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# Dairy Environmental Systems Program

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PRO-DAIRY

## Anaerobic Digestion at Spruce Haven Farm, LLC: Case Study

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June 2016

**Contents:**



**Spruce Haven Farm anaerobic digester.**

### Anaerobic digestion (AD) overview

| | |
|---|---|
| Digester type | Modified plug-flow with recirculation & mixing “RAD2 (Recirculated Anaerobic Ditch Digester)” |
| Digester designer | Larsen Engineers |
| Date commissioned | 2014 |
| Influent | Manure |
| Stall bedding material | Sand |
| Number of cows | Total (including heifers): 3,360 Milking: 1,500 |
| Rumensin® usage | Yes, for heifers and some milking cows. Not for dry cows. |
| Dimensions (L × W) | 340 × 100 ft. |
| Cover material | HDPE flexible membrane |
| Design temperature | 100°F |
| Estimated daily loading rate | ~75,000 gal. per day |
| Treatment volume | 1,500,000 gal |
| Estimated hydraulic retention time | ~ 20 days |
| Sand separation system | Yes, multi-stage McLanahan Corporation system |
| Biogas upgrading | Yes, hydrogen sulfide biotrickling filter |
| Biogas utilization | Guascor 502 kW combined heat and power |
| Carbon credits sold/accumulated | Environmental Credit Corp. |
| Monitoring results available | No |

## Farm overview

- Spruce Haven Farm, LLC, managed by Doug Young, is located in Cayuga County, New York.
- The farm herd has 3,360 Holsteins and milks ~1,500 cows.
- Digester construction began in Spring 2014, with the system operating by October 2014.

***Why the digester?***
Spruce Haven Farm decided to build their AD system in part since they were able to receive funds from NYSERDA. The farm's goals of the AD project were to improve waste, odor, and nutrient management while reducing greenhouse gas emissions and offsetting energy usage. The farm was keen on finding an affordable system and worked with Larsen Engineers to develop the modified plug-flow system with recirculation and mixing; a less expensive option that an above ground continuously mixed system.

## Digester system

***System and process description***
The AD system has several subsystems (see Figure 1.) including:
- Manure collection and transport
- Sand-manure separation system and reclaimed sand storage
- Anaerobic digestion, plug-flow (recirculated & mixed)
- Digester effluent solid-liquid separation
- Hydrogen sulfide biotrickling filter (biogas scrubber)
- Effluent long-term storage

***Liquids and solids process description***
The manure treatment system (see Figure 1.) currently processes sand-laden manure from 6 of the 7 barns which contain sand bedded mature cows (~1,500). Sand-laden dairy manure from these barns is mechanically scraped into a manure pit which gravity feeds a piston pump used to transfer the material to a centralized "raw" manure storage pit. The gravity collection system is not well-suited for the sand-laden manure. Milking center wastewater is diverted into a long-term earthen storage. Manure from the raw pit is pumped to the sand-manure separation (SMS) system. Overflows are directed to a short-term earthen storage.

The SMS system (equipment provided by McLanahan Corporation), is a multi-staged process. A sand manure separator reclaims sand from the manure for reuse as bedding. It is equipped with an optional hydrocyclone which is used to reclaim residual sand particles not captured in the primary separator. Manure solids and liquids (both the liquid fractions of manure and liquid used in the SMS process) are then collected in a sump. Most of these liquids, the liquids separated from AD effluent via a rotary drum, and a designated well provide dilution water for the SMS system. Remaining manure solids and liquids are piped by a gravity "sand lane" to further capture any fine sand particles.

The use of digestate liquids as SMS dilution water helps 'preheat' the sand-free manure before it is pumped through the heat exchanger into the mixing tank then AD. With the recycling and use of the heat exchanger, temperature is maintained around 108-110°F spring to fall and 100-102°F in the winter. The influent is pumped into the AD system at a loading rate of 70,000 to 115,000 gal per day, depending on farm production. The loading to recirculation ratio is around 10:1.

The AD system is a hairpin design, below-grade vessel lined with 60 mil ABS. The inflatable, flexible cover is made of 2 sheets of 60 mil ABS plastic with 2 in. of insulation between them. Four submerged impeller mixers are used to agitate the in-vessel materials and assist with material flow. Recirculation of effluent maintains temperature and flow even in the absence of loading and with the agitators, increases process efficiency. Environmental Fabrics Inc. products were used for the liner, cover, gas collection system and flare. Calculated hydraulic retention time is ~20 day. The biogas collection system (digester headspace and associated collection and transport piping) operates under pressure at 0.7-0.8 in. WC.

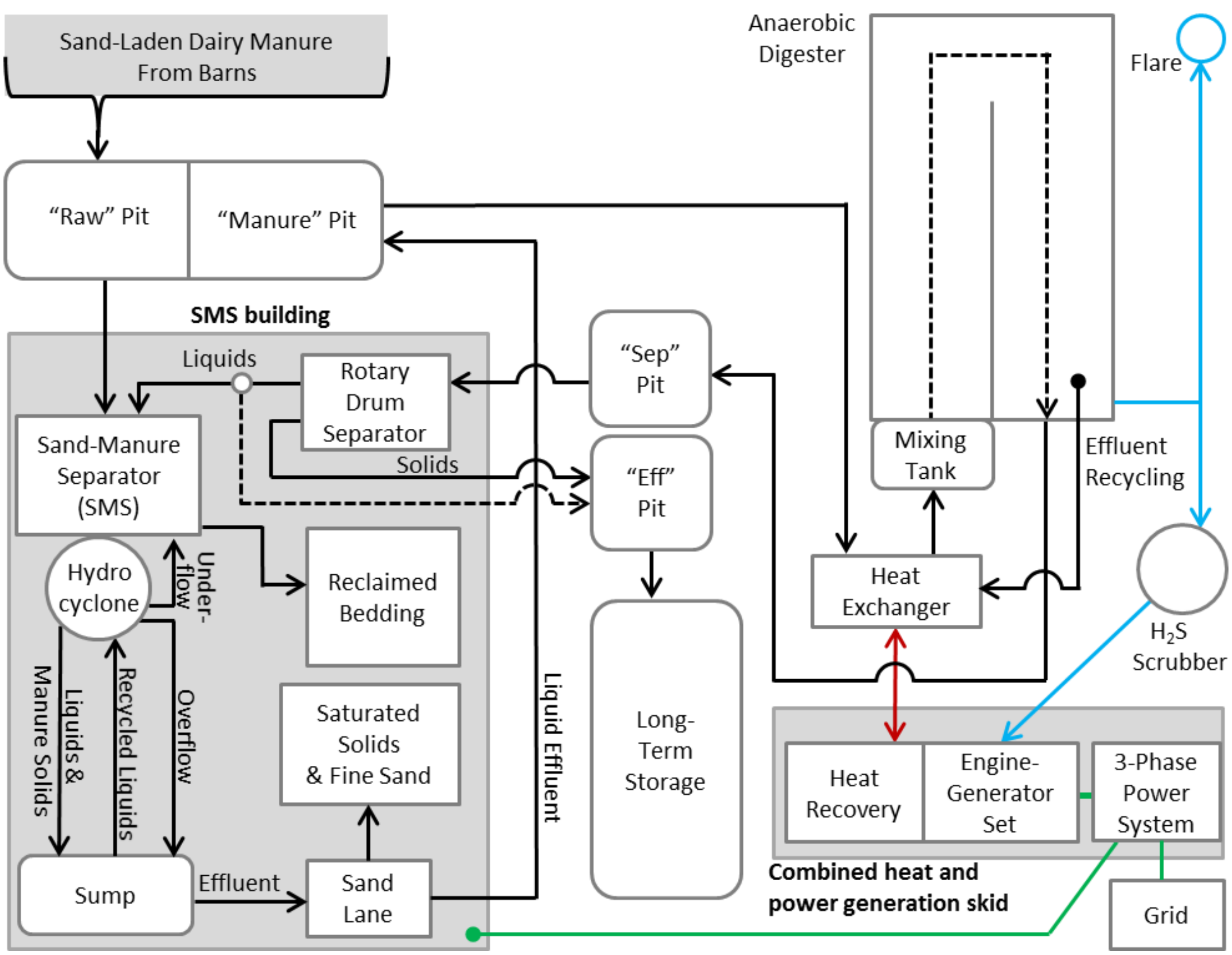


**Figure 1. Schematic of Spruce Haven Farm waste management, anaerobic digester, combined heat and power generation and usage systems. Flows for organics/wastes are in black, biogas is in blue, electricity is in green, and recovered heat is in red.**

## Biogas Utilization

### *Combined heat and power generation*

The combined heat and power generation enclosed skid is shown in Figure 2. A Larsen Engineering designed scrubber removes hydrogen sulfide from the collected biogas. Following desulfurization, the biogas is cooled to condense some of the moisture and densify the gas before its use for fueling the Guascor 502 kW engine-generator set. In 2015 the system generated 2,749 MWh, equivalent to a capacity factor of 0.62. Currently, biogas-fueled engine-generation set energy is used only to power the digester and SMS systems. The farm is net-metered with NYSEG. In the winter all recovered heat is used to warm the AD influent, in the summer only a portion of the heat is needed and excess heat is released to the ambient air using rooftop heat exchangers.

**Figure 2. Combined heat and power generation skid (foreground) with adjacent $H_2S$ scrubber (right background).**

## Economics

### *Costs*

The total capital cost of the AD system was approximately $1,804,000 broken down as follows:

- Construction/installation of the AD system (liner, insulated cover, impeller mixers, gas collection and flare system): $508,000.
- Biogas conditioning and utilization systems (hydrogen sulfide scrubber, blower, chillers, gen-set, heat recovery system): $766,000.
- Engineering consultation: $250,000.
- Wiring and electrical connection: $98,500.
- Utility interconnection: $60,000.
- Miscellaneous costs (including influent and effluent tanks, pumps and plumbing): $121,500.

The annual expense of running and maintaining the digester and the SMS systems was approximated at $209,500. This includes SMS system maintenance, AD system maintenance, biogas conditioning system nutrients and maintenance, and labor costs. While the need for major repairs has not yet occurred, the anticipated cost of an engine rebuild, part of long-term biogas-fueled engine-generator set maintenance, is $80,000.

### *Incentives*

Under the NYSERDA - PON 2684 program, the farm received $1,175,500 in capacity incentives for the costs of construction. Performance incentives totaling $80,000 per year for 10 years is also provided by NYSERDA based on the contracted generation capacity of 375 kW.

Carbon credits received by the farm are valued at $80,000 per year.

***Income & Savings***

The annual income from the system in the form of electricity sales and saving, and bedding and nutrient savings is $385,250. A breakout of these total savings is:

- The value of surplus electricity generated is figured at $245,250 based on the rate of $0.07 per kWh (based on utility payment & NYSERDA performance payment ($0.025 per kWh)
- Reclaiming sand bedding via the SMS system saves approximately $120,000 in procurement sand cost annually.
- Nutrient distribution savings which have resulted from the enhanced manure/bedding processing are estimated at $20,000.

The difference in operating cost and income results in net annual benefit before taxes and depreciation of roughly $176,000.

**Lessons Learned**

The farm reported the following lessons learned to date from implementing the digester system and managing it.

By modifying a typical plug-flow, below-grade digester with recirculation and mixing, increased process efficiency at reduced capital cost. Applying this design with sand bedding required special attention to sand separation and resolving sand related operational issues.

While the use of sand bedding has significantly reduced the incidents of mastitis on the farm, there have been several initial operational challenges with the SMS system, with these challenges sometimes impacting digester performance due to their tight integration. These issues include:

1) Formation of struvite has led to several mechanical problems with the system. The farm now adds slow release hydrogen peroxide as an oxidizing agent to prevent the formation of struvite. A 55-gallon drum cost ~$1,400 and last ~ 4 months.
2) Pipe clogging has resulted in numerous shutdown times for cleaning. An in-line shredder has huge improved system operation and minimized clogging.
3) Pipe freezing has also resulted in numerous shutdown times and created significant maintenance problems.
4) Many of the sensors used to control the system have also failed during cold periods in winter.
5) The system requires significant water supply. Despite using available liquid farm effluents (digestate liquids and leachate from the bunk) a well was drilled specifically to run the SMS system.
6) The hydrocylcone used to improve sand recovery as designed creates a significant mess in the SMS area.
7) Originally a pressure meter was used to monitor manure viscosity. A camera pointed at the meter and display in the control skid were used to control liquid additions to optimize viscosity for the SMS system. This cumbersome control system resulted in inexact management. The pressure meter has been replaced by a potentiometer that directly regulates the rate of piston pumps to control

manure and liquids mixing and viscosity. This upgrade and automation has resulted in more consistent viscosity and sand separation.

8) The SMS system is housed in a pre-engineered steel building where ammonia and hydrogen sulfide gases emitted by the manure processing concentrate. These gas levels have caused significant corrosion to the building and some equipment, specifically the rotary drum separator which has had to be rebuilt multiple times. These levels also irritate and could pose some health risk to employees working in the building. Improving building design is being considered to reduce building and system damage and improve the safety of the work environment.
9) A drying off pad below the shaker to collect sand and keep it above draining water has reduced drying time of the sand.

There have also been some issues with the digester cover design. The most significant issue is when the digester pressure gets high the mixers, which are attached to the cover, lift up, and when the pressure subsides, the framing of the mixers have been bent as the mixers come back down into the digester. The farm is considering installing a bladder system to help maintain more stable digester pressure and is optimizing the recirculation and loading to maintain steadier biogas production. Larsen Engineers are developing a next generation system that will mix by bubbling biogas and not with mechanical mixers. The cover has had little maintenance issues, but pumping water off of the digester cover following rain events and snow melt is required.

To avoid flaring of methane, Spruce Haven Farm will throttle up their engine to burn down biogas levels prior to scheduled shutdowns for oil changes and servicing.

Electricity rates are considered too low by the farm which currently receives the utility avoided cost rate (currently ~$0.03/kWh) but buys electricity at $0.11/kWh. As a result the farm must generate ~40% more electricity than it uses to break even on electricity costs. Spruce Haven and other farms net-metering are negotiating a rate change.

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