2013 State of the Biochar Industry

A Survey of Commercial Activity in the Biochar Field

A report by the International Biochar Initiative (IBI)



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Executive Summary

In a world increasingly confined by resource limitations and impending climatic uncertainty, there is a search for strategies to mitigate these risks. In recent years, biochar has been identified as a possible tool to increase agricultural productivity, enhance agriculture's resilience to the impacts of climate change, reduce greenhouse gas emissions, and produce sustainable energy. In response, a biochar industry has emerged. Biochar, when added to soils, may enhance the resilience of soil ecosystems in the face of intensifying weather events and pressures to improve soil productivity. But not all biochars are created equal. Diversity in feedstocks, production technologies, and biochar end uses creates a complex web of variables that are not yet completely understood. Even so, early successes in biochar commercialization are evident in some areas and a biochar supply chain has emerged—from equipment manufacturers to biochar purveyors to production and use consultants. The biochar industry at present is in a fledgling state but there is upward trending growth for those companies working in specific markets. The future success of the industry will depend on the convergence of factors relating to research, investment, policy, innovation, and public education.

Key Findings

- In 2013, **the biochar industry is in a fledgling state**, comprised largely of enterprises selling relatively small volumes of biochar products locally for end uses such as gardening and tree care. **Biochar has yet to make a substantial entry into large-scale agricultural operations**.
- Unblended biochar and biochar products blended with other materials are being sold in many countries at a wide range of retail prices ranging from **$0.08 to $13.48 per kilogram**. The average price reported was $2.48 per kilogram.
- Companies reported **volumes of biochar sales totaling 827 metric tons**. 90% of those transactions were made by businesses in North America and Europe with the remainder made in Asia and Africa.
- **Woody biomass is by far the largest source of feedstock** for the biochar industry. Globally, the forestry and wood products sector offers a widely accessible source of woody residues that are often centrally located for ease of collection and transportation.
- The **scales and types of biochar production technologies being developed and marketed range widely**—from micro-scale cookstoves to large-scale industrial facilities. This diversity in technologies, and other characteristics like feedstocks and end uses, may be characteristic of an industry at an early stage of development and experimentation.
- The main **barriers to industry expansion are a lack of consumer awareness, technological constraints, and access to financing**. It is not yet possible to predict the yield gains from biochar in a way that would allow proposed applications to be valued. Education of stakeholders—from farmers to regulators to lenders—is key to expanding the industry.
- Scientific research into the various facets of biochar continues to expand rapidly. The number of **peer-reviewed biochar-related publications increased nearly five-fold over the last five years** with over 380 papers published in 2013.

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1 Introduction – Purpose of this Report

This report is intended to provide a broad overview of the current state of the biochar sector as identified by surveys and other data throughout 2013. It will give the expert as well as the layperson a snapshot of commercial and non-commercial biochar operations and activities, and put this information into the context of larger forces that influence the biochar space including agriculture, greenhouse gas (GHG) or carbon markets, and public policies. The report is based primarily on information gathered through public surveys and internet-based research but also on accumulated knowledge of the present biochar landscape offered by the authors and contributors of this report. It is the intent of IBI to produce this report on an annual basis to track trends and growth in the biochar industry—both on the commercial side as well as the project side.

1.1 Biochar Research Activities Facilitate Industry Growth

The establishment of a successful for-profit biochar industry ultimately depends on the ability of businesses to generate sustained positive revenues. Although there are, by now, hundreds of businesses set up to operate in the biochar space across the globe, the biochar industry is still in its infancy. On the other hand, biochar research and development (R&D) at universities and research institutions has experienced robust growth in recent years. As of fall 2013, IBI identified nearly 100 public and private institutions dedicated to biochar R&D. This is mirrored by a dramatic increase in biochar-related publications in the peer-reviewed scientific literature over the last 5 years (Figure 1).

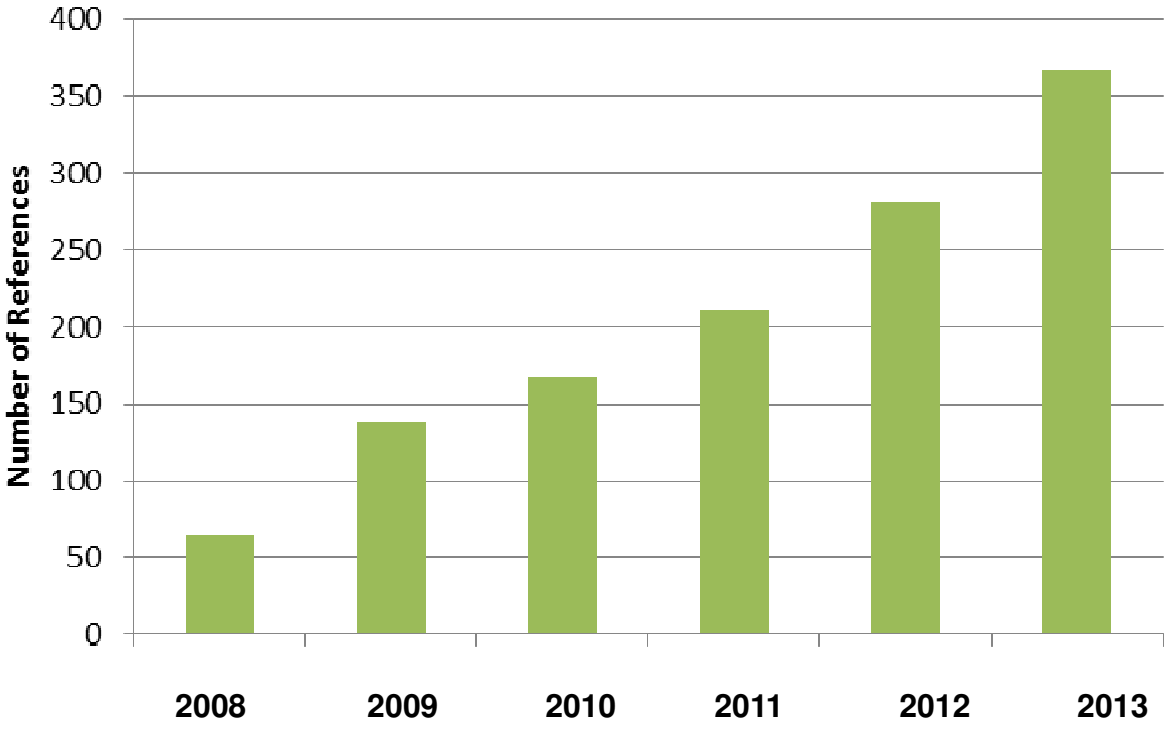


Figure 1. Growth in peer-reviewed biochar-related publications from 2008 – 13

In parallel with the basic R&D activities are the hundreds of biochar pilot projects actively being implemented worldwide that engage potential biochar consumers (e.g., farmers, landscapers, horticulturalists, etc.), raise awareness of biochar's benefits among key stakeholders like regulators, agronomists and extension agents, and aim to demonstrate the potential overall viability of biochar systems ranging from feedstocks to conversion technologies to cropping systems. In some cases, projects lead directly to for-profit ventures, but most often, they serve to raise awareness, identify overlapping opportunities, highlight barriers to implementation, and provide priorities for more research in the emerging field.

In the following pages, we report on the state of commercial (i.e., industry) and non-commercial (i.e., project) activity in the biochar space. We do not, however, report on the state of R&D; those activities, as in other technology sectors, will be ongoing even in a mature biochar industry. (More information on biochar R&D can be found on IBI's website at http://www.biochar-international.org/.)

1.2 Sources of Information

Information in this report is derived primarily from three sources: 1. two public surveys conducted by IBI during the summer of 2013; 2. data aggregated from the IBI member database; and 3. internet-based research of biochar-related company websites. Further information was gleaned, when possible, from consultations with stakeholders ranging from biochar entrepreneurs to scientists, and review of existing publications and analyses on biochar and related industries.

1.2.1 Online public surveys

The online public surveys were conducted by IBI in May and August 2013 to collect information on biochar project and industry activity, respectively. IBI designed the surveys and widely announced a call for participation amongst its 11,000-person network and all biochar stakeholders. In total, 95 project and 52 industry surveys were completed and submitted. Information in the industry survey was compiled and merged with an existing database derived from web research (see the following section) to create a master database comprised of 175 unique biochar businesses (see Appendix 1. List of Biochar Companies.

1.2.2 Internet-based research

Internet-based research was conducted in spring, summer, and fall 2013. IBI staff and interns built on existing lists of biochar-related businesses to create a database ultimately comprised of 212 businesses purporting to have a commercial link to biochar. This list was then reduced to 175 businesses deemed to be viable and sufficiently associated with biochar to be included in the database. To date, numerous businesses seeking to create intellectual property or other financial benefits from biochar have come and gone. When deciding whether to include an entity in the analysis outlined in this report, IBI used its best judgment based on the information available and its knowledge of the industry.

2 A Brief History of Biochar

Although the modern biochar industry is relatively new, using charcoal to improve soils has been part of soil management strategies by cultures for centuries. Charcoal is found in soils around the world as a result of vegetation fires as well as historic soil management practices. It is believed that the use of charcoal in soils in the Amazon goes back at least 2,000 years—and led to the creation of the dark, nutrient rich *terra preta de indio* (Portuguese for 'black earth of the Indian') soils of the Amazon which differ markedly from adjacent soils, in terms of having higher fertility and greater carbon content. The fact that these *terra preta* soils are still so fertile and productive today attests to biochar's persistence, even in relatively harsh conditions, and the ability of charred biomass to sequester and retain carbon in soils for long periods of time.

In addition to these soil management practices in the Amazon, charcoal has been used in traditional agricultural practices throughout Asia, especially in Japan, India, China, and African farming communities as well as in North America and Europe. The modern biochar industry should seek to use environmentally sustainable technological practices to produce biochar by reducing emissions from the production process. Additionally, for the most positive environmental benefits, the industry should ensure the sustainability of feedstock production and harvest in order to have a positive GHG balance.

The recent renewed interest in biochar stems from the discoveries by soil scientists working in the Amazon Basin from the 1960s onwards. Since that time, research into 'black earth' soils has increased significantly with a number of research programs focusing on biochar in the 1990s and into the early 2000s. Currently, the IBI website lists nearly 100 academic institutions worldwide working specifically on biochar research and the body of knowledge about this material continues to grow rapidly.

To help facilitate the growth and spread of credible biochar research, information, and projects worldwide, IBI was formed in July 2006 at a side meeting held during the World Soil Science Congress (WSSC) in Philadelphia, PA. At the 2006 meeting, individuals and representatives from academic institutions, commercial ventures, non-governmental organizations, federal agencies, and the policy arena from around the world acknowledged a common interest in promoting the research, development, demonstration, deployment (RDD&D), and commercialization of the promising technology of biochar production.

The first international biochar conference was organized and held in New South Wales, Australia, in April/May 2007, and attracted the participation of 107 attendees from 13 countries, representing a spectrum of backgrounds. By unanimous consent at the 2007 Conference, the IBI was established as a non-profit 501(c)3 in the US. Since that time, IBI has supported, organized, and hosted several biochar conferences, developed a strong website and international presence, developed and released the first internationally accepted biochar characterization standards (i.e., the *IBI Biochar Standards*), and launched the *IBI Biochar Certification Program* (see Section 3.8.1). For more information on IBI, please see www.biochar-international.org.

3 State of the Biochar Industry

The emergence of biochar as a promising soil management tool has instigated widespread R&D activities. As the unique biological, physical, and chemical properties of the material become clearer, investigations into applications for biochar other than addition to soils/carbon sequestration have arisen—from super-capacitors to contaminant filtration. Although IBI's focus is on biochar for soil application and for soil carbon sequestration, other uses for the material are being researched. This surge in research has created publicity in popular science outlets and the mass media. Entrepreneurs have clearly begun to take note. Businesses related to biochar production and uses have emerged around the globe in recent years and the world is witnessing the early stages of the formation of a biochar industry. In the following sections, we report on the state of this biochar industry—the size and types of enterprises and their geographic distribution; the economics of biochar markets; and the conditions for overcoming barriers to scale-up commercialization.

3.1 Biochar is a Spectrum of Materials

Any analysis of the biochar industry must begin with a discussion of the biochar material itself. Simply put, biochar is *a solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment*, as defined by IBI. Biochar can be distinguished from charcoal—used mainly as a fuel—in that a primary driver for its production is to use it as a soil amendment with the intention to improve soil functions and to reduce emissions from biomass that would otherwise naturally degrade to greenhouse gases. Among the community of researchers and stakeholders that use the term, although biochar is generally understood to be used first and foremost as a soil amendment, biochar is also being used for other purposes such as soil remediation and water filtration.

Biochar can be made from diverse feedstocks using a wide range of thermochemical conversion technologies (discussed in detail in the following sections). As a result, a biochar falls within a spectrum of materials with a common suite of physical and chemical (physicochemical) properties. These include variables typically used to measure and quantify the fertility of soils and soil amendments such as: carbon content; pH; electrical conductivity; cation exchange capacity; and macro- and micronutrient content, among others. Additional properties of relevance to biochar are ash content; the molar ratio of hydrogen to organic carbon (to estimate biochar carbon stability in the soil); and external and total surface area. Furthermore, biochar materials may contain undesirable contaminants depending on the feedstocks used as well as the thermochemical process conditions (e.g., heat and residence time). Examples of potential contaminants include heavy metals and organic pollutants like polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

What all biochars do share is a common set of characteristics that make them much more stable than their uncharred precursor materials and that can improve soil functions. While there are various methods to measure stability, some still undergoing refinement, there is widespread scientific agreement that biochar's stability is conferred by a high concentration of certain types of carbon compounds formed during the thermochemical conversion process. These compounds create a physical structure—a matrix—(Figure 2) that makes it particularly well-suited to

enhancing soil biological and physical processes while reducing mineralization. The interactions of different biochars with different soils are not yet fully understood. Application of biochar can reduce crop yields also, and the effects need to be investigated carefully in advance of any planned usage.



Figure 2. Biochar is a spectrum of materials made up of differing physicochemical properties. Note the well-defined pore structure in the scanning electron micrograph image on the right. Images courtesy of the UC Davis Biochar Database and biocharproject.org.

Because of the heterogeneity of the solid end-products of thermochemical conversion, characterization of the material is vital to understanding and relaying information on impacts from the material when placed in soils. To this end, IBI and other organizations, with the input of biochar experts, have developed characterization standards intended to provide assurances to researchers, regulators, consumers, and other stakeholders about biochar safety (see Section 3.8.1 for further information). The importance of these standards cannot be understated; in a largely unregulated industry the potential for misinformation and abuse abounds.

3.2 The Biochar Industry

Biochar as an emerging technological sector is still in its infancy. The term biochar to describe a soil amendment has only been in popular use for less than 10 years, yet there is a growing sense among biochar proponents of the potential for establishment of a biochar industry that delivers associated positive environmental and social benefits. The biochar space is characterized by wide-ranging and sometimes disparate activities including, among other things, rigorous academic investigation, industrial-scale research and development at large multinational corporations, backyard experimentation with homemade biochar kilns, and livelihood and food security engagements with communities in the developing world.

Given this backdrop, IBI defines the biochar industry as those *enterprises encompassing the commercial production, distribution, and marketing of biochar and biochar-related products and services*, for the purposes of this report. Within this definition, three sectors of biochar business entities can be broadly identified: 1) biochar production and/or product sales; 2) biochar

production equipment manufacturers; and 3) other biochar-related enterprises, such as consultants, product developers, and others.

Of the 175 commercial enterprises in the current IBI company database, close to half are involved in equipment manufacturing, one-third are in biochar production or sales, and the remainder are involved in related enterprises (Figure 3).

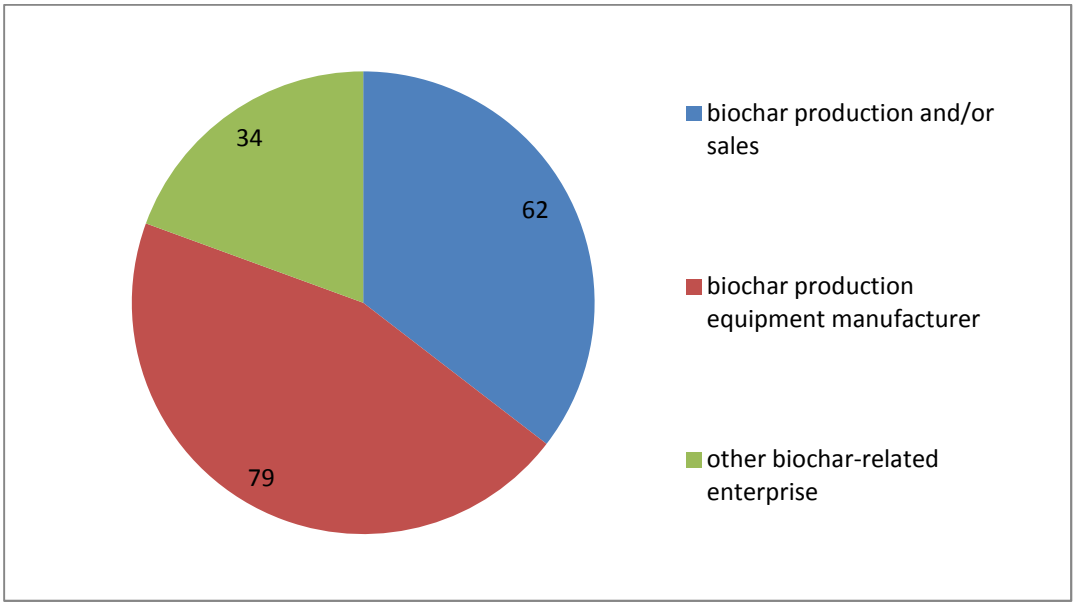


Figure 3. Companies in the biochar industry by sector

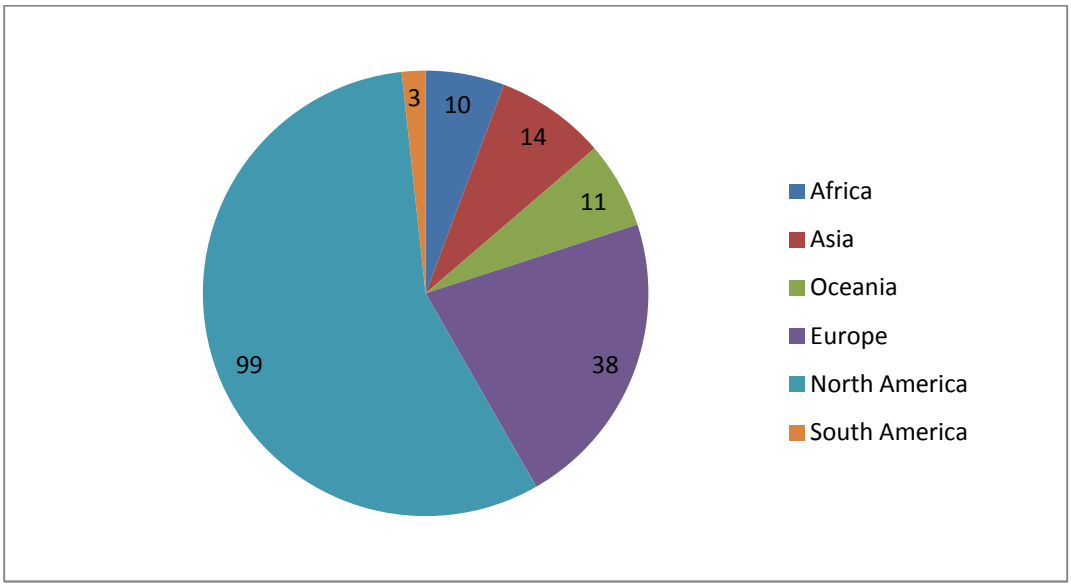


Figure 4. Geographic distribution of biochar businesses

At present these enterprises are located primarily in the developed world; over half are in the United States and another quarter is located in Europe (Figure 4). This distribution is not surprising at this stage in industry development; biochar enterprises often arise from active research and development efforts that seek to identify successful biochar technologies, systems, and business models.

3.3 Biochar Feedstocks

Biochar can theoretically be made from any source material or feedstock with high carbon content. The carbon-containing compounds in the feedstock are converted into persistent (stable) and labile (unstable) fractions in the final biochar product. Based on numerous scientific studies, the stable carbon compounds, primarily aromatic ring structures, are likely to remain in the soil for hundreds or even thousands of years, whereas the labile carbon compounds are usually microbially degraded within short periods of time from weeks to years, depending on climate.

Biomass—that is, the biodegradable fraction of materials derived from biological origin—is a logical feedstock source. Biomass can be subdivided into unprocessed feedstocks (for example, wood chips or corn stover) and processed feedstocks. The latter are those feedstocks that have undergone chemical (e.g., paper pulp sludge) or biological (e.g., digestion to produce animal manures or sludge from waste effluent treatment) processing. But other carbon-containing non-biomass materials such as plastics can, in theory, be converted into biochar. The use of such waste-stream feedstocks raises concern over potential contaminants such as chlorinated plastics. There are fewer problems with biomass-based feedstocks, in particular those derived from residues in agriculture, forestry, and related industries.

3.3.1 Feedstocks and environmental, social, and economic issues

While a wide range of feedstocks can theoretically be converted into biochar, certain issues limit the practicality of using some feedstocks. First, feedstock conversion challenges can arise due to the physical properties of the feedstock such as size or moisture content, or chemical properties such as high silica content. While the feedstock can be mechanically or chemically processed to facilitate conversion, it can be the case that the added cost of pre-processing makes the use of that feedstock cost prohibitive. Second, serious safety concerns could arise from the presence of contaminants in the feedstock. For example, municipal solid waste (MSW) or biomass grown on contaminated soils may contain plastics or heavy metals which can lead to the concentration, formation, or emission of environmental pollutants during the conversion process and in the final product.

To address these above-described concerns, the *IBI Biochar Standards* were developed to identify and prescribe common tests for the physicochemical properties of biochar, including safe levels of potential toxicants. The *IBI Biochar Standards* are intended to provide certainty to biochar consumers regarding biochar safety; to demonstrate that a product meets a minimum set of criteria to show that it is acceptable as a biochar; and to ensure regulators that the biochar industry is self-policing and assuring quality and product safety. A similar initiative has

arisen in Europe through the European Biochar Foundation's European Biochar Certificate. For further information on biochar standards and certification programs, please see Section 3.8.1.

The acquisition and procurement of biochar feedstocks should also be considered. There exist millions of hectares of degraded lands across the world currently unsuitable for high-value cultivation that could be rehabilitated through the use of properly selected biochar feedstocks in order to increase productivity for future food production. Increases in soil organic matter, reduced erosion, and overall improvements to soil health and fertility could result. No large-scale examples of this type of biochar feedstock production system have been documented, however, so such approaches must be well-considered and evaluated prior to adoption. There are also food security and livelihood concerns around the diversion of feedstocks from existing uses such as fodder, fuel, and fiber. Existing patterns of feedstock usage might be disrupted but this is only likely to occur if the biochar, or the increased crop yield it produces, is of higher value than the previous uses. Further, the removal of biomass from soils that would otherwise be left in place could lead to soil degradation if undertaken at unsustainable rates.

The feedstocks offering the best chance of financial viability are derived from biomass *residues*—the by-products from agriculture, forestry, livestock rearing, food production and processing, and related industries, which under a baseline scenario are not returned to the soil. In many cases, residues present waste management challenges, and biochar production can thus be viewed as a win-win solution. This is the case with urban green waste, for example; many municipalities around the world currently pay large sums of money to incinerate and landfill this material, and there are environmental and GHG impacts associated with its degradation.

Perhaps the greatest limitation to using any one feedstock, however, is the ability to procure it in large and continuous quantities and at low cost (including the costs of harvesting and transport). While biochar producers may find feedstocks that are low cost, free, or even cash-positive (e.g., due to tipping fees), as soon as demand for feedstocks increases—as it would with an established biochar industry—the price of feedstocks can be expected to rise in line with the economic principles of supply and demand. Biochar producers will have to factor this into their business models until feedstocks reach equilibrium price points.

3.3.2 The forest/wood products sector is the primary source of biochar feedstocks

Exactly 100 businesses were identified through the survey that provided information on feedstocks. The analysis shows that the forest products industry is by far the primary source for biochar feedstocks at present (Figure 5).

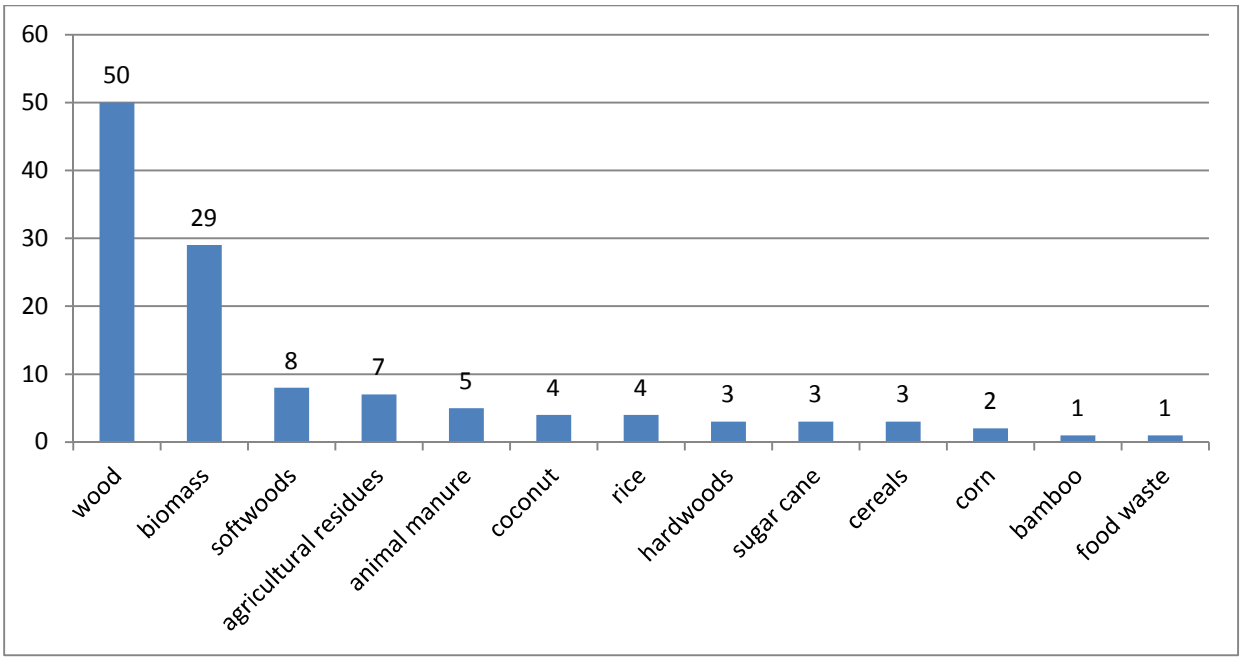


Figure 5. Feedstocks reported by companies producing biochar

Woody biomass—softwoods, hardwoods, or a combination—were listed as feedstocks in nearly 50% of biochar products (though this percentage is likely higher given that simply "biomass" was reported in one quarter of responses). Agricultural residues including bagasse from sugar cane, corn stover, rice husks, cereal straw, and coconut shells made up fewer than 20% of feedstocks. In total, plant-based residues made up nearly 70%. This contrasts with animal-based residues, primarily manure, that comprised just 4% of feedstocks. This is of particular interest given the attention that has been focused on using thermochemical conversion as a strategy to convert manure from a waste management concern into an asset. The low frequency of its current use as a biochar feedstock is likely a reflection of technological constraints around high moisture content, heterogeneity of material, and other physical characteristics of manures.

The current dominance of forest-based materials as biochar feedstocks seems to run counter to analyses of total biomass residue availability. Generally speaking, agricultural and forestry residues are often available in similar quantities (e.g., Milbrandt 2005). In the US, for example, there are around 157,000 and 167,000 tonnes of crop residues and forest and wood residues, respectively, available for utilization every year (Milbrandt 2005). In these early stages of biochar industry development, the prevalence of forest-based feedstocks may be due to several factors: 1) the relatively high concentration of forest residues centralized around, for example, industrial wood mills as compared to agricultural residues which tend to be dispersed in fields; 2) the homogeneity and consistency of woody materials making them relatively easier to use; 3) lower moisture contents than, for example, animal manures which eliminate the added cost of drying; and 4) a transfer of accumulated experience with woody biomass as a feedstock for bioenergy production.

Nonetheless, given the wide availability of agricultural residues at a global scale, an increase in their use for biochar production can be expected.

3.4 Use of Biochar

While biochars are a spectrum of materials, they do share some distinctive physical and chemical properties such as a stable carbon fraction and high surface area. For this reason, it is a material that is actively being investigated for diverse applications ranging from plant and animal agriculture to toxicant filtration to soil rehabilitation. In terms of market activity, however, nearly all enterprises focus on biochar end use as a soil amendment.

3.4.1 Soil use is the primary market target for biochar sales

Certainly the most widely marketed application for biochar is as an agricultural soil amendment. Scientific investigation of diverse agronomic properties is being conducted at research institutions around the world. Documented soil benefits of biochars can include the following:

- soil carbon sequestration and enhancement
- increased water holding capacity
- enhanced nutrient retention and cation exchange capacity
- enhanced crop nutrient bioavailability
- reduced nutrient leaching
- increased microbial activity
- pH amelioration
- enhanced aeration, structure, porosity, and tilth

Careful matching of biochar to a particular soil is needed to capture some of these benefits. Biochar can sometimes reduce crop yields for reasons that are still being investigated. An up-to-date bibliography on scientific publications investigating biochar's effects on soils and crops is available at: http://www.biochar-international.org/biblio.

While the potential agronomic benefits of biochar are wide-ranging, it is critical to note here that not all biochars will confer these benefits in every cropping scenario, and, as previously indicated, they may in some cases be detrimental to soil and crop health. Biochar is a spectrum of materials with diverse properties arising from feedstock choice and conversion process conditions. While physicochemical properties such as pH, macronutrient content, ash content, particle size, and surface area vary, sometimes widely, all biochars do share the property of much greater stability in soil than the biomass they are produced from characterized by the presence of specific carbon compounds (see Section 3.6 for further information). This underscores the importance of creating and utilizing biochar industry standards—such as the *IBI Biochar Standards*—to demonstrate that the product of the thermochemical conversion process can be classified as biochar. With this baseline information in hand for a given biochar

material, further work is needed to match soil types and cropping systems suited to the particular suite of physicochemical properties of any given biochar.

3.4.2 Diverse non-agricultural uses for biochar are proposed

While use as a soil amendment for increased soil health and plant productivity is currently the predominant marketed application for biochar, the essence of biochar's unique physical structure—essentially a matrix of stable carbon compounds—makes it useful for other purposes. Ongoing R&D activities investigating other uses include:

- Filtration – Whether in smokestacks in industrial settings or distributed in the landscape, the high sorption capacity of specific biochar types makes them a good option for filtering toxics from the air, water, and soil. For example, numerous studies have shown that specific biochars adsorb and bind heavy metals making them less environmentally available. Biochar that has absorbed toxics in its matrix could be accumulated and disposed of in a safe location, or even chemically processed to flush out the toxics, essentially recharging the biochar for re-use. This application for biochars been tested in commercial settings with some success.
- Livestock operations account for a large percentage of GHG emissions, and overall resource utilization. Numerous research groups have found positive benefits of utilizing specific biochars as an animal feed additive and in other aspects of animal agriculture. Among these are reductions in enteric methane emissions from ruminants, enhanced weight gain and growth, increased animal vigor when used as a feed additive, and reduced ammonia emissions from poultry litter when added to bedding material, which can enhance animal health and reduce mortality and morbidity in poultry houses where it is used.
- Supercapacitors – Power supply devices similar to batteries that are currently used in a wide variety of technologies, supercapacitors are usually made with activated carbon. Researchers recently demonstrated early successes with wood-biochar supercapacitors at a fraction of the cost of activated carbon. It should be noted that this application is still in the early stages of R&D.

Despite significant and global R&D into non-agricultural uses, only a handful of for-profit biochar enterprises are focused on these other uses, mainly in the area of soil remediation. However, if the research bears more promising results, it is anticipated that entrepreneurs will respond by launching enterprises focused on these and perhaps various other biochar uses.

3.4.3 Biochar and climate change mitigation

In addition to agronomic benefits, a significant amount of research has been conducted on the potential of biochar as a tool for reducing the risk of climate change. Biochar is a much more stable material than uncharred biomass. When placed in the soil, the stable carbon component of biochar may stay there largely unchanged for hundreds or even thousands of years, as evidenced by *terra preta* soils. If used on a planetary scale, analyses have shown that biochar soil incorporation could appreciably reduce net atmospheric GHG emissions (Woolf et al 2010).

An important aspect of this GHG mitigation potential relates to the feedstocks that are used to make biochar. In order to draw down GHGs from the atmosphere via biochar, feedstocks should come from waste residues from agriculture, forestry, or related industries that would otherwise have been burned or left to decompose, thereby emitting GHGs to the atmosphere. Current agricultural and forest management practices include the burning or decomposition of many gigatonnes of residues (e.g., corn stover, rice hulls, forestry slash, milling waste, and others) annually across the globe. In some cases, the residues are left to decompose, and can create other negative environmental impacts such as eutrophication of waterways; in other cases, prohibitions on burning agricultural or forest residues creates a need to cost-effectively and sustainably deal with these residues, in which case, biochar production can resolve multiple issues. Since biomass residues originally withdrew carbon from the atmosphere during their growth phase prior to harvest, when these unutilized residues burn or decompose—aerobically or anaerobically—they simply release the carbon back to the atmosphere as part of the carbon cycle. These management practices are thus said to be *carbon neutral* and do not have an impact on atmosphere GHG concentrations. If, on the other hand, those residues are converted into biochar and the recalcitrant carbon remains in the soil for a longer period of time than the uncharred biomass, the carbon therein will essentially be pulled out of the carbon cycle for what may be an extensive period of time. In this case it can be said that the management practice of converting waste residues into biochar and placing them in the soil can be *carbon negative*.

When calculating the GHG impact of biochar used for agriculture, however, it is necessary to consider the entire life cycle of its use, beginning with feedstock procurement and progressing through all of the intermediary steps to final soil incorporation. At any stage in this process there may be ancillary GHG emissions that could offset the carbon sequestered in the stable portion of the biochar, thereby making the overall biochar system carbon neutral, or, indeed, even carbon positive over a certain period of time. For example, biochar that is transported long distances over land and then tilled into the soil may have significant emissions associated with transportation and tillage. Life Cycle Assessments (LCAs) are established tools to quantify the impacts of products throughout supply chains and are applicable to biochar in this context.

3.4.4 Marketing the climate benefit of biochar

The emissions reduction and climate change mitigation benefits of biochar are frequently touted on biochar product labels and websites. However, pinpointing a consumer's motivation to purchase biochar specifically for reasons of climate change mitigation is difficult. At this stage in the industry, those considerations are less likely motives to purchase than benefits such as improving soil functions and increased plant vigor. In the biochar industry survey, 14% of respondents from the three categories of biochar businesses (n=74) believed that the main obstacle to commercialization of biochar was a lack of access to carbon markets (see Figure 13 later in the report). While this is a minority opinion, it does reflect the belief or recognition that carbon market revenues from biochar projects may in the future be an important component in the bottom line of biochar enterprises. IBI is studying the issues but the current view is that the ability to sell carbon credits for proven storage of biochar in soil or elsewhere may contribute to the revenues of a biochar business but will be too small to sustain biochar production alone.

A critical advance necessary to make the climate benefit of biochar a quantifiable component of its revenue generation potential is the establishment of a mechanism for crediting biochar projects in the carbon offset marketplace. Such a mechanism would facilitate the monetization of biochar carbon sequestration and put it on par with other accepted offset methodologies such as energy efficiency, enhanced forest management, and others. An encouraging development is the recent publication of a draft methodology for biochar carbon offset projects (see the following section).

Even with a verified carbon crediting mechanism, to have a significant impact on atmospheric GHGs, vast quantities of biochar must be produced. This would require large, sustained commitment of capital in the form of production equipment over range of sizes. Long production runs of successful designs should reduce the cost of equipment. Presently the volume of sales of units with large capacity (defined as a throughput of > 10 tonnes per day; see Table 3 below) needed to produce the quantities of biochar necessary to have any meaningful impact on GHG concentrations is minor. However, increasing research and investment in biochar manufacturing technologies suggests that production capacity is poised to increase in the coming years.

3.4.5 The American Carbon Registry's Methodology for Emissions Reductions from Biochar Projects

In fall 2013, the American Carbon Registry (ACR), a project of Winrock International, posted for public comment the Methodology for Emissions Reductions from Biochar Projects. ACR is a leading carbon offset program active in both the voluntary and regulatory markets. The methodology—designed to credit biochar projects within voluntary carbon markets—quantifies the stable carbon component of biochar, defined as carbon expected to remain in soil 100 years after biochar application, as well as the avoided emissions from feedstock combustion and decomposition. This methodology represents the first robust attempt to develop a market-based mechanism to monetize the carbon sequestration potential of biochar. As of publication of this report, the methodology was still under review. More information on the methodology is available on ACR's website (http://americancarbonregistry.org/).

3.5 Cost of Biochar

The cost of biochar is a key component in the business plan of any company intending to produce or market biochar. In cases where biochar is the primary product, gross revenues from biochar sales must cover operating expenses including production, maintenance, marketing, and distribution to ensure long-term business viability. In other cases, biochar may be an ancillary byproduct from processes designed to create efficiencies in established agricultural or land management operations as well as heating systems. In these instances biochar sales may contribute to the revenues of the business. For example, an animal feedlot operation may install pyrolysis equipment to deal with excess manure thereby solving a waste management problem while simultaneously creating a marketable biochar product. Whether biochar is a primary or secondary product in any given operation, its value will be determined by the price customers are prepared to pay for it. In this section, we report on prices and markets for biochar identified in surveys and web-based research.

3.5.1 Global biochar price averages

Forty-three businesses provided pricing information for their biochar product (Table 1). The companies were spread out across North America, Europe, Oceania, Asia, and Africa (though interestingly none in Latin America); however, over half of these companies were located in the United States (23) with only the UK, Germany, and the Philippines home to more than one company. Based on survey responses and web research, it was not always clear whether the prices quoted were retail (point of final sale) or wholesale/producer prices (that the manufacturer of the biochar could expect to obtain). As most businesses appear to be selling biochar or biochar-containing products in small packs, large differences between producer prices and retail prices are to be expected.

In Table 1, the number of companies reporting sales in various countries is listed with the mean prices claimed for pure and blended biochars. Globally, the mean price for pure biochar was US$2.65/kg; this ranged from a low of US$0.09/kg in the Philippines to a high of US$8.85/kg in the UK. For blended biochars the mean price was US$3.29/kg with a low of US$0.08/kg in India and a high of US$13.48/kg in the US.

Table 1. Prices of pure and blended biochars[1] reported by companies

Price biochar ($US/kg)[2] updated November 2013						
Country	**N**	**Mean (Pure)**	**Mean (Blend)**	**Min**	**Max**	**Std Dev**
Australia	1	3.44	-	-	-	-
Austria	1	0.68	-	-	-	-
Canada	2	3.47	-	1.50	5.45	2.79
Germany	2	3.40	1.85	1.85	3.40	1.10
Ghana	1	0.35	-	-	-	-
India	1	-	0.08	-	-	-
Ireland	1	-	3.40	-	-	-
Kenya	1	-	1.00	-	-	-
Philippines	2	0.09	0.10	0.09	0.10	0.01
South Africa	1	-	0.30	-	-	-
Spain	1	1.83	-	-	-	-
Sri Lanka	1	0.32	-	-	-	-
Switzerland	1	0.66	-	-	-	-
UK	4	5.06	0.41	0.41	8.85	3.55
USA	23	2.74	5.94	0.27	13.48	2.87
TOTAL	43	2.65	3.29	0.08	13.48	2.68

[1] Where companies offered different quantities and prices, the values reported here reflect the lowest price per unit quantity listed. Prices do not include any shipping or handling costs or VAT. The minimum, maximum and standard deviations were calculated across pure and blended biochars.

[2] Assumes 1 US quart (volume) = 1 pound (mass)

3.5.2 Biochar sales target high-end niche markets

Of the 62 companies selling or planning to sell biochar, the vast majority of those (more than 90%) are focused on sales to high-end niche markets as opposed to large-scale agricultural operations. In practice, this means that companies are mostly selling retail—either directly on their websites or at nurseries, garden centers, or similar outlets—not wholesale, and for end uses such as home gardening, landscaping, plant nurseries, and other small-scale consumer markets. By contrast, less than 10% of the companies focused on other markets such as land remediation, or larger scale farm applications, and of these only three companies actually listed a product for sale.

Based on this data, it appears that biochar market activity is largely centered on small specialist retail outlets, even while R&D focuses primarily on the benefits for large-scale production agriculture and GHG reduction. This opposition of market and research activities leads us to conclude that production costs are too high, and the demonstrated value too low, for large-scale application at this time. As a result, biochar prices at present are only viable for small-scale applications where customers are willing to pay $10 for a few kilograms of biochar product—for home gardening, for example, or high-value horticulture or specialty crops.

3.5.3 Marketing biochar blends is common practice

Biochar products currently offered for sale are often blended with additional ingredients including (in order of prevalence): compost/compost tea, fungal mycorrhizae, soil micro-organisms, kelp meal/seaweed, clay/other minerals, animal manure/urine, vermicastings, and peat. Of the 43 companies in Table 1, 26 sell only pure biochar while the other 17 offer biochar blends. Overall, two-thirds of the companies selling or planning to sell biochar offer pure biochar and the other third offer biochar blends.

Blending does not, however, correlate to the price of the product. For example, in the US the average price for pure biochars and biochar blends was $2.74/kg and $5.94/kg, respectively. In the UK and Germany, however, prices for pure versus blended biochars were the opposite; that is, pure biochars were twice as expensive as blends in Germany, and nearly 14 times as expensive in the UK (note the small sample sizes in both cases). These oscillations in the prices of blended biochar products may depend on the value associated with the blending ingredients. For example, "effective micro-organisms", marketed as an ingredient by more than one seller, may be costly whereas manure, compost, and other readily available additives are less expensive relative to biochar. Or, the differences in prices may simply reflect different commercial strategies rather than raw production costs.

3.5.4 Biochar sales are small but growing

Because the biochar industry is still young, there is a dearth of data available on the volumes of biochar being transacted. Nonetheless, information gleaned from a subset of respondents to the online survey reveals some interesting trends. Sixteen companies reported combined sales in excess of 800 tonnes of biochar (Table 2); the vast majority of which (91%) was sold in Europe

and North America. However, because at least 62 companies globally are selling or planning to sell biochar, these volumes are almost certainly an underestimate. For example, in Australia no data was gathered but anecdotal reports indicate that biochar is being transacted commercially in that country. The difficulties encountered in completing this dataset points out a stumbling block in estimating financial transactions at this phase of evolution in the biochar space; in a fledgling industry entrepreneurs are hesitant to share information about their businesses.

Table 2. Volumes of biochar product sales by region reported by companies over the previous 12 months

Region	Volume transacted (tonnes)	% market share	N
Africa	25	3.0	2
Asia	56	6.7	3
Europe	205	24.8	3
North America	542	65.5	8
TOTAL	827	100	16

In terms of dollar amounts, approximate annual revenues reported to us by companies totaled nearly $800,000 and $1.25M for biochar vendors (n=12) and equipment manufacturers (n=7), respectively. The relatively small number of respondents (roughly an order of magnitude less than the actual number of enterprises claiming to sell biochar and production equipment) means that these reported revenues may be an underestimate of total sales in the biochar industry. It may mean that many enterprises are not yet selling product but may (or may not) do so in future.

3.5.5 Comparing biochar with compost and fertilizer industries

Presently, the 23 US-based companies that give pricing information sell their biochar products for a median price of US$2.86[3] per kg, or US$2,860 per metric ton (tonne). Compare this to compost, another organic soil amendment, that typically retails for US$30 – 50 per tonne—a factor of 10 less than biochar. While compost is physically and chemically different from biochar, the well-established compost industry nevertheless serves as an interesting comparison and benchmark for the emerging biochar industry.

Compost enjoys significant market share as a soil amendment. According to the US Department of Agriculture Economic Research Service (USDA ERS), in 2011 nearly 86,000 tonnes of compost was consumed in the US. Assuming a price of $50 per tonne, that equals sales of around $4.3 million. This number is likely a gross underestimate, however. For example, a 2003 analysis estimated that in California alone, over nearly 10 million tonnes of compost was sold for an estimated $52.5 million in revenue (Coker and Goldstein, 2004). Given increases in demand and regulatory drivers mandating composting it can be assumed that this number has

[3] Note that this price also includes biochar products that are blended with other ingredients.

increased in the last decade. Most likely the discrepancy between the estimates is a reflection of the USDA data only capturing a fraction of the actual annual compost consumption.

Comparisons to the chemical fertilizer industry can also be made. In March 2013, the average US farm price of common fertilizers such as urea and triple superphosphate was $537 and $635 per tonne according to the USDA National Agricultural Statistics Service (NASS). These prices are within the low end of the range of some of the prices biochar vendors in the US are currently offering. The comparison may end there, however. The immediate productivity gains that chemical fertilizers offer are typically realizable in the same growing season in the form of higher yields and thus profits to the farmer.

The value proposition for biochar is not as straightforward. In effect, most of the benefits of biochar are realized as multi-year investments in the soil with dividends payable over time, likely several growing seasons. In a world where farm productivity is often measured in yield per unit area rather than in soil health, the business case scenario for biochar is thus not as clear-cut. Additionally, with up to half of all farmland in the US and some other countries farmed via leases or short-term (12-month) rentals, long-term investments in soil health are less likely to be a priority for those farmers renting or leasing land. Yet in a world with constrained natural resources, limited land, and rising costs for inputs—not to mention increasing frequency of erratic climatic events such as droughts and severe storms—there is an opportunity to develop quantified arguments that biochar may be a useful tool for increasing soil productivity while reducing the need for some inputs, and enhancing on-farm resilience.

3.6 Biochar Production

Biomass feedstock can be converted into various products including solids, liquids, gases, and heat through a range of thermochemical decomposition processes, beginning with the slight charring of biomass—browned and brittle but not fully charred—and ending with complete combustion—the burning of biomass resulting in the production of heat, gases, and ash. Along this span of thermal decomposition processes lies pyrolysis (Greek for "decomposition by fire"), the primary means of maximizing the production of the solid byproduct, biochar. Pyrolysis occurs at temperatures ranging from 300 – 600C and under low or zero oxygen conditions. Gasification, occurring at slightly higher temperatures and with limited oxygen flow, maximizes the production of producer gas (impure synthesis gas) for energy production but can also produce a solid biochar byproduct.

3.6.1 Scales of biochar producing technologies have a wide range

While pyrolysis and gasification are fixed processes that are governed by the laws of thermodynamics and chemical kinetics, the technologies capable of generating and sustaining these processes are highly diverse. On one end of the spectrum lie simple, low-cost cookstoves that can be built from spare metal such as coffee tins (Figure 6). On the other end are multi-million dollar industrial facilities engineered to process many tons of feedstock per day. An example of the latter is the Tokyo Bureau of Sewerage's sludge carbonization facility that processes up to 300 tonnes of sewage sludge on a daily basis into a carbonized fuel for energy production (in this case the material is combusted as a fuel rather than used for a soil



Figure 6. Scales of biochar production technologies. Biochar producing cookstoves (above) and the Tokyo sewage sludge carbonization facility (below). Images courtesy of Jock Gill and the Tokyo Metropolitan Government.

amendment and would not be considered biochar). Bookended by these two examples are a wide range of technologies that span an array of size, design, and complexity.

The survey identified a total of 84 companies selling or planning to sell biochar production equipment. Although there is a wide range of possible sizes for biochar production equipment, the majority of active vendors produce mid- or large-scale units (Table 3), defined here as the capacity to process feedstock at rates >1 ton and >10 tons per day, respectively. The numbers of companies involved in small- and micro-scale technologies is not trivial, though.

There is a clear geographical overlay to the scale of technologies being offered. As might be expected companies located in North America, Europe, and Oceania are overwhelmingly producing technologies in the large- to mid-scale range whereas those located in Africa and Asia are primarily producing small- and micro-scale units. It is also important to note that many projects around the world in developing countries are focusing on small- and micro-scale units and may not be run by for-profit companies. This is not surprising; the scale of interventions in the biochar space is a reflection of the scale of activities needed to support biochar development including such factors as access to industrial machinery and other inputs for agriculture and forestry, the overall infrastructure (e.g., transportation systems, power supplies, etc.) of a country or region, and the ability of entrepreneurs to access the capital resources needed to drive production.

Table 3. Scales, examples, and numbers of biochar producing technologies

Scale	Capacity (throughput)	Example technology and use	N
large	>10 tons/day	Industrial pyrolysis plant used to produce heat energy for power generation and a biochar byproduct for wholesale	30
mid	1 – 10 tons/day	Mobile continuous feed pyrolyzer used to convert forestry slash *in situ* to biochar for forest soil regeneration	29
small	10 – 1000 kg/day	Batch retort kiln used by small farmers to convert agricultural residues to biochar for retail sale via niche outlets	17
micro	<10 kg/day	High efficiency biochar-producing cookstove used in developing countries to cook meals and produce biochar for home gardens	8

There is a wide variety of technological configurations for pyrolysis and gasification equipment. Figure 7 below depicts the frequency of biochar producing technologies in use. These can be roughly divided into two main categories: 1) continuous feed and 2) batch processes. Continuous feed systems rely on auger screws or other mechanisms to deliver a constant supply of feedstock to a reaction chamber to maintain the pyrolysis or gasification process. Batch systems, on the other hand, use a single-load construction that requires loading of the feedstock and unloading of the product each time the pyrolysis process is completed. A common example of batch systems are retort kilns which can be visualized as a "can inside a can" construction.

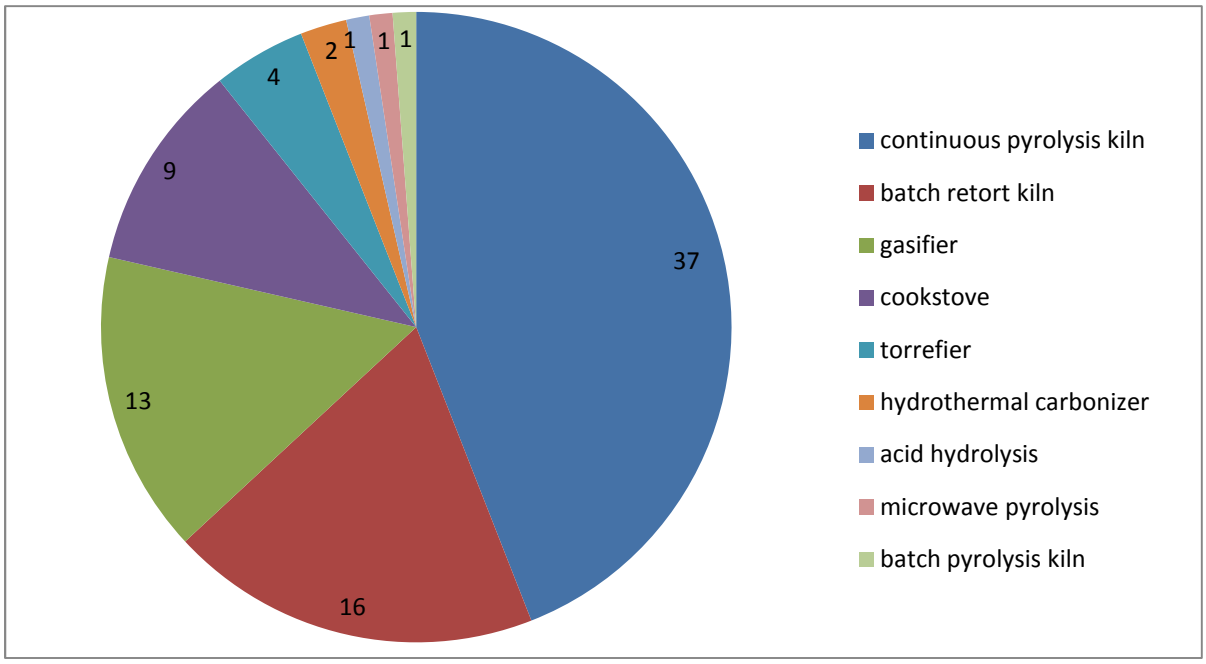


Figure 7. Frequency of type of biochar production technology (n=84)

3.6.2 Equipment manufacturing is focused in North America and Europe

Eighty-four businesses were identified across the globe that are developing or selling biochar-producing technologies (Figure 8). Over three-quarters of these are located in Europe and North America, but all regions show some level of entrepreneurial activity around biochar production equipment.

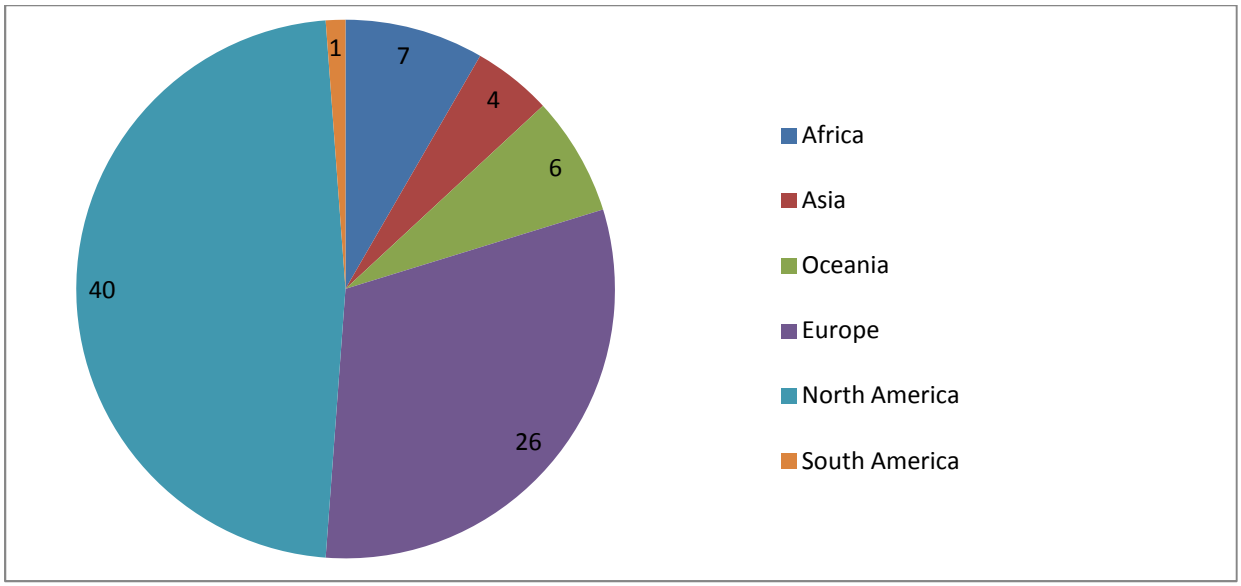


Figure 8. Numbers of companies producing or selling biochar production technologies by region (n=84)

The apparent lack of business attention given to biochar in South America—the origins of the current R&D interest in biochar—is an interesting phenomenon. This could be due to language barriers or a less organized and focused industry group. There is ample degraded arable land as well as intense agricultural and forestry activities in various parts of the South American continent. The utilization of biochar would seem worthwhile from multiple perspectives. Although the project surveys identified projects based in Central and South America, few were for-profit industries that are included in the business database.

3.7 Purveyors of Biochar-Related Goods and Services

In addition to the two main categories of enterprises discussed in the previous sections—those producing and selling biochar and those involved with manufacturing and distributing biochar production equipment—there exists a third category of enterprises engaged in or identifying with the biochar space. Activities here span a broad range and include (in decreasing order of prevalence): consulting, biochar enhancement, materials testing, marketing services, biofuels R&D, training and capacity building, and a small number of other related services (Figure 9).

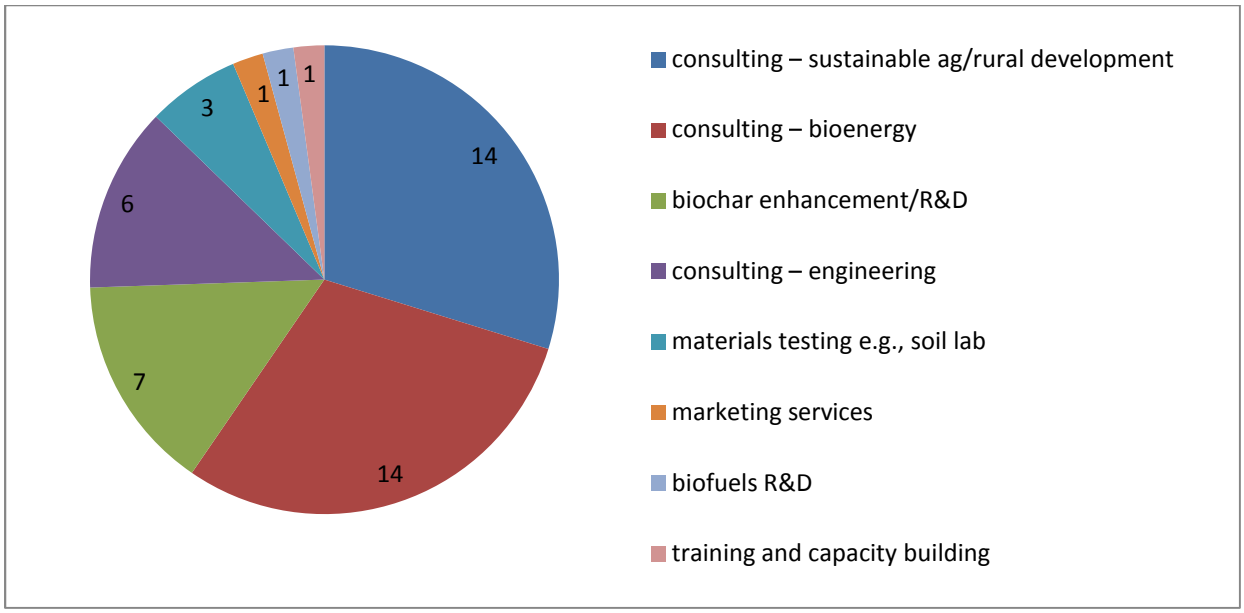


Figure 9. Types of services offered in the biochar space as listed by survey respondents (n=27)

3.7.1 Consulting on agriculture, bioenergy production, and engineering dominate biochar-related services

Consulting services offered in the biochar industry are varied. Sustainable agriculture and rural development as well as bioenergy production are the predominant categories of consulting services offered. In the former case, businesses seek to enhance the agricultural impact of biochar projects—often smaller scale initiatives in rural, developing country settings—by analyzing factors such as soil type, crops, climate regime, farmer capacity, and available inputs, making recommendations on biochar production techniques and application rates, and offering training and capacity building. These consultants are contracted by project developers that include entities such as local community groups, farmer cooperatives, rural development institutions, and, in some cases, individual farmers looking to implement biochar projects.

In the case of bioenergy (and by extension engineering) consulting, a primary service is to work with biochar project proponents and equipment manufacturers to find ways to enhance the efficiency of thermochemical conversion systems and to utilize the heat energy, producer gases (low-grade syngas), and bio-oils created during the conversion of feedstock into biochar. Indeed, capturing and utilizing these byproducts may be critical to the financial viability of a given project, because revenues from biochar alone will often not recoup the costs associated with the business. There are numerous ways that the thermal energy, fuel gas, and bio-oils can be utilized as part of the biochar life cycle, as demonstrated by survey respondents in Figure 10 below.

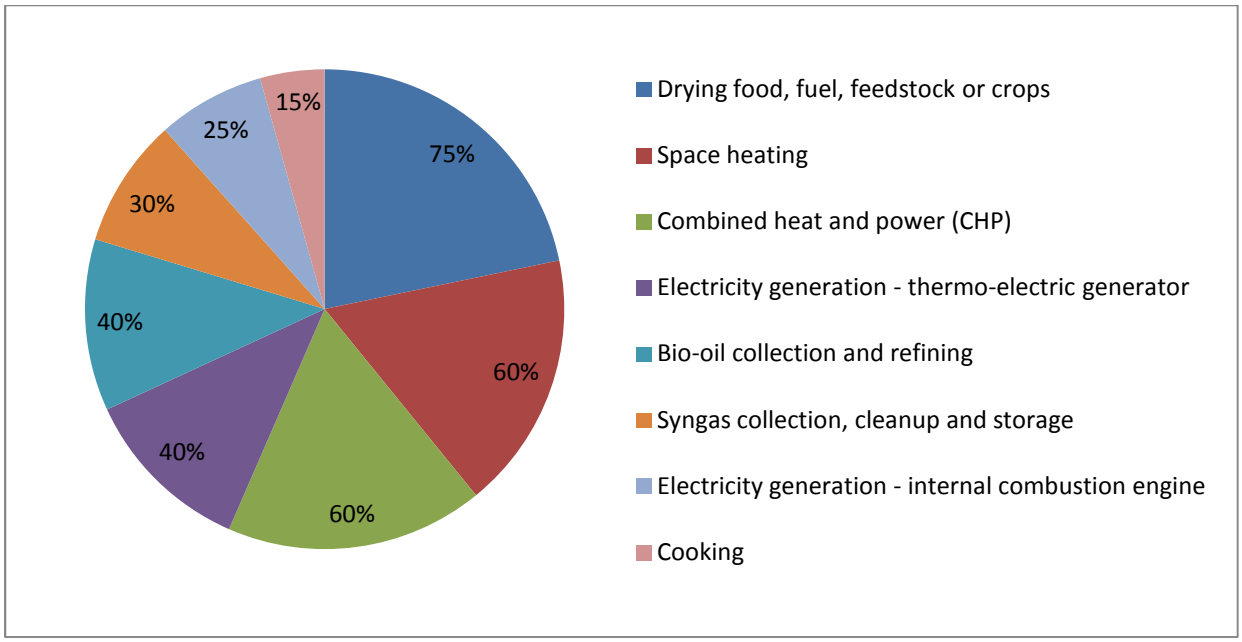


Figure 10. Uses for energy capture listed by biochar production technology manufacturers (n=20)

Furthermore, there are also cases where consultants work with bioenergy projects to maximize the biochar production quality and potential of an existing conversion technology. For example, gasification systems designed to process excess poultry manure and utilize thermal energy for heating poultry barns have been retrofitted to also produce a biochar co-product. This illustrates how the bioenergy sector—relatively well-established in comparison to the biochar sector—can add to its revenues through the additional value stream associated with biochar.

3.7.2 Biochar enhancement is key to future commercialization

Survey data also revealed that considerable emphasis is placed on "biochar enhancement" i.e., biochar product research and development (see Figure 9 above). This involves activities around custom formulation to identify biochar characteristics and traits—including when mixed with ingredients such as compost, minerals, and chemical fertilizers (see Section 3.5.3 above)—that can be targeted at specific soil and crop uses.

Although this was not the main activity identified by respondents to other biochar-related services, it is likely that biochar R&D is more common than would seem based on the data in the business survey. In the project survey data, over 45% of the survey respondents stated that research institutions were the key lead in developing and implementing the biochar project. In-house R&D on biochar products by producers and vendors will be an integral component of developing the value proposition for biochars. Research into biochar has clearly demonstrated that not all biochars are created equal, and that biochar is rather a spectrum of materials with some common characteristics, not the least of which is the long-term stability of the stable carbon fraction of the biochar in soils. Matching specific feedstocks with thermochemical conversion parameters to produce biochars with consistent characteristics, and further

understanding and identifying impacts of those biochars in soils, is a critical part of being able to communicate the value of a specific biochar to a unique soil and cropping regime.

3.8 Policies and Programs to Advance the Industry

The nascent biochar industry is largely being shaped through the actions of entrepreneurs and other stakeholders from the private and non-profit sectors. Picking up on advances in the biochar research and science community, these actors are helping to develop and demonstrate technologies and applications for biochar. As this industry continues to emerge and gain more attention, stakeholders are recognizing the importance of working within the framework of laws, regulations, codes, and other public policies—from the local to the international—that can support (or hinder) the commercial success of biochar. In addition to public policies, private sector market-based initiatives are emerging as tools in advancing the commercialization of biochar. The following sections examine both private and public sector programs that are helping shape the biochar industry.

3.8.1 Standards, certification, and labeling



Figure 11. The *IBI Certified™ Biochar Seal* used in the *IBI Biochar Certification Program*

The use of a consumer-facing label is a well-established technique used to differentiate products in the marketplace. The label is typically based on the producer complying with a standard and is assessed within the framework of an associated certification program. The standards range from loosely defined criteria created by a company or set of companies intending to use the label, to rigorous third-party programs developed by standards-setting organizations and enforced by independent, accredited auditing bodies. Included in these are programs that are enforceable by governmental regulations. For example, in the US the certification of organic agriculture is overseen by the US Department of Agriculture's National Organic Program (NOP). According to the Ecolabel Index—the world's largest directory tracking the use of ecolabels defined as "a sign or logo that is intended to indicate an environmentally preferable product, service or company, based on defined standards and criteria"—there are currently 445 recognized ecolabels in 197 countries and 25 industry sectors.

In the biochar industry, several standardization and certification programs have recently arisen. Most notable among these for its transparency and depth of participation in development are the *Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil* (also known as the *IBI Biochar Standards*) and the associated *IBI Biochar Certification Program* http://www.biochar-international.org/certification[4]. Developed by the US-based non-

[4] Note: The authors of this report are associated with IBI—the administrators of the *IBI Biochar Standards* and *IBI Biochar Certification Program*.

profit organization the International Biochar Initiative, the *IBI Biochar Standards* seek to establish a common definition for biochar, and testing and measurement methods for selected physicochemical properties of biochar. Creation of the document involved a multi-year process involving the input and participation of hundreds of research scientists, entrepreneurs, farmers and other stakeholders in its drafting and review. Version 1.0 of the *IBI Biochar Standards* was published in May 2012 after it was approved by an overwhelming majority of IBI's voting members. The *IBI Biochar Standards* are continuously improved through consultation with experts and public input including regular public comment periods, and in response to scientific\advances.

The *IBI Biochar Certification Program* was launched in summer 2013 for biochar manufacturers in the US and Canada to enable them to certify their biochar product as having met the requirements of the *IBI Biochar Standards*. Approved manufacturers are able to place the *IBI Certified™ Biochar Seal* on their product packaging (Figure 11). As of publication of this report, one biochar manufacturer has successfully been approved as a certified IBI biochar manufacturer, and several others have applied for product certification through the program.

The European Biochar Certificate (EBC) is a project of the non-profit European Biochar Foundation (http://www.european-biochar.org/en). Similar to the *IBI Biochar Standards*, the EBC seeks to provide assurances around biochar safety and efficacy for use as a soil amendment. It extends further than the *IBI Biochar Standards*, however, by also addressing sustainability and environmental impacts of feedstock procurement and biochar production technology. The EBC requires that biochar materials be tested for a specified list of parameters at accredited testing laboratories. The certification is carried out by an independent, third-party auditing firm. While the EBC is intended to target biochar producers throughout the European Union, at present no information is available on the number or scope of certificates that have been issued. Furthermore, there is no official mechanism for public input to the development and/or evolution of the EBC, in contrast to the *IBI Biochar Standards* which provide documentation of program development and opportunities for public comment and other input on revisions through its website and mailing lists.

In the United Kingdom, the British Biochar Foundation recently launched the Biochar Risk Assessment Framework (BRAF) aimed at developing "a framework methodology in order to identify, prevent and minimize any potential risks associated with the production of biochar and its deployment in soils" in the UK (http://biocharbraf.wordpress.com). Within the BRAF, a Biochar Quality Mandate (BQM) was drafted and released for public review in mid-2013. The BQM essentially proposes to evolve into a certification program for UK-based biochar producers. It draws from the IBI and EBC standardization and certification programs and adapts them to the UK context. As this report was published, no further information was available on the status or release of a final BQM document.

3.8.2 Market-based incentives in the private and public sectors

A primary driver for biochar commercialization will be the expansion of incentives in the marketplace for developing biochar projects. Biochar carbon offset methodologies are one of the most discussed incentives that could facilitate market opportunities. As discussed above in

Section 3.4.5, ACR's biochar carbon offset methodology, once finalized, will provide carbon credits for the use of biochar via ACR's voluntary carbon offset registry. In the future, efforts to include biochar offset projects in regulatory programs such as California's mandatory Cap-and-Trade Program or Alberta Canada's Offset Program may create financial incentives that may then motivate more and larger biochar operations.

But other more accessible options exist that do not depend on the complex quantification of biochar carbon stability and longevity necessary in carbon offset markets. For example, some municipalities are already prioritizing the use of biochar in landscaping and restoration projects on public lands as part of efforts to reduce carbon footprints and maintain a green image. Among others, Chicago, New York City, and Vancouver are all in the process of developing guidelines for biochar use.

Furthermore, industries such as green building, sustainable agriculture and forestry, and composting all have various types of standards and certification programs. Because linkages can be made between biochar and most natural resource management industries, there exist opportunities for embedding biochar crediting into sustainability programs such as the US Green Building Council's Leadership in Energy & Environmental Design (LEED), Forest Stewardship Council (FSC) certification, and numerous others (Figure 12). In essence, biochar could become another tool to reduce waste, sequester carbon, or enhance soil productivity, depending on the related program and industry. However, much education and outreach needs to be done on the part of biochar proponents to elevate the status and recognition of biochar's multiple benefits before these types of incentives can become a reality.



Figure 12. Examples of market-based programs that could embed biochar criteria: Forest Stewardship Council (FSC) forestry certification, LEED green building certification, Rainforest Alliance sustainable agriculture certification, and USCC sustainable composting certification

In addition to incentives arising from the private sector, there are regulatory programs initiated by governmental entities that can advance the industry by providing new marketing opportunities and educating consumers about biochar. For example, the USDA's National Organic Program (NOP) has classified biochar as an amendment acceptable for organic agriculture. In April 2013, the NOP made a call for comments to clarify terminology and rules around biochar's use in the program. The listing of biochar as an organic soil amendment opens doors to the $28 billion a year organic foods industry in the US. Similar incentives in other regions such as the European Union could also provide a needed boost to the biochar industry. In this vein, in April 2013 Switzerland became the first European country to officially recognize biochar as a soil amendment when the Swiss Federal Ministry of Agriculture issued conditional approval for the use of biochar in agriculture.

3.9 Barriers to Moving Forward

When taking the relative immaturity of the biochar industry into account—the term biochar as a soil amendment was only coined within the last decade—it is evident that there has been significant growth in recent years, albeit on a low level. Yet it is also evident that there is much room for expansion. The current state of the industry is nascent. This is in part due to the simple fact that entrepreneurs are still coming to the biochar space and will require time to build their own knowledge base and establish viable businesses and clientele. But there exist barriers that inhibit a more rapid and unencumbered expansion of the industry, some of which we identify below.

3.9.1 Lack of consumer awareness is a major constraint

According to survey data, the major barrier identified by companies in the biochar space irrespective of sector of operation, is a lack of consumer awareness about the benefits of biochar (Figure 13)—which tend to be less straightforward than fertilizer. Roughly one out of three survey respondents considered this the primary factor hindering expansion of their businesses. This is not surprising. While the characteristics of specific biochars and their potential positive impacts on agriculture are at this point well known amongst a certain segment of soil scientists, biochar producers, and other select constituencies, in general, this knowledge has yet to diffuse to other potential stakeholders critical to the commercial success of biochar.

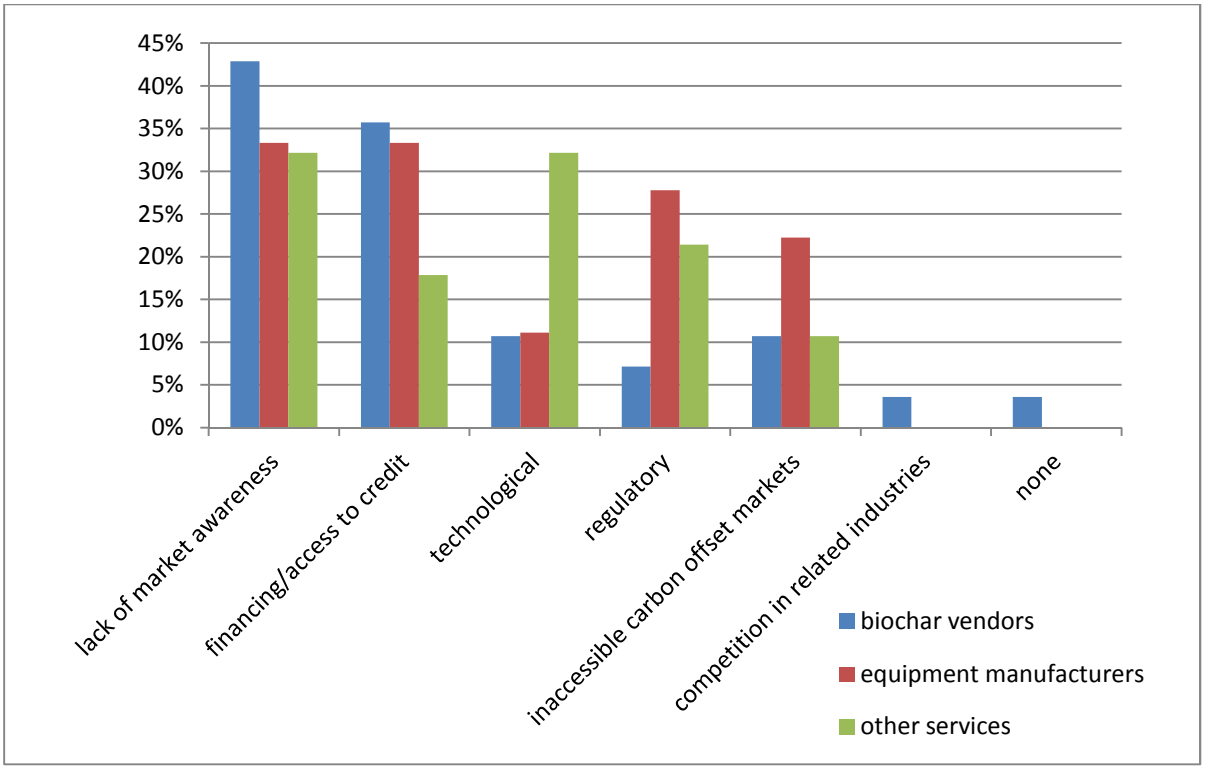


Figure 13. Perceived barriers to market development for biochar vendors (blue), equipment manufacturers (red), and purveyors of biochar-related services (green) (total n=74)

Market development for biochar begins with educating, most importantly, the potential end users and buyers of biochar—the farmers, ranchers, horticulturalists, and others who may elect to purchase biochar for their businesses. A significant portion of this market may include agricultural producers with waste management issues for whom biochar might be incorporated into their sustainable production activities as a part of their production systems. Eventually, in a robust biochar industry, a substantial number of these constituents must be making decisions to invest in biochar as part of their operations, just as they would with fertilizers, pesticides, irrigation systems, and other inputs that add to their bottom line. The business case scenario for biochar must be convincingly made to these potential customers. One avenue for reaching this constituency is by developing business cases and extending educational and training opportunities on biochar to those working directly with these potential buyers or end-users in farm planning and management, such as extension agents, crop advisors, representatives from fertilizer and seed companies, and farm supply retailers, among others.

Other noteworthy barriers identified by the survey include technological, financial, and regulatory constraints discussed below.

3.9.2 Technological barriers restrict production capacity/scaled agricultural use

Survey data indicate that only biochar service providers (e.g., consultants) considered technological constraints a significant barrier whereas only around 10% of biochar producers and biochar equipment manufacturers perceived issues around technologies to be a constraint (see Figure 13 above). On the one hand, this may represent optimism on the part of businesses which are already using technologies that enable them to successfully commercialize biochar or production equipment. On the other hand, it might be that biochar service providers are observing that technological issues are constraining their abilities to expand their businesses as third-party entities in the biochar space. In any case, the very limited size and scope of the biochar industry at present attests to the need for further investments that lower technological barriers to entry.

Of high priority is the development of biochar manufacturing equipment that is reliable, produces consistent product, and that minimizes the 'capital cost' element of the total cost of manufacture per tonne of biochar product. At present, there are few examples of turn-key, "shovel ready" technologies that produce a consistent biochar product while also returning positive revenues in a reasonable timeframe for investors. This constraint must necessarily be overcome to reduce technological cost, which is one of the significant factors hindering development of biochar systems today. While this may not be the case for some of the smaller scale technologies like cookstoves, for the biochar industry to thrive there must be the capacity to produce biochar at rates commensurate with the market size of large-scale farming and other applications. With a potential demand on the order of tens (or even hundreds) of thousands of tonnes per year in the US alone, and millions of tonnes globally, there is much room to vastly increase the capacity to produce biochar in large quantities with large-scale technologies.

Second, in addition to hardware, the scientific and technical understanding of the chemical, physical, and biological characteristics of biochars—and biochar blends—must be further advanced. While research into this area has shed much light on the functionality of biochar in the last several years, the industry has yet to reach a maturity where specific combinations of feedstocks, conversion technologies, and other production parameters result in biochars with properties understood by farmers, agronomists, and crop advisors to consistently and positively impact an operation's profitability when deployed in a prescribed manner. For biochar as a soil management tool to move out of the R&D phase and into widespread commercial practice this is an important step.

3.9.3 Financial barriers limit business investment opportunities

Raising finance for biochar operations and projects is widely perceived as a challenge by survey respondents. Figure 13 above demonstrates that this was the second most common perceived barrier to commercialization by biochar producers and equipment manufacturers. When asked how the start-up expenses of operations were financed, fully 85% of biochar vendors and equipment manufacturers indicated they utilized either personal capital or loans from family or friends, whereas just over one quarter accessed more traditional financing vehicles like banks or venture capital investors (Figure 14). Furthermore, nearly one quarter of ventures sought philanthropic (non-repayable) funding from public or private granting sources.

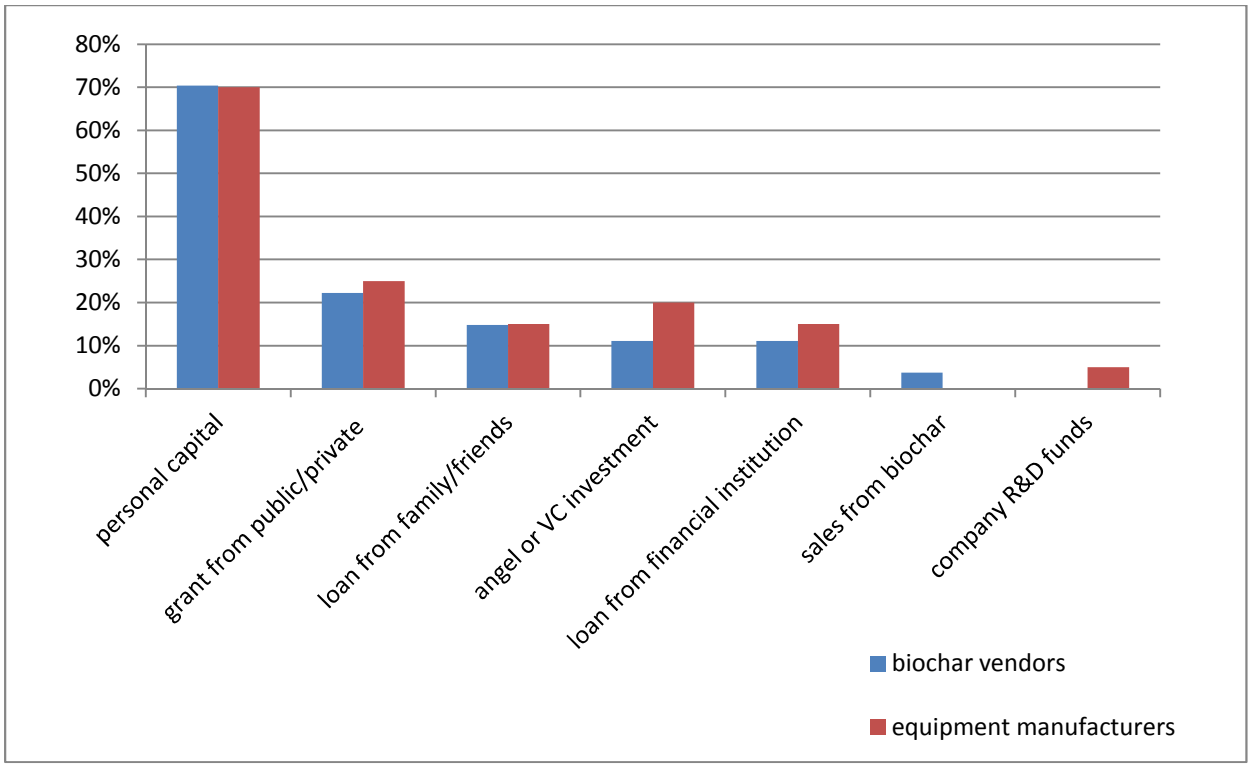


Figure 14. Survey responses to start-up financing sources for companies selling biochar (blue; n=27) and producing biochar manufacturing equipment (red; n=20)

These data convey revealing information about the economics of biochar ventures. First, banks and other traditional lenders are hesitant to invest in biochar projects most likely because there is no established industry track record that demonstrates profitability and risk mitigation. As such, biochar is still viewed as a very high risk venture. Second, because personal capital is by far the largest source of financing, the current industry landscape can be envisaged as one comprised of small start-ups that are personally funded by entrepreneurs who are building businesses in their backyards and garages. There are, of course, exceptions to this scenario. A number of prominent biochar-based ventures have received multi-million dollar cash injections to establish and grow large-scale businesses. However, the data laid out in the previous pages of this report points to an industry currently dominated by small businesses selling relatively small volumes of biochar products locally or via the internet to individual consumers. This is the fledgling state of the biochar industry in 2013.

3.9.4 Regulations impact various stages of the biochar life cycle

The physical infrastructure and products of any industry are subject to environmental and other regulations in most industrialized nations. The biochar industry is no exception to this rule. While biochar operations at present are typically so small and distributed that they may essentially be operating largely outside of the reach of regulatory agencies, it behooves businesses involved in the biochar space to be aware of the existing, or impending, regulatory implications of their operations.

Chief among these for biochar are rules that govern the use of soil amendments, whether for agriculture, land remediation, or other purposes. Of equal importance are rules pertaining to air, water, or other emissions associated with the production of biochar. Additional rules relate to storage and transportation with respect to potentially flammable materials, the siting of production facilities, the procurement of feedstocks, among other things. Many of these may be local rules while others are state/regional, federal, or even international in scope.

During the thermochemical conversion process, the responsible biochar producer should aim to minimize emissions and maximize system efficiency. However, the release of some volatiles is inevitable. The feedstock used may be an important aspect of the extent to which the conversion process is regulated for emissions. Depending on feedstock composition, it may be classified as a solid waste and be subject to strict oversight including stack monitoring to ensure that air emissions are below thresholds for criteria pollutants like CO, NOx, and SOx. Furthermore, the conversion technology itself—whether gasification, pyrolysis, or some modified biochar production method—may determine the extent of regulation. For example, the US EPA recently released new rules that govern emissions for Commercial/Industrial Solid Waste Incinerators (CISWI) under the Resource Conservation and Recovery Act. While most biochar producers would argue that their process does not involve the incineration of solid waste, the exact wording of the rules may determine otherwise.

For biochar use as a soil amendment, the feedstock type will likely be one of the important factors that determine the extent to which the product may be regulated by local authorities. Forestry and agricultural residues, generally speaking, do not currently have strict rules that govern their use for land application. For feedstocks such as animal manures or municipal solid

waste, however, it is an entirely different story. Permits are required that include provisions for detailed plans for land application, assessments of impacts on soils, water, and other natural resources. Of course, the conversion of all feedstocks into biochar fundamentally changes the physicochemical properties of the material to the extent that regulations governing the raw feedstock may no longer be applicable. As biochar use advances, regulatory agencies may adopt new guidelines for biochar soil applications that are directly relevant to the unique properties of biochar.

3.10 Market Trends and Outlook

The present state of biochar commercial activity as revealed above is indicative of the early evolutionary stage of the industry. This applies not only to the market share of biochar sales—miniscule compared to related industries such as compost and fertilizer, and its potential for growth—but also to other important indicators of success for an industry, such as consumer awareness, market development, technological maturity, and investor confidence.

The collected survey information offers a glimpse into future market growth for biochar-related products. Thirty-six companies reported on changes in revenue from biochar sales in the last 12 months as compared to the previous 12 months (Figure 15). For both biochar vendors as well as biochar equipment manufacturers, the large majority reported at least some increase in revenues. Interestingly, companies in both sectors exhibited a similar trend in that modest revenue increases of less than 25% as well as increases greater than 100% were common, whereas revenue changes in the 25 to 100% range were less frequent. This may indicate that a certain segment of new biochar businesses are targeting key identified market niches that enable them to greatly expand their sales year over year.

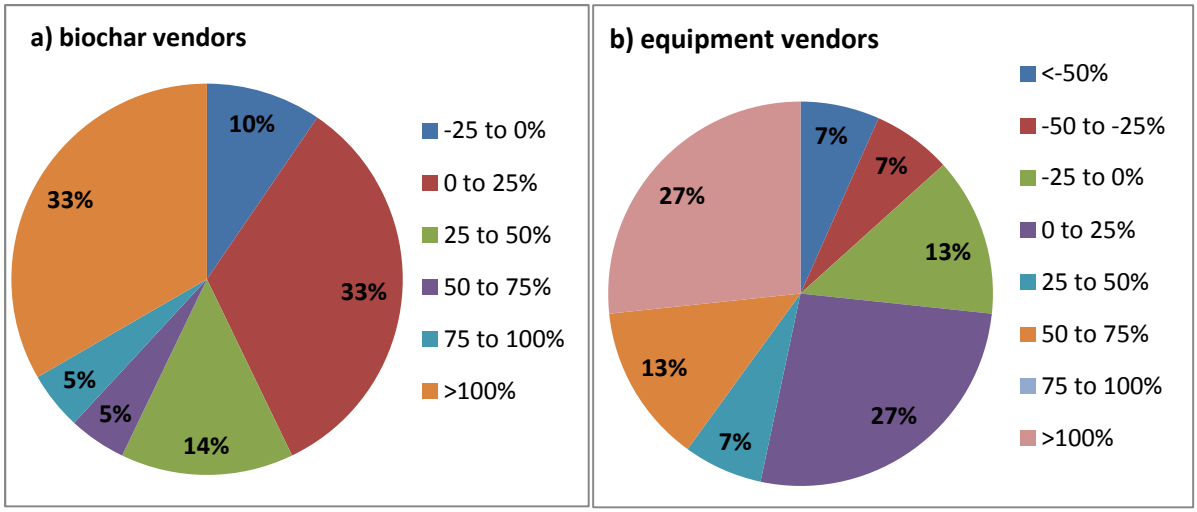


Figure 15. Changes in revenue reported by companies selling a) biochar (n=21) and b) production equipment (n=15) in the last 12 months compared to the previous 12 months

These trends indicate that sales are growing for existing businesses. Projections on future growth are difficult given the paucity of industry tracking data available in the biochar space.

Nonetheless, within the limited dataset collected via surveys, there was a belief that revenues from sales in the biochar space would increase in the coming 12 months (Figure 16).

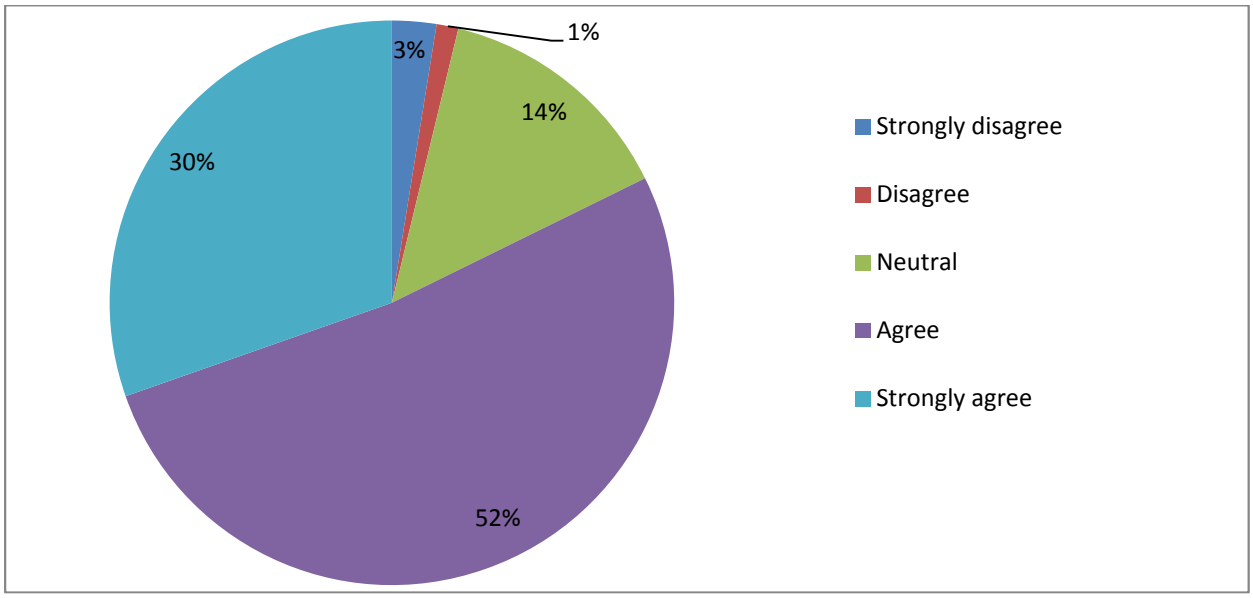


Figure 16. Survey responses to sales for biochar related product or service increasing in the next 12 months (n=79)

Overall, the trends revealed in the data discussed throughout the report are indicative of the direction the biochar space is headed: namely, over the next 3 – 5 years survey respondents expect that there is likely to be an increase both in sales volumes and number of companies participating in biochar production, marketing, and utilization. But the exact trajectory of the industry and pace of growth is uncertain. That will be dependent on such factors as consumer education and outreach, market development, the potential emergence of regulations, technological advances, and investments in business development; and most important of all, by demonstrations that biochar businesses can be profitable.

4 State of Biochar Projects

For the purposes of this report, IBI defines *biochar projects* as those being carried out by universities, non-profits, commercial enterprises, community-based organizations, and other entities, with the participation of local stakeholders (e.g., farmers), and with the goal of establishing operational biochar systems—from feedstock sourcing to biochar production and application. At this time, the definition of *biochar projects* is wide—and includes both for-profit and not-for profit entities. As IBI's work in tracking biochar activities continues, we look to separate those for-profit and not-for-profit projects to generate more specific data.

This section utilizes information primarily from a May – June 2013 project survey that IBI undertook which benefited from the submission of 96 completed surveys from 35 countries. Additional insight is provided from IBI's Member Database which allows users to input project information (this information is not restricted to not-for-profit work and potentially contains

duplicate information as it is user based, not project based). The IBI Member Database includes 427 overall biochar projects from 42 countries. Much of the current tracking of biochar projects originated from a survey conducted by IBI and Cornell University on behalf of the World Bank in 2010. This survey was an initial attempt to catalog the worldwide distribution of developing-country small-holder biochar projects for an as yet unpublished report. The survey had 154 responses from 41 countries and showed that at the time of the survey, most projects were still in the initial development period. The majority of respondents that completed the 2013 survey (on which this section is based) noted they had not participated in the World Bank survey in 2010.

4.1 Biochar Project Locations

IBI's 2013 public survey resulted in responses from projects spanning 31 countries and covering all continents except Antarctica. As noted in Figure 17 below, the majority of biochar project reporting came from Europe/United Kingdom, Africa, and the United States. IBI is aware of projects in countries where there was no reporting in the survey (for example, the Cool Veg project in Japan is making great inroads into the Japanese vegetable markets for biochar-labeled produce in parts of the country, but is not represented in the results). Of the projects, over 50% are in rural areas, over 30% are in small town/peri-urban areas, and the remainders are in urban areas.

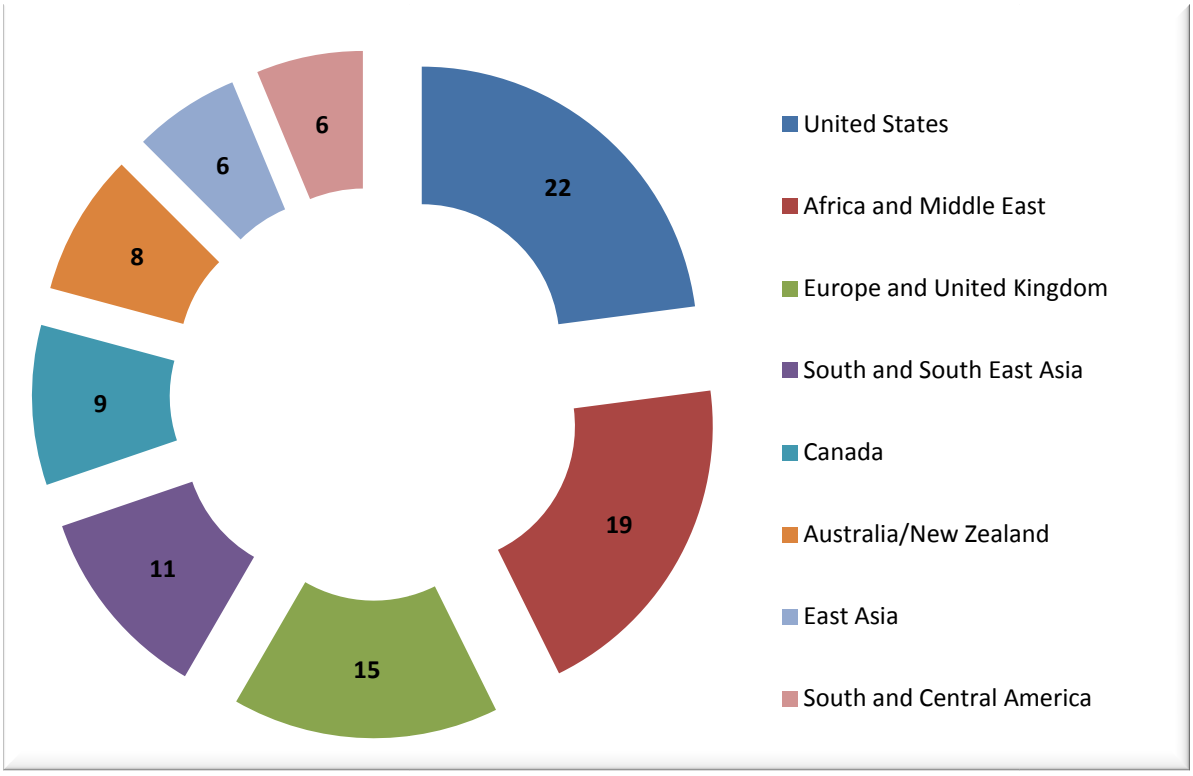


Figure 17. Survey responses to location of biochar project

4.2 Biochar Project Goals and Leadership

At this time in biochar project development, IBI found that a majority of the biochar projects are conducted by research institutions with the primary purpose being collection of information for academic purposes. The project goals may also include commercialization models, technology, and policy development. Figure 18 highlights the project leaders as identified by type. Stakeholders included mainly researchers, students, and farmer/farm groups. For-profit entities were also included, but due to the high response rate by research institutions, the majority of stakeholders were listed as having a connection to academia. These results may reflect the high number of biochar projects at this time that have a research component, but may also be influenced by the connection of academia to the biochar community and their ability to take time to provide survey input over the ability of those farm groups/project developers in the field to provide responses.

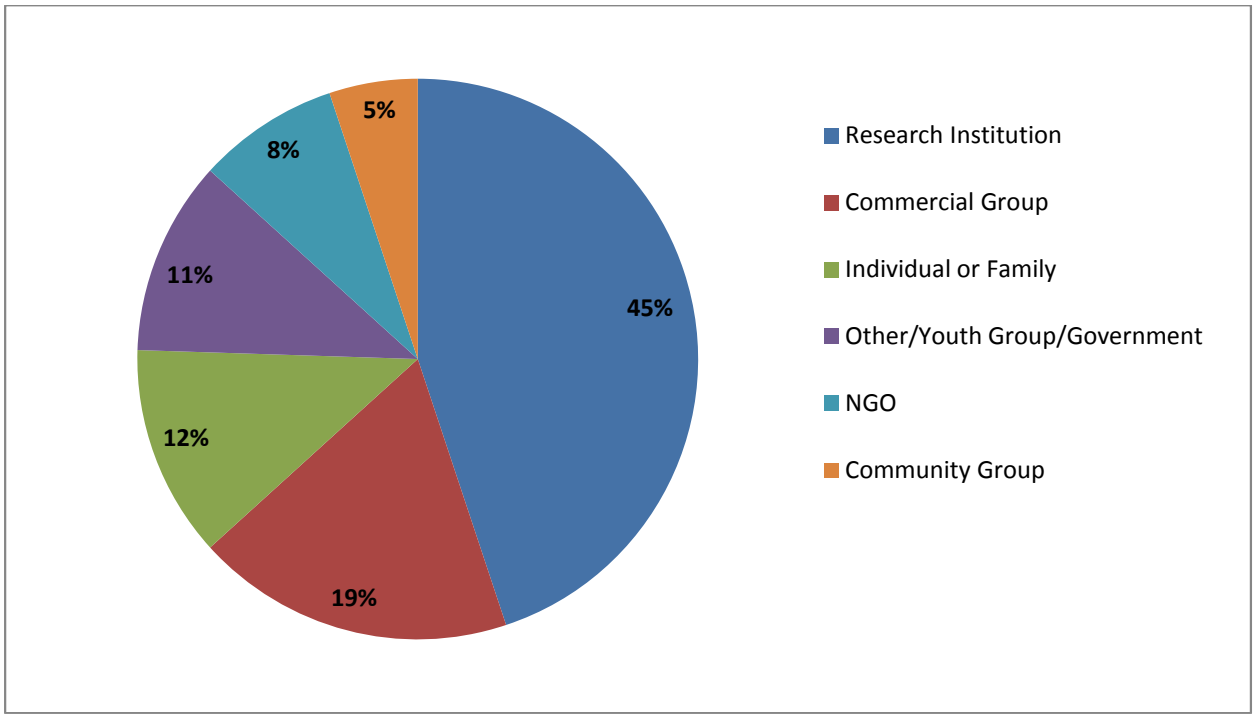


Figure 18. Frequency of type of organization leading biochar projects (n=98)

Project goals varied considerably, but as noted by project leadership, the primary goal of 50% of the projects was for research—mainly for agronomic purposes. The goals also included income for farmers, income for project developers, and training programs. Often these goals will overlap so that a training program will provide field research data as well as possible income generation for participants. Figure 19 highlights the multiple goals given by participants—note the ability of respondents to choose more than one option for project goals. Over 75% of biochar projects had between 1 – 15 participants.

Carbon sequestration from biochar was not mentioned as a primary project goal. However, when survey participants had the opportunity to list multiple project goals, the importance of carbon sequestration increased significantly. Over 75% of respondents felt the carbon sequestration benefits from biochar were important to their project, but a minority of projects plan or hope to access carbon markets at this time for their biochar. This number may change in the future if stakeholders are able to bundle the carbon sequestration benefits of biochar projects to better access carbon markets—particularly if carbon prices increase.

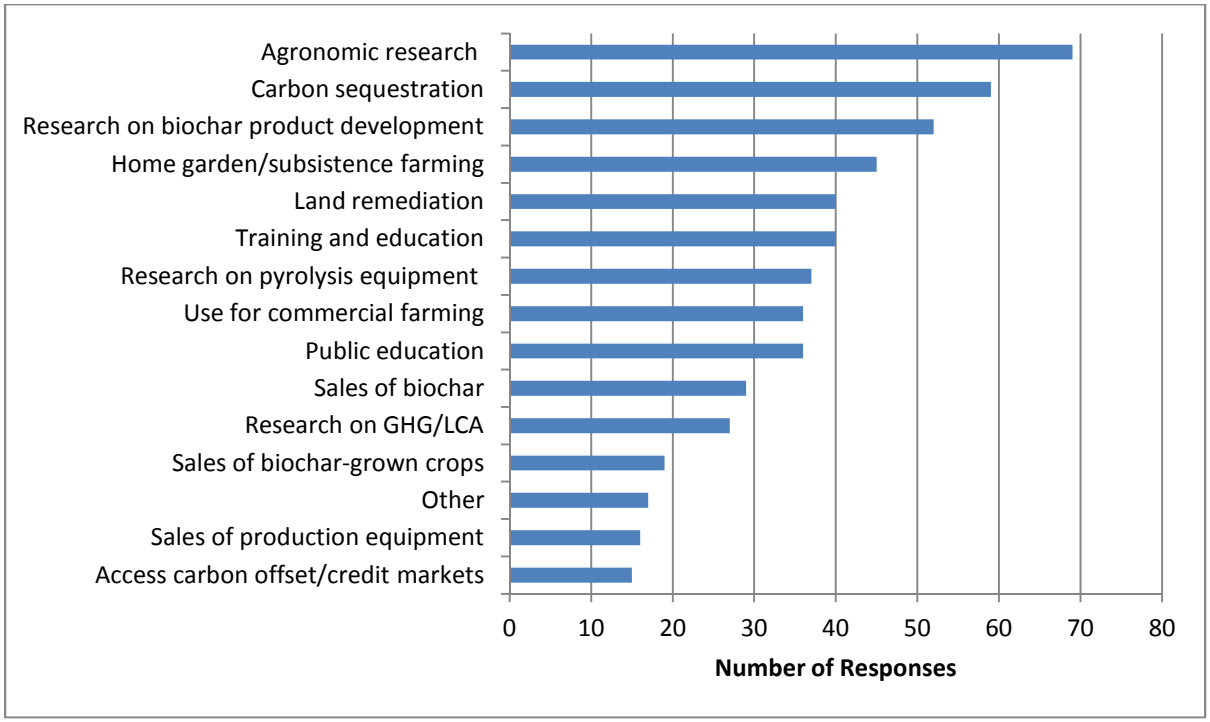


Figure 19. Biochar project goals listed by survey respondents

4.3 Biochar Production and Use Results

Projects appear to be using a wide variety of technologies to produce biochar—from very small systems such as stove projects to large continuous process gasification systems (Figure 20) and vary based on scale of the project, the feedstock resources, and biochar requirements (Figure 21).

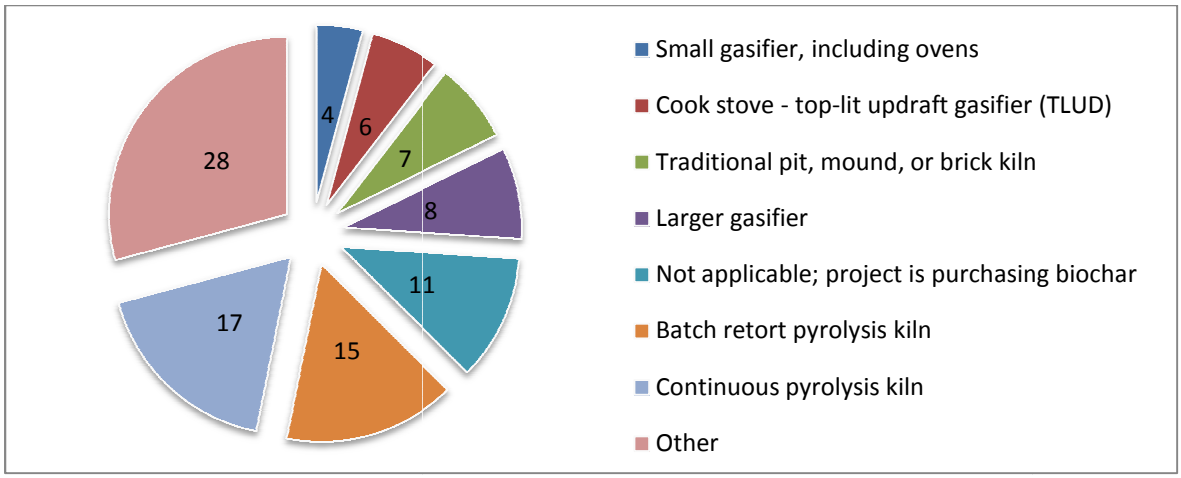


Figure 20. Types of biochar production technologies utilized by projects

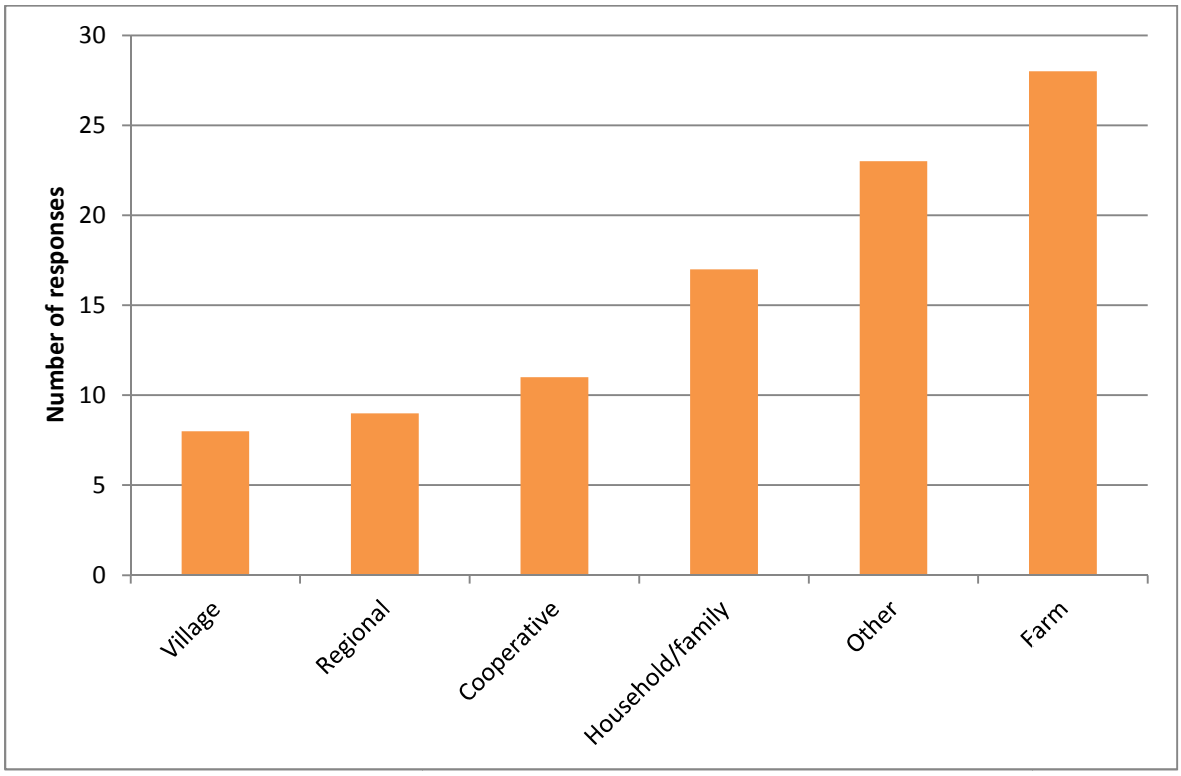


Figure 21. Scales of production systems utilized by projects

The majority of projects had between one and five distinct production units in operation with very few having more than 100 (which are assumed to be wider stove distribution projects).

Project feedstocks varied widely (Figure 22), but as seen from the industry section of this report, woody biomass is used a majority of the time as a feedstock. Although projects did mention competing uses for feedstocks such as fuel for cooking, fuel for energy uses, animal

fodder, and direct soil amendments, 95% of respondents said no dedicated crops were grown or used for biochar production.

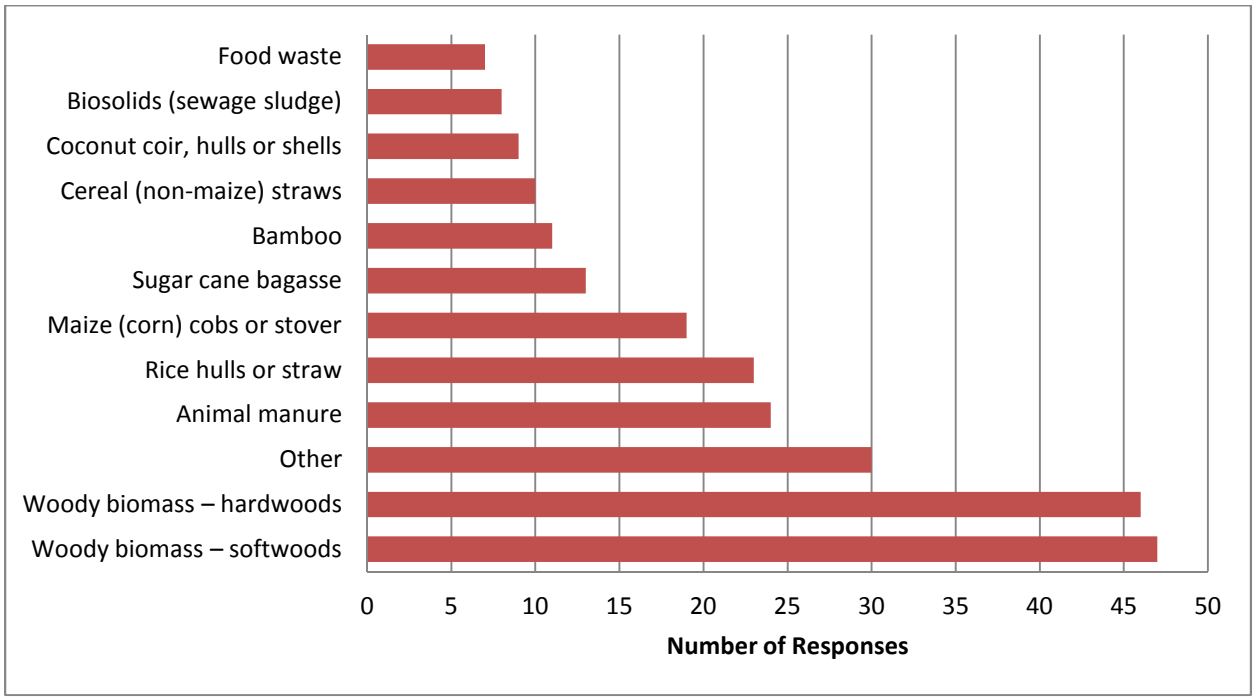


Figure 22. Feedstocks utilized by biochar projects

Much of the biochar that is produced by the projects is used for agricultural purposes—both for subsistence farming as well as for sales as a direct soil amendment. The biochar that is used directly for soil amendments is most often used on its own, but respondents noted that it is also blended with fertilizers, compost, manure, human waste, and/or made into bokashi prior to soil addition. These findings likely show the influence of researchers studying the best combination of biochar blends with certain soils. A fair amount of the material is also used for remediation purposes for land and water filtration.

Of the biochar that is utilized in soil, projects showed the following measurable results (Figure 23); note that the survey only asked for measurable results—these are not reported as necessarily positive or negative results.

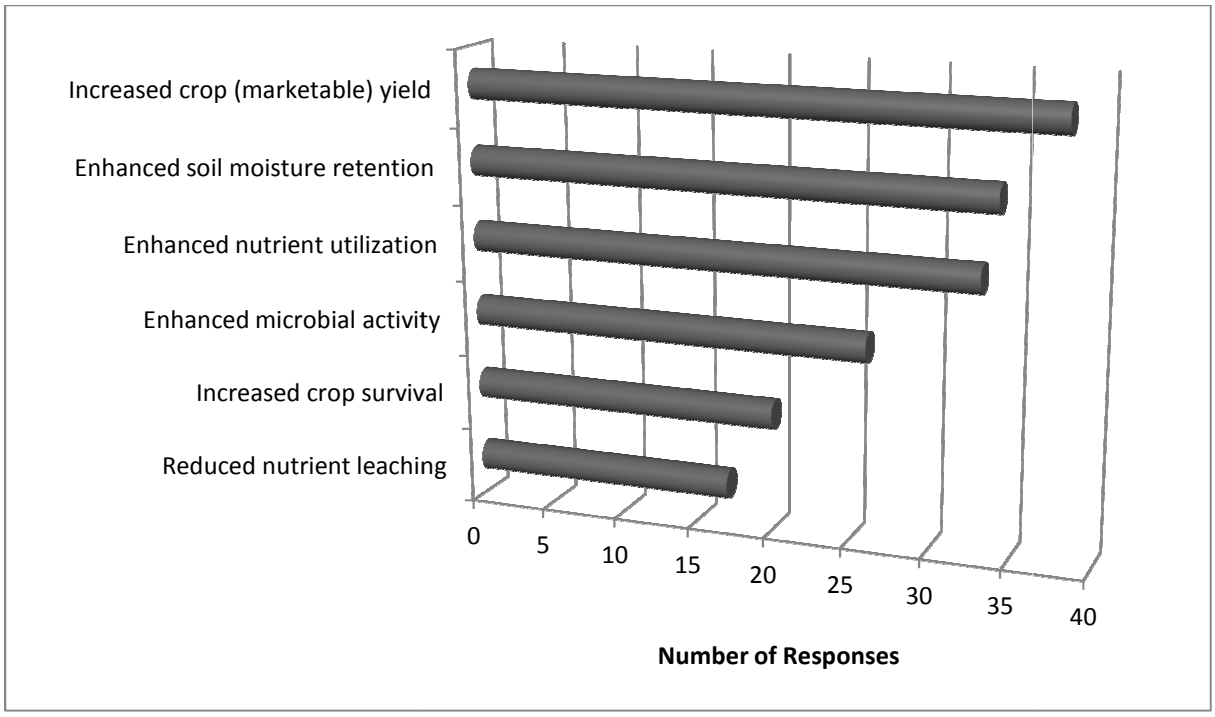


Figure 23. Enhancements in soil and crop variables reported from biochar use

4.4 Overall State of Biochar Project Development

Compared to the 2010 World Bank survey when most projects were in early development stages, respondents reported that most projects are able to convey their first measurable responses (Figure 24). This is an encouraging trend as more and more projects get off the ground with adequate support. As has been seen in the past, financing still remains a major barrier to those planning projects. A majority of projects at this time showed that the project itself could not fully support staff from its income; however, a minority of projects is financially self-sufficient (Figure 25).

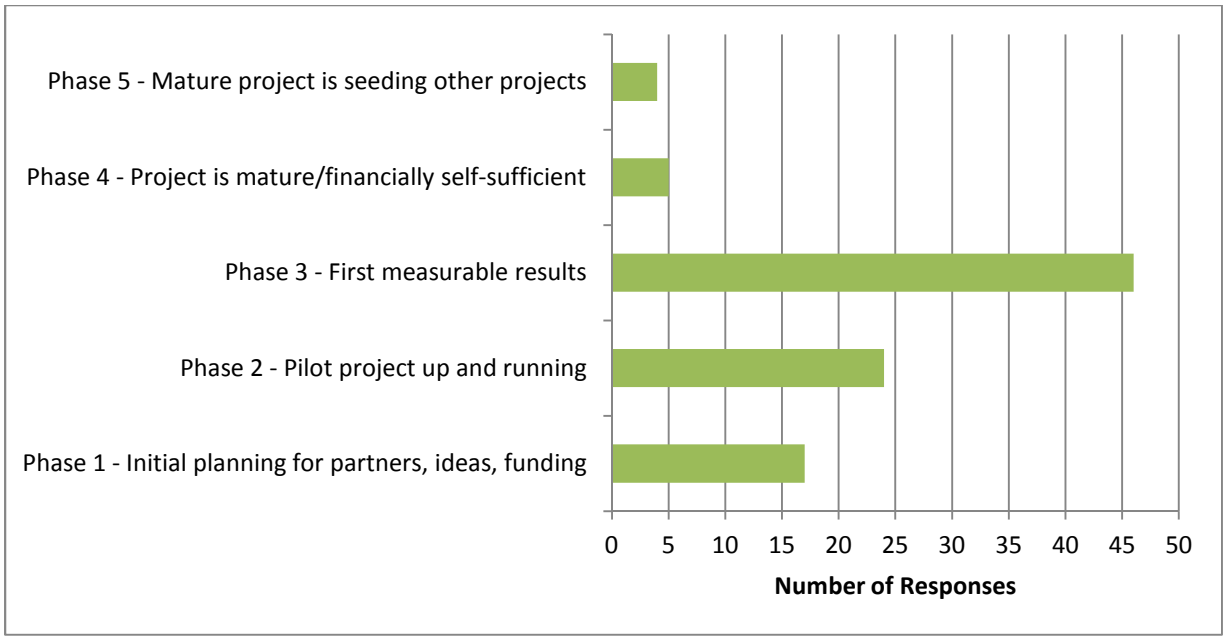


Figure 24. Phases of biochar projects to date

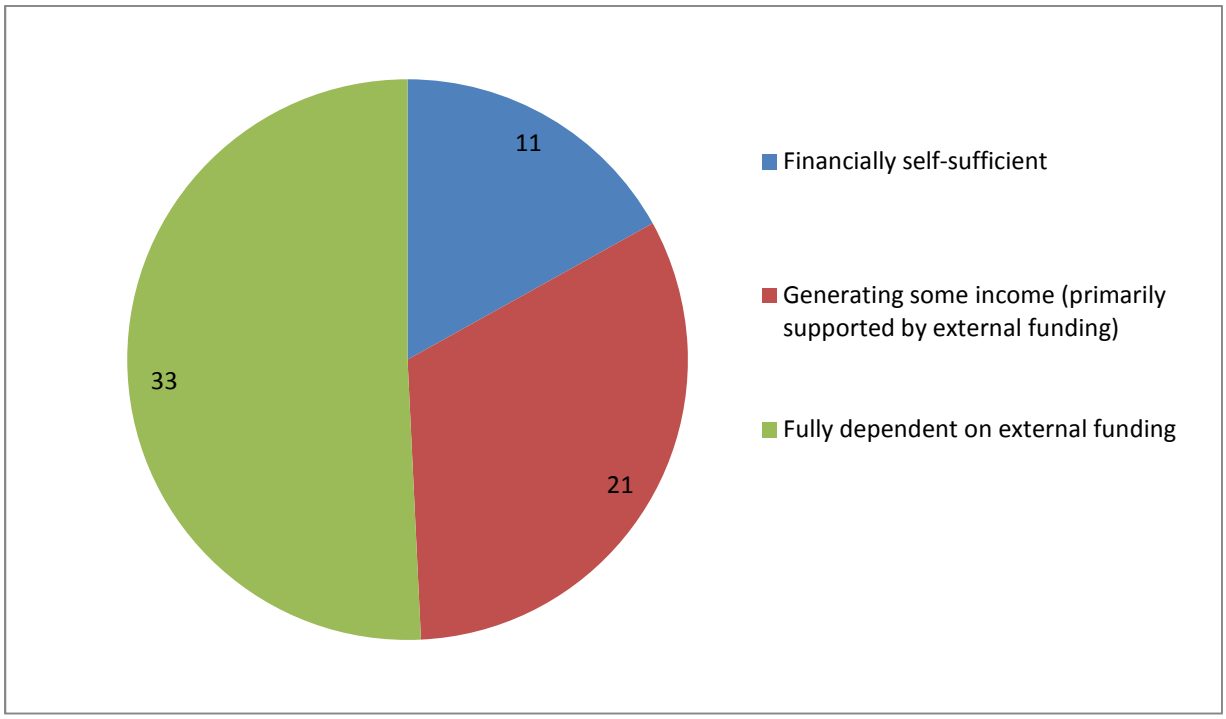


Figure 25. Project financing reported by biochar projects (N = 65)

Biochar projects are receiving funding from a number of different sources at this time (Figure 26). Due to the high response from the academic community, the results showed funding

sources more heavily weighted towards institutional funding, but also a large portion of project funding from private/individual financing, echoing similar results from the business survey.

	0%	<25%	25-50%	50-75%	75-100%
Public/government grant	14.5% 9	12.9% 8	17.7% 11	19.4% 12	37.1% 23
Private/individual financing	5.8% 4	13.0% 9	18.8% 13	13.0% 9	49.3% 34
Revenue from sales	38.9% 7	38.9% 7	11.1% 2	5.6% 1	5.6% 1
Carbon credit payments	91.7% 11	8.3% 1	0.0% 0	0.0% 0	0.0% 0
Other	44.4% 8	16.7% 3	22.2% 4	0.0% 0	16.7% 3

Figure 26. Sources of financing reported by biochar projects

Overall, the trends show that project implementation is growing in most parts of the world, hindered mainly by access to continued finance. It is expected that if the market demand for biochar as a product increases, the demand for specific research into biochar interactions with soils, remediation, etc. would increase in parallel. Also, if it becomes possible to obtain income from the sale of biochar carbon credits, more projects may seek to benefit from the additional income stream.

5 Recommendations for Future Industry Growth

The information provided in the previous sections provides a snapshot of current trends in the biochar industry. Significant advancements have clearly been made in an industry that barely existed five years ago. Biochar is being produced for sale across the globe, consumers are utilizing biochar products for a wide range of purposes, and income is being generated for businesses involved in the biochar space.

Yet, it is also true that there is ample room for growth. To meet this goal, certain gaps need to be filled. While there are many needs, the following is a list of high-priority recommendations for biochar scientists, producers, technology developers, project developers, and stakeholders to accelerate the pace of growth and lower barriers-to-entry.

1) *Create biochar decision support systems.* As outlined in this report, biochar is a spectrum of materials that contain unique properties. The specific combination of physicochemical characteristics of any one biochar material is dependent on feedstock type and process parameters. Because of these differing properties, biochar impacts on soils and crops will vary with specific biochars. To facilitate decision-making, there is a need to characterize biochars before use, and for decision-making tools or systems—designed with the biochar end user in mind—to determine the suitability of using a specific biochar in the context of defined soils and cropping scenarios. This system should consider such variables as feedstocks, characterization of the biochar, soil types, climatic patterns, crop needs, and others. Furthermore, such a system should be integrated with existing efforts to develop comprehensive soil fertility management and ecosystem service support systems.

2) *Conduct long-term field trials.* Biochar differs from other soil amendments that are more familiar to the farming community, chiefly chemical fertilizers and compost. The value proposition of biochar includes longer term effects on soil functions—factors such as increased water retention, drought tolerance, nutrient bioavailability, aeration, microbial activity, and others—as opposed to just immediate gains in crop productivity. Because these benefits accrue and change over multiple growing seasons, there continues to be a need for long-term field trials, covering a range of feedstocks, biochars, crops, soil types, and geographies, to get a better grasp of the cumulative effects biochar has when used as a soil amendment. Included in this is a need for a full characterization of the biochar material combined with *in situ* monitoring of biochar to better understand its effects and fate in soils.

3) *Invest in technology R&D and alternative financing mechanisms to bring down the upfront cost of production equipment*. At present, the economics of biochar as a commercial enterprise are not usually favorable in most situations. One of the main factors holding back the industry is the cost of biochar production equipment. While activities investigating technologies to create biochar are ongoing, the amount of money being funneled into biochar production R&D is small relative to related industries developing new technologies for similar markets such as biofuels. The capital cost of biochar production machinery is an important contributor to the manufacturing cost per tonne of biochar. Investment in the form of grants and subsidies to support financing of biochar production equipment, particularly on the part of governmental entities, could instigate public-private partnerships and drive innovation in biochar production equipment. As technology development matures, costs will likely go down, as well.

4) *Enhance international collaboration*. Relevant to all of the above recommendations, the biochar field is, at present, comprised of a somewhat disparate set of actors often operating in distinct geographic and focal areas. For example, the biochar-producing cookstove sector may share only some common goals with the large-scale biochar production sector but, additional dialogue between these groups could benefit the field overall. Sharing lessons learned across geographies—from both the research and commercialization perspectives—could help significantly speed up the implementation of successful biochar businesses. Protection of intellectual property is, of course, important. But at this early stage in industry development, collaboration among existing businesses through information sharing, and reporting in the aggregate can help to raise the profile of biochar, creating consumer awareness—one of the key obstacles to wide-scale dissemination—and growing global markets for biochar. One potential activity is the sharing of business case studies to get a nuanced understanding of how biochar entities are shaping their activities in their local context, how they are communicating about the costs and benefits of biochar to their customers, and the methods they are using to expand to new markets.

5) *Increase education and outreach.* While education and outreach activities are ongoing within the biochar community, the conversation needs to spread beyond the community to include stakeholders critical to the success of the biochar industry. An articulated campaign to educate farmers and ranchers, horticulturalists, agricultural researchers, regulators, and others could greatly increase awareness around the need to characterize biochar as well as the material benefits of biochar. Outreach with a wide range of stakeholder communities including agribusiness, farmers, ranchers, foresters, compost producers, regulators, and proponents of bioenergy, climate change mitigation and sustainable agriculture, could

potentially be followed by a more well-defined campaign to target key decision makers, project developers and market players.

6 References

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7 Appendix 1. List of Biochar Companies

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
3R Environmental Technology Group	X			Polgardi		Hungary	www.3ragrocarbon.com
Abri Tech Inc		X		Namur	QC	Canada	http://www.advbiorefineryinc.ca/
Adam + Partner		X		Addis Ababa		Ethiopia	http://www.biocoal.org/3.html
Adsorb		X				South Africa	http://www.adsorb.co.za/index.htm
Advance Renewable Technology International			X	Ames	IA	USA	
Advanced Gasification Technology		X		Arosio		Italy	http://www.agtgasification.com/eng/agt_srl.htm
African Christians Organization Network	X					Kenya	http://aconetwork.weebly.com/index.html
Agrichar Soil Ameliorant	X			Cagayan De Oro City	B2	Philippines	
Agricharge	X			Fort Collins	CO	USA	http://agri-charge.com/AC/how-its-made/
Agri-Tech Producers LLC		X		Columbia	SC	USA	http://www.agri-techproducers.com/

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
AgriTherm		X		Ilderton	ON	Canada	http://agri-therm.com/
AirTerra Inc.	X			Calgary	AB	Canada	www.airterra.ca
Alberta Innovates			X		Alberta	Canada	http://www.albertatechfutures.ca/
All Power Labs		X		Berkeley	CA	USA	http://gekgasifier.com/gasification-store/biochar-units/
Alterna BioCarbon		X		Prince George	BC	Canada	http://alternabiocarbon.com/applications/bioenergy
Amaron Energy		X		Salt Lake City	UT	USA	http://www.amaronenergy.com/Amaron_Energy/Amaron_Energy.html
Appropriate Rural Technology Institute ARTI			X	Maharashtra		India	http://www.arti-india.org/
AVA-CO2		X		Zug		Switzerland	http://www.ava-co2.com/web/pages/en/technology.php
Avello Bioenergy		X		Ames	IA	USA	http://www.avellobioenergy.com/
Aztec Wonder Inc.	X			Forsyth	MO	USA	http://www.aztecwonder.biz
B.N.W Industries			X	Tippecanoe	IN	USA	http://www.beltomatic.com/
Balt Carbon		X		Riga		Latvia	http://www.baltcarbon.lv/mode=invest&lang=ru
Bartlett Tree Experts	X					USA	http://www.bartlett.com/fertilization.cfm

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Basques Hardwood Charcoal	X			Saint-Luce	QC	Canada	http://www.basquescharcoal.com/horticulture.php
Bio Manure production	X			Coimbatore	25	India	
Biochar Central	X			Lawrenceville	GA	USA	http://www.linkedin.com/company/biochar-central
Biochar Global Solutions	X			Ashland	OR	USA	http://biocharglobal.com/biochar.html
Biochar Ireland	X					Ireland	www.biocharireland.com
Biochar Marketing Solutions			X	Prior Lake	MN	USA	www.biocharmarketingsolutions.com
Biochar Merchants	X				OH	USA	http://biocharmerchants.com/
Biochar Now	X			Loveland	CO	USA	http://www.biocharnow.com/
Biochar Products		X		Halfway	OR	USA	http://www.biocharproducts.com/
Biochar Solutions		X		Carbondale	CO	USA	http://www.biocharsolutions.com/
Biochar Supreme	X			Everson	WA	USA	http://www.biocharsupreme.com/
Biocharm Farms	X			Ocean Park	WA	USA	www.biocharmfarms.com
BioCharWorks	X			Pawling	NY	USA	http://www.biocharworks.com/
Bioenergy LLC		X		St Petersburg		Russia	http://gasifiers.bioenergylists.org/gasdoc/Yudkevitch/charcoal/index.html
Biofine Technology, LLC		X		South Glen Falls	NY	USA	http://www.biofinetechnology.com

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Biogreen-Energy		X				France	http://www.biogreen-energy.com/
BioMaCon		X		Algermissen	6	Germany	http://www.biomacon.com/index.html
Biospecific LLC	X			Richfield	WI	USA	http://wearebiospecific.com/
Bioware		X				Brazil	http://www.bioware.com.br/#
Bison Soil Solutions	X			Buffalo	SD	USA	http://www.bisonsoil.com/
Black Carbon		X		Barritskov		Denmark	http://www.blackcarbon.dk/
Black Earth Products	X			Kurwongbah	Queensland	Australia	https://www.blackearthproducts.com.au/
Black is Green (BiG)		X		Brisbane	Queensland	Australia	http://www.bigchar.com.au/
Blue Sky Biochar	X			Thousand Oaks	CA	USA	http://blueskybiochar.com/
BuyActivatedCharcoal.com	X			Crawford	NE	USA	http://www.buyactivatedcharcoal.com/page/478223609
Carbo Consult & Engineering Pty		X		Johannesburg		South Africa	http://www.carboconsult.com/gas-producer.asp
Carbon Brokers International	X			Boulder	CO	USA	http://carbonbrokersinternational.com/
Carbon Char/ East Coast Compost	X					USA	http://www.carbonchar.com/
Carbon Compost Company	X			Exeter	Devon	UK	www.carboncompost.co.uk

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Carbon Cultures	X				WA	USA	http://carboncultures.com/
Carbon Gold	X			Bristol		UK	http://www.carbongold.com/
Carbon Resources Research			X	Morrisville	VT	USA	
Carbon Terra		X		Augsburg	Bayern	Germany	http://www.carbon-terra.eu/en
Carbonscape		X		Blenheim	Marlborough	New Zealand	http://carbonscape.com/
CarbonZero		X		Caslano		Switzerland	www.carbonzero.ch
Carolina Clean Energy		X			SC	USA	http://carolinacleanenergyllc.com/
Center for Application of Renewable Energy		X				India	http://care.india.tripod.com/id31.html
Chargrow LLC	X			Charlotte	NC	USA	
CharKing International	X			Plymouth	ID	USA	http://www.char-king.com/index.html
Chip Energy		X		Goodfield	IL	USA	http://www.chipenergy.com/brochuregrillcart.htm
Christina	X			Shanghai	23	China	www.seekfertilizer.com
Chronos Bioenergy / Celebrity Dirt	X			Pittsboro	NC	USA	

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Cleanfuels		X		Enschede		Netherlands	http://www.cleanfuels.nl/index.htm
Coaltec Energies		X		Carterville	IL	USA	http://www.coaltecenergy.com/
Control Labs			X		CA	USA	
Cool Planet Energy Systems		X		Camarillo	CA	USA	http://www.coolplanetbiofuels.com/
Crucible Carbon		X		Newcastle	New South Wales	Australia	http://www.commercialisationaustralia.gov.au/OurParticipants/Pages/The%20Crucible%20Group%20(Crucible%20Carbon%20Pyrolysis%20Pty%20Ltd).aspx
Delinat Institute			X	Ayent		Switzerland	http://www.delinat-institut.org/en/ithaka-journal
Development Alternatives			X	Jhansi	36	India	www.devalt.org
Diacarbon Energy Inc	X			Burnaby	BC	Canada	http://www.diacarbon.com/
Earth Systems		X		Melbourne	Victoria	Australia	http://www.esenergy.com.au/services/mobile-pyrolysis-plant
EcoEra		X				Sweden	http://ecoera.se/
ECOSUS Special-Substrates	X			Leopoldshöhe	7	Germany	www.ecosus.de
EcoTrac Organics	X			East Wenatchee	WA	USA	http://ecotracorganics.net/company/

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
EcoZoom		X			OR	USA	http://ecozoomstove.com/index.php
Encendia Biochar	X			New Haven	CT	USA	http://www.encendia.com/
Energy Anew Inc	X			San Rafael	CA	USA	http://www.biocharm.com/biochar
Energy Farmers Australia			X	Geraldton		Australia	http://www.energyfarmers.com.au/
Energyflex			X	Houghton	MI	USA	
Enginuity Energy LLC		X		Mechanicsburg	PA	USA	http://www.enginuityenergy.com/
Ensyn Corp.		X		Ottawa	QC	Canada	http://www.ensyn.com/
Environmental Power International Ltd (Epi)		X		Wingfield	Wiltshire	UK	http://www.epienergy.com/
Eprida Power and Life Sciences			X	Marietta	GA	USA	http://www.eprida.com/home/index.php4
Finger Lakes Biochar			X	Victor	NY	USA	http://fingerlakesbiochar.com/
Forest-Char	X					UK	http://forestryfuels.com/biochar/
Four Seasons Fuels		X		Coneyhurst	West Sussex	UK	http://www.fourseasonsfuel.co.uk/charcoal-retorts.asp
Full Circle Biochar	X				CA	USA	http://fullcirclebiochar.com/
General Energy & Environment Engineering		X				Tunisia	

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Genesis Industries		X		Redondo Beach	CA	USA	http://egenindustries.com/
Global Gateways S.A.		X		Brussels		Belgium	http://www.globalgateways.eu/Pages/default.aspx
Green Charcoal International		X		Paris		France	http://www.green-charcoal.com/
Green Pyro	X			Silicon Valley	CA	USA	http://www.greenpyro.com/
Guangdong Dazhong Agricultural Science and Technology Co. Ltd	X			Dongguan	Guangdong	China	http://www.dazhongnk.cn/english/index.asp
Hawaii Biochar Products	X			Pahoa	HI	USA	http://hawaiibiochar.com/
HM3 Energy		X		Gresham	OR	USA	http://www.hm3e.com/
HydroCarb GmbH		X		Geeste		Germany	http://www.revatec.de/index.htm
Hydronova			X	Santiago	12	Chile	
ICM		X			KA	USA	http://www.icminc.com/
InStove		X		Cottage Grove	OR	USA	http://instove.org/60-100-liter-cookstove/
Integro Earth Fuels Inc		X		Arden	NC	USA	http://www.integrofuels.com/

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
International Tech Corp		X				USA	http://www.internationaltechcorp.net/
Interra Energy, LLC	X			San Diego	CA	USA	http://interraenergy.us/
Iwamoto Corporation		X		Osaka		Japan	http://superstoneclean.com/iwamoto-mineral-biochar-machine/
KANSAI Corporation		X		Hikone	Shiga	Japan	http://www.biwako.ne.jp/~kansai/e-index.html
Kaskad-E GmbH		X		Basel		Switzerland	www.kaskad-e.ch
Kavi Protein and Feed Pvt Ltd	X					India	
KIS Biochar	X			Redmond	WA	USA	http://www.kisorganics.com/products/shop/kis-biochar
Lambiotte & Cie, S.A.		X		Brussels		Belgium	http://www.lambiotte.com/solvent_by_Lambiotte_and_Cie-index.htm
Lanstar			X	Johannesburg	6	South Africa	www.vermichar.co.za
Logical Solutions Consulting, LLC			X	Waitsfield	VT	USA	
Microbeix Pty Ltd	X			Albany Creek	4	Australia	www.microbeix.com
Micromeritics Analytical Services			X		GA	USA	http://www.particletesting.com/
N			X	Toronto	ON	Canada	
New Biomass Energy		X		Quitman	MS	USA	http://newbiomass.com/

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
New England Biochar		X			MA	USA	http://newenglandbiochar.org/
New England Small Farm Institute			X	Belchertown	MA	USA	http://www.smallfarm.org/
NiCan Environmental Technologies			X			Nigeria	
Novotera		X		Montreal	Quebec	Canada	http://novotera.ca/
Out of Ashes Bioenergy Inc	X			Prince George	BC	Canada	http://turtlebackbiochar.com/
Oxford Biochar			X	Oxford		UK	http://www.oxfordbiochar.com/
Pacific Pyrolysis		X		Somersby	New South Wales	Australia	http://pacificpyrolysis.com/
Phoenix Energy		X		San Francisco	CA	USA	http://www.phoenixenergy.net/
Plantación Amazonia el Vita S.A.S.			X	Bogotá	34	Colombia	http://www.co2tropicaltrees.com
Proininso SA	X			Malaga		Spain	http://www.proininso.com/biochar-biocarbon.html
Proton Power		X		Lenoir City	TN	USA	http://www.protonpowerinc.com/index.html
Pyreg		X		Doerth		Germany	http://www.pyreg.de/
Pyrolyzer LLC		X		Boca Raton	FL	USA	http://www.pyrolyzer.net/Default.aspx

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
R & A Energy Solutions			X			USA	http://www.randaenergysolutions.com/
Re:char		X		Austin	TX	USA	http://www.re-char.com/
Renewable Oil Corporation Pty Ltd		X				Australia	http://www.renoil.com.au/pyrolysis.html
Renewable Oil International		X		Florence	AL	USA	http://www.renewableoil.com/
Samuchit Enviro Tech Pvt Ltd		X		Pune		India	http://www.samuchit.com/index.phpoption=com_content&view=article&id=1&Itemid=3
Seattle Biochar		X		Seattle	WA	USA	
Secura International Corp.	X					Philippines	
Sexing Technologies	X					USA	http://sexingtechnologies.com/
Shell Oil Company			X			USA	www.shell.com
Sixth Element Sustainable Management			X	Ottawa	Quebec	Canada	http://www.6esm.com/
Sonnenerde	X			Riedlingsdorf		Austria	http://sonnenerde.at/
South Fork Wood Products	X			Eagle	ID	USA	http://www.conichar.com/index.html
Splainex		X			Flevoland	Netherlands	http://www.splainex.com/

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
StardustEarth		X		Auckland	E7	New Zealand	
Sunmark Environmental	X				OR	USA	http://www.permamatrix.com
Sustainable Biofuels Solutions, LLC			X	Hanover	MD	USA	www.biofuels-solutions.com
Sustainable Energy Ltd			X	Cardiff		UK	http://www.sustainable-energy.co.uk/
SVC Holdings	X			Saint Albert	AB	Canada	
Swiss Biochar	X			Lausanne		Switzerland	http://www.swiss-biochar.com/eng/biochar.php
T. R. Miles, Technical Consultants, Inc			X	Portland	OR	USA	http://trmiles.com/
Takesumi Ltd	X					UK	http://www.takesumi.co.uk
Terralogix Group LLC			X	Annapolis	MD	USA	http://terralogix.net/Home_Page.html
Tesaki		X		Osaka		Japan	http://www.tesaki.co.jp/sumiyaki/
The Biochar Company LLC	X			Berwyn	PA	USA	http://www.soilbiochar.com/learn/biochar-soil-amendment.php#.UNCMReSw_1E
The Prasino Group			X	Calgary	Alberta	Canada	http://www.prasinogroup.com/
Thompson Spaven		X		London		UK	http://www.thompsonspaven.com/index.html

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Three Dimensional Timberlands		X		Ophir	OR	USA	http://threedimensionaltimberlands.com/vacuum-pyrolysis-technology.html
Tigre Energy		X		Horwich	Bolton	UK	http://www.tigre-energy.com/
Tolero Energy Llc		X		Sacramento	CA	USA	http://www.toleroenergy.com/
Topell Energy		X		The Hague		Netherlands	http://www.topellenergy.com/
Umpqua Bio-Alternatives Cooperative	X			Roseburg	OR	USA	
University of Ghana	X			Accra	1	Ghana	www.ug.edu.gh/CACS
Vagga Till Vagga			X			Sweden	http://www.vaggatillvagga.se/
Vee-Go Energy	X			Easthampton	MA	USA	http://vee-goheatingpellets.com/char.html
Vermont Biochar	X			West Danville	VT	USA	http://vermontbiochar.com/biochar/
Victory Gasworks		X		Seattle	WA	USA	http://gasifier.wpengine.com/personal-energy-grid
Vuthisa Technologies		X		Msunduzi		South Africa	http://vuthisa.com/
Waste to Energy Solutions	X			Destin	FL	USA	http://wesionline.com/index.htm

COMPANY NAME	INDUSTRY SECTOR			CITY	STATE	COUNTRY	URL
	Biochar production and/or sales	Biochar production equipment manufacturer	Other biochar-related enterprise				
Whitfield Biochar LLC		X		Burlington	WA	USA	http://www.whitfieldbiochar.com/
Wijaya Saw Mills Ltd	X					Sri Lanka	
Wilson Biochar Associates			X	Cave Junction	OR	USA	www.wilsonbiochar.com
World Biochar			X			Australia	http://www.worldbiochar.com/index.html
WorldStove		X				Italy	http://worldstove.org/
Wuni Zaligu Development Association			X			Ghana	www.wunzalgufieldwork.moonfruit.com
Zero Point Clean Tech		X		Potsdam	NY	USA	http://www.zeropointcleantech.com/company