



Council of Western State Foresters Biochar Market Analysis – Final Report

December 31, 2018



*Top: Planting trees in biochar amended soil, Rogue-Siskiyou National Forest.
Bottom: Biochar produced on site and left for forest soil improvement at the
Drew Veg Stewardship Contract, Umpqua National Forest*

Executive Summary

Biochar is an emerging new industry that is dependent on consistent supplies of biomass feedstocks. Woody debris is an ideal biochar feedstock that can be used even in existing biomass boilers and furnaces to produce biochar. Most of the recent growth in biochar volume production is utilizing such technologies, and much of it is occurring in the Western states, where large volumes of biomass are in need of treatment to reduce wildfire risks. We interviewed 26 biochar industry leaders active in the Western states, to get a better understanding of the potential of the biochar industry and to learn what state governments could do to help address barriers.

Biochar markets have been slow to develop because of high prices and a lack of understanding or articulation of biochar benefits. However, fast growing markets are developing in several areas: green infrastructure for stormwater management in cities; soil water retention in turf, landscaping and urban tree plantings; biochar soil blends for horticulture; biochar seed coatings and root zone applications in field crops; remediation of mine tailings and brownfields; and replacements for activated carbon and carbon black in a variety of industrial uses. Future markets that could be developed with the help of beneficial government policies and investment include use of biochar in animal feed (requires lifting the current restrictions); use of biochar to manage many different kinds of organic waste streams and reduce GHG emissions of manure, compost, digestate and sludge; use of biochar in row crops for improving soil resilience to drought; use in tile drained fields to manage nutrient runoff; restoring natural ecosystems and forests; and for sequestering carbon in soils.

State foresters are well-placed to convene industry participants and help them develop local value chains around biochar as a component of waste management, environmental improvement, and fire risk reduction, while providing value to agriculture, bioenergy and industry. Biochar markets can help support rural economic development as capacity is built to create value out of under-utilized and problematic forest biomass. States have many tools to help advance the biochar industry, including policy support, regulatory support, research, economic development programs, partnerships with private and government entities, extension programs and networking. USBI has provided a detailed list of such actions that states could undertake in order to promote the biochar industry.

Introduction

The objectives of this project are to examine biochar production capacity and market demand for biochar in both current and future time frames (five-year projection). The geographic focus is on the Western United States, and the feedstocks of interest are different forms of woody waste, especially where conversion of woody waste to biochar addresses other resource concerns such as

wildfire mitigation and forest health. This report also addresses economic and regulatory incentives and barriers to biochar production and use. The ultimate purpose of the analysis is to provide the Council of Western State Foresters with a comprehensive picture of the potential of biochar development within the region over the next five years.

The main body of this report consists of summaries and analysis of interviews with 26 industry participants, categorized as producers, users or industry experts. The complete set of interviews is attached as an appendix. Following the summary of interviews is our discussion of the results and conclusions. The discussion draws on USBI resources including the expert opinions of USBI board members, preliminary data from an industry survey being conducted by Dovetail Partners with help from USBI,¹ and a biochar policy survey recently published by USBI board member Ghasideh Pourhashem.²

We also supply a directory of biochar industry entities that are active in the Western States Region that is derived from the USBI mailing list and lists of attendees to the USBI conferences in 2016 and 2018.

Contents

1. Industry-wide Survey from Dovetail Partners and USBI
2. Methods
3. Interview Summaries
 - 3.1. What are the top current markets for biochar?
 - 3.2. What are the most promising future markets or markets in development?
 - 3.3. What are the biggest barriers to biochar markets?
 - 3.4. What are the top biochar research needs?
 - 3.5. What are you doing to develop biochar markets?
 - 3.6. What could the public sector be doing to develop biochar markets?
 - 3.7. How could a biochar industry association help develop biochar markets?
4. Summary Discussion
 - 4.1. Biochar Applications
 - 4.2. Biochar Production
 - 4.3. Overcoming Barriers
 - 4.4. Available Policy Opportunities
 - 4.5. Potential Policy Opportunities
5. Recommendations for Action
6. Conclusions
7. References
8. Appendix – Table – US policy programs relevant to biochar production and application
9. Appendix – Survey and Analysis of the US Biochar Industry, Dovetail Partners, Inc., November 2018
10. Appendix – Full text of all interviews
11. Appendix – Western States Biochar Industry Database

1. Industry-wide Survey by Dovetail Partners and USBI

To meet the objectives of this report given the time and resource constraints, USBI determined that the best value would be to conduct individual interviews with industry leaders, as a complementary activity to an ongoing industry-wide survey that is in progress under the leadership of Dovetail Partners (<http://www.dovetailinc.org/>) with assistance from USBI. To give some context to the interviews and to round out the picture of production volumes and market volumes, we attach the interim results from that survey as an appendix to this report. The final report, Survey and Analysis of the US Biochar Industry, will be available from Dovetail Partners, Inc. in March, 2019.

2. Methods

Using the USBI database of subscribers and attendees from the 2016 and 2018 USBI conferences, we selected about 30 individuals representing different industry segments to contact for interviews. All of the interviewees are active in the biochar industry in the Western States region. We attempted to balance the interviews between producers, users and experts, and also between small and large producers. Of those contacted, 26 were interviewed. Below is text from the email request that we sent, showing how the interview request was portrayed to the participants:

USBI has been contracted to do an analysis of biochar markets and production capacity by the Council of Western State Foresters. We are to interview biochar researchers, industry experts, producers and users in 17 western states and territories to gain information about current and projected biochar markets and production capacity. The purpose of the study is to provide information to forestry departments to help them assess the potential of biochar as a wood utilization industry.

Interviews lasted between 30 minutes and one hour and consisted of open-ended responses to seven questions. We informed participants that they would have a chance to review their interview text and make corrections if needed. All interviews were conducted by USBI board member Kelpie Wilson between August 2018 and December 2018. The interviews were not recorded on audio, but extensive notes were taken and the text was subsequently drafted based on the notes. The finished text was sent to each interviewee, and they were asked to submit any corrections. Most interviewees either submitted corrections or acknowledged that the interview text could stand as is. A few people did not respond. In those cases, we took a lack of response as tacit approval of the interview text for publication.

Analysis, discussion and conclusions were drafted by principle investigator, Kelpie Wilson, with input and review from other USBI board members. Opinions expressed by interviewees are not necessarily shared by all USBI board members.

3. Interview Summaries

We asked seven open-ended questions of each interviewee:

1. What are the top current markets for biochar?
2. What are the most promising future markets or markets in development?
3. What are the biggest barriers to biochar markets?
4. What are the top biochar research needs?
5. What are you doing to develop biochar markets?
6. What could the public sector be doing to develop biochar markets?
7. How could a biochar industry association help develop biochar markets?

Table 1. lists all of the respondents who were interviewed. Complete contact info is found in the attached biochar directory.

Organization	Initials	first	last	Interview Category	State
California Biochar Association/Sonoma Biochar Initiative	RB	Raymond	Baltar	expert	CA
Regenis	CF	Craig	Frear	expert	CA
Milt McGiffen	MMG	Milt	McGiffen	expert	CA
Guam Department of Agriculture	JM	Joseph	Mafnas	expert	Guam
USDA Forest Service	DPD	Deborah	Page-Dumroese	expert	ID
USDA Forest Service	JA	James	Archuleta	expert	OR
Oregon Department of Forestry	MrK	Marcus	Kaufmann	expert	OR
Utah State University Forestry Extension	DMA	Darren	McAvoy	expert	UT
Washington State Department of Ecology	MF	Mark	Fuchs	expert	WA
Northern Arizona University	HSH	Han Sup	Han	producer	AZ
Pacific Biochar Benefit Corporation	JoH	Josiah	Hunt	producer	CA
Biochar Now	JG	James	Gaspard	producer	CO
Biochar Solutions	JL	Jonah	Levine	producer	CO
OrganiLock	SL	Scott	Laskowski	producer	KY
TerraChar	PB	Phil	Blom	producer	MO
ROI	MOC	Matthew	O'Connor	producer	NH

Industry Experts – Top Current Markets

Industry experts saw top current markets for biochar in the new cannabis industry and soil blends for the retail market, as well as storm water filtration, green infrastructure infiltration basins, landscaping, horticulture, compost, and waste management, especially for use in composting manures and digestate. Some land managers are using biochar made in the field for onsite remediation, and there is a growing interest in using mobile kilns onsite to process woody debris generated through forest health treatments or fire suppression activities. This activity is driven as much by the need to treat waste as by biochar markets or end uses. Overall, there was the sense that demand for biochar is still very low, and there is a long way to go.

"Biochar as a component for custom soil blends for high-end horticulture. Cannabis is the current growth market. Not sure how long it will expand." MrK

"Monterey Pacific Vineyard Management Company is participating in one of Sonoma Ecology Center's field trial sites for a Cal. Department of Water Resources grant project measuring biochar's ability to save water in one of their Pinot Noir vineyards. We have also heard of great results with biochar use on farms growing citrus, avocados, strawberries, and blueberries." RB

"Current markets that are developing now are the high end horticultural markets such as fruits, nuts and berries. We have good research showing the benefits of biochar to these crops." JA

"I don't see a big market for biochar in the general agriculture sector, rather, biochar markets are in more targeted applications. I see developing markets in the use of biochar for odor control in compost, wastewater filtration to sorb metals and organics, and for scrubbing H₂S from biogas in anaerobic digesters. Biochar is very useful in compost in general, for odor control, and also for removing chlopyralid and other pesticides that end up in compost. There is good data showing how small amounts of biochar in compost can bring down the levels of pesticide residue. Biochar can also help with composting biosolids. Biosolids are not a stable, pathogen-free product like thermophilic compost. They need further composting and biochar could be helpful." CF

"There are no really big markets for biochar yet. Current production capacity exceeds demand. If demand were there, producers have plenty of capacity. I am seeing some big ag applications, but not much." MMG

"Currently there are no big markets in Utah. Some arboriculturists are using biochar in tree planting, mostly the non-profit groups that are trying to grow the urban forest. They have been getting their biochar from Amaron Energy. We have been using the simple, flame cap kilns (Oregon Kilns) in some grant-funded pilot projects. We treated 19 semi-truck loads of PJ (Pinyon-Juniper) last year with our 4 kilns. In this case, biochar is a side benefit of the waste disposal." DMA

“Interest in biochar is growing, especially among land managers. More and more people are looking at biochar as a way to capture value from all the unmerchantable slash piles out there that nobody wants to burn. I see this as a way to improve rural economic development. We can use some of the biochar in the forest to improve forest soils, and some of it can be sold to nearby farmers. But currently we lack the infrastructure to do this at scale.” DPD

Biochar Producers – Top Current Markets

Cannabis and soil blends top the list of biochar markets identified by biochar producers. Fruit, berry and vegetable crop growers are also purchasing biochar direct from producers. Other current markets include mine site and brownfields remediation, turf management, stormwater management and water filtration. One producer is developing a biochar system to treat leachate from tile-drained ag fields. One mobile biochar processor uses biochar produced onsite at a transfer station with a composting operation at the transfer station. One company is selling biochar mixed with organic fertilizers as a seed coating for grain crops. Some companies sell both biochar products and biochar conversion machinery, so markets reflect both sales of biochar product and sales of biochar technology. Some producers sell only raw biochar in bulk, while others create soil blends or other value added products. One of the larger biochar companies (Biochar Now) claims to be on the verge of very big contracts for use of biochar in asphalt. Production volume could become limiting in this case.

“Our top markets currently are with growers of vineyards, vegetables, and cannabis. In general, they are farms which grow crops that are high in value and/or are long term in returns.” JoH

“The top markets we sell into currently are hemp, cannabis, soil blenders, stormwater filtration media, and nurseries as a peat replacement. We are selling a lot to tree seedling nurseries. Green Diamond Resources is the third largest private landowner in the US, and they were very impressed when they found that 25% biochar added to the media improved growth of redwood seedlings. We have sold our biochar to Canada for the cattle feed study at University of Lethbridge. We are selling to a soil remediation project on the East Coast. A recycling center in Portland, Oregon is using our biochar in a large filter vessel for e-coli capture from effluent. We have also sold biochar for use in golf course soils.” GrS

“Our biochar is being used by DuPont for environmental remediation of superfund sites in Delaware. Because of the connection with DuPont, we are getting carried over into many other projects around the country working with large corporations on brownfields remediation. We are developing 13 major markets right now. The most cost-effective markets are those that replace other products. We have been working with large companies developing products. These companies put a lot of research into this. They take years to test the materials in their applications. Many of them are ready

to start, but we don't have the volume yet. For instance, we worked with the asphalt industry to test our products in their labs. We have several hundred million dollars worth of biochar sales in the pipeline , at our price of \$2,000 - \$6,000 at ton.” JG

“Most of our markets are in agriculture. Our background is in agriculture, so we know farmers. We sell to farmers in the Midwest, California and elsewhere. We sell to the turf and landscaping markets and to gardeners. Selling to farmers is a challenge because their margins are so small and getting worse. We make a seed-coating blend of biochar powder, humic acid, minerals and microbials, that greatly improves germination. It costs about \$3.00 an acre to mix with a bag of seed. It is affordable and farmers see results, so this is a good way to get them started seeing the benefits of biochar.” PB

“Reliable markets for char have been hard to find, so we are making our own by creating a value-added soil product. It is hard to educate people about biochar because it is not easy to use on its own. It works much better if we pre-charge the biochar by adding nutrients. We then add that nutrient charged biochar at 10% by volume to a soil blend and sell that. We won't have any trouble selling that product. We are selling to the hemp, cannabis and other high end horticulture markets, including urban gardeners.” SL

“Our first target markets will be the local retail outlets we already sell into. Our small diameter sawmill already sells bundled firewood to Fred Meyers, Safeway, Kroger, and Walmart. These outlets are interested in carrying a bagged soil blend that includes biochar. The same procurement departments that buy our firewood are responsible for bagged soil amendments, so the connection is already there.” MtK

“Purchasers of our machines so far have been mostly green waste and c&d (construction and demolition debris) collection sites or transfer stations. They are using our machines to make biochar from woody debris to then use in applications such as an additive to composting operations, keeping all of that material out of landfills. Other customers include large construction and clearing companies, agriculture and forestry-logging companies.” MOC

“We are making soil blends using manure from a feedlot. We are also working with the state of South Dakota to make de-watering filters for construction sites and road-work sites to clean up the water that drains off of them. We are working on systems to use biochar in tile-drained ground that will capture nutrients and then we can take that biochar and spread it back out on the field. We are also making seed bombs - mixing biochar and other ingredients to coat seeds. Then you drop the seed bombs from an airplane to revegetate burned areas or other bare ground. The hemp biochar is perfect for this application because it is so fine.” MB

Biochar Users – Top Current Markets

The biochar users we interviewed are mostly soil blenders or compost operators, with one consultant who uses biochar in stormwater management. They provided some interesting detail on how they use biochar. Some composting users value the improvements that biochar makes to the composting process, and they are able to sell the biochar compost at a premium price. Others question the economics of biochar use in compost given that the economic model for composting depends on tipping fees; spending money on inputs is unusual. One composting operation is exploring the idea of acquiring a biochar conversion facility to make their own biochar from waste wood they get tipping fees to process.

“We also use biochar in some of our compost. We need to keep it at about 5-7% by volume or it will raise the pH too much. But that is a good level and when we compare the amount of beneficial bacteria and fungi in compost with biochar, it is much higher than standard compost. But it is hard to get people to pay for that biology. The biochar compost we make amounts to less than 1% of our sales. That's not much, but we see it growing. We really believe in it, and if you don't take the trouble to make a product available, you will never have a market.” JaH

“We make 1500 yards of our Green Frontier (Super) compost per year. That works out to five finished batches of 300 yds each. Each batch gets 48 yds of biochar on the front end of the process. Our Green Frontier compost gets Azomite (ancient sea minerals) and rhyolite (granite dust) also. We find that the biochar reduces odors and helps keep the moisture level high throughout the process.” SS

“Activated carbon is four times more expensive than the biochar we use. Biochar quality is important to us. We cannot use material that has too many fines because we need a high flow rate and the material can't pack too densely. We pay a bit more for a granular biochar and we still have to screen out fines because softwood biochar is very friable and some of it becomes powderized in transport. But in terms of quantity, the use of biochar for water filtration is not a huge market. Green Infrastructure is the bigger market. States on the West Coast, Chesapeake Bay and elsewhere are struggling to meet the clean water directives they are under. More and more cities are requiring the use of bioswales and infiltration basins. Cities invest a lot in this green infrastructure, and it is often very costly to maintain because the plants keep dying. They use sand for drainage, but the plants die. Biochar keeps the plants alive because it holds water and nutrients in the root zone.” MG

“Compost is not a high value market and compost producers have low profit margins. Some composters in California have experimented with biochar, but I don't know of anyone who uses it regularly now. Composting follows the 60-40 rule: Sixty percent of income comes from tipping fees and forty percent from product sales. Compost producers need to get materials for free and they won't pay for inputs. However, there are some materials that are more contaminated and take more work to clean up. Only biosolids processors will pay for ingredients to help clean up the end product. They might potentially pay for biochar.” DN

"We use biochar in one of our products - a liquid seafood waste fertilizer with micronized biochar. The biochar comes from the Karr Group and it is made from sawdust. We basically make a 1500 gallon smoothie with seafood waste and biochar in a big blender. The product goes through drip irrigation systems. We screen it through a 150 mesh screen. What's left over still has a lot of biochar and nutrients and we are developing a pelleted product from that. We are processing 10 million pounds of seafood waste a year and produce about one million gallons of product." MM

"We have added biochar to some of our retail garden products. Initially we had two products with biochar, a potting mix and a soil blend, that we test marketed at a Big Box store. Unfortunately, we were only in 50 stores. Those stores were low performing stores, and we have a premium brand, so it was not really a good test. Those products are now gone. We still have biochar in two products in our Gardner & Bloome line that we sell to independent retailers. We have had some success with those." GiS

3.2. What are the most promising future markets or markets in development?

acre agriculture air ammonia animal applied area barns benefits biomass
burned capacity carbon city compost conservation cost
dairy design digester dry effective emissions equipment expanding expensive
farm farmers farmland feed filtration fire food forest furnaces future generate green
growth health heat holding improve increase infiltration invasive kilns land machines
manufacture manure market mill mixed native nitrogen nutrient odor
organic pain plants price quality rangeland reduce regulations requires resource restore
site soil solids solve streams supply transportation volume waste
water wood

Industry Experts – Top Future Markets

Industry experts saw potential future markets in control of compost GHG emissions and odors, and H₂S sorption in wastewater treatment. They identified stormwater and green infrastructure as high potential growth markets. Biochar use in animal bedding has potential, as well as its use for sorbing phosphorus from dairy flush water. They also saw a lot of potential for using biochar to increase soil carbon and mitigate soil acidity in broadscale agriculture, and they were hopeful that the ability of biochar to retain soil moisture would also be valued in agriculture. Water use considerations should also lead to biochar market growth in landscaping and turf, especially in drought-critical areas. Experts were interested in promoting

technologies to farmers and foresters that would help them carbonize waste materials in place for use in fields and forest soils. Land managers thought that biochar could help restore native ecosystems, revegetate mine tailings and help with burned area recovery. Another idea was to use biochar to increase the real estate value of degraded land. Experts saw great potential in future carbon markets that may include biochar. They hoped that carbon market payments would allow producers to lower the price of biochar and make it more affordable for end users.

“Carbon markets are the big one - once those are in place it will provide a baseline price to support other uses and build economy of scale for producers.” MrK

“Biggest potential market is dry eastside ag lands. Acidified soils and drought are the problems that biochar can solve, and it cannot solve these problems with small or light applications. It takes a lot of biochar to fix these soils. This is good because we need to add a lot of biochar to soils as a climate mitigation strategy. Water is also a critical need and is becoming our biggest resource constraint. Biochar helps water conservation, by improving infiltrating precipitation in the non-irrigated dryland production areas, and conserving irrigation in the droughty irrigated soils of the central basin. Biochar for odor control and process improvement in managing organic waste streams of all kinds, e.g., potato processing water or other vegetable process waste waters; compost; food waste and food processing waste; dairies and animal manure. Also lots of potential for teaching orchardists to carbonize prunings and dead trees for biochar to use in their soil. And lots of potential to incorporate biochar in Firewise Community projects - we need extension staff to teach landowners how to turn slash piles to biochar using techniques that generate less smoke and are safer than open burning.” MF

“A potential growth area is for manufacturers of small kilns to make biochar onsite for waste disposal in onsite uses such as forestry. This has promise because transportation of forest waste is expensive and transportation of biochar is expensive.” MMG

“That is how we have to look at scaling biochar use—looking for farming problems or pain points in industry where biochar can help offer a solution. For example, some farmers have challenges such as sandy soil that won’t hold nutrients or water, and adding biochar can help address these issues. Or, in areas of California where water is excessively expensive, enabling farmers in those areas to reduce water use by blending biochar into their soils can reduce their costs. A farmer with rich soil and cheap water probably would not see the financial proposition in purchasing biochar, other than as a long-term hedge against climate change or as a way to earn a few bucks in future carbon markets. Where water costs \$600-700 an acre-foot, biochar can help. This also goes for landscaping, like median strips and roadsides where CalTrans is requiring more carbon in soils to hold water. Air burners and other portable units address another pain point: forest fires and air quality. If these become widespread to process dead trees and forest fuels, we may have a glut of biochar that would bring the price down. At \$25 a cubic yard, it would be much easier to sell it to farmers.” RB

“Another potential future market for biochar will develop as more compost emissions are more regulated to control GHG emissions like methane and VOCs like ammonia. California is starting to do this. We have many studies that show biochar is effective in controlling compost emissions.” CF

“Forest soils need carbon, especially cut-over forests. Most logged forestland soils have lost about 25% of their carbon. We know that charcoal is a natural component of these soils, and after decades of fire suppression, we are missing charcoal. I think you could easily add ten tons of biochar per acre of forestland, and you'd just be scratching the surface. Adding biochar gives you a lot of benefits: Improved water holding capacity, more microbes and mycorrhizal fungi, resistance to insects and disease, healthier forests.” DPD

“Our goal is to restore forest land on Guam, but this is very difficult. The soils are very bad after many years of agriculture and we have many invasive species. We would like to use biochar as a soil amendment for our re-forestation work.” JM

“Mineland reclamation is another use for biochar. In Colorado and in Oregon we are using woodchips, biochar and biosolids to re-create the O-horizon on mine tailings. We find that this combination works even on dredge mine tailings that have no fines at all, just cobbles. We are able to initiate soil genesis and grow grasses and forbs. Long term, I see biochar being used to improve farmland real estate. It's an investment and with the right application rate, you can change the real estate value of an acre of farmland. It could be a business like fixing up and flipping houses.” JA

Biochar Producers – Top Future Markets

Biochar producers are actively pursuing many different kinds of biochar applications. Positioning biochar as a cheaper substitute for activated carbon applications is one strategy. Producers working with agriculture markets saw their best approach was to sell biochar to farmers for targeted uses for conservation of nutrients and water. They also looked to increasing concern with controlling nutrient pollution as a driver of biochar markets in manure management, composting and storm water management. The use of biochar in animal feed was seen as a huge potential market that is waiting to be developed as soon as it can be permitted. Some producers felt that the need to process forest fuel biomass with low emissions would drive their business as much as the biochar product they can make. Others anticipate that the demand for biomass energy would result in more opportunities to make biochar co-products. Some felt that large markets would only develop when technology problems are solved and production costs come down, lowering the price of biochar to what consumers will pay.

“We want to be competitive with existing products. Biochar can perform better than perlite as a direct substitute in soil blends. We want to be competitive with activated carbon for many different applications. AC is mostly imported and has a high carbon footprint. Also, carbon black replacement for industrial uses in tires, plastics, pigment.

Wageningen University in the Netherlands is working with our char to see if it can work as a peat substitute. They found that 25% worked well and now they want to go up to 50%.” GrS

“Biochar and compost applied together can be more effective than either one applied alone, and biochar applied to raw compost can benefit the composting process. Biochar can be a useful manure management tool, and when the regulations will permit, a feed supplement for animals as well. Compost/manure management and their application is an area where biochar will be used a lot more. And this fits very well with increasing concern for managing and increasing soil organic matter content for plant growth benefits and climate change mitigation.” JoH

“In five years, we will have ten production sites, producing enough volume for 300 to 400 million dollars in sales. Each site can have up to 800 kilns operating, and still meet our emissions targets. Usually, we won't have that many. Most sites will have about 100 kilns. We need economies of scale to be able to afford the Crambo, the shredder that produces the specific size of large wood chunk that we use.” JG

“I don't see a lot of [pure] biochar being added directly to soil. In the future, most biochar will get into soil through one of two ways: after passing through an animal as a feed supplement; or as a mix in a compound fertilizer mixed with other organic ingredients as odor control. There are high nutrient waste streams like brewery waste that need odor control and can make very good organic fertilizer when mixed with biochar.” JL

“We think that using biochar in livestock barns and CAFOs is a huge potential application with many benefits. We are working with both poultry and cattle operations to develop methods. The thing about using biochar to manage manure, is that you start getting benefits immediately in odor reduction and animal health. You eliminate emissions of ammonia, which not only harms animal health, but causes smog and air pollution harming human health. Then you get the benefit of improving the manure because the biochar captures ammonia and keeps it during the composting process which turns it into organic nitrogen with amino acids and proteins. But this takes time, so you have to add the biochar in the barn. If you add it after cleaning the barn, it will not do much because the ammonia has already been lost.” PB

“With more biochar, we can look at more markets. We have 45,000 acres of irrigated farmland in our county, and our initial goal is to treat 15,000 acres with biochar. At 20 tons of biochar per acre, that is a potential market volume of 300,000 tons of biochar.” MtK

“An example of how we can benefit an operation is Knott Brothers Farm in Kentucky. They have 33 poultry barns and several thousand acres under cultivation. They have multiple waste streams that we can integrate, using our furnaces to make biochar and heat. Farms can be more self-sufficient and turn waste into another income stream.” SL

"Now and in the future, the problem of excess fuels is a more important driver of the biochar industry than markets. This is a huge and urgent waste management problem. Once we have developed biochar production capacity at volume, I think that in the future there will be very high demand for biochar. We have shown that biomass supply is not a constraint for biochar production; in fact we have an almost limitless supply of biomass for this and other uses. If we can solve the biochar production technology challenges, this will be a very big market." HSH

"We also see our equipment being used as a new tool for forest fire prevention and disaster clean-up. Whether it's post fire in the Western USA or post-hurricane in the East, our equipment can convert what's often considered a costly waste stream into a valuable end-product that can be applied to the surrounding soils or sent off to market. Our equipment is mobile-tracked and can drive into remote terrain to treat logging, thinning and post-fire cleanup operations." MOC

"We see ourselves expanding up to 10 machines in five years' time. We are working on a second machine now that is three times bigger than our first one. We will have our next 2 machines complete within a month. I could see one of our plants set up every 200 miles or so, wherever there is a supply of biomass from city green waste or forest waste and a need for heating buildings or process heat for manufacturing." MB

Biochar Users – Top Future Markets

Biochar users cited the increasingly stringent requirements for stormwater treatment as a powerful driver for possible future markets. They also saw growth in the use of biochar in compost, but only if the economics work for them so that benefits balance the cost. Soil blends with biochar are a steady market where they see constant growth. One user recommended that the forest products industry should develop biochar production as a way to add value to their waste. Using biochar for manure management is also a promising way to add value to both waste streams, especially as an alternative to expensive anaerobic digesters.

"The price we pay now for biochar is about \$.25 a pound. That would not stop us from expanding if we had the markets for the product, but we would like to get it cheaper. The problem with expanding the biochar market for us is really the problem of expanding the compost market. About half our revenues are from tipping fees and the other half is from sales. We just got a new de-bagger so we can handle a lot more food waste now. We have the potential to double our compost production. We either need to find new markets, or we need to lower the price so we can sell more." SS

"The stormwater management market is growing. The City of Eugene now requires a water infiltration basin to be located on every property in the city, including residential lots. The Oregon Department of Environmental Quality is pushing the regulations strongly and people are finally starting to see that the combination of soil

health, water infiltration and biology really works. It allows an urban area to manage storm water within its own footprint without needing conveyance. That can save a lot of money. We find that for stormwater management, compost is really good and can take you part of the way there, but that biochar enhances the compost with synergistic effects.” JaH

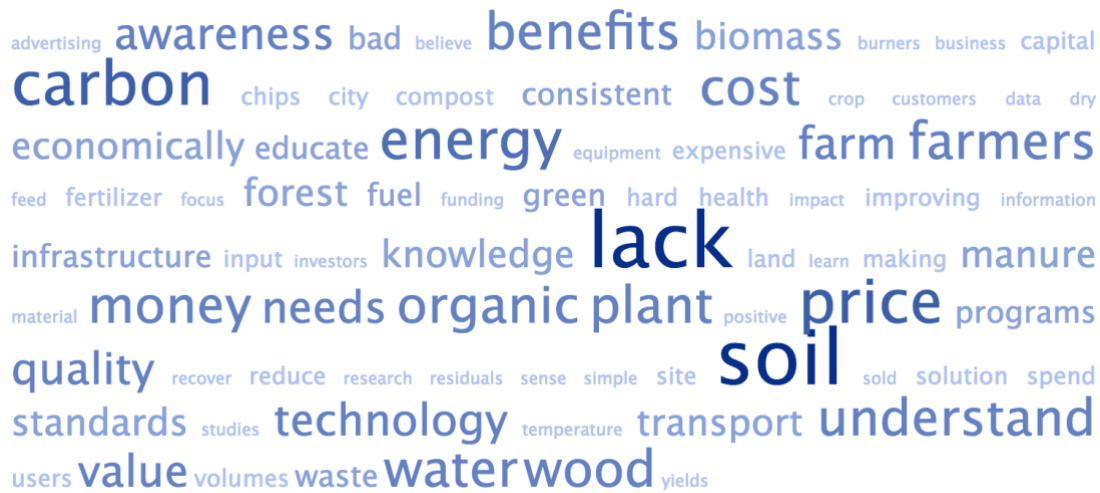
“Green infrastructure is a huge and growing market for biochar. The City of Portland is the leader, with more than 10,000 green street facilities. These are curb bump-outs with infiltration basins and plants. Each bump-out is about four feet wide and 20 feet long, filled with media down to two feet, using 160 cubic feet of media. We apply about a half of a cubic yard of biochar to each one of these. Green infrastructure is a perfect application for biochar that really utilizes its strengths. Biochar is most effective in sandy soils and in the root zone of plants which is right where we use it. Biochar increases water holding capacity, improves plant health and growth, supports microbes and mycorrhizal fungi, filters pollutants and reduces compaction.” MG

“The wood industry needs to approach this like we did in the dairy industry. We had a waste problem and were getting pressure to solve it. We solved it by creating a product out of washed dairy solids that we are now marketing successfully as a peat substitute. We think biochar and our NuFiber are a better solution to dairy waste than anaerobic digesters. Digesters are not a complete solution because the fiber still needs to be processed to remove pathogens. The economic model for digesters does not work because they can't sell the fiber and the power prices for electricity don't cover the cost of the digester. Dairymen don't need to have the added responsibility of a complicated anaerobic digester. They need to focus on their cows and keeping them healthy and productive.” DMG

“In the future, I hope that we will have more emphasis on the post fossil-fuel integrated, sustainable bioeconomy. When that is valued, then there may be real markets for biochar, mostly based on its ability to manage water.” DN

“It's hard to say where we will be in five years with biochar. A lot will depend on the price of biochar.” GiS

3.3. What are the biggest barriers to biochar markets?



Industry Experts - Barriers

Industry experts saw the high price of biochar as a big barrier to market development, but they also identified structural barriers such as lack of capital for producers, an immature carbon market, short timelines for mine land remediation bonds that don't allow realization of biochar long term benefits, and a federal crop insurance program that does not recognize the ability of biochar to protect soils from drought. The inability to monetize ecosystem benefits is a barrier. Lack of options for efficient, low emissions biochar production technology is still a barrier, especially for remote or mobile production, as is the challenge of feedstock transportation and getting woody residues to centralized facilities in a consistent and economical manner. Immaturity of biochar product standards is a barrier, as is a lack of awareness, knowledge, and information about biochar performance in specific applications.

"Piecemeal approach to enterprise development. We need a large size pilot project like those found in biomass energy and torrefaction. Need outreach and extension programs." MrK

"At current prices, biochar is too expensive for large scale use on farms. No farmer will pay for the amounts that are truly needed to address soil acidification and drought. Banks will not fund farmer operating loans for biochar because we do not have enough research. Another opportunity is the federal crop insurance program. Biochar should help to assure a productive crop against drought, aluminum toxicity, and perhaps some blight such as wheat rust and potato blight. However, the data to help the federal insurance programs isn't there yet." MF

“Biochar is a long-term solution, but the mining industry has only 3 years to recover their bonds, so their mitigation does not have to last longer than that. Short-term thinking kept us from doing more with biochar. We have talked with BLM about adding biochar to their BMPs as the solution.” DMA

“Biochar is too costly. Producers overvalue it and try to sell at too high a price. They need to just move volumes of it to build the industry. The more you can get it into products from big manufacturers like Scotts and Kelloggs, the more quickly the industry can grow.” CF

“Our main barrier is lack of knowledge. We don't know what kind of technology we need. We also have environmental concerns about smoke, so we need to find clean technology.” JM

“Another barrier is the lack of methods for measuring biochar value. How do you put a dollar value on improved site productivity or water holding capacity or ecosystem services, in general? There are also transportation barriers. Making biochar in centralized bioenergy plants is a good idea, but we have challenges getting a consistent flow of material to these plants.” DPD

Biochar Producers - Barriers

Biochar producers see the biggest barrier to their expansion is the lack of high volume markets. Lack of awareness is part of the problem, but there were also early instances of biochar being oversold, or hyped, that left a bad impression and lasting trust issue that must now be overcome. Lack of capital and high costs of production were also a barrier. Structural and regulatory barriers include lagging carbon markets and no monetary valuation of positive externalities such as nutrient management. The prohibition of biochar use in animal feed has hindered one of the most promising high-volume markets. Low energy prices are hurting the biomass energy industry, which also hurts biochar production as a co-product of energy. Transport cost of biochar as a low bulk density material is also a barrier, as is product consistency when biochar is made at remote sites. A lack of clear standards for distinguishing biochar materials is a cause for confusion in the industry as buyers may not understand what they are getting.

“Lack of high volume markets is our biggest barrier. We can produce, and the biochar industry can produce to meet the need, but markets have to come first. One of the biggest barriers is the classification of what is biochar. We need standards to distinguish between different chars. Wood vs manure - we need a better way for the end user to understand what they are buying. That will cause problems down the road if users have to deal with too much confusion.” GrS

"Another barrier is finance. We need investment to build our business and pay for things like retail bags and marketing materials. We are having success in finding investors and hope to have what we need very soon." SL

"Financing is also an issue. Banks don't understand what we are doing at all. Investors don't want to come in until you have already done all the work. We need capital and we work with the Southern Hills Economic Board, but they don't have any money." MB

"Removing the prohibition of biochar in animal feed should be a top industry priority. Low energy prices are a big barrier to the biomass energy industry. If we could fully utilize available waste biomass in energy facilities, we have the technology today to recover 15% of that biomass (estimated at a billion tons in the US) as biochar while recovering energy. That could have a huge impact." JL

"Education is the biggest barrier. I spend a lot of time educating customers, and I don't have any back up. We are the only industry that is out there on our own, without extension services to help us. So we try to focus first on the bigger users. We need articles in magazines and newspapers in farm country. We have been advertising in organic ag journals, but we are going to start advertising in conventional ag publications and I am looking at hiring someone with editorial skills to work on articles for those publications. We have challenges especially working with CAFOs. The management is split between producers, waste management and integrators and no one wants to take responsibility for the nutrients or to try something different. We can save them money, but we have to educate them first. Our solution is really simple, but they have to see the big picture to understand how it can work, and not just think of it as another input they have to buy that they don't want to spend money on." PB

"The biggest barrier to biochar production at remote sites is the biochar production technology. The technologies we have looked at produce no more than 600 kg biochar per hour. This is too low for good economics." HSH

Biochar Users – Barriers

Biochar users cited price and lack of consumer awareness as the biggest barriers. A carbon protocol for biochar could make a difference if it reduced the price of biochar enough to make it affordable for farmers to use. Users we interviewed are all resellers, and must sell their customers on the value of the biochar in their products. They sometimes run into the problem of skepticism about biochar due to historical over-hyping of its benefits. They felt there is a great need for a more consistent story about biochar and what it can do, along with a need for more consistent and well-tested biochar products.

"Lack of awareness is our biggest barrier. We cannot afford to advertise, so we rely on word of mouth. People need to experience the benefits of biochar and share on social

media. It's happening, but will probably take another year or two to generate the momentum we need." JaH

"Carbon markets would be one new development that would remove a lot of barriers to biochar. We are working with the voluntary market to get credits for composting food waste - that keeps a lot of methane out of the atmosphere. Unfortunately the higher priced California compliance market does not have a protocol for food waste or for biochar yet, but even so, at \$6-7 a ton, the carbon credit from our project developer's sales will really help our bottom line for food waste composting." SS

"The biggest barrier to use of biochar in the green infrastructure market is lack of knowledge on the part of implementers. First of all, they do not understand the cost of plant death. Green infrastructure saves money because it reduces the amount of water that needs to go through a water treatment plant, but it can be costly to maintain when the soils compact and the plants start dying. Lots of cities do not realize that their operations and maintenance budgets are going to go up and they don't know that biochar can help." MG

"Biochar is hard to sell because it lacks consistency and standards. The wood products industry needs to figure out how to make a consistent product, whether it's done in the woods or at a biomass power facility. There need to be clear standards for biochar that are reported using terminology that we can understand. And the price needs to come down. Biochar also needs a consistent story. With marketing it is all about the story." DN

"Another barrier is awareness of the benefits of biochar and organic fertilizers in general. We need to shift the paradigm. Farmers need to feed the soil first, and let the soil feed the plant. But there also has to be awareness that improving soil takes some time. Applications of biochar are incremental so we need long-term commitments to improve soil health." MM

"In trying to market our biochar soil blends, we have run into a lot of skepticism. Customers have questions about sustainability and they worry that we are cutting down healthy forests to make biochar. Other customers think biochar has been hyped and that there are no real benefits." GiS

“Our goal is to apply enough biochar to reduce water use by 20%. We need to compare the cost of some different approaches to long term drought in southern Utah. A lot of money is going to test new technologies for water efficient center pivot irrigation, like attaching drip lines that are dragged by the pivots. Those ideas have a lot of problems and they are expensive. Biochar could end up being a much simpler and cheaper solution.” DMA

“There is some ongoing research at Michigan State on biochar in anaerobic digestion that could make a difference. They are finding that particle size is very important for H₂S gas scrubbing. Nano and micro sized biochar is much more effective than bigger sizes. That could lead to more efficient use of biochar so you don't have to add so much to a digester to get good results and it will be more affordable.” CF

“We need more work to show the benefits of biochar to forest health. We need to know more about biochar effects on microbes, tree disease resistance, water holding capacity and insects. We put sensors in our biochar plots that show biochar increases soil water. Colleagues are working on a landscape scale analysis of biochar impact on soil water and they are creating a model to predict that. We will see if biochar reduces runoff and erosion.” DPD

“We need to know more about the longevity of biochar in soil for carbon sequestration purposes. We also need to know more about emissions from biochar technologies, especially emissions of methane.” JA

Biochar Producers – Research Needs

Most biochar producers would like to see more USDA funded large scale field trials, but some producers are working with clients to do their own research and felt less need for publicly funded research. Some top research needs are for application rates and techniques for use in manure management and compost, as well as field application rates and methods. In some cases, producers who are working with farmers would like help with monitoring, data collection, and analysis. Research into better biochar production methods is also needed, as is specific information on matching biochar types with end uses. Producers who work directly with farmers see a need for more research on regenerative farming methods in general as they feel the current ag commodity production system is not working well for a lot of farmers.

“We don't really need more academic biochar research. Big corporate buyers do their own research. They do not rely on academic research. They may look to universities for ideas, but they do their own investigations for their applications.” JG

“One important research need is to quantify the portion of pyrogenic organic material (biochar) naturally occurring in soils, which is quite significant in some areas. This

inventory should be added to the existing body of NRCS Soil Survey data as a layer of information regarding soil organic matter. This knowledge can help us better understand optimal application rates for biochar for agricultural production, and will be increasingly important in the conversations of climate change mitigation and adaptation going forward, of which soil organic matter plays a key role." JoH

"We need researchers to look more at how biochar interacts with other organic ingredients to make balanced organic fertilizers. Too many studies still use plain biochar, which we know does not work very well. We especially need research on using biochar in manure management. We need researchers to work with CAFOs to find the best ways to use biochar to capture N and improve animal health. We need to see what difference a complete organic fertilizer with high fixed carbon, organic nitrogen and beneficial microbes can do for plants. The farmers we work with have seen outstanding yield increases with this kind of biochar fertilizer." PB

"We need a lot more field trials to give us data so we can better quantify the benefits of biochar. These trials are very expensive and USDA needs to get more involved and fund them." MtK

"For filtration applications, we need more work to identify specific biochar characteristics for each application and its specific media and target pollutants. Look at the activated carbon industry - they have hundreds of different products engineered for specific applications. They are also starting to use more bio-based products, so there is some overlap between activated carbon and biochar." JL

"The top research need is for better biochar production technologies, both for remote operations and for larger power plants. I would also be very interested in seeing smaller scale technologies that can provide district heating and biochar production in rural communities. We also need more research on the economics of biochar production and use." HSH

"Farmers depend on agronomists to tell them how to farm. The modern farmer gets instructions from the agronomist, sets the GPS on his machine and that's about all he does. We need the agronomists to study biochar and regenerative farming and stop pushing chemicals. Grain prices won't come back up until we stop pushing the chemicals and GMOs. Those chemicals are killing our prices. We need subsidies for biochar and organic approaches to get our dead soil back to life. We are doing our own experiments on our own organic farm. My great grandfather started our farm near the ND - SD border and that farm has never had chemicals. It can be a challenge managing the weeds, but our soil is healthy. Farmers around here are interested in what we are doing. Farmers are realizing that it's not all about chasing yield. They want to get costs down and chemicals are expensive. You can produce 100 bushels an acre that sell for \$3, or you can produce 50 bushels that sell for \$20 - what makes the most sense?" MB

Biochar Users – Research Needs

Biochar users called for more field trials and research into the impacts of biochar on composting and in stormwater management. Soil blenders are very interested in more research on biochar as a substitute for common ingredients such as peat, perlite and vermiculite. Users were also skeptical of the value of some academic research on biochar, or felt that generic biochar research has only marginal value for marketing blended biochar products. Some called for research that looks at the role of biochar in managing larger flows and cycles of water, carbon and nutrients. Some would like more research that addresses product development.

“We need field trials on real farms that demonstrate the impact of biochar super compost on soils and crops. The work by Missouri farmer JR Bollinger is really impressive and should be all that any farmer needs to know that biochar is worth trying. He cut his chemicals in half and raised his yield. The valuable thing about on-farm research is that it is holistic. It might not advance the science the way more controlled trials do, but it does allow you to discover synergies with other practices that university research will never get around to.” SS

“We also need more research on biochar's impact on the composting process and compost greenhouse gas emissions. About ten years ago, San Diego State did some baseline measurements of compost emissions of methane and VOCs that was sponsored by the California Air Board. We know biochar reduces emissions but we need to know more so we can quantify it.” JaH

“We need a five year minimum longitudinal study with side by side trials of bioretention soil media with and without biochar to discover effects on plant survival and water quality. Portland would be the ideal location of such a study, but the question is, who would fund it?” MG

“We need more research in the horticulture and nursery industries to test biochar as a substitute for perlite and vermiculite. We need to see how it works with dairy fiber, coco fiber and other renewable waste stream by-products. We can find the best combination of renewable ingredients to make a product that substitutes for peat, which is not renewable and also not always consistent.” DMG

“Generic biochar research that has been published is not a big help to us. We need research that is specific to our products. But university research is very expensive. It does not have to be a university that conducts the trials, but it does need to be a third party, so it has credibility.” MM

“We also need more whole systems research because that is where you will really capture the value. Our society is rapidly moving to a bio-based economy from a petroleum-based economy and biochar is right in the thick of it as we learn to do a better job of managing carbon, nitrogen and water cycles in farms, forests and pastures.” DN

3.5. What are you doing to develop biochar markets?

ac agriculture air annual application approach
benefits biomass blends blog building burner
carbon compost consulting cost dairy
economic education effectiveness extension facilities
farmers farms feasibility feedstock field finding
forest funding grant improve inc income increasing integrated learned log
manage manufacture market material meet mill
mix mobile network nutrients operation plant portable powdered promoting
proposals purchased quality research residuals resources
results sawmills service soil solutions source technology test
transport travel trees trials trust university usbi uses
utilizing volume wastewater yield

Industry Experts – What Are You Doing?

Based on their roles, industry experts vary in the way that they can help build biochar markets. State agency respondents were able to support some biochar enterprises with grants and access to low cost loans. They also provided information to state legislators about biochar markets and supported demonstration projects. Respondents from the USFS mentioned Wood Innovation Grants as a source of funding for biochar projects. Researchers support student projects in addition to their own work, and also participate in networking and extension programs, as well as field trials with farmers and work on forest ecology, mineland reclamation, and ecosystem regeneration. NGOs also engage in extension and training work, and receive grants for demonstration projects that they manage in cooperation with biochar producers.

"ODF helped Rexius and Biomass One develop soil blends. ODF supported Walking Point Farms to develop a biochar fertilizer project, but a partner bankruptcy caused project failure. ODF is preparing a brief on low-carbon forest products (including biochar) for the Joint Carbon Reduction Committee of the Oregon State Legislature working on Cap & Invest bill. Talk of 20 million dollars becoming available for forest projects. Biochar could be part of this." MrK

"We have supported a large number of biochar feasibility studies and biochar research, in production, use and economics." MF

"As a UC researcher in plant biology and ag extension, I have been spending more than half my time on biochar research, extension, and networking. My grad students also have biochar research projects. I give extension talks on biochar, have a blog, the Biochar Blog, hosted by UC Division of Agriculture and Natural Resources at: <https://ucanr.edu/blogs/biochar/index.cfm>" MMG

"Sonoma Ecology Center and Sonoma Biochar Initiative purchased a small-scale pyrolysis system called an Adam-Retort, and we managed another small-scale pyrolysis system from Biochar Solutions last year for the Redwood Forest Foundation, Inc. We conduct two to four conservation/biochar trainings per year, have annual educational booths at local permaculture or agriculture related shows, are consulting on several forestry-related biomass reduction / biochar production projects that showcase innovative solutions. We are also managing a Department of Resources grant and have several other grant proposals pending for measuring emissions from conservation burns, flame-cap kilns, and a new air curtain burner design that also produces biochar." RB

"We have one study going that looks at soft-bodied creatures like slugs and worms. Does biochar hurt their bellies when they crawl over it? We have proposals out to do more investigation of biochar effects on soil insects and pollinators. We have been working on the Stanislaus NF using biochar to combat drought. There have been fires and a lot of tree death there. We made biochar from dead ponderosa pines and put it around the roots of some residual big trees. We need to monitor that work and see if it helps those trees survive drought." DPD

"The US Forest Service is providing the Wood Innovations Grant funding source to help commercialize biochar. We have funded 4 or 5 of these grants in the past few years. I have been working on a new mobile biochar processing technology with Air Burners, Inc. The Forest Service has a patent on this technology. It will help address the biomass transportation barrier by giving us new capability for in-woods biochar production. I am also working with a group in Oregon called Forest 2 Farm that is promoting the use of biochar to farmers." JA

Biochar Producers – What Are You Doing?

Producers have invested in education, research and technology. They have also donated char to university research programs and to end users who want to test biochar for new applications. Some work very closely with end users to work out application rates and practices. Many producers are interested in the bigger picture and developing sustainable, closed loop systems that address climate change and other issues. Many are involved in promoting collaboration within the industry for mutual benefit.

"We are collaborating with different universities and industry professionals, and providing char to researchers working on cattle feed, field trials, and compost trials. We are also working with other biochar producers on marketing and product development, and with other industries. We are involved in the Biomass Power Association (BPA) and facilitating a connection between BPA and USBI to collaborate on promoting biochar as a co-product of energy facilities." GrS

"We work on building a groundswell of acceptance within certain farming communities, which can be done by working with clients directly, one at a time, using a donations-for-data kind of approach. We often invest thousands of dollars per client in providing and shipping our biochar materials for field tests. We travel to farms and work with them to determine how our biochar materials might work best for their operation, and if the experiments work well, if the field trials yield sufficient benefit, then they might decide to purchase product from us (and their peers will notice). And if not, well at least we have gained valuable information about what doesn't work." JoH

"I make progress by contacting big corporate buyers and make the case to them that biochar will fit their application. I work with their research labs to test my biochar. This takes years, but there is a lot of interest, and things are starting to move forward pretty quickly." JG

"Our current project takes the next step beyond what we learned in the Waste to Wisdom project. We learned that mobile biochar production alone is not workable, so we combine biochar production with a portable mill and an Air Burner power source. These mobile sawmills are needed because many small sawmills have closed in recent years, and it is not economical to transport a small log more than 200 miles. This gives us an opportunity to re-create saw mill capacity in a mobile format with modernized equipment for more efficient operation with less waste." HSH

Biochar Users – What Are You Doing?

Biochar users are active in researching the effects of biochar in their own applications and potential applications for customers. In some cases they are actively lobbying for best management practices that specify biochar products. Compost producers also work with farmers to help them understand the value of their product. Soil blenders are hiring sales staff and reaching out to promote their biochar products.

"We are doing some work with farmers. We are working with a filbert orchard on tree establishment and water use. We add a mix of biochar compost and mycorrhizal fungi. Using 2 shovelfuls per tree, at a cost of \$.50 to \$.75 per tree, we hope to show that this treatment can bring trees into production earlier. It takes a filbert 5-7 years after planting to start bearing a crop, so if we can shave a year off of that, it is a significant economic benefit." JaH

"I am a consultant and I use and spec biochar for industrial stormwater filtration and for green infrastructure. I advocate for more research in this field because my results indicate that biochar can improve the cost effectiveness of green infrastructure." MG

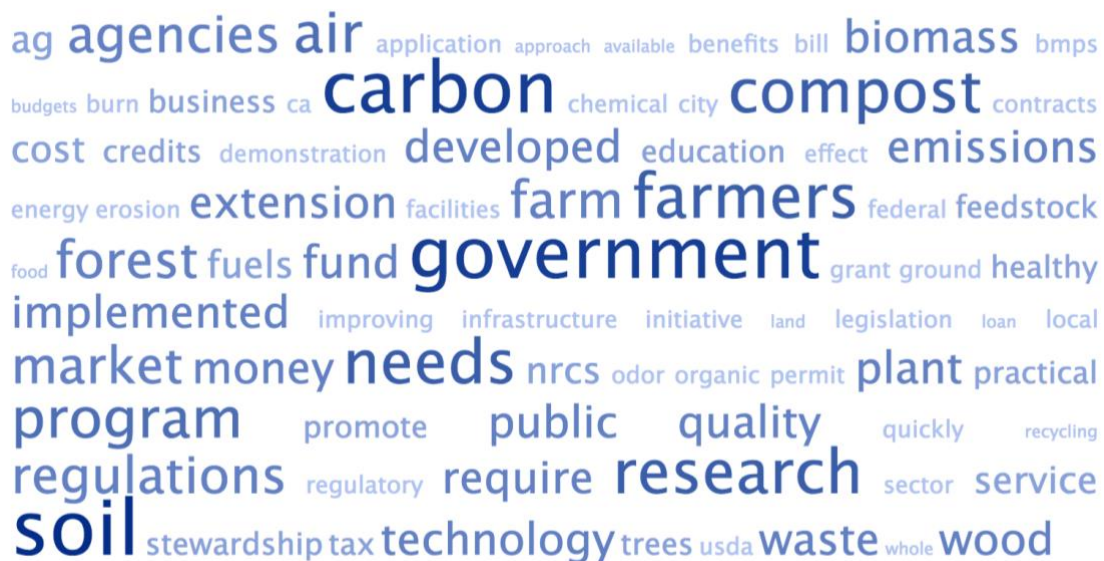
"We work directly with dairies to process dairy solids onsite at the dairy into a peat substitute called NuFiber. This solves a problem for the dairy and gives them some income from the material. We are beginning to add biochar to our compost and dairy fiber mixes to make soil blends." DMG

"Our group is the Association of Compost Producers. We represent the California compost industry with more than 200 facilities that compost 6 million tons of material annually, producing 15-20 million cubic yards of compost. My goal is to grow the bioeconomy and transform waste into feedstocks for bioproducts. I want to help change the way we look at water, energy and solids so we don't think of them as waste but as integrated utilities that support life. Using that approach, we can create a portfolio of bioproducts." DN

"We have just hired a sales force and we are starting to go to ag conferences and sell our product." MM

"We have one salesperson who is very enthusiastic about biochar and his sales are increasing. So he is able to tell the story that brings in customers." GiS

3.6. What could the public sector be doing to develop biochar markets?



Industry Experts – Public Sector

Experts shared a wide variety of ideas for government action at state and federal levels that could build biochar markets, including carbon markets and other incentives, crop insurance programs, support for research and extension, regulatory help, and adding biochar to best management practices (BMPs). Increasingly, states are enacting bans on the land-filling of organic waste materials and this may open up opportunities to specify the use of biochar for better composting of food waste and other organics. Government should use the waste biomass resource to build in biochar as a component of rural economic development plans. One intriguing idea would be to require farmers seeking loans to invest in soil resilience. Farmers could work with NRCS to bring farm soils up to a minimum level of carbon as a condition of the loan. Biochar can also be used to reduce GHG emissions from soils, as required by the California Healthy Soils Initiative. In general, government agencies in charge of many different environmental and economic development programs should get out of their silos and look at how biochar can bring about beneficial synergies in a number of different areas.

“There is limited regulation of odor from organic waste in our state. If we had better regulations in place, it would support the use of biochar to control odors.” MF

“Air quality - air burners and other technology like the Oregon Kiln can help landowners burn during times of air quality limitations. This can be done at the permit level. ODF and DEQ manage burning and could change guidelines to permit air burners and clean biochar kilns when open burning is not allowed.” MrK

“Extension budgets have been slashed and the public sector needs to grow to provide more extension services. We also need to train the trainers, and educate extension staff about biochar, both its use and onsite production on farms. We also need to hold technical workshops for the biochar industry to discuss how to produce the best biochar materials. Currently the best production methods are bulk production in large, re-engineered biomass energy boilers and small-scale, low tech biochar produced in simple pans or bins from slash that is widely distributed across the landscape.” MF

“Governments need to help biochar producers through the regulatory process. I know one producer who had to travel to Sacramento every month for a year to defend his small biomass energy and biochar plant from being regulated out of existence. Government also needs to fund the needed research. One priority is for government to research and reinstate the use of biochar in cattle feed.” MMG

“Government can help with support and incentives. Beyond the carbon market, we need incentives for farmers to put biochar in soil as a natural part of the soil organic matter. The California Healthy Soils Initiative should require biochar.” RB

We need government to do several things: First, BLM can include biochar in their BMPs for oil, gas and mineland remediation. It is good that NRCS now has a cost share

for biochar activities under the Conservation Stewardship Program, but they should expand that to other programs such as EQIP.” DMA

“Look to the compost industry. Government buys a massive percentage of all the compost that is produced. Get governments to add biochar to their fertilizer procurement standards. As wildfire and fuels management is a growing problem, government will require better ways of disposing of waste wood and we can work with the wood products industry to get more support for biochar production.” CF

“At the Forest Service and other land managing agencies, we need to do more public education about the benefits of biochar. We need to talk a lot more about biochar and water, biochar and carbon sequestration. We can do this through our education and extension programs and things like our science night talks at the local pub. State agencies can really make a difference by incorporating biochar into their rural economic development programs. They have all these piles of biomass sitting out in the woods and they can get people back to work in the woods converting that to biochar. I see this already happening through programs in MT, WA, CA and OR. CA has an initiative to limit GHG emissions from soil. They should look at using biochar to mitigate methane emissions from soil.” DPD

“USDA researcher Stephen Machado has found that many farms in eastern Oregon have lost more than 50% of their soil organic matter. We should measure SOM on farms and if it is below a certain amount, require that SOM be increased as a condition of farm loans. It would not have to be biochar, but biochar would help do that quickly.” JA

Biochar Producers – Public Sector

Biochar producers are actively following government actions that could help promote biochar markets and they identified many areas where government could help. Carbon credits and approval of biochar use in animal feed were high on the list of desirable policies, as were BMPs that specify biochar products for odor control, nutrient management and stormwater management. Producers would like to see more government infrastructure spending applied to their industry and more access to biomass feedstocks appropriate for biochar production.

“Government should move quickly on two things: approve biochar use in animal feed, and implement a price on carbon. It does not matter if it is regulatory, a carbon tax, a feebate or other approach. We just need some valuation of sequestered carbon.” JL

“Need manure management BMPs that specify biochar for odor control and nutrient management. Nutrient rich waters are a huge issue.” GrS

“Providing critical infrastructure is another area where states could help. As a producer we are running into feedstock constraints due to lack of forestry infrastructure. One of our production facilities is a modified biomass co-gen plant that

was idled for several years for economic reasons. California recently provided legislative support for biomass energy facilities that use feedstock primarily from designated high fire hazard forest areas, which includes ours, but in the last decade or so, the number of logging contractors who can bring the material out of the woods to the plant have effectively dropped from about eighty to less than a dozen. Even though the forests are burdened with excessive fuel loads, leading to catastrophic fires, the state lacks capacity to move biomass from the woods to the plant. Gathering dust is a biochar production project greenhouse gas emission reduction accounting methodology protocol adopted by CAPCOA for a voluntary carbon market that needs more attention. I would like to see that moved forward and implemented as part of California's Cap and Trade Program with CA Air Resource Board. Additionally, the Healthy Soils Action Plan includes mention of supporting biochar research, which is great. I want to see this process move quickly through research and into practical implementation.” JoH

“Feedstock supply is important, and government can help us get access to feedstock. At the federal level, the firefighting budget needs to change so that it does not eat up all the money for fuels reduction and mitigation. We need more stewardship contracts to reduce fuels. Currently there is not enough money to remove dead trees through stewardship contracting. One thing the Forest Service did for us that was very helpful was to name our business in the stewardship contracts as the only local buyer of this material. We pay \$50 a ton for the dead trees.” JG

“The public sector should dedicate more funding to technology developers for improving the technology so we can produce higher volumes of consistent quality biochar. The public sector needs to act on this quickly. We have a very urgent problem with forest health and public safety. The fuels load in our forests has become a huge waste disposal problem with over 100 million dead trees just in California.” HSH

“The USDA Biopreferred program has been helpful. It is good to have our products registered - that helps with sales. USDA and NRCS have been helpful, but there is a lot more that they could do for biochar.” PB

“For the last 120 years, farmers have been following the recommendations of the USDA and the professional agronomists. The result has been to severely degrade farm soil so that it has lost most of its carbon. We need a long-term solution to this problem, and farmers need help. The US government should include, in the next farm bill, incentives for farmers to put biochar in the soil. This problem developed over a long period of time and it will take time to fix, but farmers should not have to do it alone and pay the whole cost. They need a little bit of subsidy to bring the soil back to life.” SL

“It would be really great if farmers could get some help to apply biochar to their fields. Many of our local farmers would use it if they could get it for free or low cost. I would like to see NRCS subsidize biochar application through EQIP, for instance.” MtK

"The US EPA is mostly a reactive agency that does not promote technology advancements based on their regulations supporting only existing technologies. If there were a practical program through the EPA that supported new technologies for recycling, instead of placing them into the "closest" category, there could possibly be an advancement in technologies for recycling." MOC

"Government should fund more grants for small producers. They make the process really difficult and the money always goes to the money - the big projects, not the small projects. We tried for 2 years to get a greenwaste grant, but the money always went to the big ethanol plants that will burn anything." MB

Biochar Users – Public Sector

End users of biochar also felt that government has a critical role to play in developing biochar markets, mostly through regulatory processes and BMPs that drive markets. They would also like to see more cost share programs to help their customers and clearer and more detailed technical guidance from agencies like the NRCS.

"Regulations are really important. Regulatory pressure is what is driving the stormwater treatment market. Most of that business comes through consultants who have clients that are non-compliant and trying to meet the requirements. Air emissions regulations are also becoming more important for composting facilities. California is now trying to regulate best available control technologies (BACT) for compost facilities, requiring forced air and biofilters for composters. They should take a look at biochar as an alternative. Biochar also drastically reduces the amount of compost turning needed. That represents a lot of diesel emissions from machinery." JaH

"The public sector needs to fund the upfront research that will provide that data to help city managers understand the benefits of biochar for their green infrastructure projects. But there is a chicken and egg problem getting the funding because it is hard for agencies to justify funding the studies when they don't understand they have a problem - that their operations and maintenance budgets are going to get very costly as these projects age." MG

"Government should provide grant money for research. It would also be helpful to have BMPs for applications like erosion control that specify use of biochar." DMG

"Right now we are undergoing massive regulatory changes in California regarding waste management. AB 1383, the California Global Warming Solutions Act of 2006, governs a whole suite of recycling and composting processes for food waste, manure and other organics. But it has been a piecemeal approach so far." DN

"Our business got a big boost from last year's tax cut legislation that created Opportunity Zones for investment. This program allows investors to put money into

certain regions instead of paying capital gains tax. Our region qualifies and this brought us a good group of investors that let us hire good consultants and expand our business. Another thing that would be really helpful would be for NRCS to add biochar to all of their cost share programs. That would help farmers get biochar in the ground and start seeing the benefits. They also need to add biochar information to their FOTGs - Field Office Technical Guides.” MM

3.7. How could a biochar industry association help develop biochar markets?



Industry Experts – Industry Association

Industry experts interviewed saw the value of industry associations to deal with policy issues, promote biochar standards and to network and provide information to the public and end users. However, they also acknowledged that an industry association would take resources that are not currently available.

“An industry association needs to deal with government regulations, network all the industry players, and help them find the value chains that will drive profitability in the industry.” MMG

“We started the California Biochar Association to promote the industry in California. If we could raise the funds, we would use it to create an almanac of research results, an industry directory, a catalog of available production technologies and for education. But we don't have time to do the fundraising required.” RB

“The biochar industry needs standards: quality standards, testing standards, and also standards for weights and measures.” DMA

“An industry association is needed because there are so many different applications for biochar it is mind boggling. Producers cannot get a grasp on where they should look for markets. An association could help with that.” JA

Biochar Producers – Industry Association

Biochar producers saw that biggest value of an industry association was to produce standards for testing and labeling biochar products, lobby for more favorable regulations, and to network biochar producers. Some producers were skeptical that the industry would have enough resources to support an industry association at this time.

"We need a biochar lobby to advocate for our industry. We could do this in conjunction with the compost industry. Compost and biochar are the perfect marriage. I would like to see the USBI work on the AAPFCO labeling for biochar. Right now I have to go to each state to get my products registered. It would be great to have some help." PB

"An industry association should lobby for the industry and work on creating supportive policies for biochar. The AAPFCO soil amendment label rules need work. Animal feed rules need to be changed to allow biochar as a feed." JG

"We need a biochar producers association. We have talked with a few producers about this and there is interest. There are 130 producers and 45,000 tons produced annually according to Tom Miles. Reach out to everyone and ask them to give 1% of sales?" GrS

"An industry association needs to herd the cats and correct some of the bad information that is out there about biochar. Biochar is not a miracle and it has been oversold. That hurts us. We need good quality information with a consistent message." SL

"Currently, I don't think the industry is big enough to support an industry association. When there is more money, then it will be time. For now, USBI should continue its work of offering conferences, newsletters and other communications and education." JL

"The biochar industry needs more cooperation. Right now, producers don't talk to each other very much and want to protect their trade secrets. But that is slowing development. Companies should talk to each other more and share information. They need to work together to build the industry." HSH

Biochar Users – Industry Association

Biochar users were most interested in the education and awareness that an industry association could provide. They wanted an industry association to help with focus and branding to better tell the story of biochar. They thought biochar characterization standards were important and hoped that an association might be able to raise funds for developing standards, field trials, case studies and webinars.

"An industry association for biochar could help raise awareness and educate people about biochar. Companies like mine cannot afford to advertise, so that would help us." JaH

“We also need to have better biochar standards that report on the characteristics that end users need. For instance, the standards should include hardness data. I have a lab that will do a hardness test on biochar using a coal hardness standard and that is useful information for me.” MG

“The biochar industry also needs to help companies like ours understand the technology. We would like to buy some equipment, but we don't know where to go for help to understand what equipment is right for our compost facility. A good webinar or two on choosing technologies would be a big help.” SS

“A biochar industry association is needed. It should support research, develop standards and promote markets. It should develop a story for biochar that is consistent to help with marketing.” DMG

“The biochar industry needs to invest in markets. Biochar will not sell itself. You do that one customer at a time and you focus on branding. Focus what resources you have on establishing product quality and value for specific markets such as stormwater or cannabis. It would be helpful to develop case studies for these high value applications. That would be more useful at this point than additional university research. You need branding. Biochar should be about water management.” DN

“I would like to see a meeting to develop standards. It could start with a session of academics who outline problems and approaches and end with a session of industry leaders to agree on solutions to the standards problem.” MM

4. Summary Discussion

Summarizing all of the responses, the main conclusions are that biochar markets are very promising under certain circumstances, and that biochar production capacity is available now and is scalable to meet increased demand. Biochar is a unique, but underappreciated material that has real benefits in many applications in environmental remediation and agriculture. These benefits are not yet well articulated and not always easy to monetize in an economy that often fails to value improvements to the environment or mitigation of the existential threat posed by climate change.

Below we categorize and list important points that need to be addressed in order to realize the potential of biochar made from woody biomass over the next five years. We have sorted these into the categories of biochar applications, production issues, overcoming barriers, available policy opportunities and potential policy opportunities. We have supplemented the lists of policy opportunities that were identified by the interviewees with policies drawn from a table of biochar-supportive

policies identified in a paper co-authored by USBI board member Ghasideh Pourhashem, that is a review of recent and proposed US public incentives and funding programs that could support biochar production and use. That table is included as an appendix.

In the final section of this report, we build on the points below by identifying some priority actions that state governments could take to promote the biochar industry.

4.1 Biochar Applications

1. Water filtration, stormwater management and green infrastructure – Biochar and compost perform better than either compost alone or activated carbon alone. Once cities realize the cost savings they can see, this should be an easy sell and we will begin to see BMPs that are written to include biochar-compost blends.
2. Mineland remediation – Biochar and compost are very effective at improving acid mine tailings, but who will pay for it?
3. Fracking pad revegetation – Biochar and compost are very effective, but compost alone is sometimes equally effective in the first few years, so the value of biochar may only come into play after reclamation bonds are returned. Biochar should be specified by managing agencies for its superior performance over time.
4. Brownfields reclamation – With involvement of DuPont, this application may be poised for rapid growth.
5. Activated carbon substitute – Applications like H₂S filtration and wastewater treatment that currently use activated carbon may be amenable to cheaper biochar as a substitute, but each application will need to be proven separately. This is a long term process that only biochar companies can undertake successfully, but academic research is already available to help point the way.
6. Turf and landscape trees – Biochar retains water in soil, but there is a need for better information on application rates in different soils and cost is an issue. Public demonstration projects could be helpful to educate citizens, as well as landscapers, arborists, and city planners.
7. Bagged soil blends – Buyers exist now for these blends, but more consumer education is needed. Product developers also need help from researchers to understand how to get the most out of the biochar they add as substitutes for peat, perlite and vermiculite.
8. High value horticulture – Vineyards, orchards and vegetable growers have been willing to try biochar and some are finding benefits, but more field trials and application data are needed for these markets to grow. Ag extension services should take this on.
9. Nursery potting media – Tree seedling nurseries for reforestation are beginning to embrace biochar as they see the benefits. Other nursery operations may follow.

10. Broadscale agriculture – The cost of biochar is often prohibitive for farmers, but good results have been achieved with targeted applications in the root zone where biochar serves to help retain nutrients and water. The best way forward may be for biochar producers and extension agents to work directly with farmers to experiment with application rates and methods, including innovative methods utilizing techniques such as no-till drills with seed row banding, seed coating, and liquid applications through drip lines and foliar sprays.
11. Animal feed – Very promising results from European and Canadian cattle feeding trials should be used to lift the prohibition on biochar in animal feed in the US. Some US producers are already selling biochar to Canada for animal feed and are well-positioned to respond to this market. This would likely do more to create biochar demand than any other single action.
12. Manure management – There has been very little published research on the benefits of biochar to control odors, GHG and nitrate pollution from manure, but benefits are clear to early adopters. Case studies should be developed and programs like California’s Alternative Manure Management Program should add biochar to their list of supported practices.
13. Biochar and compost – This is another area where more practical research is needed, but already compost companies that have tried adding biochar are impressed with the results. Emissions reductions methodologies should be developed so compost operators can document reductions and receive appropriate credit for doing so.
14. Industrial uses – Biochar for use in building materials, plastics recycling, and as a carbon black substitute are beginning to develop, but still constitute a relatively small market. The USFS Forest Products Lab could undertake research in this area.

4.2 Biochar Production

1. Feedstock availability – Feedstocks are generally widely available essentially for free, but pre-processing and transportation may be barriers in certain situations. However, many communities or companies already have consolidated waste areas at landfills or sawmills, which could be utilized as biochar production sites.
2. Wildfire threat as driver – The increasingly dangerous wildfire situation requires that society invest in removing and treating excess fuels with minimal emissions of smoke. Carbonization is a beneficial use for this material and should be supported.
3. Scalability – Biochar production is very scalable, but best economies will result when renewable energy in the form of heat and/or electricity can be recovered from the process.
4. Energy co-products – Low energy prices have depressed biomass energy development in recent years. Biochar can improve economics of biomass energy by adding another revenue stream to biomass power plants.

5. Remote production – Where biomass is thinly distributed on the ground, it will often be more economical to use low tech conversion processes that do not produce energy, and leave at least part of the biochar onsite for improvement of soils in forests and other natural landscapes.
6. Waste management – Co-location of biochar production with landfill transfer stations and compost yards has promising economic advantages.
7. Enhancing wood products industry – Co-location of biochar production at small sawmills can provide an additional revenue stream for small producers while also serving to reduce the volume of underutilized biomass.
8. Technology development – More work is needed to develop appropriate biochar technologies for different scales and settings and to help companies identify and implement appropriate technology solutions..
9. Carbon price – A carbon price with recognition of biochar carbon benefits would also help support and finance biomass energy development.

4.3 Overcoming Barriers

1. Academic research – More academic research specific to applications is needed, especially for organic fertilizers, compost, manure management, green infrastructure, peat replacement, animal feed, and other rapidly developing markets.
2. Standards – Support development of biochar standards, grades, weights and measures.
3. Information and extension – provide more and better information and extension programs for end users, farmers, foresters, investors and regulators.
4. Business development – Provide help for entrepreneurs who want to produce biochar, especially those who want to add a biochar line to an existing biomass energy, waste management or wood products business.
5. Forest products industry capacity – Rebuild the capacity of the forest products industry to handle and process small diameter hazardous fuels to make useful products, including biochar and energy.
6. Resource management – At the state level, network across natural resource agencies responsible for forests, agriculture and environmental quality to promote use of waste biomass to make biochar for improvement of soils and for better management of organic waste streams like manure, food waste and digestate.
7. Policy – Provide information to policy makers about the multiple benefits of biomass utilization for biochar production and carbon sequestration.

4.4 Available Policy Opportunities

1. Commercial financial incentives: Federal – These include loan guarantees, grants, and matching payments under the USDA and DOE. In addition, a new federal tax incentive, the Opportunity Zone Program, under the 2017 Tax Cuts and Jobs Act, has helped one interviewee (see Michael Maki interview) gain access to investment dollars.

2. Commercial financial incentives: State – At the state level, production tax credits for renewable energy and chemicals are available from Iowa, Oregon and Colorado.
3. Policy support: Federal – USDA has several programs that can be used to support biochar production. The USDA Biopreferred Program provides a certification for biochar products that is helpful with marketing, and the National Organic Program has identified biochar as an acceptable material for organic agriculture. The NRCS provides a cost-share incentive that is specific to biochar, the Conservation Enhancement Activity E384-135Z: Biochar production from woody residue, available under the NRCS Conservation Stewardship Program to landowners who need to dispose of woody debris. This activity supports production of biochar onsite in small, mobile kilns.
4. Policy support: State – Renewable energy standards in Colorado, Missouri and Wisconsin could be used to support biochar production. California has enacted a definition of biochar as a soil amendment, and the state has an approved Biochar Production Project Reporting Protocol for GHG Emission Reduction Accounting. California also includes biochar research as a directive under its Healthy Soils Initiative. Colorado has enacted legislation to support research, development and application of biochar, and Washington has such legislation under consideration.
5. Research & Development funding: Federal – USDA and DOE have provided funding for biochar under the Biomass Research and Development Initiative (BRDI). The US Forest Service has funded a number of biochar projects under the Wood Innovation Grant program, and the NRCS has funded several biochar projects through its Conservation Innovation Grant program.
6. Research & Development funding: State – At the state level, Maryland, Nebraska and Kansas have offered grant funding for biochar projects.

4.5 Potential Policy Opportunities

1. Commercial financial incentives: Federal – Federal support for carbon markets is the most important potential policy that could change the economics of biochar.
2. Commercial financial incentives: State – There are many possibilities for financial incentives at the state level. The most effective incentives should not only promote the biochar industry, but enable biochar to solve other environmental problems that states currently spend money on, such as water treatment and waste management. California is beginning to focus on reducing GHG emissions from dairies and livestock operations under its Alternative Manure Management Program.³ The California Strategic Growth Council recently funded research on using biochar to control GHG emissions from manure. If results are favorable, this could lead to biochar being approved as an alternative manure management strategy.
3. Policy support: Federal – As many of our interviewees pointed out, the best thing that federal regulators could do for the biochar industry would be to lift

the restrictions on the use of biochar as a supplement to animal feed. This could also help mitigate many other problems with GHG emissions (cattle eructation of methane) and nutrient waste stream management (manure management at feedlots). There are also many requests for NRCS to provide biochar cost-share incentives under more of their program areas, including the popular EQIP program. These requests could be implemented under the new Farm Bill that was recently passed, which includes language that incentivizes farmers to build soil carbon for soil health and carbon sequestration.⁴ Recently, the heads of three federal agencies, DOE, USDA and EPS, signed an agreement to cooperate with each other and with states to develop bioenergy projects from forest biomass for purposes including forest health and carbon sequestration.⁵ This directive could be used to help support biochar production as part of forest management for forest health and bioenergy.

4. Policy support: State – States could dedicate funds for biochar extension services. States should also look at biochar as a component of rural economic development programs and for dealing more effectively with urban waste streams. States could develop BMPs for use of biochar to improve stormwater management and to reduce emissions related to compost, landfills and manure management. While federal action on climate change is stalled, some states are moving forward to develop climate policies.⁶ These policies could include biochar.
5. Research & Development funding: Federal – Research funding for biochar should focus on practical applications that mitigate environmental problems, including environmental remediation, wastewater treatment, stormwater management, composting, manure management, soil health, soil water holding capacity, and carbon sequestration.
6. Research & Development funding: State – Research funding should provide support for farmer-led field trials of biochar in the most important state agricultural sectors, and for research into use of biochar for the top environmental concerns in the state. States could pursue public-private partnerships to support this work.

5. Recommendations for Action

Since its formation in 2010, the US Biochar Initiative has been working with the biochar industry in North America. Based on their wide range of experience with the biochar industry and the results of this study, USBI board members have recommendations to the Council of Western State Foresters for actions that could help promote biochar markets and the biochar industry. These recommendations are presented below under several action categories:

1. Biochar in Animal Feed – State regulators have an important role to play in the effort to gain approval for biochar as a feed ingredient from the

- Association of American Feed Control Officials (AAFCO), which currently prohibits it. As members of AAFCO, they can submit important information to the approval process. Given that certain states are beginning to regulate emissions related to enteric emissions and that research has shown that biochar fed to cattle can reduce enteric emissions, approval of biochar as a feed ingredient should be a priority. The University of Nebraska has already progressed to the second phase of a research program on biochar in animal feed, and they are developing protocols for measuring enteric emissions reductions from biochar in feed. States can work together to develop standards, building on prior work in other countries. For instance, the European Biochar Standard for biochar use in animal feed is restricted to biochar made from wood, with a carbon content of >80% (dry weight).⁷ Until further research provides confirmation about other types of biochars being beneficially used in feed, these guidelines are a good starting place.
2. Air Emissions Permitting – air quality regulations are administered by state agencies who are responsible for both emissions from stationary sources and for ag and forest burning. Most biochar production technologies can meet existing air quality regulations without problems, but some biochar producers are developing mobile technologies for processing ag and forestry waste into biochar as an alternative to open burning. Compared to emissions from open burning, these technologies are much cleaner, however, in some cases, states have regulated them as stationary sources. This is inappropriate and can lead to shutting down a beneficial alternative to open burning. Raymond Baltar of the Sonoma Biochar Initiative has been working with the California Air Pollution Control Officers Association (CAPCOA) to do emissions testing of these technologies to fill in some information gaps for regulators. Baltar and Kelpie Wilson of Wilson Biochar Associates have been working with engineer Raul Dominguez at the South Coast Air Quality Management District on establishing definitions and standards for biochar burning techniques at ASTM (Draft ASTM Standard for the Conservation Burn Technique 100118_RD). This effort has just begun and will benefit from input from other agencies and states.
 3. Air Emissions Protocol development for biochar and compost. Much practical demonstration work is needed to determine the most effective ways to use biochar for the purpose of controlling GHG and VOC emissions from composting and manure management. Emissions reductions methodologies should be developed so farmers and compost operators can document reductions and receive appropriate credit for doing so.
 4. Biochar BMPs for Stormwater and Green Infrastructure – The 2018 USBI conference was held in Delaware, part of the Chesapeake Bay watershed where stormwater management is a major concern. Biochar for stormwater management was a key focus of the conference with many speakers (including keynote speaker, Deputy Director, Water Protection Division, USEPA Region 3, Dominique Lueckenhoff) addressing biochar for stormwater management. Researchers at University of Delaware reported that biochar was less expensive than 20 of 23 currently recommended storm

- water management techniques, calling it “the only realistic option when land is scarce.” States can begin to sponsor demonstration and monitoring projects that document the benefits of biochar and use this information to write new BMPs that include biochar. They can draw on the expertise of consultants like Myles Gray, who has already installed multiple projects using biochar in Portland, Oregon. It should not be necessary to go through this process in every state if states are willing to learn from each other and adopt practices already proven elsewhere.
5. Urban Trees – Tree diseases and pests like the emerald ash borer are devastating large sections of the urban forest. In the interest of sanitation, dead trees must be heat treated. Usually this means incineration, however, conversion to biochar is equally as safe and will keep carbon from entering the atmosphere. The biochar created can be used in new tree plantings to improve future tree health and resistance to pests, drought and disease.
 6. Wildfire – The growing problem of wildfire and maintaining fire safe communities will necessitate increasing expenditures of public funds. As trees are removed and post-fire recovery projects are implemented, states need to find ways to work with multiple partners to execute actions that are cost effective, have low emissions and that contribute to the health and resilience of future forests.^{8,9,10,11,12} A few pilot projects in Oregon, California and Utah are exploring biochar production methods using simple kilns and biochar burn piles that can be deployed by wildland firefighters in pre- and post-fire conditions. Oregon Department of Forestry and other partners are supporting a demonstration tour of a new air curtain burner from ROI (see Matt O’Connor interview) that can make biochar from forest slash. Another potential for constructively dealing with hazardous forest fuels is to support transportation to nearby biomass energy power plants, such as Biomass One in White City, Oregon (see Grant Scheve interview), where they are converted to electricity and a biochar co-product.
 7. Public-Private Partnerships – There are many different entities operating at the state level that could potentially have an interest in biochar and in partnerships that contribute to industry development: commodity boards for key state agricultural products, private forest land owner associations, environmental remediation groups like the American Society of Mining and Reclamation, conservation groups such as the Nature Conservancy, local watershed councils, soil and water conservation districts, industry associations in the tree care and timber industries, and other industries including biomass energy and waste management. These groups and others may want to contribute information and perspectives on biochar industry development, or to participate in public-private initiatives to start demonstration projects and support key research at state universities. Alternatively, state agencies and universities can contribute research support and expertise to privately funded demonstration projects where it is needed.
 8. Federal Partnerships – In several instances, we have seen the US Forest Service enter into CRADAs (Cooperative Research and Development Agreements) with private industry to develop biochar production

- technologies and biochar applications. States can promote this program to their constituents. State universities could also potentially work with the USFS Forest Products Lab to undertake research on biochar for use in building materials, plastics recycling, and as a carbon black substitute. Other opportunities for biochar R&D can come from the Wood Innovation Grants administered by the USFS and the Conservation Innovation Grants from the NRCS. States can be valuable partners in these kinds of projects, providing matching funds and expertise, or as recipients themselves. For instance, the Nebraska State Forest Service received a WIG in 2017 that allowed them to form the Great Plains Biochar Initiative along with Kansas, and now North Dakota. This successful project has provided biochar workshops through the state extension programs and a small grant program to encourage biochar production and applications. A WIG in Oregon helped Oregon Department of Forestry work with a compost producer to develop products using biochar.
9. Federal Programs at the State Level – States can also help with the implementation of federal biochar programs at the state level. The NRCS Conservation Stewardship Program recently added a biochar cost share for landowners (CSP Activity E384-135Z) that has yet to be implemented on the ground in many states. State foresters could have important input into developing practice guidelines specific to local conditions, as they work with many of the same landowners.
 10. Economic Development – Biochar producers and re-sellers need access to capital and could be assisted by existing economic development programs at the state level. State extension services can bring biochar industry players, including banks and other potential investors, together at meetings and seminars to explore ways that various industries – farming, forestry, bioenergy, waste management, and reclamation, can build locally integrated supply chains for making and using biochar. State foresters would have an especially important role in this work as they are already working with many of the potentially interested parties.
 11. Interagency Cooperation and Purchasing. Many states have multiple agencies working in natural resources with different objectives, such as biomass utilization, waste management, pollution control, erosion control, roads and transportation, forest fire prevention, soil health, ecosystem restoration, and agricultural extension. Where these agencies have purchasing power, they could use it to support local biochar producers by direct purchases of biochar for stormwater management or for roadside stabilization, for instance. State owned tree nurseries could purchase biochar for use in growing media.
 12. Technology for Energy and Waste Management. Biochar may complement existing state programs that support bioenergy development. This potential should be explored for each state. Most important would be state support for biochar technology development specific to needs in that state for rural, distributed energy generation, or that addresses feedstocks in that state, building value chains. For instance, in California there is a large biomass resource in almond hulls, shells and prunings that could be used as biochar feedstock with the right technology. Some almond processors might need

- process heat energy, while others would benefit more from a cheaper, simpler but low emissions technology that only produces biochar.¹³ Furthermore, a lower value, less consistent biochar made with simple technology may find its most beneficial use in animal bedding and lagoons for managing manure and reducing emissions from California dairies.
13. State-Sponsored Research – Washington State Department of Ecology has funded a large set of feasibility studies and technology assessments for biochar, in conjunction with researchers at state universities.¹⁴ Other states could pursue similar research, focused on locally and regionally important applications.
 14. Carbon Footprint – States that have carbon reduction mandates should explore the possibility of using biochar for carbon sequestration, along with all of its other uses. In preparation for carbon protocol development, states can support life-cycle-analysis (LCA) of biochar systems to establish carbon footprint data.
 15. Biochar Standards – The International Biochar Initiative has developed biochar characterization and testing standards that are generally accepted by the industry, but more work needs to be done to determine exact biochar specifications and quality levels, such as the relative percentages of carbon and mineral ash, for individual applications. Perhaps this can best be accomplished through use cases that are developed at the local level as producers find markets for their products. For instance, use of biochar in compost may be constrained by ash content and pH levels, while another use in acid soils may benefit from ash and alkalinity. States can work with producers, users and the Association of Plant Food Control Officials (AAPFCO) to register products with state agriculture departments for specific uses. IBI, USBI and biochar producers have been working with AAPFCO to establish consistent labeling standards that represent quality levels that are meaningful to end users. States could facilitate this process by convening meetings and bringing producers and end users together. State ag and forestry extension services would have a lot of expertise to contribute to this effort.
 16. Extension Services – One of the biggest barriers identified by the biochar producers, users and experts interviewed for this study is applied information about biochar that is targeted to the user. Universities have produced a large body of valuable research that is not being transferred to farmers and other end users. State extension services are typically the conduit for such information and a major effort should be initiated to work with private and federal partners to provide such information.
 17. Education and Training – As the biochar economy develops, there will be an increasing need for education and training in both biochar production and applications. States could establish or support programs for training firefighters, forestry contractors and arborists in how to make biochar on site with simple kilns. The proliferation of biomass energy facilities that produce biochar will need trained operators. In applications, there will be a need to train farmers, landscapers, grounds keepers, compost yards, and city

managers in how to use biochar. Community colleges could offer a degree in biochar management.

18. Networking and Sharing – Associations like the Council of Western State Foresters are perfectly placed to conduct networking operations that ensure that quality work is shared among states and agencies to avoid duplication of effort. For instance, when leaders like the City of Portland establish BMPs for biochar use in stormwater management, these can be copied to other locations. Extension information produced by one state can be shared with others via the knowledge base at Extension.org. States with established biochar programs and knowledge can help others get started. For instance, the Nebraska Forest Service is working with the Guam Department of Agriculture to develop biochar production on the island of Guam.

6. Conclusions

The status of the biochar industry five years from now will depend on many factors, not least of which is effective action and support at the state level. Biochar production, like any business dependent on biomass, is inherently a local and regional activity. Biomass residues that form the feedstocks for biochar are a low value material, but the cost of using them goes up very quickly once they have to be transported. Biochar end products are also expensive to transport, and even though they have more value than raw biomass, they are still a low bulk-density material and are not cost effective to transport for long distances.

The biochar industry has made great strides in recent years as producers have improved production efficiencies and product quality. Biochar can be made from many feedstocks, including manure and crop waste, but the wood products side of the biochar industry is growing mostly through the mass production of biochar in modified biomass boilers and furnaces. Further innovations are ahead, with the deployment of air curtain burner technology for producing biochar in the field that can avoid the cost of chipping, grinding and transporting woody biomass to centralized plants.

Producers are finding that economies of scale are available at all scales, from small, low tech batch kilns used in the forest, to combined heat and biochar (CHAB) furnaces that provide heat for buildings and small industries, to large bioenergy facilities. Each scale can take advantage of its relative proximity to feedstocks, appropriate capital investment for the technology level, and any energy co-products. There is no one-size-fits-all for biochar production.

As the production costs go down, price reductions will be passed along to users who are eager to include biochar in soil blends, bio-fertilizers and compost, but cannot afford biochar at current prices.

If the industry can overcome several important market barriers, it has bright prospects. Some of these barriers can be addressed by state and federal entities through incentives, R&D funding and policy changes, as discussed above.

However, other barriers are incumbent upon the industry itself to solve. Most crucial are the development of biochar standards to properly identify and categorize biochar materials. The development of the biochar industry could be significantly accelerated by public support for an industry association to solve the standards problem. As yet, it seems that the industry is not profitable enough to fund such an entity by itself.

Biochar can do a lot of good for soils, environmental management in general, and ultimately as an important tool to mitigate the impact of climate change. This lends urgency to the development of the biochar industry and earmarks it as a priority for support from the citizens of the United States and especially the western states where so much of the nation's forests, farms, and rangelands are found.

7. References

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- ⁵ https://www.epa.gov/sites/production/files/2018-11/documents/epa_usda_doe_response_to_congress_re_forest_biomass_11-1-18_1.pdf
- ⁶ https://www.washingtonpost.com/opinions/states-can-lead-the-way-on-climate-change-lets-get-to-work/2018/12/11/2f3e4590-fd75-11e8-83c0-b06139e540e5_story.html?noredirect=on&utm_term=.e30196c1dd49
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- ¹² <https://www.agclimate.net/2018/05/03/biochar-and-forestry/>
- ¹³ <http://www.almonds.com/sites/default/files/content/attachments/Almond%20Orchard%202025%20-%20Zero%20Waste.pdf>
- ¹⁴ <http://csanr.wsu.edu/publications-library/energy/biochar/>

Table 2: US policy programs relevant to biochar production and application

Policy category	Incentive type	Level	Program	Status	Supporting/ Funding agent	Fund size (if any)	Eligibility of biochar	E.g. of awarded cases of biochar production and application
Commercial Financial Incentives	Loan Guarantee	Federal	Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (Section 9003)(USDA-RD, 2015)	Ongoing	USDA	\$250 million (2017)	Explicit	Cool Planet received \$91 million in 2014 to construct a biofuel plant with co-produced biochar.
			H.R. 3748 - Water Efficiency via Carbon Harvesting and Restoration (WECHAR) Act of 2009 (WECHAR Act, 2009)	Bill introduced			Explicit	
	Grants	Federal	Small Business Innovation Research Program (SBIR)	Ongoing	USDA and DOE	\$8 million (2017 USDA)	Implicit	
			Biofuel Infrastructure Partnership (BIP) Grants to States (USDA-FSA, 2015)	Ongoing	USDA	\$100 million	Implicit	
			Project Development for Pilot- and Demonstration-Scale Manufacturing of Biofuels, Bioproducts, and Biopower (USDOE, 2016a)	Ongoing	DOE	\$90 million (2016)	Implicit	
			Integrated Biorefinery Optimization(USDA-NIFA, 2017)	Ongoing	DOE & USDA	\$2.9 million (2017 USDA)	Implicit	
			Value Added Producer Grants(USDA, 2016)	Ongoing	USDA	\$18 million	Implicit	
	Matching Payment	Federal	Biomass Crop Assistance Program (Farm Bill, 2014)	Ongoing	USDA	\$12.5 million (2017)	Implicit	
			Conservation for Very Erodible Row Cropland Act of 2018 (COVER Act)(COVER Act, 2018)	Bill introduced			Explicit	
	Carbon Market	Federal	American Clean Energy and Security Act of 2009(ACES, 2009)	Bill introduced			Implicit	
		Carbon Farming Act (Carbon Farming Act, 2017)	Bill introduced	State of New York		Implicit		
		Iowa's Renewable Chemicals Production Tax Credit Program (IEDA, 2017)	Ongoing	Iowa Economic Development Authority	\$10 million/fiscal year*	Potential		

	Tax Credits	State	Biomass Tax Credits (ODOE, 2016)	Ongoing	Oregon Department of Energy	Varies based on biomass feedstock	Implicit	
			EZ Investment Tax Credit Refund for Renewable Energy Projects(Enterprise Zone Program, 2015)	Ongoing	State of Colorado	Up to \$750,000/year per project	Implicit	
	Production Payments	State	AGRI Bioincentive Program (MDA, 2015)	Ongoing	State of Minnesota	†	Implicit	
	Product Certification	Federal	Biopreferred Program (USDA, 2014a)	Ongoing	USDA		Explicit	10 biochar products identified for mandatory federal purchasing, 6 of which are also approved by USDA as Certified Biobased Product.
	Materials for Organic Crop Production	Federal	National Organic Program (USDA-AMS-NOP, 2016)	Ongoing	USDA		Explicit	Classifies biochar as an amendment acceptable for organic agriculture.
	Forest Conservation	Federal	Conservation Stewardship Program (Farm Bill, 2002)	Ongoing	USDA		Explicit	
	GHG Emissions Reduction Reporting	State	California's Biochar Production Project Reporting Protocol - GHG Emission Reduction Accounting	Ongoing	State of California		Explicit	
	Food and Agricultural Code	State	Fertilizing materials: auxiliary soil and plant substances: Biochar(Fertilizing Materials, 2016)	Approved by Governor	State of California		Explicit	24 biochar products are registered in the program, of which: 4 are approved, 2 pending review, 5 revisions required, 6 re-submitted, and 7 expired.
	Product Procurement	Federal	Environmentally Preferable Purchasing Program(E.O. 13693, 2015)	Ongoing	EPA		Explicit	
		State	Environmentally Preferable Products Procurement Program (EPP, 2009)	Ongoing	State of Massachusetts		Explicit	
	Renewable Portfolio Standards †	State	Renewable Energy Standard (RES, 2004)	Ongoing	State of Colorado		Implicit	
			Renewable Energy Standard (RES, 2008)	Ongoing	State of Missouri		Implicit	
Renewable Portfolio Standard (RPS, 2010)			Ongoing	State of Wisconsin		Implicit		

Policy Support	Research Support	State	Supporting the continued research, development, production, and application of biochar from our forests and agricultural lands (Support for Biochar, 2017)	In committee	State of Washington		Explicit	
			Concerning the Colorado General Assembly’s Support for the Continued Research, Development, and Application of Biochar from Our Forests. (Support for Use of Biochar, 2017)	Ongoing	State of Colorado		Explicit	
Research and Development Funding	Grants for Research and Demonstration Project	Federal	Biomass Research and Development Initiative (BRDI) (USDA-NIFA, 2011)	Ongoing	USDA, IBCE, and DOE	\$9 million (2017)	Implicit	In 2010 \$5.3M was awarded to a 5-year project “Integration of biofuels and bioproducts production into forest products supply chains using modular biomass gasification and carbon activation”.
			United States Forest Service Wood Innovations Grants (USDA-USFS, 2018)	Ongoing	USDA	\$7 million (2018)	Implicit	Number of biochar projects and total federal funding between 2015 and 2018: 2015: 6 (out of 43) projects, \$1.2M. 2016: 2 (out of 42) projects, \$202K. 2017: 5 (out of 38) projects, \$1M. 2018: 3 (out of 34) projects, funding not yet available.
			2013 Hazardous Fuels Woody Biomass Utilization Grant Program (USDA-USFS, 2013)	Closed	USDA	\$3 million	Implicit	Family Forests of Oregon awarded for its "Biochar Project for Pollution Remediation in Sweet Home, OR"
			Conservation Innovation Grants (CIG) (USDA-NRCS, 2017)	Ongoing	USDA	\$10 million (2018)	Implicit	In 2011, \$12K awarded to Earth Dharma Farm’s "Sustainable on-farm biochar production". In 2013, \$75K awarded to Sonoma Ecology Center’s “biochar farm and fuel”.
			Sustainable Energy Development Reform Act (SEDR, 2017)	In committee			Explicit	

		State	Maryland's Animal Waste Technology Fund Grant(MDA, 2018)	Ongoing	Maryland Department of Agriculture	\$3.5 million (2018)	Implicit	\$1.2 million awarded to Renewable Oil International MD, llc for animal manure management demonstration project to reduce poultry litter (50-63%). Biochar was identified as one of the by-products from thermal decomposition/fast pyrolysis.
			Carbon Farming Pilot Project in Columbia and Dutchess Counties (Carbon Farming Pilot Project, 2017)	In senate	State of New York		Implicit	
			Great Plain Biochar Initiative Grants for Biochar (NFS, 2018)	Ongoing	Nebraska and Kansas	\$40,000 (2018)	Explicit	

Ongoing: we define program status as ongoing if (1) the program is currently effective or has announced renewal, (2) the program continues to seek applications at the time of writing or (3) the program has completed and closed after Jan 1, 2015 (and is likely to be renewed).

*5 cents per pound produced by eligible businesses: up to \$1 million for start-ups and \$500,000 for established businesses

† 3 to 6 cents per pound of renewable chemical produced; \$1.053 to \$2.1053 per the equivalent of MMBtu of advanced biofuels produced; and \$5 per MMBtu of thermal energy produced

‡ All these three state programs include pyrolysis of waste materials as eligible technologies