
# Duke Carbon Offsets Initiative

## Loyd Ray Farms: Best Practices Guide

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DUKE UNIVERSITY

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## History

In 2007, Duke University signed the American College and University Presidents' Climate Commitment (ACUPCC) and set a target of achieving climate neutrality by 2024. After being aggressive with reducing emissions on campus, Duke will have to offset an estimated 185,000 metric tons per year of carbon dioxide in 2024. The Duke Carbon Offsets Initiative was created as a branch of Sustainable Duke to help Duke University reach climate neutrality. Since its beginning in 2009, it has developed a variety of innovative carbon offset programs in swine waste-to-energy, energy efficiency, solar, and urban forestry.

## Vision

To make Duke University a model climate-neutral institution and to lead peer institutions in their efforts to become climate neutral.

## Mission

- To meet Duke University's climate neutrality goal by 2024 by **developing and implementing the University's strategy** for identifying, creating, and purchasing carbon offsets.
- To implement the strategy in a way that **provides educational opportunities** for students, faculty, and staff.
- To **prioritize local, state, and regional offsets that provide significant environmental, economic, and societal co-benefits** that are beyond the benefits of greenhouse gas reduction.
- To **facilitate and catalyze high-integrity, unique offset projects** by serving as a resource for other institutions.

# Loyd Ray Farms: Best Practices Guide

## Introduction

This document aims to entail the "lessons learned" at Loyd Ray Farms (LRF), an innovative swine waste-to-energy system at an 8,640 feeder-to-finish farm in western North Carolina. The project began in 2011 as a partnership between Duke University, Duke Energy, and Google, Inc., to produce carbon offsets and Renewable Energy Credits (RECs) and meet North Carolina's Innovative Swine Waste Management Permit using an anaerobic digestion and aeration system. The project is led by Duke University's Carbon Offsets Initiative (DCOI) and managed by Cavanaugh and Associates, P.A.

The system has two parts:

1. Methane capture and conversion to biogas to reduce the global environmental impact, and
2. anaerobic and aerobic treatment of the waste to reduce the localized environmental impact.

The first part of the system operates by capturing methane from the swine waste in an anaerobic digester (AD) and sending it through a gas conditioning skid to reduce the moisture content. This biogas is then used primarily to power a 65-kW microturbine at LRF, but in the case of high biogas production can also be flared onsite. This system generates qualifying RECs for Duke Energy under North Carolina's Renewable Energy Portfolio Standards, and carbon offsets for Duke University and Google, Inc. through the mitigated methane emissions.

The second part of the system takes the liquid waste from the anaerobic digester and aerates it. This process promotes bacterial treatment for the nitrification of ammonium to nitrite, and further destruction of volatile organic compounds (VOCs) and fatty acids, which contribute to the odor and other localized environmental impacts often associated with large-scale animal agriculture. This liquid is then transferred to a lagoon, where it is stored until irrigation on agricultural fields.

The project continues to be a learning experience. This document describes some of the challenges and solutions from LRF, and is intended to be a guidance document for project managers that may be interested in implementing similar technologies. In addition to the case-bycase "lessons learned" section featured below, resources from Duke University, government entities (such as the USDA), and other universities can be found at the conclusion of this document.

# Faulty Gas Conditioning Skid

**The Problem**: Multiple gas conditioning system failures.

**The Solution**: Replacement with an industrial scale skid.

Because of the concentration of hydrogen sulfide and the high moisture associated with biogas production, the initial gas conditioning skid installed at LRF failed. The original skid could not handle the corrosive nature of the biogas, leading to multiple system failures. Because these system failures halted all biogas utilization, complete replacement was required and occurred over 6 months between 2012 and 2013. The original skid was replaced with an industrial-scale gas skid which came at a higher cost, but offered much greater reliability, as it was able to withstand the corrosivity of the biogas.

## Key Takeaways:

- Consider the system size and expected biogas production
- Determine the standard (commercial, industrial, etc.) of the gas conditioning skid necessary to meet the moisture demands of the system size.
- Ensure the skid can handle high levels of $H_2S$

**Before:** The original smaller, unsuitable gas conditioning skid.

**After:** The new, industrial-scale gas conditioning skid at LRF

# Liner Failure

**The Problem:** The anaerobic digester liner was improperly installed with leaks located around the concrete sump for the mixing pumps, requiring replacement.

**The Solution:** The natural clay soils of LRF were augmented with bentonite to meet permeability standards.

A liner failure was discovered in April 2013. To determine the best replacement liner to meet the North Carolina standards for permeability, the project management team met with the Division of Water Resources (DWR). While North Carolina had typically required a plastic HPDE liner for newly constructed animal waste lagoons and digesters, the industry-wide failure rate associated with these plastic liners (~10%) led to the use of an innovative alternative. LRF, located in western North Carolina, contains predominantly clay soils. Clay soils have relatively low permeability by nature and can be augmented to reach permeability levels above and beyond the legal requirements by an order of magnitude. Thus, the clay soil was augmented with bentonite, limiting the permeability to less than $1 \times 10^{-7}$, surpassing the standards for groundwater contamination prevention set up by the Natural Resources Conservation Service (NRCS).

The augmentation was completed by applying bentonite to the digester at a 1.25-centimeter depth, and then tilling the Bentonite into the clay soils with an agricultural tiller. Once the bentonite was applied and sufficiently incorporated into the clay soils, the permeability was tested and confirmed to meet the required NRCS standard of $1 \times 10^{-6}$. While this case represented an exception from the traditional HPDE liners recommended by the DWR, it proved sufficient given the geological characteristics of LRF.

## Key Takeaways:

- Consider the suitability of native soils associated with the system site.
- Keep in mind that traditional plastic synthetic liners can fail.
- Consider that innovative liners are costlier, but may have less risk of replacement compared to HPDE liners.
- Keep an open line of communication with your local permitting agency to identify and consider all options.

**Before:** The improperly installed synthetic liner.

**After:** Bentonite being applied.

# Sludge Waste Removal/Recycling

**The Problem:** Sludge build-up in the digester and aeration basin over time.

**The Solution:** Monitoring solids and sludge accumulation, removal of sludge as needed.

Given the design and construction of anaerobic digester and aeration basin systems, a certain amount of sludge build-up is anticipated over time. To ensure that the system continues to run properly, it is expected that the sludge should be transferred from the digester and aeration basin to the crop fields annually, or as warranted by the accumulation rate. The liner failure in summer 2013, regular flushing of the digester and aeration basin, and the large size of the digester at LRF has not required annual sludge removal as part of regular system operation as predicted. Instead, sludge levels in the lagoon have decreased since the system was installed.

Upon recognition of the liner failure mentioned above, the digester was drained to determine the location of the issue and repair the problem. This act combined with regular flushing and the volume of the digester has limited the need for sludge removal. Periodically, some of the sludge from the aeration basin has been pumped back to the anaerobic digester to keep the total solids concentration around 1% in the aeration basin and to promote biogas production.

## Key Takeaways:

- Remove sludge from the digester and aeration basin regularly
- To facilitate biogas production and keep the aeration basin <1% total solids, return accumulated sludge from the aeration basin to the digester.
- Proper management of the digester and aeration basin may lead to a decrease in sludge in the existing lagoon.

**Before:** Some sludge accumulation in the aeration basin at LRF.

**After:** Very little sludge accumulation in the basin

# Aeration Basin Foaming

**The Problem:** Excessive foaming occurred occasionally when aerating the aeration basin.

**The Solution:** Adjusting the length of aeration and periodic removal of accumulated solids until improvements were observed.

During aeration of the aeration basin, foaming is sometimes observed. While the foaming is not detrimental to any part of the system's processes, it does violate the innovative permit should foam leave the aeration basin. The liquid volume of the basin varies naturally given system function and rainfall, and upon higher-than-normal volumes within the basin, foaming can become an issue. The foaming process is not completely understood, but thought to be the result of a few factors including: phosphate levels in the liquid, high solids, overgrowth of filamentous bacterial, a high C/N ratio, or an undesirable pH.

To limit the concern associated with aeration basin foaming, the aeration process was reduced in duration until improvements were observed. Thus far, limiting the time associated with the aeration process and regular solids removal to the digester has proven a sufficient process for reducing foaming without hindering system function. In addition, cameras were installed on site so the system could be observed remotely, especially during times when the aeration basin had high levels.

## Key Takeaways:

- Weather and conditions in the aeration basin can result in high levels of foaming upon aerating.
- Consider aerating for limited amounts of time and monitoring the process to ensure controlled foam levels.
- Consider systems for remote monitoring to manage foam remotely.

**Before:** High foam levels in the aeration basin.

**After:** Normal and controlled foam levels in the aeration basin.

# Cover Holes

**The Problem:** Tears and holes in the anaerobic digester cover.

**The Solution:** Select your cover design and installation contractor carefully.

Throughout the early months of 2015, the anaerobic digester cover exhibited several holes and tears. While a short-term solution involved using adhesives and welding, the recurrence of the issue meant more needed to be done. The tears and holes were not easy to locate across the large surface area of the cover, and required smelling for methane. Given this difficulty, DCOI and LRF decided to replace the cover.

The cover exhibiting tears and holes was the second cover used at LRF. Using a different contractor than the one associated with the original cover, the second cover was installed "dry", when the digester was empty, resulting in excess cover material. This extra material allowed for the digester cover to "balloon" and store gas, but caused problems during heavy rains or low biogas conditions in the digester as the excess material folded, creased, and pinched to produce fissures, tears, and holes.

The third cover, recently completed in mid-2017, more closely resembles the original cover. It involves a system of pipes and weights to limit the ballooning height and reduced the total amount of cover surface area. In addition, the anchor trench was dug deeper to support some gas storage.

**Key Takeaways:**

- Consider doing a "wet" cover install – installing the cover with the digester liquid level at normal operating conditions.
- Review contractors carefully and collect multiple references prior to selection.

**Before:** The second cover at LRF that exhibited issues.

**After:** The new, better fitting cover at LRF.

# Surge Protection

**The Problem:** Rural areas often see a spike in substation energy during thunderstorms.

**The Solution:** Implementing surge protection throughout LRF and the waste-toenergy system.

Given the expense associated with the innovative system and the weather patterns associated with North Carolina, surge protection was a necessary addition. The frequency and intensity of thunderstorms in the area put the technology required to operate the system at risk. By implementing surge protection at LRF, the technology is safeguarded from any unanticipated energy spikes.

**Key Takeaways:**

- Rural areas are prone to surges, particularly those that experience heavy thunderstorms.
- Consider surge protection with the system to avoid technology damage from energy spikes.

# Heat Exchanger Replacements

**The Problem:** Sulfur build-up in heat exchanger pipes led to system shut-downs and necessitated replacement.

**The Solution:** Careful examination of pipes for build-up on a regular basis.

In 2014, the heat exchanger had to be replaced twice. These replacements were closely attributed to system shut-downs due to the accumulation of sulfur deposits restricting the flow of biogas and causing gas skid alarms. The heat exchanger pipes were examined after the alarm soundings, and each time a yellow substance was found in the pipes. This yellow substance was believed to be sulfur build-up. The final solution was use of a tube-in-shell heat exchanger that was less susceptible to blockage from sulfur deposit and regular, annual cleaning of the heat exchanger.

**Key Takeaways:**

- Failed heat exchangers can cause the gas skid system to shut down.
- A yellow substance, believed to be sulfur, can build-up in heat exchanger pipes throughout the system life, restricting the flow of biogas in the conditioning system.
- Consider monitoring these pipes regularly to avoid system up-time loss and costly heat exchanger replacement.

# Seasonal Decreased Biogas Production

**The Problem:** Lower biogas production is observed at lower ambient temperatures.

**The Solution:** Select the appropriate design and equipment for the climate.

LRF is located in western North Carolina, a temperate climate with some fluctuation between seasonal temperatures. The AD system installed at LRF operates at ambient temperature, with no supplemental heat provided. While the AD system works well in this climate, resulting in biogas production across all months, particularly cold winters have resulted in decreased biogas production.

Animal agriculture does not exhibit seasonality in production. Thus, a more uniform and warm environment would likely render a steadier stream of RECs and offsets for the project management team, relative to a highly seasonal climate.

## Key Takeaways:

- Biogas production is dependent on the operating temperature of the digester. Select the appropriate operating temperature, and required equipment, based on your typical climate and ambient temperature.
- When estimating offsets and RECs, consider how seasonal changes in temperature may affect biogas generation.

Loyd Ray Farms, 2015.

# Duke University Resources

| Resource Citation | Description |
|---|---|
| Xu, J., Adair, C., and Deshusses, M. Performance evaluation of a full-scale innovative swine waste-to-energy system. Bioresource Technology (2016). | This document looks at biogas production and aeration basin function at LRF. It analyzes the performance of both parts of the innovative system and proposes possible methods for system optimization. |
| Adair, C.W., Xu, J., Elliott, J.S., Simmons, W.G., Cavanaugh, M., Vujic, T., Deshusses, M.A. *Design and* Assessment of an Innovative Swine Waste to Renewable Energy System. American Society of Agriculture and Biological Engineers (2016). *(Link not currently available)* | This paper aims to describe the system at LRF and explain some of the best practices, as of publication in 2016. The document explains the system set-up, environmental benefits, and entails, in slightly more detail, some of the cases presented above. |
| Xu, J., Vujic, T., & Deshusses, M. A. (2014). Nitrification of anaerobic digester effluent for nitrogen management at swine farms. Chemosphere, 117708714. | This document presents a highly technical description of the best system properties (pH, aeration time, etc.) to effectively start a large-scale innovative waste management system. |

# External Resources Guide

## General Resources

| Resource | Description |
|---|---|
| United States Based Resources | |
| US EPA's AgSTAR Program | A resource designed to promote the use of biogas recovery systems in US agriculture. |
| AgSTAR "Stories from the Farm" | Intended to provide case studies and fact sheets on anaerobic digestion projects in the US. |
| Anaerobic Digestion and Bioresources Assocation: Case Studies | Provides numerous case studies on anaerobic digesters, separated categorically by associated industry. |
| American Biogas Council Map of Biogas Systems in the US | An online resource that provides an interactive map of all biogas systems in the United States, separated into respective category, such as agriculture, landfill, wastewater, and food scraps. |
| United Kingdom Based Resources | |
| 2017 Annual Report: Anaerobic Digestion Deployment in the UK | A for-purchase publication that breaks down regional trends and highlights market changes in the anaerobic digester sector in the UK. |
| UK Biogas Map | Provides a map-based resource detailing all anaerobic digester sites in the United Kingdom. |
| European Union Based Resources | |
| European Biomass Industry Association | An informational page detailing the AD energy production by country over three time-steps, and additional information on industry drivers and basic system design. |

# University-Based Resources

| Resource | Description |
|---|---|
| NCSU: Biogas Production | An article from North Carolina State University that highlights variations in temperature, loading, and other factors, and the effects on overall biogas production. |
| Clemson University: Burrows Hall Farm | Slideshow presentation from Clemson University. Offers some "lessons learned" in the form of bullet points, and could be a reputable point of contact for project managers. |
| U Penn: Considerations for AD Technology Implementation | Guideline document from the University of Pennsylvania regarding considerations to make prior to implementing AD technology. This resource includes documents to consider, cooperatives to contact, incentives, and resource sites for projects in the Pennsylvania/North East area. |
| U Penn: Slideshow on AD project | Extensive slideshow offering information on the Crone Farm AD project, as well as lessons learned from the project. |
| U Penn: Overview of AD in Pennsylvania | Paper providing background information on AD in Pennsylvania, a general understanding of the process, as well as a case-by-case look at dairy, swine, and poultry AD in Pennsylvania, and associated unique challenges with each system. |

# Additional Scholarly Resources

| Resource Citation | Description |
|---|---|
| Ye Chen, Jay J. Cheng, Kurt S. Creamer, Inhibition of anaerobic digestion process: A review, Bioresource Technology, Volume 99, Issue 10, July 2008, Pages 4044-4064. | Provides a detailed description on some of the inhibitors to anaerobic digesters. These inhibitors often cause problems with waste treatment and biogas production. |
| Wilkie, Ann C., Anaerobic Digestion of Dairy Manure: Design and Process Considerations. Dairy Manure Management: Treatment, Handling, and Community Relations. NRAES-176, p.301-312. | A document primarily focusing on Dairy AD, but provides insights on process optimization, design characteristics, and the impact of solid characteristics on digester function. |

*For questions, comments, or general offset guidance, please contact the DCOI staff at:*

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For more information on the Duke Carbon Offsets Initiative, please visit sustainability.duke.edu/offsets