CAPCOA GHG Rx Protocol Addendum:

To the Biochar Production Project Reporting Protocol, GHG Emission Reduction Accounting, June 14, 2016

(Approved by the CAPCOA Board on August 31, 2016)

TO:	CAPCOA GHG Rx Review Committee (GRRC)
FROM:	Erik White, APCO, Placer County Air Pollution Control District
REVIEWED BY:	Barbara Coler, CAPCOA GHG Rx Administrator
SUBJECT:	*Addendum to the Biochar Production Project, Reporting Protocol, GHG Emission Reduction Accounting, Version 3.4, September 10, 2015*
DATE:	June 14, 2016

Background

The subject greenhouse gas (GHG) offset protocol (Protocol), developed by the Prasino Group, The Climate Trust, the International Biochar Initiative, and Carbon Solutions, and sponsored by the Placer County Air Pollution Control District (PCAPCD), was approved and adopted by the Board of Directors of the California Air Pollution Control Officers Association (CAPCOA) for use in the GHG Rx on September 28, 2015.

Relatedly, on March 23, 2015, a very similar protocol was not accepted by the American Carbon Registry (ACR) (ACR, 2015b). The status of the protocol by ACR is inactive. Based on peer review comments and the response document (ACR, 2015a), ACR states:

> *"The conclusion of the peer reviewers is that the methodology should not be accepted at this time. They stated that the scientific literature does not provide sufficient evidence of the stability of soil carbon sequestration in fields treated with biochar using H:Corg ratio correlations as cited in the International Biochar Initiative's Standard Test Method for Estimating Biochar Carbon Stability (BC+100)."*

The Protocol was also submitted by PCAPCD to the California Air Resources Board (CARB) for acceptance into the Cap and Trade compliance offset program in October 2015. CARB did not accept it and provided verbal comments to PCAPCD staff that referenced the ACR denial and concerns regarding biochar production, feedstock, economics, and permanence.

Based on the actions by ACR and CARB, on February 16, 2016, the CAPCOA GHG Rx Review Committee (GRRC)[1] requested PCAPCD to address the relevant ACR concerns and verbal comments from CARB through an addendum to the Protocol.

[1] The GRRC is comprised of the Executive Officers of the seven Participating Districts of the CAPCOA GHG Rx.

<u>Comments and Responses</u>

Comment 1:

The basis of the Protocol's procedure to ensure biochar carbon stability for 100 years – the biochar's hydrogen to organic carbon (H/Corg) ratio – only considers a limited range of chemical and microbial degradation mechanisms, is from laboratory studies, and covers limited biochar types. The laboratory studies cannot adequately simulate, and cannot be related to, real world environmental conditions.

Specifically, it does not address:

- *Physical degradation including that from weathering, water dissolution, freeze/thaw cycling, mechanical fragmentation, and ultraviolet (UV) photo oxidation. For example, even rock erodes/degrades, and charcoal disintegrates when touched. Biochar erosion, eluviation, disintegration, and solubilization may result in smaller sized biochar to be trans-located to undesirable environmental conditions. Smaller particle sizes have an increased degradation rate. These mechanisms are significantly greater than microbial degradation.*

- *Complexities in a real soil environment. It is not possible to represent and predict all combinations and ranges of soil fungi, microbial populations, minerology composition variations, and atmospheric conditions such as temperature and moisture.*

- *Different processes and feedstocks that will produce biochars with different properties.*

Response:

The hydrogen/organic carbon (H/Corg) ratio is an extremely conservative and robust indicator of biochar persistence over long time periods, as detailed in Lehmann et al. (2015), Enders et al. (2012), and Budai et al. (2015), and confirmed for parameters such as the oxygen/carbon (O/C) ratio (Spokas, 2010), which is related to H/Corg ratio (Enders et al., 2012):

- A low H/Corg ratio is directly indicative of material with highly fused aromatic ring structures, consisting of graphitic like compounds including black carbon, soot, and activated carbon. These polyaromatic compounds, the primary component of biochar and other charred materials, are well established to be highly stable and resistant to microbial and physical degradation – as they are not a preferred energy source for microorganisms due to their high activation energy required for metabolization.

- The well-established correlation between the biochar H/Corg ratio and long term stability is based on over 40 studies involving both laboratory and field measurements. The studies were conducted at worst case conditions of temperature, moisture, and soil mineralogy and microbials. Most studies used biochar ground to small size (large surface and activation areas), with conditions conductive to degradation including high temperature, sandy soil, high moisture, and small particle size and wide range of soil types. Many were conducted over multiple years.

- The correlation based on the above described 40+ studies comprehensively shows that biochar materials with an H/Corg ratio of less than 0.4 consistently have a mean residence time of greater than 1,000 years, and with over 90% of the original carbon remaining after 100 years (Lehmann et al., 2015, page 270).

- The Protocol uses highly conservative 70% and 50% discount adjustment factors, depending on the H/Corg ratio – where the amount of biochar carbon credited as stable for 100 years is reduced by 30% from the actual measured carbon if the H/Corg is less than 0.4, and reduced by 50% if the H/Corg is between 0.4 and 0.7.

- The Protocol further provides an additional 5% reduction factor to GHG offset credits to account for potential biochar impacts on soil "priming" (GHG releases from carbon present in native soil). Recent data demonstrate that biochar in most cases reduces soil priming (Wang et al., 2015), especially over long periods of time (Dharmakeerthi et al., 2015).

There is no theoretical expectation or strong experimental support that physical degradation mechanisms will have a significant adverse impact on long-term biochar stability:

- Mechanical fragmentation. It is not expected that the stability of the biochar's polyaromatic structures will be significantly impacted by size reduction through tilling or plowing. Microbial energy requirements to metabolize biochar organics are independent of biochar particle size. Changes in biochar particle size do not alter the chemical composition or microscopic structure of the biochar. It is likely that smaller particles will be more easily incorporated into soil clay mineral aggregate surfaces, leading to increased stability and lower degradation (Vasilyeva et al., 2011).

- UV oxidation. The literature does not indicate that UV will impact biochar degradation (e.g., Hammes et al., 2007; Skjemstad et al., 2004). Biochar is expected to be highly resistant to UV, as evidenced by "cousin" charcoals' well established stability to UV. Further, most of the applied biochar will not be present at the soil surface due to tilling requirements and its relatively small application rate for agricultural applications; and in most agricultural applications there will be plant and tree canopy shade cover for most of the year.

- Erosion/leaching/water dissolution. This is not a significant mechanism for releasing carbon from aromatic structures. Potential erosion and leaching of biochar into subsoils has been shown to increase soil carbon sequestration (Quinton et al., 2010; Van Oost et al., 2007). Biochar that erodes or leaches and gets buried will lead to enhanced preservation due to unfavorable conditions for microbial activity in oxygen deprived deposition sites such as lake sediment, river and coastal sediments, and ocean sediments.

- Freezing/thawing. The literature does not support that freezing/thawing will have a significant impact biochar degradation (Kuzyakov et al., 2009; Carcaillet, 2001).

Overall, the Protocol GHG benefits are conservative (undervalued) because, as described above, a significant discounting methodology is applied to determine the biochar carbon content that is credited as stable over a 100 year period. Additionally, as an additional measure of conservatism, the Protocol does not utilize (does not apply GHG emission reduction credits to) the significant GHG co-benefits associated with biochar use through reduced water use, reduced fertilizer requirements, and enhanced plant growth – particularly through increasing soil fertility and reducing nutrient leaching in coarse-textured soils.

<u>Comment 2:</u>

The Protocol does not require any field based measurements to demonstrate biochar sequestration rate during the lifetime of the project implementation.

<u>Response:</u>

It is not feasible to directly monitor in-field biochar sequestration rates over the project lifetime (De Gryze et al., 2010). This is in part because it is not possible to accurately quantify biochar carbon over the life of the project or the background carbon content of native baseline soils, due to the inability to collect representative samples from fields where soil composition distributions are highly heterogeneous (and due to the associated high economic costs). As described above, by taking a conservative approach in assessing GHG benefits, the Protocol addresses this comment.

<u>Comment 3:</u>

Using historic soil records of biochar to demonstrate stability is not helpful because there is not an accepted way of determining pre-existing biochar concentrations and because biochar may have been encased in soil clay.

<u>Response:</u>

Carbon dating of historic biochar-containing soils provides valuable and direct evidence of the *potential* for long term (hundreds to thousands of years) biochar stability (Calvelo Pereirs et al., 2014; Pessenda et al., 2001; Glaser et al., 2001). However, this information is not, and could not, be used to determine the relationship between biochar H/Corg and stability.

<u>Comment 4:</u>

Biochar, especially in nano-sized particles, can have a negative impact on plant growth and water and other ecosystems.

Response:

Recent meta-analysis has demonstrated enhanced plant growth (crop yields) and reduced water requirements when biochar is properly applied (Jeffrey et al., 2014; Biederman and Harpole, 2013; Jeffrey et al., 2011). None-the-less, as discussed above, the Protocol "takes no credit" for potential increases in plant growth (carbon sequestration) or reduced water use benefits (reduced energy use). Further, biochar's porous structure provides significant soil nutrient and microbial housing and retention benefits. There are limited ecosystem risks when proper biochar composition and application rates are adhered to, such as those standards recommended by the International Biochar Initiative (IBI).

Comment 5:

Biochar addition can increase the albedo effect by adsorbing solar radiation and warming the earth.

Response:

See above response to Comment 1 discussing the subsurface use of biochar.

Comment 6:

The Protocol baseline should account for potential addition of other organic carbon containing amendments.

Response:

Biochar carbon sequestration, stability, and decay are unrelated to the degree of carbon saturation in the native soil. In fact, as mentioned above, addition of biochar to soil will increase soil carbon saturation levels by increasing the surfaces to which native organic material can react with and become stabilized (Vasilyeva et al., 2011).

Comment 7:

There is a potential for loss during the in-field application of fine powered biochar.

Response:

The Protocol references the International Biochar Initiative Biochar Standards regarding the use of best management practices for biochar production and material handling. They include wetting of biochar to reduce losses to the atmosphere during mixing or application. Further, injection or slurry application and subsequent incorporation into the soil via tilling are common modes of application and greatly reduce losses to atmosphere and translocation.

Comment 8:

Addition of biochar to soils has been shown to increase soil nitrous oxide emissions.

Response:

The literature varies on the impact of biochar on soil nitrous oxide emissions (this is expected given the differing soil and biochar properties). The majority of the work shows reduced emissions, alternatively some, particularly for the more uncommon condition where the biochar is high in nitrogen content, indicates increased emissions (Xie et al., 2015; Spokas and Reicosky, 2009; Yanni et al., 2007; Case et al., 2014; Smith et al., 2010). Either way, with mild biochar application rates such as those from the International Biochar Initiative (IBI) best management practices, the impact is not expected to be significant. More importantly, these studies neglect the comparison to the alternative baseline addition of uncharred organic material which will always have greater nitrous oxide emissions compared with charred.

Comment 9:

The laboratory and field data show a wide range of biochar carbon stability times (decades to millennia).

Response:

This strongly supports the highly conservative nature of the Protocol's H/Corg indicator for the target 100 year time period. Note, the few studies that show biochar stability residence times less than 100 years are from non-woody material feedstocks (Lehmann et al., 2015), which are not the intended feedstock for the Protocol. Also see response to Comment 1 above.

Comment 10:

Fixed carbon to volatile matter and oxygen to carbon ratio should be further explored as surrogate indicators of carbon stability.

Response:

Biochar's oxygen to carbon ratio (O/C), and to a lesser degree volatile matter, similar to H/Corg ratio, are direct indicators of biochar aromaticity (and stability) (Spokas, 2010). However, the International Biochar Initiative (IBI) expert panel determined that the H/Corg was the most robust and predictable indicator of biochar stability (Budai et al., 2015) as it is less dependent on operational variation than these alternative elemental ratios (e.g., O/C).

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