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Policy support for biochar: Review and recommendations

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Abstract

Significant evidence has accumulated demonstrating that soil biochar amendment has many environmental benefits; however, adoption has been slow. This raises the question of how to align the environmental benefits with commercial motivations to drive more widespread implementation. Here, we examine the role that government policy can play in accelerating production and use at commercial scale. We identify three types of programs that can support biochar production: commercial financial incentives, nonfinancial policy support, and research and development funding. We also describe how these programs are currently used to support biochar production. For example, financial incentives can motivate immediate changes in business practices while nonfinancial policies can be important mechanisms to educate consumers and expand market demand. Research and development support can provide the necessary funding for early-stage innovations that may one day become commercially viable options, even without other types of policy support. There are different risk–reward profiles for each policy mechanism, and these must be considered when evaluating a policy direction. Finally, we offer broad recommendations to the development of policy that maximizes the net benefits of biochar adoption. Key recommendations include improving policies that allow for the monetization of environmental benefits and avoided costs, recognizing soil as a resource through national preservation policy, and developing a broadly accepted set of product standards for biochar.

KEYWORDS

biobased product policy, biochar, biochar adoption, biochar commercialization, biochar policy, financial incentive, policy incentive, soil health, US renewable products programs

1 | INTRODUCTION

In the United States, pollution and soil degradation from agricultural activities like inefficient use of fertilizers have resulted in millions of dollars in economic damages distributed among the public, industries, and federal and local governments (EPA, 2015). Since the first Soil Conservation Act in 1935, the US government has recognized the central importance of soil health to food security and has acted to improve soil health. Government actions have included programs to increase public awareness and economic attractiveness of sustainable farming approaches and soil conservation practices (USDA-NRCS, 1994). The "Dust Bowl" era of the 1930s revealed the scale of problems possible in the absence of proper soil preservation practices (Phillips, 1999), and it is now clear that key moments of regulatory intervention can significantly improve food security by protecting soil health (Steiner, 1988). In fact, following the 1930s significant research was initiated in soil preservation practices and policies that resulted in higher adoption of activities that reverse the existing damages and benefit future agricultural output.

An emerging soil preservation practice that carries multiple direct and ancillary benefits is amending soil with biochar, charcoal that has been intentionally produced for environmental uses. When made from a plant biomass source, biochar is highly porous (Brewer et al., 2014) and absorbent (Yao, Gao, Zhang, Inyang, & Zimmerman, 2012). Adding biochar to soil can enhance agricultural soil performance by improving soil hydrological properties (Kinney et al., 2012; Liu et al., 2016; Omondi et al., 2016) and soil nutrients thereby increasing crop yield (Ding et al., 2017; Jeffery, Verheijen, van der Velde, & Bastos, 2011). Although biochar's performance varies by biochar properties and application condition (e.g., soil and crop type; Joseph & Lehmann, 2009; Sorrenti, Masiello, & Toselli, 2016), meta-data analyses (Jeffery, Verheijen, Kammann, & Abalos, 2016; Nguyen et al., 2017; Omondi et al., 2016) have shown that using biochar can, on average, improve crop performance and enhance ecosystem services through long-term increases in soil carbon inventory (Spokas, 2010) and soil aggregate stability (Ajayi & Horn, 2017). These benefits, in turn, lead to increased plant-available water (Burrell, Zehetner, Rampazzo, Wimmer, & Soja, 2016), a reduction in nutrient leaching to soil and water and increased plant-available nitrogen (Zhou, Berruti, Greenhalf, Tian, & Hal, 2017), which each acts to drive crop improvement by an average of ~15% (Jeffery et al., 2011). Biochar amendment can also lead to reduced fertilizer-related releases of nitrogenous gases including N_2O (Cayuela et al., 2014), NO_x (Nelissen, Saha, Ruysschaert, & Boeckx, 2014), and ammonia (Chen et al., 2017), potentially leading to improved regional air quality (Pourhashem et al., 2017).

Despite biochar's demonstrated environmental and agronomic benefits and its potential to increase farm incomes, biochar soil application has not been widely adopted by farmers as a soil preservation or carbon sequestration practice. While farmers must consider many variables when changing land use practices (Burton, Kuczera, & Schwarz, 2008; Stroman & Kreuter, 2015), cost is most likely the largest impediment to biochar. The initial upfront expense of biochar followed by a long-term payoff from improved crop yield, for which there is uncertainty in the precise outcome making the revenue implications also uncertain, is likely a significant reason for pause when considering biochar land amendment as a farming practice (Vochozka, Maroušková, Váchal, & Straková, 2016). As a product, biochar and biochar-blended soil enhancers are not yet economically

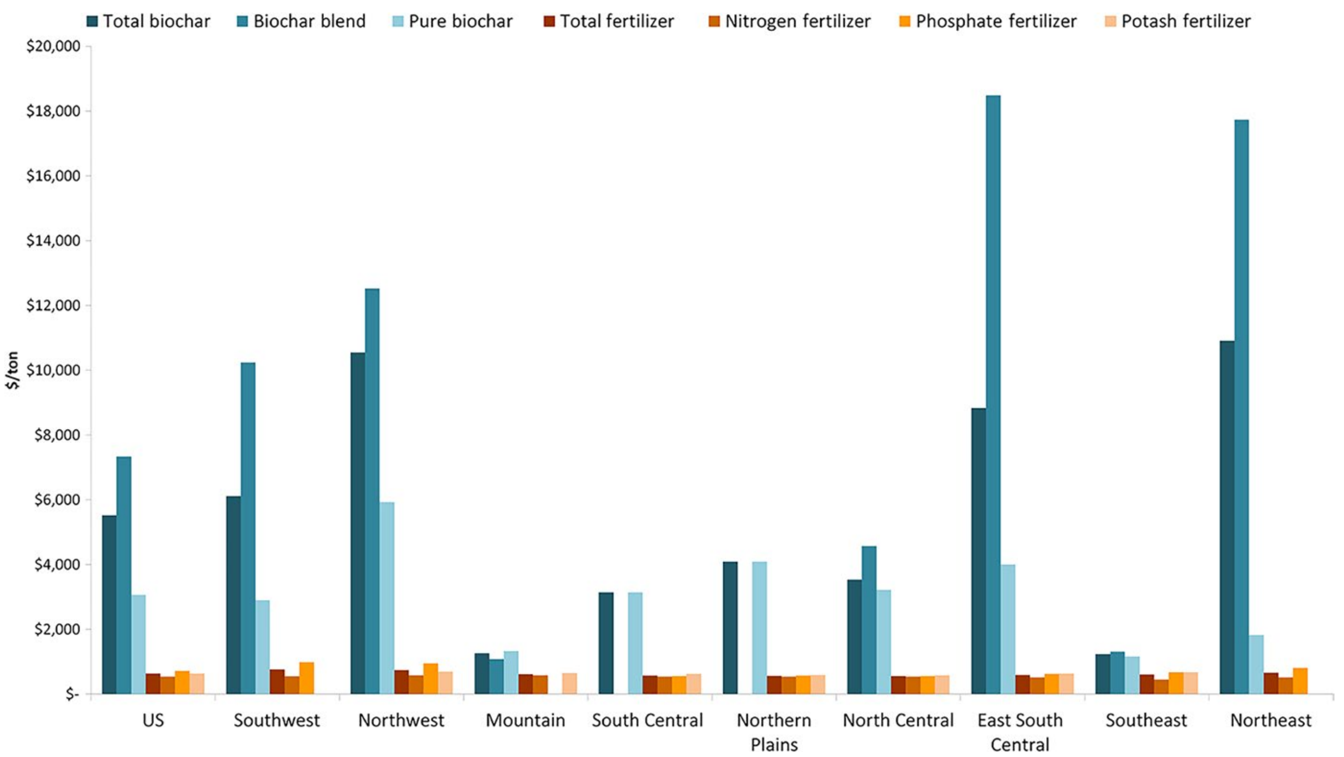

FIGURE 1 US average pricing of biochar (Baker Institute Survey of Biochar Producers) and fertilizer by region (USDA-NASS, 2014). Numbers represent averages within each region. Total biochar is the total average of pure biochar and biochar blend (biochar blended with nutrients). Total fertilizer is the average of all fertilizer types. All prices are in 2016 dollars

competitive against better established products (e.g., zeolite, vermiculite, perlite, conventional fertilizers) in the market (Figure 1). The variation in prices of biochar across the United States is the result of a complex relationship between available biomass resources, cost and scale of biochar production, competing biochar application(s), and market dominance of a few biochar production facilities as well as the absence of market mechanisms that value its ancillary environmental benefits.

Biochar's environmental benefits minimize larger ecosystem damages that would otherwise impose an economic cost to businesses or cleanup cost to government (e.g., algal bloom and drinking water contamination, damage to fisheries, and damage to tourism industries; EPA, 2015). Many environmental benefits (positive externalities) that derive from biochar soil application are not priced and hence do not have a market value. This presents a market failure, as biochar benefits represent a nonpriced positive externality whereby the market failure renders the benefits remain largely irrelevant for cost–benefit analyses for large investment decisions. For biochar to become a viable option in the agriculture sector, it may be that regulatory and financial incentives that allow financial capture of the avoided environmental costs are necessary. Currently, policy incentives for biochar production and application that allow monetization of its demonstrated benefits do not exist.

Well-developed legislation can reduce the financial disconnect between those who bear the costs of land management changes and those who reap the benefits. One way this can occur is by creating mechanisms that facilitate payment to farmers for ecosystem services resulting from their improved land management practices—this can be through markets that allow monetization of ecosystem services as a property right (Blackburn, Mooiweer, Jones, Parks, & Kellerman, 2016), or some other more direct policy mechanism. Such an approach can internalize the costs and benefits of improved land management for appropriate sectors and allow biochar to be a competitive choice for consumers. In addition, for the nascent biochar industry (Jirka & Tomlinson, 2013), a well-designed biochar-targeted policy incentive can provide a driving force for a reliable production technology, economic feasibility, and market development. One could argue that an "infant industry" argument is valid for biochar (Black, Hashimzade, & Myles, 2009), particularly given its potential longer term benefits. For example, government support in the form of financial incentives—such as tax credits, subsidies, or loan guarantees—can help the industry grow. Growth can, in turn, facilitate standardization and learning-by-doing in production and application, which would allow the capture of economies of scale thereby lowering costs. To the extent cost reductions occur, government support could then be reduced. In fact, a prudent approach could schedule the reduction in support a priori to avoid a scale-up of the cost of the policy concomitant with expansion of the industry. Small agri-biodiesel and ethanol producer tax credits (USDOE, 2008) are examples of incentives that were designed to encourage investment in diversifying the nation's energy portfolio. While the small producer incentives expired in 2011 (USDOE, 2011), ethanol production and blending with gasoline increased to constitute the current 10% of the total transportation fuel consumed in the United States. Policy need not be limited to the federal scope, particularly if there are distinct local benefits. Rebates on eligible composts for reducing nonpoint source pollutions from Texas highways that were offered between 2004 and 2006 are a different example of how local, rather than federal, incentives can successfully encourage the use of manure composts (TCEQ, 2017).

The objective of this paper was to review recent US public incentives and funding programs aimed at assisting biochar production and application. We develop a database to analyze the existing programs supporting biochar and provide recommendations for future policy pathways. We investigate US governmental support for biochar amendment as a renewable and low-carbon biobased strategy for soil preservation and climate change mitigation. Based on biochar's characteristics and its potential applications in agriculture and energy sectors (discussed in the following sections), biochar can potentially receive funding through a variety of available programs from agencies such as the U.S. Departments of Agriculture (USDA) and Energy (DOE) as well as state governments. Therefore, the aim of this work was to allow stakeholders and the general public to better understand the status of available governmental support and compliance conditions for biochar production and application. We also aim to identify the scope of opportunities for local and federal investments in commercial-scale biochar production to support a sustainable agricultural management practices. In addition, we comment on the adequacy of existing policy pathways and potential pathways that could be further explored.

2 | MATERIALS AND METHODS

The terminologies of legislation and of biochar production do not closely overlap, introducing challenges in determining which legislative tools can be used to assist in particular steps of biochar production. To connect current biochar production to existing legislation, it was necessary to map concepts and terminologies, which we undertook in a two-step approach. First, we defined the stages of biochar production (a.k.a. the value chain) through literature review and survey of biochar producers, which enabled the collection of price and production details for 82 products from 60 companies. This allowed us to make clear the points in the value chain where government support can and does occur, and also to set boundary limits for further analyses. Second, we searched past, current, and pending legislation at federal and state levels to identify legislative language and policy programs that are either directly or indirectly applied to biochar and therefore incentivize production and application.

2.1 | Biochar value chain

Biochar production starts with collection and preparation of a biomass feedstock for thermal processing (pyrolysis or gasification). These thermal processes convert a part of the biomass to solid (char) and the other parts to gaseous and liquid products. The chemicals and bioenergy generated during the process can serve several markets, including chemicals, the transportation fuel market, and power sector. The biochar product typically goes to uses in the agricultural sector but is also distributed to a lesser extent to other end-uses, for example, as a highly absorbent product.

The life cycle stages considered here (Figure 2) include (a) feedstock management, (b) production—process platforms, and (c) product distribution and application—bioenergy, biofuels, biochemicals, etc. (defined below in Section 2.2). Defining the stages of biochar production in this manner allows us to identify how various policies can influence biochar investment and production. For example, the first stage of biochar production can be influenced by programs that directly target biomass or bio-waste management. Biochar production can be a waste management strategy (Navia & Crowley, 2010) capable of handling a wide range of biomass types—including agricultural and forestry residues as well as animal and municipal solid wastes (Figure 2)—as long as care is taken not to use feedstocks that contaminate the end product (such as heavy-metal-rich feedstocks). In our research, we specifically considered the feedstock that is used for biochar products (both pure and blended) offered in the US market by the producers and sellers we surveyed (Figure 1). These feedstocks are comprised of wood/forest biomass (85%), agricultural biomass (8%), and other feedstocks, including manure (7%).

For the biochar production process (defined above as stage b), we examined policies based on the nature of this nascent industry. Most US biochar producers operate at a very small scale and often seek support for capital investment and growth. Policy programs that provide financial support during this stage can allow the industry grow at a steady pace. Moreover, support for technology innovation can also help advance the growth of the industry by reducing the initial production costs. For the biochar distribution and application stage (indicated above as stage c), we considered biochar's environmental and agricultural conservation benefits. Of course, in every case where policy is considered, critical to the observed outcome is the extent to which economies of scale can be captured and the extent to which ancillary costs and benefits are accounted.

2.2 | Biobased products and biochar definitions in regulatory language

The first step in determining if a program potentially supports biochar is evaluating whether a program's language technically supports biochar's characteristics and properties. Table 1 presents the terms and definitions we identified in program descriptions that make biochar an eligible applicant (for full terms and definitions of biobased products considered in our search, please refer to Supporting Information Table S1).

According to these descriptions (Table 1), if produced on a commercial scale, biochar is a biobased product whose feedstock can be a raw biomass or a processed biomass output of a biorefinery. Additionally, it is important to note that biochar can qualify as a value-added agricultural product even though it is not explicitly identified in the legislation because its characteristics meet the specified requirement. Namely, (a) biochar can be produced from agricultural commodities such as forestry and agricultural biomass with an irreversible change in its physical and chemical state, and (b) biochar's wide application for soil amendment expands the customer base of its feedstock as an agricultural commodity.

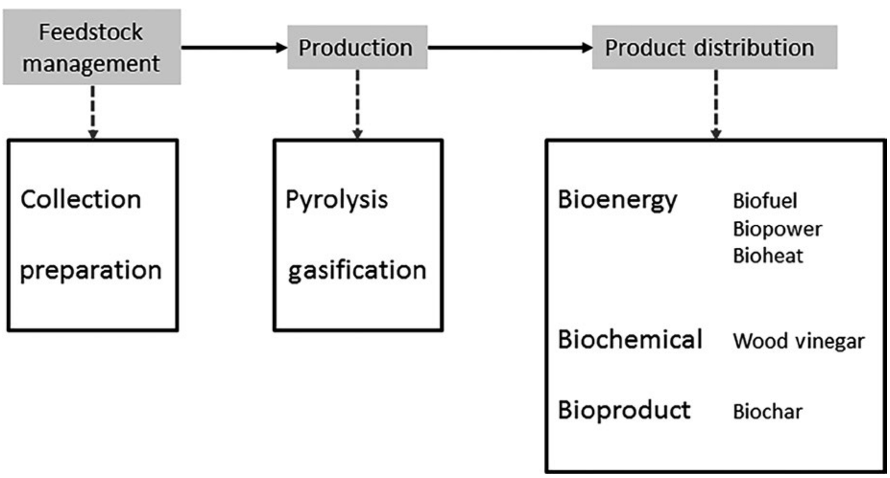

FIGURE 2 Life cycle stages of biochar production considered for program analysis in this study

TABLE 1 Legislative definitions of selected terms pertaining to biobased production and products

Term	Definition
Agricultural commodity (USDA, 2016)	An unprocessed product of farms, ranches, nurseries, and forests and natural and man-made bodies of water, that the Independent Producer has cultivated, raised, or harvested with legal access rights. Agricultural commodities include plant and animal products and their by-products, such as crops, forestry products, hydroponics, nursery stock, aquaculture, meat, on-farm generated manure, and fish and seafood products. Agricultural commodities do not include horses or other animals raised or sold as pets, such as cats, dogs, and ferrets
Biobased product (USDA-RD, 2015)	Biobased product is a product determined by the Secretary [of Agriculture] to be a commercial or industrial product (other than food or feed) that is either: (a) composed, in whole or in significant part, of biological products, including renewable domestic agricultural materials and forestry materials; or (b) an intermediate ingredient or feedstock
Biobased product manufacturing (USDA-RD, 2015)	The use of Technologically New Commercial-Scale processing and manufacturing equipment and required facilities to convert Renewable Chemicals and other biobased outputs of Biorefineries into end-user products on a Commercial Scale
Biochar (Fertilizing Materials, 2016; WECHAR Act, 2009)	(a) Charcoal or black carbon derived from organic matter through pyrolysis; (b) Materials derived from thermochemical conversion of biomass in an oxygen-limited environment containing at least 60% carbon
Change in physical state (USDA, 2016)	An irreversible processing activity that alters the raw Agricultural Commodity into a marketable Value-Added Agricultural Product. This processing activity must be something other than a post-harvest process that primarily acts to preserve the commodity for later sale. Examples of eligible Value-Added Agricultural Products in this category include, but are not limited to, fish fillets, diced tomatoes, bio-diesel fuel, cheese, jam, and wool rugs. Examples of ineligible products include, but are not limited to, pressure-ripened produce; raw bottled milk; container grown trees; young plants, seedlings or plugs; and cut flowers
Value-added agricultural product (USDA, 2016)	Any Agricultural Commodity produced in the U.S. (including the Republic of Palau, the Federated States of Micronesia, the Republic of the Marshall Islands, or American Samoa), that meets the requirements specified in paragraphs (a) and (b) of this definition. (a) The Agricultural Commodity must meet one of the following five value-added methodologies: (i) Has undergone a Change in Physical State; (ii) Was produced in a manner that enhances the value of the Agricultural Commodity; (iii) Is physically segregated in a manner that results in the enhancement of the value of the Agricultural Commodity; (iv) Is a source of farm- or ranch-based renewable energy, including E-85 fuel; or (v) Is aggregated and marketed as a locally-produced agricultural food product. (b) As a result of the Change in Physical State or the manner in which the Agricultural Commodity was produced, marketed, or segregated: (i) The customer base for the Agricultural Commodity is expanded and (ii) A greater portion of the revenue derived from the marketing, processing, or physical segregation of the Agricultural Commodity is available to the producer of the commodity

2.3 | Categorizing the available programs based on their functions

To develop a point of reference of current government funding for biochar production as of September 2018, we searched for funded programs—introduced, closed, or ongoing—at federal and state levels. We focused on the eligibility levels that these programs could provide biochar with and thus we refer to them to as the following:

1. Explicit Programs: They are explicitly designed for or mention biochar in their description,
2. Implicit Programs: They do not explicitly mention "biochar," but
   a. their definition of biobased products and bioprocesses covers biochar and biochar production processes,
   b. they focus on biomass or bio-waste which can be used directly as feedstock in biochar production, or
   c. they focus on the technology innovation and application for ecosystems conservation, in which biochar industry fits the description, and
3. Potential Programs: They do not explicitly mention biochar, nor their definition of products and processes covers biochar production, but slight modifications to the language or program can target biochar as well.

We then categorized the results of our search for programs into three policy categories.

1. Commercial financial incentives: Commercial financial incentives provide financial assistance to producers or production facilities at a commercial scale. Importantly, applicants need to own and/or operate a business to be eligible for such incentives. This type of assistance is designed to reduce capital costs and/or operating costs for commercial production of biobased outputs.
2. Nonfinancial policy support: Nonfinancial policy support includes government programs that do not offer financial

incentives but provide other forms of public support to promote biochar or biobased products, such as product certification. These types of programs are designed to achieve long-term goals by promoting public awareness of biobased products.
3. Research and development funding: Research and development funding consists of grants for (nonacademic) applied research and pilot/demonstration projects associated with biochar, biochar technology, or different stages of the biochar value chain identified above. This type of funding is typically awarded to promising projects on a competition-based application process to sponsor the development of cutting-edge technology.

Finally, we identified the following information from the collected programs.

1. Policy level—whether the program was/is administered by a federal or state-level agency.
2. Legal status—whether the program is currently effective.
3. Funding agent (if any)—the source of funds
4. Funding availability (if any)—the total amount of funding available for the program in current or most recent fiscal year regardless of maximum amount available per applicant.
5. Eligibility of biochar—whether the program explicitly, implicitly, or potentially supports the use of biochar or biochar production.
6. Awarded cases of biochar production (if any)—whether a biochar-related project was awarded by the program and the award amount received.

3 | RESULTS

We found 35 US policy programs that directly or indirectly support biochar production. These programs include those oriented toward environmental remediation and climate change management, energy and food production, and agricultural waste management. Fifteen programs can be classified as commercial financial incentives, twelve as nonfinancial policy supports, and eight as research and development funding (Table 2). The US Department of Agriculture administers majority of the identified programs.

3.1 | Commercial financial incentives

Commercial financial incentives are programs that support producers of biomass and biobased products including biochar and biofuel through various grants, loan guarantees, matching payments, and tax credits. The only active loan guarantee identified in our search that can support biochar production is the Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program. This federal program provides up to $250 million per project and provides commercial facilities with loan guarantees for up to 80% of the total eligible project cost. According to the literature, the total investment cost of a medium-scale (200 ton/day) to large-scale (2,000 ton/day) biochar facility may range from $50 to over $400 million ($2010; Brown, Wright, & Brown, 2011; Carrasco et al., 2017; Kung, McCarl, & Cao, 2013; Pourhashem, Spatari, Boateng, McAloon, & Mullen, 2013; Wright, Daugaard, Satrio, & Brown, 2010). In 2014, Cool Planet received a $91 million loan guarantee through this program to complete the construction phase of its production facility that is designed to produce biofuel and biochar at an industrial scale (USDA, 2014b). The facility is expected to start operating by 2019, producing 400,000 tons of biochar product per year.

Under the subcategories of grants, matching/production payments, and tax credits, a combined amount of $242.2 million is provided through the DOE, the USDA, and the Iowa Economic Development Authority, Oregon Department of Energy, State of Colorado, and State of Minnesota. Although most of these grants support biofuel and biopower production, some explicitly specify pyrolysis as an eligible technology and some list bioproducts as a category under which biochar may qualify. The four ongoing state-level programs in this category are Iowa's Renewable Chemicals Production Tax Credit Program (IEDA, 2017), Oregon's Biomass Tax Credits (ODOE, 2016), Colorado's EZ Investment Tax Credit Refund for Renewable Energy Projects (Enterprise Zone Program, 2015), and Minnesota's AGRI Bioincentive Program (MDA, 2015), the remainders are federal.

3.2 | Nonfinancial policy support

Nonfinancial policy support programs are programs that do not provide financial incentives but help a business maintain resilience. Parallel to financial support, programs that define biochar as a product with desirable environmental benefits are essential to generate social awareness and impact and can help facilitate investment decisions. The programs in Table 2 under the policy support category explicitly allow biochar to be considered as a viable option to address an environmental challenge, such as forest conservation or carbon emissions mitigation. Including biochar in programs such as forest conservation and fertilizing materials can create demand for biochar, helping to promote an anchor customer base (Biochar, 2018). This type of policy support can be a vital step to broad-scale commercialization of biochar production because market demand and public awareness of positive direct and indirect benefits of biochar use can be facilitated through government action aimed at educating consumer groups.

3.3 | Research and development funding

Research and development (R&D) funding programs are dedicated to emerging technologies and are typically designed to promote innovation. To enhance the competitive aspect of these types of ventures, R&D funding is obtained through a competitive process. The eight programs identified in this category have a total fund size of $29.54 million. They can be viewed as supporting biochar production implicitly through funding research for technological innovation in agriculture, conservation of biomass, and biowaste utilization. Some of these programs provide financial support on a recurring basis, while others offer support as a one-time grant.

3.4 | Funding eligibility and proportion allocated to biochar under existing programs: Biochar constitutes a minor but growing target

The total ongoing funding identified in our search of programs that could potentially benefit biochar is $521.74 million. This compares to an average funding for agricultural conservation and commodities support more broadly under the Farm Bill of approximately $6 and $5 billion annually, respectively. Of the funding we identified, 48% of the total amount explicitly includes biochar as qualified applicant, while 50% implicitly includes and the remaining 2% has the potential to include biochar.

Typically, most of this funding is administered by the USDA or the DOE and falls into program areas in the Office of Rural Development (RD) and the Office of Energy Efficiency and Renewable Energy (EERE), respectively. The USDA supports sustainable agriculture through various programs, such as the Conservation Stewardship Program and Conservation Innovation Grants through the Office of Natural Resources Conservation Service (with an enacted budget of $4.4 billion in 2016 and a similar estimated budget for 2017). DOE offers annual funding opportunities for research and development of bioenergy technologies—$225 million allocated (USDOE, 2016b) and $46 million awarded in 2016—to support bioenergy/bioproduct/biorefinery development, which implicitly includes biochar production.

Despite biochar's wide application and environmental benefits, only fourteen out of thirty-five programs identified in our research specify biochar or biobased products as eligible topics. The Water Efficiency via Carbon Harvesting and Restoration Act of 2009 (WECHAR Act, 2009) is the only program in our search that targets biochar production and provides commercial financial incentives (i.e., loan guarantees) to biochar producers to assist the establishment of production facilities. However, the bill was not able to pass the 111th Congress. Among all the programs identified as "explicit," only three of them provide commercial financial incentives. The Conservation Stewardship Program (CSP) is a nonfinancial incentive that supports biochar production for forests and associated agricultural lands following fuel reduction harvests or wildfires (Farm Bill, 2002). We identified 20 programs that implicitly support biochar by allowing producers to apply for incentives that provide support aimed at reducing production costs for small agri-businesses, biorefineries, or biomass utilization.

Iowa's Renewable Chemical Production Tax Credit Program, a program to encourage the development and use of biorefinery coproducts, is the only program we identified that does not specify or contain a language that supports biochar but could potentially support biochar. Biochar is not a chemical; however, other products generated at the biochar facility/biorefinery such as bio-oil or wood vinegar may be eligible to receive such credit and therefore improve the overall commercial viability of the biorefinery. Biochar itself has the potential to serve multiple markets as an end product and can even be blended with polymeric materials to create composites for building materials (Das, Sarmah, & Bhattacharyya, 2015a, 2015b). In addition, it can be used as an intermediate material to generate products such as CO_2 sorbent (Li et al., 2016) and activated carbon (Tan et al., 2017). So, while Iowa's renewable chemical production tax credit may not currently cover biochar as a renewable product, the framework can be used to frame similar programs that incentivize the production of renewable by-products more generally. Ultimately, monetizing by-product streams at a facility through such programs generates extra revenues that increase the market viability of facility's core product.

4 | DISCUSSION

4.1 | The biochar policy opportunity set

Despite growing support for and recognition of the potential value of biochar, it has been less successful to date in receiving policy support relative to other more established renewable bioproducts, such as biofuels. One example of a program that can benefit biochar is the Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (Section 9003 of Farm Bill 2008), formally known as the Biorefinery Assistance Program. In 2015, the USDA added renewable chemicals and biobased product manufacturing to the program in the final rule (USDA-RD, 2015). The broad applicability of the Biorefinery Assistance Program opens the door for greater support for biochar production, but competition for limited government funds will ultimately dictate that longer term success in growing biochar production and use will depend on commercial viability.

Meanwhile, participation of biochar producers in available programs such as forest conservation and fertilizing materials

TABLE 2 US policy programs relevant to biochar production and application

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

(continues)

TABLE 2 (continues)

Policy category	Incentive type	Level	Program	Status	Supporting/ Funding agent	Fund size (if any)	Eligibility of biochar	Example of awarded cases of biochar production and application
			EZ Investment Tax Credit Refund for Renewable Energy Projects (Enterprise Zone Program, 2015)	Ongoing	State of Colorado	Up to $750,000/ year per project	Implicit	
	Production payments	State	AGRI Bioincentive Program (MDA, 2015)	Ongoing	State of Minnesota	[b]	Implicit	
Policy support	Product certification	Federal	Biopreferred Program (USDA, 2014a)	Ongoing	USDA		Explicit	Ten biochar products identified for mandatory federal purchasing, six of which are also approved by USDA as Certified Biobased Product
	Materials for organic crop production	Federal	National Organic Program (USDA-AMS-NOP, 2016)	Ongoing	USDA		Explicit	Classifies biochar as an amendment acceptable for organic agriculture
	Forest conservation	Federal	Conservation Stewardship Program (Farm Bill, 2002)	Ongoing	USDA		Explicit	
	GHG emissions reduction reporting	State	California's Biochar Production Project Reporting Protocol—GHG Emission Reduction Accounting	Ongoing	State of California		Explicit	
	Food and agricultural code	State	Fertilizing materials: auxiliary soil and plant substances: Biochar (Fertilizing Materials, 2016)	Approved by Governor	State of California		Explicit	Twenty-four biochar products are registered in the program, of which: four are approved, two pending review, five revisions required, six resubmitted, and seven expired
	Product procurement	Federal	Environmentally Preferable Purchasing Program (E.O. 13693, 2015)	Ongoing	EPA		Explicit	
		State	Environmentally Preferable Products Procurement Program (EPP, 2009)	Ongoing	State of Massachusetts		Explicit	
	Renewable portfolio standards[c]	State	Renewable Energy Standard (RES, 2004)	Ongoing	State of Colorado		Implicit	

(continues)

TABLE 2 (continues)

Policy category	Incentive type	Level	Program	Status	Supporting/ Funding agent	Fund size (if any)	Eligibility of biochar	Example of awarded cases of biochar production and application
			Renewable Energy Standard (RES, 2008)	Ongoing	State of Missouri		Implicit	
			Renewable Portfolio Standard (RPS, 2010)	Ongoing	State of Wisconsin		Implicit	
	Research support	State	Supporting the continued research, development, production, and application of biochar from our forests and agricultural lands (Support for Biochar, 2017)	In committee	State of Washington		Explicit	
			Concerning the Colorado General Assembly's Support for the Continued Research, Development, and Application of Biochar from Our Forests (Support for Use of Biochar, 2017)	Ongoing	State of Colorado		Explicit	
Research and development funding	Grants for research and demonstration project	Federal	Biomass Research and Development Initiative (BRDI) (USDA-NIFA, 2011)	Ongoing	USDA, IBCE, and DOE	$9 million (2017)	Implicit	In 2010, $5.3M was awarded to a 5-year project “Integration of biofuels and bioproducts production into forest products supply chains using modular biomass gasification and carbon activation”
			United States Forest Service Wood Innovations Grants (USDA-USFS, 2018)	Ongoing	USDA	$7 million (2018)	Implicit	Number of biochar projects and total federal funding between 2015 and 2018: 2015: 6 (out of 43) projects, $1.2M. 2016: 2 (out of 42) projects, $202K. 2017: 5 (out of 38) projects, $1M. 2018: 3 (out of 34) projects, funding not yet available
			2013 Hazardous Fuels Woody Biomass Utilization Grant Program (USDA-USFS, 2013)	Closed	USDA	$3 million	Implicit	Family Forests of Oregon awarded for its “Biochar Project for Pollution Remediation in Sweet Home, OR”

(continues)

TABLE 2 (continues)

Policy category	Incentive type	Level	Program	Status	Supporting/Funding agent	Fund size (if any)	Eligibility of biochar	Example of awarded cases of biochar production and application
			Conservation Innovation Grants (CIG) (USDA-NRCS, 2017)	Ongoing	USDA	$10 million (2018)	Implicit	In 2011, $12K awarded to Earth Dharma Farm's "Sustainable on-farm biochar production." In 2013, $75K awarded to Sonoma Ecology Center's "biochar farm and fuel"
			Sustainable Energy Development Reform Act (SEDR, 2017)	In committee			Explicit	
		State	Maryland's Animal Waste Technology Fund Grant (MDA, 2018)	Ongoing	Maryland Department of Agriculture	$3.5 million (2018)	Implicit	$1.2 million awarded to Renewable Oil International MD, llc for animal manure management demonstration project to reduce poultry litter (50%–63%). Biochar was identified as one of the by-products from thermal decomposition/fast pyrolysis
			Carbon Farming Pilot Project in Columbia and Dutchess Counties (Carbon Farming Pilot Project, 2017)	In senate	State of New York		Implicit	
			Great Plain Biochar Initiative Grants for Biochar (NFS, 2018)	Ongoing	Nebraska and Kansas	$40,000 (2018)	Explicit	

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

[a]5 cents per pound produced by eligible businesses: up to $1 million for start-ups and $500,000 for established businesses. [b]3 to 6 cents per pound of renewable chemical produced; $1.053 to $2.1053 per the equivalent of MMBtu of advanced biofuels produced; and $5 per MMBtu of thermal energy produced. [c]All these three state programs include pyrolysis of waste materials as eligible technologies.

is instrumental in promoting biochar in future programs. An example of current participation can be seen in the number of producers engaged in the USDA's Biopreferred program, a USDA program promoting the purchase and use of biobased products through mandatory federal purchasing and voluntary labeling initiative. We identified over 100 biochar products offered in the market in our biochar product survey in 2016, while only 10 biochar products are involved in the Biopreferred program. Explaining the low participation of producers can range from the possibility that they choose not to partake in a specific program as they find the process of receiving such certification complicated and not financially valuable (which may be the case for very small-scale outfits), to the possibility that they simply may not be familiar with the policy programs for which they can qualify.

4.2 | Existing programs do not yet encourage facility designs optimized for biochar production

The existing landscape of government programs shapes the choices biochar producers make about facility design, and tilt firms away from biochar and toward bioenergy. For example, with a change in process temperature and residence time (e.g., fast pyrolysis vs. slow pyrolysis), more bioenergy and fuel can be recovered compared to biochar (Onay & Kockar, 2003) and current policy incentivizes such outcomes. At larger scales, biochar-producing facilities are capable of recovering more of the coproduced heat, biofuels, or biochemicals. Since bioenergy and biofuels benefit from more established incentives in the market, such facilities may be able to recover their investment cost with a partial cover from government's loan guarantees and product subsidies (e.g., the case of Cool Planet). However, due to the large upfront investment costs and technological barriers of large biochar-focused production facilities (e.g., slow pyrolysis plants), facilities primarily focused on biochar production in the United States have mostly been developed at small scales where the lower costs can be financed through personal capital (Jirka & Tomlinson, 2014).

Our review of past funds awarded to biochar facilities shows that the majority of these were research and development grants supporting small-scale biochar production. Despite the support received by these facilities, the development of biochar in the market has been slow and challenging.

4.3 | Federal vs. state

Policies at different administrative levels may differentially shape the industry. For example, regulations at the state or regional level, but not federal—such as a state or regional carbon tax or credit—may influence the willingness of affected industries to operate in a certain region. For instance, a local carbon tax may discourage activity by some businesses while a carbon credit may provide incentives for others (Carbon Farming Act, 2017).

Programs that directly support biochar production may be easier to administer and more targeted to local goals when introduced at the state level. The states of California, Colorado, and New York have initiated more successful local programs concerning biochar than other states, which reflects a difference in policy priorities. If, however, action at the federal level were required, then, for example, the California-centric policy priority would be forced to compete with many differing state priorities at the national level. Thus, a state-administered program can accelerate local priorities relative to a federal program, particularly when the benefits are local. Moreover, local circumstance can play a role, particularly when there are large biomass resources available. An example of this can be seen in the State of Colorado, where the use of low-cost and abundant resources such as beetle-killed and fire-damaged trees as well as forest fuel for biochar production was encouraged under existing programs. This has greatly contributed to Mountain region having the lowest biochar prices in the United States (Figure 1). In these situations, the policy priority is set by the regional opportunity endowment, and policymakers in those states/regions may be better capable of providing a suitable environment for the biochar industry (2016).

Federal programs also play a valuable role. Although states can tailor their regulations to fit their available resources and stakeholder demands, federal regulations can establish a clear and level playing field for all market participants across all states (Larsen, 2008). This can create a broader competitive base for the biochar industry and in turn help facilitate economies of scale and cost reductions across the industry. Nineteen out of thirty-five programs identified in our search are administered by federal agencies. While local benefits of biochar such as reducing water use and local pollution may provide a stronger case for state policies, those benefits may not be achievable at scale absent federal government involvement.

5 | RECOMMENDATIONS

5.1 | Developing product standards can provide a basis for future regulations

In general, standardization of bioproduct specifications ensures compliance with programs and policies, and regulating bodies are most often responsible for administering quality and environmental performance standards of those products. One of the major challenges currently facing the biochar industry is the lack of development of legislated product certification or standards (van Laer et al., 2015). While biochar implicitly qualifies for many of the funding opportunities we identified, the majority of the technologies which have successfully received financial support are more established, such as biofuels. Algal biofuel is an example of a product that may still face difficulty in establishing economic production, but, unlike biochar, the properties and environmental footprint requirements for this product to receive governmental support are well-defined (EPA, 2017).

There has been progress on this front for biochar. In recent years, the International Biochar Initiative (IBI) has established international biochar standards, which are designed to encourage consistent levels of biochar quality and, thus, further development of the industry (IBI, 2015). However, until now in the United States, biochar certification has only been voluntary, and despite attempts to establish such standards, there is wide variability in the properties of biochar, which creates performance variability (Bach, Wilske, & Breuer, 2016). Moreover, insufficient industry participation has hindered the establishment of legislated product standards for biochar.

A uniform set of product standards is important for policy because compliance is a critical and auditable metric. If a market tool such as tax credit or subsidy is deemed most effective to support biochar, certification is necessary for identifying products to receive such support. The lack of standards means that there is no basis for comparison among biochar products to evaluate whether they can comply with regulations and receive support. Therefore, a broad set of biochar certification standards is an important next step in the legislative playbook for including biochar in a variety of programs concerning bioproducts, soil quality, or carbon sequestration.

5.2 | Data on biochar production and application is limited

Unlike the long-established industry for conventional fertilizer, there are limited or incomplete public databases for biochar sales (Jirka & Tomlinson, 2013) due to fewer large-scale market participants operating in a smaller, less mature industry over a relatively short amount of time. As the industry matures, more data will almost certainly become available. Regardless, it is incumbent upon biochar producers to establish auditable metrics if effective policy is to be created and maintained, if nothing else as a means to track the evolution of the market and the effectiveness of the policy measures.

Along with a lack of commercial data, there is also little consumer knowledge of biochar or biochar-blended products relative to conventional fertilizer or composts, although there has been rapid growth in the number of biochar agronomic performance (Jeffery et al., 2011; Zhang et al., 2016) and techno-economic (Ahmed, Zhou, Ngo, & Guo, 2016; Brown et al., 2011; Pourhashem et al., 2013; Wright et al., 2010) studies. To overcome this knowledge deficit, farmers and other potential consumers must be included in the biochar policy discourse. Studies show that farmers are more likely to adopt practices that have demonstrable environmental benefits or private benefits for agricultural productivity (Dumbrell, Kragt, & Gibson, 2016). In addition to the cost of biochar, many farmers are not accepting of biochar because they are disconnected from the research on biochar's environmental benefits (Latawiec et al., 2017; Rittl, Arts, & Kuyper, 2015) and are uncertain about future environmental policy drivers (Dumbrell et al., 2016).

5.3 | Future policy development

Not all studies consider the broader ecosystem benefits that biochar may provide, despite the virtual explosion in literature on biochar benefits. The avoided costs associated with larger positive externalities of biochar use (e.g., water and air quality improvement and GHG emissions reduction; Pourhashem et al., 2017) are largely missing from discussions of developing a designated biochar policy program. The ability to monetize those benefits would help communicate biochar's economic potential compared to other mitigation strategies competing for governmental funds. In general, economic evaluation of biochar's benefits provides a useful tool for local governments when assessing biochar for addressing an environmental or ecological concern such as local air or water pollution. The challenge in including biochar in policy, however, is the availability and accessibility of information regarding the monetary benefits of biochar. This requires a forward shift in analyzing the bigger economic picture of the damages biochar application prevents, as well as better communication of these analyses and their importance in local decisions to local stakeholders and policymakers.

Compared to more established biobased products like biofuels, biochar is not the center of policymakers' attention. While biofuels such as conventional ethanol have received incentives as a part of a long-term plan to diversify the nation's energy portfolio, biochar may warrant greater support as part of a long-term soil and food security strategy, as well as capture general environmental benefits provided through, for example, its nitrogen remediation capabilities and its implications for local air quality and nearby and downstream water quality.

When the ecosystem services that biochar may provide are monetized, it will become much easier to design programs that directly account for avoided damages in supporting biochar's wider production and application. Such programs can include using policy tools like tax credits, subsidies, loan guarantees, and mandates on blending conventional fertilizers with biochar. For example, a biochar-blend requirement could mandate fertilizer companies to blend a certain amount of biochar into their products to increase the efficiency of delivering nutrients to reduce their runoff to the environment. This will provide farmers with an option to mitigate unintended negative environmental impacts when applying conventional fertilizer, which is one of the most effective ways in reducing nutrient load from farms (Wu & Tanaka, 2005). At all levels, establishing product standards are necessary to reduce barriers in deployment of eligible biochars.

5.4 | Final remarks

Well-designed policy can play an important role in establishing pathways to achieving a wide range of biochar's benefits and lead to increased use. Until a designated biochar program is established, the best opportunities for biochar production to receive funding through existing programs are

- as a coproduct of biofuel and biopower production (implicit),
- as an integrated biorefinery where biochar is produced from the output of another commercial-scale bioproduct facility (implicit), and
- as a biobased product under USDA's Biopreferred program, a registered fertilizing material (e.g., under CDFA), and a main product under forest conservation programs (explicit).

While persistent efforts at federal and local levels can provide incentives for biochar production and use, greater funding for research is important for driving improvements in the technology. Improved knowledge on designing biochar properties will help develop product standards, which will drive consistency in biochar products by providing guidelines to producers and ensuring compliance with future laws and regulations. Further investigation of biochar ecosystem benefits and improvement in environmental and economic models to accurately assess and monetize biochar benefits can better inform biochar policy discussions.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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