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The Biochar System in the EU: the Pieces are Falling Into Place, but Key Policy Questions Remain[1]

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Highlights

- The biochar system presents itself as an exceptional negative emissions technology in that it can readily provide multiple public goods at relatively low cost, notably restoration of soil carbon and water conservation in addition to climate mitigation, as well as multiple private goods related to the use of biochar as a soil amendment and other possible uses. To realise this potential at scale, however, a holistic and coherent cross-sectoral policy approach is needed.
- So far, the lack of an enabling and supportive policy framework at the EU level and, consequently, low demand for biochar as a soil amendment, has been the main barrier to widespread diffusion of the biochar system. Such framework is now under construction, but its final configuration is still undefined.
- Financial reward of greenhouse gas removals from the atmosphere, as well as of soil carbon restoration, would likely propel the diffusion of the biochar system. While evidence on non-economic barriers to the uptake of the biochar system is scant, public acceptance is not of concern. Notably, the co-benefits of properly regulated biochar for soil amendment suggest that this product may well appeal to farmers, who however need to be trained.
- Which policy instruments should be used to reward greenhouse gas removals produced by the biochar system and other negative emissions technologies, is a question that should be addressed soon. Setting specific targets for emission reductions and removals, rather than aggregate targets for net emissions, would help address this question as well as avert the risk of delaying either emission reductions or removals. Given the urgency of tackling climate change, opportunities for cost-effective greenhouse gas removals, such as those already offered by the biochar system, should be exploited without delay.

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1. Background

For the international community to meet the goal of the Paris Agreement, namely holding the increase in the global average temperature to well below 2°C above pre-industrial levels, some large-scale deployment of negative emissions technologies (NETs) is likely to be needed. Greenhouse gas (GHG) removals serve to compensate for residual GHG emissions that are technically impossible to eliminate or too costly to eliminate, as well as to recover from possible overshoots of GHG emissions (Fragkos, 2020; Minx et al., 2018; Smith et al., 2016; Woolf et al., 2016). Broad categories of NETs are: a) industrial processes, such as bioenergy with carbon capture and storage, b) direct air carbon capture and storage, and c) ecosystem management approaches. The biochar system belongs to the last category, which also includes afforestation and reforestation, soil carbon sequestration practices, blue carbon, enhanced weathering, and ocean fertilization (Nemet et al., 2018). Over the past decade, the biochar system has received ever increasing attention. This is reflected in a booming scientific literature (Morgan et al, 2020) and, what is particularly significant, in references and consideration in recent reports of the Intergovernmental Panel on Climate Change (IPCC, 2019, 2018).

Biochar itself is a solid carbon-rich material obtained from the heating of biomass in the (near) absence of oxygen, in a process called pyrolysis. It can be made from different feedstocks, including wood, straw, organic wastes, animal manure, digestates, and sewage sludge. When obtained from wood, biochar is indistinguishable from charcoal. The difference is in its use: while charcoal is made to be burnt as a fuel, the typical use of biochar is for improving agricultural soil. Crucially, when applied to soil, most of the biochar remains there in a stable form for hundreds or even thousands of years (Bruun et al., 2016). 'Biochar system' (BS) refers to the production-use cycle in which biochar is first obtained from biomass through pyrolysis and, then, it is used for improving agricultural soil or for any other purpose that does not result in GHG emissions. As this cycle results in the long-term removal of carbon dioxide (CO_2) from the atmosphere, the BS is considered a NET. Estimates of the negative emissions potential of the BS vary widely. Still, to give an indication of the orders of magnitude, authoritative estimates of the global potential include 1.1. $GtCO_{2\text{-eq}}$ $year^{-1}$ (Bossio et al., 2020), 2.6 $GtCO_{2\text{-eq}}$ $year^{-1}$ (Smith, 2016) and 6.6 $GtCO_{2\text{-eq}}$ $year^{-1}$ (Woolf et al., 2010), which correspond to about 1.9%, 4.6% and 11.9% of current global GHG emissions (55.6 $GtCO_{2\text{-eq}}$ in 2018, according to Olivier and Peters, 2020), respectively.[2]

Defining features of the BS concern the multiplicity of: a) biochar co-products, b) biochar uses, and c) benefits relevant to sustainable development. With reference to the first aspect, syngas, bio-oil, and process heat are three co-products of biochar which could be used as renewable energy sources. If so, these co-products allow the reduction of CO_2 emissions by replacing fossil fuels in energy generation and they could add value to biochar production (Figure 1).

The relative proportions of biochar and its co-products vary depending on specific conditions of the biomass conversion process. Slow pyrolysis, characterised by slow heating rates (up to 100°C/min) for heating the feedstock to peak temperature (200-700°C), is the process – and a fully mature technology – that maximises the biochar yield and, therefore, the potential for GHG removals.[3] The other two important aspects of the BS that have been mentioned, namely the versatility of biochar as a raw material for diverse possible uses, and the multiple benefits that biochar as a soil amendment offers for sustainable development, are discussed below.

2. According to Hansen et al. (2017), larger industrial-scale biochar carbon storage is conceivable, but its environmental impacts and costs require scrutiny.

3. On the different technologies for biochar production, see, e.g., Mašek et al. (2016).

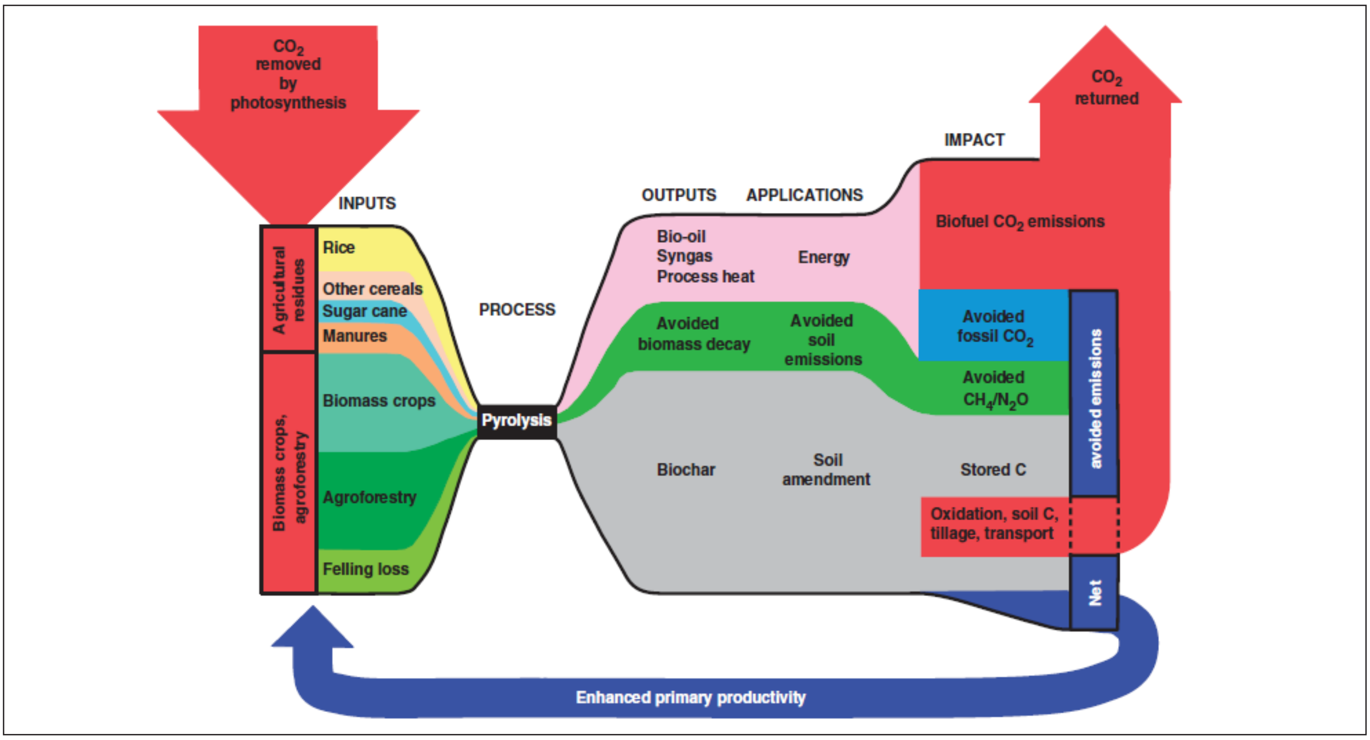

Figure 1 Flowchart of the biochar system. **Source:** *Woolf et al. (2010).*

2. Key messages

The biochar system presents itself as an exceptional negative emissions technology in that it can readily provide multiple public goods at relatively low cost, notably restoration of soil carbon and water conservation in addition to climate mitigation, as well as multiple private goods related to the use of biochar as a soil amendment and other possible uses. To realise this potential at scale, however, a holistic and coherent cross-sectoral policy approach is needed.

In the realm of NETs, the BS stands out in multiple respects. Notably, the BS exhibits: a) a relatively low cost of climate mitigation, which varies depending on site-, feedstock-, and process-specific conditions of biochar production; b) the provision of further much-needed public goods beyond climate mitigation, as well as potentially multiple valuable private goods for biochar users;[4] and c) accuracy in the measurement of permanently sequestered carbon as compared to other land-based NETs, notably soil carbon sequestration practices such as minimum tillage and permanent soil cover, among others.[5] Focusing on the second of these aspects, the BS not only allows the capture and

4. In economics, a 'public good' is a good or service that is both 'non-rival' and 'non-excludable'; that is, a good or service whose consumption by one agent does not prevent simultaneous consumption by another (non-rival), nor can its consumption be excluded to agents who have not paid for- or contributed to it. Climate mitigation is an example of a public good (service). Public goods are normally provided by the government or, alternatively, by the private sector if this is given specific incentives (e.g. subsidies, corrective taxes). By contrast, a 'private good' is a good or service that is both rival and excludable.

5. One key and distinguishing feature of the BS is indeed the possibility to measure the amount of fixed carbon that is deployed and stored in the soil (Wang et al., 2015). Thus, compared to other carbon farming solutions, the benefit of the BS in terms of GHG removal is evidence-based.

sequestration of CO_2 from the atmosphere, but it also benefits agricultural soils and water conservation by increasing the organic carbon content of soils and their water retention capacity (see, e.g., Smith et al., 2019). In the current context of intensifying climate change, depletion of soil organic carbon, land desertification and stress on water resources – global trends that do not spare the EU –, the social benefit of these services cannot be ignored.[6] In addition, biochar as a soil amendment can boost crop yields, though variation is large depending on the specific types of crop, soil, feedstock used for biochar making, and process conditions (see, e.g., Jeffery et al., 2011). What is more, there are many possible uses of biochar that precede its final application to the soil or do not contemplate it at all but still result in long-term carbon sequestration. For example, biochar can be used as an additive in animal feed, in paints, in textile fabrics, as insulation material, building material, it can be used to produce high-tech materials, as material for batteries, etc. (see, e.g., O'Toole et al., 2016, and Schmidt and Wilson, 2014). However, to realise the environmental and economic potential of biochar at scale, both via its ecosystem services and its many possible uses in innovative value chains, environmental and sectoral policies and regulations need to be well integrated.

So far, the lack of an enabling and supportive policy framework at the EU level and, consequently, low demand for biochar as a soil amendment, has been the main barrier to widespread diffusion of the biochar system. Such framework is now under construction, but its final configuration is still undefined.

In the EU, the diffusion of the BS as a NET and as a multi-purpose sustainable technology has so far been precluded by the lack of an enabling and supportive policy framework. The fact that net GHG emissions from the land use, land-use change and forestry (LULUCF) sector did not count toward the EU's 2020 emissions reduction target (20% reduction below 1990 levels) is emblematic in this sense. That is, the irrelevance of LULUCF carbon sinks toward the achievement of any legally-binding target, withheld the most obvious justification for policy support aimed at increasing the same sinks. Mainly as a result of the European Green Deal (European Commission, 2019), however, the institutional context relevant to the BS is quickly changing, in a favourable way. Recent key developments at the EU level include: a) the adoption of the new Fertilising Products Regulation, with which biochar has made its first appearance in EU legislation (European Parliament and Council, 2019); b) the proposed reform of the Common Agricultural Policy (CAP) for the period 2021-2027, in which stronger support for soil carbon sequestration is very prominent[7]; c) the adoption of a new Circular Economy Action Plan by the European Commission (European Commission, 2020a); d) the announcement of an EU certification system for carbon removals by 2023 (European Commission, 2020a, 2020b, 2020c); e) increased ambition in climate change mitigation as reflected in the new EU targets of climate neutrality ('net-zero' emissions) by 2050 and 'at least 55%' emissions reduction by 2030 (European Commission, 2020c); and f) the taking into account of net GHG emissions in the LULUCF sector toward the achievement of the 2030 emissions reduction target (European Parliament and Council,

6. In the EU, the extension of marginal land that would benefit from biochar application is very substantial (Panoutsou and Chiaramonti, 2020; Chiaramonti and Panoutsou, 2019). In the EU-MED area, 8.5 million hectares of marginal land has been estimated by the S2BIOM project (www.s2biom.eu).

7. In June 2018, the European Commission presented its legislative proposals for the future CAP. At the time of writing (January 2021), negotiations on the CAP reform are under way between the European Commission, the Council, and the European Parliament. See Guyomard et al. (2020) for an in-depth analysis of the current state of things, the links between the European Green Deal and the CAP reform, and the references to all relevant official texts. The blog www.capreform.eu is also a unique relevant information source.

2018a, 2018b)[8]. All these developments suggest that tailored regulation and policy support for the BS, at the EU and member state levels, may not be very far off in time. The final configuration of this framework, however, still remains undefined.

Financial reward of greenhouse gas removals from the atmosphere, as well as of soil carbon restoration, would likely propel the diffusion of the biochar system. While evidence on non-economic barriers to the uptake of the biochar system is scant, public acceptance is not of concern. Notably, the co-benefits of properly regulated biochar for soil amendment suggest that this product may well appeal to farmers, who however need to be trained.

Absent significant policy changes – such as those that we have started witnessing – biochar production in the EU would remain very modest. Indeed, beyond the market of organic soil amendments, demand for biochar is usually insufficient to spur its production. Since the quantity of sequestered carbon is the sole outcome that matters when it comes to climate mitigation, the BS as a NET can only be of interest if it is deployed at large scale. Policy support that monetises the added social value of biochar use in terms of climate mitigation, as well as restoration of soil carbon, is of the essence for the economic viability of new scalable business models with biochar at their core.[9] From an economic policy perspective, appropriate reward of GHG removals is desirable (i.e. welfare enhancing) in that it is tantamount to internalising a positive externality. The European Commission is aware of this and, today, the question is which policy instrument should be used for that purpose (see next paragraph).[10] In theory, optimal reward of GHG removals would equal the corresponding marginal social benefit. On the other hand, the abatement cost of the BS (€/tCO_2) indicates the level of reward needed to make BS projects economically viable if private benefits (e.g. agronomic benefits) were nil – in this sense, the abatement cost is a conservative metric of economic viability. Depending on specific conditions of biochar production, estimates of the abatement cost vary widely, from as little as €20/tCO_2 up to ten times as much, or even more (see, e.g., Fuss et al., 2018).[11] As for most bioenergy value chains, the cost of the feedstock is particularly important. However, capital expenditure also becomes relevant for industrial-scale biochar production. Once EU regulations for safe production and uses of biochar as well as for the certification of GHG removals are in place, appropriate reward of GHG removals – and ideally of soil carbon restoration too – would start stimulating

8. The Effort Sharing Regulation (ESR) sets national emissions reduction targets for the sectors not covered by the EU Emissions Trading System (EU ETS), over 2021-2030 (European Parliament and Council, 2018b). The ESR allows Member States to collectively offset up to 280 million tonnes of CO_2-eq, over the period 2021-2030, against net removals in the LULUCF sector. The purpose of this flexibility is to acknowledge the lower mitigation potential of the agriculture sector covered by the ESR. The LULUCF Regulation (European Parliament and Council, 2018a) sets a binding commitment for each Member State to ensure that accounted emissions from land use are fully compensated by an equivalent removal of CO_2-eq from the atmosphere through action in the sector. This is known as the 'no debit' rule. A Member State may however be able to 'beat' the no-debit rule, whether by increasing removals or reducing emissions in the LULUCF sector, if so contributing to compliance with the ESR.

9. With reference to the US context, Pourhashem et al. (2019) reach the same conclusion.

10. "Farming practices that remove CO2 from the atmosphere contribute to the climate neutrality objective and should be rewarded, either via the common agricultural policy (CAP) or other public or private initiatives (carbon market)." (European Commission, 2020b).

11. Chiaramonti and Panoutsou (2019) consider an abatement cost of €55/tCO_2.

the most cost-competitive projects. As regards non-economic barriers to uptake of the BS, empirical evidence is scant (Dal Ferro et al., 2020; Latawiec et al., 2017). Public acceptance is not expected to be a major issue, as the co-benefits of properly regulated biochar applications may well appeal to farmers. These, however, would need dedicated training to maximise the potential benefits.

Which policy instruments should be used to reward greenhouse gas removals produced by the biochar system and other negative emissions technologies, is a question that should be addressed soon. Setting specific targets for emission reductions and removals, rather than aggregate targets for net emissions, would help address this question as well as avert the risk of delaying either emission reductions or removals. Given the urgency of tackling climate change, opportunities for cost-effective greenhouse gas removals, such as those already offered by the biochar system, should be exploited without delay.

Different policy instruments could be used to reward GHG removals achieved through the BS (€ per tonne of CO_2 removed from the atmosphere). Options include: a) granting payments to farmers under the CAP, which probably would be the quickest and most convenient way to kick-start BS uptake; b) establishing an obligatory market for certificates of GHG removals, similar to that of tradable green certificates for renewable energy; and c) introducing a quota of GHG removals as offsets in the EU ETS. Importantly, from a policymaker's perspective, which of these options (and possibly others) is preferable is not immediately obvious. One reason is that making a choice implies determining who is liable for GHG removals: should it be taxpayers (as with option 'a' above) or specific economic sectors (as with options 'b' and 'c')? Another reason is that there is far from a consensus on the equivalence of emission reductions and removals as ways to stabilise the climate. Notably, a major concern is that, at a macro level, large substitution of the latter for the former would expose society to the risk of getting locked into a high temperature pathway (Anderson and Peters, 2016). A growing literature points to this risk-related difference and, consequently, the importance of adopting distinct objectives for emission reductions and removals (Geden and Schenuit, 2020; Meyer-Ohlendorf, 2020, McLaren et al., 2019, Peters and Geden, 2017). Having separate targets would prevent the risk of delaying emission reductions or removals. Separate targets would also enable effective (targeted) support for specific NETs or outcomes. As it stands, the EU's 2050 net-zero emissions target does not subsume specific targets for emission reductions or GHG removals, let alone for specific types of GHG removals (e.g. nature-based removals and technology-based removals). However, if the history of EU climate and energy policy can offer any hint about the future, it seems likely that specific objectives for GHG removals will be set. The process of establishing targets and instruments would take some time. In any case, opportunities for cost-effective GHG removals and other societal benefits, such as those already offered by the BS, should be exploited without delay.

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