An Objective Consideration of a BTS Biogas Anaerobic Digester for Potential Development on the PES Refinery's Land

by Richard Ling

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August 21, 2019

To the members of the PES refinery advisory committee,

My name is Richard Ling, and I'm a senior at the University of Pennsylvania studying Systems Engineering and Environmental Science. I'm writing to provide an objective overview of an anaerobic digester (AD) technology that is sourced by BTS Biogas, a European leader in anaerobic digester technology, and developed by their sister company, Bioenergy Development Company. The purpose of this piece is to discuss the technology at hand and its environmental implications; I will therefore not discuss any economic or corporate matters. The information contained in this piece is graciously informed by Vinnie Bevivino, Director of Organics at Bioenergy DevCo, and Shawn Kreloff, CEO at Bioenergy DevCo. Importantly, I am not affiliated with Bioenergy DevCo or BTS Biogas in any way; I am an independent student writer with a genuine interest in circular economy measures for the sake of our city.

An Overview of Anaerobic Digestion

Broadly speaking, AD is a series of biological processes in which microorganisms break down organic waste in the absence of oxygen. AD has four steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Biomass (e.g. food, manure, produce, fats, etc.) is usually comprised of long organic polymers, so hydrolysis breaks down these polymers into usable, simple chains —namely, amino acids, fatty acids, and simple sugars. Acidogenesis, the second stage, breaks down the residual components that bacterial hydrolysis cannot handle, which results in volatile fatty acids, ammonia, carbon dioxide, and hydrogen sulfide. Acetogenesis then digests these products to produce acetic acid, carbon dioxide, and hydrogen. Finally,

methanogenesis converts the residual products from the first and second stages to yield methane, carbon dioxide, and water. Unlike composting, AD is a closed-chamber system, so the products of methane and carbon dioxide do not leach into the atmosphere. Instead, methane and carbon dioxide are the primary constituents of biogas, which can be further processed to produce renewable natural gas, or transformed into heat or electricity in a combined heat and power plant (CHP).

Technology Overview

BTS Biogas, headquartered in Bruneck, Italy, is a European pioneer in the field of AD with over 20 years of experience and over 200 plants in operation globally. Bioenergy Development Company's acquisition of BTS Biogas allows it to increase BTS's presence in North America, with particular emphasis in municipalities. BTS's AD technology is a continuous-fed, wet process, which means that high-moisture feedstock is continually fed into the plant. The feedstocks are source-separated organics, which includes packaged food, food processing waste, fats, oils, animal manures, animal processing waste, and more. Such feedstocks are fed into the plant, processed, and converted into renewable natural gas (RNG) or organic soil amendment. The RNG can be utilized in cogeneration to produce electricity and heat, injected into the local natural gas pipeline, or compressed for CNG fleet vehicles. The organic soil amendment is dewatered, pelletized, nutrient-stripped, and/or dried for application in landscaping or horticultural projects. This plant is fed and material moves throughout the facility through automation and is monitored both locally and remotely, providing on-site staff with operational support. .

Environmental Implications

The environmental benefits and drawbacks of this technology can be considered in three domains: the feedstock, RNG production, and soil amendment production. The feedstock must be organic waste with a high moisture proportion, which is usually around 70-80% (moisture content can vary from 10-95%, though the process is generally optimal at around 82%). The BTS pre-treatment technology is designed to handle both packaged and loose solid waste, as well as liquid organic waste, and can be installed on plants ranging from 500kW to 1.5MW. This ability to handle packaged and loose organic wastes is an important distinction, and can lead to unique programs, such as a curbside collection program for municipal households. In such a program, households can request pickups for their packaged, contaminated, and/or loose wastes, which

can be hauled to BTS's AD facility on a consistent schedule. Other feedstock materials, such as fats, oils, greases, and food product packaging, can come from restaurants, food processing facilities, hotels, retail centers, and other commercial or public sectors. All in all, the feedstock must be a high-moisture, organic waste that can be provided to the facility on a consistent basis. In doing so, the BTS plant provides an alternative to landfills and incinerators, which, concomitantly, obviates methane emissions from landfills and particulate emissions from incinerators. That said, BTS's technology cannot handle waste with a high lignin content, such as wood, which is better suited for composting. The BTS technology is also not suited for mixed waste, as all of the waste must be source-separated to only include organics with a diminutive amount of contamination (typically less than 5% by weight).

The second domain of environmental impact comes from the production of RNG. The most obvious benefit of RNG is that it is natural gas produced from organic waste, rather than from fossil fuels. Pennsylvania is one of the most popular states for fracking, which presents numerous problems, including methane emissions, local waterway contamination, and exorbitant natural resource consumption. A BTS facility would allow Philadelphia to produce renewable natural gas that can be directly funneled into the local natural gas pipeline. This allows governments to continue investments in natural gas pipelines without promoting fracking. Furthermore, RNG produced from a BTS facility has a favorable Carbon Intensity (CI) Score, when compared to that of traditional natural gas. The CI score is under the jurisdiction and evaluation of the Low Carbon Fuel Standards, which was created by the California Air Resources Board. Therein, the CI score measures the lifecycle greenhouse gas emissions associated with the transportation, production, and use of a given fuel. Traditional natural gas production has a CI score of about 70g/kJ of energy created, while the BTS facility has a CI score of -40g/kJ of energy created. This means that the BTS facility generates roughly -40g of greenhouse gases per kJ of energy created. Thus, the BTS facility has a net benefit for the environment, in terms of greenhouse gas emissions. This CI score was calculated and verified by a third party, and not by BTS or Bioenergy DevCo internally.

The final domain of environmental impact derives from the production of soil amendment. Soil amendment is another term for fertilizer. Thus, its primary environmental impact is to reduce our dependence on synthetic fertilizers. Synthetic fertilizers are man-made combinations of chemicals and inorganic substances, and they typically combine nitrogen, phosphorus, potassium, calcium, magnesium, and other elements in different ratios. Synthetic fertilizers

provide nutrients to soils immediately, whereas organic fertilizers must decompose before nutrient absorption. That said, synthetic fertilizers degrade soil quality by killing microorganisms that convert dead human and plant matter into nutrient-rich matter. Nitrogen and phosphate-based fertilizers may also leach into groundwater or runoff into nearby waterways during storm events, which can induce eutrophication and algal blooms. Algal blooms consume vast amounts of dissolved oxygen in a given waterway, and the subsequent decomposition of the algae by microbes further depletes oxygen supply. In effect, dead zones may result, wherein no plant or animal life can survive. By producing organic fertilizer in a municipal-scale AD plant, the BTS facility would provide a localized, consistent source of organic fertilizer for farmers, home gardeners, and real estate owners across Philadelphia. Furthermore, the production of soil amendment is a form of carbon sequestration, since the carbon inside organic waste is being reintroduced into soils.

Parting Words

Notwithstanding the tragedy of the PES refinery's explosion, Philadelphia has an unprecedented opportunity to prudently bolster our methods of circular economy. In consideration of everything addressed above, I'd like to end by highlighting a few points. First, the BTS biogas facility has a couple key distinctions: it is continuous, automated, and accepting of packaged waste. Second, the facility possesses a negative CI score, which accounts for the entire lifecycle of RNG production. Lastly, the consequences of synthetic fertilizers are significant environmental problems, and a large-scale AD facility could facilitate economies-of-scale for greater organic fertilizer adoption. All that said, I'd like to thank you for reading, and I welcome any questions or followup discussion.

With truth and sincerity,

Richard Ling

University of Pennsylvania Class of 2020

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