
**ADJUSTING CARBON MANAGEMENT POLICIES TO
ENCOURAGE RENEWABLE, NET-NEGATIVE PROJECTS
SUCH AS BIOCHAR SEQUESTRATION**

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I. INTRODUCTION

Prominent scientists believe the world concentration of carbon dioxide already exceeds a “safe” level.¹ Thus, there will likely be a need to not only reduce the pace of net emissions but also to develop technologies for effectively removing carbon from the atmosphere. One promising technology is the use of biochar to sequester carbon in soil. This article considers legal changes needed to fully accommodate credits for biochar and otherwise encourage net-negative projects.

Part II of this article examines the science behind biochar, the manufacturing process, and its potential as a method of carbon sequestration.² Biochar is created through pyrolysis—a process of heating biomass in a low-oxygen environment.³ The end result is a substance containing, for practical purposes, a permanent form of carbon.⁴ When used as a soil amendment, this biochar increases soil fertility, water retention, and crop productivity.⁵ Moreover, it yields secondary greenhouse gas-related benefits by suppressing greenhouse gas (GHG) emissions from soil, and increasing the soil’s capacity for carbon storage.⁶ There are some accordant risks, but, as Part II describes, such risks appear manageable and may be

1. See, e.g., James Hansen et al., *Target Atmospheric CO₂: Where Should Humanity Aim?*, 2 OPEN ATMOSPHERIC SCI. J. 217, 217 (2008), available at www.columbia.edu/~jeh1/2008/TargetCO2_20080407.pdf.

2. See *infra* Part II.

3. Johannes Lehmann & Stephen Joseph, *Biochar for Environmental Management: An Introduction*, in *BIOCHAR FOR ENVIRONMENTAL MANAGEMENT* 1, 1–3 (Johannes Lehmann & Stephen Joseph eds., 2009).

4. *Id.* at 1.

5. *Id.* at 5–9.

6. *Id.* at 8–9.

worth taking in light of the proven benefits of biochar.⁷

Part III of this article describes the current regulatory regimes, and outlines their shortcomings as they relate to carbon sequestration.⁸ Specifically, select provisions of the Kyoto Protocol, the Regional Greenhouse Gas Initiative, and the California Global Warming Solutions Act are examined.⁹ Although each provides incentives for alternative energy, none sufficiently encourages the use of biochar-related carbon sequestration.¹⁰ The science appears to support a more comprehensive approach to allowing biochar sequestration carbon credits than any of the above have adopted.¹¹

Part IV, accordingly, suggests that the regulatory schemes be modified to provide appropriate incentives as justified by the best available science.¹² Carbon credits for biochar should be available, and should account for the actual greenhouse gas reductions achieved through biochar's direct and indirect effects.¹³ In order to achieve an accurate prediction of carbon offsets, each stage of biochar must be considered.¹⁴ That is, to optimize the benefits of biochar, the feedstock, the method of pyrolysis, and the end use must all be addressed under such a regulatory regime.¹⁵

II. BIOCHAR: OLD TECHNOLOGY WITH NEW POTENTIAL

Large pockets of black soils in the Amazon—*terra preta* as much as 7000 years old—have proved remarkably fertile, producing substantially greater crop returns (up to twice as much) than the surrounding soils.¹⁶ The black soils were created by the region's original human residents, who systematically charred vegetation and other organic matter, resulting in a carbon-rich earth as indicated by its color.¹⁷ The *terra preta* soils may contain as much as eighteen times more carbon than nearby areas.¹⁸ The

7. See *infra* Part II.

8. See *infra* Part III.

9. See *infra* Part III.A–C.

10. See *infra* Part III.A–C.

11. See *infra* Part II.

12. See *infra* Part IV.

13. See *infra* Part IV.

14. See *infra* Part IV.

15. See *infra* Part IV.A–F.

16. Emma Marris, *Black is the New Green*, 442 NATURE 624, 624–25 (2006).

17. *Id.* at 624; Peter Winsley, *Biochar and Bioenergy Production for Climate Change Mitigation*, 64 N.Z. SCI. REV. 5, 5 (2007).

18. Marris, *supra* note 16, at 624.

charred material is both beneficial to the soil and stable as a form of carbon. Biochar is the modern equivalent, and it provides a viable method of removing greenhouse gases from the atmosphere.¹⁹

A. *Biochar and the Carbon Cycle*

Biochar is the carbon-rich, charcoal-like substance formed when biomass (for example, wood chippings or agricultural waste) is heated at relatively low temperatures (under 700°C) in a low-oxygen environment, a process known as pyrolysis.²⁰ The resulting biochar is extremely stable, and the carbon it contains may be sequestered in that form for thousands of years.²¹ Moreover, using the substance as a soil amendment carries numerous possible benefits, such as increasing water retention, soil fertility, and crop productivity.²² Its potential as a tool for the management of GHGs is therefore significant.

The critical characteristic of biochar is that it stores carbon in an inert, relatively permanent form.²³ Processes that create biochar from less stable forms of carbon—such as biomass that would otherwise be transformed into carbon dioxide through combustion or through decay in the carbon cycle—therefore represent a net-negative method of carbon storage.²⁴ In other words, these processes actually *remove* carbon from the natural carbon cycle and therefore take it out of circulation in the atmosphere. Biochar can be made on the same land over and over again, making it a “renewable” sink of carbon.

Carbon is naturally circulated among soil, water, and the atmosphere.²⁵ Vegetation (and other biomass) participates in that cycle by absorbing carbon at the beginning of its life cycle, such carbon being released at the end through decay and oxidation, thereby returning to the atmosphere.²⁶ Whereas the carbon in

19. Winsley, *supra* note 17, at 5.

20. See Lehmann & Joseph, *supra* note 3, at 1, 3.

21. E.g., Bruno Glaser et al., *Ameliorating Physical and Chemical Properties of Highly Weathered Soils in the Tropics with Charcoal—A Review*, 35 *BIOLOGY & FERTILITY SOILS* 219, 225–28 (2002).

22. E.g., Winsley, *supra* note 17, at 6–7.

23. *Id.* at 5.

24. See *id.* (contrasting “slash and char” practices with “slash and burn” practices).

25. *Id.*

26. Peter Read, *A Copenhagen Initiative?: Curing Kyoto With a “Leaky Bucket”* 6

biomass can turn over in as little as one to five years, the inert carbon in biochar may take thousands of years to oxidize.²⁷ The formation of biochar therefore removes carbon from the carbon cycle on a long-term basis.

Furthermore, targeting the carbon cycle for carbon sequestration has certain advantages over carbon capture and sequestration (CCS) of fossil fuel emissions. As described above, generating biochar is a carbon net-negative activity. Conversely, even if all fossil fuel-based carbon emissions were captured and sequestered, it would be a net-neutral undertaking at best. The scale of the carbon cycle also allows for a higher ceiling of carbon sequestration via biochar. The soil, water, and atmospheric carbon pools are collectively hundreds of times larger than global annual emissions from fossil fuels.²⁸ Systematic removal of a relatively small percentage of the carbon in this cycle can therefore generate substantial gains in absolute terms. Standing alone, biochar may not offer a comprehensive solution to mitigate climate change, but the ability to store carbon in biochar offers an important tool for limiting and ultimately reducing the concentration of heat-trapping GHGs in the atmosphere.

B. Examining Pyrolysis

1. Possible Feedstock

Almost any biomass can be effectively converted to biochar, though no consensus exists as to optimal feedstocks.²⁹ Indeed, there may be no single optimal source, considering the wide range of applications to which pyrolysis may be tailored. Typical feedstocks include wood-based waste (e.g., wood chips or pulp), crop residues (e.g., straw, nut shells), switch grass, and other organic wastes (e.g., distillers' grain, bagasse, olive waste).³⁰ Although

(U.K. Biochar Research Ctr., Working Paper No. 3, 2009), available at <http://www.geos.ed.ac.uk/scs/biochar/documents/WP3.pdf>.

27. Winsley, *supra* note 17, at 5.

28. Johannes Lehmann, *Biochar for Mitigating Climate Change: Carbon Sequestration in the Black*, 18 FORUM DER GEOÖKOLOGIE 15, 16 (2007).

29. Saran Sohi et al., *Biochar, Climate Change and Soil: A Review to Guide Future Research*, COMMONWEALTH SCI. & INDUS. RES. ORG. LAND & WATER SCI. REP., Feb. 2009, at 5–6.

30. Johannes Lehmann et al., *Bio-char Sequestration in Terrestrial Ecosystems—A Review*, 11 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 403, 411–12 (2006) [hereinafter Lehmann, *Bio-char Sequestration*]; Sohi, *supra* note 29, at 5–6.

pyrolysis of industrial and municipal waste is also workable,³¹ the resulting biochar's use as a soil amendment can raise specific concerns—for instance, the possible presence of organic pollutants or heavy metals.³² Agricultural and related waste is therefore the usual focus of discussions on biochar.³³

The feedstock used in creating biochar will have important ramifications. Feedstocks with high lignin concentration such as sawmill and forest residues produce the highest biochar (and therefore carbon) yields.³⁴ A higher mineral content may also produce more biochar.³⁵ Feedstock with higher moisture content will require a higher energy input to convert to biochar, with lower yield.

2. *Byproducts of Pyrolysis*

In addition to biochar, pyrolysis creates a combustible synthesis gas (syngas) and bio-oil that can be used to produce heat and/or power.³⁶ Pyrolysis is therefore an effective method of both carbon capture and bioenergy production.³⁷ Syngas contains a mixture of four primary constituents: hydrogen (50%), carbon dioxide (30%), nitrogen (15%), and methane (5%).³⁸ The gas can be purified to yield pure streams of each.³⁹ Bio-oil is likewise an important energy stream to capture, although it consists of 25%–70% water depending on the method of pyrolysis.⁴⁰ It is therefore understood to have less than half the energy content of fuel oil.⁴¹

3. *The Pyrolysis Process*

One of the great benefits of pyrolysis is its efficacy at capturing the carbon in feedstock. The process is generally understood to convert 50% of the feedstock carbon into biochar.⁴² Though the

31. Sohi, *supra* note 29, at 5–6.

32. *See, e.g.*, Lehmann, *Bio-char Sequestration*, *supra* note 30, at 405.

33. *Id.*

34. *Id.* at 411; Sohi, *supra* note 29, at 6.

35. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 411.

36. Sohi, *supra* note 29, at 3–5.

37. *Id.* at 20.

38. *Id.* at 8.

39. *Id.*

40. *Id.* at 5 tbl. 1.

41. Winsley, *supra* note 17, at 7.

42. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 407, 413; Sohi, *supra* note 29, at 20.

other half is released into the atmosphere immediately, this emission would be exceeded within a few months by the carbon emitted in decomposition if the feedstock were instead applied directly to the soil.⁴³ The conversion to biochar is therefore well worth the accelerated release of the carbon not converted.

Biochar can be manufactured via slow pyrolysis, fast pyrolysis, and intermediate pyrolysis.⁴⁴ The primary difference among the methods is the temperature used.⁴⁵ The varying temperatures will affect the final biochar-syngas-bio-oil proportions,⁴⁶ but will not substantially alter the amount of carbon converted into biochar.⁴⁷ Although lower yields of biochar are generated with higher temperatures, the carbon concentration in the resulting biochar actually increases.⁴⁸ At high enough temperatures, however, this inverse relationship of higher carbon concentration to lower biochar yield breaks down, as additional carbon is converted into ash rather than biochar.⁴⁹

Additional steps can be taken during pyrolysis to create a nitrogen or ammonia-rich biochar, which may offer further benefits as a fertilizer.⁵⁰ This enriched form of biochar has not been fully examined, but if effective it could reduce the manufacture and application costs of related fertilizer products, leading to increased GHG-related savings.

C. *Biochar as a Soil Amendment: Benefits and Risks*

The mechanisms contributing to the numerous benefits of applying biochar to soil are only partially understood, but the benefits are widely recognized nevertheless.⁵¹ Such benefits are thought to stem largely from biochar's physical structure. In general terms, biochar is an effective absorbent.⁵² On the micro

43. Sohi, *supra* note 29, at 19.

44. *Id.* at 6–9.

45. *Id.*

46. *Id.* at 5 tbl. 1.

47. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 413.

48. *Id.*; Sohi, *supra* note 29, at 11.

49. Sohi, *supra* note 29, at 11.

50. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 414; Sohi, *supra* note 29, at 10.

51. See, e.g., Sohi, *supra* note 29, at 32–36; S. D. Joseph et al., *Biochar for Carbon Sequestration, Reduction of Greenhouse Gas Emissions and Enhancement of Soil Fertility; A Review of the Materials Science*, PROC. OF THE AUSTRAL. COMBUSTION SYM. (2007) [hereinafter Joseph, *Biochar*].

52. See generally David A. Laird, *The Charcoal Vision: A Win-Win-Win Scenario for*

level, the substance has a “vast surface area and complex pore structure,”⁵³ which promotes beneficial chemical and microbial interactions. Application of biochar “improves soil structure and water retention, enhances nutrient availability, lowers acidity,” and may reduce the toxicity of pollutants such as heavy metals.⁵⁴

The high surface area of biochar encourages microbiota⁵⁵—bacteria and fungi—which can begin to grow in the pores within the first month of application to soil.⁵⁶ Necessary for plants to absorb nutrients from soil,⁵⁷ such microbiota leads to reduced nitrogen loss and increased nutrient availability.⁵⁸ The nanopores of biochar also interact with soil and with water to increase soil porosity and dissolution of organic and inorganic compounds.⁵⁹

These and other mechanisms allow for a variety of benefits. Applying biochar to soil increases soil fertility and productivity of fertilizer, and reduces leaching of nitrogen into the water table.⁶⁰ Biochar improves water retention and reduces soil acidity.⁶¹ Biochar may also have secondary GHG-related benefits. Soils amended with biochar display dramatically reduced emissions of other GHGs, such as methane and nitrous oxide.⁶² Biochar may also lead to stabilization of other organic matter, thereby increasing organic carbon storage capacity of the soil.⁶³ Thus, application of biochar sequesters additional soil carbon—the “organic carbon and enhanced bacterial biomass that the char sustains.”⁶⁴

Using biochar as a soil amendment also improves crop productivity. For example, the productivity of crops in *terra preta* may be twice that of crops grown in nearby soils.⁶⁵ Similarly, the use of biochar plus chemical amendments has demonstrated the ability to

Simultaneously Producing Bioenergy, Permanently Sequestering Carbon, While Improving Soil and Water Quality, 100 AGRONOMY J. 178 (2008).

53. David J. Tenenbaum, *Biochar: Carbon Mitigation from the Ground Up*, 117 ENVTL. HEALTH PERSP. A70, A71 (2009).

54. Winsley, *supra* note 17, at 6; *see generally* Malcolm Fowles, *Black Carbon Sequestration as an Alternative to Bioenergy*, 31 BIOMASS & BIOENERGY 426 (2007).

55. Winsley, *supra* note 17, at 6.

56. Joseph, *Biochar*, *supra* note 51, at 133.

57. Tenenbaum, *supra* note 53, at A71.

58. Winsley, *supra* note 17, at 6.

59. Joseph, *Biochar*, *supra* note 51, at 132.

60. Fowles, *supra* note 54, at 427–28.

61. *Id.*

62. *Id.*; Lehmann, *Bio-char Sequestration*, *supra* note 30, at 418.

63. Sohi, *supra* note 29, at 19.

64. Marris, *supra* note 16, at 625.

65. *Id.*

double grain yields over use of fertilizer alone.⁶⁶ Although productivity gains will depend “on factors such as soil and crop type, char concentrations, and nutrient levels”⁶⁷ which requires some tailoring to local conditions, it is well recognized that biochar is an effective method of improving biomass production.⁶⁸

Lastly, there are no known limits to the amount of biochar that can be applied to soil, though a ceiling certainly exists.⁶⁹ Biochar and related material, like black carbon from wildfires, have been shown to occur in concentrations above twenty percent in soils “with no apparent ill-effects.”⁷⁰ Indeed, “[m]ost of the results of deliberate bio-char additions to soil showed increasing crop yields with increasing additions up to very high loadings,” showing “growth reductions only at very high applications.”⁷¹ Heavily amended soil may feasibly contain two and a half times the amount of carbon as unimproved soil (once the secondary carbon storage effects are accounted for), with beneficial effects still realized.⁷²

Systematic application of biochar to soil does give rise to certain risks, but these are largely manageable, and small in comparison to the known benefits. Perhaps the most important consideration is that the use of biochar as a soil amendment is irreversible; the biochar is effectively permanent, and it cannot be removed.⁷³ There are primary sources of concern: (1) the source of feedstock, (2) the safety of the biochar itself, and (3) the effect of biochar on the soil and crop production.

Although the source of feedstock generally will not affect the efficacy and safety of biochar, the effect on feedstock soil must be considered. “[S]oil fertility depends on degradation of organic matter, and the recycling of plant nutrients.”⁷⁴ Over-extraction of crop residue may therefore lead to the degradation of the feedstock soil through depletion of nutrients.⁷⁵ Return of the biochar to the feedstock soil may actually return the majority of nutrients while improving nutrient retention, thereby alleviating the concern

66. Tenenbaum, *supra* note 53, at A72.

67. Winsley, *supra* note 17, at 7.

68. *E.g.*, Johannes Lehmann, *A Handful of Carbon*, 447 NATURE 143 (2007).

69. *E.g.*, Winsley, *supra* note 17, at 5.

70. Fowles, *supra* note 54, at 427.

71. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 416.

72. Marris, *supra* note 16, at 625.

73. Sohi, *supra* note 29, at 37.

74. *Id.* at 32.

75. *Id.*; Laird, *supra* note 52, at 178–79.

of soil fertility depletion.⁷⁶

Cropping for biochar may therefore be a possibility, with short rotation woody plants and grasses being the most likely candidates.⁷⁷ Extensive use of non-waste feedstocks for biochar, however, “could impact not only commodity prices but, in a manner analogous to that seen with large-scale bio-ethanol production in the United States, impact on the economics of continued energy production through feedbacks on land and input prices.”⁷⁸ Moreover, pressure on farmable land should be considered, as “only a finite area of land [is] available without compromising food production.”⁷⁹ The proposed scales of biochar implementation, however, are unlikely to compromise land use for food production.⁸⁰ The current overabundance of possible feedstock should also alleviate the concern.

The safety and efficacy of biochar as a soil amendment must also be addressed. The pyrolysis process can, at higher temperatures, create “toxic compounds that are associated most often with combustion processes, namely PAHs and dioxins.”⁸¹ These compounds occur most frequently at temperatures above 700°C, but may form in smaller quantities at lower temperature ranges.⁸² At the other end of the spectrum, less carbonized forms of biochar may contain higher levels of volatile compounds, leading to negative effects on crops.⁸³ Further, stability of the biochar itself will depend on the method of production.⁸⁴

Biochar’s effect on crop productivity, though generally positive, is also a potential concern. Depending on the type of soil and crop being grown, biochar could actually decrease crop productivity,⁸⁵ or require increased fertilizer to compensate for biochar’s tendency to absorb certain nutrients.⁸⁶ But the inherent incentive on an individual basis for greater crop efficiency should protect against widespread adoption of harmful applications of biochar.

76. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 415–16.

77. *Id.*; *see also* Winsley, *supra* note 17, at 7–8.

78. Sohi, *supra* note 29, at 28.

79. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 416.

80. *Id.*

81. Sohi, *supra* note 29, at 37.

82. *Id.*

83. Tenenbaum, *supra* note 53, at A72.

84. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 417.

85. *Id.* at 418.

86. *Id.* at 419.

D. Potential and Practicability of Implementing Biochar

Due to the massive availability of biomass and the capacity of soil to take in biochar, the potential of biochar as a method of carbon sequestration is significant. Estimates and assumptions vary, but under present day scenarios, carbon sequestration from biochar could total roughly 10% of emissions from fossil fuels.⁸⁷ One estimate places an achievable number at 29% of current fossil fuel emissions.⁸⁸ As fossil fuels are replaced by renewable sources of energy, this percentage could increase.

Biochar's potential far exceeds other CCS methods. "[T]he storage capacity of biochar is not limited in the same way as biomass sequestration through afforestation, conversion to grassland or no-tillage agriculture."⁸⁹ As an initial matter, it is a lower-risk strategy than other options. Whereas geological carbon storage or afforestation are exposed to the possibility of sudden massive carbon release—by leaks or fires, for example—biochar is not at risk for a similar loss of stored carbon. Implementation of biochar also does not require the initial massive capital outlays of geological carbon storage. Rather, it could be effectively implemented on a relatively small-scale, localized basis, to maintain close proximity to both the feedstock and the end use.

Further, biochar sequestration is not only relatively permanent, but also relatively easy to monitor. It appears to be widely presumed that biochar sequestration is "easily and cheaply verified."⁹⁰ Indeed, scholars have suggested that "[n]o complex predictive models or analytical tools are required" to include biochar into emission trading schemes, because the conversion of biomass into biochar and its application to soil are easily calculated and monitored.⁹¹

Although the carbon directly sequestered and going into ground is easy to monitor, secondary effects on soil are important but not as readily monitored. In particular, biochar's suppression of off-gassing and promotion of soil's carbon capacity are significant.⁹² Though these effects are not easy to verify, they should

87. *Id.* at 416.

88. Tenenbaum, *supra* note 53, at A72–A73.

89. Lehmann, *A Handful of Carbon*, *supra* note 68, at 143.

90. Fowles, *supra* note 54, at 428.

91. Lehmann, *A Handful of Carbon*, *supra* note 68, at 144; *see also* Lehmann, *Bio-char Sequestration*, *supra* note 30, at 420.

92. Increasing fertility is measurable, but probably least important, as there is

nevertheless be accounted for in order to allow credit for the full scope of carbon sequestered. Further life cycle analyses of biochar are necessary to implement a precise and accurate set of policies that fully account for both direct and secondary effects of biochar. But the perfect should not be the enemy of the good. Implementation within parameters known to be safe and effective should not be forestalled for lack of perfect information.

In sum, pyrolysis has been shown to effectively sequester carbon and capture energy from biomass. The science suggests that the relative distribution of energy or sequestration can be adjusted through changes in three components of the technical system: the feedstock used, the pyrolysis process used, and the location where the resulting biochar is applied.⁹³ This technical flexibility therefore presents an important and under-studied policy question: how to encourage the location and configuration of pyrolysis systems that yield the socially optimal level of energy and carbon sequestration.

III. CARBON CREDITS FOR PYROLYSIS OF BIOMASS UNDER EXISTING CARBON MARKETS

By providing both energy and sequestration opportunities, pyrolysis of biomass offers a range of well-documented climate change mitigation benefits. These include: avoiding emissions from the conventional use of feedstock biomass, sequestration of carbon in biochar, avoided emissions of GHGs from soils, displaced fertilizer and other agricultural inputs, enhanced agricultural yields, and displacement of fossil fuel usage.⁹⁴ This section evaluates how some of these mitigation benefits translate into potential carbon credits under several of the major regulatory regimes that create markets for carbon offset credits,⁹⁵ including

a natural incentive to maximize these gains. In addition, increased soil fertility by itself does not remove carbon from the carbon cycle.

93. See John A. Mathews, *Carbon-negative Biofuels*, 36 ENERGY POL'Y 940, 940–45 (2008); Sohi, *supra* note 29, at 4–6, 28–30.

94. See, e.g., BIOCHAR FOR ENVIRONMENTAL MANAGEMENT 321–24 (Johannes Lehmann & Stephen Joseph eds., 2009).

95. A complete analysis of how pyrolysis is treated under the various credit markets is beyond the scope of this article. For a review of additional credit markets and regulatory schemes see ANJA KOLLMUS ET AL., MAKING SENSE OF THE VOLUNTARY CARBON MARKET: A COMPARISON OF CARBON OFFSET STANDARDS (W.W.F., Germany 2008), available at <http://www.opencarbonworld.com/carbon-library/wwf-making-sense-of-the-voluntary-carbon-market-a/wwf-standcomp->

the Kyoto Protocol (Kyoto), the northeast Regional Greenhouse Gas Initiative (RGGI), and the California Global Warming Solutions Act (CGWSA). The discussion will show that current regulatory barriers and limitations often prevent full accounting of the mitigation benefits of biochar projects. In particular, carbon sequestered as biochar does not always generate credits under the current regulatory system. As a result, the current systems tend to distort market incentives *away* from projects with net-negative carbon footprints.

A. *Kyoto*

Parties to the 1992 United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol in December 1997;⁹⁶ it has been ratified by 187 countries.⁹⁷ The protocol creates obligations for thirty-eight industrialized countries (referred to as Annex I countries) to reduce global GHG emissions between 2008 and 2012 to 5% below 1990 levels.⁹⁸ The rules governing what qualifies for carbon credits under Kyoto play an important role in shaping the types of projects that qualify for carbon credits in domestic and international emission control schemes.⁹⁹

The use of pyrolysis to meet energy needs—by using biomass as a renewable biofuel, for example—would count directly under Kyoto as a reduction of GHG emissions. If the project is implemented in a sector that has not been capped by the relevant national program, it would typically generate credits for avoided GHG emissions for displacement of fossil fuel usage in that country.¹⁰⁰

Kyoto also allows participating countries to meet allowance goals by obtaining a limited number of carbon credits to offset emissions that exceed each country's allotment. Such credits may be generated within the Annex I country itself (through Articles 3.3 and 3.4), in another Annex I country (through Article 6), in a non-

080305-20-web.pdf.

96. John Gaunt & Annette Cowie, *Biochar, Greenhouse Gas Accounting and Emissions Trading*, in *BIOCHAR FOR ENVIRONMENTAL MANAGEMENT* 317, 319–20 (Johannes Lehmann & Stephen Joseph eds., 2009).

97. UNFCCC Status of Ratification, http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php (last visited Mar. 28, 2010).

98. Gaunt & Cowie, *supra* note 96, at 317.

99. *See id.* at 321.

100. *See id.* at 324–25.

Annex I country (through Article 12), or by trading with other Kyoto participants (through Article 17).¹⁰¹

Credits under these provisions of Kyoto are less clear for sequestration of carbon in biochar. Scholars have noted that while increases in soil carbon could theoretically be recognized as an eligible sequestration activity under Articles 3.3, 3.4, 6 and 12 of Kyoto, technical and logistical hurdles often make such credits infeasible.¹⁰² For example, Article 3.3 provides for “removal credits” based on the amount of carbon stored in soil, but only for qualifying afforestation or reforestation projects.¹⁰³ In addition, estimation and reporting requirements add significant complexity and transactions costs.¹⁰⁴

One of the primary mechanisms for fostering carbon credits under Kyoto is the Clean Development Mechanism (CDM) established under Article 12.¹⁰⁵ This program allows investors from industrialized countries with legally binding emission reduction commitments to obtain carbon credits from developing countries that cut emissions or increase carbon sinks.¹⁰⁶

When establishing the CDM for the first commitment period (2008–2012), the Kyoto participants chose to significantly limit credits for changes in land use that result in carbon being sequestered in the soil. Objections to these forms of sequestration credits included the following:¹⁰⁷

- Carbon sequestered in soil and plant materials is volatile, whereas reductions in emissions are permanent;
- Sequestration activities are less certain, because they are subject to both natural factors and human intervention;
- Mitigation through carbon-sequestering land-use changes are more complicated and uncertain than that obtainable through reductions in emissions;
- Sequestration activities are difficult to monitor.

The Conference of the Parties to Kyoto decided “[t]hat the

101. *See id.* at 319–21.

102. *See id.*

103. *See id.* at 319.

104. *See id.* at 325 (noting the varying approaches to estimating and verifying carbon content in soil over time).

105. *See id.* at 321.

106. *See id.*

107. Food & Agric. Org. of the U.N., *The State of Food and Agriculture 2002: Agriculture and Global Public Goods Ten Years After the Earth Summit 194* (2002) [hereinafter FAO].

eligibility of land use, land-use change and forestry project activities under the clean development mechanism is limited to afforestation and reforestation.”¹⁰⁸ In other words, unlike credits available for developed countries under Article 3.4, purely soil-based carbon sequestration is not eligible for carbon credits under the CDM.¹⁰⁹ Indeed, the regulations governing afforestation/reforestation projects allow for soil carbon pools to sometimes be completely ignored.¹¹⁰

Biochar proponents have argued, however, that biochar sequestration does not suffer from the problems identified above. They note that biochar is more permanent than other sequestration options (including afforestation and reforestation), in which stored carbon could be released through forest fires or changes in land use practices.¹¹¹ “Once biochar is incorporated into soil, it is difficult to imagine any incident or change in practice that would cause a sudden loss of stored carbon.”¹¹² In addition, proponents assert that calculating and verifying carbon credits from biochar would be relatively simple.¹¹³

To date, the international authority for establishing acceptable CDM technologies has not recognized carbon sequestration in biochar as an approved CDM methodology.¹¹⁴ This may change through negotiations of commitments and offset allowances under a second commitment period, to commence in 2012.¹¹⁵ Indeed, biochar sequestration was specifically included in the negotiating text for discussion at the UNFCC’s climate conference in Copen-

108. See Framework Convention on Climate Change, Marrakesh, Morocco, Oct. 29–Nov. 10, 2001, *Report of the Conference of the Parties on Its Seventh Session: Addendum*, FCCC/CP/2001/13/Add.1 (Jan. 21, 2002) [hereinafter Marrakesh Accords].

109. FAO, *supra* note 107, at 194.

110. See Withman & Lehmann, *Biochar—One Way Forward for Soil Carbon in Offset Mechanisms in Africa?*, 12 ENVTL. SCI. POL’Y 1024, 1025 (2009).

111. See Lehmann, *A Handful of Carbon*, *supra* note 68, at 143.

112. *Id.*

113. See *id.* at 144 (noting that no complex predictive models or analytical tools are required to include biochar into emission trading schemes, because the conversion of biomass into biochar and its application to soil are easily calculated and monitored); Fowles, *supra* note 54, at 428.

114. See CDM, *METHODOLOGIES FOR CDM PROJECT ACTIVITIES*, <http://cdm.unfccc.int/methodologies/PAMethodologies/index.html> (last visited Mar. 1, 2010).

115. The Marrakesh Accords explicitly called for the treatment of land use, land use change, and forestry project activities to be decided as part of negotiations on the second commitment period. See Marrakesh Accords, *supra* note 108, at 22.

hagen in December of 2009,¹¹⁶ and has the support of many African nations.¹¹⁷

B. RGGI

The Northeast Regional Greenhouse Gas Initiative is a regional cap-and-trade program that applies to carbon emissions from power plants.¹¹⁸ The RGGI caps emissions from plants in the ten participating states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont) at 2009 levels and requires ten percent reductions by 2018.¹¹⁹ To meet their individual allotments, power plants may offset a portion of their emissions through offset allowances.¹²⁰

Offsets under the RGGI are governed by a Model Rule designed to ensure that allowances are “real, additional, verifiable, enforceable, and permanent.”¹²¹ Credits would be available under the Model Rule for pyrolysis of two specific feedstocks: animal manure and organic food waste.¹²²

The Model Rule also authorizes credits for sequestration through afforestation,¹²³ with credits determined by measuring the net change in carbon pools from baseline.¹²⁴ Credits for biochar sequestration might therefore be available, but only for projects in which the biochar is applied to qualifying forestry projects. Projects approved for offsets are limited to forest areas placed under a legally binding permanent conservation easement, which requires the land to be maintained in a forested state in perpetuity.¹²⁵ Considering that carbon sequestered as biochar will be stable

116. See U.N. Framework Convention on Climate Change [UNFCCC], *Ad hoc Working Group on Long-term Cooperative Action Under the Convention*, U.N. Doc. FCCC/AWGLCA/2009/INF.1 (June 22, 2009).

117. See, e.g., HELENA PAUL ET AL., BONN CLIMATE CHANGE TALKS, AGRICULTURE AND CLIMATE CHANGE: REAL PROBLEMS, FALSE SOLUTIONS (2009) (advocating for the inclusion of biochar credits in the next commitment period).

118. Regional Greenhouse Gas Initiative, About RGGI, <http://www.rggi.org/about> (last visited Mar. 28, 2010).

119. *Id.*

120. *Id.*

121. REG’L GREENHOUSE GAS INITIATIVE MODEL RULE Subpart XX-10.1 (2007).

122. See *id.* Subpart XX-10.5(e); Gaunt & Cowie, *supra* note 96, at 324.

123. See REG’L GREENHOUSE GAS INITIATIVE MODEL RULE Subpart XX-10.3(a)(1)(iii) (2007).

124. See *id.* Subpart XX-10.5(c)(4).

125. See *id.* Subpart XX-10.5(c)(6).

for hundreds or thousands of years, restricting biochar sequestration to forests under perpetual conservation easements appears unnecessary and counterproductive.

C. CGWSA

The California Global Warming Solutions Act of 2006 sets a goal of reducing GHG emissions in California to 1990 levels by 2020.¹²⁶ The CGWSA calls on the State's Air Resources Board (ARB) to establish statewide emission limits and early action measures that are acceptable under the law.¹²⁷ While the ARB has not yet issued binding regulations governing credits for afforestation or reforestation,¹²⁸ commentators expect ARB's sequestration regulations to track methods employed by the California Climate Action Registry (CCAR), which was created by the California legislature in 2000.¹²⁹ The CCAR rules provide sequestration credits for ongoing storage of carbon stocks in wood products.¹³⁰ Commentators have suggested that biochar made from qualifying forest products may be eligible for carbon sequestration credits under the CGWSA.¹³¹ These provisions offer the mirror image of RGGI's regulations in that California provides credits only for carbon taken out of approved forests, whereas the RGGI only allows credits for carbon placed in approved forests. Neither regime appears to allow credits for biochar produced from agricultural waste and applied back into the agricultural land, which would arguably optimize climate change mitigation effects for the reasons discussed in the prior section.¹³²

126. See California Global Warming Solutions Act of 2006, CAL. HEALTH & SAFETY CODE § 38550 (West 2009).

127. *Id.* §§ 38550, 38560.5(a).

128. See ARB Scoping Plan Measures Implementation Timeline Nov. 25, 2009, http://www.arb.ca.gov/cc/scopingplan/sp_measures_implementation_timeline.pdf.

129. See Elizabeth C. Brodeen, *Sequestration, Science and the Law: An Analysis of the Sequestration Component of the California and Northeast States' Plans to Curb Global Warming*, 37 ENVTL. L. 1217, 1226 (2007) (explaining that "[i]n 2000, the California legislature created the California Climate Action Registry").

130. See CAL. CLIMATE ACTION REGISTRY, FOREST PROJECT PROTOCOL, VERSION 2.1 34-38 (2007).

131. See Gaunt & Cowie, *supra* note 96, at 325.

132. See, e.g., Brodeen, *supra* note 129, at 1236 (noting that the RGGI does not allow for credits based on agricultural sequestration of biochar).

IV. ADJUSTING CARBON MANAGEMENT POLICIES TO ENCOURAGE RENEWABLE, NET-NEGATIVE PROJECTS SUCH AS BIOCHAR SEQUESTRATION

The preceding sections have shown that pyrolysis of biomass offers potential benefits both as a source of renewable energy and as a method to capture and permanently remove carbon from the atmosphere. The science suggests that these benefits may be optimized through careful selection of feedstocks, pyrolysis processes, and locations for biochar application. Yet these three levers of control are not well-coordinated under prevailing carbon management regimes.

This section identifies categories of changes that should be considered by policy makers to better align regulatory incentives with the emerging science on biochar. These categories offer starting points for discussions addressing these carbon credit issues when negotiating the next commitment period under Kyoto or potential climate change legislation in the United States.¹³³

A. *Embracing the Full Range of Benefits Offered by Pyrolysis*

Credits under the existing carbon management regime appear to favor the use of biomass for energy production over carbon sequestration. Under Kyoto, RGGI and CGWSA, carbon credits appear easier to obtain for displacing fossil fuels with renewable biomass than for storing carbon in biochar. Such disparate treatment may not be optimal, especially considering the range of secondary benefits of biochar application. These secondary benefits include increased crop yields, decreased nutrient runoff, absorption of pollutants, suppression of GHG emissions from soils, and increased capacity of soil to store other organic carbon. Especially important secondary health benefits from pyrolysis in developing countries, such as lower inhalation of smoke, further call into question the current carbon management regime, which precludes sequestration credits for agricultural sequestration in developing countries (under the CDM facility under Article 12), yet allows such credits in developed countries (under Article 3.4).

For the reasons identified by biochar proponents in Part III.A above, including the relative permanence of carbon stored in

133. See, e.g., Clean Energy Partnership Act of 2009, S. 2729, 111th Cong. § 104(b)(2)(I) (2009) (including biochar projects as eligible for domestic offset credits).

biochar and the ease of calculating and verifying what has been sequestered, policy makers should provide credits for biochar sequestration. The following issues may be helpful when designing such credits.

B. Targeting Proper Feedstocks

Current regulations provide sequestration for some feedstocks but not others. For example, the RGGI makes credits available for the pyrolysis of two specific feedstocks, animal manure and organic food waste.¹³⁴ The CGWSA may offer credits for wood materials from forests that meet certain requirements. The science does not appear to support the elevation of these feedstocks to the exclusion of others. To the contrary, recent research suggests that the most promising candidates for pyrolysis into biochar are certain types of agricultural waste (e.g., sawmill or forest residue), or specific biochar crops (short rotation woody plants and grasses).¹³⁵ The higher lignin content yields higher levels of carbon capture, and the feedstocks are more readily available than non-waste forest wood materials.¹³⁶

Policy makers should also consider additional effects that regulating potential pyrolysis feedstocks can have, such as putting pressure on cropland availability and influencing commodity prices. These effects may be negligible—especially in light of the current abundance of possible feedstocks—but still warrant careful consideration.

C. Encouraging Optimal Pyrolysis Processes

Current carbon management controls do not appear to regulate the process used for the pyrolysis of biomass. Such a hands-off approach has certain advantages. Once the relative incentives for energy production and carbon sequestration have been established, it may be helpful to allow flexibility for producers to adjust their pyrolysis processes to optimize the benefits produced. There may be some circumstances, however, where greater control would be beneficial. For example, if biochar were allowed as a soil

134. REG'L GREENHOUSE GAS INITIATIVE MODEL RULE Subpart XX-10.5(e) (1) (i) (2007).

135. Lehmann, *Bio-char Sequestration*, *supra* note 30, at 411; Sohi, *supra* note 29, at 6.

136. Sohi, *supra* note 29, at 6.

amendment for food crops, both the feedstock and the pyrolysis process used may need to be tightly controlled. The risks of heavy metal contamination in feedstock and development of toxins through pyrolysis warrant additional regulatory safeguards to prevent irreversible contamination of soils intended for food crops. Even here, however, a wide range of safe feedstock and methods of pyrolysis may remain viable. Prohibitions may turn out to be necessary only on the margins—for example by precluding the use of municipal waste and higher pyrolysis temperatures—to ensure long-term food safety.

D. Targeting Proper Locations for Biochar Deposit

Current RGGI regulations appear to restrict sequestration credits for biochar deposited into qualifying forests. As with feedstock regulations discussed above, these restrictions do not seem to be supported by current science. As an initial matter, these authors have not seen studies suggesting that forest application provides the biggest bang for the buck in terms of secondary benefits or otherwise. If anything, current research seems to suggest application into agricultural fields where the biomass was grown offers the greatest benefit in terms of maximizing the sources of biochar without depleting important nutrients. While this area probably requires further research, it may be wise to discourage complete removal of crop residues on long-term, repeating bases.

Because biochar is so stable, there is no reason to condition sequestration credits on the requirement that the land to which it is applied be protected by restrictive easements in perpetuity, as currently required under RGGI. Biochar is not a delicate or volatile substance. It has shown to be relatively immune to degradation from destructive physical stresses.¹³⁷ One exception where restrictive easements or other regulation may be needed is to address possible health issues with applying biochar on agricultural land. Because biochar would be very difficult, if not impossible, to remove from the soil, some caution may be warranted before allowing application on lands that could later be used to grow crops for direct or indirect human consumption.

Additional research may identify other locations where biochar application should be restricted. For example, if adding biochar increases the oxidation of carbon already stored in some

137. Sohi, *supra* note 29, at 23.

soils, then such addition might have the opposite of its intended effect, by actually *increasing* the release of GHGs. These types of negative secondary effects should be considered when developing guidelines for when carbon credits are available and how they are calculated.

E. Coordinating Multiple Forms of Control

Policy makers should consider a range of options when setting parameters for feedstock sources, pyrolysis conditions, and biochar application sites. Some policy preferences may best be expressed by conditions for conducting pyrolysis or obtaining carbon credits. Examples might include specific prohibitions against using certain feedstocks or pyrolysis temperatures for biochar that would be applied to land that could later be used to raise crops for humans. Additional technical issues have been suggested in the literature for further consideration when designing such controls.¹³⁸

Other preferences could be expressed less forcefully through incentives built into the calculation of carbon credits. In other words, credits could be weighted to more accurately align incentives with perceived benefits. Such carbon credit multipliers have been proposed to address social priorities in other aspects of the carbon credit economy.¹³⁹

F. Providing Other Incentives

Of course, policy makers have tools beyond tweaking the parameters addressed above. Subsidies are one powerful example. Under the Emergency Economic Stabilization Act of 2008 and the American Recovery and Reinvestment Act of 2009, U.S. law currently provides subsidies of twenty dollars per metric ton for owners of facilities that capture large amounts of carbon dioxide from fossil fuel facilities.¹⁴⁰ Congress could offer similar or more enticing subsidies to producers of biochar and other net-negative technologies, such as “artificial trees” that use ion exchange resins to remove carbon dioxide out of the atmosphere. In addition to being net-negative, these simpler technologies appear to offer a

138. See, e.g., Lehmann, *Bio-char Sequestration*, *supra* note 30.

139. See Mathews, *supra* note 93, at 944 (explaining how a multiplier of two or three on credits for preserving rainforests would recognize the increased importance of intact rainforests over biomass plantations).

140. See I.R.C. § 45Q (2009).

number of advantages over more ambitious CCS technologies.¹⁴¹

V. CONCLUSION

This article has identified a number of possible adjustments to carbon management policies to better optimize benefits from proven technologies, such as biochar sequestration of carbon, that appear to offer significant promise for mitigating climate change. The first step is to adjust current carbon management policies to provide clear credits for storing carbon through biochar sequestration, which is easy to identify and calculate. The next, more difficult step is to develop policies and guidelines to further account for secondary effects of sequestration (both positive and negative). Biochar's effect on other carbon stored in the soil is probably the most important such secondary effect for managing GHGs. Additional effects on crop productivity and safety, however, will likely also be important for policy makers to consider. When addressing these issues, policy makers should consider policy tools that address the selection of feedstocks, pyrolysis processes, and locations for biochar application.

141. *Id.* at 942–43 (“Geosequestration represents the ‘hard path’ towards carbon removal, while biosequestration represents what is best described as the ‘soft path’ —the forgiving, flexible and benign option.”).