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Starting new methods for green energy

Companies in the USA develop pyrolysis and gasification systems to generate electricity from biomass and sell the by-product. Up to now it is interesting for agriculture and livestock producers.

To reduce human impact on the globe one of the best things humans can do is produce as little carbon as possible – or sequester it, reducing the carbon in the atmosphere. Universities, scientists and governments have invested years of research and tons of money into complicated schemes to pump carbon underground or into the ocean. But there's another way, a way developed 1,500 years ago in South America, which resulted in dark soil called terra preta that's still fertile. Today scientists and startups are harnessing this ancient knowledge to use biomass in new ways and in the process creating clean, base-load quality electricity, as well as a soil amendment that retains moisture and increases soil nutrients while sequestering carbon. All thanks to a material now called biochar.

There are many means and methods to create biochar, but it starts with placing biomass in a low-to-no-oxygen environment and starting a pyrolysis-based reaction. An initial external heat-source, like a blowtorch, is required to get the process going but after reaching a certain temperature the reaction becomes self-sustaining. The pyrolysis process can be converted into a variety of processes, which includes torrefaction, further pyrolysis at lower temperatures, carbonization or gasification, depending on the biochar manufacturing process.

Torrefaction, which is accomplished at roughly 250 °C can produce a carbon neutral green coal that can be used as a replacement for coal. In Europe several companies are working on such methods, but are in the early stages (see page 241). As companies and consultants in the USA say, they are not interested in using biochar as a replacement for coal. They say biochar or biocoal costs more than the price of coal in the US, and that it has more value as a soil amendment that provides carbon sequestration by locking the carbon in the soil amendment or its other uses like a replacement for charcoal filtration systems. They work on the development of biochar systems, which generate syngas, process heat and biochar as a by-product.

In these biochar systems, applications which convert biomass into biochar, roughly 1 MWh of electricity per ton of biomass introduced can be generated by the originated syngas or biogas, burning it in an internal combustion engine or in a turbine system. Process heat created during production is useful for industrial purposes like drying biomass for the biochar process or agricultural waste, or heating collocated buildings or even a town – if a big enough system was made. At the same time, the systems can be adjusted to produce more or less biochar, equivalent to 9 % to 25 % of the feedstock's weight depending on the producer's needs. These systems currently offer the greatest benefit when collocated with or close to a biomass source like agriculture, wood, poultry or livestock waste.

US players in the biochar development

Some US companies like Phoenix Energy of California and Biochar Solutions Inc. of Colorado are realizing the potential of biochar with the pyrolysis process and are operating and selling small biochar manufacturing plants. Others are just starting to introduce their first biochar projects like Full Circle Biochar of California and Whitfield biochar furnace. And they're gaining international recognition: both Full Circle and Biochar Solutions were among the 11 Virgin Pioneers in the Virgin Earth Challenge.

Ronal Larson, PhD, a retired scientist focused on sequestering carbon, was the first principal scientist at the US National Renewable Energy Laboratory's predecessor and has worked on renewable energy since at least 1973. Within the biochar community, he says, many are focused on producing as much biochar as possible and not necessarily biofuels. But, he asks, "Do we have enough to do both? Can we get all the fuels we need and all the char we need for sequestration for heat and electricity? That question is very controversial. I think we can."

A multitude of opportunities for power

A tantalizing thing about biochar manufacturing is the variety of ways the energy it produces can be used. Biochar Solutions exemplifies this. The company has systems in the US, Estonia and India, it is now building its tenth system. Its B-1000 Thermal Conversion System takes in chipped woody biomass with a 10 % moisture content at a rate ranging between 226 kg and 317 kg and produces 45 kg or more of biochar and 527 kWh of process heat every hour. The heat from the process often is used to pre-dry the feedstock and the gas produced is at a very minimum burned cleanly, says company co-founder and Vice President of Equipment and Materials Jonah Levine.

The equipment is adaptable to other applications, like heating a boiler, an application one customer in Idaho is using to kiln-dry timber products. The kiln's exhaust heat also will eventually warm a greenhouse, he says. "There are other things we would like to do with our produced gas," Levine says. He's been looking into both stirling engines and organic rankine cycle turbines to produce electricity. "But the capital expenditure to use that relative to the energy payback in the continental US is just not possible at this time," he explains.

Other companies, like Phoenix Energy and Full Circle Biochar contend that producing electricity is an essential part of the biochar process. Phoenix Energy has three of its systems in the wild, two in Poland, one in California and three more on the way in California. Those systems use gasification to produce biochar and biogas. The biogas is passed through a three-way catalytic converter and is used to generate electricity via an internal combustion engine designed to operate on natural gas. The company's PHX-1000

This Whitfield biochar furnace prototype uses pyrolysis to heat a greenhouse and produce biochar from wood pellets.

Photo: T.R. Miles Technical Consultants Inc

system gasifies about 750 kg of biomass hourly producing about 125 kg of biochar. "We require no external heat source. We use a propane torch to start the process and as long as you keep the blower on and keep adding fuel to the gasification chamber the reaction continues," says CEO Gregory Stangl. The electricity is primarily used onsite. "We normally generate at around 580 kWh per hour or so," although the system could generate up to 640 kWh per hour. The system's process heat is used to dry agricultural commodities, like grape and tomato pomace, which are then used for other applications.

People are taking more interest in Phoenix Energy's systems as agriculture and livestock producers move from diesel-powered machinery to electric machinery both to improve air quality and reduce the impact of rising electricity and diesel prices, and in California, burning of agricultural waste is increasingly not allowed, according to Stangl. Phoenix systems cost about 4 to 5 million US$/MW depending on the amount of customization and interconnection requirement, according to Stangl. The company is working on a co-ownership model. "We find that because the technology is new people are more comfortable when we put our own capital at risk," he says. The systems, he says, have a roughly 3 to 4-year payback time. That's largely because they're highly localized, using biomass produced onsite and providing heat and electricity onsite.

You might think the electricity the systems generate would be their most valuable asset, but you'd be wrong. "We make more money selling biochar than we do selling electricity," Stangl asserts. That's because there aren't incentives to generate electricity via biomass. But biochar, depending in the mix, can sell for up to US$ 1 per 0.45 kg. Electricity produced in California at Phoenix Energy's scale is worth about 11 US$-ct/kWh on the grid. If used where produced that power is worth 18 to 30 US$-ct/kWh – what the consumer would pay for grid electricity, Stangl explains. However, the system can respond to grid demand by producing more or less electricity as needed by the grid, like a coal or natural gas power plant albeit on a small scale.

Biochar produced by Phoenix Energy's gasification system

Full Circle is completing a 50 kg/h research and development biochar unit at Cornell University later this year and is in project development with two facilities, each capable of taking in more than 2 t of biomass an hour, one in California, another in the Mid-Atlantic region of the US. The syngas produced by the systems will be used to produce electricity. The company is developing agricultural products that can restore soil organic carbon and biochars embedded with nutrients, like biochar-based fertilizers, says COE and founder Dr. David Shearer. The facility at Cornell will allow Full Circle and researchers to explore how to develop biochars optimized for specific feed stock and use applications.

As the company moves toward commercialization it understands the need to maximize monetization, which will come through using the syngas and waste heat. Shearer says, "In many respects the revenue from the kiln itself, 50 % of it or greater could be from the syngas production, from the production of electricity, or other forms of use for the syngas."

What is holding biochar back?

Even though biochar power plants are capable of providing clean base-load quality energy, the industry remains small. Many issues are holding back wide-spread or commercial scale adoption of biochar power plants in the US. Chief among them are lack of incentives for generating power from biochar facilities. "Technically we know how to do it. It's just not worth doing. It is too expensive especially at a small scale. Especially in the case of biochar – you have to be processing 20 or 30 t/h to make it worthwhile to generate power.", explains Tom Miles, a biomass consultant and founder of T.R. Miles Technical Consultants Inc. "We don't have any places in the US where you can really get enough money generating power. The utilities won't pay you enough for power to make it worth while to make power along with biochar."

Another factor is a lack of carbon markets in the US. While biochar has plenty of uses and is gaining traction in new markets, from soil amendments to filtration – pollution abatement, its most important function, the ability to sequester greenhouse gases like carbon dioxide and even nitrogen oxides, isn't valued. Biochar also lacks quality standards. The International Biochar Initiative has draft standards, but they are not finalized. Such standards will help assure potential purchasers of the quality of biochar products, supporters say.

To further popularize the benefits of biochar in the US, commercial-scale demonstrations need to be undertaken, according to Miles. "What we need is the support of the same public agencies that we are cutting back on. We need the colleges, the extension people and so on to do greenhouse trials and landscape-scale testing so they become familiar with the product, so the experts on campuses can write fact sheets and give industries the confidence to use biochar," Miles says.

Chris Meehan