Chapter 2: What is biochar and what are the claims?

The International Biochar Initiative (IBI) defines biochar as "the carbon rich product when biomass is heated with little or no available oxygen…produced with the intent to be applied to soil as a means to improve soil health, to filter and retain nutrients from percolating soil water, and to provide carbon storage."[i] They thus define biochar primarily by its purpose, not by its physical or chemical properties.

Biochar refers to materials produced through Pyrolysis, which means exposing biomass to high temperatures with little or no oxygen. This produces a liquid fuel called pyrolysis oil or bio-oil, a gas called syngas, and generally between 12 and 40% of (bio) char. Strictly speaking, any type of combustion with restricted oxygen is 'pyrolysis', whether or not the energy is captured: Traditional charcoal making, even the charring of biomass during a wildfire, in a fire-place, etc. are all forms of pyrolysis. The idea behind modern pyrolysis, supported by biochar advocates, however, is to capture and use all of the energy, as syngas and/or pyrolysis oil. Modern pyrolysis is being developed at different scales, ranging from large pyrolysis plants to pyrolytic cooking stoves ('biochar stoves'). Modern pyrolysis is largely still at the pilot- or demonstration stages, with particular problems relating to the fact that pyrolysis oil and syngas cannot be blended with fossil fuels and that syngas has very low energy density when compared to natural gas.

Biochar can also be produced by means of Gasification, which means exposing biomass to high temperatures with a controlled amount of oxygen or steam. This produces mainly syngas and less than 10% of the original biomass into (bio)char. That char can be retained, but is more commonly gasified further until only ash remains. In a recent review of small-scale gasification the authors state: "*In fact, it is possible to convert dry wood or rice husks into gas and electricity. However, it is not as easy as some manufacturers would like to make us believe... A comprehensive World Bank study in 1998 examined gasification plants installed in the 1980s and found that virtually all had been taken out of operation due to technical and economic problems*" – a situation which appears not to have changed since then.[ii]

Hydrothermal carbonization (HCT) is another method that produces biochar – this involves exposing biomass to moderately high temperatures in water, under pressure and together with a diluted acid which acts as a catalyst. This process, which is still in the very early research and development stages, produces no energy that can be captured. Instead, all of the carbon is turned into a type of biochar or 'bio-coal', with a great variety of chemical structures, depending on the catalyst used. It is being developed to a large part in the context of nanotechnology research.

Of the three methods described, pyrolysis is by far the most important in the context of biochar. No studies exist about biochars produced through gasification and very little is known about the properties of biochar produced through HTC. We found just one study about HTC biochars, a laboratory rather than field study and that found that the carbon was likely to be lost as CO2 within 4-29 years on average, i.e. that it was anything but stable[iii] .

Some companies use the term "biochar" to refer to the use of charcoal as fuel (generally a "coal substitute"), in some cases materials made not only from biomass but also municipal waste, tires and coal dust.[iv]

The carbon in biochar, charcoal, and even coal, is all "black carbon". There is a broad spectrum of different forms black carbon can take, which confers different properties. Many factors influence the physical and chemical characteristics of black carbon, including the type of biomass used, the temperature to which it is heated, how it is cooled and other variables. Exactly where biochar falls on this spectrum, is ambiguous. What is clear, is that in fact the precise details of the physical and chemical nature of black carbon referred to and used as "biochar", has major implications on how

soils and plants are influenced, making it a focus of much research. This is further discussed in detail in chapter 3.

CARBON NEGATIVE

Biochar advocates refer to biochar as a "carbon negative" technology, a logic based first on the false assumption that burning biomass for energy is "carbon neutral", and second that biochar is guaranteed to further sequester carbon in soils for long time periods, taking it a step further as carbon "negative". Both steps in this logic are simply false. The bioenergy industry is under threat due to a growing scientific literature and public awareness that the resulting emissions are in many, if not most cases, even higher than those from using fossil fuels. Even if those emissions may eventually be resequestered by new plant growth, the time frame for regrowth is long – in the case of forest biomass- at least 50-200 years. This time lag between emissions from harvest and burning to regrowth is referred to as a "carbon debt". In the American state of Massachussetts, citizens opposing the construction of 5 new biomass incinerators demanded that the state commission a study – the Manomet Biomass Sustainability and Carbon Policy Report". A key finding of this report: after 40 years, the net GHG emissions from biomass burned for electricity are still worse than coal, even when considering forest regrowth, and worse than natural gas even after 90 years. The state is responding by revising biomass regulations in the Renewable Portfolio Standards. The Environmental Protection Agency has been taking public comment and is grappling with the complexities of accounting for "biogenic emissions", partly as a result of the growing awareness that these emissions cannot reasonably be defined, regulated and subsidized on the assumption that they are categorically "carbon neutral". The second step in the logic – from "neutral to negative" is clearly flawed given the lack of evidence for biochar remaining stable in soils for long periods, reviewed in chapter 3. There is a strong possibility that large scale implementation of biochar could result in very large emissions from harvest, soil disturbance and transport of biomass, from the pyrolysis process and combustion of syngas and bio-oil products, from more transport as biochar is redistributed, from more soil disturbance as it is tilled into soils, and finally from the oxidation of some- potentially large- portion of the biochar and from the "priming" effect that biochar has – causing oxidation of preexisting soil organic matter. All combined would result in a massive increase in emissions, far from being "carbon negative".

In general however, it would seem that the most useful working definition of biochar might be 'char left behind after modern biomass pyrolysis' - after all, that is what biochar advocates actually promote. Unfortunately, this is not reflected in most biochar studies. Modern pyrolysis is largely still at the pilot stages, i.e. it does not exist at a commercial scale and biochar produced this way is still difficult to obtain. Of the 13 peer-reviewed biochar field studies (based on 11 different trials) which we found in the literature[1] only two used biochar from modern pyrolysis; all of the others looked at traditional charcoal which was ground up, often by crushing it under the wheels of a tractor. Many studies about 'biochar properties' are not even confined to charcoal or biochar that has been produced intentionally but instead look at charcoal remains from wildfires or swidden agriculture, or in some cases even at carbon deposited as soot from biomass or fossil fuel burning[v].

1 See Appendix; note that the definition of a 'field study' used here is one where biochar has been newly applied to plots of soils on which crops or other plants are then grown.

Terra preta

According to the UN Food and Agriculture Organization (FAO), some terra preta soils may be up to 2,500 years old. They are found in patches, generally along the Amazon and tributaries, and are otherwise surrounded by the infertile soils typical of this region. Researchers have found evidence of "garden cities" along the Berbice River in Guyana Amazon: areas with rich Terra Preta soils where a large variety of trees, shrubs and perrenial crops were grown in long crop cycles with intercropping and seasonal flooding. The soils contain large amounts of turtle shells, fish and mammal bones, pottery shards, kitchen waste and human excreta – as well as charcoal. These provide insights into the production of Terra Preta, but as the FAO states: " The knowledge systems and culture linked to the Terra Preta management are unique but have unfortunately been lost. Amazon Dark Earths are, however, still an important, yet threatened resource, as well as an agricultural heritage that needs better scientific understanding". Win Sombroek, described as the "founding father of the carbon-negative biochar initiative" had prior to his death, worked to "replicate and emulate the anthropogenic black earths of the pre-Colombian Indian tribal communities."

Many soils around the world do contain charcoal – from wildfires and in some cases likely the result of swidden cultivation in the past. British researchers have begun studying ancient dark, carbon-rich soils in different West African countries, the African Dark Earths Project. Problematically, the project aims combine studying "indigenous knowledge and practices" with looking at "the value now attributed to biochar for soil enhancement, carbon sequestration and clean energy production". As with terra preta, this raises the concern of indigenous knowledge being appropriated and used to help attract subsidies and carbon offsets for biochar entrepreneurs and companies in the North. Various patent applications and trademarks for biochar and 'terra preta' production have already been submitted by companies.

Traditional terra preta methods appear to be a lost art - according to an agronomist with 35 years experience working with small farmers across different states in Brazil, the deliberate use of charcoal as a soil amendment was never encountered (she had only heard about biochar in the context of carbon offsets). Elsewhere there are anecdotal reports that farmers in the Batibo region of Cameroon use charcoal made by burning mounds of grass covered by earth as a soil amendment. The indigenous Munda communities in Northern India reportedly add charcoal from cooking stoves with burnt grass and farmyard manure to their soils.

Biochar advocates claim that burying charcoal in soils is a viable means of sequestering carbon for hundreds or even thousands of years. According to the IBI, biochar could sequester 2.2 billion tonnes of carbon every year by 2050 and that carbon would be stored in soils for hundreds or thousands of years. This and similar claims are repeated over and over in biochar literature. In addition, they state that using syngas and pyrolysis oils to displace burning of fossil fuels, will further reduce carbon in the atmosphere. Advocates claim that using biomass is carbon neutral, but that biochar goes yet further to be "carbon negative" because not only will trees/plants grow back, but also some portion of the carbon from each generation of biomass produced and charred will supposedly be more or less permanently sequestered.

The assumption that biochar carbon will remain stable in soils for hundreds or thousands of years is based on making an analogy between modern biochar and ancient Terra Preta soils. Terra Preta, also called "Amazon Dark Earths" are soils made by indigenous peoples in the Amazon region long ago, using charcoal along with various other materials. Those soils remain highly fertile and carbon rich hundreds and even thousands of years later. The processes involved in creating Terra Preta are no longer known, but likely bear little resemblance to modern biochar. The addition of modern biochar to soils as it is has been practiced in the limited number of field tests to date, involves industrial agriculture practices – monocultures, using some combination of biochar with synthetic fertilizers, manure, or both, as well as pesticides and other agrochemicals. Terra Preta soils contain charcoal, but this is likely the extent of any commonality.

Given that there are so many known, and likely more unknown differences between modern biochar practices and the creation of Terra Preta, it is a stretch to draw the analogy. Yet some companies even refer to their biochar products as "Terra preta", or make claims that use of their biochar will enable users to turn their soils into Terra preta.[vi]

What is deeply concerning is that the long term stability of biochar carbon in soils, the basis for claims that biochar is a viable solution for climate change - is *assumed* on the basis of this weak analogy. A review of research on the stability of biochar carbon in soils is therefore quite important, and follows in chapter 3.

Irrespective, many biochar advocates envision very large scale global deployment with the idea that it will contribute significantly to reducing greenhouse gas emissions. James Amonette describes the potential for sequestering 130 billion tones of CO2 over a century. Jim Fournier goes so far as to claim that biochar could resequester all carbon ever emitted from fossil fuel burning over 50 years. While some biochar advocates have been adamant in claiming that only "wastes and residues" should be used for biochar production, clearly many have no hesitations in calling for quite large scale land conversion and dedicated plantations for biochar feedstocks. An article published in Nature Communications and authored by members of the International Biochar Initiative examined the "theoretical potential" for biochar.[vii] They claim that very large scale implementation of biochar on a global scale could reduce global emissions of greenhouse gases by 12% annually. This number is based on calculations of biomass availability that would require fantastic infrastructure and capacity to harvest and transport large quantities of biomass from virtually all landscapes, process in pyrolysis facilities, and then redistribute the biochar and till it into soils – over very large areas of the earth's surface. They also base this number on the conversion of over 556 million hectares of land to the production of biomass crops for char production. All based on the assumption that biochar actually "works".

At the pinnacle of large scale biochar promotion is the push to have biochar considered as a viable means for climate geo-engineering, under the category of technologies that are referred to as "Carbon Dioxide Removal" (CDR). Members of IBI submitted a recommendation to the Royal Society consultation on geo-engineering and a number of IBI science advisory committee members advocate directly for biochar as climate geo-engineering, (or indirectly – by advocating very large scale deployment and land conversion). In this context, advocates have taken to describing biochar as a means to "manage" and "enhance" the carbon cycle to withdraw more CO2 from the atmosphere.[viii]

In addition to the claims regarding the potential for biochar to sequester carbon, other claims are also made, including 1) that biochar improves soil fertility, therefore can increase crop yields and reduce fertilizer demand. 2) that biochar reduces N2O emissions from soils, 3) that deforestation can be reduced by transitioning from traditional slash and burn to "slash and char" agriculture, and 4) that pyrolytic (biochar producing) cookstoves can benefit the poor by providing more efficient and cleaner cookstoves while at the same time providing a soil amendment that will enhance yields. Each of these claims is also analyzed in more detail in the following chapters.

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i http://www.biochar-international.org/biochar/faqs#question1

ii Dimpl, E, Blunck, M. 2010: Small-scale Electricity Generation From Biomass: Experience with Small-scale technologies for basic energy supply: Part 1: Biomass Gasification. Gtz, commissioned by the Federal Ministry for Economic Cooperation and Development

iii Effect of biochar amendment on soil carbon balance and soil microbial activity S. Steinbeiss et al, Soil Biology & Biochemistry 41 (2009)

iv See for example: http://www.carbonbrokersinternational.com/ This website states: "we sell sustainable, renewable replacements for fossil fuel. We offer coal substitutes, bio crude oil, activated carbon and soil biochar… Carbon products resulting from the waste conversion process offer an additional revenue stream in the form of biochar, coal substitute and activated

carbon. These products can be used as a substitute for coal based activated carbon, metallurgical coke and for power generation, cooking and heating, a fertilizer enhancer/soil amendment, and many other uses currently using coal."

v See for example Black carbon contribution to stable humus in German arable soils, Sonja Brodowski et al, Geoderma 139 (2007) 220-228

vi See, for example: http://www.alibaba.com/product-free/113485176/Terra_Preta.html

vii Sustainable biochar to mitigate global climate change, Dominic Woolf et al, Nature Communications Vol 1, Article 56, 10th August 2010

viii See for example: Geo-engineering is the artificial modification of Earth systems to counteract the consequences of anthropogenic effects, such as climate change. Large-scale (industrial) deployment of biochar thus qualifies as a geo-engineering scheme. F. Verheijen1, S. Jeffery1, A.C. Bastos, M. van der Velde, I. Diafas,

http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR24099.pdf