1. Aerobic Digesters: The Circular Economy and Beneficial Reuse

Key Takeaways

• One third of the food produced globally for human consumption is wasted.
• Americans throw out the equivalent of $165 billion of food as waste and 25 percent of all freshwater each year
• We must move the solid waste industry to the concept of a circular economy (keep resources in use for as long as possible, extracting the maximum value from them while in use, then recovering and regenerating products and materials at the end of each service life) vs linear (make, use, dispose).
• The food digesters of old – grinders with water as a dilution – are not aerobic digesters. Through the use of specific blends of microorganisms and improved machine design with a focus on the scientific processes of digestion (oxygen, temperature, and maintaining neutral pH), aerobic food digesters have become a viable onsite solution.
• Some available options for landfill diversion are aerobic digesters with big data cloud capabilities, composting, and anaerobic digestion.
• BioHiTech offers an onsite aerobic digester technology in addition to data analytics to arm organizations with the tools to minimize the creation of organic food waste.
• BioHiTech's Cloud platform will assist in making purchasing decisions which could in turn reduce waste and provide for significant cost savings
• 70% of the food waste digested by a BioHiTech Digester is returned to the overall water cycle as water.
• The Digester's environmental impacts and benefits are comparable to or superior to alternative methods of organic waste disposal.
• BioHiTech doesn't ask customers to trust it; it simply asks customers to try it; because BioHiTech is convinced (and its digesters prove this out via data) that it can change business outcomes.

ment of a circularGlobally, an estimated one third of the food produced is wasted[1]. In the United States, 40
percent of the food goes uneaten, more than 20 pounds of food per person per month. Not only are Americans throwing out the equivalent of $165 billion each year, but also 25 percent of all freshwater. During the process, large quantities of chemicals, energy, and land are wasted.

Moreover, almost all of the uneaten food ends up rotting in landfills where organic matter accounts for 16 percent of U.S. methane emissions[2].

[1] Food and Agriculture Organization of the United Nations. http://www.fao.org/savefood/resources/keyfindings/en/. Obtained October 2016.

[2] Gunders, Dana. Wasted: How America is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill. Natural Resources Defense Council Issue Paper. August 2012 IP:12-06-B

There is no one solution for the management of food waste. There are several options available to assist in moving away from landfilling. Among the many, below are a few:

- Aerobic Digesters with Big Data capabilities
- Composting
- Anaerobic Digestion (AD)

While all of these technologies are positive with respect to landfill diversion, only one of them can have an impact on food waste reduction, be beneficially reused as a biosolid in composting, and be utilized as a feedstock for AD. The effluent generated from the aerobic food digester can be discharged directly to the sanitary sewer and this can further reduce Greenhouse Gas emissions by removing the need to transport the solid waste via truck. Benefits derived from using BioHiTech's Digester® goes beyond the ordinary on-site aerobic solutions for the management of waste. BioHiTech's Digesters are a smart Internet-enabled machine that sends real-time data to the BioHiTech Cloud®. Using the BioHiTech Cloud, end users can quantify organics diversion, measure environmental impact, manage digester operations, and gain insights into waste created in the supply chain by analyzing and measuring various aspects of the digester's waste stream.

For many years the solid waste industry has looked at solid waste management in terms of linear economics – "make, use, dispose". However, more recently, the concept of a circular economy for solid waste has grown and will continue to grow as we develop more technologies to reuse our waste for environmentally beneficial purposes. A circular economy turns away from a "make, use, dispose" approach toward technologies that keeps resources in use for as long as possible, extracting the maximum value from them while in use, then recovering and regenerating products and materials at the end of each service life. According to the New York City Mayor's Office of Sustainability, "achieving a circular economy requires a focus on innovations in product design and technology, source reduction, reuse, recycling and organics diversion, and advanced efforts to extract materials and value from any remaining waste – returning these resources to market as inputs to new products and services.[3]" The Digester fulfills the goals of the circular economy in ways that composting and AD can't do as standalone technologies. If the requirements set forth by the City of New York are an example of a model towards the achieve economy, we can evaluate the BioHiTech Digester against this model.

[3]New York City Mayor's Office of Sustainability. New York City's Roadmap to 80 X 50. 2016.

Innovations in Product Design and Technology

The aerobic digesters of old – grinders with water used as a dilution aide – are not well received in the marketplace today. Today's improved machine design uses specific blends of microorganisms focusing on the scientific processes of digestion (oxygen, temperature, and maintaining neutral pH), rather than the mere grinding, making them a more municipally acceptable on-site solution. The effluent from digesters contains significantly less organic content than that generated from the grinding similar to garbage disposals, a reduction of over 99%.

Source Reduction

Measurement is the foundation of effective waste reduction. While BioHiTech's Digesters provide a cost-effective on-site solution for disposal of organic waste, the BioHiTech Cloud provides insights into the waste stream, allowing organizations to more effectively manage the supply chain before food waste is generated. In a recent article in the online publishing platform Medium, Dallas Salazar wrote, "… what's great about BioHiTech is that BioHiTech has built its entire business model on data — it doesn't have any "other stuff". It doesn't ask customers to trust it; it simply asks customers to try it; because BioHiTech is convinced (and its digesters prove this out via data) that it can change business outcomes.[4]"

Utilizing an on-board weighing system, BioHiTech's Digesters collect, accumulate, and provide empirical data about the organic waste stream that allows organizations to reshape their purchasing decisions, positively impact employee behavior, and realize further savings due to improve operational efficiencies. When looking at the use of composting and AD as solutions to our current food waste disposal problem, they are linear in nature, encouraging the production of waste to sustain a process instead of circular in nature whereby reusing, recycling and preventing the generation of waste are the desired goals. The BioHiTech solution arms organizations with the tool to minimize the creation of food waste and then recycle what is left.

Reuse/Recycling/Organics Diversion

In states and cities like California, Massachusetts, and New York City, legislation has been passed that requires the diversion of food waste from landfills. Composting and AD while acceptable alternative methods for disposal require costly infrastructure, extensive transportation efforts, and ultimately a market for the by-product. Composting can be conducted using a variety of methods. Despite many compelling drivers, there are a number of obstacles to widespread implementation of composting: low potential for high monetary return, new trash

[4] Salazar, Dallas. BioHiTech: A Startup using Slack to Power a Global Chat Bot Platform. Medium. October 4, 2016.

incinerators coming online, availability of persistent herbicides, and the lack of policies to support development of adequate infrastructure will limit the large scale adoption of composting[5] , the transportation of the food waste to composting facilities can be costly, adding to environmental degradation, which the various state regulations are trying to curb. In addition, facilities accepting source separated food waste are further burdened with the additional sorting and removal of non-organics from what is received.

Standalone AD technology is experiencing limited growth in the U.S. primarily because of its financial infeasibility unlike the financial assistance or favorable energy status being offered in other parts of the world[6]. Anaerobic digesters directly associated and located within wastewater treatment plants (WWTP) are the more feasible solution in the use of diverted food waste. The additional biosolids generated from processing food waste at WWTP provide the feedstock needed for the AD process.

The Digester's effluent is beneficial to the wastewater-to-AD model of energy production. 70% of the food waste digested by BioHiTech's Digester is in the form of wastewater and eventually returned to the overall water cycle[7]. The remaining 30% is organic matter which is digested in the Digester with the aid of microorganisms similar to the ones used at the WWTP before being discharged to the sanitary sewer lines. The microorganisms involved are mainly in the bacilli and protozoa families, with added fungi and rotifers to assist with the more woody-like organics[8]. The discharge of the digested food waste mixed in with these microorganisms into the sanitary sewer is beneficial to the customer as they can clean the sewer lines between the digester and the co-mingled discharge point and beneficial to both the local community and the WWTP as the microorganisms continue to digest additional food waste found throughout the sanitary sewer system.

The effluent from the Digester is a valuable commodity to the AD facility because it contains energy value while also requiring less energy to process. Because the Digester performs the hydrolysis stage of anaerobic digestion at the point of origin it allows much of the effluent to pass through their primary, secondary and in some cases tertiary steps in the wastewater treatment process. The benefit of using the existing infrastructure of the sanitary sewer to

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[5] Platt, Brenda and Nora Goldstein. State of Composting in the U.S. BioCycle July 2014, Vol. 55, No. 6, p. 19

[6] Klinker, Blake Anthony. Anaerobic Digestion as a Renewable Energy Source and Waste Management Technology: What Must Be Done for This Technology to Realize Success in the United States? UMass Law Review, Rev 9, p 68.

[7] Brown, Amy Christine. (2011) Understanding Food: Principles and Preparation. 5th Edition. University of Hawaii, Manao.

[8] VonSperling, Marcos. (2007). Basic Principles of Wastewater Treatment. 12 Caxton Street, London, UK. IWA Publishing, Alliance House.

transport digested food waste is that it removes the environmental impacts of truck hauling over long distances.

In some instances, where BioHiTech has customers who are closely located (within 25 miles) to an AD facility, tanking the effluent and hauling it to the co-located WWTP/AD facility is still a viable solution from a cost and environmental perspective. Because the aerobic digestion process begins with the breakdown of solid organics to liquid slurry, the effluent can be pumped and transported, arriving at the AD facility in a “predigested” condition allowing for efficient feedstock transfer. This process is currently being tested at a high-volume supermarket in New Jersey and transported to an anaerobic digestion facility operated by the Village of Ridgewood, at its WWTP with successful results. However, if “predigested” or solid food waste has to be transported to an AD facility distances beyond 45-50 miles, the environmental benefits are depleted and costs may be prohibitive.

There are additional benefits of having the Digester effluent become biosolids. WWTP’s recycling the biosolids created from the effluent of the food waste processed have the following additional benefit through land application serving several purposes. It improves soil properties, such as texture and water holding capacity, which make conditions more favorable for root growth and increases the drought tolerance of vegetation. Application of biosolids supplies nutrients essential for plant growth, including nitrogen and phosphorous, as well as some essential micronutrients such as nickel, zinc, and copper. Biosolids can also serve as an alternative or substitute for expensive chemical fertilizers. The nutrients in the biosolids offer several advantages over those in inorganic fertilizers because they are organic and are released slowly to growing plants[9].

Return to the Market as a New Product or Service

Determining the environmental impacts of BioHiTech’s Digesters and alternative methods of disposal is a large factor in determining the value of it as a product in the marketplace. For these purposes we will consider an evaluation of impacts from energy consumption, water use, ecosystem/soil, Green House Gas emissions, waste production, and air quality. In previous portions of this paper, we have discussed the impacts to waste water, so no further discussion will be provided.

[9] Environmental Protection Agency. (2000). Biosolids Technology Fact Sheet: Land Application of Biosolids. (EPA Publication No. 832-F-00-064). Rockville, MD: U.S. Environmental Protection Agency.

	BioHiTech Digesters	Collection for Composting	Collection for Anaerobic Digestion[10]	Collection for landfilling
Energy Use	Energy consumption is less than the equivalent energy use for vehicle based collection and transportation, and energy generated from AD (if applicable) is likely to more than compensate for the energy that is used.	Energy is consumed in collection and transportation processes with no return to energy production.	If biosolids are taken from receiving WWTPs then this is an optimal use of the biosolids. Trucking feedstock to AD facilities will consume energy in the collection and transportation process. This is definitely offset by what is generated through AD energy production; however, the environmental benefits are diminished.	Energy is consumed in collection and transportation process. Some landfills may have gas collection systems that generate energy.
Water Use	The Digesters do consume water, but in relatively low volumes (maximum 300 gallons/day) when compared to industrial uses. However, the	Consumes moderate amounts of water. Leachate must be collected and will most likely be contaminated.[11]	Consumes moderate amounts of water. Digestate can be reused for beneficial purposes.	Minimal water is consumed; however, water generated can be highly contaminated and not fit for re-

	BioHiTech Digesters	Collection for Composting	Collection for Anaerobic Digestion[10]	Collection for landfilling
	Digester returns water to the water cycle (food waste is 70% water) adding upwards of 150 gallons per 24-hour period.			use.
Waste Production	Digesters avoid the production of solid waste as they convert food waste to an effluent that has beneficial uses.	Solid waste is generated through the contaminated materials that must be discarded during the collection process for composting.	Generates nominal amounts of solid waste. Digestate has beneficial reuses.	Involves total solid waste.
Air Quality	There are no notable odors or air quality issues generated from the Digester	Potential for odor issues in the storage and transporting.	Potential for odor issues in the storage and transporting.	Significant odor issues have been attributed to landfills.
Greenhouse Gas Emissions	Likely to have a net positive CO2e impact compared to landfill disposal. Digestion in the Digester results in CO2 and water (there is no methane gas associated)	Likely to have a net positive CO2e impact compared to landfill disposal.	Likely to have a net positive CO2e impact compared to landfill disposal.	High levels of CO2e. Even with gas capture at landfills, there will be negative GHG impacts.
Ecosystem/Soil Impacts	If biosolids are beneficially used, the organic matter and nutrients are cycled back into the sols. If biosolids are used for land reclamation benefits are reduced, but they are not negative impacts. If biosolids are landfilled, the organic	If biosolids are beneficially used, the organic matter and nutrients are cycled back into the sols. If biosolids are used for land reclamation benefits are reduced, but they are not negative impacts.	If biosolids are beneficially used, the organic matter and nutrients are cycled back into the sols. If biosolids are used for land reclamation benefits are reduced, but they are not negative	All waste placed in the landfill results in leachate which has no beneficial use.

10 Information concerning environmental impacts of Anaerobic Digestion were all collected from the following document:
California Department of Resources Recycling and Recovery (CalRecycle). 2011. Statewide Anaerobic Digester Facilities for the Treatment of Municipal Organic Solid Waste. Final Program Environmental Impact Report. SCH No. 2010042100.

11 https://www.epa.gov/sustainable-management-food/types-composting-and-understandingprocess

	BioHiTech Digesters	Collection for Composting	Collection for Anaerobic Digestion[10]	Collection for landfilling
	matter and nutrient value are lost and there are potential impacts to landfill leachate.	If biosolids are landfilled, the organic matter and nutrient value are lost and there are potential impacts to landfill leachate.	impacts. If biosolids are landfilled, the organic matter and nutrient value are lost and there are potential impacts to landfill leachate.	

Meeting the Goals of Solid Waste Management

There are four tiers that are discussed in the U.S. Environmental Protection Agency (USEPA) hierarchy of solid waste management: source reduction/reuse, recycling, energy recovery, and treatment/disposal. There are many methods for the disposal of organic waste. All of them have possibilities and merit in the market place. However, BioHiTech's Digester with BioHiTech Cloud technology meets all three of the tiers of the solid waste management hierarchy.

"Reduce/Reuse" - While the other alternatives provide larger scale solutions, they do not provide a mechanism to reduce the waste generation at the source. The Digester, combined with BioHiTech Cloud, provide a technology to quantify the waste generated, thereby assisting organizations in reducing their waste generation. The alternatives provide a beneficial reuse for the organic waste.

"Recycling" - The water used by the Digester is recycled back into the water system by the wastewater treatment systems. Being that food waste is 70% water, the digester can return that water back to the water cycle.

"Energy Recovery". The effluent from the Digester can work in conjunction with the alternatives to generate energy from biosolids and as a potential feedstock directly to the anaerobic digester facility.

Finally, and the least preferred – *"Treatment and Disposal"*. With the use of the Digester, there is no need for landfill disposal, eliminating the negative environmental impacts from transportation of waste.

In summary, there is strong evidence to support that the BioHiTech's Digesters fit into the Circular Economy Model, the environmental impacts are comparable and in many instances are more beneficial than most waste management alternatives, and the use of the Digesters and BioHiTech Cloud technology meets all of the USEPAs hierarchy for the best method for the management of waste which the alternatives evaluated do not.

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