Section 4. Biochar: cooling the planet with charcoal?

"They want to follow what the green revolution did for the developing world's plants with a black revolution for the world's soils", Emma Marris[49]

"By driving, you will be saving the planet. And the more you drive, the more you prevent catastrophic climate change." Biopact[50]

Plantar, Minas Gerais: Eucalyptus plantation and pig-iron production ovens, photos by World Rainforest Movement www.wrm.org.uy

4.1 What is biochar and what are its promises?

The second type of 'carbon negative' bioenergy being promoted is biochar. Biochar is charcoal derived as a waste product from thermal conversion of biomass by a process known as pyrolysis (see box below). This process produces bio-oil, which can be used as fuel, although not a high-grade one, syngas, a mixture of hydrogen, carbon monoxide and other trace gases, which can also be used as a fuel source and as a precursor to making synthetic diesel char (another type of charcoal).

Proponents of biochar support pyrolysis methods which maximise the amount of char produced and its application to soils. This, they believe will sequester about 50% of the original carbon in the biomass permanently in soils whilst, at the same time, increasing agricultural productivity and also reduce nitrous oxide and methane emissions from agriculture.[51]

Biochar promises to do what BECS cannot offer: a presumed way of sequestering carbon from biomass burning while guaranteeing a new income source for bioenergy companies in the form of a new patentable fertiliser, replacing, or adding value to synthetic fertilisers. The potential for carbon finance may be the same as for BECS, however such funding is less likely to be a precondition of investment. Furthermore, attempts to include biochar into the Clean Development Mechanism (CDM) are now fairly advanced: at the UNFCCC Conference in Poznan, the United Nations Convention to Combat Desertification (UNCCD) introduced a formal proposal for including biochar into the CDM[52] raising the spectre of CDM credits, most likely from 2012. Furthermore, carbon offsetting companies, such as Action Carbone and Carbon Crucible already support biochar research and development.

Fertiliser prices are at record levels and expected to rise further, to a large extent due to agrofuel expansion. Selling biochar as a fertiliser or fertiliser component is thus likely to be highly profitable. Many of the min proponents of BECS today advocate biochar either as a better alternative, or as a complementary strategy, including James Hansen, Peter Read, and Laurence Rademakers, formerly of Biopact, a bioenergy lobbying group with close industry links, and now involved with the Biochar Fund.

Biochar is particularly attractive because the process through which it is produced, pyrolysis is very versatile: Not only is it a precursor to synthetic biodiesel production and could play an important role in future biorefineries, but in the meantime, it can also be used for heat and power production. Furthermore, biochar and pyrolysis are being promoted in the context of rural cooking stoves, even though the patenting of the technology can be expected to undermine or rule out any community-controlled small-scale use.

Second Generation Agrofuels and Co-products from Thermal Conversion of Biomass

Second-generation agrofuels are agrofuels made from solid biomass. There are two types of technologies for turning solid biomass into liquid fuel: Biochemical conversion (involving enzymes and microbes, almost certainly genetically engineered) which produces liquid agrofuel, and thermal conversion which amongst other products produces biological char of 'biochar'. The cheapest and most advanced technology is a type of thermal conversion called pyrolysis, in which solid biomass is exposed to high temperatures (ideally 350-450^{o}C) for a short period of time in the absence of oxygen. This yields syngas, bio-oil and the by-product 'biochar'. The bio-oil and syngas can be used as fuels for heat and power and bio-oil for 'bunker fuel'. Syngas and bio-oil could also provide feedstocks for future agrofuel refineries that produce synthetic biodiesel for cars and possibly airlines, through a process called Fischer-Tropsch gasification. Syngas can also be used as a precursor for diesel-char (see main text) which can be used as a solid fuel, for use in steel manufacturing, in purification and filtration, tyre manufacturing, ink-jet printer ink, or as a soil supplement. All second generation agrofuels are still at the research and development stage.

4.1.1 Terra preta: fertile soils created by small farmers

The rationale for biochar comes from the study of highly fertile soils found in Central Amazonia, called terra preta, which cover an area of more than 50,000 hectares. The soil is believed to have been created by farmers over a long period between 1000 BC (and possibly as early as 5000 BC) and 1500 AD. Instead of slash-and-burn agricultures, those farmers are thought to have practiced slash-and-char, burning a variety of biomass on low-intensity smouldering fires, covered, possibly with dirt and straw, to reduce oxygen. The charcoal was mixed with a variety of biomass, including fish residues, turtle shells, weeds and river sediments, manure and kitchen waste.[53]

Whilst most of the surrounding soils in the Amazon are relatively low in carbon and nutrients and cannot be used for agriculture for more than three years without needing substantial amounts of fertilisers, terra preta, contains up to 70 times as much carbon as well as high levels of nutrients such as nitrogen, phosphorus, calcium and potassium. It also has a high capacity for retaining nutrients and moisture, and maintains higher pH values. Terra preta has remained fertile for up to 2,500 years and is associated with high agricultural productivity. The long-term retention of nutrients and possibly carbon appears to be linked to increased microbial and fungal activity in terra preta.

Other soils with remains of ancient charcoal have been found elsewhere, which suggest that charcoal can, under certain circumstances, remain in soil for thousands of years, and has played a role in sustainable agriculture in different cultures. Amongst the soils with charcoal additions are ones found in Germany, where they date back to Neolithic times, in the United States, where the soils have not yet been dated precisely but are believed to have been under prairie or oak savannah with regular fires for some 5,000 years.[54] Soils containing ancient charcoal have also been found in other countries, including Australia.[55] All those soils are of ancient origin and it is not known exactly how they formed, except that they almost certainly formed over long periods. Even less is known about them than about the Amazonian terra preta."

The history of the terra preta soils is one of small farmers who, over thousands of years, sustained highly biodiverse farming systems which increased soil fertility, rather than depleting it, as modern industrial agriculture does. Given the catastrophic environmental impacts of modern intensive agriculture – species extinctions, nitrogen overloading, soil depletion, pollution, and high greenhouse gas emissions – learning from sustainable practices, such as those that led to terra preta, is vital.

However, without any deeper understanding of how terra preta formed, companies, scientists and lobby groups are today calling for large-scale carbon funding and public subsidies for a by-product of bio-oil and syngas production. They claim that this will create fertile soils and reduce global CO_2 levels.

> *"The biochar sequestration technique is now confirmed to boost soil fertility while storing carbon long-term. No other renewable energy technology has both the advantages of being carbon-negative while at the same time being physically tradeable", Biopact,*[56]

Modern biochar, developed by companies such as Dynamotive, Eprida and BestEnergies, is an industrial product, with feedstock derived from monocultures. Lobby groups such as the International Biochar Initiative, promise that this modern biochar, mixed with soil, re-creates terra preta, not over a period of decades or centuries, but instantaneously. How credible is that?

4.1.2 Do the claims made for modern biochar add up?

> *"Bio-char sequestration could amount to 5.5–9.5 $PgCyr^{-1}$ if this demand for energy was met through pyrolysis, which would exceed current emissions from fossil fuels."* [57]

> *"No one is sure what types of biomass should be used as raw material or exactly what production methods work best, so calculating the costs is really an exercise in speculation.",* John Kimble, former USDA soil scientist.

Even if modern biochar were identical to terra preta, that would not necessarily make it a credible tool for climate change mitigation. Many agrofuel feedstocks have been shown to have positive greenhouse gas balances in micro-studies which only look at a small plot and ignore the wider impacts of converting large areas of land to agrofuels. However, as two recent studies published in Science confirm,[58] direct and indirect emissions from land-use change greatly outweigh any greenhouse gas savings recorded in micro-studies.

This will be discussed further below, but indicates that even if small-scale pyrolysis with biochar projects could be shown to sequester carbon dioxide from the atmosphere, this does not mean that such carbon sequestration gains will be achieved from large scale industrial plantations linked to pyrolysis biochar.

In this section, we will look at whether the claims made for modern biochar can be substantiated at the field-level.

4.1.3 Will soil with modern biochar retain nutrients and carbon?

Before moving onto concerns of scale, we consider whether the aforementioned claims for modern biochar can be substantiated at a field-level.

Terra preta has retained carbon and nutrients for thousands of years, although nobody doubts that the black carbon will eventually be mineralised and will one day find its way back into the carbon cycle, i.e. the atmosphere, vegetation or oceans. As Bruno Glaser et al state: "Charcoal is also mineralised in soil and there is no doubt that charcoal is not a permanent sink of atmospheric CO_2".[59]

This means that, if biochar could indeed be used to sequester substantial amounts of carbon within a century, it would effectively set up a 'carbon timebomb' for the future when all that carbon would be released.

The question however is whether modern biochar will sequester the carbon for similarly long periods and, if so, under what circumstances?

Johannes Lehmann, one of the leading scientists on biochar advised Biofuelwatch in March 2008:

> *"So far, there are no longer-term studies looking at the retention of carbon and nutrients from biochar in soil. One four year experiment was abandoned and another four-year old study is still ongoing, however neither of those has been published. There appears to be no other study older than about two years."*

A 2007 article by Johannes Lehmann[60] sums up the different issues which still need to be resolved before modern biochar can be said to improve long-term soil carbon storage and fertility:

1) We do not know what the half-life of biochar is, i.e. how long the carbon and nutrients will stay in the soil. The answer will depend on the type of biomass used, production conditions, soil properties and climate. Not all biochar will have the same properties.

2) Terra preta is highly fertile, not just because it is rich in nutrients, but because it provides the nutrients to plants in an easily accessible form. This property is called high cation retention and high cation exchange capacity. Terra preta has a high cation exchange capacity, but this is not the case for modern, newly produced biochar which has low cation retention and a low cation exchange capacity, at least initially. At temperatures between 30 and 70^{o}C, it takes several months for soil with fresh biochar to develop good cation retention. Those temperatures are, of course, higher than under natural conditions. Nobody knows under what circumstances and during which time-scales those processes can happen in the tropics, let alone in cooler climates.

3) Different feedstocks and production conditions affect how many phytotoxic and possibly carcinogenic materials are produced during pyrolysis. This means that a full

environmental risk assessment is needed, which must examine possible public health impacts.

4) Nobody knows how to incorporate biochar into the soil in a way which prevents it from eroding and, in the worst case, aggravating soil depletion.

Although the ash from charcoal production contains micro-nutrients and can serve as a fertiliser, charcoal itself is not a fertiliser as such. It is being promoted for carbon sequestration precisely because the charcoal remains in ancient soils represent carbon in a relatively inert form, not available to microbial breakdown and thus to plant growth. It must be said, however, that some of the carbon will oxidise after being added to the soil and that, as Johannes Lehmann's review confirms, it is therefore not known how much of the carbon in modern biochar will be truly inert and remain in the soil for long periods. Only long-term field studies can answer that question, and the results may well vary according to soil type and climate.

Charcoal has been shown to have certain properties which are linked to higher plant yields: it can reduce soil pH (make less acidic), particularly in the cases of sandy and loamy soil, and this will improve the growth of many agricultural crops. Charcoal is also associated with improved water retention in sandy soil, though not in other types of soil, as well as with improved soil structure.[61] Furthermore, charcoal can increase the soil's cation exchange capacity and thus make it easier for plants to take up nutrients from soil although, as Johannes Lehmann's 2003 review confirms, this is not automatically the case for modern biochar.[62] That review explains some of the differences between the properties of terra preta and modern biochar: In terra preta, all nutrients showed a high uptake-to-leaching rate. In modern biochar, this was the case for most, but not for all nutrients. Additional fertilisers are be required to maintain high plant yields over several growing seasons on soil containing modern biochar, something not needed with terra preta. The authors concluded: "Long-term studies with charcoal applications are needed to evaluate their effects on sustained soil fertility and nutrient dynamics.

Virtually all of the findings about biochar and soil fertility and carbon storage rely on laboratory study and soil analyses, rather than on field experiments. A limited number of field experiments are ongoing but results have not yet been published.[63]

An exception is a field experiment near Manaus, Brazil, in which the effects of adding synthetic fertiliser, chicken manure, biochar, and organic compost were compared over four crop cycles.[64] After four harvests, carbon retention was by far the highest where biochar was used. However, if no soil amendment other than biochar was applied then there was no plant growth at all after two harvests, proving that biochar on its own will not guarantee high or indeed any soil fertility and thus does not replicate terra preta. Using biochar as well as synthetic fertilisers resulted in higher yields than using synthetic fertilisers on their own, i.e. charcoal made fossil-fuel based fertilisers more efficient, at least in this particular case. It may also make organic fertilisers more efficient. By far the highest yields in this experiment were reached using chicken manure, which was greatly superior to biochar and synthetic fertilisers or to compost, even after four harvests following just one single application of manure.

This experiment shows that promises about biochar offering increased yields and soil fertility to farmers are dangerously premature. In some circumstances and combinations with other synthetic or organic fertilisers, biochar has been shown to increase yields, at least in the short term during – no long-term field trials have as yet been tested. However, adding large amounts of charcoal or coal-derived humic acids to soil has also been shown to lead to reduced yields of soya and maize.[65] As Glaser et al state: "For optimum plant growth, the amount of added charcoal may have to be determined for each type of soil and plant". Glaser has commented elsewhere that, in order to replicate terra preta "You would need 50 or 100 years to get a similar combination between the stable charcoal and the ingredients".[66]

In the absence of detailed knowledge of the effects of biochar, in different circumstances and combinations, on soil fertility, encouraging farmers to adopt biochar for soil fertility, either on its own or as a soil amendment, could have very detrimental impacts. Farmers, persuaded by promises of high soil fertility, could well pay the price in terms of lower yields and harvest failure.

There are further hurdles faced by researchers before modern biochar can be said to help with climate change mitigation.

A recent comparative study of black carbon measurements in soil showed that a wide range of methods is being used to measure black carbon in soil and sediments, yielding very different results.[67] No one method has been identified which would be applicable to all soil samples and scientific questions making a comprehensive review of scientific studies on biochar very difficult.

Various other recent 'findings' have been announced, based on press releases by scientists or on abstracts without full studies being publicly available and without clear information on methodology. For example, an abstract on "Soil Organic Matter Stabilization and Land-use Change in Tropical Ecosystems" by Joseph Kimetu et al claims that "we demonstrate that highly weathered tropical soils possess great potential for C increase", yet no information about the experimental set-up and methodology is given.[68] Researchers at NSW Department of Primary Industries have press-released findings that "reinforce[d] the potential of 'biochar' to revolutionise climate mitigation and adaptation", however no details are publicly available at present.[69]

Even if modern biochar was to bind black carbon in soil for long periods, those effects could be at least partially offset by increased loss of soil organic carbon in humus. Those were the findings of a 10-year long study published in May 2008 in which a Swedish team mixed charcoal with forest soil and left the soil in each of three different forest stands in boreal Sweden. According to the authors, charcoal substantially increased soil bacteria and fungi which, in turn, decomposed the organic carbon already present in the soil and led to soil organic carbon losses through respiration or leaching. Much of that soil organic carbon was emitted as carbon dioxide and thus greatly reducing any 'climate benefits' from adding biochar to boreal soils.[70] The study was criticised by Johannes Lehmann and Saran Sohi,[71] who argued that one could not conclude from the study that it was carbon in the humus rather than charcoal carbon which was lost and who also suggested that it was not clear that carbon loss was due to mineralization rather than physical export, i.e. whether it actually resulted in any CO_2 emissions to the atmosphere. Lehmann and Sohi concluded their critique by saying: "The answer to the broader question of what influence charcoal has on soil ecosystem carbon storage remains open and proves highly intriguing to follow." – thus agreeing with Wardle et al that further research is needed before drawing conclusions about the potential of biochar as a means of carbon sequestration. The authors of the original article replied by explaining why they believe their findings to be robust and conclude: "strong advocacy for the addition of charcoal or biochar to soil to offset human-induced CO2 emissions remains premature."[72]

Finally, there are major gaps in the general scientific understanding of the role of soil organic carbon in the global carbon budget and thus in global warming. Some studies suggest that losses of soil organic carbon through soil erosion are a major source of CO_2 emissions.[73] Others suggest that soil erosion has a negligible impact on CO_2

emissions although it is a very serious concern for many other reasons.[74] In the absence of any knowledge about the impact of biochar additions on soil erosion rates, and without any firm understanding of what soil erosion means for climate change, any claims that biochar will help mitigate climate change are premature.

4.1.4 Other claims made for modern biochar

Various other claims have been made about modern biochar which have even less scientific backing than claims about long-term carbon storage and soil fertility.

A 2007 article in the Bio Science Magazine, for example, written by two members of Eprida, a bioenergy company involved in biochar development, claimed for example:

> *"Because charcoal increases soil retention of water and nitrogen, runoff is reduced and nitrogen is prevented from leaching into groundwater and surface water."* [75]

Others make observational claims that biochar reduces emissions of nitrous oxide and eliminates methane emissions from agriculture.

However, according to the 2007 article by J Lehmann, quoted above:

> *"No information exists at present whether this adsorption behaviour would translate into a significant reduction of non-point source pollution of ground and surface waters by fertilizers or other pollutants in agricultural watersheds…The environmental benefits of bio-char applications other than C [carbon] sequestration are still poorly quantified externalities."*

Even Lehmann's assertion about biochar sequestering carbon is highly optimistic given the large number of uncertainties he himself has revealed.

4.1.5 Conclusion

The farmers who, hundreds to thousands of years ago, created terra preta in Central Amazonia succeeded in creating highly fertile soil which retained carbon and nutrients over very long periods. The formation of terra preta may well have depended on a combination of soil type, choice and diversity of biomass, climate, and it may have taken many decades to establish. Modern biochar, made from the pyrolysis of monoculture feedstock or from a small range of forestry and agricultural residues, has not been shown to be comparable to terra preta. No conclusive evidence exists about its potential for long-term carbon storage or its long-term impact on soil fertility. Indeed, some of the findings on biochar and soil fertility show that biochar will not have a positive impact, except in combination with other fertilisers and can, in some circumstances, even reduce yields. Even if biochar can, in some combinations and circumstances, increase yields, it may still not provide optimum conditions for plant growth, as the field experiment comparing it to chicken manure shows. Farmers may thus effectively be asked to trade high yields against potential carbon sequestration, something not made clear by biochar lobbyists. Conversely, the longest running study on biochar in Boreal forests indicates a significant risk of soil organic carbon loss as a result of charcoal additions.

4.2 The Investment Rush Begins

> *"The case for substantial investment in R+D, as well as changing the regulatory incentives to sequester carbon, is overwhelming.",* Carbon Commentary on biochar, November 2007 [76]

Scientists may be years away from finding out how to use charcoal to sequester carbon and nutrients long-term. This, however, is not slowing the enthusiasm of bioenergy companies, particularly those already investing in pyrolysis.

Lobbyists efforts to have biochar included into carbon trading and supported by governments worldwide are being coordinated by the International Biochar Initiative, a stakeholder forum comprising scientists, industry and some NGOs. Regional forums are being set up, including the Canadian Biochar Initiative, Biochar Europe, and the Mongolian Biochar Initiative. They work primarily at the higher policy level, seeking to influence decision making by governments and UN agencies, but also disseminate promotional materials, including to the international media.

4.2.1 Industry-science links

Many of the science institutes working on biochar have close links with the industry:

Iowa State University, for example, has signed a £22.5 million research programme with Conoco Phillip, with support from the US Department of Energy, to develop pyrolysis technology, as well as cellulosic ethanol. The same university works closely with the US Department of Agriculture's National Soil Tilth Laboratory, with the company Heartland BioEnergy LLC, and with the Iowa Soybean Association.

Wollongbar Agricultural Institute in Australia is the New South Wales Department of Primary Industries' Centre of Excellence for the Environment, the main agricultural science centre within the NSW government. They are involved in joint research on biochar with BEST Energies Australia.

One of the carbon trading firms promoting biochar is Crucible Carbon, a collaboration between the Crucible Group Ltd and Pekabu investors. They work closely with scientists at Macquarie University in New South Wales and Deaking University in Victoria.

Bruno Glaser of the University of Bayreuth, one of the leading soil scientists working on biochar, is also a member of Biochar Europe, an organisation with the declared political aims of getting biochar included in the European Emissions Trading Scheme, establishing a European Technology Platform for biochar, and making it part of the European Union's Research and Development Programme. Biochar Europe also includes a Senior Programme Officer of UNCCD, Mike Parr of the consultancy and market research company PWR, Christella Braun, PhD student and member of Terra Carbona, who is working on promoting biochar amongst school pupils, the global financial services firm JP Morgan Chase, the Norwegian company New Energy Systems, as well as Shell.[77]

Christoph Steiner, a research scientist at the University of Georgia-Athens and contributor to peer-reviewed studies on soil science involving charcoal, played a key role in lobbying UNCCD to formally propose the inclusion of biochar into the Clean Development Mechanism.[78]

A significant number of scientists are on the Advisory Board and Steering Committee of the International Biochar Initiative, which promotes not just research into biochar but also deployment and commercialisation.[79] It is of particular concern that several of the scientists involved in the International Biochar Initiative, either directly or through their membership of that initiative, support statements which do not in any way reflect the scientific uncertainty which they themselves have confirmed in peer-reviewed studies".

4.2.2 NGOs and the biochar lobby

Several NGOs work closely with the International Biochar Initiative or other industry-science lobby groups which are promoting government support and carbon finance for biochar. These include:

- Clean Air Task Force (represented in the Board of the International Biochar Initiative);
- Pro Natura (http://pronatura.org) , which has begun a biochar project in Senegal;
- The Indian NGO Geoecology Energy Association (GEO), which is involved in a biochar project in partnership with the carbon offsetting company Action Carbone;
- The Indian NGO Appropriate Rural Technology Institute (ARTI) which is running a three-year "Scale up project" for the "Commercialisation of Improved Biomass Fuels and Cooking Devices in India", funded by the Shell Foundation. This project includes a charcoal technology set aimed at using sugar cane residues;[80]
- Beyond Zero Carbon, an Australian NGO which promotes biochar as a means of climate change mitigation, and which has promoted the company BEST Energies in particular;
- Zero Waste Australia, represented on the International Biochar Initiative's Science Advisory Committee;
- The US-based NGO Forest Trends, which has close industry links and promotes "market –based approaches to forest conservation", and which funds a biochar project in Costa Rica;
- GoodPlanet, the NGO which runs Action Carbone.

4.2.3 Pyrolysis making second-generation agrofuels profitable

Investment in bioenergy and in particular in agrofuels for transport is fast increasing, however poor or negative energy balances and rising feedstock costs (the latter at least in part driven by the agrofuel industry itself) makes the industry highly dependent on public subsidies and incentives. According to researchers at UNICAMP, Brazil, "the future of biofuels is very likely to be linked to the ability of clustering biofuel production with other agro-industrial activities at an appropriate scale and mode of production to take advantage of the potential supply of valuable co products."[81]

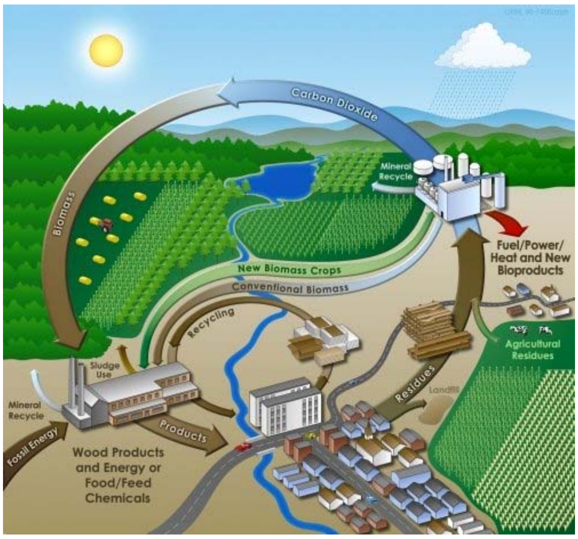
Growing concerns over rising food prices and rainforest destruction in particular are being countered with promises of 'second generation' agrofuels from non-food crops and agricultural and forest residues. The US government, the US Airforce and the European Union are amongst the supporters and funders of second generation research and development. There are two broad pathways to second generation, or solid biomass to liquid fuels (agrofuels): The first one, biochemical conversion involves the use of enzymes made from microbes or fungi to break down the plant cell walls so that the sugars in the plant can be turned into s. Cellulosic ethanol and biobutanol are the two main areas of research involving biochemical conversion. Those technologies currently yield considerably less net energy than the least efficient type of first generation biofuels, corn ethanol. Any future breakthrough in turning those fuels into a net energy source will heavily depend on genetic engineering.

The second pathway is thermal conversion, particularly Fischer-Tropsch gasification, which produces synthetic biodiesel. Significant R&D will be needed to make Fischer-Tropsch gasification commercially viable, however, there is evidence that energy efficiency from this process is just over 50%, considerably better than for cellulosic ethanol at present.[82] A first Fischer-Tropsch gasification plant relying solely on solid biomass has been opened by Choren in Germany. Choren are planning a much larger facility which will use one million tonnes of wood every year.

Another company investing in research and development of synthetic biodiesel is the Finish pulp and paper company UPM, which is developing a pilot plant near Chicago, together with two other firms.[83]

One of the barriers to making Fischer-Tropsch gasification cost-effective lies in having to ensure a large constant stream of biomass to a capital-intensive central plant. Transporting large amounts of wood and other biomass will reduce the overall efficiency of the process. One way of overcoming this problem is to have small, decentralised plants where wood and other biomass is 'pyrolised' to make syngas and bio-oil. Fischer-Tropsch gasification could use the bio-oil and syngas as a feedstock, rather than the much bulkier and less energy dense original feedstocks. Pyrolysis could thus make future synthetic biodiesel production far more efficient. In the meantime, pyrolysis plants can be used to produce fuel for heat and power or bunker fuel for shipping.

> *"By bringing the factory to the forest, instead of the forest to the factory, 'biomass-to-liquids' production becomes much more economical." , Biopact.*[84]



http://www.repp.org/bioenergy/bioenergy-cycle-med2.jpg

One of the first companies to develop decentralised pyrolysis plants is the Canadian energy firm Dynamotive. They currently run a commercial bio-oil and biochar plant as well as two pilot plants and a research laboratory in Ontario. Dynamotive, also a minority stakeholder in a similar venture by Ecolution Biofuels Inc., is developing a plant in Taiwan, and planning six pyrolysis plants in northeastern Argentina which will produce bio-oil for export, rather than energy for domestic use, as well as a plant in Taiwan.

The US Department of Energy, in their new Multi-Year Biomass Program, describes pyrolysis as an important component of future integrated biorefineries, a concept which would integrate the companies currently involved with agrofuels more closely with the pulp and paper industry as well as the livestock industry Maximising the use of by-products will be essential if biorefineries are to become profitable.

Finally, a different process, called 'fractination' is being developed by Biofine Renewables LLC, in cooperation with Embrapa (Brazilian Agricultural Research Corporation), the University of Sao Paulo and the University of Limerick. This has been reported to produce biochar as a by-product, amounting to 25-30% of the original biomass.[85] Fractination involves several processes to separate lignin, cellulose and hemicellulose and it yields a variety of products which can be used by the chemical industry as well as energy. The company has commissioned a first commercial plant in Italy. A similar technology is being developed by Scott Convertech in New Zealand. The by-product, called 'Cellulig' is understood to be similar to biochar and can also be used either as a soil additive or as an energy source.

4.2.4 Biochar: a by-product in search of a market

> *"Char is a secondary product, but from that perspective, one is always looking to see what one can do with it. The activated carbon market is very big. But (agricultural uses) would be a potentially very big market.",* Desmond Radlein, Dynamotive's chief scientist[86]

At best, biochar accounts for 35% of the biomass in weight after pyrolysis, though it could contain up to 50% of the original carbon. Such high biochar yields are linked to a process called slow pyrolysis, where biomass is heated to 350-450 ^{o}C rather than higher temperatures. Slow pyrolysis is used by US companies Eprida and BEST Energies.

Many other companies, including Conoco Phillips, ADM, Dynamotive and Heartland BioEnergy, however, are investing in fast pyrolysis, which yields at most 20% char.

The profitable use of by-products is vital for companies investing in this technology. Fertilisers are in ever greater demand and fertiliser prices were rising considerably in line with recent agrofuel expansion, up until the recent decline in oil and commodity prices linked to the global financial crisis. Already, companies like Eprida have patented biochar-based fertilisers as well as different pyrolysis processes, depriving communities of potential affordable access to both.

To quote the Best Energies website:

> *"We are well positioned to win the current land grab in next-generation fuels"*[87]

Biochar supporters claim that pyrolysis and char can provide poor rural communities with fuel and more fertile soils. The Biochar Fund, set up by Biopact, for example invests in trial biochar and pyrolysis projects in villages in Southern Cameroon and the Democratic Republic of Congo. They promise to help small farmers gain access to modern agricultural inputs and markets, to connect them to the carbon market, to help them use biochar and to acquire small pyrolysis plants. No information is provided about the financial risks and any liability in case the projects fail, nor about the financing of the pyrolysis plants and any possible future debt burden.

Other companies, meantime, are patenting pyrolysis and biochar processes. A 'terra preta' patent has been granted for the identification and isolation of micro organisms in that soil.[88] Different pyrolysis technologies, biochar-based fertilisers, types of bio-oil and biochar have already been patented. It is clear that companies, not communities will profit.

Much of the research into biochar is focused on potential carbon funding. Carbon trading almost exclusively benefits larger companies that can afford specialist consultants, not rural communities. A 2006 study looked at three biochar projects to establish the feasibility of carbon finance.[89] This study provides insight into the types of projects likely to benefit from any future carbon finance for biochar:

The first project involved pulp and paper companies that own an acacia plantation in Sumatra. The second project used wood residue from a eucalyptus pulp and paper monoculture in Australia, and in the third project heat from a waste incinerator was used for turning sawdust into biochar.

Plantation, and in particular pulp and paper companies, together with agribusiness firms are likely to benefit the most from the development of pyrolysis and biochar and from any future government support in the name of climate change mitigation.

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49 Putting the carbon back: Black is the new green, Emma Marris, Nature 422, 624-626, 10 August 2006) | doi:10.1038/442624a, www.nature.com/nature/journal/v442/n7103/full/442624a.html

50 Biopact, 29th October 2007, http://biopact.com/2007/10/strange-world-of-carbon-negative.html

51 Lehmann, J. 2007 A handful of carbon. Nature 447, 143-144 http://www.css.cornell.edu/faculty/lehmann/publ/Nature%20447,%20143-144,%202007%20Lehmann.pdf

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