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Converting Municipal Solid Waste to Biochar in North America
The Climate Foundation

Project Summary - Part I. Description

Participating organizations and geographic location(s) of the project (a small

The project was led by The Climate Foundation, based in Mountain View, CA. Stanford University (Stanford, CA) partnered with The Climate Foundation in the creation of the first-generation biochar reactor.

The two organizations worked in close proximity. Demonstrations in 2012 included a system demonstration at the North American US Biochar Initiative, where we demonstrated pyrolysis of 60% input moisture material. Later, we took the demonstration to Seattle Washington, where we demonstrated the system for the Gates Foundation and King County (Seattle), leading to further collaboration in 2012.

Background or problem statement

There is a need for sustainable sanitation across North America. From Cape Cod to the San Juan Islands, from Alaska to Central America, nutrification of our estuaries, rivers, ponds and lakes pose a serious hazard to sustainability and biodiversity in our watersheds. In addition, increasing droughts throughout most of North America pose a hazard as populations increase and arable land decreases. Finding an agricultural solution using less water with increased productivity is imperative. There is a worldwide need for high-quality nutrients sustained in soil for growing populations. There is also an acute need to reduce agricultural water consumption in the face of climate-change-induced droughts and other episodic severe weather conditions.

The developed biochar reactor converts biosolids into sanitary biochar that can be applied directly to agricultural fields with complete safety. When this biochar is applied to the land, it has several benefits. First, biochar acts like a sponge, absorbing water and holding it near to the roots of the plants, reducing the water needed for high productivity in marginal soils. Additionally, biochar reduces fertilizer requiremenst. The fertilizer is buffered by the biochar, keeping the nutrients near the roots of the plants where they are needed the most. Because most of the fertilizer stays with the biochar, even in rain, the nutrient runoff is dramatically reduced, resulting in order-of-magnitude reductions in runoff to watersheds.

General description of the project

We rigorously evaluated the challenges of making a biochar machine with the criteria laid out. After the machine was designed in 3D computer-aided design, the reactor was built, tested using a NASA human solid waste simulant, and refined. Testing included the successful creation of biochar, and syngas burning led to further input material pyrolysis. After discovery that the input moisture tolerance of such an apparatus should be higher, we explored appropriate pre-drying technologies for use in the next generation biochar machine. This next iteration of the system is laid out in the figure below. One of the crucial components of the second generation system is recovering the latent heat of evaporated water, in order that higher moisture level input streams can be processed with the available reactor output power. With that energy recovery, the new system will be able to support a wide range of community scales, from several hundred to several thousand people per day.

Outcomes and follow-up

The project achieved its primary goal of designing and building a biochar reactor that converts human solid waste simulant into biochar. We also realized the need for a pre-dryer for our reactor to go to higher moisture inputs, and have researched two possible solutions that can dry 80% moisture input material down to 20%. Follow-up work includes finalizing and designing the appropriate pre-dryer for use in the next generation biochar machine. For further information on our ongoing work, please contact Dr. Brian Von, Herzen, Executive Director of The Climate Foundation Brian@ClimateFoundation.org.

Project Summary - Part II. Analysis

Successes

Describe the most significant successes achieved during the implementation of the project.

We succeeded in making biochar in a proof-of-concept biochar reactor. This success has validated the concept and helped assess the performance of the biochar reactor.

We designed, fabricated, assembled, tested and demonstrated the first biochar reactor, after completing a CAD/CAM three-dimensional design and model of the system. Testing was done using a simulant material recommended by NASA Ames in its work on the International Space Station. We engaged with several municipalities in North America, receiving advice, input and suggestions from King County (Seattle), Town of Falmouth (Massachusetts), and have interacted with City of Palo Alto and City of San Jose, California, on understanding needs and opportunities in biosolids processing in communities like these. This feedback is being utilized in our scale-up of the biochar reactors for North American applications.

We pursued scaling questions and performance optimization for North American application of this technology, in particular efficient pre-drying and pelletization technologies. We believe that this step is crucial to creating biochar robustly in a variety of different biochar machines.

Challenges

Describe the most significant challenges encountered during the implementation of the project.

Moisture content of the syngas produced in the pyrolysis chamber is a key challenge for managing biosolids with moisture ratios commonly close to 75%. There is an opportunity to utilize a pre-drying process to reduce the moisture content in the syngas. Cogenerated heat from syngas combustion and associated lean-burn combustion can be utilized in this drying process.

Managing the rheology of the biosolids as they transition from 60% moisture to 40% moisture can also be challenging. This so-called Sticky Zone is widely acknowledged in industry as a valley of difficulty that has to be surmounted.

We have been working on approaches to the mechanical handling of the material in this moisture range, with one of them including Stool-On-Slab (SOS) technology enables drying processes over a wide range of moisture contents given sufficient surface area and thermal input. In addition, at a larger scale, we are developing a combination drying, mixing, and shredding apparatus that deals with the entire input moisture range, and creates uniform prills that can be pyrolyzed in a reactor. Another key challenge and opportunity is to reduce the moisture content while managing the energetics of the biochar reactor. Leveraging heat exchange of exhaust gases and latent heat of vaporization can enhance the efficiency of the overall system.

Lessons Learned

Pre-drying is a key design aspect of biochar reactors. Reducing the input moisture levels allow for consistent and reliable syngas generation, while higher moisture levels in the input cause the system to be heavily influenced by small mass flow fluctuations of the input stream.

One of the best practices is to recirculate dry material into the input of the dryer. This approach avoids having to cross the Sticky Moisture zone and keep the mixture in a well characterized moisture regime. Additionally, leveraging heat exchange of exhaust gases and latent heat of vaporization can enhance the efficiency of the overall system.

Odor management and exhaust management in the lean oxidation chamber require controlling the moisture content of the syngas to ensure even processing in the lean oxidation chamber. This moisture control can be achieved by adjusting the ratio of biosolids to greenwaste. It also can be achieved by predrying the biosolids to a consistent moisture content and pellet size. Even pellet size is also useful in minimizing finer particle generation.

What next?

We are continuing our research and development into a Phase 2 biochar reactor with supplemental funding by Gates Foundation, taking into account the challenges we encountered with the first version.

This reactor will include a robust pre-drying solution that is versatile enough to accommodate the entire 80% to 20% moisture range. We are also continuing the development of the reactor itself, with a changing of the core technology to
better suit the North American markets. Aside from technology development, we are continuing to enhance our partnerships with North American cities, to promote the many benefits of using biochar locally. The City of Palo Alto just approved by popular vote use of the land for a solution such as the dry anaerobic digester. This popular support and victory for the green initiative presents a unique opportunity to build upon the European success of dry
anaerobic digestion, bring the technology to North America, where Palo Alto may be the very first North American municipality to adopt dry anaerobic digestion, and support the bio-hybrid pyrolyzer being developed by The Climate Foundation, which can take the products of the dry anaerobic digester and pyrolyze the residues into sanitary biochar that can be applied directly to food crops safely, while potentially also producing electricity for the community.
While this initial project is in the developed community of Palo Alto, California, the benefits for developing communities across North America are potentially enormous. This approach is pioneering a new way to process biosolids that does not require any water input, uses no external electricity, and can be transported by container/ truck to any community in North America that is truck accessible. As a result, the implications for this technology can be applied across North America.

For more information about this project, please contact:

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