Market Study:
BioChar

A product of the Oregon State University Advantage Accelerator

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Contents

Executive Summary

The goal of this document is to assess the potential size of the biochar filtration markets in Oregon and Washington. Biochars best application seems to be in the filtration of hard metals in large volume industrial storm water due to the high expense of current competitor technologies and the optimistic outlook on a market characterized by increasingly stringent water quality benchmarks. The rise in bioswale use as well as Best Management Practices (BMPs) in general presents an additional market for biochar as a medium. In general, Oregon is less organized and legislated than Washington, yet both present potential marketplaces. As far as production, questions arise regarding the need to fully monetize on all co-products including char, energy (oil, heat, etc.), and other carbon byproducts in order to compete in the marketplace. Additionally, decisions in whether to sell biochar as a product (in the form of simple bulk substance) or product and service, are relevant in assessing the marketplace in the future.

Here we will first outline several of the key questions regarding the potential market opportunity from material comparison, regulatory considerations and stormwater management options. With this we have outlined our expected market opportunity via permit holders for industrial water filtration, biochar as a material to be used in bioswales (thought to represent a key bulk material opportunity) and a look at activated carbon and biochars potential to be a substitute within this market.

(3) Key Questions – Summary

(1) Industrial Permit Holders - Potential Biochar Market Opportunity

From the standpoint of the consumer (the industrial stormwater discharge permit holder), the priority in storm water remediation is to avoid being fined by treating water in the most cost efficient manner as possible. Oregon and Washington both have different permit systems, with similar benchmarks for pollutant concentrations in discharge water. Of these pollutants, Zinc (Zn) and Copper (Cu), have the most stringent requirements (in terms of difficulty of treatment), which happen to be two metal ions that are very favorably attracted to biochar.

Given that there are currently approximately 2000 industrial stormwater discharge permit holders between Oregon and Washington, we estimated the market for industrial storm and waste water remediation to be approximately $30M (which was based on an annual average filtration related cost of $15,000 per permit holder). We estimate biochar's potential application to be worth about $4.5M, a significant portion of the permit holders budget on filtration media.

(2) Biochar in Bioswales - Potential Market Opportunity

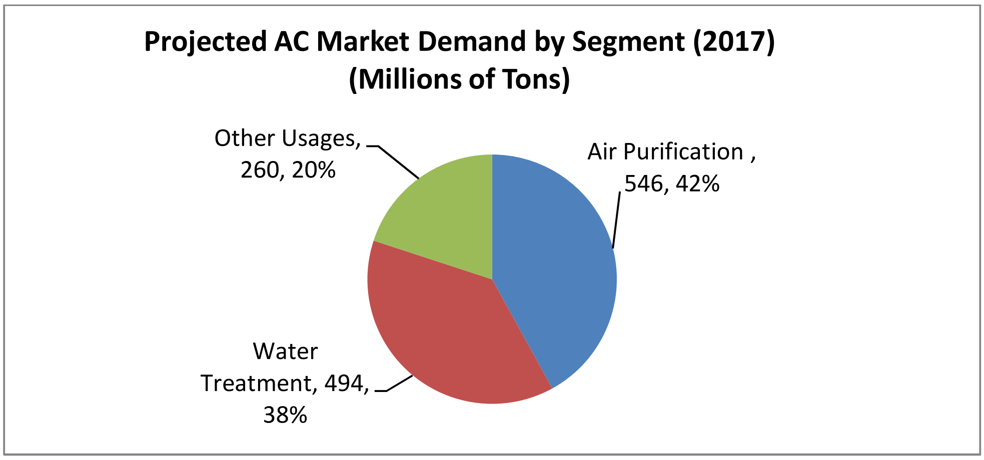
The utilization of biochar as a medium in bioswales serves a similar purpose as to the industrial storm and wastewater sector. Bioswales utilize a slow flow rate, emphasizing the need to target hard metals and organics such as oil in run off water. Bioswales will generally treat street run off water, as is the goal in the City of Portland's Green Streets program and Tabor to the River project, which are examined. Biochar's effective lifespan in a bioswale application varies, but 5-10 years is a consistent range according to various sources. Although the bioswale sector does not show the potential for significant profits from providing a service or maintaining a filter system, it still represents a significant portion of the market in terms of bulk amounts of biochar.

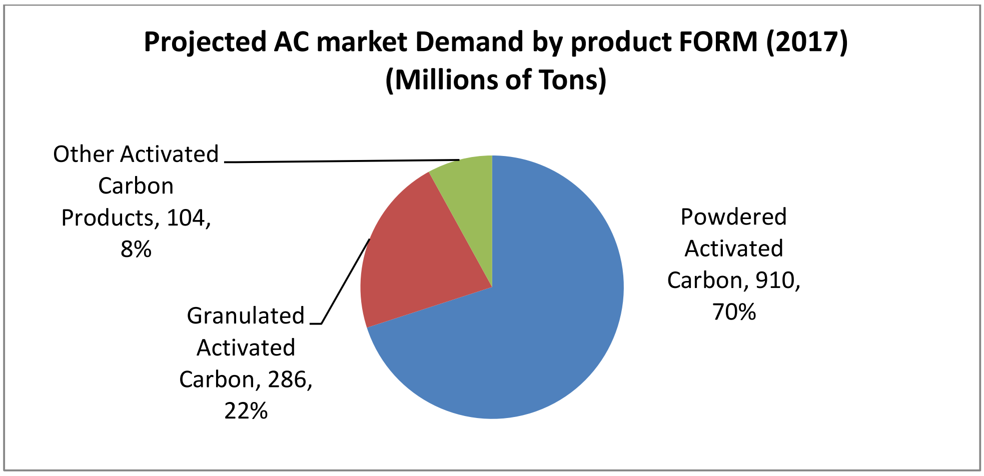
Currently, compost, a very popular media in bioswales, is being reconsidered by many, as a variety of studies indicate rises in the level of toxins over time as a result of what is believed to be the re-release of toxic compunds into the water. Bioswales are generally efficient in handling gasoline and other organic compounds, yet not effective in treating heavy metals and other specific nutrients, as is apparent in rising Zinz (Zn) levels in the City of Portland's 2010 Report. Thus there is an opportunity in introducing a new media for the application in bioswales.

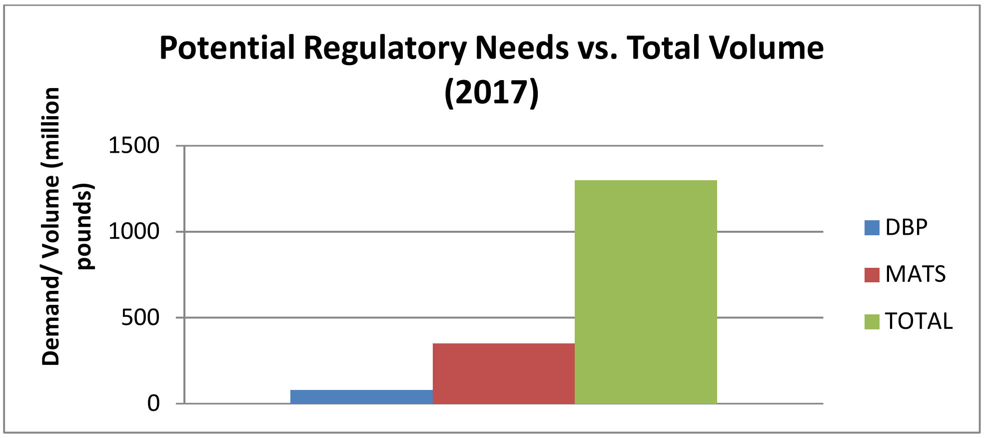
The MBA group estimated a total of 476 Bioswales per year to be installed in the surrounding Pacific NW region, whch is equivalent to approximately 142,800 sq. ft. of bioswale per year.

(3) Biochar as a substitute for Activated Carbon – Market Opportunity

Activated Carbon (AC) is thought to be the most closely related filter media (absorbant) to biochar currently available on the market today and used widely in water filtration along with a host of other applications where an absorbent material is required (automotive, pharmaceutical, mining, chemical industrial, etc.). AC's current market is anticipated to reach 3.3 billion dollars by 2017, accounting for 1.3Billion tons per year to be consumed within the United States. In this forecast horizon, it is anticipated that regulations including the EPA's Mercury and Air Toxics Standards (MATS) (for air purification in coal fired power plants) and EPA's Stage 2 Disinfectants and Disinfection Byproducts (DBP) Rules (water filtration) will be the primary drivers of growth within the AC market. Please see below for projected AC demand by category and type by the year 2017 (as outlined within this segment of the market report):







Material Positioning / Relevant Background Information

Background - Biochar as a Material

Biochar has a high surface area due to its irregular, porous structure, enabling it to absorb organic pollutants. Oxygen containing functional groups on the surface of biochar molecules give it a high cation exchange capacity which favors the absorption of metals from water. Biochar, across a body of recent research, is known to absorb Zinc (Zn), Cadmium (Cd), Lead (Pb), Copper (Cu), Phosporous(P), High molecular weight polycyclic aromatic hydrocarbons (PAH), and many other substances. Additionally, biochar is known to enhance the water holding capacity, porosity, and bulk density of soil. We perceived biochar's ability to attract metal ions to be its most favorable property in its water filtration application.

Given that chemical properties of biochar are dependent on a variety of factors, including feedstock, method of production (pyrolysis or combustion), temperature, and so forth, production can be altered to favor certain characteristics, such as surface area, or produced in a manner as to save money. For example, "cooking" biochar at high temperatures at around 600-800 Celsius as opposed to 300-400 Celsius would significantly reduce yield, yet favor the treatment of organics in water. Regardless, most biochar is similar in its applications. The grid below provide a visual for our assessment of the need to treat water for certain categories of substances within different sectors

Comparison Grid – Water Filtration Needs By Sector

	Product Attribute/ Proficiency/ Need		
SECTOR	**Organics**	**Heavy Metals**	**Phosphorus / Nitrates**
Municipal	H	H	
Industrial	H	H	
Agriculture			H

[Priority : H -- High, M – Medium, L – Low]

As mentioned, biochar can be used as a component in media mixes (with compost, or as a layer in a filtration bed) to absorb heavy metals, hydrocarbons, and in some cases phosphorus, with the primary benefit of remediating heavy metals. When cross referencing this performance capability of biochar with the needs of the different market sectors for water filtration, it is apparent that biochars market potential is most closely aligned with the market demand within the municipal and industrial segments. As such, these two sectors will be the primary focus of this paper, along with a comparative analysis of the market for activated carbon (AC).

Background – Biochar in Commerce

The International Biochar Initiative (IBI) report provides an expansive overview of the state of the biochar industry. These numbers are presumed to be severely under-estimated, yet still do provide pertinent information.

> **Biochar Industry:** "those enterprises encompassing the commercial production, distribution, and marketing of biochar and biochar-related products and service"(IBI)
>
> IBI reported 99 companies in the North America sector of the biochar industry.
>
> **Number of Business's:** "175 commercial enterprises in the current IBI company database, close to half are involved in equipment manufacturing, one-third are in biochar production or sales, and the remainder are involved in related enterprises"(IBI)

Gross Sales: "Sixteen companies reported combined sales in excess of 800 tonnes of biochar; the vast majority of which (91%) was sold in Europe and North America." Of the 827 Tonnes of biochar sales reported, 542 tonnes were reported from North America, representing a 65.5% market share (IBI).

Revenues: 21 biochar vendors reported revenues, 90% of which experienced an increase, and 33% of which had their revenue figures at least double in the preceding 12 months. 63% of biochar equipment vendors reported an increase in revenues. "In terms of dollar amounts, approximate annual revenues reported to us by companies totaled nearly $800,000 and $1.25M for biochar vendors and equipment manufacturers respectively"(IBI). Note that the total revenue has to be severely inaccurate, yet still does show how low revenues are for the average company reporting significant growth.

Price: "Globally, the mean price for pure biochar was US$2.65/kg; this ranged from a low of US$0.09/kg in the Philippines to a high of US$8.85/kg in the UK. For blended biochars the mean price was US$3.29/kg with a low of US$0.08/kg in India and a high of US$13.48/kg in the US…Presently, the 23 US-based companies that give pricing information sell their biochar products for a median price of US$2.863per kg, or US$2,860 per metric ton (tonne)."(IBI)

Industrial Stormwater/Wastewater

Extent of the Problem

The bottom line in industrial stormwater filtration is cost management. Although biochar does present a favorable environmental image, most companies focus exclusively on cost reduction (and this means avoiding fines). Thus biochar needs to offer a cheaper solution that works in a similar manner to meet the same requirements (as detailed below). Certain companies express concerns over maintenance, such as the frequency of filter replacement, issuing the potential for profitability in providing a service in addition to the raw material.

Market Size

As far as market size, currently about 2000 industrial water permits are issued between the state of Oregon and Washington. According to surveying by Oregon State students, the average company (in Oregon with a 1200Z permit) spends approximately $15,000 on water filtration systems (filters and media), with similar (if not higher) numbers expected in Washington (MBA Group). This in turn produces a rough estimate of $30M in annual spending by private firms on filtration costs in order to satisfy Oregons 1200Z and Washingtons ISGP benchmarks for industrial wastewater. Of this cost, we estimate 30% or $9M in filtration related media expenses for stormwater and wastewater systems. We estimate activated carbon and similar materials that biochar can replace to make up about 50% of this cost. As a result, we estimate the market potential for biochars application in industrial stormwater filtration to be approximately $4.5M annually between Oregon and Washington.

Market Landscape & Regulations

The engineering requirements for a potential BioChar wastewater filtration system need be capable of meeting the benchmarks for pollutant concentrations of Oregon DEQ's 1200-Z (or 1200-COLS) Stormwater Discharge Permit or Washington DOE's Industrial Stormwater General Permit (ISGP), as presented in tabular form below:

	Oregon (Columbia)	Oregon	Washington
Parameter/Benchmark	1200-COLS	1200-Z	ISGP
Copper (Cu) (μg/L)	36	20	West: 14
Lead (Pb) (μg/L)	60	40	
Zinc (Zn) (μg/L)	240	120	117
Suspended Solids (mg/L)	50	100	
Oil & Grease (mg/L)	10	10	No visible
Phosphorous (μg/L)	160		
BOD_5 (mg/L)			
Turbidity			25

Note that these numbers are subject to variability in the future (likely to decrease in magnitude - and yes, these are the "New" regulations).

Oregon 1200-Z:

Sampling:

Oregon permits require to "Grab samples of stormwater a minimum of four times per year" for Cu, Pb, Zn, pH, Solids, and Oil/Grease.

Fines*:*

"Under ORS 468.943 and 40 CFR 122.41, modified by 40 CFR 19.4, unlawful water pollution, if committed by a person with criminal negligence, is punishable by a fine of up to $32,500 or by imprisonment for not more than one year, or by both. Each day on which a violation occurs or continues is a separately punishable offense."

According to the Oregon DEQ website, approximately $25 million in fines have been issued by DEQ since 1997, $6.5 million of which are for water quality violations (on average approximately $400,000 annually)

Concerns:

Oregon DEQ is implementing a system called "Tier II" as a result of environmental groups raising lawsuits over the DEQ's ineptitude with developing and enforcing properly stringent requirements. As a result, noncompliant companies will be flagged and receive a limited time period to comply with discharge benchmarks. As of now there is apparently no list of companies who will receive the "Tier II designation," but they will be flagged in December 2014 (according to Oregon DEQ official Jennifer Weaver).

Washington ISGP:

Sampling:

Washington permits require "at least one sample taken each quarter, year round"(ISGP)

Fines*:*

The ISGP Washington Fact Sheet reported the following number of actions for each "action":

Informal: 3,278
Civil Penalty: 35
Administrative Order: 29
Notice of Violation: 8
Notice of Correction: 178

Concerns:

Washington faces high barriers to entry, more specifically in biochar gaining appropriate approval as a substance. BioChar needs to become certified at a biochar specific level through the TAPE program (Technology Assessment Protocol – Ecology), Washington State Department of Ecology's process for evaluating and approving emerging stormwater treatment BMPs. New stormwater treatment BMPs that are not in the current Stormwater Manual or have not been approved by TAPE must first be approved by Ecology's TAPE Program.

Washington has requirements for the installation of BMP's for Low Impact Developments (LID). "Government agencies have issued increasingly strict requirements on so called 'low impact development', requiring 2-3% of impervious land to have 2 ft. deep biofiltration systems. Anything discharged to surface water is stormwater and thus needs testing." (Myles Gray)

Market Trends

Current Costs:

For industrial permit holders, according to David Smith's students, filter bed replacement costs vary from $2,000 to $25,000 annually (averaging at $15,000), and replacement filters average approximately $375 per filter per month (375$/mo.*12 mo. = $4,500 per filter per year.).

Myles Gray emphasized how expensive basic filtration systems are, referencing for example a Sand - Activated Carbon - Sand layered box filter with the capacity to process 8 gallons/minute with a price tag of $8,000. Even if his quote is not completely accurate, this is an example of a system that biochar could be utilized in as a more economic medium alternative to activated carbon.

Projected Trends:

OR: 1200Z requirements were revised (and made more strict) in 2012 and will most likely continue in this direction given the severity of water quality issues as well as pressures placed on Oregon DEQ. Tier II corrective actions for non-compliance is another indicator of this trend. In general, Oregon still faces looser legislation than Washington in putting biochar to use. Hypothetically, if a civil engineer were to design a box filter system utilizing biochar that worked (in filtering water to meet 1200Z benchmarks as well as Tier II requirements), it could have commercial applicability in the near future.

WA: The demand for water filtration solutions is rising in Washington as well, as is apparent in Low Impact Development (LID) requirements. However, barriers to entry for biochar as a substance remain difficult to overcome due to the TAPE program.

Anticipated Supply Chain:
BioChar Producer → Filter Cartridge Producer → Industrial Consumer , OR
BioChar Producer → Consumer

Company Example: Contech:
Contech Engineered Solutions (company) manufactures a large variety of different stormwater management technologies and provides detailed technical specifications on their website as well as case studies about the use of their BMP filtration systems (links available in references section).

Most notably, Contech produces a "Stormwater Management StormFilter", which is "a best management practice designed to meet stringent regulatory requirements, remove the most challenging target pollutants using a variety of sustainable media."(Contech) Andrea Simescu, a Senior Designer at Contech, said "We use the GAC with the ZPG media that targets sediment, oil and grease, nutrients, soluble metals. Maintenance frequency will depend on the site, but it ranges from 1 to 3 years in the NW." Below is a list of media that Contech uses:

Zeolite-Perlite-Granular Activated Carbon (ZPG): "A proprietary blend of zeolite, perlite, and GAC to improve the performance of perlite and target organics, soluable metals and other pollutants."(Contech) " ZPG is a mixed media that shall be composed of a 1.3 ft^3 outer layer of 100% Perlite and a 1.3 ft^3 inner layer consisting of a mixture of 90% Zeolite and 10% Granular Activated Carbon." (Simescu) Note that the volumes are specific to a ZPG StormFilter Cartridge.
Granular Activated Carbon (GAC): "GAC has a micro-porous structure with an extensive surface area to provide high levels of adsorption. It is primarily used to remove oil and grease and organics such as herbicides and pesticides.**"** "Granular activated carbon (GAC) shall be made of lignite coal that has been steam activated. The GAC media shall have a bulk density ranging from 28 to 31 lb/ft^3 and particle sizes ranging from that passing through a U.S. Standard #4 sieve to that retained on a U.S. Standard #8 sieve"(Simescu). Additionally, According to Simescu, GAC is Contech's elite medium and has a lifespan of approximately two years.
Zeolite: "A naturally occurring mineral used in a variety of water filtration applications, is used to remove soluble metals, ammonium, and some organics."(Contech)

CSF Lead Media and Metal RX: "A granular organic media created from deciduous leaves, CSF is most effective for removing soluble metals, TSS, oil and neutralizing acid rain. MetalRx, a finer gradation, is used for higher levels of metal removal." (Contech)

Perlite: "Perlite is expanded volcanic rock. Its porous, multi-cellular structure and rough edges make it effective for removing TSS, oil and grease."(Contech)

PhosphoSorb: "PhosphoSorb™ is a lightweight media built from a Perlite base that removes total phosphorus (TP) by adsorbing dissolved-P and filtering particulate-P simultaneously." (Contech)

Filters and Technologies

Comparison of Current Methods:

Electrocoagulation has a high a level of technology and a high level of performance in treating heavy metals. More specifically, by utilizing electricity, electrocoagulation effectively removes heavy metals, suspended solids, and organics such as emulsified oils and Total Petroleum Hydrocarbons (TPH). This method does not require any input filter or chemicals. In case industry individuals refer to "radio frequency diathermy" or "short wave electrolysis," this is what they are referencing. The technology is very expensive and thus is not economically sustainable for most targe:t markets for biochar.

Underground and Catch Basin Filter Systems are popular and utilize a variety of medias to serve as filters at a more economic rate. This general category of filtration systems faces large variability in size and application as well, and thus is incorporated into treatment systems by a large amount of Oregon and Washinton permit holders. The Box filter is the most useful application for biochar, according to Oregon State researcher Myles Gray. Below are general details about filter systems.

Filters:

Replacement: Varies (companies often schedule regular replacement on multiple filters, which is realistically dependent on volume of rainfall, level of pollutants, etc.)

Media: A large variety of media are used in Industrial applications, as is apparent in forvexample Contechs inventory of options. However, the three substances below are common media used in industrial water filtration systems.

> **Activated Carbon (AC):** Activated carbon is very similar to, but more expensive than biochar. AC is more favorable in treating organics, yet not as effective in treating metals. (See Final Section for detailed overview),
>
> **Compost (and leaf mixes):** Very cheap but has seen some stoppage in use due to re-releasing toxins over time as the organic material erodes. Compost "typically retails for US$30 – 50 per tonne—a factor of 10 less than biochar"(IBI).
>
> **Sand/Gravel:** Even cheaper than compost and is generally the media bought in the greatest volume to serve basic filtration purposes.

Primary Concerns:

The filtration system needs to be capable of filtering water facing high variability in the concentration of solutes and not require excessive levels of maintenance (to for example avoid clogging). The concentration benchmarks for Copper (Cu) and Zinc (Zn) are traditionally the hardest to meet for discharged industrial water.

Municipal Stormwater & Bioswales

Background

Application:

The utilization of biochar as a medium in bioswales for the slow flow rate filtration of hard metals and organics such as oil in run off water is the primary application. Biochar's effective lifespan in a bioswale application varies, but 5-10 years is a consistent range according to various sources.

Primary Concerns:

Currently Biofiltration relies on microbe consumption of gasoline and other organic compounds, yet is not effective in treating heavy metals and other specific nutrients. Additionally, the media used in Bioswales (compost specifically) has shown negative side effects (degrading and re-emitting compounds into the water over time). The cost of biochar is higher than most media used in bioswales, yet its metal attracting properties still show potential to have an economically realistic application in bioswales.

Market Landscape

Current Regulations:

Oregon: Oregon does not have a specific approval process for the use of a substance like biochar in BMP's.

Washington: As mentioned in the industrial sector, Washington faces strict legislation in its TAPE program and thus does not present as optimistic of a market outlook for biochars application as a BMP media.

Market Trends

The potential application of biochar in bioswales should focus on new developments as bioswale filter medium maintenance does not operate as periodically as it does in the industrial stormwater sector. Below is information gathered by David Smiths students for annual BioSwale installation by city in Oregon and Washinton.

Average Annual Bioswale Installations by city:

1. Seattle Washington 86
2. Portland Oregon 83
3. Spokane Washington 30
4. Boise Idaho 29
5. Tacoma Washington 28
6. Vancouver Washington 23
7. Eugene Oregon 22
8. Salem Oregon 22
9. Bellevue Washington 17

10. Gresham Oregon 15
11. Everett Washington 15
12. Renton Washington 14
13. Hillsboro Oregon 13
14. Yakima Washington 13
15. Beaverton Oregon 13
16. Nampa Idaho 12
17. Bellingham Washington 11
18. Bend Oregon 11
19. Kennewick Washington 11
20. Medford Oregon 11

Market Size

The total of 476 Bioswales per year is equivalent to approximately 142,800 sq. ft. of bioswale per year (using the 300 sq. ft. per bioswale unit standard supplied by Emily Hauth from City of Portland). We estimate this to represent a potential market for 476 cu yd. of biochar (as based on the MBA group's sassumption of 1 cu. yd. biochar per unit), representing approximately $150,000 in value.

Anticipated Supply Chain

Producer/Supplier → Government Agency/Dept. → Application to Bioswales, etc.

City of Portland: Examination of BMP Practices

Background:

The City of Portland is a front- runner in the application of bioswales with an 18 year history of installment with programs such as Green Streets. Most recently, the currently occurring $81 Million Tabor to the River Project is presumed to add 500 green streets and 100 private stormwater projects to East Portland. Emily Hauth of the City of Portland claims that about half of the bioswales in the project are installed and about 100 of them are for private entities. "Green Streets" refer to one bioswale unit that is owned and maintained by the city whereas "private swales" are the responsibility of the property owner.

Spending:

In 2012, Portland spent $101 million (46: capital improvements, 29: facilities operation/maintenance, 13.9: watershed program/habitat restoration) on stormwater management requirements (according to the MBA groups research)

BMP Quantities:

"1500 Green Streets
600-700 Private Swales
200 Private basins/ Rain Gardens

1400 Private Planters
600 (425 extensive, 175 intensive) EcoRoofs" (Kurtz)

BMP Size:
"the average size we use when referring to one green street (bioswale) facility is 300 sq. ft" (Hauth)

BMP Cost:
"the average cost per facility that we use is $50/ sq. ft. … cost includes planter style facilities (concrete walls) as well as bioswales"(Hauth)

The 2010 Stormwater Management Facilities Report (Portland, OR)

Commentary:
According to Tim Kurtz of City of Portland, an equivalent 2013 report should be released in the next few months with updated information. The 2010 Stormwater Management Facilities Report provides summaries on flow rate (volume) retention in Green Streets projects, many of which utilize sytems in which Biochar could potentially serve a purpose. The City of Portland also provides a summarized report, which contains the majority of relevant information to our interests.

Several tables in the report (such as Table SW-3) show detection levels of E.coli, Motor oil, pH, copper, lead, mercury, zinc, benzo(a)pyrene, benzo(b)fluoranthane,benzo(g,h,i)perylene, chrysene, flourenthene, indeno(1,2,3-cd)pyrene, and pyrene for years 2005, 2007, and 2010 as well as Control Limits for 2010 for specific BMP sites across Portland.

The media used in the different facilities were fairly consistent, predominantly made up of a "facility soil: Sunderland Yard 3-way mix (equal parts topsoil, sand, and compost)" and/or a "native soil: silty, urban mixture. "

Stormwater Management Facilities: "Stormwater management facilities handle runoff from impervious areas and alleviate potentially negative impacts to the combined and storm sewer systems, and to watershed health. In particular, they can be used to reduce peak flows, reduce runoff volume, and improve water quality. "

Monitoring Objectives: "Gathering performance data for stormwater facilities is important to quantify their benefits to sewer and open channel systems, lower maintenance costs, ensure public safety, and improve overall design and function. Monitoring data can be used in a detailed way, such as in hydrologic and hydraulic modeling, or more specifically to determine the suitability of a facility type at a particular site."

Performance Measures:

1. Peak flow attenuation (peak out / peak in) – in particular, provide the expected protection for homes in risk of basement sewer backups in the combined sewer area, and help control erosion in open channel systems.

2. Flow volume retention (volume out / volume in) – in particular, quantify the benefit to CSO control in the combined sewer area, or provide flood and erosion control in open channels or storm sewer systems.

3. Water quality – determine the impact of the facility on water quality and watershed health.

4. Soil infiltration rates – determine the ability of the facility to recover its storage capacity after a large storm event. This is also an important issue for vector control.

5. Sediment / soil sampling – determine whether pollutants accumulate in stormwater facility soils to levels that may pose a human or watershed health risk.

6. Maintenance – identify any major issues during the current monitoring period associated with the facility and the vegetation. Recommend modifications that may decrease the amount or frequency of maintenance.

7. Design modifications / improvements – identify issues that would suggest altering the design of the facility, or the design of future facilities.

8. Facility sizing – evaluate the performance of the facility as it relates to the ratio of facility area to drainage area. This includes a comparison to the sizing specified under the "Simplified Approach" in the BES Stormwater Management Manual (SWMM) used for new development and re-development projects.

9. Performance baseline – test results will build a performance history that can be used to track changes caused by antecedent moisture, seasonal variation, and facility age.

Types of Monitoring:
Infiltration: "For infiltration facilities, the rate at which water moves into the ground is the primary variable that determines how well it will manage large storm events, recover capacity between storm events, and prevent vector control problems." Regarding media, "In most infiltration facilities, the first 18 inches of soil is replaced with a specified mixture of topsoil, sand, and compost."

Soil Sampling : "done to ensure that surface stormwater facilities do not create localized areas of high pollutant concentrations.Samples are tested for heavy oils, metals, and polycyclic aromatic hydrocarbons (PAHs). As samples are taken over time, pollutant concentrations will be analyzed for trends."

Flow Testing : "an efficient way of collecting performance data in response to design storm events used by BES as performance standards"

Flow Metering: "full-time monitoring of the inflow and/or outflow from the facility. "

Water Quality Sampling: "involves storm event-based analysis of facility influent and effluent" by using sampling criteria established by BES

Facility Types:
Ecoroofs: "Ecoroofs consist of soil media and vegetation atop a waterproof membrane. They reduce peak flows and total runoff volume. Soil depths typically vary from 4 to 6 inches, and a variety of soils and plantings are possible. The primary consideration is the structural rating of the roof, which must be able to support the weight of the plants and soil when fully saturated. Ecoroofs are also referred to as Green Roofs, Living Roofs, or Roof Gardens." Ecoroofs utilize a variety of media as displayed in the cases below and have used other substances such as encapsulated Polystyrene.

Hamilton Apartments (West Side):
Media: 5 inches of sandy loam, perlite, digested paper fiber, coconut coir, compost
Reports: "Zinc and copper levels in the runoff are highly variable. Potential metal sources include the soil media, corrosion of roofing materials – flashing, railings, etc. – and metals present in rainfall [Sullivan, 2005]. Ecoroof zinc levels were substantially lower than conventional roof runoff samples collected from the building penthouse (8.9 – 39.3 µg/L ecoroof versus 67.2 – 239 µg/L conventional), but ecoroof copper levels were notably higher (6.8 – 20.6 µg/L ecoroof versus 0.61 – 3.9 µg/L conventional). This would suggest the ecoroof can capture zinc from conventional roof sources like galvanized metals, but that copper in the ecoroof soil media can leach out and raise effluent levels. All events had concentrations well below human health guidelines, but even low levels (down to 3 µg/L) of dissolved copper may adversely impact salmonids and other aquatic life [Hecht et al, 2007]. Efforts to reduce copper export should be investigated in the future."

"Phosphorus concentrations appear to be decreasing over time but are still high when compared to in water benchmarks (0.13-0.16 mg/L) established in some Portland watersheds. There was little or no phosphorus or nitrogen found in conventional roof runoff at the site."

Portland Building EcoRoof :

Media: 3 inches of sandy loam, pumice, compost, and Sockosorb polymer

Multnomah Country Green Roof:

Media: 6 inches of perlite, pumice, paper pulp, digested paper fiber

All Three EcoRoofs:

Peak Flow : "all configurations were effective at reducing peak flows (76% to 100%). "

Flow Volume: "long-term annual runoff retention has been shown to be as high 49%, but retention is highly dependent on the soil media and irrigation. Soil media containing smaller soil particles (like sandy loam) have provided the best volume retentions. Ecoroof design should minimize the need for summer irrigation to maintain storage capacity in the soil media and to prevent irrigation runoff. "

Water Quality : "copper and phosphorus concentrations appear elevated in ecoroof runoff at Hamilton and the Portland Building, and are significantly higher than concentrations in conventional roof runoff at Hamilton. On the other hand, zinc concentrations are much lower for the ecoroof on Hamilton, which appears to buffer washoff from the galvanized metals on the roof. While more information is needed to determine specific sources and how effluent concentrations will impact in-stream watershed health benchmarks, minimizing metal and nutrient export should be a consideration when choosing an ecoroof soil media and building materials. "

Infiltration Systems:

Green Streets (public right-of-way infiltration facilities):

"Their design is highly flexible making them a versatile tool in managing peak flows, flow volume, and water quality. All facilities typically range from 3 – 8 feet wide and have a ponding depth of 4 – 9 inches. Sizing depends upon the goals for the facility (peak flow reduction, flow volume reduction, and/or water quality improvement). Any overflows during large rain events are directed to a conventional drainage system."

Planters: Utilize vertical walls and are "typically 3 to 4 feet wide, with additional space needed for a step-out if curbside parking exists. The presence of utility vaults and street trees are common design challenges "

Swales: Remove pollutants through filtration by utilizing varying media to minimize flow rate to maximize the absorption of pollutants. Swales are "typically 8 to 10 feet wide, linear… The main challenges are existing street trees, utility poles, and water services. "

Basins: "very similar to swales, but are typically larger and can be of any shape. Basins are sometimes referred to as Rain Gardens or bioretention facilities"

Private Infiltration Facilities: "This category includes infiltration facilities on private property that manage roof and parking lot runoff. The facility types are the same as those under Green Streets – planters, swales, and basins. As with all infiltration facilities, the infiltration rate of the native soil is a primary design factor."

Flow-through Facilities: "Flow-through facilities look just like standard infiltration facilities but they are lined. Any runoff not held by the soil and plants makes its way to an underdrain system which is connected to a conventional drainage system. Lining is accomplished through the use of a plastic (HDPE or PVC) liner, coated concrete, or impermeable soil."

Note: Facilities are constructed by the city and by private contractors to meet the requirements of the Stormwater Management Manual. Maintenance for all right-of-way facilities eventually falls to the city. Privately built facilities will typically have a warranty period of 2 years before becoming the city's responsibility.

Facility Studies:

Oregon Zoo Parking Lot Swales

Type: Flow-Through Basin

Size: 6,500 sq. ft^2

Design: runoff flows over surface vegetation and percolates through approximately 18 inches of soil media (below ½ -1" river rock mulch)

M**edia:** Basin 1, "Row 4" = 55% sandy loam / 45% compost

Basin 2, "Row 7" = City of Portland Sunderland Yard 3-way mix 67% sandy loam / 33% leaf compost..

Metals & Oils: "Small amounts of total oil & grease were present in the untreated parking lot runoff, but were not detected in the swale runoff. The soil media appears to be filtering the oil & grease well."

"some export of phosphorus and nitrates"

"Row #7 had much higher total dissolved solids, conductivity, and hardness when compared with Row #4 for both events. The elevated levels of all three parameters indicate the presence of at least calcium in the runoff. "

Flow: "For this test, the swale retained 23% of the inflow volume. The result is consistent with other flow through facilities that have been monitored"

"It is also important to note that the flow-through swales are only intended to manage the smaller Water Quality Design Storm (0.83 inches in 24 hours), but this storm is not ideal for flow testing because the storm's flow rates are low and were not expected to produce significant flow into the sewer."

SW 12th & Montgomery Green Street:

Design: Street Planter (four bays)

Media: Facility soil: 3-way mix (equal parts topsoil, sand, and compost) ,

Native Soil: silty, urban mixture

Concerns: "Sediment / debris accumulation is significant in the first bay – leaves, sweet gum burrs, and sediment from the upper portion of SW 12th. Must be removed 6 times a year"

Reports:

Metals: "Levels are well below screening levels, though zinc levels were found in some samples that exceeded plant and invertebrate health guidelines. However, there are no apparent problems in the facilities – the plants appear healthy and earthworms are typically seen. "

e. coli : "Results for **e**.coli were generally low with a median value of 30 mpn / dry g. Higher values were found in some facilities, but colonies do not survive for extended periods in soil. Subsequent sampling at the same locations showed a return to very low levels."

PAHs(polycyclic aromatic hydrocarbons): "PAHs were found in all facilities, but the only compound with levels that approach or exceed human health screening levels was benzo(a)pyrene."

ReBuilding Center Planters :

Design: "Flow-through planters placed against the building which manage runoff from a 8,400 sq ft section of roof. Underflow and overflow are piped to a drywell."

Size: 8,400 sq. ft. facility area

Media: "facility soil": 65% sandy loam, 15% digested paper fiber, 10% coconut coir, 10% compost

General Detection Trends:

Metals: "Metals have been generally consistent with the control, but lead and zinc have shown potential signs of an upward trend. All metal levels are well below concentrations considered a threat to human health. " Copper levels have also risen at some sites.

Oil: High variability

PAHs: benzo(b)fluoranthene, benzo(g,h,i)pyrelene, and pyrene have risen above control levels in numerous tests.

Thoughts on MBA Project:

The MBA teams findings about the market opportunities for biochar in water filtration in Oregon and Washington coincide with ours for the most part. However, their specific cost calculations for an alternative biochar-based bioswale contrasted ours. The team based their business plan on an alternative bioswale design that utilized biochar. They claimed their design would operate on a budget of $45/ sq. ft., which they believed to be economically competitive in contrast to the $50/sq. ft. that the City of Portland budgets on bioswales (Hauth). In their cost breakdown for the $45/sq. ft., the team assumed the cost of Biochar to be $684 / cu. yd., which constrasts the quoted prices we were supplied with in our initial meeting with the stakeholders team. The stakeholders stated that they could potentially produce the low temperature char at approximately $300/ cu. yd. and the high temperature (pyrolysis/combustion?), "ultra" biochar at approximately $500 / cu. yd. Although the ultra biochar is more favorable for organics predominantly due to surface area chracteristics, the biochar produced at a low temperature is cheaper to produce and thus is more realistic in application to a bioswale. This bulk biochar sales price is less than 50% of the MBA projects' quoted price, which would bring the price of their proposed 27.5 cu. yd. design cost of $4,029 down by upwards of $400 a unit (assuming that a cu. yd. of biochar is truly needed). Since the quoted price for sand and gravel were $35 / cu. yd. (which also seems high) in the MBA report, recalculation of media costs with the assumption of biochar supplied at $300/cu. yd. would hypothetically reduce the City of Portland's budget for media materials in a bioswale installation by 50.9%. The MBA project estimated that a little bit less than 50% of The City of Portland's $101 million annual budget is spent on stormwater management, including bioswales and other infrastructure with potential for biochar applicability. This is due to the division of the 2012 Stormwater Budget for the City of Portland into Capital Improvements ($46M), Facilities Operations and Maintenance ($29M), Watershed Programs & Habitat Restoration ($13.9M), and Enforcement and Development Review ($11.2), the middle two of which are perceived to be the most relevant to the market for biochar applications.

Activated Carbon

Market Size/ Extent of the Problem

"The market for activated carbon in 2012 was valued at USD 1,913.2 million and is forecast to reach USD 4,180.5 million by the end of 2019, growing at a CAGR of 11.9% between 2013 and 2019. The powdered activated carbon is the fastest growing product segment, growing at a CAGR of over 13.7% from 2013 to 2019 in terms of revenue. However, granular activated carbon is forecasted to account for over 32% share of the global market in 2019."[1] "North America was the second largest market for activated carbon which accounted for over 27% share of the global market in 2012. Owing to the significant increase in demand for activated carbon in Asia Pacific and RoW, the market share of Europe and North America is expected to decline over the forecast period."[1]

"The largest market for activated carbon is currently in the municipal water purification industry, where charcoal beds have been used for the dual purpose of physical filtration and sorption. In fact, activated carbon filters are used today in drinking water treatment to remove the natural organic compounds (i.e. tannins) that produce carcinogenic chlorinated by-products during chlorine disinfection of water. In wastewater treatment, activated carbon is usually used as a filter medium in tertiary treatment processes. In these applications, carbon filters are usually quite effective in removing low concentrations of organic compounds, as well as some inorganic metals." [5]

What is Activated Carbon?

"Activated carbon also known as activated charcoal and activated coal is a processed non-graphite porous form of carbon formed by activation of carbonaceous material such as sawdust, bamboo, coconut shells, wood chips, lignite, coal, paddy husk etc. Powder, granular and extruded are the common products used in activated carbons market. Impregnated carbon is another variety, which contains different elements such as polymer coated carbons, iodine and silver. Activated carbon is used in wide range of applications in gas, vapor, and liquid treatment." [1]

BioChar vs. Activated Carbon (Basic Comparison)

While Biochar is related to activated carbon, there are distinct differences which need to be addressed when comparing activated carbons existing market and Biochar's potential.

Similarities:

- Both are biomass conversion processes in their production (coal/wood products)
- Char (whether AC or biochar) filters work through the process of adsorption. As a background, adsorption, is the surface interaction between dissolved materials and the char, and is distinct from absorption, which means "to soak up" or "to take into."
- Both can be packed in columns as a filter generally (activated carbon can also be applied to water in a powdered form)
- There is the potential that they can be used together within a system?

Advantages:

- Anions (negatively charged biochar) attracts cations (positively charged metals)
- Biochar could be more for stormwater as activated carbon would be "overkill" in this purpose since the price/performance ratio wouldn't be ideal due to the dilute amounts of organics (such as gasoline).
- Biochar is substantially cheaper to produce
- Biochar is negatively loaded with anions as hydroxyl- and carboxyl groups and therefore functions as cation-exchanger. (Lee et al., 2010; Meyer, Glaser and Quicker, 2011)
- In addition the carbon in biochar has a classical graphite structure. This enables the carbon to connect with neighbouring atoms or atoms from foreign molecules to establish linear or cyclical bondings (R.Schlögl, 1994). Through this the biochar becomes even more stabilized and increases its capacity as absorbent.

Disadvantages:

- Less effective in removing (if not repulsive to) nonpolar, organic compounds
- Likely "5-6 times less capacity" (Myles Gray) due to less surface area – though this may not be as important due to inevitable clogging issues
- Lower surface area, unactivated biochars have a lower affinity for organic contaminants than activated carbons, so activation is necessary for their performance to match that of activated carbons

Possible Break Even Point:

- The estimated break-even price for biochar is US $246 The estimated break-even price for biochar is US $246 t ^- 1 approximately 1/6 of commercially available activated carbon (US $1500 t ^-1) Converting waste biomass into biochar will also promise an effective solution for the safe and beneficial disposal of a number of materials. In particular, solid waste material such as animal litter and sewage sludge will be removed of all active pathogens through conversion to biochar. The evolved volatiles and gases can be captured and condensed into bio-oil and syngas during biochar production" (Ahmad 31)

	Product Attribute/ Proficiency/ Need		
TECHNOLOGY	**Organics**	**Heavy Metals**	**Phosphorus / Nitrates**
BioChar	M	H	L
Activated Carbon	H	M	L

H - High, M – Medium, L – Low Efficiency

Filtration Mechanisms

"Because of the high adsorption capacity as well as the cation exchange ability biochar is applicable as sorbent in sewage treatments and filtration plants" [10]

" For water treatment, contaminants diffuse into char pores (absorption) where they bind to char surfaces (adsorption). The large porosity and high surface area of biochars provide many reactive sites for the attachment of dissolved compounds. These reactive sites can also bind non-problematic dissolved organic matter present in all natural waters as well as the targeted hazardous contaminants. This organic matter can clog the char pores and make it less effective; to mitigate this occurrence, a filtration system uses gravel and sand filters to remove a large portion of the organic matter from the water before it encounters the char. The idea is to achieve a high level of treatment prior to the char filter, to "save the carbon" for removing the SOCs.

Biochar filters do differ from Activated Carbon filters in a couple key ways. Local biochar is ideally made from agricultural and forestry residues and/or sustainably harvested renewable woody biomass whereas most commercial ACs are made from (nonrenewable) coal. Both local biochars and ACs undergo a carbonization step where the feedstock is heated to several hundred degrees C under restricted oxygen. Commercial ACs are subsequently "activated" in an additional step that requires processing not usually available in rural areas. Compared with AC, locally-produced biochars may contain substantial proportions of incompletely carbonized tars and oily compounds (especially if the biochar is produced at a temperature below ~ 600 °C). Local biochars may also contain a high proportion of ash depending on the feedstock (such as rice hulls). Since the local biochars are not "activated" and may contain higher proportions of ash or residual tars and oils, they may not have the same water filtration capacity as commercial ACs, and so the water filtration design will use a greater amount of biochar as compensation."[9]

Market Landscape

Needs/ Pains/ Regulations:

"Implementation of the EPA's new mercury removal standards will be the single most important factor impacting activated carbon demand through 2017." [2] The implementation of Mercury and Air Toxics Standards (MATS) and National Primary Drinking Water Regulations issued by the US Environmental Protection Agency (EPA), and several other regional regulations for air and water purification are expected to drive the activated carbon market over the forecast period (2017). [1]

Market Trends

General Concerns/ Trends:

Trade tariffs, regulatory uncertainties, mergers and acquisitions, and raw material shortages are the major concerns in the current market scenario. Rapid developments in the field of reactivated carbon market are expected to open new growth window for manufacturers as well as end-users. The use of reactivated carbon by industrial facilities and municipalities reduces their carbon footprints and saves money."[1]

Activated carbon markets are entering a period of fast growth. The next four years could see world consumption almost double. Enough new production capacity should be in place by 2017 to meet new demand, but the potential exists for a shortage. Raw materials availability is a concern. [12]

Anticipated Future Demands / Regulatory Context:
"US demand for activated carbon will rise 11.2 percent per year to 1.3 billion pounds in 2017 (today's market being 758 million pounds, driven by the EPA's new mercury removal standards. Implementation of the **US Environmental Protection Agency's Mercury and Air Toxics Standards (MATS**) will drive most of the growth, as utilities and industrial manufacturers upgrade their coal-fired power plants to comply with the regulations. Compliance with the **EPA's Stage 2 Disinfectants and Disinfection Byproducts (DBP) Rules**, which will be fully implemented by 2015, will lead to healthy gains in water treatment applications as well. Additionally, rising motor vehicle production, increased pharmaceutical output, and improving economic conditions will drive strong growth in several smaller applications. Overall, Industrial air purification will be the fastest growing application, surpassing water treatment as the largest use by volume. [6, 11]

- New EPA mandates to be main driver of demand
- Implementation of the EPA's new mercury removal standards will be the single most important factor impacting activated carbon demand through 2017.

EPA – MAPS/DBP: Powdered vs. Granular Markets:
"Mercury-emitting industrial facilities such as coal-fired power plants, cement kilns, solid waste incinerators, and other plants with large industrial boilers will predominantly turn to activated carbon injection (ACI) systems to meet these requirements. With an ACI system in a large industrial facility consuming up to two million pounds of powdered activated carbon annually, the phase-in of these new rules is expected to have a powerful impact on activated carbon demand, and powdered products will expand their market share to 70 percent of total US demand in 2017. As powdered activated carbon is generally not reactivated, sales of powdered activated carbon are expected to remain high even beyond the phase-in deadline for the mercury removal standards."[11]

"Compliance with EPA regulations will also boost activated carbon demand in water treatment applications. Demand will increase by over 50 million pounds through 2017 as the EPA's DBP Rules go into full effect. While some compliance with the DBP Rules had been achieved by 2012, the final phase-in of the Rules will continue to promote growth. The majority of activated carbon used to address DBPs will be granular activated carbon, making water treatment applications the best growth opportunity for suppliers of granular products, both virgin and reactivated." [11]

"The major reason for projected activated carbon market growth in the next five years is the new market for mercury removal from flue gas at coal-fired power plants that could require 500 to 800 million pounds of powdered activated carbon annually by 2016. The US EPA's Final Rule passed in November 2011 and coal-fired power plants have three to four years to comply with the requirement of 91-percent mercury removal efficiency. Some pending litigation that questions the validity of the mercury-removal rule and timing until implementation, and the Cross State Pollution Control Act, could reduce the amount of activated carbon required by 20 percent; however, the market seems poised to add large growth on activated carbon demand. There is also a projected 70 to 90 million pounds per year of activated carbon needed to help potable water plants in the US meet US EPA's Disinfection By Product Rule commencing in January 2013. Another reason for increased activated carbon demand is the growing Chinese economy, which will have its own large demand for activated carbon products as it increases its industrial and commercial base and continues to be a major world exporter of manufactured products." [8]

Another Report States:
"Activated carbon injection systems are the dominant mercury control technology used by coal-fired power plants in 2014. The EPA Mercury and Air Toxics Standard and the cement and industrial boiler mercury control standards that will accompany it are together expected to increase the North American market for powdered activated carbon by approximately 300,000tpy before 2017. The standard coincides with the US EPA Disinfection By-Products (DBP) Rule, which is expected to increase the US market for granular activated carbon in water treatment by at least an additional 35,000tpy by 2017."[7]

Other Anticipated Market Demands
"Among the smaller uses for activated carbon, motor vehicle applications, including emissions canisters and cabin air filters, will benefit from rebounding US motor vehicle production. Increased pharmaceutical output will promote demand for activated carbon in pharmaceutical and medical applications. Mining applications will also register gains, as increased processing will be necessary to maximize mine output. An improving economy will promote demand for activated carbon in chemical purification and other industrial processes. Many of these smaller applications use higher value specialty products, such as activated carbon fiber or cloth and carbon monoliths, boosting demand in value terms despite accounting for a small share of overall volume demand. On the other hand, activated carbon use in food and beverage processing and solvent recovery will remain stable". [11]

Powered vs. Granulated Activated Carbon
"Apart from the activated carbon product to be selected, a key issue to address is the type of

technology to apply. Typically, powdered activated carbon is dosed into the process stream (gas or liquid) and, after a certain contact time, separated by filtration or settling. Some of the issues involved: required contact time, dosing system, single or multi-stage dosing, carbon separation, safety measures.

Granular Activated Carbon (GAC) is mostly used in fixed filter beds, or alternatively in (pseudo-) moving filter beds. Some of the issues involved: required contact time (alternatively: hydraulic space velocity), permanent or mobile filter vessels, filling and emptying facilities, safety measures. Further, a crucial consideration regarding GAC refers to possible regeneration, in situ or off site." [13,14]

Liquid Phase vs. Gas Phase End Usage:

Liquid-phase end uses were still by far the largest application for activated carbon in 2012, accounting for an estimated 80% of total consumption. Gas-phase uses accounted for 20% of the world market in 2012 and their share of the market will increase to 2017. Water treatment was by far the largest individual market for activated carbon in 2012 and is the largest liquid-phase end-use. [12]

Competing/ Existing Technologies

Supply and Demand:

In 2013, the capacity of activated carbon across the globe outnumbered 2 million tons/a, as opposed to the demand approximating 1.3 million tons/a, which was an indicative of severe overcapacity. Thus, a grim situation to integrate or eliminate capacities is expected to linger in the future. On a global basis, activated carbon capacity largely concentrates in a few of countries or regions including the U.S., Japan, Western Europe and China. In particular, the capacities in the United States, Japan and Western Europe are dominated by a small number of industrial players, such as America-based Calgon Carbon Corporation with activated carbon capacity over 75,000 tons/a, and Cabot Norit with the capacity of 60,000 tons/a. (see Others included Japan-based Osaka Gas Chemicals Co., Ltd. which was promoted to the world's third largest activated carbon producer through taking over Jacobi Carbons in October 2013. Also, Osaka Gas Chemicals has grown into the largest producer in cocoanut active charcoal market segment. [3]

Industry Participants:

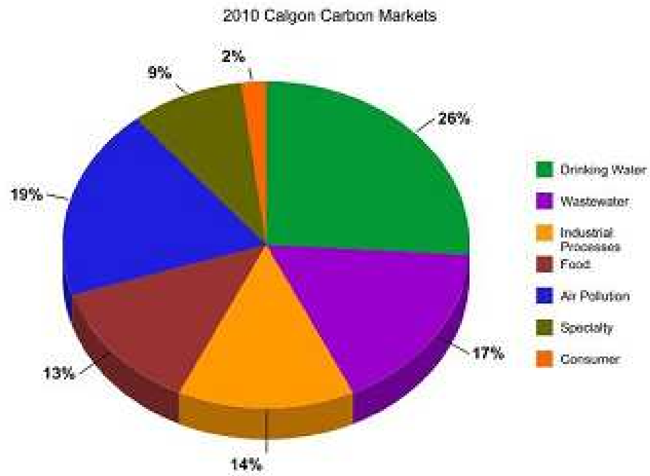
"The activated carbon market is highly concentrated and top three companies occupy about 68% of the total market for activated carbon by revenue. Calgon Carbon Corporation is the leading participant in the global activated carbon market and occupies a healthy market share. Carbon Resources LLC., Haycarb PLC, Jacobi Carbons AB, Meadwestvaco Corporation, Cabot Norit Activated Carbon., and Siemens Water Technologies Corp., are some of the other key participants in the market."[1]

AC Market Leaders [2]	%

CalgonCarbon	26.80
Cabot	24.10
MeadWestVaco	16.10
ADA CarbonSolutions	13.40
Other	19.60

Likely Division of Activated Carbon Market – Calogon Carbon Insight

"The Robinson environmental products and services firm said net income totaled $9.8 million, or 18 cents per share, comparable to results in the same quarter a year ago. Sales declined 3 percent to $131.6 million. Sales of activated carbon and related services, which accounted for about 90 percent of quarterly revenue, fell 1 percent." [4]



http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9ODc0MjV8Q2hpbGRJRD0tMXxUeXBlPTM=&t=1

Source:[15]

Market Economics/ Supply Chain Dynamics

The value chain of activated carbon includes raw material suppliers, production process, product supply channels, end-use industries and post sales service. [1]

Commercial Variants [16]

Activated carbon is usually made from charcoal, but can be produced from wood, peat or even coconut shells. There are over 150 grades of activated carbon, each with their own uses and applications. Commercially, there are three major product groups:

- Powdered activated carbon; particle size 1-150 µm
- Granular activated carbon, particle size 0.5-4 mm
- Extruded activated carbon, partilce size 0.8-4 mm

The pore size distribution is highly important for the practical application. Ideally, the carbon material used should have a pore structure that is larger in size than the material it is trying to adsorb. The best fit depends on the compounds of interest, the matrix (gas, liquid) and treatment conditions.

According to the International Union of Pure and Applied Chemistry, there are three distinct groups of pores:

- Macropores (> 50 nm diameter)
- Mesopores (2-50 nm diameter)
- Micropores (< 2 nm diameter)

Other Potential Applications/ Industries

Activated carbon as a kind of effective adsorbent finds wide application in water treatment, food & beverage, metallurgy, chemical, pharmaceutical and automotive industries.

[4] Automotive- Activated carbon plays an integral role in purifying the world's air quality and is used in several ways by automobile and automotive parts manufacturers. Activated carbon canisters reduce the hydrocarbon emissions from gasoline-powered automobiles and trucks. Also many cars now include air purification systems that utilize activated carbon in their cabin air filters.

[4] Beverages- Cabot Norit Activated Carbon products are used to improve the quality of beverages ranging from water to fruit juices to distilled liquor. Customers expect their beverages to look good, smell good and taste good. Beverage makers rely on activated carbon to remove bad tastes and odors and help ensure the long-term stability of their products. Trust Cabot carbons to make your products more appealing.

[4] Catalyst- Cabot Norit Activated Carbon products, whether standard or tailor-made, make the perfect catalyst carrier. In comparison with other carriers, like silica or alumina, Cabot carbons have a greater internal surface area. Other key attributes of our carbons for this use include their consistency, optimal pores structure, high density, high purity and exceptionally low attrition. Plus you can draw on Cabot's expertise to ensure you put exactly the right carbon to use for your process and expectations.

[4] Chemicals - Perhaps no one appreciates Cabot Norit Activated Carbon products more than our chemical industry customers. From achieving purity levels to meet exact standards to ensuring intermediary products do not add contaminants that impact downstream processes, they apply our

carbons in countless ways. They also utilize Cabot carbons in many forms, including from a fixed bed as a catalyst and via powder injection for contaminant removal.

[4] Flue Gas Treatment - Cabot Norit Activated Carbon engineers are experts in understanding the numerous variables that impact the ability of activated carbon to remove flue gas contaminants. We factor in facility parameters such as boiler type and combustion efficiency, fuel source, pollution control equipment configuration, and flue gas temperature when optimizing our customers' carbon, equipment and process packages. And we select the precise carbon needed to maximize the contact time between the activated carbon and the flue gas both to meet stringent requirements and ensure cost-effectiveness.

[4] OTHERS: GAS/AIR, MINNING, PHARMACEUTICAL, WATER

'55' Uses of BioChar [17]

1. Silage agent
2. Feed additive / supplement
3. Litter additive
4. Slurry treatment
5. Manure composting
6. Water treatment in fish farming
7. Carbon fertiliser
8. Compost
9. Substitute for peat in potting soil,
10. Plant protection
11. Compensatory fertiliser for trace elements
12. Insulation
13. Air decontamination
14. Decontamination of earth foundations
15. Humidity regulation
16. Protection against electromagnetic radiation ("electrosmog")
17. Soil additive for soil remediation [for use in particular on former mine-works, military bases and landfill sites.]
18. Soil substrates [highly adsorbing, plantable soil substrates for use in cleaning waste water; in particular urban waste water contaminated by heavy metals]
19. A barrier preventing pesticides getting into surface water [Sides of field and ponds can be equipped with 30-50 cm deep barriers made of biochar for filtering out pesticides.]
20. Treating pond and lake water [Biochar is good for adsorbing pesticides and fertilisers, as well as for improving water aeration.]
21. Biomass additive,
22. Biogas slurry treatment
23. Active carbon filter,
24. Pre-rinsing additive,
25. Soil substrate for organic plant beds,
26. Composting toilets,
27. Micro-filters,
28. Macro-filters in developing countries
29. Controlling emissions,
30. Room air filters
31. carbon fibres,
32. plastics
33. semiconductors,
34. batteries
35. metal reduction
36. soaps,
37. skin-cream,
38. therapeutic bath additives
39. food colorants,
40. industrial paints
41. pellets
42. substitute for lignite)

43. detoxification,
44. carrier for active pharmaceutical ingredients
45. Fabric additive for functional underwear,
46. Thermal insulation for functional clothing,
47. Deodorant for shoe soles
48. Filling for mattresses,
49. filling for pillows
50. Shield against electromagnetic radiation

Conclusions/ Considerations

Further Considerations:

Product and/or Service:

This relates to placement within the biochar supply chain. The profit margins in providing a service in addition to a combusted carbon product in bulk form will most likely be greater than solely doing the latter. It may also be that the bulk demand for biochar is not sufficient enough, yet private companies such as contech who design and manufacture filters and their systems will still be able to profit from their specialty designs and designer media mixes.

Energy & Biochar : Power Cogeneration:

Is biochar the logical choice in the conversion of biomass to a product? And if so, is biochar or energy the byproduct in the most logical (economic) system? In other words, is creating "char for char" a sustainable practice?

Should the supply chain include tailored char production, or rather solely the utilization of a waste char form (from local mills for example)? Cool Planet is currently operating under a $100 million grant to develop a carbon negative lifecycle characterized by the production of gasoline and biochar from non-food source biomasses, which could yield results relevant to this topic

Evidence:

More credible research and testing is needed to confirm the performance capabilities of biochar. The purpose of this is to not only convince researchers and consumers, but to generate a body of evidence upon which to base future government legislation and in turn give biochar the potential to for example penetrate the water filtration market.

Production:

What are the non-financial goals (i.e. sequestration of carbon, improve environment, rroduce clean energy, etc.)?

What is the effect of quality control on price (specifically in regards to the the potential need for consistency in feedstock and the effect on the supply chain and cost of the final product)?

What performance criteria will be sufficient in meeting the majority of bulk biochar markets? What specifications are sufficient with respect to permeability (for water flow rate), particle size (avoid residue), surface area, and so forth?

What will the price stability of biochar be (assuming potential variability in supply and demand)?

Consumer Opportunity Cost:
For the target consumer that buys biochar in a bulk form and has economical resources to produce it, will private small scale production opportunities pose a competitive force?

General Competition:
In case a company does try to produce biochar for commercial purposes, do they have a legitimate chance against established companies with access to high capital who are already knowledgeable and producing char?

Concluding Statements:
The market for biochars application in storm and waste water treatment in Oregon and Washington is very much dependent on each states respective legislation in regards to benchmarks for pollutant concentrations in discharge water, as well as each states legal environment for the acceptance of biochar as a substance to be used in BMP's and other filtration methods.

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