

# Biochar production opportunities for South East Asia

An overview of the many different ways in which biochar can be created.

By Trevor Richards

This is a follow-up article to “Biochar - reversing the flow of carbon” which was published in the inaugural issue of this journal in January 2014. In the first article I provided some background on charcoal and the history of biochar. I provided an introduction to some of the agricultural and environmental applications for biochar and also its potential for climate change mitigation. I very briefly introduced some of the biochar production concepts and opportunities and promised to expand on this in a (this) follow-up article.

**B**iochar can be created from simple burning (combustion) systems or more complex gasification and pyrolysis technologies. It is easy to drown oneself in chemistry and physics when looking deeply at the science of fire. I’m not qualified to say too much about complex thermal processes but I’m willing to get my fingers burnt, trying to present a layman’s view.

In its elemental state, biomass is made up of mostly carbon, hydrogen, oxygen and nitrogen (C, H, O & N). As you heat biomass above 100°C you drive off the water molecules. As the temperature rises above 200°C other volatile, flammable gases evolve and progressive chemical changes start to take place in the hemicellulose, cellulose and lignin components of the biomass (Yang *et al.* 2004). If enough O<sub>2</sub> (or air) is available within the hot zone (fire) and temperatures are high enough then eventually all of the H and C will be ‘oxidised’ or transformed to heat and gases (mainly H<sub>2</sub>O and CO<sub>2</sub>) leaving behind ash (minerals, metals, salts that were part of the biomass). The atmospheric N<sub>2</sub> is relatively inert but at temperatures above 1000C can react with O<sub>2</sub> to form NO<sub>x</sub> (Werther & Ogada 1999). This process describes complete combustion. But combustion is often incomplete due to a lack of O<sub>2</sub> &/or cooling of the remaining mass below

gas ignition or reaction temperatures. This is where you will find charcoal—smothered in the ash bed of any combustion device. This is why some chars can be extracted from combustion systems.

This char is the residual C that did not see enough O before cooling below reaction temperatures. Pyrolysis technologies focus on restricting or eliminating O (air) from the heating zone so that C cannot react with O. In this environment, the C starts to combine to form very stable 6-sided aromatic rings of almost pure C. Biomass also often retains its original porous plant structure which is one of biochar’s most important attributes. ‘Slow’ pyrolysis is generally the preferred option for charcoal and biochar production because it optimises the amount of C that is retained and provides time for the char formation chemistry to take place. However, low-temperature fast pyrolysis biochar has also been reported to help enhance soil properties (Brewer *et al.* 2011).

There are other potentially valuable products of pyrolysis such as wood vinegar, bio-oil, fuel gases and heat but if the focus is on renewable energy, then gasification is often in the frame and biochar becomes the by-product.

Gasification could be viewed as an intermediate process between pyrolysis and combustion. By controlling the amount of O<sub>2</sub> that can interact with the hot volatile gases as they evolve from a biomass heating process, one can optimise for the creation of carbon monoxide (CO) and H<sub>2</sub> and then burn (oxidise) this ‘syngas’ as a fuel for power production. This two-step process can be conducted at a wide range of scales and can often be ‘tweaked’ to produce more or less carbon residue but there is generally less process control (temperature/time) over the resulting charcoal/biochar.

Temperature and holding time are the two important process conditions that affect the qualities of biochar. Other important variables are the type of biomass used and its physical state (moisture content, particle size, density) and these variables will have an influence over the selection of technology for a project.

The opportunities for co-production of bioenergy with biochar are closely linked to the chosen production method and could be grouped based on technology scale: micro; small; medium and large scale. Let’s take a close look at technology scales and see if they could be appropriate in the South East Asian context.

### **Micro-scale biochar production**

You can produce charcoal in small quantities by putting biomass in a metal container with a hole in it and placing the container in a hot environment (open fire or combustion chamber). You could also extract lumps of charcoal from the fire itself!

Micro-scale biochar production could be a major contributor to biochar development via the kitchen. Biomass cook stoves are a surprisingly big topic. There are many reasons:

- About 3 billion people still cook or heat their homes using open fires or simple stoves according to the World Health Organisation.
- There is more death associated with cooking than malaria and AIDS combined. Surprised? According to the WHO (2012), "*4.3 million people a year die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels.*"
- Gathering of wood for cooking fires is often dangerous work carried out by women and children and carries a huge cost in labour that could be better directed for income or food production.
- Charcoal production for urban cooking fuel is a major cause of deforestation, environmental degradation, erosion, desertification and subsequent poverty (Gwenzi *et al.* 2014). Charcoal production also funds wars in places like Somalia (Anon. 2015).

The development and introduction of clean and efficient cook stoves is a hidden industry with a huge potential to make a difference to the lives of over 40% of the world population. The Improved Biomass Cooking Stoves (<http://stoves.bioenergylists.org/>) website lists over 130 organisations working on the issue around the world. So where does biochar and SEA fit into this?



Rice husk and pellet TLUD gasifiers from Dr Paul Olivier in Vietnam (<http://www.epwt.net/>).

Some of the stove designs being developed and promoted use sustainably harvested biomass (such as crop residues like rice husk) as a clean burning fuel that also produces a charcoal residue. This residue is being directed to impoverished soils in projects in Africa, Central America, South Asia and SEA. The International Biochar Initiative IBI have a dedicated section on their website (<http://www.biochar-international.org/technology/stoves>) looking at biochar stoves (mainly Top Lift Up Draft or TLUD gasifiers). Many posts in the SEA Biochar Interest Group website have been published on biochar producing stove projects and research in the region. If this subject is of interest to you then click on stove label at the BIG-SEA site (<http://sea-biochar.blogspot.com/search/label/stoves>) for some regional links.

Also, some of the stove designs are so attractive and functional that I have hope we will all be aspired to having one in our homes in the future.

### Small-scale biochar production

In this category of production system I include the many backyard inventions that have grown from worldwide interest in biochar. There are a plethora of options and opportunities for anyone with a few simple tools and some recycled materials. Retort drums, TLUD drums and now TFOD systems (Top Fed Open Draft) all fit into this category. Additional reviews on this are available in the open literature (Nsamba *et al.* 2015)

The choice of system and its design may depend on many things: type, size and moisture content of the biomass; available materials for system fabrication; labour availability, skill and cost; local emissions management and fire risk rules; secondary objectives (heat and/or condensate recovery); process control objectives (temperature, time, refueling). Some systems combine technologies such as TLUD's or rocket stoves firing retort systems.

You can explore the level of development by trying an internet image search (<http://images.google.com>) on the various terms above—just include ‘biochar’ in the search line.

**Top Fed Open Draft:** A special mention on TFOD’s, also described as cone kilns and KonTiki kilns. This may be the ‘poster child’ of biochar production right now due to its simple, low cost design, scalability and portability. Further details on this development can be found here: <http://soilcarbon.org.nz/tag/tfod/>

**Open burning:** It may seem like a backward step to suggest that biochar production could be undertaken from open burning but a well-constructed and managed pyramid ‘bonfire’ can produce reasonable quantities of charcoal with much lower emissions and visible smoke than the unmanaged field burning of biomass. The basic principle is around ‘top-lit’ fire management. As a fire front progresses down from the top of a biomass pile, most of the smoke and combustible gases are consumed in the flames above the fire. The evolving gases from the fire front rise through the charring material above, preventing sufficient air from accessing and thus creating pyrolysis conditions. The air that is drawn up through the biomass pile below the fire front is only sufficient to feed the fire zone. Safely building and managing a large open fire to create charcoal/biochar while minimising pollution is an artisan skill that needs to be learnt. A helpful place to investigate open burn and other low-tech techniques is Kelpie Wilson's website, BackYard Biochar (<http://www.backyardbiochar.net/>) where it is described as Clean Carbon Conservation (CCC) burning.

### Medium-scale biochar production

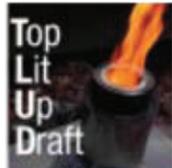
There are examples of biochar-type products being produced from industrial scale equipment but this has historically been by accident. By this I mean that a char by-product is produced in an existing process that could meet ‘biochar’ specifications and could be directed for service as a biochar. For example, rice mills currently use some of the rice husk (10–15%) as heating fuel for drying the rice (Manikam *et al.* 2012) There are many types of combustion rice dryer in service, all producing a range of ash and char. Many are old, inefficient and polluting but some are capable of producing a suitable char and could be tweaked to improve the fixed carbon output.

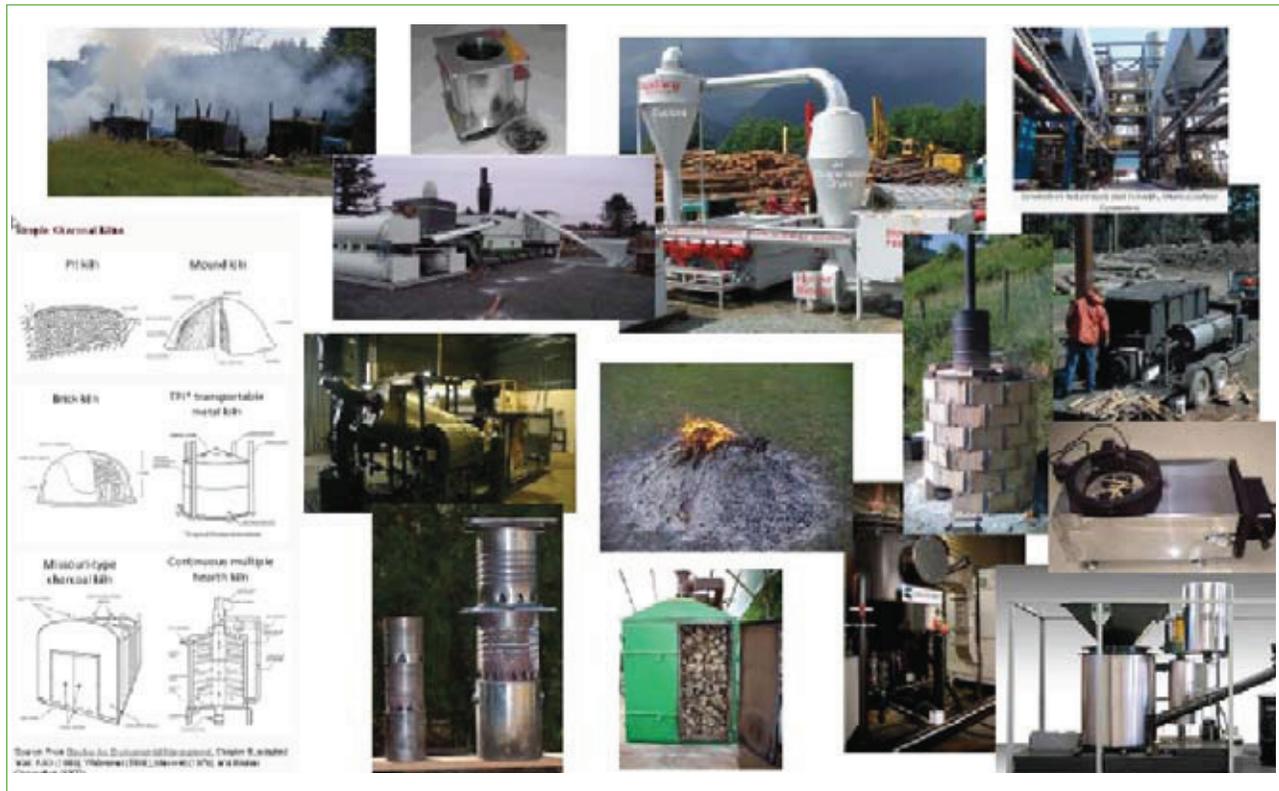
Industrial biomass boilers sometimes fail to oxidise all of the carbon in the biomass fuel. This results in chars being captured or entrained in ash residues. There is growing interest in redirecting this char-ash to roles that can be similar to biochar.

Industrial scale gasifiers target biomass for syngas, heat and power production. There are plenty of examples in the SEA region that produce a char residue that can be suitable as a biochar. Generally, 5–15% of the biomass going in ends up as a ash/char residue but they can be tweaked to adjust the ratio of syngas to char.

There are a number of companies around the world that have developed new, innovative medium scale biochar production systems. The list provided on the IBI website (<http://www.biochar-international.org/technology>) is currently quite dated. A more comprehensive list of companies in this space can be found at the

### Small to medium scale biochar production technologies and methods

Type	Biomass	Scale	Advantages	Disadvantage	Examples
Stove - TLUD (Top Lit Up Draft)	dry (below 25%MC): uniform sized is better - sieved?	Almost any tin can will do for student projects and testing	good utilisation of biomass (heat and carbon); life saving		
natural draft	fuel pellets, woodchips, crop residue (generally granular)	Almost any tin can will do for student projects and testing	low cost, simple design		
forced draft	sawdust, rice husk (can be finer)	can be larger for longer cooking times	more process control; higher temp.	power / battery required for fan; cost & maintenance impact	
Stove - other	fuel flexible, depending on design	many sizes—camping to industrial scale cooking	There are many designs and names—some use retort style and some combine TLUD or combustion with a retort chamber		
Retort	fuel flexible; wood-branch or lump to fit vessel	many sizes, depending on retort vessel	low supervision need—can be left to cool	substantial fuel / energy requirement to initiate burn	
TLUD drum	dry (below 25%MC): uniform size	many are based on 200L drums; some larger examples	minimal supervision until extinguishing		
TFOD (Top Fed Open Draft), cone Kiln, Kon-Tiki	almost any biomass of appropriate size; some wetter / greener biomass can be mixed	10L to 1000L and growing!	fuel flexible; less biomass prep. Mobile, versatile	fulltime management poor energy utilisation (but innovations coming)	
Moxam kiln or flame capped tube (FCT) klin	as above	medium to large	fuel flexible: less biomass prep. Versatile, semi-mobile	fulltime management; poor energy utilisation	
Clean Carbon Conservation (CCC) Burn	as above	very flexible	ideal replacement to convention burn pile	sizing/stacking fulltime management; poor energy utilisation	
TFOD pit	as above	very flexible	fuel flexible: less biomass prep. Versatile, semi- mobile	fulltime management; poor energy utilisation	
CHAB (combined heat & biochar)	depends on technology selection	small to large	efficient use of energy in biochar production	project complexity and cost	



Biochar & charcoal production methods: old & new; large & small

BioEnergy Lists: Biochar Mailing Lists website co/ Tom Miles (<http://biochar.bioenergylists.org/company>).

### Large-scale biochar production

Biomass can provide the fuel for large-scale combustion and gasification technologies for energy production. These types of projects try to optimise energy production and minimize un-oxidised char co-products. Future large-scale pyrolysis systems are competing for this biomass and offer a range of products including electricity, transport fuels, chemicals, fertilizers and biochar (Kong *et al.* 2014). I don't think there are examples anywhere in the world of large scale commercial systems dedicated to biochar production, but they are surely coming.

Any project associated with the processing of large volumes of biomass needs to be studied carefully for environmental and economic sustainability. There is a history of conflict in the SEA region between resource development and negative impacts on the local environment and stakeholders. Poor governance and corruption will attract suspicion to any large biomass project. But I believe there are opportunities for large scale biochar production projects in the region based around plantation industries, poorly utilised biomass and 'Combined Heat And Biochar' (CHAB) technologies.

### Biochar project opportunities in SEA

There are numerous project scenarios that can be associated with available or stranded biomass in SEA. Residual biomass from the

timber industry, planted forests and palm oil industry are in high volume. These resources have been tainted in some eyes but they should not be under-utilised. What is needed going forward are strong sustainability protocols, implemented and enforced. Rubber, rice and sugar production are other plantation industries with available or stranded biomass. By available, I mean produced as a by-product of industrial processing (furniture, rice milling, bagasse) and stranded being biomass left in the field and currently burnt or left to decompose.

Mulching residual biomass in the plantation or field is often the default strategy—at little or no cost and returning valuable nutrients and carbon to the soil. But it is often associated with pests and disease and can be associated with increased greenhouse gas production (methane). Labile soil carbon from mulch or compost does not last long in tropical climates. It is rapidly consumed under the high metabolic rate of tropical soils (compared with temperate) and cycled back to CO<sub>2</sub>. Biochar offers an alternative strategy for building soil carbon.

All biomass processing projects will benefit from being associated with existing crop processing facilities. Biomass transportation costs and logistics are often limiting factors for the scale of biomass projects that are handling a widely/thinly distributed resource. This issue is resolved at the palm oil mill, rice mill or sugar cane processing facility.

### **Biochar production integration in the palm oil mill**

The typical palm oil mill design has been around for a long time. Its development has been an

evolution and the focus has always been on optimising oil revenue. Resource utilisation and energy efficiency are not key drivers when you have an abundance of fuel to hand. The world we now live in demands that this should change. The industry can do itself a lot of favours by focusing more on its carbon footprint. Biochar production and application offer great opportunities both at the mill and in the plantation (Kong *et. al.* 2014).

A new research group dedicated to helping the palm oil industry has recently been formed. You can find details on the Academic Research on Palm Oil Sustainability (ARPOS) here (<http://sea-biochar.blogspot.com/2015/05/arpos-new-research-initiative.html>). I am hopeful that biochar research will be on their agenda in the future.

### **The annual Asian haze crisis**

Repeating myself from the previous article, open burning of crop residues for disposal or for land clearing are serious contributors to greenhouse gases and environmental pollution around the world. Slash and burn agriculture is the main culprit in the annual SEA haze problem that afflicts Indonesia, Malaysia and Singapore (Koe *et al.* 2001). Imagine a new scenario where the carbon in the 'waste' biomass (that is burnt and lost as CO<sub>2</sub>) was valued as a soil amendment. A new rural cottage industry could evolve, supplying biochar to the adjacent plantation companies and farmers. Simple, mobile, low cost and clean biochar production technologies have been developed and are easily deployable (as described earlier in this article). A percentage of the current urea or NPK applied in the plantation could be swapped out for biochar,

### Integration Opportunities for Biochar in the Palm Oil Industry

	Palm oil mill	Plantation
Biochar production	New plant design: replace inefficient and polluting boiler systems with pyrolysis or gasification CHAB	palm trunk chipping and charring (disease management)
	Retro-fitting CHAB into an existing mill energy system upgrade	frond and other plantation biomass management
	Parallel plant facilities dedicated to improved biomass utilisation and biochar production	addressing the 'Haze' issue (ref. separate discussion)
	New revenues from sale of biochar and related pyrolysis products (independent mills)	Co-production of chemical replacements (i.e. pest control - wood vinegar)
Biochar application	Biochar-compost systems (EFB / POME management) at the mill or in the plantation— reduced emissions, accelerated and improved compost	
	water cleaning / polishing services (POME management)	soil enhancement: improved water storage and water penetration
	biogas system integration— accelerated and enhanced methane production	soil enhancement: improved nutrient capture and cycling (reduced NPK application)
	nutrient capture (biochar charging) prior to field application	soil enhancement: increased soil biology, healthier soil, reduced disease
	emissions management, odour management	increased stable soil carbon: soil enhancement; carbon sequestration; reduced soil emissions
	future carbon trading revenues	

potentially providing improved economic and environmental outcomes and establishing an equivalent baseline value for the biochar.

Unfortunately, there is currently little awareness within regional governments, plantation industries or NGO's on biochar applications or efficacy. Field trials and research projects are

thinner on the ground than the biomass that is going to waste.

How do we get a demonstration project under way?

### **Biochar in the poultry industry**

Standard shed-based poultry and egg production systems around the world can have negative impacts on animal welfare / health and the local and wider environment. These problems usually have economic impacts on the industry. Biochar has been shown to have a positive effect over a wide range of issues via diverse applications. These are described well in a recent article by David Yarrow, a copy of which can be obtained from this link (<http://sea-biochar.blogspot.com/2015/05/playing-chicken-with-biochar.html>).

### **Biochar building materials, biochar composites, biochar paper and packaging, biochar animal feeds, ...**

The list goes on and on. If you would like more details about development progress on these and other biochar related innovations, then please get in touch with the author and check out the 'Biochar Journal'.

#### **Trevor Richards**

*Environmental engineering consultant*

Kuala Lumpur

[fabiochar@gmail.com](mailto:fabiochar@gmail.com)

South East Asian Biochar Interest Group:

<http://sea-biochar.blogspot.com/>

AllBlackEarth: Biochar Interest Group NZ:

<http://soilcarbon.org.nz/>

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