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Poultry Litter Anaerobic Digestion

Case Study: Anaerobic Digestion and Nutrient Capture from Poultry Litter on the Maryland Eastern Shore

Project Goal:

The goal of the technology was to produce energy from poultry litter and create a fertilizer or soil amendment. Anaerobic digestion is a biological method to create renewable energy, in the form of methane (CH_4)–enriched biogas, from organic-rich substrates, such as manure, food waste, and wastewater sludge. The sustainability of the demonstration technology was quantified based on energy production and the creation of a fertilizer product that could be more easily transported in the Chesapeake Bay region, where there are application restrictions for poultry litter. The biogas generated by the anaerobic digester was used to heat the digester and/or generate electricity. The screw-press solid separator and filter press extracted solids and nutrients in different ratios from the digester effluent.

Anaerobic Digestion of Poultry Litter:

Anaerobic digestion of poultry litter is less common than digestion of other manure substrates, with only seven operational digestion systems utilizing poultry litter in the US. Poultry litter consists of animal waste, feed residue, feathers, and bedding material, including wood chips, cleaned out of poultry houses between flocks. The primary barriers for poultry litter digestion are its low moisture content, high ammonia-nitrogen levels, and complex nature of poultry litter. Successful anaerobic digestion of poultry litter often requires the addition of water to the relatively dry (~20% moisture content) manure prior to digestion processing. Following digestion treatment, the liquid, nutrient-rich slurry must be field applied as a fertilizer or the nutrients extracted to produce reusable or dischargeable water. While nutrient capture technologies have existed for over a decade, there has been relatively few projects that recover nutrients from poultry litter due to its relatively low-moisture content. Planet Found Energy Development (PFED), LLC received funding to demonstrate anaerobic digestion of poultry litter to produce on-farm energy and partition the nutrients into products using a nutrient capture system.

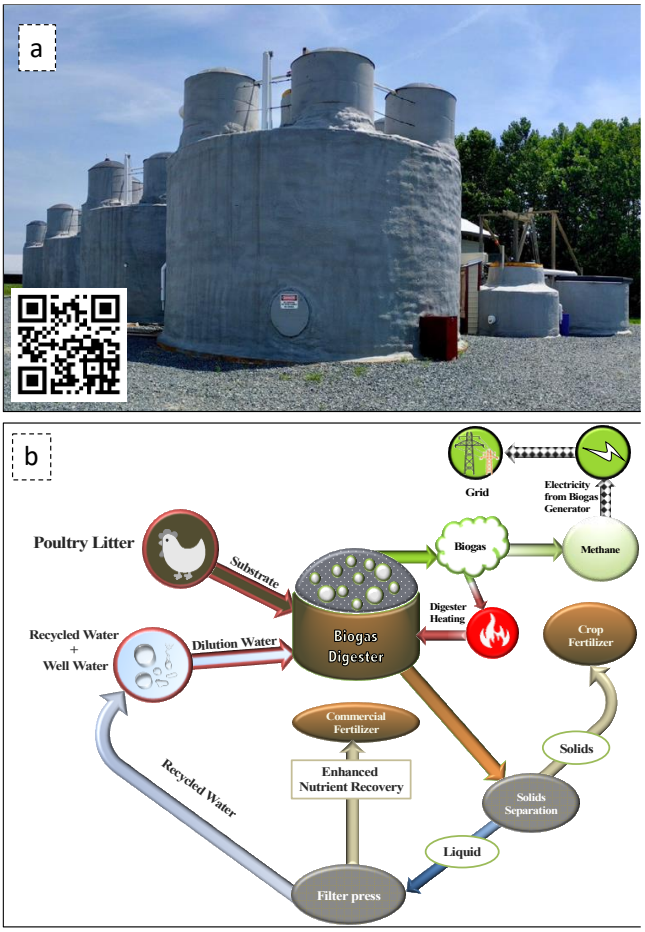

Figure 1. Planet Found Energy Development, LLC (PFED) poultry litter anaerobic digestion system, [a]: scan the QR code for 3D system overview; [b]: Process overview of the digestion and nutrient capture system at PFED.

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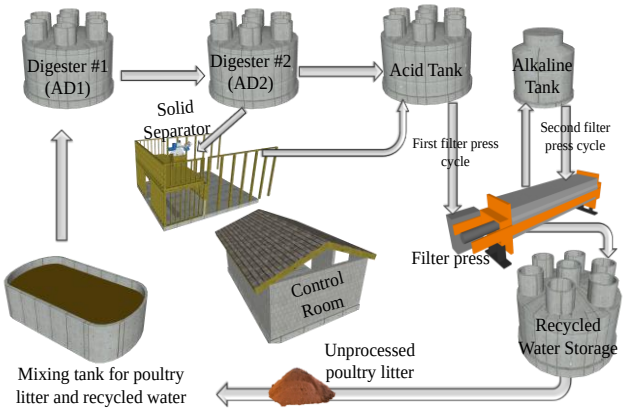

Figure 2. Individual components of the Planet Found Energy Development, LLC (PFED) demonstration systems.

System Components and Operational Process:

The PFED anaerobic digestion and nutrient capture system process is as follows:

1) A mixing tank was used to mix poultry litter with recycled water from the filter press.
2) The poultry litter and water mixture were added to the first digester (AD1).
3) The effluent of AD1 flowed directly to the second digester (AD2), with a combined target retention time of 30 days in the two digesters.
4) The AD2 effluent continued to a screw-press solid separator, with the separated solids used as a solid fertilizer.
5) The liquid portion from the solid separator continued to an acid tank and the filter press.
6) The solids from two runs of the filter press create two types of filter cake fertilizer.
7) The liquid portion from the filter press was used as recycle water in the mixing tank at the beginning of the digestion system.
8) The biogas produced from the two digesters passed through a scrubber system to remove hydrogen sulfide (H_2S) before use in the boiler for digester heating, in the engine generator for electricity generation, or flared.

Monitoring Results:

The PFED system processed 122 ton of poultry litter per year, with the highest energy production (from October 2019-December 2019) averaging 1490 m^3 biogas/month (949 m^3 CH_4/month; 222 L CH_4/kg VS), and 2019 yearly average of 677 m^3 biogas/month (430 m^3 CH_4/month). While biogas can be used in a broiler or generator, there were challenges with biogas usage due to high H_2S concentration. In 2019, only 6.7% of the biogas used for electricity generation, 22.1% was used in the boiler for digester heating, and 71.1% of the biogas was flared. Propane (4303 gallons/yr; 16.2 m^3/yr) was, therefore, needed to heat digesters. The generator processed 504 m^3 of biogas, producing 460 kW of electricity, with a 15% conversion efficiency. The electricity consumption (51,239 kWh/yr) to run pumps, mixing, the solid separator, and filter press was more than the electricity generated.

The solids separator and filter press were operated intermittently during the monitoring period. In 2019, the cumulative solids produced from 8 runs of the nutrient capture system was 6.2 tons of separated solids, 15.6 tons from the first cycle of the filter press, and 1.1 tons from the second cycle of the filter press.

In the digester, the total nitrogen (N) and phosphorus (P) concentrations increased 229% from October 2017 (849 mg/L) to December 2019 (2793 mg/L), likely due to the use of recycled water. The average nitrogen and phosphorus in the separated solids (after digestion) was 1.9 and 0.9%, respectively (based on dry weight), with the phosphorus increasing in the filter press cake from the first run (1.4% N and 0.9% P) to the second run of the filter press (1.6% N, and 1.8% P) through the addition of the alkaline material between runs.

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Life Cycle Assessment (LCA)

The life cycle assessment (LCA) using the PFED biogas production rate had higher Climate Change impacts (1,176% more) than the Baseline scenario of transporting unprocessed poultry litter due to the propane use for digester heating. If double or triple the litter was processed and the biogas was used in the combined heat and power generator, the impact would be 529% and 722% less, respectively, than the Baseline. Eutrophication potential was lowest when triple the amount of litter was processed and the biogas was used in a combined heat and power generator (510% less than the Baseline). Eliminating propane use, increasing the poultry litter loading rate, and using the biogas for digester heating (broiler use) or in a combined heat and power generator would be more sustainable than transporting unprocessed manure 50 miles roundtrip (Baseline Scenario).

Lessons Learned

- The hydrogen sulfide (H_2S) concentration in the biogas (>10,000 ppm) prevented the use of the biogas in many applications, i.e. in the generator and boiler. It is imperative that the H_2S scrubber is fully functionally to utilize the produced biogas.
- Using a separate generator and boiler was acceptable for the pilot-scale design monitored here, but the life cycle assessment showed that a combined heat and power system is recommended for better conversion efficiency of the produced biogas.
- Poultry litter settling rate appeared to be high inside the digester, and therefore, proper mixing inside the digester should be used to increase the digestion efficiency.
- The microbes in the digester adjusted to the rising ammonia rates inside the digester over the two-year period, with the highest CH_4 production rates seen at the end of the study when the ammonia levels were high, but it was shown that keeping the pH below 8 and the temperature above 30°C had the highest biogas production rates.

Conclusions

A demonstration anaerobic digestion and nutrient capture system was evaluated for its energy and fertilizer production. Over 30 months, University of Maryland personnel collected monthly samples from 13 sampling points to verify the system performance. The results showed that using anaerobic digestion to convert the poultry litter to biogas and fertilizer is possible in the US. The digestion efficiency rose to during the last three months of the monitoring period (October to December 2019), with three types of solids produced to be used as fertilizer. The life cycle assessment results showed that double or triple the poultry litter loading rate would have led to more biogas production and net environmental gains compared to transporting unprocessed poultry litter 50 miles, roundtrip, off the Eastern Shore.

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