorado	www.carbonbrokersinternational.com/
Char King International	Idaho	www.char-king.com/
Encendia Biochar	New England	www.encendia.com/
Genesis Biochar	California	www.egenindustries.com/
Hawaii Biochar	Hawaii	www.hawaiibiocharproducts.com/
New England Biochar	Massachusetts	
Phoenix Energy	California	www.phoenixenergy.net/biochar1
Soil Reef	Pennsylvania	www.soilbiochar.com/
Sonoma Biochar	California	www.sonomacompost.com/biochar.shtml

Biochar Standards

Biochar as a soil amendment has received great interest. In an effort to provide more certainty to biochar producers and users, to establish a framework for a certification program, and to encourage the development of a biochar industry the International Biochar Initiative (IBI) published the ©Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil (2012). This provided "a standardized definition of biochar and biochar characteristics related to the use of biochar as a soil amendment" (IBI, 2012). IBI developed the guidelines in collaboration with a wide variety of industry and academic experts and through public input on an international level. By providing standardized information regarding the characterization of biochar materials, IBI hopes to support more consistent biochar product quality. The guidelines were developed to assist biochar producers in providing consumers with "consistent access to credible information regarding qualitative and physicochemical properties of biochar" (IBI, 2012).

The guidelines were developed as a means of providing information and market certainty about the attributes of biochar for use in soil applications. Ultimately, IBI hopes that "the use and promotion of these Guidelines will build consumer and regulatory confidence about biochar, through the provision of consistent and reliable information regarding biochar properties" (IBI, 2012). It is recognized that biochar can be made from many feedstocks, using a variety of production methods that result in biochar which may possess many different attributes.

Supporting this industry, the guidelines will create consistent reporting of biochar properties and characteristics and "ensure that pertinent information about biochars for use in soil applications is systematically communicated, regardless of feedstock type, production process, or final properties" (IBI, 2012).

It is critical to develop fully equipped laboratories in Washington and regionally that are capable of certifying the quality of bio-char according to the new Standards proposed by IBI.

Research

Scientists at Washington State University are building a program to develop engineered bio-chars for environmental applications. The first product that is being developed is a biochar that sorbs nutrients (P and N) from anaerobic digesters. Dairies in Washington State produce over 1.5 million tons of manure annually accounting for 18,900 tons of phosphorous that is concentrated in lagoons prior to land application. Annual land applications have led to concerns of environmental degradation caused by NO_3 leaching and P runoff. These applications may deliver > 600 kg N ha^{-1} y^{-1} and 160 kg P ha^{-1} y^{-1} exceeding the needs of crops, resulting in leaching to groundwater or runoff losses to waterways. The land disposal of manure from dairy operations has led to excess phosphorous accumulation causing an extreme risk to the environmental quality of the Pacific Northwest (PNW) region. One method for nutrient management and reclamation of nutrients on dairy farms is the use of anaerobic digesters for the production of methane gas and electricity production. After digestion, the effluent flowing from the digester is a combination of nutrients and undigested fiber while the liquid effluent remains high in P and N. Ideally the excess P and N within the effluent stream could be recovered as a fertilizer and exported off farm.

The design of biochar with simultaneous buffering and nutrient adsorption capacity is currently being investigated by researchers at WSU. Also, scientists at the WSU Pullman campus are in initial talks with extension scientists at the Low Impact Development (LID) Stormwater Research Program to develop engineered bio-chars for stormwater cleaning technologies.

Engineered Biochar

Engineered biochar for environmental application is char that has been produced with specific physical and/or chemical sorption properties for targeted pollutants and chemicals found in air emissions, waste water and storm water discharges or that occur as contaminates in soils or base sediments in water courses. Engineered char is seen as an alternative lower-cost adsorbent to activated carbon.

Carboxylic acid groups on the surface of biochar are essential for improving the biochars nutrient holding capacity, as well as polarizing the surface which may also increase water retention of the material. A high proportion of carboxyl acids as well as other acidic oxygen groups may also provide biochar many of the desirable properties of humic acid which is an important degradation product of soil organic matter. The relatively high concentration of acidic groups can allow the formation of chelates with metal ions and help to bind positively charged ions to the surface of the carbon. When the surface density of carboxylic acid groups is very high, chelates with metal ions can almost completely immobilize potentially toxic metal compounds. The results obtained by Valdes (2002) indicate that total acidic groups on activated carbons can reach at least 2 $meqg^{-1}$ with half the acidic groups being carboxyl groups. Smith (2011) showed that biochar ozonation could be an excellent approach to generate acidic functional groups on biochar surface and enhance its capacity to remove nitrogen from waste streams. New oxidation strategies are being studied at WSU. The author (Smith 2011) proved that the pH at zero charge of oxidized biochars is considerably reduced. The acidic nature of oxidized biochars means that they may be well suited for retention of basic ions such as ammonia or other cation compounds (Kastner, 2009). Chiang et al. (2002a, b) has shown a strong correlation between the quantity of ammonia adsorbed by the oxidized carbon and the concentration of acid groups on the surface.

The adsorption of phosphate ions will depend mostly on the concentration and accessibility of cations found in the ash. Effects of metal ion concentrations in fly ash have been the subject of significant research (Lu, et al., 2009; Agyei et al., 2000; 2002; Namasivayam and Sangeetha 2004; Oguz, 2005; Xue et al., 2009). The use of fly ash has been considered for its potential to remove phosphate compounds from waste water. The biochar ash composition plays an important role in the adsorption or precipitation of suspended phosphates (Xue et al 2009), in basic solutions (pH>7) biochar ash with high content of calcite is effective in phosphate removal (Lu et al 2009), in acidic conditions, biochar ash rich in aluminum and iron induces precipitation of phosphates (Oguz 2005). The application of this information to biochars for the removal of relatively low concentration phosphates is of interest, because of the desire to develop an adsorbent capable of removing both nitrogen and phosphorous compounds from waste streams. The addition of appropriate metal ions to the structure of the biomass should aid in creating additional basic sites on the char surface which will become positively charged in solution and attract anions to the surface.

Streubel et al. (2011) studied the role untreated and freshly produced biochar can have on nutrient adsorption by allowing AD effluent to be filtered through the char-media for 15 days. Results showed that the char sequestered an average of 381 mg/L P from the AD effluent as a coating on the biochar. There was an increase of total (1.9 g kg-1), Olsen (763 mg kg-1), and water extractable P (914 mg kg-1) bound to the biochar accounting for a recovery of 32% of the P in the AD effluent. While the study was completed with untreated biochar, it is possible to design biochars with modified surface acidity/area, and cation/anion exchange capacities and with a different ash composition to further enhance nutrient removals from AD effluents.

Carbon Storage in Soils

The least fertile soils can benefit the most from the addition of biochar. According to Amonette (2010), sustainable biochar technologies can offset up to 130 Gt CO_2-C eq emissions worldwide during the first century of adoption. With regard to biomass type, global soil fertility, and carbon intensity of fuel offset, biochar offers a 22% advantage over the combustion of biomass. The three most important variables that affect the impact of biochar uses are the recalcitrance of biochar, the carbon intensity of the fuel being offset, and the biochar effect on biomass growth (Amonette 2010, Woolf et al. 2010). Maximum avoided emissions by the production of biochar and heat, as estimated by Woolf et al. (2010) and Amonette (2010), could range from 1.0 to 1.8 GT CO_2 Ceq yr-1. For 100 years, the cumulative avoided emissions range from 66 to 130 GT CO_2 – Ceq. Producing value-added biochars that can substantially enhance soil fertility as well as carbon storage is critical since payment for carbon storage alone is unlikely to fully recover production costs.

Feasibility Studies

Baranick et al (2011) conducted a feasibility study as part of the Seattle University MBA Sustainable Business Practicum course researching the environemental, social and economic value of a bio-char business converting slash piles from forest management activities in the Methow Valley of North Central Washington (Okanogan National Forest) into bio-char to be marketed solely as a soil amendment:
(http://www.biochar-international.org/sites/default/files/Biochar_Final%20Paper_For%20Distribution%20v9.29.pdf).

Baranick et al (2011) noted that the biochar industry is in the market introduction stage and that during this phase costs tend to be high and sale volumes low with poor competition and low demand. Along with the recommendations of Dr. Whitfield, Baranick et al (2011) argue that under existing conditions "*demand must be created, which require educating the potential consumer base to try the product and then working to retain them as a custumer*". Baranick et al (2011) recommend building small production units first and then considers the "*growth stage*" in which production cost will decrease together with prices due to increased competition (Baranick et al 2011). More research must be done to convince end users (the market) of the benefits of bio-char use (Baranick et al 2011). The state of Washington should have the capability to routinely conduct feasibility studies of business models targeting the production of bio-char in the region.

Potential marketable products

The three examples of regional biochar producers all state that feedstocks will not compete with high value hog fuel and higher value pulp chip. Biochars can be produced from feedstocks with lower energy value. Biochar may be also produced from materials with higher mineral and ash content. Mineral elements (Fe, Mn, alkalines) contained in the subsequent char can have a profound impact on the ability of biochar to "cleanup" pollutants in waste gas and liquids, perhaps at much lower costs than activated carbon. However, the market for activated carbon for industrial and household use is not large enough for the amount of biochar that could be produced from waste, agricultural and forest materials generated in the region. If biochar could achieve a substantially similar result as "activated biochar" at a percentage of the cost of activated carbon, the market for ecological and environmental applications may grow dramatically.

Using biochar to enhance soil fertility is a market that could utilize a vast majority of the organic waste generated in the state (Granatstein et al 2009, Garcia-Perez and Smith 2011). While public interest in the potential of biochar to sequester carbon and enhance soil fertility is growing (Lehmann and Joseph 2009), the main obstacle for this application is that the price for carbon sequestration with biochar is not high enough to justify its production (Granatstein, et al 2009). To increase the economic viability of using biochars as soil amendments, functionalized biochars are needed. Benefits from engineered biochars in agriculture include:
1) Improved water holding capacity at the root zone; 2) Improved fertilizer holding capacity at the root zone and 3) improved soil biological productivity, and 4) in-situ sorption of pesticides. These multiple benefits can improve the value of the biochar product.

The economics of carbon sequestration through biochar (if biochar is approved for carbon storage payments) could improve dramatically if it is inserted into a mandatory carbon cap with associated markets or carbon cap and tax. Today, the value (based on its calorific content) of crude biochar without additional treatment is approximately $66 per ton. If biochars are engineered to improve soil fertility, over those obtained with untreated biochar, higher prices may be obtained. The economic value of biochar could also be increased by its ability to adsorb nitrogen and phosphorous from waste water streams and by increasing its cation/anion exchange capacity. Development of strategies to improve the capabiltities of biochars to adsorb nitrogren and phosphorous from waste streams is an area of of intense study (Smith 2011). The potential use of biochars, used to remove nutrients from waste streams, as a soil amendment and improving fertilizer efficieny is receiving growing attention (Lehmann and Joseph, 2009).

The following uses provide insight into the potential for industry market development.

Near Term:

1. Biomass use as a near carbon neutral heat source for commerce, building heat and industrial thermal applications Combined with highly efficient CHP, biomass for power could be among the potent applications. Biochar is a by-product of CHP.
2. Biochar for multiple environmental applications, an economical solution to capturing N and P, zinc and other metals and organic contaminants in storm water and waste water systems. This could also help prevent eutrophication and subsequent acidification of surface water bodies.
3. Improve soils in diverse high value settings such as greenhouse potting mixes.

Intermediate Term:

4. Sorption of gas phase emissions and odor mitigation from industrial processes and compost operations including at least: ammonia, sulfur and VOC compounds.

Longer Term:

5. Biochar as a soil amendment to sequester carbon to improve nutrient sorption and fertilizer efficiency, increase water holding capacity, and limit nitrous oxide and methane release from soil.

The Industry Opportunity

Biochar has been shown to have many applications. The uses identified above are expected to begin to create biochar demand. Current markets and environmental needs would indicate that biochar opportunities may first be in stormwater remediation and wastewater applications. However, market development is needed to support uses across a number of opportunities.

Support is needed to develop a biochar industry in the Pacific Northwest

Ideally, a trade association or other group would form to support the industry development. However, we are at early stages in this industry. Therefore, the leadership of a team is needed to bring biochar to the market place to provide the numerous environmental services identified above. The support group will need to provide the following functions:

- Coordination, convening and visioning for organizing an industry development effort.
- Establish a trade group and industry practice areas to help organize specific committees. Committees could include: building robust and expanding markets, industry marketing for biochar producers, educational needs, consultants and applications, feedstock biomass

resources, environmental, agronomic and forestry applications, functionalizing biochar for specific characteristics and niche markets, regulatory and permitting for production facilities.

- Identify funding needs and securing source funds. Conduct a needs and opportunities assessment, write and or coordinate grant applications with Industry partners, agencies, universities and NGO's as necessary to support the developing industry.
- Create connections among industry technology leaders and developers with regional and international research leaders and potential investors.
- Develop markets for biochar uses for numerous applications.

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