©The City of Stockholm

Biochar-Urban Forestry Strategy

CALCULATIONS OF POTENTIAL CARBON STORAGE IN THE CITY OF STOCKHOLM

April 2022

Prepared by:
Jacqueline Hellmann, Mattias Gustafsson, Lotta Ek
EcoTopic AB

With support from:
Carbon Neutral Cities Alliance
Nature-Based Climate Solutions

Table of Contents

Carbon sink from biochar

Literature review

In 2018, the UN Intergovernmental Panel on Climate Change (IPCC) recognized biochar as a technology for negative emissions due to its high resistance to degradation (Schmidt, 2018). Acceptance, interest, control and methodology for calculating and trading negative emissions from biochar are developing rapidly, especially in Europe and the USA. As usual in new industries, different methodologies are developed in parallel, with the consequence that the carbon sink potential of one and the same biochar is valued differently in different systems and methodologies. The main differences in calculated carbon sink potential are due to:

- More or less optimistic assessments of the stability of biochar over time
- More or less optimistic assessments of LCA for the production of biochar
- At what stage the carbon sink is considered to be created; immediately after production or when mixing in soil (or other application)

The two most used methodologies for biochar as a negative emission available on the European market today are the European Biochar Certificate (EBC) C-sink and Puro.earth (Puro). In addition, the Verified Carbon Standard (Verra), the world's largest standardization organization for voluntary climate compensation, is currently developing its own methodology with a mailing for referral in August 2021. Their methodology is currently still under development (Verra, 2022).

The stability of biochar is a parameter that is being more or less included in today's carbon sink calculations, depending on the methodology and carbon trading platform in question. The factor that – after two decades of research – has been identified as most significant when it comes to calculations of the stability of biochar in soil is the ratio between hydrogen and organic carbon molar ratio (H/C_{org}) in the biochar. This ratio correlates with charring temperature where higher temperature gives lower proportion of hydrogen and a more stable biochar.

Usually, 100 years is used as a time frame in calculation models of biochar stability. In 2019, the IPCC released a simplified calculation model to be regarded as an indication of the stability of biochar (when used in cropland and grassland mineral soils) in relation to charring temperatures (IPCC, 2019), see Table 1.

Production temperature	Fraction of biochar C remaining after 100 years
High (>600 °C)	89% (± 13%)
Medium (450-600 °C)	80% (± 11%)
Low (350-450 °C)	65% (± 15%)

Table 1. *General calculation of the stability of biochar in relation to charring temperatures (IPCC, 2019).*

The advantage of the IPCC model of calculation is that anyone can make an estimate of the biochar carbon (C) stability if the carbonization temperature is known. However, for increased credibility and trade in carbon sinks, better precision is required with lab analysis of each specific biochar, which for e.g. EBC results in slightly more conservative calculations of biochar stability than what is proposed by the IPCC.

According to EBC, H/C_{org} of the biochar must not exceed 0.7, which otherwise indicates that the material is of a non-pyrolyzed type, and oxygen to organic carbon molar ratio (O/C_{org}) must not exceed 0.4 (EBC, 2022). The BC_{+100} index is a functional method to predict how much of the biochar C that remains present 100 years after land application (Budai, o.a., 2013). By measuring the biochar's H/C_{org} ratio in a simple analysis and comparing it to the index, a reliable result of biochar stability over time can be generated, see Figure 1 and Table 2.

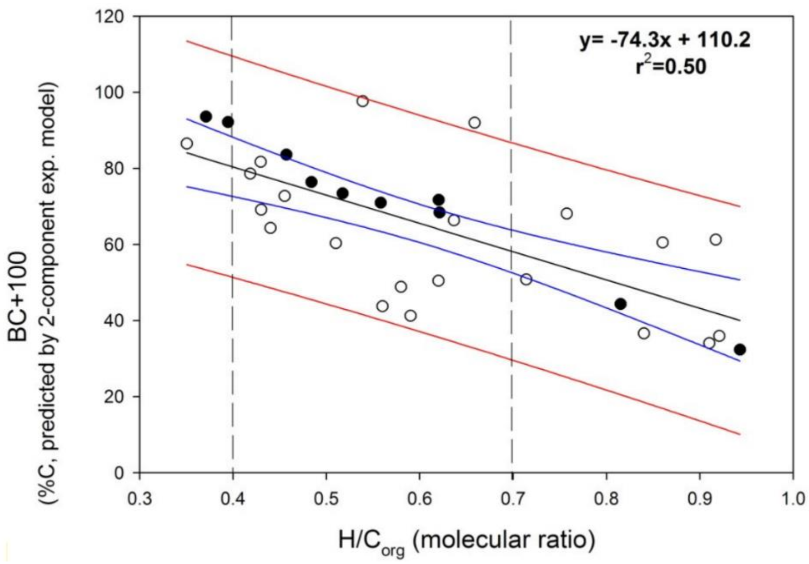

Figure 1. *Illustrates how data and calculations show the correlation between biochar's H/C_{org} and biochar C predicted to remain after 100 years (i.e. BC_{+100}). The black diagonal line is the mean value. Source: (Budai, o.a., 2013).*

	BC_{+100} (%)			
H/C_{org}	Mean	Lower limit	Upper limit	Chosen value
0.4	**80.5**	**72.6**	**88.2**	**70**
0.5	73.1	67.1	78.9	50
0.6	65.6	60.5	70.6	50
0.7	**58.2**	**52.5**	**63.8**	**50**

Table 2. *Shows which values of BC_{+100} EBC assumes in their estimations on biochar stability based on biochar's H/C_{org}. Their chosen values of how much biochar C (%) that remains after 100 years are slightly more conservative than the lower limits. Source: (Budai, o.a., 2013).*

However, the EBC C-sink certification system calculates the carbon sink potential from biochar *directly after production*, generating a snapshot of the biochar C-sink potential at current moment rather than over time (Schmidt, Kammann, & Hagemann, 2021). Similarly, the trading platform for carbon sinks Puro.earth CO_2 Carbon Removal Market Place sells the carbon sink from biochar, basing the LCA on a cradle-to-gate calculation (puro.earth, n d). This means i.a. that the quantified carbon sink is the same regardless of how far the biochar is transported to the place where it is used (and the carbon sink is secured). So even though EBC provides a methodology on how to calculate the stability of biochar over time, the aspect of biochar stability is not included in their C-sink potential calculation (see Figure 3). This is because EBC has not designed a method to track the path of biochar to a secure carbon sink application after production.

The competing trading platform Carbonfuture believes instead that the final carbon sink is to be calculated by including postproduction emissions from biochar handling and degradation during use (BC_{+100}) and have designed a tracking system accordingly, see Figure 2.

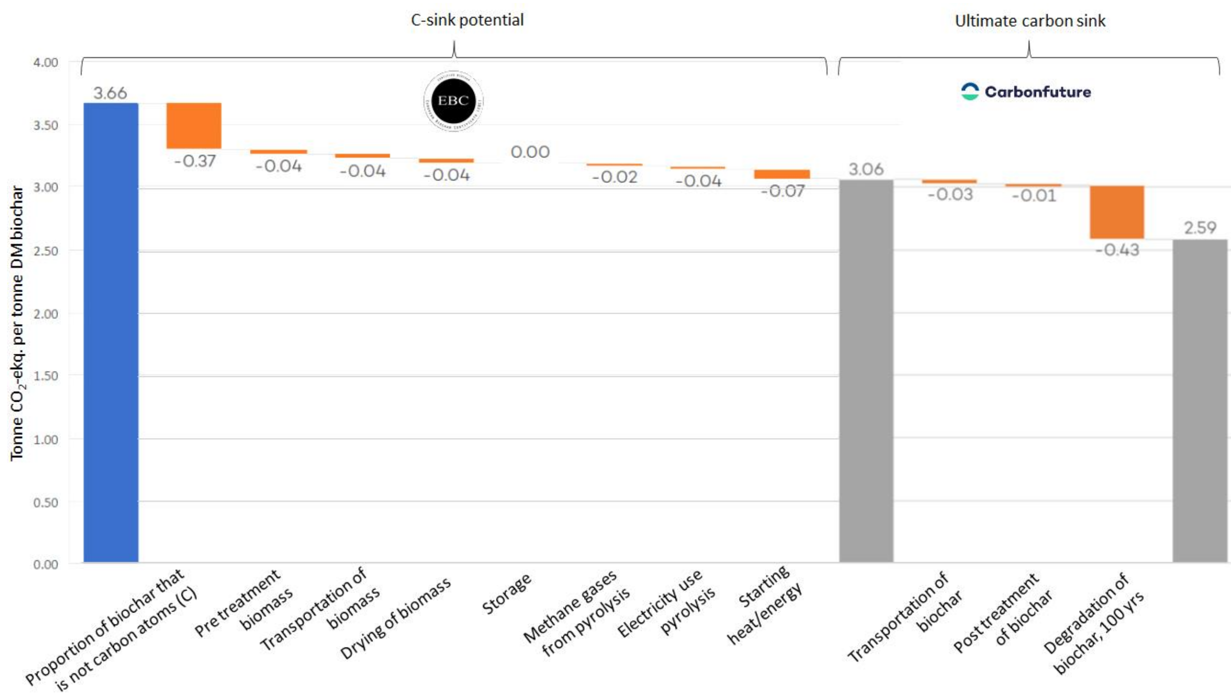

Figure 2. Calculation of what is being included in the EBC C-sink potential, and additional calculation leading to the ultimate carbon sink according to Carbonfuture. The figure illustrates an actual calculation example with data received from Carbonfuture, 2021.

The latest and, so far, most rigorous compilation of scientific data on the topic of biochar in climate change mitigation was published in 2021 (Lehmann, o.a., 2021). The report highlights the role of biochar in various systems and applications. The report accounts more broadly for the potential effects that biochar systems have, directly as well as indirectly, on greenhouse gas emissions and CO_2 removal. This report is predicted to contribute to increased harmonization globally between different methodologies in global trade in carbon sinks from biochar.

Method of carbon sink calculation

To make preliminary estimations of created carbon sinks from biochar we need to use a simplified but reliable calculation method. The main question we intend to answer is “What amount of carbon dioxide equivalents (CO_2-eqv.) will remain from this biochar in 100 years?”. To answer this, we must first know what kind of biochar we are dealing with.

Based on the BC_{+100} index, a simplified but reliable calculation on the generated carbon sink from a specific biochar can be made. The calculation model looks like this:

$$3.67 * X\% \ C * BC_{+100}$$

Here’s what it means: 3.67 is the carbon dioxide equivalent of every carbon atom in the biochar. This is being multiplied with the amount of carbon in the biochar (%) which in turn is being multiplied with the BC_{+100} index (%) which we base on the mean value demonstrated in Figure 1 above.

For example, one tonne of biochar with 85% carbon content and a H/C_{org} ratio of 0.2 would generate the following calculation: 3.67 tonnes of carbon dioxide equivalents (CO_2-eqv.) * 85% C * 80% BC_{+100} = 2.5 tonnes CO_2-eqv. will remain after 100 years.

When comparing the result from this method of calculation with the calculation data provided in Figure 3 above, it can be concluded that our proposed method ends up with an amount of CO_2-eqv. closely to that of Carbonfuture’s (2.5 and 2.6 tonnes CO_2-eqv. respectively). The 2.6 tonnes CO_2-eqv. is based on a case with short transports of the biochar; longer transports would entail a smaller created carbon sink.

It is suggested to use a calculation method such as this until the actual carbon sink from biochar is certified with every aspect of the process included in the final carbon sink calculation.

Estimation of potential carbon sinks created by biochar in Stockholm urban public green areas

This section calculates the potential carbon sink in urban public green areas in Stockholm, based on the calculation model presented under section *1.2 Method of carbon sink calculation*. The calculations are based on the potential amounts of biochar for each application (read more in the report *Urban feedstock availability and biochar use potential*, Table 3 and 4). The calculations are also based on experience from the kind of biochar that is produced from garden waste and commonly used in Stockholm today, which usually contains 50-70% carbon and has a H/C_{org} of 0.2, see Table 3. This gives us a factor of 2 tonnes of CO_2-eqv. that will remain after 100 years with a carbon content of 70%.

Application area	Biochar potential	Potential carbon sink
Green roofs	Total: 30-150 000 m³ biochar (approx. 6-30 000 tonnes)	Total: 12-60 000 tonnes CO_2-eqv
Tree plantings/urban forests, in vegetation area	Total: 400 m³ biochar (approx. 80 tonnes)	Total: 160 tonnes CO_2-eqv
Tree plantings in structural soil, Stockholm model (Stockholm stad, 2017)	Yearly: 1 400 m³ biochar (approx. 280 tonnes)	Yearly: 560 tonnes CO_2-eqv
Urban plant beds, perennials	Yearly: 1 000–2 500 m³ biochar (200–500 tonnes)	Yearly: 400-1000 tonnes CO_2-eqv
Green areas (parks etc.)	Yearly: 250 m³ biochar (approx. 50 tonnes)	Yearly: 100 tonnes CO_2-eqv
Peat substituent (in e.g. potting soil)	Yearly: 75-330 m³ biochar (approx. 15-66 tonnes)	Yearly: 30-132 tonnes CO_2-eqv
Concrete (tree pit foundation + concrete floor slabs)	Yearly: 3.6 tonnes biochar + 825 m³ biochar (approx. 165 tonnes)	Yearly: 330 tonnes CO_2-eqv

Table 3. *Describes the application areas of biochar in the City of Stockholm along with the calculated potential carbon sink.*

References

Budai, A., Zimmerman, A., Cowie, A., Webber, J., Singh, B., Glaser, B., . . . Joseph, S. (2013). *Biochar Carbon Stability Test Method: An assessment of methods to determine biochar carbon stability.* International Biochar Initiative. Hämtat från https://www.biochar-international.org/wp-content/uploads/2018/06/IBI_Report_Biochar_Stability_Test_Method_Final.pdf den 14 12 2021

EBC. (2022). *European Biochar Certificate - Guidelines for a Sustainable Production of Biochar.* European Biochar Foundation (EBC). Hämtat från https://www.european-biochar.org/media/doc/2/version_en_9_3.pdf den 17 09 2021

IPCC. (2019). *Appendix 4 Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development.* Hämtat från https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch02_Ap4_Biochar.pdf den 18 03 2022

Lehmann, J., Cowie, A., Masiello, C. A., Kammann, C., Woolf, D., Amonette, J. E., . . . Whitman, T. (2021). *Biochar in climate change mitigation.* Nature Geoscience. Hämtat från https://doi.org/10.1038/s41561-021-00852-8 den 18 03 2022

puro.earth. (n d). Hämtat från Carbon Removal Methods: https://puro.earth/carbon-removal-methods/ den 31 03 2022

Schmidt, H.-P. (2018). Biochar and PyCCS included as negative emission technology by the IPCC. *The Biochar Journal*. Hämtat från https://www.biochar-journal.org/en/ct/94 den 31 03 2022

Schmidt, H.-P., Kammann, C., & Hagemann, N. (2021). *EBC Guidelines for the Certification of Biochar Based Carbon Sinks Version 2.1 from 1st February 2021.* EBC. Hämtat från https://www.european-biochar.org/media/doc/139/c_en_sink-value_2-1_track-changes.pdf den 31 03 2022

Verra. (2022). *Verified Carbon Standard*. Hämtat från Methodology for Biochar Utilization in Soil and Non-Soil Applications: https://verra.org/methodology/methodology-for-biochar-utilization-in-soil-and-non-soil-applications/ den 30 03 2022